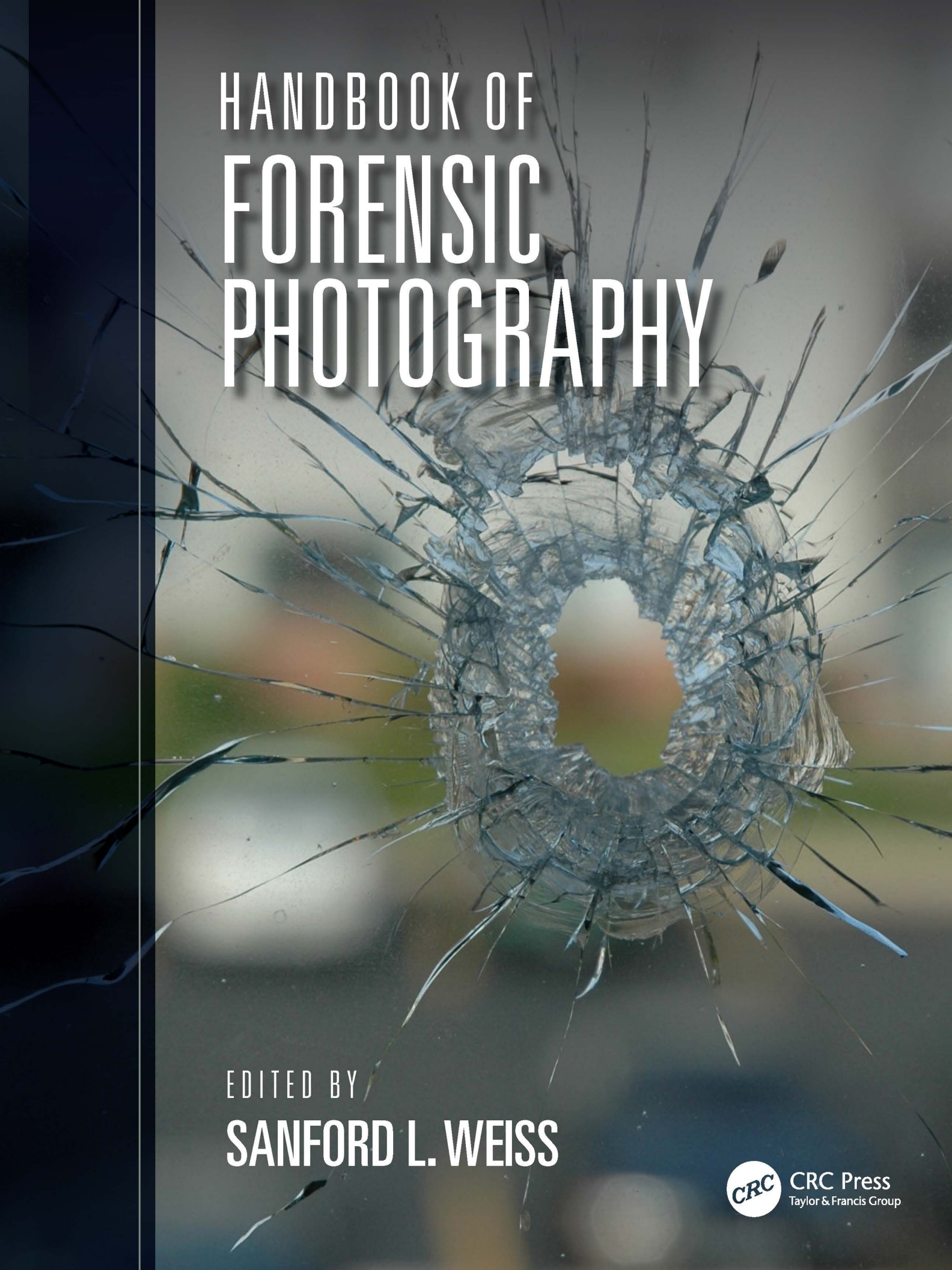
HANDBOOK OF FORENSIC PHOTOGRAPHY



EDITED BY

SANFORD L. WEISS

CRC Press
Taylor & Francis Group

Handbook of Forensic Photography



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Handbook of Forensic Photography

Edited by

Sanford L. Weiss

With special contributions from
Art Borchers

CRC Press
Taylor & Francis Group
Boca Raton London New York

CRC Press is an imprint of the
Taylor & Francis Group, an **informa** business

First edition published 2022
by CRC Press
6000 Broken Sound Parkway NW, Suite 300, Boca Raton, FL 33487-2742

and by CRC Press
2 Park Square, Milton Park, Abingdon, Oxon, OX14 4RN

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CRC Press is an imprint of Taylor & Francis Group, LLC

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Library of Congress Cataloging-in-Publication Data

Names: Weiss, Sanford L., 1948- editor.
Title: Handbook of forensic photography / edited by Sanford L. Weiss.
Description: First edition. | Boca Raton : CRC Press, 2022. | Includes bibliographical references and index. |
Summary: "Handbook of Forensic Photography is the most-comprehensive, definitive reference for the use of photography in the capture and presentation of forensic evidence. The intent is to inform the reader about the most complete and up-to-date methods to capture and reproduce images that most accurately representing the evidence. With the rise in importance of forensic science, crime and accident scene documentation has likewise increased on importance-not the least of which has been forensic photography. The need to use excepted practice and protocols to guarantee the authenticity of images for evidence documentation is paramount for using it in court. And as with any discipline, there is an art to the science of forensic photography. Contributing authors from various backgrounds-each experts in their field-have provided numerous case examples, best practices, and recommendations for recognizing, recording, and preserving evidence using cameras and the latest digital image technology, including video and other imaging technologies. Chapters present such topics such as videography, drone photography, underwater photography, crime scene photography, autopsy photographs, fire documentation, forensic odontology, and more. The book closes with coverage of courtroom displays, presenting imaging evidence, and expert witness testimony in the courtroom. Handbook of Forensic Photography is a must-have reference for experienced crime scene photographers, death and crime scene investigators, police, and forensic professionals-including medical examiners, odontologists, engineers, and forensic anthropologists-who frequently need to capture investigative photographs in the course of investigations"-- Provided by publisher.
Identifiers: LCCN 2020034348 (print) | LCCN 2020034349 (ebook) | ISBN 9780367498931 (hardback) |
ISBN 9781003047964 (ebook)
Subjects: LCSH: Legal photography--Handbooks, manuals, etc.
Classification: LCC TR822 .H35 2021 (print) | LCC TR822 (ebook) | DDC 770--dc23
LC record available at https://lccn.loc.gov/2020034348
LC ebook record available at https://lccn.loc.gov/2020034349

ISBN: 978-0-367-49893-1 (hbk)
ISBN: 978-0-367-68226-2 (pbk)
ISBN: 978-1-003-04796-4 (ebk)

Typeset in Times LT Std
by KnowledgeWorks Global Ltd.

Dedication

In the period between the selection of our illustrious crew and the publication of this book, we had the misfortune to lose one of our valued contributors. Dr. Mark Feil succumbed to an extended illness just as the book was going to press. Mark was editor in chief of the Forensic Teacher Magazine *as well as being a good friend. He will be missed.*



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Contents

Preface xi
Editor xiii
Contributors xv

Chapter 1 Forensic Photography: The Purpose 1
Sanford L. Weiss

Chapter 2 Fair and Accurate Representation 11
David "Ski" Witzke

Chapter 3 Development of Agency Standard Operating Procedures 17
Lawrence Stringham

Chapter 4 Getting Ready to Go 23
Sanford L. Weiss and Robert Wyman

Chapter 4A Using a Tripod 37
Arthur Borchers

Chapter 4B Mirrors and Go-Kits 42
Sanford L. Weiss and Robert Wyman

Chapter 5 Visual Storytelling 45
Sanford L. Weiss

Chapter 6 Digital Processing of Evidentiary Photography 55
David "Ski" Witzke

Chapter 6A Impression and Pattern Evidence 122
Dawn Watkins and King Brown

Chapter 7 Necessary Hardware: Operating, Holding, and Focusing 139
Sanford L. Weiss and Robert Wyman

Chapter 7A Light Metering for Exposure 149
Sanford L. Weiss and Robert Wyman

Chapter 7B High Dynamic Range (HDR) 161
Sanford L. Weiss and Arthur Borchers

Chapter 8 Photography in Technical Investigations 167
John M. Fildes

Chapter 9 Three-Dimensional Photography and Its Applications 179
Sanford L. Weiss

Chapter 10 Human Vision and Low-Light Photography 207
Paul Kayfetz, George Pearl, Sanford L. Weiss, and Robert Wyman

Chapter 10A Existing Light Photography 230
Robert Wyman

Chapter 10B Painting Evidence with Light 235
George S. Pearl

Chapter 10C Dealing with Retroreflective Light 238
Robert Wyman

Chapter 11 Macrophotography 243
Sanford L. Weiss and Robert Wyman

Chapter 11A Cellphone Forensic Photography 272
Robert Wyman

Chapter 12 Image Rectification and Angular Correction 275
Arthur Borchers

Chapter 13 Firearms and Toolmarks 285
Carlo Rosatti and Marcelo Jost

Chapter 13A Bullet Trajectory Laser Photography 310
Arthur Borchers

Chapter 14 Questioned Documents 313
Emily J. Will and J. Wright Leonard

Chapter 14A Photography and Human Vision 317
J. Wright Leonard

Chapter 15 Clandestine or Surveillance Photography 337
Patrick Linnenbank

Chapter 16 Videography 345
Kathryn McMillan

Chapter 17 Surveillance Videos Capture the Path of a Killer (Forensic Analysis) 359
Litigation Animation

Chapter 18 Working the Field/Accident Scene 367
Robert Wyman

Chapter 19 Laser Scanning 387
Ryan Hacker

Chapter 20 Large Scene Investigation 399
John L. Larsen

Chapter 21 Photographing Crime Scenes 405
Sanford L. Weiss and Robert Wyman

Chapter 21A Public and Private Scene Investigations: Fire, Crash, and Crime Scenes 423
Arthur Borchers

Chapter 21B Crime Scene Photogrammetry 435
Eugene Liscio

Chapter 21C Single-Photo Perspective Photogrammetry 444
Arthur Borchers

Chapter 22 Aerial Coverage from Light Planes and Helicopters 453
Robert Feuerstein

Chapter 23 Drone Photography 459
Abbe L. Lyle and Mark Johnson

Chapter 23A Forensic Aerial Imagery and Drone Photogrammetry 474
Mark Johnson

Chapter 24 Inspection for Auditing Conditions 481
Sanford L. Weiss

Chapter 25 Water and Underwater Photography 495
Jennifer Idol

Chapter 26 Forensic Fire and Explosion Photography 507
Noah Ryder

Chapter 27 Injury Photography 517
Eric Johnson

Chapter 28 Documenting Findings in Interpersonal Violence 555
William M. Green

Chapter 29 Autopsy Photography 569
Sanford L. Weiss and P.J. Schoebel

Chapter 30 Entomological Photograph Protocols 581
Neal H. Haskell, Leon G. Higley, and Pat Cicero

Chapter 31 Forensic Odontology 599
Denise Murmann

Chapter 32 Photography and Forensic Archaeology 605
Karl Harrison

Chapter 33 Forensic Anthropology and Photography 611
Özgür Bulut and Amy Wedge

Chapter 33A Forensic Facial Analysis 612
Özgür Bulut

Chapter 33B Forensic Age Progression 619
Özgür Bulut

Chapter 33C Forensic Facial Reconstruction and Postmortem Depiction 632
Amy Wedge

Chapter 34 Photography for Publication 639
Mark R. Feil

Chapter 35 The Role of the Forensic Scientist as Expert Witness in Court 643
Julia Garcia de Leon

Chapter 36 Technology for Courtroom Displays and Demonstrative Presentations 651
Mark Johnson

Chapter 37 Teaching Forensic Photography in the 21st Century 659
Sarah Graham

Glossary 665

Index 697

Preface

I have a favorite word in the English language: **previsualization**. This single word kept me grounded as a forensic photographer for the last 40 years. It is the word which separates forensic photographers from everyone else on the planet who takes pictures, or snapshots, or portraits or weddings. The word is like a disease. The thing is, everyone else who takes photographs has it, but forensic photographers shouldn't. Isn't that an amazing concept?

The people who take photographs for work or play have some idea what their images are going to be once shown, printed, or distributed. They are meant to document a time and a place. They are meant to make people go, WOW, isn't that beautiful? Some folks give slide shows of trips to Europe to educate and impress their audiences with their singular knowledge of architecture and custom. But not forensic photographers.

The best of us are able to keep previsualization out of their work. They follow a protocol or best practice in order to collect a set of images showing, to the best of their ability, the scene and evidence from a crime or crash, and sometimes for the training of newer forensic photographers. The one thing making their images stand out is, they show the evidence and tell a story, but they are not previsualized and never planned in advance. Their images show a search for truth and document an incident without bias or prejudice.

If you are able to keep the word out of your thoughts. If you are the kind of person who is able to expose excellent images to follow a protocol or best practice, but not care about composition or ever seeing your work hanging in a gallery in New York, this book is for you! There are plenty of books with ideal photographs to train the other photographers to make the images needed for their job – the family in the yard with the dog, the bride and groom walking down the aisle, the face of wealth and wisdom, the thousand-year-old cathedral, and/or the beauty of the National Parks and the wildlife. If those are the kind of images you are about, this book is definitely not for you – unless you are looking to change careers.

Sanford L. Weiss



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Editor

Sanford L. Weiss, BCEP, is a forensic photographer and the author of *Forensic Photography: The Importance of Accuracy*, and is now the leader of the indomitable crew writing the new version, *Forensic Photography for the Preservation of Evidence* to be published by CRC Press as soon as it is completed. Mr. Weiss is also an Evidence Photographers International Council (EPIC) Board Certified Forensic Evidence Photographer, a competitive intelligence specialist, and was an Illinois State Licensed Private Detective (#115-001807) and head of the Packer Detective Agency (#12002454). He holds a State of Illinois Certified Teacher rating (#1535733) for any and all photography-related subjects. He worked for Packer Engineering, Inc., in Naperville, Illinois, from 1980 to 2009 for whom he documented the artifacts and scenes of hundreds of investigations and carried out complex human vision studies for almost 30 years. He also spent time performing competitive intelligence analysis, being corporate librarian, then graphic artist, marketing specialist, and corporate historian. He is an expert in photo lab management and all aspects of photographic chemical processing and was in charge of the Packer Engineering Photo Laboratory for over 17 years.

Mr. Weiss has a BS degree in management from National Louis University. He has taught in many venues and on many levels for over 30 years, from government agencies to universities. He is regularly published on forensic photography in national periodicals, including *Evidence Technology Magazine*. In 2003, Mr. Weiss received the R.C. Hakanson Evidence Photographer of the Year Award from EPIC, in 2005 the Nikon Evidence Photographer of the Year Award, then in 2006 he was presented the prestigious Lifetime Achievement Award in Forensic Photography from Nikon USA, one of the world's leading companies in professional photographic products and technologies.

When he began his career in forensic photography, he was a beginner and the options for learning the craft were limited. In his case, the on-the-job training consisted of watching, talking, asking, and mostly concentrating on the problems he was tasked with. He quickly learned there were similarities in all projects and experience was a great teacher. He learned one must have a passion for figuring out how to most accurately document evidence photographically. To be successful in this work, any other person must have that passion, too. Since 2009, he has been the principal of Sandy Weiss Forensic Photography Consulting. From 2010 to 2016, he taught accredited online courses in forensic photography for the University of California Davis Extension Service.



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Contributors

Arthur Borchers is a good friend, a brilliant, hard worker, and always able to be counted upon for the most challenging assignments! He received his first camera from his father in the early 1960s and has tirelessly worked to improve his skills. He worked as a police officer, evidence technician, detective, and a Sergeant with the Investigations Division of the Oak Park Police Department, Oak Park, Illinois, where he began a career in crime scene and traffic crash investigation.

He now continues to work as the owner of Wreck Technology, Berwyn, Illinois. He provides expert technical consulting services based on more than 25 years of law enforcement, crash reconstruction, and crime scene experience, with particular expertise in technical follow-up investigations and mathematical and physics based reconstruction and analysis. He is an Accredited Traffic Accident Reconstructionist (ACTAR #336) and a member of the International Association for Identification as well as the Illinois Division of the IAI.

King Brown holds a master's degree in criminal Justice and is an IAI Certified Senior Crime Scene Analyst, Certified Forensic Photographer, and Certified Latent Print Examiner. He is currently the Crime Scene Supervisor for the West Palm Beach (Florida) Police Department, Past President of the Florida Division of the IAI, Chairman of the Crime Scene Certification Board for the FDIAI, Recipient of the Good of the Association Award and a Distinguished Member too. He has been in the field of Forensic Science for 32 years. He is the President of the Gold Coast Forensic Association and is an Adjunct Professor at Eastern Florida State College in the Crime Scene Technology Associates Degree Program. He also instructs for other forensic organizations. He has been a lecturer at the IAI Training Conferences since 1996.

Özgür Bulut, PhD, his background is in forensic anthropology, 3-D craniofacial anthropology, and forensic facial identification. He has an MA degree from Gazi University of Ankara, Turkey. Following that study, he completed his graduate work for his MSc in the Forensic and Medical Art program majoring in facial anatomy and 3-D facial reconstruction at the University of Dundee, United Kingdom. During the MSc studentship, he completed an international internship program at the Center for Anatomy and Human Identification at the University of Dundee. He earned his PhD degree from the Department of Anthropology at the University of Ankara. He then worked in their forensic laboratory as a forensic anthropologist and forensic facial identification expert for 15 years. He dealt with over 2000 forensic cases related to craniofacial identification. He also gave facial reconstruction trainings/workshops to participants from the United States, UK, Scotland, South Africa, Turkey, Germany, and China who work as an anatomists, anthropologists, archaeologists, fine artists, police officers, and sculptors. He also taught undergraduate and graduate courses. His teaching experience includes forensic anthropology, facial reconstruction, 3-D facial reconstruction, and craniofacial identification courses for Ankara University, Yildirim Beyazit University and Atilim University in Ankara and is currently on faculty for the University of Tübingen in Germany.

Christopher Cali, ex Lt. Naperville, IL PD, recently retired, he was a Police Officer in Naperville, Illinois, who had 21 years of experience as a State Certified Crime Scene Investigator. Lt. Cali has a total of 25 years in law enforcement and was assigned to the Traffic Unit where he investigated fatal and serious injury crashes. He has had hundreds of hours of specialized training related to police investigations including death, criminal sexual assault, fire, home invasion, robbery, burglary, battery, motor vehicle theft, domestic violence, and much more. Lt. Cali is a member of the International Association for Identification (IAI) and he earned a Level I Crime Scene Certification through IAI. He has also belonged to the following organizations: The International Association of Law Enforcement Intelligence Analysts, the Airborne Law Enforcement Association, the International Association of Arson Investigators, the International Association of Auto Theft Investigators, the National Tactical Officers Association, and several others. His formal education consists of a master's degree in science, a bachelor's degree in arts, an associate degree in arts, and an associate degree in science. All four of his degrees were earned with honors. Additionally, Lt Cali has received numerous commendations and chief's commendations, as well as a Meritorious Unit Award while working in the Crime Scene Unit.

Julia Garcia de Leon is a Forensic and Data Scientist with a BSc (Hons) in Archaeology from Reading University and an MSc in Forensic Anthropology from Boston University School of Medicine. Her research interests include applied data science, 3-D technologies in forensic anthropology, forensic taphonomy, and the use of virtual anthropology in developing population-specific standards for elaborating biological profiles. She is a mentor under Reading University's THRIVE mentoring scheme. She currently works as a data scientist and educator in Mexico, providing training in forensic taphonomy, standard anthropological methods, and expert witness testimony to scientists, lawyers, and law enforcement personnel. She is an associate member at the American Academy of Forensic Sciences and an affiliate at the International Institute of Forensic Sciences.

Mark R. Feil, EdD, MBA, taught high school chemistry, physics, physical science, and forensics to inner city children for 10 years before retiring from public education. His master's thesis used DNA fingerprinting to solve an ecological puzzle. He is also an adjunct faculty member at Neumann and Wilmington Universities. Dr. Feil is an award-winning, recognized expert on differentiated instruction, multiple intelligences, brain-based learning, and engagement. Besides attending the Harvard Graduate School of Education, he has performed on the stand-up comedy circuit, and is available for talks, seminars, workshops, and judging KCBS BBQ competitions. Dr. Feil is also the founder and editor-in-chief of *The Forensic Teacher Magazine*, a publication aimed squarely at forensic educators in secondary, post-secondary, law enforcement, and government settings. Each issue features an interview with a forensic professional, helpful how-to articles, lessons and labs, new forensic products on the market, mini mysteries, upcoming conferences, and more. You are encouraged to visit the website at www.theforensicteacher.com. While there you'll also be able to download the current and immediately previous issue for free. Circulation is about 16,000 and the magazine is in its 12th year of publication.

Robert Feuerstein received a BPA from Brooks Institute of Photography, Santa Barbara, California, in 1973 after receiving his associate of arts degree from El Camino College, Torrance, California. Then he worked toward a master of science in administration at California State University, Dominguez Hills. Since then he has worked for the County of San Diego Cartographic Services 2008–present as a Photographic A/V Specialist responsible for photographic and audio visual production to support all county departments including law enforcement and courtroom exhibits. Before that he worked for the County of Los Angeles District Attorney's Office 1991–2008 as Photographer I & II. He was Photographer for the Trial Support Division. He was responsible for Investigative and Forensic Photography, Videotaping, Photographic Lab operation, Photographic field assignments including infrared and aerial photography, Statistical tracking and reports, and testimony. He is expert at the substantiation of cases using law enforcement reports to re-enact the crime scene, including photographs from observation points where it was necessary, among other things, to convert the magnification of binoculars to the equivalent photo lens. He has often qualified as expert witness in Photography for court testimony in both Superior Court and Municipal Court. One of his more interesting past positions was for Noritsu America Corporation 1980–1989 as Senior Customer Training Instructor. He trained owners in set up and use of 1-hour photo equipment, the sophisticated equipment requiring knowledge in chemistry, physics, optics, geometry, and photography. He developed and wrote training materials. Trained instructors and wrote team reviews of instructors' performance. He was extensively trained in Compliance with OSHA safety regulations for chemicals (MSDS). He has been a Photography Instructor at the Fallbrook School of the Arts, teaching courses in Basic Digital Photography, Digital Photography and Image Editing, Exploring Photoshop Elements, Capturing Video with Digital Devices, Photographing Artwork, and People & Things in the Studio.

John M. Fildes, PhD, is a Consultant in Chemistry, and virtually any other engineering and human factors area. He has formal training in chemistry, physics, thermodynamics, and materials. He has decades of experience of successfully conveying highly technical issues to laypeople. He tackles highly challenging technical problems and often sees key issues and devises approaches which others have missed, through a combination of vast experience, extensive technical knowledge, creativity, an excellent understanding of testing and analysis, and strong project planning and management capabilities. He is a doctoral-level scientist who has organized, written proposals, conducted and managed $26 million in funded projects including research, development, litigation expert witness investigations, and collaborations involving government labs, large defense companies, and leading universities with funding from the Army, Navy, the Defense Advanced Research Projects Agency (Technology Reinvestment Program), the Great Lakes Composites Consortium, the Gas Research Institute, the Electric Power Research Institute, First Alert, ABB, Westinghouse, Bell Helicopter, the Illinois Technology Development Authority, the State of Illinois, and others. He is an expert in materials science, advanced composite materials, materials processing including process sensors and controls, materials compatibility, materials selection, protective coatings and lubricants, decorative coatings, coatings fabrication, semiconductor materials, gas sensors, tribology (the science of friction and wear), materials property modeling, corrosion, statistics, and experimental design. He is a uniquely qualified litigation expert witness whose extensive scientific experience coupled with broad experience with product and process design processes, the conduct of research and development, and innovation management, provides comprehensive insight of both the technical issues and their relation to R&D and design issues; specialization throughout his career on the role that materials contribute to the limitations and failures of products and systems. His education includes Postdoctoral Research Associate, chemical at Virginia Polytechnic Institute and State University: engineering, Virginia Polytechnic Institute and State University: PhD chemistry (physical), and Georgetown University: BS chemistry.

Sarah Graham has worked for the Durham Constabulary since September 2017 as a Policing Skills Trainer. Her duties include the preparation, development, and administration of all training, technical and practical, for the Department. These sessions include the gamut of Student Officer Training Programs, and she is not limited to training for the Officers. Other departmental employees and even outside customers will hire Ms. Graham's services for

training in both the UK and for International Security. She is also trained to develop and monitor test results and assess her students' progress. She worked for Forensic Services Companies from 2010–2017 recovering and recording Biological Evidence and interpreting and uploading Genetic Profiles to the National DNA and Missing Persons Databases. Her position brought her into close daily contact with a variety of Law Enforcement personnel. She wrote training guides for the extraction, quantification, storage, and destruction of DNA yielding Biological Evidence. Ms. Graham ensures her own continuous professional development by working with operational CSIs. Her leisure time is spent bettering her talents in art and photography. She loves to read and is currently studying Japanese.

Annabelle Green is a Forensic Photographer and has been a crime scene investigator for over 11 years, starting in 2004 in Greater Manchester, UK. She has specialist training in the areas of photography and video capturing and enhancement, bite mark photography, fire investigation, bomb scene investigation, and covert forensic techniques to name a few. Originally from Staffordshire in England, Ms. Green moved to London to attain her degree in biology and sport science. The logical choice for a person fascinated with how the human body works and moves. She moved to Manchester in 2000 and worked her way into becoming a crime scene investigator a few years later. Ms. Green immigrated to Canada in 2015 and took a position with Home Depot. In early 2017, she began her role in the Forensic Department of a police oversight body. She has continued her professional training in Canada and has completed a qualification in forensic video analysis and fire scene investigation. Ms. Green currently lives and works in Vancouver, BC.

William M. Green, MD, FACEP, specializes in emergency medicine and the evaluation and treatment of sexual abuse. He is a Clinical Professor in the Department of Emergency Medicine at the University of California, Davis, and Director of the Sexual Assault Forensic Medicine Education Program at the California Clinical Forensic Medical Training Center, UC Davis Health System in Davis, California. He has been Clinical Professor, Department of Emergency Medicine at the University of California, Davis, CA, since 1990. He received his MD from Northwestern University Medical School, Chicago, IL, 1973 and did a Family Practice Residency at University of California Davis School of Medicine, Davis, CA, 1973–1976. His certifications include: American Board of Family Practice, American Board of Emergency Medicine, American Board of Forensic Examiners, and American Board of Forensic Medicine. Responsibilities for this book include Injury Documentation of Abuse Victims.

Ryan Hacker is the President and Owner of TruePoint Laser Scanning, LLC. TruePoint was started in 2011 and is an Ohio registered engineering firm that focuses solely on providing 3-D laser scanning services to its nationwide client base. Mr. Hacker attended Miami University (Ohio) for his undergraduate studies and earned his MBA from the University of Toledo. His primary role is focusing on the business development, financial and operational aspects of the company, while entrusting his team of Professional Engineers, Architects and Scan Technicians to deliver exceptional service and the highest-quality product to a wide variety of industries, including the forensics field with a particular focus on airplane crash investigations.

Karl Harrison, DSc, was awarded an honorary Doctor of Science, by the University of West London in recognition of his service to forensic science practice and research and has completed a part-time PhD investigating the interface between archaeological excavation techniques and forensic fire investigation. He is one of the UK's leading academic researchers in forensic archaeology and a Lecturer in Forensic Archaeology at Cranfield University's campus at the Defense Academy for the United Kingdom. He has lectured often and has been published widely. He is an experienced and dedicated forensic archaeologist and forensic ecology adviser with a strong background in operational crime scene investigation working for UK police forces. Over the past 17 years, he has examined approximately 6000 crime scenes as a general criminalist and in excess of 150 scenes as a forensic archaeologist.

During this time, he managed the searches for Madeleine McCann, who vanished from Praia da Luz holiday resort in Portugal in May 2007 at the age of three and authorities are still trying to understand what happened to her and Ben Needham, the toddler who disappeared on Kos, a Dodecanese island chain in the southeastern Aegean Sea, off the Anatolian coast of Turkey, 26 years ago.

He also supervised the scene investigations of Didcot Power Station, where four men were killed when the boiler house collapsed in February 2016. The disused station fell while under demolition and the Thames Valley Police Force said it was considering charges of corporate manslaughter, gross negligence manslaughter, and serious health and safety breaches. Also, the Grenfell Tower fire that broke out on June 14, 2017 at the 24-storey block of public housing flats in North Kensington, West London: 71 deaths and over 70 injuries resulted as occupants of 23 of the 129 flats died.

Neal H. Haskell, PhD, received his MS Forensic Entomology in 1989, the first such degree in the country, and his PhD FE also the first in 1993, both from Purdue University. Along with a career in farming, Dr. Haskell entered a new graduate program at Purdue to study how insects could be used to answer questions at murder scenes. He has presented hundreds of scientific lectures, seminars and training classes worldwide to provide coroners, medical examiners, death scene investigators, and others with valuable information regarding entomological evidence from death scenes. He has also written several books and book chapters in his specialty. He was also featured in a number

of other books and in over 150 news articles and other news media. In a book by Dr. Michael Baden and Marion Roach, *Dead Reckoning*, an entire chapter is devoted to stories of Dr. Haskell, the pig research and training in Rensselaer, and other interesting case studies. Dr. Haskell is a Professor Emeritus of Forensic Science and Biology at Purdue and now he continues as a private international forensic entomology consultant to hundreds of law enforcement agencies across North America and Europe. He holds adjunct appointments at the Universities of Wisconsin and Nebraska. He is a Board Certified Entomologist with the Entomological Society of America. He has worked with the Indiana State Police, the FBI, the Office of the Chief Coroner, Ontario Canada, the Florida Department of Law Enforcement, the New York State Police, the Seattle Washington Medical Examiner's Office, the Las Vegas Metro Crime Lab, and the Montana Medical Examiner's Office. He has assisted in over 1000 cases with questions regarding insects. He has been accepted and recognized as an expert witness in both state and federal courts in 33 states in the U.S. and regional and provincial courts, and the Ontario Court of Appeals, in Canada. He has given testimony in approximately 140 trial and hearings, many of which were capital murder cases. He assisted in insect collections at the Branch Davidian Compound in Waco, Texas and the criminal investigation of the Scientology Group in Clearwater, Florida. He conducted research with others at the University of Tennessee, "Body Farm" where actual human corpses were compared to pig corpses for establishing a replacement for humans in decomposition and forensic entomology studies, needed across the United States, the first major funding provided to forensic entomology by the U.S. Justice Department. Due to the current interest in crime fighting by the general public (*CSI* and others), Dr. Haskell has been featured on over 40 television programs including *The New Detectives*, Discovery Channel; *Secrets of Forensic Science*, The Learning Channel; *How Things Work*, A&E; and *Forensic Files* on Court TV; and recent filming for National Geographic and the History Channel.

Jennifer Idol is a native Texan. In 2010, she flew over the Deepwater Horizon oil spill in the Gulf of Mexico from the BP-operated Macondo Prospect, now considered the largest marine oil spill in the history of the petroleum industry. It was caused by an explosion on the Deepwater Horizon oil rig, located about forty miles off the coast of Louisiana. The rig exploded and sank resulting in the death of eleven workers and a staggering ecological disaster, affecting people and wildlife, including sea turtles, dolphins, crabs, shrimp, and plankton. Witnessing that horror moved Ms. Idol to raise international awareness of the value and importance of local waters. She began a 5-year quest to become the first woman scuba diver to dive in all 50 United States and cover her journey in both words and photographs.

She is the author of *An American Immersion*, the documentation of that journey. She overcame serious time and financial obstacles and applied rugged passion and dedication in her quest to transform herself from a successful graphic designer into a conservation artist to showcase our underwater resources through vivid photography and to help illuminate our beautiful world. She is an Ambassadiver, committed to elevating diving in their communities and across the planet, with the Professional Association of Diving Instructors (PADI), the world's leading scuba diver training organization. Ms. Idol is also a member of the Ocean Artist's Society, and a professional graphic designer. Her award-winning photography and articles have been widely published in periodicals including DIVER, SCUBA Diving, Alert Diver, and Sport Diver. She has been diving for 23 years and has earned more than 29 certifications, including PADI Master Instructor, certified in underwater investigation, photography, recovery and tactical police diving.

Eric Johnson retired from the Michigan State Police as a First Lieutenant in 2009 with over 30 years of service to his credit. He has been a professional photographer since 1983 and has won numerous awards and recognitions, including two "Top-Ten-in-the-State" awards with the Michigan Professional Photographers Association. During this same period, he had a distinguished career in law enforcement, retiring in 2009 with more than 30 years of service with the Michigan State Police. His background in law enforcement, combined with his professional photography experience, led him to specialize in forensic photography after his retirement. He began offering forensic photography services to the legal community, and also started teaching forensic photography in Michigan and across the country. Mr. Johnson is recognized throughout the United States as an expert in forensic photography and he is currently the only Certified Evidence Photographer and the only Certified Forensic Photographer in Michigan–sharing both of these designations with only five other photographers worldwide. His photographic specialties include Difficult Lighting Techniques, Crime Scene, Macro, Product Failure, Personal Injury, Advanced Digital File Management, Digital Image Authentication, and Accident Scene Documentation. Since 2007 he has owned and operated Forensic Photography Services, LLC, offering services including on-location photography for personal injury, hazardous conditions, etc., digital photography instruction to law enforcement officers, digital image analysis and authentication, digital image integrity consultation with law enforcement agencies, and on location photography services for law enforcement. He has been teaching for many years and has provided photography training to more than 1000 police officers, fire investigators, and evidence technicians from 255 departments and work sites throughout Michigan and the United States.

He holds a Certified Forensic Photographer Designation by the International Association for Identification (IAI) since 2012, and Certified Evidence Photographer Designation by the Professional Photographic Certification Commission since 2010. He is the Chair of the Forensic Photography

Certification Board of IAI since February 2016 and sat on the boards of the Forensic Certification Management Committee of IAI and the Forensic Photography Certification Board of IAI.

Mark Johnson received his bachelor's degree cum laude from Kansas State University in Manhattan, Kansas in 1975. He was awarded the Putnam Scholarship and inducted into Phi Kappa Phi honor society. He next attended the University of Kansas School of Law in Lawrence, Kansas where he received his Juris Doctorate degree in 1978.

As a practicing plaintiff's trial lawyer through the 1980s, he developed innovative uses of film, video, and graphics for litigation and mediation. As computer graphics evolved, he acquired skills for the creation and manipulation of 3-D computer models, and he also developed a number of innovative demonstrative exhibits for the courtroom, used successfully in trial.

After relocating to San Jose, California in 1993, he founded Second Chair Litigation Support, a company devoted to the application of high-level demonstrative evidence techniques for both civil and criminal trials. In 1998, he cofounded with Dr. Arthur Ginsburg, Visual Forensics in San Ramon, California. As the director of forensic animation there, Mr. Johnson animated the flight of a Marine Prowler jet striking a ski gondola near Cavalese, Italy. The incident received worldwide coverage. His work has been featured on CBS *60 Minutes*, *NBC Today Show*, *ABC Good Morning America*, and several network affiliates. His work was also shown several times on Court TV and has been featured in articles appearing in the *New York Times*, *San Francisco Chronicle*, *San Jose Mercury News, Law Office Computing,* and other media outlets. In 2002, he founded Forensic Arts, in Los Angeles, and today he is the founder and president of Visual Law Group in San Jose, California, where he has pioneered the use of remote-control drone technology and laser scanning for forensic visualization. Mark is a consultant for Pix4D (a leading developer of photogrammetric mapping software) and FARO Technologies (a manufacturer of laser and optical scanners, now the standard for accident reconstruction and forensic work). To date, Mr. Johnson has handled cases in every State of the Union except Vermont and Delaware. He is a frequent speaker and contributor of articles for trade publications and treatises in fields involving demonstrative evidence and computer animation.

Marcelo Jost was born in the South of Brazil and later moved to Brazil's Capital, Brasília. There, at Brasília's University, he made his undergraduate degree in Chemistry, and later his master's degree in Organic Chemistry. From there he went to work at the Brazilian Institute of Environment and Renewable Resources as a technician responsible for the Basel Convention on the Transboundary Movement of Hazardous Wastes. In this work he traveled to Geneva, Switzerland, in 1999 thru 2001, to the Convention Meetings and was the person behind the UNEP Title *Technical Guidelines for the Environmentally Sound Management of Waste Lead-Acid Batteries*, published in 2003. He also traveled to Trinidad and Tobago when the Caribbean countries decided to discuss a common approach about the disposal of lead batteries. Finally, he went to Lima, Peru to attend a meeting of the Pan American Health Organization (PAHO) in lead contamination and the incorrect disposal of lead acid batteries.

Shortly before the *Guidelines* was published, he decided to make a career change and went to work, after a hard trial examination, as a Forensic Expert for the Brazilian Federal Police. His office was in the National Institute of Criminalistics, the most important laboratory of the Brazilian Federal Police. He started at the drugs and chemistry laboratory and soon afterwards moved to the ballistics lab, where he worked with firearms and tool mark examinations for 16 years. At the ballistics lab he produced about three thousand technical reports for the Brazilian Justice System and worked for several years as a ballistics instructor at the Federal Police Academy. He taught thousands of students the concepts of his field and also produced or helped in the production of several technical guidelines for ballistic examinations adopted by the Brazilian Federal Police. He also taught for several years at the Tactical Operations Command of the Federal Police, in the field of long-range shooting for the upcoming snipers. He wrote the ballistics booklet used in the Police Academy and a chapter dealing with ballistics in the book *Local de Crime: Dos Vestígios à Dinâmica Criminosa* (*Crime Scene: From Evidence toward Criminal Dynamics*), which won several awards in Brazil. In 2015, he left the National Institute of Criminalistics and moved to the city of Rio de Janeiro, where he continued working in the firearms and tool mark examinations field at the Brazilian Federal Police, leading a small group of experts. At the end of 2018 he moved to Germany, where he lives now.

Paul Kayfetz is with Paul Kayfetz Inc., Engineering Photography in Bolinas, California He is an expert witness in the areas of visibility studies, comparison photogrammetry, computer virtual reality simulations, and video. He has a background in engineering photography, primarily based on the experience obtained during more than 40 years of consulting work. Related employment experience involved designing and operating measuring devices using optical and photographic principles. Related foundational academic work includes courses in basic engineering measurements, analytic geometry, calculus, physics, and chemistry at UC Berkeley School of Engineering. He performed more than 4000 visibility studies during the past 44 years, of which some 1800 were at night. The techniques of defining testing parameters, making related measurements, and analyzing the results have been derived in collaboration with many engineers, physicists, and human factors psychologists who have participated in producing these studies. He has also worked with comparison photogrammetry, which

is a methodology involving parallax location of camera positions at the scene, the establishment of a grid system of coordinates, and the use of overlay prints that have been developed through application in more than 2000 cases. Computers are now extensively used.

John Louis Larsen is the Founder and President of Larsen Forensics & Associates, Inc. of Glen Ellyn, Illinois. As a retired Special Agent for the Federal Bureau of Investigation he served as an Anti-Terrorism Advisor for the U.S. Department of State he worked on the forensic processing of numerous crime scenes. He also instructed the Chicago Police Department and the West Suburban Violent Crimes Task Force in the development of Evidence Response Teams (ERTs). He has significant experience as a testifying expert in the reconstruction of shooting incidents. For several years, he served as an investigator for the Office of the Special Prosecutor of Cook County, Illinois. He provided training for Sirchie Laboratories Inc., a pinnacle in the crime scene investigation and forensic evidence collection supply world, in the use of the Reflective Ultraviolet Imaging System (RUVIS). Their products are used by law enforcement agencies around the world to identify, collect, record, analyze, evaluate and archive physical evidence. He has taught law enforcement officers for the Suburban Law Enforcement Academy at the College of DuPage, Glen Ellyn, Illinois. He has been a licensed Private Detective in the State of Illinois since 2003 and expanded Larsen Forensics & Associates into a licensed Detective Agency in Illinois, in 2014. From 1981 to 2003, Mr. Larsen was a Special Agent for the FBI and was one of the founders of their ERT program. Since 1984 he has been a Fire Investigator on the national and state levels and an Arson Coordinator for the FBI Chicago Office from 1988 until his retirement. During his career with the FBI he worked as a Senior ERT Leader on assignments including the 1996 Summer Olympic Centennial Park bombing, the 1998 U.S. Embassy Nairobi, Kenya bombing, and the 9/11/2001 United Airlines Flight 93 crash in Shanksville, Pennsylvania.

He is a certified police instructor and has taught around the world, including courses at the FBI Academy in forensic processing and crime scene interpretation.

J. Wright Leonard, CDE, has testified in civil and criminal matters in federal, state, and local courts in over 240 trials/hearings in matters related to questioned documents. She was certified by the National Association of Document Examiners in 1994 and recertified in 2005, 2010, 2014, and 2018. Her experience includes retention by state and federal governments, as well as the legal community and corporations. Her office location base is Philadelphia, Pennsylvania. Ms. Leonard's clients have included the United States Patent and Trademark Office, the National Board of Medical Examiners, the U.S. Army Corps of Engineers, the Associated Press, Amtrak, the Pennsylvania Department of State, General Dynamics, BMW of North America, the Hartford Insurance Company, and the *Philadelphia Inquirer.* She testified as a joint expert for the U.S. Attorney's Office and the Federal Defender in Philadelphia, and has been retained by various district attorney, prosecutor, and defender offices. She completed 5 years of semiannual proficiency testing in handwriting identification by the Forensic Profiling Laboratory of Latrobe University in Melbourne, Australia. She also completed the Image Analysis Program at the Rochester Institute of Technology, as well as Microscopy for Document Examiners at the Hooke College of Microscopy in Chicago. A typical year includes 40–50 hours of continuing education in Document Examination and Handwriting Identification. She currently serves as Secretary and Board Member of the Association of Forensic Document Examiners, and Trustee, as well as Secretary and Board Member, of the National Association of Document Examiners. She served as an Editorial Board Member of the *Forensic Journal* of the National Association of Document Examiners, 1999–2004. She is a voting member of ASTM International, a member of the International Association for Identification, New York, and the Certified Fraud Examiners, Philadelphia. She is also a past member of the Evidence Photographers International Council (EPIC). Currently, she provides services including handwriting and hand-printing identification with photographic documentation, examination of documents for alterations, indented writing, and nondestructive ink and paper differentiation using state-of-the-art equipment such as the Foster and Freeman Video Spectra Comparator.

Patrick Linnenbank, PhD, is a Dutch national who holds a unique combination of medical, business, forensic, and security expertise. He started out his career as a Medical Doctor, later earned his MBA from INSEAD and served as Vice President (Partner) at the Strategy Consulting Firm Bain & Company in their Technology Media Telecom and Healthcare practices. While working at Bain he also qualified and worked as a Forensic Medical Examiner, Mass Grave Investigator and an Expedition Doctor, the latter allowing him to become Fellow of the Academy of Wilderness Medicine (FAWM). After leaving Bain & Company, Dr. Linnenbank further specialized in security and investigations in Israel and the United States and founded a high-risk security and investigations company, Seraph Protection Group. Intel and (photo) surveillance are a core part of the Seraph integrated security solution, daily operations and the curriculum at the Seraph Security Academy.

Eugene Liscio is a registered Professional Engineer in the Province of Ontario, Canada and is the owner of ai2-3-D, a consulting company specializing in 3-D forensic documentation, analysis and visualizations. Mr. Liscio has testified in court in both the U.S. and Canada utilizing 3-D technologies including photogrammetry and laser scanning and he has also provided interactive 3-D crime scene testimony at courts in Canada and the United States. He was called to assist

the Ontario Provincial Police in the 10/22/2014 shooting at Parliament Hill, Ottawa, Canada at the House of Commons and has also worked with the RCMP, OPP, SIU, and other police agencies to assist in officer involved shootings. He is the Past-President of the International Association of Forensic and Security Metrology (IAFSM) and is also a member of Professional Engineers Ontario, the International Association of Bloodstain Pattern Analysts, Canadian Identification Society and the American Society of Photogrammetry and Remote Sensing. Currently, Mr. Liscio is an Adjunct Professor at the University of Toronto, where he teaches a 3-D Forensic Reconstruction and Mapping course as part of the Forensic Sciences Program. He is actively engaged in research and validation by mentoring students in areas including Bullet Trajectory Analysis, Area of Origin Analysis of Bloodstain Impacts, Laser Scanner Accuracy, Clandestine Grave Documentation, and 3-D Scanning for Autopsies.

Abbe L. Lyle is a professional photographer, private pilot, educator, and writer. She studied English at the University of London, UK and worked as a speechwriter, lobbyist and research associate for a member of the European Parliament before emigrating from England to America in 1997. Ms. Lyle currently specializes in forensic scene visualization, utilizing the latest in mapping and animation technologies, including, photogrammetry, drones and laser scanners for the development of detailed interactive 3-D exhibits. She teaches the fundamentals of drone flight, including FAA regulations surrounding the professional use of drones commercially. As a passionate advocate for women in the UAV industry, she often speaks at conferences, educating and helping women to succeed in this highly skilled and competitive marketplace. Her forensic work includes still photography with a specialty in infrared imaging, and post production in a multitude of software programs. She conducts research required for development of case studies and white papers as well as handling the primary research required for individual forensic case preparation. Ms. Lysle emphasizes that in order to successfully produce the required work for clients, it is crucial to remain impartial. It is most important to be able to think logically and execute tactically to deliver accurate results.

Kathryn McMillan is a Video Producer, Camera Operator, and Location Scout with over 25 years in the television and corporate film business. Since 1992, she has written and produced hundreds of television programs, commercials and web videos for small businesses, government agencies and non-profit organizations. She has traveled overseas as a Director of Photography shooting in over 10 countries including Peru, Burma, China, and Thailand. When not working behind the camera on corporate films, she utilizes her camera-eye as a Location Scout helping out of town producers find the perfect location to shoot in Florida. She is known for specialization in producing on a "budget!" Her specialties include Camera Operator (HD), Director (Self Shooting), Director of Photography, Editor (Final Cut Pro), Floor Manager, Location Scout, Producer/Director, Production Coordinator, Production Manager, Stage Manager, and Videographer. In addition, her Forensic Video business is growing rapidly.

Jorge Mendoza graduated from the University of Texas at El Paso in 1985 with a bachelor of science degree in mechanical engineering. He then worked in the Aerospace Industry for 8 years, first at Rockwell International, El Paso, Texas on the B1 Bomber, and then at the Naval Air Station Alameda, California. He gained extensive experience in producing accurate 3-D computer models for engineering analysis (Finite Element Analysis), production (manufacture) and animation (presentations). Mr. Mendoza began his career in forensic analysis and animation at the Naval Air Station in Alameda in 1992, when an A6 Intruder crashed into the San Francisco Bay, killing both pilot and copilot. He then founded Litigation Animation, Inc. in 1993. As of March 3, 2019, Litigation Animation, Inc. has produced over 2000 forensic exhibits for mediations and trials. Litigation Animation, Inc. handles both civil and criminal cases. These cases vary widely from surveillance video (biomechanical movement, vehicle trajectory, skid marks), laser scanning (accident scene, machines, vehicles), shootings (bullet trajectory analysis and human positions), robberies, as well as vehicular, aircraft, and boating accidents analyses and day/night visibility analysis. When Mr. Mendoza first started Litigation Animation, Inc. there were zero surveillance video cases, but today, roughly 50% of his work involves surveillance and photogrammetric analyses. Mr. Mendoza's ability to accurately make measurements from surveillance video and to track human movement is outstanding. Litigation Animation, Inc., is a technology-based company assisting clients developing case strategies using the latest tools, to put forward compelling and defendable analyses and visuals for mediation and trial. Litigation Animation uses laser scanners, aerial drones, underwater drones, as well as 3-D and 2-D visualization software. The scientific procedures used in his photogrammetric work can be reviewed in "Reverse Projection Photogrammetry" (SAE Technical Paper Series 1999-01-0093 "Using Computer Reverse Projection Photogrammetry to Analyze an Animation"). Mr. Mendoza is currently Vice President of the Society of Forensic Engineers and Scientists and is a licensed Federal Aviation Administration (FAA) drone pilot. Litigation Animation, Inc. also provides aerial and ground-based laser scanning services. He has taught computer animation at local community colleges and today continues teaching forensic animation privately.

Denise Murmann, DDS, graduated from the University of Illinois at Chicago Dental School in 1992. She practices general dentistry at and is the owner of Murmann Dental Health, PC in Naperville, Illinois. In 1999, she became a member of Disaster Mortuary Operational Response Team (DMORT) Region V, as a forensic odontologist. DMORT is

the federal disaster team that is part of the National Disaster Medical System (NDMS). She was deployed twice. The first time was in 2001 as part of the 9/11 World Trade Center Dental Identification Team. The second deployment was in 2005 after Hurricane Katrina.

Dr. Murmann serves as a consultant for several local coroner offices: DuPage, Kane, Kendall and Will. She is a member of the Cook County Medical Examiner's Disaster Response Team. She is also a Volunteer Forensic Odontologist (VFO) with the National Missing and Unidentified Persons System (NamUs). In 2004, she was the principle researcher in a study presented at the American Academy of Forensic Sciences annual scientific session in 2005 and then published in the *Journal of Forensic Sciences* (JFS) in 2006 with the title "A Comparison of Animal Jaws and Bite Mark Patterns." She was a contributing author to the textbook *Manual of Forensic Odontology* (Fifth Edition, 2013). In 2016, she brought together a team to study the holes or defects that are found on most Tyrannosaurus rex skulls. As a part of collecting the data on SUE in Chicago, Illinois, a 3-D scan was completed using a Kinect sensor. She was a contributing author to the paper explaining the technique, published in *PLoS ONE* in 2017, "A Method for Rapid 3-D Scanning and Replication of Large Paleontological Specimens." Dr. Murmann is a board certified diplomate of the American Board of Forensic Odontology (ABFO), a member and past president of the American Society of Forensic Odontology (ASFO), a fellow in the Odontology Section of the American Academy of Forensic Sciences (AAFS), and a member of the Academy of General Dentistry (AGD).

George Pearl is the owner and President of Atlanta Legal Photo Services (ALPS) Inc. They are a specialized technical lab and services company which has for 40 years been providing demonstrative evidence for use in litigation. They help attorneys win cases by telling comprehensible stories that juries understand with photography. He has testified as an expert witness in hundreds of cases in federal courts, superior courts, state courts, and others in and out of the State of Georgia. He is one of only a few Board Certified Evidence Photographers in the country, being qualified as a forensic evidence photographer by the Professional Photographers of America. He produces scale drawn maps, diagrams, illustrations, technical drawings, scale aerial photos shot to order, panorama photography, medical photography, IR/UV and microscopic, Reverse Projection Photogrammetry, and Night Visibility Studies and Conspicuity. Night Visibility is a George Pearl specialty, showing what people could have seen or not seen under various lighted conditions. He has the expertise to study the scene and connect the amount of illumination there to the images presented in the courtroom.

Video productions include *Day in the Life*, reconstruction demonstrations, and Time and Distance study videos of what the driver saw, and so on. His laboratory is expert at the duplication of X-ray film and digital scanning, copy services, blow-ups, dry mounting, lamination, building of scale models, fetal heart monitor video scans, still frame prints from video, audio enhancements and high-speed dubbing. His company is also qualified to perform the Examination of Questioned Documents. An unusual aspect of their business is ALPS, Inc., works for the plaintiff and defense as well as providing criminal defense where they have proved many defendants as to be innocent!

Carlo Rosatti has been in the field of Firearms/Toolmarks for the past 38 years. FBI and ATF Trained and Certified Forensic Firearms/Toolmarks Examiner (1990–2009). Contract Examiner at the FBI Laboratory TEDAC Program (2009–2013). Contract Examiner at the FBI Laboratory Firearms/Toolmarks Unit (2014–2016). Firearms/Toolmarks Technician (1979–1990). Court Qualified forensic firearms, toolmarks, gunpowder/gunshot residue, serial number restoration, and shooting incident reconstruction in federal, state, and international jurisdictions. He completed an FBI as well as ATF training program. Each of these programs is accredited by the American Society of Crime Laboratory Directors Laboratory Accreditation Board. Mr. Rosati has examined thousands of items of evidence while employed with the Federal Bureau of Investigation, Laboratory Division, Firearms/Toolmarks Unit as well as the Bureau of Alcohol Tobacco and Firearms. His experience at the FBI and ATF involved working a variety of cases, including: shootings, homicide, suicide, burglary, bombings, auto theft, serial number restoration, shooting incident. He accepted a position as Adjunct Instructor at the Virginia Commonwealth University where he teaches an undergraduate class in firearms/toolmarks for the Forensic Sciences Department. He has provided his training model at the International Law Enforcement Academy Bangkok, Thailand as well as U.S. Department of Justice, International Criminal Investigative Training Assistance Program (ICITAP) in Bogota, Colombia. He has also lectured at the University of Central Oklahoma, University of Maryland, George Mason University, Virginia Commonwealth University, Keystone College, and the University of Padova in Italy. Mr. Rosati is a Distinguished Member of the Association of Firearms and Toolmark Examiners (AFTE), a past member of the Board of Ethics, a past member of the Board of Directors as well as a Past AFTE President. Mr. Rosati also holds memberships in the Association of Crime Scene Reconstruction (ACSR) as well as the International Association of Auto Theft Investigators (IAATI). He is a past member of the Scientific Working Group for Firearms Identification (SWGGUN). Mr. Rosati has inspected and assessed laboratories as both an ASCLD/LAB Inspector and ASCLD/LAB ISO Assessor. Mr. Rosati has been court qualified in federal, state and international courts. He has been on CNN, *FBI Gives Glimpse inside Real CSI*; CNN, *FBI Waits for Access to Site of Kenya Mall* Attack, *FBI Files* "Season 2, Episode 2." He has worked on such high-profile cases such as the Italian Unabomber in 2007, Penttbomb (9/11), *State of Florida v Nathaniel R. Brazill*, the United States Holocaust

Museum Shooting, as well as historic cases such as the examination of the John Wilkes Booth Derringer, and the Columbia Space Shuttle Disaster.

Noah Ryder serves as a Managing Partner at Fire & Risk Alliance, a firm focused on fire protection design, suppression testing, computer modeling and risk. In 2012, Mr. Ryder co-founded Custom Spray Solutions. For over 20 years, Mr. Ryder has focused on understanding the physics of fire in order to improve safety. He is involved in applied research efforts across a wide range of topics involving fire and life safety. He is the recipient of numerous applied research grants including NSF and FPRF. He has patents pending on innovative suppression and detection devices and is the recipient of a number of awards including the Best Paper Award at the AUBE/SUPDET 2017. Mr. Ryder is qualified Subject Matter Expert for Saudi Aramco in Fire Protection, Loss Prevention and Hazard/Risk analysis. He is actively engaged in applied research related to advanced fire detection and fire state determination, fire suppression, and battery energy storage solutions. He is working on a PhD in Mechanical and Mechatronics Engineering, University of Waterloo and holds a MBA as well as a MS in Fire Protection Engineering from University of Maryland. He has taught Fire & Explosion Investigation, Firefighting Robot and Industrial Fire Protection Engineering courses at UMD and Advanced Enclosure Fire Dynamics course at the University of Waterloo (Ontario, Canada).

Lawrence Stringham has been connected with law enforcement since 1985 when he joined the U.S. Air Force as a Security Policeman. Working with the USAF and later with the National Guard, Mr. Stringham became a certified police officer in Little Rock, Arkansas. Retuning to Hernando County, Florida, where he was raised, he was hired by the Hernando County Sheriff's Office as a 911 dispatcher and in 1991 became a crime scene technician. He worked there for 6 years, during which time he attended basic and advanced courses in crime scene and arson investigation and fingerprint technology. In 1997, he became a Forensic Technician for the Cape Coral Police Department. At that time, this assignment was a one-man position. He worked hard to grow the department and its forensic section. Being promoted to supervisor of the Forensic Section in 2005, Mr. Stringham now supervises 11 employees and has increased the department's viability by creating latent, computer, video, and lab units within the Forensic Section. In 2017, he oversaw the accreditation of the Crime Scene Unit and the lab to ISO/IEC 17020 standards. He has an associate degree in criminal justice and has testified as an expert in the fields of latent print identification, 10-print identification, and crime scene procedures to include forensic light sources, photography, scene processing, and crime scene reconstruction. He presently sits on the board of directors for the IAI and is on the Crime Scene Subcommittee. He is presently serving as the Conference Planner for the Florida Division of the International Association for Identification (FDIAI) and is a past president of the FDIAI.

Dawn Watkins holds a master's degree in criminal justice and is a Certified Latent Print Examiner, Certified Forensic Photographer, and a Certified Senior Crime Scene Analyst with the IAI. She is a recipient of the Good of the Association Award and a Distinguished Member too. She has been in the field of Forensic Science for 43 years, formerly with the Federal Bureau of Investigation, Washington, DC. She recently retired as the Senior Latent Print Examiner/Crime Scene Investigator with the Palm Beach (Florida) Gardens Police Department. She serves on the Educational Board of the Gold Coast Forensic Association and is an instructor for various forensic organizations. She is on the Latent Print Committee for the FDIAI and the Ten Print Science and Practices Subcommittee of the IAI. She has been a lecturer at the IAI Training Conferences since 1996.

Amy Wedge is a freelance Forensic Artist and Medical Illustrator with a first-class honors degree in Illustration from Edinburgh College of Art and an MSc in Forensic Art and Facial Identification from Dundee University. During her time studying at the Centre for Anatomy and Human Identification she was trained in facial reconstruction, age progression, craniofacial superimposition and forensic photography. Since graduating from Dundee in 2017, Ms. Wedge has obtained human remains training certification and completed a 4-week internship program with Odyssey Field-School where she was responsible for creating and implementing a standard operating procedure for forensic photography. She currently resides in Scotland as a self-employed forensic artist and illustrator with an interest in missing persons cases.

Emily J. Will, D-BFDE, was awarded her Board Certification as a Forensic Document Examiner by the Board of Forensic Document Examiners in 2003 and she was recertified in 2008 and 2013 by the BFDE. The BFDE is accredited by the Forensic Specialties Accreditation Board. She was also awarded certification by the National Association of Document Examiners in 1997 and recertified in 2005, 2010, and 2015. She has held the designation, Certified Fraudulent Document Examiner by AllRegs Academy since 2008.

She has been in private practice for 30 years, examining cases from 43 of the United States, and also internationally. She has been accepted as an Expert Witness and testified in State Civil/Criminal courts in 11 states, and in federal court—appointed to testify by state and federal courts. She is proficient in both Handwriting Examination and Document Examination and she participated successfully in the Handwriting Identification Proficiency—testing program of the Forensic Expertise Profiling Laboratory at Latrobe University in Australia. Ms. Will is a member and Past President of the Association of Forensic Document Examiners (AFDE) and was an Editorial Board member for the Journal of Forensic Document Examination (AFDE Journal) from 2005–present. She was the Secretary, Board

of Forensic Document Examiners, 2007–2012 and has been the Treasurer, 2015–present.

She is a member of the International Graphonomics Society (IGS)—a society for the science and technology of handwriting and other graphic skills. She is also a member of the National Association of Document Examiners (NADE) and was the Editor of the *Journal of the National Association of Document Examiners* from 1999–2004. She is the Director, Forensic Specialties Accreditation Board (FSAB), 2008–present, the Secretary FSAB 2015–2017 and Vice-President 2017–present. And, she was a member of NIST, Human Factors Expert Working Group for Handwriting Examination during a 3-year project from 2015–2018.

She has both a BS in education and a MA in counseling from Syracuse University, 1969 and 1970, and she studied the Fundamentals of Microscopy for Forensic Document Examiners at the McCrone Institute College of Microscopy in 2005. She has had many articles published in nationally recognized periodicals and delivered presentations to highly regarded audiences at many levels and venues.

David "Ski" Witzke is Vice President, Program Management in Foray Technologies.

He has more than 25 years of AFIS and forensic digital imaging experience, is considered to be one of the foremost experts in forensic digital imaging technologies. Mr. Witzke is an associate member of the International Association for Identification (IAI) as well as the European and regional divisions of the IAI, is a member of the Canadian Identification Society (CIS), and is an associate member of the European Network of Forensic Science Institutes Fingerprint Working Group (ENFSI FWG). In addition, Mr. Witzke was elected to the ENFSI FWG Steering Committee at the organization's 2017 annual meeting in Cergy, France. He was recently named as the Chairperson for the Digital Evidence Subcommittee for the IAI. Mr. Witzke has been invited to speak at hundreds of regional, national, and international IAI conferences; AFIS user group meetings; and the ENFSI FWG meetings in Split, Croatia; Taormina, Italy; and Barcelona, Spain. He was also the guest instructor of the Digital Imaging of Evidentiary Photography training program at the FBI Academy in Quantico, Virginia for more than 7 years, and was the instructor for the Forensic Digital Image Processing program at the British Columbia Institute of Technology (BCIT) in Vancouver, BC for more than 6 years. In addition, he has provided digital imaging training for the Automatic Fingerprint Recognition systems (AFR) Consortium at police agencies throughout the United Kingdom, and for the Federal Department of Justice and Police AFIS/DNA Services in Berne, Switzerland. Mr. Witzke is a contributing writer for three well-known forensic books: *Crime Scene Photography* (Third Edition, 2016, Academic Press), *Introduction to Crime Scene Photography* (2012, Academic Press), and *Footwear, The Missed Evidence* (Third Edition, 2013, Staggs Publishing). *Crime Scene Photography* has been chosen by the IAI certification committees for the Certified Crime Scene Investigator (CCSI) Certification Test, the Certified Crime Scene Analyst (CCSA) Certification Test, the Certified Senior Crime Scene Analyst (CSCSA) Certification Test, and the Forensic Photography Certification Test. Mr. Witzke is also working on a fourth book on forensic digital imaging; the book is currently scheduled to be published in the second half of 2021.

Robert Wyman is the Owner of Wyman Enterprises, Inc., in the Miami/Fort Lauderdale area in Florida. He is a consultant to attorneys, engineers, architects, medical doctors, risk managers, fleet managers, insurance representatives, investigators, and accident/incident victims. He is an expert witness, accepted in federal, state, and local jurisdictions. He has published contributions in four books and numerous periodicals. His specialties include the production of PowerPoint presentations approved by the Florida Bar for Attorneys' Continuing Legal Education (CLE) credits on subjects including Forensic Photography, Photogrammetry, GPS Forensics, Video Forensics, Low-Light/Nighttime Photography for Crash Reconstruction, and iPhone/iPad Apps for Crime Scene, and Traffic Crash Reconstruction.

1 Forensic Photography
The Purpose

Sanford L. Weiss

CONTENTS

The Powers of Observation 1
Forensic Engineers 3
A Brief History of Photography—With an Emphasis on the Acceptability of Photographic Images in Court 3
Visualization 5
Conclusion 9
Appendix I 10
Notes 10

Digital imaging is the way of today's world. Of course, there are still limited uses for traditional, film-based technologies, but they are now mostly relegated to the photo-artists and to some Third World countries.

Anything written regarding digital image resolution, sensor size, camera size, camera function, camera cost, etc., is mostly out of date before the words hit the street. However, we must start somewhere, so we shall speak about the state of the art, 2019. For the sake of consistency, I have chosen to show mostly Nikon camera equipment for the subject hardware in this book. Some are more affordable (prosumer) and some are at the more expensive professional level, but all are certainly adequate for evidence photography. There are other good, reliable brands of cameras on the market. It is totally up to the photographer to choose what works best for them. I choose Nikon because they chose me over a decade ago. So, I am prejudiced in their favor and I hold the pen.

Some technological aspects of digital imaging are beyond the scope of this book. In forensic, evidence, and technical photography, the actual purpose of the photographic technology is to capture adequate images for the best possible documentation and preservation of an "accurate" version of reality and then bring them into the courtroom. Accurately documenting the evidence is the reason we carry cameras and accessories. We need to bring today's evidence, if only by proxy, into the courtroom at some faraway date in the future. The scene and evidence itself are highly perishable. Tomorrow is too long to wait for making images of everything important. And most of the time certain aspects of the incident are too large to transport to the courtroom. In forensic photography, accuracy of the reproduction is the key. You can never settle for mediocrity. You must always strive to be the best.

There are certain fundamental difficulties involved with attempting this discipline. The difficulties are due to the laws of optics, physics, and physiology. Our brains are the most powerful computers in existence, and our brains can easily discern differences between images and reality. For us to create images with anything other than our eyes and then say to our brains, "this accurately and realistically portrays what we see" is daunting.

Some of the major roadblocks to the creation of realistic images are the limitations of photography to capture the contrast, color, texture, perspective, dimensionality, and resolution of an original scene or object.

It is the intention of this book to educate the reader about the most complete and up-to-date methods to capture and reproduce images most accurately representing the evidence. It is also necessary for the reader to understand the difficulties in attempting to produce perfection in imaging and then to explain the difficulties to anyone examining either the images or the photographer.

The text, case studies, and exercises presented in this book are meant to be read and then practiced. Of course, no two projects are ever alike. Aspects may seem familiar, but there are always differences. The practitioner must maintain an open mind and be careful, diligent, and creative. The photographer must be an investigator first and a photographer second, using photography as a tool.

Above all, there is no way to learn this skill without practice. But trying to be a forensic photographer by practicing what you remember may lead to tragedy; each case contains an aspect of learning from scratch.

THE POWERS OF OBSERVATION

Proper use of the basic principle of the scientific method not only helps develop solutions to difficult questions, it teaches people to reason analytically in each step of their investigation and/or project. People must use a certain pattern of thought to lead from one step to the next in any endeavor. If they leave out steps due to preconceived notions of results, they are doing a disservice to their work. It is necessary

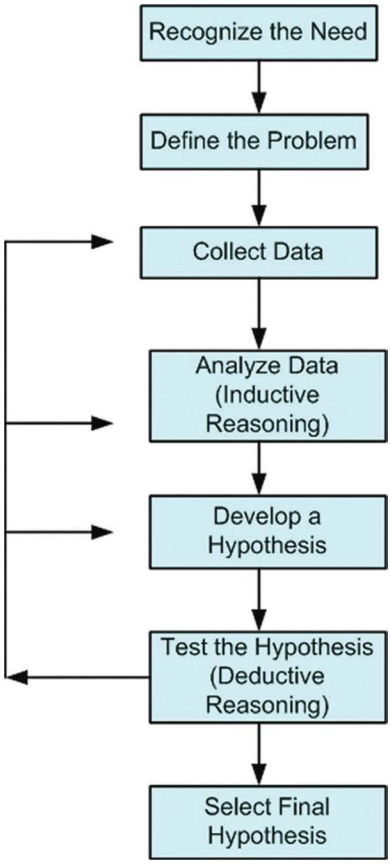


FIGURE 1.1 Steps of the scientific method.

(From Sandy Weiss/Packer Engineering.)

to use good, sound, scientific reasoning to ensure success. Above all else, the powers of observation are what we need to practice and hone and become the basis of the way we work.

American jurist William Wirt once said, "Perhaps there is no property in which men are more distinguished from each other, than in the various degrees in which they possess the faculty of observation. The great herd of mankind pass their lives in listless inattention and indifference as to what is going on around them, while those who are destined to distinction have a lynx-eyed vigilance that nothing can escape."[1]

A familiar character with notoriously astute powers of observation is the fictional detective Sherlock Holmes. In Sir Arthur Conan Doyle's Sherlock Holmes story, "The Red-Headed League," Holmes states about Jabez Wilson, whom he has just met, "Beyond the obvious facts that he has at some time done manual labor, that he takes snuff, that he is a Freemason, that he has been to China, and that he has done a considerable amount of writing lately, I can deduce nothing else."[2] Holmes was able to deduce all these points about the man after what the untrained observer would classify as a single glance. He stated of his method of detection, "You know my method. It is founded upon the observation of trifles."[3] Holmes also said to Dr. Watson, "Not invisible but unnoticed, Watson. You did not know

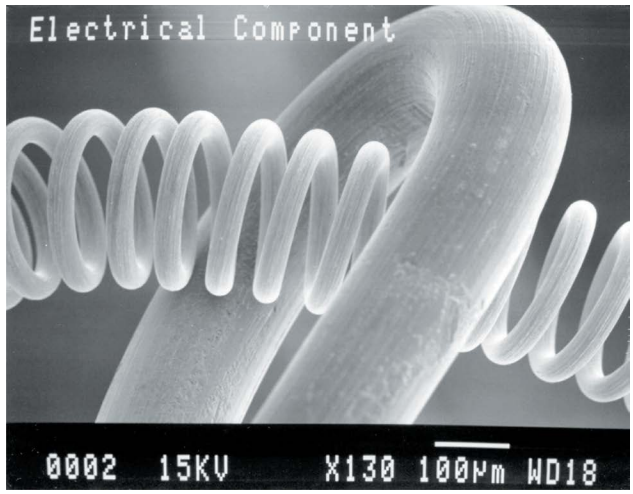


FIGURE 1.2 Electric lamp filament by SEM.

(From Sandy Weiss/Packer Engineering.)

where to look, and so you missed all that was important. I can never bring you to realize the importance of sleeves, the suggestiveness of thumbnails, or the great issues that may hang from a bootlace."[4] Holmes was a proponent of the basic theorem that everything is significant.

Thomas Edison spent years observing electrical and mechanical phenomena while inventing the electric light bulb. He performed many experiments before he found the correct solution to the problem. He once wrote, "The average person's brain does not observe a thousandth part of what the eye sees. It is almost incredible how poor our powers of observation, genuine observation, are."[5]

The same principles of observation apply to forensics. A good investigator will use their training and intellect to decide what details of a project are truly significant. Missing important details, no matter how small, during an investigation can lead to incomplete or erroneous conclusions.

When photographing evidence, the photographs should substantiate what the investigator can see but not be a substitute for thorough observation. When looking through the camera lens, the photographer should be consciously aware of what story the resultant photographs will tell. Each image is a chapter or subchapter of the story of the evidence. Photographs must be taken to tell every possible story. It takes training and mental discipline to resist telling and illustrating a specific or preconceived story before knowing what the true story is. Once the investigation is completed and an educated conclusion is reached, photographs must be available to substantiate the conclusion. Insurance investigators may capture a required set of overall photos from each claim. We have all seen those photosets. The problem with performing at that level is the photos are "documentation" rather than "investigation." It is dangerous when working backwards from a general set of photographs to assume the photographs will, upon later inspection, yield the substantiation to prove any concept.

Educators at the Brooklyn Museum of Art originally developed what they call an "Object Observation" exercise as a strategy for honing their skills as careful "lookers" and gallery teachers. New York City Museum School teachers refined the exercise further for use with students. After studying an object for 10 to 15 minutes, students present their objective and subjective observations in writing and their questions to others in the group as an exercise.[6] In observation, it is necessary to eliminate false assumptions and misleading generalizations. By focusing on the actual rather than the presumed, educated observation leads to proper solutions.

How does a person become an effective observer? The first way is by consciously practicing the discipline of looking and remembering. Effective observation depends on a properly trained memory. In science, vision is worthless if not retained.

Photography is a mechanical means of retaining vision. A properly executed photograph is one of the only ways to capture and stop time. Luckily, the camera was never intended to replace vision because it cannot. But the trained photographer can substantiate and even enhance vision with photographs.

The photographic go-kit will change by specialty. Obviously, the sports photographer will carry different tools than the portrait or evidence photographer. Evidence photography is its own sub-discipline. The protocol of evidence photography is one that forces the observer to work backwards. It relies upon the documentation of the effect while eventually focusing on the root cause. No matter the magnitude of the event, the documentation always tunnels down to the examination of something under magnification.

FORENSIC ENGINEERS

Forensic engineers apply their knowledge of engineering to the interpretation of the characteristics of physical evidence. For example, a forensic engineer with a background in materials engineering might examine a component of an aircraft engine to reconstruct an accident and determine whether a manufacturer is responsible for the injuries suffered by an owner's family suing for damages after a crash.

In addition to all the certifications required of an engineer, forensic engineers in an area of specialization such as materials engineering require certification by the American College of Forensic Examiners or the American Board of Forensic Engineers. To qualify as expert witnesses, they also need years of experience. Some engineers work full-time in forensics. Forensic photographers, like forensic engineers, need proper training, certification, and practice to retain their skills and credibility.

Any company or firm using imaging for evidence documentation must have either an accepted practice or protocol to guarantee the authenticity of their images. The practice or protocol must be published, accepted, and adhered to in order to guarantee chain of custody of the images. It is recommended for the company do their own image processing and storage.

A Brief History of Photography—With an Emphasis on the Acceptability of Photographic Images in Court

Photography became a reality in 1827 when Joseph Nicephore Niepce, a French lithographer, succeeded in permanently capturing the view outside his window on a metal plate coated with bitumen. In 1839, the French government purchased both the patent it had granted to Niepce and the one they had granted to Louis Jacque Mande Daguerre for a process by which he was able to capture images on silver-coated copper plates. The French presented both inventions to the world as gifts, and news of the discoveries spread rapidly. Within just a few years, photographers were practicing their craft upon architectural subjects, still lifes, portraits, and landscapes. On July 5, 1853, George Barnard took the first known photograph for journalistic purposes of the fire at the Oswego Mill, in Oswego, New York.

During the same year, the Crimean War became the first major conflict to be documented photographically. Photography was commonplace by the time the American Civil War was documented in the 1860s. Photography was, however, still an awkward discipline to practice, and the photographers of the time needed to haul enclosed wagons as portable darkrooms used to both coat and process their wet-plate collodion images. To avoid some of the battlefield danger, it was standard practice for a photographer to appear on-site after a battle and pose the dead in ways making for the most graphic compositions, often using the same bodies for many different images.[7] Prebattle images also exist depicting live soldiers posing as dead ones.[8] It would be an interesting point of discussion to decide if images generated then, using those practices, should be considered inaccurate or deceptive. The intent of the images was to inform the viewers of the conditions of the war, not to create a scenario that could not have occurred. "Technical limitations made it necessary to 'enhance' the photographs by staging them, in order to give the Public, the most accurate depiction of the war."[9]

One of the earliest known forms of photographic deception was spirit or ghost photography. Due to the long exposure times necessary for early film media, subjects not moving in the frame came out looking normal and solid in the finished photograph, but subjects moving during the exposure were often recorded in a see-through, blurry manner.[10] After the discovery of this phenomenon, ghostly images were taken on purpose, intended for amusement, and then published and distributed to the public. When a photographer named Richard Mumler from Boston claimed to have photographed real ghosts, his work initiated a wave of international popularity with spirit photography and started a scientific controversy lasting well into the 20th century. It is human nature to practice deception to achieve personal gain.

By 1870, Richard Leach Maddox had discovered the process for making dry plate negatives, and the "ghosts," who were also part of the scam, were exposed onto the plates ahead of time and the negatives were then double-exposed with the second image. Due to the fuzzy and see-through nature of the ghosts, any person could pose as the ghost and then the photo-salesman would imply the ghost was a part of the departed family, and gullible customers would accept the explanation as the truth. A photo of long-dead Aunt Lucy, Uncle Harry, or Cousin Earl would compel the family to pay large sums of money for the photos. In 1872, Richard Mumler himself was put on trial for fraud, and his trial became the start of a battle between "Science and the Séance," lasting for decades.[11] These photographs and the groups formed to study them were afforded a degree of credibility by the people associated with them. Sir Arthur Conan Doyle was vice president of the Society for the Study of Supernatural Pictures, and Harry Houdini was later to be a charter member.

Within a very short time after its invention, photography became a standard means of documenting evidence by the police departments of the world. The Belgian police used photographs of arrested persons as photo mug shots since 1843.[12] Photography in any of its forms was then, and is now, the only way to permanently capture accurate images of an object or event. By written standards, "to be admitted in evidence in a court trial, a photograph must be a *fair and reasonably accurate representation of the subject portrayed*"[13] (see Chapter 2), which has been the major prerequisite for the admissibility of courtroom photographic images since they were first introduced in 1859.[14] Most of the very early use for photographs in the courtroom was for the analysis of questioned documents[15] (see Chapter 14).

Photographic evidence has always been challenged by enterprising individuals finding the content of the images in question to be damaging to their side of a case or trial. This quote was entered into evidence in 1899: "It is common knowledge that as to such matters, either through want of skill on the part of the artist, or inadequate instruments or materials, or through intentional and skillful manipulation, a photograph may not only be inaccurate but dangerously misleading."[16] It should be remembered that the photograph itself is not the evidence. The testimony of the witness is the evidence, and the image is an exhibit with the testimony.[17] "The party seeking to introduce the photograph into evidence must be prepared to present testimony saying the photograph is accurate and correct."[18] This rule applies no matter what the media of the photograph.

With regard to forensics, in 1983 John Duckworth wrote, "We carry photographic evidence into court that tells the story and is accurate and understandable."[19] The question is, how accurate does a photograph have to be in order for it not to be determined inaccurate? "All 2-Dimensional (2-D) photographs are an abstraction in one way or another. Even if the picture reveals a completely realistic and recognizable subject, it is only a 2-D representation of a 3-D scene, consisting of a pattern of dyes on a piece of chemically treated paper a few millimeters thick."[20] This reasoning does not seem to jeopardize the admissibility in court of 2-D still or motion images. Many factors contribute to the definition of a photograph as an abstraction. Perspective changes through the use of wide-angle and telephoto lenses, differences in magnifications between print and original, variable viewing distances, hardware distortions, film/digital limitations either expanding or contracting the contrast range of the scene as compared to human vision, color limitations, etc., are just a few. There is no way for us to create artificial images totally duplicating what we can see due to the inherent differences between human vision and the media we use to capture the images (see Chapter 10).

Our eyes are very much like cameras, except our eyes are able to adjust to a wider range of brightness than any camera/film/digital combination possibly could. Normal human vision operates at a range between strong sunshine with a light intensity approaching 10,000 foot candles (fc) and moonlight at about 1/1,000 of a fc. Night vision after full dilation of the human eye pupil may reach limits of 1/1,000,000 of a fc.[21] The eye cannot see this whole range at one time, but it adjusts from one brightness range to another by a dilation and contraction process called **adaptation**. The maximum brightness ratio the healthy eye can perceive at any one point is about 1,000:1. The camera/film or digital camera combination can capture and reproduce a brightness range of about 300:1 or better, but not close to the human eye. "The intensity level of illumination depicted in a photograph is inferred rather than seen."[22]

People with normal color vision can discriminate about 1,000,000 distinct colors. Photo reproduction, either on print or electronic media, does not come close to recreating that range, although the computer is also able to distinguish more than the same number.

The factor allowing us to accept photographs, movies, and television as reasonable facsimiles of reality is, *we see what we expect to see*. Photographic identification requires the pattern in the picture be relatable visually to the image the observer has formed of it, or is expected to form of it, in his mind. Today's television and video productions have made Americans a truly visually oriented people. Regardless of language differences or degrees of literacy, most people can understand a picture or drawing; hence, visuals can be regarded as a truly 'universal language.' People are so used to seeing 2-D representations of 3-D subjects that their minds automatically reconstruct the 3-D images for examination. There was no color in photographic images until well into the 20th century, but black-and-white photographs were still accepted as representations of reality. Most of the small percentage of people in the world who are almost completely color blind are still able to distinguish some colors. Obviously, people are able to recreate reality in their minds by viewing images that are only minimal representations of that reality.

Commercial photographers often attempt to enhance certain details of a photograph through the use of software to represent special lenses, filters, or lighting. Evidence

photographs should be totally honest and unenhanced in any way to most accurately portray the subject photographed. All of the equipment-related limitations affecting the capture of an image seem to be acceptable in the eyes of the court as long as there has been no attempt to consciously deceive the viewer. Only changes in the content of the image should be classified as affecting authenticity. Changes in the elements of contrast, color, density, and enlargement do not necessarily alter the ability of an image to accurately depict the original scene. Certain procedures for enhancing digital imaging files are analogous to the once customary basic darkroom techniques for image enhancement. These procedures are normally applied to an entire image. Digital imaging software can, for example, be used to control the contrast of images or to enlarge them. The idea of deception can become an interesting point when the deception is not a conscious effort but instead the limitation in knowledge and/or talent on the part of the photographer. For example, the representation of a night scene meant to show a jury what the actual scene "looked like" to the original viewer is a physical impossibility. Given enough exposure, a moonlit scene will not only show a normal (daytime-like) brightness range but it will also look like it was taken in bright daylight in the captured image. Sadly, images of this type often go unchallenged in court. A photographer probably will not be faulted, the photographer's intent is clearly not to deceive.

Most people have had experience with digital photography but have no idea what it would take to create a digital image. The inner workings of computers and the methods of image digitization are difficult concepts. In 1985, an article in the *Whole Earth Review* predicted the "end of photography as evidence of anything" due to the ease of manipulation of digital images. As recently as February 2000, digital images were being thrown out of court as being too difficult to defend as tools to properly investigate, evaluate, and defend a claim in the insurance industry. As Lee Parker said in Digital Images Still Don't Hold Up in Court, "Good photographs don't lie; people do. And, people can make digital images lie."

One answer to image authentication is protocol; another is software. It is possible for anyone with a computer to alter any digital photograph up until the time the photograph has been subjected to authentication software. It is usually possible to detect the alteration.

A photograph provides evidence about a scene and about the way things were. People have a strong intuitive feeling that photographs provide better evidence than any other kind of picture. We feel the evidence presented corresponds to a sense to reality, and is true because it looks true. As with any other type of evidence, it is the responsibility of the people introducing the evidence to make sure it is a fair and accurate representation of the truth. The job of the person presenting the exhibits is to be able to testify as to how the exhibits were prepared. There have been instances where digital photographs have been known to be enhanced and were still admitted into evidence. In two trials, *State of California v. Phillip Lee Jackson* and *State of Washington v. Eric Hayden*, enhanced digital images of fingerprints passed Kelly-Frye hearings and were used to convict the accused. Digital imaging is now completely acceptable in legal proceedings. With the state of digital technology, an attorney is able to go into court with a laptop computer and have access to all documents and images pertinent to the case. All exhibits can be easily found and are accessible and able to be projected on a screen in large size for all to see.

VISUALIZATION

People often ask why it takes a professionally trained and experienced photographer to produce accurate images of evidence. After all, the evidence is just sitting there, the camera is simple to use, and it looks so easy on TV.

One truthful answer must be that it looks easy when a talented practitioner does it. It is like watching the Olympics on television—everyone must think to themselves at least once in a while that all they would have to do is eat right and jog occasionally to win the decathlon. It looks so simple.

Obviously, the only way to gain experience and build expertise in a skill-based activity is to practice. But there must be a place to start for everyone, no matter what their current proficiency level. The place is purely mental. People must prepare themselves in every possible way to be successful. The evidence photographer *must* be able to *see* their finished work before they ever touch the camera.

Like any other skill, visualization is a discipline to be nurtured and then practiced. The simple definition of the term is planning ahead. To be successful in this work, a photographer must be prepared to take any photograph *before* the actual instant of the exposure.

Most of the variables involved in creating a photograph can be predicted and planned. Some setting up, mentally and physically, of the photograph can be preset into the camera and eliminated from the "time of exposure thought processes." Some of the environmental aspects of a photo location can also be accounted for in advance so the photographer can be more prepared and comfortable. When actually arriving at the time and place of the photograph, more of the photographer's senses will be required to concentrate on the investigation, rather than having to worry about mechanics. The setting up can take an instant or hours to days or weeks, depending on the complexity of the photograph and the habitat or location.

Some of the variables to be planned for are:

What – Have some idea of the subject of the photograph so a selection of the proper equipment and accessories can be made; for example, camera, memory, boots, gloves, umbrella, sunscreen, mosquito repellent, parka, etc.

Where – Taking photographs indoors requires different preparations than taking photographs outdoors. Is the venue in the daylight or at night? Will it be hot or cold? What about radiation? Will there be any action? And will it be fast or slow?

Why – What is the intended use of the finished photographs? Choose the right equipment and all the other factors affecting the character of the finished images.

How – To make the intended images, will anything unusual be needed? Planning ahead and having thought of the necessities will afford a better chance of the project being successful.

The substance of this book is to educate the reader in the methods of making the most accurate evidence photographs.

To get started:

- Make sure to check and double-check everything in your control.
- Have the camera ready to go before arriving at the photographic location.
- Preset any known settings into the camera to save time and effort later.
- Always attempt to visualize the finished photograph in your mind before pressing the shutter release. This mental exercise will increase the chances of success of the project and it will save time overall.
- However, do not *ever* preconceive what the images are supposed to say in court!

If you say to yourself before you take the photograph, "what is the purpose of capturing this scene or moment," you might prevent yourself from making errors or even think twice about clicking the shutter at all. *It is necessary to try to improve the quality, not the quantity, of evidence images*. However, too many photographs of a scene are impossible to capture. Is it not an interesting conundrum?

CASE STUDY FOR CHAPTER 1

The International Association of Identification (IAI) has a special certification for forensic photography. It is called Certified Forensic Photography & Imaging. There are very few individuals certified in the world. These individuals would appear as "Certified" on the association websites and receive inquiries from perspective clients because of their credentials.

The stringent requirements of the certification program are designed to ensure evidence photographers, whether specializing in civil or law enforcement/public work, maintain a level of competence and professionalism serving as the international standard in the field.

The IAI also includes a section on ethics for evidence photographers on their website.

WHY DOES ANYONE NEED TO HIRE A QUALIFIED/CERTIFIED FORENSIC PHOTOGRAPHER?

Making well-exposed, sharp images has never been easier. With the developments in recent technology, attorneys, investigators, adjustors, and engineers are often taking evidence photographs themselves using everything from advanced DSLRs to cellphones, without the aid of properly trained photographers.

But bringing the evidence to a trained photographer or bringing the trained photographer to the evidence/scene to capture evidential images may make the difference between success and failure in court. Professional photographers see things differently and document things differently than even the most experienced attorneys. In one particular case, it was said, "A professional photographer can do things no attorney knows how to do with rulers, macro settings and artwork overlays to vividly demonstrate the ways a stairway violated local building codes."

It must be remembered that even though a person is a trained professional photographer, it may not make them adept at documenting evidence. It is recommended procedure to hire certified forensic evidence photographers, when possible. Forensic photographers, like properly trained attorneys, investigators, engineers, and adjustors, know what is needed to demonstrate evidence in court.

CIRCUMSTANCES

On a dreary morning in April 2003, I received a phone call at Packer Engineering from a plaintiff's attorney with a job proposal involving a flood. There was an insurance shortfall and thus a litigation brought by a dentist against the city in which he maintained his office. It was not a project Packer's expertise would be called for, so no possible conflict of interest could arise from me being a certified forensic photographer and working for the plaintiff. The project was accepted as a stand-alone, photography only. The work came to me, of course.

The project involved three separate field studies to three different locations. At the time the job was accepted, only one aspect and one location were known. The client was pleased with the work on the first location, so he subsequently rehired Packer, through me, twice. The significance of the confidence will be apparent by the end of this case study.

As with many accidents, the root cause of this flood was a series of small incidents leading to a disaster. City workers were maintaining the sewers in the alley behind the dentist's office. A spring rainstorm caused a flash flood, the sewers backed up, and before receding, several inches of waste-contaminated water flooded the floor of the dentist's office.

Due for grand opening in a matter of weeks, the dentist had spent over $500,000 refurbishing and decorating this location. But sadly, he had very limited flood insurance. The insurance company offered him a $37,000 settlement which he refused, hired a lawyer, and sued the city.

LOCATION 1

The interior walls of the building had been covered with custom-designed and manufactured water-filled, air-bubbling Plexiglas panels. All had been installed and tested to be free from leaks before the flood. After the flood they were removed from the walls, packed, and shipped back to the manufacturer for reproduction and disposal.

On a visit to the panel factory (Location 1), the damaged panels were inspected and every aspect photographed to document the nonremovable sewage stains on the inside surfaces. The manufacturer determined it would be cheaper to start from the beginning and remake everything rather than try to remove the stains and contamination. The pumps and wiring were covered in sewage and were photographed and scrapped.

The panels were laid out and labeled by the manufacturer by interior wall location and stacked on pallets on the factory floor in anticipation of the arrival of the photographer. All of the pieces were photographed, pallet by pallet, taking prolific notes to be able to match the photographs to the pieces after processing.

The attorney demanded traditional film-based images rather than digital for this case. 200 ASA Kodak color negative film was used and processed in-house in a roller-transport C-41 processing machine. The prints were made on a RA-4 roller transport mini-lab printer. Only one of four available camera bodies was used: a 50 mm macro lens, a Vivitar 283 electronic flash with a Quantum rechargeable battery pack, and a SunPak flash grip. Backups for each piece of hardware were available in the go-kit.

Many special problems were encountered in this phase of the documentation. Of utmost importance was the severity of the sewage contamination. Plastic gloves and a face mask had to be worn when touching the panels, and the photo equipment was packaged—both camera and flash—in plastic bags at all times. Gloves and bags needed to be replaced each time the film was changed. It should be noted that it is very difficult and warm work to spend hours making macrophotographs of evidence under haz-mat conditions with camera equipment not having a review monitor.

The panels were manufactured from clear Plexiglass about 3/8 inch thick. The water compartments were about 1½ inches front to back, 24 inches wide, and 8 feet tall. Only the bottom few inches were contaminated, so it was unnecessary to document the upper parts in close-up after overall documentation.

A Kodak 18% grayscale card was placed behind each clear section before making the photograph so only one panel would be imaged in each photograph.

Each photograph taken contained a Kodak color chart and size scale because there was no other reference for the degree or size of the stains. Photos without the charts and scales were unnecessary in this case because there was no allegation of covered evidence.

All images were printed to be the best possible match of the imaged grayscales; negatives and prints were turned over to the client. Normally, Packer Engineering retained all negatives documenting a project, but in this case no engineering project was forthcoming, so giving the negatives to the client was justified. (In a legal sense, the negatives belong to the photographer as protected work product.)

LOCATION 2

All the office furniture—desks, patient examination chairs, cabinetry, appliances, couches, televisions, telephones, computers, and even a pinball machine—was taken to a warehouse. The pieces were grouped by office location in the warehouse but not individually labeled.

Again, all pieces were haz-mat, and protective equipment needed to be worn at all times. There was a loft in the warehouse, and overall images of each grouping of furniture were taken from an elevated position at the beginning of the documentation. Traditional film-based imaging was again used at the request of the attorney.

Ideally, each piece of furniture would have its own distinct roll of film. But there were hundreds of pieces and the attorney did not want to pay an individual processing charge for each roll. So, a system of overall images and sketches was used to keep everything in order. Each room grouping was documented by a map and then a piece number. The number was noted on the map by putting self-adhesive numbers onto the piece.



FIGURE 1.3 Always carry an assortment of number/letter labels in your go-kit.

(From Sandy Weiss/Packer Engineering.)

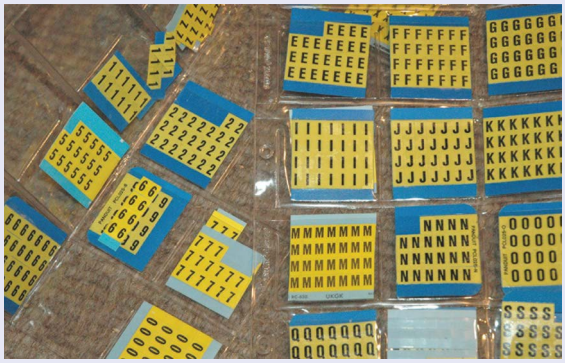


FIGURE 1.4 Stick-on numbers and letters.

(From Sandy Weiss/Packer Engineering.)

In this case, the numbers were left on the pieces after the photo documentation. In many cases it is necessary to remove the numbers afterwards. It should be noted that spoliation of evidence may be an issue unless specific permission is granted for destructive treatment. Never put markings directly onto evidence (like with a permanent marker) unless permission in writing has been obtained in advance.

Appropriate color cards were used at the beginning of each roll of film for color match. The adhesive letters were used for scale in most instances.

All negatives were processed and printed to match color scales and turned over to the client.

LOCATION 3

The office was located in a 1930s, 4,000-square-foot storefront of brick construction with some of the original internal and external features intact. There were three entrances/exits, two on the west side and a back door on the east side. The main front door was on the southwest corner and opened onto a reception area.

There was a 48-inch-tall cement wall along the west interior wall, behind the studs, under high rectangular windows. There was only one main open floor drain besides the sealed ones for the sinks and toilets. The space was divided into a number of rooms with framed 2 × 4 construction: 16 inch on centers, double floor plates, and door frames.

Most of the wallboard, paneling, and all the bubbling walls were removed prior to my arrival, except for the wallboard on the outside of the studs next to some of the exterior walls. The assignment was to document the water marks on the bottom of each of the studs, indicating how high the water rose at its maximum depth.

The same unusual imaging circumstances of the previous locations applied to this location. All images were made on Kodak 200 ASA color, 35 mm, 36-exposure film.

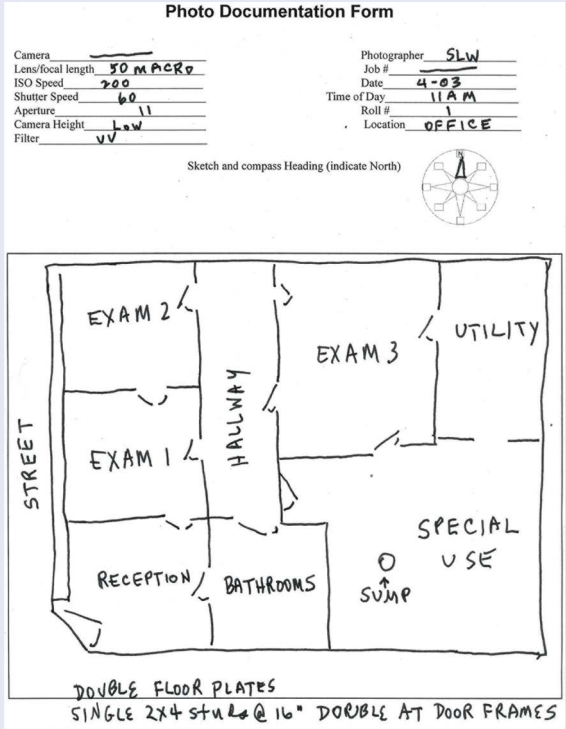


FIGURE 1.5 Sketch of the premises.

(From Sandy Weiss/Packer Engineering.)

Knowing the stains would be low to the ground, a rolling, library type, one-step footstool was brought to sit on and move from stud to stud. All images were made with the same camera and flash hardware as the first two locations.

Documentation began in the reception area in the southwest corner and labeled the first stud R W 1. It then went on to R W 2, R W 3, etc., until the corner and then changed to R N 1, etc. Exam room 1 photos started with the south side of the door frame as 1 E 1, 1 E 2, etc., to the corner and then 1 S 1, 1 S 2, etc.

The included photo [see photo 2 (2 N 5)] is of exam room 2, north wall, fifth stud.

Each stud received a label and only close-up/macro images were exposed. Normally each stud would have an overall before a close-up, but they all looked the same and only the water stains were an issue. The tags were left in place after imaging.

One of the most critical aspects of the project was the documentation of the water testing at the floor drain. As the plastic drain hose was removed from the floor drain in the special-use room, the contaminated water remaining was photographed.

The attorney wanted images to prove chain of evidence of the sample of water removed from the trap, as it had been there since the flood and chemical analysis would show the degree of sewage contamination.



FIGURE 1.6 Water stain on stud.

(From Sandy Weiss/Packer Engineering.)



FIGURE 1.7 Floor drain.

(From Sandy Weiss/Packer Engineering.)

The photographs of the collection and packaging of the evidence were critical. Fourteen 36-exposure rolls of film were exposed on this aspect of the project.

OUTCOME

All film was removed from the premises. A receipt was written for the attorney. The film was taken back to Packer for processing. The usual leader tabs and identification were placed upon the rolls prior to feeding the rolls into the C-41 machine, 2 × 2.

Surprisingly, *not one image was exposed by the camera on phase 3 of this case*. Obviously, the correct film was put into the machine for processing. Roll after roll came out of the machine, totally clear and blank.

The attorney was contacted immediately, and of course he was grossly unhappy. The studs were still in place, so it was just a matter of going back and reshooting. But the water evidence collection was now already completed, and no images other than a backup videotape of the operation remained, nor could they be redone.

The scene was revisited with a different camera body, and all the studs were reshot on the next day. The photos came out fine on the second attempt.

RATIONALE

Many times, no second chance is afforded the photographer. It is too late. So, a forensic photographer working on critical projects must strive for perfection. Failure of this magnitude is both unusual and unforgivable. The attorney refused to pay the bill. In a higher-profile case, the failure could have been catastrophic. That is why it is a good idea to carry indemnification insurance if you work for the public. Illinois requires $1 million for a private investigator to keep a license, and that is a good indicator of how much to have.

The nonperforming camera body was taken in for repair. The shutter speed adjustment had suddenly malfunctioned for no good reason, and the 1/60th second setting was actually firing at about 1/200th of a second—too fast for there to be any benefit from the flash. The camera felt fine on location, the flash fired each time, and there was no way to tell it was going to be an issue.

Had this project been undertaken digitally, this failure would not have occurred. It would have been immediately evident the images were turning out blank. Another camera would have been used.

CONCLUSION

If photography done properly requires art and skill, forensic evidence photography is a subset requiring art, skill, intelligence, and training. There is so much more involved than just being present on a scene and taking photographs of anything and everything on hand and hoping for the best. The trained practitioner will understand the what, where, why, and how of the process and visualize the products of the photographic investigation before ever taking the camera out of the bag.

This does not mean the photographer should be prejudiced about what images to capture. It means the photographer has a grasp of the scientific method and understands what photographs may be necessary to tell the complete story of the evidence presented. Having this understanding, the properly trained forensic photographer will seldom be caught short of images by the time the case comes to court.

The expertly trained forensic photographer will be aware there is a root cause, source, and heart of every event, whether it is a crime or a crash, a murder, or a fire. All

photographic investigations should include images taking the observer from the outside in or the inside out, in a logical manner, from the heart of the matter.

Images are eventually going to be questioned in terms of their authenticity. The photographer is responsible for the images until they are transferred to the person(s) who, maintaining chain of custody, takes the images to the next phase. The whole chain must be properly documented to maintain the authenticity of the images to their ultimate end.

There can never be too much education or too much training. The better prepared, smarter, skillful photographer stands a better chance of bringing home the images necessary to make the difference in court.

TIP:

Remember, seldom, if at all, does the photographer get a second chance to make their images. Everything possible must be done to limit error.

APPENDIX I

Being certified by the International Association for Identification, and being actively engaged in the forensic photography profession, I dedicate myself to my work in the forensic community and respect the constitutional rights of all people to liberty, equality, and justice.

I will never act officiously and will strive to always make objective decisions in my profession. I will devote myself to unite, promote, and distribute within the profession any advancements in my effort to more effectively photograph items of evidentiary value.

I will apply my technical knowledge factually, with perseverance and conviction to preserve the ethical standards of the profession of scientific investigation.

I will constantly strive to achieve these objectives and ideals, dedicating myself to the highest professional ethics in my chosen profession.

NOTES

1. http://www.madwed.com/Quotations/Quotations/Transfer3/Mirth Misanthropy Mischie/body oaths obedience obligati .html
2. Doyle, Sir Arthur Conan, "The Adventure of the Red Headed League."
3. Doyle, Sir Arthur Conan, "The Boscombe Valley Mystery."
4. Doyle, Sir Arthur Conan, "A Case of Identity."
5. http://members.aol.com/ELECTRPOW1/POWER1.HTM
6. http://www.nysut.org/newyorkteacher/2000-2001/010314museum-exercise.html
7. Hulick, D.E., If the Truth Be Known, Analog vs. Digital in Historic Perspective, *Journal of Evidence Photography*, Spring/Summer 1998, pp 16–20.
8. Hulick.
9. Hulick.
10. American Museum of Photography, www.photographymuseum.com, *A Ghostly Gallery.*
11. The American Museum of Photography.
12. Moenssens, Andre A. and Inbau, Fred E., *Scientific Evidence in Criminal Cases,* Foundation Press, 1986, p. 601.
13. Evidence Photographers International Council, Inc., *Standards for Evidence Photography Criminal and Civil,* 1998, p 1.
14. *Luco v. United States*, 23 Howard 515 (U.S.1859).
15. Osborn, Albert Sherman, *Questioned Documents: A Study of Questioned Documents with an Outline of Methods by Which the Facts May Be Discovered and Shown,* Lawyer's Co-operative Publishing Company, 1910.
16. *Cunningham v. Fair Haven & Westville R. Co.* (1899) 72 Conn. 244 at 250, 43 A. 1047 at 1049.
17. *Digital Imagery in the Courtroom,* Kodak Professional Imaging, www.kodak.com/global/en/pro
18. *You Won't Believe Your Eyes: Digital Photography as Legal Evidence,* www.seanet.com
19. Duckworth, John E., *Forensic Photography,* Charles C. Thomas, Springfield, IL, 1983, p. intro.
20. Hedgecoe, John, *Complete Guide to Black & White Photography,* Sterling Publishing, 1996, p. 6.
21. Bomback, Edward S., *Manual of Color Photography,* A.S. Barnes and Co., 1966, p. 73.
22. *The Focal Encyclopedia of Photography,* Psychology of Vision, p. 934, 1957.

2 Fair and Accurate Representation

David "Ski" Witzke

CONTENTS

What Is a Fair and Accurate Representation? 11
Photography's Capacity for Documenting Evidence 13
Protocol for Forensic Activity/Authentication 14

WHAT IS A FAIR AND ACCURATE REPRESENTATION?

The Scientific Working Group on Digital Evidence (www.swgde.org) defines two categories of digital images, including but not limited to images captured using a digital camera—including cellphones—or a flatbed scanner and a single image frame from an analog video tape or a digitally recorded video, which are commonly used throughout the criminal justice system in the United States. These categories were originally defined by the Scientific Working Group on Imaging Technology (SWGIT) in Chapter 11, Best Practices for Documenting Image Enhancement. These categories are identified as:

- *Category 1:* Documentation images that are demonstrative or illustrative and that may be used to memorialize a time, place, or event. These images may include general crime scene or investigative images, surveillance images, autopsy images, or arrest photographs (such as mug shots, photos of tattoos or scars, etc.). Photographs that are taken of evidentiary items in the lab can also be classified as Category 1 images.
- *Category 2:* Evidentiary images are thought to have probative value and are used for scientific analysis and comparison. These images include impression evidence (latent fingerprints, palm prints, footwear and tire tread, firearms examinations); questioned documents; tool marks; gunshot residue; bloodstain patterns (aka blood spatter); and other images that are subject to analysis, such as fire debris, etc.

One vital distinguishing characteristic between these different types of images is that Category 2 images may be used in lieu of the physical evidence itself. For instance, fingerprints may be developed on a porous substrate (for example, paper) using a chemical development process such as ninhydrin. Over time, the latent prints developed using ninhydrin will fade and the quality of the latent impression may degrade, or it may even disappear entirely. There are also a number of other development techniques that do not age well, and the quality of the latent impressions developed using those techniques may also degrade or disappear entirely. These types of evidentiary impressions are commonly referred to as "nonrecoverable" impressions. In these cases, the only item bearing the "proof" of the fingerprint is the digital photograph of the evidence. Therefore, the digital photograph provides the probative value in lieu of the actual evidence.

Another type of nonrecoverable evidence would be when there is a fingerprint on the door frame where the suspect entered the premises. While it is possible to cut the wood out of the trim around the door, that is not typically done. Therefore, the latent fingerprint must either be "lifted" or photographed in place.

Even though an image may have been captured because of its probative value in the case, the trial judge is still responsible for the final decision as to whether or not the image "proves" anything and/or whether the probative value of the evidence outweighs whether the evidence will prejudice the minds of the jurors.

It should also be noted that some Category 1 images may end up being used for analysis. For example, a photograph of a bruise recorded during an autopsy or sexual assault examination may have probative value in a case involving strangulation, or a photograph of an incision in a bone recorded during an autopsy may have probative value in a death investigation.

The significance of distinguishing between Category 1 and Category 2 images is important. Category 1 images may be captured using a compressed file format, such as Joint Photographic Experts Group (JPEG), who created the file format standard); Category 2 images should be captured using a lossless file format, such as a tagged image file (TIF) format or camera raw (the nonconverted "raw" data captured directly from the imaging sensor that has not been processed by the image processing software inside the digital camera).

Previously, Category 2 images *were* (note the past tense) required to be captured as TIF or raw *only*. That requirement was relaxed as a result of a court case in which a high-quality JPG image of a latent fingerprint impression was deemed inadmissible in court solely because the image was captured using a JPG format. The capturing of a latent impression using a compressed JPG file format was at the time not permissible in accordance with the then-current guidelines provided by SWGIT.

In this case, the latent print was a noncomplex print where the pattern type, ridge events, and ridge detail were clearly visible and captured using a high-resolution digital camera configured to save images using a high-quality JPG format. Even though the latent impression was clearly identifiable, the judge ruled the "standard" was not followed (i.e., using a noncompressed image format) and thus the image was inadmissible. It should have been argued at the time that the SWGIT guidelines were precisely that: guidelines or recommendations and that the SWGIT Guidelines do not constitute a standard for evidentiary photography.

The SWGIT guidelines (now managed by the Scientific Working Group for Digital Evidence [SWGDE]) were changed shortly after that case to allow the use of a high-quality JPG format. (In Chapter 6, we will discuss what details or artifacts are considered when making the decision about whether images captured using a compressed format may be used for purposes of identification.)

The second distinction between Category 1 and Category 2 images is that a detailed history log must be maintained for the processed (enhanced) images. In accordance with the SWGIT guidelines, "[t]he use and sequence of any enhancement technique in Category 2 images should be documented in every case."

In contrast, the enhancement of Category 1 images may be completed using "basic" imaging processes that only need to be specified within the agency's standard operating procedures (SOPs). In other words, a detailed image enhancement history is not required. Based on the original SWGIT guidelines, "a trained professional should be able to produce comparable results [when enhancing Category 1 images] even in the absence of documentation of specific parameterization or software settings."

Many people misinterpret the meaning of the requirement for Category 2 images. The image processing history should be sufficient to allow a "comparably trained person to understand the steps taken, the techniques used, and be able to extract comparable information from the image. Documenting every change in every pixel value is discouraged because it adds nothing of value to the analysis."

Some individuals interpret this guideline to mean a person must be able to start with the same original image and reproduce an image identical to the originally processed image pixel for pixel. To achieve this goal, some people believe you should use "adjustment layers" so you can demonstrate every single step taken during the image enhancement process. This is *not* a correct interpretation of this requirement.

A multitude of things can cause the same image file to appear "different" on two or more monitors or in two or more printed outputs. For example, what video card was used? What video driver was used? What are the make, model, manufacturer, size, and resolution of the display device? Or if the image is printed, how was it printed? Was the image file printed using a color laser printer? Or was it printed using a color ink jet printer or a dye sublimation printer? How many inks did the printer have? Four, eight, nine, or fourteen different ink colors? What were the size(s) (picolitre volume) of the ink droplets used by the printer?

Moreover, using Adobe Photoshop, multiple processes can be used to suppress background colors that interfere with the visualization of an impression. For example, color values can be suppressed using red, green, blue (RGB); cyan, magenta, yellow, black (CMYK), and lab color. Multiple color values can be suppressed using black and white, hue and saturation, channel mixer, selective color or replace color. The use of these techniques varies depending upon how the image was captured (for example, whether the image was digitally photographed or scanned or whether an alternate light source [ALS] or forensic light source [FLS] was used).

The clarity of the image can be improved or it can be deteriorated depending upon how the light was used, such as direct lighting, indirect lighting, bounce lighting, filtered lighting, and oblique lighting. Regrettably, this information rarely is documented. For example, how an impression is lit can make all the difference in whether the impression could be captured in the first place or whether the ridge detail is suitable for analysis and comparison.

While it would be nice to develop specific standards for image processing, it is unrealistic to attempt to develop or enforce such standards. It is unrealistic to imagine any court or accreditation body could require every law enforcement agency dealing with Category 2 images to use a specific camera (make, model, year of manufacture, resolution, lens, etc.). It would also be unrealistic to envision every crime laboratory would use the same forensic light source with the same wavelength setting for every item and would process evidence using the same development technique. Latent impressions on porous objects (such as currency, checks, or money orders) to be developed using a mix of 1,2 indanedione and zinc chloride is preferred; however, not every crime laboratory uses 1,2 indanedione–zinc or 1,2 indanedione by itself.

When teaching forensic examiners (fingerprint examiners, footwear examiners, firearms and toolmark examiners, questioned document examiners, etc.), use the "reasonably prudent person" standard. This is a legal standard based on the principle of "What would a reasonably prudent person do." In accordance with the Federal Rules of Evidence, Rule 901, knowledge, experience, training, and special skills are used to determine what a hypothetical competent, reasonable person would do in the same or similar circumstances.

The bottom line is that we must adjust our expectations of what is required (i.e., "standards") to what is realistic based upon the tools available—from camera to printer. In addition, we must ensure that people who do image processing are trained properly. Far too many law enforcement agencies today believe you can give anyone a camera and they can be a photographer or that you can give anyone a copy of Adobe Photoshop and they can enhance images. Being a good photographer or being an expert in Adobe Photoshop takes skill and training. (Some people are great using Microsoft Word to format a document, while others

can barely get two paragraphs to be numbered properly or look the same. Even word processing requires skill and training, which comes as a total shock to some people!)

PHOTOGRAPHY'S CAPACITY FOR DOCUMENTING EVIDENCE

In December 2016, Richard Harris wrote, "More data will be created in 2017 than [in] the previous 5,000 years of humanity." In May 2018, Bernard Marr wrote in *Forbes Magazine*, "There are 2.5 quintillion bytes of data created every day at our current pace …. Over the last two years alone, 90% of the data in the world was generated." I can vividly recall the first time I read his article. At that time, I could not wrap my head around how much data that is, and I still cannot wrap my head around that number. There is, however, one statistic that helped me put this into some perspective. A Google search of "how much data does Facebook generate per day" revealed Facebook creates about 500+ terabytes of data every single day.

When we talk about photography's capacity for documenting evidence, we must consider the three types of capacity:

- *Technology capacity:* What tools do we use at the crime scene or in the laboratory? Are we using high-resolution, professional digital single lens reflex (DSLR) cameras; "point-and-shoot" cameras; video cameras; cellphones; body-worn video cameras; in-car video cameras; or some other type of capture device? In the recent past, first responders frequently used "point-and-shoot" digital cameras; many of those cameras are being replaced today by smartphones that have a digital camera as well as a video recording capability. (To have suggested that someone would use a smartphone at a crime scene a few years ago would have been considered the height of heresy.)
- *Human capacity:* What is the level of knowledge we possess about photographic processes and/or the technology we have available? What training is available, or have we received any training on photographic processes and/or technologies?
- *Organizational capacity:* What are the policies and procedures in our organizations? Do we have unlimited storage capacity for keeping and retaining all our digital image files? What file format must be used for long-term storage of image files? Is there a conversion plan in place for when cameras change or technologies change to update and/or replace file storage media? (I still have image files on oversized PCMCIA cards used in the late 1990s.)

Historically, a cost estimate was associated with traditional film photography: there was a cost for the film, a cost for the development of the film and a cost for the printing of the film. In today's digital-based environment, no direct cost is associated with capturing additional images, so officers are taking significantly more photographs.

Traditionally, crime scene photographers were required to capture three separate photographs: a close-up image (used to show fine details), a mid-range image (used to show the evidence in context), and an overall image (used to show the overall layout of a crime scene). Some people are now capturing multiple close-up photographs to show relevant detail, such as shadows, to help authenticate the images they captured.

With the recent increased capture of images and videos, there is an ever-increasing need for more data storage. The question on the tips of many IT tongues is: Is there any evidence that the growing capacity of digital evidence can or will be sustained?

Technology capacity also affects how examiners do analysis and comparison. Traditionally, latent print examiners used a 2× magnifier (and a pick) to view both the latent and comparison impressions. Not only does this process create a physical strain on the examiner, it creates a visual strain as well. But latent print examiners are not the only ones who suffered from this challenge.

In a medical malpractice wrongful death action, *Rodd v. Raritan Radiologic Associates, P.A.*, the defendant (a radiologist) used a magnifying glass to examine the x-ray images from the decedent's 1997 and 1998 mammograms and found them negative for cancer. During the trial, the defense stated that the mammograms were studied to detect cancer by placing the x-ray in a view box and analyzing them with his naked eye and a handheld magnifying glass.

To help the jurors understand the details of the x-rays, the plaintiff digitized and "super-magnified" portions of the contested x-rays and displayed them on a 6-foot by 8-foot projection screen in the courtroom. In this case, the trial judge reasoned the enlarged x-ray images not only helped the jurors understand the complicated factual scenario but he also believed the use of this process would be a meaningful improvement to the entire radiological field:

> The message may get out now, that in radiology, and I know the radiologist is under awesome pressure reading these films, that maybe they ought to blow them up like that… . *[M]aybe the whole industry is negligent.* Maybe in this case, something ought to be done … maybe this message is going to get out … *it seems to me, to be very simple and very easy to implement practice, in a radiology group, to blow them up on a screen.* (emphasis added)

While many younger examiners are more comfortable with using technology to help with their work, many examiners are still using the old-fashioned magnifying glass process for analyzing and comparing impression evidence. It is apparent that these individuals have not heard about the *Rodd v. Raritan Radiologic Associates* case! If they were familiar with this case, they would want to ensure they were using the most technologically sound and reliable process available.

Digital photography has also drastically changed the way forensic nurses and other investigators handle sexual assault, abuse, and domestic violence cases. In addition to being produced quickly and easily, one key advantage of most digital cameras is they can produce images of much better quality and more accurate color than film. More importantly, digital images can be shared almost instantaneously.

In the past, crimes including abuse or domestic violence had very low successful conviction rates for prosecutors, and they were often not pursued in court because of the victim's fear of retribution by the suspect. Photographs of bruises, handprints (around the neck or arms), or other injuries were taken with a Polaroid camera—if they were taken at all. The pictures were often of low quality and the bruises or other injuries were not visible. If the investigator needed to take additional pictures after the initial interview and examination, the victim frequently recanted her or his story and would not allow better pictures to be taken.

In addition, the photographs taken often took days to get to the court. It was not uncommon to discover the judge had already granted bail to the suspect or simply ordered the suspect released from jail.

Today, with the tools available to the forensic nurse (sexual assault nurse examiner [SANE]) or sexual assault response team (SART) or the officers responding to a domestic violence call, photographs of physical injuries or damaged property can be taken quickly, and there is no waiting to see if an image accurately represents the severity of the injury or the damage.

With the ability to transmit digital images electronically, the pictures can be received and viewed by the prosecutor and/or the judge in time to keep the suspect in jail or to issue a protective order for the victim.

Digital image processing tools, such as Adobe Photoshop or GIMP, are used to help make images clearer and injuries visible.

PROTOCOL FOR FORENSIC ACTIVITY/AUTHENTICATION

To begin this discussion, it is important to understand the distinction between **data integrity** and **data authentication**, as these terms are frequently confused and often used interchangeably.

SWGIT Guidelines, Chapter 13 – Best Practices for Maintaining the Integrity of Digital Images and Digital Video defines integrity as a process that ensures "the information presented is complete and unaltered from the time of acquisition until its final disposition." For example, encryption does not protect the integrity of a digital image; encryption merely hinders access to the digital image. In contrast, a secure hash algorithm (SHA) creates a hash value (also known as a message digest) based upon the data contained within the image file. If the content of the image is changed, the hash value will also change; so as long as the image data produces the same hash value, it is possible to confirm the integrity of the image. In forensic digital imaging, the message digest is created to demonstrate at a future time that the image file has not changed.

Merriam Webster defines authentication as "an act, process, or method of showing something (such as an identity, a piece of art, or a financial transaction) to be real, true, or genuine**;** the act or process of authenticating something." For instance, an officer at a crime scene typically authenticates by his or her sworn testimony that the image(s) is(are) an accurate representation of the crime scene as he or she saw it. The officer can authenticate a gun was, in fact, lying next to the body of the victim as shown in the photograph.

In the case of forensic evidentiary photography, it is much more difficult for the officer to authenticate a specific fingerprint impression was found on a particular piece of evidence because the impression was not visible until the item of evidence was processed and checked for latent impressions.

SWGIT Guidelines, Chapter 14 – Best Practices for Image Authentication identifies a number of tasks that may be used for image authentication. These tasks include but are not limited to "evaluation of image structure and content," which may include detection of artifacts consistent with image manipulation, alteration, or fabrication, as well as inconsistencies in metadata, origin, or source. If additional images are available, evidence of staging may be exposed. It is recommended that the investigator/photographer read these two sections of the guidelines.

One crucial key component for properly authenticating forensic activity is to ensure the agency has a detailed standard operating procedure identifying not only how the images are to be captured but when they are to be captured—for example, captured by first responder as well as captured by crime scene technician/crime scene photographer when he or she arrived on the scene so issues such as staging can be detected.

The SOP should also include detailed instructions on how, when, and where images for the captured devices are to be downloaded, as well as how and where the images are to be stored, including what format should be used for storing digital images (both Category 1 and Category 2). These instructions should also include whether file names may be changed, which could be considered a breach of protocol for identifying the sequential integrity of digital image files, or whether digital image files may be deleted on the camera at the scene of the crime as well as in the crime laboratory.

Another risk to be considered when developing a SOP is whether the images must be downloaded immediately upon returning to the unit or if the officer may wait until the following day to upload the images if he or she left the crime scene and went directly home instead of returning to the unit. It could be argued the images were not controlled properly or someone would have had time to manipulate the images and write the image files back to the storage media in the camera. If using a camera raw format, this argument has no merit, as camera raw data must be converted to image data before it can be viewed and/or processed. Once the image has been converted, it is not possible to

convert the modified image back into the camera manufacturer's propriety camera raw format. If a JPG file format is used, the argument would have a better chance of succeeding, as it is possible to edit image data in a standard JPG image and then write the file back to the camera's storage media because of limited (or total lack of) physical security. However, often a sufficient number of traces are left in the image metadata, as well as file header data, to determine whether the image was manipulated.

This author highly recommends creating a hash reference using a SHA 256 hashing application. While Section 13 of the SWGIT guidelines identifies the use of visual verification, some alterations to digital image files may not be noticeable visually. Again, there are a number of organizational issues to be considered and addressed in the department's SOP. These issues affect the digital image or video file from the time it was captured until presented in court. Since Category 2 images carry the same probative value as the physical evidence they represent, access to these images should also be controlled in a manner similar to the physical evidence. The **chain of custody** should include who had access to the digital image(s)/video(s); how long they had possession of the digital image(s)/video(s); what, if anything, was done to the digital image(s)/video(s) while in their possession; who received copies of the digital image(s)/video(s) (for purposes of discovery); and when they received those copies.

In addition to establishing the requirement for authentication, Federal Rules of Evidence, Rule 901 provides general guidance for the acceptance of computer-generated evidence requiring the proponent to produce sufficient evidence to support the finding that the item is what it is purported to be based upon standards that generally can be satisfied by proof that:

1. The computer equipment is accepted in the field as standard and competent and was in good working order
2. Qualified computer operators were employed
3. Proper procedures were followed in connection with the input and output of information
4. A reliable software program was used
5. The equipment was programmed and operated correctly
6. The exhibit is properly identified as the output in question

Further, Federal Rules of Evidence, Rule 702 identifies "an expert witness" as someone who is "qualified [in a specific case] as an expert by knowledge, skill, experience, training, or education and may testify in the form of an opinion or otherwise if:

- The expert's scientific, technical, or other specialized knowledge will help the trier of fact to understand the evidence or to determine a fact in issue;
- The testimony is based on *sufficient facts or data*;
- The testimony is the *product of reliable principles and methods*; and
- The expert has *reliably applied the principles and methods* to the facts of the case." (emphasis added)

And finally, the "best evidence rule" requires that any digital image offered as probative value must be an *original* (Federal Rules of Evidence, Rule 1001-04). This means you should be able to easily identify what is an original and what is a copy. The question then becomes: Can you distinguish between the two, especially if the trial doesn't occur until two, three, or four years later?

AUTHOR'S NOTE

These six standards defined in Federal Rules of Evidence, Rule 901 as guidelines for authentication of evidence were reiterated by the Connecticut State *Supreme Court in State of Connecticut v. Alfred Swinton* and have become commonly known as the "Swinton Six."

In this case, Alfred Swinton was convicted of first-degree murder but appealed on the grounds that some of the evidence introduced against him should not have been admitted. The argument for the appeal was the reliability of photographic images. More specifically, the defendant based this argument on an Adobe Photoshop superimposition (overlay) of the defendant's teeth over the bite mark on the victim and a set of computer-enhanced photographs (enhanced using LucisPro software, a plug-in for Adobe Photoshop).

Based on its review, the Connecticut State Supreme Court ruled the trial court properly admitted the computer-enhanced images on an adequate foundation (the images were admitted by an experienced forensic expert who was knowledgeable of the creation process). However, it is this author's opinion that the overlay images should not have been admitted because the forensic odontologist relied on the overlays for his opinion, yet:

- He was not familiar with the imaging formats, processes, or techniques used to create the images as well as create the overlays
- He had "no more than an elementary familiarity" with either Adobe Photoshop or LucisPro, the software applications used
- He could not answer simple basic questions, such as whether the techniques were commonly used in the greater odontology community as a standard practice

The defendant, Alfred Swinton, was exonerated and released from prison in 2017. The odontologist in this case also recanted his testimony.



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3 Development of Agency Standard Operating Procedures

Lawrence Stringham

CONTENTS

Importance of Training 18
Standard Set of Required Photos and Lack of Unrelated Images 18
"Job"/Assignment Identification Card 19
Imaging Software 19
Scales 20
Standard Method of Record Keeping 20
Standard and Consistent Processing Methods for Digital File Storage 20

To develop meaningful operating procedures, we must first understand the difference between general orders and standard operating procedures (SOPs) and how each functions within a department. The development of any procedure should be done in accordance with the first priority being the task that needs to be accomplished first and ensuring the procedure follows the adopted general orders of the department.

General orders are created by the administration of a department, whether federal, state, or local government. They are the overall orders that must be adhered to so there is consistency within the department operation. In general, they are the overviews of subjects but sometimes can be very specific, such as liability issues or reporting guidelines.

SOPs are detailed descriptions on how the job will be done; in photography, they will list who, where, what, and how the job will be accomplished. In some departments they can be quite general, such as saying "best forensic practices," but other departments are more specific and detail the employee on how they will handle every type of case. The size of the department, the employer's need, and if they are accredited will determine how general or specific SOPs will be written.

To develop meaningful SOPs the writer will need to know several things, including their general orders and how detailed they were written, the acceptable practices of their local state attorney's office, the standard practices of the forensic field in general, and if accredited, the mandatory requirements necessary to adhere to **International Organization for Standardization** (ISO) rules.

Every state has different laws pertaining to admissibility of evidence into court, and the state attorney's office can assist in the ability to ensure all requirements are met. Also, the acceptable practices will change when new procedures are developed. Keeping the SOP within that standardization ensures all forensic personnel are kept up to date with changes. For instance, 35 mm photography is essentially gone from the forensic field, so keeping a SOP that has 35 mm in it, like the development of film, is no longer useful or within today's standards.

Accreditation standards will work in conjunction with a department's SOPs. If going through initial accreditation, some changes of SOPs will be done to ensure a department falls within the standards set by international guidelines. If accredited or not, reviewing of SOPs should be accomplished yearly and changes should be made if necessary. Then all personnel must be advised of any changes. Always remember, one change in an area may affect or change several things in other SOPs. For example, if a procedure determines a ruler with metric scaling be used in photographs at all times, training in the metric system and the purchase of necessary scales may be required; also make sure the state attorney understands the change as well. The state attorney may not want to use this type of measuring standard, as it can confuse juries about distances and sizes when testifying in court.

Today's forensic technician has several tools within their toolbox to complete a job. Digital cameras, digital scanning devices, and cellphones provide the ability to document the scene with unprecedented versatility. Yet with these advancements we must use standard terminology so our industry can proceed further without confusion. To describe our devices used to capture our information, we use several different terms. No matter what digital device a department is using, it is a digital capturing device, which, for good or bad, is the best way to describe any device mentioned in the department's SOPs. For example, if taking photos at a crime scene, the investigator or first responder may use a Canon or Nikon or Apple iPhone, all capturing the images utilizing a digital camera. Or if utilizing a crime scene scanning device or an Android to determine **global positioning system** (GPS) coordinates, this is still a digital capturing device. Replacing terminology with a single descriptive phrase can assist in SOP development, and as

technology changes, precludes changes of specific equipment or cameras.

After research is done, check to see if all parties are aware of and agree with the changes, the purchasing, and implementation of the SOP so it can be started. When implementing a new SOP, it is important for every employee affected to be notified and trained and for that notification and training to be documented and maintained.

But the question is: Why is this so important? Why do we need SOPs and all the hassle? The importance of procedures is so a standardization has been set to be followed, the employees have guidelines to fall back on when supervision is not available, and accountability can be determined by management when the job is not completed to the level of standards set. SOPs reduce the liability to management, the employee, and the court system in general.

IMPORTANCE OF TRAINING

Can you imagine going to a crime scene without any training in the proper techniques of photography or evidence collection? Although formal education is very important in today's forensic world, the job itself is taught through training and observation. But with training comes responsibility for the individuals; first, is the person being trained; second, is the trainer; and lastly is the department in general qualified to train. All three have something to do with the success of the training and the success for the department.

The person being trained, or the trainee, must have standard acceptance or failure guidelines so they are aware of the material they are responsible for knowing. A quality SOP for training should be established by every department regarding the minimum knowledge and practical testing the trainee will need to accomplish. This SOP should have clear standards and effective dates so the trainee has specific and complete understanding about what they should know and what is expected of them. Most agencies refer to this as a **field training program**, and it is the basis for qualifying trainees to pass or fail probation. To accomplish this task, a **field training officer** (FTO) is assigned to a trainee.

The FTO is the most important person within the training program. They should be well versed in all general orders and SOPs, and they should be able to test the trainee in written, verbal, and proficiency tests. Guidelines regarding how the FTO shall document the progress of the trainee should be clearly defined in the SOP, and authorization to release the trainee to real- world cases should also be written and documented.

The department has a huge investment in the trainee and should take an active role in his or her success. The SOPs are developed for the success of the trainee but also to protect the department in terms of minimum performance. The department is putting thousands of dollars into training, equipment, and salary into the trainee. A SOP monitoring successes and failures should be followed very closely by supervisors and managers to assure the department is getting its fair value for the trainee. If released to complete outside work, the trainee will adhere to and follow established rules and guidelines.

Continued training in changes to general orders and SOPs should be completed as soon as a new guideline is established. Documentation of the guideline change should be completed and saved for future reference.

Lastly, training in your SOPs is essential for effectiveness on the scene, and in effect the SOP will establish operations within a crime scene. The appointment of a lead forensic technician needs to be established so job duties within the scene can be assigned and followed.

VERY IMPORTANT:

The job responsibilities within the scene need to be standardized so that when given a task, such as photographing the scene, the forensic technician can accomplish the task with little direct supervision.

VERY IMPORTANT:

Since no two crime scenes are ever exactly alike, SOPs need to be flexible enough to allow the technician to accomplish their task but strict enough so the technician knows the value of the task they are performing.

STANDARD SET OF REQUIRED PHOTOS AND LACK OF UNRELATED IMAGES

To understand the importance of a SOP, it would be useful to establish rules for developing one. In the SOP for forensic photography, what are some areas where the digital capture devices will be used? In most departments there are only two areas where digital capture devices are utilized: the crime scene and the lab. One could imagine the areas would be the same, but the lab is a controlled environment where safety protocols and equipment should be mandatory on every case. The crime scene is not controlled: the temperature may be extremely hot or very cold, raining, or windy; you may have to deal with obnoxious smells; and your evidence may be lying in the middle of a pool of blood or maggots. So, in the lab, straightforward SOPs can be written to cover many aspects of the job, while crime scene SOPs need to have some flexibility to allow the forensic technician the ability to improvise if needed.

Your crime scene SOP for photography should be written in a way that the images are exposed in a specific order to tell a story, but with the ability to ad lib when necessary. Mandatory things to be in the SOP are:

- Photo identifier
- Overall pictures of the scene at different angles
- The rule of three, which means taking a photo:
  - At a far distance for perspective
  - At a closer distance to show a relationship to the other items around it

    - As a close full-frame image with and without a scale
- Victim's bruises
- Suspect overall photographs (normally taken in a controlled environment)

These mandatory items are for general purposes and do not include things like capturing a reconstruction or blood spatter.

Lab photography SOPs should contain some of the same mandatory information, like a photo identifier, but vary because the item in question probably has been photographed at the scene already. Things to be photographed in a lab are:

- The photo identifier
- The bag the item came in
- The item at all angles
- Any other items that may have come from or with that item (for example, a semiautomatic handgun may contain bullets that have become separated from the original handgun)
- A scale should be contained in all these photos to provide size determination

A photography SOP should also address some of the newer technological capabilities, like the camera as a digital capture device. With the creation of the smartphone, capturing evidence has never been easier or more dangerous at the same time. With a well-written SOP about digital capture devices, with protocols from when and where to photograph and how the images will be downloaded, these concerns should be answered. When using the smartphone as a work tool, it should be treated as such, and a detailed SOP can provide the employee correct direction on how it can be used. For example, all material created by a digital capture device will be downloaded or transferred by acceptable means after the completion of the scene or case.

With different applications (apps) on a smartphone, the capture of potential evidence it can provide is very important. By using digital capture device verbiage, all material collected can use the same SOP for its usage, collection, and downloading. It should be noted that for the last several years, law enforcement in general has utilized the smartphone for email and texting photos, messages, and voice recordings. Developing a standardized SOP covering all these areas is essential.

"JOB"/ASSIGNMENT IDENTIFICATION CARD

One of the most important things developed in a SOP is the utilization of an assignment identification card or photo identifier. With any story you're going to tell, one of the most important parts is the beginning. The set of photographs of a crime scene or a lab case starts with the photo identifier. This vital piece of documentation can be very simple or highly complex, but it should say the same thing. The photo identifier is the way the forensic technician provides the case information, which when collected will always be the first image taken. This should be written in the SOP with a direct purpose that is mandatory to complete unless circumstances dictate it is not.

The photo identifier, at a minimum, should include the following:

- The name of the photographer
- The date and time the first photograph was taken
- The identifying case number or unique identifying number relating to the case
- The location being photographed

Some additional information which may be provided includes:

- Standardized photo color chart for identification of the lighting

When a case or scene is concluded, an additional photo of the photo identifier should be made indicating no other photographs for that scene follow. If the forensic technician goes to a new scene, a new photo identifier should be established.

With smartphones, there are photo identifier apps that can insert all this information, and then a simple **screen shot** can be taken of the app. The screen shot will save the item as a photo, making it both your first and last shot.

IMAGING SOFTWARE

When creating SOPs for a unit, it is imperative not to include things that change regularly. With that in mind, software is updated periodically, which changes it. Most imaging software purchased was probably not written for forensic applications and was adapted for forensic use. When the manufacturer updates or upgrades the software, it may change a procedure or policy previously adopted.

Although a SOP can be written for specific operations, most software has uses never totally utilized and therefore not formally written into procedures. The most common utilization is the manufacturer's operating instructions, which comes with all software, now usually provided in a **PDF format**. By writing a SOP this way, it eliminates small changes from occurring when new upgrades or complete changes are made.

It is also very important before an upgrade is performed within the SOP that it is described in the backup information, not the software, but the data collected within that software. When a new version of the software is installed, a comparison of the data should be inspected so it can be confirmed that no additional data has been inserted or deleted. Although the new data might appear different, depending on the newly installed software, the data being outputted should remain the same.

With new technology comes new ideas and new concepts not necessarily intended for the law enforcement community. One such is storing data in the **virtual cloud**. Several agencies are already doing this, and it may become an industry standard, if it is not already. Within your SOPs there should be some consideration for the storage and retrieval of this data, be it documentation, photographs, or video.

SCALES

One of the most important items a forensic photographer carries with them is a selection of scales. But these most important items may be overlooked within the SOPs other than saying "a scale must be used." This can lead to confusion, as a SOP can be so detailed in other areas but lack clarity and purpose in reference to scales.

Scales come in all shapes, sizes, and information, and choosing the right scale for the job is imperative. Utilizing a standard American Board of Forensic Odontology (**ABFO #2**) scale for fingerprints or bite marks would be very useful and appropriate, but using the same scale for shoe and tire prints would not be advisable. Within the SOP, the correct scale and description of the scale should be clearly written.

IMPORTANT:

If your agency is accredited, the scale in use should be marked with a unique number and certified by another scale that has been accredited by **National Institute of Standards and Technology** (NIST) and ISO 17025 Standards. This calibration should be noted and stored so if inquired by attorneys or in court, it can be determined that the scale is accurate. If proper scales are not available for an aspect of an investigation, use any decent scale and prepare to include it with the rest of the collected evidence. That way, if the credibility of the scale is called into question in court, it can be certified or quantified at that time.

Proper utilization of scales should be addressed in SOPs as well, because just putting a scale in a photograph does not always make the item to scale. Making sure the scale is at a 90-degree angle to the camera helps ensure the scale is captured without distortion. When taking photographs of injuries or bruises, if the scale has a color chart attached, make sure the color chart can be seen and the flash does not wash out the colors. When photographing shoe and tire impressions in loose dirt or sand, have the scale at the same height/depth of the shoe or tire impression. Again, all these points can be put in some area of your SOPs.

If capturing an image that will be required as a 1 to 1 reproduction. Include in your SOPs the procedure on how to do that. If you are resizing images, this instructive documentation will not be necessary. We do not mention the reproduction of film photography in this chapter, as it is not done within our industry anymore. But old cases in which the reproduction of 35 mm film is involved should be mentioned in your SOPs, even if all you are going to do is scan the negatives into a digital format.

STANDARD METHOD OF RECORD KEEPING

With the invention of the digital camera came the ability to document photography with ease. The days of completing a photo log of every picture, logging in the time, date, and things like shutter speed, ISO, and F-stop are unnecessary with the advancement of metadata (the embedded picture documentation information). A log now only needs basic image descriptions that can apply to one or groups of images.

It should be noted first that not all federal, state, or local laws and procedures are the same. Some areas believe the picture becomes evidence as soon as it is captured and should be treated like evidence. Some areas believe the picture is a first-person testimony item, meaning the picture is not evidence until authenticated in court as being accurate as to what the photographer witnessed. Either way, the digital image must be stored in such a way as not to be altered or changed, and the SOP should reflect how that is completed and documented.

With 35 mm photography it was very simple to document how many photos were taken and from what location. The negative, if utilized properly, should have had a photo identifier card to start a scene and one when completed, and it was a simple procedure to count the negatives for the pictures one took. With the digital age, though it became very easy for the photographer to delete an underexposed photo and take another, what did the SOP say about this practice? For that reason, a very clear and defined SOP regarding record keeping should be created. A common practice is that since the camera is a computer and keeps track of the photos by assigning them numbers, no photographs should be deleted either during or after capturing the scene.

The department must also be careful that with the advancement of smartphones and the ability for officers and technicians to utilize this equipment that documentation of the number of photographs, video(s), or other pieces of digital information must be clearly written in the SOP.

STANDARD AND CONSISTENT PROCESSING METHODS FOR DIGITAL FILE STORAGE

The one area above all the rest needing defined SOPs would be the digital file storage and backups of **digital evidence**. The majority of photographs a department creates are downloaded and then stored for later use. That means having correct steps on how things like downloading, retention, and backing up file systems must be accomplished.

With negatives, it was simple to keep accurate records of the number of photographs taken; simply count the negatives and then indicate on a report how many there are.

Reproducing photos from negatives was also a simple procedure. But with the acceptance of digital evidence into our systems, new record-keeping procedures and software were necessary, as well as a safe way to keep the original images in the unaltered state. Early digital photos were stored on either CDs or hard drives, and the potential for fabricating material was introduced.

Providing the authenticity of digital photographic evidence is crucial, if not the most important part of any forensic unit mission. The avenue in which all evidence is accepted is that it is presented in the same condition or it appears to be in the same condition as first observed. Observations are almost always recorded by digital capturing devices, be it photographs, videos, or scanning. The ability to testify counts on the strong general orders, SOPs, and procedures created and the ability to follow them correctly.

When creating the procedures, a process called **reverse engineering** is done to find out, first, what you want to accomplish and then find the way to accomplish that goal. Every agency and department wants strong security for their digital evidence. But depending on the size and financial needs of the department, some things must be accepted as reality. Reverse engineering the goal, which could include having all your material stored in the cloud, brings risks and many rewards. So, researching the cost analyses, expandability, accessibility, and security protocols can assist in the search. More importantly, it can assist in your procedural guidelines, which will be your general order or SOP.

Several outstanding companies can work with your agency to develop the hardware, software, and general orders needed with a turnkey approach. These companies will take your old data and incorporate it into your new system and can supply the department with failsafe backup and history on all items seen, changed, or printed. Normally a representative from the company will work with the agency in developing a general order and a separate SOP as part of their package.

No matter what method or storage procedure you choose, it *must* be something where the original digital material is kept and maintained in its original format and condition.



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4 Getting Ready to Go

Sanford L. Weiss and Robert Wyman

CONTENTS

Choosing a Digital Camera 24
- What to Buy? 24
- What Is the Perfect Camera? 24
- Analyzing Your Needs 24
- Understanding Megapixels 24
- Pixels and Usage 25
- Printers and Pixels 25
- Camera Size 25

The New Camera 25
Getting Started 25
Defaults and Menus 26
Camera Handling 26
Camera Batteries 27
- Rechargeable Battery Care and Maintenance 27
- NiMH Batteries 27
- Li-Ion Batteries 27
- Battery Tip 27
- Cold Weather and Batteries 27
- Battery Grip 27

Camera Memory 27
- CompactFlash (CF) Memory Card 27
- Secure Digital Memory Cards 28
- Erasing Images from a Memory Card 28
- Formatting a Memory Card 28

Camera Lenses 28
- Focal Length 28
- What Is Normal? 28
- Fixed Focal-Length Lenses 29
- Zoom Lenses 29
- Image Sensors 30
- Angle of View 30
- Accessory Lenses 30

Aperture and Depth of Field 30
- The Effect of Aperture on Depth of Field 31

Distortion Correction 31
Camera Maintenance 31
- DSLR Sensor Cleaning 32
- Recommendations and Warnings 32

Special Situations 33
- Inclement Weather Photography 33
- Snow Photography 33
- Dew Point 33
- Airport Security 33

Making Better Evidence Photographs: A Checklist 34
Summary 36

4A Using a Tripod 37
- Why Are Tripods Needed? 41

4B Mirrors and Go-Kits 42

Photography with Mirrors 42
Go-Kits for the Forensic Photographer 42
What to Pack in a Go-Kit 43
A Typical Go-Kit for Traffic Accidents 43

CHOOSING A DIGITAL CAMERA

What to Buy?

With the wide-ranging differences in prices and styles and the diverse needs of the photographer, picking the right camera is often fraught with confusion. By staying within the boundaries of cameras manufactured by reputable companies, buying a "good" camera is guaranteed. Using cost, size, brand, and features as parameters will normally yield hardware with capabilities appropriate for the task and furnish reliability and durability for the circumstances of use.

Photographic hardware is divided by features, styles, and prices into amateur and professional. However, a great deal of crossover occurs within those groupings, and it is difficult to determine a choice for forensic applications when using only those parameters.

What Is the Perfect Camera?

No one brand or type of camera is going to be the perfect choice for every forensic photographer. The best method for determining which camera to buy is to examine a checklist of relevant features and make a choice that best fulfills the need and is within the budget.

Many private-sector photographers will already own an array of entry-level photographic hardware and may wonder if what they have is sufficient for entering into this field. If the equipment is good quality and reliable, and digital, it will probably be suitable—as a start. Conversely, photographers working as employees of public safety agencies may have little to no input in hardware purchases, as fiscal management or purchasing departments may be making such decisions, even if they have no knowledge of what equipment is truly needed in forensic assignments.

One idea is to browse through consumer guides to discern what brand of equipment is currently receiving accolades for value and reliability. Every current still and video camera should be reviewed someplace online at various websites specializing in product reviews.

A trip to a local retailer of electronic equipment should allow the potential buyer to examine an array of cameras and decide if any particular one feels better in their hands. It is never a good idea to buy a camera that feels too heavy or does not feel comfortable at eye level or in the hand because it is never likely to feel any better. Of similar importance are the camera's display, graphic icons, and menu structure. Are the menu items easily seen and legible? Are the menu choices easy to navigate?

Anything bought today may rapidly become "out of date" due to continually new improvements made by manufacturers. Many users do not buy expensive cameras, even if the more expensive equipment is affordable, because they do not want to endure the disappointment caused by finding the same equipment selling for hundreds of dollars less in a matter of months, or even weeks.

One useful purchasing parameter is to purchase a camera system with the maximum image resolution available at the time. However, the resolution parameter alone is not enough to determine the right choice of camera.

Consider the following questions (some of which will have more meaning after you read other sections of this chapter). Remember what type of photographer you are going to be and what type of projects you will undertake. Answer the questions honestly and fairly before selecting a camera to purchase:

- How important are camera size and weight?
- Is it going to be necessary to have a range of lenses or a zoom or two?
- How much money can you afford to spend?

Analyzing Your Needs

The next step in the selection process should be to correlate the answers to the preceding questions with hardware currently on the market. If the choice is too confusing, take your list to a reliable dealer and ask for assistance. Buying mail-order equipment is often a way to save money, but do not be surprised if what arrives fails to meet expectations. Photos of equipment in camera catalogs do not lie, but they may be confusing to the inexperienced buyer.

A wealth of information about currently available cameras is available on the Internet. Special-interest groups are often free to join, and a question posted to the group usually brings an array of well-conceived and informative responses to questions unanswerable anywhere else by people who already use the equipment.

Understanding Megapixels

Digital camera images are composed of rows of colored light receptors, captured on an **image sensor**, forming a rectangular grid and becoming a photograph. (See Chapter 6.) These receptors are called **picture elements, or pixels**. An image on a web page might be composed of 500 rows with 400 pixels per row. The total number of pixels in the image would then be 500 × 400 for a total of 200,000 pixels. (In digital images, pixels are red, green, or blue [RGB]). The pixels are assigned a brightness value within a standard range. The number of pixels per image is determined by the overall size and receptor density of the camera image sensor.

One megapixel (MP) is equal to 1 million pixels. Digital camera images generally contain multiple MPs. An image containing 24 MPs is equal to 24,000,000 pixels.

Pixels and Usage

The number of pixels needed in any situation depends on the intended use of the image. For viewing on a computer screen (or TV), fewer pixels (lower resolution) are required than when the image will be printed. The larger the print will be, the greater the number of pixels needed for satisfactory results.

Printers and Pixels

Whether printing on a desktop printer or one owned and operated by a magazine or newspaper, the number of pixels needed per inch of the output (print size) is dependent upon the technology used. If the software and hardware for image reproduction are properly designed and matched, the minimum pixel density needed to supply a reasonably resolved image is defined by the ability of the eye to resolve detail within the image—usually about 200 to 300 pixels per inch (PPI).

Camera Size

Size is certainly an issue with cameras. Whatever its physical size and weight, the camera must be comfortable to use and convenient to carry. Sometimes, the smaller the camera, the better it is. However, it must never be too small to hold securely or too large, becoming unwieldy or inconvenient.

When carrying an array of lenses is necessary, size is again a limiting factor. The interchangeable lenses of digital single-lens reflex cameras (DSLRs) are as large as their film-based kin, and perhaps even larger. If a very large sensor size or image resolution, or both, are needed, the **DSLR** is going to be the best choice.

Many smaller cameras available do not offer viewfinders, except on a viewscreen at the back of the camera, and that may be an issue, especially on bright days when viewfinder images are difficult to see.

Nobody wants to carry more equipment than needed, and it is always inconvenient to carry extra weight. A good rule to follow may be to pick the smallest available camera with the required features and image quality necessary for the photographer's typical investigation.

A number of classes of digital cameras are denoted by size:

- Covert cameras may be so small they are not easily recognizable as cameras. They may still have enough inherent resolution to qualify as challengers in the camera decision. These cameras are useful for photographers who are hampered by limitations on the size or weight of their kits. It should be recognized there are some extremely fine cameras available in very small sizes. Remember, though, a forensic photographer who shows up to document a project with a camera the size of a box of raisins will be scrutinized regarding whether the photographer and camera are truly professional.
- Compact cameras are about the same as point-and-shoot models. These cameras may be too large for the average pocket but will fit easily inside larger pockets or briefcases.
- Mirrorless cameras are too large to be called compact and are normally carried on a neck strap. These include cameras about the size of the older, small film-based single-lens reflex cameras (SLRs) and weigh up to around 700 grams or 1.5 lb, including lens.
- Large cameras are the DSLRs which, including a lens, may weigh over 1,000 grams or 2.2 lb or heavier.

THE NEW CAMERA

When opening the box of a new camera, a large percentage of users will charge the battery, insert a memory card, set the camera on its easiest and most automatic setting, and start taking photographs. These users may not know the settings of the factory defaults and may not care. They will ignore the built-in clock and calendar. Some weeks later, after having mastered the basics of operation, they may never go back to the instruction manual but will continue to expose all their photographs with the camera set as it came out of the box. In many cases, the camera's most simplistic and automatic settings allow these users to expose relatively adequate images. Since seeing the images immediately on the review screen provides instant gratification, the user is assured the photographs taken are essentially well exposed and relatively in focus.

A medical examiner's office bought new cameras for all the staff and distributed them without supplying specific instructions or training. The new director was subsequently supplied with many images labeled beginning with "P000101.jpg." Trying to associate the images with the office's various cases and having all of the images labeled as having been taken at 12:00 on 1/1/01 was an insoluble problem. The ramifications of not setting even the most basic camera functions can be severe.

The instruction manuals supplied with new cameras are often confusing. Most of them are either translated from a foreign language or written by someone whose first language is not English. The manuals are also organized in a manner not directly conforming to the steps of normal use and may lead to extra confusion. Two solutions to the instruction manual problem are recommended. First, use the quick-start menu usually included as an addition to the manual. Second, check the Internet for an aftermarket publication written about your specific camera brand and model by someone proficient in your language.

GETTING STARTED

How much information is needed to comfortably use a new camera on a forensic assignment and make use of a significant number of its capabilities? The first step is to

select a picture-taking mode. All cameras include a choice of automatic settings. To start, most users select an auto-everything setting. After acquiring some experience, it may be advisable to pick a type of automation allowing the user to set a lens aperture while the camera picks an appropriate matching shutter speed. This type of automation is called aperture priority and is suggested for most forensic photography because it allows the user to maximize the depth of field (discussed in Chapter 7).

Setting the lens focus on automatic or manual is dictated by the situation. If the lens aperture is wide and the depth of field limited, or if numerous objects are in the viewfinder and the camera's digital computer needs to make decisions about what exactly to focus on, setting the camera on manual focus may be the right choice. If the lens aperture is small, the depth of field will be deeper and, even if the camera has many objects on which to focus, automatic focus may supply sharp images throughout the field of view. When exposing macrophotographs, manual focus is always recommended due to the inherently shallow depth of field when focusing close up.

It is usually difficult to judge if a photo is properly focused by inspecting the small image displayed on the viewscreen. It may be necessary to zoom in on the display or to inspect the image on a computer monitor to ensure the recorded image is the intended image.

DEFAULTS AND MENUS

Your new camera left the factory with some settings programmed into its memory. These are referred to as its **default settings**. Many of the settings may never be adjusted because there will be no reason during the course of normal photography to make changes. Some of the settings will be adjusted by the user at certain times. Whether or not the settings will be changed, it is important for the user to be familiar with everything the camera is doing. Eventually the user may find themselves in a situation where they must consult the camera manual to determine what the camera is going to do if it is left on its own to make a decision.

Owner's manuals typically define default settings. Every function of the camera that can be set has a default. In many cases, the camera defaults may change when the camera system is reset to a different mode setting. Find and study the appropriate section(s) of the manual for your camera. Run the camera through all of its menu settings after doing a system reset to determine all the default settings.

Following are some of the important questions users should ask about any camera they will be using:

- If the user changes a setting during operation, will the camera retain that new setting after it has been turned off and then back on?
- Is there more than one way to insert a + or − exposure correction into the camera meter system, and how is the user notified if that manual correction is in use?
- Does the built-in flash mode revert to the default setting after use, or does it stay at the new setting?
- Does the white balance reset to the default if it has been reset to anything other than auto?
- Does the ISO setting remain at a number other than the default setting after the camera has been turned off and then back on?
- What happens if the user programs for a focus area other than the default?
- Will the camera shutter release operate if no memory card is inserted in the slot?
- What is the default image quality?

The list is not endless, but it is extensive. At this time, no industry standards have been established to apply to all these functions. Every one of these questions, and many more, may be answered by studying the menus on the camera's display. Familiarize yourself with the menus and learn the factory settings. If a crime scene unit has distributed the camera to you, learn what settings were programmed for you. If the department is adhering to an imaging protocol, it may be important for the user not to change some of the set defaults, including image quality.

Camera functions can be changed or adjusted using buttons or menus included on the camera for that express purpose. Menu options will allow users to do everything that can be done with a button, but the buttons will not allow users to do everything possible with the menus. It is important to remember that using the menu options and reviewing settings and images on the viewscreen are a drain on battery power.

CAMERA HANDLING

To ensure you are comfortable with the camera you choose, consider the following specifics:

- Check how comfortable the camera is to hold in your hands.
- Put your eye to the viewfinder and look through it to see how easily you can compose an image.
- How good is the image on the viewscreen? Does it show roughly the same view as you saw in the viewfinder?
- Having taken one photo, especially with flash, how much time is necessary before you can take the next?
- Are the autofocus and autoexposure rapid, or do you get a noticeable delay between pressing the shutter and the picture being taken?
- How easily and quickly can the zoom setting be altered?
- Can you lock the focus and the exposure?
- Can you set the focus or the exposure manually?
- How sharp is the image?
- How good is the color reproduction?

CAMERA BATTERIES

Rechargeable Battery Care and Maintenance

Two types of rechargeable batteries are commonly used in today's cameras:

- **Nickel metal hydride (NiMH)**
- **Lithium ion (Li-ion)**

Some of the older cameras may still run on **nickel cadmium (NiCad)** batteries too.

NiMH Batteries

NiMH batteries have the same power advantages as NiCad batteries, but they do not have the same battery memory problems, which may be why they are more expensive. They also have a longer useful life cycle: three or four years before requiring replacement. NiMH batteries have a fairly fast discharge rate while in storage. A fully charged NiMH battery left unattended for a week will lose about 20% of its charge. Keep them in a battery charger when not in use.

Li-Ion Batteries

Li-ion batteries have all the advantages of NiCad and NiMH batteries, plus they have a longer useful life. The main disadvantage of Li-ion batteries is they lose about 10% of their useable capacity each year due to chemical breakdown within the cells. Nothing can be done to prevent this condition.

Li-ion batteries have a typical useful life of between 300 and 500 discharge cycles, or about four or five years. Maximize the useful life of Li-ion batteries by always keeping them on a charger when not in use. Because these batteries are "smart," they cannot be overcharged. It is advisable to charge Li-ion batteries every night.

Battery Tip

- Always try to use batteries produced by the manufacturer of the camera. They usually seem to supply the most consistent life. If it is necessary to purchase generic batteries, it may be useful to keep an even closer watch over their performance.

Cold Weather and Batteries

When a camera is taken from a warm place to a cold one, battery power may be diminished. This can be a serious problem with some cameras, so the photographer must anticipate a loss of power and plan for it by carrying spare batteries and trying to keep them warm.

To keep the camera and accessories as warm as possible, carry them close to your body, even under your coat. When using a tripod, keep the camera warm until you need it and then put it on the tripod.

Battery Grip

An excellent accessory to buy with a DSLR is a battery grip—if one is available. It will connect through the camera's battery compartment and screw into the camera's bottom tripod mount and provides extra space to store and connect multiple batteries.

A battery grip enhances the stability of handheld cameras, and it provides a convenient shutter release button for vertical exposures. With a battery grip, the photographer may safely expect around 5,000 (nonflash) exposures between charges.

The battery grip is a good choice for cold weather because it increases the amount of power inherent to the camera. The downside is the increase in overall camera weight.

CAMERA MEMORY

A digital camera needs digital memory. Smaller images will take less memory than larger ones. Cameras have removable memory cards. Always purchase an extra memory card or two. Most digital cameras arrive from the factory with a small card containing a small amount of memory, so buying an extra memory card when purchasing a camera proves to be a good idea.

Different types of memory cards are available, so it is important to check the memory options of the camera you are buying. If the camera resolution is high, it is necessary to use high-capacity cards.

TIP:

No predetermined number of images can be stored on a particular memory card. The number depends on the kind of images, the file type of the images, and the compression rate per photograph.

Many kinds of memory cards are used and available. The following are some of the more common ones.

CompactFlash (CF) Memory Card

CF is usually available and is compatible with some cameras. These cards have a built-in controller allowing for fast data transfer speeds.

- Lack of battery power is a major cause of card lockups.
- After long periods of use, fragments from past use may remain on CF cards. This happens because



FIGURE 4.1 CompactFlash memory card.

the camera performs only minimal reformatting and does not completely remove old images. To improve CF card performance, reformat them in the camera every six to eight weeks and before each new project to ensure their freshness.
- Keep the same group of CF cards with one camera system. It is not a good idea to switch CF cards between different camera systems, although it can be done if the card is first reformatted in the camera system in which it will be used.
- Do not overshoot a memory card by trying to put a few extra images on it, because it may cause the card to overwrite and corrupt the last images. This may also lead to CF card lockup. The card can be salvaged using a recovery utility as long as the user has not tried to reformat the card in the meantime.
- Purchase image recovery utility software so you can recover images if a card locks up due to overshooting or shooting with a low battery.
- Do not remove cards before the camera has completed data writing of the last image exposed.
- Do not remove cards from readers until the computer accessory is properly turned off.
- Wait several seconds before removing cards from readers after use.
- Do not launder, freeze, expose to large magnetic fields, or otherwise mistreat cards.
- Do not put a CF card into your pocket unless it is in its plastic case.

Secure Digital Memory Cards

- *Secure digital and multimedia cards*: Secure Digital (SD) and multimedia cards are somewhat larger than micro cards. The difference between SD cards and multimedia cards is SD cards come with an additional write-protect switch for data security.
- *Card reader*: You will probably need a card reader to transfer images to a computer. Card readers do not require battery power.

Erasing Images from a Memory Card

When images are erased from a memory card, either individually or all at once, space becomes available on the media for more photos. The camera will allow you to erase image and video files.



FIGURE 4.2 SecureDigital memory cards.

Formatting a Memory Card

Formatting a memory card in the camera ensures it is going to work properly in the specific camera. Like computers, memory cards have filing systems, folders, and so on. By formatting the card in the camera, the card is set up in the way the camera needs to function properly.

If you put an unformatted memory card into a camera, it will usually function properly. Most cameras will automatically program the card appropriately regardless of whether it has been formatted or not.

CAMERA LENSES

Focal Length

Lenses with variable focal lengths are called zoom lenses. A normal lens is one yielding an image on the receptor corresponding approximately to that of normal perspective in human monocular vision. The focal length of a normal/standard lens producing a 24 × 36 mm (1 × 1.5 inch) image with a 35 mm film camera is approximately 50 mm. The focal length of a normal/standard lens on a digital camera depends upon the physical dimensions of the image receptor, and it varies according to the proportions of the width and height of the receptor (see Figure 4.3).

What Is Normal?

The image sensor in a digital camera is sometimes smaller than the physical dimensions of a 35 mm negative. Therefore, a 50 mm lens is not necessarily the normal field of view lens on a digital camera. To find the size of the sensor in any camera, look it up in the camera's user manual.

Most interchangeable-lens cameras physically resemble old 35 mm cameras. However, many of these cameras have photosensors smaller than 35 mm negatives and full-frame digital image sensors. Therefore, the angle of view for any given focal-length lens will be narrower than it would be when used on a full-frame camera because the smaller sensor captures less of the image projected by the lens. The camera manufacturers provide a **crop factor** (sometimes called a field-of-view factor or a focal-length multiplier) to explain how much smaller the sensor is than a full-frame 35 mm film. (For crop factors, see Chapter 6.)

Perspective in photography is defined as the spatial relationship between objects as they relate to one another in the image. A telephoto lens reduces and a wide-angle lens increases the perceived distance between objects in a photograph.

A 1.5 crop factor indicates the angle of view of a lens on the camera is the same as a full- frame camera with a lens focal length 1.5 times longer, which explains why the crop factor is also known as a focal-length multiplier. So, to determine the focal length of a lens for a camera giving the equivalent angle of view as one on a full-frame camera, the full-frame lens focal length must be divided by the crop factor.

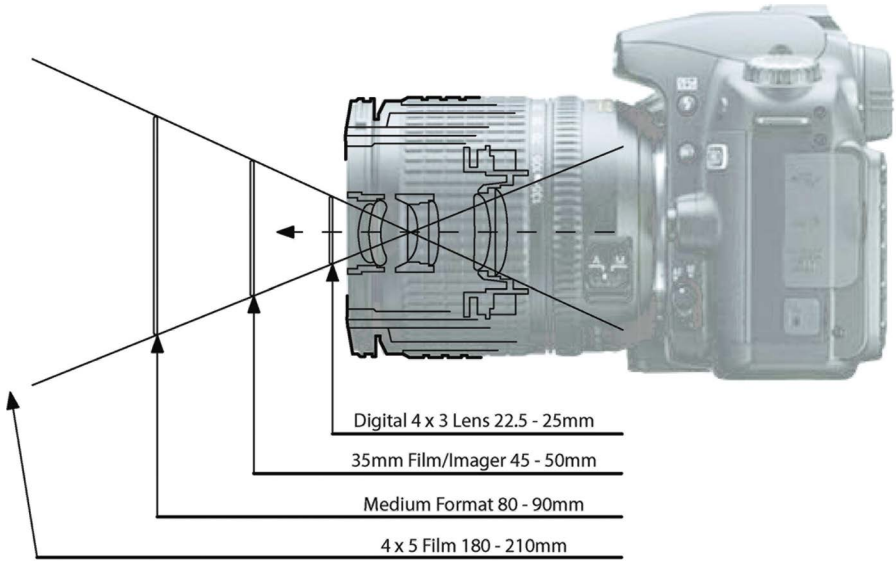


FIGURE 4.3 Normal focal length is determined by format.

(From Jessica Weiss.)

For example, to get the equivalent angle of view of a 28 mm lens on a full-frame camera from a camera with a 1.5 crop factor, one would use an 18 mm lens.

To respond to this problem, lens manufacturers are making wide-angle lenses of shorter focal lengths for DSLRs. At the same time, they limit the diameter of the image projected through the lens to slightly more than the diagonal measurement of the photosensor. This gives the designers the ability to provide the necessary optical corrections while economically producing high-quality images at short focal lengths, especially for zoom lenses. Examples include 10 mm minimum focal-length zoom lenses from several manufacturers. At 10 mm, these lenses provide the angle of view of a 15 mm lens on a full-frame camera when the crop factor is 1.5.

Any lens with a focal length shorter or numerically smaller than a normal lens for a given image receptor size is considered a wide-angle lens. Any lens with a focal length longer or numerically larger than normal for a given image receptor size is considered a telephoto lens. A wide-angle lens shrinks a given subject to a size smaller on the receptor than a corresponding normal lens, and a telephoto lens magnifies the subject. For example, a 200 mm telephoto lens used with a full frame camera yields a 4× magnification on the sensor over the normal 50 mm lens, and a 24 mm lens yields a magnification of 0.5×.

It would seem that a zoom lens would be the answer to every photographer's dream of versatility. The wider the zoom range, the greater the variety and size of subject a camera may capture with the least effort of the photographer. However, wide-angle and telephoto lenses may distort the photographic perspective of objects in the finished photograph. It is more important to represent the image perspective as relatively normal than it is to lessen the photographer's effort necessary to capture the image.

Fixed Focal-Length Lenses

In photography, a prime lens is a lens whose focal length is fixed. Prime lenses are not as versatile as their zoom counterparts but are often of superior optical quality and lower cost. This is because the designs are less complicated by having fewer moving parts, and these lenses can be optimized for one particular focal length. They also produce images with a perspective that is the closest to matching the angle of view of monocular human vision.

Compared to zoom lenses, a fixed lens will normally be smaller and lighter and will have a larger maximum aperture. This makes fixed lenses a good choice for exposing photographs in low light. Fixed focal-length lenses are normally higher in resolution and contain fewer aberrations (image errors needing to be fixed) than do zoom lenses.

The disadvantage of wide-angle lenses is that the subject may appear smaller in the photograph than it would appear to normal vision unless the camera is close to the subject at the time of exposure. Moving closer to the subject is not always possible for obvious reasons. The closer proximity may also cause problems in perspective. Some photographers prefer to work with fixed focal-length lenses because all the photos taken with the same lens can be grouped and used together if photogrammetry is being used to derive measurements. Also, the visual perspective of all the images will be the same.

Zoom Lenses

A zoom lens is a mechanical assembly of lens elements with the ability to vary focal length across a range of focal lengths.

Photographic zoom lenses should not be confused with telephoto lenses. Some zoom lenses are telephoto, some are wide-angle, and others cover a range from wide-angle to telephoto. Lenses in the latter group, sometimes referred to as "normal" zooms, have displaced the fixed prime lens as the popular one-lens selection on many contemporary cameras.

The major advantage of a zoom lens is its versatility. A photographer using a zoom lens can quickly change framing and more easily photograph a moving subject while keeping the size of the object constant. Zooms may also capture many different compositions of the same subject in less time than it would take for the photographer to physically change location or lenses. However, most forensic photographers capture photographs of objects that are not moving, so attempting to maintain a fixed subject size is not normally an issue.

The typical inexpensive zoom lens on a camera is manufactured to yield images with angles of view equivalent to about a 35 mm to a 105 mm lens on a full-frame camera, representing approximately a 3:1 zoom ratio.

Optical zoom and digital zoom differ in a fundamental way. In optical zoom, the lens has moving elements that change relative position to change the physical focal length of the lens. In digital zoom, the camera computer crops the image to a smaller size so that the image appears as if it were taken with a longer focal-length lens. The difference between the two types is that the optical zoom yields maximum resolution throughout its focal length. Digital zoom downgrades images whenever it is engaged because it limits the number of effective pixels involved in creating the image.

Zoom lenses often have relatively small maximum apertures—usually about f 3.5 to f 5.6—which makes the lenses difficult to use without a slower shutter speed or higher ISO when the light level is marginal or low. One of the more popular methods enabling the use of zoom lenses in low light is the use of a flash. However, many flashes may not be powerful enough to illuminate a large scene and may also cause problems with reflections or shadows.

Modern optical design techniques have enabled the construction of zoom lenses with good aberration correction over widely variable focal lengths and apertures.

Image Sensors

The charge coupled device (CCD) and complementary metal-oxide semiconductor (CMOS) are the two main types of image sensors used in digital cameras. The sensor used to detect the image in DSLRs is usually smaller than the film frame in a film camera.

Angle of View

The angle of view is the **horizontal field of view** measured in degrees for a specific lens and camera body combination. For example, a 50 mm lens covers approximately 47 degrees horizontal field of view on a full-frame camera. The angle of view is also the angle at which light rays pass through the lens to form an image on the sensor.

The **point of view** of an image is the aspect from which a particular scene or object is seen or imaged. An image exposed from a particular point of view is variable only by changing the focal length of the imaging lens.

Accessory Lenses

Macrophotography is close-up photography in which the image projected on the sensor is either about the same physical size as the subject or even larger.

Macro lenses are designed and constructed for close focusing. A macro lens may be optimized to provide its best performance at a magnification of 1:1. Some macro lenses can achieve magnifications up to 5:1 or 5× the actual size with the proper accessories. Other accessories for macrophotography include extension tubes, bellows, auxiliary close-up lenses, and reversing rings (see Chapter 10).

APERTURE AND DEPTH OF FIELD

Only one actual plane of focus is in front of the camera at the distance where the lens is set. Any other part of the image is increasingly blurred by a factor equivalent to its distance from the plane of focus. Actually, the plane of focus is not a vertical plane, but part of the surface of a sphere whose radius is the distance of the focus point from the camera.

TIP:

No distinct boundary exists when an image is within depth of field and when it is outside the limits of acceptable depth of field. It amounts to whether an image appears acceptably sharp in the finished image.

Depth of field is defined as the region within which the level of blur will be undetectable to most people under normal viewing conditions. The farther away an object is from the plane of focus, the more blurred it will be.

If the image of a subject is focused perfectly on the image plane, then a small point on the image plane will represent a small point on the subject. However, if the precise point of focus lies in front of or behind the image plane, then each point of the subject will be represented by a circle on the image plane. This is termed the **circle of confusion**.

People have varying abilities to detect fuzziness within an image. Viewing conditions also will have an effect on this ability. For example, the farther away the viewer is from an image, the harder it will be to detect blur. Therefore, conventions exist that define the maximum circle of confusion size for adequate viewing.

Acceptable focus, by definition, is the largest circle in an image the eye cannot differentiate from a dot. In full frame format cameras, a 0.03 mm-diameter circle of confusion is considered acceptable. The larger the image, the larger the circle is allowed to be because larger images tend to be viewed at greater distances. If 2,000 pixels are distributed

across the diagonal of a digital image, the circle of confusion must be slightly smaller than a single pixel.

The Effect of Aperture on Depth of Field

Aperture restricts the diameter of the beams of light striking the image plane. This means that for the same subject distance and focus point, the circles of confusion are smaller if the aperture is smaller.

DISTORTION CORRECTION

A perfect lens would yield even illumination across the entire image, would yield excellent image sharpness for all colors of light across the entire image, and would yield acceptable linearity, meaning that if the lens was rectilinear, it would represent any straight line in reality by a straight line in the image. A perfect lens does not exist. All lenses have defects or aberrations. All photographic lenses contain multiple elements, combining converging and diverging lenses made of different glasses to cancel out some of the inherent problems.

Following exposure, digital images may be corrected in various ways. Cameras often incorporate lens-specific algorithms to correct some inherent lens faults. This increases the necessity of using original equipment manufacturer (OEM) lenses, rather than after-market accessories, for forensic photography.

Almost all lenses show some distortion from a perfectly rectilinear shape. When photographed, a rectangle may bulge out in the middle into a barrel shape or squeeze inward to create a pincushion effect. It is not uncommon for zoom lenses to show both effects, often with pincushion effects at wide-angle focal lengths and barrel effects at telephoto lengths. Prime lenses also suffer from pincushion or barrel distortion, although it is usually less noticeable. Software can analyze the lens used to take a photograph and then correct lens-induced aberrations.

CAMERA MAINTENANCE

Taking photographs in the field is difficult under the best of conditions (see Figure 4.8). The sites of accidents, explosions, fires, and crimes are hard on the equipment and hard on the photographer. The temperature range may be very hot to very cold. The air may be damp. The atmosphere may be dusty and polluted with dirt and ash. Use of a camera protected from the elements with some type of weatherproof housing to prevent inevitable and expensive damage, if only a plastic bag, is recommended.

TIP:

The environment where you take your camera will not always be sterile. In a hazmat situation, do what you can to protect the camera.

A good camera, like any other fine mechanical device, will maintain operational status if it is used regularly. Normal use prevents lubricants from becoming stiff and gummy. If the camera in use has been dormant for a while, do not be surprised if it has developed mechanical problems, no matter how much it cost.

Impact damage from being dropped is the worst problem for a camera. In addition, blowing dirt, dust, and sand can enter the camera's mechanisms and cause problems that can only be repaired by a trained technician. If your camera gets rained on, dry it with lint-free materials as soon as possible. Remove surface dirt and dust with a lint-free cloth, a camera brush, or compressed air before changing lenses, batteries, or memory media.

Avoid leaving cameras in closed areas at high temperatures. Heat can damage media, melt plastics, and cause lubricants in the camera and lenses to melt and run onto surfaces where lubricant was unintended.

A hot and damp environment (see Figure 4.5) is as difficult for the photographer as it is for the equipment. When the relative humidity is over 65%, moisture may condense on the inside surfaces of the camera and short-circuit the



FIGURE 4.4 Fire scenes are always damp and dirty, so use utmost care to protect photographic equipment at all times.

(From Sandy Weiss/Packer Engineering.)



FIGURE 4.5 A swamp is an example of a moist and warm environment that could harm a camera.

(From Jimmy Brown.)

electronics. It may also form cloudy deposits on interior lens surfaces. This may happen to new cameras, and if it does, the damages will not be covered under warranty.

Never leave a camera in a sealed bag in direct sunlight. Condensation that forms inside the bag may penetrate the camera and lenses, causing interior mechanisms to rust.

TIP:

Check your camera's strap and strap lanyards periodically. If any part is worn or loose, tighten or replace it.

Keep photographic optics clean. Dirt, dust, and fingerprints on lenses will cause the degradation of images. Lenses can be cleaned with lens tissues or any soft, absorbent, lint-free cloth (but not paper like toilet or paper towels).

Anything safe for use on eyeglasses is appropriate. Do not use facial tissues, which are soft on your face but not lint free; if used repeatedly on coated optics, they may scratch off the lens coating.

DSLR Sensor Cleaning

Cameras producing images with small white or dark spots may have dust on the sensor. Some cameras have sensor vibration cleaning systems built in.

Image sensors attract dust. Even a new camera may leave the factory with a dusty sensor. Some cameras are less prone to this problem than others. One possible reason for this problem is static electricity.

DSLR camera manuals may not offer practical solutions for the dust problem. Camera manuals state the actual CCDs in their cameras are protected from dust by a low-pass filter present in front of the CCD to reduce moiré effects, which are interference patterns caused when regular patterns in the subject interact with the regular array of the image sensor. Sensor cleaning is a relatively simple process and should be done on a regular basis. Most dust particles are too small to be visible with the naked eye. Many attempts to remove dust result in the filter gathering even more dust. Unless you use a camera with a self-cleaning sensor, the equipment may require professional maintenance.

Recommendations and Warnings

Major camera manufacturers recommend that their equipment be cleaned by factory-authorized service personnel. The cost, inconvenience, and time involved may make that an impractical solution. As previously noted, it is possible to damage the filter (and possibly also the sensor) by excessive force, scratching with hard materials, or using excessive or unsuitable liquids.

TIP:

Any work photographers perform on their own cameras is undertaken entirely at their own risk—and may invalidate the camera warranty.

Before cleaning a camera sensor, be sure that the mirror chamber, mirror, and back of the lens are clean. Be

sure to work in the cleanest and most dust-free area available. Kits and gadgets are available at most photo shops for cleaning cameras but be very careful when doing your own maintenance.

TIP:

Read the camera's instruction manual to determine how to lock the mirror safely for cleaning, but remember, mirrorless cameras do not have one.

TIP:

Do not use canned air around a camera mirror because some propellants and moisture can damage the camera.

Use a large rubber bulb blower-brush with the brush removed to blow dust out of the inside of a camera. Do not touch the filter or sensor with anything but air. After cleaning, replace the lens on the camera body and take a test exposure of a sheet of paper or a similar clean, detail-free surface, using even lighting and a high number (small) aperture using autoexposure. Inspect the resultant image on a computer monitor, and any remaining dust will be clearly visible. If dust is still an issue, go through the cleaning procedure again.

SPECIAL SITUATIONS

Inclement Weather Photography

Forensic photographers will be forced to work outdoors under every type of weather condition. Living and working in a warm climate may eliminate the need to prepare for cold weather, just as living and working in Alaska may eliminate the need to prepare for excessive heat. Yet everyone must prepare for moisture in the form of rain or high humidity.

Unless photographic hardware is waterproof, it must be protected from rain. Another concern for the forensic photographer is that rain creates shiny surfaces on most materials. Thus, the photographer working in overcast or rainy conditions blocking direct sunlight may need to use longer shutter speeds, wider apertures, or higher ISO settings. To be properly prepared for rain, always carry some type of waterproof enclosure for camera equipment, as well as an umbrella to shield the top and front of the lens so water does not reach the lens elements. A rain sleeve should be readily available for immediate deployment if conditions at a job site deteriorate quickly.

IMPORTANT:

Always be cognizant of possible condensation on your hardware!

Snow Photography

The whiteness of snow adds contrast to the normal colors of a scene and can cause difficulties when using a light meter. The light meter built into cameras sees snow as a very bright object, which causes the camera to set the exposure for the brightness of the snow and to create underexposed images. Most experienced photographers routinely overexpose snow photos to make the snow appear as bright as it actually is and to properly expose the rest of the frame.

Dew Point

All air contains water vapor. The amount varies. The dew point is an indication of the amount of moisture in the air. A higher dew point indicates greater moisture content at a given temperature. The dew point of humid air always will be higher than the dew point of dry air.

Air is saturated when it is holding the most water vapor possible at the existing temperature and pressure. Dew point temperature is defined as the temperature to which the air would need to cool (at constant pressure and constant water vapor content) to reach saturation.

Condensation of water vapor begins when the temperature of air is lowered to its dew point and beyond. For this reason, never bring a camera that is cold into a warm and damp environment. Moisture will immediately condense on the camera surfaces and may cause electrical and eventually oxidation problems.

The camera manufacturer does not warranty its equipment against short circuits caused by moisture. Use of a plastic bag over the camera is a very inexpensive but satisfactory solution to the moisture problem. Position the lens so it protrudes through an opening in the bag. Clean off water droplets on the front of the lens with a lint-free cleaning cloth.

Airport Security

When comparing digital technology to the older and more established conventional film technology, much is published on the subjects of acceptability in court, archival characteristics, resolution, quality, cost, ease of manipulation, versatility, reliability and durability of cameras, and, of course, the susceptibility of images to airport scanners and x-rays.

Are airport scanning and x-ray inspection as harmful to digital equipment and image files as it is to unprocessed film? According to most current authorities, digital cameras, memory cards, and exposed images will not be adversely affected by airport scanners or x-rays. However, even the authorities leave room for doubt. A major manufacturer of digital memory has stated that a possible cause of damaged digital files could be airport x-ray machines, and it recommends carrying cards through the scanner rather than packing them in luggage. It is not certain how the newer security screening devices will affect digital cameras or memory cards. For this reason, it may be best to request that these



FIGURE 4.6 Outside Anchorage, Alaska (January 2006). The camera was being used on a weeklong project, and the temperature never rose above –10° F. Even at the very low temperature, the humidity was relatively high. The camera could only be taken outside of the photographer's jacket for the brief moments required to make the photographs. To prevent condensation, the camera had to be placed into a sealable plastic bag every time it was brought into a warm environment.

(From Sandy Weiss/Packer Engineering.)

items be hand inspected to avoid any possibility of damage to the images they contain.

The semiconductors used in electronic systems, including CF (and other memory), may be irreparably damaged if subjected to the irradiation process being used by the U.S. Postal Service (USPS) to sanitize the mail[7] (for example, during anthrax inspections). Such damage will not only cause loss of data stored on the cards, but the cards will no longer be operable. It is not advisable to send image media by USPS because other carriers, including UPS and FedEx, may be safer. Many articles and discussion forums address the subject of x-rays and scanners in relation to digital memory and hardware. Some people state they have sustained damage to their cameras and camera memory when transporting them through x-ray exposure. The only factor all the claims have in common is the lack of substantiated proof.

You may ask, "What is the bottom line? Should I worry?" To this question it seems best to respond yes, always worry; use good sense when it comes to irreplaceable images.

MAKING BETTER EVIDENCE PHOTOGRAPHS: A CHECKLIST

The following parameters are relevant to creating better evidence photographs:

1. Your camera is available and ready for use
2. It contains an empty and appropriately sized image storage card
3. The camera and lens are clean and dust free inside and out
4. All camera batteries are charged

What more can a photographer do to prepare for the successful recording, storage, and transportation of appropriate images for evidence documentation? The next recommended step is to stop and think, if only for a moment, about the current project and any similarity it may have to previous evidence documentation experiences. Before commencing photography, mentally compare the current and planned documentation with prior experiences. Follow your mental roadmap to the current documentation that you used successfully for previous projects. The more practiced and automatic the steps the photographer takes to accomplish the photographic documentation, the more capacity the photographer will have means for documentation. If the photographer must think about every step taken to produce the photographs, it is probable that photography is the only part of the investigation that will be successfully accomplished. For all projects, always follow established and appropriate documentation protocols—both physically and mentally.

For every project, ensure the following are in place:

1. A reason for the documentation
2. A plan for the steps of the documentation
3. A vision of the end product and eventual use of the images for legal purposes

The preceding quantifiers, properly used, should promote sound photographic decisions regarding the following:

1. Choosing purposeful images to expose
2. Setting the correct resolution format, lens focal length, sensor sensitivity, metering mode, and so on
3. Elimination of the practice of exposing photographs for the sake of exposing photographs—that is, shooting just to shoot

Learning to make well-exposed and properly inclusive photographs in evidence situations and environments is a learning process that takes a lifetime for some people. The

point is that photography, taken seriously, is like any other discipline: creating outstanding work requires focused and persistent effort, the correct equipment, and the appropriate mind-set.

Follow these 10 basic steps to promote photographic quality:

1. *Use lighting properly:* When exposing photographs outdoors, the ambient lighting conditions present minimal and maximal opportunities for achieving the desired effect. In evidence work, two additional qualifiers apply to opportune timing: (1) the specific time the photographer has with the evidence and (2) when the photographer chooses to be with the evidence to characterize the situation as it appeared at a specific time in the past.

   In either case, the ambient lighting will be used to greatest advantage by exposing the photographs with the sun or other light source illuminating the subject at the most appropriate angle. Proper light metering procedures must always be performed. Camera automation should be used only in situations in which the camera's internal metering systems are not easily confused.

   If the photographer is utilizing auxiliary lighting of any type, exposure must be adjusted to take proper advantage of the additional lighting.

   If the scene being photographed is the subject of a vision study intended to portray what someone could have seen at the same place but at another time, lighting to approximate the situation at a specific time in the past must be used. If the photography is performed in low light with no supplementary lighting added, the following must be in place:

   - A tripod must be used to hold the camera steady during exposure.
   - Proper metering must be performed to expose the digital image for the desired effect.
   - If the scene is to be measured for the quantity of light and/or compared to human vision, luminance or illuminance metering must be performed.
   - Camera f-stops should not be compared to the amount of illumination enabling human vision.

2. *Determine the appropriate composition:* Good composition is desired and even mandated in aesthetic photography. In evidence photography, composition is not as important as content. Photographs must portray a reasonable representation of the evidence to be meaningful.
3. *Expose images from an appropriate point of view:* Taking photographs with the camera at the photographer's eye level (5 to 6 feet above ground) is common practice, and that vantage point represents the way most people are accustomed to seeing the world. It may be useful to expose photographs from a higher or lower vantage point to document aspects of a subject that would be invisible from eye-level height.

   When photographing an accident or crime scene, it is necessary to expose photographs from the angle and height occupied by a possible eyewitness. It is then necessary to document the position from which the eyewitness images were captured.
4. *Maximize the depth of field:* Use the smallest appropriate lens aperture (highest number) when exposing each image to maximize depth of field. Use the slowest appropriate shutter speed to maximize lens aperture. If a larger aperture is needed to reduce unwanted image elements (i.e., depth of field reduction), remember to change the aperture again when depth of field is a limiting factor.

   With most photographic systems, depth of field may be predetermined before exposure to determine whether the whole subject will be in focus in the finished image. If the depth of field will be insufficient, you may do the following:

   - Expose multiple images at various depths closer and farther from the subject.
   - Add supplementary light to the subject to allow the use of smaller lens apertures.

5. *Use light metering accurately:* Camera meters are preset at the factory to register scene reflectance at a level of 18% of the light falling upon it. If the reflectance of the scene is greater than 18%, the camera will still calculate the reflectance at 18%, and if the camera meter is set on automatic, the resulting image will be underexposed. If the reflectance of the scene is less than 18%, the camera will still calculate the scene at 18%, and if the meter is set on automatic, the resulting image will be overexposed. In-camera metering systems that are weighted in particular patterns and set properly will yield more accurate exposures than camera meters with automatic averaging systems.

   The most accurate light metering methods require the acquisition of exposure information from the most important part of the scene. Using exposure information obtained in either of the following ways will yield properly exposed and more consistent images:

   - A handheld light meter with an appropriate measurement angle
   - The camera's built-in meter and moving close to the important area of the scene until that area fills the camera viewfinder

6. *Optimize contrast:* Unless appropriate for a visual situation, avoid placing the light source behind the subject. If the light source must be behind the

subject, use extra care to meter properly on the subject. On bright, sunny days, expose images for the best detail in the shadows or use supplementary lighting to minimize the darkness of the shadows. Use of a polarizing filter will also help to reduce contrast.

7. *Use appropriate references:* Visual references are necessary to best approximate, within the capabilities of the media, the following:

   - Color
   - Dimensions
   - Location

   If forensic references are unavailable, use any appropriate and available object of known color, size, or location as a reference. If the reference blocks any part of the subject evidence, expose a second photograph without the reference in the image.
8. *Choose the proper focal length:* Wide-angle and telephoto lenses should be used minimally for evidence photographs because they may exaggerate image perspective. If a normal lens is not sufficiently wide-angle to document the entire scene from the photographer's position, expose overlapping photographs that can be assembled into a montage.

IMPORTANT:

Do not refocus the lens when exposing a montage of photographs of a single object or scene.

9. *Compromise as needed:* Control of the visual depth of field, or the area of the finished photograph that is in acceptable focus, is valuable to most evidence photographs. It requires practice and an understanding of optics to properly capture optimum depth of field photographically. The lens aperture used to expose a photograph is the variable that controls the finished depth of field in the photograph.

   Controlling shutter speed is necessary to minimize camera and subject movement. The relationship between lens aperture, shutter speed, and the ISO set into the camera meter is what governs proper exposure. Every photograph involves some degree of compromise between the three exposure variables for image optimization.
10. *Optimize perspective:* Perspective is a graphic device used to describe the reproduction of a three-dimensional subject in a two-dimensional representation. Proper perspective is a representation of a subject with spatial relationships corresponding to how the subject appears with the unaided eye. Using sufficient visual clues is important to the capture of appropriate perspective and a correspondingly proper visual sense of depth. The use on any format camera of a lens with a normal focal length will promote the production of images with similar visual perspective to what is seen by a person with two healthy eyes. In general, a normal focal-length lens approximates the diagonal measurement of the image format. Deviations from normal lens focal length will produce images with distorted perspective unless the images are printed in an appropriate size and viewed from an appropriate distance to minimize the distortion.

Remember, photographs should tell as much as possible of the story of the evidence. Notes, drawings, and human testimony will substantiate the images.

SUMMARY

A camera system for forensic photography may be assembled in many ways. It is best to consider many issues before spending money on a system you are going to use for a long time. Most important, the equipment must be appropriate for the type of work it is expected to perform.

A new camera will arrive from the factory with predetermined default settings. Always consult reference material to understand how the camera you buy has been preset and to determine which of those settings you will want to use and which you will want to change.

Photographers must care for and respect the memory media in their cameras to ensure the capture of images. If the camera memory has problems, irreplaceable images may be lost.

Understanding the various types of lenses and what they do is fundamental for good photography. One of the hardest things to explain in court is how to correlate a camera image with what a person sees. The photographer should be properly prepared to address this issue.

Assembling a go-kit is a lifetime endeavor. Always design your kit for usefulness and portability, and always keep the kit together and ready to go for any eventuality.

4A Using a Tripod

Arthur Borchers

A tripod can either be a great advantage to the photographer or the photographer's worst enemy. When going on a long field assignment—for example, when performing surveillance (see Chapter 15)—a photographer should always bring a tripod. If the assignment requires photography in low light, a tripod is also essential. However, carrying a heavy tripod to every job site may not be practical (see Figures 4.7 to 4.13 for alternatives). To bring a tripod or not becomes a question only the photographer can answer by assessing the situation.

Tripods have been used in photography since the earliest days. Tripods were big and bulky, like the cameras they supported (see Figure 4.13) Similarly, tripods have shrunk in weight and design, just like the cameras. The wood used in the early units has been replaced by aluminum and carbon fiber composites. As the name implies, three highly adjustable legs attach to a central chassis, often called a "spider" (see Figure 4.14). The tripod unit may have a central column that can increase the overall height, be positioned horizontally, or allow the camera to be positioned under the tripod spider, close to the ground. Tripods without a center column are generally stiffer than ones with a column. Horizontally positioned columns allow the camera to be pointed directly at the ground, often without the tripod legs appearing in the image. Design options are unlimited. Tripods can be found in tabletop to jumbo sizes along with versions that can be bent and shaped around objects or others little more than a flat plate with a simple ball head for unobtrusive use.



FIGURE 4.8 Tabletop miniature tripod.

(© Can Stock Photos/pinkblue.)



FIGURE 4.7 A travel tripod may be an acceptable alternative for a standard tripod.

(From A. Borchers.)



FIGURE 4.9 Jobi GorillaPod features bendable grip legs.

(© Can Stock Photo/michaklootwijk.)



FIGURE 4.10 A Platypodwith head. The screws are reversable for either a soft rubber leg or spike depending on need.

(From A. Borchers.)



FIGURE 4.11 The platypod strapped to a pole.

(From A. Borchers.)



FIGURES 4.12 AND 4.13 Wooden tripod with large format camera.

(© Can Stock Photo/©2d3dmolier.)

Between the chassis and the camera is the tripod head, which allows the camera to swivel and move up and down. Two basic types of head are available (see Figure 4.15): the three-way pan tilt head and the ball head. Three-way heads have three different axes of movement, and each is controlled with its own mechanism and lock. The mechanisms allow the camera to be rotated around a central axis, leveled



FIGURE 4.14 Tripod chassis "spider" with attached angle adjustable legs and central column.

(From A. Borchers.)



FIGURE 4.15 Ball-type friction pistol grip head (L) and three-way pan tilt head with knob and quick adjust levers (R).

(From A. Borchers.)

horizontally for portrait or landscape orientation, and tilted vertically. A ball head, as its name implies, consists of a ball within a clamping mechanism. When the clamp is loosened, the three axes are all free to move and be adjusted at once. A three-way head is adjusted one axis at a time. There are specialty heads such as gimbal heads for telephoto lenses, precision nodal heads for panoramic photography, and geared heads for precise three-axis adjustment (see Figure 4.16).

Design issues aside, the tripod must be sufficiently strong to support your camera and any equipment you mount. Whether strength means leg strength or tipping stability, no one wants valuable equipment damaged if the tripod fails. Some tripods will have a hook under the spider or column on which you can hang a camera bag or other weight to increase stability. The legs may be linked to the column or may be fully adjustable for increased spread to lower the center of gravity.

The method for attaching the camera to the tripod can be as simple as using a small bolt, generally 1/4" diameter with



FIGURE 4.16 Precision nodal point panorama head.

(From A. Borchers.)

20 threads per inch, on the tripod head and screwing it into the threaded socket on the bottom of the camera. More preferable methods include attaching a plate to the bottom of the camera that mates to the tripod head (see Figures 4.17 and 4.18). This allows quick changes between cameras or with a right-angle plate between landscape and portrait orientations (see Figure 4.19). Most tripod spiders or column attachments have 3/8" diameter with 16 threads per inch to screw into the tripod head base. Commercially made adapters can be screwed into a 3/8-16 tripod head to allow attachment to a 1/4-20 tripod bolt.



FIGURE 4.17 Manfrotto locking camera plate vs. Arca-Swiss camera plate.

(From A. Borchers.)



FIGURE 4.18 Bottom of Manfrotto and Arca-Swiss camera plates. The pins on the right plate limit left-to-right movement in the tripod head.

(From A. Borchers.)

The type of tripod the photographer uses depends on the weight of the camera being supported. Lighter-weight, digital, and camcorders may be properly supported on lightweight tripods. Heavy medium- and large-format cameras, longer lenses, and video cameras require heavier tripods. Tripods are rated by the weight they can properly support. The stiffest and lightest tripods are constructed with the fewest sections. For most purposes, the maximum tripod height should allow the photographer to use the camera at a comfortable standing position. (A tripod higher than this is rarely needed.) Monopods are suitable in situations where tripods are either too heavy or too cumbersome (see Figure 4.20). A painter's pole can be modified to accept a tripod head for a simple method of getting a camera into a raised position (see Figure 4.21).



FIGURE 4.19 Right angle plate for instant switching from landscape to portrait mode images.

(From A. Borchers.)



FIGURE 4.20 Convertible monopod with foldable tripod legs that are stored within the central tube when not needed.

(From A. Borchers.)



FIGURE 4.21 Three height-adjustable commercially available painter's poles with a paint roller handle adapted to accept a small ball-head camera mount.

(From A. Borchers.)

The most expensive tripods are constructed of composite materials, including carbon fiber, which is lighter and more durable than either aluminum or steel. Expensive tripods are usually equipped with quick-release mechanisms for adjusting the legs and camera mount (see Figures 4.22 and 4.23).

Why Are Tripods Needed?

The primary purpose is to hold a camera as steady as possible with the minimum movement or vibration when slow-speed exposures are being taken or extreme focal-length lenses are being used. The tripod will reduce camera shake and help increase image sharpness. They also assist in precise image framing or when bracketing exposures or other forms of image stacking.

Hand-holding a camera when taking a photograph at a slow shutter speed can result in image blur. The general rule for safe handheld photos is the shutter speed should be no slower than one over the focal length of the lens. For example, if a 200 mm lens is used and the shutter speed is slower than 1/250 second and the lens is not stabilized, a steady



FIGURE 4.22 Tripod legs can be adjusted to better position the camera in relation to the subject, along with reversing the central column.

(From A. Borchers.)

hand or a tripod is required to avoid blurry images. Image blur is especially noticeable in photographs exposed at slow shutter speeds and becomes more apparent when photographs are enlarged. The use of a tripod minimizes movement caused by shaky hands. Most people cannot hand-hold a camera with a normal lens at a shutter speed under 1/30 of a second. Modern lens and/or camera stabilization reduces the chance of image blur, but knowledge of the issue goes a long way toward eliminating the problem. Knowing the chance of blur is likely, a photographer may decide to brace themselves against a door frame or window ledge rather than setting up a tripod for capturing just a few images.



FIGURE 4.23 A tripod where the central column can be extended horizontally.

(From A. Borchers.)

4B Mirrors and Go-Kits

Sanford L. Weiss and Robert Wyman

PHOTOGRAPHY WITH MIRRORS

One of the most important categories of tools to keep in a go-kit is a selection of mirrors. Mirrors are used to add light to an area otherwise difficult or impossible to illuminate in other ways and/or mirrors may be used to reflect the image of an object to be photographed. Mirrors come in different sizes and are made of different materials.

The reflective material of rear-surfaced reflectors is on the back of a piece of glass or plastic. These mirrors should be used only for reflecting a light source onto another surface. Using a camera to photograph images on rear-surfaced reflectors will produce photographs with double images (see Figure 4.24). Most common household, hardware, and automotive mirrors are rear-surfaced. These mirrors are easily identified because there is a matte gray surface on the opposite side of the image in the reflector.

Front-surfaced reflectors are constructed of glass, plastic, or metal. All reflectors intended for bouncing an image for photography are front-surfaced and must be purchased from medical, dental, or scientific supply companies (see Figure 4.25). Many have specialized purposes, such as the stainless-steel reflectors designed to be placed by a dentist (or photographer) in a person's mouth to view upper and lower teeth without having to bend over or stand on a ladder. Mirrors may be the only tool making it possible to tell multiple aspects of the same visual story in single photographs. Mirrors are also useful for making photographs of aspects of objects where it is impossible to physically place the camera. It may be necessary to photograph aspects of mechanisms where disassembly would be the cause of **evidence spoliation**. It is necessary to maintain a selection of front-surfaced reflectors of different sizes in a go-kit. Front-surfaced reflectors are fragile and expensive. Dentists who routinely use disposable plastic front-surfaced mirrors on patients may be a good source of supply for completely sterilized mirrors of that size.



FIGURE 4.25 Intraoral imaging with a dental mirror.

(From Dr. Denise Murmann.)

GO-KITS FOR THE FORENSIC PHOTOGRAPHER

Whether it is called a go team, emergency response team, special response team, special operations group, multidisciplinary investigation team, special weapons and tactics (SWAT) team, or anything else, the unit represents a focused approach to problem solving and situational response.

A forensic photographer may be part of such a squad or may operate independently. In some circumstances, and often dependent upon whether the photographer is a government employee or private-sector practitioner, the photographer's participation in a team may be dictated by the size and scope of the situation to which the team is responding.

Specialized knowledge and equipment are required of any go team and its go-kit.

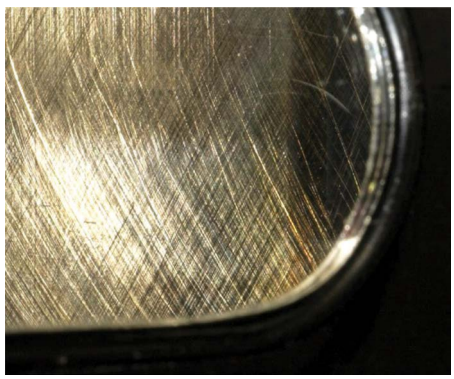


FIGURE 4.24 Using a typical hardware store inspection mirror for photography will yield photos of double images. This was the scratches on the inside of an aircraft piston cylinder engine.

(From Sandy Weiss/Packer Engineering.)



FIGURE 4.26 Automotive disassembly imaged off a surplus plastic dental mirror. This was in a car the owner swore went out of control and ran into a crowd of people while driving.

(From Sandy Weiss/Packer Engineering.)

The photographic equipment contained in any go-kit may be dictated by the composition of the go team and the type(s) of situations to which the team is dispatched. In addition to a typical camera bag, a photographer attached to a SWAT team may need personal protective equipment and possibly the same body armor worn by other team members. A photographer attached to a medical examiner's unit may require an entirely different style of personal protective equipment. Photography at traffic and industrial accidents and other catastrophic events requires another set of tools. Larger scenes require the use of larger scales to properly measure the location of artifacts. Larger scenes may also require the use of aerial photography and all of the equipment necessary for that discipline. The accepted protocol dictated by the needs of these types of situations will dictate the types of images necessary for the documentation of injury causation, component failure, compliance with legal standards, and other related issues.

It is always necessary to address the weather conditions on site. A photographer working in snowy mountains requires different equipment than a photographer working in a swamp.

What to Pack in a Go-Kit

Only the photographer can decide, based on the types of situations and locations to be encountered, what equipment is necessary. Forensic photographers realize their go-kits will change and grow as they encounter new situations and new equipment becomes available.

The go-kit list in the following section is a small sample based on traffic accident experience.

A Typical Go-Kit for Traffic Accidents

- Vehicle equipment
  - Emergency beacons (LED or halogen flashers, strobes, etc.)
  - Work zone lights, tripods, power supplies, extension cords, etc.
  - Flares or portable electronic strobes/flashers
  - Traffic cones and traffic barriers (Manual Uniform Traffic Control Devices [MUTCD] compliant)
  - Portable advance warning signs (MUTCD compliant)
  - Other equipment as needed

- Personal safety equipment
  - Traffic safety vests (American National Standards Institute [ANSI] Class 3)
  - Personal conspicuity lighting (portable electronic LED strobe/or flasher
  - Traffic control flags and traffic baton lights
  - Hard hat
  - Safety glasses
  - Respirator
  - Gloves
  - Safety-toe shoes
  - Safety harness, etc.
  - Specialized personal protective equipment for hazardous duty, environmental contamination, etc.

- Personal health items
  - First-aid kit
  - Ice chest
  - Drink cooler
  - Portable refrigerator or personal hydration system
  - Skin protection items, such as sunscreen and insect repellent
  - Coveralls or other work clothes
  - Other items as needed

- Site and component documentation equipment
  - Global positioning system (GPS) navigation system
  - GPS measuring/surveying system
  - Laser measuring/surveying system
  - Optical measuring equipment
  - Measure wheels and tapes
  - Contour gauges, depth gauges, and calipers
  - Macro measuring tapes and scales
  - Optical and radar vehicle-speed measuring instruments
  - Roadway traffic volume counting system
  - Vehicle acceleration and braking force measurement systems
  - Evidence markers and survey flags
  - Aerial photo target equipment

- Photography equipment
  - Cameras and lenses
  - Camera memory cards
  - Filters
  - Batteries and/or power supplies and cables
  - Cases and accessories applicable to the camera brand(s) and model(s) being used
  - Electronic flash units: macro flash units, axial lighting devices, flash cables, or wireless flash modules
  - Lens shades
  - Flash umbrellas
  - Light reflectors
  - Mirrors
  - Gray cards
  - Color-checker cards
  - Other illumination and electrical accessories
  - Tripods, monopods, tabletop mini-pods, or copy stands
  - Clamps and specialized mounting equipment (such as suction cup mounts for vehicle interior or exterior camera mounting)
  - Portable computer with photo management software, computer cables, and power supplies



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5 Visual Storytelling

Sanford L. Weiss

CONTENTS

The Scientific Method 46
Locard's Exchange Principle 47
Structuring a Forensic Photography Project 47
Current Scientific Method Steps 48
- Defining the Problem 48
- Collecting and Analyzing Data 48
- Developing a Hypothesis 49
- Testing the Hypothesis 49
- Selecting the Final Hypothesis 49

Use of the Scientific Method in Evidence Photography 49
Scientific Storytelling with Photographs 49
Steps for Scientific Documentation 50
Photography of Fractures 52
- Sinking of the *Titanic* 52
- Fractography 53
- Failure Mechanisms and Causes 53
- Reading Fractures through Witness Marks 53

Conclusion 53
Notes 54

Since the dawn of time, humans have left their marks on the world around them. On cave walls, animal tusks, clay pottery, and any available surface, people have drawn, scratched, rubbed, carved, and printed everything from pictures to words. When we see their markings today, we are looking back through a window of time at the way our ancient ancestors lived, hunted, dressed, worshipped, and celebrated life.[1]

Early people were constantly searching for better ways to give visual form to ideas and concepts, to communicate, to store knowledge, and to bring order and clarity to information.[2] Some images already exist in nature or are generated automatically as the result of experimental procedures.[3] Cave paintings are not the beginning of art as we know it, but rather the dawning of visual communications.[4]

The early Egyptians used symbolic objects and pictures to make the transcendental and unseen both immediate and understandable.[5] Aristotle, the acute observer, proposed we cannot think without images.[6] Observation includes the simple use of illustration as a device to record vision, with no particular analysis of the thing observed. In other words, **I looked, and this is what I saw**.[7]

Photography was invented by 19th-century artists for their own purposes. These people were seeking a lasting, literal record of their visual surroundings.[8] Art critics of the time decided photography was not and could not be an art. The final photograph could be artistic, but the technology used to create it was definitely a science: "The world in which we live has a strong grip on photography and pictures are dependent upon mechanical means and are not a part of man's creative imagination."[9] The most important use of photography was in the field of communication. Here the value of photography was seen in its quality of immediacy and of the literal description and convincing presentation of reality.[10]

Today, a common use for photographs is as memories.[11] Scientists, however, use technical images in specific ways to communicate what they have learned.[12] Scientific studies are often published using words indecipherable by the general public. "Images; even complex ones; can however, impart the scientist's objectives in startlingly direct ways."[13] Scientific illustrations and photographs offer an incomparable view of humankind's intellectual evolution. Yet another, quite different, experience may be evoked from the contemplation of such images.

The following paragraph is a well-written description of the plastic deformation on the head of a screw removed from the engine of a small aircraft:

> *The slotted heads on the screws where they were plastically deformed [see Figure 5.1] (is seen) on the outside edges of the slots. What was initially a rectangular slot is now rounded above and below the original slot centerline on the slot surfaces nearest the outside edge of the screw head.*
>
> *The slot areas nearest the center of the screw head remain mostly intact. Some screws show some oxidation, and a few also contain obvious tool markings. There is slightly more deformation on the upper right and lower left faces of the slots. The underside of the screw heads are fitted with a lock*

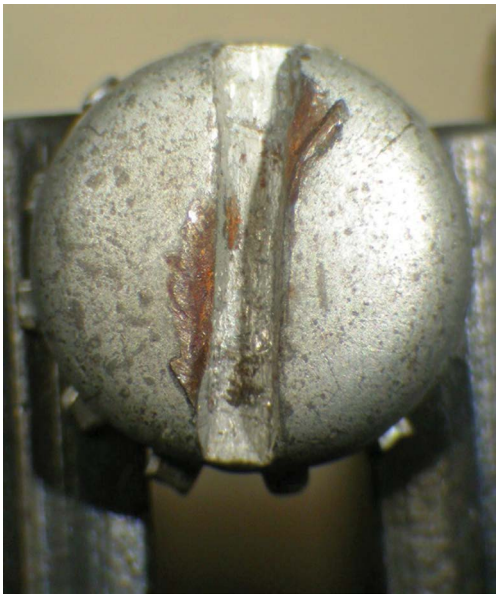


FIGURE 5.1 Deformed screw head.

(From Sandy Weiss/Packer Engineering.)

washer. The washer teeth are angled, creating sharp edges which come in contact with the underside of the screw head when compressed. Teeth marks were observed on the underside of the screw heads with increasing depth in the clockwise direction. The markings on the heads of the screws indicate torque was applied to the screws in both the clockwise and counterclockwise directions. The magnitude of the moment about the screw head is defined as the product of the magnitude of the force and the perpendicular distance from the line of action of the force to the axis, or center of the screw head. Since a singular amount of force must be applied to the screw slot at any given moment, the amount of torque the slot experiences increases as the radius from the center of the screw head increases. As a result, the screw slots experience the greatest torques on the outermost surfaces. This is clearly observable on the screw head as the amount of deformation of the slot increases as the radius from the center of the screw head increases. The deformation on the lower right side of the slot and the upper left side of the slot indicate torque being applied in the clockwise direction while deformation on the upper right side of the slot and the lower left side of the slot indicate torque being applied in the counterclockwise direction. Since the upper right side of the slot and the lower left side of the slot were deformed upon receiving the engine, a counterclockwise torque had been applied to the screws, indicating they had been removed at least one time before we received the engine. There is more deformation in the counterclockwise direction than there is in the clockwise direction, indicating more force was used to remove the screws than to install them. This un-asymmetrical torque history could be explained by the resistance to rotate the screw created by the lock washer and minor oxidation of the screw causing it to bind together with surrounding surfaces.[14]

What gives the uninitiated viewer a better idea of the deformation: the preceding paragraph or the accompanying photograph?

At a commission investigating the *Challenger* shuttle accident in 1986, a link between the cold weather and the loss of resiliency of O-rings was obvious to engineers, but various officials had camouflaged the issues in the obscurest language of evasive technical jargon.[15] Is it possible a few photographs of the previously obvious problems encountered by observers in "O-rings in cold weather conditions" could have alleviated the *Challenger* disaster?

Understanding the content of a scientific illustration requires some description of the phenomenon to be studied, as well as an understanding of its labels and terms. "Unlocking the meaning can form a shared intellectual passion, a passion that animated the scientific community throughout the history of mankind. It may lead to new ways of understanding some aspect of ourselves and the world in which we live."[16]

The most abstract thing in nature is, of course, the human mind itself, which still eludes scientific explanation. There are many "realities" existing only in the mind. Mythology, black holes, the structure of the universe, etc., are phenomena that cannot be directly perceived but which we have no trouble imagining and illustrating.[17]

"The limitations of speech are the fallibility of human memory and an immediacy of expression that cannot transcend time and place."[18] Images trigger visual motion: the perusal of the elements in the picture. By looking into the picture, the viewer transforms the static image into a dynamic intellectual experience. In some instances, this may evoke an aesthetic response or pleasure in the talent of the scientist/illustrator.[19]

Even though we live in a perceptual world of three spatial dimensions (or four), the world portrayed and accepted by all human observers as reality in our information displays is often the two-dimensionality of paper and video imagery.[20]

Categorization, prioritization, and sorting are something people do automatically whenever encountering a set of data. Grouping things forces us to think about why they are the same or different. When showing someone an image, we can say, "Think of it this way."[21] In a technological endeavor, it is necessary for the observer to have an innate underlying structure on which to rely for a basis on which to sort.

THE SCIENTIFIC METHOD

Each photographic project is different from every other one the photographer has ever handled or seen, even though they may be alike in some ways.[22] There are often similarities, and it is critical to remember the steps taken for both; add them to your experience database. Experience is a great teacher, but there MUST be an underlying structure for the photographer to follow to furnish a framework upon which to rely, so the thought process is free to think of the WHAT to photograph rather than the WHY or the HOW. There is also a need to make the work the photographer furnishes to the client straightforward and easily understood. Initially,

it may seem each project is daunting, but reliance on past experience makes the work easier.

Why jurors in criminal trials behave as they do in voting to acquit or convict has always been a source of bemusement and befuddlement to both watchers and actors at the trial.[23] Looking back, an early forensic education was afforded to jurors from TV and was called "The Perry Mason Effect." In the 1950s and 1960s, juries were schooled by Perry Mason, as played by Raymond Burr, to expect a full confession—in the last act. Later, things changed to "The Quincy M.E. Effect," from 1976 to 1983, when juries were taught to anticipate the mystery would be solved by the pathological genius of Jack Klugman portraying Quincy, M.E. And today, it is "The C.S.I. Effect." The results of the three popular C.S.I. TV programs, participants in the criminal justice system firmly believe, are biasing the jury's minds, to the delight of defense attorneys and the dismay of prosecutors, often watching guilty criminals go free.

During interviews with jurors after acquittals, the reasons for their decisions are often found to be a lack of credibility on the part of the prosecution's star eyewitnesses or experts. But reports also attribute some acquittals, in part, to the C.S.I. effect, said to be and defined as "a heightened skepticism among jurors expecting hard forensic evidence" who do not see it produced. It was not observed during the trial, jurors report: "Eyewitnesses cannot be trusted to be accurate in their recall of the criminal episode under scrutiny."[24]

C.S.I. programmers state, "If it happens on C.S.I., it should happen in a real-life courtroom." In a quote from the newsletter of the American Academy of Forensic Science, "Regardless of the bogus science displayed before the millions who watch and ingest the rubbish displayed on C.S.I. programming, some things on the program truly have no scientific value."[25] One of the areas most often glossed over are the methods used by TV investigators making photographs. Apparently, the people who review C.S.I. content for accuracy do not think people will notice if the photographic practice on the show is lacking in accuracy.

Part of the C.S.I. effect is a change in the burden of proof applied by a jury in deciding on guilt or not. "Reasonable doubt is the legal standard, not scientific doubt, and certainly not beyond C.S.I.'s doubt, or even no doubt."[26]

"It is not only the attorneys, prosecution and defense, who have been touched by the C.S.I. effect. Crime labs, police investigators, legislators and legitimate forensic science and scientists have felt the sting of the C.S.I. effect; sometimes to the good and at other times to the bad. Naturally the effect can also be seen as a propagation of more, not less, junk science and junk scientists."[27]

LOCARD'S EXCHANGE PRINCIPLE

The Locard exchange principle, also known as Locard's theory, another well-known aspect of the C.S.I. effect, was postulated by 20th-century forensic scientist, Edmond Locard, the director of the very first crime laboratory in existence, in Lyon, France. Locard's exchange principle states, "With contact between two items, there will be an exchange."[28] Essentially, Locard's principle is applied to crime scenes in which a perpetrator comes into contact with the scene, bringing something into the scene with him or her and leaving with something from the scene. In other words, according to Locard, every contact leaves a trace.

> "Wherever he steps, whatever he touches, whatever he leaves, even unconsciously, will serve as a silent witness against him. Not only his fingerprints or his footprints, but his hair, the fibers from his clothes, the glass he breaks, the tool mark he leaves, the paint he scratches, the blood or semen he deposits or collects. All of these and more bear mute witness against him. This is evidence that does not forget. It is not confused by the excitement of the moment. It is not absent because human witnesses are. It is factual evidence. Physical evidence cannot be wrong, it cannot perjure itself, it cannot be wholly absent. Only human failure to find it, study and understand it, can diminish its value."[29]

According to Locard's principle, every crime scene contains evidence of the perpetrator of the crime. Fragmentary evidence is any type of material left at or taken from a crime scene, or it can be the result of contact between two surfaces, such as shoes and the floor covering or soil.

After a crime is committed, fragmentary evidence must be collected from the scene. A team of specialized law enforcement technicians goes to the scene and takes photographs and often videos of any victims and items of evidence. They check for shoe and tire mark impressions, examine any vehicles, and check for fingerprints, etc. Failure to find evidence or failure to capture sufficient or proper photographs at a scene is often enough to acquit a guilty perpetrator.

STRUCTURING A FORENSIC PHOTOGRAPHY PROJECT

Forensic photography encompasses the documentation of either a tiny piece of evidence or a giant accident or crime scene, or anything in between. And although every forensic project is different from all others, the structure of every project is, or should be, something so basic it can be used for every project. For example, documenting a scratch on a ball bearing in the laboratory is a different project than the in-the-field documentation of the catastrophic collapse of the World Trade Center. But what these investigations have in common is the way in which the photographer mentally organizes which images are necessary for visual storytelling—in other words, visually relating the story of what happened to a remote observer. Either of these projects would be daunting to the photographer given the responsibility of doing such work, regardless of their expertise or experience, unless they had some idea of where to start. I often considered the idea of photo-documenting and individuating something simple, like a wooden match or a grain

of sand, and writing a whole book about what the project entails if done properly. Of course, it would contain many photographs. It may also take a person's whole life to complete, especially if done properly.

The **scientific method** is the only protocol appropriate for every project, of any size, of any purpose, from today till the end of the world. Having the method ingrained upon the photographer's thoughts before embarking upon a project will help accomplish success.

Photographic projects, like any other endeavor, must have a logical beginning, middle, and conclusion. But this structure must serve only to furnish a direction, not tie the photographer down to a rigid delineation of preconceived steps. Entering into a project with visions of conclusions in mind rather than suggestions of hypotheses leads to backwards thinking and the possibility of missing important data along the way. This is not meant to be a paradox. Be assured, downplaying the importance and rigidity of a protocol is not a paradox—rather, it is simply that the protocol is the key to the map and the project is the map itself.

Many practitioners consider the scientific method to be its own branch of science. Others say it is actually more a philosophy of logical thought than a science. Regardless, it has a direct impact upon the day-to-day practice of science and law. The scientific method depends on observation to properly define the subjects(s) under investigation, to perform reproducible experiments, and to draw viable conclusions.

We often find ourselves in a not readily understandable world. We may disagree with others about what is found and seen in the world around us, and some aspects of things are beyond our present level of understanding. The scientific method helps provide a way in which we can reach an understanding with ourselves and our community.

In practicality, the scientific method is the normal protocol and best practice of most current scientific investigations and is, by definition, the inductive method of knowledge gathering based upon available evidence (see Figure 5.2). Hypotheses, or tentative assumptions, are tested by experiment using the scientific method. If the hypotheses are proven true, they are assumed correct; if they are proven false, they are assumed wrong. If they are wrong, new hypotheses are tried until one is found to be proven true.

Induction uses a slightly more refined form of imagery: one that incorporates an element of interpretation. The scientist says, in effect, "I looked, and this is what I thought."[30]

Early attempts to delineate a scientific method acceptable to humanity were met with the problem of justification of the theory of induction. By definition, induction does not necessarily lead to the truth, so its results may not necessarily be valid. Inductive reasoning, or inductive logic, is the process of reasoning in which the answer to an argument may be true but depending on the premises, may also not be true. Given the premise, "It is to ascribe properties or relations to types based on limited observations of particular tokens; or to formulate laws based on limited observations of recurring phenomenal patterns."[31] This difficulty has led to the rejection of the theory that there is a single scientific method universally applicable to all the sciences.

Thus, the scientific method has been defined and diagrammed in many ways since its appearance in professional literature. For example, H.G. Wells said, "For the true Scientific Method is this: to trust no statements without verification, to test all things as rigorously as possible, to keep no secrets, to attempt no monopolies, to give out one's best modestly and plainly, serving no other end but knowledge."[32] Today, a state-of-the-art definition reads more like this: "A process being the basis for scientific inquiry."

Apparently, some ideas have changed over time, but are not entirely different from what they were. In the judicial system, testimony deviating from accepted scientific practice is grounds for rejection as "junk science." "Junk science is a term used to derogate purportedly scientific data, research, analyses, or claims that are driven by political, financial, or other questionable motives" (see Chapter 37).

The type of methodology used in the scientific method is, in fact, a means of communication of understanding; it allows the scientist to say, "This is how I think it works." Then it suggests to the scientist the proper steps to prove the theory.

CURRENT SCIENTIFIC METHOD STEPS

The steps of the scientific method include the following:

- Defining the problem
- Collecting and analyzing data
- Developing a hypothesis
- Testing the hypothesis
- Selecting the final hypothesis

Each step must withstand peer review for verification. Any conclusion becomes accepted only after it is known by others and criticized by publication or review.

Defining the Problem

Defining the problem demands careful preparation and use of accepted terminology for all relevant concepts. It depends upon a careful characterization of the subject, problem, unknowns, and theories of the investigation.

Collecting and Analyzing Data

If an experiment supports a hypothesis, it MAY become a theory or law. If experiments do not support the hypothesis, they must be rejected or modified. What is key is the predictive power of the hypothesis or theory as tested by experiment. It is often said in science that theories can never be proved, only disproved. It is always possible a new observation or a new experiment will conflict with a long-standing theory.

Errors in experiments have several sources. First, there is possible error in measurement. This type of error has equal probability of producing a measurement higher or lower numerically than the "true" value, called random error. Second, there is nonrandom or systematic error due to factors that bias the result in one direction or another. No measurement, and therefore no experiment, can be perfectly precise. At the same time, science defines standard ways of estimating, and in some cases reducing, errors. Thus, it is important to determine the accuracy of a particular measurement and, when stating quantitative results, to quote the measurement error, or standard deviation. A measurement without a quoted margin of error is often meaningless. Therefore, any comparisons made between experiment and theory are made within the context of experimental errors.

Developing a Hypothesis

Any hypothesis must include a basic explanation of its purpose. When evaluating a hypothesis, scientists often strive to design theories that are elegant or beautiful. In contrast to the usual dictionary definitions of these terms, scientists have more specific meanings. Elegance refers to the ability of a theory to neatly explain as many of the known facts as possible, as simply as possible, while at the same time being aesthetically pleasing. Beautiful is something which works almost perfectly every time.

Testing the Hypothesis

A hypothesis is a prediction formulated through deductive reasoning. It can be tested experimentally. If results prove the hypothesis wrong, then the hypothesis is incorrect or incomplete and requires change. If the hypothesis proves to be correct, then it can be either correct or complete.

Scientists often use empirical observation to determine the acceptability of some of the hypotheses within a theory. When a researcher makes a hypothesis, it is likely someone will ask them for justification. Thus, once a prediction is made, an experiment must be designed to test it.

Once the steps of an experiment or investigation are complete, the researcher must determine if the results are as predicted. If the experimental conclusions fail to match the predictions or hypotheses, the next step must be to return to the failed hypothesis and reiterate, restate, or repeat. If the experiment/investigation proves to be a success, then its details are adopted and made available for peer review.

Empirical evidence does not necessarily help a researcher choose one theory or another, nor does it imply all theories are equal. The scientist or investigator must make the choice of one theory over another. Thus, scientific philosophers stress that scientific observations must be restricted to disciplines where general agreement on the nature of the observations is involved. It is easy to agree about observations of physical phenomena. But a record of the results must be maintained, and words are often insufficient; thus, well-taken evidence photographs become a necessity.

Detailed documentation of the testing is necessary to record and report the experimental results and to provide evidence of procedural success. This should also guarantee the reproducibility of the experimental results.

Part of testing is observation. Observation involves **visual perception**, a cognitive process. That is, one does not make observations passively, but must be actively and mentally involved in distinguishing the thing being observed. Therefore, observations depend on an underlying understanding of the way the world functions, and that understanding may influence what is perceived, noticed, or deemed worthy of consideration.[33]

The scientific method is used to separate science from nonscience and science from junk science.

Selecting the Final Hypothesis

If the experiment or investigation is successful, then its details are adopted and made available for peer review. After peer review, if no significant discrepancies from acceptable limits of accuracy are found, the hypothesis may be accepted as fact.

USE OF THE SCIENTIFIC METHOD IN EVIDENCE PHOTOGRAPHY

When testing a hypothesis or a theory, the scientist or investigator may have a preconceived preference for one outcome or another. It is critical this preference not bias his or her investigation. The most fundamental error is to use a hypothesis for an explanation of a phenomenon without performing the necessary tests.[34]

It is easy to assume the obvious and totally overlook the truth. If the obvious is accepted in the experimental stage, it is often impossible to return to the time and/or place of the investigation to capture evidence images overlooked or missed in the initial experiment or investigation.

It is also simple to prioritize an investigation improperly and miss information that disappears due to the appearance or interference of other investigators or changes in the light and/or weather.

SCIENTIFIC STORYTELLING WITH PHOTOGRAPHS

When photographing an accident, a crime scene, and/or evidence, it is mandatory to capture sufficient images and take specific notes to ensure the work will tell the whole story. The documentation must be able to stand alone, with no oral explanation to another person(s), at a remote location, at another time, and/or in front of a jury. Always review your work and how you present it mentally to ensure everything, including "the story," is easy to decipher from what you have done.

STEPS FOR SCIENTIFIC DOCUMENTATION

The following steps apply to scientific documentation by digital photography. It is important to remember that image files are the raw material of documentation, making them critically important to the investigation and the results it produces. Files cannot be replaced if they are lost or damaged.

- Always properly maintain photographic equipment after use and before storage.
- Use proper cleaning supplies to ensure cameras and lenses are clean and dry.
- Store equipment in a temperature-controlled environment. Too much heat will cause damage to hardware and lubricants. Too much cold will deplete battery power, stiffen lubricants, and possibly cause problems due to moisture condensation.
- When downloading digital images, maintain strict adherence to best practices and be sure the images are as secure as possible before reusing the capture media.
- Taking digital cameras and media (exposed or not) through multiple passes of airport security x-rays and scanners should cause no known problems.
- If possible, record evidence photographically and record all pertinent factual information in notes, as the pertinent factual information may be helpful.
- Record the date of work and location at the time of photography.
- If the project is located at the scene, be certain to photograph a permanent landmark and connect it through sufficient images to enable the viewer to place the landmark, and thereby the subject, into the universe. Global positioning system (GPS) hardware and/or apps are helpful, readily available, and usually affordable.
- Always expose sufficient photographs to fully document the subject.
- Work within time constraints to complete the documentation. If the scene is subject to change, document the location before photographing subject-specific information.
- Always avoid exposure of irrelevant photographs.
- The initial photographs should be taken with the camera lens at a "normal" focal length and as close as possible to perpendicular to the front, rear, and sides of the subject to document the magnitude and location of all damages. These photographs may need to be compared to photographs of an undamaged exemplar to illustrate the magnitude of damage(s). This comparison may be used to confirm or disprove witness statements and/or collected reported data.
- Unless the subject is a sphere, to supply sufficient image information to properly measure the severity of damages directly from the images, it is necessary to complement the perpendicular views with photos taken toward the corners of the subject. The corner-view images allow two planes or sides of the subject to be seen in each photo and an accurate depth analysis to be performed photogrammetrically (see Chapter 21C).
- Use appropriate scales and include images of the scales in the photographs.
- Measure and record in writing sufficient dimensions to enable the re-creation of the damages in 3 D.
- When scales cover damaged areas on the subject, expose images both with and without the scales in the frame.
- Always use universal or retainable color references because color is a factor in the documentation.
- ALWAYS perform the photographic documentation in an orderly fashion. Start at one position and work around in a single direction. Jumping from one position to another is incredibly confusing to everyone involved, including the photographer. If something is forgotten or noticed only after being passed by, wait until the end and capture images of those aspects separately.
- If using a zoom lens, try not to use the zoom feature when performing the initial walk-around or view-around of the subject.
- After overall documentation, close-up photos of individual areas of damage should be taken.
- ALWAYS expose an overall image of the area (see Figure 5.2a) before exposing mid-range (see Figure 5.2b) and close-up or macro images (see Figure 5.2c). Make sure the subject area of higher-magnification images is contained within the overall image subject area, making it easier for an observer to determine where the photograph was taken and what part of the subject is documented.
- Always include an image of a scale when changing magnifications.
- Always capture images from relevant points of view. Document what the victim and/or the witness(s) could have seen before the incident. This may help explain why the incident occurred.

It is critical to remember that image files are the raw material of the documentation and are a most important part of the ultimate result of the investigation. Neither can be replaced if lost or damaged.

Often, by the time the subject is available for documentation, it may have been moved to a remote location where it is difficult, if not impossible, to gain access to all of its aspects. For example, it may be in a salvage yard, a warehouse, garage, or attorney's office, where ambient illumination is often poor. In such cases, it is vital to photograph as much detail of damages as possible, using whatever means are at your disposal. Carry enough accessories in your go-kit to make your work easier—but not so much that the kit becomes unwieldy. A solvable conundrum!







FIGURE 5.2 (A) Overall view of an area of damage. (B) Mid-range view of an area of damage. (C) Close-up view of an area of damage.

(From Sandy Weiss.)

Remember to ALWAYS take photographs of the subject from different points of view. If all the images are exposed from eye level, valuable information may be missed. Bend down, lie on the ground, stand on a ladder or any other nearby elevated surface, and generate images of surfaces missed by a documentation carried out in only one plane (see Figure 5.3).



FIGURE 5.3 Using a mirror to show both sides of the rod threads in the same image using a front-surfaced dental mirror.

(From Sandy Weiss/Packer Engineering.)

Carry convenient gadgets. A small mirror may be the handiest thing a photographer could carry. It can be mounted on a tripod to reflect the sun onto small details under a vehicle where a flash will not reach. Photos can be captured of the reflection in the mirror if the subject is close to an obstruction and the camera cannot be maneuvered to the desired location, or the mirror can be used to document multiple aspects of the same subject seen best imaged in the same frame.

Bright sunny days are the best time to use fill-flash (see Chapter 7A for information on exposure). The distance of coverage from the flash to the subject is limited by the size of the flash, but the light the flash provides within its suggested parameters of use will lighten the shadows caused by the high-contrast lighting of the sun. This is especially useful in recessed areas of a subject, like the wheel well of a vehicle. Photos improperly captured without flash show nothing but blackness in the shadows. Photos taken with flash will show details inside recesses. Be sure to account for the added lighting of the flash and set the proper exposure if the camera does not do it automatically. Be sure to set the correct shutter speed for the flash if the camera does not do that itself too. If possible, remove the flash from the camera and hold it at an angle to properly illuminate the detail important for documenting without gaining reflections.

If it is possible to set the camera manually, expose the photographs at a shutter speed fast enough to avoid blurry images from camera movement but slow enough to allow proper exposures while using smaller lens apertures (see Chapter 7A). The use of the smallest possible lens apertures will yield photographs with the greatest possible depth of field. Images with extended depth of field will be easier to analyze and will provide the greatest detail of subject objects.



FIGURE 5.4 Scene of a catastrophic refinery explosion.

(From Sandy Weiss/Packer Engineering.)

PHOTOGRAPHY OF FRACTURES

When material failure ends in breakage, fractography may identify the fracture origin, direction of crack propagation, failure mechanism, material defects, environmental interaction, and nature of stresses (see "Fractography" later).

Many forensic photography assignments will funnel down from overall documentation to macrophotographs. No matter how large the catastrophe (see Figure 5.4), there is usually something small and critical that broke (see Figure 5.5). The break may even be the root cause. When the project originates at a fracture, it becomes a matter of failure analysis.

Properly trained observers may be able to deduce the nature of the failure from the observation of the fracture or from its facsimile. It is a fact: engineered materials fail, often with catastrophic results.[35] For example, consider the sinking of the *Titanic*.



FIGURE 5.5 Root cause of the catastrophic refinery explosion: a fractured/broken wire tie (exemplar). When the tie broke, the wires sagged down inside a high-voltage panel, caused a short circuit, and eventually an explosion.

(From Sandy Weiss/Packer Engineering.)

SINKING OF THE *TITANIC*

The *Titanic* sank on April 14, 1912, after a glancing collision with a large iceberg. In 1996, metallurgists from the University of Missouri-Rolla, Bethlehem Steel, and National Institute of Standards and Technology (NIST) studied a piece of the *Titanic*'s hull retrieved from the wreck site in 1991. The piece was 1-inch thick, included three rivet holes (1.25" diameter), and showed remnants of the original paint. "The steel edges appeared jagged, shattered like broken glass, and displayed no evidence of bending."[36] For modern steel to shatter as the *Titanic*'s steel did, the water temperature would need to be 130° F below zero.

Titanic's rivets were wrought iron and different in composition from the hull plates, but also failed in a brittle manner due to high-impact energy and low temperature. These findings support the theory that the iron rivets along plate seams were sheared off upon impact with the iceberg and the brittleness of the steel resulted in breakage of the plates, causing splits in the hull. The splits allowed 39,000 tons of water to enter at the bow and sink the ship.

Chemical, stress, and Charpy impact tests performed on appropriate samples of the steel show it was approximately 10 times more brittle than modern steel when tested at freezing temperatures, as the water and the steel would have been at the time of the collision. When *Titanic* was built, shipbuilders used the best available steel, but at the time were more concerned about tensile strength than toughness. The steel used was high in oxygen and sulfur, key ingredients for brittleness.

In a failure analysis, proper photographs to accompany intelligent testing and observations should tell the whole story of the event. Without documented evidence of each stage, the story must remain a hypothesis rather than becoming an educated conclusion.

Historically, material failures provide the impetus for the development of comprehensive failure analysis methods, including photography. It should be noted that many of the established techniques used for the failure evaluation of metals are also applied to plastics, composites, glass, and other materials, with minor modifications.

Fractography

Fractography is a descriptive treatment of fractures of materials, particularly of metals, specifically through photographs of the fracture surface. The primary objective of a material failure analysis is to determine the root cause of failure. Whether dealing with metallic or nonmetallic materials, normally the root cause of failure can be assigned to one or more of four categories: design, manufacturing, service, or material. Fractography is important in its ability to identify and document unanticipated stresses and catastrophic failures arising from any of the four categories. Fractography is also used to reconstruct material information through the documentation of the topography of the fracture-generated surfaces. These investigations provide engineers with the opportunity to recognize and interpret the various features of a fracture. This enables improvements and adds to the knowledge base regarding failure analyses and how to better determine the relationship of the fracture mode to the microstructure of the material. Fractographic investigations usually start with documentary photographs, proceed to optical microscopy at lower magnifications, and finish with scanning electron microscopy (SEM) for topographic studies at higher magnifications and also for the microanalysis of the material.

Failure Mechanisms and Causes

On a macroscopic scale, most fractures fall into one of two categories: overload and time-dependent processes. Subcategories of overload include ductile and brittle and those of time-dependent processes include fatigue, corrosion, and wear.

Reading Fractures through Witness Marks

Materials must be subjected to load prior to failure. A load is produced by energy, energy creates forces, and forces leave traces to be read on the faces of the resultant fractures. The failure analyst must be able to read the resultant fractures to understand the clues presented in order for the fracture to tell the story of the failure.

Ductile fractures exhibit plastic deformation and are characterized by material tearing. Brittle fractures display little or no macroscopically visible plastic deformation. Whether a material is brittle or ductile often depends on temperature, strain rates, and other environmental conditions. At moderate temperatures, materials may exhibit characteristics of both types of fracture. Materials with greater elongation can be considered ductile, and those with less elongation can be considered brittle.

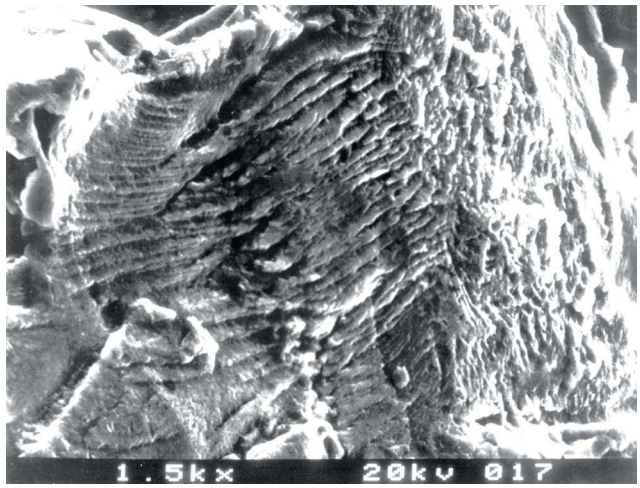


FIGURE 5.6 A fatigue fracture image from a scanning electron microscope (SEM).

(From Sandy Weiss/Packer Engineering.)

Brittle fracture is the end product of rapid cracking with little plastic deformation through a stressed material and with the failure zone perpendicular to the direction of the applied stress. The cracks usually travel at a high rate of speed, and the fracture appears instantaneously. In most cases, this type of fracture allows no repair of the material before failure because there is no visible sign of damage before the breakage.

This type of brittle fracture leaves a relatively flat surface at the break and often displays a pattern on the fracture surfaces. Some brittle fractures have lines and ridges beginning at the origin of the crack that spread out across the fracture surface. The surface of such fractures may appear crystalline, and some display continuous V-shaped markings called chevrons, pointing to the origin of the fracture. Very hard or fine-grained materials may not display a pattern on their fracture surfaces, and amorphous (without crystallization in a solid) materials may have shiny and smooth fracture surfaces.

Some materials fail from fatigue. The origin of the fracture; the appearance of the fracture face; the shape of the beach-marks (see Figure 5.6), if any; the location, shape, and size of the fast failure zone; and the direction of the failure propagation tell how the fracture occurred. In some situations, high-powered microscopy is required, but most of the time careful observation with proper lighting and low-power (5× to 25×) magnification is all that is needed.

CONCLUSION

Humans have five overlapping senses. Sight augments hearing as smell augments taste. If a person has a medical problem and loses the ability to utilize one or more of their senses, they do not die; they learn to rely more on the ones they have left.

Sensory input builds memories. A smell, a sound, or a touch may bring out a memory from years past just as strongly as if it were something that happened yesterday. An author works to convey visions to the people who read his or her work. The better the writing, the more detailed the vision. A photographer works to convey words to the people who see his or her photographs.

Normally, a forensic documentation requires many photographs to fully illustrate the subject. It is the unusual case for which several or even one photo will show enough information so more is not required. The photographer must take enough photos, and in the proper order, to relate to the viewer the whole story behind the work. In order to tell the story correctly, the documentation must follow an accepted and understandable pattern and structure.

It is a mistake to approach a project with preconceived ideas of what happened or how and to make photographs only illustrating that particular mental process. It is never simple, and most of the time impossible, to go back and get another chance to document the evidence. The forensic photographer is responsible for capturing all the relevant images, in the smallest number possible, to relate every aspect of the story visually in the least time.

NOTES

1. *The History of Printmaking*, New York, Scholastic Press, 1995, p. 2.
2. Meggs, Philip B, *A History of Graphic Design*, 2nd Ed, New York, Van Nostrand Reinhold, 1992, p. xiii.
3. Robin, Harry, *The Scientific Image: From Cave to Computer*, New York, Abrams, 1992, p. 9.
4. Meggs, *History of Graphic Design*, p. 4.
5. Wilkinson, Richard H., *Reading Egyptian Art: A Hieroglyphic Guide to Ancient Egyptian Painting and Sculpture,* New York, Thames and Hudson, 1992, p. 9.
6. Ibid.
7. Ibid.
8. Pollack, Peter, *The Picture History of Photography from the Earliest Beginnings to the Present Day,* New York, Abrams, 1969, p. 13.
9. Ibid, p. 14.
10. Ibid, p. 14.
11. Ibid, p. 14.
12. Robin, *Scientific Image*, p. 9.
13. Ibid.
14. Fenske, Jamie, Packer Engineering, Inc., Naperville, IL, personal communication.
15. Tufte, Edward R., *Visual Explanations, Images and Quantities, Evidence and Narrative,* Cheshire, Graphic Press, 1997, p. 50.
16. Robin, *Scientific image*, p. 99.
17. Ibid.
18. Meggs, *History of Graphic Design*, p. 4.
19. Robin, *Scientific Image*, p. 9.
20. Tufte, *Envisioning Information*, p. 12.
21. Robin, *Scientific Image*, p. 9.
22. This section is based on the writings of Steven D. Schafersman, *An Introduction to Science: Scientific Thinking and the Scientific Method*, 1994, www.freeinquiry.com/intro-to-sci.html.
23 Starrs, James E., The C.S.I. Effect, *Scientific Sleuthing Review* (28), pp. 32–34.
24. Ibid.
25. Ibid.
26. Ibid.
27. Ibid.
28. Thornton, John I., "The General Assumptions and Rationale of Forensic Identification," in *Modern Scientific Evidence: The Law and Science of Expert Testimony*, eds. David L. Faigman, David H. Kaye. Michael J. Saks, and Joseph Sanders, St. Paul, West Publishing Co., 1997.
29. Kirk, Paul L., *Crime Investigation,* New York, Interscience Publishers, 1953, p. 4.
30. Robin, *The Scientific Image,* p. 9.
31. https://www.coursehero.com/file/14388842/Induction-or-inductive-reasoning/
32. Wells, H.G., *The Outline of History, Vol. 3,* New York, Collier, 1922, p. 860.
33. Robin, *Scientific Image*, p. 99.
34. Schafersman, "An Introduction to Science."
35. Kuhn, Thomas, *The Structure of Scientific Revolutions,* Chicago, University of Chicago Press, 1962, p. 168.
36. Foecke, T., *Metallurcy of the RMS Titanic,* Gaithersburg, NIST, 1996.

6 Digital Processing of Evidentiary Photography

David "Ski" Witzke

CONTENTS

History of Digital Imaging 56
Out of This World Digital Imaging 57
Visualization 57
Bias and Uncertainty 57
Image Capture Standards and Best Practices 58
    Digital Imaging Standards Today 58
    Why Are They What They Are? 58
    Creating Your Own Standards and Best Practices 58
Image Capture Formats 59
    JPG (Joint Photographic Expert Group) 60
    Raw (Original Unprocessed Data as Downloaded from the Camera Imaging Sensor) 62
    TIF (Tagged Image File Format) 63
Resolution 64
    Concepts and Concerns 64
    Pixels and Dots 64
    Quantitative Analysis of Printed Output 66
Maintaining Image Quality 67
    Image Manipulation 67
    Image Sensor Size 68
    How Large Is the Image on the Screen? 68
Calibrating Digital Images 69
    Accident/Crime Scene 69
    Identifying Distortion 70
    Calibrating Medium Objects 73
    Calibrating Small Objects 76
Forensic Imaging Hardware and Software 79
    Verifying Settings in Adobe Photoshop 80
    Not Meeting System Requirements and Its Effects 81
Image Analysis 81
    Bit Depth 82
    Resolution 83
Cognitive Image Analysis 84
Quantitative Image Analysis 84
Digital Processing of Evidentiary Photographs 85
    Concepts 86
Best Practices for Image Capture 89
    Best Practices for Image Capture Using a Digital Camera 91
    General Guidelines 92
Resolution and Resampling 94
    Resolution Resampling: "Upsampling" and "Downsampling" 95
    Adjusting Size and Resolution 96
A Brief History of Scanners and Resolution 98
    To Photograph or to Scan, That Is the Question 99
Image Processing Guidelines 102
The Order of Processing (Aka Processing Sequence) 102
    Capture 102

Storage 102
Duplicate 103
Process 103
Save 104
Best Practices for Suppression of Background Color Values 105
Helpful Hints: Basic Ninhydrin Print Processing 108
Ninhydrin Print Processing Using Calculations 108
Sharing Files: Hard Copies versus Electronic Transfer 110
Mitigation of JPG Artifacts 111
Artifact Reduction 112
Degradation by PDF 113
Legal Ramifications of Digital Imaging 113
Admissibility and Reliability … 118
The Challenges Continue 120
"Illusory" Expert Testimony 121
6A Impression and Pattern Evidence 122
Introduction 122
Footwear Impressions 124
Footprint Nomenclature 124
Photographic Documentation of Footwear Impressions 124
Dust Footprints 127
Footprints in Other Mediums 128
Tire Tracks 128
Definition 128
Photographic Documentation 129
Casting 130
Cast Preservation 130
Toolmark Impressions (See Instrument Marks, Above) 130
Nomenclature 130
Characteristics 130
Toolmark Impressions 131
Photographic Documentation 131
Bite Mark Impressions 132
Nomenclature 132
Bite Mark Photographic Documentation 133
Firearms and Bullets 133
Nomenclature 133
Photographic Documentation 134
Indented Writing 135
Nomenclature 135
Indented Writing Photography 135
Notes 136

HISTORY OF DIGITAL IMAGING

The advent of digital imaging technologies goes back to the 1930s when Chester Carlson, an amateur inventor, developed the first "xerographic image." After working many long hours manually copying expensive law books he could not afford for law school, he was motivated to develop an electrophotography technique to make the creation of copies faster and easier. After a few "fired up" and "explosive" experiments, he settled on an idea to utilize static electricity using a handkerchief, light, and dry powder. His first successful attempt to make a "copy" was on October 22, 1938, in Astoria, New York.

The Haloid Corporation, a New York–based manufacturer and wholesaler of photographic papers and that would later be known as the Xerox Corporation, introduced the first electrophotographic copier, the "Model A," in 1949.[1] But the first commercially available copiers were not available until 1959. Development of this technology continued during the 1950s through the 1980s, but the fundamental technologies have remained largely unchanged since the 1950s.

These fundamental technologies later became the foundation upon which the Automated Fingerprint Identification System (AFIS) would be built. And today, it remains a core



FIGURE 6.1 "Astoria 10.22.38" (The first xerographic image).

(From Xerox Images Library. Xerox Corporation. Retrieved September 13, 2018.)

technology for live scan fingerprint devices ("live scan"). This technology is able to capture the minute ridge detail and characteristics, including pores, creases, scars, etc., electronically and then transmit that information to a law enforcement agency for an applicant or criminal background check or other identification purpose. In fact, live scan technology has been lauded as one of the greatest advancements in fingerprinting technologies, and it has completely modernized and revolutionized the science of fingerprints. So, while we owe gratitude to Sir Edward Henry and Francis Galton for the classification of fingerprints and fingerprint detail, we also owe sincere thanks to Chester Carlton for his contributions to the modernization of the science of fingerprints.

OUT OF THIS WORLD DIGITAL IMAGING

The first "digital images" were captured of Mars and transmitted back to NASA by the *Mariner 4* spacecraft on July 15, 1965.[2] These images were captured using a video tube camera and a digitizer. The first recorded attempt to develop a digital camera was in 1975.[3] The camera weighed approximately 8 pounds (3.6 kg) and had a resolution of 0.01 megapixels (10,000 pixels). The captured images were recorded in black and white, and it took 23 seconds to capture its first image.

It is believed that the first truly digital camera was developed by Fuji-Film in 1988.[4] The digital image file was recorded to a 16 MB internal memory card, which required battery power to retain the computerized image data on the memory card.

The first commercially available digital camera was the 1990 Dycam Model 1. Images were captured on this digital camera using a charge coupled device (CCD) digital imaging sensor, and images were stored on an internal memory card. This camera connected directly to a computer to download images.[5]

Adobe Photoshop 1.0 was then released in 1990. Between 1990 and 2003, Adobe released 13 versions prior to the introduction of their Creative Suite bundling, released in October 2003. There were seven versions released as Creative Suites. On June 17, 2013, Adobe released what is now known as its Creative Cloud packages. Since then, there have been 12 major and minor releases, as of this writing.[6]

Besides Adobe Systems, another widely used application within the forensic imaging environment was a product known as Image-Pro, developed by Media Cybernetics Inc., founded in 1981. Image-Pro was advertised as a world-renowned, scientific software application for image capture, processing, analysis, display, and management.[7] But it was significantly more expensive and more challenging to use than Adobe Photoshop.

Today, Adobe Photoshop is a ubiquitous part of the digital imaging community, including law enforcement. Adobe Photoshop has cemented itself as an essential forensic tool for forensic scientists and crime scene technicians and is widely used around the world for processing impression evidence, especially hard-to-photograph items, like latent prints, questioned documents, footwear, trace evidence, crime scene photographs, and more.

VISUALIZATION

There will always be conjecture about how information is visualized and presented and whether it is presented in an accurate and meaningful way.[8]

In terms of digital evidentiary photography, visualization (aka memorializing) means capturing information in the form of a digital record. The purpose of this record is to show what may have happened, could have happened, did happen, or is believed to have happened. In many instances, this digitally recorded record may have probative value, which means the image demonstrates (proves) a fact is accurate and reliable.

Digital imaging technologies also provide judges and jurors visual access to things they would otherwise not be able to see, such as fingerprints on a piece of paper; a bite mark left on a victim's body; obscured, obliterated or indented writing; etc. As a result, some defense attorneys argue that digital images are "prejudicial" in the courtroom.

BIAS AND UNCERTAINTY

"Bias" is understood to mean "the extent to which one response is more probable than another when a condition or stimulus is present in the equation."[9] Today, "bias" is often interpreted as "human factors." Human factors can play an important role when processing, analyzing, or comparing images. For example, some law enforcement personnel have a different attitude about how they process a crime scene involving a person, such as a death investigation, rape, assault, etc., versus a crime scene where a person was not involved, such as a burglary. This is particularly true in the event of a high-profile case.

Other stimuli that can create bias are whether or not the subject of the crime is known; whether or not the suspect is a known repeat offender; whether or not children were involved; whether or not family members, friends, or family members of friends or relatives were involved; and/or whether or not animals were involved.

Health conditions may also cause bias, as these conditions can affect how clearly crucial detail can be seen within a digital image. From a psychological perspective, two processes affect an individual's decision (conclusion): (1) the sensory processes and (2) the inference and decision processes. The sensory processes are based on the input and/or stimulus, while the inference and decision processes are based upon the internal (emotional) state of the individual, leading to the response or conclusion.

IMAGE CAPTURE STANDARDS AND BEST PRACTICES

Digital Imaging Standards Today

Today, digital imaging is used in almost every sector of the criminal justice community. Digital images and video (audio/video) are captured by first responders for investigators and/or detectives. Examinations of sexual assault, domestic violence, abuse, and neglect victims are captured by sexual assault nurse examiners (SANE); digital images are captured at the scene as well as in the laboratory by crime scene technicians and/or evidence technicians; images of specimen collections are captured in the biology section for recording the recovery of DNA samples; digital images are captured both before and after processing for analysis by footwear, firearms, toolmarks and latent print examiners; and digital images are captured for analysis by questioned document examiners.

Each discipline has its own "guidelines" for the proper capture of digital images. For example, the Scientific Working Group on Digital Evidence (SWGDE), which is now responsible for the digital imaging guidelines proposed by SWGDE as well as Scientific Working Group on Imaging Technology (SWGIT), provides guidelines for the capture of latent prints and footwear, while the Scientific Working Group on Friction Ridge Analysis, Study and Technology (SWGFAST) and Scientific Working Group for Shoeprint and Tire Tread Evidence (SWGTREAD), respectively, have created additional guidelines for the capture of latent prints and footwear.

Similar to the Federal Rules of Evidence, the working group guidelines were developed with the intent to provide uniformity and consistency of the digital evidence provided to the courts. These guidelines focus almost exclusively on the reliability of the systems used. For example:

- Is the equipment accepted as "standard" in the field?
- Are reliable ("standard") software programs used?
- Is the equipment in good working order?
- Is the operator of the equipment properly trained?

The good news is that some law enforcement agencies followed the guidelines and created standard operating procedures (SOPs) based upon the recommendations set forth in the SWG documents. The bad news is that many other agencies did not adhere to the guidelines and all but ignored the recommendations because of the financial implications involved.

Some guidelines have been taken out of context regarding the meaning and intent of the original requirement. For example, SWGIT, SWGDE, and SWGFAST have all created guidelines for latent print capture based on a "requirement" of a minimum resolution of 1,000 pixels per inch (PPI). This so-called "requirement" is based on a requirement specified in the FBI's Integrated Automated Fingerprint Identification System (IAFIS) Image Quality Standards (IQS) Appendix F. This requirement was intended to ensure the images submitted to the AFIS were of sufficient quality, but more importantly, to ensure reliability of image size (i.e., so that a thumb would be the size of a thumb and not the size of a little finger, etc.).

Unfortunately, many agencies used the 1,000 PPI as a "requirement" for the capture of latent impressions, which had a negative impact on the ability to process the captured images.

Why Are They What They Are?

The Scientific Working Groups (SWGs) were initiated by the Federal Bureau of Investigation (FBI) to evaluate best practices, identify research needs, and disseminate information. By design, these working groups were intended to create guidelines, which, in turn, were not enforceable standards. Each law enforcement agency was free to accept or reject the guidelines as proffered by the various SWGs.

In an effort to create more enforceable standards, the Organization of Scientific Area Committees (OSAC) for Forensic Sciences was created by the National Institute of Standards and Technology (NIST). The documents created by the various OSAC subcommittees are intended as "written documents that define minimum requirements, best practices, standard protocols, and other guidance to help ensure that the results of forensic analysis are reliable and reproducible" (https://www.nist.gov/news-events/news/2017/08/nist-seeks-input-osac-20). After a document has been drafted, it is then reviewed by a standard development organization (SDO) such as ASTM International (formerly known as the American Society for Testing and Materials) for consensus and publishing. Once published, these documents carry significantly more weight in the forensic science community and the criminal justice system.

Creating Your Own Standards and Best Practices

The goal of forensic digital imaging is to ensure maximum image quality as well as ensure admissibility when the digital evidence is presented in the courtroom. It is important to remember that this goal must be considered throughout the entire forensic digital imaging process, from the point of capture at the scene of the crime or accident/incident until the digital images are presented in the courtroom.

It is important to create a detailed SOP to optimize the likelihood of having digital images admitted in the courtroom during trial. Ignoring one component of this process can create a hole in the overall process.

Many organizations fail to appreciate the level of risk they face by not having an SOP. This can prevent critical digital evidence from being admissible in court, or it can result in challenges about the authenticity and integrity of digital evidence. One of the biggest challenges being faced today has to do with the attribution of the image.

For example, many crime scene units have a SOP in which it states three pictures must be taken of every piece of evidence at the crime scene: overall image, mid-range image, and a close-up image of the item. They fail, however, to specify what is required in the photo lab. It is common practice to photograph impression evidence by filling the frame with the impression and a scale. While this is a correct procedure, it is not the only procedure that should be used to document impression evidence.

An overall photograph of the entire piece of evidence should also be required, especially in the case of "nonrecoverable" evidence. In some instances, the impression may fade over time (such as the situation with use of ninhydrin or ThermaNin). Also, plastic bags are made from a petroleum distillate, which causes the bond between a cyanoacrylate fumed impression to break down over time and the impression will literally flake off. Or perhaps the impression was developed on glass and the glass was broken or lost. In these instances, the photograph of the latent impression is the best evidence and may be presented in court in lieu of the physical evidence.

Without a photograph of the entire piece of evidence with the developed impression, it is extremely difficult to "prove" the attribution or source of the impression. Most agencies rely upon written documentation describing the source bearing the impression. But this level of documentation may not always be done, or it may not be reliable. With the ease of use of digital cameras today, it is a very simple and easy process to take another picture for reference/historical significance.

Other considerations for your SOP should include:

- Image size based on camera resolution and capture format, which affects the number of images that can be stored on your storage medium in the camera and on the computer or server.
- What is the required image quality based on the type of lens used (macro lens, wide-angle lens, or zoom lens)?
- Is a digital single-lens reflex (DSLR) camera required or is a point-and-shoot sufficient for the type of image(s) being captured?

What file format(s) should be used for digitally capturing crime scene photos, evidentiary photos, sexual assault photos, domestic violence photos, etc.? Chain of custody issues include but are not limited to:

- Who captured the image digitally?
- How long was the image file in their possession?
- If the possession of the image file was transferred from one person to another, when did the change of custody occur?
- If the possession of the image file was not transferred from one person to another and the person who captured the image is required to transfer the digital image files to the computer or server, when did that acquisition (upload) process occur?
- Who had access to the files after they were uploaded to the computer or server?
- Was processing of the digital images required? If so, when, by whom, and what was done?
- Are there additional imaging requirements for interoperability between systems, such as a digital evidence management system and AFIS?

Another major consideration has to do with discovery. In this case, the question is what images have been shared with the prosecutor and the defense. The last thing you want to do is be on the witness stand describing a particular image and the defense counsel interrupts you and says that he or she has not received a copy of that image.

Other SOP considerations should include backup and archiving routines to ensure data security and prevent catastrophic loss of data. Another topic that fails to receive appropriate consideration is conversion. How often do you convert (transfer) your data from one medium to another? Some agencies today still have digital images stored on media that is no longer easily accessible, such as floppy disks or even PCMCIA cards. Alternatively, maybe the original files were stored in their original format and were not converted to a readable format, and the original technology to read the original format is no longer available.

IMAGE CAPTURE FORMATS

Digital images can originate from many different sources. These source devices include digital point-and-shoot cameras, DSLR cameras, digital or analog video cameras, flatbed scanners, cellphones, body-worn video cameras, dashboard cameras, etc.

There are almost as many video formats as there are video solutions. However, there are a lesser number of video frame sizes, such as 480 × 360, aka 360p; 640 × 360, aka 360p wide format; 640 × 480, aka 480p; 960 × 720, aka 720p; 1280 × 720, aka 720p wide format; 1440 × 1080, aka 1080p; and 1920 × 1080, aka 1080p wide format, just to mention a few of the more common formats used today.

Some software applications, such as Adobe Premiere, include a function providing the ability to "export" a frame from a video clip. Conversely, other video player applications only provide a playback function, which requires the video to be played to the point where the desired frame is visible on the screen ("freeze frame"), and then the frame is captured using a print screen function. After the video frame is captured into memory, the operator must open

an application such as Paint, Adobe Photoshop, Adobe Photoshop Elements, Gimp, etc., and paste the image into a new file. There are other applications providing the ability to grab a still frame. But regardless of how it is captured, how do you save the digital image file?

Most image capture devices, as well as frame grabber software and other applications, provide an option for saving **video files** in a TIF and/or JPG format. Some applications provide the ability to save the captured frame image as a JPG, TIF, or DNG file, which is Adobe's proprietary lossless raw image file format.

Most digital still cameras capture images using a TIF, JPG, or raw file format. Some cameras provide a raw plus JPG option. Once the camera raw image is captured into a standard image file format, it can be saved as a DNG file too in most, if not all, Adobe software applications.

After using digital imaging technologies in the criminal justice system for more than two decades, one would think there would be an agreement on something as simple as image file formats. But that is *still* not the case. This should not be a total surprise, because some people still do not know the difference between a dot and a pixel. While choice comes down to an opinion, the winning opinion is that held by the person with the greatest degree of control—not always the person with the highest rank. (In most law enforcement agencies, the IT department holds the winning opinion about anything and everything digital.)

What are the advantages and disadvantages to using these different formats?

JPG (Joint Photographic Expert Group)

JPG (also referred to as JPEG) is the most commonly used (or misused) digital camera image format.

When images are captured with a digital camera, the imaging software in the camera uses the camera settings such as white balance, sharpness, hue and saturation, etc., to process the actual image data. Once that data has been downloaded from the imaging sensor and processed in the camera, the image data is compressed and the file is stored.

Of the three most commonly used file formats, JPG produces the smallest files. Because of their smaller size, they are also the fastest to download, both from the sensor in the camera to the camera's storage media and when moving images from the camera (or the camera's memory device) to the computer.

Most digital cameras (and digital imaging applications) provide multiple image quality (compression) settings, such as fine, normal, and basic. Depending on the processor speed, the memory, and the software within the camera, some digital cameras compress images to smaller sizes. For example, images generated from the least compressed JPG setting in some digital cameras are difficult to distinguish from their uncompressed counterparts.

Therefore, some people believe a JPG image provides outstanding image quality (or at least "good enough" image quality) while delivering the fastest speed for all camera functions with the least amount of storage required.

Technologically, JPG compression removes features; relocates boundaries; alters the size, shape, and color of features; and reduces resolution differently for different locations in the same image. This process also alters pixel values differently, depending on whether they lie at the center or boundaries of the pixel grid into which the image is divided.

IMPORTANT:

There is no such thing as a fast, high-resolution, lossless-compressed image format.

Most JPG algorithms divide the image into an 8-pixel-by-8-pixel grid in which a Fourier-related transform is used. Depending upon the frequency components of the pixel values in that block, multiple types of artifacts are visible:

- Ringing (artifacts caused when there are sharp transitions within the block, which may be particularly visible around text in pictures)
- Posterizing (artifacts caused when portions of the original image with a gradual transition are replaced by abrupt changes in shading and gradation from one area of tone to another)
- Staircase noise (aliasing) along curving edges
- Blockiness (also called checkerboarding)

All of these artifacts are visible in Figure 6.2.

The primary benefit of the JPG file format is JPG files can be written to the storage media much faster than any other file format, and smaller JPG files require less storage space. When photographing evidentiary items, the speed at which the files are written is not usually an issue. In some instances, however, the amount of space required for storing larger files may be an issue. Usually the problem is not major, given the low cost of storage space today.

The interesting thing is that many people still do not realize the total range of implications compression has on forensic evidentiary images. They only know the compression algorithms do not reduce image resolution during compression. The fact that these algorithms discard pixel color values is not well known. (In other words, the pixel is a mere shell of itself.) For example, a compressed JPG file from a 6 MP camera (3000 × 2000) produces a compressed file size of less than 2 MB. These values are the result of compressing 18 million bytes of data (1 byte for red, 1 byte for green, and 1 byte for blue *per pixel*) to approximately

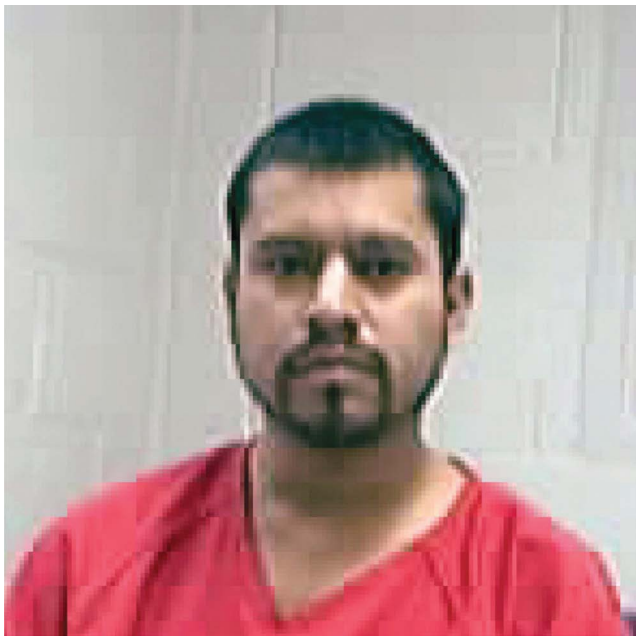


FIGURE 6.2 A mugshot compressed using a medium-quality JPG compression algorithm. The 8-pixel-by-8-pixel blocks are easily identifiable, as are the aliasing artifacts around the outside of the individual's head and along the edge of the shoulder.

one-ninth of the actual pixel color values with "high-quality" compression.

When the image is opened and decompressed, its size still reads 3000 pixels × 2000 pixels with a size of 17.2 MB. Once the original pixel values from the imaging sensor in the camera have been lost—when the image is saved by the camera as a JPG file—the *original* pixel values can *never* be recovered. The pixel values created when the image is reopened are an approximation of what existed before.

The loss of original color values can—and will—have an impact on the suppression of background noise, etc. This is especially true when trying to process fingerprints in blood that were developed using Amido black on bedding materials. The weave pattern and ridge detail will be blurred because of the compression and decompression process.

As a rule, images processed (aka enhanced) for scientific analysis and comparison should not be compressed in JPG format; they should be stored using a noncompressed image file format.

If a digital image is captured in JPG format and the image has been processed, the processed image must not be saved again in a compressed JPG format. The processed image must be saved using a noncompressed file format.

JPG files can be opened and closed multiple times without further degradation; however, once the file is opened and just a single pixel value is changed, the entire image file must be recompressed to incorporate the new pixel value into the image data. This causes further degradation (more manipulation) of image pixel values.

NOTE:

One major concern for this author is that many IT people do not fully comprehend the difference between crime scene images (Category 1 images) and evidentiary images (Category 2 images). Crime scene images are typically presented in court for demonstrative and/or illustrative purposes, and the testimony of the officer is the "evidence." Evidentiary images (Category 2 images such as latent prints) are used for "scientific analysis" and comparison, and these images may also be presented in court in lieu of the original evidence. Vital characteristics, such as the shapes of the edges of ridge detail or pores, can be lost during compression, which can also affect the examiner's ability to make an identification or classify the impression as "not of value."

However, there are JPG compression algorithms "less lossy" or "nearly lossless," such as JPG 2000. JPG 2000 requires complex encoders and decoders that may produce visual impairments, such as "ringing artifacts" that often appear as blur ("rings") near edge detail in the image. While JPG 2000 has been published as an ISO standard (ISO/IEC 15444), JPG 2000 is not widely supported in web browsers, nor is it supported by digital camera manufacturers and other software developers.

So, what are the advantages of using a JPG format?

- JPG images require less space on the camera media as well as for permanent storage.
- JPG images not only provide faster processing in the camera but can be downloaded and viewed faster.
- JPG images are compressed using a standardized format, which means they are compatible and can be shared easily.
- JPG images do not have to be converted to be viewed or processed.
- JPG images are smaller and can be transmitted easier in emails as well as imported into word processing files (for reports) and PowerPoint presentations (for courtroom presentations) much more easily. Because of their smaller file size, JPG images enable PowerPoint slides to transition rapidly.

TIP:

In many instances, the advantages of the JPG format outweigh the disadvantages.

What are the advantages of using a JPG format?

- JPG images have a maximum dynamic range of only 8 bits (maximum of 256 shades) per color channel.
- Original pixel values are discarded, and the original pixel values cannot ever be re-created as they were originally captured
- Opening, viewing, and then closing a JPG file without making any changes does *not* have an effect on the stored pixel values. However, each time a JPG file is opened, processed, and then *resaved*, the entire image is recompressed, causing even more data loss.
- **Resampling** techniques are used to restore discarded pixel values when digital images are decompressed for display and/or printing. Depending on the level of compression used when the image was saved, the resampling techniques may affect the visualization of image characteristics.

Raw (Original Unprocessed Data as Downloaded from the Camera Imaging Sensor)

Most digital camera manufacturers—and a growing number of cellphone manufacturers—include a camera raw format as one of the means/methods for capturing and storing images on the media inside the device. When saved, the file contains only the unprocessed brightness data (filtered light intensity) as it was downloaded from the imaging sensor. Camera raw files are smaller than a noncompressed TIF file, but they are larger than a JPG because all of the original data is retained when the file is saved.

Camera raw image files are stored using a manufacturer-specific (proprietary) format and must be converted from "raw data" to "image data" before they can be viewed. Software applications like Adobe Photoshop have a raw image converter integrated into the application that will convert most, if not all, camera raw files.

In Adobe Photoshop, the camera raw converter, shown in Figure 6.3, may be used to correct traditional camera functions such as white balance, exposure compensation, brightness, and contrast, as well as perform basic image enhancement functions, including sharpness, lens aberration, temperature, hue and saturation, perspective, etc. With this flexibility comes a higher level of sophistication and complexity that generally require specialized training or a lot of self-learning.

Most camera manufacturers use a unique file extension to identify their proprietary camera raw files. Some camera manufacturers, such as Canon, use multiple file extensions to identify different formats. For example, Canon uses CRW and CR2 to distinguish between their 12-bit camera raw format and their 14-bit camera raw format, respectively.

Camera raw format provides several advantages over the traditional JPG or TIF file formats, including but not limited to:

- Camera raw files are smaller in file size than TIF, yet they do not discard any of the original values captured by the imaging sensor.
- Camera raw files provide a higher dynamic range—12- or 14-bit (4,096 tonal range values and 16,384 tonal range values, respectively)—compared with only 8-bit grayscale values (256 tonal range values) available with JPG files.

Note: While the camera stores the original 12- or 14-bit values as a data file, the corresponding image files must be stored as either an 8-bit or 16-bit image. This means the raw tonal range values for each pixel must be discarded when the image is opened as an 8-bit image or that the remaining bits (4 bits for a 12-bit image and 6 bits for a

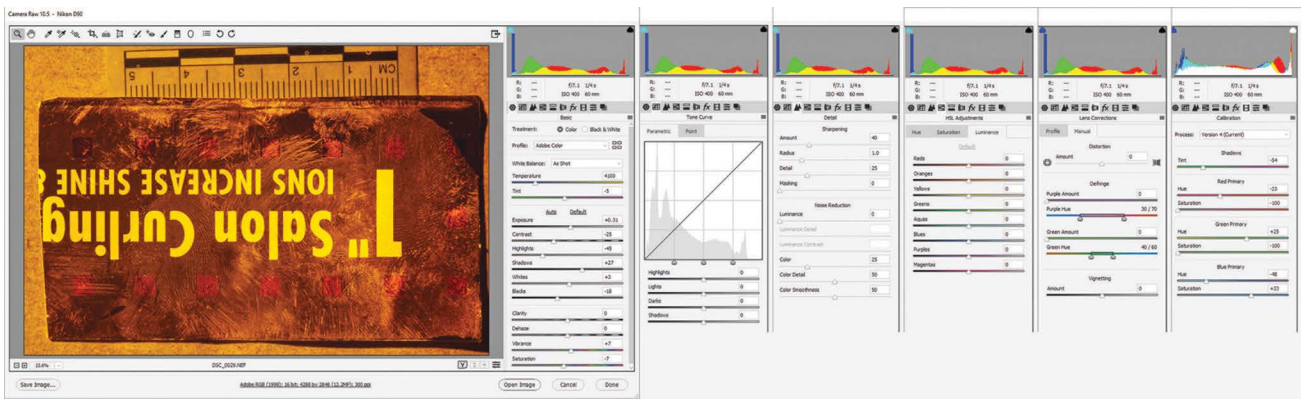


FIGURE 6.3 Adobe Photoshop's camera raw converter provides a wide range of functionality to correct a multitude of functions in the camera raw format. The camera raw format is recommended for crime scene photography because of this flexibility to correct parameters and produce more accurate color values and contrast.

14-bit image) are padded with null values to fit in the file space allocated for a 16-bit image. Camera utility programs that convert their raw files to TIF or JPG automatically truncate the tonal range values to the standard 8 bits or 256 shades per color channel.

- Camera raw files are not processed inside the camera; all processing is deferred until the file is opened on the computer.
- Camera raw files are read-only. All changes made during the conversion process, such as the white balance, brightness and contrast, etc., are written to an XMP "sidecar" file as well as the image file metadata. Since the original camera raw file cannot be altered or manipulated easily, camera raw files are typically preferred over image file formats such as JPG, where the original file can be altered quickly and easily using almost any software application.
- When stored in their proprietary camera raw format, the files are approximately one-third the file size of a noncompressed TIF image and can be written to the camera's storage media significantly faster than a TIF file. They can also be downloaded much faster than TIF files from the camera storage media.

Disadvantages of using raw files include the following:

- Raw files cannot be shared easily because special software, such as Nikon Camera Control Pro 2 or Adobe Photoshop, are required to open their proprietary file formats. This means the recipient may not be able to open the files.
- Not only must the original raw file be stored but also the converted file and the processed (enhanced) image file must be too. Maintaining the relationship between all three files can be troublesome, not to mention the challenges related to storing and retrieving the images.
- Accuracy of tonal range can be argued, especially in the case of bruising. For instance, in domestic violence or sexual assault cases, the person processing the raw files may not have been the person who captured the image(s). Because the person opening the file can adjust the hue and saturation subjectively, the true nature of the image has the potential of being compromised.

TIF (Tagged Image File Format)

Over the years, **TIF** files (also referred to as TIFF, which is short for Tagged Image File Format) have been identified as "the truest interpretation of an image." However, this description is only partially true.

In the past, some digital camera manufacturers, such as Kodak, used a proprietary file format with a TIF extension as part of their naming convention. Unfortunately, these TIF files could not be viewed or processed as TIF files without the use of Kodak's proprietary software or Adobe Photoshop's "Twain" driver. This caused a great deal of confusion and frustration because TIF files are supposedly compatible with most imaging applications and operating systems. The Kodak TIF files were neither. The Kodak TIF file was the first original camera raw file format. (With the standardization of TIF and JPG file formats, camera manufacturers no longer use the TIF extension for images stored using a proprietary file format.)

Some of the more common advantages of using a TIF format include but are not limited to:

- TIF is the most accurate and reliable method for storing processed images captured as either raw or JPG.
- TIF files support multiple layer functions, including text layers and graphics layers, as well as adjustment layers and/or smart layers now available in Adobe Photoshop.
- TIF is the most reliable format for storing digital images processed for forensic image analysis, **and comparison is required**.

Some of the typical disadvantages include but are not limited to:

- The noncompressed TIF format creates large files requiring vast amounts of storage space and significantly more time to upload and download.
- Large TIF files cannot be shared easily across the Internet.
- Large TIF files require more time and computer resources to display and/or print.

As described earlier, there is a common distinction between the file formats used for Category 1 and Category 2 images. Typically, digital images captured for documentation or illustrative purposes (Category 1 images) may be captured and stored as JPG files, whereas forensic digital evidentiary photos (Category 2 images) are typically captured using either a camera raw or TIF file format.

In the subject case, the image contained sufficient detail allowing the latent print examiner to make a positive identification. However, the examiner could not articulate or elaborate on the technology to calm the court's concerns about compression artifacts even though the image was compressed using a less-lossy compression algorithm. This algorithm did not incur significant (grossly detrimental) loss of detail; therefore, the image was still "of value." It should also be noted that one of the contentions put forth by the defense was the FBI attempted to explain the fingerprint misidentification in the Brandon Mayfield case occurred

NOTE:

SWGIT changed the "requirement" (standard) to capture images as TIF or camera raw because a latent print identification was challenged in a high-profile case when the local law enforcement agency used a JPG image for latent print processing, analysis, and comparison. The court cited and interpreted the SWGIT guidelines as "Thou shall not use JPG" even though the print had more than enough detail to make the identification. As a result, SWGIT changed the guideline to avoid having evidence thrown out of court in the future if there were sufficient Level 1, Level 2, and Level 3 detail positively identifiable in the image.

because the latent print submitted by the Spanish police was a poor-quality, compressed, JPG image.[10]

One would think—and hope—that image quality would win out over smaller, less accurate formats, but it has not. While many law enforcement agencies make a distinction between evidentiary (analysis required) and documentation photographs, many do not. Many IT departments in both large and small law enforcement agencies mandate that photographs will be captured and stored using JPG format solely because of the numbers of images now being taken with digital cameras at the crime scene and in the lab and the corresponding space required on the department server to store those images. Clearly, those individuals do not have to put their career on the line using inadequate images. (Think about how you might feel if you could not solve a case just because the digital images of the latent prints in the case were not good enough, or how you might feel if a family member was raped or murdered because poor-quality images prevented a thorough analysis of the evidence and failed to lead to the identification of a serial rapist or murderer.)

After enhancing a digital image, the image must be saved using a lossless compression format such as TIF, because compression formats, such as JPG, will degrade the image.

RESOLUTION

Concepts and Concerns

During the 1980s through the 1990s, Kodak developed a sensor with 1.4 million pixels. Then the first Kodak DCS 100 was released in 1991 using a Nikon F3 SLR camera body modified with digital components. In 1992, Kodak released the Kodak DCS 200 series, using a Nikon F-801s SLR camera body. This model was followed by the upgraded Kodak DCS 420, released in 1994; it cost between $10,000 and $13,000. That same year, Kodak also released the 6-MP (megapixel) Kodak DCS 460, which retailed for $28,000 on launch.[11]

One of the early adopters of this revolutionary technology for law enforcement was the Tacoma Police Department in Washington State. As will be discussed later in this chapter, Erik Berg, a forensic specialist at the Tacoma Police, was responsible for digitally enhancing images of latent fingerprints and palm prints, which resulted in the first case (*State of Washington v. Eric Hayden*) in the United States where a digitally enhanced fingerprint was used to convict a suspect of a murder and it was subsequently upheld on appeal. The system defined a new market and is still widely sold to U.S. and foreign law enforcement departments today. This product was the precursor to the Foray Adams system (also known as Digital Workplace) still being sold by Foray Technologies.

When digital cameras were first introduced in law enforcement, there was a huge concern regarding the use of digital imaging technologies in criminal cases. It was then, and still is, interesting to note that there was a complete lack of realization—or even awareness—that the evolving digital technologies were the same technologies enabling the early development and implementation of AFIS systems in Europe, North America, and Japan in the 1970s. The adoption and use of these systems expanded significantly in the mid-to-late 1980s and the early 1990s while the courts were challenging the use of digital imaging technologies in the criminal justice system.

Pixels and Dots

As demonstrated by the widespread use of Facebook, Snapchat, Lightbox, Flickr, LiveShare, and literally hundreds more, people have proven very willing participants in the development, use, and acceptance of digital imaging technologies, technologies which advanced sharply over the years. However, the level of knowledge and understanding of these technologies has not made the same quantum leap.

For example, walk into any store selling smartphones, digital cameras, or printers and ask two different people to explain the distinction between the resolution of a digital camera and the resolution of a printer. The resolution of one is measured in pixels, whereas the resolution of the other is measured in dots. What's confusing about that? Everything!

To eliminate some of the confusion and frustration in a meaningful discussion about digital imaging technologies, start with the premise that you should not use the terms "dpi" and "ppi" interchangeably. These terms have totally separate and distinct meanings. For instance, pixels are square, they appear as a continuous tone, and each pixel represents a unique color value (theoretically, a pixel can be one of 16,777,216 different colors).

In contrast, dots are irregular in shape (based upon how the ink bleeds or is absorbed into the paper. This is dependent upon the quality, thickness, and absorption rate of the paper as well as the ambient heat and humidity; dots use white space to simulate a specific color value; and multiple dots (aka "device dot clusters") are used together to simulate a color value for a single pixel value.

The confusion between dots and pixels begins with the specifications often discussed when talking about monitors.

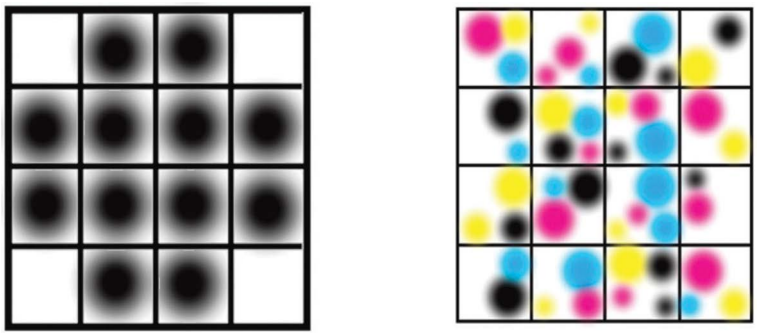


FIGURE 6.4 Comparison of device dot clusters for a black-and-white laser printer (left) versus a four-color inkjet printer (right).

Most computer monitors and televisions use an array of red, green, and blue light-emitting diodes (LEDs) to trick the human eye into visualizing a full range of color values, based upon the brightness and intensity of the individual red, green, blue (RGB) diodes.

Similarly, when an image is printed on a color laser printer or an inkjet printer, each pixel is made up of device dot clusters. The output resolution of these devices varies based upon the different colors and volumes (picoliters) of ink dots in the cluster. For example, some inkjet printers use only four colors of ink—cyan, magenta, yellow, and black—while other inkjet printers have four, six, seven, eight, or more ink colors, such as cyan, light cyan, magenta, light magenta, yellow, light yellow, black, light black, light light black, red, green, and blue. The sizes (volume) of the dots can vary from 1.0 to 5 picolitres, with most printers capable of producing three different size droplets in a single pass. Using a high-quality ink jet printer with premium photo glossy paper with both a quick drying agent covering the paper and the glossy surface causes the applied ink to retain its bubble-like shape as it sets and dries, thus providing the ability to create the appearance of specific color values, like wheat, sky blue, candy apple red, etc.

Before a digital image can be printed, the printer driver must determine how many pixels can be printed within a 1 inch area horizontally. The number of pixels is based on:

1. The number of ink colors used by the printer
2. The number of nozzles per print head
3. The size of the print (multisize dot technology);
4. The number of droplets able to be printed in a single pass
5. The type of paper used
6. Other printer settings (such as High Speed [on/off], High Quality [on/off], etc.)

Once the printer driver has determined how many pixels can be printed within a 1 inch area horizontally, the image is downsampled to the printer's output capability. This determines what the resampled pixel values should be. Then those pixel values are dithered (converted into the corresponding device dot cluster size and color values as illustrated in Figure 6.4). Some high-quality printers also include functions in the printer driver for automatic noise reduction and automatic sharpening.

NOTE:

Quick-drying premium photo glossy paper provides a better-quality image for forensic evidentiary imaging than either matte finish or all-purpose plain paper. With glossy paper (remember, it is not really paper; it is a combination of plastic layers), the ink actually floats on the surface, and because of its quick drying capabilities, the dots actually can overlap one another for enhanced visualization. With matte finish or plain paper, the ink cannot be placed as precisely because the ink colors bleed into one another, because of:

1. The microscopic irregularity of the surface
2. The absorption rate
3. The heat and humidity in the room
4. The resulting moisture level of the paper

Today's digital cameras match the performance (image quality) of film (something many people never thought would happen), and computer graphics have achieved the goal of photorealism.

However, today's printers do not provide the same level of image quality. In addition, not all types of printers work the same way, and they do not provide the same image quality as shown in Figure 6.5. But every printer has a purpose:

- Some printers provide very good image quality, but at the cost of slow output.
- Some printers provide high-speed output, but at the cost of lower image quality.
- Some printers cost very little to buy, but the cost per print is exceedingly high.
- Some printers have a hefty price tag, but the cost per print is relatively low.

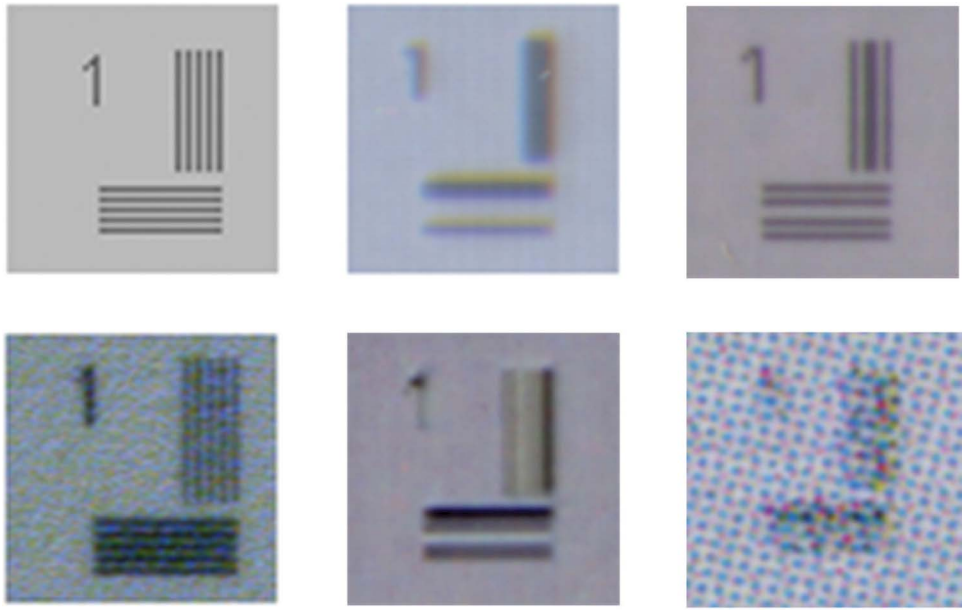


FIGURE 6.5 When testifying that an image is a true and accurate representation, it is important for it actually to be so. From left to right, top row: A portion of the original FBI test target, then output from a Kodak Dye Sublimation printer, and output from a Fargo Dye Sublimation printer. Bottom row: Output from an Epson Stylus Photo R2000 Inkjet Printer, output from a Fujifilm Dye Sublimation Printer, and last the output from a laser jet color laser printer.

Everyone should decide which printer will best fulfill their specific needs. They must determine:

- Average number of prints required in a specific time (output capacity)
- Use of prints (image quality desired for a 1:1 print, crime scene photos, evidence documentation, etc.)
- Size of prints (what print sizes are most commonly used, such as 4 × 6, 8 × 10, and 12 × 18 inches)

It is a matter of determining what trade-offs and/or sacrifices one is willing to make. Unfortunately, far too many law enforcement agencies are more concerned about cost instead of image quality.

Quantitative Analysis of Printed Output

The loss of image quality from printing is simple to measure quantitatively. For instance, using a 6-MP camera with an image sensor resolution of 3000 pixels wide by 2000 pixels high, to capture an area 3″ wide by 2″ high, the image resolution would be 1000 pixels per inch, both width and height. Using a dye sublimation printer with an output of 300 pixels per inch, the 1:1 life-size output of the 3″ by 2″ area would use only 900 pixels by 600 pixels—the printed output would contain only 30% of the total pixel values of the original image. If the image were printed at three times its life size (i.e., 3:1), 3″ would become 9″, and 2″ would become 6″. At 300 pixels per inch, 9″ would require 2700 pixels and 6″ would require 1800 pixels, thus providing the ability to see almost every pixel of the image file.

As shown in Figure 6.6, a pixel with a grayscale value of 142 and a pixel with a grayscale value of 130 would be represented by the same grayscale value (halftone dot pattern) of 136. This is problematic for latent print examiners when viewing the output values for a light (faint-colored) ridge in a latent print with a grayscale value of 142 and the adjacent furrow has a grayscale value of 130. Using standard dithering algorithms, the output for both the ridge and the furrow would be represented using the same dot pattern, thus losing the ability to distinguish contrast between the actual values.

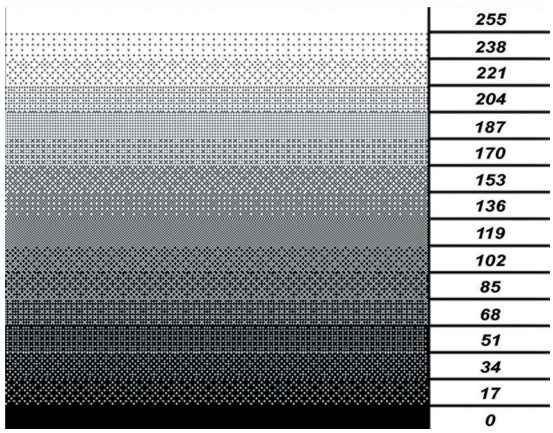


FIGURE 6.6 Laser printer output values are based on the ability to produce only 17 monotone values (aka grayscale values), which means multiple pixel values (17 grayscale values) can be represented using the same dot pattern even though the pixel values are different.

An inkjet printer with seven ink cartridges uses the same the 4 × 4 dot grid to produce a total of 119 color tones. Some of the newer inkjet printers use an 8 × 8 grid. With multiple ink colors, varying size droplets, and multipass technology, the 8 × 8 dot grid yields a significantly greater number of color tones. For example, an 8 × 8 grid using three variable size droplets with seven inks can yield a total of 455 color tones.

- 8 × 8 = 64 plus 1 for all white = 65 monotones
- 65 monotones × 3 varying size ink droplets = 195 monotones
- 195 monotones × 7 inks = 1,365 possible color values

Studies have shown that the healthy human eye, under optimal lighting conditions, can distinguish somewhere between 16 and 64 shades of gray in a range from black to white. By use of 8-bit grayscale, computers can distinguish 256 shades of gray between black and white, which is approximately four times greater than the ability of the human eye.

Using 8 bits per color channel, there are 256 shades of red, 256 shades of blue, and 256 shades of green; the computer can render a total of 16,777,216 different color combinations for each pixel. Although 1,365 possible color tones are nowhere close to the more than 16 million possible shades available, they do produce a good-quality, photorealistic print.

MAINTAINING IMAGE QUALITY

IMPORTANT:

To maintain image quality, the best procedure is to view all images on screen, where the image can be zoomed in and out. It is recommended that digital images be zoomed in on a computer monitor at a ratio of 1:1 (one pixel of image resolution is displayed using a single monitor pixel value) for both analysis and comparison.

Image Manipulation

For years, many people in the criminal justice community had the mistaken idea that traditional film processing provided a higher level of image integrity and provided a more secure (both physical and long-term) method for storing images. That is not true!

Photographs have been retouched using a number of image capture, development, and printing techniques since the late 1800s. For example, the first patent for airbrushing in the United States was registered to Mr. Charles Burdick in 1893. Until the 1920s, airbrushing was used primarily for photographic (color) retouching. As new machines and technologies were invented, new airbrushing techniques were used to create "modified" pictures, like the propaganda posters created by the U.S. Army during World Wars I and II.

In addition to airbrushing, a number of techniques have been practiced over the years to "enhance" and even manipulate photographs. In 1969, John Cohen exhibited more than 40 "special effect techniques" he devised based on photographing "projected" images years before computer manipulation existed.

With the introduction of film scanners and flatbed scanners, images could be digitized and then output to film using a laser projection device called a film recorder. Film recorders were used extensively in the early 1990s when computers were being used more frequently to create slides for presentations, using tools like Adobe Photoshop, PowerPoint, etc. With a film recorder, "slides" were projected directly onto film from the computer.

Because of their increasing image quality (both in lumens and resolution), liquid crystal display (LCD) projectors have replaced the need to create slides with film using film recorders, and the images are displayed directly by the computer. There is no doubt John Cohen would have been able to produce more than 40 special effect techniques with today's technologies!

In the not-too-distant-past, the use of digital technologies created questions about the integrity of computer-enhanced images. Today, digital cameras provide the ability to discern an original image from an altered image using data embedded within the file itself. Almost every camera available today captures information about the image together with information including date and time the image was taken and camera settings, including but not limited to aperture, shutter speed, ISO, flash settings, exposure compensation, lens used, focus distance, etc. These data elements (also known as "metadata") are then stored as part of the image file in a collection of data fields called the file "header." The most common header format used today is the Exchangeable Image File (EXIF) header. In fact, EXIF has become the standard for storing camera information, thus providing interoperability between digital cameras and other imaging devices. Using this EXIF data, photographers can also go back later and analyze this information, such as which camera settings provided the best results, and thereby learn from their photographic experiences.

Some image viewing and editing applications can display or edit the EXIF data. On the other hand, some image editing programs lose (do not write) the EXIF data when the image file is resaved after editing. Therefore, it is imperative to always save the original image to be able to authenticate and preserve the integrity of any digital image.

In addition to the EXIF data embedded in digital images captured by digital cameras, Adobe Photoshop captures the image processing history (aka history log) in the metadata of the digital image. The history log contains the settings and parameters for each of the tools and/or functions performed. These details are maintained in sequential order and are retained even if the "undo" or "step backwards" functions are used.

Through the use of image editing applications such as Adobe Photoshop, it is easy to avoid the question of "what did you do to manipulate this image to make the print visible?" or "what did you do to alter this image to make the image detail more visible?"

Image Sensor Size

One of the least understood issues in digital imaging pertains to imaging sensor size. Original equipment manufacturer (OEM) lenses are designed to accommodate (to a certain extent) the size of the imaging sensor, but the lens does not account for the difference in the size of the photo receptors on every sensor.

Imaging sensors come in a variety of sizes. For example, some are the same size (full frame) as the traditional 35 mm film (36 mm × 24 mm), while others are smaller, such as the APS-C (Advanced Photo System Classic) negatives, at approximately 25.1 mm × 16.7 mm. (APS-C negatives were a standard size, but camera manufacturers including Canon and Nikon have APS-C imaging sensors different in size.) Based on the relative sizes of the full-frame imaging sensor and the APS-C imaging sensor, a full-frame sensor provides approximately 2.5 times the surface area of a typical APS-C sized one.

This difference in physical size typically does not affect image quality when dealing with point-and-shoot digital cameras. However, the difference in size can have a significant impact when using a DSLR camera with interchangeable lenses.

Because of its larger size, a DSLR camera with a full-frame imaging sensor can approximate the subject area seen (aka "field of view"). In comparison, a DLSR camera with an APS-C imaging sensor would need to be approximately 1.5 times farther away from the object to encompass the same field of view when using the same identical lens.

In camera speak, this relationship between the size of the imaging sensor, the lens, and the area of focus is commonly referred to as "focal length multiplier." When photographing impression evidence, such as a single latent fingerprint impression, it is common for crime scene or evidence processing technicians to use a full-frame imaging sensor DSLR camera with interchangeable lenses and a 60 mm macro lens. If the technician is using a DSLR camera with APS-C imaging sensor, a similar distance-to-object ratio used to photograph the same area (field of view) can be achieved using a 40 mm macro lens. Using the "focal length multiplier" value provided in the detailed specifications for the camera, it is easy to calculate which lens should be used to achieve similar results. (A Nikon 50 mm *f*/1.4 lens on a Nikon DSLR with an APS-C sensor—and a 1.5 focal length multiplier—would provide the same field of view as a 75 mm lens on a full-frame DSLR.) This is particularly important to understand when photographing small objects, such as latent prints, toolmarks, ejection marks, rifling characteristics, etc.

In comparison, the focal length multiplier issue could be a "benefit" in other circumstances, such as surveillance photography. For example, using a Canon camera with an APS-C imaging sensor with a 1.6 focal length multiplier would cause a Canon 70-200 mm *f*/2.8 telephoto lens to behave like a 112-320 mm telephoto lens. While this may be helpful to those on a tight budget, it is still recommended that the best overall image quality be obtained using a DSLR camera with a full-frame imaging sensor with a longer telephoto lens.

NOTE:

In this author's opinion, the best website to use for getting highly detailed specifications for any camera, present or pending release, is *dpreview.com*. In addition to identifying the overall size specification and focal length multiplier, the site provides detailed information about the relationship between the width and height of the imaging sensor (commonly referred to as "aspect ratio").

Another important aspect of sensor size is the resolution of the sensor. A Nikon DSLR camera with an APS-C imaging sensor can have the same resolution (number of photo receptors) as a Nikon DSLR camera with a full-frame imaging sensor. Therefore, it is important to note both the sensor size and the resolution of the device when considering which digital camera would work best for you.[12]

How Large Is the Image on the Screen?

Size matters, and with image files, this is nothing short of the truth. In most instances, image files from digital cameras have a resolution of either 300 PPI or 72 PPI. These numbers are based on the default settings of the application used to open the images. In the case of Adobe Photoshop, these image size settings are based on the default values under Units and Rulers | New Document Present Resolutions.

Generally speaking, image size (aka resolution) is meaningful in only two circumstances:

1. When determining how large an image will be when it is printed
2. When sharing images with one or more "other" digitally based imaging solutions, such as AFIS, PDF, PowerPoint, etc.

For example, a picture captured with a Nikon D850 DSLR camera, with a size of 45 megapixels (8256 pixels × 5504 pixels) with size of 300 PPI would create a printout approximately 27.5 inches × 18.33 inches. At 72 PPI, the printout would be 114.6 inches × 76.4 inches. Neither of these are popular print sizes, so the image must be "downsampled" to be printed as an 8 × 10 or an 8.5 × 11.

To print the image as an 8 × 10 inch photograph, the image size would have to be reduced (downsampled) to 8 inches × 12 inches, or 688 PPI. Similarly, to print the image as an 8.5 × 11 inch photograph, the image size must be reduced to 8.5 inches × 12.75 inches with a resolution of 647.529 PPI. Due to the aspect ratio of the imaging sensor, the photo must be cropped to maintain its original aspect ratio and fill the page when printed as a borderless photograph.

In contrast, a picture taken with a Canon EOS 6d Mark II DSLR, which has a full-frame imaging sensor with a resolution of 26 megapixels (6240 pixels × 4160 pixels) with an image size of 300 PPI would create a printout approximately 28.8 inches × 13.867 inches. At 72 PPI, the printout would be 86.667 inches × 57.778 inches. Again, these are not popular print sizes, so the image must be "downsampled" to be printed as an 8 × 10 or an 8.5 × 11.

To print the Canon image as an 8 × 10 inch photograph, the image size must be reduced (down-sampled) to 8 inches × 12 inches or 520 PPI. Similarly, to print the image as an 8.5 × 11 inch photograph, the image must be reduced to 8.5 inches × 12.75 inches with a resolution of 489.412 PPI.

The aspect ratios of the imaging sensors are identical, so the photographs from both cameras must be cropped to maintain their original aspect ratios and fill the page when printing a borderless photograph.

Another consideration of downsampling occurs when viewing minute details of a digital image, such as pores or hair and fibers, on a computer monitor. Monitors come in a wide variety of shapes and sizes with multiple resolutions, including:

- 1920 × 1200 pixels (2.3 MP)
- 1680 × 1050 pixels (1.8 MP)
- 1440 × 900 pixels (1.3 MP)
- 1280 × 800 pixels (1.0 MP)
- 1024 × 768 pixels (0.8 MP)

For purposes of comparison, some of the more common image resolutions for digital cameras are:

- 8256 × 5504 pixels (45 MP)
- 6240 × 4160 pixels (26 MP)
- 6016 × 4016 pixels (24 MP)
- 4928 × 3280 pixels (16 MP)

In the case of the 45 MP image, the image must be downsampled approximately 19.5:1 to view the entire image on a computer monitor with a resolution of 1920 × 1200 pixels. A great deal of data would not be visible because 20 pixels are represented by (resampled to) a single pixel value. This is a very important consideration when viewing any type of forensic image on a monitor for analysis. The critical importance of this issue is magnified when considering tasks including background noise suppression, etc.

CALIBRATING DIGITAL IMAGES

Digital images acquired from a digital camera or from a film scanner are not calibrated (scaled) for 1:1, life-size comparison or output. Photographs captured with a digital camera have variable distances of image sharpness from lens to object (aka depth of field), which changes the field of view or the area of interest. For example, an 18 MP digital camera can be used to capture a single fingerprint; a series of two, three, or four sequential fingerprints; a palm print; a footwear impression; or a tire track.

No depth of field is involved when images are captured using a flatbed scanner—the object is placed directly on the face of the scanner, the size of the area is specified using a marquee tool, and the resolution to be used for the capture is also specified. As a result, images acquired using flatbed scanners are acquired as life-size images in two dimensions, unless an image is being scanned that had been enlarged previously, such as a latent fingerprint photographed and then enlarged and printed as an 8 × 10 inch print. This enlarged image could still be resized to 1:1 for use with an AFIS if a scale was included with the image.

Using an 18-megapixel digital camera with a sensor resolution of 5184 pixels × 3456 pixels, an area of interest 2 inches × 3 inches could be photographed, or an area four times larger—8 inches × 12 inches—could be photographed. It makes no difference to the camera! The camera, although smart, is also stupid and has no idea how large the area it just captured. All it knows is that an image consisting of 5184 pixels × 3456 pixels was captured.

Any digital image can be calibrated in at least two dimensions using Adobe Photoshop as long as the image contains a scale or some other element that can be used to determine size. Three elements make up the image size of any digital image. First there are the "measurable" physical attributes: width and height. Then there is a more obscure dimension known as resolution (aka pixels per inch). By knowing one of the measurable attributes, the other two attributes of image size can be quickly and easily determined.

In some instances, it is critical to know the size of the object, especially when analyzing and comparing fingerprints, footwear impressions, etc., or if a latent impression was captured digitally and it must be sent to an AFIS.

Accident/Crime Scene

Calibrating large areas, such as traffic accidents, crime scenes, or even video frames from video surveillance systems, such as banks, convenience stores, liquor stores, drones, etc., is a very tricky and challenging process. The reason why calibrating these types of images is so challenging is 3-D imaging requires a great deal of knowledge about the location being photographed, the position and angle of the camera/lens, and much more. In fact, there is an entire science to be understood for correctly calibrating these types of images.

Identifying Distortion

Calibrating medium-sized objects is fairly easy. Most of the objects photographed in this category are footprint or footwear impressions and tire tracks. Images in this category are photographed with a scale placed along the impression on the same plane. It is important to note that the scale must be placed at the same depth of field as the object itself.

In addition, when photographing medium-sized objects, it is important to check for lens or barrel distortion.

This can be done following a two-step process using Adobe Photoshop CS4 or later:

- Rotate the image until one leg of the L-shaped ruler is on a 90-degree horizontal angle or on a 90-degree vertical angle.
- Enable the Ruler tool (Ctrl + R) in the image window and drag guide lines onto the image and place them along the two sides of the L-shaped ruler.

To perform this task, open the subject image in Adobe Photoshop.

1. From the View menu option, at the top of the Photoshop window, click on the Rulers option or press and hold the Ctrl key and type the letter R. To confirm this feature is enabled, click on the View menu and confirm that a checkmark appears next to Rulers.

NOTE:

Now is also a good time to the check the View menu and confirm that the Snap function is disabled. If a checkmark appears next to the name of this feature, turn if off by clicking on the Snap menu option.)

2. From the toolbar, select the Ruler tool (see Figure 6.7).
3. Position the Ruler tool at a starting point on one leg of the scale in the image, and then click and hold the left mouse button, and drag the cursor along the edge of the scale. *(Please keep the ruler line along the edge of the scale as the Ruler tool icon is moved.)* Release the mouse button as soon as you have moved the cursor a portion of the length of the leg of the L-scale. A dashed line will appear along the edge of the scale.

NOTE:

Zoom in on the image using either Ctrl and + or the zoom scroll option available under Preferences. Use this technique to confirm the ruler line is, in fact, traveling along the side of the scale.

4. On the Tool Options bar, which is located directly beneath the Menu bar at the top of the window,

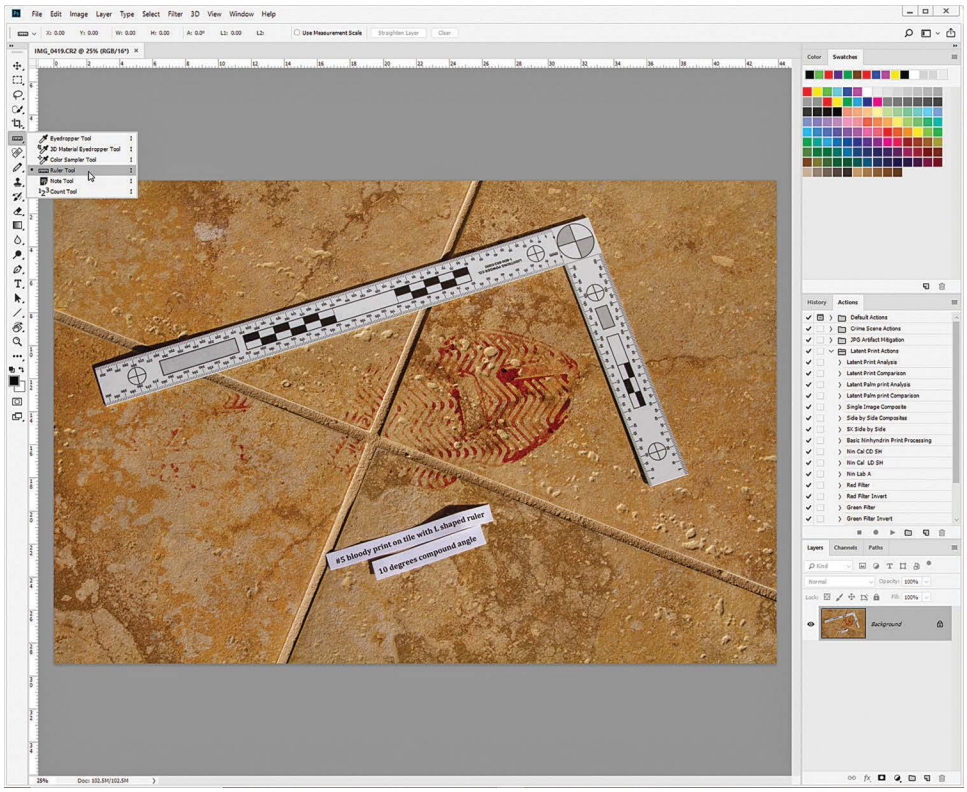


FIGURE 6.7 The ruler tool is one of the Eyedropper tool options.

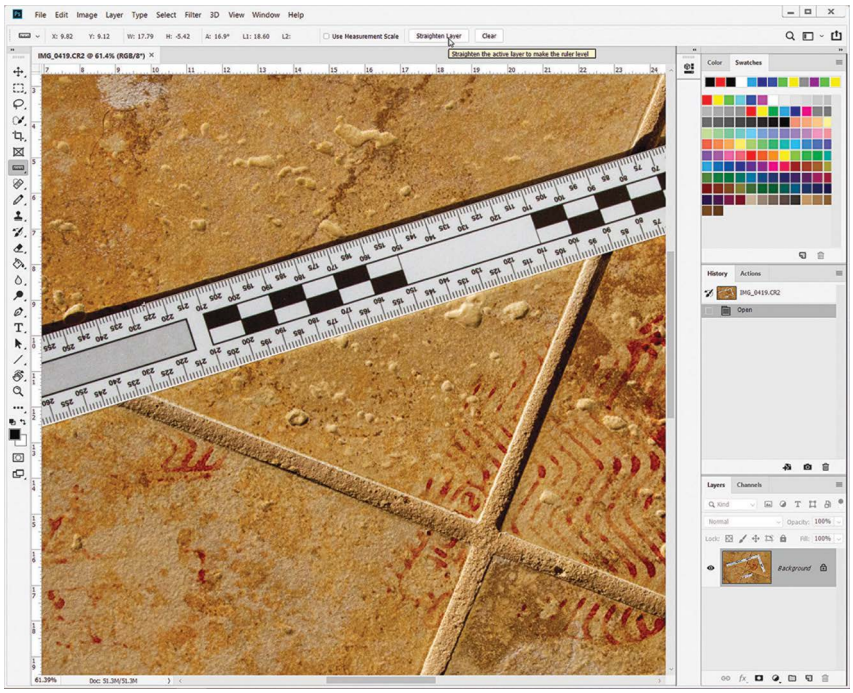


FIGURE 6.8 The Ruler tool options bar includes a "Straighten Layer" function for correcting the orientation of the image.

click the option button for Straighten Layer. The image will be rotated automatically to match either the horizontal or vertical axis along the leg of the selected scale leg.

5. Move the cursor to the top of the image window and place the cursor on top of the ruler line, then click and hold the left mouse button and drag the cursor down over the top of the image. A horizontal guideline will appear in the image window. Continue to drag the cursor until the horizonal line is even with the horizontal edge of the L-shaped scale.
6. Move the cursor to the left edge of the image window and place the cursor on top of the ruler line, then click and hold the left mouse button and drag the cursor down over the top of the image. A vertical guideline will appear in the image window. Continue to drag the cursor until the horizonal line is even with the horizontal edge of the L-shaped scale, or at least some portion of the vertical leg of the L-scale.

If the edges of both legs on the scale do not match with the two guidelines placed on the image, then there is distortion within the image. In this image, the vertical leg of the L-ruler does not match with the vertical guideline, which means that the camera was not parallel to the surface bearing the impression when the image was exposed.

Also, if the legs of the scale are bowed (curved) inward or outward, the image could be distorted because of lens barrel distortion (curves outward) or pincushion distortion (curves inward).

NOTE:

While many footwear photographers prefer to use a tripod when photographing footwear, footprints, or tire track impressions, I strongly encourage the use of a device known as a Quadrapod. The camera mount of the Quadrapod also helps to ensure the camera is parallel to the subject surface area.

7. If the edge of the scale does not match up with the vertical guideline, this distortion can sometimes be corrected using the Perspective Warp function (Edit > Transform > Perspective Warp).

   When the transform box appears over the top image, position the cursor on the lower right box handle, press the Shift key, and then move the cursor to the left. (The Shift key MUST be used to constrain the movement of the cursor when adjusting the transform box so the picture maintains its original aspect ratio and to avoid substituting one form of distortion for another.)

   It may also be desirable to reposition the image inside the image window by placing the cursor on top of the image inside the transform box and clicking and holding the left mouse button and repositioning the image to ensure both legs of the L-shaped ruler are now parallel with the guidelines placed on the image.
8. When satisfied with the perspective of the image, press the Enter key to complete the transform function.

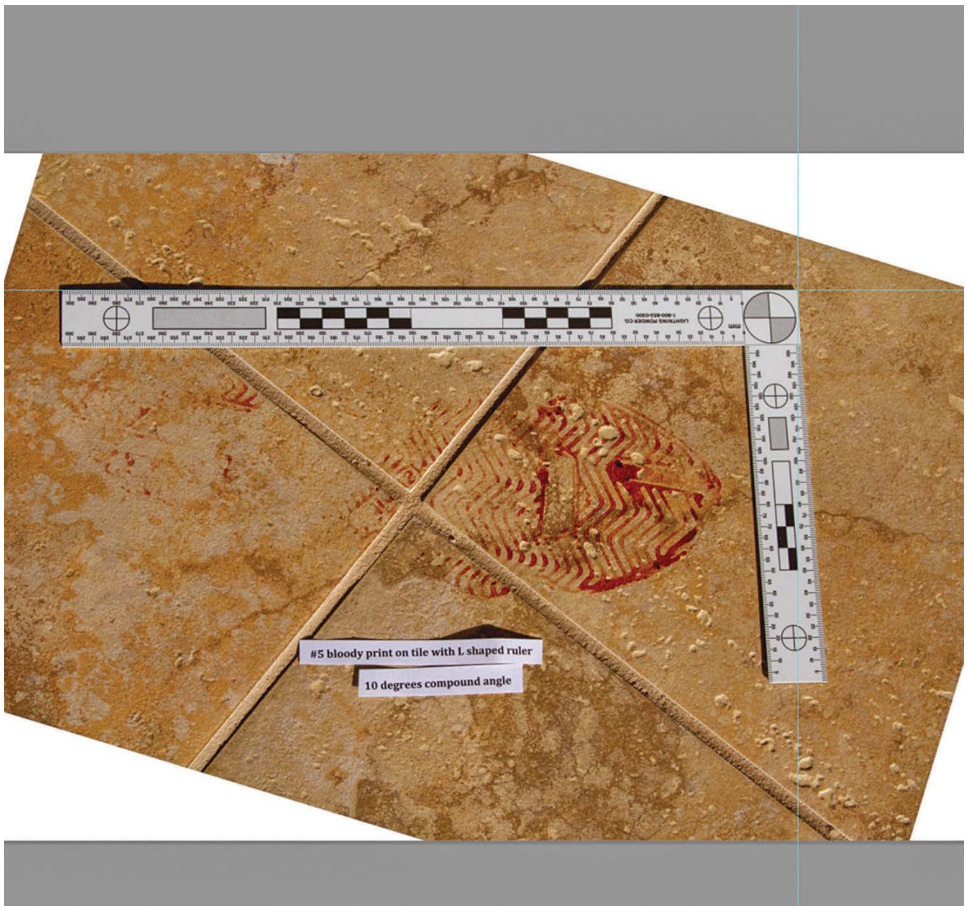


FIGURE 6.9 Footwear impression with L-shaped ruler where legs of the scale in the image do not match the vertical lines in the image.



FIGURE 6.10 The length of the telescoping legs can be adjusted to the same height, ensuring a picture of a footprint, footwear, or tire track is captured correctly on angled as well as flat surfaces. When photographing multiple images of an object with the Quadrapod Elite, the camera can be moved along the length of the bar ensuring one or more images can be stitched together for a high-quality impression of a wide subject.

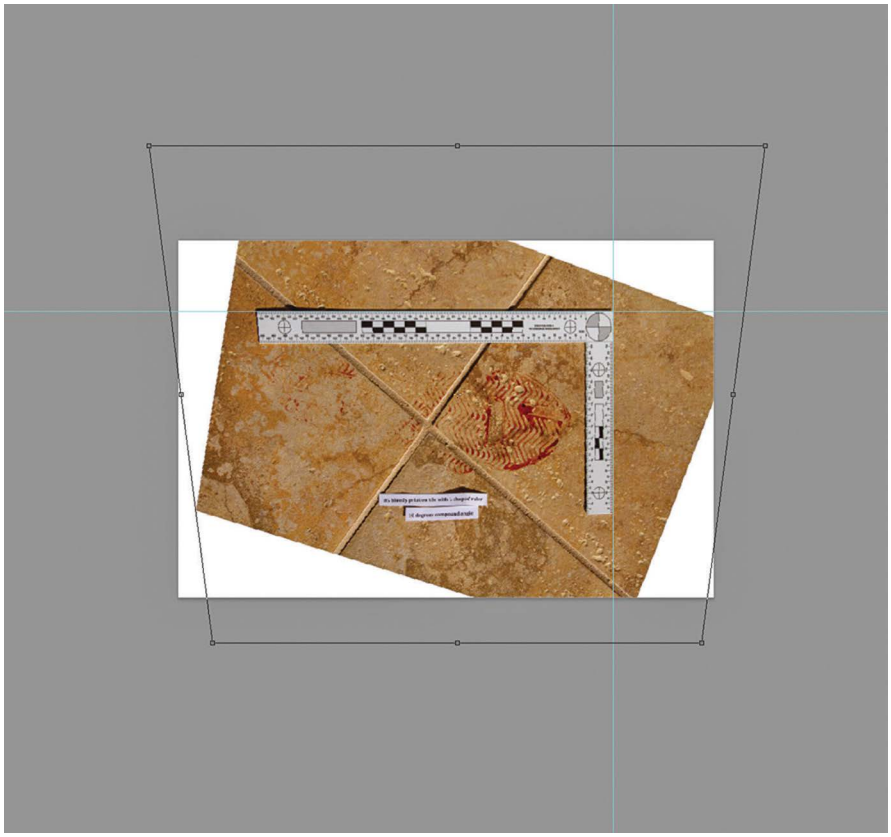


FIGURE 6.11 Using the Perspective Warp Transform feature in Adobe Photoshop, the distortion of the photograph can be corrected.

Calibrating Medium Objects

Once the image perspective distortion has been corrected, the image can be calibrated. There are two commonly used methods for calibrating images in Adobe Photoshop: the Ruler tool method and the Crop tool method. It is highly recommended that the Crop tool method be used for calibration of medium-size images.

When using the Crop tool method to calibrate images, it is easy to determine if distortion remains in the image. More specifically, the pivot point in the center of the crop box plays a crucial role in identifying distortion when using the crop method.

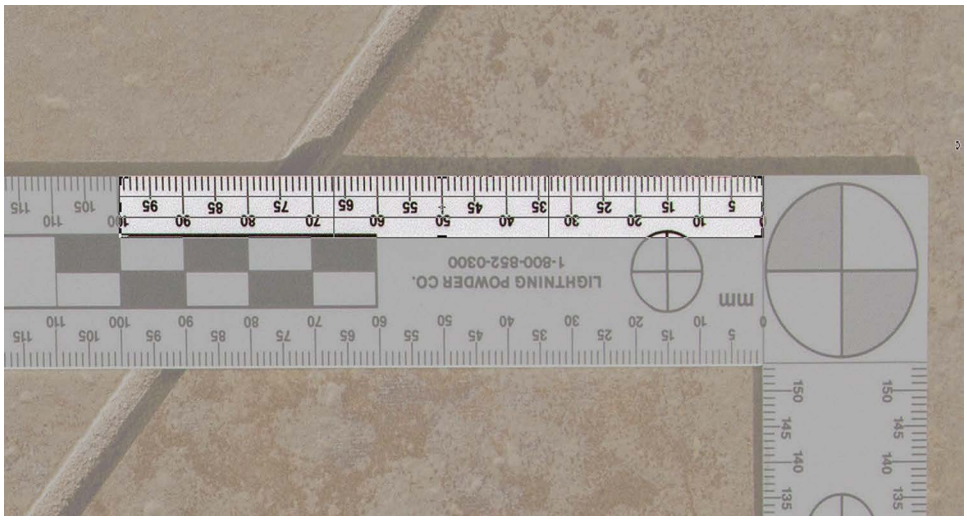


FIGURE 6.12 If there is no distortion, the pivot point in the center of the Crop tool should appear at the center of the scale bar.

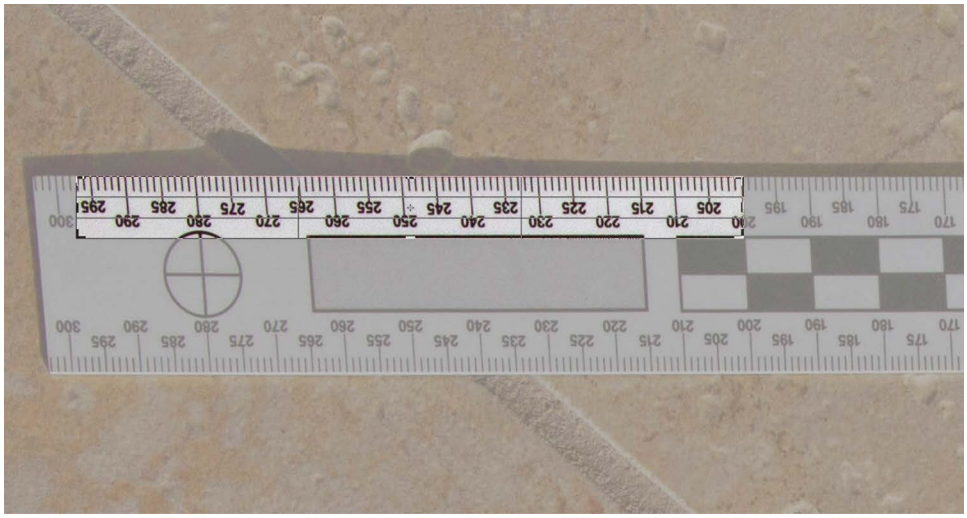


FIGURE 6.13 When using Adobe Photoshop CS 6 or later, the figure can be moved behind the crop box. At the beginning of the scale, the crop distance was 10 centimeters. By moving the image behind the crop box, we can see that the crop box no longer measures 10 centimeters. In fact, the scale appearing in the crop box shows the margin of error because of the perspective distortion.

Follow these procedures for calibrating medium-sized images using the crop method:

1. From the toolbar, choose the Crop tool. Then move the cursor to a starting point on the scale in the image. Click and hold the left mouse button and move the cursor to another known point on the scale.

It is recommended that the longest possible distance be included inside the crop box for calibrating the image. It is also recommended that the image be moved behind the crop box to confirm that no distortion is present in the image.



FIGURE 6.14 Using the Crop tool, select a known distance using a starting point on the scale and an ending point on the scale. Pay special attention to the pivot point in the middle of the crop box to ensure there is little (or no) distortion in the selected area.

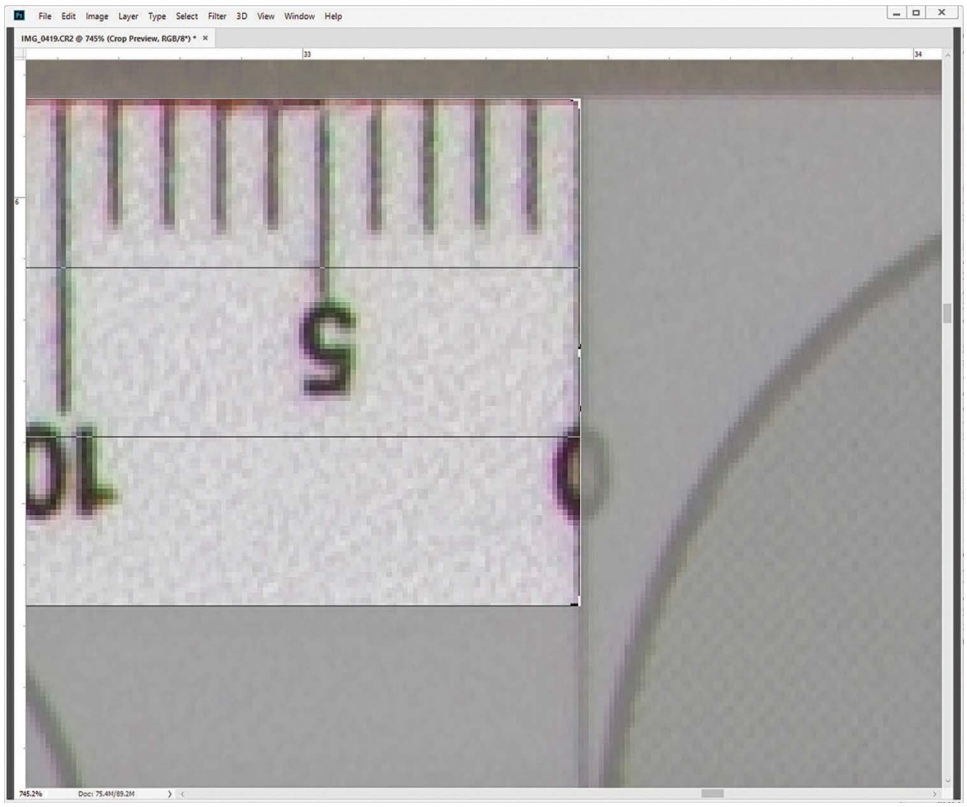


FIGURE 6.15 To determine the highest level of accuracy when calibrating a medium-sized image, zoom in on the image to confirm the crop box goes through the center of the scale bar.

CAUTION:

When adjusting the position of the "marching ants" (crop box) for the starting and stopping points, ensure that the marching ants go through the middle of the bar on the scale. (It is extremely important to ensure that the marching ants are parallel to the edge of the scale when cropping the image. If they are not parallel, move your cursor outside of the marching ants, then click and hold the left mouse button as you drag the cursor to rotate the crop box to make it parallel.)

NOTE:

For maximum accuracy when calibrating medium-sized images, zoom in on the image to verify the marching ants go directly through the center of the scale bar, for example, if an individual scale bar is 7 pixels wide or 23 pixels wide. The farther off center the crop box lines are positioned, the less accurate the size of the image.

2. Press the Enter key to complete the cropping function to the scaled area.
3. From the Image menu, choose Image Size. The Image Size dialog box will be displayed on the screen (see Figure 6.16).

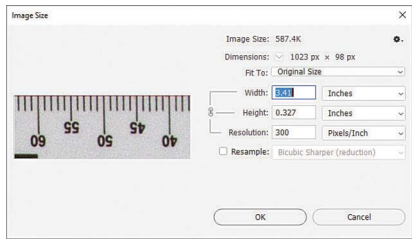


FIGURE 6.16 The Image Size dialog box is the key element for calibrating images captured with a digital camera.

4. Before changing any settings in this dialog box, it is *imperative* the Resample Image option be disabled before changing any of the values in the dialog box. There should not be a checkmark in the box to the left of the Resample option. In addition, a bracket with a chain should be displayed on the right side of the Width, Height, and Resolution fields indicating that these three fields are linked. When Resample is disabled, two of the size parameters will be adjusted proportionately to the known (cropped) distance.

   If the cropped scale is horizontal in the image window, specify the known distance in the width option. If the cropped scale is vertical in the image window, specify the known distance in the height option. The Resolution field will display the actual

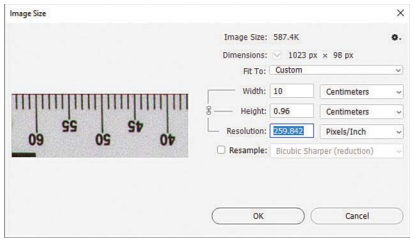


FIGURE 6.17 The Image Size dialog box is the key element for calibrating images captured with a digital camera.

number of PPI of the image based on the known distance of the cropped area.

5. If necessary, change the unit of measurement (i.e., centimeters or inches) for the known size of the cropped area, and then highlight the width measurement and type the appropriate number of units for that known dimension. (In the current example, the known distance is a width of 10 centimeters.)

   The corresponding PPI measurement will appear in the Resolution field, as shown in Figure 6.17.
6. Position the cursor next to the number appearing in the Resolution field and double-click to highlight the full contents of that field. Then copy the highlighted resolution value by either:
   - Pressing Ctrl + C
   - Clicking the right mouse button with the cursor positioned over the resolution field and then choosing Copy from the options provided.
7. Move the cursor over the Cancel button and then click the left mouse button; or press the Escape key on the keyboard to close the Image Size dialog box.
8. Restore the full, uncropped image by choosing Step Backward from the Edit menu or pressing Ctrl + Alt + Z.
9. When the uncropped image is redisplayed in the image window, choose Image Size from the Image menu again, or press Ctrl + Alt + I.
10. When the Image Size dialog box is displayed again, ensure the resample option is turned off. (As stated in step 4 earlier, there should not be a checkmark in the box to the left of this option and a bracket with a chain should be displayed on the right side of the Width, Height, and Resolution fields indicating all three fields are linked.)
11. Position the cursor over the Resolution field and double-click the left mouse button to highlight the contents of that field.
12. Paste the resolution value obtained in step 6 by either:
    - Pressing Ctrl + V
    - Clicking the right mouse button while the cursor is positioned over the Resolution field and choosing Paste from the list of options provided.
13. Click the OK button in the Image Size dialog box to lock in the calibrated image resolution. The image is now calibrated for accurate, 1:1 life-size output.

    Please be advised that even though the perspective may have been corrected prior to calibrating the image, the accuracy of the image calibration process may be affected. To determine the accuracy of the calibration process:
    - Select the Ruler tool from the toolbar (co-located with the Eyedropper tool).

    Position the cursor over a starting point on the scale, then click and hold the left mouse button and move the cursor to the known distance marker on the opposite side of the scale and release the mouse button.

    Be sure to zoom in on and verify the accuracy of the placement of the starting and ending points on the scale. Then note the distance shown for L1, which will display the length of the selected distance.

    In the image used in this example, after correcting for distortion and calibrating the image, the actual measured distance from 0 to 30 centimeters provided a result of 30.61 centimeters for a margin of error of 6.1 millimeters. By measuring the footwear impression, the estimated shoe size would be either a men's shoe size 11.5 (28.3 cm) or 12 (28.6 cm).

Calibrating Small Objects

Smaller objects, such as fingerprints, shell casings, magazines, etc., are generally small enough that size distortion is not a significant concern when calibrating their images. In addition, small objects should always be photographed with the camera as close to the object as possible using a macro lens or other close-up gear.

For small objects, either of the two methods of calibration are sufficient (Ruler tool method or Crop tool method). In this section, we will discuss the Ruler tool method for calibrating images. It should also be noted that this is just one of the methods for using the Ruler tool to calibrate small objects.

This calibration technique provides the ability to measure, one, two, or more units (inches or centimeters) quickly and easily and does not require any math, such as division, to determine the number of pixels for a single unit of measure when multiple units are measured.

1. Open the image to be processed in Adobe Photoshop.
2. From the View menu, select Rulers (or Ctrl + R) to turn on the Rulers. Rulers will appear at the top and left edges of the image window (see Figure 6.18).
3. Move the cursor and position it so that the cursor is sitting on top of the Ruler bar at the top of the image window, then click the right mouse button to display the Ruler options, as shown in Figure 6.19.

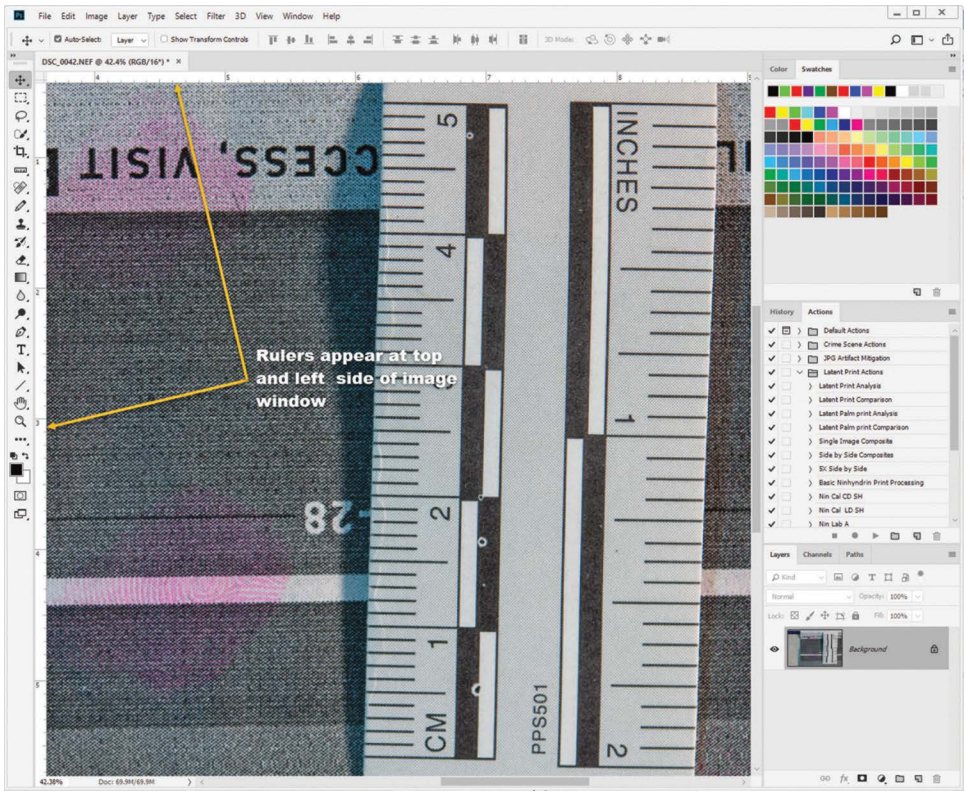


FIGURE 6.18 Rulers will be displayed along the left side and top of the image window when the Rulers function is enabled.

4. Choose either Inches or Centimeters as appropriate. (Photoshop will automatically convert the pixel count [L1 value] to pixels per inch based on the setting specified in this step.)
5. From the Photoshop toolbar, select the Ruler tool. The Ruler tool options will appear on the options bar located directly beneath the menu bar at the top of the window.

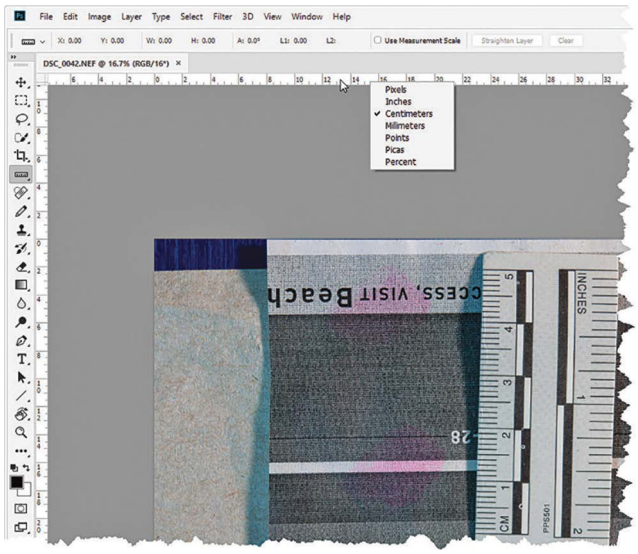


FIGURE 6.19 The Ruler option selected must match the scale in the image that will be used to calibrate the image.

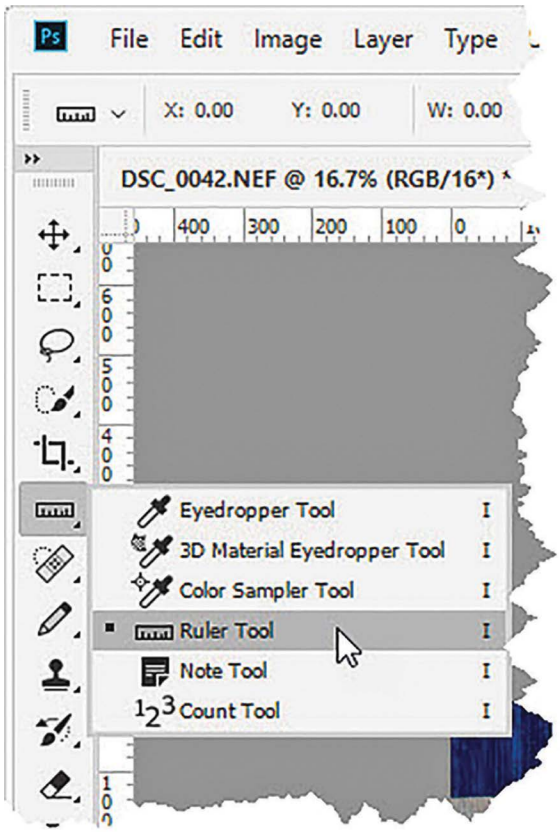


FIGURE 6.20 The Ruler tool is an option under the Eyedropper tool.

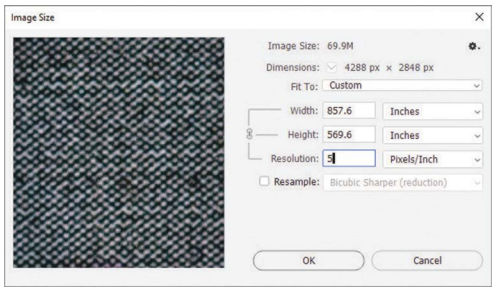


FIGURE 6.21 Specify the number of units (centimeters or inches) to be measured using the Ruler tool. The measurement must be at least one unit; thereafter, units can be measured in incremental measurements.

6. From the Image menu, choose Image Size (using the shortcut Ctrl + ALT + I).
7. Verify that the Resample Image option is turned off (no checkmark in the Resample Image box). The fields Width, Height, and Resolution will be linked.
8. Change the Resolution to the desired number of values to be used for sampling—the longer the distance measured, the more accurate the image resolution will be. For example, as shown in Figure 6.21, you have the option of sampling 1 centimeter (10 millimeters), 2 centimeters, or 5 centimeters. Since the longest known distance is 5 centimeters, type 5 into the Resolution field. (Similarly, if the measured distance was only 2 centimeters, the number 2 would be entered for Resolution.)

NOTE:

Do *not* change the Resolution from Pixels/Inch (PPI). As stated earlier, Photoshop will automatically convert the distance measured from metric to pixels per inch based on the unit of measure set in the Rulers bar, as described in step 4.

9. Click OK to save the changes and close the Image Size dialog box.
10. Position the Ruler tool at a starting point on the scale in the image, then click and hold the left mouse button and drag the Ruler tool cursor to the desired ending point (indicating the length of the sample, as defined in step 9).

More specifically, calibrating an image 6 cm wide with a margin of error of 9 pixels (starting 11 pixels below the center of the bar for the starting point and then ending 14 pixels above the center of the bar at the ending point on the scale in the image) when just 1 centimeter is measured, that error rate must be multiplied for the entire image (9.52 cm) for a total margin of error of 238 pixels. On a small image, this may not be significant. But the larger the object, the more important this margin of error becomes.

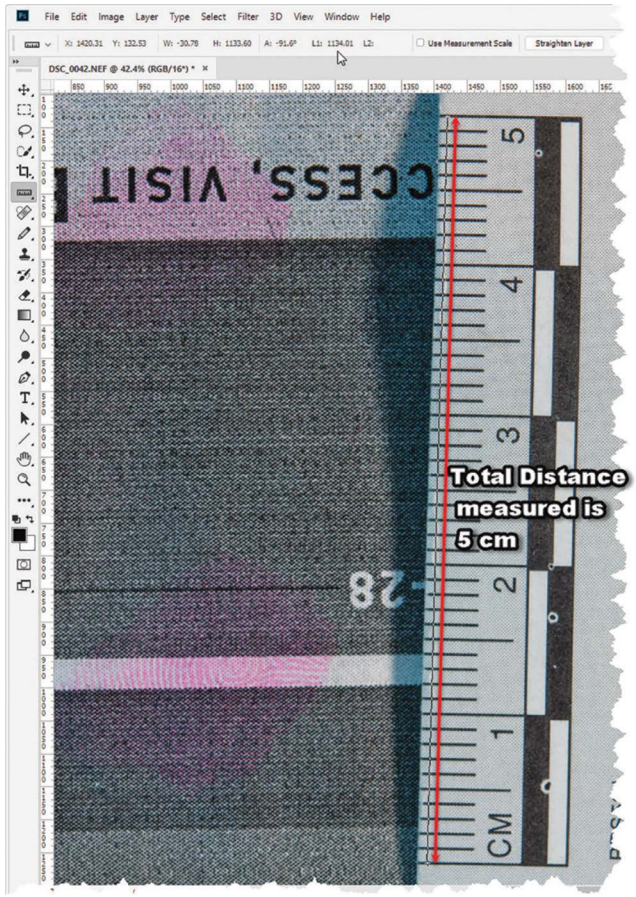


FIGURE 6.22 Use the Ruler tool to identify the number of units (centimeters or inches) entered in the Image Size dialog box in step 8.

CAUTION:

It is very important for the measurement to begin in the center of the starting bar on the scale and end in the center of the ending scale bar. Positioning the cursor at the bottom edge of the starting bar and then dragging the cursor to the opposite (top) edge of the ending bar on the scale will create a margin of error. This error will prevent the printed image from measuring properly when a scale is placed next to the scale in the printed image. The scale in the printed image may align with the scale for a short distance, but the farther along the scale, the printed image will no longer match the scale. This is particularly true when calibrating a large object based on a single centimeter or a single inch.

Additional notes:

- The measure line *must* be parallel to the edge of the scale in the image.
- Use only the area on the scale that is not distorted. (For example, use the part of the scale appearing

in focus if the other part of the image [and scale] appears to be out of focus.)

1. In the Ruler option ribbon (which is located directly beneath the menu bar), note the number of pixels shown for the value L1.

NOTE:

Do not use the Width (W:) or Height (H:) values. These numbers do not consider situations when the scale in the image is not parallel to the vertical or horizontal side of the image. For images where the scale appears at an angle greater than about 5 to 10 degrees, this could make a significant difference in both the resolution and the physical size of the image.

2. Open the Image Size dialog box again by either choosing Image Size from the Image menu or by pressing Alt + Ctrl I.
3. Again, verify the Resample Image option is disabled (no checkmark should appear in the Resample Image box), then type the pixel count identified in step 11; the Height and Width values will change automatically to correspond to the new resolution (PPI).
4. Click the OK to close the Image Size dialog box. The digital image is now calibrated, and the image can be printed as a life-size image (1:1).

FORENSIC IMAGING HARDWARE AND SOFTWARE

Many law enforcement agencies have quality assurance managers who are very sensitive to the requirement for validating processes and methods in their agencies, especially when it comes to laboratory accreditation. In many instances, the assurance managers come from the agency's DNA lab, in which there typically are two types of equipment used for processing DNA specimens: a mass spectrometer and a benchtop-style centrifuge. This equipment is used to perform the exact same test repeatedly, which makes it very easy to validate. Also, DNA analysts view the repeating sequences of DNA across 13 different loci using the same processes and methods.

As an aside, the odds are about one in a billion for two people to have the exact same sequence (or match). Based upon the world's population today of 7.2 billion, there could be 6 or 7 people in the entire world who have a match. (As a latent print examiner, it is frustrating to know that DNA analysis uses only 13 different loci and that there could be multiple people with the same loci. With latent prints, the courts want latent print examiners to identify a single fingerprint "to the exclusion of all others" in the world.)

When discussing validation, three definitions must be clarified:

- *Tool*: A specific device or equipment (hardware and/or software) used to perform a particular function.
- *Procedure*: A series of actions or steps conducted in a certain order or manner.
- *(Scientific) method*: A systematic observation, measurement, and experiment and the formulation, testing, and modification of hypotheses. (Since this term is a bit vaguer and more ambiguous, the full Merriam-Webster definition is "principles and procedures for the systematic pursuit of knowledge involving the recognition and formulation of a problem, the collection of data through observation and experiment, and the formulation and testing of hypotheses.")

Based on this definition of "method," the use of digital imaging tools (such as Adobe Photoshop) does not fall within this definition in any manner. Moreover, the use of Adobe Photoshop cannot be defined as a procedure because (1) there are multiple ways of processing an image depending upon the type of capture device used, the type of processing used to develop (i.e., make the invisible visible), which can be done using a chemical process, power, or dye stain that may or may not require a specific light source, i.e., wavelength, on the impression on the evidence. However, certain protocols should be followed when using sequential processes to develop an impression on evidence depending upon whether it is porous, nonporous or semi-porous. These procedures vary depending upon the matrix and substrate of the evidence.

With Adobe Photoshop, there are multiple techniques to calibrate (scale an image for 1:1 life-sized output) regardless of whether it is a fingerprint, footprint, toolmark, or tire mark. Some images (such as those captured using a flatbed scanner) do not require calibration, as they are captured as 1:1 life-size images.

There are a number of ways to suppress background colors interfering with the visualization of an impression. For example, to suppress color values you could use RGB, CMYK, Lab Color, Black and White, Hue and Saturation, Channel Mixer, Selective Color, and Replace Color. The use of these techniques varies depending upon how the image was captured (digitally photographed, scanned, Alternate Light Source [ALS] used, etc.). Even the lighting can be adjusted, such as direct lighting, indirect lighting, bounce lighting, filtered lighting, or oblique lighting.

The bottom line is there are a number of issues that could affect whether a digital image can be processed. Some images are beyond processing because of poor photographic procedures, including but not limited to wrong camera (sensor size), wrong lens (field of view), improper settings (ISO, aperture, shutter speed, white balance, focus, etc.), wrong orientation (parallel) to the surface of the object, etc.

Furthermore, the sequence of actions or steps completed in Adobe Photoshop cannot be required to be performed "in a certain order or manner" because imposing such restrictions and limitations could make the image of less value for analysis and comparison. And some images require the use of a pattern removal filter, commonly known as a fast Fourier transform (FFT) filter or noise reduction filter.

It is simply not possible or feasible to test or validate the use of Adobe Photoshop considering all the possible numbers and combinations of issues involved in digital image processing. ISO 17025 recognizes these types of situations where the validation procedures would be daunting and it would be impossible to test all possible combinations of issues.

These issues also underly the argument that proficiency testing of people who carry out digital image processing of evidentiary photography is not valid because you cannot test someone's proficiency based upon the quality of the image. However, proficiency of these individuals can be tested in performing certain tasks, such as image calibration and general image processing techniques. It should also be remembered that the effectiveness of these tests can be affected by the computer equipment (such as video card, monitor size and monitor resolution, version of software, etc.) provided for proficiency testing.

ISO/IEC 17025:2005(E) section 5.4.7.2 reads:

> When computers or automated equipment are used for the acquisition, processing, recording, reporting, storage or retrieval of test or calibration data, the laboratory shall ensure that:
>
> Computer software ***developed by the user*** [must be] documented in sufficient detail and [must be] suitably validated as being adequate for use; (emphasis added)

ISO/IEC 17025:2005 also states that commercial off-the-shelf (COTS) software (e.g., word processing, database, image processing and statistical programs) in general, used within their designed application range, may be considered to be sufficiently validated.

It should also be noted that most popular—and most commonly used—software applications such as Microsoft Windows, Microsoft Excel, Adobe Photoshop, etc., have been developed and tested in accordance with ISO/IEC 25051:2005, which defines the quality testing requirements for COTS software products.

Quality requirements for COTS software products include "the product description, the user documentation, and the software contained on a computer sensible media. The quality requirements, functionality, reliability, usability, efficiency, maintainability, portability, and quality in use are consistent with the definitions of SQuaRE" (source: https://www.iso.org/standard/37457.html).

In addition, ISO/IEC 17025:2005 (E), section 5.4.5.2 (Note 4) states that "[v]alidation studies can be conducted by the scientific community (as in the case of standard or published methods"). There are three primary keystones of ISO/IEC 17025:2005:

- *Accuracy:* The agreement between the accepted and the obtained value (e.g., analysis and comparison of Level 1, Level 2, and Level 3 fingerprint characteristics).
- *Repeatability:* Demonstrating that one examiner using a particular instrument (e.g., a computer), using a series of methods (e.g., ninhydrin, black powder, R6G, Amido black, basic yellow, indanedione, zinc chloride, RAM, and more) can process the same sets of samples (digital images) on different days and obtain the same (or similar) results that were demonstrated to be acceptable.
- *Reproducibility* (i.e., the ability of a result to be replicated by someone else independently): Demonstrating that the image processing technique can be reproduced reliably and satisfactorily by a competently trained and experienced practitioner in another laboratory with the same equipment and resources.

There is sufficient case law clearly stating that Adobe Photoshop fulfills the evidentiary requirements for the admission of digitally processed photographs. So, there is no requirement to validate the use of Adobe Photoshop, as it is considered "sufficiently validated" as being adequate for its intended use.

Verifying Settings in Adobe Photoshop

The courts have accepted the use of Adobe Photoshop for the digital processing of forensic evidentiary photography for more than 20 years. This acceptance has been based, in part, on the fact that Adobe Photoshop maintains a detailed history log of every function (mouse click) made during the processing (enhancement) of digital images.

The history log is enabled through the Preferences function, which is the last item on the Edit menu in Adobe Photoshop. (From the Edit menu, choose Preferences, and then choose either the History Log option from the submenu, or open the General Preferences dialog box and choose History Log from the options panel on the left side of the Preferences dialog box.)

By default, the history log is disabled and must be enabled when processing Category 2 images—images used for scientific analysis and comparison, such as fingerprints, footwear impressions, questioned documents, etc. The history log information should also be saved in the metadata for the image so the processing information (steps, settings, and parameters) is always available with the image.

The Edit Log Items setting must also be set to Detailed. The default setting for this parameter is "Sessions Only," which would display only the name and storage location (path) of the file that is being edited together with the date the image was processed.

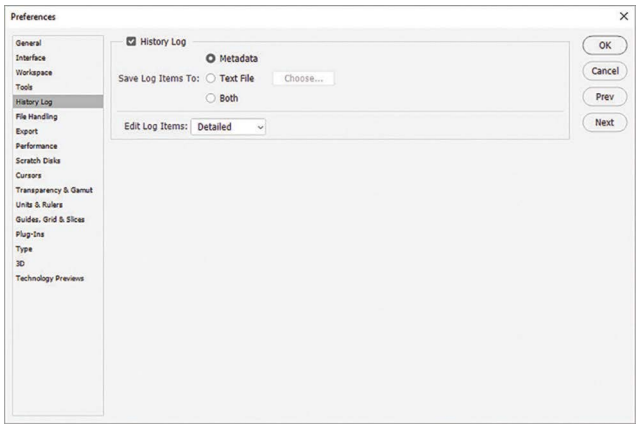


FIGURE 6.23 The History Log feature must be enabled before opening any forensic evidentiary image.

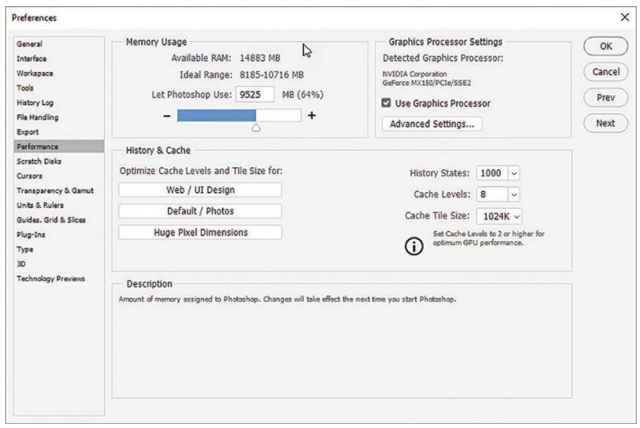


FIGURE 6.24 In the Adobe Photoshop Preferences for performance, the Graphics Processing Settings option "Use Graphics Processor" must be enabled.

Not Meeting System Requirements and Its Effects

Another preference setting that should be considered is the Graphics Processor Settings. As described in Chapter 1, there are a number of items to consider when choosing a computer for the digital processing of evidentiary photography. As illustrated in Figure 6.24, these items include but are not limited to the following:

- The physical size of the monitor being used. For the digital processing of evidentiary photography, this author recommends a *minimum* size of **26 to 30 inches**. (Bigger is better, and dual monitors or an ultrawide monitor should be considered for analysis and comparison!)
- The resolution of the monitor being used. For the digital processing of evidentiary photography, this author recommends a *minimum* resolution of **1920 × 1080**. For side-by-side comparisons, this author recommends a resolution of **2560 × 1440**. (Higher resolution is better!)
- The monitor display type/display technology. This author recommends **LED/LED-lit monitors**.
- The video card in the computer used to support the monitors, as well as the connectivity technology and drivers available. (This author recommends a **video display card** that supports **DVI or HDMI connectivity**.)
- The amount of **video RAM** (video memory) that is available. The amount of video RAM your video card can support depends upon the operating system in your computer, as well as whether you are using the 32-bit or 64-bit version of the operating system.

Under the Advanced [Graphics Processor] Settings, the first three options should also be enabled (see Figure 6.25).

Failing to meet these minimum requirements will affect how picture information is displayed on the monitor. For example, a test target with specific, quantifiable values should be used to validate the integrity of the system. This author uses a 5 inch × 8 inch test target with a file resolution of 500 PPI. This A8 test target was created for the FBI by Mitre to test the accuracy of display and output devices. The use of this test target enables the viewer to make an objective analysis of the values displayed. It is not up to the viewer to make a subjective value; the pixel value is either displayed or not displayed.

In the following two examples it is easy to determine exactly what pixel data is displayed versus what is not displayed when the image is opened at precisely the same resampling rate, based upon whether or not the "Use Graphic Processor" setting is enabled or disabled (see Figures 6.26 and 6.27).

IMAGE ANALYSIS

Image quality is a more challenging topic for many people to grasp. Unfortunately, most people think of image quality as how they view or perceive detail within an image. The level of detail often varies from one discipline to another. But in terms of digital imaging technologies, image quality can be separated into two specific components, discussed in the following sections.

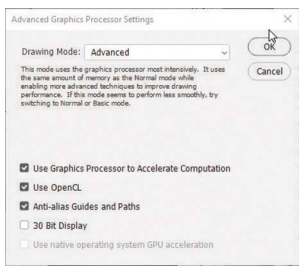


FIGURE 6.25 Advanced Graphics Processing Settings.

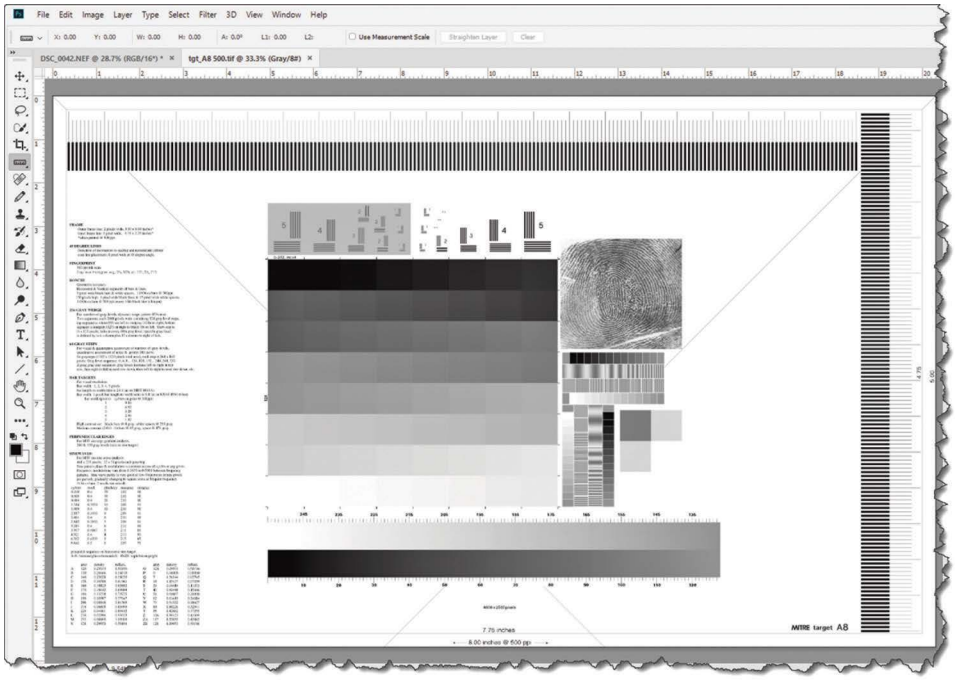


FIGURE 6.26 The test target file (tgt_A8 500.tif) displayed at a zoom size of 33%. All lines are visible and clearly distinguishable at the top and right side of the image when the Use Graphics Processor function is enabled.

Bit Depth

In "geek speak," a **bit** is the smallest element used by a computer—or a digital camera. A bit can be only one of two values: one or zero/on or off. No other values exist except these two. In its most basic form, all digital information is stored electronically in a camera or on a computer as a series of ones and zeros.

In contrast, a **byte** is used to express storage capacity—a string of 8 bits—to store a specific value, such as a single pixel in a digital image. With a total of 8 bits, a single byte can represent a total of 256 different values, such as

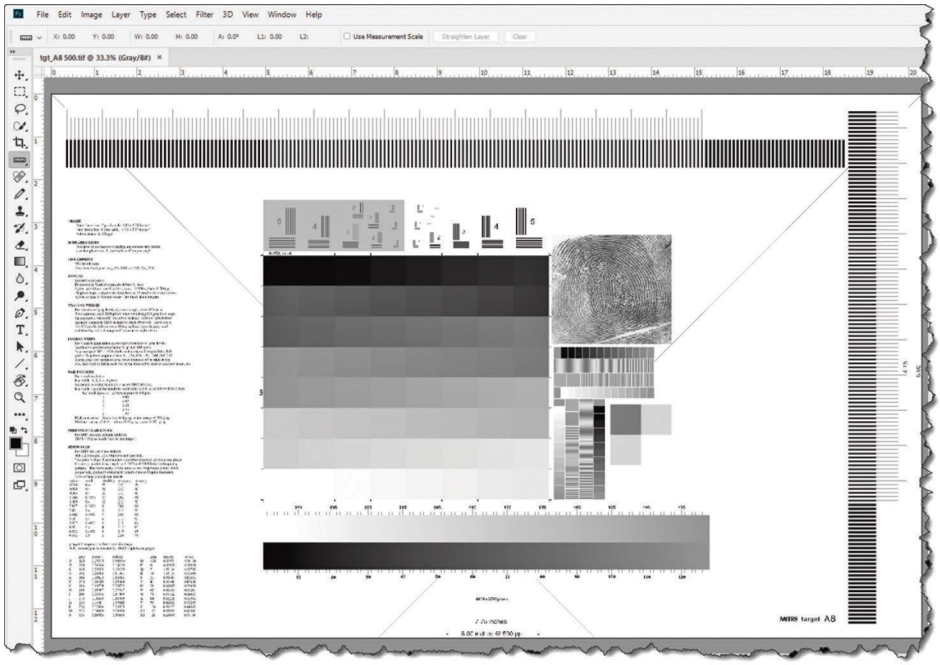


FIGURE 6.27 The test target file (tgt_A8 500.tif) displayed at a zoom size of 33%. Not all the lines are visible and the lines that are visible are of different thicknesses when the Use Graphics Processor function is disabled.

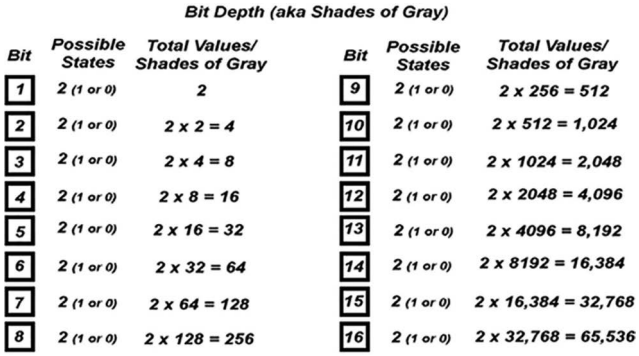


FIGURE 6.28 Maximum bit depth for 8-bit grayscale is 256 shades of gray, while maximum bit depth for 16-bit grayscale is 65,536 shades of gray.

256 different shades of gray ranging from pure black to pure white (see Figure 6.28).

While most digital cameras capture camera raw images as 12 or 14 bits, all operating systems today require data to be stored as 8 bits or 16 bits. When these values are converted into "bytes," the last two positions are filled as a "null" value, which means the two additional bits do not add any more shades of gray.

As described earlier, 8 bits is stored as 1 byte. Therefore, to store more than 8 bits, the file size would double (2 bytes per pixel) for any shade of gray more than the initial 8 bits. While 16-bit images provide maximum image processing capabilities, 16-bit images require twice as much storage space than 8-bit images. For example, to store a 12-megapixel image as a 24-bit color image, there would be 8 bits or 1 byte per pixel for shades of red, 8 bits or 1 byte per pixel for shades of green, and 8 bits or 1 byte per pixel for shades of blue. The file size would be approximately 34.3 MB. To store a 12-megapixel image as a 48-bit color image (16 bits per channel), there would be 16 bits/2 bytes per pixel for shades of red, 16 bits/2 bytes per pixel for shades of green, and 16 bits/2 bytes per pixel for shades of blue. The file size would be approximately 68.6 MB. Stored as a grayscale image, the file size would be 11.4 MB for an 8-bit grayscale image and 22.8 MB for a 16-bit grayscale image file.

While this additional contrast may not be visible to the human eye, the computer *does* recognize the additional color values (or shades of gray) and can distinguish between the different shades. This additional contrast can be extremely beneficial when processing an image where some of the detail is obscured because of a lack of contrast, such as a faint ridge against a faint background, and the human eye cannot distinguish between the two pixel values side by side.

The additional bit depth (color information) can also be extremely beneficial when trying to suppress color backgrounds, when there is limited contrast between the ridges and background in chemically processed evidence.

It is this author's recommendation that "noncomplex" images be processed as 8-bit grayscale/24-bit color image, and "complex" images be processed as 16-bit grayscale/48-bit color images.

The bottom line is, bit depth provides "clarity" within an image, which aids in the analysis of a digital image.

Resolution

The discussion about resolution is where the real confusion begins. Resolution provides the forensic analyst with something easily measurable:

- How many megapixels does the DSLR capture?
- How many megapixels can be viewed on a monitor?
- What is the calibrated resolution (aka pixels per inch [PPI]) of an image area (field of view) captured with the digital camera?
- What is the output resolution (capability) of the printer used to print an image?
- What is the output resolution required for transmission of images between dissimilar systems, such as between a digital imaging system and an AFIS system?

In its truest sense, resolution is the key component of image quality in digital images: the higher the resolution, the higher the image quality. When capturing impression evidence, high-resolution images are used to distinguish ridge detail from backgrounds; if the resolution is too low, a single pixel can be required to provide coverage for both the ridge and the background. Since a pixel can only store one value, the value would be an average of both the ridge value and the background value.

With high-resolution images, the examiner can zoom into a specific area in a fingerprint or questioned document to view the detail for an accurate and reliable analysis of the detail. If the image resolution is too low, the image becomes pixilated when the examiner zooms into the image, and it is often extremely difficult to distinguish between different ridge characteristics.

NOTE:

To avoid human intervention/subjective processing, a macro (aka Photoshop action) was created to process the images and ensure the same settings and parameters would be applied throughout the imaging process.

The bottom line is, the higher the resolution, the higher the quality image. Higher-resolution images allow background noise interfering with the visualization of ridge detail to be suppressed, as demonstrated by the images in Figures 6.29 and 6.30. The black printed background can be suppressed so the ridge detail is visible and identifiable.

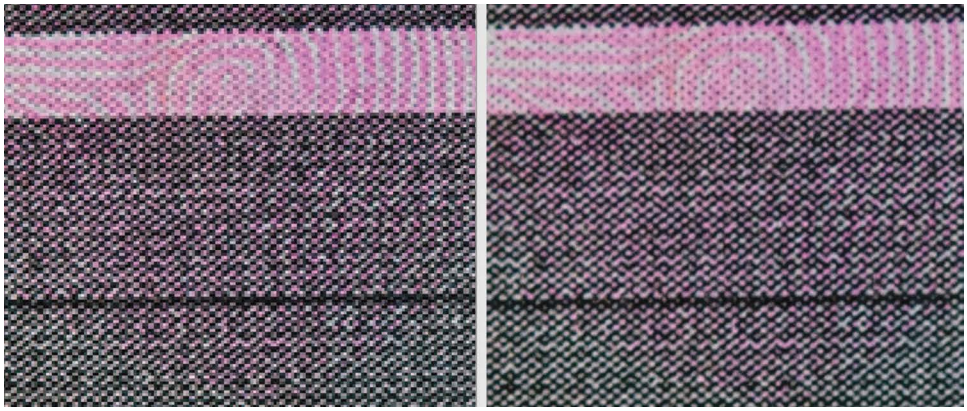


FIGURE 6.29 Comparison of a latent impression developed using ninhydrin. The low-resolution image appears on the left and the high-resolution image appears on the right.

COGNITIVE IMAGE ANALYSIS

Cognitive image analysis can be described as the visual inspection and interpretation of image data (perception) by a person who is knowledgeable and skilled in the evaluation of image data. For a latent print examiner, this perception could include things like how long they have been performing analyses and comparisons (what they know), how accurately or reliably they can distinguish between various shades of gray, and how they can distinguish between background noise and ridge detail (how they think), as well as whether or not the examiner can make an identification with 8, 10, 12, or 16 minutiae characteristics when viewed with respect to the totality of characteristics (i.e., Level 1, Level 2, and Level 3 detail) in the impression (how they make decisions).

This is the area in which the skills, training, experience, and expertise of the examiner matter the most.

QUANTITATIVE IMAGE ANALYSIS

Quantitative image analysis can be described as "mathematical details." For anyone involved in digital imaging in forensic science, this measurable data would include information such as colorimetry, image authentication (metadata), and accurate size measurements (calibration aka "pixel spacing").

It must be noted, however, that **quantitative image analysis** does not consider distortion, such as perspective distortion, which may be considered during **cognitive image analysis**. Quantitative image analysis is often referred to as "objective" analysis, as it takes the human component out of the analysis.

Quantitative image analysis is also the area in which an examiner can provide statistical views. For example, in latent analysis and comparison, it is not just about having 8, 10, 12, or 16 minutiae characteristics. There are other

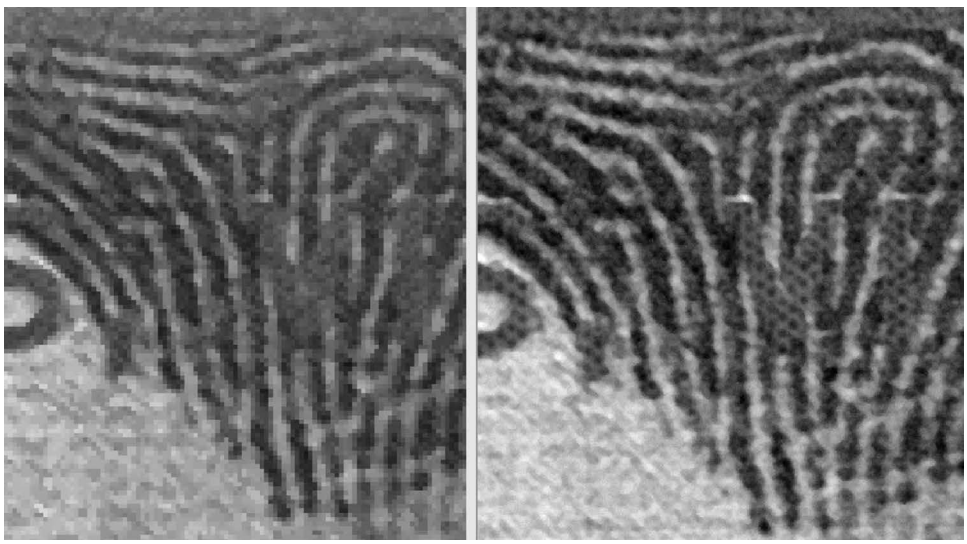


FIGURE 6.30 Comparison of the same latent impression after being processed digitally. The low-resolution image (1134 PPI) appears on the left and the high-resolution (1593 PPI) image appears on the right. The minutiae are clearer on the high-resolution image, while the low-resolution image appears blurry and the classification of some Level 2 characteristics cannot be identified properly.

considerations that apply, such as the direction (angle) of the ridge event and the number of intervening ridges between point 1 and point 2, point 1 and point 3, point 1 and point 4, point 1 and point 5, point 2 and point 3, point 2 and point 4, point 2 and point 5, point 3 and point 4, point 3 and point 5, point 4 and point 5, etc.

The quality of forensic digital evidence can also be quantified. The most commonly used quantitative method for assessing digital image quality is PPI. But the quantitative analysis of an image can also be expressed at different intervals throughout the imaging process to assess image quality.

For example, using a 16 MP digital camera, a 24-bit color image from this camera would be 45.4 MB when the file is captured as a noncompressed TIF image. However, if the image were captured using a "high-quality" JPG format, the image size would be approximately 5.07 MB. Since we know how the JPG algorithm works, we can calculate the number of actual pixel values discarded when the image is saved to the media in the camera.

One of the challenges faced with JPG compression is that in most instances, the physical (measurable) size of the image is not modified along with the loss of pixel values. Instead, the image opens as a 16 MP image. To fill in the gaps created by the disposal of the actual image file values, 89.54% of the image must be re-created using only 10.46% of the original values.

Another way quantitative analysis is used is to evaluate the potential impact associated with a specific process, such as using a printed document for latent print analysis and comparison. More specifically, the question could be asked: "How much data is lost when a digital image is printed at 1:1 on an inkjet printer capable of producing an output equivalent of 540 PPI?"

The mathematical equation is quite simple:

(original dimensions – new dimensions = decrease in pixel dimension) ÷ original pixel dimensions × 100

Using this equation, we can easily calculate the percentage of data loss mathematically:

Original file size: 34.9 MB
Image file pixel dimensions: 4288 × 2848 pixels
Total number of pixels: 12,212,224 pixels
Calibrated resolution: 2228 PPI

We can also calculate the number of pixel values that were printed:

1:1 file size: 2.06 MB
1:1 dimensions: 1040 × 691 pixels
Total pixels: 718,640 pixels
Resolution: 540 PPI
Applying the calculation:
12,212,224 – 718640 = 11,493,584 pixels
11,493,584 pixels ÷ 12,212,224 = 94.1% of pixel values lost in printing

It is for this very reason that **latent print examiners are encouraged to do all of their analysis and comparisons on screen** where the loss of pixel information can be reduced and analysis and comparison can be done faster and easier, and it is also easy to document the analysis and comparison process on screen at the same time.

DIGITAL PROCESSING OF EVIDENTIARY PHOTOGRAPHS

One of the first uses of forensic digital image processing (aka "enhancement") occurred in the early 1970s. Jim Roberts, an officer in the San Diego Police Department, submitted to the Jet Propulsion Laboratory (JPL) a photograph of a fingerprint impression found in blood on bedding materials. There it was digitized in an effort to remove the weave pattern of the material, so the fingerprint ridge detail would be visible and the latent impression could be analyzed and compared to a suspect. (This was the first attempt to use an FFT filter to suppress background noise in a digital image.) Unfortunately, the results were not significant.

In the early-to-mid 1990s, various law enforcement agencies began using digital cameras for the exposure of evidentiary images. However, some of these agencies were disappointed with the quality of the digital images. They did not understand or distinguish between the quality of the captured image, how it was displayed, and more specifically, how it was printed. (They did not understand the distortion caused by the resampling of the digital images to the resolution of the output device [printer], and they did not fully understand why there was a loss of detail in their images, including fingerprint ridges.)

With digital photography, detectives or crime scene technicians could check recently exposed digital images and make additional photographs of them, if necessary. Also, the detectives or crime scene technicians no longer needed to carry multiple rolls of different types of film. Once they returned to the department and properly logged in their images, they could make as many copies as they wanted without any loss of image quality or without loss of a significant amount of time as it would have taken to process and print the images from film. They could also share those images with other law enforcement agencies around the world via email, or the photos could be shared almost instantly with the local court, district attorney's office, state's attorney's office, etc.

Many law enforcement agencies were eager to rid themselves of their expensive film developing equipment and the large photo printers costing tens of thousands of dollars to run and maintain. Along with the costly equipment went the messy chemicals, not only expensive to buy but also costly to properly dispose of. And all the different types of specific photographic papers required for traditional film-based photographic printing would be become unnecessary.

Besides, companies like Nikon, Fuji, and Kodak began discontinuing their film-based camera business and their film and photographic papers. Digital photography

became the new normal for image capture, and companies once thriving for decades, like Kodak and Polaroid, went bankrupt.

Replacing traditional photography were:

- Digital cameras costing only several hundred dollars, instead of silver-based cameras costing thousands
- Film and flatbed scanners costing less than a thousand dollars
- Printers costing from less than a hundred dollars to as much as several thousands of dollars

There was now a digital imaging budget for every law enforcement agency, regardless of its size.

The benefits of digital photography came at a price, though—often a very high price and not necessarily in dollars. Law enforcement agencies began feeling the pinch of declining budgets and sometimes the loss of outside funding opportunities. However, the lower cost of "less expensive" digital technologies perhaps lowered the quality standards and expectations. Today, we still hear the expression, "JPG is 'good enough' for crime scene photos." Because of the larger files (raw or TIF) created by high-resolution digital cameras, the IT departments in some law enforcement agencies may require photos to be exposed in a JPG format to limit the amount of storage needed for high quantities of crime scene photos.

Many forensics experts, including footwear and tire tread examiners, firearms examiners, latent print examiners, and questioned document examiners, know and understand that output technology has lagged far behind capture technology. But many examiners still want to use a 1:1, life-size printout of the digital image. There currently is no "low-cost" output solution to produce the same quality photographs once generated by the huge and expensive film printing and processing devices available not so many years ago. (In the early 1900s, we experienced the industrial revolution, and in the early 2000s, we experienced the "digital" revolution with digital phones, digital clocks and watches, digital televisions, and more.)

The critical issue of latent print examiners continuing to use 1:1 copy generated by inkjet, laser jet, or dye sublimation printers is that a cluster of dots must be used to represent a single pixel. Dye sublimation printers use a process known as resampling, in which multiple pixel values are averaged using a mathematical equation to determine a single value that is then used to represent the multiple pixel values.

To view the 1:1 image, the examiner must also use a magnifying glass (commonly referred to as a "loop") together with a "ridge counter" (also known as a "pick") to analyze and compare a latent impression to a known fingerprint. This back-breaking, tedious process has been simplified with improved digital technologies: high-resolution digital images displayed on high-definition monitors with simplified tools for marking ridge events and tracing ridges as well as marking areas of distortion, etc. Many agencies in Canada and Europe *require* latent prints (also known as latent "marks") to be examined on-screen, so the examiners can take advantage of the high-quality resolution of the monitor to view the impressions enlarged. Analyzing and comparing impression evidence on a computer screen allows the images to be enlarged significantly and compared side by side quickly and easily.

The rest of this chapter focuses on understanding the best practices for digital processing of forensic evidentiary photography using Adobe Photoshop. This program is too sophisticated and too widely used in the law enforcement community to be ignored. But more importantly, there are very few books focusing on the application of the tools and techniques of the software in a forensics environment. Almost every book you read about Adobe Photoshop describes how to manipulate digital images or how to use the tools creatively to produce new artwork. While some of these techniques may aid in the investigative process, forensic analysts must understand not only what tools and methods may be used but how to use them in a manner ensuring their digital images are accepted in a court of law. Not only must the expert testify about the conclusions made using the digital photos, but the expert must also testify and explain what procedures were used, why those procedures were used, and what the effect of those procedures had on the image.

Under Federal Rules of Evidence, Rule 702, "an expert witness is qualified as an expert by knowledge, skill, experience, training, or education, and may testify in the form of an opinion or otherwise if:

a. The expert's scientific, technical, or other specialized knowledge will help the trier of fact to ***understand the evidence*** or to determine a fact in issue;
b. The testimony is based on ***sufficient facts or data***;
c. The testimony is the product of **reliable principles and methods;** and
d. The expert has ***reliably applied the principles and methods*** to the facts of the case." (emphasis added)

Concepts

Any latent ridge detail captured with a digital camera must be calibrated and often may need to be processed so the impression can be viewed more clearly before the ridge detail can be analyzed and compared. In the past, photographic images of evidence were processed using traditional darkroom techniques used for more than a hundred years. The difference now is we have high-resolution digital cameras; high-resolution flatbed scanners; powerful computer technologies; and highly developed, sophisticated image editing applications such as Adobe Photoshop to make it possible for anyone to manipulate digital images. Unfortunately, it is also possible to use digital imaging technologies to mislead, misrepresent, and confuse anyone looking at a digital image.

In forensic sciences, with digital images of items of critical, probative value in court—such as latent fingerprints or palm prints, footwear impressions, tire marks, tool marks, questioned documents, bloodstains, gunshot residue, etc.—the visual acuity must often be improved for an accurate and reliable analysis, comparison, and evaluation of the evidence. As a result, forensics analysts face unique challenges not involved in any other digital imaging scenario. In some instances, the evidence can be adequately seen upon physical examination or with basic capture-and-recovery techniques. In many situations, however, the forensic analyst must use special "processing" techniques to develop the impressions of the physical evidence. For example, a latent print examiner may need to use physical enhancement methods including ninhydrin, indanedione, DFO, or zinc chloride on porous surfaces like money or paper, or cyanoacrylate fuming on nonporous surfaces like plastic, glass, or metal. Some processes, such as indanedione, Ardrox, basic yellow, rhodamine 6G, Coomassie Blue, and so forth, require forensic light sources to view as well as digitally capture the images. These images often require special image processing techniques to make the images visible to the human eye.

In October 2007, the police in London, England, were accused of "manipulating" a photo of Jean Charles de Menezes, so his picture could be compared to a photo of one of the alleged plotters of the July 21, 2005 bombings in London. In this case, a forensic consultant stated in court that the police created a composite image appearing to have "greater definition" than the two images used to create the composite. When asked if the primary features of the face had been changed, Mr. George replied, "I don't believe there has been any … but making the image brighter has changed the image." When the jury went into deliberation on the case in March 2008, the judge told the jury "a serious allegation has been made that a picture has been manipulated to mislead."[13]

Manipulation is commonly believed to mean "the altering of an image using software tools to produce an artificial image and create new meaning." In the London case, the forensics consultant's statement was misleading. By adjusting brightness and contrast, the image did not take on a new meaning.

So why would making an image brighter make it misleading? Could it be an issue of perception? Alternatively, could the problem be caused by not understanding the technology or by the expert not explaining the processes adequately in the courtroom? One of the concerns raised in the *State of Connecticut v. Alfred Swinton* case dealt with a similar issue: the expert's opinion based on a perception (conclusion) about an analysis and comparison of digital images, as well as a lack of knowledge about the technology and the process in Adobe Photoshop used to create the overlays.

Regrettably, the term *image enhancement* has come to mean different things to different people. To a divorced wife, it could mean she "photoshopped" her pictures to remove her ex-husband from the scene (and her memories) both figuratively and literally. To the photojournalist, it means "photoshopping" a digital image to persuade or invoke a strong emotion about a story (it could be about an event, place, or person). To the marketing or sales director, "photoshopping" means "creating" an image or perception invoking an action to buy something or do something.

It has also been alleged that Adobe Photoshop produces results so high in quality most people cannot tell if the photo is real or if it has been manipulated. In Wiktionary, the term "photoshopped" means "[o]f an image: digitally edited or altered." The familiarity, knowledge, and use of Adobe Photoshop has become so widespread that even though image editing or altering can be done in a wide variety of image editing applications, any image alteration or manipulation is commonly referred to as being "photoshopped."

NOTE:

When testifying in court, I do not use the term "enhancement" because of the negative connotations associated with this term over the years. I prefer to use the term "process(ed)" when describing the procedures (tools and techniques) employed in the "development" of the image to improve its visualization to the naked eye. For example, when a latent fingermark is made on a piece of paper, the paper is not "altered" or "enhanced" to visualize the impression. A chemical "process" is applied to the paper to "develop" the impression; the impression itself is neither altered nor enhanced.

Historically, we have stated in our testimony that film was processed to develop the negatives for printing—so until the film was processed, the images on the negatives were not visible. Similarly, when talking about developing a fingerprint on a piece of paper, a chemical process (such as ninhydrin or indanedione) was used to develop the impression so the ridge detail becomes visible. (One of the definitions in the Merriam-Webster Dictionary for "enhance" is to "intensify, increase, or further improve the quality, value, or extent of"; as stated earlier, this term also means to "change.")

In forensic digital imaging, once the evidence has been processed and the impression is visible on the physical evidence, it is then digitally documented using a digital camera or flatbed scanner. Next, a series of steps (techniques) may be used, for which the specific settings and parameters must be documented. Then the detail of the impression can be viewed more precisely, a conclusion can be made more accurately, and the weight of the judgment in the case can be based on the reliability of the evidence.

The challenge for forensic digital evidentiary photography is that every digital image must be exposed, stored, processed, and managed correctly to ensure its probative value will be admissible in the courtroom. To meet this challenge, law enforcement agencies are required to have an SOP describing the digital imaging process from the time the evidence is recovered at the scene until the evidence is processed and the ridge detail is processed digitally and then presented in court. For example, the courts generally require the original, unedited image file be available and authenticated, and if image processing was involved, the changes must be made to an exact, pixel-for-pixel copy of the original image, and each step of the process is documented so the digital imaging process may be repeated if necessary.

As of the writing of this book, there is no case law in the United States, Canada, or Europe addressing the processing of digital images from a specific camera or a particular photo-editing software application. Previously, the SWGIT and today, OSAC for Forensic Sciences is developing standards for forensic practitioners providing foundation for the acceptance and use of consistent practices and methodologies for digital imaging in all forensic disciplines. (Note: OSAC has taken over the role of most of the SWGs, including SWGIT.)

Although invaluable, these guidelines still do not offer specific, enforceable requirements for hardware or software, nor do they provide specific requirements for the capture, processing, and storing of digital images. Given the sheer volume of hardware and software applications, such a task would be unwieldy. Moreover, no organization or agency developing actual standards would ever be permitted to recommend a particular device or application developed only by a single manufacturer.

Nonetheless, some features and functions must be supported by these applications, such as the ability to:

- Resize (calibrate) images
- Adjust brightness and contrast
- Adjust hue and saturation
- Adjust white balance
- Crop
- Remove backgrounds
- Eliminate noise
- Sharpen the image

Some applications provide the ability to perform batch processing, such as changing file names for a batch of images or processing a batch of images using the same color adjustment or the same brightness and contrast settings simultaneously. The protocols (authorization) for performing these tasks must be defined in the agency's SOP.

In addition to defining procedures for image processing, SOPs should include topics including but not limited to:

- By whom and how are crime scenes to be photographed?
- By whom and how are evidentiary items discovered at the crime scene to be photographed?
- What special equipment and other considerations, if any, are required when photographing evidentiary items at the crime scene, including:
  - Footwear
  - Tire tread
  - Blood spatter
  - Latent prints, and so forth

For example, consider, a DSLR camera with a full-frame imaging sensor and an interchangeable lenses is required for capturing evidentiary photographs; a scale must be used for close-up images of evidence photographed at a crime scene; a tripod must be used for evidentiary photos; and so forth.

- How are digital image files and the corresponding evidence collected at the crime scene transported back to the department?
- How are digital image files of the crime scene and the evidence collected to be downloaded from the camera(s)/media?
- How and where are the original digital image files/digital evidence to be stored?
- By whom, when, and where are copies of the digital image files made after the images are downloaded? (As stated previously, the Best Evidence Rule says "[i]f data are stored in a computer or similar device, any printout or other output readable by sight, shown to reflect the data accurately is an '*original*.'" **Further, processing of a digital image, if any, must be performed on a *copy* [exact bit-for-bit duplicate] of the original image**.)
- How are original and enhanced digital image files authenticated to prove their authenticity and integrity?

NOTE:

Encryption alone is not sufficient to authenticate the integrity of any digital file (including but not limited to digital images, audio/video files, and document files). Anyone who knows or has access to the encryption key can unencrypt, edit, and modify the data without documenting the alterations and changes and then re-encrypt the digital file without anyone's knowledge. The use of a technique such as a message digest (also known as a Secure Hash Algorithm [SHA] value) can accurately identify whether or not a digital file has been altered. The hash value for the original image should be maintained independently of the original image file so the initial hash value can be used for comparison any time the digital data needs to be authenticated.

- Who is responsible for processing the physical evidence, if required?
- When must digital images be captured to preserve the results of individual processing steps, such as

preserving ridge detail previously developed on a sheet of paper, after it was processed with ninhydrin but before it was processed with DFO?
- When and where are the original image files backed up?
- Who has access to the original files as well as to the processed copies of the original records?
- How are step-by-step image processing histories to be created and maintained for each Category 2 image (i.e., images used for scientific analysis), including sufficient detail (settings and parameters) to allow another person with comparable skills, training, and expertise to create a similar result? (A pixel-by-pixel re-creation is *not* required!)

Each piece of evidence, whether or not it will be processed, should be photographed multiple times, for example, (1) a complete, overall digital photograph should be captured of a beverage container (such as a can or bottle bearing possible ridge detail); (2) a complete, overall digital photograph of all the impressions, if any, developed on the can or bottle; and (3) a close-up photograph of sequential impressions ("[t]wo or more friction ridge impressions from the same hand or foot deposited concurrently"[14]), as well as an individual impression(s). Together, these digital images may help distinguish not only which hand deposited the ridge detail but may help distinguish simultaneity of "[t]wo or more friction ridge impressions from the same hand or foot and may be used in the aggregate as a single impression when conducting image analyses and comparisons."[15]

BEST PRACTICES FOR IMAGE CAPTURE

All impression evidence (including but not limited to latent impressions, palm prints, tool marks, footwear impressions, and blood spatter) should be photographed using a camera raw format.

More specifically, JPG files and TIF files captured using a digital camera only have a dynamic range of 8 bits, or 256 shades of gray, or 8 bits per color channel, or 256 shades per color channel. Today, most professional-level DSLR cameras preserve the full dynamic range of 14 bits, or 16,384 shades of gray, when the data from the imaging sensor is written to the storage media using a camera raw format.

NOTE:

The JPG file format is used to reduce image file size—sacrificing image quality (as shown in Figures 6.31 and 6.32)—to conserve storage space. The original pixel values are lost and *can never be retrieved*. Moreover, JPG compression uses an 8-pixel by 8-pixel grid in which actual pixel values are removed, pixel boundaries are relocated, pixel colors are altered, and pixel values are reduced differently for different locations in the image.

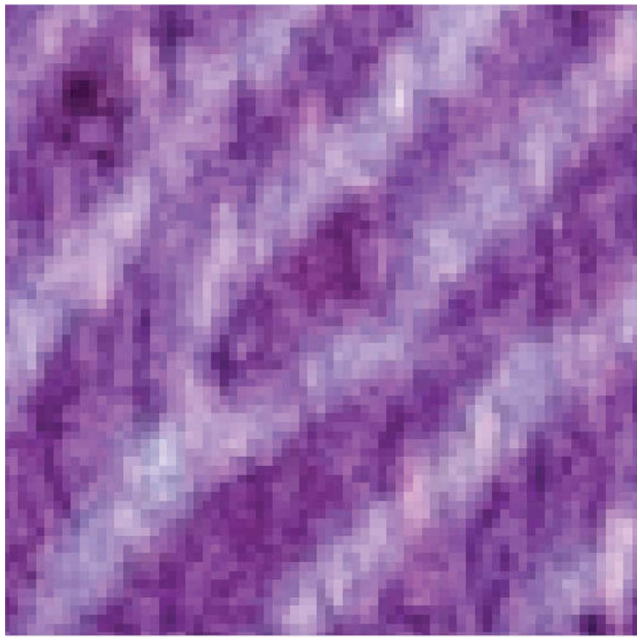


FIGURE 6.31 When zoomed, you should see this.

After the impression evidence (including but not limited to latent impressions, palm prints, tool marks, footwear impressions, and blood spatter) has been processed successfully, **the processed image file should be saved using a TIF file format**.

When scanning latent impressions, such as latent print lifters or latent print lift cards, the scan resolution must be set to a number where the optical resolution (hardware resolution) is divisible by 2 and the quotient produces



FIGURE 6.32 NOT this!

an even number when divided by 2, for example, 4800 PPI / 2 = 2400 PPI; 4800 PPI / 4 = 1200 PPI; 4800 PPI / 6 or 4800 PPI / 8 = 600 PPI; 4800 PPI / 12 = 400 PPI; 4800 PPI / 16 = 300 PPI.

Examples of uneven resampling producing odd numbers (or fractions of a pixel) include but are not limited to 1000 PPI / 2 = 500 PPI, where 500 PPI is not an even divisible number (500 PPI / 2 = 250 PPI / 2 = 125 PPI / 2 = 62.5 PPI); 1,400 PPI / 2 = 700 PPI, where 700 is not an even divisible number (700 PPI / 2 = 350 PPI / 2 = 175 PPI / 2 = 87.5 PPI).

All impression evidence (including but not limited to latent impressions, palm prints, tool marks, footwear impressions and blood spatter) should be photographed using only DSLR cameras with interchangeable lenses. (Digital cameras with interchangeable lenses provide greater flexibility when photographing large objects, such as palm prints, footwear, blood spatter, firearms, tire tread, and so on, as well as greater flexibility to capture images up close more accurately using a lens with macro capabilities.)

All impression evidence (including but not limited to latent impressions, palm prints, tool marks, footwear impressions, and blood spatter) should be photographed using only digital cameras with a full-size imaging sensor (36 mm × 24 mm).

When latent impressions appear on large objects, a photograph must be taken of the entire object for purposes of preserving the source (attribution and position of the impression as it relates to the physical evidence).

For maximum image quality (when zooming in on a specific area within a digital image), the capture area for large areas containing forensic evidence (including but not limited to footwear impressions, tire track impressions, and blood spatter) should not exceed the size of the camera imaging sensor divided by 500 PPI. For example, the area captured using a 24 MP DSLR camera with a sensor resolution of 6016 × 4016 should not exceed 12 inches × 8 inches; the area captured using a 16 MP DSLR camera with a sensor resolution of 4928 × 3280 should not exceed 10 inches × 7 inches when rounding to the nearest whole inch.

Any forensic digital evidentiary image to be used for analysis and comparison (such as a latent fingerprint or palm print, footwear impression, tire mark, tool mark, questioned document, bloodstain, firearms comparison, gunshot residue, and so forth) captured with a digital camera must include a scale. While a scale technically is not required in digital images captured using a flatbed scanner, many law enforcement agencies require a scale to be placed in **all** digital images regardless of the type of device used to ensure consistency, as well as to prove the image can be produced (printed) accurately and reliably at life-size (1:1) scale.

When preserving evidentiary items digitally (whether using a digital camera or a flatbed scanner), it is imperative the image be captured in color even if the item is a black powder lift card or a ninhydrin print on a check.

NOTE:

All forensic images captured using a flatbed scanner must be captured using a photo mode. Using a text or line drawing mode will degrade the quality of the scanned image. Also, the 16-bit grayscale mode should be used only when attempting to capture a complex (ugly) latent impression. Using a 16-bit grayscale mode on a flatbed scanner requires each sensor to capture two 8-bit values; those values are then added together to create the 16-bit grayscale value for the corresponding pixel. Using 24-bit color mode is preferred over 16-bit grayscale. Using 24-bit color mode, red, green, and blue filters are applied to the imaging receptors to obtain better detail. As a result, the bit depth (dynamic range) is significantly better. The 16-bit grayscale mode should be used only when scanning black-and-white impressions, such as a very (extremely faint) impression on a latent lift card or transparent lifter.

Once the digital image is captured successfully, many variables affect not only whether or not the digital image can be processed but how the image can be processed for better clarity. For example, a latent print developed on a plastic baggie processed with cyanoacrylate (Super Glue fuming) may only need to be inverted to convert the white ridge detail to black ridges. Similarly, a gray or white power lift may also need to be inverted to convert the white ridge detail into black ridge detail for analysis and comparison.

In the case of porous evidentiary items, a latent impression may be developed on a check or money order with one or more background colors, or perhaps the background consisted of checkered patterns from lines or dots. Alternatively, maybe the latent impression was on a brown, rough-textured paper bag; a yellow, smooth-surface paper bag; or a white, smooth-surface paper bag. All of these scenarios are possible. The bottom line is that images may be captured digitally from an unlimited number of surfaces (including skin) that may have been developed using any number of powders, chemical processes, dyes, fluorescent powders or dye stains, and more.

Forensic light sources may be used to aid in the visualization and capture of latent prints, body fluids, gunshot residue, and so forth. The angle of the light, as well as the distance of the light from the surface of the evidentiary item, can and will affect the clarity and the ability to visualize and digitally photograph the impression.

All images—even evidentiary items processed using the same development method (such as ninhydrin) on the same type of surface (such as paper) and the same kind of light source—may require the use of different techniques to make the impression visible. Therefore, it is impossible to provide a scenario in which the same process with the same settings and parameters will always be used.

Best Practices for Image Capture Using a Digital Camera

When photographing evidence using a digital camera, there are two "physical" concerns. One of these concerns what lens is being used to capture the evidence. As stated earlier, capturing evidentiary photographs requires a DSLR camera with a full-frame imaging sensor and interchangeable lenses.

Like crime scene photos, a minimum of three photographs should be captured for every piece of evidence of evidentiary value:

1. An overall photograph of the object
2. A mid-range photograph of the object before it has been processed during the visual examination to document the location on the object of any ridge impressions visible before processing
3. A close-up photograph of any ridge detail visible during the initial visual examination of the evidence before processing

If any ridge detail is visible on the evidence after physical processing, steps 2 and 3 should be repeated for each impression developed.

To optimize the resolution for the close-up photographs, use a lens designated as a "macro" lens. (Generally speaking, a macro lens allows a camera to have a sharp focus closer to the evidence, which increases resolution and optimizes clarity.)

Another distinction of a macro lens is it uses a "flat field" design, which helps eliminate the distortion issues of normal lenses. Normal lenses have a concave (curved) design, which may distort the image: either the center of the image may be slightly out of focus or the edges may be slightly out of focus.

There is one major issue for consideration when using a DSLR, especially when selecting a lens for close-up/macro photography. This issue is known as the focal-length multiplier or crop factor corresponding to the size of the imaging sensor. For reference purposes (see Figure 6.33), a 1:1 focal length uses a traditional 35 mm film format as the reference format when discussing image sensor size.

If two digital cameras with the same resolution were positioned at the same distance from an object being digitally photographed with the same macro lens, where one camera had a "full-frame" imaging sensor and the other camera had an APS-C size imaging sensor, the size of the area covered by the APS-C size imaging sensor would be smaller, appearing as a cropped portion of the same area captured by the camera with the full-frame imaging sensor. To capture the same size area as the full-frame camera, one of two things needs to happen:

1. The camera with the APS-C imaging sensor would have to be moved farther away from the object to capture the same area (with a focal-length multiplier of 1.5, the APS-C camera would have to be moved to approximately 1.5 times farther away from the object, as shown in Figure 6.34).
2. Alternatively, a substitute macro lens could be used. For example, if a 40 mm macro lens were used with a DSLR camera using an APS-C imaging sensor, the camera could be positioned at the same height as the DSLR camera using a full-frame imaging sensor and a 60 mm macro lens. For example, **40 mm multiplied by 1.5 equals 60 mm**.

Even if the two DSLR cameras were to capture the same area (also known as the field of view), the digital image from the camera with the smaller imaging sensor would contain more noise than the image from the full-frame DSLR camera.

Moreover, keeping the DSLR imaging sensor as close to the object as possible increases resolution, which

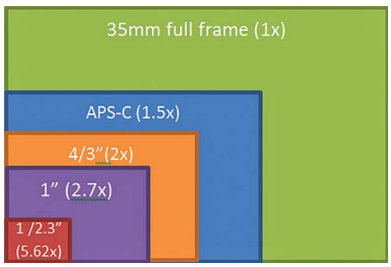


FIGURE 6.33 Comparison of imaging sensor sizes relative to a full-frame imaging sensor.

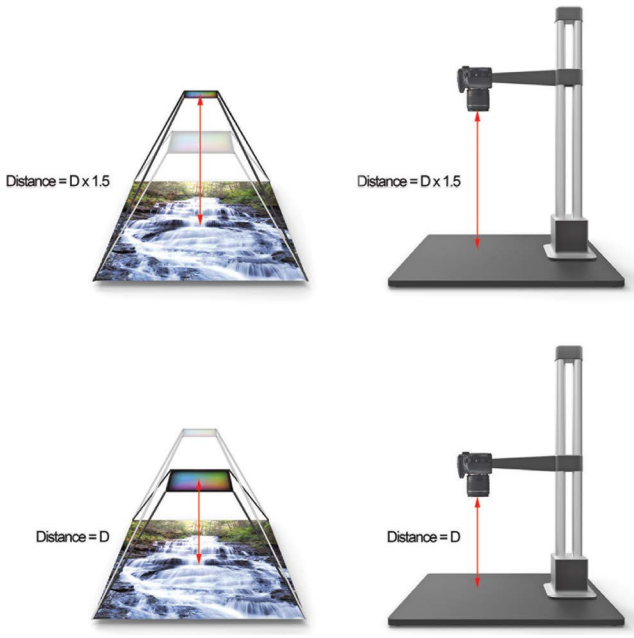


FIGURE 6.34 Distance-to-object comparison using a camera with a full-frame imaging sensor and a camera with an APS-C imaging sensor.

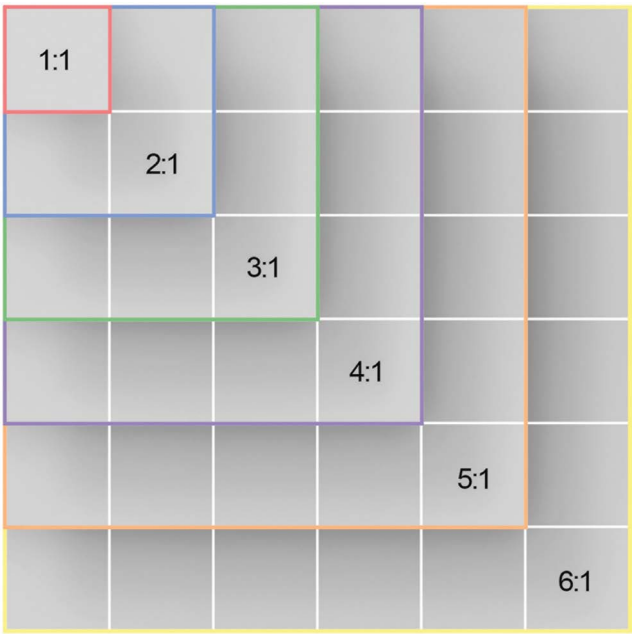


FIGURE 6.35 Ratio of multiplier of increased field of view to original field of view.

provides a sharper, clearer image. Image resolution declines rapidly the farther away the camera is from the field of view. For example, if a 1 inch × 1 inch field of view (1 square inch) were digitally photographed using a DSLR camera, the ratio of pixels to field of view would be 1:1 or 100% of the sensor's resolution. If the field of view were doubled to 2 inches by 2 inches, the field of view would be 4 square inches, which means the field of view for one 1-square-inch area would be 1:4 or 25% of the sensor's resolution.

As shown in Figure 6.35, when the size of the original field of view area is compared to a larger field of view, the 1 square inch is captured by a significantly smaller percentage of the original resolution of the imaging sensor. For example, the 1:1 area would use 100% of the sensor imaging receptors or be 100% of the overall imaging sensor resolution. An increase of 2:1 (multiplying both width and height) would result in an area of 4 square inches; so, each square inch of the subject field of view would be captured by only 25% of the photoreceptors of the imaging sensor. An increase of 3:1 would result in an area of 9 square inches, so each square inch would only be 11% of the overall imaging sensor resolution. An increase of 4:1 would result in an area of 16 square inches, so each square inch would only be 0.625% of the overall imaging sensor resolution. Ad infinitum.

The bottom line is this: keeping the camera (imaging sensor) as close to the object as possible limits the size of the field of view as much as possible. In other words, the closer the camera is to the object, the higher the resolution; the farther away the camera is from the object, the lower the resolution for the comparable area of the image.

General Guidelines

The forensic science community in the United States recognizes two categories of digital evidentiary images: Category 1 and Category 2 images.

- *Category 1* images are considered to be documentation, not evidentiary, and are not used for analysis.
- *Category 2* images are considered evidentiary in nature and are typically used for analysis and comparison.

SWGIT has defined different processing guidelines for these two categories.

Category 1 images may be captured using a JPG file format. Also, a detailed history is not required for Category 1 images. Instead of a complete image processing history, the agency can specify precisely what image editing functions may be used to enhance Category 1 images in its SOP.

Also, most digital cameras today provide three image quality settings when saving JPG images. Remember, the higher the image quality, the larger the file size; the lower the image quality, the smaller the file size. The following descriptions are provided to help create a better understanding of the three basic JPG formats:

- *Low image quality* (also known as "small" on some digital cameras): Highest compression/lowest image quality (this format is good for viewing digital images on the Internet, such as on web pages or emails, but it is not good for printing unless printed as a small image, such as a wallet-size image or thumbnail image)
- *Medium image quality*: Medium compression/average image quality (good for making 3 × 5 prints and perhaps 5 × 7 prints and can be emailed easily; generally, too large for use on web pages or social media)
- *High image quality* (also known as "fine" on some digital cameras): Least compression/best JPG image quality (suitable for making 8 × 10 prints and can still be emailed relatively easily)

When defining acceptable image quality standards within their SOPs, law enforcement agencies should always establish a policy when using a JPG format with the least compression for the best image quality for Category 1 images. Please remember, the original pixel values are discarded when the image data is written to the media inside the camera, and once the original pixel values are lost, they can never be recovered.

However, there are times when a JPG file format is not acceptable for use with Category 1 images beyond the capture and storage of the original images. For instance, it may be necessary to process an image to reveal details hidden in the shadows, annotate the picture, and so forth.

Once a JPG file is decompressed and then processed, it is vital to save the image in a standard TIF format so the image will not be recompressed, causing additional degradation of the image. Also, annotations should never be made directly on the original image. A blank layer should be added to the image and the annotations made on that layer, so the annotations can be turned on or off as necessary. Also, the annotated image *must* be saved as a TIF file. Saving an annotated image using a JPG format not only compresses the image data but all layers are flattened/combined, and any annotations made to the image overwrite and replace the underlying pixel values. Once this process occurs, it cannot be undone.

In addition to defining image quality standards, the SOP must describe what tools and techniques may be used for Category 1 digital images. Since the department's SOP is discoverable, along with all digital image files associated with the particular case, keep it simple!

Typically, these basic techniques are used to improve the overall appearance of an image (Remember, never perform any of these operations on an original image. Make a copy first and then perform these actions on the copy.):

- Adjusting brightness and contrast
- Adjusting color balance
- Adjusting hue and saturation
- Adjusting white balance
- Basic image sharpening or blurring
- Cropping
- Rotating

Category 2 images are another matter entirely. SWGIT recommends Category 2 images be captured using a noncompressed file format, such as raw or TIF. SWGIT changed the "requirement" to capture images using a noncompressed file format to provide examiners more flexibility in accepting images where there is sufficient detail to make an identification. All processed Category 2 images must include a detailed image processing history in which each tool/technique used must be documented, as the sequence and parameters of the tools used will affect the results when used with advanced enhancement techniques on the same digital image.

Some of the more commonly accepted advanced image processing techniques include:

- Color and tonal range corrections
- Color channel selection and subtraction
- Fourier analysis (pattern identification and extraction)
- Advanced noise reduction (such as dust and scratches)
- Advanced image sharpening (such as Unsharp Mask and Smart Sharpen tools)

In addition to maintaining a sequence log of the steps used during the image enhancement process, the settings and parameters must be documented for each step. The information must be detailed sufficiently so a person with comparable skills, training, expertise, and experience could repeat the process and achieve a *similar result*. There is no case law, guideline, or other recommendation requiring the imaging process to be reproduced identically pixel by pixel. The results should be "visually indistinguishable," which means the image should be a "reasonable likeness."

There are also some guidelines for both Category 1 and Category 2 digital images:

1. All original digital image files must be preserved in their original file format precisely as they came from the digital camera. At no time is it permissible to overwrite an original image file! For legal purposes, the "original" electronic file must be retained and, if requested, must be available for discovery or court.
2. Any processing performed on a digital image must be performed on a copy (duplicate) of the original. The parent–child relationship of the original image and the copy of that image must be maintained so the images can be appropriately identified following Federal Rules of Evidence 901.[16] Both the original and processed image must be authenticated to the extent that it can be demonstrated the images are true, accurate, and reliable.
3. All digital images must be handled with the same care and control as physical evidence, and a chain of custody must be maintained for all digital images. ASCLD/LAB-International Supplemental Requirement 5.8.4.2 to ISO 17025 states that "digital photographs of nonrecoverable latent impressions much be treated with the same care and control as the physical evidence itself." Access to digital images stored on a workstation or server, accessible by one or more individuals, must be regulated. User rights and permissions must include but not be limited to privileges for viewing, printing, copying, exporting, archiving, deleting, etc. The chain of custody record should identify anyone who has accessed either or both the physical evidence and the digital image of that evidence and any related workflow.

In addition to defining the procedures used for digital image processing within an SOP, the procedures should be consistent and should make sense. For instance, one law enforcement agency stated in its SOP that "[y]ou may not delete any digital image from a media card or digital camera…. All digital image files are to be preserved in their original format to ensure sequential integrity…." A few pages later, that SOP states "all digital image files are to be downloaded to the server," and after the files are downloaded, the "file names are to be changed to reflect the case number, officer id …" for easy identification.

While this contradiction may not appear to be an issue, this practice does not comply with SWGIT guidelines. Changing file names is not a practice generally accepted (or practiced) for digital images of evidentiary items taken at a crime scene. Prosecutors and defense attorneys have questioned the practice of renaming files because of the subsequent inability to prove sequential integrity.

While most "tech-savvy" individuals in the forensic community have no problems with the idea of deleting an image on the camera, they express concerns about renaming files, citing issues about human error, loss of timeline, and so forth.

The basis for the guideline/recommendation of not deleting images goes back to the use of film, when it was illogical to remove a frame in the middle of a strip of film. With digital cameras, it is technically possible (and feasible) to delete a digital image if it is out of focus or the camera settings (such as white balance, shutter speed, aperture setting, and exposure) are not correct. Of course, if the SOP allows images to be deleted inside the camera, guidelines should be established to define *when* it is acceptable or permissible to delete a digital image file.

The bottom line is that SOPs must be reviewed and evaluated carefully for apparent contradictions and mistakes and to ensure the policies and procedures make sense and are easy to follow. As the old saying goes, keep it short and simple (or straightforward). Try to define consistent procedures that work in all situations to avoid confusion and frustration and not be so elaborate that steps can be missed or skipped unintentionally.

For example, expecting a person capturing images at a crime scene to change the file format settings on a digital camera back and forth from JPG to raw between photographs most likely is not a reasonable expectation. There is a potential for human error, and a critical piece of evidence may be photographed using a compressed file format, resulting in a digital image not suitable for processing.

RESOLUTION AND RESAMPLING

There are many monitor resolution settings. These settings are frequently controlled by the video card or by the monitor itself. As a result, images must frequently be resampled before being displayed on the monitor. The good news is that when an image is zoomed in or zoomed out on the monitor, the actual pixel values of the image are not changed.

There are, however, times when the resolution of an image must be changed so the image will print at a specific size or be resized to meet a specific sizing requirement. For example, if a system, such as an AFIS, requires an image to be 1000 PPI and the image must always be 1.25 inches by 1.25 inches, then all files received by the workstation must be exactly 1250 pixels by 1250 pixels; the first 1000 by 1000 pixels would occupy an area of 1 square inch, and the remaining 0.25 inch would require 250 pixels (1000 PPI ÷ 4). If the requirement is 500 PPI, then all files sent to the AFIS must be 625 pixels by 625 pixels, where 500 by 500 pixels would occupy an area that is 1 square inch. Hence, if an image measuring 1250 pixels by 1250 pixels was shared with an AFIS requiring 500 PPI, the image would occupy an area of 2.5 square inches and the image would not match a corresponding known print even if it were in the database.

When calibrated, most images captured using a 16MP DSLR have a calibrated resolution between about 1900 PPI and 2900 PPI, depending upon the size of the area captured with that specific camera. Most AFIS providers now support a resolution of 1000 PPI for latent prints, which would mean most, if not all, prints would have to be resampled and cropped to fit the specified resolution/size.

Even images scanned on a flatbed scanner must be resampled because there are no scanners available today with a native resolution of 1000 PPI, unless the scanner has been adapted to meet a specific requirement, such as for image acquisition on an AFIS workstation.

For optimum image quality and uniform resampling, the optical (hardware) resolution should be divided by 2, and each additional step to reduce the resolution (because of file size) should also be divided by 2. All flatbed scanners have an optical density or hardware resolution containing an even number of photoreceptors on the imaging sensor, such as 600, 1200, 1600, 2400, 4800, 6400, etc. To simplify this discussion, think of the number of photoreceptors as 100%. Dividing 100% by 2 equals 50%, and dividing 50% by 2 equals 25%. You would not use a lower resolution because 25% divided by 2 equals 12.5%. Since pixels represent only one value, there is no way that a single pixel could be represented using one half of a pixel value. (The resampling algorithm cannot add the 0.5 values of two pixels to make one pixel.) This problem becomes more obvious when dividing 100% by 3, which equals 33.33333333333331 pixels. The 0.3-pixel value presents the problem immediately, as one pixel can be only one value, not one-third of a value. The problem of resampling scanned images for AFIS where 1200 PPI is resampled to 1000 PPI is the same as dividing 1200 by 1000, which equals 1.2. It would take 5 pixels each with 0.2 of a value.

Further, the Epson Perfection V850 has an optical (hardware) resolution of 4800 PPI. Scanning a 3 inch by 5 inch lift card using the scanner's full optical (hardware) resolution would create a file that is 988.8 MB, which is unmanageable. To reduce the file to a more manageable size, divide 4800 by 2, or 2400 PPI, which would produce a file size of 247.2 MB, which is still too large for most law enforcement network environments. To make the file size smaller, divide the resolution by 2 again, which would yield a resolution of 1200 PPI for a file size of 61.8 MB, which is a more manageable and realistic file size.

The bottom line is using a divisor of 2 works in almost every case. There are exceptions where it is possible that using a divisor of 2 or a divisor of 3 would result in an even value at some point, but those times are rare. Using a divisor of 3 would yield an even result of 400, but 400 divided by 3 equals 133.333333. Computers and printers can deal

with whole pixel values only, and the odd numbered resampling creates disparities in the appearance of the image.

The reason for dividing by 2 instead of any other number is a resampling issue. When resampling, it is essential to have an even resampling or a ratio of 2 to 1. For example, in resampling an image containing 1000 pixels using a divisor of 2, the 2:1 resampling ratio would be 2:1 or 50%. Using a divisor of 3 would yield a 3:1 ratio or 33.3333333333333%. Since pixels are a singular entity, there is no way to handle a 0.3333333333333 pixel equally.

The bottom line is that using a divisor of 2 works in almost every case. There are exceptions when it is possible that using a divisor of 2 or a divisor of 3 would result in an even value at some point, but that also would be rare. Again, using a resolution of 1200 PPI and a divisor of 2 would yield, 600; 600 divided by 2 equals 300; 300 divided by 2 equals 150; 150 divided by 2 equals 75; 75 divided by 2 equals 37.5; etc. When using an odd-numbered lower resolution (PPI), the loss of detail becomes more visible; hence, using a divisor of 2 whenever possible maintains the most consistent quality.

NOTE:

The "1000 PPI requirement" for latent print capture is only applicable as either

1. a minimum image capture resolution for latent impressions (fingerprints or palmprints) or
2. an output (export) resolution (defined in the FBI's CJIS Electronic Biometric Transmission Specification [EBTS] documentation) as a transmission standard for interoperability (exchanging images) between dissimilar digital imaging systems. The reason this standard was established was to ensure 1:1 (life-size) accuracy. For example, if an image with a resolution of 500 PPI were compared to an image with a resolution of 1000 PPI, the 500 PPI image would be only 25% the size of the corresponding image. Thus, the minutiae plotting of the smaller image would not "match" the larger image because of the difference in size.

Resolution Resampling: "Upsampling" and "Downsampling"

Now that we have had a history lesson about dots and pixels, let's get back to the issue of resampling. When the physical output size of an image must be changed, the number of pixels in the digital image must be resampled. Typically, images are either enlarged or reduced in terms of physical size. In terms of pixel values, this means increasing ("upsampling") or decreasing ("downsampling") the number of pixels. In some instances, both the physical size and resolution must be reduced, such as when creating a thumbnail image. Conversely, the resolution may be decreased or increased to print a small picture or a large picture, respectively.

Downsampling requires removing multiple pixel values and substituting a single value to represent those multiple pixel values. Upsampling means adding pixel values between original pixel values. Some people refer to downsampling as "destroying" image detail and upsampling as "counterfeiting" image detail. While these terms sound harsh, I have seen images become unusable because of the level of downsampling, so maybe the word is not so harsh after all!

Adobe Photoshop provides several different resampling methods, including:

- Automatic resampling is a technique in Adobe Photoshop where the resampling process is based on the contents (pixel values) of an image and then whether pixel values are added to or removed from the image.
- Preserve Details is a resampling process similar to Bicubic Smoother, meant for enlarging images. A "Noise reduction" slider is used for reducing the noise as additional (new) pixels are added to the image.
- Bicubic Smoother is a resampling process typically used for enlarging images where added pixel values are calculated using a group of pixel values to produce smoother tonal gradients.
- Bicubic Sharper is a resampling process used primarily for decreasing the number of pixel values where the remaining pixel values are calculated using a contiguous group of pixel values and then increasing the contrast of those pixel values.
- Bicubic resampling is a more precise method of adding or removing pixel values based on a group of adjacent pixel values to produce smoother color gradations than Nearest Neighbor or Bilinear.
- Nearest Neighbor resampling uses a process where visibly distinct edges are preserved.
- Bilinear resampling adds or removes pixel values based on the average of pixel values in a linear process with moderate results.

No single method is the best process for all types of evidentiary images.

To provide an idea of what resample does to an image, Figure 6.36, 6.37, and 6.38 illustrate the artifacts of changing the actual number of pixels in an image file using different resampling options.

Resampling is ONLY required for output or for sharing images at a specific, measurable size. Resampling is not necessary to view the contents of a digital image file on a monitor. When printed, original pixel values in the image are resampled and the original pixel values discarded. The resulting pixel values are "dithered". (Dithering is the method used by most inkjet and laser printers to convert pixel values to a cluster of dots based on the printer's ink

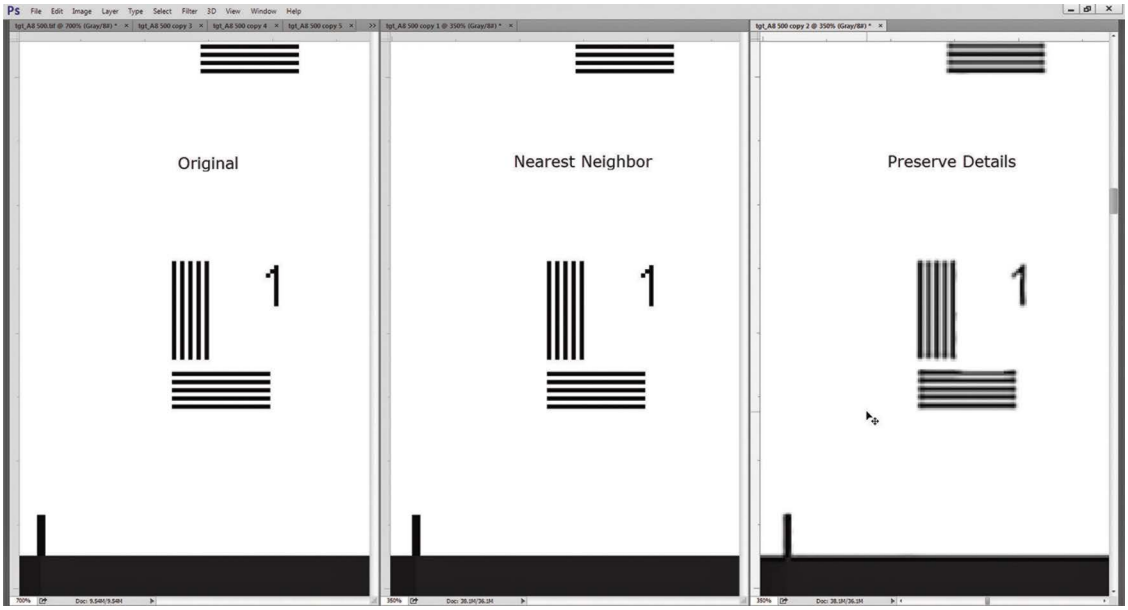


FIGURE 6.36. Upsampling by doubling 500 PPI to 1000 PPI.

color palette and dot size(s).) Since the monitor can display a significantly higher number of pixels than can be printed, forensic examiners more frequently rely on high-resolution monitors for their analyses and comparisons. Besides, they can zoom in and zoom out to more carefully analyze the detail in an image, since the image detail is not lost, as it is when it is printed. On-screen analysis and comparison can provide a significantly higher degree of accuracy, especially when analyzing fingerprint detail such as the size, shape and formation of pores, ridges, and so forth. Based on personal experience, bigger is better during image analysis and comparison!

Adjusting Size and Resolution

One of the most confusing issues of digital imaging is the resolution measurement known as pixels per inch (PPI). Pixel is short for picture element, the smallest identifiable characteristic in a digital image. PPI is a measurable number of pixels represented within a 1 inch area. For example, a printer can represent the value of 300 picture elements in a 1 inch area measured horizontally and vertically. On a computer monitor, a pixel is the smallest cluster of red, green, and blue photodiodes; a computer monitor with a resolution of 72 PPI can display a total of

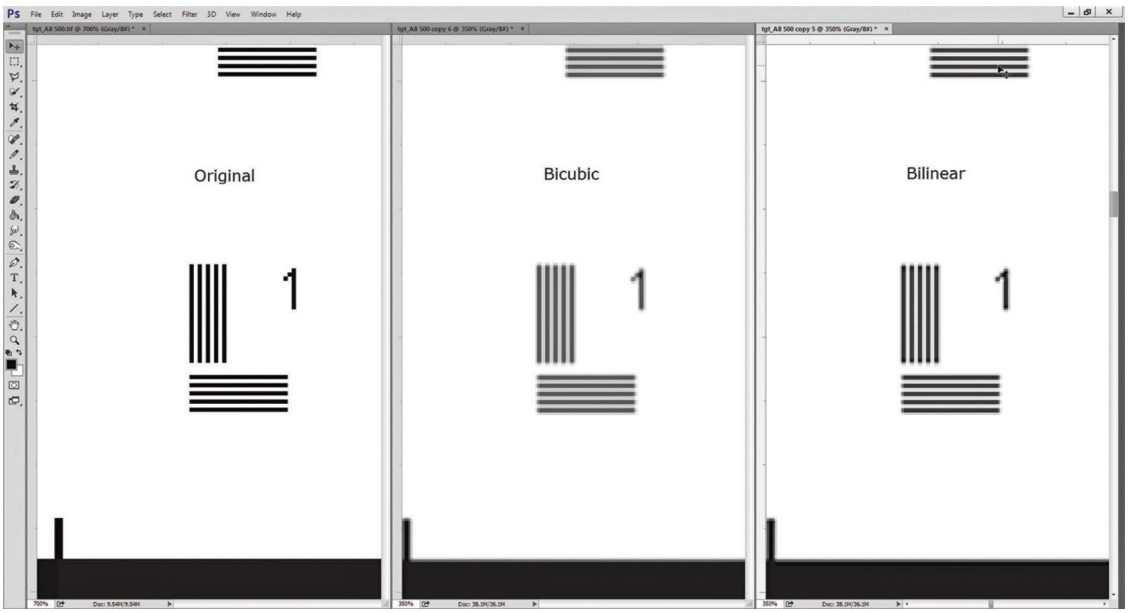


FIGURE 6.37. Upsampling by doubling 500 PPI to 1000 PPI.

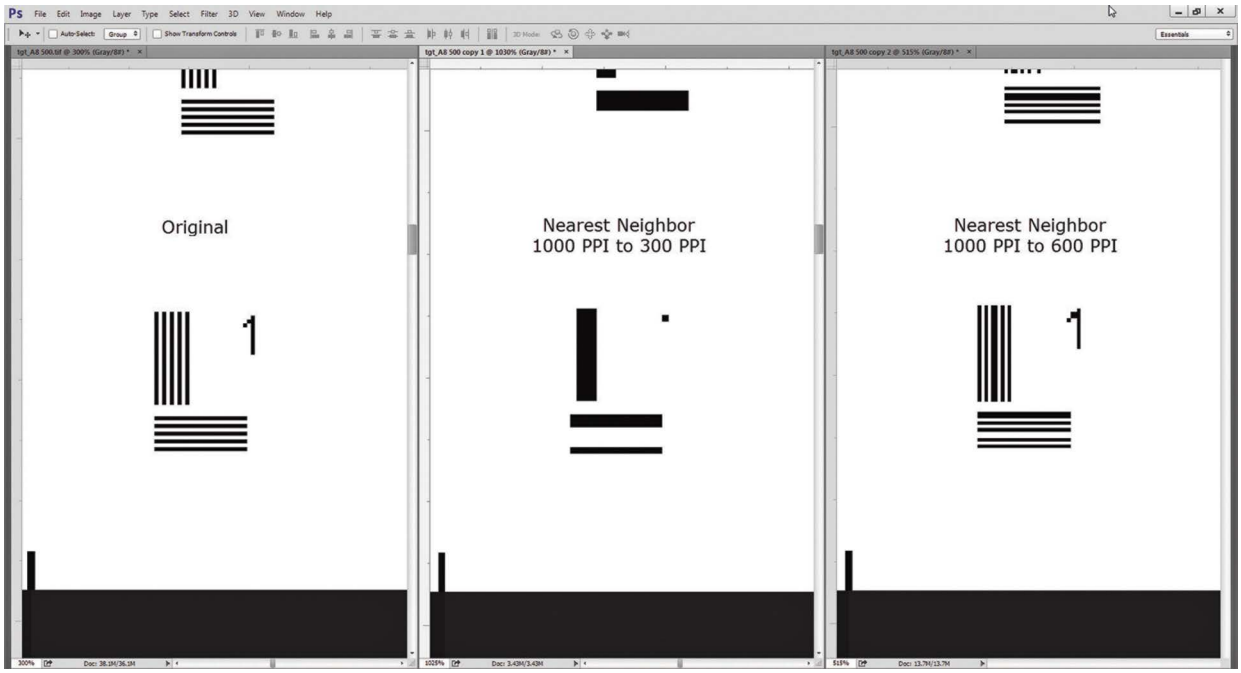


FIGURE 6.38. Down sampling by resizing 1000 PPI to approximately two-thirds of its original resolution (600 PPI) and to approximately one-third of its original resolution (300 PPI).

72 red, green, and blue photodiode clusters in 1 inch of the monitor.

In digital imaging, one reason for this confusion is that digital cameras have an extremely wide range of resolutions and image sensor sizes. The physical (hardware) resolution of digital cameras range from less than 5 MP to more than 50 MP. As a result, the same impression on the same piece of evidence could be photographed using two different cameras, each with different resolutions. As a result, the image from the lower-resolution camera could have a measurable (calibrated) resolution of 1050 PPI, while the picture of the same evidence using a higher resolution camera could have a resolution of 3894 PPI. For the purposes of analysis and comparison, the higher the resolution, the higher the image quality.

Documentation images (images used for demonstrative or illustrative purposes and nonevidentiary) may also require resizing for printing. Adjusting the resolution of nonevidentiary images can be confusing, especially when the images are opened on a computer screen using a default display resolution of 72 PPI, or a default print resolution of 300 PPI. The sad and unfortunate issue is that far too many people do not understand what this means.

Some camera manufacturers "size" the images coming from their digital cameras using a default resolution based on a customary monitor resolution, which has historically been 72 PPI. Some of the newer monitors have a display resolution of 96 PPI or higher. Using these monitor resolutions will cause images from high-resolution digital cameras to be extremely large. For example, the Nikon D810 is a 36-MP digital camera with a full-frame imaging sensor and a resolution of 7360 pixels by 4912 pixels; the Nikon D7500 is a 21-MP digital camera with an APS-C imaging sensor and a resolution of 5568 pixels by 3712 pixels.

If an image from the Nikon D810 was opened in an imaging application like Adobe Photoshop, using the default of 72 PPI, the image size would be displayed as 102.222 inches by 68.222 inches, even though the entire image is displayed on a monitor with only 1920 by 1080. If this image were opened using a default of 300 PPI, the image size would be displayed as 24.533 inches by 16.373 inches. If the image from the Nikon D7500 were opened in an imaging application like Adobe Photoshop, using the default of 72 PPI, the image size would be displayed as 77.333 inches by 51.556 inches even though the entire image is displayed on a monitor with only 1920 by 1080. If this image were opened using a default of 300 PPI, the image size would be displayed as 18.56 inches by 12.373 inches.

Regardless of which camera produced the digital image, and regardless of which default setting was used to open the image, the digital image would have to be resized to print as an 8 × 10, 5 × 7, or 4 × 6 output. Resizing the image from the Nikon D810 to fit an 8 × 10 page would produce an image size with a resolution of 614 PPI; resizing the image from the Nikon D7500 to fit an 8 × 10 page would result in a resolution of 464 PPI. In most instances, the resolution would still be higher than what could be printed, depending upon the type of printer (ink jet, dye sublimation, or laser).

In either case, the image resolution should be adjusted to match the output device or other use. Failure to follow the appropriate procedure for resizing digital images can be *very* destructive and can degrade image quality, image integrity, size proportions of objects in the image, and aspect ratio very quickly.

To resize images for printing or sharing electronically, and maintain image quality and size proportions properly, follow these steps:

1. In Photoshop, go to Image and then Image Size.
2. When the Image Size dialog box opens, verify the Resample option is disabled. (There should not be a checkmark in the checkbox.)

NOTE:

The Constrain Proportions option in Adobe Photoshop, or any other imaging editing software application, should *always* be enabled. The Constrain Proportions function ensures the aspect ratio of the original image does not change. Enabling the Constrain Proportions function is destructive, as it changes the relationship between the width and height (scaling) of objects contained in a digital image.

3. Change the width or the height to the desired print size.

NOTE:

Depending upon the aspect ratio of the imaging sensor in the camera, if you change one dimension to a typical print size, such as 4 × 6, the physical properties of the image may meet one of the specified sizes, but the width may be longer than 6 inches or the height less than 4 inches. If you are printing to a specific paper size (4 × 6, 8 × 10, 13 × 19, etc.), the printer will trim the extra width of the image to the physical size of the paper. (I always size the image based upon the shortest dimension, so the excess image is "cropped" to fit the specified print size.)

4. Click OK to lock in the physical size of the image.

NOTE:

Steps 6 and 7 could be completed before step 4, but I prefer being cautious and verifying things don't happen mysteriously (i.e., "shit happens" and I don't like it when it does!).

5. Go to Image and then Image Size again.
6. This time when the Image Size dialog box opens, enable the Resample option. A checkmark now appears in the checkbox, and for most images in Adobe Photoshop, the resample option should be Bicubic Automatic. (Bicubic Automatic is an algorithm used to add or remove pixel values to produce a smoother transition between adjacent pixel values. For forensic image processing using Adobe Photoshop, Bicubic and Bicubic Automatic are the most commonly used interpolation algorithms. Images consisting of straight lines, such as line art, should use Nearest Neighbor to retain the highest level of sharpness and clarity.)

NOTE:

Depending upon the camera's image sensor size and resolution, you may be required to adjust the image size and resolution of the image before printing or sharing the file. For example, using the default settings (resolution of 72 PPI) to open a digital image in Adobe Photoshop from a 12-MP digital SLR camera with an imaging sensor resolution of 4288 × 2848 pixels, the default image size would be (width) 59.556 inches by (height) 39.556 inches. To print the image as an 8 × 10 landscape print, change the height to 8 inches; the width will adjust to 12.045 inches, and the resolution will adjust to 356 PPI automatically. If printing on precut paper, the printer driver will automatically crop the width of the print to 10 inches, removing a little more than an inch on both sides of the printed image. If you are not printing on precut paper, you will want to crop the image to a specified crop size of 8 × 10.

7. Change the resolution as desired for a specific publisher or printer.

NOTE:

For images consisting of distinctive geometrical lines or textures, such as brickwork or siding on a building, the resampling option of Nearest Neighbor may provide better results than Bicubic Automatic. If you do not like the result produced using one option, press and hold the Alt and Ctrl keys and type the letter Z in Adobe Photoshop to go backward and restore the image to its prior, non-resampled image size so you can change the resampling option and the resolution.

8. Again, click OK to lock in the desired resolution (PPI) of the image.

A BRIEF HISTORY OF SCANNERS AND RESOLUTION

Scanners create three separate values for each photoreceptor on the imaging sensor—one for red, one for green, and one for blue. Those three values are used to create a single pixel value. Regrettably, the industry-wide measurement used to specify image quality for flatbed scanners is dots

per inch (dpi), even though scanners do not use a cluster of dots where each dot is a single value (red, green, or blue) to represent a single pixel value. This misnomer dates back to the 1950s when the first photocopy machines were developed. (Xerographic office photocopying was introduced by Xerox in 1959.)

As this technology became more popular, these techniques were used to make the "copies" of original documents. One of these techniques involved the use of toner, in which toner was picked up in negatively charged spots (aka "dots"). The output quality was measured based upon the number of possible dots on the imaging drum. The toner was then transferred to a piece of paper and melted onto the paper by heat and pressure rollers.

Even though the technologies for scanners and printers have been relegated to separate boxes (i.e., flatbed scanners and laser printers), the "quality indicator" of dots per inch (DPI) is still used for both printers and scanners today, even though flatbed scanners now create high-resolution images based upon pixel values.

The Epson Perfection V800 and V850 include two separate scan heads: one for reflective documents of nontransparent objects, with 4800 photoreceptors for a 1 inch area (4800 PPI), and one for transparencies (film or other transparent objects), with 6400 photoreceptors for a 1 inch area (6400 PPI), which is far greater resolution than any printer available today.

To Photograph or to Scan, That Is the Question

One of the biggest concerns for latent print examiners is how to decide when a flat piece of evidence (such as a piece of paper, currency, check, money order, etc.) should be scanned or when it should be photographed using a digital camera. Typically, the rule of thumb has been "if it's flat, then scan it." But this rule of thumb does not always provide images suitable for optimum digital processing results.

Another reason why some latent print examiners, questioned document examiners, and footwear examiners like to use a flatbed scanner whenever possible is that digital images produced by flatbed scanners do not require calibration (resizing the image for one-to-one, life-size output).

When an object is laid flat on the glass platen of a flatbed scanner, the size of the area to be imaged is set using the scanner's marquee tool. Each inch of the image area is scanned with the same number of photoreceptors regardless of whether it is 1 square inch, 2 square inches, or 3 square inches. (Flatbed scanners with an optical resolution of 4800 PPI have a maximum scan area of 8.5 inches by 11.7 inches, with an effective resolution of 40,800 pixels by 56,160 pixels—the equivalent of 2,185 MP.

Today, there are no digital cameras with a similar resolution. But there is also no flatbed scanner that can digitize an area of interest as quickly as it can be imaged with a digital camera. Nonetheless, digital images of evidentiary items must be calibrated, which is perceived by some examiners as an unnecessary, time-consuming process.

But image size and resolution are not the only issues an examiner should consider. The primary concerns should be:

- How was the ridge detail developed? Or what color ink was used on the questioned document?
- What chemical process or dye stain was used to make the ridge detail visible on the evidence?
- What is the background (substrate) on which the fingerprint or palm print was developed? Or what is the background (substrate) of the questioned document?
- Does the background contain two or more colors, or is the background a consistent single-color value?
- What is the level of contrast between the lightest detail in the impression or signature and the background?

These issues will have the greatest impact upon whether or not a scanned image can be processed so the image detail can be clearly visualized for analysis and comparison. In other words, the level of clarity between the color details in the image can be the deciding factor in whether or not background color or other artifacts interfering with the analysis and interpretation of forensic digital imaging can be suppressed.

One of the distinctions already discussed in this chapter deals with color and contrast. With digital cameras, the clarity of an image is based upon the bit depth of the image, which identifies the level of detail distinguishable by two adjacent imaging receptors. In flatbed scanners, this contrast is measured as a dynamic range (Dmax) between black and white.

Digital cameras can use a wide range of forensic light sources as well as ambient light. The intensity of the light striking the imaging sensor inside the camera can vary from photoreceptor to photoreceptor.

In contrast, flatbed scanners have only one light source, which generates the same light intensity for every color sample captured by the photoreceptors on the imaging sensor.

When all color values—red, green, and blue; hue, saturation, and brightness; and lightness, channel a and channel b—are set to the value of 0, red and black share the same light intensity (aka Brightness) as shown in Figure 6.39. Thus, there is an increased level of difficulty when trying to suppress a black background from a red or magenta foreground. This level of difficulty is intensified when ridges in a latent print (developed using ninhydrin) overlay a black background (such as printing or text) are captured using a device with a single light wavelength (a flatbed scanner).

Another difference between a digital camera and a flatbed scanner is flatbed scanners capture three values for each photoreceptor: a red value, a green value, and a blue value. These three values are added together to create a composite or RGB image, as shown in Figure 6.40.

Digital cameras, on the other hand, capture only *one* value for each photoreceptor on the imaging receptor.

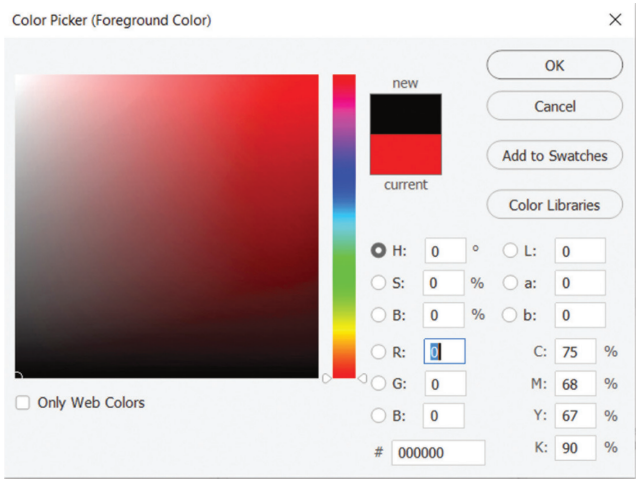


FIGURE 6.39 The Color Picker dialog box displays the combination or values (like a recipe) that define every color value for each color mode.

Almost all digital cameras manufactured today have a "color filter array" overlaying the imaging sensor. Most color filter arrays consist of alternating rows of red and green filters and green and blue filters, which filter the light for each underlying photoreceptor (see Figure 6.41). The design uses 50% green color filters, 25% red color filters, and 25% blue color filters. This design concept was chosen because the human eye is more sensitive to green (which appears in the middle of visible color wavelengths) than red (which is closer to the long color wavelengths or infrared color space) or blue (which is closer to the short wavelength or ultraviolet color space). This design concept is also the reason why digital cameras are not as effective as traditional silver halide film when it comes to capturing digital images using ultraviolet or infrared light sources.

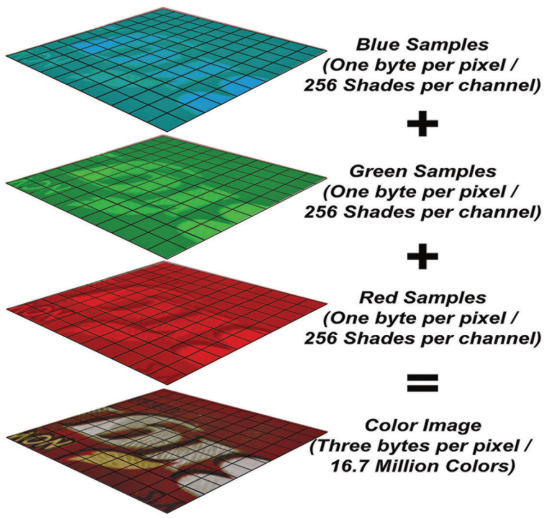


FIGURE 6.40 Flatbed scanners capture three separate light values for each photoreceptor, filtered using a red filter, a green filter, and a blue filter. The three values are then added together to create a composite RGB value for every sensor (pixel).

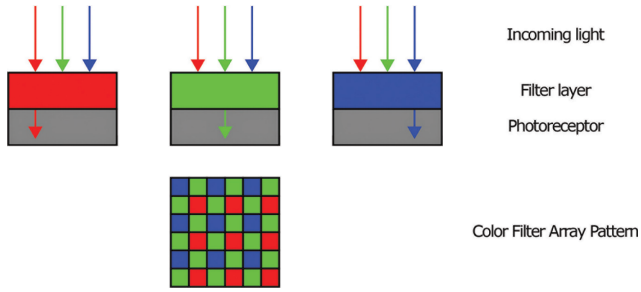


FIGURE 6.41 The photoreceptors on the imaging sensor in a digital camera measure only the brightness of the light striking the sensor; the photoreceptors do not measure the color of the light. Bryce E. Bayer is the scientist who invented the "Bayer filter," which is used in almost every digital camera available today.

When a picture is digitized in a digital camera, the light reflecting off the object is captured and focused by the lens. Once the light passes through the lens, the light passes through a color filter array and the brightness and intensity of the light are captured by the photoreceptors on the imaging sensor, where the light values are converted into binary data values (aka bits).

When the light strikes the filters on the color filter array, the light is broken down into "visible light" wavelengths: red, orange, yellow, green, cyan, blue, and violet. (Most digital cameras have filters that block light wavelengths in the ultraviolet and infrared light spectrum range.)

The red filters on the color filter array pass light values within the red-orange-yellow wavelengths (between approximately 560 nm and 700 nm) as white or light shades of gray; light values within the green or blue light wavelengths are absorbed (blocked) by the filter and do not pass through.

Similarly, light values striking the green filters on the color filter array pass only the light values within the yellow-green-cyan wavelengths (between approximately 590 nm and 490 nm) as white or light shades of gray; light values within the red or blue light wavelengths are absorbed (blocked) by the filter and do not pass through.

Correspondingly, light values striking the blue filters on the color filter array pass only the light values within the cyan-blue-violet wavelengths (between approximately 490 nm and 400 nm) as white or light shades of gray; light values within the red or green light wavelengths are absorbed (blocked) by the filter and do not pass through.

Digital images captured using a camera raw file format preserve the original light values only, exactly as they were captured by the photoreceptors on the imaging sensor. Color is added back into the image when the image is opened in a photo editing application such as Adobe Photoshop. Adobe Photoshop includes a data-to-image converter using a demosaicking process to turn the "raw" light data from the imaging sensor into a full-color (see Figure 6.42) pixel grid.

As illustrated in Figure 6.43, the color values for each pixel in the image are based on the light values of the corresponding photoreceptor together with light values of the eight nearest-neighbor photoreceptors. The image pixel

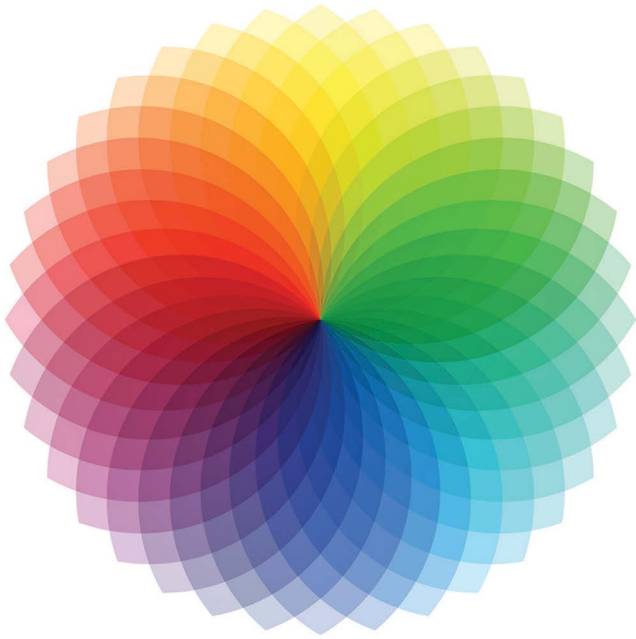


FIGURE 6.42 The intensity of each color-filtered light value is combined to create a wide array of color values. An image using 8-bit grayscale values for each color channel (256 different shades per color value) can have a total of 16,777,216 different colors. What's the point of having all of these colors when the human eye cannot detect that many different colors? It is significantly easier to suppress background noise in images having more contrast because of the increased number of light intensity values.

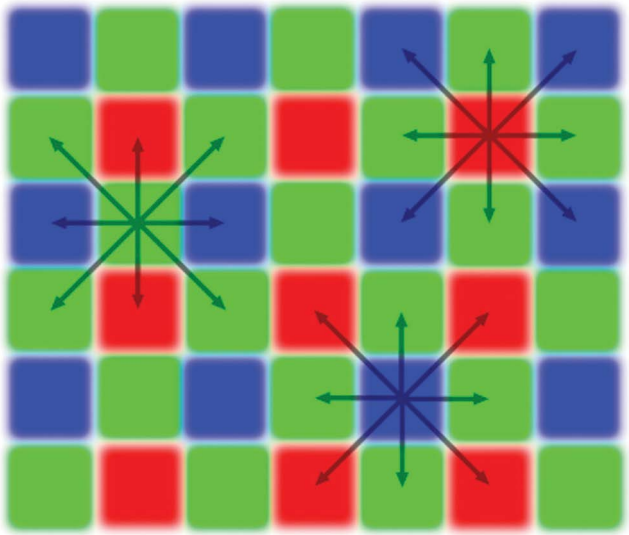


FIGURE 6.43 The image pixel value for each corresponding photoreceptor is calculated based on the filtered light values of itself and the nearest neighbors. This use of nearest neighbors also explains why digital camera specifications show numbers for both "sensor photodetectors" and "effective pixels." The outer photoreceptors on the imaging sensor do not have neighbors on all sides; therefore, they are missing light values required to calculate the corresponding pixel color value.

values derived from corresponding photoreceptors covered with green filters are based on the light values of the individual photoreceptor together with four additional green-filtered light values, two blue-filter light values, and two red-filtered light values. The image pixel values derived from corresponding photoreceptors covered with red filters are based on the filtered light values of the individual photoreceptor together with four green-filtered light values and four blue-filter light values. The image pixel values derived from corresponding photoreceptors covered with blue filters are based on the filtered light values of the individual photoreceptor together with four green-filtered light values and four red-filter light values.

If images are captured in the digital camera using a compressed JPG format, the color is added back into the image in the image processor of the digital camera. In addition, the JPG conversion process reduces the number of light (grayscale) values from 16,384 shades of gray to only 256 shades of gray. After the number of shades of color is reduced, color is added back into the image. The image is then sharpened, and a noise reduction filter is applied to the data. And finally, the image data is compressed based upon the preset camera settings. Once the original data is discarded during this processing, it can never be restored to its original values.

Background color value, patterns, and other artifacts interfering with the clear visualization of images captured using a digital camera can be suppressed using a number of different techniques because of the different light wavelengths used to calculate the individual pixel values in the image. For example, black backgrounds, such as text or borders on checks, can be suppressed using a function in Adobe Photoshop known as Calculations. The difference in frequencies for the varying light values also make it easier to remove repetitive patterns.

NOTE:

In Adobe Photoshop, Calculations is a mathematical function used to blend color values of two-color channels using the brightness values of corresponding pixels, where the pixels share the identical location in the image. The resulting values are combined into a single grayscale channel. But even with the increased bit depth of the imaging sensor, the additional light (filtered) wavelengths, and so forth, a ninhydrin print photographed with a DSLR camera will not be of any benefit, nor will it be easier to suppress background noise, if the appropriate camera settings are not used. Using the automatic setting on a digital camera will reduce the ability to suppress background colors, which results in the equivalent of scanning the impression. However, it may still be possible to use a color mode in Adobe Photoshop, known as Lab Color, to suppress the background in a scanned image or an image photographed using automatic settings.

NOTE:

The Lab Color mode displays digital images using three color channels: lightness, a, and b. The Lightness channel represents the combined red, green, and blue brightness values of each pixel in the image. Channel a represents the combined red and green brightness values of each pixel in the image, and channel b represents the combined green and blue brightness values of each pixel in the image.

The bottom line is that there are no fixed rules or guidelines about what items should be scanned or digitally photographed. Sometimes it may be a matter of trial and error to select the device that works best for a particular scenario based on the type (make, model, and specifications) of the flatbed scanner or digital camera available for use; the size of the area of interest; the resolution required, if any, for the image type (category); and the image processing techniques available to process the image.

IMAGE PROCESSING GUIDELINES

With all of the image processing software and tools available today, image processing is not rocket science! More than 40 years ago, however, digital image processing was rocket science. The National Aeronautics and Space Administration (NASA) first introduced digital image processing to repair the degradation of image signals captured in space and sent back to earth.[17] Dr. Robert Nathan developed the concept of digital image processing in 1959 at the Jet Propulsion Laboratory (JPL). But before the first images from space could be enhanced, the video film converter had to be constructed to transform analog video signals into digital images. The video film converter was not completed until 1963, for use with video images captured by the Ranger and Surveyor programs. Even then, digital image processing had not gained full acceptance by NASA, which did not occur until the *Mariner* Mars missions in 1969.

In 1968, research started under a series of grants from the National Institutes of Health in the area of digital image processing to aid in microscopy and medical diagnosis in the enhancement of x-rays. Unfortunately, the government canceled all fundamental research grants in the field by 1973. And as the old saying goes, "the rest is history." Digital image processing has gained widespread acceptance in literally every facet of life and discipline in science. It affects nearly every area of our daily lives as well, from enhancing signals displayed on televisions, computers, etc., to improving the quality of digital images captured using cellphones, digital cameras, etc. It is nearly impossible to think of an area in which digital image processing is not used.

THE ORDER OF PROCESSING (AKA PROCESSING SEQUENCE)

While there are some basic guidelines for the image enhancement process, there are no specific requirements dictating the order in which these processes should be used. The primary reason is because it is impossible to define every possible image enhancement scenario, as well as every possible combination of tools possibly used for each scenario. But there is a suggested order to generally follow when processing digital images.

The following steps are offered only as a recommended order, and in no way are these steps intended or implied to be the required order of processing for the enhancement of all digital images.

Capture

Capture (photograph or scan) the evidence following the procedures described in the SOP. Be sure to capture overall images, mid-range images, and close-ups of the evidence, and ensure a scale is included in at least one image from each distance, as described in Chapter 8, "General Guidelines for Capturing Latent Impressions Using a Digital Camera," Version 1.3 2010.06.11, and Chapter 9, "General Guidelines for Photographing Footwear and Tire Impressions," Version 1.0 2013.09.27, of the SWGIT Guidelines.

Download the electronic files from the digital camera and authenticate the image files following the guidelines described in Chapter 13, "Best Practices for Maintaining the Integrity of Digital Images and Digital Video," "Overview of SWGIT" and the "Use of Imaging Technology in the Criminal Justice System," Version 1.0 2007.06.04.

Storage

One of the more important rules still not receiving the recognition it should when using digital imaging technology is the chain of custody. Like physical evidence, digital evidence can carry probative value, and in some instances, such as in the loss—intentional or unintentional—of evidence or in consideration of nonrecoverable evidence.

Maintaining a chain of custody for digital images of nonrecoverable evidence is extremely critical because, in many instances, the digital image of the evidence must be used when the case goes to trial. This is especially true for latent impressions, developed using a chemical process, such as ninhydrin, which fades over time. Other processes used for porous surfaces, such as thermal paper, result in the evidence turning black. And even latent impressions developed using a cyanoacrylate process (aka Super Glue fuming) may, with time, become nonrecoverable because the residue from the fuming process separates from a plastic bag and falls into the bottom of the evidence bag. In each of these examples, the digital image of the evidence is used instead of the evidence, and the digital images, like their physical counterpart, must be managed using the same care and control as the physical item itself.

In an article published in March 2006, in the *Computer Law Review and Technology Journal,* David Hricik[18] pointed out a concern at the time, now become one of the greatest fears of law enforcement agencies across the country. In 2006, David stated there is a high level of sensitivity about storing digital files on networked computers and servers, because such files may be accidentally or intentionally viewed, printed, shared, deleted, and possibly even modified by unauthorized third parties, including computer maintenance personnel. This concern has become an even more important issue because of the increased use of, and the need for, easily expandable cloud storage with easy access from anywhere to support the ever-growing arsenal of video and image files from body-worn cameras, dashboard cameras in squad cars, interview/interrogation rooms, and surveillance cameras.

The past 30 years have seen a lot of digital imaging companies come and go. And there is a growing number of companies now trying to make their niche in forensic digital imaging technologies.

Duplicate

Copy (duplicate) the original image files and authenticate the copied files following the guidelines described in Chapter 13, "Best Practices for Maintaining the Integrity of Digital Images and Digital Video," Overview of SWGIT and "The Use of Imaging Technology in the Criminal Justice System," Version 1.0 2007.06.04.

CAUTION:

At no time is it permissible to overwrite the original image file! For legal purposes, you must maintain the "original" electronic file so it is available, if requested, for discovery and court. **Any processing performed on the digital image must be performed on a copy of the original**.

Process

If required, process the digital images following the procedures defined here. As defined in SWGIT Guidelines, Chapter 11, "Best Practices for Documenting Image Enhancement," version 1.3 2010.01.15, "[a]ccurate documentation is necessary to satisfy the legal requirements for introducing forensic images as evidence in a court of law and to allow other professionals to understand the enhancement and produce comparable results." Therefore, it is extremely important to document the processes and techniques used "when performing a variety of enhancement operations on still images, regardless of the tools and devices used." It is equally important to ensure the agency's SOP includes instructions regarding the level of documentation appropriate or required.

1. Calibrate (scale) the image for life-size output, which includes printing as well as exporting to an AFIS.
2. Review and evaluate color modes and channels to suppress background noise (color values interfering with the accurate and reliable analysis and comparison of image detail); alternatively, adjust one or more color values of the image to increase contrast or to suppress one or more color values.
   a. Image > Mode > RGB (Red, Green and Blue).
   b. Image > Mode > CMYK (Cyan, Magenta, Yellow and Black).
   c. Image > Mode > Lab Color (Lightness channel—Channel a represents green and red pixel values; Channel b represents green and blue pixel values).

   When choosing either channel a or channel b in Lab Color mode, use the Levels function to adjust contrast to distinguish between the background and image detail (image detail may be ridge details in a fingerprint, or characteristics in a footwear impression, or difference of ink fluorescence in a questioned document.
3. If none of Adobe Photoshop's color modes provide the desired results, then adjust individual color values to isolate and suppress background noise. In other words, using one color channel may not be sufficient to eliminate all the background color values interfering with the visualization of the ridge detail. Therefore, it may be necessary to adjust the color values so a single-color channel can remove the background or remove all the background color information and convert the image to grayscale. The following tools may be used to remove one or more color values, as well as adjust color values to eliminate interfering backgrounds:
   a. Image > Adjustments > Hue & Saturation (eliminates two or more color values; may be used in conjunction with Calculations to eliminate background noise).
   b. Image > Adjustments > Color Balance (after adjusting color balance, it may be possible to suppress background noise and patterns using color modes and channels, Calculations, etc.).
   c. Image > Adjustments > Black & White (available in Adobe Photoshop CS3 and later; may be used to suppress background and noise by increasing or decreasing specific color values).
   d. Image > Adjustments > Variations (after adjusting color variations, it may be possible to suppress background noise and patterns using color modes and channels, Calculations, etc.).
   e. Image > Adjustments Photo Filter.
   f. Filter > Camera raw Filter (available in Adobe Photoshop CC 2014 and later; provides the ability to adjust white balance as well as hue, saturation, and brightness values to suppress background noise using a variety of color processing techniques).

g. In some instances, you may not be able to suppress the background using the tools described here, and it may be necessary to subtract background information using Image > Calculations. This process creates a multichannel image and most often is used to eliminate backgrounds in chemically processed prints, such as ninhydrin-processed prints on checks or money orders.

4. Convert the active color channel(s) to grayscale (after selecting the appropriate color channel and removing the background noise, as required).
   a. Image > Mode > Grayscale.

5. If a continuous, consistent, and repetitive pattern can be identified within the image, a pattern removal filter, if available, may be used immediately after the image is converted to grayscale. (This must be done before adjusting tonal range and contrast, except when using Lab color, to avoid raising the tonal range of the fingerprint, etc., to the same frequency as the obstructing pattern.)
6. Adjust and contrast: There are a variety of options for creating better contrast in a digital image. Use one or more of the following options together to achieve the desired result:
   a. Image > Adjustments > Levels (balances contrast between all pixels).
   b. Image > Adjustments > Curves (creates extraordinary contrast between two closely adjacent contrast points, such as a ridge and furrow).
   c. Image > Apply Image (increases and separates contrast using blending techniques such as multiply, overlay, screen, color dodge, linear dodge, and so forth).
   d. Image > Adjustments > Shadows/Highlights (creates contrast within a designated contrast value, such as shadows [dark values/left side of the histogram] or highlights [light values/right side of the histogram]. as well as creates additional contrast overall).
   e. Image > Adjustments > Exposure (increases or decreases contrast of the image).
   f. Burn and Dodge tool (increases and decreases, respectively, individual areas in the image based upon the size of the brush).
   g. Image > Adjustments > Brightness/Contrast (increases and decreases contrast in the image; this tool is not recommended because it does not provide the same level of controls available in menu-driven functions such as Black and White, Curves, or Exposure).

7. Once the desired tonal range and contrast have been achieved, it may be necessary to remove hotspots (aka "noise") created by an alternate light source when used to photograph fluorescent/dye-stained items digitally. Or the image requires a slight contrast adjustment to eliminate any blurring caused in the digital imaging process. While several filters may be useful, the following filters are those most commonly used:
   a. Filter > Noise > Dust & Scratches (Remove artifacts—using dissimilar pixel values—introduced through instrumentation, etc.).
   b. Filter > Noise > Reduce Noise (Removes random artifacts—based on edges—introduced through instrumentation, etc.).
   c. Filter > Sharpen > Unsharp Mask (adjusts the contrast of edge detail and produces a lighter and darker contrast on each side of the edge, emphasizing the edge and creating the illusion of a sharper image).
   d. Filter > Sharpen > Smart Sharpen (Similar to Unsharp Mask but provides significantly more control).
   e. Filter > Sharpen > Sharpen Edges (Like Unsharp Mask, sharpens areas where significant color changes occur, but significantly less control than Unsharp Mask or Smart Sharpen).

8. After completing the image processing successfully and if no additional processing is required, the image may be rotated. Rotate the image once—and only once! Rotating an image multiple times can and will exacerbate aliasing (color or grayscale artifacts) in the image.

Save

Save the processed image using a noncompressed file format, such as TIF. Not only is the TIF file format compatible with most, if not all, computer operating systems and applications, the TIF file format is a noncompressed file format and layers are maintained separately. Finally, maintain the same file naming convention as the original to help identify the relationship between the original (parent) image and the processed copy (child).

NOTE:

This author recommends saving the processed image in a separate folder apart from the original image. Moreover, after saving the images to the Originals subfolder in a case folder, copy the images into a second subfolder entitled Processing Copies, Working Copies, or something similar. Then set the file attributes for the files in the Originals folder to read-only. This step prevents inadvertently overwriting the original file if the original file is opened by mistake. As stated earlier, the original image must be available, if requested, for discovery and use in court.)

If the processed image is to be submitted to a local, state, or regional AFIS or the FBI's NGI (Next-Generation IAFIS) system, follow these additional steps.

1. Make a duplicate copy of the processed image file in the Processing Copies folder. Do not overwrite the previously processed image file when preparing the image for submission to AFIS!
2. If required, rotate the image so the fingerprint or palm print impression is displayed with a vertical orientation (the axis of the image should correspond to the axis of the image in the AFIS).
3. Go to Image and then Image Size and set the image resolution to correspond to the resolution required for the receiving AFIS, which is typically 500 PPI or 1000 PPI.

CAUTION:

Before changing the image resolution in the Image Size Dialog box, verify the Resample checkbox is checked. Failure to check the Resample box before changing the image resolution will change the physical size of the image and will prevent the impression from being found, even if a corresponding known image is stored in the database!

4. Using the Crop tool, crop latent fingerprint images to a maximum of 1.5 inches by 1.5 inches. (Depending upon the AFIS system being used, latent palm prints should be blocked and saved as multiple 1.5 inch by 1.5 inch clips.)
5. Save the AFIS clip and transfer the electronic file directly to the appropriate AFIS. Do **not** print and then scan the printed copy for entry into AFIS. While it may not look bad on the screen, this process degrades the quality of the original image and may result in a lower score or may be missed entirely during the search, even if a corresponding known impression is in the database. Moreover, the electronic file contains more grayscale definition between the ridges and the background and provides a higher-quality image, making minutiae extraction easier as well as more accurate and reliable.

BEST PRACTICES FOR SUPPRESSION OF BACKGROUND COLOR VALUES

There are endless clichés about photorealism, such as "a picture is worth a thousand words" or "photos don't lie." But in the courtroom, a very different image often emerges because of clichés like "Can juries believe what they see?" "Digital images can be manipulated easily," "Digital images are **not** photographs," and dozens more. These clichés can be very persuasive and invoke an emotional or cognitive response.

Special procedures must be followed with digital images so they can be validated as a "true and correct copy" "accurately and reliably depicting" what it purports to depict. Also, the forensic analyst, as well as the juror, must be able to "visualize" ("analyze") the content of the image to reach the "correct" conclusion.

The reason why lawyers (and others) often take the position that digital images are not photographs is they want to instill the idea that jurors cannot believe what they see. This confusion exists because digital cameras capture images using an electronic sensor to record light values such as a charge-coupled device (CCD) or complementary metal-oxide semiconductor (CMOS). These light values are then converted into numerical values that can be displayed or printed as an image, can be reproduced "accurately and reliably," and do not degrade over time.

Traditional film cameras rely on a light-sensitive emulsion containing silver halide crystals suspended in a gelatin coating on films of cellulose acetate or cellulose nitrate. Once the film is exposed and then developed, a negative is created. The negative then becomes the "original" and can be reproduced "accurately and reliably," within reason, but suffers the effects of aging over time.

In the past, the quality (clarity and contrast) of the photographs produced from film negatives were the interpretation of the person making the print. Frequently, this person printing the photograph was not the person who exposed the image. Sometimes things went wrong, and the photographs did not appear as they should. Photographers who developed and printed their own photographs usually got the most realistic and accurate photographs. The good news with digital imaging is that many forensic examiners are now processing the evidence into the system, photographing the evidence, and then processing the images of the evidence, which helps to achieve a higher level of accuracy and reliability.

Television programs like *Brain Games* and others have featured optical illusions demonstrating how optics can affect how we visualize an object which, in turn, affects the reliability of our analysis of the image. So, whether it was a film image or a digital image, the same issues exist regarding "visualization" or "interpretation" of the image.

In Figure 6.44, an optical illusion is created by the light hitting the green cylinder from the right, which causes a shadow to appear over the squares adjacent to square B, thus making those squares appear much darker. The darker color values trick the eyes into visualizing square B as a lighter shade of gray when compared to its counterpart, square A. (The identical color values of the pixels in squares A and B can be validated using the Eyedropper tool and the Color Picker in Adobe Photoshop.)

Crime scene technicians, forensic analysts and examiners, investigators, prosecutors, defense attorneys, jurors, or anyone who relies on "pictures" within the criminal justice community must make conclusions based upon their "interpretation" of a visual representation (input). This process must account for biases and other factors influencing

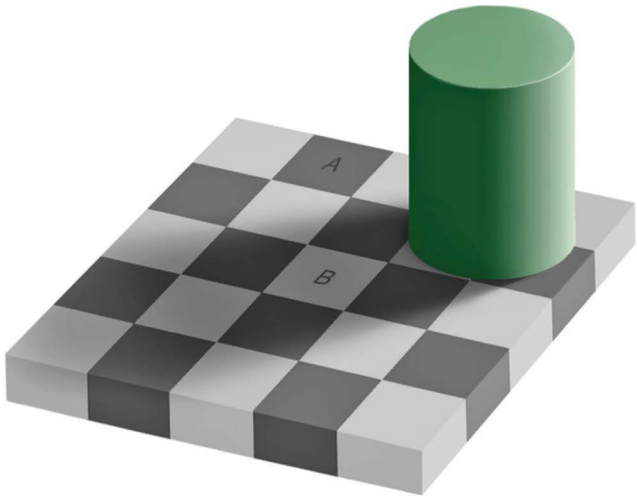


FIGURE 6.44 One famous optical illusion, known as the "checker shadow illusion" developed by Edward H. Adelson, shows two squares (A and B) that are the same shade of gray, but they appear as different shades of gray.

their decision, such as the proper evaluation of ridge detail appearing inverted in photographed images of impressions on evidence developed using cyanoacrylate fuming.

In their book *Detection Theory, A User's Guide*, published in 2004 by Psychology Press in New York, Neil A. Macmillan and D. Douglas Creelman used an illustration similar to that in Figure 6.45 to explain the psychology of how real-world visual or auditory signals are processed internally to form an appropriate response or reaction.

In forensics, a digital photograph or scanned image of a latent fingerprint, footwear impression, or toolmark may be the input to be analyzed by an examiner. Their analysis and evaluation may be based on the quality of the image combined with his or her experience, training, and expertise, or biases, to reach a particular conclusion. In terms of a latent print, the conclusion could be a determination of the ridge detail depicted in the image being unsuitable for analysis or if it is suitable and perhaps subsequently identified to a suspect in the case.

Improper color values could cause a witness to miss the identification of a suspect or misidentify a possible suspect. (Was the suspect wearing a yellow shirt or a light green shirt, etc.?) Improper white balance or the failure to remove background patterns can produce significantly different results and conclusions when analyzing latent impressions.

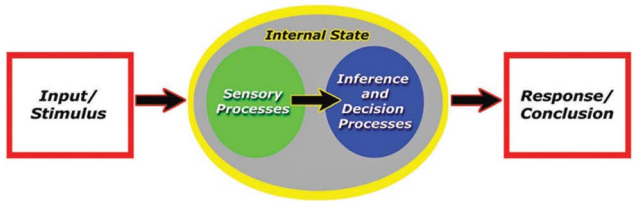


FIGURE 6.45 A derivative illustration based on a drawing in a book by Macmillan and Creelman that they used to show the psychology of a decision-making process.

Figure 6.46 shows the before and after illustration of a latent impression developed on duct tape using a fluorescent dye stain known as basic yellow. The ridge detail was digitally photographed using a forensic light source and was then processed to produce a print more easily identified. The ridge detail was revealed using a color mode in Adobe Photoshop known as Lab Color. The thread lines in the image were removed using a fast Fourier transform (FFT) filter, also known as a pattern removal filter.

While the courts have widely acknowledged for more than a hundred years that photography is the most accurate way of documenting evidence,[19] the issue of accuracy (reliability) and bias (fallibility) has become a sensitive issue in today's courts.

"When judgments are made under uncertainty, two general types of errors are possible – false positives and false negatives. A decision maker cannot simultaneously minimize both errors because decreasing the likelihood of one error necessarily increases the likelihood of the other."[20]

Some photographic processes can also be used to manipulate an image "creatively." For example, changing exposure, camera angle, or choosing the wrong lens can change (manipulate) the appearance of an image. For example, someone viewing a picture of a small hole in the ground could be misled easily just by using a wide-angle lens, thus making the hole appear as a large abyss. This is also one of the reasons why a scale is required to be placed adjacent to the evidence, so it can be photographed alongside the evidence and appear in the digital image, which would enable the image to be calibrated.

Most digital cameras today provide data to help identify if an image has been altered or if it is an original, unaltered image. All digital cameras (including cameras in smartphones) developed within the past decade capture information about the image pixels, together with information such as the date, time, and location of when and where the image was photographed, together with camera make, model, and serial number, as well as camera settings such as aperture, shutter speed, ISO, exposure compensation, lens used, focus distance, and so forth. These data elements, also known as camera EXchangeable Image File format (EXIF) data, are stored as part of the image file in a collection of tagged data fields called the file header. (These fields are also known as metadata.) Maintaining this data is a requirement for all evidentiary images, which also provides interoperability between digital cameras and image processing programs, such as Adobe Photoshop. EXIF data has also proven to be very useful for accurate analysis and to reach an accurate conclusion.

Further, the imaging sensors in most "consumer-grade" digital cameras today can detect more than 265 separate, distinct shades of gray. The imaging sensor in most professional DSLR cameras can distinguish between 4,096 individual gradients for 12-bit dynamic range or 16,384 individual gradients for 14-bit dynamic range.

Digital images consist of pixels, where each pixel has a specific color value, such as teal, fuchsia, orange, or brown, based on the hue, saturation, and brightness values of red,

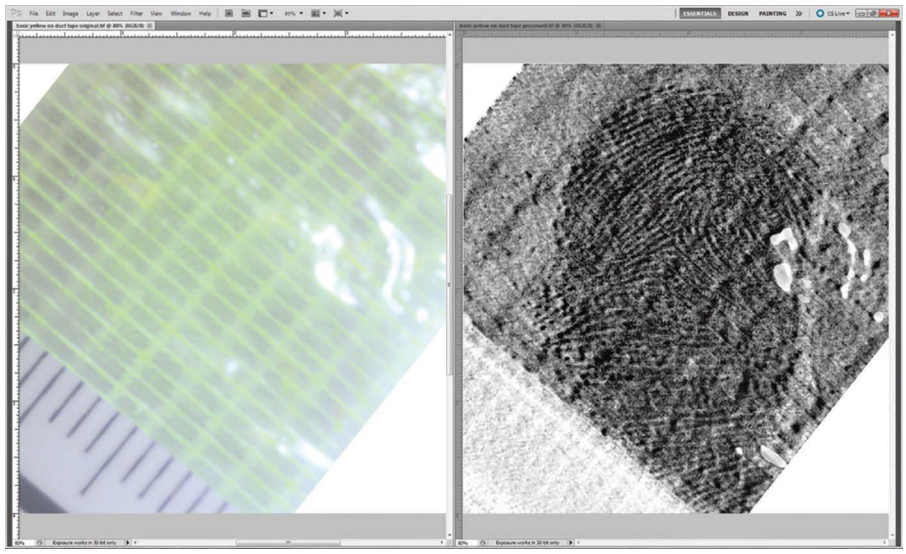


FIGURE 6.46 A before and after illustration depicting a latent impression developed on duct tape.

green, and blue for each pixel. Most digital images are stored as 24-bit color (8 bits per channel), which provides 256 possible shades of red, 256 possible shades of green, and 256 possible shades of blue for a total of 16,777,216 possible color values for *each* pixel in the image.

Some people argue that capturing anything other than 256 shades per color channel is a waste of file space because the human eye cannot see that many different shades, and many video cards and monitors do not support the display of that many different color values. It should be remembered, however, that applications like Adobe Photoshop can process up to 65,536 different shades per channel, which can be crucial when trying to suppress background noise.

Computer screens also have a pixel-based resolution, but that resolution has no direct correlation to the pixels in a digital image. For example, typical monitor resolutions today range from 1024 pixels by 768 pixels to 1920 pixels by 1200 pixels and can be 17, 24, 27, or 29 inches wide (diagonally).

The monitor resolution refers to the number of color pixel values represented on the screen, which are also made up using a combination of red, green, and blue photo diodes. These light values (aka picture elements) are displayed using different technologies, such as liquid crystal display (LCD) technologies, light-emitting diode (LED) technologies, gas-plasma technologies, etc.

The result is a combination of red, green, and blue lights coupled with an intensity or brightness value of each light creating a display causing the human eye to perceive a specific color value for the pixels comprising the digital image.

This perception is also based on a "resampling" of the actual image data when viewing the image on the screen. The resolution of digital cameras used by law enforcement agencies varies greatly, depending upon the user and use of the digital camera:

- 6016 × 4016 pixels (24 MP)
- 4928 × 3280 pixels (16 MP)
- 3968 × 2976 pixels (12 MP)
- 3872 × 2592 pixels (10 MP)
- 3072 × 2048 pixels (6 MP)
- 800 × 600 pixels (0.4 MP)
- 640 × 480 pixels (0.3 MP)

When considering the resolution of the image and the resolution of the monitor, the video card (and the video driver) must also be considered. For example, a monitor can be set to resolutions such as 1024 × 768 pixels, 1280 × 1024 pixels, 1366 × 768 pixels, 1600 × 1200 pixels, 1680 × 1050 pixels, or 1920 × 1200 pixels. Larger screens can have even higher resolutions.

In other words, resolution by itself does not imply image quality or output size, because the same number of pixels can be displayed as a small area (when zoomed out) or as a large area (when zoomed in) on a monitor or printed image. For example, minute detail may be overlooked when 6016 pixels horizontally are resampled to approximately 1600 pixels horizontally; this means one pixel displayed on the monitor represents almost four image (file) pixel values averaged together. Images resampled for printing lose far more image quality and detail due to the technical aspects of today's printers.

Historically, forensic experts, such as latent print examiners, footwear and tire tread examiners, and questioned document examiners, relied on one-to-one prints for comparison. That practice is discouraged today because regardless of the type or model of printer used, the image quality is not as good as traditional film-based photograph prints in the past.

Over the years, numerous articles were written comparing film to digital cameras. While the estimates vary, a standard 35 mm image (36 mm wide × 24 mm high) of ISO 100-speed film is estimated to have a resolution of somewhere between 18 and 23 million pixels. Of course, the resolution could be higher if fine-grain film was used or if higher-quality optics were used. Today, DSLR cameras can match or exceed those

resolution estimates. Unfortunately, consumer-grade printers do not come close to providing an equivalent resolution. Depending upon the type of printer, the quality of paper, the number of inks, size of dots, print driver, etc., the typical resolution of most consumer-grade printers ranges between 300 and 720 pixels per inch, which does not even come close to meeting the resolution of traditional photographic prints.

Moreover, if a latent print is scanned on a flatbed scanner with a resolution of 1200 PPI and the output device prints an equivalent of 500 PPI (based on dot to pixel ratio), then the latent print image must be resampled to eliminate a total of 700 pixels. This loss of data means that more than **50%** of the actual pixel values are lost when the image is printed. It also means latent print examiners must either retrain their eyes to use lower-quality images for comparison; do comparisons on the screen; or use images printed at two, three, or five times life size.

Many forensic experts find it much easier to view the images displayed side by side on a computer screen, where they also can zoom in and out of the image for a more accurate and reliable analysis and comparison.

We cannot, however, forget that the accuracy of every conclusion in any forensic discipline begins with accurate and reliable image capture. Therefore, the goal is to capture the best possible image with the highest possible resolution.

To capture an object with a digital camera with the highest possible resolution, fill the frame with the object and a scale. Failure to optimize image resolution creates problems when attempting to suppress background patterns, such as backgrounds on checks or money orders. As the size of the area of capture increases, the camera must be moved farther back from the object, unless a wide-angle lens is used, and a single photoreceptor must capture a larger area, using all the color values in the area covered by that single sensor and the light intensity to determine the resulting pixel value recorded by that photoreceptor.

One major consequence of trying to capture an area too large with a digital camera is the optics in the camera will blend multiple color values (from multiple source elements) as a single pixel. In addition to losing detail and sharpness in the image, other problems are created, such as moiré patterns. (Moiré patterns most often occur when the frequency of repetitive patterns of objects in the image occur at a higher rate than the imaging sensor's resolution. A common moiré pattern may be seen on television when a newscaster is wearing a sport coat or tie with repetitive patterns that create the appearance of wavy or circular patterns.)

By moving closer to the object and capturing a smaller area, the area covered by each photoreceptor is minimized and will provide clearer (and sharper) image detail. This also provides better image quality, because the more accurate color values provide greater image detail.

Even with all the sophisticated tools and features in Adobe Photoshop today, the image quality of a low-resolution image cannot be improved. That only happens on CSI—and that is only television. The most anyone can hope to accomplish with a low-resolution image is to make it look less ugly. (Kind of like putting lipstick on a pig!)

The bottom line is that with the proper digital image processing standards and guidelines in place and appropriate training (for the photographer, the person enhancing the images, and the person analyzing the images), there should not be questions about whether or not the original image was altered or that the interpretation of the image data provided an accurate, reliable conclusion.

Helpful Hints: Basic Ninhydrin Print Processing

Frequently, latent impressions on porous items (such as paper, checks, money orders, newspaper, paper bags, etc.) must be developed using techniques such as ninhydrin, which is a chemical reagent (a poisonous crystalline oxidizing agent) used for the detection and analysis of primary and secondary amines, such as amino acids typically found in fingerprint impressions. When this chemical reagent reacts to the amino acids deposited by the finger, it forms a derivative with a purple (red and blue) color value. When the developed latent impressions are photographed in color, the red and blue values form the color purple (often referred to as magenta); they have a different light intensity when compared to the background color values. Therefore, it may be necessary to adjust color values in the image to suppress the background colors interfering with the visualization of the latent impression. One technique used with some success is to convert the image to Image > Mode > CMYK and then select the Magenta channel. This technique does not, however, suppress dark (black) backgrounds, such as printing, trim and borders on checks or money orders, etc., because black and white appear in every color channel for RGB and CMYK modes.

There are a number of ways in which the ridge detail can be separated from the dark background colors so they do not interfere with the visualization of the latent impression. These techniques are based on the difference of light intensity (of pixels) between the purple ridge detail and the black background.

Please note, not all capture processes work the same. Using a flatbed scanner, there is only one light intensity striking the surface of the object on the scanner. As a result, the light intensity for the pixels in the various color channels (Red, Green and Blue, or Cyan, Magenta, Yellow and Black) are very similar and cannot be separated easily and must be processed using a different technique.

Ninhydrin Print Processing Using Calculations

Ninhydrin prints can sometimes be digitally processed using the Calculations function in Adobe Photoshop. The Calculations function uses a number of blending algorithms, including but not limited to Darken, Multiply, Color Dodge, Linear Dodge, Screen, Overlay, and more.

The Calculations blending algorithms use the brightness (intensity) of the red, green, and blue values for each pixel

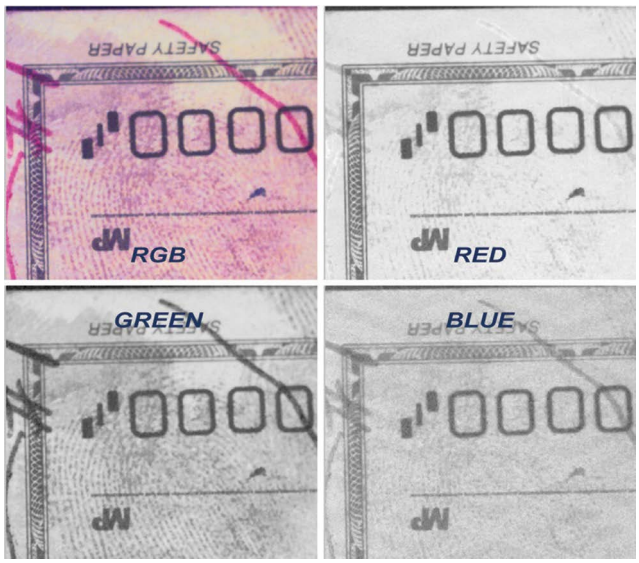


FIGURE 6.47 The image appearing in the upper left shows the original image in RGB color. The image in the upper right shows the image filtered with the Red channel, the image in the lower left shows the image filtered with the Green channel, and the image in the lower right shows the same image filtered with the Blue channel.

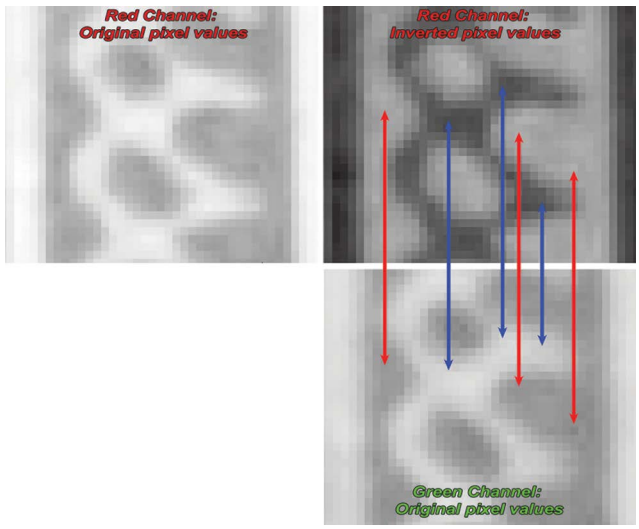


FIGURE 6.48 When the brightness (intensity) values of the two channels are processed, the results are displayed in a new "Alpha" channel, which is also referred to as a multichannel value, because it consists of the processed brightness pixel values from two channels: source 1 and source 2. The new Alpha channel appears on the color Channels palette in addition to the Red, Green, and Blue color channels.

in a manner unique in each blending option. Using these blending options, background noise can be neutralized or suppressed by blending one channel intensity for a pixel (such as the brightness value of a pixel in the Red channel) with the Channel intensity (such as the brightness value of the exact same pixel in the Green channel) to suppress background noise.

Figure 6.47 illustrates the difference in brightness values for the pixels in the digital image of a latent impression developed using ninhydrin on a porous substrate (a check in this instance).

The appearance of the fingerprint ridge detail is less visible in the Red channel while appearing darker in the Green channel. In addition, the intensity of the check border in the Red channel is almost identical to the intensity of the border in the Green channel. In the Blue channel, the ridge detail blends into the background and the border also appears to be a lighter shade of gray. In addition, there is more background noise in the Blue channel than in either the Red channel or the Green channel.

Due to the similarity of the background in the Red and Green channels and the ridge detail being more visible in the Green channel, it is possible to subtract the values of the Red from the Green channel using an algorithm simulating mathematical equations or Calculations. However, there is more to the process than simple subtraction. For example, we do not want to subtract the subtle ridge values in channel Red from channel Green because the ridge detail is already a light grayscale value and the contrast will have to be increased.

Using Calculations, the Red channel is selected as source 1, because of the limited amount of ridge detail visible in this channel. In addition, source 1 is inverted. The Green channel is selected as source 2 because the background is nearly identical to the background in source 1, and the Green channel contains the highest level of visible ridge detail. The algorithm color dodge is selected to suppress the background noise (i.e., letters, border, line, etc.).

The Color Dodge algorithm (i.e., the mathematical calculation used for the pixel values) compares the pixel value in source 2 to each pixel's corresponding value in the inverted source 1. More specifically, when the dark values of the border pixels in the Red channel, as shown in Figure 6.48, are inverted, they appear as a lighter shade of gray. In the case of a latent impression, the ridge detail is practically nonexistent on the Red channel, so the pixel values for the background and whatever ridge detail is present are inverted from white to black on the histogram. And since the Color Dodge function only reduces source 2 pixel values on the left side of the histogram, the ridge details and background in the Green channel are lighter shades of gray (on the white/right side of the histogram), so no action occurs, because the corresponding pixel values for that area on the Red channel are all on the dark (left) side of the histogram.

Any time a new Alpha channel is created in a digital image, the Alpha channel must be converted to grayscale, because other applications do not recognize multichannel values; if the image is saved with RGB channels and the Alpha channel, the image will appear as the RGB image outside Adobe Photoshop, and the processed results will not be visible. To fix this problem, select the Alpha channel and convert the image to Mode > Grayscale.

After the background has been suppressed and the Alpha channel has been converted to grayscale, the next step is to perform a basic contrast adjustment. In this action, the brightness and contrast values are adjusted automatically using the Shadows/Highlights feature.

Shadows and Highlights was first introduced in Adobe Photoshop CS, which was released in October 2003. Before this tool became available, Levels was the most commonly accepted method for adjusting contrast in digital images.

The Shadows/Highlights command provides greater control when adjusting contrast. Using this tool, the adjustment of pixel values can be limited to a very specific range of values in both the shadows and/or highlights. In other words, the contrast can be adjusted for pixels in the Shadows range without affecting the values of pixels in the Highlights range and vice versa. Also, one range of pixel values can be adjusted without affecting all of the other pixel values in the image, which is a vast improvement over the use of Levels.

Similarly, using Calculations with a blending algorithm known as Linear Dodge may also be helpful in removing background patterns or noise in digital images. The Linear Dodge blending technique works in much the same way as Color Dodge. However, with Linear Dodge, the dark values are suppressed even more than in Color Dodge, which is sometimes required because of the background contrast. In this case, the Opacity must also be adjusted because the additional background suppression makes it appear as though the image were overexposed in those areas where the black background has been suppressed. By adjusting opacity, you can adjust the exposure for these overly suppressed (overexposed) areas.

While Calculations may be very useful, the process does not work in all instances, as it depends on the intensity values for two channels in the image. This process does not typically work well for digital images captured using a flatbed scanner, because the intensity (brightness) value for pixels in the Red channel and Green channel are too similar. Flatbed scanners have only one light source, so the same light intensity is used for capturing red, green, and blue pixel values. Similarly, images photographed digitally using an alternate light source have brightness values far too similar in all color channels.

In these instances, ninhydrin-developed prints or other chemically processed impressions may be easier to process by converting the image from RGB to Mode > Lab Color. Then channel A, which displays the chromatic (color) values of all pixels using only the green and red color filter array values, is selected, and the image converted to grayscale.

Since the luminance values (Lightness channel) are separated from the Chrominance values (channels A and B), Levels is the only process used to spread the Chrominance (midtone) values across the full width of the histogram, and thus create contrast between the values. In this action, the levels are set to Auto to balance the contrast within the image.

SHARING FILES: HARD COPIES VERSUS ELECTRONIC TRANSFER

One of the final considerations in the digital imaging process is the sharing of files, whether it is for the investigator, the prosecutor, or discovery. A couple of the steps also apply to printing, regardless of whether or not the image is printed as a 1:1 print for comparison or the image is printed as an 8 × 10 inch image using Adobe Photoshop.

The first step is to use Dust and Scratches (Filter > Noise > Dust and Scratches) to suppress some of the background "noise" (extraneous, random pixel values). In most instances, the Dust and Scratches settings are:

- Set Radius to a value of 1, 2, or 3 (maximum)
- Set Threshold to a value between 0 and 50 (maximum), where 0 is more blur and 50 is less blur

Zoom into the image to at least 100% magnification during this process to ensure the image is not blurred too much.

The second step is to use Unsharp Mask (Filter > Sharpen > Unsharp Mask). While this function is similar to Dust and Scratches, it is used to refocus (resharpen) the image after using Dust and Scratches. This tool provides better clarity of edge detail. There are three settings for this tool: Amount, Radius, and Threshold.

- Set Amount to a value between 50% and 100% depending upon the darkness of the image.
- Set Radius to a value of 1, 2, or 3 (maximum).
- Set Threshold to a value between 0 and 50 (maximum), where 0 is less blur and 50 is more blur.

The combination of Dust and Scratches and Unsharp mask can eliminate random noise from processed digital images, which provides a higher-quality output and clearer image for viewing by others.

NOTE:

Some high-end printers (using specialized printer drivers) perform these functions automatically, but these functions are not performed on standard inkjet or laser printers.

There are several specifications playing a role in accurately and reliably printing digital images. These specifications include dot-to-pixel ratio, number of ink colors in the printer's color palette, the number and size of the droplets (picoliters) horizontally, and the number of lines vertically. (If an inkjet printer has a resolution of 2880 × 1440, the printer can place a maximum of 2,880 dots in 1 inch measured horizontally. The printer can also create a maximum of 1,440 lines (rows of dots) in 1 inch measured vertically.

To create a test target, use Adobe Photoshop to create a new document approximately 2 inches by 3 inches. For the new document resolution, enter the "supposed" resolution to be tested. For example, to test a printer with an output capability of 720 PPI, create a document with that resolution. If the printer can only print 600 PPI, then use that for the new document resolution.

Once the new document is created, zoom into the image until the individual pixel grid is visible. Using the Line tool, create a line that is one pixel wide. Then, leaving a space that is one pixel wide, draw another line one pixel wide. This process is made much easier by turning on the pixel grid in Adobe Photoshop. (From the View menu, choose Show and then select Pixel Grid.) Repeat the process of creating a one-pixel line and one-pixel space to create a series of at least nine or ten lines.

Then copy that block of lines and paste the duplicated block of lines away from the original set of lines. (Each time the block of lines is pasted onto the image, the block becomes a new layer which can be rotated, flipped, etc.)

The Transform function (Edit > Transform > Rotate 90° Clockwise) may be used to rotate the lines, so one or more sets of lines are going vertical, one or more sets of lines are going horizontal, one or more sets of lines are going diagonal left to right, and one or more sets of lines are going diagonal right to left. (Pressing and holding the shift key as the block of line is rotated will cause the block of lines to be rotated in 45-degree increments.)

For an accurate (objective) measurement (validation) of the printer's effectiveness, never assess image quality using something other than line pairs. With line pairs, it is easy to determine if lines (pixels) are missing, blurred together, etc. This technique of measuring image quality also eliminates bias and takes subjective opinions out of the decision.

For a quick evaluation of the output, use a flatbed scanner to capture the output from the printer of the test print at the scanner's maximum resolution. After the output is scanned, open the scanned image file in Adobe Photoshop and zoom in until the individual lines are visible. Evaluate each block of lines to accurately and reliably assess (validate) the resolving power of the printer.

MITIGATION OF JPG ARTIFACTS

Far too often, people use a high compression setting on their digital cameras and flatbed scanners or in the software they use to make images smaller in size so they can store more images on their memory cards and/or download or email their images faster. Unfortunately, what far too many people don't realize is that JPG (also known as JPEG, which is short for Joint Photographic Experts Group) compression discards actual pixel values. Depending upon the level of JPG compression used, the images can be damaged significantly, the details within the image can be lost, and the image can become noticeably "blocky," as well as appearing pixilated.

Most JPG compression algorithms are considered "lossy" because actual pixel values in the image are permanently lost. JPG algorithms losing less detail are "less lossy." Today, some algorithms are considered to be "lossless," meaning no details are lost in the compression process but color values can be changed within the image, which can affect the image enhancement process.

Lossless compression allows the original data to be reconstructed from the compressed data, whereas lossy compression *creates* replacement values for the missing data, using the sampled data values saved in the compressed file.

Lossless compression is used in many applications, including email or ZIP files or other applications where deviations from the source data could be catastrophic, such as executable computer program files, text documents, spreadsheets, etc.

In digital imaging, JPG-LS or JPG 2000 algorithms provide near-lossless compression. JPG 200 and JPG XR are argued to be a lossless compression method. The bad news is that JPG-LS, JPG 2000, and JPG XR are not used by camera manufacturers, who have developed their proprietary compression algorithms. These algorithms are said to be optimized for the quantization of data unique to the imaging sensor in the specific camera. Typically, these algorithms also include an automatic noise reduction process, as well as an automatic sharpening process.

The image shown in Figure 6.49 was captured using a 10-megapixel (MP) digital camera, and the image was compressed using the highest-quality image setting, which has the least amount of compression. When stored on the memory card in the camera or when saved on the computer, the size of the file on disk is 3,645,440 bytes or 3.48 megabytes (MB). When the file is decompressed (such as in Photoshop), the image size is 28.6 MB.

NOTE:

Data stored on a computer system is measured in blocks of 1024: there are 1024 bytes in a kilobyte, 1024 kilobytes in a megabyte, 1024 megabytes in a gigabyte, etc. To convert the number of bytes shown for file size, divide the number of bytes by 1024 to determine the number of kilobytes, then divide the number of kilobytes by 1024 to determine the number of megabytes.

Frequently, digital images are zoomed out so the entire picture can be displayed on a computer monitor. For example, to display an 8 MP image that contains 3648 pixels wide by 2736 pixels high on a 27 inch monitor with a screen resolution of 1920 pixels by 1200 pixels, the digital image must be resampled to 38.5%, or approximately

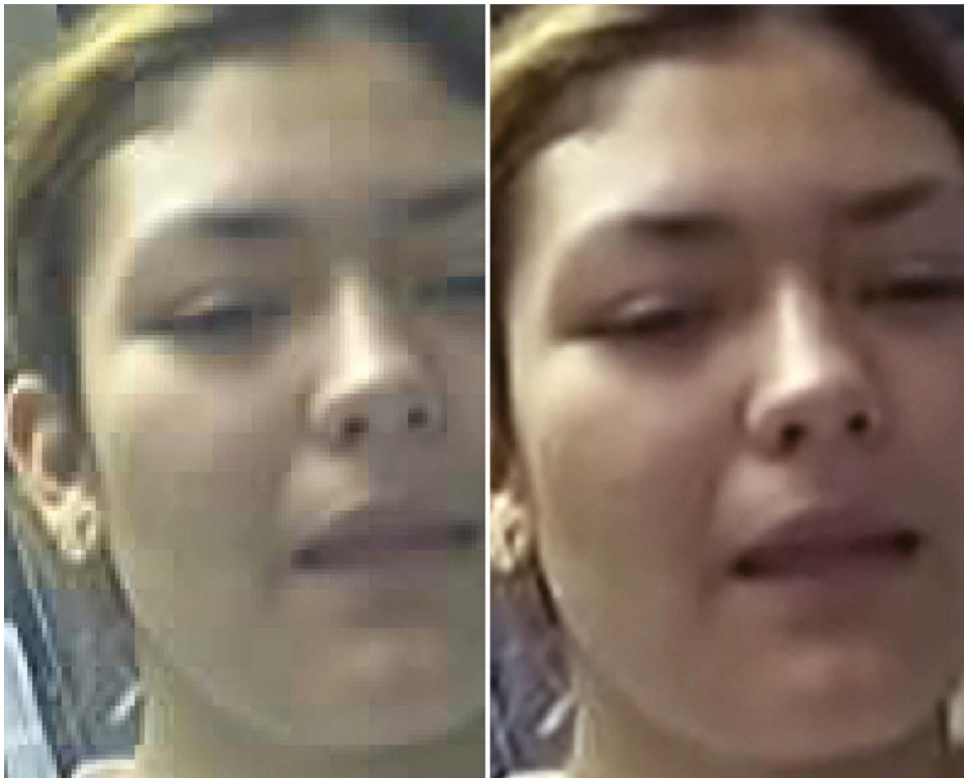


FIGURE 6.49 It is impossible to repair the damage done to an image during the compression process, it is possible to make the compression artifacts appear less distracting.

a ratio of 2.6:1 (where 2.6 pixel values are resampled and displayed as 1 pixel on the monitor). There is also a significant resampling of pixel values if the image is printed, but we are not going to talk about that here because of the variables involved in that particular process, such as what type of printer is used (i.e., ink jet printer, laser printer, or dye sublimation printer), what type of paper is used (i.e., plain, matte finish, luster, glossy, etc.), what the technical specifications of the printer are (i.e., 1.5, 2.0, 3.5, 4.0, 6.0, or 9.0 picoliter droplets or toner), what is the dot-to-pixel ratio of the printer, etc. In other words, printing digital images can disguise a significant number of flaws in poor-quality, low-resolution JPTG images, and most laypeople don't think about or notice the loss of image quality. The loss of image quality can be enormously apparent if the image is viewed and enlarged on a computer monitor.

All these numbers of pixels, percentages, inches, and droplet sizes may sound confusing; however, failure to understand this detail can result in a loss of detail not noticeable when the entire image is printed or reduced for display on a monitor, but it will be noticeable when the image is zoomed (enlarged), especially during image processing, analysis, and comparison.

For example, zooming in on a compressed fingerprint image during analysis may make the image unsuitable for comparison. This occurs when dealing with other types of evidentiary images used for forensic analysis, such as footwear, bloodstain pattern analysis, etc.

Artifact Reduction

It is amazing—and frustrating—that some examiners still use compressed images for footwear, tire tread or questioned document analysis, because they argue enough detail is still present when the image is zoomed out (and visible detail within the image is reduced) even though portions of the image are unusable and certain characteristics within the image cannot be determined. Admittedly, some "non-complex" images may still be suitable for analysis and comparison using a *high-quality* JPG image.

Over the years, various techniques and processes have been suggested to reduce the effects of image compression, so people (in our case the law enforcement agencies) retain the benefits of compression (such as lower sized transmission requirements and reduced storage costs). To date, there has been no "postprocessing" technique demonstrated to improve image quality in all images. As a result, none of the techniques or processes has gained wide acceptance in law enforcement, particularly in the forensic science community.

The process can be performed in Adobe Photoshop in four simple steps:

1. From the Filter menu, select Noise and then select Reduce Noise.
   a. In the Reduce Noise dialog box, set Strength to 5, Preserve Details to 50%, Reduce Color Noise to 45%, and Sharpen Details to 25%.

   b. Enable the Remove JPEG Artifact option (a checkmark must appear in the checkbox).
   c. Click on the OK button to accept the changes.

2. From the Image menu, select Image Size.
   a. In the Image Size dialog box, set the Width and Height measurements to the desired image size. (Images with a smaller image size will provide the best results.)
   b. Enable the Resample option (a checkmark must appear in the checkbox).
   c. Set the Resolution to either 300, 500, or 1000 PPI. (The decision for resolution must be based upon the image size set in step a earlier, where resolution is an inverse function of size. For example, use the higher resolution for a smaller image.)
   d. Click on the OK button to accept the changes.

3. From the Filter menu, select Noise and then select Dust and Scratches.
   a. In the Dust and Scratches dialog box, set the Radius to 2 pixels and Threshold to 0.
   b. Click on the OK button to accept the changes.

4. From the Filter menu, select Noise and then select Unsharp Mask.
   a. In the Unsharp Mask dialog box, set the Amount to 50%, Radius to 2 pixels, and Threshold to 0.
   b. Click on the OK button to accept the changes.

While this technique works with most compressed images, it is not a panacea for all images damaged by JPG compression. This process should never be used on forensic digital images that are the subject of analysis and comparison, such as fingerprints, tool marks, or footwear, because minute detail, including pores and ridge edges in fingerprint images, striations in tool marks, or minute imperfections in footwear, cannot be recovered by this process.

Degradation by PDF

Recently, more and more forensic examiners have been sharing information and images using a PDF format. The unfortunate part of this discovery is that most of those forensic examiners have no idea of the level of destruction occurring within the images embedded in their PDF files.

It must be understood that images embedded in PDF files are compressed using a far more destructive process than that used for JPG compression. The JPG image format is used to reduce image file size—sacrificing image quality—so images do not require as much storage space. As stated in the previous chapter, the pixels in an image are blocked using an 8-pixel by 8-pixel grid, in which pixel values are removed, pixel boundaries are relocated, and pixel colors are altered.

Since this process starts in the center of the image and works its way to the outside perimeter of the image, the resolution is reduced differently (meaning there are different numbers of original pixel values in the 8-pixel by 8-pixel grids stored) for different locations within the same image.

PDF compression also uses JPG compression, but that is the second step in the compression process. The first step in compressing images in PDF documents is to reduce the resolution of the images. Disturbingly, most PDF programs do not provide options to control the settings used in this step.

Most PDF creator applications (which include the vast majority of "free" applications) are designed to optimize the file and image for rapid viewing on a web page. Therefore, the Object Level Compression rate is set to a maximum compression value.

For text documents, this still provides sufficient quality for text, as most document applications are based on a resolution of 150 PPI, and the typical display rate of most monitors is 72 PPI. As a result, the text retains sufficient clarity.

But for images embedded in the PDF file, the process is quite different. Using standard default PDF settings, images with a resolution greater than 225 PPI are down-sampled to 150 PPI (see Figure 6.50). (So, if your image was scanned at 1200 PPI, the image will be resampled to 150 PPI, which means 87.5% of the original pixels are lost in this first step.)

After the image resolution has been resampled, the image undergoes additional damage, as the resampled image is then compressed (most commonly, being resampled using bicubic downsampling) using a JPG "medium" image-level compression algorithm (see Figure 6.51).

Even to maintain sufficient image quality for "viewable" evidentiary images (images which may be used only for demonstrative or illustrative purposes), the default Adobe PDF image quality setting must be changed to High Quality Print. (The increase in image quality increases the amount of image data preserved in the file, which means the PDF will be larger.)

For best practice, zoom in when viewing a JPG image. If the blocking (the 8-pixel by 8-pixel grid) is visible, the image should be used only for elimination purposes (i.e., Level 1 detail does not match). Level 2 and Level 3 detail in these images should not be used for identification purposes.

Similarly, if a PDF file contains images in which the pixilation is noticeable, the image(s) should be used only for demonstrative or illustrative purposes and not for purposes of identification.

Legal Ramifications of Digital Imaging

The first known case in which a photograph was used in court occurred in California in 1859 (*Luco v. United States*, 64 U.S. 515 [1859]). In this case, photographically enlarged copies of signatures on the deed for a sale of territory were ruled as admissible in court. The photographic enlargements were used to prove the seal and signatures on the land grant papers were forgeries.

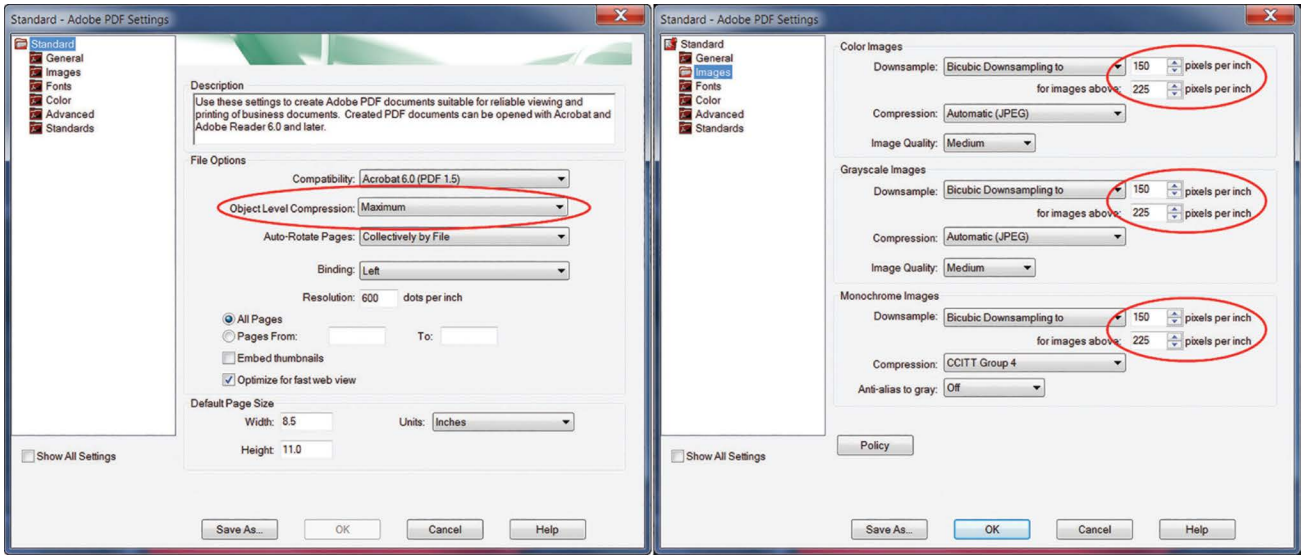


FIGURE 6.50 While many PDF creator applications do not provide the options to control the quality settings for embedded images, Adobe Acrobat DC Pro provides complete control of these settings.

In *Luke K. Blair v. Inhabitants of Pelham* (*Blair v. Pelham*, 118 Mass 420 [1875]), a photograph was submitted as evidence for the first time in an accident case. The case involved a horse and buggy that went off the embankment and sustained damage and injury. We still follow the same principle discussed in that case: "A plan or picture, whether made by the hand of man or by photography, is admissible in evidence, if verified by proof that it is a true representation of the subject, to assist the jury in understanding the case."

In 1902 in *Commonwealth v. John C. Best* (*Commonwealth v. Best*, 180 Mass 492 [1902]), the defendant was found guilty of the murder of George E. Bailey in 1901. In this case, photographic evidence was presented of three bullets: a bullet fired from the suspected weapon and two bullets found in the body of the victim. The enlarged photographic evidence was used to prove all three bullets had passed through the same rifle barrel.

In 1911, there was a turning point not only for fingerprint identification but for photography as well. During the trial of Thomas Jennings (*People v. Jennings*, 252 Ill 534, 96 N.E. 1077 [1911]), photographs of Jennings's fingerprints from the crime scene were determined to be a conclusive match to Jennings's fingerprints. At the time, there was no means of effectively "lifting" prints found at the crime scene, so photography was the only method available to document his prints at the scene. Because of Jennings's African American heritage, the trial was considered racially biased. On appeal, the Illinois State Supreme Court stated: "We are disposed to hold from the evidence of the four witnesses who testified, and from the writings we have referred to on this subject, that there is a scientific basis for the system of fingerprint identification, and that the courts cannot refuse to take judicial cognizance of it …." (It should also be noted that three of the four experts who

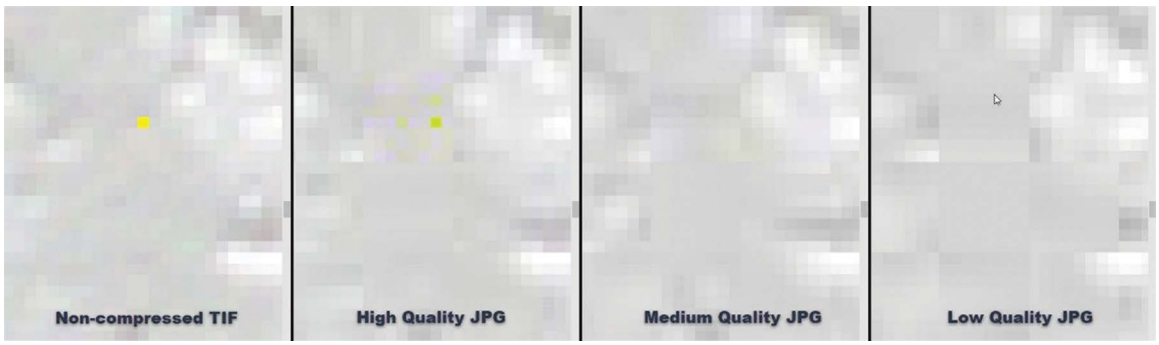


FIGURE 6.51 JPG artifacts can be highly destructive when viewing minute details. From left to right: the original pixel values are displayed in the noncompressed TIF file; the single pixel value affects the neighboring pixel values in the pixel grid when saved as "high" quality; only a faint residue of the yellow pixel value remains when saved as "medium" quality; the yellow pixel is replaced with posterizing and checkerboarding artifacts in the "low-quality" JPG image. The degree of manipulation and loss of data increase with each level of compression.

testified were trained at the St. Louis World's Fair in 1904 by Scotland Yard experts.)

One of the next milestones in the history of forensic evidentiary photography involved the use of digital imaging technologies to present fingerprint evidence in court. In 1990, the case of *The Commonwealth of Virginia v. Robert Douglas Knight* was the first case to establish a precedence for the acceptance of digitally enhanced evidence. A pillowcase from the scene of the crime was taken to the Henrico County Police Department Forensic Unit. Upon examination of bloodstain on the pillowcase, a faint stain seemed to show ridge details. The evidence was transferred to the Virginia Division of Forensic Science in Richmond where they used 1,8-diazafluorene-9-one (aka "DFO"—a chemical process for developing latent impressions that was relatively new at the time) applied to the bloodstain, which caused the ridge detail to fluoresce. After the ridge detail was developed, the print was photographed. Due to the poor quality of the ridge detail in the image, which was further affected by the distracting weave pattern of the fabric, the ridge detail could not be used to identify the suspect. A new image enhancement technique was used by Hunter Graphic Information Systems in Charlotte, North Carolina, to suppress the background noise and improve the quality of the latent print image. The image enhancement process ultimately was successful to the extent the ridge detail could be used for comparison to the side of the left thumb of a suspect in the case: Robert Knight. During the trial, the defense attacked the digital imaging process used to enhance the print and requested a Kelly-Frye hearing to determine the scientific validity and acceptance of the digital enhancement process. The court determined digital imaging techniques were consistent with traditional photographic processes, and on June 18, 1991, Robert Knight plead guilty and was sentenced to four life terms.

As technologies have improved over the past few decades, the use of photographic evidence has intensified and expanded to include a wide range of forensic analysis from visualizing bullet trajectories with lasers (see Chapter 13) to enhancing fingerprint images for analysis and comparison.

On Sunday, May 14, 1995, Dawn Fehring, a 27-year-old student, was found dead on the floor of her Kirkland, Washington, apartment. During their investigation, the Kirkland Police Department took the bedding to Dan Holshue, a latent print examiner at the King County Police Department at the time. The examiner cut out five areas of a fitted bedsheet containing what appeared to be ridge detail in blood. He then processed the cutouts using a procedure involving Amido black (a dye stain that reacts with the proteins in blood). After processing, the contrast between the weave pattern of the bedsheet and the possible ridge detail was insufficient for analysis.

Dan then took the pieces of sheet to Erik Berg, an expert in enhanced digital imaging at the Tacoma Police Department, for computer enhancement. Erik photographed the cutouts using a Kodak DCS 420 camera and then downloaded the images (see Figures 6.52 and 6.54) into the PC Pros' More Hits system.

Using the More Hits system, Erik processed the images in Adobe Photoshop using a special Grayscale Pattern Removal Filter (FFT)—developed by Erik while working with PC Pros—to suppress the background noise interfering with the visualization of the ridge detail in the images. Erik also used several tools in Adobe Photoshop to adjust the contrast so the ridge detail was more clearly visible (see Figures 6.53 and 6.55).

Using the processed digital images, Dan Holshue identified not only the pattern type but he found more than 10 minutiae points of comparison on the latent fingerprint

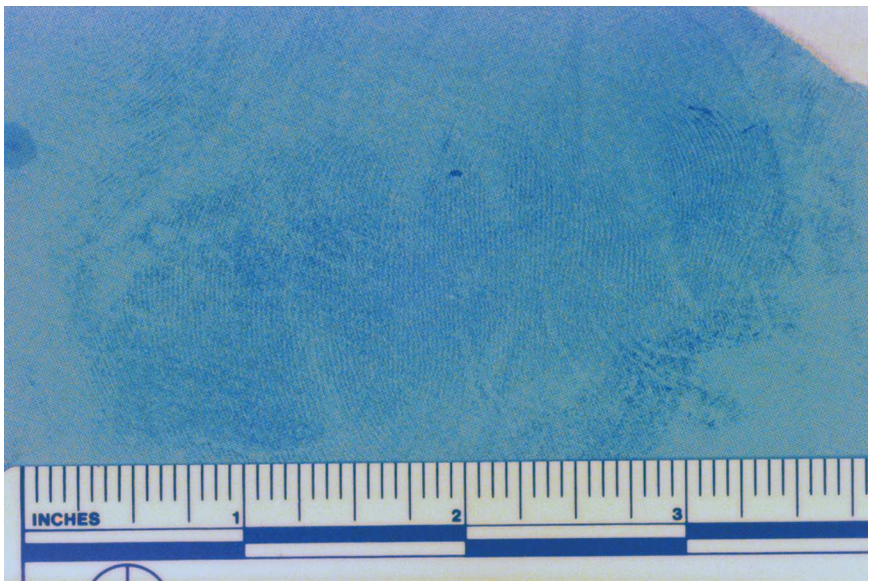


FIGURE 6.52 Digital photograph of the palm print of Eric Hayden on the bedsheet before processing.

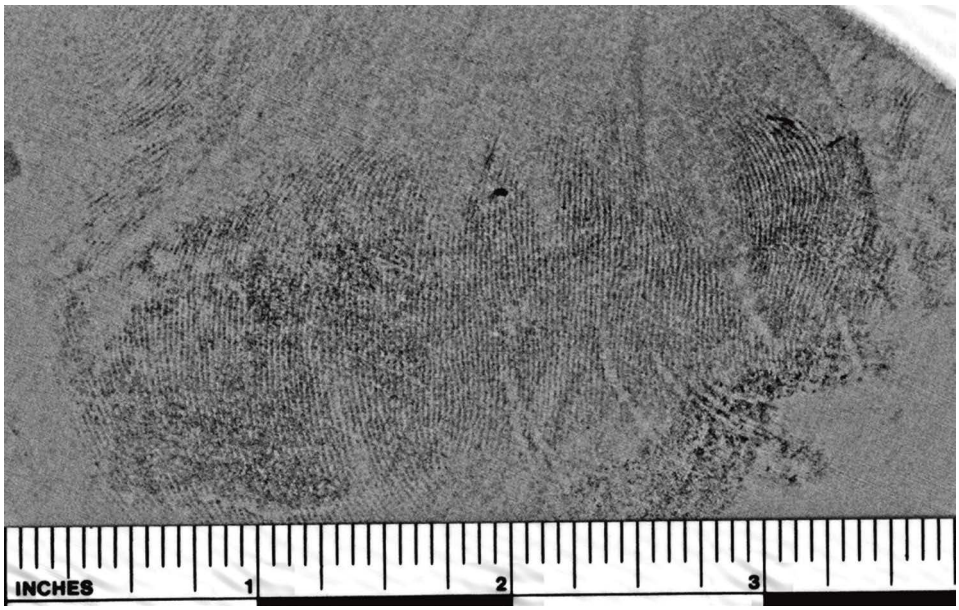


FIGURE 6.53 Digitally processed photograph of the palm print of Eric Hayden on the bedsheet.

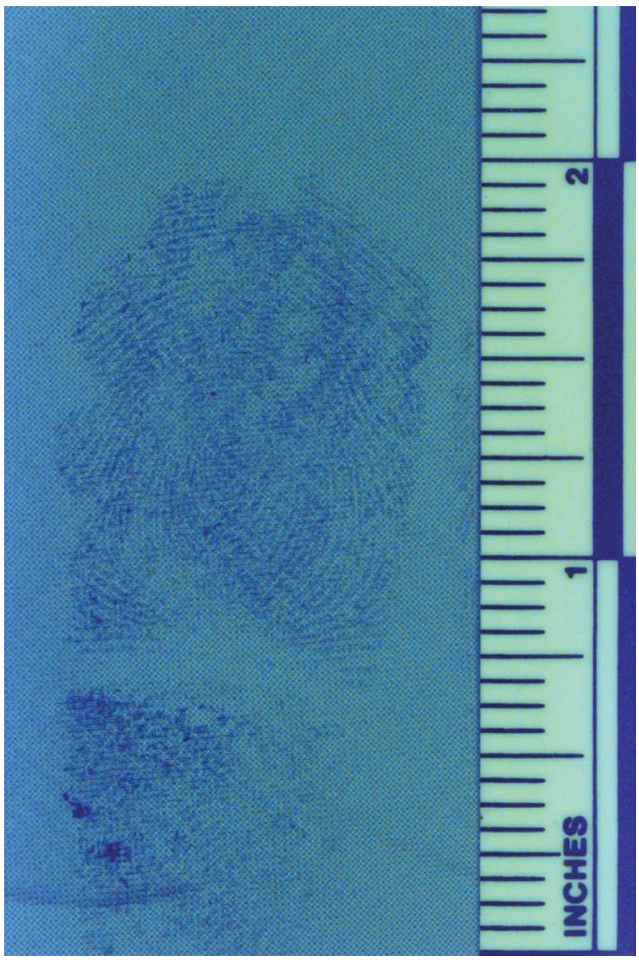


FIGURE 6.54 Digital photograph of the fingerprint of Eric Hayden on the bedsheet before processing.

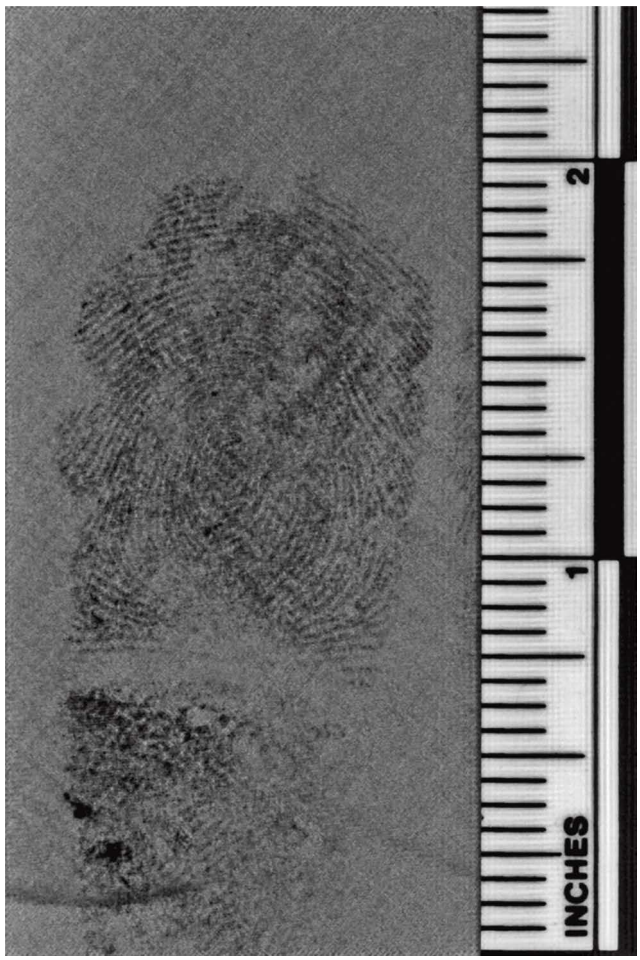


FIGURE 6.55 Digitally processed photograph of the fingerprint of Eric Hayden on the bedsheet.

image and more than 40 minutiae points on the palm print image. Thus, Dan positively identified the latent impressions on the bedsheet as belonging to Eric Hayden.

During the trial, the court conducted a Frye hearing to determine admissibility of "novel scientific evidence." Following the Frye hearing, the trial court concluded the digital processing of the images was admissible, as the process was "generally accepted in the relevant scientific community."

On February 17, 1998, the Court of Appeals for the state of Washington held that:

> Because there does not appear to be a significant dispute among qualified experts as to the validity of enhanced digital imaging performed by qualified experts using appropriate software, we conclude that the process is generally accepted in the relevant scientific community.

By 1997, only a handful of law enforcement agencies were using digital imaging for casework. Of those, the majority were using digital imaging only for specialized work, such as the enhancement of latent fingerprints. But the interest in digital imaging was growing rapidly. At the 1997 International Association for Identification's (IAI) 82nd Annual Training Conference in Boston, Massachusetts, the IAI passed Resolution 97-9, which recognized digital imaging as a "scientifically valid and proven technology" for the first time. This resolution provided legitimacy to the technology and jump-started its adoption among the members of the IAI. Since that time, digital imaging technology has spread to nearly every major law enforcement agency in the United States.

Now, more than 20 years later, the capabilities of the technology have continued to expand exponentially. The use of digital cameras is no longer restricted to capturing latent impressions, footwear, tire tread, blood spatter, or other specialized purposes. Digital cameras of all shapes and sizes are used today including but not limited to body-worn cameras, dash-mounted cameras in patrol cars, surveillance cameras, and smartphones. Some smartphones have even been adapted for special-use functions, such as by sexual assault nursing examiners.

Moreover, the potential for budgetary savings and the ability to deliver images faster continue to drive the growing demand for digital-based technologies. The use of digital imaging systems has literally exploded in a wide range of scientific fields, such as radiology offices and hospitals where digital capture systems eliminate the need for film-based imaging systems, including x-rays. Rapid moves toward any technology in any discipline, without adequate research, planning, or training needed to demonstrate competency and proficiency, can leave an agency vulnerable to misinformation and legal challenges.

For example, in a medical malpractice wrongful death lawsuit (*Rodd v. Raritan Radiologic Associates, P.A.*), the defendant (a radiologist) used a magnifying glass to examine x-ray images from the decedent's 1997 and 1998 mammograms and found them negative for cancer. During the trial, the defense stated that mammograms were studied to detect cancer by placing the x-ray in a view box and analyzing it with his naked eye and a handheld magnifying glass.

To help the jurors understand the details of the x-rays, the plaintiff digitized (scanned the negative) and "super-magnified" (zoomed in) portions of the contested x-rays and displayed them in court on a standard 6-foot by 8-foot projection screen.

The trial judge reasoned the enlarged x-ray images not only helped the jurors understand the complicated factual scenario, but he also believed the use of this process would be a meaningful improvement to the entire radiological field:

> The message may get—get out now, that in radiology, and I know the radiologist is under awesome pressure reading these films, that maybe they ought to blow it up like that…. [M]aybe the whole industry is negligent. Maybe in this case, something ought to be done … maybe this message is gonna get out … it seems, to me, to be very simple and very easy to implement, in a radiology group, blowing it up on a screen…

On appeal, the defense argued that the "standard of care" among radiologists required only a visual inspection with a 2.5-power magnifying lens. (Does this sound like a latent print examiner you know?)

Not only did the appellate court uphold the trial judge's reasoning in admitting the digitized and "super-magnified" portions of the contested x-rays but went on to highlight the fact that the plaintiff's malpractice claims focused on an "error in visual observation."

Due to procedural errors made by the trial court, the Court of Appeals reversed and remanded the case for a new trial. For example, the defendant did not receive notice regarding the use of the "super-magnified" images in discovery and only learned of the existence of the enlarged images at a pretrial conference, which the defense argued was "too late to adequately test the process by which the images were created." Moreover, the plaintiff's expert could not adequately explain how the enlargements were made, etc. (How many forensic experts do you know who could not adequately explain what they are doing when using a computer to enhance or display their images?)

Another procedural error noted by the appellate court was the trial judge had also rejected the defendant's requests for plaintiff's computer operator and all the computer images created from the x-rays, even those rejected by plaintiff, be made available to the defense. In fact, the defendant only received printouts of selected images, and those were not made available to the defendant until midway through the trial.

In contrast, with two successful wins under its belt, the use of digital imaging technologies in the forensic science community moved forward in 1998 with a homicide trial similar to the state of Washington versus Eric Hayden case, involving bloody prints on the victim's bedding. *The State of Ohio v. Brett X. Hartman* was the third court case in

the United States in which a court ruled favorably on the computer enhancement of fingerprint images. In 1997, Brett X. Hartman was charged with murdering Winda Snipes by stabbing her 138 times, slitting her throat, and cutting off her hands.

Due to numerous pieces of evidence, including latent print images on a chair and a bedspread, a jury found Hartman guilty of murder and kidnapping and sentenced him to death. In 2001, Hartman appealed his conviction, stating 13 different challenges. The challenges dealing with the latent prints were:

1. The admission of digitally enhanced fingerprint evidence, their reliability, and the qualifications of the state's fingerprint expert, Patrick Warrick, to testify regarding such evidence.
2. The court failed to make a threshold determination concerning Patrick Warrick's qualifications, stating that "It was error for the trial court to admit the opinion of witnesses who had not first been qualified as an expert." The court ruled that "the use of the computer in this instance is no different than *** would be the use of an overhead projector, microscope, a magnifying glass or anything else like that, that would enhance an expert's ability to make his determination…." It was ruled that since Patrick had used computer enhancement for more than a year and a half, he was not blazing new ground; therefore, Patrick's testimony was appropriate.

The Court of Appeals also determined that although Patrick was not formally tendered as an expert witness, the defense did not challenge Patrick's qualifications when he testified during the trial, and the court determined him to be qualified to identify the defendant's fingerprint on Snipes's bedspread. The appellate court affirmed Hartman's conviction on October 3, 2001. Brett Hartman was put to death by means of lethal injection on November 13, 2012.

ADMISSIBILITY AND RELIABILITY …

While the foregoing cases set the precedent for admissibility of processed (aka enhanced) latent impressions in the court, there have been a limited number of cases directly addressing the admissibility of digital evidence.

In the *State of California v. Phillip Lee Jackson*, the police department in San Diego, California, used digital image processing on a fingerprint in a double homicide case in 1995. The defense asked for a Kelly-Frye hearing, but the court ruled the Kelly-Frye hearing was unnecessary based on the argument that digital processing is a "readily accepted practice in forensics" and that "new information" was not added to the image.

In another California case (*People v. Perez*[21]), the court admitted into evidence at trial digital images of a footwear impression processed using Adobe Photoshop. The defense argued the digitally enhanced footwear impressions should not have been admitted into evidence because no Kelly-Frye hearing was held, which should have been required since the software and processes used were "new scientific" techniques. The court held that Adobe Photoshop was not a new or novel scientific process and the evidence was reliable since it did not alter the shoeprint images. The court also held that Adobe Photoshop is an easier method for the processing and development of pictures, and digital enhancement is generally accepted by the scientific community as "reliable."

In the Supreme Court of Georgia case, *Mastro Almond v. the State of Georgia*,[22] the attorneys for Almond argued, among other errors, that the trial court had erred in admitting various photographs taken with a digital camera. During the court's review, it was found the trial court records showed the pictures were introduced after the prosecution properly authenticated them as "fair and truthful representations of what they purported to depict." The Georgia Supreme Court affirmed the lower court's decision stating there was no authority for the proposition that the procedure for admitting digital images should be any different than when taken by a traditional film camera.

On September 30, 1999, in *The People of the State of New York, Respondent, v. Israel Rodriguez, Defendant-Appellant*, the New York Supreme Court, Appellate Division, First Department concluded that the trial court "properly exercised its discretion" in admitting images made from bank surveillance videotapes. The court decided that expert testimony describing the digitizing process that was used in the FBI laboratory to capture the footage and extract frames from a video surveillance tape was not required since the bank employee who was responsible for the bank's surveillance system testified that he had compared the original tapes and that what was represented by the still photographs was "identical except for speed." (The bank employee's testimony also resolved the issue of the images being both relevant and authenticated for admissibility.

In yet another case, the *State of Florida v. Victor Reyes* in November 2001, the defense challenged the use of certain digital image processing practices for the enhancement of fingerprints developed on duct tape. In particular, the defense challenged the use of Adobe Photoshop's Burn and Dodge tools, as well as using color channels to suppress background noise; the defense also challenged the use of the PC Pros More Hits Enhancement History recording feature. (This tool was available in the More Hits system for recording the enhancement history, the sequence, settings, and parameters of the image processing in Adobe Photoshop versions 5.0, 5.5, 6.0, and 7.0, which was prior to Adobe's creation of its own image enhancement history log in Adobe Photoshop CS, first released in October 2003.) The court found that "the use of digital imaging to enhance a latent print is not new or novel and that it is accepted within the relevant forensic community" and "the process of recording of digital enhancement processes is actually

more thorough than the recording process of traditional photographic processes."

In a letter dated April 10, 2003, to Sergeant James Kammerer, supervisor of the Broward Sheriff's Office (BSO) Crime Scene Unit from two assistant state attorneys for the state of Florida in Broward County, they stated:

> Recently we completed a five-week trial involving the above designated defendant (RE: State of Florida v. Victor Reyes, Case No. 02-12239CF10), Victor Reyes. During the trial, we had the opportunity to utilize and benefit from testimony revolving around the digital imaging/enhancement technology. In light of the fact that this was the first occasion on which this technology was vigorously contested here in Broward County, we though[t] that you would be interested in the jury's receipt of the evidence developed via the use of this technology.
>
> Nine of the jurors stopped us in the hallway and discussed the case with us at some length. Relative to the enhanced latent evidence, they advised that they did indeed accept the latent enhanced by the technology as a latent left by Victor Reyes. In fact, they confirmed our decision that we had no need to further and present testimony of any of the developers of the technology. They accepted the competency and knowledge of David Knorlein and the work that he had completed. Their problem with the latent was only the location of the latent. They wanted to know where it was in relationship to all the tape used to wrap the body. This astounds me for it was argued that the latent was on tape overlapped by other tape and thus indicated a person involved in disposing of the body. In their minds, however, the wrapping of the body could have easily been somebody was merely an accessory after the fact. Thus, where was the problem?
>
> The problem they had with the case revolved around a lack of certain testimony. In our opening statement, we had elaborated upon testimony that would come from a key witness, Bruce Mitchell. The jury was told that Mitchell would testify that while he was in North Carolina with the defendant's brother, he overheard a telephone conversation between the brother and the victim, Henry Guzman, who was calling from the defendant's house. During that conversation, gunshots were heard over the phone. Mitchell would have then explained to the jurors how Reyes subsequently drove from South Florida to North Carolina and detailed how and why he had killed Henry Guzman while Guzman was on the phone. The jurors expressed that they were astounded that we rested the case without presenting Mitchell's testimony. I explained to them how Mitchell—on the day he was to testify—refused to testify. They conveyed that had they had his testimony the outcome of the case would have been different.
>
> In the end, it should be underscored that the reliability of the enhancement process was not questioned by the jurors. This was given great weight and accepted by the jurors, but in a purely circumstantial case … which this case became once Mitchell refused to testify … they needed more of a nexus between the victim and the defendant in order to say that Victor Reyes was the shooter or responsible to a greater extent tha[n] possibly merely wrapping the body.

The letter was signed by Deborah Zimet, Assistant State Attorney, Florida Bar No. 369731 and Thomas Kern, Assistant State Attorney, Florida Bar No. 108287.

However, within weeks of the trial, two south Florida newspapers, the *South Florida Sun-Sentinel* and The *Miami Herald,* as well as several other forensic newsletters, cited many "alternative" facts about the trial of Victor Reyes. The only truth contained in those articles is that the jury acquitted Victor Reyes of first-degree murder, rejecting the prosecutors' argument that Victor Reyes was guilty of the fatal shooting, because his fingerprint appeared on duct tape wrapped around the victim's body.

The articles stated the defense attorney, Barbara Heyer, had attacked "new fingerprint technology the Broward Sheriff's Office used to connect Reyes to the slaying."

During a *60 Minutes II* interview in November 2002, and again during a post-trial interview, Barbara Heyer referred to the digital imaging technology as "junk science." This statement led to the shocking headline "Jury Cites 'Junk Science' in Clearing Man of Murder." Unfortunately, the headline itself was more shocking than the statements made by the defense attorney, for the simple fact that the jury did not cite junk science as any part of their decision, which was substantiated in the foregoing letter from the state attorneys to Sgt. Kammerer.

Moreover, the articles made specific misstatements by reporting the BSO crime lab technician used a "new fingerprinting technology" called "dodge and burn."

The *Sun Sentinel* stated this technique was used to make the image darker in some places and lighter in others. The *Miami Herald* stated this technique works by removing noise or "distracting background designs." While the *Sun Sentinel* was accurate in its description of the technique, the *Miami Herald* was completely wrong in its description of the technique.

Moreover, this is not a new technology. Dodge and burn techniques have been used by photographers as far back as the Civil War. The dodge function does indeed lighten an area, while the burn function darkens an area. Dodge and burn are local enhancement techniques like adjusting the brightness and contrast control on your TV, and they can be applied to a specific area of an image. In addition, specific guidelines are available for the use of these tools within a forensic environment.

Both articles stated the dodge and burn software was "developed by a Tacoma, Wash., forensic expert, and the technique is similar to the software of Adobe Photoshop…." This statement is entirely false. Erik Berg did not develop the dodge and burn techniques. These are the digital implementation of traditional photographic tools, and they are basic tools offered by Adobe Photoshop.

The *Miami Herald* also reported, "For example, 'Dodge and Burn' put a Washington rapist and murderer away for 26 years in a landmark case allowing investigators to extract a print from a bedsheet, by erasing the bedsheet's fabric design."

Quoting a statement from Erik Berg, "There is not a single truth in the entire sentence. Dodge and burn techniques were not applied to any image connected with the Eric Hayden case." Erik also stated he used a technique called "Curves" in the Hayden case. This technique is used to create extraordinary contrast and was used throughout the entire image, not just a select portion of the image.

Erik also stated the fabric pattern were removed using the More Hits Pattern Removal Filter, a filter he helped to develop. This filter runs in Adobe Photoshop and is based upon a mathematical formula known as an FFT designed by a French scientist, Jean Baptiste Fourier, in the 1800s to measure heat transfer in metal. The FFT is an algorithm that breaks down the brightness values in a digital image into a frequency domain where the frequencies creating the noise (pattern) can be clipped (removed) from the displayed frequencies. The image is then converted back into its normal brightness values, and the pixels containing the clipped frequencies acquire a new brightness value interpolated using neighboring pixel values. This noise filtering process has been used in a variety of digital processing tasks, including eliminating pops and scratches from audio recorded on vinyl records, removal of repetitive frequencies in digital images, and the encoding of fingerprints stored in the FBI's digital fingerprint database.

During a post-trial interview with the *Sun Sentinel,* Barbara Heyer said, "The methods cross the line between uncovering evidence and creating it.… The computer programs used to enhance the print were too susceptible to being tampered with and do not have enough safeguards to prove that law enforcement is not manipulating the evidence." Heyer further stated, "They take something that is of no value to begin with and start doing this boosting and they turn up something that they claim is someone's print."

What Ms. Heyer failed to mention, however, was that the same negatives were submitted to the FBI, where the prints were independently enhanced by an FBI forensic photographer and subsequently identified by an FBI latent print examiner.

Ms. Heyer's stated belief that the Adobe Photoshop software could be used to create fraudulent prints had no basis in fact, and the insinuation that it might have been so used is without a factual basis and is highly prejudicial and unwarranted. In *Cross v. U.S.*, 149 F.3d 1190, 1998 WL 255054 (10th Cir. Kan. 1998) the court stated that the "mere possibility" of tampering was insufficient to prove bad faith. Similarly, in *United States v. Balzano*, 687, F.2d 6, 7-8 (1st Cir. 1982) the court also approved the trial court's decision to admit duplicate audiotapes where the defense had alleged "hypothetically" tampering could have occurred.

Unfortunately, a lot of focus was put on the use of dodge and burn and other enhancement tools available within Adobe Photoshop for several years after the Reyes case. (Some law enforcement agencies in Florida and elsewhere are still afraid to use burn and dodge.)

There has also been a great deal of emphasis placed upon maintaining a detailed history (recording) of the enhancement process. In fact, Adobe Photoshop CS (aka version 8.0)—released in October 2003—was the first version of Adobe Photoshop to include the History Log function. (Adobe Photoshop Version 7.0 and the More Hits History Tracker were used in the Victor Reyes case.)

The underlying concept for the History Log was twofold. First, it is necessary to maintain records of the digital imaging process (enhancement history) to validate the accuracy of the imaging process. Second, it should be possible to give the same "original" image to another individual and based on the previously recorded history, they should be able to enhance the image and produce a comparable result, meaning analyses of the two images would result in an identical conclusion.

Maintaining a detailed history of the steps used during the image enhancement process is required for satisfying the burden of proof essential for demonstrating the image was not altered or manipulated. It also eliminates the doubt and confusion implied by defense attorneys, such as Ms. Heyer, when they make claims of "[t]hey take something that is of no value to begin with and start doing this boosting and then turn up something that they claim is someone's print." The reliability, instant results, and advanced capabilities of digital versus analog make this a valid, more accurate, and reliable science, not "junk science."

THE CHALLENGES CONTINUE

As digital imaging technologies advance, new techniques are also developed for creating and using computer-generated techniques. While the rules of evidence are far behind the development and use of these technologies, the criminal justice system has quickly learned to appreciate the benefits of digital imaging, both in terms of demonstrative evidence as well as probative evidence.

Unfortunately, it has not been smooth sailing for all forensic disciplines. There have been a number of cases in which the conviction of the suspect was vacated or the indictment was dismissed based, at least in part, on the improper use of digital technologies.

For instance, the Texas Forensic Science Commission was a group organized in 2016 in conjunction with the Texas "Junk Science Law" (Texas House Bill 1068) to review the validity of "questionable" fields of forensics. The commission finalized their first report on the Forensic Video Analysis—Height Determination complaint filed on behalf of George R. Powell III on April 12, 2016. During their investigation of video imaging technology, the commission retained Grant Fredericks, a forensic video expert, to review the reports and testimony presented during Powell's trial.

The commission found the qualifications and analytical methods of the forensic video analysts in this case were as different as their conclusions. This gap between experts' claims and the scientific findings raised concerns about forensic video analysis and the methodologies used to identify defendants in criminal cases. The commission also

found fundamental issues existed in the validation and publication of standards and test methodologies. Plus, the lack of accreditation creates an issue concerning oversight for a rapidly growing and valuable forensic discipline.

In another report, Bite Mark Case Review Report dated November 3, 2017, the Texas Forensic Science Commission recommended a moratorium on the use of bite mark analysis in courts based, in part, on the improper use of computer-generated images of bitemark overlays.

"ILLUSORY" EXPERT TESTIMONY

Another legal issue that raised its ugly head, which may lead to a determination of junk science, is the concern that the courts often presumptively recognize a technique or technology based the qualification of an expert. In other words, the trial courts are often too dependent upon the qualifications of the testifying expert because of the court's lack of knowledge and understanding in the matter. This causes the judge to accept a scientific technique or technology as "reliable" when it is not.

By overstating their background, expertise, and experience, experts can mislead the judge and the jury. In some cases, Frye or Daubert hearings have been held to determine the qualifications of both the expert and the technology. The bottom line is that developing reliable (validated) standards supported by training and experience will help establish the reliability of expert testimony. It is inherent upon every practitioner in any discipline using digital imaging to become as knowledgeable in all facets of the technology, including but not limited to:

1. What digital imaging equipment is accepted in the field as "standard"
2. What standards or procedures must be followed in connection with the capture, storing, processing, management, and output of digital evidence
3. What photo-editing software is accepted in the field as "standard"
4. What photo-editing techniques are accepted in the field as "standard"

Accreditation of the law enforcement agency combined with the certification of its employees can also help further the acceptance of digital technologies, as well as mitigate the issue of "illusory" expert testimony.

6A Impression and Pattern Evidence

Dawn Watkins and King Brown

INTRODUCTION

Impression evidence is created when two objects come in contact with enough force to cause an impression. Typically, impression evidence is either two-dimensional—such as a fingerprint—or three-dimensional—such as the marks on a bullet caused by the rifling inside the barrel of a firearm.

Pattern evidence may be additional identifiable information found within an impression. For example, an examiner will compare shoeprint evidence with several shoe sole patterns to identify a particular brand, model, or size. If a shoe is recovered from a suspect matching this initial pattern, the forensic examiner can look for unique characteristics common between the shoe and the shoeprint, such as tread wear, cuts, or nicks, to individuate the shoe evidence.

Impression and pattern evidence can help link a suspect or tool to a particular crime scene. New or improved techniques to identify, collect, analyze, and preserve impression and pattern evidence would greatly aid the forensic community.[23]

Footwear impressions. Whenever an individual takes a step, a footwear impression may potentially be left behind on the walking surface (see Figure 6.56).

Such an impression may be two-dimensional, the print left behind on a flat surface in some deposited material, or three-dimensional, formed in a soft surface such as soil. Numerous techniques are available for the enhancement and recovery of footwear impressions, though the nondestructive methods should always be employed first if possible.

Two-dimensional impressions may be treated in a similar way as fingerprints. The gentle application of a fine powder may develop footprints on flat surfaces. Certain chemicals and dyes may enhance impressions on surfaces such as glass or tile. However, paper and similar porous surfaces will simply absorb such chemicals, rendering the impression useless. The application of alternative light sources can possibly enhance two-dimensional footwear impressions. The light source should be positioned to give a low angle of incident light, creating shadows to provide a contrast.

Impressions in dust are obviously extremely delicate, though they can be carefully recovered using electrostatic treatment (see Figure 6.57). An electrostatic lifter passes a voltage across a thin layer of conductive film, composed of a lower layer of black insulating plastic with an upper layer of aluminum foil. The electrostatic charges cause particles of the impressions to jump onto the black underside of the film, recovering the dust impression. As dental stone emits heat as it sets, it is evidently not suitable for casting impressions in snow. In this instance aerosol products exist, such as Snow Impression Wax. This is applied to the impression numerous times at intervals of one to two minutes and then left to dry. The impression can then be cast as normal. Alternatively, flour sulfur may be used to cast snow prints. This is boiled to produce a hot casting compound, which, upon contact with the cold snow, solidifies to produce a detailed casting.

Any footwear impressions collected from a crime scene may be useless unless there are suspect samples available for comparison. By applying a film of light oil to the under sole of a shoe and pressing it into a sheet of oil-impregnated foam rubber, a test impression can be produced. Alternatively, the under sole is oiled and pressed onto plain white paper, which is then dusted with fine black powder



FIGURE 6.56 Footwear model.

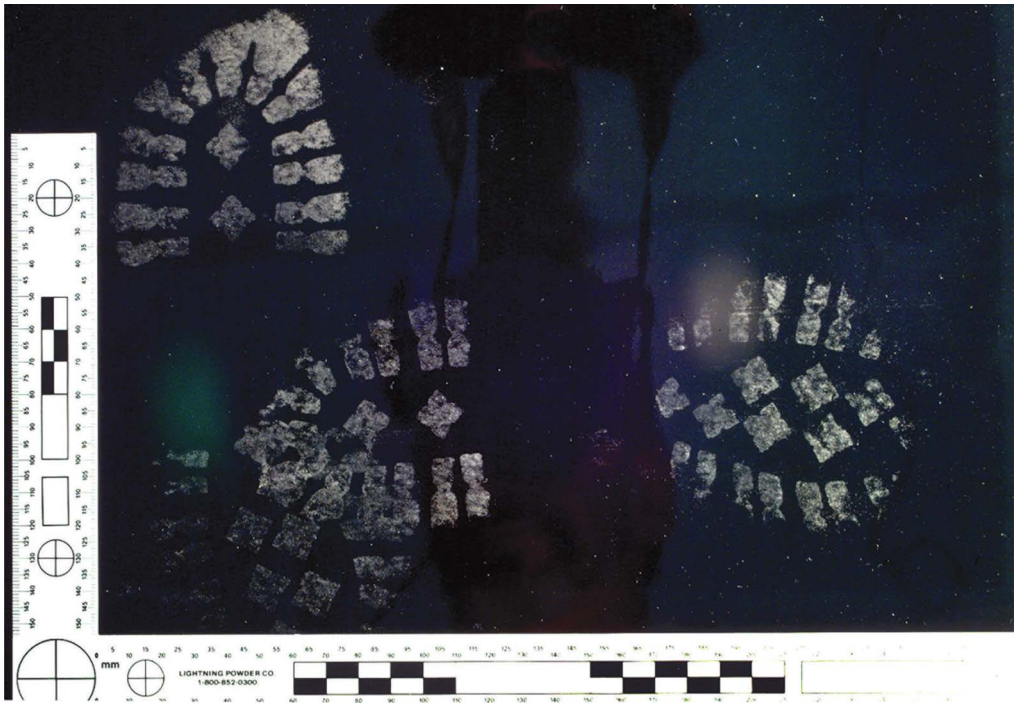


FIGURE 6.57 Two-dimensional dust footwear impression.

similar to that used to develop latent prints. If a three-dimensional impression is to be obtained, it should, if possible, be produced using the same methods and mediums as the original impression.

Even if no other samples are available for comparison, a recovered shoe impression may yield a vast amount of information. Almost all items of footwear will bear an under sole with distinctive patterns. Manufacturers are increasingly designing to be specific to their brand. In some locations, such patterns have been stored in databases for comparison purposes. Though these patterns are identical for the same brand and type of shoe, a certain degree of individuality may be imparted from the manufacturing process or general wear. As a shoe is worn, certain details fade in different places, depending on the weight and walk of the wearer, and specific damages may be caused. The size of the shoe, which may easily be obtained by examining the recovered impression, may prove useful, though not as a positive identifier.

Tire impressions. As vehicles may be present at crime scenes before, during, or after the crime, tire impressions may be discovered at the scene, usually left behind in soil (see Figure 6.58). The enhancement and collection of these are similar to that of footwear impressions. If a tire impression is discovered at a scene, the impression corresponding to the opposite tire should also be searched for, as the distance between these may provide further information regarding the vehicle in question.

Instrument marks. Instruments and tools used during a crime will often leave marks behind at the scene. These may



FIGURE 6.58 Tire track impression.

prove beneficial in establishing links between a particular object and the scene. Common instruments encountered fall into two categories: cutting instruments and levering instruments. Common cutting instruments include knives, bolt croppers, and drills, with screwdrivers and jimmies being common levering tools. Such instruments will often suffer severe damage when used, giving them characteristic features, which may leave behind a distinctive impression at the scene the next time they are utilized. A cast can be made of the impression at the scene, usually using a type of silicon rubber. This can then be used in comparison with other impressions or instruments to establish a match and determine which tool was used. The cast itself will be a negative of the original mark and so should not be directly compared with the suspected tool. Instead, the suspected instrument can be used to make a number of test marks in a similar medium.[24]

FOOTWEAR IMPRESSIONS

Footprint Nomenclature

Definition of footprint: An impression of the foot on a surface, the area on a surface covered by something, a tire with a wide footprint, the footprint of a laser beam, range of operation os a global footprint, a marked effect, impression, or impact left a footprint in the field of research; something that identifies a genetic footprint.[25]

Photographic Documentation of Footwear Impressions

Forensic footwear evidence can be used in legal proceedings to help prove a shoe was at a crime scene. Footwear evidence is often the most abundant form of evidence left and in some cases can prove to be as specific as a fingerprint. Initially, investigators will look to identify the make and model of the shoe or trainer that made an impression. This can be done visually or by comparison with evidence in a database; both methods focus heavily on pattern recognition and brand or logo marks. Information about the footwear can be gained from the analysis of wear patterns, which are dependent on angle of footfall and weight distribution. Detailed examination of footwear impressions can help link a specific piece of footwear to a footwear imprint, as each shoe will have unique characteristics.

In the realm of crime scene investigations is the recovery of footwear evidence. This evidence can be extremely useful in the identification of a suspect or suspects. However, since most of us live in concrete jungles, this type of photography and recovery of evidence are becoming a lost art, especially when referring to impressions in a soft material. As investigators, it is our job to recover the best evidence possible during our investigations—leaving or ignoring footwear evidence is not an option. So, how can we best recover this type of valuable evidence?



FIGURE 6.59 Tripod at the location of the evidence.

For the photography of impression evidence, it is recommended a professional DSLR camera be used. A minimum of 8 MP resolution is recommended by the SWGIT. Interchangeable lenses, detachable flash (with a 6-foot cord or remote capability), manual control of exposure, and remote shutter release are also recommended by SWGIT and by the SWGTREAD.[26]

Photography is by far the best way to preserve and recover this three-dimensional evidence. We must then become familiar with the photography and recovery techniques to best preserve footwear evidence. Footwear evidence photography is not a difficult process in itself, but a few tips and tricks along with basic camera knowledge are necessary for accuracy.

When photographing footwear evidence, be sure to take overall, mid-range, and close-up photographs with and without scale.

After setting up your tripod, be sure to frame the image in the correct format, landscape or portrait, and fill the frame with the image—be sure to photograph with a proper



FIGURE 6.60 Photographing straight down to eliminate as much distortion as possible.

scale. This is critical so the item of measurable evidence is recorded properly and the highest-quality image is captured. The camera should be set with the image quality setting to raw plus JPG Fine. This provides the examiner with the best possible quality image and a JPG photograph for the investigator's file.

Selecting the correct *f*/stop for depth of field is of major importance due to the three-dimensionality of the evidence. These photographs must be clear, sharp, and concise. The *f*/stop should be set at a minimum number of *f*/8.0 and should be bracketed to *f*/11.0 and possibly *f*/16.0 depending on the depth of the impression.

Recording the footwear photographs should be completed quickly. Frame your subject, focus the image, ready the cable release, and hold the flash at approximately 3 to 6 inches above the ground and approximately 12 inches to the side of the impression. Take one photograph with the flash at each of the hours of the clock (for example, 12, 1, 2, 3, 4, etc.). Continue to the next footprint impression and repeat the process. If you don't take 12 photographs, at least capture all four sides of the footwear print. Note: After the first set of images is complete, review the images in the camera and be sure to check the focus and framing of the images. Be sure to properly frame your subject. Reshoot if necessary.

As we explore this type of evidence, the correct equipment is required for proper preservation.



FIGURE 6.61 Use of proper scale.

Required equipment:

- Digital SLR camera
- 60 mm macro lens or lens capable of close focusing
- Electronic flash
- Flash extension cord
- Cable or electronic release
- Tripod
- Footwear scale



FIGURE 6.62 Imprint with scale placed gently on the same plane.

Directions for three-dimensional footwear photography:

- Mount camera on tripod
- Attach the cable release or activate the time delay shutter release
- Attach the coiled extension cord
- Attach the flash to the cord
- Camera settings
  - Image quality on raw + JPG Fine
  - Camera Mode to Aperture Priority *f*/8 or *f*/11
- Camera should be positioned directly above the footprint (see Figures 6.59 and 6.63)
  - Camera should be perpendicular to the footprint
- Place the scale even with the bottom of the footprint
  - Do not touch the footprint with the scale
  - Be careful not to damage the footprint when placing the scale
- Flash usage
  - Be sure the flash is approximately 3 to 6 inches above and 12 inches to the side of the print

- Using the built-in bounce white card (if available) will assist in the angulation of the flash



FIGURE 6.63 Camera positioned directly above footprint.

- Take a series of photographs from the clock points (12 photographs or at least 4 at a minimum)
  - Check your photographs for proper exposure
  - Check the photographs for proper focus—focus on the scale
  - Use an assistant if necessary

Directions for two-dimensional footprint photography:

- Mount camera on tripod
- Attach the cable release or activate the time delay shutter release
- Attach the coiled extension cord
- Attach the flash to the cord
- Camera settings
  - Image quality on raw + JPG Fine
  - Camera Mode to Aperture Priority *f*/8 or *f*/11
- Camera should be positioned directly above the footprint
  - Camera should be perpendicular to the footprint (see Figure 6.64)
  - Camera must be even with the footprint

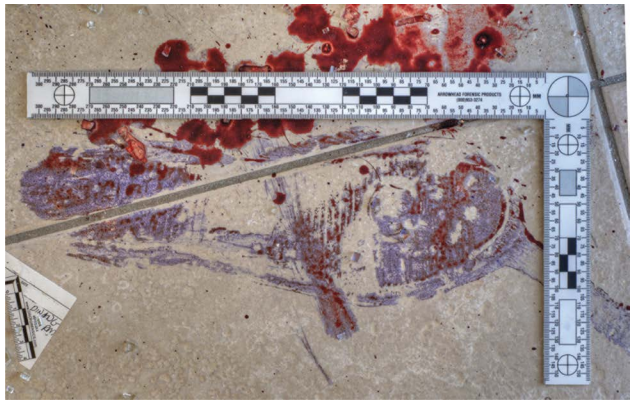


FIGURE 6.64 Flash usage.



FIGURE 6.65 Take a series of photographs, tripod mounted and using existing light.

- Place the scale adjacent to the footprint
  - Do not touch the footprint with the scale
  - Be careful not to damage the footprint when placing the scale

- Be sure the flash is at approximately 30 to 45 degrees above and to the side of the print and 24 inches away from the print to reduce reflection of the material or background
  - Using the built-in bounce card will assist in the angulation of the flash
- Take a series of photographs, tripod mounted and using existing light
  - Camera mode is aperture priority *f*/8 or *f*/11
  - Check your photograph for proper exposure
  - Check the photograph for proper focus, and focus on the scale
- Use an assistant if necessary

Directions for three-dimensional casting:

- Determine the amount of material needed (usually one cast per bag of material)
- Photograph the impression

- Spray hair spray across the impression to solidify the sand
- Prepare the casting material
  - Open bag
  - Pour in 8 oz. water
  - Close bag and mix until the mixing colors dissolve
  - Pour the casting material into your gloved hand for control into the cast (easier with an assistant)
    - Evenly distribute the material into the cast, being careful not to damage the cast
    - Use all of the material if the cast is deep enough
  - Allow casting material to dry until set
    - To determine if the material is set, test the back of the cast
    - If set, it should be hard
  - When set, remove the cast from the sand by digging a trench along the exterior of the sand/dirt
  - When the cast moves, pick it up carefully
  - Clean the cast, after it is set—about an hour, depending upon temperature
  - On the back of the cast add the following:
    - Name
    - Badge number
    - Case number
    - Date and time
    - Cast number if making multiple casts
    - Direction
    - Cast preservation
    - Storage of these types of lifts can be done by using a pizza box or a gun or knife box depending on the size of the lift itself. Be sure to wrap the cast in bubble wrap or brown paper to pad against breakage.

Dust Footprints

Nomenclature

When patrol officers and/or first responders arrive at the scene, they should look for dust footprints by taking a flashlight and rolling it along the floor. If they simply shine it into the room from a standing position, they're likely to miss the prints. When they find prints, they should mark them with plastic or disposable tent markers. Next, remember to photograph the footprints. Even if you're going to use an electrostatic dust lifter to retrieve the prints, photograph first. After all, collecting evidence is a one-shot deal. If something goes wrong, that's it; you don't get a second chance. But if you document the evidence by photographing it first, you have something to fall back on. After photographing, you can use an electrostatic dust lifter, if you have one, to retrieve the prints. Be sure to photograph the lift film. Then place the lift film in a shallow, covered box to keep dust off of the surface.[27]

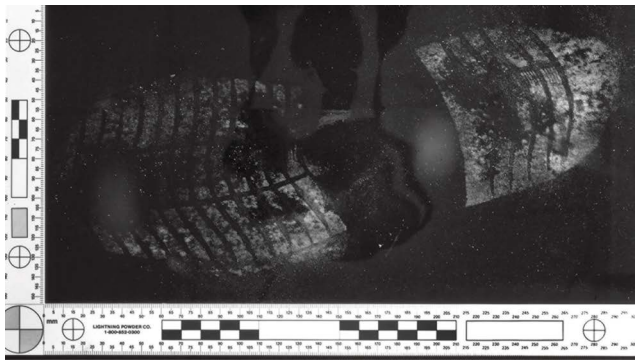


FIGURE 6.66 Electrostatic dust lifter.

Photographic Documentation

When you photograph, set your camera on a tripod, use a side light to illuminate the print, and expose at a 90-degree angle to the evidence. Make sure you insert a scale, so you know how big the footprint is. You may need to experiment with the light position to find the best angle (see Figure 6.66).

Electrostatic Dust Lifter

Electrostatic dust print lifting devices operate by charging a plastic film, which is then placed over the dust print, creating electrostatic adhesions, and draws the film onto the surface bearing the print. The dust particles are attracted to the film because of its charge and adhere to it. The film retains a charge after the unit is turned off, thus retaining the particles of dust. The print must be composed of loose residue, and the residue must be dry for this process to work. Also, a proper ground must be achieved when applying the electrical charge. On some surfaces it is difficult or impossible to achieve a ground and the procedure will not work, necessitating alternative lifting methods.[28]

Gel Lifters

Gel lifters have been specially developed to lift fingerprints, shoeprints, dust marks, and micro traces. The thick, nonaggressive, low-adhesive gelatin layer makes it possible to lift traces from almost any surface, including porous materials such as paper or cardboard. Lifted prints can be taken away/along for photography or closer examination. The black-and-white gel lifters have a carrier of linen rubber. The transparent gel lifters have a clear polyester film which acts as a carrier. All gel lifters are protected by a transparent polyester film. Black-and-white gel lifters can easily be marked, since the white linen rubber backing can be written on. The transparent gel lifters have nonstick paper edges, making it easy to mark them and to lift the cover sheet. Lifted prints or marks can readily be photographed after removing the cover sheet. When the prints have been photographed, the cover sheet can be replaced (after carefully cleaning it to remove any possible contamination). Gel lifters are normally stored at room

temperature (20° C, 68° F), though storage in a refrigerator is not harmful. Black-and-white gel lifters have no known shelf life. Due to the presence of food-grade preservatives in the gelatin layer, fungal growth on the gel lifters will not occur.[29]

Stat-Lift

As seen in the article Validation of Vinyl Static Cling Film for the Collection and Preservation of Dust Impressions, *Journal of Forensic Identification,* 2011, Vol. 61, No. 4, p. 317, the Stat-Lift is a revolutionary, cost-effective way to recover, transport, and preserve impressions. Traditional methods for collecting dust impressions (electrostatic dust lifters and gel lifters) can be expensive and in certain conditions yield undesirable results. The Stat-Lift works great in all temperature conditions and holds detail when properly stored. The Stat-Lift's natural state properties do not require any additional charge. Stat-Lift photographs well because it has a matte finish, reducing the degree of specular highlights from a flash. It can be packaged and preserved using simple storage methods. Free samples are available. Stat-Lift measures 9 × 14 inches.[30]

Lift Preservation

Storage of these types of lifts can be done by using a pizza box or a gun or knife box depending on the size of the lift itself.

Footprints in Other Mediums

1. Water
2. Oil
3. Grease
4. Blood
5. Snow

Photographic Documentation

Prints in water must be documented immediately—stop everything and photograph the prints. The critical factor is evaporation: the more time goes by before capture, the greater the chance of loss or degradation. Use side lighting, with the camera mounted on a tripod, and capture as many photographs as necessary. Camera settings are raw + JPG Fine—this is measurable evidence.

Prints in oil or grease Although oil and grease are more stable substrates, time is still a factor in the photographic recovery of this type of evidence. Photograph the print(s) as soon as possible, so the detail is still visible—oil dissipates and can cause the print to become cloudy.

Prints in blood Photography of these types of footprints should be conducted as soon as possible during the investigation of the crime scene. Photography is always the first step prior to any types of further development of the footprints. A slightly visible fingerprint or footprint can be developed using the following chemicals

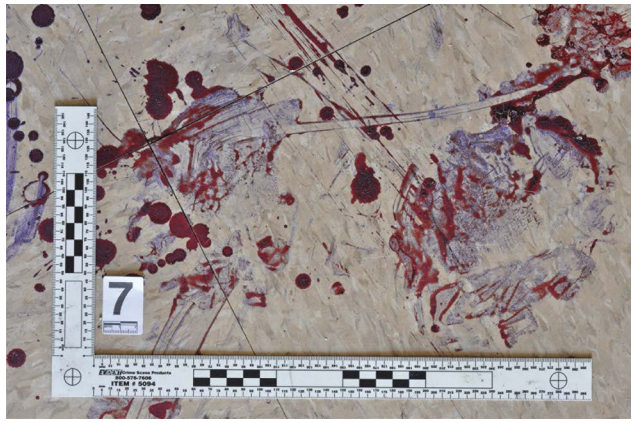


FIGURE 6.67 Enhanced footprint in blood.

to enhance the print and make it more visible for further photography.

- Lueco crystal violet (LCV)
- Coomasie blue
- Sudan black
- Amido black
- Hungarian red
- Fluorescein (must be lit with an ALS)
- Merbromin
- Ninhydrin

Prints in snow. In snow, highlighting the impression with gray paint primer or snow print wax to increase the contrast in the photograph usually works better than oblique lighting. A word of caution: spraying snow with a dark coating material may cause the impression to melt quickly in ambient sunlight. Melting time is a consideration when allotting time for photography and casting of an impression in snow.[26]

TIRE TRACKS

Definition

Forensic tire tread evidence records and analyzes impressions of vehicle tire treads for use in legal proceedings to help prove the identities of vehicles/persons at a crime scene. Every tire will show different amounts of tread wear and different amounts of damage in the form of tiny cuts and nicks or even pebbles stuck into the tread.

Tire tracks are the impressions left by tires on the surface onto which a vehicle drove. Not all tires and all surfaces will leave tire tracks. If the surface is soft or semi-soft, such as mud, dirt, or snow, the tire will leave an imprint under the weight of the vehicle. If the surface is hard, such as road pavement, the tire might still leave a trace if dirt or dust was present. As with other traces, such as fingerprints or shoeprints, tire tracks are extremely important in forensic investigations. They enable identification of the

vehicle at the scene. Tire tracks are usually found in road accident scenes or in the access and escape routes of other crime scenes.

Tires are made of semi-hard rubber and are characterized by class and individual style characteristics. **Class characteristics** include size and general patterns. **Individual characteristics** include the type, regular wear and tear, and accidental cuts or holes. These characteristics may be reproduced in the tracks left by the tire, depending on the surface and the circumstances under which the tracks occurred.

When tire tracks are present at a crime scene or in the immediate vicinity, one must properly observe and record them. First, they need to be photographed at a 90-degree angle to the evidence. This allows for a permanent record of their class and individual characteristics. Then, the tracks are carefully measured. Not only is it important to note the width but also the circumference of the tire, if the lengths of the tracks permit it. In addition, if multiple tire tracks from the different wheels of the vehicle are present, it is important to make as many measurements as possible in order to determine the toe (the distance between the front of the tires and the rear of the tires on the same axle) and turning radius of the vehicle. Finally, if the tracks are present in relief, it is also possible to make casts from them. Usually, plaster of Paris is used and, if the whole track cannot be cast, the most pertinent spot is cast.

Once the general size and pattern of the track is determined, it is possible to consult a database of tires to determine the brand and model of the tire that left the impression. In addition, there are databases listing which tires are installed from the factory on which vehicles. Finally, with the dimensions of the vehicle, it is also possible to determine which vehicle could have left the tracks. Recent advances in technology and research allow for the characterization of tire tracks by chemical analysis of the rubber. Based on Locard's exchange principle, if a tire leaves rubber residue on the surface, as is the case with skid marks, crime scene investigators can collect these traces and compare them with the tires from a suspected vehicle. The result of this analysis is not as powerful as having individual characteristics to identify the exact tire, but it adds one more piece of information to the investigation.[31]



FIGURE 6.68 Correct tire track orientation.

Photographic Documentation

Tire Track Impression Photography

The recoveries of tire track impressions are very much like the recoveries of footwear impressions. The major difference is the overall size and length of the impression(s). When photographing these types of impressions, select an area of approximately 18 to 24 inches in length. It is more logical to take multiple overlapping impression photographs than make the image so small the examiners cannot make a comparison. Remember, this type of evidence is usually three-dimensional.

Photograph the impressions and then prepare them for casting. Be sure to mark each impression with a crime scene number to keep the impressions in order of discovery.

Directions for Tire Track Impression Photography Guide:

- Mount camera on tripod
- Attach the cable release or activate the time delay shutter
- Attach the coiled extension cord
- Attach the flash to the cord
- Camera settings:
  - Image quality on raw + JPG Fine
  - Camera mode to Aperture Priority *f*/8 or *f*/11
- Select the impression or several impressions to be photographed
- Camera should be positioned directly above the impression
  - Camera and image sensor plane should be parallel with the impression
- Place the scale even with the bottom of the impression on the same plane
  - Do not touch the impression with the scale (see Figure 6.69)
  - Be careful not to damage the impression when placing the scale
- Flash usage
  - Don't cause a shadow across the impression with the tripod leg or other items
  - Be sure the flash is approximately 3 to 6 inches above and 12 inches away from the print
  - Using the built-in bounce card will assist in the angulation of the flash
- Take a series of photographs from the clock points (12 photographs or at least 4)
  - Check your photographs for proper exposure
  - Check the photographs for proper focus (focus on the scale)
- Use an assistant if necessary

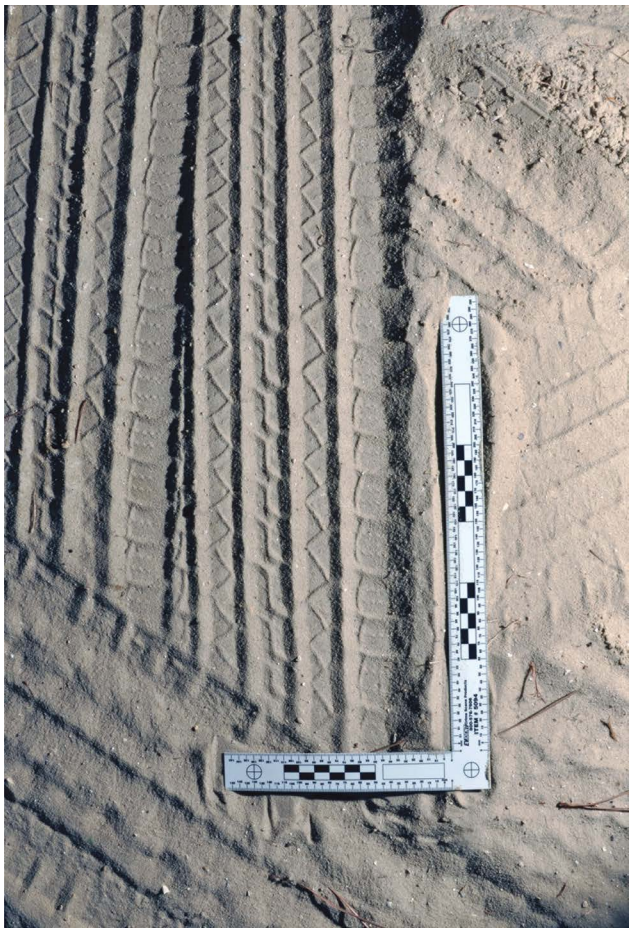


FIGURE 6.69 Tire track photo scale at level of impression bottom proper lighting.

Casting

1. Casting material types
   i. Traxtone
   ii. Arrowstone
   iii. Plaster of Paris
   iv. Dental stone
   v. Shake N Cast

Directions for Casting

- Determine the amount of material needed (one cast per bag of material)
- Photograph the impression
- Spray hair spray across the casting to solidify the substrate, allowing the spray to fall upon the impression; do not spray at the impression
- Prepare the casting material
  - Open bag
  - Pour in 8 oz. water
  - Close bag and mix until the mixing colors dissolve
- Pour the casting material into your gloved hand for control and then into the cast (easier with an assistant)
  - Evenly distribute the material into the impression, being careful not to damage the impression
  - Use all of the material if the cast is deep enough
- Allow to dry until the casting material is set
  - To determine if the material is set, test the back of the cast
  - If set, it should be hard
- When set, remove the cast from the substrate by digging a trench along the exterior of the sand/dirt
- When the cast moves, pick it up carefully
- Clean the cast after it has set about an hour, depending upon temperature
- On the back of the cast add the following:
  - Name
  - Badge number
  - Case number
  - Date and time
  - Cast number if making multiple casts
  - Direction

Cast Preservation

1. Storage of these types of lifts can be done by using a pizza box or a gun or knife box depending on the size of the lift. Be sure to wrap the cast in bubble wrap or brown paper to pad the cast against breakage.

TOOLMARK IMPRESSIONS (SEE INSTRUMENT MARKS, ABOVE)

Nomenclature

Definition

Tools are often used by criminals to force entry into premises, and the tools can leave behind evidence for the forensic scientist. Two tools of the same kind and made by the same manufacturer may look the same, but through use, each tool can and will acquire differences (unless both tools are brand new). It is these differences that makes them unique.

Characteristics

The examination of tool marks, as with other physical evidence, is based on two characteristics: class characteristics and individual characteristics.

Class characteristics are those characteristics common to a group of objects. For example, a hammer has a distinctive shape and typical size.

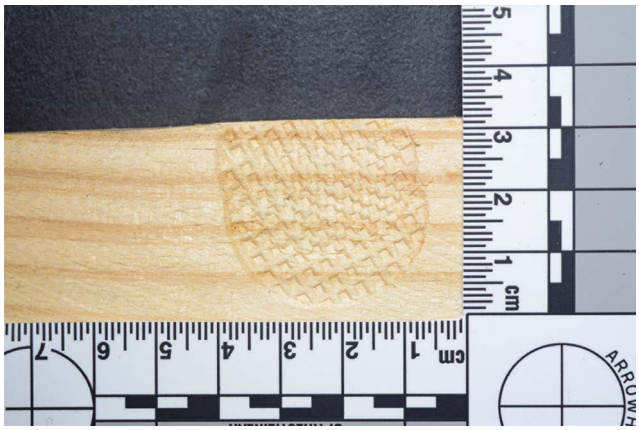


FIGURE 6.70 Impression evidence.

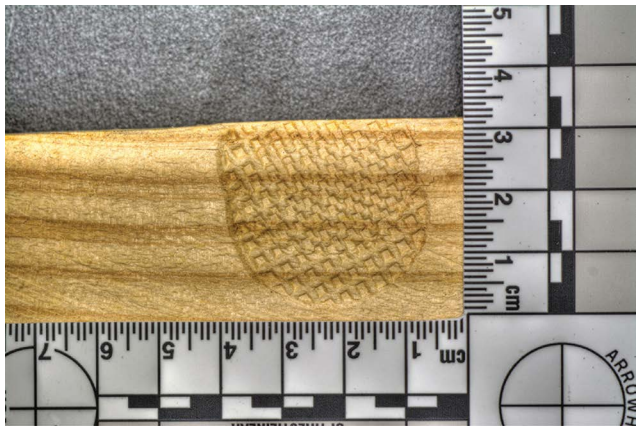


FIGURE 6.71 Impression HDR direct light.

Individual characteristics are those characteristics unique to a given object. They are generally as a result of wear and tear or may be caused by isolated incidents during manufacture. For example, you buy a new pair of shoes and as you wear the shoes, over time you will get scratches and gouges on the soles. These marks are unique to your shoes.

Toolmark Impressions

Caused by the interaction of two objects, toolmark impressions are distinguished in a variety of ways:

Static marks are made when the tool is pressed into a softer material, leaving an impression. A good example is a crowbar being used to force open a window and a subsequent impression is left in the softer surface of the wood. The forensic scientist will examine the marks and may be able to identify what type and size of tool caused the damage.

Dynamic marks are made when a tool slides or scratches across a surface. Think of a key being dragged along the side of a car: such an instrument leaves behind a pattern of lines or striations in the painted metal of the car. The pattern of striations may be enough for the examiner to identify a match with a tool belonging to a suspect.

Cutting marks are a result of pressure being applied at both sides of an object and are often associated with scissors, wire cutters, or shears. When used, these tools can leave behind marks and striations along the cut edges of the material. If a knife is used, the witness marks may be evident only along one side.

Multistroke marks are caused by repetitive action, such as a saw moving back and forth.[32]

Photographic Documentation

The documentation of tool mark evidence goes along with the documentation of any type of impression evidence. Photographs must be clear and concise, properly marked with a scale, and photographed to fill the frame.

Since this is also measurable evidence, it is imperative to capture the images in the raw format for comparison purposes.

Toolmark Photography Guide

- Mount camera on tripod
- Attach the cable release or activate the time delay shutter
- Attach the coiled extension cord
- Attach the flash to the cord
- Camera settings:
  - Image quality on raw + JPG Fine
  - Mode to Aperture Priority *f*/8 or *f*/11
- Select the toolmark to be photographed
- Camera should be positioned directly above the toolmark
  - Camera should be perdendicular with the tool mark

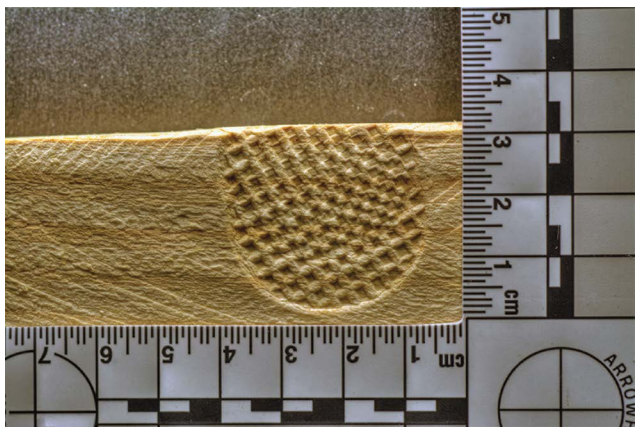


FIGURE 6.72 Impression HDR side light.

- Place the scale even with the bottom of the tool mark on the same plane
  - Do not touch the tool mark with the scale
  - Be careful not to damage the tool mark when placing the scale
- Flash usage:
  - Don't cause a shadow across the tool mark with the tripod leg or other items
  - Be sure the flash is approximately 3 to 6 inches above the print and 12 inches away from the print
  - Using the built-in bounce card will assist in the angulation of the flash
- Take a series of photographs to document the tool mark
  - Check your photographs for proper exposure
  - Check the photographs for proper focus, including focus on the scale
- Use an assistant if necessary

Cast Preparation

1. Photograph the tool mark
2. DNA swab around the tool mark

Casting

1. Casting material types
   i. Accutrans
   ii. Durocast
   iii. Mikrosil

Cast Preservation

1. Casts should be dry prior to packaging
2. Package in clean paper and then in a cardboard box

BITE MARK IMPRESSIONS

Nomenclature

Definition

Although the Chi Omega murder trial had bite mark evidence as its centerpiece, the type of evidence is usually used in conjunction with other types of physical evidence. Bite mark analysis is extremely complex, with many factors involved in a forensic dentist's ability to determine the identity of the perpetrator. (See Chapter 31 as well).

The movement of a person's jaw and tongue when he or she bites contributes to the type of mark left. Depending on the location of the bite, it's not typical to find bite marks where both the upper and lower teeth leave clear impressions—usually one or the other is more visible. If the victim is moving while being bitten, the bite would look different from that inflicted on a still victim.

If an investigator sees something on a victim even resembling a bite, the forensic dentist must be called in immediately, because bite marks change significantly over time. For example, if the victim is deceased, the skin may slip as the body decays, causing the bite to move and change.

The first step in analyzing the bite is to identify it as human. Animal teeth are very different from human teeth, so they leave very different bite mark patterns. Next, the bite is swabbed for DNA, which may have been left in the saliva of the biter. The dentist must also determine whether the bite was self-inflicted.

Forensic dentists then take measurements of each individual bite mark and record them. They also require many photographs, because of the changing nature of the bites. Bruising can appear 4 hours after a bite and disappear after 36 hours. If the victim is deceased, the dentist may have to wait until the lividity stage, or pooling of the blood, clears and details are visible. The bite photography must be conducted precisely, using rulers and ABFO #2 scales to accurately depict the orientation, depth, and size of the bite. The photos are then magnified, enhanced, and corrected for distortions.

Finally, bite marks on deceased victims are cut out from the skin in the morgue and preserved in a compound called formalin, which contains formaldehyde. Forensic dentists then make a silicone cast of the bite mark.

Forensic dentists use several different terms to describe the type of bite mark:

- **Abrasion** – a scrape on the skin
- **Avulsion** – a bite resulting in the removal of skin
- **Contusion** – a bruise
- **Hemorrhage** – a profusely bleeding bite
- **Incision** – a clean, neat wound, cut or gash
- **Laceration** – a torn or ragged wound

In addition, there are several different types of impressions teeth can leave, depending on the pressure applied by the biter. A clear impression means there was significant pressure, an obvious bite signifies medium pressure, and a noticeable impression means the biter used violent pressure to bite down.

A forensic dentist can tell a lot about the teeth of the biter based on the bite mark. If there's a gap in the bite, the biter is probably missing a tooth. Crooked teeth leave crooked impressions, and chipped teeth leave jagged-looking impressions of varying depth. Braces and partials also leave distinctive impressions.

Once investigators have identified a suspect, they obtain a warrant to take a mold of his or her teeth as well as photos of the mouth in various stages of opening and biting. They then compare transparencies of the mold with those of the bite mark cast, and photos of both the bite mark and the suspect's teeth are compared to look for similarities. Bite mark analysis has been in the news often in recent years due to its controversial nature.[33]

Bite Mark Photographic Documentation (See Chapter 31 Also)

The photographic capture of bite mark evidence is critical to any case and can show class characteristics of the individual. A very important part of bite mark evidence is the possible DNA left from the bite. It should be recovered as soon as possible.

Since the bite mark can be a three-dimensional impression, it should be treated the same as any other three-dimensional object. Side lighting must be used to record the depth of the impression and gain more detail in the image. An ABFO#2 scale (see Figure 6.73) should be used for the photography, thus allowing the examiner the ability to adjust the perspective of the image as needed.

It is always necessary for any type of forensic image to be captured in the raw format. The image in the frame of the photograph must be as large as possible; **filling the frame is of the utmost importance.** Be sure to take several images of each bite mark so the examiner can have the best possible views of the bite.

It should also be noted that ultraviolet and infrared photography may be used for older bite marks and bruises to bring out detail for the investigation.

Cast Preparation

1. Photograph the bite mark
2. DNA swab the bite mark, if new
3. Clean the bite mark
4. Cast the bite mark

Casting

1. Casting material types
   - i. Accutrans
   - ii. Durocast
   - iii. Mikrosil

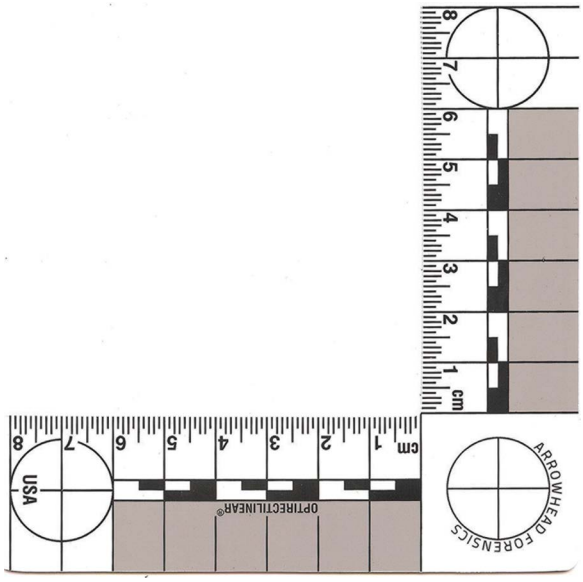


FIGURE 6.73 An ABFO #2 scale.

Cast Preservation

1. Casts should be dry prior to packaging
2. Package in clean paper and then in a paper box
3. Submit to the examiner or property and evidence department

FIREARMS AND BULLETS

Nomenclature (See Chapter 13 Also)

Most modern handguns and long guns are manufactured based on blueprints specifying their configurations. One of these specifications is a characteristic known as rifling, which refers to the spiral lands and grooves placed into the firearm's barrel to impart spin on the bullet when traveling along the barrel for increased accuracy and stability. The number of lands and grooves and the direction in which they twist, either right or left, can be determined by observing the rifling engravings in the barrel. Figure 6.74 shows the rifling in a barrel having eight lands and grooves inclined to the left, as seen from the muzzle end of a firearm. The lands and grooves appear as raised and lowered areas, respectively, in the barrel. These rifling characteristics are then imparted onto a projectile as it spins down the barrel, leaving land and groove impressions on the fired bullet (see Figure 6.75).

Manufacturers use various cutting, swaging, and electrolytic processes to introduce rifling into a barrel, and these processes, as well as others used in the finishing of a firearm, make each barrel unique. A barrel will produce individual markings in addition to a bullet's land and groove impressions as the bullet passes through. It is these unique markings that an examiner evaluates to determine whether a given bullet was fired from a particular firearm.

The rifling characteristics alone can reveal what brand and/or model of firearm could have fired a specific projectile. To figure out if a bullet could have originated from a specific firearm, however, a forensic firearm and toolmark examiner uses an instrument called a comparison microscope to compare a questioned bullet (one recovered from

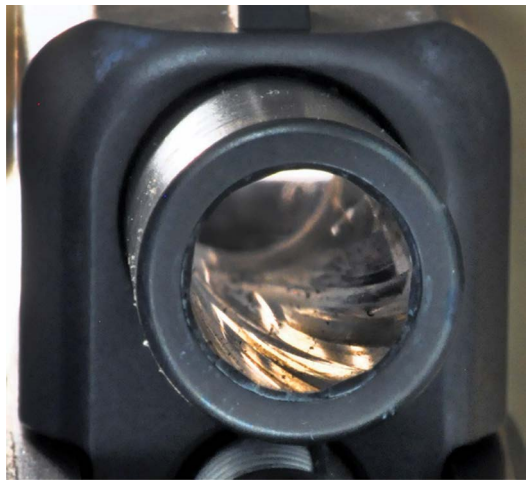


FIGURE 6.74 Barrel lands and grooves.

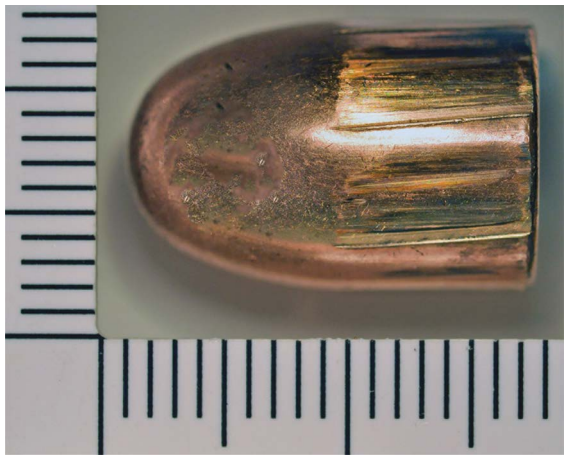


FIGURE 6.75 Bullet lands and grooves.

a crime scene, for example) to bullets test-fired from a suspect firearm. Examiners generally test-fire the subject weapon into a water recovery tank to obtain comparison bullets for evaluation under the microscope.

A comparison microscope comprises two compound microscopes joined by an optical bridge and one set of eyepieces, or oculars. This particular configuration allows the examiner to evaluate items on each of the microscope stages at the same time. A dividing line separates the two items in the field of view and allows the examiner to vary how much of each item is observed simultaneously.[34]

Photographic Documentation

Directions for the firearms photography and documentation:

- Be sure the firearm is safe/unloaded
- Prepare the camera, lens, and flash
- Use a piece of brown paper or other item as a background (see Figure 6.76)
- Camera setting
  - Aperture Priority Mode, or manual
  - *f*/8.0
  - ISO 100-400
  - Quality raw or JPG Fine
- Set the firearm as found on the background
- Photograph each side for documentation purposes
- Photograph with scale to show relative size of the firearm
- Photograph each side to show the firearm identifiers (see Figures 6.77 and 6.78)
- Photograph the serial number of the firearm (see Figure 6.79)
- Photograph the firearm with the magazine removed (see Figure 6.80)
- Photograph the firearm with the bullets removed from the magazine (see Figure 6.81)
- Process the firearm according to your department's protocol

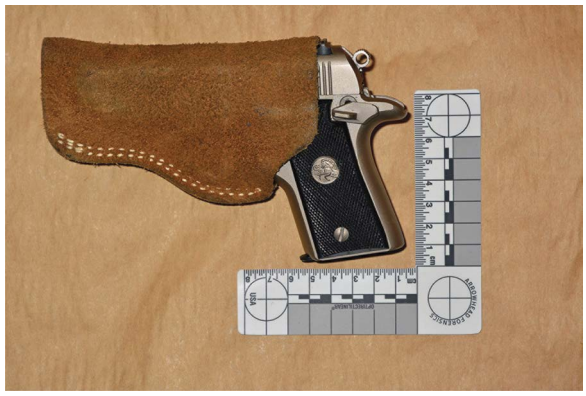


FIGURE 6.76 Firearm establishing photo of evidence.



FIGURE 6.77 Firearm left side close-up.



FIGURE 6.78 Firearm right side close-up.

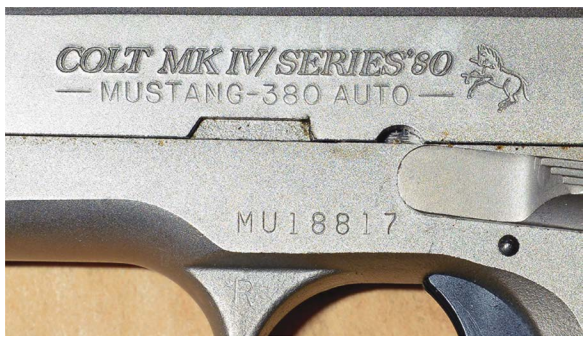


FIGURE 6.79 Serial number close-up.



FIGURE 6.80 Firearm with magazine loaded.

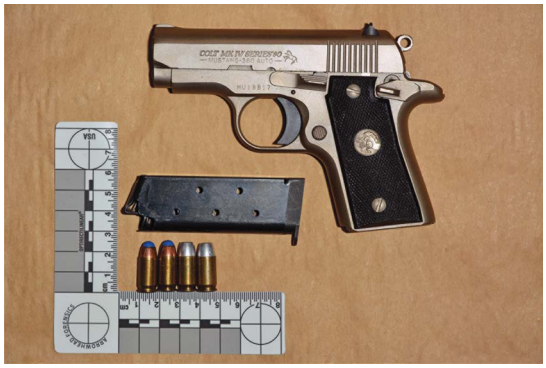


FIGURE 6.81 Firearm with magazine unloaded.

INDENTED WRITING (SEE CHAPTER 14 ALSO)

Nomenclature

Indented writing, or second page writing, is the impression from the writing instrument captured on sheets of paper below the one containing the original writing. This often manifests itself when pads of paper are used or in some record-keeping situations. Indented writing can be a source of identification in anonymous note cases, and their study can be an invaluable investigation procedure when medical records are suspected of containing alterations. Often, a writing addition to a record or file can be revealed by an impression transferred to the page below it. Indented writing on subsequent pages may not be in agreement with what appears on the surface of the document (see Figure 6.82). Writing found to be out of position, missing, or added after the fact can often be demonstrated by recovering and preserving indented writing from other pages. Indented writing is normally recovered by one of two methods: either photographically using oblique (glancing) light or by use of an apparatus commonly referred to as ESDA, short for electrostatic detection apparatus.[35]

Indented Writing Photography

- Mount camera on tripod or copy stand
- Attach the cable release or activate the time delay shutter
- Attach the coiled extension cord

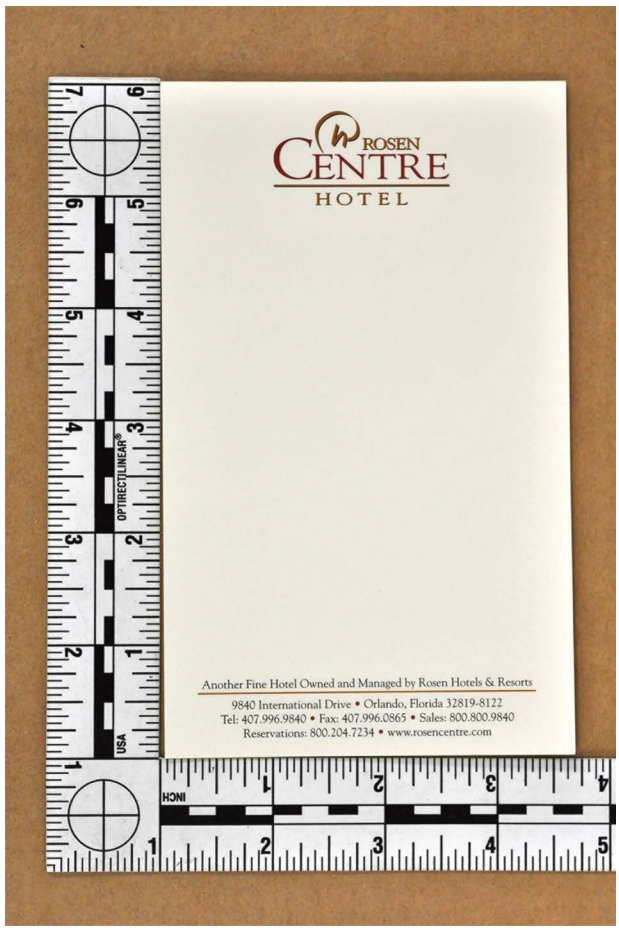


FIGURE 6.82 Photographic documentation for indented writing.

- Attach the flash to the cord
- Camera settings
  - Image quality on raw + JPG Fine
  - Mode to Aperture Priority *f*/8 or *f*/11
- Select the indented writing to be photographed (Figure 6.83)
- Camera should be positioned directly above the indented writing
  - Camera should be perpendicular with the indented writing
- Place the scale even with the bottom of the indented writing on the same plane
  - Do not touch the indented writing with the scale
  - Be careful not to damage the indented writing when placing the scale
- Flash usage
  - Don't cause a shadow across the indented writing with the tripod leg or other items
  - Be sure the flash is approximately 3 to 6 inches above the print and 12 inches away from the indented writing
  - Using the built-in bounce card will assist in the angulation of the flash

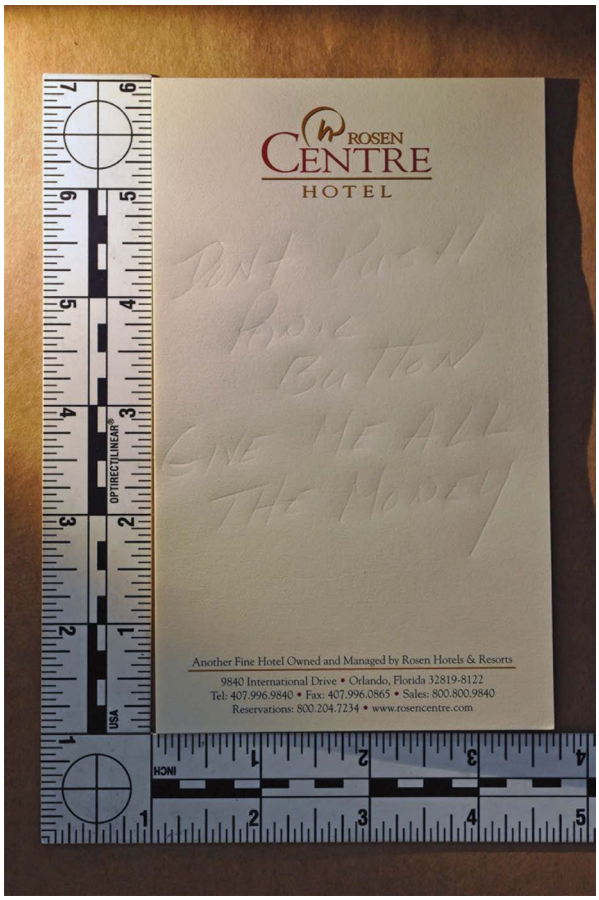


FIGURE 6.83 Indented writing 90-degree side light.

- Take a series of photographs to document the indented writing
  - Check your photograph for proper exposure
  - Check the photograph for proper focus and focus on the scale
- Use an assistant if necessary

NOTES

1. Xerox: Company Facts, Xerox Corporation History, https://www.xerox.com/about-xerox/company-facts/enin.html
2. National Aeronautics and Space Administration Space Science Data Archive, https://www.nssdc.gsfc.nasa.gov/nmc/spacecraft/Mariner_4. "The camera sequence started at 00:18:36 UT on July 15 (7:18:49 p.m. EST on July 14) and 21 pictures plus 21 lines of a 22nd picture were taken. The images taken during the flyby were stored in the onboard tape recorder. At 02:19:11 UT Mariner 4 passed behind Mars as seen from Earth and the radio signal ceased. The signal was reacquired at 03:13:04 UT when the spacecraft reappeared. Transmission of the taped images to Earth began about 8.5 hours after signal reacquisition and continued until August 3. All images were transmitted twice to insure no data were missing or corrupt."
3. Digital Photography Milestones from Kodak. *Women in Photography International*. https://petapixel.com/2010/08/05/the-worlds-first-digital-camera-by-kodak-and-steve-sasson/
4. Discover Fujifilm, https://www.fujifilmusa.com/about/corporate_profile/discover_fujifilm/index.html
5. 1990. *DigiCam History Dot Com*. https://petapixel.com/2010/08/05/the-worlds-first-digital-camera-by-kodak-and-steve-sasson/
6. Adobe Photoshop Version History, https://en.wikipedia.org/wiki/Adobe_Photoshop_version_history.
7. About Media Cybernetics, http://www.mediacy.com/company/about.
8. Fowle, Ken, and Schofield, Damien, Visualizing Forensic Data: Investigation to Court, 2011. DOI: https://doi.org/10.4225/75/57b2bc7240cec
9. Green, David M., and Swets, John A., *Signal Detection Theory and Psychophysics*, 1966; John Wiley & Sons, New York.
10. U.S. Department of Justice, Office of the Inspector General. A Review of the FBI's Handling of the Brandon Mayfield Case, Unclassified Executive Summary, January 2006.
11. Holusha, John, Kodak See a Future Where Film Is Optional, *New York Times*, July 10, 1995, http://www.nytimes.com/1995/07/10/business/kodak-sees-a-future-where-film-is-optional.html.
12. It is a well-documented fact that the size of the image sensor affects image quality. The following is a list of references for more information about the effect of image sensor size on image quality:
    - Why Small Sensor Size May Leave Your Photos Feeling Inadequate, https://www.digitaltrends.com/photography/image-sensor-size-matters/
    - Sensor size, not megapixels, is what matters. Compare the size of a DSLR to a pocket camera or smartphone—the difference is noticeable. A camera with a larger sensor will also produce images with less noise, especially at high ISO. Of course, the trade-off in image quality means more convenience. Camera Sensor Size & Image Quality: Definitive Photography Guide, https://www.davemorrowphotography.com/camera-sensor-size-guide
    - Sensor Sizes Explained: What You Need to Know, https://www.techradar.com/how-to/sensor-sizes-explained-what-you-need-to-know
    - A Beginner's Guide to Camera Sensors and Pixels, https://www.youtube.com/watch?v=9ADepqkpf5g
    - The Effect of Pixel Size on Noise, https://www.dpreview.com/articles/5365920428/the-effect-of-pixel-and-sensor-sizes-on-noise
    - 6 Benefits of Using Cameras With Larger Sensors, https://digital-photography-school.com/6-benefits-of-using-cameras-with-larger-sensors/
    - Compare Digital Camera Sensor Sizes: 1″-Type, 4/3, APS-C, Full Frame 35mm, http://photoseek.com/2013/compare-digital-camera-sensor-sizes-full-frame-35mm-aps-c-micro-four-thirds-1-inch-type/

    There are many additional references and resources that explain the distinction between imaging sensor size and image quality/noise.
13. BBC NEWS UK, Menezes Picture 'Was Manipulated, http://news.bbc.co.uk/2/hi/uk_news/7048756.stm
14. Scientific Working Group on Friction Ridge Analysis, Study and Technology (SWGFAST), Document #20, Standard for Simultaneous Impression Examination (Latent), page 1.
15. Ibid.

16. Rule 901. Authenticating or Identifying Evidence
(a) In General. To satisfy the requirement of authenticating or identifying an item of evidence, the proponent must produce evidence sufficient to support a finding that the item is what the proponent claims it is.
17. Castleman, Kenneth R., *Digital Image Processing*, Englewood Cliffs, NJ, Prentice Hall, 1979, p. 389.
18. Hricik, David, The Speed of Normal: Conflict, Competency, and Confidentiality in the Digital Age, *Computer Law Review and Technology Journal*. March 13, 2006, pp. 74–99.
19. H Singh, P Kumar, R Nanra, A Kumar. *Why Is The Crime Scene Photographed? .... There Is Not A Single Answer!*. The Internet Journal of Forensic Science. 2012 Volume 5 Number 1.
20. Green, David M., and Swets, John A., *Signal Detection Theory and Psychophysics*, first published by Wiley & Sons, New York, NY, 1966; 1988 reprint edition published by Peninsula Publishing, Los Altos, CA.
21. *People v. Perez*, No D039428, 2003 WL 22683442, Cal. Ct. App. 2003, is not a published case. While nonpublished cases normally are not considered as a legal precedent, this case and the *State of California v. Phillip Lee Jackson* case should be very "instructive" regarding the admissibility of digital images in court, as well as the use of Adobe Photoshop for digital processing evidentiary photographs.
22. *Supreme Court of Georgia, Almond v. The State of Georgia*, No. S01A1185, decided on October 05, 2001.
23. https://nij.gov/topics/forensics/evidence/impression/pages/welcome.aspx
24. http://aboutforensics.co.uk/impression-evidence/
25. https://www.merriam-webster.com/dictionary/footprint
26. https://www.forensicmag.com/article/2011/06/step-toward-better-track-evidence-photos
27. https://www.forensicmag.com/article/2014/10/look-dust-footprints
28. https://dps.mn.gov/divisions/bca/bca-divisions/forensic-science/Pages/forensic-programs-crime-scene-edpl.aspx
29. https://www.arrowheadforensics.com/a-2915-gel-lifters-black-5-2-x-7-2-10-lifters.html
30. https://www.arrowheadforensics.com/products/impression-evidence/dust-impression-lifters/arrowhead-stat-lift.html
31. https://www.encyclopedia.com/science/encyclopedias-almanacs-transcripts-and-maps/tire-tracks
32. http://www.spa.police.uk/forensic-services/chemistry/150770/
33. https://science.howstuffworks.com/forensic-dentistry3.htm
34. https://www.scientificamerican.com/article/how-can-a-bullet-be-trace/
35. https://www.questioneddocuments.com/document-examinations-services/indented-writing/



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7 Necessary Hardware
Operating, Holding, and Focusing

Sanford L. Weiss and Robert Wyman

CONTENTS

Hand-Holding the Camera 140
Focusing 142
- Manual Focus 142
- Depth of Field 142
- Visual Acuity 142
- Sensor Size 142
- Print Viewing Distance 144
- Hyperfocal Focusing 144
- Computerized Active Autofocus 145
- Computerized Passive Autofocus 145
- Phase Detection Autofocus 148
- Contrast Detection Autofocus 148

7A Light Metering for Exposure 149
- Spot Metering 150
- Matrix Metering 150
- Reflected Light Averaging Metering 150
- Reflected Light Spot Metering 151
- Incident Light Metering 151
- Multizone Metering 151

ISO 152
Lens Aperture 152
- Mathematics of F-Numbers 152
- Elements of Depth of Field 152

Shutter Speed 153
- Shutter Speed Rules 153

Exposure Compensation 154
Image Histogram 154
- If the Exposed Image Is Too Dark 156
- If the Exposed Image Is Too Light 156

RGB Histograms 156
Digital Zone System 157
- Determining Exposure 158
- Adding Dynamic Range 158
- Retaining Highlight Detail 159
- Film Quality versus Digital Quality 159

Conclusion 159

7B High Dynamic Range (HDR) 161
Histogram 161
Admissibility 162
Raw versus JPEG 162
HDR Imaging 162

HAND-HOLDING THE CAMERA

When photography was new, cameras were physically large, and light-sensitive media took a long time to expose. Then the use of a tripod was always necessary to produce images undistorted by camera movement. Over time, cameras became smaller, media became faster (more light sensitive), and tripods became less of a necessity. Currently, tripods are used for low-light photography; sports and action photography with long telephoto lenses; and time lapse, surveillance, copy-stand, and other related disciplines—but most general photography is accomplished with the camera hand-held. This has not necessarily been a good change.

Lightweight cameras are convenient to carry but are easily moved during exposure. Some of the newer point-and-shoot cameras focus by viewing an image on the rear viewing panel and must be held away from the body during exposure (see Figure 7.1), often with one hand. The farther away from the photographer's body the camera is held, the more significant the chance of moving the camera during exposure. It may be impossible to discern if an image is out of focus when reviewing it on such a tiny monitor. A small amount of camera movement will create a blurry image.

Some method must be practiced for holding the camera sufficiently still during exposure. Assuming a constant sensitivity of media, camera shutters stay open longer to achieve proper exposure when the light level is low in intensity. When the shutter is open for an extended period, camera movement is more likely to occur unless the camera has been placed on a stable platform. The use of a telephoto lens or the telephoto position of a zoom lens also may require the use of a stable camera platform of the image. The magnification and narrower field of a telephoto lens make it more difficult to hold the camera steady during exposure. The same thing happens when a viewer looks through a telescope or binoculars.

Using a tripod is one way to diminish camera movement if the tripod is sufficiently heavy to support the weight of the camera and its accessories. Extra-heavy tripods should be used on windy days.



FIGURE 7.1 This is the way many point-and-shoot cameras are held during normal photography.

(From Sandy Weiss/Packer Engineering.)



FIGURE 7.2 This is a *proper* hand-holding method to support and operate a DSLR camera, especially with a longer lens.

(From Sandy Weiss/Packer Engineering.)

All modern cameras are designed to be held primarily in the photographer's right hand. The forefinger should be positioned above the shutter release, and the other three fingers should wrap around and hold the front of the camera. The right thumb should be placed firmly on the top of the back of the camera. Many cameras have a rubberized grip to indicate where the photographer's fingers should rest for maximum efficiency. The thumb should be positioned to easily operate the camera's rear dial. If this orientation is difficult for left-handed photographers, they may consider performing right-hand exercises to strengthen hand muscles.

TIP:

Always hold a camera firmly—but not so firmly the muscles of the hand jerk during shutter release.

The positioning of the left hand depends upon the camera. The wrist should be flexed with the palm up to support the weight of the lens or the camera (see Figure 7.2), depending upon which is heavier. The left hand is used for focusing and for zooming the lens when necessary. A digital single lens reflex (DSLR) camera should never be held by putting both hands on the sides of the camera body during exposure (see Figure 7.3).

When using the viewfinder of a point-and-shoot camera, keep the camera close to your eye during exposure so you can utilize the additional stability of your arms and legs (see Figure 7.4). If using the liquid crystal display (LCD) panel to focus, keep the camera as close as possible to the eye to enable review of the image display on the LCD (usually 10 to 12 inches) (see Figure 7.5). It may be difficult to hold very small cameras and keep your fingers out of the way of the lens, flash, and sensors during exposure.

Some point-and-shoot cameras have built-in electronic antishake or image stabilization (IS) systems. Consider



FIGURE 7.3 This is an *improper* hand-holding method to support and operate a DSLR camera.

(From Sandy Weiss/Packer Engineering.)



FIGURE 7.4 This is a *proper* hand-holding method to support and operate a point-and-shoot camera when focusing through the viewfinder.

(From Sandy Weiss/Packer Engineering.)



FIGURE 7.5 This is a proper hand-holding method to support and operate a point-and-shoot camera when focusing on the LCD.

(From Sandy Weiss/Packer Engineering.)

the purchase of a camera with one of these systems if your point-and-shoot photographs are often blurry. Image stabilization in cameras or lenses enables sharper photographs by damping vibration.

When using a slower shutter speed, if possible, lean against a solid object when making exposures. Take a deep breath, hold it, let some of the air out, and then release the shutter. The photographer must concentrate on keeping his or her body as still as possible when releasing the shutter of a camera. Maintaining the proper body position can make a positive difference. Keep your elbows tucked in and either lie down with your elbows resting on the ground or sit up with your elbows resting on the knees. Make a tripod out of your body using your elbows as two legs. Keeping your muscles relaxed is necessary to reduce camera movement during exposure.

The choice of shutter speed must be made with consideration for the subject, whether moving or stationary. Sharpness may be increased in any case by using faster shutter speeds. With a normal lens and a handheld camera, a shutter speed slower than 1/250 second may produce (surprisingly) less than a completely sharp image.[1]

The photographer's heart is always beating and may contribute to camera movement, especially during extended handheld exposures. Use of the optimum shutter speed and aperture combination allows the use of the shortest shutter speed.

TIP:

- For practice, tape the switch of a laser pointer in the on position and tape the pointer on a camera. Point the camera at a wall and try to hold the camera as steady as possible during an exposure. With practice, the movement of the bright dot should define smaller and smaller circles of movement.

  Always wear a camera strap on the neck or the wrist. This may not help to keep images in focus, but it will prevent the camera from being dropped and damaged.

  If possible, obtain a rubber eyecup for the viewfinder of the DSLR. This will make the camera more comfortable to use, especially for eyeglass wearers. Also, by pressing the camera against your eye during exposure, you will have an extra point of contact, which will provide additional support and steadiness.
- When hand-holding the camera, select a shutter speed that is approximately the reciprocal of the focal length of the lens in use. This will help prevent blurring due to camera movement. For example, when using a 300 mm lens, the shutter speed should be set no slower than 1/250 second. Always set the next speed faster, not slower, than the numeric value of the focal length.

Lenses can be effectively longer in focal length and narrower in field of view (the extent of the observable world at any given moment) when used on digital cameras than they would be when used on film cameras. This is due to the crop factor of the smaller digital image sensors. Inherently, the same lens is more difficult to hand-hold and use to capture sharp images on a digital camera than it would be on a film camera.

These recommendations are pertinent only if the photographer is deciding on the shutter speed used to expose the photographs. Keeping the camera set on fully automatic is convenient but may yield improperly focused photographs if the subject or camera is moving during exposure.

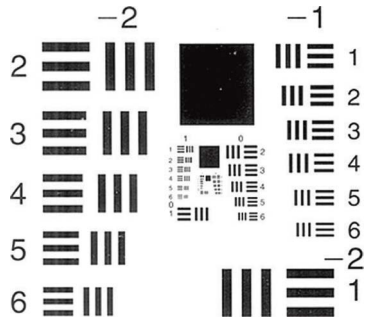


FIGURE 7.6 A chart of line pairs of different sizes.

(From Sandy Weiss/Packer Engineering.)

FOCUSING

Manual Focus

Until recently professional cameras, both range finder and single lens reflex (SLR), primarily utilized manual focusing. The design and operation of their focusing systems were meant to optimize fast and accurate operation. In manual focusing range-finder cameras, the image of the subject is normally seen through two separate windows on the top of the camera. When the lens is properly focused, the two images are superimposed.

In manual-focusing SLR cameras, a mirror behind the lens reflects the image of the subject to a pentaprism. The pentaprism rectifies and intensifies the image before it is projected onto a focusing screen. The screen is often made of ground glass or ground glass with a focusing aid, such as a microprism or split image.

Focusing aids are used to improve the accuracy of focusing and to generate sharper images. They are useful only with lenses at large maximum aperture. They may appear black to the photographer's eye and be useless or detrimental if the lens used has a small maximum aperture or if lens attachments are used, diminishing the quantity of transmitted light.

As a lens turns, the beam of light it transmits is focused and judged in the viewfinder by the photographer. The SLR design allows the camera to focus through any lens attached to it. This design has been used in film cameras for many years, and most photographers are experienced and comfortable with its use.

Depth of Field

In evidence photography, there is never a good reason to minimize the depth of field (DoF) of an image. The range of distances over which an image is acceptably sharp is one of the most important factors for the evidence photographer to learn to maximize for accurate evidence documentation.

Consider a circle to be a point with an opening in the center. If a point is not in sharp focus, the open center will be visible to the viewer. The circle of confusion (CoC) is the fuzziest a point can be and still be called "in focus." CoC quantified is the largest circle in an image to be perceived as a point rather than a circle when the image is enlarged to 8 × 10 inches and viewed from a distance of 2 to 3 feet.

If quantification of the DoF is necessary, the photographer must be able to calculate the largest CoC perceived as a dot, or in acceptable focus, in the finished image. The circle of least confusion also is the smallest dot a lens is capable of producing.

Visual Acuity

For most people with reasonable uncorrected or corrected vision, the closest comfortable distance for viewing a printed image is approximately 10 inches (25 cm). At that distance, a person can normally resolve an image of 5 line pairs per millimeter (lp/mm) (see Figure 7.6), which equates to a CoC of 0.2 mm on a printed image.

RULE:

The maximum CoC size at which a printed image will be perceived as sharp overall when viewed at about 10 inches is 0.2 mm.

Sensor Size

Using the image sensor size of a digital camera as a parameter when choosing which to buy is a decision filled with trade-offs. The focal length multiplier is a mathematical term relating the focal length of a lens used on a sub-35 mm digital sensor to the focal-length lens producing an equivalent angle of view on a full-size 35 mm sensor. This multiplier is equal to the crop factor.

For example, a Nikon D70s has an image sensor with the physical dimensions of 23.7 mm × 15.6 mm (3008 × 2000 pixels). Its crop factor is 1.5× compared to a full-frame 35 mm sensor or film.

A 50 mm lens used on an image sensor with a 1.6× crop factor, such as the Canon Rebel XT, will capture an image with the same field of view as an 80 mm lens (1.6 × 50) used on a 35 mm full-frame sensor (see Figure 7.7).



FIGURE 7.7 The same focal-length lens captures two different fields of view as the sensor size changes. **(From Sandy Weiss/Packer Engineering.)**

RULE:

The physical focal length of a lens does not change when it is used on cameras with different size sensors, but its effective focal length and angle of view does.

If the same lens is used on a DSLR with a sub-35 mm sensor and a 35 mm film camera body and the resultant 35 mm film image is cropped to yield the same field of view as the digital image, the DoF in the two images will be identical.

If the same lens is used on a DSLR with a sub-35 mm sensor and a 35 mm film camera body and the same subject is photographed from two different distances so the field of view is the same in both images, the DSLR image will exhibit 1.6× more DoF than the film image.

When photographing the same subject, filling the frame, and using the same aperture on the same lens, DoF decreases as sensor size increases. The larger the sensor, the closer the camera must be to the subject to fill the frame with the subject when using the same lens. If the distance from camera to subject is constant, a lens with a longer focal length must be used on a camera with a larger sensor to fill the frame with the subject.

When using the same lens on cameras with larger sensors and the field of view is constant, a higher-number (smaller) lens aperture must be used to maintain the same DoF.

On a DSLR with an image sensor having a 1.5× crop factor, a lens of 1.5× the focal length and 1.5× the aperture number must be used to capture an image with the same visual perspective and DoF on a camera with a full-frame 35 mm sensor. For example, an image taken with a Nikon D70s and a 20 mm lens set at *f*/8 must be exposed on a 35 mm film camera with a 35 mm lens set at *f*/11 (the next available aperture).

Larger image sensors are usually constructed with physically larger pixels. Due to their higher capacity for the capture of light, sensors with larger pixels may produce images with less noise and greater dynamic range than sensors with smaller pixels.

DoF is reduced when photographs are made using sensors of larger size, when all other factors remain constant. However, the use of smaller apertures is possible with larger sensors without the image reaching CoC size and subsequently appearing out of focus.

TIP:

DoF is inversely proportional to format size. Format size is inversely proportional to the focal-length multiplier. The higher the multiplier, the smaller the format and the greater the DoF.

RULE:

If print size is constant, angle of view is constant, lens aperture is constant, and the image sensor size is halved, DoF will be doubled.

Print Viewing Distance

Human eyes do not zoom. Humans perceive the perspective of a scene at only one magnification unless they move physically closer or farther away. It is not reasonable to assume that camera lenses will capture images of a visual scene at the same magnification as human vision. The magnification of a given scene will also change when the image is printed in different sizes.

The most comfortable distance for the viewing of printed images is 14 to 15 inches from the eye. This is considered the normal viewing distance of prints for people with reasonable uncorrected or corrected vision. To ensure images are viewed without perspective distortion, divide 14 by the focal length (in inches) of the lens used to make the image, then multiply the result by the crop factor for the sensor, and then enlarge the image to the resultant number. This formula works only when the image file is not cropped, as in the following example for a 50 mm lens on a Nikon D70s:

$$50\,\text{mm} = 2\,\text{inches}$$

$$2 \times 1.5 = 3$$

$$14/3 = \text{about 5 inches}$$

Print the image to 5 inches wide and view it at 14 inches to represent proper perspective. If the viewing distance is doubled, the dimensions are doubled, and the surface area must be quadrupled.

A print larger than 8 × 10 inches enlarged from an uncropped file must be viewed at a distance greater than 25 cm to represent proper perspective. When viewing prints from farther than optimum distances, it may be possible to use an image file yielding CoC values larger than 0.2 mm because the human eye is unable to differentiate the circle from a dot at the larger distance.

When printing from a digital image file, if the file measures 8 × 10 inches at any resolution and the final print measures 8 × 10 inches, there is no enlargement. The CoC requirement for this print is therefore the same as the original image file. If a 35 mm image is enlarged to 8 × 10 inches, the enlargement factor is 8×, making the CoC requirement for the original image on the negative 0.2 mm divided by 8, or 0.025 mm.

How sharp does an 8 × 10 print need to be to look sharp at a viewing distance of 14 inches? How large can a point on the print be before it looks like a small disk rather than a point? A typical value is about 250 microns, 0.25 mm, or 0.001 inch.

Conversions

$$1\,\text{micron} = 0.001\,\text{millimeter}$$

$$1\,\text{millimeter} = 0.0393700787\,\text{inch}$$

Question: Assume the diameter of a dot is a 250-micron spot on an 8 × 10 print. What size is the dot in the original image (negative or digital file)?

Answer: It depends on the final magnification needed of the original image to achieve the 8 × 10 print.

For example: When enlarging a 35 mm negative (24 mm × 36 mm) to an 8 × 10, the file must be magnified by a factor of about 8. The size dot on the negative that would yield a 250-micron spot on the print is 250/8 microns, or about 30 microns. This is the CoC value for this print. It is the largest spot in the original image file that looks like a point in the print. The minimum requirement for the quantification of acceptable 35 mm DoF calculations is often 30 to 35 microns. Any CoC larger than 35 microns in any area of a finished print made from a 35 mm negative will be considered out of acceptable focus.

RULE:

Proper viewing distance in inches for any print is equal to the focal length of the camera lens in inches times the enlargement factor of the print.

If the print is then enlarged to a larger size or is viewed at a shorter (closer) distance, a proportionally smaller CoC is necessary for the appearance of sharpness.

Viewing distance of a print
= Focal length of taking lens × enlargement

Hyperfocal Focusing

If a lens has manual focusing controls, it may include DoF indicator points or lines to calculate the approximate range in which the subject and its surroundings will appear acceptably

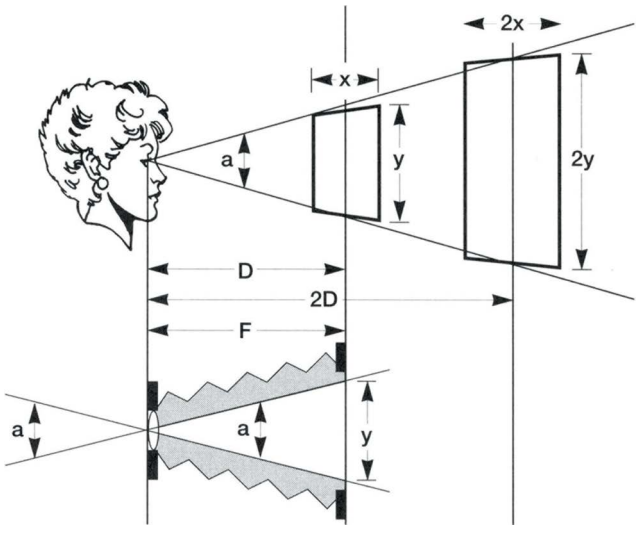


FIGURE 7.8 The ideal distance for viewing a print made with a lens with a normal focal length is the focal length of the lens times the degree of enlargement of the image file.

(From Sandy Weiss/Packer Engineering.)



FIGURE 7.9 A manual-focusing zoom lens from a 35 mm camera.

(From Sandy Weiss/Packer Engineering.)

sharp when the lens is focused at a given distance and set at a given aperture. In the image of the older zoom lens (see Figure 7.9), the lines slanting in toward the center above the aperture ring are the hyperfocal focus indicator lines. On a fixed focal-length lens, the slanting lines are absent. On a zoom lens, DoF varies with focal length, so the lines need to vary as the lens is zoomed. When the lens is set at a longer (telephoto) position, DoF is narrower or compressed.

To judge the DoF of the finished photograph before exposing the image, do the following:

- Determine the lens aperture appropriate for a given exposure. (In this case the lens was set at *f*/8.)
- On the DoF ring, each aperture number appears twice, once on either side of center. (In this case the *f*/8 indicators are interpolated because not enough room was available to stencil them in.)
- Left of center, the *f*/8 line would appear between *f*/5.6 and *f*/11. Right of center, the line would be about where the red R appears.
- If the following are true:
  - The image was exposed at *f*/8
  - The focal length was set at about 95 mm
  - The lens was focused sharply on the subject

The indicators show that everything in the image between about 35 feet and almost to infinity should appear sharp (with sufficiently small CoC) in the finished image.

Computerized Active Autofocus

Some autofocus point-and-shoot cameras have eliminated controls to allow convenient manual focus or manual focus altogether, and that has made manual focus difficult, inaccurate, or impossible. Some manufacturers have substituted scrolling devices for lens focusing, usually controlled by switches on the back or top of the camera. Optical viewfinders are usually small and do not include such focus aids as split images or microprisms. In most cases, the camera allows the photographer to preview the image on an LCD preview/review panel, essentially making these cameras true through-the-lens (TTL) focusing cameras. LCD panels are difficult or impossible to see under many conditions, especially when the ambient lighting is bright. Also, the display image is small and may lead to a misleading impression of sharpness.

The inexpensive point-and-shoot digital cameras usually have active autofocus systems. The correct focusing distance is determined when the camera projects a beam of light, usually infrared, onto the subject. Some systems measure the distance to the subject by quantifying the reflectivity of the returning beam, others calculate the lag time before its return, and others rely simply on triangulation.

If the camera has an infrared focusing system, it is critical to keep the emitter/sensor clean and unobstructed during exposure. Exposing photographs through glass (windows, windshields, and display cases) is difficult with this system, and sharper images may be obtained under these conditions if the camera is able to be focused manually.

Extraneous objects in the frame may cause the camera to focus on the wrong place or in the wrong plane. Consider the image of the goat in the bushes in Figure 7.10. An active autofocus system may focus on the bushes rather than the goat. This would cause the goat to be either out of focus or improperly exposed if the camera focus controls the flash output. If the camera has a spot-focusing capability, set the spot on the part of the scene of utmost importance before exposure of the image. Insufficient lighting or lack of image contrast is not a problem with this type of focusing system.

Computerized Passive Autofocus

The passive autofocus system used in some DSLR cameras judges the camera-to-subject distance by analyzing the contrast of the image. Before the camera will make an exposure, the onboard computer examines the scene and signals a small motor to focus the lens until the scene is determined to be focused optimally. Some lenses are built with manual focus override so the photographer is able to also focus manually.

The autofocus sensors are located on the camera's image sensor. They provide the necessary data to compute the contrast of adjacent pixels in the image. The autofocus section of the sensor is usually a strip of specialized pixels, whose location is selected by the photographer when setting the area of autofocus for the image. Light from the scene is evaluated by the autofocus strip, and the onboard computer compares the values, pixel to pixel.



FIGURE 7.10 This is an underexposure caused by an autofocus camera focusing on the wrong part of the subject. The head of the goat was the intended subject, but the camera focused on the bushes, yielding the underexposed image with a flash.

(From Sandy Weiss/Packer Engineering.)

The computer examines the pixel values and judges the difference in intensity between adjacent pixels. If the scene exposes out of focus (see Figure 7.11), adjacent pixels will have had similar intensities. The computer then refocuses the lens, reevaluates the strip, and determines if the difference in intensity between adjacent pixels is now higher or lower. The computer calculates the point where the difference between adjacent pixels is the greatest (see Figure 7.12). This is considered to be the point of optimal focus.

Accurate passive focus requires sufficient ambient lighting and image contrast. If the camera attempts to focus on a scene of all one color or low in intensity (low in contrast or just dark), the camera may not focus and will refuse to expose an image if it is set on autofocus. Some cameras contain and utilize autofocus assist lamps to illuminate the subject in low light. These lamps can help if the subject is close to the camera. (In the Nikon D70s, the beam works up to a distance of 3 meters.) The minimum and maximum autofocus distance limits for passive autofocus are determined by the choice of lens, not by any limitations inherent in the computer system.

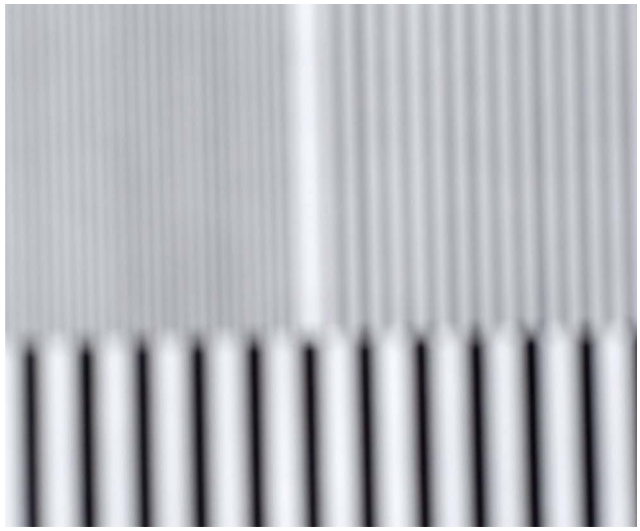


FIGURE 7.11 This image of a test strip is out of focus. Pixel intensities are similar across the strip.

(From Sandy Weiss/Packer Engineering.)

Passive focusing works best when scenes include vertical detail, like the vertical focusing target pictured in Figure 7.13. If the camera is turned in a vertical orientation, making the vertical detail horizontal, the camera may be more challenged to determine the proper focus. Some cameras contain both vertical and horizontal focus sensors to alleviate this difficulty.

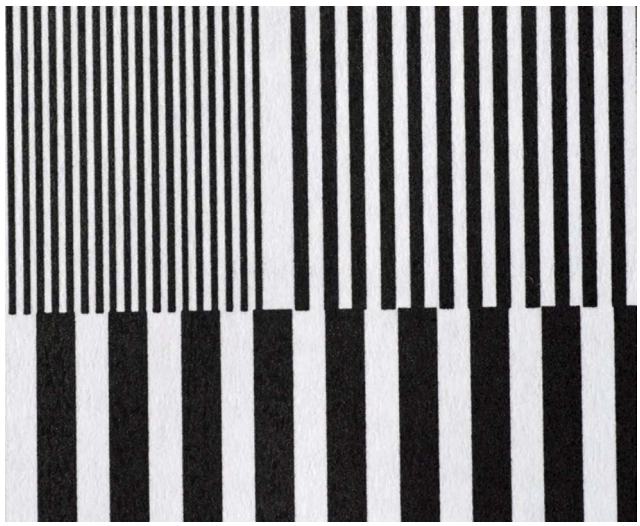


FIGURE 7.12 This image of a test strip is in focus. Pixel intensities are different from pixel to pixel across the strip.

(From Sandy Weiss/Packer Engineering.)

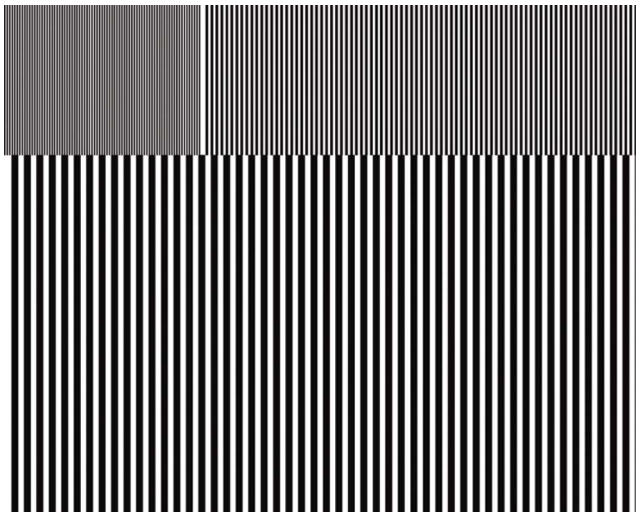


FIGURE 7.13 Representative test target with its bars in a vertical orientation.

(From Sandy Weiss/Packer Engineering.)

TIP:

If focus accuracy is in question in any digital camera focusing situation, check the image on the LCD panel after exposure. If the camera has an LCD magnification option, zoom in to magnify the image. This will enable finer evaluation of the small test image.

When using passive autofocus with a DSLR, the onboard computer evaluates the focus of the scene and then sends a signal to the lens motor, telling it which way and how much to turn. If the scene is then evaluated as sharp, the camera will expose the image. If the scene is evaluated as not sharp, the computer will make the lens focus again. Some autofocus lenses have manual focus rings, and some do not. The Nikon 70-300G zoom (see Figure 7.14) is strictly autofocus.

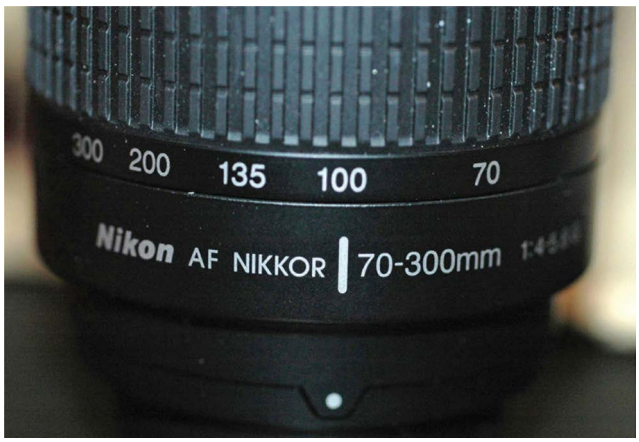


FIGURE 7.14 This Nikkor 70-300G zoom lens has no manual focus control.

(From Sandy Weiss/Packer Engineering.)



FIGURE 7.15 This Nikkor 18-70 zoom lens has manual focus override.

(From Sandy Weiss/Packer Engineering.)

Some original equipment manufacturers (OEMs) market lenses of this type to allow photographers the option of purchasing medium-length zoom lenses for very low prices. The Nikkor 18-70 zoom (see Figure 7.15) was the default on the D70 and D70s. It was low priced, sharp, and efficient for many situations. It has manual override of the focus but not of the apertures. The Nikkor 60 mm macro lens (see Figure 7.16) is intended for professional use. The price is high, but the lens is high quality in every way. Because it is designed for critical professional use and DoF is an important factor during macrophotography, both the focus and aperture controls can be overridden manually.



FIGURE 7.16 This Nikkor 60 mm macro lens has full manual override, including settable lens apertures equivalent to a 90 mm micro lens on a Nikon DSLR with smaller than a 1:1 sensor.

(From Sandy Weiss/Packer Engineering.)

The two types of autofocus systems in use in more modern digital cameras are:

- Phase detection
- Contrast detection

Phase Detection Autofocus

Phase detection is perhaps the better method for use in most applications, especially when using the camera in video format.

Phase detection is able to determine when a subject is in focus and when an out-of-focus subject in the frame is behind or in front of the main subject. This allows the camera to tell the lens which direction to turn the focusing ring to bring the borderline subjects into focus.

In phase detection, an image is split by a prism. If the focus ring is in the correct position, the split images will form a continuous image. Conversely, the images will be split apart if the whole image is not properly focused. This system is faster when done by the camera's computer.

This focusing method is much faster than trying to detect where the contrast edge is the hardest. When a digital camera says it has "425 phase detection points," it means there are 425 places on the sensor where it can compare the split images. Because the sensor knows which split image is which, it knows precisely in which direction and how much to move the focus motor to bring the split image together. DSLRs use an actual prism to split the image onto the focus sensor, while mirrorless cameras do this directly on the sensor. The technology is more expensive and in a DSLR adds a little more weight.

Contrast Detection Autofocus

Contrast detection works by looking for contrast alone, as maximum contrast occurs when an image is in focus. While this technique can be just as accurate as phase detection for nonmoving subjects, it will generally be slower and less accurate for moving subjects, as it can only tell whether or not something is focused or defocused but not which direction it needs to move the lens. Contrast detection systems are known for focus "hunting," in which the lens turns from one end of the focus range to the other trying to find the area of most contrast.

Contrast detection is the simplest, most accurate method of camera autofocus. The camera compares the contrast between edges of object elements and moves the focus motor until the scene contrast is the best/sharpest. This is also how human vision works. With the camera and manual focus, we look at edges and move the focus ring until the edge contrast is the sharpest. We turn the ring quickly at first and then more slowly as the image comes into focus.

Contrast detection autofocus is the simplest, most accurate, and least complicated method to build into a camera system. But on the minus side, it is also the slowest. It may be inadequate for certain applications, especially when the focus distance changes quickly, as in a sports video.

7A Light Metering for Exposure

Sanford L. Weiss and Robert Wyman

Light metering involves using a device to determine the optimum amount of light necessary for the photographic equipment to capture an image of a given subject with the qualities of reasonable and appropriate contrast and density. Understanding light metering is a necessary and recommended practice to improve photographic results.

Handheld photographic meters used for judging exposure perform metering by measuring reflected or incident light. The intensity of the reflected light is defined as the subject luminance.

The earliest light meters were extinction meters. They used a series of neutral-density filters of increasing densities as a reference for judging appropriate exposure. The meters were not very accurate, but the film media was very slow (low ISO), and mistakes in light determination were compensated for by long exposure times. These meters depended on the light sensitivity of the photographer's eye to determine which was the proper filter reference.

Later meters were developed using selenium, cadmium sulfide (CdS), and silicon photosensitive sensors. In time, the meters were miniaturized sufficiently to allow them to be added to small cameras.

Selenium and silicon photovoltaic sensors generate a voltage proportional to the amount of light affecting them. CdS light meters use a sensor based on photo resistance, and they require a battery. Most modern handheld and built-in light meters use silicon or CdS sensors. They indicate the suggested correct exposure either by the deflection of a needle galvanometer or by digital readout on an LCD screen. Point-and-shoot camera meters judge the exposure through the use of an onboard sensor.

The major breakthrough of metering accuracy was the ability of meters to measure the subject luminance through the lens (TTL). All modern DSLR cameras use TTL metering. Some TTL meters determine exposure automatically, and some work manually, suggesting the intensity of the subject luminance to the photographer. Automatic metering cameras set either the lens aperture or the shutter speed, or both. The meters that set both adjust to programmed parameters, setting the variables to where the onboard computer judges is correct exposure for the image.

Reflected light meters are designed and calibrated to yield the appropriate exposure for the luminance of "average" scenes. Difficult scenes with high or low contrast may yield either underexposed or overexposed images due to the camera meter being affected by large areas of too-bright highlights or too-dark shadows (see Figure 7.17). It is recommended to meter high-contrast scenes off of an 18% gray card placed in the same illumination as the subject. This will yield an exposure very close to average for the scene and should place the highlights and shadows safely within the imaging capabilities of the camera sensor and media.



FIGURE 7.17 This image was metered using the overall luminance of the scene and was exposed improperly because of the high-contrast lighting. This resulted in a photograph with underexposed, flat shadows.

(From Sandy Weiss/Packer Engineering.)

For safety and accuracy, many experienced photographers and motion picture cinematographers use handheld incident-light meters to measure the light falling on various parts of the scene (illuminance), thus avoiding the exposure mistakes easily made by inappropriate luminance readings on subject scene sections. Making incident light readings entails placing the meter at the subject's position and pointing the meter in the direction of the camera. If in doubt, exposing an image using the reading from the placement of the shadows (see Figure 7.18) is one possible way to produce an image with reasonable detail from its entire brightness range.



FIGURE 7.18 This image was metered only from the shadows of the scene and was exposed accordingly, yielding a photograph with good detail in the shadows and in the highlights.

(From Sandy Weiss/Packer Engineering.)



FIGURE 7.19 An early Pentax 1-degree spot meter.

(From Sandy Weiss/Packer Engineering.)

Spot Metering

Spot meters measure light reflected from subjects at a small angle (usually 1 to 10 degrees). Using a spot meter is one way to avoid underexposure or overexposure of images with high contrast. Sampling multiple light readings from the shadow, mid-tone, and highlight areas of a scene, a photographer combines the readings and uses the information to determine optimal exposure. The zone system developed by Ansel Adams is the seminal work on this metering method.

The photographer may also pick a tone in the subject similar to the tone of a gray card, determine its exposure with the meter, and use it to expose the whole image. This re-creates an 18% reflectance tone from that surface area. This exposure is then used as the correct exposure for a whole scene. This practice has a high probability of exposing images that capture reasonable highlight and shadow area details of almost any scene.

The Pentax spot meter was introduced in 1961 (see Figure 7.19). In-camera spot meters were introduced in 35 mm cameras in the 1980s. Most current professional-quality DSLRs include a spot metering option.

Matrix Metering

Most newer digital cameras have multisegment or matrix-metering system options to measure the luminance of different parts of a scene and use computer algorithms to combine the readings and determine optimal exposure.

TIP:

It is easy to fool the light-metering computers of automatic cameras. Even cameras that meter manually can be fooled if the photographer reads the luminance of the wrong portion of the subject. The photographer must watch for conditions where error is most likely to occur and learn how to prevent the occurrence of common exposure problems. If an automatic camera is allowed to function without input from the photographer, certain scenes may create exposures difficult or impossible to process and accurately represent the original scene.

The following are the different methods of TTL light metering:

- Reflected light averaging
- Reflected light spot
- Matrix

Reflected Light Averaging Metering

The amount of light admitted to the camera for exposure is controlled by two settings: shutter speed and lens aperture. The combination of these two settings determines how much light reaches the image sensor, and setting these variables correctly is the intended function of the camera metering system.

When metering a scene manually—and after setting the shutter speed of the camera at a level appropriate for the action of the subject or setting the lens aperture to predetermine the DoF—a light meter (see Figure 7.20) reading taken off a gray card or an appropriate area of the scene supplies the other variable. Then the photo is exposed.



FIGURE 7.20 This is a Gossen Luna-Pro exposure meter for reflected and incident light metering. Shutter speed and aperture combinations appear in exposure value (EV) numbers. Each EV number indicates a constant exposure obtained by utilizing an appropriate pair of shutter speeds and apertures. If the shutter speed is slower, the aperture is smaller. If the shutter speed is faster, the aperture is larger.

(From Sandy Weiss/Packer Engineering.)

A gray card reflects 18% of its luminance. All camera manufacturers calibrate their built-in light meters as if every scene reflected 18% of its luminance. When taking photos in the snow, for example, or where a large proportion of the scene is in shade, the scene does not reflect 18% of the light. Most scenes reflect more or less than 18%, and 18% is just an accepted average.

Using a Gray Card

1. Place the gray card in the same intensity of light falling on the main subject.
2. Meter off the card and use the shutter speed and lens aperture reading information the card yields to expose the photograph of the subject. This will guarantee at least the main subject of the photograph will be properly exposed. If no gray card is available, meter off a part of the scene appearing gray and use the information for the exposure of the whole scene.

Reflected Light Spot Metering

Some scenes do not have an illuminated area the photographer would call normal or 18%. In such situations, take a narrow-angle or close-up meter reading off the brightest part of the scene and a meter reading off the darkest part of the scene. Then set the camera for an exposure directly between the two readings and expose the image. This method will usually provide reasonable exposures and usable images across the whole range of subject brightnesses. This is equivalent to a very elementary zone system.

If the camera meter is allowed to register the entire scene when making photographs of interiors where a room is dark and the doors and windows are bright, the resultant image will be properly exposed for the windows and doors but not for the interior of the room (see Figure 7.21).



FIGURE 7.21 Interior of a room illuminated only by exterior daylight and metered for the exterior.

(From Sandy Weiss/Packer Engineering.)



FIGURE 7.22 Interior of a room metered for the interior.

(From Sandy Weiss/Packer Engineering.)

If the important part of the image is the room and not the windows, as it would be at a crime scene, allow the camera meter to register off an interior wall without a window. Maintain the same exposure reading to make the rest of the subject photographs. The windows and doors will be overly bright, but the room will be properly exposed (see Figure 7.22).

Incident Light Metering

Exposures may be metered by measuring the light falling onto the subject rather than the light reflected off it. This can be done by the use of an handheld incident meter with a translucent spherical attachment covering the meter cell. Incident light meters have some distinct advantages. The amount of light incident upon a scene is normally greater than the amount reflected from it. Therefore, incident light meters have a greater amount of light to measure, making the measurement more accurate in low-ambient lighting. Incident meters have a wide acceptance angle—the maximum cone half-angle for which incident light is captured by and will travel through the optical fiber—so the light does not have to be measured off a specific surface.

Multizone Metering

The default on many newer cameras is a multizone setting, where light is measured across the entire subject and averaged, regardless of the subject brightness range. This system produces reasonable images under most conditions.

When digital cameras set both the aperture and shutter speed automatically, the most common metering formula is matrix. The matrix is a collection of areas in the scene the camera measures and averages to calculate appropriate aperture and shutter speed settings. Sometimes the matrix is weighted at the center, and sometimes it is weighted at the bottom.

ISO

The light sensitivity of the imaging sensor is designated by its ISO number. Less light is necessary for proper exposure when higher ISO sensitivity is used. Higher ISO numbers are associated with low-light conditions or when action needs to be stopped by a short exposure.

RULE:

Images exposed at higher ISO numbers will generally exhibit coarser noise than those with lower ISO numbers.

LENS APERTURE

The lens aperture is the diameter of the opening through which light is admitted to the image sensor. Aperture is expressed as an f-number or f-stop. The lower the f-stop number, the larger the lens opening and the greater the amount of light admitted to the image sensor within a specific amount of time. Releasing the camera shutter allows light to pass through the lens aperture and expose the sensor, which creates an image.

RULE:

Each consecutive f-value represents double or half the amount of light.

Mathematics of F-Numbers

RULE:

The f-number (*f*/#) is the ratio of the focal length (L) of the lens to the diameter of the aperture (D).

Thus, a lens with a focal length of 50 mm and an aperture with a diameter of 25 mm has an f-number of 2.0, usually written as "*f*/2."

$$f = \frac{L}{D}$$

The largest possible aperture for a lens is observed when $D = L = f/1.0$.

It is common terminology to refer to the speed of a lens in terms of its maximum aperture. Thus, a 50 mm lens with a maximum aperture of *f*/1.4 would be a full f-stop faster than a 50 mm lens with a maximum aperture of *f*/2. The lens would be described as a 50 mm *f*/1.4 lens. A lens two full stops faster than an *f*/2 lens would be rated at *f*/1, the fastest possible lens speed for the focal length.

TIP:

Aperture affects DoF. If the goal of the image is to achieve the ultimate DoF in a photograph, it is best to use a slower shutter speed to adequately capture the action in front of the camera and allow, depending on the amount of illumination, the use of the smallest possible lens aperture.

Elements of Depth of Field

- *The lens opening:* The bigger the aperture, the shallower the DoF
- *The focal length of the lens:* The wider angle, the greater the DoF
- *The lens-to-subject distance:* The nearer the subject, the shallower the DoF

For times when it is necessary to visualize the DoF to exist in the final image before the image is exposed, some cameras have a DoF preview button allowing the photographer to see the image through the lens at the aperture the camera will use to expose the image (see Figure 7.23). The use of aperture priority automation entails selecting the aperture for a given exposure while allowing the camera to set the appropriate shutter speeds for optimum exposure.

When the focal length of a lens is divided by the f-stop number, the result is the diameter of the aperture. Lenses with longer focal lengths admit less light at the same aperture size than do shorter lenses. For example, a 50 mm lens using a 14.3 mm aperture diameter (*f*/3.5) will admit more

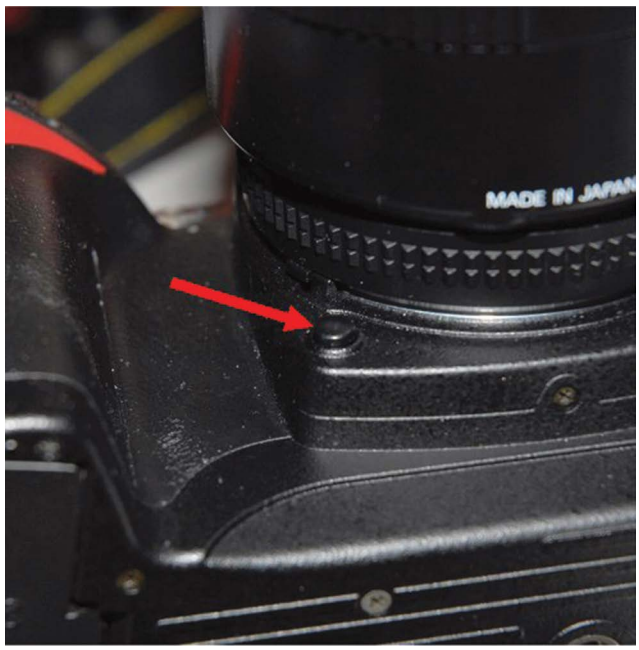


FIGURE 7.23 The DoF preview button on a Nikon D70s.

(From Sandy Weiss/Packer Engineering.)



FIGURE 7.24 An exposed image in which the axis of the object is parallel with the axis of the image plane.

(From Sandy Weiss/Packer Engineering.)

light than an 80 mm lens using the same 14.3 mm (*f*/5.6) aperture diameter.

- The same f-stop number will admit the same amount of light, regardless of the focal length of the lens.
- Where the axis of the object is parallel with the axis of the image plane (see Figure 7.24), exposed images will display the greatest overall sharpness by utilizing the inherent DoF.
- Where the axis of the object is perpendicular to the axis of the image plane (see Figure 7.25), exposed images will display the least DoF.
- The closer the camera is to the subject, the less the DoF (see Figure 7.26).



FIGURE 7.25 An exposed image in which the axis of the object is perpendicular to the axis of the image plane.

(From Sandy Weiss/Packer Engineering.)

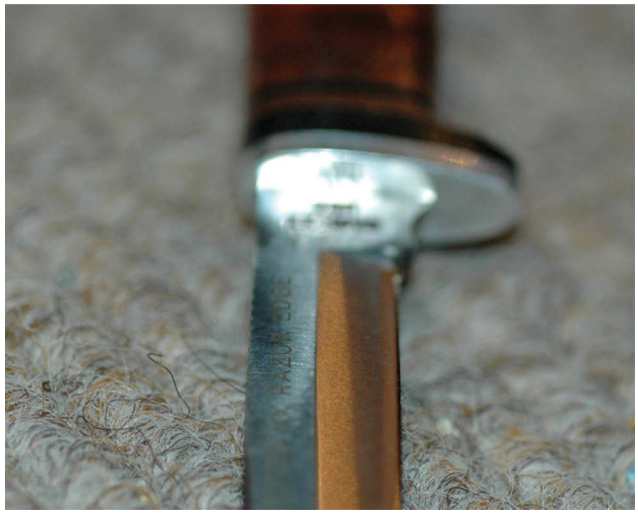


FIGURE 7.26 Close-up image with shallow DoF.

(From Sandy Weiss/Packer Engineering.)

SHUTTER SPEED

The shutter speed should be set to stop the action as required by the situation. The higher the number set, the faster (the smaller part of a second) the shutter speed will be. The lower the number set, the slower the shutter speed. The numbers on the shutter speed dial are the denominator of a fraction—for example, 500 stands for 1/500 second.

Shutter Speed Rules

- Most human motion can be stopped with a shutter speed of 1/250 of a second.
- Speeds faster than 1/250 second may be necessary to freeze the motion of fast-moving vehicles in a perpendicular plane.
- Speeds as slow as necessary for proper exposure may be used for stationary subjects.

TIP:

A camera support to reduce movement of the image will be needed at speeds of 1/30 of a second or less. (See Chapter 4 for information on tripods.)

Some cameras have shutter speed and aperture units referred to as *stops* or exposure values (EVs). Changing the EV by one full stop will either double or halve the amount of light exposing the media. The values used for correct exposure of any scene (shutter speed, aperture, and ISO) is infinitely variable.

Shutter priority automation entails selecting the shutter speed for a given situation while allowing the camera's metering system to select the appropriate aperture for

optimum exposure. Fully automatic and program automatic exposures entail allowing the camera to select both the aperture and the shutter speed for what it computes as the optimum exposure.

TIP:

A relationship exists between f-numbers, shutter speeds, and ISO. A change of ISO by a factor of 2 corresponds to a change in the f-number of one full stop. Therefore, doubling the film speed (in ISO units) decreases the necessary lens aperture or shortens the necessary shutter speed by one unit for an equivalent exposure.

EXPOSURE COMPENSATION

Many photographers desire to maintain camera meter automation while programming for intentional overexposure or underexposure in a particular photograph or group of photographs due to the contrast of the lighting. This meter adjustment may be accomplished by using the exposure compensation program of the camera. Exposure compensation allows all camera functions to work as originally designed, while a selected amount of exposure change is programmed into the metering system. This feature is usually available within all camera metering modes. If a particular metering mode or lighting situation consistently yields underexposed or overexposed images, an overexposure or underexposure compensation factor may be programmed into the metering process. Most cameras allow up to two stops of exposure compensation in quarter- or third-stop increments. The placement of the control for this function will be in different places on different cameras. Use the camera instruction manual to find the location for any specific camera.

Zero compensation is the default compensation setting in all cameras. Exposure compensation is often reset to zero or canceled when a camera is turned off.

IMAGE HISTOGRAM

Most digital cameras include an optional histogram display either in capture mode or in playback mode on the rear LCD screen. A histogram is a graphic representation used to judge the brightness range of an image. The graph includes a quantification of all the pixels in a digital image. The left side of the histogram shows how many dark pixels were captured, the right side shows how many light pixels, and the center shows the mid-tones. A total of 256 brightness levels exist between black (0) and white (255), and 18% gray reflectance has a numeric RGB value of 119, which is just below the 128 middle value giving the common name of middle gray. The vertical axis, the height of points on the graph, indicates how much of the image was exposed at any particular brightness level.

TIP:

When using an 18% gray card as a metering reference and exposing the image of a scene with the card, where the luminance value of the card is found in about the center of the histogram should allow the camera to capture the maximum dynamic range for any subject.

An accurate light meter reading suggests an exposure that will reproduce an 18% gray card in the scene as a mid-tone in the image. In reality, this setting is a compromise. The calculated exposure is intended to place the subject brightness range safely within the dynamic range capability of the image sensor. If the mid-tone values in the image fall about halfway between the darkest and the lightest values of the normal scene, all the values should be differentiable. This practice only works properly if the scene or object has a full range of tones. If the image is intended to be bright or dark for a particular reason, the position of the gray card on the histogram must be adjusted to the right or the left.

If a histogram indicates most of the pixels are in the dark zone, it is a bad exposure unless the subject was primarily dark. If the dark pixel peak is cut by the left edge of the graph, it indicates the image may be underexposed.

A histogram tending toward the left side of the graph does not necessarily indicate an underexposed image. The night image of the mall (see Figure 7.27) exposed with only a few point-light sources displays a histogram tending toward the left, but it is properly exposed. The dark peak does not touch the left side of the graph (see Figure 7.28).

The locomotive (see Figure 7.29) is a high-contrast scene with very few mid-tones. Its histogram display (see Figure 7.30) contains only two distinct peaks: one for the highlights and one for the shadows.

If a histogram indicates most of the pixels are in the highlight zone, it may be a bad exposure unless the scene



FIGURE 7.27 An intentionally dark image of an outside mall at night.

(From Sandy Weiss/Packer Engineering.)



FIGURE 7.28 Histogram of the mall image in Figure 7.27.

(From Sandy Weiss/Packer Engineering.)

contains primarily bright subjects (see Figures 7.31 and 7.32). If the pixel peak on the right is cut by the edge of the graph, it indicates the image may be overexposed.

If a histogram display shows most of the pixels are in the middle zone of the graph, it is only a proper exposure if it was a low-contrast scene (see Figures 7.33 and 7.34).

If the histogram indicates three distinct peaks, all inside the edges of the graph, it was probably what the camera would consider a normally illuminated scene (see Figures 7.35 and 7.36).

TIP:

If the camera does not include a histogram display, or the one in the camera is insufficient for detailed evaluation, a program such as Photoshop can provide a more detailed version.



FIGURE 7.29 An image of a steam locomotive exposed with the camera set on automatic exposure.

(From Sandy Weiss/Packer Engineering.)



FIGURE 7.30 Histogram with two distinct peaks.

(From Sandy Weiss/Packer Engineering.)



FIGURE 7.31 An image of a snow scene.

(From Sandy Weiss/Packer Engineering.)

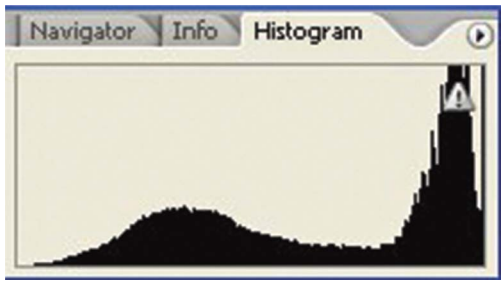


FIGURE 7.32 Histogram of the snow scene in Figure 7.31, another example of only two peaks.

(From Sandy Weiss/Packer Engineering.)



FIGURE 7.33 An image of Alcatraz Island.

(From Sandy Weiss/Packer Engineering.)

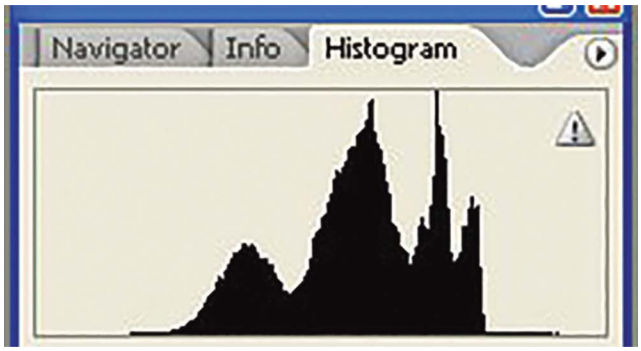


FIGURE 7.34 A histogram of the Alcatraz Island image in Figure 7.33, a low-contrast scene with peaks bunched in the center of the graph.

(From Sandy Weiss/Packer Engineering.)



FIGURE 7.35 What the camera would consider a normal photo with a full range of tones.

(From Sandy Weiss/Packer Engineering.)

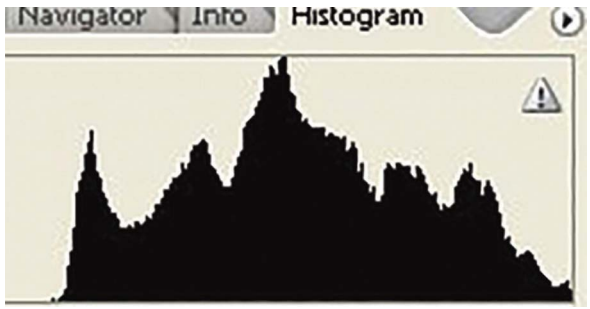


FIGURE 7.36 A histogram of a normal photo, indicating peaks for shadows, highlights, and mid-tones.

(From Sandy Weiss/Packer Engineering.)

If the Exposed Image Is Too Dark

In an underexposed image, most of the pixels will be toward the left side of the graph. If the pixels touch the left edge, the image is underexposed, with too many pixels in the shadows. The following should help you correct the exposure:

- **If the camera is set on fully automatic**, either Auto or Program, set a + (positive) exposure compensation.
- **If the camera is set in manual mode**, set a slower shutter speed and keep the same aperture, *or* select a larger aperture and keep the same shutter speed.
- **If the aperture is already at maximum**, set a higher ISO.

These operations instruct the camera to ignore the recommendations of the light meter and allow more light to reach the image sensor. The histogram must shift to the right.

If the Exposed Image Is Too Light

In an overexposed image, most of the pixels will be toward the right side of the graph. If the pixels touch the right edge, the image is overexposed, with too many pixels in the highlights. The following should help you correct that exposure:

- **If the camera is set on fully automatic**, either Auto or Program, set a – (negative) exposure compensation.
- **If the camera is set in manual mode**, set a faster shutter speed and keep the same aperture, or set a smaller aperture and keep the same shutter speed.
- **If the aperture is already at minimum**, set a lower ISO or use a polarizer or other neutral density filtration to reduce the quantity of light affecting the image sensor.

These operations instruct the camera to ignore the light meter and allow less light to reach the image sensor. The histogram must shift to the left.

RGB HISTOGRAMS

LCD image replays are often insufficient to properly evaluate exposure, especially in bright ambient illumination. Some cameras display an image histogram along with the thumbnail review image—the histogram may be the better choice for image evaluation.

In some newer cameras, especially DSLRs, a three-channel (red, green, blue [RGB]) histogram, showing a graph for each of the three colors, is available (see Figure 7.37). A three-channel histogram displays the full range of luminance values, from 0 to 255, for each color channel. RGB histograms are a more precise indicator of exposure because they show if the photograph is clipping any of the color channels at either end of the graph.

Clipping, or placing underexposed or overexposed pixels at the 0 or 255 levels on a color channel, may provide overexposed, flat highlights or nearly flat, black shadows.

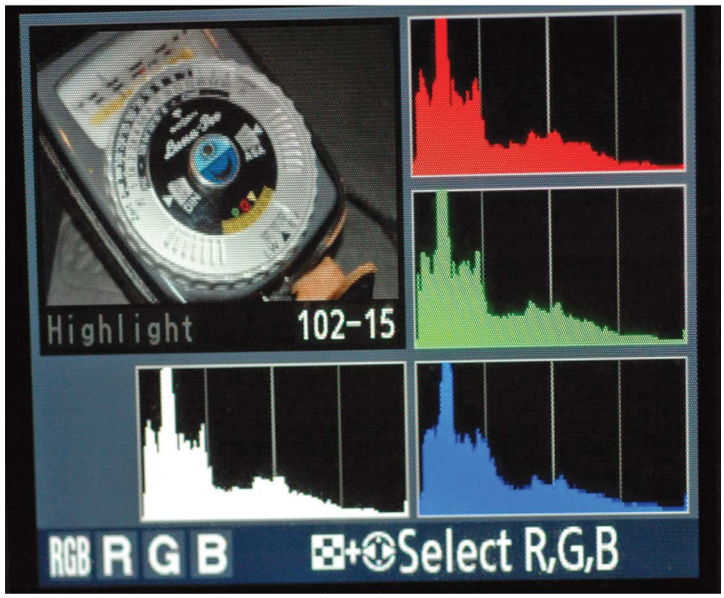


FIGURE 7.37 RGB histogram representation of an image of a Luna-pro exposure meter.

(From Sandy Weiss/Packer Engineering.)

When exposing raw files, the camera's built-in software must set a white point, black point, and midpoint to display the in-camera histogram for that image. Raw images have no white, black, or midpoint setting until they are opened in a raw converter. Therefore, the camera builds the in-camera histogram for raw images based on the parameters already set for JPEG images. When exposing in raw and using an aftermarket raw converter, check the in-camera histograms against the histograms for the same images in the raw converter to see if they are the same. If not, a manual change may be programmed into the converter.

DIGITAL ZONE SYSTEM

The zone system, which was made popular for black-and-white film by Ansel Adams, also applies to digital photography. The computer used for processing the images must meet the following criteria:

- It must be calibrated for black level, brightness, and contrast.
- The gamma of the computer monitor must be properly set. (In computer image processing, the term gamma refers to the relative brightness of the intermediate tones [grays].) Changing the value of the gamma affects the middle tones while leaving the white and black areas of the image unaltered. (Gamma should be set to 2.2 for Windows.)
- Color temperature should be set at 6,500 K (about the temperature of noon daylight sunshine on a clear day).
- Color quality should be 24 or 32 bits.
- Color balance should be set so a gray image looks gray and does not have a pink or yellow cast.
- Color space should be set at sRGB. (A color space indicates the color capabilities of a particular digital device or file. It represents what a camera can see, a monitor can display, a printer can print, etc. There are a variety of color spaces, such as RGB and cyan, magenta, yellow, black [CMYK].)

DSLRs may capture well-exposed images with dynamic ranges up to 9 or 10 f-stops, which is comparable to film negatives and better than film positives. The dynamic range of a subject or scene is the measurement of the range of light intensities from the highlights to the shadows. In brightly lit conditions the dynamic range is the difference between the lightest and the darkest part of the subject; if the scene is like Figure 7.35, the range is wide. The wider the range, the less the exposure latitude. In other words, the more brightly lit the scene, the more difficult it is to capture a well-exposed image where the highlights and/or the shadows are not clipped. In dimly lit conditions, the dynamic range is low and there is much more exposure latitude.

All exposure meters are calibrated to set all scenes with a middle gray tonal value of about Zone V. When a scene is very bright—for example, a snow scene—and the meter reading suggested by the camera meter is used, the snow will appear middle gray in the unprocessed image and will be underexposed. If the scene is very dark—for example, a night scene—and the suggested meter reading is used, the unprocessed image will be overexposed, making the night look brighter.

Ansel Adams's zone system, if properly used, helps the photographer visualize the final image by determining a correlation between portions of the scene and tones in its representation. Adams would meter, expose, and develop

a negative according to how he visualized it would eventually look. His basic rule was "Expose for the shadows; develop for the highlights," which works for negatives but not very well for digital imaging. Digital images are essentially positives, so they must be exposed like film positives, not negatives, to avoid losing detail in the image highlights.

TIP:

In post processing programs, details in shadows *MAY* be recoverable. Details obscured in highlights are lost and *NOT* recoverable.

In the digital zone system, the photographer is not required to process film. Exposure with the camera is the variable factor for capturing images with extended tonality.

In the digital zone system (see Figure 7.38):

- The eight steps between the nine zones represent a luminance range of 256.
- Zone V corresponds to middle gray of 18% reflectance.
- As with film positives, overexposure in digital files results in images with flat, white highlights.

In digital photography, the photographer is able to do the following with image processing software:

- Correct color
- Adjust contrast

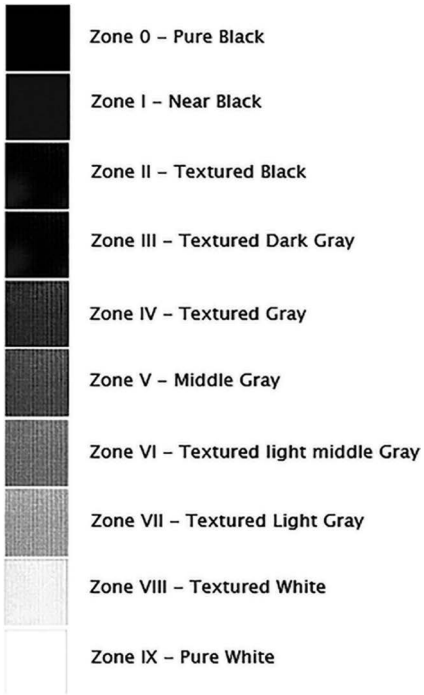


FIGURE 7.38

Determining Exposure

The first step of the digital zone system is to visualize how specific areas of the scene should appear in the final image. Then select an area of the scene, meter it with a spot meter, and then adjust the camera exposure in stops or partial stops by the difference between the zone you want the specific zone to occupy in the final image and Zone V (middle gray).

The second step is to figure out how to determine the region to meter. The correct choice should be the light shadows, not the deep ones. Make a test exposure and look at its histogram to be sure its highlights are not touching the edge of its graph.

The third step is setting the proper exposure.

The final step is to examine the histogram of the image, both in and out of the camera. If the images are underexposed, it may be necessary to decrease the ISO speed setting. If they are overexposed, it may be necessary to increase the ISO setting. If the histogram looks proper for the imaged scene, the result will contain the maximum possible dynamic range of the subject.

Adding Dynamic Range

Digital images may be produced with too many pixels in the highlights or shadows when they are exposed in less-than-optimum lighting. Some cameras provide the option to display the highlights overexposed in the image by their blinking on the LCD. Even if an exposure is correct and not overexposed, blinking highlights may be displayed, depending on the situation. It may mean the highlights in those areas will not contain any noticeable texture. That particular area will have a pixel value greater than or equal to 255.

At times, a pure white area (Zone IX or X) is proper for an image. The evidence photographer should always attempt to create exposures with a dynamic range as close as possible to fitting within the dynamic range capability of the camera sensor. In some situations, it is not possible. Ansel Adams mentions full-range prints with areas of shadow and highlight with no detail—but only when they should be that way. Having a pure black and a pure white in an image may be absolutely accurate (see Figure 7.39).

An image may exhibit a complete range of tones, as well as the extremes of black and white, to properly display a scene. The amounts of pure white and solid black may be small, but when either one or both of these extremes appear, they are used to provide the viewer with a visual key to the dynamic range of the representation.

In digital images, the highlights can reach a value of 255 and can never become any brighter. An overexposed digital image has a peak on the right side of its histogram, with the peak touching the right edge of the graph.

The R, G, and B channels in a digital image are exposed independently unless the subject is neutral gray, white, and black. This means one color channel may maximize before the others. This makes single-channel histograms difficult to read when color issues are present. When one channel has maximized at 255, the other channels may retain contrast capability. In cameras with differences among the



FIGURE 7.39 An image of a shuttle launch. This scene has totally flat, white highlights, but that is the way it actually looked.

(From Jimmy Brown.)

capabilities of the R, G, and B channels, it may lead to hue shifts in the final captured image.

Retaining Highlight Detail

If highlight detail is being lost, set the exposure compensation in the camera for intentional underexposure and lighten the image gradually in postprocessing. If desired, expose a series of images of the same scene with the camera on a tripod. One exposure should be at –2.0 EV, then one at normal, and then one at +2.0 EV. The images must stack perfectly on top of each other. Combine the images in Photoshop to bring the best parts of each exposure into the final result. (See the chapter on HDR that follows.) When the processing is completed, the resultant image will display lower contrast but higher dynamic range than the image exposed normally. This process is widely accepted by digital photographers. However, it may be difficult to explain in court, so be extra careful to document all steps and save all original image files.

Other techniques may be used to expand the dynamic range of images when that range is insufficient in nature.

Film Quality versus Digital Quality

The dynamic range capability of an image taken from a modern professional DSLR is equal to or better than those made from scans of ISO 100 negatives or transparencies on a Kodak film scanner. A modern Kodak digital film scanner converts 35 mm, 126, 110, Super 8, and 8 mm film negatives and/or transparencies to JPEG images of 14/22MP, a good size for most any purpose. The images have high levels of scan quality, color rendition, dynamic range, and overall control.

Remember, though, a film scanner creates a second-generation image. The first generation is the film image created by the camera. The second generation is the image being reproduced on the scanner charge coupled device (CCD). Digital camera images are always first generation, no matter how many times the digital file is duplicated. With each succeeding generation, the possibilities and probabilities exist for noticeable depreciation of image quality.

Factors causing image depreciation include the following:

- Light dispersion in the film emulsion during exposure
- Blurred effect at the edges of a highlight area of a photograph caused by reflection of light passing through the film (halation)
- Lack of critical film plane flatness in the film scanner
- Film grain aliasing during scanning
- Digital noise incurred during scanning
- Scanner lens and focusing issues
- Inaccurate color interpretation by the film dyes or by the scanner
- Dust and contrast control

RULE:

Film has low resolving power in low-contrast situations.

Modern digital camera technology has nearly eliminated noise artifacts in DSLRs. ISO 400 and 800 images are comparable to or better than the same ISO images on film.

CONCLUSION

A camera, like any other tool, must be properly used to yield optimum results. Many modern cameras are electronic, automatic, and user friendly. In many cases, this is a very good thing, but it also may lead to complacence from the photographer. The camera is purchased and the box opened, battery and memory are installed, and when the camera is switched on, it accompanies the photographer into the field and immediately yields good-to-decent images. It is far easier today to go from absolutely nothing to a reasonable something without reading instructions or asking for help. When this happens, the level of competence of the user immediately levels at a plateau of adequacy and will stay there until a situation arises that cannot be handled by the user's level of competence.

This is never more evident than when it involves intuitive actions such as holding, focusing, and metering with a camera. The manufacturer designs the camera to be ergonomically comfortable, so why should the user need to concentrate

on a specific protocol for best results? Focusing is done automatically, so why should the user need to learn how to do it manually? Hand-holding a camera to capture in-focus images may be compared to the operation of a high-powered rifle (see Figure 7.40). Without using appropriate precautions and accessories, it is difficult or impossible to achieve accuracy.

Metering is the easiest photographic operation of all. Just turn on the camera, set it at fully automatic, and the camera takes care of everything, doesn't it? This chapter takes those incredibly simple, intuitive operations of our modern do-everything automatic cameras and makes them more difficult. It instructs the user about how to take the camera off automatic and do the settings manually to improve the finished images.



FIGURE 7.40 Use of proper position and accessories increases accuracy with a firearm and with a camera.

(From Christopher Cali.)

CASE STUDY: NEVER TAKE ANYTHING FOR GRANTED

I taught photography at West Chicago High School for five wonderful years. For those of you who have not taught, I highly recommend it. It is the ultimate learning experience and one of the best possible ways to make a lasting impression upon the world.

My classes were limited to 25 students per semester because our darkroom only contained five enlargers and class was five days a week. Everyone had one hour per week of darkroom time in which to complete their assignments.

The pedagogy was to teach everything the students needed to progress from the idea of an image to a finished image. The curriculum started with photographic history and ended with theory. Everyone who did not own their own camera was loaned a 35 m SLR camera to use for the whole semester. The students viewed demonstrations of loading film in cassettes, loading film on reels, processing, enlarging, and image presentation. Everyone loaded their own film from bulk loaders.

Each student prepared a weekly assignment involving locating, planning, photographing, processing, and printing a single image of a subject of their choosing to fulfill the weekly assignment. A written paper explaining their image and how their idea evolved, what they thought they did right or wrong, and what they learned was also required. There were no right or wrong answers or ideas.

Normally, the semester's work started slowly but gained speed with proficiency. Usually, by the second week nobody ended up with a blank roll of film. All necessary adjustments were routinely made, and the students' first images were produced. By the end of the semester, the submitted images were well exposed and printed, and the explanatory papers were well written and intelligent.

One young lady experienced failure after failure, week after week, with her photographs. I watched her film processing and printing, and her technique was fine. Her camera exposures were fine. The main problem with her work was all her images were consistently out of focus. I checked her camera and exposed and processed a test roll myself, and it was fine. I let her try again, only to see her again disappointed.

I decided to accompany her on an excursion to make images. We did everything together; I was hoping to determine the problem through observation. We loaded the film together. We loaded the camera together. We walked the school grounds together. I watched her make exposures. Her stance was fine. Her shutter release was smooth and comfortable. We took the film into the lab and processed it. Again, it was hopelessly out of focus.

I was stumped. I sat and discussed all the steps and conditions with her until we finally solved the problem: **she was neglecting to focus the lens** before she exposed her photographs. I asked her, "Why have you been making photographs without focusing?" Her answer was simply, "Well, you never told us to!"

The truth of the matter is, she was absolutely right. After all my years teaching and all the students I'd taught, it never occurred to me anyone would not know they had to focus the lens.

I learned a lesson from this event. Since then I have never taken **anything** for granted. Now I try to put myself into my students' positions and ask myself when writing instructions, "Have I included enough information to curtail any possible confusion?" That event made me a better teacher.

You, too, can learn from your mistakes. Each should occur only once.

7B High Dynamic Range (HDR)

Sanford L. Weiss and Arthur Borchers

Photography cannot be accomplished without illumination. Thus, the key variable in any photograph, even more than composition, is the type and amount of lighting used to create the image. A subject in total darkness cannot be photographed by visible light, no matter how hard the photographer tries. If the image is being exposed by just the ambient visible light, there must be some illumination, and some contrast, to capture the image. If there is even the slightest illumination and contrast, a shutter speed of sufficient length, an aperture of sufficient circumference, and an ISO speed set to sufficient sensitivity on the camera, this will allow an image of the subject in question to be captured in sufficient detail to discern most or all of the subject elements.

Dynamic range is the difference between the brightest and darkest areas in a photograph. Most DSLR cameras have a dynamic range capability of 11 to 13 stops. A stop, from f-stop, is also called an EV and has a precise relationship with the others. Each full-value increment is exactly double or half of the original (i.e., ISO 400 is twice as sensitive as ISO 200; 1/500 is half the shutter speed of 1/250; and *f*/8 allows half the amount of light as *f*/5.6).

The contrast of the subject may be compressed if the illumination level is low. In a situation like this, most any camera with manual settings may be used to capture the image with no problem or worry on the part of the photographer about the dynamic range of the subject image being beyond the capabilities of the camera. There is no black, there is no white, and most probably no colors—only relative shades of gray. Once successfully captured, the image made by the camera should be easily printed by a printer with a normal dynamic-range output capability, or the image may be seen on a monitor or projected by a normal projector with no issues of image detail loss due to being too dark or too bright.

Now, consider a subject in the other end of the illumination scale, where the given subject has almost too much illumination. The lighting of a midday sun can be so bright, the dynamic range of the subject so wide, that it may be difficult to capture an image of the subject and retain full detail in both its brightest highlights and darkest shadows. Situations like this may also arise when using artificial illumination like electronic flash at a fire scene or on a roadway at night. It is quite possible for parts of the scene to be black and others to be white. The problems arising in this case in capturing an image with full detail at both ends of the illumination scale may be because the scene is beyond the capabilities of the equipment or the scene is beyond the capabilities of the photographer.

Every part of the imaging process has its own limitations and capabilities. The camera may certainly be out of its depth when capturing images at a fire scene in bright sunshine. If the digital images do capture the whole dynamic range of the subject, the printer used to make reflective images of the subject may not have the dynamic range capabilities to output images without constricting the true dynamic range of the subject. There is no possibility for the printer to print a white brighter than the color of the paper being used to make the prints. There is no possibility for the printer to print a black blacker than the maximum blackness designed into its capabilities. Even if everything is working properly up to this point, every time an image is shared, there is the possibility of a link in the imaging process of someone else's lab may not have sufficient capabilities to output images being an accurate representation of the subject in question.

So, this is the important question: Will the final image be accurate? Is the dynamic range of the image being submitted an accurate representation of the original subject? It is up to the photographer as the first link in the imaging chain to do everything possible to capture images of the subject to be taken into court and be testified to as the best and most accurate representations of the original subjects possible to be captured.

HISTOGRAM

In what ways may the photographer ensure success in capturing accurate images? The first and simplest aid to accuracy is the use of the image histogram. This graph of the dynamic range of the photograph is easily accessible with any camera that has manual settings. Consider the histogram to be a graphic representation in Cartesian coordinates of the captured image. Every time an image is made, the accompanying histogram is available to be viewed as a menu option. The bright pixels of the image are graphed on the right side of the X-axis and the dark on the left. Everything in between is the representation of the mid-tones. Each peak in the histogram on the Y-axis is a graphic representation of the number of pixels of that particular brightness in the captured image. If an image is captured of a subject in bright sunshine or with highly reflective white subject elements and the graph of its pixels on the right side does not rest at zero at the Y-axis, it means the highlight detail of the subject is incomplete, or clipped, in the photographic representation. Conversely, if the graph of the dark pixels on the left side is not at zero at the Y-axis, it means the shadow detail of the image is clipped. Either way, the image is not complete and therefore not totally accurate.

One way to attempt greater accuracy is to take a light meter reading in the subject illumination off of an 18% gray card and use that reading as the midpoint of a manual exposure. But even after this routine, it is still possible to capture images with clipped details in the shadows, the highlights, or both.

Is there a way to ensure the optimum capture of dynamic range in any photograph under any lighting situation? This is where HDR imaging takes over from straight photography.

ADMISSIBILITY

When images are brought to court—civil or criminal—the party entering them into evidence must show they are relevant to the issue at hand and tend to prove or disprove a material fact in the case (e.g., the existence of skid marks or lack thereof.) Someone who was present at the scene (not necessarily the photographer) must authenticate the photograph fairly and accurately represents the conditions, person, or scene it depicts. Each photograph introduced must be authenticated, sometimes ad nauseum. Questions about who took the photo, how it was taken, and other matters generally do not go towards admissibility questions unless some special technique was used, such as HDR, focus stacking, or infrared or ultraviolet lighting. In those situations, the person applying the specialized technique must testify to the basis of the technique to show it is reliable.

A photographer must be cognizant when a digital photograph does not fit the traditional definition of an original photograph. In the film days, an "original" image was the result of light being allowed to shine on a layer or layers of sensitive silver crystals bonded to a media like acetate or glass. Then the image was developed by chemical processes, revealing a positive or negative duplicate of the focused light image allowed through the lens. If reflective prints were necessary, copies could be made by photographing the original negatives or prints and chemically processing the duplicates the same as the first.

A digital photograph starts in the same way, where a focused light image strikes a digital sensor replacing the film. The sensor measures the color value and intensity of the light falling on a grid of tiny picture elements (pixels) numbering in the millions (megapixels) and are considered a measure of camera quality as the number of pixels increases. The sensor then sends the information to the camera's microprocessor, which then writes all the image's information to a file on a memory device, such as a Secure Digital (SD) or CompactFlash (CF) card. The file name relates to the sequential order in which the image was taken and is written following exchangeable image file format (EXIF) rules agreed upon by camera manufacturers. The EXIF format includes metadata about each photograph, including camera information, exposure data, and even global positioning system (GPS) coordinates. The file extension, such as JPG, will designate the rules followed in creating the image and how the data file was decoded and viewed as an image on a computer screen or printed on paper. The traditional piece of film, which could be held in a hand and viewed by holding it up to a light source, no longer exists. The data file should be transferred to secure storage media as soon as possible. The major difference between digital- and silver-based photography is that the original data file, once moved from the memory card to a hard drive, is still considered an original. Pains must be taken not to modify the original image file, so generally any postprocessing work is done on a "working copy." A copy of a digital photo does not require a new photo to be taken, just a *copy* and *paste* command on a computer.

Raw versus JPEG

What's the difference? All digital cameras capture raw images then internally process the images according to the settings on the camera. These settings include white balance, saturation, contrast, sharpening, and color. The final setting applied is quality, which compresses the color values from 12-bit (4096) increments per color channel to 8-bit (256) increments per color channel and squeezes the double-digit megapixel resolution of the camera's sensor down to an image grid of 4352 pixels by 3268 pixels or smaller. This reduction in resolution may be perfectly adequate for day-to-day photographs, but when faced with challenging lighting or situations where detail is critical, keeping the raw image becomes necessary.

Be warned, a raw image is significantly larger in size than even a very high-quality JPEG. Agency standard operating procedure (SOP) should address both the use of raw images and their storage. For example, JPEGs may be stored on a secure photo drive, but raw images may be saved to CD-R or DVD and inventoried separately. Raw images are generally proprietary to the camera maker (Nikon's "NEF" or Canon's "CR2" formats). Adobe Systems has proposed a digital negative (DNG) standard, but it has not been as well received as their Portable Document Format (PDF).

HDR IMAGING

HDR photography has its origination in artistic photography but has true value for evidentiary purposes. In the early days of film photography, the tonal range of the printed images produced was normally extremely limited. In the 1850s, Gustave LeGray used two negatives to capture a seascape: one for the sky and a second longer exposure for the water to present an image to mimic the luminance levels seen by the eye. Later, Ansel Adams used special film exposure, developing techniques, and

selective print exposure methods called dodging and burning to expand the tonal range of prints produced. However, color photography eliminated most of the creative darkroom techniques used with black-and-white film and prints. Color-film manufacturers designed new films with increased range and sensitivities. When digital imaging started, Adobe Systems created Photoshop and later Lightroom software packages used to manipulate digital images. Those who may be hesitant to use or accept any form of photo editing should be aware that the **International Association of Identification** approves of the practice, with the caveat stating that any manipulation of an image be done on a working copy of the original image and any process be documented so it is repeatable and the results consistent if someone else tries to replicate the modifications.

IMPORTANT:

In HDR photography, only the shutter speed is adjusted between exposures in order to maintain a constant depth of field across the captured images.

HDR photos are usually captured with the camera mounted on a tripod to minimize movement between exposures. Visible movement within the images is called "ghosting." If the image contains plants or water, some movement is inevitable. The available software packages typically compensate for ghosting by taking object outline information from the image with the fastest shutter speed to freeze movement and fill in tonal information taken from the other exposures.

The major software tools for HDR imaging are Photoshop (Adobe Systems), Photomatix (HDRsoft), and Aurora (Skylum). Note: Aurora has previously been a Macintosh-only program, but the Aurora HDR 2018 iteration is also being released for Windows. All three programs are capable of producing court-ready images. Some HDR photo modifications are so extreme as to be almost unrecognizable when compared to the original. But any forensic image needs to be faithful to the original scene. The technician needs to be ethical and knowledgeable about any manipulations and modifications. A good example of a lack of ethics is that it is possible to enhance specific colors like reds in a bloody photo to increase the shock effect.

The important part of the process is to know when the image to be captured will not work as desired. This knowledge is only obtainable through study and practice. If the image highlights are too blown out or the shadows too flat, that is a good opportunity for HDR to assist. Modern DSLR cameras typically have an Autoexposure Bracket (AEB) function to automatically take three, five, or even seven bracketed photographs in sequence with an exposure difference the photographer defines. For three exposures, ±2-stops is usually sufficient. If the camera does not have AEB, then it is necessary to switch to manual mode, determine the correct average exposure for the scene, and take the first photo. Then input a 2-stop faster shutter speed for the second exposure and a 2-stop slower shutter speed for the third. The manual method will certainly take more time and likely have camera movement, so a tripod will be a necessity. Use of a single photo to produce an HDR image from a normal image is possible but not necessarily prudent. After all, image details that do not exist in the original are normally not possible to display with enough difference to the original image just by selective manipulation of the same image.

The image samples for this chapter were taken in the Chicago Transit Authority's LaSalle Street Blue Line station and show part of the track crossover. The exposures were made at ISO 3200 with a Canon G1X camera. Figures 7.41 to 7.43 were captured with a ±2 stop AEB at *f*/8 with shutter speeds of 1/5, 1/20, and 8/10 seconds with both raw and JPEG files created simultaneously.

In order to convert the images in Photoshop, the three images were selected together in Adobe Bridge and the *Tools > Photoshop > Merge to HDR Pro* command selected. The



FIGURE 7.41 This is the standard, normal exposure. **(From A. Borchers.)**

images were then sent to Photoshop, where they were converted to individual layers and the *Remove Ghosts* checkbox was clicked. None of the options to modify the image tone were selected, and the OK button was clicked. The resulting HDR image was saved and is shown in Figure 7.44.

In Photomatix, the same three files were selected in the workflow window. Then the *HDR Merge* options were selected: alignment and cropping with allowance for handheld, perspective correction, noise, and chromatic aberration reduction. Figures 7.45 and 7.46 are two rendered samples demonstrating basic presets, the first with "Detailed" and the second with "Natural."

Next, another image was created using the newly released Aurora HDR 2018 from the three raw files, with minor tweaking of color and sharpness (Figure 7.47).

You will note the inclusion of the signal lights at the right and the full second alcove at the left. These were cropped out by the camera's 13:9 image setting for the JPEG, but the entire 4:3 image was still recorded in the raw version. No color correction was made. Many photographers do not shoot in raw, as the file size is so much larger the JPEG. Raw format 12- to 14-bit color is reduced to 8-bit during JPG processing. The color bit depth loss can result in a brightness loss of 32 to 256 times.

The time involved in creating a final image is minimal, but the benefits of HDR imaging can be substantial. This section previously published in *Evidence Technology Magazine* V15N4 #23.



FIGURE 7.43 This is the +2-stop exposure clearly showing camera shake.

(From A. Borchers.)



FIGURE 7.42 This is the –2-stop exposure.

(From A. Borchers.)



FIGURE 7.44 Some ghosting is still visible in the signs at the right, but overall, there is more detail visible in the shadow areas.

(From A. Borchers.)





FIGURES 7.45 AND 7.46 Two output samples.

(From A. Borchers.)



FIGURE 7.47 Aurora HDR output from raw originals.

(From A. Borchers.)

NOTE

1. Adams, Ansel, *The Camera,* Boston, Little, Brown, 1980, p. 116.



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8 Photography in Technical Investigations

John M. Fildes

CONTENTS

Introduction 167
Perspective 168
Color Rendition 170
Tonal Rendition 174
Texture 175
Computational Photography 176
The Photography Market and Market-Driven Technologies 177
Conclusion 178
Note 178

INTRODUCTION

Technical investigations as discussed herein encompass research and development (R&D); insurance; and litigation-related legal, scientific, and engineering investigations. Photography is used in these cases to document experimental setups, results, and field conditions. The essential requirement of the photographic images in these uses is accurate depiction of what is in the scenes.

This chapter presents an experience-based look at the practical uses of forensic photography in technical investigations and the digital imaging issues involved in these uses.

Technical investigations involve many science and engineering disciplines and encompass a wide spectrum of functions, including fundamental research, applied research, product development, industrial problem solving, customer and marketing support, and insurance and litigation-related investigations of accidents and product failures. Technical investigations occur in controlled laboratory environments and in the uncontrolled conditions of the field. Although the uses of photography differ across this wide landscape of technical issues, the uses generally fall under a much smaller number of intended functions, primarily including the documentation of experimental and test procedures, experimental and test results, accident scenes, and the appearance of product failures. Accurate depictions of the overall contents of any scene are the essential photographic goals in these situations. Less frequently, photography is also used as part of the experimental and investigative process for making measurements of the incremental timing of events and the construction of 3-D models.

Most researchers and technical investigators utilize photography in one or more of many types, but few are professionally trained or accredited in the process of forensic photography.

Forensic photography is a specialized field of knowledge requiring extensive training and deep understanding for credentialing.

Technical investigators are users of photography, not necessarily photo enthusiasts. They use photography by necessity and may have little interest in understanding the discipline other than to the degree needed to perform their particular purposes. That is why there is little discussion in this chapter of issues that dominated the transition from film to digital photography—things including increased noise as ISO is raised, dynamic range, tonal range, image capture rates, electronic viewfinder quality, autofocus speed, accuracy, and low-light performance. The reason these issues are not discussed here is they are no longer issues. Digital cameras currently have no significant limitations for use in all technical investigations (and in most types of recreational photography). Most digital still cameras today also offer video capture capabilities. The pixel count and arrangement of modern imaging sensors allow much larger prints to be made with higher quality than could be achieved with some medium format film cameras. Even consumer-grade fixed lens digital cameras with small sensors are very capable. With the addition of live view with histograms and focus aids, modern digital cameras meet the needs of virtually every technical investigator.

Current digital imaging technology in general is not the main point of this chapter, because the purpose of forensic photography for technical investigators is fundamentally different from imaging performed by the gamut between professional commercial photographers and consumers. The camera manufacturer's emphasis, due to obvious financial concerns, is mainly on providing the most people the best quality and appearance of first-generation camera-made images, whereas technical photographers simply require accurate depictions of scenes. The issues remaining for technical investigators in using photography are caused by optics, physics, and photographic techniques, not equipment, although equipment may contribute complexity to the proceedings.

To begin, we shall identify the four essential issues facing technical investigators in attempting forensic photography. They transcend the current state of photographic hardware. They existed in the film era too, continue to exist in the digital era, and will likely exist long into the future. Digital camera technology has in some cases provided new tools to address these issues, and more improvements may be expected in the future. But these improved tools do not and will not eliminate the four basic issues. They can create new aspects for these issues needing to be understood. These four issues exist because forensic photography is conducted by technical investigators with technology-based consumer products:

- Depiction of perspective
- Color rendition
- Tonal rendition
- Depiction of texture

These four factors provide a framework delineating the photographic issues technical investigators normally face and discuss practical ways to overcome them.

PERSPECTIVE

The transition to digital photography did nothing to alter how perspective is conveyed by a 2-D image. This is because perspective is determined solely by the physics of optics. Perspective is a function of the field of view of the lens and the distance from the lens to the nearest plane of the scene. Digital photography utilizes a variety of sensor sizes, which are the digital version of film formats, and we assume many people do not understand how sensor size relates to perspective.

Perspective is important in technical investigations whenever the investigator needs a depiction of the spatial relationship of objects in a scene. Perspective allows a 2-D image to provide the **brain clues** from which a 3-D image is created, thus denoting the **spatial relationship of objects**. Examples of where accurate perspective depictions are important include accident and failure sites such as stairways; sidewalks; swimming pool aprons; roadway intersections; and large structures like aircraft, buildings, roadways, and bridges. Although we may include a tape measure(s) for scale to help clue the spatial relationship of a scene, it is also important for the image to depict a reasonable facsimile of the pre-incident or new spatial relationships. It is simple to overlook adequate keys to the depiction of perspective. For example, is one tape measure enough? There are usually artifacts in all three axes—X, Y, and Z—unless the photograph shows a roadway surface or similar flat surface, in which case only two are fine.

The film or sensor size, lens focal length, and distance from the lens to the front X-Y plane of the scene being imaged determine perspective. A focal-length lens range of 35 mm to 50 mm on a full-frame sensor camera provides images with a perspective approximating normal human vision. This means photographing with a 35 mm to 50 mm lens on a full frame digital camera provides images with the same relative sizes of objects in the foreground of the scene relative to the size of objects in the background of the scene, as one would normally perceive them in human vision. This allows our brains to perceive if the objects in the foreground are close or far from those in the background. This is why 50 mm lenses were a mainstay of technical investigators and forensic photographers in the film era, the same as they are now in the digital.

Although we could standardize the use of 50 mm lenses on full frame cameras to achieve this accurate depiction of perspective in 2-D images, there are many compelling reasons not to. We sometimes need to include a wider field of view of the scene and cannot stand back far enough to use a 50 mm lens. A lens with a focal length less than 50 mm, for example 24 mm or wider, could be used with a full frame camera in this situation.

In documenting field conditions when space limitations exist and a field of view wider than normal is necessary and crucial, the use of a wide-angle lens, such as 24 mm or shorter on a full frame digital camera, is an attractive option and is able to be positioned near the front X,Y plane of the scene. But this combination produces substantial perspective distortion. Wider or longer focal-length lenses will cause a noticeable change in the size of the objects in a photograph and either shrink or expand the field of view of images, thus causing a shift in the apparent perspective.

The farther away the focal length moves, up or down from 50 mm, especially in the down (wide-angle) direction where a few millimeters can appreciably change the field of view, and the closer the lens is to the front plane of the scene, the more will be the amount of distortion of perspective. Distortion of perspective means the relative sizes of objects in the foreground and background of an image will make our brains perceive distances between the foreground and background objects closer or farther than actuality. Think of what it may say on the sideview mirror of your automobile. The car manufacturer uses a mirror bent in a concave manner and writes upon it, "Objects in mirror may be closer than they appear." This is exactly the same principle as what happens to perspective when taking photographs with a wide-angle lens.

Another common situation producing substantial perspective distortion is macro photography. A moderate-to-high magnification lens that can focus up close may reduce the minimum focal distance. Use of a 50 mm macro lens for higher magnifications may require the front of the lens to be within just inches from the subject. A telephoto lens with macro capabilities may allow several more inches of separation but distinctly less magnification. The extra separation may be necessary for safety reasons.

Cameras with sensors smaller than full frame can offer attractive advantages for technical photographers and

investigators. Smaller sensors allow cameras and lenses to be smaller, lighter, and less expensive. Smaller sensors enable the creation of very capable fixed lens cameras, some with zoom lenses covering wide angle through moderate to long telephoto focal lengths and may even include close focusing capability. This combination of capabilities is very attractive but not possible with full frame cameras.

Some of the small sensor cameras produce 1:2 (half-life-size) or 1:1 (life-size) magnification ratios in very small and affordable packages. These cameras are often seen at inspections. Their small size allows them to be held above the head, or low to the ground, or placed into walls and other cavities to document plumbing, structures, water intrusion, mold, etc.

The variety of sensor sizes in common use today require the investigator to understand how sensor size affects the focal length approximating the perspective of normal vision and also the focal lengths at which appreciable perspective distortion could occur, especially if the camera is placed close to the front X,Y plane of the scene.

The straightforward way to think of the effect of sensor size relative to perspective is to understand the critical parameter for perspective distortion related to sensor size and lens focal length, which is the field of view.

The field of view is determined by the combination of the image sensor size and the lens focal length. As the sensor size changes, the focal length of the lens may be changed to maintain a constant perspective, or not. For example, by maintaining the field of view of a 50 mm lens, a constant perspective is retained as long as the sensor size is constant. Digital sensor sizes are described in Table 8.1.

TIP:

Try an experiment with your hardware arsenal. Take two photos of the same subject from the same distance in front of the X,Y axis with two different sensor sized cameras and the same focal-length lens. Be certain to include a legible scale in the frame of both images. Process both images and display them, not resized, on your computer screen. The first thing that will be obvious is the main subject and field of view of both images will display as different sizes.

TABLE 8.1
Crop Factors

Crop Factor = 1.0	1.5 and 1.6	2.0	2.7	4.6	6.0
50 mm	35 mm	24 mm	18 mm	11 mm	8 mm

The image of the subject will be smaller on the screen when taken with a smaller camera and smaller image sensor. When you enlarge images to a fixed size subject from what is captured by different-sized sensors, the images from the smaller sensors need to be enlarged more to result in subjects of the same size. When you put the same lens on different cameras with different-sized sensors, the lens put on the camera with the smaller sensor is said to have a larger equivalent lens size or longer focal length.

Table 8.1 shows the approximate focal length necessary to maintain the field of view of a 50 mm lens on a full frame digital camera, and therefore maintain the same approximate perspective of human vision.

The next thing to understand is that a sensor smaller than full frame crops the resultant field of view by the ratio of the full frame sensor's diagonal to the diagonal of the smaller sensor. The smaller the sensor relative to a full frame sensor, the larger the ratio. This ratio is well known for all common sensor sizes, and these values were used to create Table 8.1.

- APS-C sensors have a crop factor of 1.6 for Canon and 1.5 for cameras other than Canon.
- Micro four-thirds cameras have a ratio of 2.0
- 1-inch sensor cameras have a ratio of 2.7
- 1/1.7-inch sensors have a crop factor of 4.6
- 1/2.5-inch sensors have a crop factor of 6.0

These last two sensors are typically found in consumer-grade fixed lens digital cameras, also called "point and shoots." These cameras are popular with technical investigators and the general public because of their small size, low cost, and close focus distances providing good macro capabilities.

A small sensor crops the image field of view in the same way a telephoto lens does on any camera. Using the crop factor allows a mathematical computation of the focal length necessary to provide the same field of view on a small sensor as does a full frame lens on a full-frame sensor. The field of view for various lens and sensor size combinations are readily found tabulated online, as are the crop factors. The general formula is:

(Lens FL for equivalent FOV on smaller sensor)
= (Lens FL used on the larger sensor)/
(Smaller sensor crop factor)

where:
FL = Lens focal length in millimeters
FOV = Image field of view in degrees

For example, a 50 mm lens on a full frame sensor camera has a FOV of 46.8 degrees diagonally. For APC-S, the crop factor is 1.5 for other than Canon cameras, so the focal length providing an approximately 47 degrees FOV with the APC-S sensor equivalent to the 50 mm lens on the full frame camera is 50 mm/1.5 = 33.3 mm. Use of either of

these focal lengths with their respective sensor size will produce images with a similar perspective.

TIP:

To maintain a perspective approximately equivalent to human vision when needed:

- Use a 50 mm lens on a camera with a full frame digital sensor.
- Use a focal length of 50 mm / (sensor crop factor) for sensors smaller than full frame.
- When the situation dictates using a wider field of view lens, move the lens as far back from the front plane of the scene as is practical.
- When none of these are possible, recognize perspective distortion will occur to an increasing degree as the focal lengths deviate more from these guidelines, especially as the distance between the lens and the front plane of the scene decreases and for use of wider-angle lenses.
- In any case, if proper perspective is important, perspective distortion should be visually characterized and noted.

COLOR RENDITION

Accurate color rendition is not always essential in technical investigations or forensic imaging but can be important in cases involving degradation of materials. For example, a color change may at times provide clues to the degree(s) of degradation. Organic materials such as adhesives can be degraded by curing at too high a temperature and/or by exposure to excessively high temperatures during use or repair procedures. Many applications for polymers also require high color accuracy, deviations from which may be the subject of an investigation to determine if a manufacturing deviation caused the color shift. Some chemical laboratory tests produce a color change needing to be accurately documented as part of an investigation.

The limits of digital imaging sensors are not the primary source of deviation from high color fidelity. The photographer's selection of using a JPEG image format; the photographer's understanding of the physics of light, such as how light interacts with objects and how the spectrum of light differs from various sources; and the photographer's understanding of color management during image processing cause far larger deviations in color fidelity than do the performance of the imaging sensor and imaging pipeline. Nonetheless, we will start with a brief description of the imaging sensor to demonstrate it is not inherently unable to capture accurate color fidelity.

IMPORTANT:

The transition from film to digital imaging improved the inherent accuracy of color rendition. Color films depended on a number of factors, including the sophisticated dye chemistry used to achieve accurate and precise color rendition. Post-manufacture storage factors of color films, depending upon duration and ambient temperatures, would and could cause certain color shifts to begin in film stock, making accurate eventual rendition all but impossible across the full spectrum of positive colors. Even mixing rolls or sheets of film from different manufacturing runs on the same project opens the accuracy of color rendition to question.

Then there was the processing of the exposed negatives or positives. The processing itself was or is the first time the film would be completely open and receptive to a broad range of factors causing color shifts in the future positive images. Any multistep process involving the aspects of time, temperature, concentration, agitation, and aging is an absolute nightmare to maintain in control. That is why any automated processor will be checked for control accuracy at least once, and probably twice, per day. Even when the control checks as slightly off from a baseline, there is no guarantee the steps the operator takes to get back to base will actually work out.

Then there is the aspect of printing color negatives to paper positives. If no 18% gray target was included in any of the images, the person printing the images must look at the gamut of finished images and decide if they look visually too yellow, blue, green, magenta, or whatever. It is a matter of opinion, and even the color of the light used for viewing the prints comes into question. Consider if everything worked out right, the film was in date and properly stored, the lighting used to expose the images was in the range of 6000° Kelvin color temperature, the machinery doing the processing of the film and the paper necessary to produce positive prints was held close to proper control, and the light used to display the finished images was also in the range of 6000° Kelvin. The photographer may have used two different batches of film, which were different ages or even from different manufacturers. When the images were exposed in the camera, the photographer may have used two different lenses to make an assortment of images. One lens may separate colors differently than the other. One lens may have had a skylight filter and the other a UV haze **filter** attached for lens protection. Even the tiniest of inherent changes will cause changes in the overall colors of the finished prints. If the analyst places two of the prints under a reflective color densitometer, the same piece of evidence in two separate images may register as two completely different colors. Which is accurate? Who can say?

If exposing positive transparency film in the camera, most all of the same problems exist as for negatives. The only result that is radically different is if the person

producing the displays for court decides to make paper print positives from the film positives to take into court. The process for making paper positives from film positives is, and always was, a risky process for color accuracy (and contrast accuracy too).

IMPORTANT:

Film positives were never really intended to be converted to paper prints.

Moving ahead to the digital form of forensic imaging, the color accuracy and precision of most CMOS imaging sensors is determined by a fixed-formula color sensor array across and above the whole sensor, imparting and allowing color discrimination to the monochromatic silicon-based CMOS sensor cells. The color filter array has a color arrangement called a Bayer pattern, which attempts to mimic the eye's color reception by providing twice as many green filters as red and blue to represent the eye's greater sensitivity for green.

Since each pixel records only a single primary color, but three primary colors are needed for full color fidelity, the two missing colors for each cell are interpolated from each pixel's neighbors. This approach is the most practical by far and usually provides good color fidelity. However, the interpolation process does lower the color fidelity to some degree.

There are two other image capture approaches providing noticeably better color fidelity but are not as practical as the use of the Bayer array. One approach is a sensor structure using three photodiodes set at different depths in the sensor chip at each pixel location. This exploits the fact the more energetic, shorter wavelengths (the blue end of the visible spectrum) of light penetrate deeper into the silicon chip than do the less energetic, longer wavelengths (the red end of the visible spectrum). This type of sensor is difficult and costly to manufacture, and it can be difficult to fully isolate each of the three vertically stacked photodiodes. This situation increases noise.

The other approach is to use a Bayer sensor but to capture three distinct images for each subject, where the sensor is moved in one-pixel steps for each image. This is typically called pixel shift, and sometimes half-pixel shifts are used to capture eight images, further increasing resolution. These pixel shifts capture all three colors at each pixel location, but (at present) require static scenes for the duration of exposure of the multiple images. Several currently manufactured cameras offer this second approach as an option, and the use of this approach may produce the best image capture color fidelity when needed.

The inherent color fidelity of even Bayer image sensors is very high, and deviations from reality may likely be ignored in some technical investigations. What is more important for achieving high color fidelity when needed are three issues unrelated to the imaging sensor. These are the use of the JPEG file format, the lack of understanding and control of the spectrum of light incident on the scene, and how to use a color-managed workflow.

TIP:

In the lighting industry, the word "incident" is used to describe light falling onto a surface. So, in this context, "incident" does not relate to the circumstance, situation, or crime scene being documented, but instead means the light encountered at a scene falling on a specific surface.

Use of the JPEG file format is an attractive option for forensic photographers and technical investigators. Use of JPEGs provides a fully processed final image directly from the camera. By using JPEGs, the technical investigator avoids the need to understand an external image processing program and the time it takes to process images with the program. The perception of JPEG as only a file format is a problem because a JPEG image has had many manipulations altering the color, brightness, and sharpness of the image by the time the image is available on the viewing screen. This is an issue in terms of achieving high color fidelity. An example of the limitations this creates is shown in Figure 8.1. The image on the left was shot with a camera that recorded 14 bits of tonal information for each pixel in the raw image, which produces 16,384 tonal levels. The image on the right is a JPEG produced from the raw image. The JPEG compresses the 14 bits of tonality for each pixel to 8 bits, which reduces the 16,384 tonal levels per pixel in the raw image to 256 tonal levels in the JPEG version. This results in a visible loss of distinction between grayscale tones.

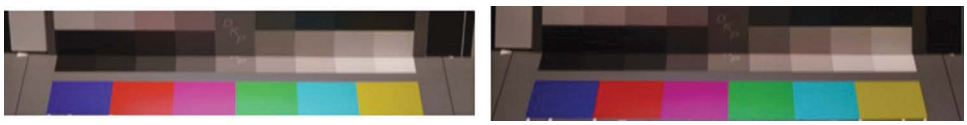


FIGURE 8.1 Compression of the 14-bit raw file to an 8-bit JPEG reduces the tonal graduation from 16,384 tones to 256, which causes loss of the distinction between grayscale tones.

(From J. Fildes.)

To convert "raw" sensor data to a final image, a number of manipulations must be performed. First the white balance must be set. This will be more fully discussed later. The color of an object recorded by the camera is established by two parameters: the color of the light incident on the object and the way the object reflects or absorbs the different colors of the incident radiation. The camera sensor measures the intensity of the three primary colors (red, green and blue) at each pixel of the light reaching the camera's sensor. This measurement will change as the color of the light incident on the object changes. This may have nothing to do with the true color of the object. Setting the white balance amounts to telling the camera what the color of the incident light is, which removes one of the two parameters, so what the sensor measures is then related solely to the true color of the object. Use of an out-of-the-camera JPEG image may have high color fidelity if an accurate white balance is set for each image, but this is often not practical and therefore not done. It is more common to let the camera attempt to automatically determine the white balance of the scene. The camera does this by trying to identify objects in the scene for which it knows the color, especially objects that would be white, black, or a shade of gray. The deviation of the scene's color from what is expected allows the white balance to be inferred or just interpolated. The camera determines the white balance nearly correctly about 50% of the time. This has been the case for about the past decade and will likely improve only slowly in the future.

Even if the technical investigator or forensic photographer enters an accurate white balance for each image, use of camera-generated JPEGs has another inherent issue that cannot be eliminated. The first row of the example in Figure 8.1 shows the variation of color rendition using the camera's white balance determination with a raw image, as defined later. More inaccurate and variable results would be obtained with JPEGs from the camera because there is no unique formula for producing a JPEG. Each camera manufacturer has a proprietary JPEG engine producing observably different results from other manufacturers, and each manufacturer changes its JPEG engine over time. Additionally, the mass market for cameras is consumers, not technical photographers, and consumers like vivid colors, not necessarily accurate colors. Published tests of JPEG color fidelity routinely display large deviations from accurate colors.

IMPORTANT:

Use of a JPEG format image is not ever a prescription for producing accurate and precise color fidelity in a technical investigation.

The alternative to using JPEGs for a project is to record raw sensor data, which is called using camera raw images, and postprocessing the images with a recognized image processing program. This transfers the adjustment stage of all the parameters determining the final image color from the camera to the photographer, and the more powerful computers off-board from the camera. Processing a raw image involves (at the minimum) setting:

1. The white balance, which will be discussed later
2. The black point, which is setting the darkest tone in the image for the darkest part of the scene
3. The white point, which sets the brightest tone in the image for the brightest part of the scene
4. The distribution of the histogram between the black point and the white point
5. Application of noise reduction and sharpening

Setting the black point and white point determines the contrast of the image. Setting the distribution of the histogram between the black point and white point determines the mid-tone contrast of the image. Both of these have a significant impact on the appearance of the image and its accuracy in depicting a scene.

This is demonstrated by the following comparison of the raw and JPEG histograms for the same image. These histograms are different in important ways, reflecting the impact of the JPEG processing adjustments to the images as they are performed by the camera. Optimizing appearance to be more pleasing for the consumer's eye is the whole point. The JPEG processing typically expands the separation between the black and white points by moving the points (respectively) to the extreme left and right of the histogram, increasing the contrast. In doing this, the curves for the three primary colors are also shifted relative to each other in the mid-tone regions (middle region of the histogram), which changes the color rendition to one thought to be more pleasing to consumers. Each JPEG engine, be it in the camera or in an image processing program, would produce a different JPEG histogram for this particular image.

Setting the white point and black point to accurately depict a scene will be discussed further in the next chapter on tonal accuracy, and setting the sharpening will be discussed in the section after that on texture.

Establishing an accurate white balance involves more than capturing a raw image and feeding it into an image processing program. The establishment starts with understanding the light incident on the scene or subject to be captured and possibly using alternative lighting. Lighting technology has advanced, and the nature of some lighting types is more suitable than others for the capture of accurate color rendition in an image.

A thorough discussion of light requires a book in itself, but this text is more of a practical guide. The aspects of light needing to be considered here will be described without a full discussion of their bases.

Light is composed either of discrete wavelengths or of a continuous spectrum of wavelengths. The distribution of intensities of the various wavelengths of the source



FIGURE 8.2 Even modest changes in white balance can affect the accurate portrayal of color. The image on the left accurately portrays how the color chart appears visually.

determines its color temperature, which is the parameter needed to accurately set the white balance. The color temperature is expressed in degrees Kelvin and is the temperature causing a filament to emit a spectrum in that color. The Kelvin color temperature is not a linear parameter, as shown by Figure 8.2.

These images were recorded using the same white balance and the same lighting conditions except for the color temperature. The color temperature of the light incident on the scene was 5180° K for the image on the left and 3200° K for the image on the right. Using the same white balance of 5180° K for each image produces a substantial color cast in the image on the right. This may represent an extreme example, but using a camera's automatic white balance and not measuring the color of the light incident on the scene can produce color shifts that make the depiction of color unreliable. The accuracy of automatic white balance depends on the camera and the lighting conditions, so it is not predictable, but the rate of inaccuracy is often tens of a percent, sometimes approaching 50%. Setting the white balance accurately is more important when the light has a lower Kelvin color temperature. This result is important because photography in many technical investigations occurs under lighting with a lower Kelvin temperature, for example, any type of incandescent source. Another important factor is the nature of the spectrum of the light source. Some sources have a set of discrete bands of wavelengths, while some have continuous spectra. A camera's automatic white balance determination requires a continuous spectrum that falls within a defined range of light intensity distribution.

The use of electronic flash to illuminate a scene offers a potential solution to achieving accurate color rendition. This is because the Kelvin temperature of electronic flashes is known and usually reported. This method has its own limitations, because the flash has to be powerful enough to dominate the ambient lighting of the scene. This is not always practical. Also, the dark shadows in the scene may have a different color temperature. The light from the flash does not dominate these areas, and the flash itself creates more shadows than existed in the first place. Due to shadow and highlight issues, the use of electronic flash has diminished in the digital era because digital cameras offer good image quality at higher ISO values than film. Also, an electronic flash is considered a transient light source because it is instantaneous and then disappears. This negates the live-view advantage of digital cameras. Live view shows the precise effect of continuous lighting and shows what reflects and causes specular highlights and where there are shadows. This is much more difficult to observe beforehand with a transient light source.

Another issue in achieving accurate color rendition is it depends on both the way the image sensor captures the scene and the way the device displays the scene. There are various types of liquid crystal displays (LCDs), and they differ in their contrast ratios as well as their color spaces. Prints differ in these respects from LCDs, and pigment prints differ in these respects from dye prints. Also, different pigments differ from another, different dyes differ from each other, and the choice of printing paper/plastic affects color rendition. Overcoming this issue requires the use of a color-managed workflow. This is something few technical experts or forensic photographers probably use because it requires specialized tools, knowledge and patience. In a color-managed workflow, each device (camera and display) and physical display medium (printer, its ink set, and paper) are required to have a profile defining its color space. Camera raw files usually have a proprietary color space, and most cameras offer the option to produce JPEG files with the Adobe RGB or the sRGB color space. Older LCD monitors have color spaces smaller than the sRGB space, and some newer monitors have a full sRGB color space, with a few having the Adobe RGB color space. Image processing programs usually offer a choice of sRGB, Adobe RGB, and ProPhoto color spaces as their working color space (see Figure 8.3).

To use a color-managed workflow, the image processing software needs to have functionality allowing it to read these different color spaces and convert between them to display the image during processing, to print the image

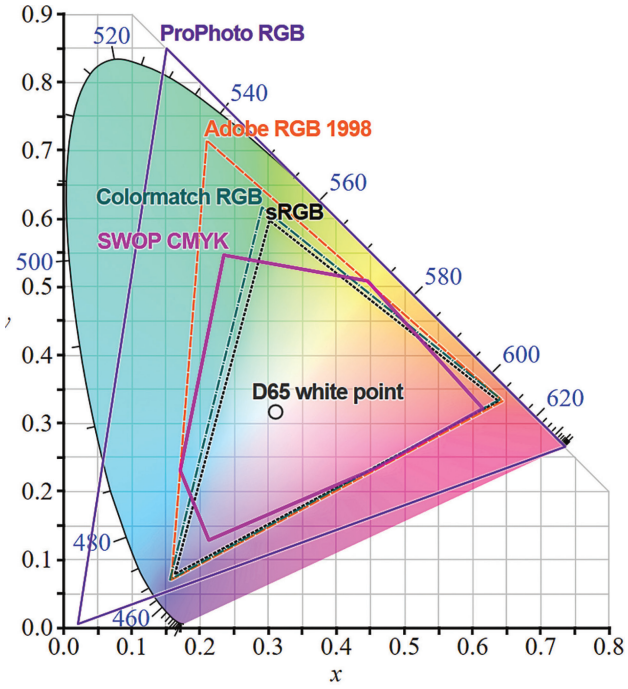


FIGURE 8.3 The distinction between sRGB, Adobe RGB, and ProPhoto.

(From Wikipedia, Used per Creative Commons 3.0, Uploaded by user: BenRG and cmglee.[1])

with a predictable (but possibly not accurate) color rendition, and to embed the color space in an exported image file for use by others. The color spaces of the various devices will often not include all of the color spaces of other devices in the chain, so the image processing software must be able to map colors existing in one space but not in another to similar colors existing in the second color space to achieve the most similar (but again not necessarily accurate) color rendition.

To achieve accurate color rendition when necessary:

- Capture a raw image.
- When the highest color fidelity is needed and the scene is static, use a camera with pixel shift technology that directly measures the intensity of each of the three primary colors at each pixel location. Alternatively, and for dynamic scenes, use a camera with a sensor measuring all three primary colors for each pixel location in one image capture. (This is an alternative guideline rather than a primary one because there is very limited choice in these cameras, and they have what can be significant image quality trade-offs and other limitations.)
- Use the largest, usually the Adobe RGB, color space for JPEG output. Raw files are produced in the camera's native color space.
- Use a continuous light source with a known color temperature if possible.
- Use a handheld light meter with color temperature capability to measure the color temperature of the incident light.
- Use the measured color temperature of the incident light to set the color temperature in the image processing software. As an alternative, but not as accurate, include a graycard in the image and adjust the color temperature of the image processing software to remove color cast from the gray tones.
- Use a color-managed workflow. Use devices supplied with accurate color profiles, or purchase and use colorimeters to create accurate calibrations and profiles for the various devices that come without profiles. Use image processing software allowing a color-managed workflow and providing soft proofing, so printed and displayed results may be accurately visualized as the image processing parameters are adjusted. Download and use color profiles from commercial printing services. Also download and use color profiles for the printing papers used with your own printers.
- Use the largest color space as the working space for your image processing program. This is usually the ProPhoto color space. Also use the largest number of bits, usually 16, during image processing. These two options retain the most color fidelity during image processing.

TONAL RENDITION

The tonal range of a captured scene is the distribution of brightness of each of the three primary colors for a color image or the distribution of the shades of gray for a black-and-white image. Inaccurate depiction of tonal range may alter color accuracy, and for technical investigations, it may change the appearance of surfaces in a way that obscures details. It takes fairly large deviations from accurate tonal depiction to significantly affect color accuracy and surface detail, so accurate depiction of the tonal range in a scene is often not as demanding as accurate color reproduction.

As described in the previous chapter, the tonal distribution of a scene is conveyed by a histogram that plots the number of pixels exhibiting each shade of a primary color in a color image or gray in a black-and-white image. The darkest values are on the left of the plot, and the brightest values are on the right. The histogram for a color image will contain three curves, whereas there will be one curve for a black-and-white image.

There are several important issues to consider, necessary for forensic photographers and technical investigators to achieve accurate tonal depiction. The first is the same issue with JPEG versus raw images that was discussed earlier. The following graphic provides the histograms for both the raw and JPEG versions of the same image, as was used earlier for discussing color rendition. Here we are focusing on tonal rendition, which is the separation between the

black and white points establishing the image's contrast and also where the region between the black and white point sits on the horizontal axis, which establishes the image's nominal brightness.

The JPEG engine will typically expand the black and white points to use the entire histogram, which produces the most contrast but which may not be an accurate depiction of the scene. The JPEG engine will also shift the peaks of the curves left to darken the image or right to brighten the image, which again may not be an accurate tonal rendition. The color rendition may also change in this process, which was described earlier.

An image processing program improves upon the camera JPEG engine by giving the photographer more control over adjustment of the histogram, but no tools or guidance are provided to help the photographer determine which adjustments will provide the most accurate depiction. Uneducated photographers may assume the raw histogram is the most accurate depiction of the scene, and this may or may not be the case. The separation of the black and white points, which establishes the contrast of the image, may be an accurate rendition of the contrast of the scene, but the position of the region between the black and white points on the horizontal axis may not provide an accurate rendition of the overall brightness, because light meters in digital cameras are not perfect. Although light meters have become more sophisticated, the same problem existing in the film era continues in the digital. The brightness of the scene depends on two parameters: the intensity of incident light on the scene and the reflectivity of various regions of the scene. Light meters cannot inherently separate these two contributions, so they cannot perfectly determine whether a scene is brightly illuminated or highly reflective. A highly reflective scene may be rendered too dark, and a poorly reflective scene may be rendered too light. Both will need to be manually adjusted by the photographer either in the camera during capture by altering exposure or in the image processing program by shifting the raw histogram on the X-axis.

Another reason using the raw histogram may not produce the most accurate depiction of a scene is that, similar to color rendition, tonal rendition depends on both the way the image sensor captures the scene and on the way the device displays the scene. Different films had different tonal and color rendition, as did different printing papers, and development chemistry and the times for film and print developing could also alter tonal and color depiction. Digital imaging did not remove these issues, but it did provide camera settings and image processing tools to replace chemistry and made the adjustments more accessible to photographers. Nonetheless, these settings and tools did not provide the means or guidance to achieve accurate color and tonal rendition.

A practical and serious issue, which is a reminder that technical investigators and forensic photographers are using consumer products for photography, is that virtually no camera and very few image processing programs display the raw histogram. Why should they provide a raw histogram when the raw image will appear dull to consumers? Instead, virtually all cameras and most image processing programs display the JPEG histogram.

To achieve accurate tonal rendition when needed:

- Capture a raw image.
- Since the camera histogram comes from the JPEG image even if a raw image is captured, set the JPEG settings (which will control the JPEG histogram even when capturing raw images) for the lowest contrast and most neutral appearance.
- Carefully evaluate the exposure and use exposure compensation or adjust the exposure settings to set the white point so the brightest parts of the image appear accurate in the JPEG displayed on the camera's histogram. This requires setting the camera's LCD to provide a neutral image. This may mean the LCD must be shielded in bright conditions. Alternatively, adjust the white point during image processing so the brightest parts of the scene are accurately depicted.
- With modern digital cameras, having wide dynamic range and low noise, the use of what is called "expose to the right" or ETTR (i.e., placing the histogram so that it just touches the right side during image capture) is not generally needed. Avoiding the use of ETTR when not needed will make the image processing adjustments to achieve accurate tonal rendition easier to accomplish.
- Do not further adjust the white point, and do not adjust the black point during image processing. Adjust the distribution of tones between the black and white points as needed using a color-managed workflow and soft proofing to achieve accurate tonal rendition on the final image, be it a print or an image displayed on an LCD panel.

TEXTURE

Texture in an image is typically associated with sharpness and possibly mid-tone contrast. In commercial and consumer photography, the goal is to achieve as much sharpness as possible without producing halos around edges or other artifacts. Texture is enhanced in commercial and consumer photography by different types of edge sharpening and by tailoring sharpening to edges with different widths. This landscape defines the goals and approaches to sharpening images in the camera and in image processing programs. The photographic needs and goals of the technical investigator are different and are not necessarily well served by the tools offered by cameras and image processing programs.

Accurate depiction of the texture of an image may be important in technical investigations involving surfaces and fractures. The roughness of a walkway may be of interest in investigations of slips and falls. The granularity of a metal or plastic may be of interest in an investigation of a fracture.

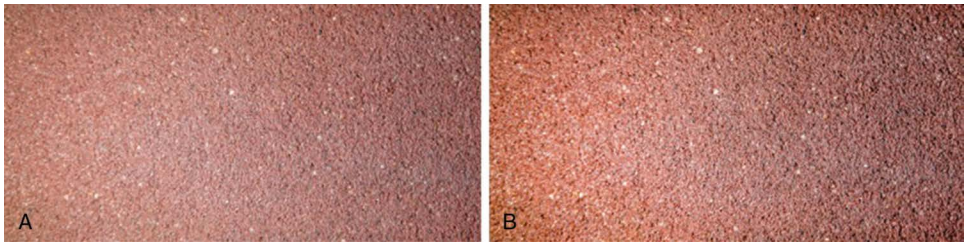


FIGURE 8.4 (A) The unsharpened image accurately portrays how the texture appears visually. (B) Sharpening a digital image can artificially accentuate texture.

The roughness of a surface may be important in investigating wear of sliding/abrading surfaces and the performance of brakes and friction materials. In these cases, the goal of the technical investigator is to accurately depict texture, not to accentuate it as much as possible.

Use of an out-of-camera JPEG allows only very crude adjustment of sharpening parameters, which will generally accentuate texture more than would constitute accurate depiction. Use of tools during image processing commonly used by commercial and consumer photographers such as "dehaze," "clarity," "detail enhancement," and "micro-contrast" should not be used at all or should be used with careful observation when accurate depiction of texture is important. These tools make complex adjustments to texture difficult to predict and control. Figure 8.4 demonstrates this. The image on the left is the out-of-camera raw image with no additional edge enhancement (i.e., no added clarity or dehaze) and sharpening. This image provides an accurate portrayal of the texture of this surface. The image on the right has a modest amount of clarity and dehaze added and is sharpened. These adjustments are typical of those that would be made by a camera in producing a JPEG, and the texture of the surface is substantially exaggerated compared to actuality. Care is also needed in the sharpening of images. The technical investigator should carefully observe the texture of the subject and process the image to accurately replicate that texture.

To achieve accurate texture when needed in an image of a scene:

- Capture a raw image.
- Avoid or carefully apply tools that adjust texture. These include "dehaze," "clarity," "detail enhancement," and "micro-contrast."
- Sharpening may need to be applied in a far more limited way, and possibly in a localized rather than global manner, than would be typical for commercial and consumer photography.
- The accuracy of the depiction of texture is something to be assessed by the photographer or investigator based on their visual examination of the subject under investigation. This will limit the use of a fully automated workflow and potentially cause a substantial amount of manual image processing.

COMPUTATIONAL PHOTOGRAPHY

A final consideration, intersecting with all the issues mentioned, is computational photography. Does computational photography improve the accurate depiction of a scene and make it easier to achieve? This is a complex question because a variety of different computational functions are involved.

TIP:

Computational photography is an imaging feature using mathematical elements instead of optical elements. This feature (or feature set) allows the camera to produce output such as horizontal or vertical panoramas, 180-degree or 360-degree spherical images, high dynamic range (HDR) images, "stacked" images, lens distortion corrections, and similar final photographs processed within the camera from the recording of individual or sequential images.

A common use today is the computational correction of optical distortions. This is used most frequently in the design of lenses to lower their cost and reduce their size and weight. Good linearity of lines and evenness of light intensity near the edges of a captured image are difficult to achieve, especially as the field of view of a lens becomes wider. Lenses for film cameras had to contain optical elements to achieve these corrections. Lenses for digital cameras do not require these elements. A 24 mm indicated focal length may in reality be significantly wider, with the image being automatically cropped to down to a 24 mm view, meant to avoid edge distortions. This is demonstrated by the pair of images in Figure 8.5. The image on the left is the image produced after applying the lens profile built into the image file. The image on the right is the out-of-camera image without applying the lens profile. Image processing software may automatically apply the built-in lens profile, as was the case for this set of images using the industry-leading image processing software. Other, more sophisticated corrections are increasingly being made in the background of captured images. This is why lenses have profiles used by image processing software.

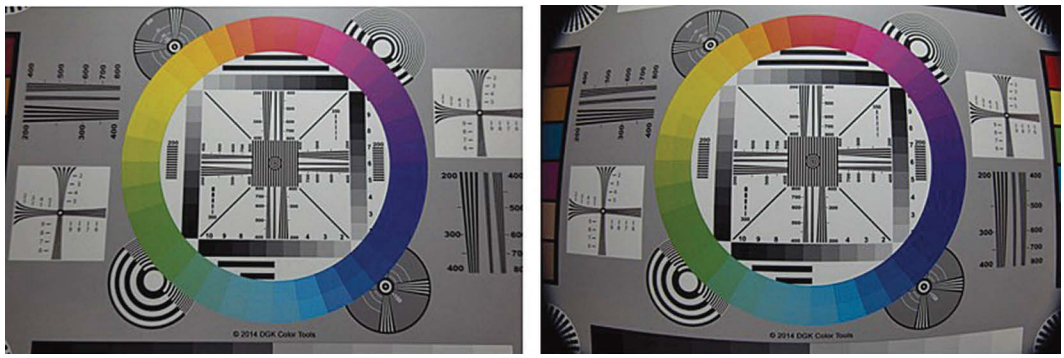


FIGURE 8.5 Computational correction of field curvature and vignetting.

These corrections may reduce image resolution, and their impact on image perspective demands evaluation. Other computational corrections include stacking images to lower digital noise and increase depth of field. This is arguably one of the most useful advances in digital photography with no perceptible downsides for technical investigators. The use of artificial intelligence (typically neural networks) also automatically optimizes an image's tonality and sharpness.

THE PHOTOGRAPHY MARKET AND MARKET-DRIVEN TECHNOLOGIES

Photographic hardware technology continues to evolve at a rapid pace. As mentioned previously, the drivers of that evolution are the desires of the consumer market, *not* the needs of technical investigators, including law enforcement. The consumer market drives where the majority of funds and hours of photographic R&D are focused. The consumer market wants more vivid colors, more image contrast, and more micro-texture and not necessarily the most accurate rendition of the targeted subject.

On balance, the transition to digital imaging has not made scene depiction inherently more accurate or easier to achieve for accuracy. Digital photography offers the tools and functionality to achieve accurate scene depiction. However, the issue these tools and functions (cameras and image processing software) were designed for is aimed at consumers and not to achieve accuracy in depiction of scenes, because accuracy is not a priority in the consumer imaging market.

For technical investigators, the transition to digital imaging may not make photography easier. Instead, it increases the knowledge and experience technical investigators need to possess to accurately depict scenes. But they may not recognize this situation because many have slight interest in photography as a profession or hobby.

Another important issue is the wide availability and use of consumer digital cameras, especially phone cameras, and the availability of online images from places like Google Earth. The impact of these are that technical investigators must deal with a wider array of images and more complex questions about the images they may encounter in an investigation.

The experience of conducting decades of R&D revealed photography in technical investigations is often based on how commercial photographers and consumers approach photography. Often this does not matter because the images only have to capture procedures or the approximate appearance of the scene.

In some cases, accurate depiction of the scene is essential, but:

- Few technical investigators control the lighting or measure its color temperature.
- Many technical investigators use out-of-camera JPEGs, and there is increasing use of fixed lens cameras with small sensors offering wide-angle and telephoto focal lengths.
- Few technical investigators create or use color profiles for their devices and display media and practice a color-managed workflow with soft proofing to ensure color rendition is accurate.
- Few technical investigators adequately understand the impact on tonal accuracy and color accuracy of setting the black and white points and adjusting mid-tone contrast.
- Few investigators adequately understand the impact on texture of commonly used image processing tools such as "dehaze," "clarity," "detail enhancement," and "micro-contrast."
- Few technical investigators adequately consider the impact in accurately depicting the perspective of lens focal-length selection and the distance from the lens to the front plane of the scene. The need for a wide view with limited space to back away from the scene calls for the use of a wide-angle lens without consideration of the impact on perspective. The multitude of sensor sizes introduced by the transition to digital cameras created new considerations as to how perspective changes with lens focal length for different sensor sizes.

CONCLUSION

Commercial photographers and consumers dominate the development of photographic technology, and the desires of commercial photographers and consumers are so different from those of technical investigators and forensic photographers that (1) most of the educational materials available are not very useful and (2) most of the technical hardware advances and software tools may not have made it easier for the technical investigators to achieve the goal of accurate depiction of a scene. In contrast, commercial photographers and consumers desire a "nice" depiction. This situation will continue in the future.

Why are the inherent challenges and technical issues of forensic photography not more generally visible? The answer is that the purpose for much of the forensic photography for technical investigations is for simple documentation in which the proper perspective, color accuracy, tonal range, and texture are not completely critical. Even the experts may adopt what is essentially a "point and shoot" approach to forensic photography, using simple digital cameras in fully automated modes. The recorded JPEGS they expose are the digital camera's automated process for the creation of viewable images, and this is often good enough. Even in more demanding situations, only one or two of the challenges discussed in this chapter tend to become important. Nonetheless, when these issues become important, they tend to be critically important.

NOTE

1. Comparison of some RGB and CMYK color gamut on a CIE 1931 X-Y chromaticity diagram, based on http://commons.wikimedia.org/wiki/File:CIE1931xy_blank.svg and data from Blatner and Fraser's "Real World Photoshop CS", p179: http://canopuscomputing.com.au/gallery2/d/8631-1/Gamuts_comparison-B_F.jpg.

9 Three-Dimensional Photography and Its Applications

Sanford L. Weiss

CONTENTS

Introduction 179
Methods of 3-D Photography 183
For Documentation and Display 183
Stereo Camera 184
Beam Splitter 185
Slide Rails 185
Two Matched Cameras 186
Scanning Electron Microscope 187
Scanning or Deep Field Photomacrography or (Zero-Perspective Imaging) 187
Lenticular Technologies 189
Anaglyph Imaging 189
Immersive/Virtual Reality Technologies 191
Laser Scanning 192
3-D Information for Analysis 193
Sketches 193
Conclusion 194
Appendix I 197
Notes 205

INTRODUCTION

Photographers are able to create images only as well as the limitations of their medium will allow in the depiction of any evidence or scene. They can, however, address the question of how many dimensions are sufficient to create a photographic representation that is indeed accurate.

Most people in the evidence photography community have assumed and then practiced as if the answer to the question is two dimensions. However, "stereo (3-D) photography can provide valuable records of subjects where an accurate indication of depth is important."[1]

> In photographing the crime, accident, or any scene, and with many types of evidence, the investigator should attempt to provide a series of images supplying a maximum of useful information and which will enable the viewer to understand how the crime/accident was committed/occurred. The photographer should show the relationships of the various important objects to one another. Locations of articles should be clearly seen with reference to recognizable backgrounds.[2]

It might appear forensic and 3-D photography are in many ways synonymous. At this point, it would be useful to consider what the real difference is between two- and three-dimensionality as they relate to vision and photography.

> Monocular vision consists of the reception on a surface (the retina) of a single 2-Dimensional image, which has been projected through the crystalline lens of one eye from a scene in space, and the resultant interpretation by the brain of this image (see Figure 9.1). Disregarding the anomalies of the photoreceptor, such an image is closely reproduced on the film or image sensor of a single-lens camera. The resultant print from such an image, when properly viewed, reproduces an image on the retina of the viewer similar to what it would have received had the eye occupied the position of the camera lens when the picture was taken. From this 2-Dimensional image, the brain infers the original 3-Dimensional space scene.[3]

If we allow this explanation to serve as a justification, we could attest to following the standard of producing photographs reasonably accurate in the depiction of the original scene. It should be considered, though, that when interpreting the resultant 2-D image, "we rely entirely on what might be called depth clues (cues), and where some or all of these are absent, we are left to draw conclusions, sometimes completely wrong, of the distance to and hence the true size of an object. In general, we assume the size of an object, in the absence of other clues, bears some relation to the amount of space it occupies in the picture area."[4]

This is why we include a known sized reference for scale in an evidence photograph. This is also the reason why special effects work in the cinema, where scale models can be used in the place of large objects with very realistic results. The question must therefore be asked: Should we settle for



FIGURE 9.1 Monocular vision.

(From Sandy Weiss/Packer Engineering.)



FIGURE 9.2 Binocular vision.

(From Sandy Weiss/Packer Engineering.)

reasonably accurate and possibly wrong interpretations from our photographs when more accuracy is often possible?

Examining the definition of vision with two eyes:

> Binocular vision consists in the reception on the two retinas of two images of a single scene in space and the resultant fusion and interpretation by the brain of these images (see Figure 9.2). Since the positions of the two eyes are not the same, different portions of objects are visible and near objects obscure different areas of far objects. Thus, the two retinal images are not identical. The brain fuses these two different 2-Dimensional images and interprets them as a single 3-Dimensional space scene in which depth appears to exist as a definite reality.
>
> If two photographs are taken from positions occupied by the two eyes and the resultant prints are properly viewed, two retinal images are produced which correspond to those which would have been formed, had the eyes occupied the positions of the camera lenses. With proper viewing aids, the resultant fusion and interpretation is substantially the same as binocular vision including the sense of the reality of depth.[5]

Of course, the left eye must see the image taken from the left side of the subject and the right eye the image taken from the right side. Photographically speaking, this reproduction of binocular vision by the use of two-dimensional images is called stereoscopic or 3-D photography.

Perspective is a term often confused with 3-D, but in perspective, the third dimension is visually simulated by objects appearing to be smaller the farther away they are from the camera. True 3-D viewing of a subject can only be accomplished by the use of a minimum of two appropriate images. Three-dimensional information can be retrieved photogrammetrically from single photographs by using perspective analysis, as will be explained in Chapter 10 concerning photogrammetry, but true 3-D viewing of the same image is still not possible.

After considering the appropriate standards and intended goals of today's evidence photographers, the obvious question is: Why aren't a larger number of evidence photographers producing 3-D photographs and displays? It could be that the inference of three-dimensionality is sufficient to satisfy most viewers, or the production, viewing, and even understanding of three-dimensional images are just too much trouble for some people.

It has been suggested that when a 3-D scene is represented on a 2-D media, such as paper or a computer monitor, the image ceases to be 3-D, so why bother? Some people might use such a theory for a justification to not make the 3-D effort. In response, it should be stated that if a representation is perceived as 3-D, it is 3-D.

No matter what medium the representation is presented in, if the viewer is able to either visualize it in 3-D or quantitatively draw 3-D information from it, it is a true three-dimensional representation. Therefore, it is possible to infer that all normal 2-D images are sufficient for extracting some 3-D information, if only photogrammetrically. In most cases, such is true. However, there are many times when a true 3-D representation of a subject would be both easier to understand and more visually explanatory to the observer than a verbal explanation of the photogrammetry used to extract the 3-D information.

In the early days of photography, most photographers felt an image needed to be three-dimensional to be accurate. As late as 1936, Morgan and Lester wrote

> 3-Dimensional photography is the only method of rendering pictures so the subject looks round and plastic. It is unfortunate, at the present time we are unable to lend this plasticity to single picture views obtained by ordinary 2-Dimensional photography, which always has and still is endeavoring to assist our imagination to see things in pictures as we are accustomed to seeing them in life.[6]

It is certainly not necessary to take all photographs in 3-D, but when it would be useful for the sake of a demonstration to have the extra dimensionality, it would be a good idea for the photographer to not only understand the techniques but also the technology necessary to create 3-D images.

Historically, in 1827 when Niepce succeeded in permanently capturing the view outside his window, he used a camera obscura combined with a light-sensitive, silver-based material of his invention, which hardened after exposure to light. This was before the days of chemical image amplification, and his initial exposure took an incredibly long eight hours to complete.

In contrast, stereoscopy was being experimented with long before photography. Around 350 BC, Euclid theorized that each of a person's two eyes saw a different scene. In 1519, Leonardo da Vinci stated that binocular vision added relief to the perception of objects. In 1838, Sir Charles Wheatstone invented the first practical stereoscope using a mirror system which, when used to view specially prepared drawings, yielded to the viewer a 3-D image. By 1845, William Henry Fox Talbot, the man who later invented chemical developer, was supplying Wheatstone with stereo photographs to look at in his stereoscope.

By the 1850s, stereo images became a popular commercial venture due to the albumin process and the new ease with which original photographic images could be generated. As with any other successful business, there was soon competition in the stereoscope field, with further inventions by David Brewster, who was the first to incorporate lenses instead of mirrors in a stereoscope, and another significant modification made by Sir Oliver Wendell Holmes (see Figure 9.3).

Stereo images were being mass-produced on cards and sold by the millions. The sudden popularity and mass production of stereo systems made a tremendous impact on the nation's social life. It is a little-known fact that "virtually all of the original (photographic) images made of the Civil War were taken as stereoscopic views"[7] because most books about the Civil War reproduce only one-half of each stereo pair (see Figure 9.4).



FIGURE 9.3 Stereo viewer.

(From Sandy Weiss/Packer Engineering.)



FIGURE 9.4 Stereo viewer 2.

(From Sandy Weiss/Packer Engineering.)

By 1870, as was written in the *Philadelphia Photographer*, "There is no parlor in America where there is not a stereoscope."[8] The huge popularity of stereoscopes and cards lasted into the 1940s. At such time in the evolution of photography, cameras were getting smaller—35 mm was popular. People could go into the field with cameras small enough to literally fit into a pocket and return with images of very good quality.

During the 1930s Leica invented a beam splitter for their 35 mm cameras to enable stereo photography. In 1936 Ihagee of Dresden, Germany, introduced the first 35 mm single lens reflex (SLR) camera.[9] Shortly afterwards Ihagee also introduced a beam splitter for their SLR, which actually allowed the photographer to view the subject in 3-D at the time of exposure. The viewing device used in the optics of the camera doubled as a viewer for the finished slides. Beam splitters are sometimes available used on the Internet and are still practical (see Figure 9.5).

"During the 1950s there was a short lived but widespread public interest in (do-it-yourself) stereo-photography resulting in a temporary proliferation of equipment and literature; but this passed, as most fads do."[10] *Life* magazine experimented with the addition of 3-D images in their publication. There was even a brief but popular trend by some major Hollywood studios into the production of 3-D feature films. "Despite the (theater) critics, it's clear the public wants 3-D, and Warner's House of Wax (1953, its first effort) is a major



FIGURE 9.5 Stereo adapter for Exakta.

crowd pleaser."[11] The studios went overboard cramming their 3-D movies with outlandish effects meant to awe and startle the viewing audiences. It is an interesting and little-known fact that the director of *House of Wax*, Andre de Toth, was hired for the job specifically because he had only one eye, and the studio wanted some extra insurance to be sure the movie would be shot so it would be equally viewable in 2-D as well as 3-D just in case the new effect was a flop (see Figure 9.6).

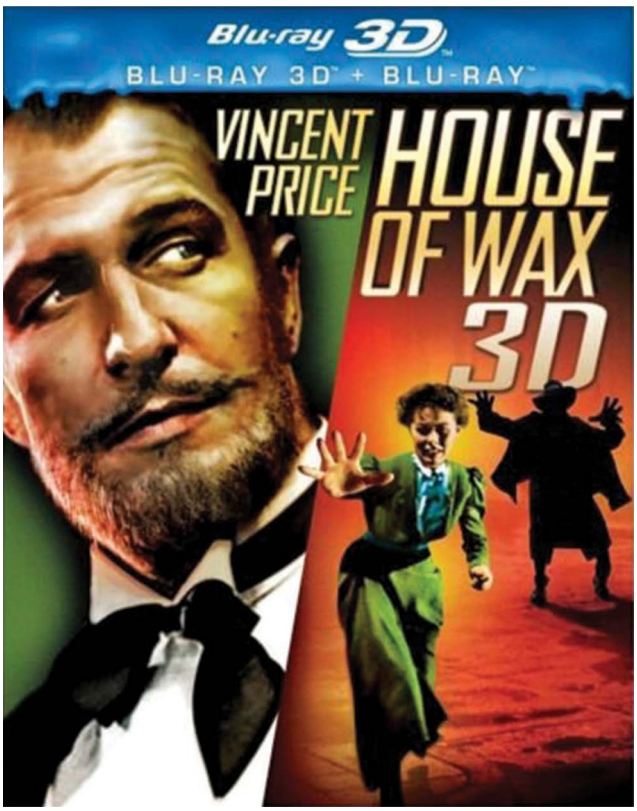


FIGURE 9.6 House of Wax.

So why did the popularity of the 3-D movie wane? One possible explanation for the demise is suggested by the following: "3-D is proving a problem with audiences. Many viewers are complaining of headaches."[12] The red and green glasses the viewers were forced to wear were uncomfortable and unusual to most. There was also the long time delay caused by the projectionist having to change two film reels at a time instead of just one. Sometimes the two reels would slip out of synchronization, reminiscent of the early sound and image problems endured by the first "talkies."

After the early 1950s the hey-day of the 3-D effect in both movies and still photography was coming to an end. Perhaps the photographers and viewers of the day no longer wanted to be bothered with those types of 3-D. Perhaps out of sheer laziness with the inconvenience, photographers started leaving at home the accessories enabling them to create their 3-D images. Another possible explanation for the loss of popularity in the technology is the fact that some people cannot under any circumstances, assisted by any available hardware and after any possible effort, ever resolve a pair of two-dimensional images in any media into one three-dimensional representation.

"Imperfect fusion reflects a failure of the eyes to coordinate. Even perfect fusion is not perfect all the time; heavy drinking, fatigue, emotional upset, or even illness will impair it."[13]

There were two landmark phenomena spelling the end of the first 3-D popularity era. The first was the availability of supplies popularizing color photography, starting about 1935. Color afforded the photo viewer a sense of 3-D–like reality just by the sheer existence of color. Seeing images the way they were accustomed to be seen, rather than in tones of gray, gave the viewer a sense of three-dimensionality previously unavailable in 2-D images. "Photographers who used color film when it gradually became available for mass use after 1935, had to overcome the idea their pictures were somehow too explicit to be art, too literal a representation of reality."[14] Even so, "there are few people now remaining who would not prefer a color print to one in black and white."[15]

Even more devastating to the practice of 3-D photography was an invention which helped to reform the 20th century. In 1932, Vladimir Kosma Zworykin's iconoscope was able to imitate the ways human eyes viewed images for television broadcast.[16] When television went public in the 1940s after WWII, it took the world by storm. Television has a three-dimensionality all its own. Even though early television was essentially a 2-D black-and-white medium, the objects on the screen were made to move back and forth in front of each other. The impression of great depth was also afforded the viewer by the utilization of changeable viewpoints and constant motion. Viewers became glued to their TV screens.

"With cinema facing increasing competition from television, the 1950s witnessed a variety of screening devices intended to entice viewers to the local drive-in or theater: Cinerama, Vista Vision, Cinema Scope and 3-D (again)."[17]

Virtually all Hollywood movies of the period were shot in color to have an advantage over TV being only a black-and-white medium.

As a result of these modern technologies, 3-D still photography was forgotten by all but the die-hard fans in two fields. First, there were the enthusiasts so enthralled by the true perception of depth, they refused to give up and continued to shoot their photographs for the full 3-D effect. Even today, there are many stereo photography clubs and societies around the world with hundreds of members, each working to keep the media alive. There is a large group named the New York Stereoscopic Association, the goals of which are to keep alive all the different aspects of 3-D imaging. The Reel 3-D catalog of February 1, 2000, had a circulation of 42,000 subscribers! Their retail shop is now closed, but their website is a good place to find many other places to shop for 3-D equipment.[18]

Second, there were the photogrammetrists who needed 3-D information for mapping and mensuration. The enthusiasm and need of these two groups have never waned. Today, the number of people involved in 3-D imaging is actually growing due to the capabilities of the computer. Technology killed the mass popularity of 3-D, but now a different technology is stimulating a rebirth.

Many blockbuster movies now show in the theater in 3-D before they come out to the public on DVD or Bluray in 2-D. The technologies involved and the popularity of modern 3-D movies shown at the IMAX and other theaters across the country are staggering. Some TV shows and regular-cinema films are also made specifically in 3-D.[19] I own a 2-D version of *Avatar* (2010) on DVD. Every time I watch it, I remember going to the IMAX and seeing it in 3-D. Someday I would love to have the opportunity again.

Should the obvious difficulties associated with 3-D photography dissuade today's forensic evidence photographer from the production of three-dimensional images? Now, more than ever before, the answer to that question is a definite NO. With the state of modern technology, there are many useful things to be done, both qualitatively and quantitatively, with stereoscopic images, and the routine capture of those images should be a part of every evidence photographer's task and at every assignment.

Even today's photographic artists are spreading the popularity of 3-D photography. In a purely aesthetic sense, and forgetting about computers for a moment,

> it is a fact that many contemporary photographers, not satisfied with current technology, are going back to a low-tech approach to photography. Techniques such as hand-coloring, multiple exposures, home-made emulsions and stereographs are slowing things down and taking us back into the darkroom to work with the foundations of photography.[20]

With regard to forensics, in 1983, John Duckworth wrote, "We carry photographic evidence into court that tells the story and that is accurate and understandable." However, he does not devote one line to three-dimensionality in his otherwise well-done book.[21]

Some people are not going to be able to resolve the three-dimensionality of some images. Should the lack of ability by the few lead to the deprivation of the third dimension to the many? It would not be fair to the many. It should be remembered that no matter how three-dimensional images are created, upon failure to assemble or resolve those images into three-dimensional displays, the individual component images would still make conventional two-dimensional displays.

Some of today's forensic photographers are working in 3-D, but some are not doing any sort of three-dimensional image gathering on their assignments.

METHODS OF 3-D PHOTOGRAPHY

The method chosen for the capture of 3-D information from any particular subject is totally dependent on the nature of the subject and the purpose of the information. Most of the techniques are basically the same as in normal 2-D photography, except there is a need to take extra photos of given subjects and then use appropriate combinations of those photos for the construction of 3-D stereo pairs. It should be remembered that there is no subject which cannot be photographically documented in 3-D unless it is totally 2-D to start with.

This chapter will discuss some types of possible subjects and the methods of documentation of those subjects based on by purpose.

FOR DOCUMENTATION AND DISPLAY

There are an infinite number of reasons why it might be better to document, for strictly qualitative purposes, some subjects in 3-D rather than 2-D. The accuracy of the representation can be directly proportional to the ease of visualization by the viewer of the comparative sizes or placements of features in the image. There is also the sheer impact the 3-D image has on the eye of most viewers. It is often not possible in a 2-D rendition to accurately assess the degree of slope to a landscape feature, how deep a dip in a roadway or artifact might be, or even if a particular formation is a dip or a rise. Immersive and virtual reality technologies can give the viewer the feeling of actually being somewhere they are not. This phenomenon can be very useful when doing virtual tours of accident or crime scenes for people removed by distance or time from the actual occurrence. Other current uses include 180-degree to 360-degree immersion in a foreign environment, flight simulation, driving simulation and training—the list is virtually endless.

Equally as infinite as the possible justifications for working in 3-D are the variety of types of subjects to be documented three-dimensionally. Fortunately, the list of possible subjects is easily organized into a few groups. Subjects can be:

- Static or dynamic
- Small or large
- Close or distant

It is the job of the photographer to assess the subject, know the purpose of the final images, and pick the proper means of capturing the necessary photographs. The simpler the subject, the larger the number of ways to accomplish the images needed for 3-D viewing. A bread box–sized object sitting on a solid table in good light will be a lot easier to document than a single human hair, a building with 20 rooms and three floors, a person running at full speed, a battleship, or a wad of chewing gum stuck to the bottom of a trash can. Obviously, there are still a variety of ways to document even the most difficult of these cases. Following is a list of some of the types of hardware and software used for these purposes, along with examples of the normal subject type for each.

STEREO CAMERA

Two-lensed cameras for making stereo pairs have been manufactured since the early days of photography. In contrast to twin-lens cameras where one lens is for viewing and one is for exposing the image, two-lens (3-D) cameras expose two images at the same time from slightly different points of view, like the relationship between the human brain and its two eyes used for information gathering (see Figure 9.8).

During the heyday of the 3-D mania in the 1950s, many companies, including Kodak, Revere, Realist, and Wollensak, manufactured cameras for this purpose. The two lenses of 35 mm stereo cameras are separated by about 2½ inches (65 mm) to yield two photos taken from angles resembling the angles of view from a person's two eyes. These cameras can still be used to take photos of subjects either static or dynamic because both images are exposed simultaneously. The cameras can be focused down to a few feet at the close end and then to infinity.

At infinity, the 3-D effect is practically nonexistent, because past about 300 feet from the camera, there is a lack of significant difference between the two captured images.

These cameras can be used with negative film but are most often used for taking positive transparencies (slides), then viewed in a handheld viewer or used for projection. The handheld viewers are small and fairly inexpensive, and



FIGURE 9.8 Stereo slide viewer.

(From Sandy Weiss/Packer Engineering.)

the slides are easily duplicatable as well as transferable to digital, which means a viewer and full set of slides can be given to each member of a jury if it should be desirable. Three-dimensional images are also possible to use on computer monitors and/or televisions. The most useful purpose for this type of slide is to illustrate in great detail the relief or relative positions of objects in a particular location.

It is important to hold the camera as level as possible during the exposure for the ease of the viewer being able to resolve the image. The format of the camera is slightly vertical, and the photographer cannot hold the camera in a fully vertical orientation while taking photos, for obvious reasons. This type of camera is still available on the used camera market in good condition and at fairly reasonable prices, although the prices are going up lately due to collectors and the new popularity of 3-D in general. There are several repair services in this country who still work on them and instruction manuals are still available on the Internet. The slides are processed conventionally, but the photographer may have to do his or her own mounting. Handheld viewers are still available new as well (see Figure 9.9).



FIGURE 9.7 Stereo Realist.

(From Sandy Weiss/Packer Engineering.)



FIGURE 9.9 Pentax beam splitter.

(From Dan Rose, Legalfoto.)

BEAM SPLITTER

These are devices for capturing 3-D stereo pairs and are adaptable to digital SLR cameras, standard 35 mm film, and/or cameras up to and including 4 × 5 inches, as long as the camera can focus through the lens. These devices screw onto the front of the existing normal lens. Wide-angle and telephoto lenses will not work (see Figure 9.10).

Leica invented these gadgets in the 1930s, and similar equipment is still being made and marketed today. Until recently, Pentax manufactured a device with very high quality. The devices produce a stereo pair within the normal single-frame limitations of any camera on which they are mounted. If 35 mm slides are captured, any commercial processor still running E-6 will be able to process, mount, and duplicate the slides as if they were normal single-frame images.

The camera device comes from the factory with a matched drop-in 35 mm viewer. If the photographer exposes digital images or negative film, any conventional lab or desktop printer will be able to print the stereo pair images from the frames. Three-dimensional print viewers are inexpensive and come in a wide variety of styles.

The splitters are usually available in just one thread size but can be adapted to most any other accessory size by the use of step-up or step-down rings. Splitters will allow slightly closer focusing distances than a two-lens stereo camera, but the fixed separation of 62 mm prohibits the use of the devices for serious macrophotography. Ihagee manufactured a special splitter for macrophotography with a smaller separation between the images, but such an item is no longer available and is quite scarce.

Due to the fact that both exposures are made at the same time, dynamic subjects can be captured with ease. One of the largest advantages of these devices is the photographer can use their normal camera for both 2-D and 3-D image capture at the same time and switch back and forth whenever they want. Normal light metering capabilities and the full range of shutter speeds are retained. If a through-the-lens meter is not used for image capture with a splitter, remember the device itself may absorb some light, so experiment before exposing anything important to keep underexposure from being a problem.

As with the two-lens stereo cameras, the format of the images is slightly vertical, and the camera cannot be turned to capture horizontal subjects due to the inability of the viewer to resolve the image from such an orientation. The devices are small, light, and moderately inexpensive and a must-have for all evidence photographers.



FIGURE 9.10 Slide rail.

(From Sandy Weiss/Packer Engineering.)

SLIDE RAILS

Any camera with any focal-length lens can be used to photograph two successive images of any static subject. Perhaps this is the simplest type of 3-D image capture to understand and utilize. For best results, the camera needs to be mounted on some sort of slide rail device, either bought or manufactured by the user, and then moved approximately 2½ inches side to side between each exposure for normal subjects. An excellent rail system, 3-D ImageTrack, was manufactured in the 1990s by Image Tech of Norris, Georgia. The price for a new ImageTrack rail was high at $250, but with excellent scales and other deluxe features, it was worth the money.

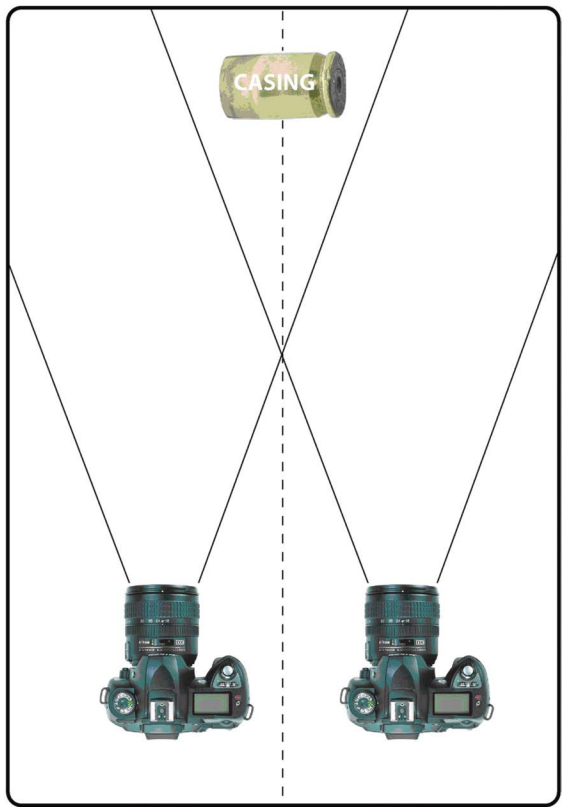


FIGURE 9.11 Correct orientation of 2 cameras for 3-D stereo photography.

(From Sandy Weiss/Packer Engineering.)

There are only a couple of disadvantages to this method of image capture. First, because the two images are captured at different times, if there is any movement in the subject, there will be a difference in the two resultant images, making the 3-D effect harder to resolve or distracting to the viewer.

Second, it takes more thought and planning to capture each image because the photographer is responsible for determining the separation between the images.

Even though there are small difficulties, the use of the same camera for the capture of both halves of stereo pairs is advantageous. Photos can be captured with any focal-length lens and from any camera-to-subject distance. Since the same camera and lens are used for both exposures, no hardware matching difficulties are evident unless the photographer changes shutter speed, aperture, or focus between exposures. In some instances when the stereo pair is going to be used for measurement and not for 3-D viewing, the camera can be moved up and down rather than side to side for the two exposures.

Macro, telephoto, and wide-angle lenses are all suitable for this work. Wide-angle lenses are preferred for some subjects because they inherently have better depth of field and the distance beyond which everything is in focus to infinity is closer than when using a longer lens.

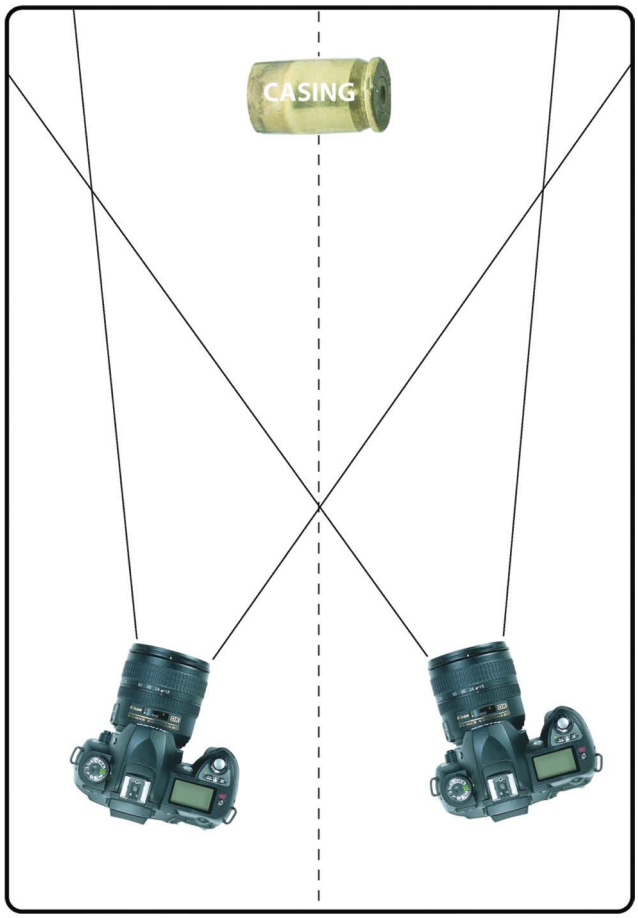


FIGURE 9.12 Incorrect orientation for normal 3-D Photography - possibly only useful for macro-photography.

(From Sandy Weiss/Packer Engineering.)

TABLE 9.1
Interocular Distances (Separation between Camera Lenses)

Camera-to-Subject Distance	Camera Separation
Infinity to 10 feet	1/50th of the camera to subject distance
10 feet to 3 feet	2½ inches
30 inches	2 inches
24 inches	1.6 inches
18 inches	1.2 inches
12 inches	0.8 inches
6 inches	0.4 inches

Images can be captured in vertical, horizontal, or even square format if desired, but the camera must always be level, at the same height for both exposures, set at the same focus, and exposure settings and at the same camera-to-subject distance during each half of the exposure. Table 9.1 lists the suggested starting points for lens separations for the capture of stereo pairs while using a single camera. The photographer is able to adjust the interocular (separation) distance under certain circumstances.

Somewhere in the range of 200 to 1,000 feet, depending upon the subject, using a lens separation of 2½ inches between exposures of the two images of the subject will capture images so similar that any 3-D effect will be nonvisible. When this is a problem, it is an acceptable practice to use a larger distance between the two exposure positions. It is the same principle in aerial photography where stereo pairs are taken from flying airplanes. The stereo effect will still be resolvable when the separation is hundreds of feet between images, and the extra separation is often an aid to the photogrammetrist doing the mapping with a plotter from the resultant stereo pairs.

It is acceptable to either "toe-in" the camera when taking 3-D photos at macro camera-to-subject distances and high magnifications or to roll the subject slightly (Figure 9.13).

The same principle is involved when a person tries to look with both eyes at a fly landed on the tip of their nose. At normal subject-to-camera distances, both images must be taken with the cameras and lenses situated in parallel orientations. At normal viewing distances, always keep the two cameras at the same sensor plane-to-subject distance (Figure 9.12).

TWO MATCHED CAMERAS

Two identical cameras may be physically attached together and used for 3-D image capture. The major consideration is that the separation between the lenses should still be about 2½ inches for most normal subjects. Lens separation (interocular) distances must be adjusted depending upon the focal length of the lenses used on the cameras. The lenses and cameras must be especially well matched, or the images will not be similar enough to resolve. The cameras must be well matched as far as mechanics so the exposures are very similar. The shutters



FIGURE 9.13 NIPSCO power plant.

(From Sandy Weiss/Packer Engineering.)

must work simultaneously if the subject is dynamic. If the cameras are mechanical, a double cable can be utilized. If the cameras have electronic shutter release, any relay assembly triggering both cameras at the same time will be suitable.

See the case study at the end of this chapter regarding the NIPSCO power plant pipe failure.

SCANNING ELECTRON MICROSCOPE

It is not likely that many evidence photographers will ever own a scanning electron microscope (SEM), but SEM services are readily available, and the images the SEM produces are not possible to capture through any other method. The SEM is able to make images at much higher magnifications than is possible with light microscopy. The equipment is also capable in other physical operations.

The limitation of light microscopes is the wavelength of light itself (about 1/50,000th of an inch). When using light microscopes, it is not possible to see anything smaller than the amplitude of the light. The SEM uses a stream of electrons focused onto and bounced off the surface of the sample and then viewed on a computer screen or sent for capture. Samples must be small enough to fit into the SEM vacuum chamber.

Because the SEM views the surface of a sample with astonishing depth of field, it makes things appear as if the viewer had been shrunk down to the same size as the sample and was standing next to it. "By restoring three dimensions to our view of the microscopic world, it has given it reality."[22]

The reality is still just an illusion when viewing individual SEM images. For a more fully realistic 3-D image, stereo pairs can be exposed and then viewed with appropriate print viewing devices. SEM stereo pairs are useful in cases where contrast and shadow alone are not sufficient for the viewer to optically resolve the relief of the image. This is especially useful in technologies like fractography where the relief of the subject fracture is instrumental in determining the fracture mechanics.

The SEM works as well at magnifications in the macro region as it does at higher magnifications. Where color of the subject is a must and the magnification of the subject is not greater than about 30× on the sensor or film, scanning macrophotography is another viable possibility.

SCANNING OR DEEP FIELD PHOTOMACROGRAPHY OR (ZERO-PERSPECTIVE IMAGING)

Scanning photomacrography was first documented in print in 1964.[23] This technique "enables the photographer to obtain a photograph in which all parts of the subject are in sharp

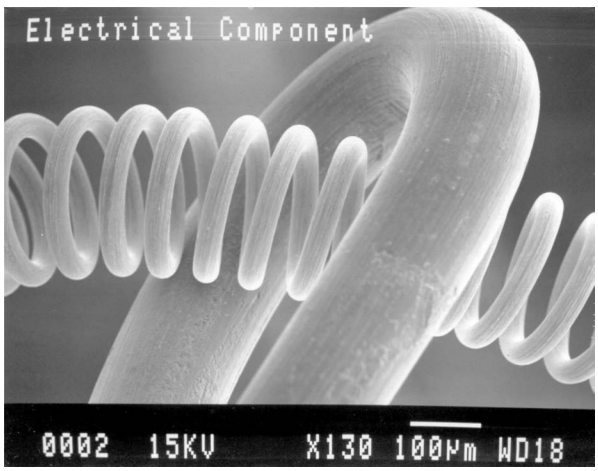


FIGURE 9.14 Scanning electron micrograph.

(From Sandy Weiss/Packer Engineering.)

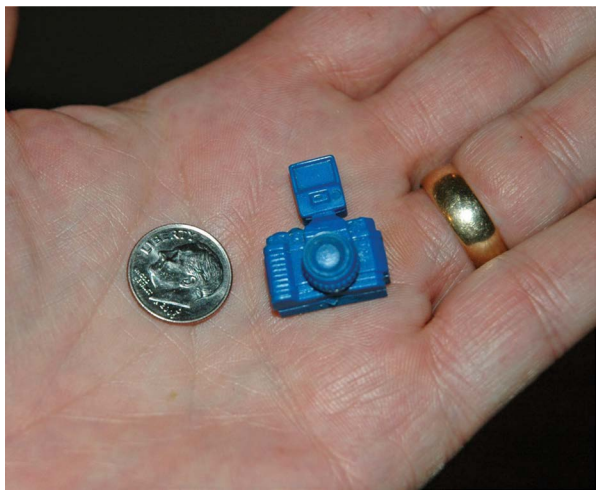


FIGURE 9.15 Scanning macrophotography.

(From Sandy Weiss/Packer Engineering.)

focus without regard to the depth or shape of the object."[24] It is a technology practiced by amazingly few people.

One of the reasons for this method never gaining great popularity may be because only one commercially available apparatus was ever built for image capture. The Dynaphot (see Appendix I) was produced by Irvine Optical of Burbank, California, for only a very short time. It was a wonderful but expensive apparatus. Finding a used device would be a good and lucky experience. Failing thus, a number of articles have been published with instructions on the manufacture of homemade machines.[25]

Consider that stereo-macrophotographs may be taken in full color of subjects at magnifications up to about 30×, with the whole subject in focus. Subjects that cannot be submitted to vacuum or are just too large to fit into the vacuum chamber of the SEM are good candidates for this technique. Any digital camera can be used, as long as it has macro capabilities

With this technology, the subject is raised or lowered through a very thin slit of light during the exposure. The camera is focused on the same plane as the slit of light and therefore only exposes the illuminated part of the subject. As the subject goes through the light, the image of the subject is literally applied to the image sensor. The image is usually very high contrast because of the lighting.

The resultant images, when captured in 3-D stereo, can be viewed in a conventional 3-D print viewer. The separation between the two images needs to be smaller as the magnification increases. The objects photographed by this technique will not only be in total focus but because the whole imaged object is always the same distance from the camera lens, the resultant images will be in a true axonometric form.[26]

The depth of field possible by the use of this technique will be up to 200 times greater than by the use of conventional macrophotography. The incredible depth alone would be enough to give the resultant images a sense of



FIGURE 9.17 Scanning macrophotography 3.

(From Sandy Weiss/Packer Engineering.)

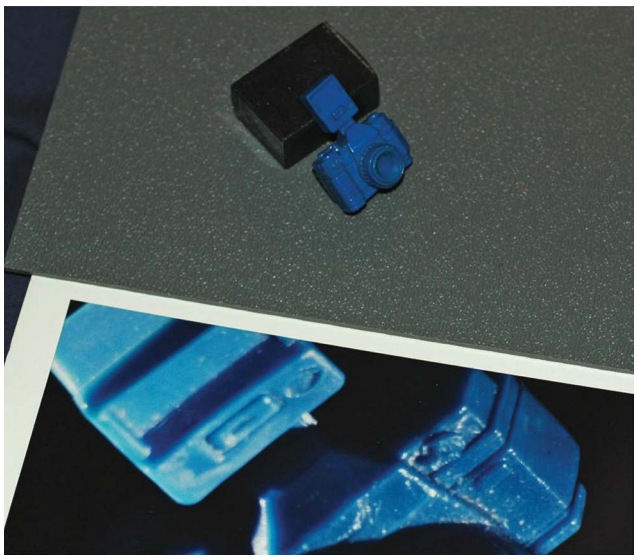


FIGURE 9.16 Scanning macrophotography 2.

(From Sandy Weiss/Packer Engineering.)



FIGURE 9.18 Lenticular technology.

(From Sandy Weiss/Packer Engineering.)

three-dimensionality. When using stereo pairs created with this technique, as with the SEM, the effect of reality is staggering. (See the Appendix.)

LENTICULAR TECHNOLOGIES

"Douglas F. Winnek made 3-Dimensional photography (without the use of a stereopticon) possible in 1940 by lenticulating ordinary film. With the help of the US Navy, he perfected his process for both B&W and color images in 1947."[27] A later development along the same lines incorporated the use of a cylindrical lenticular screen, which was built into the back of a camera just in front of the film plane. The images recorded in this way were a series of narrow interlaced strips of left and right eye viewpoints.[28]

Lenticular[29] technology has always remained popular but has been used mainly for novelty and marketing purposes. There have been items including children's book covers, DVD and Blu-ray sleeves, sports cards, point-of-purchase displays, and key chains. There was a huge boost in popularity of the lenticular process in the 1970s when Nimslo introduced and marketed their quad-lens cameras. People would use their Nimslo cameras for general purposes and send the film away for processing, receiving back snapshot-sized lenticular 3-D prints. The four images would be separated into individual layers in the prints, giving the prints three-dimensionality.

Lenticular 3-D graphics add dimension and/or motion to printed displays. "Lenticular" means "pertaining to lenses," and "lenticules" are the plastic lenses creating the illusion of dimension in depth imaging. Placing special lenses, or lenticules, over a two-dimensional print allows the eye to simultaneously view alternating sections of multiple images. The lens feels like grooved Plexiglas.

The grooves and ridges of the lens are actually lenticules focusing a person's sight on different parts of the underlying picture. The printed image is actually made up of multiple images printed in alternating lines. A narrow band of each image will be printed sequentially with narrow bands of each additional image. If three images are combined, the composite print will include a narrow band of image #1, followed by a narrow band of image #2, then followed by a narrow band of image #3. This pattern of printing is continued (1, 2, 3, 1, 2, 3, 1, 2, 3) for the entire composite print. Viewed in this state, the image is fuzzy. However, viewed under the lens pattern of the lenticular screen, a different view of the image is received from different angles. This creates the special effect. The lens pattern is described in terms of lines per inch. The composite is printed to match the lens pattern, or "pitch." Optimum viewing distances for large format graphics are 3 feet to infinity.

ANAGLYPH IMAGING

Anaglyphs are generated by superimposing a pair of stereo images printed in two different colors, usually red for the left eye and blue for the right, into one new image. When viewed with special glasses having the corresponding lens colors, the 2-D anaglyph image appears to be a 3-D object. "The principal of anaglyph presentation of 3-D images was first proposed in 1853 by Rollmann, and then adapted to practical use by Ducos du Hauron in France in 1891."[30]

The technology works by allowing only red image information to pass through the glasses to the left eye of the viewer and only blue image information to pass through to the right. Each eye only sees the part of the image information seen if viewing the original 3-D object.

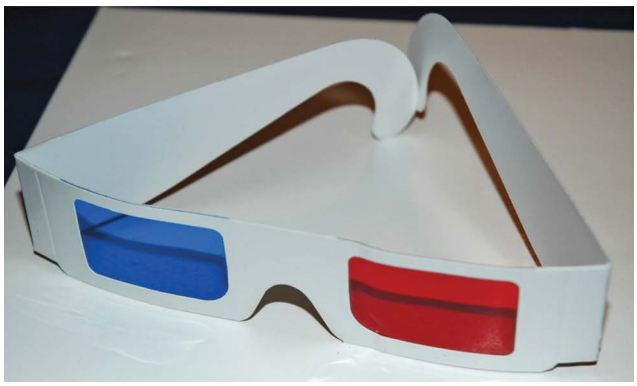


FIGURE 9.19 3-D glasses.

(From Sandy Weiss/Packer Engineering.)

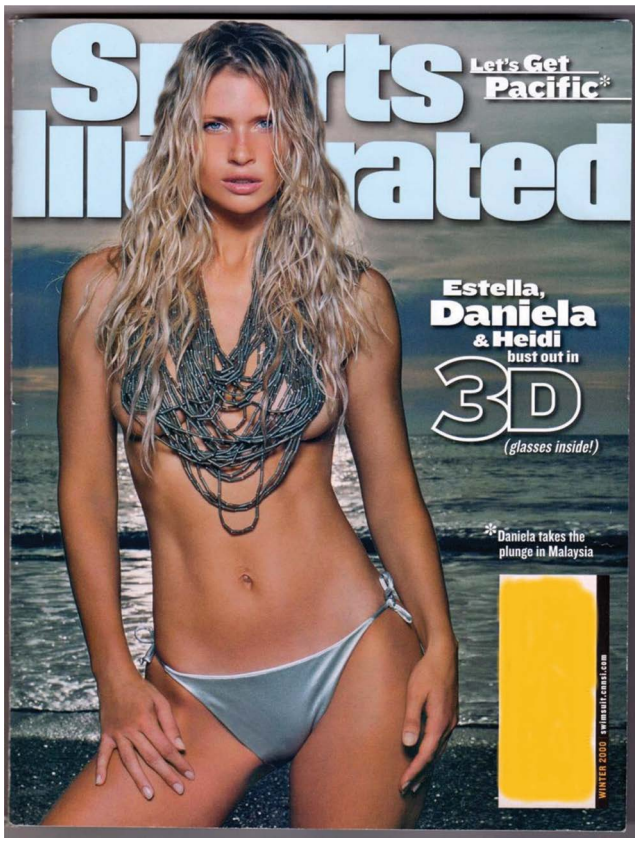


FIGURE 9.20 Anaglyph example on the cover: Daniela Pestova.

(Courtesy of *Sports Illustrated*.)



FIGURE 9.21 Anaglyph examples.

This is a technology that was dormant for over 100 years and is now staging an amazing comeback. Consider the 2000 *Sports Illustrated* Swimsuit Edition and Olympics 2000 Edition of October 18, 2000. The magazines included a pair of red/blue glasses and had both photos of the models in their swimsuits and Olympic athletes printed in anaglyph 3-D.

Using this technology affords a wonderful opportunity to the modern evidence photographer to make their work "stand out" and be more professional than the norm. There is a full-page story on page 12 of the Olympic Edition with information about the way the photographs were created, including a lot of tips for people experimenting in this technology.

Many programs are available for the computer that can be used to create anaglyphs. One can be downloaded for free from www.stereoscopy.com/downloads. It creates anaglyphs in JPEG format to be viewed on a computer monitor, projected on a screen, or printed on to paper.



FIGURE 9.22 Right eye.

(From Sandy Weiss/Packer Engineering.)



FIGURE 9.23 Left eye.

(From Sandy Weiss/Packer Engineering.)

It should be noted some liquid crystal display (LCD) projectors work better than others for anaglyph projection and viewing. If your results on screen are disappointing, try a different projector before throwing away the technology. In most cases in the past, the original anaglyph images were converted to black and white before creating the finished displays. New technologies have enabled the creation of full-color anaglyphs.

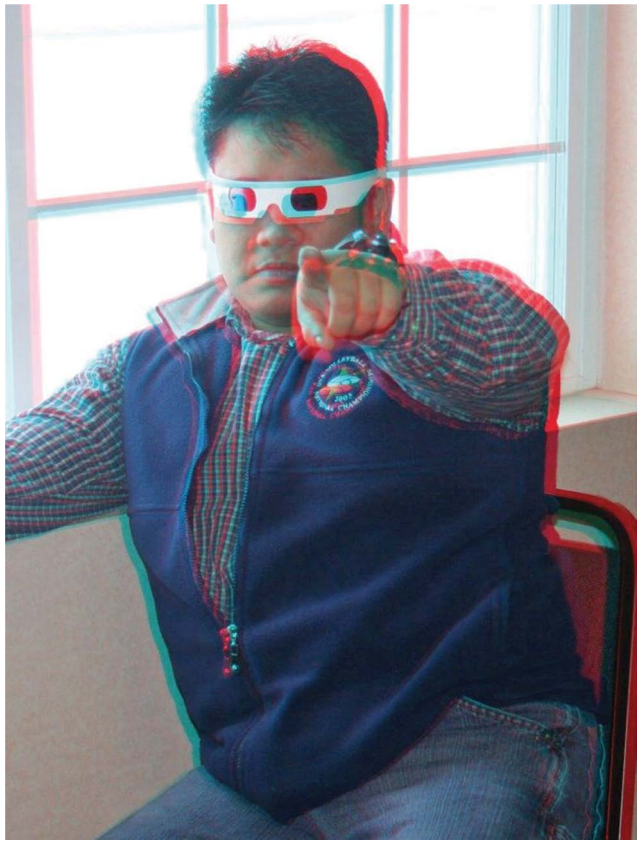


FIGURE 9.24 Assembled anaglyph.

(From Sandy Weiss/Packer Engineering.)



FIGURE 9.25 Anaglyph panorama.

(From Sandy Weiss/Packer Engineering.)

The necessary images for the creation of the anaglyphs can be captured by any of the types of cameras and techniques previously described in this chapter. Digital photography works wonderfully, and the anaglyph technology can be combined with other technologies, including panoramas.

IMMERSIVE/VIRTUAL REALITY TECHNOLOGIES

Virtual reality (VR) uses computers to generate virtual artificial spaces and objects from photographs of the actual space or object. Immersive/virtual reality visualization techniques allow the viewer a greater sense of "being there" than most other forms of 3-D visualization.

By definition, true VR is immersive—it has the need for the viewer to participate in the image and to be an active part of the space. A participant wears special headgear and gloves and may seem to open doors and walk through them. Even pseudo-VR, where the observer is essentially on the outside looking in, is a very effective demonstrative technology. The latter is the type of VR easy for today's forensic photographer to create with a camera and personal computer.

The possible applications using this technology are virtually infinite. Three-dimensional 360-degree VR panoramas, and object images can be created for almost any demonstrative reason, from almost any scene or subject, and be replayed on a computer or projected on a screen. Because human comprehension of complex 3-D objects improves with each additional visual cue, the more cues, the less the viewer needs to rely on imagination to fill in detail.

In 360-degree panoramic movies, the viewer uses peripheral vision along with normal vision for visual cues to correctly place objects in the visual field. Panoramic movies allow the viewer to stand in one place and revolve the visual field around them in order to observe a full 360 degrees of a room or a scene. The image can be zoomed in and out to study small details. The image clarity is dependent upon the resolution of the original photographs and the amount of compression of the files when the software melded the images.

The panorama in Figure 9.26 was made from 16 wide-angle images taken at one of the concourses of O'Hare Airport near Chicago. Images must be produced with a camera leveled to the horizon and are made to overlap from image to image at exactly the right spacing.

Some technologies will even allow the viewer to move the view up and down to 360 degrees in the vertical axis. In addition, it is possible to take accurate measurements between objects using these images if produced by the proper cameras.



FIGURE 9.26 VR panorama.

(From Sandy Weiss/Packer Engineering.)



FIGURE 9.27 Leica laser scanner

(From Leica Geosystems.)

The images necessary to create a panorama scene without measurement capabilities are relatively simple to capture and require a minimum of unusual equipment. A solid tripod, panorama head, and any type of camera will work. The wider the lens on the camera, the more vertical field will be included in the panorama.

There are police departments routinely using this technique to virtually walk both witnesses and jurors through crime scenes. There are companies doing tactical VR studies for law enforcement, military, malls, schools, office buildings, hospitals, etc. One reason is for police or fire department personnel to enter the facilities; they can use a computer and see the actual places they have to reach and not have to discern the location from drawings or blueprints. If a tactical VR study of a facility or scene is done at the time of an accident or crime, no matter what changes are ever done to the location, people will be able to "walk through" the location the way it appeared at the time the images were taken. If the scene is outdoors and photographed at the right time of day and right weather conditions, the panorama produced could be very valuable for vision studies. The military uses tactical VR for training soldiers in many different basic operations.

Movies can be produced of any 3-D object. The movies can be as simple as one row around a subject, so the subject can be seen from any horizontal (00) position. The movies can also be a multilevel series showing a subject from + or − from 00 elevation.

Multilevel movies are simple if the subject is small but are more complex if the subject is large. Object movies are routinely being done for any type of activity training, including applications of surgery in the medical field. (Object movies are also the subject for emergent technologies in archaeology, architecture, etc.—see Chapter 35.)

LASER SCANNING

Major factors in digitizing accident/incident scenes are the speed and quality of the scan. Many companies and departments now use 3-D laser scanning devices. 3-D laser scanning is a noncontact and nondestructive technology, making it ideal for evidence preservation at the scene of an accident/incident, and digitally captures the shape and size and relationships between physical objects using a line of laser light. The scanners create "point clouds" of highly accurate data, which would require huge amounts of data and time for accurate description and digitization from the surfaces of objects. They digitize physical, real-world objects and scenes impractical and/or impossible using any other traditional measurement methods into the computer as digital 3-D representations (see Chapter 19 for additional information).

As soon as a site is available to a scanning team, the device can capture the entire area as point cloud data. The scanner recognizes the shade of a reflective surface and builds a 360-degree point cloud, which results in an image similar to a 3-D photograph. This gives the user a perspective that cannot be achieved through conventional methods like traditional digital photography.

Additionally, scanners can be used indoors as well as outdoors, day or night, with lighting conditions not being a concern. (There may be some weather parameters, however—consult an expert.)

When using a total station, the investigator must know exactly what needs to be documented at the exact moment of the documentation. The 3-D laser scanner documents everything, allowing exactly what is needed to be extracted from the collected data. Some examples of use include the documentation of an automobile accident—the roadway can be returned to use more quickly by utilizing the laser scanner. In addition, buildings often undergo major alterations. In many instances, these alterations are not recorded in the original construction plans. An initial survey laser scan can accurately document any current condition of the building. When making renovations or repairs, the plans can be based on the exact, current status.

In industrial facilities, scans of complete production environments, including the facility itself and all equipment, are beneficial when assessments and audits are necessary.

In the future, much forensic imaging now done with photography may someday be done with 3-D laser scanning.



FIGURE 9.28 Color point cloud.

(From Sandy Weiss/Packer Engineering.)



FIGURE 9.29 Setting up scanner.

(From Sandy Weiss/Packer Engineering.)

3-D INFORMATION FOR ANALYSIS

There is a very large area of cross-over between 3-D images used for display and those used for analysis. Almost any images captured solely for 3-D display can yield some quantitative data when subjected to analysis. It is also possible to use any 3-D images captured for analysis for some type of display. However, the 3-D images captured specifically for the purpose of analysis will yield the most precision if they are captured within the guidelines of the technology for which they were meant. The greater the mathematical precision desired, the more control necessary in the image capture. (See Chapter 21 for more information.)

SKETCHES

In *Techniques of Crime Scene Investigation*, Dr. Fisher talks about the use of sketches for the documentation of the crime scene. Sketches are normally drawn by the same person or persons who do the scene photography.

> A crime scene sketch is simply an illustrative diagram which more-or-less accurately depicts the appearance of the scene. Sketching the scene requires skill on the part of the investigator. Generally, it requires more than one person to draw the diagram. One person may be responsible for the actual drawing and one person for taking measurements. Sketches offer a permanent record of the relationship to each other of items at the scene and help supplement photographs. Items must be located within the sketch and measurements must be taken from reference points.

When speaking of the admissibility of the sketch in court, he states, "the qualified individual must be able to testify the sketch is a true and accurate representation of the actual scene." One thing all of the evidence manual authors agree upon is to make a good sketch, you have to be careful and take your time. Time is the one commodity of which the forensic investigator/photographer never seems to have enough.

However, there are more efficient and precise ways to record any scene than by putting detail into a sketch. It is still always necessary to make notes and a sketch, but all of the important visual detail can be recorded photographically and then analyzed by computer.

"By taking the correct photographs of any scene, indoors or out, every item in the scene can be measured and accurately placed and compared to every other item. The situation or scene is recorded in the shortest possible time by the use of photogrammetry." The sketch and notes can be reserved for documentation and location of reference points and base measurements. Reducing the time it takes to put things on paper on an assignment can make an investigation more efficient and more accurate. Doing the scene image analysis photogrammetrically can also be proven in court to be more accurate than hand-made measurements, subject to human error, through the demonstration of mathematical principles and by the production of reference items both measured from the photos and then measured from the actual items.

The documentation of indoor scenes is similar to the documentation of outdoor scenes, except for the addition of walls and other obstructions restricting the movement of the photographer. When working indoors, there is still a need for a sketch and some base references and measurements. The structure will never again be in the same condition as it would be at the time of the incident, so all necessary images must be captured at the time of the incident. There is also no guarantee that a structure will remain standing in the future.

By taking the proper photographs of any scene, indoors or out, the three dimensions of any object that has been successfully photographed can be determined photogrametrically. In the past it was necessary to use the perspective method of photogrammetry to derive measurements when only single photographs of something existed. If stereo pairs of images were available, an analytical plotter was used to derive numerical information. With the aid of the computer and sophisticated software, it is now possible to derive precision measurements from either single photographs or multiple images by inputting the photographs to be studied into the computer, doing some necessary physical marking onto the images, and then processing the images with the software. Several software packages are available for this work. PhotoModeler is used for an example in this book. A trial version of the software may be downloaded from there.

PhotoModeler software extracts 3-D measurements and makes models from photographs taken with any ordinary camera. This is truly a cost-effective way to accurately create 3-D scans of anything for measurement, surveying, and capturing near reality.

CONCLUSION

It is important to remember that all disciplines are affected by 3-D technologies. Everyone in the various fields of forensics, especially forensic photographers, should not only be aware of the opportunities, both old and new, 3-D technologies offer but should also be experimenting with them and even offering them as services to their clients.

Some people will not be able to mentally or physically resolve the images into 3-D displays. Some people find sufficient cause to forget about the possibility of using 3-D. However, the benefits mostly overshadow the liabilities, and 3-D should not be dismissed lightly.

3-D is definitely here to stay. Everything from keychains to children's books and mainstream magazines are using 3-D to sell products. Chances are the 3-D documentation brought into court will find a familiar audience.

CASE STUDY 9.1

On July 4, 1991, the NIPSCO Bailly Generating Station on the shores of Lake Michigan in northern Indiana experienced a major circulating water pipe collapse. The 14-foot twin corrugated steel pipes ran nearly 600 feet from the plant to the lake and back. One pipe brought cool water in, and the other took the warm water out. Sand was leaking through rusted holes in the pipes for years, leaving voids in the soil around the pipes and causing the pipes to be unsupported. A piling driven in above the pipes fell through a large void and initiated a catastrophic chain reaction collapse of both pipes. Packer Engineering, Inc., supervised the removal of the old piping, investigated the accident, and supervised the reinstallation of the new piping.

The call came from the client on the morning of July 4. There was a major disaster, and the company wanted a fly-by the same day to make aerial photographs documenting the damages so the reconstruction could start immediately. Every minute the plant was shut down cost NIPSCO a lot of money. With no water, there was no operation.

It was difficult to hire a small plane to fly to Indiana from Chicago on July 4, but eventually a plane was hired, and two Packer employees did aerial photography of the damages with a Pentax 6X7 camera with a 55 mm wide-angle lens on 400 ASA color negative film. The higher ASA helped to capture sharper images because of the higher shutter speeds needed for the flying platform. The larger format was also an advantage.

The plane flew directly back to Naperville; the film was processed immediately for assurance that the images were indeed recorded, and the cranes and bulldozers could get to work at first light.

A large team was on site to document the destruction and each step of the above-ground deconstruction of the collapsed structures. Each roll of film was dated and coded with a location to document each step of the process. The pipes were each 14 feet tall, corrugated steel, and 600 feet in length. The pipes



FIGURE 9.30 NIPSCO at night.

(From Sandy Weiss/Packer Engineering.)

could not be repaired. They needed to be removed, replaced, and tested before operations could be resumed.

Every overall photograph of the excavation and removal of the pipe was imaged in 3-D stereo pairs. It would have taken too long to do transit readings at each phase, so the photos were taken for data and the data was extracted at the lab. Three-dimensional stereo pairs were especially necessary to be captured at night, as no other means of measurements could be performed under those low-light conditions.

A matched pair of Pentax MX cameras were used. They were outfitted with motor drives and 15 mm rectilinear fisheye lenses. The lenses were specially picked by Pentax at their manufacturing facility to be a matched set, and the optics were checked at the physics department of the University of Minnesota. The Pentax MX was chosen because the light meter display was a series of red/orange/green/orange/red lights, and they were easy to use to meter properly in low-light conditions.



FIGURE 9.31 Cutting the sections.

(From Sandy Weiss/Packer Engineering.)

Fourteen-foot corrugated steel pipe is very heavy. It had to be cut by torch into sections, marked for location, and then lifted by crane onto flatbed trucks to be hauled to a remote location, called a bone yard, for reconstruction. NIPSCO did not just want to get the old out and the new in; they wanted to know what happened to the old pipe to possibly keep the same thing from happening elsewhere; thus, they needed the reconstruction.



FIGURE 9.32 View from above.

(From Sandy Weiss/Packer Engineering.)

Much of the old pipe was totally flattened, and all of it was under tons of sandy soil. The pieces were marked, cut, lifted, remarked, hauled, and stored.

At the bone yard, the project called for documenting each piece of pipe. A protocol was developed for the operation. Each piece of pipe was assigned a dedicated 24-exposure roll of 200 ASA film. A Canon F1 camera with a 50 mm f3.5 Macro Lens was used. Each piece was documented by first exposing an image of the piece number marked on the surface; then an overall of each side; then an overall of each of the four edges with scales, as most of them were rectangles; then a forklift or crane operator would turn the section over and the same images were taken of the other side.

The object was to be able to take the photos and create a giant jigsaw puzzle and assemble the images to find the origin of the fracture. There were hundreds of pieces. So, the camera had to be loaded, the photos exposed, documentary notes made, and then unloaded; the roll was then marked, reloaded, and the process started again. Of course, all of the photos had to be as good as could be. Fortunately, the weather was nice in the fall, and the work went smoothly. One thing that was an issue, though, is there were no facilities of any kind in the bone yard. When this is the case, be sure to work out a system for all eventualities before going to work for the day.

Winter came, and the pipe was covered with snow. The pipe documentation project was put on hold until spring. The removal from the trench and transport to the yard, however, went full speed ahead.

The beginning of February arrived, and the project engineer decided it was time to continue the documentation. He was at the plant and the weather was lovely, and he wanted everything back online the next day.

With gear packed, the project restarted. It took over a week of steady work to finish the assignment. The temperature did not rise above 20° for one minute of the week. Luckily, the Canon F1 is a very cold-weather camera. But the Kodak film was not happy. The gray plastic lids on the black plastic film cassettes got very brittle and stiff and had to be bitten off to change film.

Upon completion, hundreds of rolls of film were taken back to Packer for processing. Every roll was developed successfully. The client wanted two contact sheets of each roll and no prints. Packer kept one contact sheet for their files. So, each roll of film needed three contact sheets.

The root cause of the failure was determined, the new pipe was installed without mishap, and the plant went back online within a year of the catastrophe.

APPENDIX I

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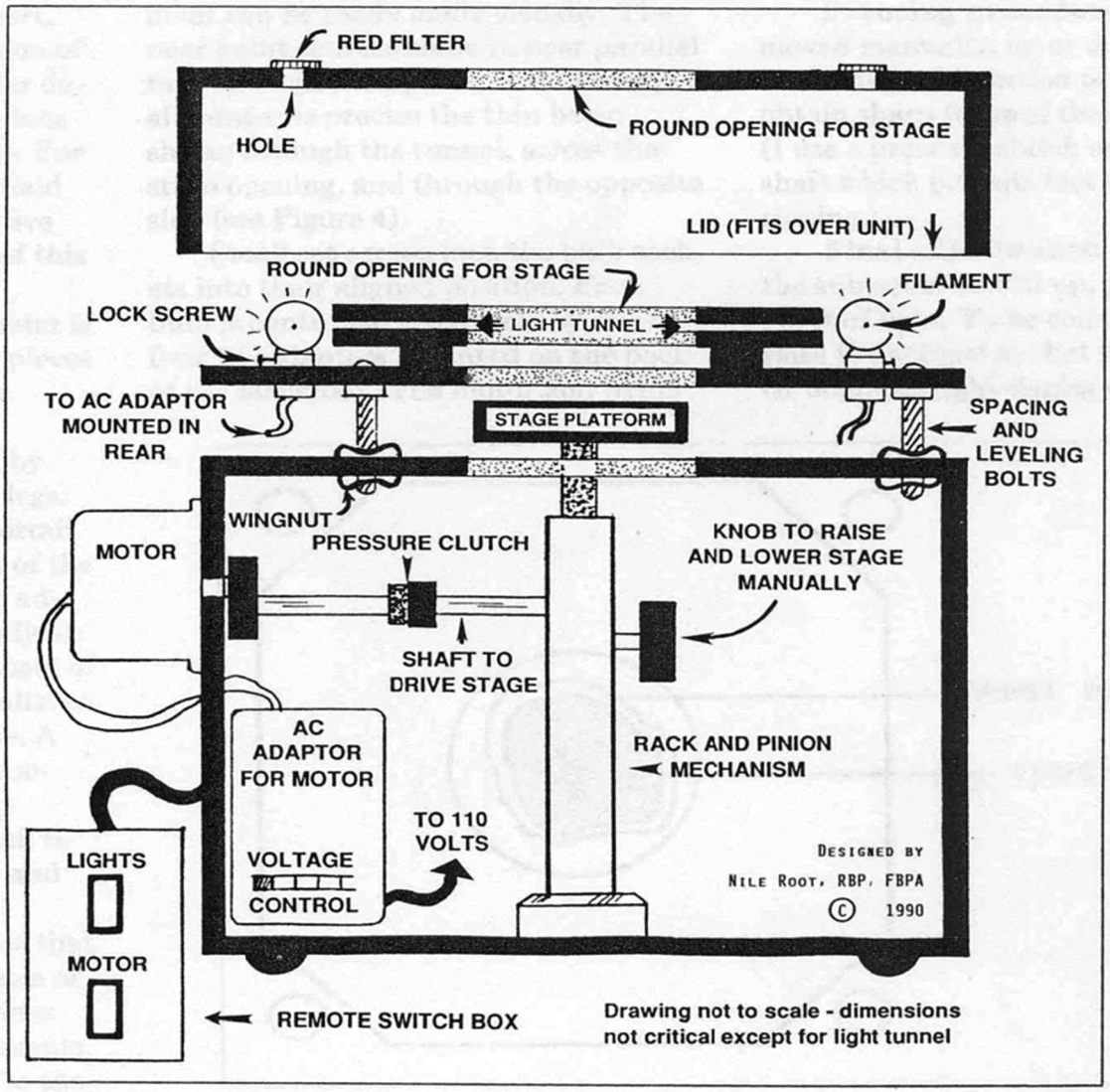
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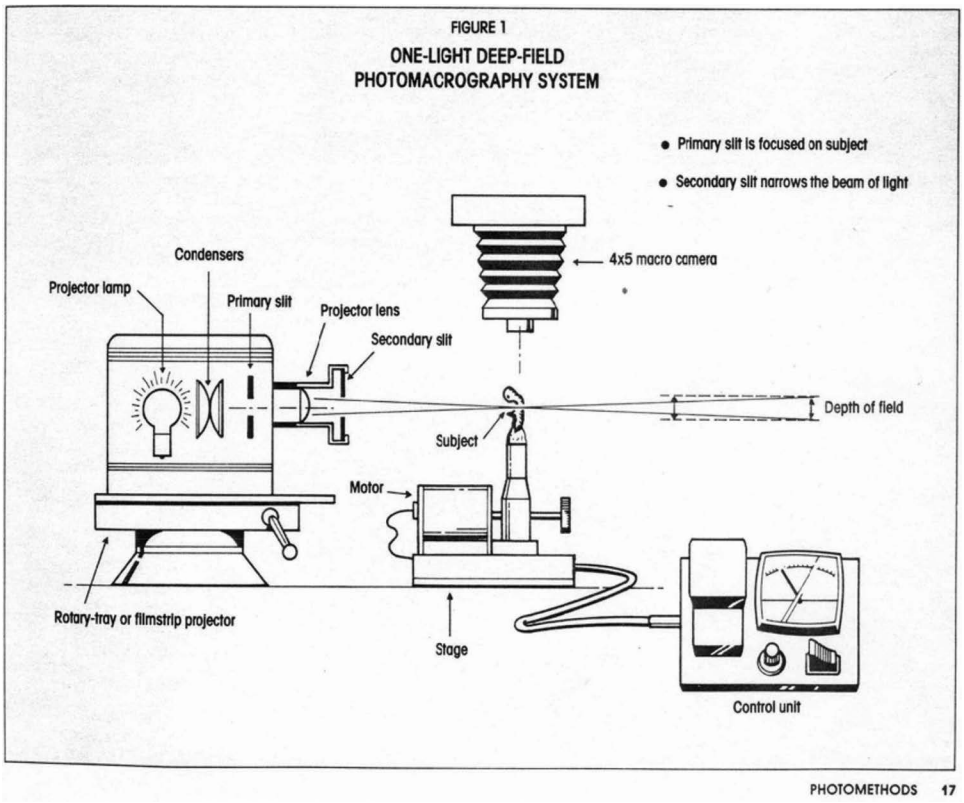
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LIGHTS
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REMOTE SWITCH BOX
Drawing not to scale - dimensions not critical except for light tunnel


FIGURE 1
ONE-LIGHT DEEP-FIELD
PHOTOMACROGRAPHY SYSTEM
• Primary slit is focused on subject
• Secondary slit narrows the beam of light
4x5 macro camera
Condensers
Projector lamp
Primary slit
Projector lens
Secondary slit
Depth of field
Subject
Motor
Rotary-tray or filmstrip projector
Stage
Control unit
PHOTOMETHODS 17

summer 1988

NEW PHOTOGRAPHIC POSSIBILITIES THROUGH THE USE OF SCANNING PHOTOMACROGRAPHY

by Jim Gerakaris

Undoubtedly the most noticeable problem encountered when making photos using photomacrographic techniques (within the image magnification range of life size to X40) is that of depth of field, or more accurately, lack of it. The most common solution to this problem is to stop the lens aperture down thus rendering a larger area of the sample in acceptable focus.

This procedure, when used with routine photographic applications, will often solve the depth problem with very acceptable results. However, with photomacrography, a problem can very quickly arise just by closing the lens aperture a few stops. This problem has to do with the resolution loss that occurs due to diffraction in which a general fuzziness, or lack of clarity appears and increases as the lens aperture is closed. When photographing **small** objects at some degree of magnification, it should be remembered that the smaller the lens aperture, the more noticeable will be the loss of detail. The added magnification that occurs when an image is enlarged to make a print, or projected as a transparency, increases the problem. As with most things in the photographic realm, it is necessary to analyze your priorities and decide whether depth of field or resolution is needed most. There may come a time, however, when both resolution and depth of field are required.

A solution to this problem can be realized whereby the subject can be recorded completely in focus without any loss of resolution from that normally obtained when the lens is stopped down enough to adequately eliminate any inherent aberrations. The technique is called **scanning photomacrography** and is accomplished through selective illumination of the subject which allows only those areas of the subject which fall within the depth of field of the camera to be illuminated. Through the work of photographers such as Darwin Dale of Lansing, Michigan, foremost pioneer and practitioner of scanning photomacrography, the technique is becoming more familiar and practical applications for its use are being found daily.

The technique in itself renders only a thin slice of the subject onto the final image and offers little improvement over the previous method where just a small section of the sample is in focus. The important thing to keep in mind, however, is that everything within the strip is exposed in focus. If the sample now could be moved up or down through this illuminated path without disturbing the positions of either the lighting or the camera, every part of the sample that crosses through the plane of illumination would be exposed in focus on the film.

The film exposure is regulated by adjusting the speed at which the subject moves through the illuminated area. The faster the movement, the less the amount of light that will reach the film from any given point on the subject, and conversely the slower the movement, the greater the exposure that will take place at any given point on the film.

The Technique

To make a scanning photomacrograph, you will need a light source (or sources depending on the subject) that can project a slit of light onto the subject to be photographed. This slit should not exceed the limits of the depth of field of the camera at the chosen magnification or else the exposure of out-of-focus areas will result in a blurred final image. A stage is necessary to hold the sample and to move it at a steady speed during its exposure to the light path projected by the illuminators. The speed of this stage must be variable to allow for exposure compensation from one exposure to another, and all of this must be accomplished with no lateral displacement or vibration transmitted to the subject to be photographed.

The composition of the photo must be chosen in the same way as for a normal photomacrograph. Using a conventional light source, or high intensity light, adjust the magnification of the camera system and compose the subject within the frame. Next, turn off the conventional light source, reduce the ambient level of light in the room, and move the stage up about one centimeter from its lowest position. Arrange the lighting so that a sharply focused slit of light parallel to the depth-of-field area is projected somewhere toward the top of the subject to be photographed. If more than one illuminator will be used, make sure that all of the illuminators are aligned and focused onto the same plane. Focus the camera on the illuminated area and check to see if any out-of-focus areas are exposed to the lens due to the slit of light being larger than the available depth of field. If out-of-focus areas are seen, decrease the size of the slit, or adjust the height of the illuminator until the entire slit exposes only those areas that are in focus to the camera.

The lighting can be set up from all sides of the sample, and the intensity or the size of the slit can be varied to create a modeling effect. Only areas that are in focus to the lens should be illuminated and the illuminators must be set up at right angles to the lens axis. This is so the image of the slit will not be distorted as it travels up or down the sample, possibly exposing areas to the film that would be out of focus due to defocusing of the image of the slit.

After this has been accomplished, the stage is lowered to take the subject out of the path of illumination, and the shutter of the camera is opened. Now all that remains to be done is to move the subject straight up through the path of illumination causing it to be exposed slowly to the film. As was mentioned previously, the speed of the subject's travel regulates the amount of exposure that the film is given. When the sample has moved entirely through the illumination plane, the camera shutter is closed and the exposure is complete.

Illuminating concavities in the sample and photographing transparent or translucent subjects can create some difficult situations when using scanning photomacrographic techniques due to the angle and the type of the lighting used. In many cases careful subject arrangement and thoughtful light placement can overcome these difficulties to provide

techbits

stunning photos that were previously not possible using conventional techniques.

In comparison to scanning electron microscopy, scanning photomacrography allows the subject to be photographed in full color without having to gold- or carbon-coat it, and the subject does not have to be subjected to high vacuum. If the photographic applications of a lab fall between X1 and X30, a scanning photomacrographic unit can be purchased for a fraction of the cost of an SEM. Unlike the SEM, where the image is acquired and transmitted electronically to the film in gradations of tone which form essentially a monochromatic image on the film and where color can be added artificially, scanning photomacrography allows the samples to be rendered in natural color the same as a photo of a landscape would be rendered on film.

Film and Equipment

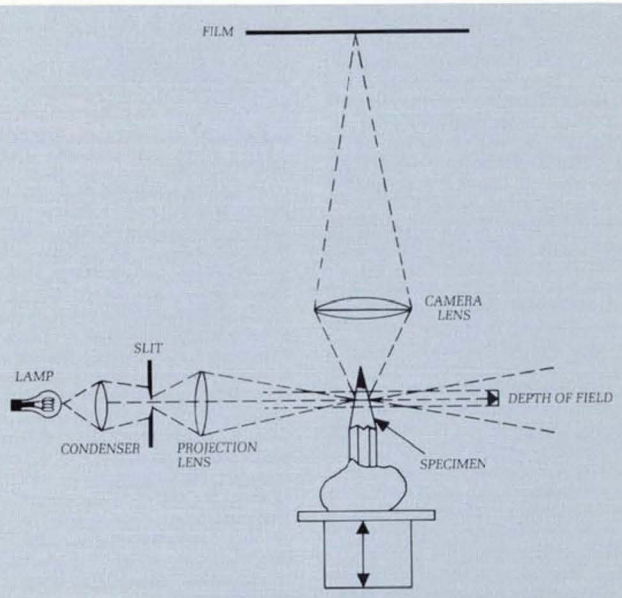
It is possible to build a scanning photomacrographic unit and get good results. This can be accomplished by using slide projectors with slits as narrow as razor blades for the illuminators and various telescope parts to construct the stage apparatus. Or, equipment can be purchased ready-to-use. A special unit called the Dynaphot®, produced by the Irvine Optical Corporation in Burbank, California, is designed specifically to make scanning photomacrographs. It features adjustable slit illuminators to accommodate the different depth of field parameters encountered through magnifications ranging from life size to X30. Its stage can accommodate speed changes necessary to make exposures within this magnification range and it makes an excellent device for non-scanning reflected light photomacrography as well due to its smooth controllable movements in the X, Y, and Z axes.

KODAK EKTACHROME 50 Professional Film (Tungsten), used for many of the illustrations shown here, is an excellent choice for scanning photomacrography. Because of its tungsten color balance, it can be used without light balancing filters, and its speed is ideally suited for use with most camera systems and formats. Its fine grain and excellent color saturation, when combined with the unique images obtained in scanning photomacrography, make for some of the most striking and informative photos ever made in this magnification range.

When higher contrast situations are encountered and more latitude is needed, a color negative film may be required. KODAK VERICOLOR Film is ideal for this type of application, but since this film is balanced for daylight, a light balancing filter is required when it is used with a tungsten light source.

Some of the uses of scanning photomacrography include metallography where high relief fractures must be examined, or forensic and archaeological photography where evidence or artifacts must show minute detail at high magnification with as much of the subject in focus as possible. Other areas of application include paleontology, geology, botany, entomology, as well as medical photography and the photography of foraminifora for the petroleum industry. The advantage of being able to photograph a subject at magnification of X1 to X30 completely in focus and with high resolution allows for a new look at seemingly impossible-to-photograph samples. This makes the field of scanning photomacrography a continually expanding one with new applications being found regularly.

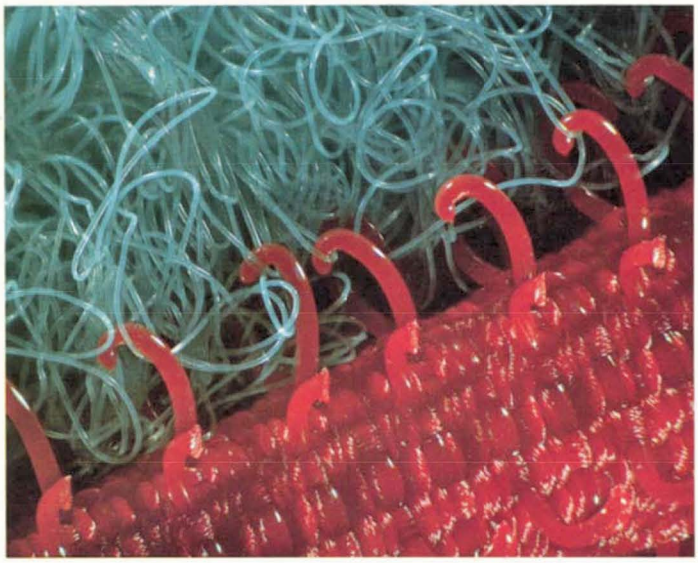
A discussion of the subject can be found in the article "Light scanning photomacrography—a brief history and its current status," Journal of Biological Photography, Volume 53, Number 2, April 1985. The author is Nile Root, professor and coordinator of the Biomedical Photographic Communications program at Rochester Institute of Technology.



SCANNING PHOTOMACROGRAPHY

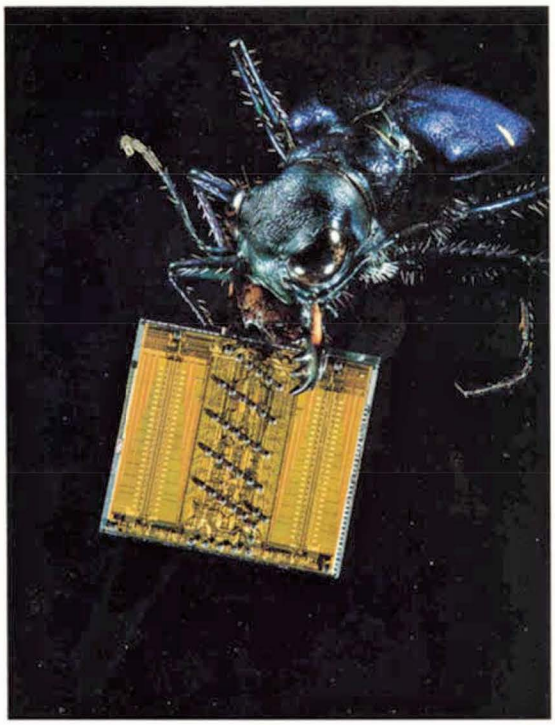
Diagram showing the lighting configuration necessary for scanning photomacrography. By lighting only the area of the sample that is within the depth of field of the camera, an image which is totally in focus is rendered onto the film when the sample is scanned through this selectively lit area.

summer 1988



Scanning photomacrograph of a Velcro fastener photographed at X10 on KODAK VERICOLOR II Professional Film 4108, Type L, and then converted to a transparency using KODAK VERICOLOR Print Film 4111. Magnification of this illustration is X30. Photograph © 1986 Darwin Dale.

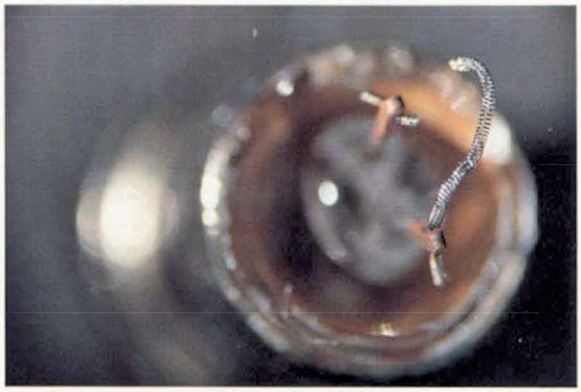
The same technique was used in this photomacrograph of a Tiger Beetle holding an IBM Integrated Circuit Chip photographed at X8. Magnification of this illustration is X20. The various colors seen in bands across the eye are not visible in most fixed preparations. Photograph © 1986 Darwin Dale.

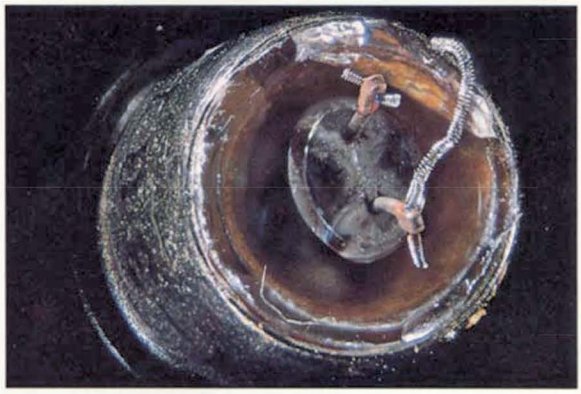


techbits

The illustrations on these pages were made by scanning photomacrography using KODAK EKTACHROME 50 Professional Film 5018 (Tungsten). They were made by Jim Gerakaris, practitioner of scanning photomacrography and author of this article.

Photo at the top was made using conventional photomacrography. It shows the filament of a small light bulb at X3 after the envelope has been shattered. The same light bulb, photographed using scanning photomacrography at X3 magnification, is seen at the bottom. Photos such as these are often used by forensic scientists to determine if the lamp was on when the glass envelope was shattered. Information of this sort often proves invaluable when trying to determine whether the driver of an auto had his headlights on or off before an accident occurred.









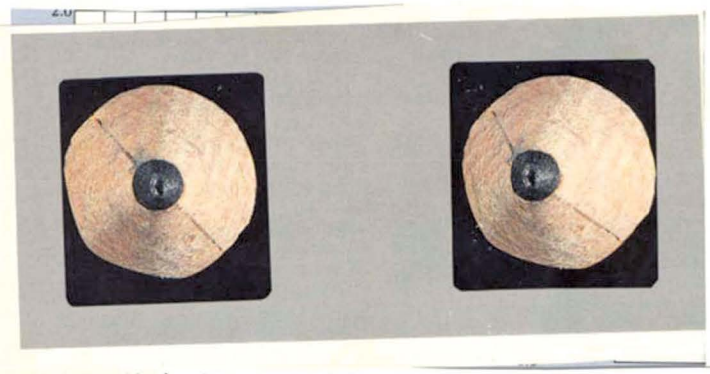
The fractured surface of a stamped metal "bank vault" key at X3 magnification is shown at the far left. This was made using conventional photomacrographic techniques. The same key photographed at X3 magnification using scanning photomacrography shows not only the fractured surface, but the machine marks along the side of the key.







A wood splinter, upper left, photographed at X4 magnification with the lens aperture fully open renders the subject with maximum resolution and minimum depth of field. The figure above right shows the wood splinter with the lens aperture fully closed illustrating maximum depth of field but great loss of resolution due to diffraction effects. At the bottom left, the wood splinter has been photographed using scanning photomacrography at X4 with the lens aperture wide open. This illustration shows the resolution gain over that in the middle figure with even greater depth than if the lens aperture were fully closed.



A stereo pair showing the tip of a pencil at X2 magnification using scanning photomacrography. A stereo pair consists of two photos of the same subject made from slightly different vantage points to simulate the different viewing positions of the eyes. When viewed in a way that allows the left eye to see only the left photo, and the right eye only the right photo, the subject will appear to the viewer to have not only length and width, as in conventional photos, but to have depth as well. Since the brain is given data similar to that received when viewing the actual object, it appears that the subject is floating and magnified in front of the viewer's eyes the same way as if the person were looking through a stereo microscope.

NOTES

1. Bomback, Edward S., *Manual of Color Photography*, 1st American Edition, A.S. Barnes and Company, London, 1966, p. 69.
2. O'Hara, Charles E., *Fundamentals of Criminal Investigation,* 5th ed., Charles C Thomas, Springfield, IL, 1981, p. 58.
3. Bush, Vannevar and Rule, John T., *Handbook of Photography*, McGraw-Hill, New York, 1939, p. 572.
4. Bomback, *Manual of Color Photography,* p. 70.
5. Bush and Rule, *Handbook of Photography,* p. 572.
6. Morgan, Willard D. and Lester, Henry M., *The Leica Manual*, Morgan and Lester, New York, 1936, p. 249.
7. Zeller, Bob, *The Civil War in Depth*, Chronicle Books, San Francisco, 1997, Introduction.
8. Spencer, Otha C., A Gallery of Stereo Life in the 1890s, *Shutterbug Magazine*, February 1997, p. 223.
9. Aguila, Clement and Rouah, Michel, *Exakta Cameras 1933-1978*, Hove Photo Books, East Sussex, 1989, p. 8.
10. Blaker, Alfred A., *Field Photography, Beginning and Advanced Techniques*, W.H. Freeman and Co., 1976, San Francisco, p. 401.
11. Brown, Julian (ed.), *The Chronicle of the Movies*, Crescent Books, New York, 1991. p. 175.
12. Brown, *The Chronicle of the Movies*, p. 179.
13. Rosanes-Berrett, Marilyn B., *Do You Really Need Eyeglasses*, Instant Improvement, Inc. New York, 1991, pp. 82–83.
14. Hedgecoe, John, *The Art of Color Photography*, Mandarin Offset, Ltd., Boston, 1st ed., 1977, Introduction.
15. Bomback, *Manual of Color Photography,* p. 67.
16. Swanson, Erik, Inventors Online Museum, July 2000, www.inventorsmuseum.com
17. Winnert, Derek, *The Ultimate Encyclopedia of the Movies*, Carlton Books, Ltd., London, 1995. p. 43.
18. Pinsky, Susan and Starkman, David, *The Reel 3-D Catalog*, available by phone at 310-837-2368 or at www.reel3d.com
19. Kirschner, Suzanne Kantra and Vizard, Frank, Everything 3-D, *Popular Science*, January 1998, p. 34.
20. *Chicago Tribune*, Vintage Photography, Old Arts Find New Practitioners, February 11, 1999.
21. Duckworth, John E., *Forensic Photography*, Charles C Thomas, Springfield, IL, 1983, Introduction.
22. Ballantyne, Marten and Mathews, *The Photo*, Marshall Cavendish Ltd., Volume 1, Part 13, 1983, p. 351.
23. McLachlan, Dan Jr., Extreme Focal Depth in Microscopy, *Applied Optics,* Vol. 3, No. 9, pp. 1009–1013.
24. Root, Nile, Deep-Field Photomacrography, *Biomedical Imaging*, May 1986, pp. 16–18.
25. Root, Nile, Light Scanning Photomacrography – A Brief History and Its Current Status, *Journal of Biological Photography*, Vol. 53, No. 2, 1985.
26. Pearl, George S., Scanning Evidence Photography, *EPIC Journal*, Spring/Summer 1998.
27. Poli, Kenneth, Ready When You Are E.T., *Popular Photography*, November 1989, pp. 98–99, 184.
28. Sussman, Aaron, *The Amateur Photographer's Handbook*, Thomas Y. Crowell, London, 1962, p. 11.
29. Hedgecoe, John, *The Photographer's Handbook*, Alfred A. Knopf, New York, 1979, p. 301.
30. http://www.big3d.com/



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10 Human Vision and Low-Light Photography

Paul Kayfetz, George Pearl, Sanford L. Weiss, and Robert Wyman

CONTENTS

Introduction 208
Low-Light, Available-Light, and Nighttime Photography 208
Contrast and Conspicuity 209
Night and Existing-Light Photography 210
Tips for Low-Light Photography 211
Metering at Night 211
Quantifying Spectral Sensitivity 211
Luminance 212
Illuminance 212
Measuring Light 213
Human Vision in Low Light 213
Digital Night Photography 214
Capturing the Scene in Low Light 214
- E.S. Bomback: 1966 215
- John Duckworth: 1983 215
- J. Stannard Baker and Lynn Fricke: 1986 215
- William Hyzer: 1988 215
- Robert Holohan: 1989 216
- Ernest Klein and Gregory Stephens: 1992 216
- James Harris Sr. and James Harris II: 1992 216
- William Hyzer: 1993 216
- T.J. Ayres: 1996 217
- Paul Olson: 1996 217
- J.B. Hyzer: 2002 218
- Paul Olson and Eugene Farber: 2003 218
- Boyd Allin, Kurt Isling, and David King: 2007 218

Hardware for Measuring Luminance and Illuminance 219
Meter Applications 219
Night Vision Low-Light Photography 220
The Eye versus the Camera 220
- Spectral Sensitivity of the Eye 221

Chaining the Amount of Illumination from the Scene to the Courtroom 223
Make a Recipe of the Scene Brightness 224
Perspective 226
Perspective Correction 226
Conclusion 227
Glare Box 227
10A Existing Light Photography 230
Ambient Light/Visual Study Exercise 230
Photo Montage 232
10B Painting Evidence with Light 235
10C Dealing with Retroreflective Light 238
Old-Style Reflectors 238
Modern Vehicle Graphics and Traffic Signs 239
Notes 240

INTRODUCTION

In the years of slow-speed film, slow lenses, large cameras, and longtime delays in film processing, nighttime images were not used extensively in court. In the 1980s, for several reasons—including high-speed film, lenses, processing, and changes in the legal system—nighttime images became more commonly used. Initially it was thought that images could be produced photographically for duplicating what a person could have seen at the time of an incident. That theory was disproved.

Due to the complex differences between vision and photography, it is now known to be impossible to accurately represent photographically the vision of a victim. But photographs can be made by evidence photographers that supply to judges and jurors an idea of what a scene looked like. The subtle difference between definitions of accuracy have led to a steady progression of updated practices in nighttime forensic photography.

Low-light or night-visibility images have been successfully entered into hundreds, if not thousands, of legal cases. We will explain the important aspects, including the methods used to provide this type evidence in court. We will present methods here to create these technical images. These are but some of the ways to validate the images captured at the scene and link the amount of illumination from the scene to the courtroom or any location the photos may be viewed.

This section relates to the technical re-creation and documentation of lighting conditions that existed at the time of an incident and should not be confused with the more standard and traditional evidentiary documentation of an incident scene. In simple terms, you are trying to show what could and could not be seen under a given lighting situation. You are not attempting to document the totality of the scene, but the light quality and level at the time. The name for this specific type of assignment is a "visibility study." The photographer is attempting to depict what is available to be seen by a person with normal, unimpaired vision under defined conditions similar enough to those at issue to provide relevant information about levels of visibility, lines of sight, timing of visibility and to demonstrate the photographer's expert witness opinions.[1] These techniques are not normally taught in a crime scene investigation (CSI) or other photography class, so this process is often unknown even to experienced photographers. Clients probably are not aware that there are valid techniques available to show "it was a dark and stormy night."

The purpose of a visibility study is to portray, from an involved person's point of view, what might have or might not have been visible during an incident. This could be what a driver saw before a crash, what a pedestrian did not see before a trip-and-fall, or what a homeowner could have seen before a defensive shooting. Here, available light is the primary issue, and the entire effort is to accurately depict the conditions as to what reasonably could or could not have been seen by an individual at the time.

Proper foundation for a visibility study is essential. Viewers must understand that any images, still or video, are not a reenactment or reconstruction of what the participant saw. Rather, it is a demonstration, prepared with described speeds, paths, and timing, intended to provide information regarding visibility factors relevant to all the other evidence in the case. The viewers also must understand that they possess advance knowledge that the driver, pedestrian, or homeowner did not have during the original incident. The original participants did not know or have any expectation that some situation was about to occur which could affect the rest of their lives.[2] Steps must be taken to reduce the effect of "expectancy" on all subsequent viewers that are beyond the scope of this text. What follows is the process of capturing and preparing available light images for a valid visibility study.

Digital photography has changed these procedures completely. The timetable of the change from film to digital is the main reason and determining factor of which technology to use today. The only reason the information about archaic film methods are included here is to give the investigator a better and more complete knowledge of the ways these investigations used to be done. Be mindful of this as you read on. If you do not want to learn the interesting history of these studies, just jump ahead in the chapter to the beginning of the digital age at the beginning of the 21st century.

LOW-LIGHT, AVAILABLE-LIGHT, AND NIGHTTIME PHOTOGRAPHY

Sanford L. Weiss

Exposing any photographs in normal light levels is usually routine and uses ISO speed, lens aperture, and shutter speed combinations recommended by a built-in meter. When ambient light levels are low, capturing good exposures becomes more difficult. Forensic evidence photographers are often required to document indoor or outdoor scenes in relative darkness or at night. In attempting to more closely replicate the conditions at the time of a past incident, use of supplementary lighting will be inappropriate to some phases of a complete incident reconstruction. The need to realistically portray a scene as it was at the time of an incident for the observer means that the limiting factor should be associated with the visual acuity of the observer of the photograph, not the resolution of the photograph itself.[3]

The addition of electronic flash units (EFUs) or other supplementary lighting to a scene may achieve "proper" exposure in the traditional sense, but the in-camera and/or portable electronic flash will create its own inaccuracies. EFUs are limited in effective range by their size. Most units will illuminate a small area within 15 to 25 feet from the camera, depending upon the environmental situation.

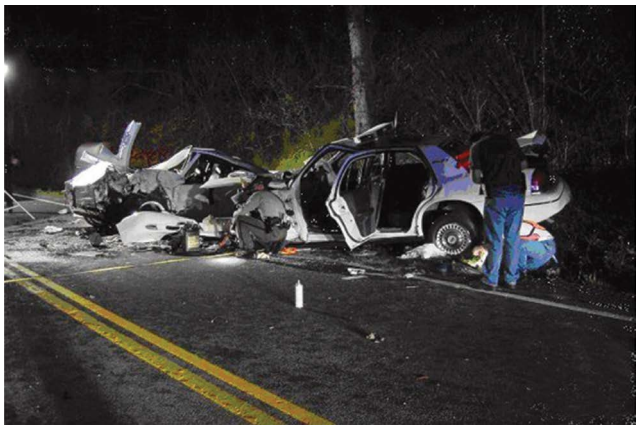


FIGURE 10.1 Wreck at night illuminated by the concentrated lighting of squad car spotlights.

(From Sandy Weiss/Packer Engineering.)

Sometimes electronic flash is the logical and expected choice because it is the only alternative. For scene documentation, law enforcement officers and evidence photographers would not be able to work outdoors at night at accident or crime scenes without EFUs.

Existing light images with action or movement often exhibit blurred details due to slow shutter speeds. The photographer and/or the camera will contribute to the blur, so electronic flash is the recommended form of supplementary lighting. The EFU will add light and freeze motion.

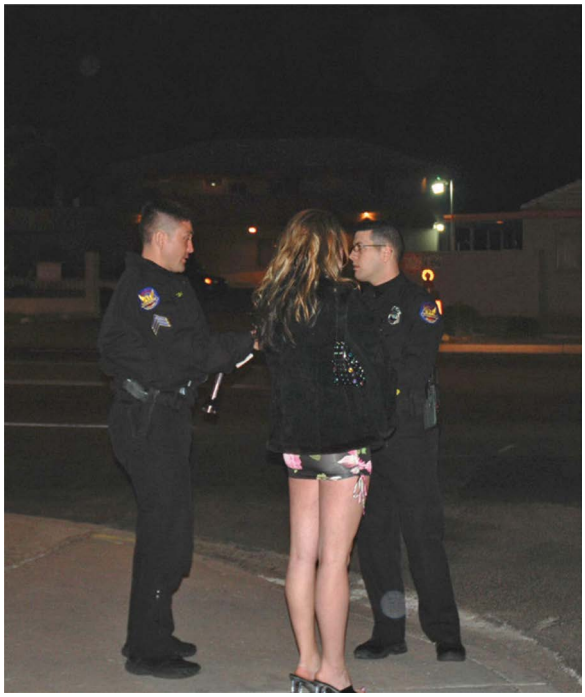


FIGURE 10.2 Handheld exposure with electronic flash.

(From Constance Rohrer, Evidence Forensics Photography.)

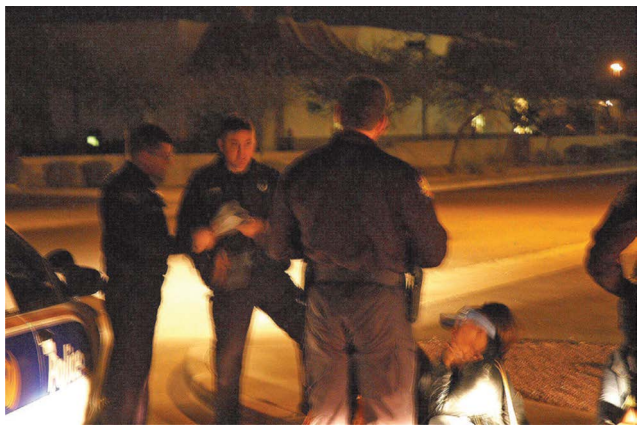


FIGURE 10.3. Handheld exposure by headlight illumination.

(From Constance Rohrer, Evidence Forensics Photography.)

TIP:

When using electronic flash in dark areas for images of objects with reflective markings, due to the shortcomings of the flash and/or camera automation, you must intentionally overexpose the images, or the main subject will appear too dark. (This happens because the high reflectivity of the reflective material causes more than the normal amount of light to bounce back to the flash from those areas, causing the EFU to turn off too quickly; see Chapter 10C for information on dealing with retroreflectivity.)

It is often necessary to use electronic flash for macrophotography of evidence in most ambient light levels because the flash enables the use of small lens apertures necessary for critical depth of field (DoF). When the subject is normal or large and immobile, standard methods are available to achieve exposures of accurate appearance in any ambient level of illumination.

CONTRAST AND CONSPICUITY

The contrast between objects is what allows our brain to differentiate among the various things it perceives. If an object is conspicuous against its background, it will be easily noticed. The contrast can be perceived as differences in tone or color, depending upon the level of ambient illumination. To photographically produce images a viewer will perceive as accurate representations of the subject, the subject brightness range and contrast will, of necessity, be exposed only by the existing or ambient illumination.

If a subject is inconspicuous against its background, the subject will be difficult for the viewer to perceive. A black car with limited reflectors parked in front of a black tree at night may be difficult to see and to photograph. A white car parked in front of a snowdrift in the moonlight is another



FIGURE 10.4 Underexposure due to retroreflectivity.

(From Sandy Weiss/Packer Engineering.)

challenging composition. These subjects are simply difficult to photograph.

Contrast is determined by the level and angle of illumination. As the light level decreases, the perception of colors, shapes, and forms decreases. If the angle of the illumination approaches zero, shadows cease to exist and subjects become less conspicuous. Humans lack color vision in low light; therefore, a person with normal color vision may perceive a subject wearing a red coat in low light as appearing identical to a subject wearing a gray coat. Dark vision will be discussed in detail shortly.

RULE:

If the ambient illumination level is greater than zero, it is possible to properly expose a photograph to accurately represent the scene. It may not be simple or feasible, but it is possible.

After exposure in low light, an image may or may not be a reasonable representation of what the photographer perceived with his or her eyes, depending upon how the image was created and processed.

NIGHT AND EXISTING-LIGHT PHOTOGRAPHY

Night photography is accomplished using the same equipment and exposure factors as daylight photography. To accomplish an adequate exposure, the aperture and shutter speed must be properly set. They are dependent on the ISO chosen, the level of ambient illumination, and the contrast desired in the final image. An EFU with a high guide number and light output will add more than enough light to show the physical conditions of the incident scene and record physical evidence but not the scene as it existed. Yet this section is dedicated to recording the lighting conditions, or lack thereof, that played a critical part in either causing or contributing to the incident itself.

The high range of ISOs available in modern cameras allows manufacturers to supply default or "kit" zoom lenses with average maximum apertures (i.e., *f*/4 to 5.6). Higher ISOs allow conventional photography to be undertaken in lower levels of ambient illumination without the necessity of supplementary lighting. The trade-off for using higher ISO values is digital noise in the resulting images.

TIP:

A normal lens with a maximum aperture of *f*/4.0 requires eight times more illumination, or eight times longer shutter speed, to properly expose an image in the same low level of ambient illumination as a lens with a maximum aperture of *f*/1.4. Consider this fact when choosing lenses to conduct existing light photography.

TIP:

When exposing photographs in marginal and low-light conditions, lenses of higher speed, with a larger maximum aperture (e.g., *f*/1.8), if available, are recommended. It may also be necessary to set the camera to a higher ISO (e.g., 400, 800, 1600, or higher).

TIP:

The slowest recommended shutter speed for handheld exposure is the reciprocal value of the lens focal length (i.e., 1/mm sec). In the case of a 50 mm lens without image stabilization, the minimum handled shutter speed is 1/50 second. With lens image stabilization, a shutter speed of 1/15 second may be possible. It is not practical to handhold a camera at shutter speeds slower than about 1/30 second. If it is necessary to go below 1/30, use of a tripod or other stable support for the camera is recommended. If a tripod is unavailable, put the camera on a steady support and use the built-in self-timer to release the shutter.

Most night scenes consist predominantly of darkness with small areas of illumination from windows, signs, headlights, reflections, and streetlights. Aesthetically pleasing photographs may be exposed with a variety of techniques over a wide range of exposures. Short exposures will enhance the well-lit areas by preserving highlight detail. The shadows will appear dark due to underexposure. Longer exposures enhance detail in the shadows, while highlight detail will likely be lost due to overexposure.

Night scenes, being predominantly dark, are difficult to meter accurately with the built-in camera meter and from the camera position. It is often necessary to perform light meter readings from the position of the subject using a sensitive, handheld meter with spot or incident capabilities. Spot meter readings from light and dark areas can be averaged for an improved result.

TIPS FOR LOW-LIGHT PHOTOGRAPHY

- Carry a small flashlight to use for seeing the settings on the camera. A camping headlamp will keep both hands free and may offer a red-light option to help maintain night vision. Some cameras will include back-lit displays.
- Make multiple exposures over a wide range. (Use the camera's built-in auto-bracketing capabilities if available. If not, manually expose overexposed and underexposed images from the built-in meter recommendation.)
- Focus carefully. (DoF is shallow at wide apertures.) Taking the same image with the focus manually set for different areas may be helpful. The images may then be combined in focus-stacking software to create a single image with a very broad focus area.
- Use the appropriate white-balance setting for the predominant light source. Exposure of a gray card or precision color palette, like an X-Rite ColorChecker Passport, will allow accurate post-processing color adjustment.



FIGURE 10.5 X-Rite ColorChecker Passport color palette exposure.

(From Arthur Borchers.)

METERING AT NIGHT

The most difficult question to answer about night exposures is "How long is long enough?" It is a question with no correct answer. The image should display reasonable contrast and density in the areas of importance. So, how is exposure properly determined? Three conventional methods follow:

1. Trial and error
2. Using the recommendation of the camera's built-in meter in different exposure metering modes (e.g., spot, center-weighted averaging and balanced)
3. Exposure bracketing varying only the shutter speed to maintain consistent DoF across the image

In the first case, trial and error can be time consuming and cumbersome. In the second case, the camera meter is not designed to "know" how the image is supposed to appear. The camera may expose the scene as it would appear in normal daylight. This result is fine only if the images are meant to be aesthetically pleasing. If the images are intended to be an accurate representation of how the scene appeared to the photographer, light metering should be performed manually to enable the photographer to decide on the appropriate rendition.

QUANTIFYING SPECTRAL SENSITIVITY

Healthy human eyes immediately perceive two main features about any object. The features are color and brightness. The relative brightness of different colors is not easily quantifiable. To most people with healthy vision, red objects appear brighter than blue ones under normal illumination. When the level of illumination is lower, blue objects appear brighter than red ones.

In many cases, it is necessary to quantify the luminosity—the amount of light energy output in a unit of time—of different colored light sources. For example, it is important to ensure traffic signals are sufficiently bright at night and in bright daylight, so motorists can distinguish between green and red. Quantification of luminosity is performed with light-measuring instruments called radiometers or photometers. These devices are not meant for photography.

Radiometers measure radiance: the energy emitted or reflected by a source. Radiance does not represent what people see. For example, if red, yellow, and green traffic signals were adjusted so they emitted equal radiance, they would be radiometrically equal. To healthy eyes, however, the yellow light would appear brighter than the red and the green. The green would appear brighter than the red. Radiometry does not adequately specify a method to make all three colors appear the same intensity. Radiometry is inadequate for measuring the perception of luminous intensity or relative brightness. Photometers measure luminance and consider the spectral sensitivity of human eyes. Photometers are like radiometers scaled to the wavelength response of the human eye.

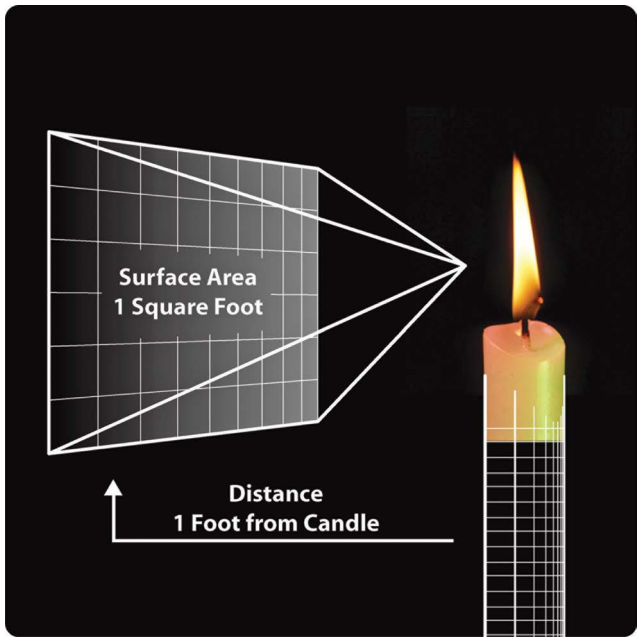


FIGURE 10.6 Visual definition of 1 foot-candle.

(From Jessica Weiss.)

LUMINANCE

Luminance is a measure of the brightness or luminous intensity of light, usually expressed in units of candelas per square meter. The candela is the current standard unit of luminous intensity. In photometry, which deals with the measurement of the intensity of light as perceived by human eyes, luminous intensity is the measure of the power emitted by a light source in a given direction. The intensity is based on the luminosity function, which describes the average sensitivity of the human eye to light of different wavelengths.

The human eye sees light with wavelengths only in the visible spectrum. In photopic vision, the human eye is most sensitive to greenish-yellow light at about 555 nm, which is why the Bayer filter array was designed to supply more green information than each of the other colors. In forensic photography, this additional green information is necessary for the accurate representation of evidence in imaging.

Originally, luminous intensity was measured in candles. One candle represented approximately the same amount of visible radiation emitted by the flame of a standard candle (see Figure 10.9 and physics.nist.gov/cuu/Units/candela.html). This was not an exact specification. The units of luminous intensity, based before 1948 on flames or incandescent filaments, were later replaced by a newer definition of candle based on the luminance of a blackbody radiator at the temperature of freezing platinum. The difficulties in construction of blackbody radiators at high temperatures and the capabilities of modern radiometry prompted the 16th Conférence Générale des Poids et Mesures (CGPM) to adopt a new definition of the candle in 1979. Candle was changed to candela. A candela is the luminous intensity, in each direction, of a source that emits monochromatic radiation at a 540 × 1012 hertz frequency and that has a radiant intensity in that direction of 1/683 watt per steradian. A typical candle produces approximately 1 candela of luminous intensity.

ILLUMINANCE

In photometry, illuminance is the total luminous flux incident on a surface per unit area. Luminous flux or luminous power is the measure of the human eye's perception of the power of light. Radiant flux is the measure of the total power of light emitted from a source. Luminous flux of a light source is adjusted by the manufacturer to reflect the varying sensitivity of the human eye to different wavelengths of light. Luminous emittance is the luminous flux per unit area emitted from a surface. Luminous emittance is also known as luminous exitance. In the International System of units (SI), these are both measured in lux (lx) or lumens per square meter (1 fc = 1 lumen per square foot, and 1 lux = 1 lumen per square meter).

NOTE:

Illuminance was formerly called brightness. However, it is not possible to quantify the concept of brightness. Brightness is only an individual perception.

The human eye is capable of identification of a contrast range of more than 100 million to 1. It is possible to see white objects by starlight illumination at 5×10^{-5} lux and

to read large text at 108 lux, or about 1,000 times the intensity of direct sunlight; however, vision in high-intensity lighting is not recommended.

MEASURING LIGHT

While in some cases, manual metering may be accomplished with the camera's built-in meter, it is usually more accurate to read exposure with a handheld exposure meter. Contemporary meters, including the predigital Gossen Luna-Pro (see Figure 10.7), can calculate the recommended exposure of a scene in exposure times of minutes and hours, over a wide range of sensor sensitivities, and by either reflected or incident lighting. Incident light metering refers to measuring the value of the light falling onto an object. Reflected light metering refers to measuring the light value reflected off an object and is the type used by almost all built-in camera light meter systems. Modern meters, including the digital Luna-Pro or the CEM DT-1301 dual-function digital lux foot candle meter (see Figure 10.8), have increased sensitivity and a more reliable power source, enabling accurate metering in a wide range of weather conditions.



FIGURE 10.7 Gossen Luna-Pro handheld exposure meter.

(From Sandy Weiss/Packer Engineering.)



FIGURE 10.8 CEM digital DT-1301 dual-function digital lux foot candle meter.

(From Sandy Weiss/Packer Engineering.)

TIP:

Use the exposure information suggested by the meter, but review test exposures to ensure the captured images appear as intended.

NOTE:

Any hardware mentioned or shown in this chapter may be unavailable or discontinued. Images are used solely as examples.

TIP:

When making images in low light, expose in raw format whenever possible and process the resultant images on the computer. JPEG images are processed in the camera and will not yield image detail comparable to raw files.

HUMAN VISION IN LOW LIGHT

Human eyes work differently in different levels of light. In dim light, the eyes see only monochrome, usually black, gray, and white. That is called scotopic vision. Scotopic vision occurs at luminance levels of 10^{-2} to 10^{-6} candles per square meter (cd/m^2). Mesopic vision occurs in intermediate levels of lighting (luminance level 10^{-2} to 1 cd/m^2) and is a combination of scotopic and photopic vision.[4]

Photopic vision occurs in normal light (luminance level 1 to 106 cd/m^2). Color vision is best in the photopic range. Visual acuity increases in reduced light situations after full adaptation to lowered levels of illumination, but color vision will remain absent.

The healthy human eye can perceive images in an illumination range ratio of over nine orders of magnitude. An amount of light equal to ten times a given amount is one

order of magnitude greater. Two orders of magnitude equal 100 times greater, 10 × 10. Human vision is possible in lighting 100 million times brighter than its darkest capability. But healthy eyes can perceive a contrast ratio of only up to 1,000 times at one time. When the light levels change, the eyes adapt and shift the perception ranges of brightness and darkness. The light level interpreted as black or white before may be moved through a range of six orders of magnitude (1,000,000:1 or 10^6).

Healthy eyes fully adapt from bright sunlight to complete darkness in approximately 20 to 30 minutes. It takes approximately five minutes for the same healthy eyes to regain the ability to perceive color in bright sunlight after total darkness.

DIGITAL NIGHT PHOTOGRAPHY

No inherent difficulties prevent the use of digital imaging for low-light photography. Digital cameras provide instant feedback, enabling the inspection and assessment of captured images. The correlation of apertures, shutter speeds, and sensor sensitivities work identically in digital as it did in film technology.

Depending on its stage and the condition of the atmosphere, the moon provides varying but slight intensities of illumination. Moonlit exposures are usually of long duration. In some cases, the movement of the moon may fill and soften the shadows the moon creates. This is not normally an issue with photos of evidence. During daylight photography, the sun may create dark shadows.

TIP:

Use a lens with a large maximum aperture to increase viewfinder and/or viewing screen brightness.

TIP:

When working in low light, the photographer should allow adequate time for his or her eyes to adapt to the darkness, which will allow for proper focus and image composition in the viewfinder or on the viewing screen.

TIP:

Low-light scenes are usually low in contrast. The absence of contrast may impair the camera's autofocus systems. Use manual focus whenever possible.

CAPTURING THE SCENE IN LOW LIGHT

IMPORTANT:

Nothing is more photographically difficult to achieve than making images for a vision study and accurately portraying what a person may have seen at the time of an event for the following four reasons:

1. The incident scene can never again be the same. Even on the same calendar day of another year, some factors are variable, including the weather, moon phase, street and advertisement lights, new construction, foliage, and so on.
2. It is impossible to know all the factors involved with a specific person's vision at the time of an occurrence. Factors may include:
   - A person's physical condition (e.g., intoxication, medication, distraction)
   - Age
   - Visual acuity/clarity of vision
   - Stage of dark adaptation
   - Eyeglass correction and cleanliness
   - Windshield condition
   - Headlight condition or supplemental lighting
3. Too many factors prevent a photograph from accurately representing reality in any lighting conditions. Accuracy problems include but are not limited to the following:
   - Re-creation of contrast level
   - Color
   - Dimensionality
   - Depth of field
   - Field of view
   - Perspective
4. A photograph captures a moment in time and a specific angular view. It is impossible to re-create the events from both a specific view and the full viewpoint of the person being represented.

In a vision study, it is critical at trial to demonstrate to the judge and jury approximately what a scene looked like to a specific person at a specific time. It may be *the* part of the presentation on which everything else will rely. The best a photographer may achieve is to capture photographs of the way the scene looked to the photographer making the images. It is critical for the photographer to make every effort to re-create the scene photographically, to look as much as possible as it looked at the time the image was taken.

NOTE:

For night and low-light digital images to resemble the lighting of the actual scene, THEY MUST BE PRINTED. Looking at a digital monitor will never produce images resembling what anyone could see in low light. Any television or monitor displaying the image is adding light. Everywhere in the following chronology where the documentation tells of making prints, it is referencing courtroom displays on paper.

Most forensic evidence photographers will adapt a proven method or various parts of several to use as their own system. Any system that works is fine if the photographer understands and can explain to their audience the inherent difficulties and shortcomings of reproducing the nighttime/low-light scene photographically. Some of the methods developed over the last 40 years follow in chronological order.

E.S. Bomback: 1966

In 1966, E.S. Bomback said in the *Manual of Colour Photography*, "In spite of every kind of exposure aid yet made available to the photographer, there remain certain kinds of subject or lighting conditions which can only be satisfactorily resolved by the time-honored method of trial-and-error."[5] He suggested making three separate bracketed exposures at night to facilitate making one adequate to illustrate the character of the scene.

John Duckworth: 1983

In 1983, John Duckworth suggested in *Forensic Photography*, "Recreating what a driver could see at a later date becomes a bit sticky."[6] He states it is important to duplicate the car being driven. He checks the weather and phase of the moon for the date of the incident. He ensures the scene photographs are exposed from the driver's viewpoint in the lane the car was using. He stresses using a lens that does not distort perspective and suggests bracketing exposures to yield darker and lighter images from which to select one looking the most like the original scene. Print final images to a reasonable enlargement to take to court.

J. Stannard Baker and Lynn Fricke: 1986

In the *Traffic Accident Investigation Manual*, Baker and Fricke stated, "It is sometimes important to have a record to explain what a driver or pedestrian could have seen at night with the light available to him/her at that time."[7] Photographic representations may easily be made to show more or less than a person with normal vision might see at any given time. For the nighttime visibility photography to be of use, the images must be as close an approximation as possible of what the person did see at the time of the incident.

The differences in the abilities of various persons to see things in low light must be considered. Adaptation level, also called dark adaptation, is very important, and there is no precise way for that to be determined. The photos must be exposed under conditions as close as possible to those in place at the time of the incident. In many situations, this involves exposing photographs using the headlights of the subject or exemplar vehicles.

Because variations in postprocessing may make a huge difference in the result of the digital image(s), they must be processed to a standard. Baker and Fricke recommend making at least three bracketed exposures of every image, so a range of images is available from which to choose. Viewing conditions must also be standardized and be like the lighting conditions in which the images were exposed.

The use of test targets (see Figures 10.15–10.17) is a method to make the images more "accurate and credible."[8] The targets must be equally recognizable at both the scene and in the image. A target must be placed in the scene at a point where it is just discernible. The final image prints must also produce the target as just discernible. Then the image and the scene should approximately match. This procedure is not without problems but is widely used. It is a recognized and useful system if the photographer can adequately explain the disparities between the resultant images and the actual scene.

William Hyzer: 1988

In 1988, William G. Hyzer wrote in *An Extinction-Type Photometering Technique for Low-Light Luminance Measurements in Accident Investigations* that several aspects of human vision are impaired at low-light levels.[9] These include the following:

- Visual acuity
- Color discrimination
- Depth perception
- Contrast sensitivity

Photometric analyses are necessary in investigations at crime and accident scenes where low-light levels may have been contributing factors in an accident or crime. It is necessary to make luminance and illuminance measurements of critical areas of the scene.

A common cause of nighttime accidents is low conspicuity, the inability of a driver to discriminate an object against its background.[10] There is a contrast threshold level at which an object should be barely discernible. This contrast level is determined by the following formula:

$$C = (L2 - L1) \div L2$$

where: C = contrast, L1 = subject or target luminance in foot-candles, and L2 = background luminance.

The threshold value varies by the ambient lighting conditions and the visual abilities of the viewer.

Robert Holohan: 1989

In *Nighttime Photography: Show It Like It Is*, Robert Holohan suggests a technique for the production of "a photograph that accurately illustrates the limits of perception for an observer's view of objects under night lighting."[11] The photograph may be used in court to illustrate the visibility issues of a nighttime incident. Holohan says one solution to the problem of low-light photography is to make images at different bracketed exposures and select the one looking the most like the scene. This likely requires a second trip to the scene on a different night, unless it is possible to create the necessary images at the original scene.

The photographs must be viewed in approximately the same lighting conditions as existed at the scene, which is not often possible because the scene is too dark to illuminate the photographs properly. The adaptation level of the eyes of the viewer must be considered, and a method must be established and used to assess the final prints. Using test targets at varying distances from the camera is recommended to assess the threshold density allowing recognition of the characters in the target, as is using the same threshold density as a standard for making the prints.[12]

Ernest Klein and Gregory Stephens: 1992

In 1992, Ernest Klein and Gregory Stephens wrote in *Visibility Study: Methodologies and Reconstruction* that it is crucial to pick a future date and time with similar lighting conditions upon which to perform any vision study of an incident.[13] The goal was to ensure the final photographs depict the objects as they were seen under the actual illumination. The limiting factor affecting visibility is the conspicuity of the subject. Digital images exposed at bracketed exposures work well too. Use the image most accurately depicting the scene. Record its exposure information and retain it as a reference for the final prints made from the actual camera images. The images exposed at the scene must be printed as bracketed exposures. The one print most closely resembling the reference image is considered the most accurate.

James Harris Sr. and James Harris II: 1992

In July 1992, James Harris Sr. and James Harris II wrote in *Forensic Photography and Nighttime Visibility Issues* that low-light incidents involve the failure of people to perceive and react to danger.[14] The argument at a trial will be the difficulty of performing in the existing light a visual task to designate those details and objects which must be seen for the performance of a given activity and include the immediate background of the details or objects.

Some specific requirements must be satisfied if photographs are to truly represent how things looked at the scene. Many nighttime photographs are frequently not a legitimate representation of the level of difficulty associated with visual tasks.[15]

The most important factor for capturing accurate nighttime photographs is the scene "lighting conditions should be sufficiently similar" to the way they were at the time of the subject incident.[16] The lens of the camera must be placed at the eye location and height of the observer.

Consider these factors when exposing the images:

- Moon phase
- Cloud cover
- Changes, additions, and/or deletions of artificial lighting
- Painting of buildings
- Road resurfacing
- Lane line painting
- Moisture on roadways and vehicles
- Window and windshield cleanliness
- Headlight condition and alignment

It is essential to assess the possible differences between the time of the incident and your photography and be aware of how they may alter results. The variables determining conspicuity include the following:

- Contrast threshold
- Angular size (the size of an object as viewed from Earth)
- Adaptation level of the viewer's eye
- Duration of stimulus

The objective of the photograph is to demonstrate the difficulty or ease with which objects can be detected or recognized.[17]

To be accurate, the measured contrast ratio between two different objects in a scene must exhibit the same ratio in the photograph.

After processing, the images may be projected on a screen, in place of printing, using a projector with neutral density filters on its lens to limit the output of the lamp. When projected, the images should produce the same luminance measurements as were measured at the scene. Luminance readings of the images are made with a spot meter directly from the screen. The light level in the room should also equal that of the scene, as well as anyone looking at the images should be visually adapted to the reduced light level.

William Hyzer: 1993

In February 1993, William Hyzer wrote in *The Eye, Brain, and Camera in Nighttime Accident Reconstruction*, "The most important low-light-level visual degradation contributing to nighttime accidents is the failure to see an object against its background, because the contrast sensitivity of the eye is reduced to the point where it can no longer discriminate between the luminance levels of the object and its background."[18]

Hyzer also notes differences between human visual images and camera images (still and video), but the camera images are being used regularly in courtrooms to demonstrate "what an observer was able or not able to see under low-light conditions."[19] He recommends two different methods for the presentation of nighttime images in the courtroom:

1. View the photographs under normal room-light conditions.
2. View the photographs at low-light levels like those existing at the scene in the photograph.

The first method is not realistic because it fails to address the inherent difficulties the human eye has in differentiating objects in the scotopic and mesopic ranges of vision.

The second method is more accurate. The images "must be rendered in the full tonal scale and color (if possible) as they would naturally appear under the extant viewing conditions, so both the judge and the jury, whose visual processes are intentionally impaired by low-light-level mesopic or scotopic viewing conditions, perceive the scene as a human observer would under the actual low-light-level conditions existing at the scene."[20]

Hyzer points out that the human eye is capable of vision in a luminance ratio at any one time of 10,000:1, or 13½ camera stops, and digital media (images to prints) are not capable of creating accurate photographic representation of scenes with luminance ratios in that range.

In digital photography, the contrast ratio is called dynamic range. Some of the latest image sensors have measured dynamic ranges of about 23,000:1. Note the following, however:

- Black-and-white prints, printed properly from good images, are only capable of a ratio of about 100:1.
- Color glossy prints from images are capable of a ratio of 50:1.
- Color matte prints from images are capable of a ratio of 20:1.

This forces the digital images to be projected in court with a projector fitted with appropriate neutral density filters over the lens. This should reduce the luminance of the projected image to the approximate luminance of the original scene. The venue must also be totally darkened to resemble nighttime. This practice contains inherent difficulties, including reflectance from the screen of the projected image adds light to the room. Light also leaks from other sources within the room.

Hyzer concluded that "forensic photographers seriously contemplating the use of photography or videography in order to 'truly and accurately' represent a nighttime scene, need to be ever mindful of the numerous physical, physiological, and psychological pitfalls, waiting to frustrate their honest efforts."[21]

T.J. Ayres: 1996

In *Psychophysical Validation of Photographic Representation*, T. J. Ayres wrote, "In order to represent how a scene would appear to a typical observer, a photographic print can be calibrated based on careful observation."[22]

Photographs are routinely produced under specific conditions of illumination from the points of view of the participants in an incident. Attorneys attempt to use photographs to explain to jurors and judges the features of a scene without the necessity of explaining the science involved in luminance and vision. Many people think doing a vision study will in some way validate the nighttime images to "establish the image faithfully represents some aspect of the visual experience an observer would have at the actual scene."[23]

Ayres said that much research has been performed on the role of visibility issues in incidents, but very little has been done on the accuracy of photographic representations of low-visibility conditions. "Most books on photography or on accident reconstruction do not discuss the problems of portraying night visibility conditions."[24]

The evaluation of a photograph must be performed using actual observations made at the scene. The procedure for test targets discussed in *The Traffic Accident Investigation Manual* places the targets at specific points in the scene, where they are just barely discernible.[25] Photographs must be exposed to duplicate the same quality of the targets. An identical image exposed without targets, under the same circumstances, lighting, camera settings, and so on may be represented as a validated, accurate representation of the scene. When viewing the image, the illumination must be a reasonable approximation of the illumination at the scene. "It is essential to note that the validated image does not necessarily show the scene as it appeared to the investigating observer. The validation procedure is tied to accurately representing featural detectability."[26]

This procedure has been adopted and adapted by many modern forensic photographers making nighttime photographs of scenes. The question of contrast linearity throughout the range of luminance is a subject that must be technically addressed. Ayres states that if luminance measurements are made of various elements at the scene, then the objects may be correlated to the resultant images by comparison readings.

Paul Olson: 1996

Paul Olson references both Harris and Hyzer in *Forensic Aspects of Driver Perception and Response*.[27] He writes, "Jurors tend to believe that what they see in a photograph is what they would have seen had they been there themselves at the time the photograph was taken."[28] In truth, most jurors are not well educated regarding the technical aspects of photography and have little idea of the limitations of the media.

Photographs of objects are normally exposed in daylight conditions. These images are automatically accepted as

accurate if the color and exposure appear correct and the subject is not outrageous, like people floating in space. Normal skills are needed to make daylight photographs. Specialized skills are needed for evidence photographs, even in daylight. Many attorneys expose their own evidence images with their own cameras to show "the visibility available to an individual in a particular situation."[29] The person(s) who made the images and the attorney using the images have little idea of the particular shortcomings of the images.

Nighttime photographs "must depict with great accuracy the luminance levels and contrast present in the scene. They must cause the perceptions of the jurors to reasonably duplicate that of the person or persons whose perceptions are at issue."[30] When showing these photographs in court, it must be assumed that the camera and accessories used were capable of accurately duplicating human vision in images. It must be assumed the judge and jury are seeing what the person(s) in question must have seen. These hypotheses, however, are faulty.

Olson offers a list of possible problems with nighttime photographic images:[31]

- The field of view commonly created in photographs is limited when compared with actual vision, and there may have been important factors involved outside the frame limits of the images. Images can then be captured with an expanded field of view, perhaps A-pillar to A-pillar, and including a view of some dash instrumentation.
- A photograph is static, and at the time of an incident the vision of the individual was dynamic. Making videos or animations is a partial answer to address this issue. Viewing of videos and prints must be limited to just one time (see Chapters 9 and 38).
- Static photographs can be studied for any length of time, but the scene was instantaneous to the person involved. The time for others to view the scene must be short.
- The level of adaptation of the person involved cannot be assessed.
- Images are often enlarged for ease of viewing in court, while the person involved could not see at that magnification at that time. Magnification is not allowed. Perspective and viewing distance must be correct.
- The person involved had certain expectations of what may have been seen before the instant in question, but expectation cannot be shown in a photograph. Expectancy on the prealerted viewer must be recognized and attempts to control it must be taken.

J.B. Hyzer: 2002

J.B. Hyzer states in *Photographically Maximizing the Information Recorded in Forensic Images* that photographs of nighttime scenes can never be totally accurate. Due to this issue, it is necessary to produce a range of prints of varying densities and to inspect different aspects of each to relate to different parts of the scene. This is a time-consuming and confusing method.[32]

Paul Olson and Eugene Farber: 2003

In 2003, Paul Olson teamed with Eugene Farber to release the second edition of *Forensic Aspects of Driver Perception and Response*, in which they state, "If the individual presenting the images can testify that the image(s) depict exactly what he or she could see, the photographs are likely to be accepted as exhibits and the jurors will probably assume that they truly represent the object or scene depicted."[33]

RULE:

Never say the images are what another person involved in an incident could see. At best, the images should represent what the photographer, investigator, or attorney could see at a similar time. This is the highest level of achievable accuracy.

Digital cameras will adjust exposure to make nighttime images appear how the photographer wants them to appear. Instant replay of the images on the viewing screen, or even on a computer monitor, determines if the exposure was successful. Exposure bracketing can be performed in the camera or in postprocessing.

Boyd Allin, Kurt Isling, and David King: 2007

In 2007, Allin, Isling, and King presented a paper entitled, "Digital Camera Calibration for Luminance Estimation in Nighttime Visibility Studies."[34] This paper is the door to digital technology for nighttime photography and vision studies. The authors' premise is that a digital camera can be calibrated so any pixel in any image exposed by the camera may be quantified for luminance. This enables the luminance ratios between any two pixels to be calculated, and it allows contrast to be determined to define conspicuity between any objects imaged in a scene under any illumination.

The forensic photographer may document any scene, in any lighting, and then use his or her computer to accurately calculate the contrast of any objects. The objective is to make images displaying the scene as the photographer saw it. The photographer may testify the images are exposed to the best of their ability. Then the visibility, contrast, and conspicuity of an object may be computed and presented with reasonable accuracy.

Proper calibration, however, is not an easy process. The calibration of cameras is a necessary and regularly requested function, so software is available to perform the procedure. Metering of luminance and illuminance is still necessary for a base reference.

HARDWARE FOR MEASURING LUMINANCE AND ILLUMINANCE

Luminance meters are specifically designed to read the illumination of a scene or an object. These meters are not designed for photographic purposes. They do not suggest shutter speeds and lens apertures. They measure the intensity of light falling onto, emitted by, or reflected from a subject. Such meters are more expensive than photographic meters and are built for precision and accuracy.

Features:

- Measuring levels ranging 0.01 to 1999k cd/m^2, 0.001 to 580.0k FL, auto-ranging 7 step
- Luminance ratio A/B, deviation %A, different B-A and peak luminance measurements
- Max/Min/AVG function

METER APPLICATIONS

The representative TES meter depicted in Figure 10.9 has a wide range of applications, including the control of light sources; adjustment of streetlights; and lighting of workplaces, public buildings, and sports facilities. Lighting designers and architects use these meters for quality control and quality assurance in the manufacture of lamps and light sources. They make possible the measurement of light over a wide range of intensities and may be certified when calibrated for inspection procedures. Note that a light meter in this application is not used to determine any photographic exposure—it is used to assist in determining the correct light level for viewing any photographs taken under similar lighting conditions.[35]



FIGURE 10.9 TES 137 luminance meter/light meter/brightness meter.

(From Sandy Weiss.)

CASE STUDY 10.1

Nighttime digital photographs afford more quantitative information than was ever available when using film, as evidenced in Figure 10.10.

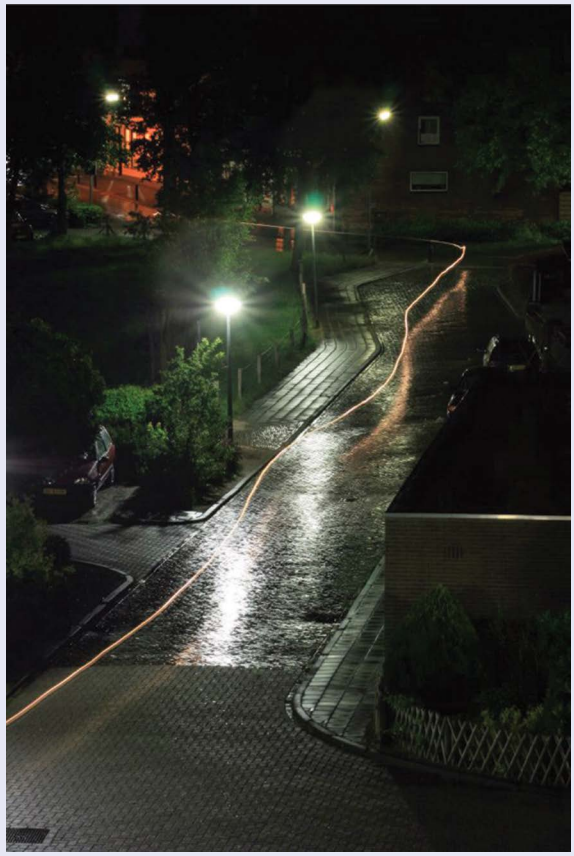


FIGURE 10.10 Timed exposure at night.

(From W. Thomas Miles, Lakeland, FL, website: wthomasmiles.com.)

EXIF data/technical specifications for Figure 10.10:

Camera Model:	Canon EOS XTi (400D)
Shooting Date/Time	5/9/2007 0:24:22 AM
Shooting Mode	Aperture-Priority AE
Tv (Shutter Speed)	30 seconds
Av (Aperture Value)	13.0
Metering Mode	Partial Metering
Exposure Compensation	+1
ISO Speed	100
Lens	EF75-300 mm *f*/4 to 5.6
Focal Length	85.0 mm
Image Size	2592 × 3888

Image Quality	Fine
Flash	Off
White Balance	Auto
AF Mode	AI Focus AF
Picture Style	Landscape
Sharpness	4
Contrast	0
Saturation	0
Color Tone	0
Color Space	sRGB
Noise Reduction	Off
File Size	1643 KB
Drive Mode	Single frame

The photo was made from a fourth-floor window in Steenwijk, The Netherlands, looking out on a small street between two apartment houses. The image was exposed just after midnight during a light rain. The only ambient lighting was from the small streetlights along the sidewalk. The streak of light evident in the frame, running from top to bottom, was from the headlight of a bicycle that started down the street the instant the shutter was released for the photo. The camera was placed on a small cardboard box on the windowsill. No tripod was available.

NIGHT VISION LOW-LIGHT PHOTOGRAPHY

One section author, Mr. George Pearl, continues to use printed display photographs in court rather than projecting video or slides because these do not require special equipment requiring specialized knowledge and time to set up and use. Mr. Pearl will go into further detail on this topic later so you will be better prepared to create these complex and demanding images.

Attorneys and judges are often leery of taking the time to do technical things in court. They do not often care for repetitive questions not meaning a lot to the issue at hand. For this reason, trying to keep things simple seems to work. Sometimes a video is used to show dynamics, and now that 4K cameras are available, it is feasible in many cases to show what could be seen on-site.

The next sections will supply the basic information needed to understand the recipe system and will illustrate how the expert is able to back up their photos or videos entered into evidence.

THE EYE VERSUS THE CAMERA

The first thing that needs to be explained here is the fact that even though a camera seems to resemble the eye in many ways, the reader needs to understand how they differ. The camera and the eye both have lenses and apertures. They both have a light-sensitive area where the image is focused; whereas the eye has a retina and the camera an image sensor, both areas operate differently. The modern digital camera has two different types of sensors used to convert light waves of different colors and intensities into electrical signals. The signals intermesh with the millions of pixels on the sensor. These signals are then processed specifically so the entire image formed can be electrically saved on a memory card and played back later. The eye operates differently, as the images are continuously being formed on the retina by cells called cones and rods and then sent to the brain for processing.

This is where in night visibility cases, it is necessary to work very carefully to document the scene correctly, so that someone later can say what they are looking at in your photo is what they think they saw at the scene. It is not correct to say the photo is what the involved person saw, but only a facsimile of what you yourself saw when you captured the photos. It will be up to the witness to make the decision if what you are displaying is similar enough to allow them to also say it is like what they saw.

A camera produces a photograph, sharp over almost the entire image in one snap of the shutter. The eye is constantly scanning the scene, and the brain interprets and combines the instantaneous impulses into what it "thinks" the image should be. The camera, depending on what lens is in use, can record images of different angles of view. Normal binocular vision creates a field of view of up to 140 degrees when including the peripheral view from each side. Despite such a wide field, humans with normal vision have a cone of visual sharpness at any one time of about 55 degrees. Only part of the retina processes the main image we see. (The area of main vision is called the cone of visual attention; the rest of what we "see" is peripheral vision.) A full frame digital camera, with a 43 mm lens will capture an angle of view of 55 degrees, which approximates the angle of view of normal human vision.

Look at a comparison of the eye and the camera, noting the functions in common (Figure 10.11).

With the normal human eye, we see light entering through the cornea, which holds the lens. In the cornea, there is an iris and pupil. The iris can open and close the pupil to allow light to enter, depending on brightness. The image passes through the lens, and the amount of light is adjusted depending on the environment and is then focused on a light-sensitive area of the eye called the retina. In the retina there are cells sensitive to light called cones and rods. The cones are for seeing colors in brighter light, and the rods are for seeing in low light. Rods do not see colors, just shades of black and white. There is only one area of the retina where the image striking it is focused the sharpest. In the rear of the retina there is an area called the macular, which is somewhat indented, and at its center is the fovea. The fovea is the spot where the sharpest focus is achieved onto the color receptor cells called cones.

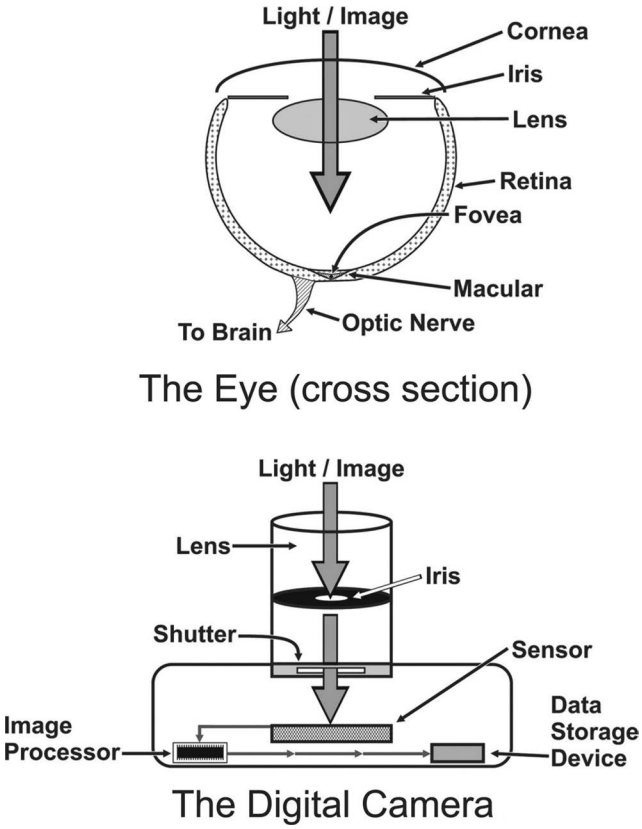


FIGURE 10.11 The eye versus the camera.

(From George Pearl.)

Spectral Sensitivity of the Eye

Human eyes are sensitive to light in the wavelengths between 400 and 700 nanometers (nm). In the eyes, the cone cells are sensitive to three wavelength ranges. The brain interprets these as blue (with a peak near 419 nm), green (with a peak near 531 nm), and red (with a peak near 558 nm). All the colors healthy human eyes may see are composed of combinations of intensities of red, green, and blue. White and black only add contrast, not more color. In low-light/scotopic vision, the rod cell peak sensitivity is about 500 nm.[36]

One may think they see sharply over the entire 140-degree view from both eyes. However, their eyes are constantly scanning the entire scene ahead and the brain is remembering the scan—the scanning process only gives the impression of seeing sharply everywhere. People are not generally conscious of their foveal vision area of sharpness because they can refocus their vision somewhere else in fractions of a second. Wherever they happen to be looking with their foveal vision, their perception is that their eyes are almost always focused. The brain integrates small samples and provides people with what they perceive to be a broad, focused view of the area in front of them.

One can test this fact by directly looking at an area of a room or wall to see how sharply in focus it is, and then while looking directly at that area, observe how areas through a doorway beyond are not in perfect focus. Look at the area not in focus, and it jumps into perfect focus. A camera can focus and record an entire scene all at once, whereas the normal human eye cannot, but does its rescanning so quickly, a person perceives the entire scene in focus.

Once an image is formed, it is transmitted from the eye through the optic nerve to the brain. Because optical illusions are a possibility, the reader is strongly advised to study the book, *Eye and Brain: The Psychology of Seeing*, by Richard L. Gregory (5th ed.) that extensively covers how humans see and perceive what they see.

Just because the eye forms an image and sends it to the brain doesn't mean that image is comprehended right away or at all. What happens, especially in a situation like night driving, is when traveling down a long stretch of highway a person may fall into the guidance mode of seeing and driving. This is where the eyes are seeing the stripes on the roadway and the brain is making automatic adjustments to keep the car between the lines. No intentional thought is involved, and it illustrates how people sometimes do what Pearl calls daydream driving. Their brain alerts them to something ten minutes down the road, and the person does not know or remember how they got there. They were in the guidance mode of driving. Consider if suddenly there is a dark-colored object, animal, or person riding a bicycle with no lights or reflectors ahead in the roadway. When the eyes transmit the scene to the brain, the brain needs time to get out of the guidance mode and into the recognition mode of seeing.[37] If the image is strong enough to alert the brain or it is conspicuous, it is analyzed to determine its hazard potential. However, if it is not conspicuous enough to cause an alert, a collision may occur with the driver never perceiving a hazard. That mode change and analysis takes time, commonly called perception-reaction time or perception-response time (PRT).

If something is conspicuous, it stands out from the background and draws attention to itself. The definition of conspicuity is an object's ability to stand out from its visual surroundings and have a high probability of being noticed. This may take a 70% or more difference in contrast (black to white) to occur! Weber's law says that if an object does not have enough contrast to be conspicuous and has the same contrast as the background, the object will be indistinguishable from the background.

The parking bumper in the shadow of the car on left in Figure 10.12 has faded into the background, becoming a trip hazard. Had the bumper been painted a contrasting color such as roadway yellow, as in the right image, there would be a high probability it would be seen in time to avoid a tripping injury.



FIGURE 10.12 Conspicuity examples.

(From George Pearl.)

CASE STUDY 10.2

Two people were riding horses on a rural two-lane roadway, and one of them was struck by a vehicle, injuring the rider. Although the incident occurred during daylight hours, dark dense pine trees lined the roads, the horse was dark brown, and the rider wore dark clothes and hat. At the correct time of another afternoon, closely matching the sun's azimuth and altitude of the subject day, Pearl, approaching another horse and rider, found the horse and rider were not conspicuous enough to be noticed. They faded into the background.

When the brain changes from guidance mode into the recognition mode, it must take the new image and go into past images to determine if it can identify another that matches what the eyes are sending. The brain, in a short amount of time, needs to determine what is ahead of it and decide to continue in the same direction, change direction, stop, or any number of other actions to protect the body. Normally, perception/reaction time in daylight is about 0.5 to 1.5 seconds—but at night the time can be much longer. Current research on this subject holds that reaction time can be highly variable.[38] A blanket perception/reaction time is also noted to be too simplistic and not applicable in all situations.[39] In 2009, Mark Green, PhD, stated: "Whenever the driver is confronted with a complex traffic or highway situation and is required to make choices, judgements and decisions, his response time may increase to 2, 3, or even 5 seconds."[40] Beyond these basic statements, further discussion of human PRT is beyond the scope of this text.

Example Scenario: A vehicle traveling 60 MPH (88 FPS) has low beams on. From studies on dark roadways, Pearl has found that the distance required to see a person dressed in dark clothing on the side of the road with low-beam headlights is about 178 feet distance. If it takes the driver three seconds to identify an object ahead, then they have traveled about 264 feet while their brain has tried to decide if they need to swerve, slam on the brakes, or just keep on driving! Obviously, there will be a serious problem if the car travels 264 feet while the driver processes the visual information.

Returning to the eyes seeing versus the camera capturing, there is no 3-D/stereoscopic rendition of the scene when a photo is captured by a camera with only one lens. Capturing images with cameras, we are technically representing what a one-eyed person would be seeing. Most people have two eyes set apart by about 2.5 inches, and the eyes see the scene at two different perspectives or angles. With this offset the brain fuses the two views into a 3-D image, creating the perception of depth. (See Chapter 9 for more information.)

TIP:

The formula to convert miles per hour to feet per second is MPH × 1.4666 = FPS

$$\text{Derivation: 1 Hour (in seconds)} / \text{1 Mile (in feet)} = (60 \times 60) \div 5280 = 1.4666$$

While the camera captures a photo in fractions of a second and can be adjusted to any exposure, normal human eyes may take up to 30 minutes to adapt to a dark environment. In most instances a photographer will be on the scene in darkness for at least this length of time. Therefore, their eyes should have fully adjusted and been dark adapted. Using a flashlight to see your notes or standing in the light emanating from a lit storefront will slow or stop the adaptation process. There is some truth to movies showing armed forces entering a battle zone in the dark when the transport in which they are riding will switch to red lights when approaching the point of departure. Traditional film darkrooms used red lights to allow vision when working with red-insensitive photopaper.

TIP:

A camping headlamp with both red-and-white light capability offers similar night vision adaptation/protection benefits.

CHAINING THE AMOUNT OF ILLUMINATION FROM THE SCENE TO THE COURTROOM

In order to properly document any low-light scene, one must first know the exact date and time of the event. For that information go to https://www.usno.navy.mil/astronomy. This website provides sun and moon data for any date. Typing in the location and the date, the resulting chart will provide the times of sunrise and sunset along with the moon's phase and its rise and set times. Another useful site is www.weatherunderground.com that will provide a specified date's hourly weather data, cloud cover, and precipitation, along with sun and moon information for any date based on the nearest airport to an incident location. The Photopills app for Android and IOS devices can provide global positioning system (GPS)–based information for past and future dates as well as extensive photographic planning information.

Sun and weather data is useful when someone claims "glare" prevented them from seeing the roadway or the pedestrian they injured. Civil twilight is the time 0.5 hours after official sundown or before official sunrise. Others define it as the time before or after sunrise or sunset when it is still light enough to work outdoors. The work necessary to capture proper documentation during this fast-changing light period is intense. Depending on how far into or out of civil twilight photos need to be captured, you may be able to capture only one or two images properly documenting the scene before the light changes significantly.

Years ago, using Polaroid 4 × 5" film, one could process and view the images against the existing scene to see if the exposure seemed correct. With Polaroid sheet film no longer available, those days are now replaced by digital cameras with viewing screens and monitors. A precision video monitor attached to a camera for viewing photos compared to the scene will allow more than one person to view the screen at one time. When all agree, that becomes the evidence exposure. The same monitor will be used back at the lab to view the same image, in the dark, to compare with the production photographs. This is a necessary step in your recipe or script for this process.

It is often impossible to expose night photos on the exact anniversary date and time of the original incident took place. If the exact time and date of the incident are known, using the research data on the Internet, another date and time may often be determined to closely match the amount of available light at the time of the original. If the incident took place 1 hour and 27 minutes after sunset, then look for a date when the sunset would be at that same time, or you can calculate the time necessary after sunset on a subsequent day. Dark is dark; it does not necessarily matter if images are exposed on the anniversary date if the process used is clearly documented and explained.

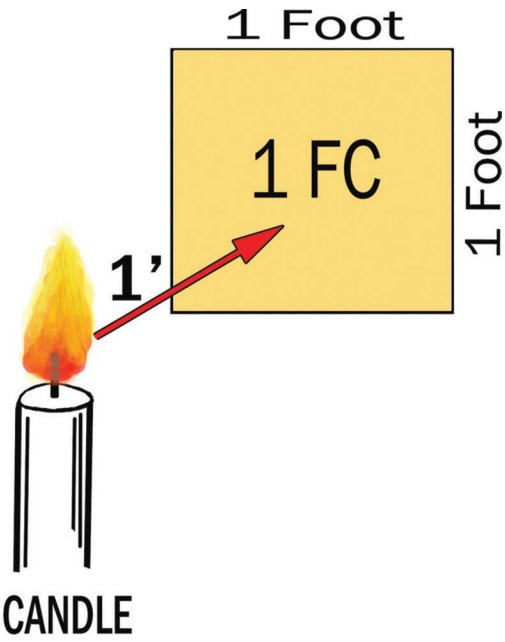


FIGURE 10.13 A candle burning 1 foot away from a plane 1 foot in dimensions is shining 1 foot-candle of illumination onto the plane.

You should attempt to make exposures under the same moonlight intensity to avoid arguments about the moon's influence on the image. However, know that at most the moon only adds between 0.015 and 0.03 foot-candles of light. In comparison, according to most city standards, commercial parking lots should have a minimum of 1-foot candle illumination at night. Once any higher magnitude light is added to a scene, any lower-level illumination, such as the moon, loses its overall effectiveness. While minimal, moonlight should be understood and explained how it was taken into consideration when the photographs were made.

Foot candles, in both illuminance and luminance, need to be explained at this point. Keeping things simple, it is possible to overlook metric measurements, including lux. The mind's eye can vary in its response to the "luminance" or how bright the objects being visualized are, versus the source "illuminance." Illuminance is light falling onto something from a source. The luminance is the light leaving or reflecting off objects in a scene.

With a precision light meter that reads in foot candles, the night vision photographer should be able to properly expose images and then present them for viewing verifiably as photographs matching the scene relatively faithfully. These meters can be purchased inexpensively. It is a good idea to buy them and provide them to the client along with the photos. Most handheld photography light meters do not contain scales for reading light in foot candles. They read in exposure value (EV) for making proper exposures in f-stops and shutter speeds.



FIGURE 10.14 URCERI MT-912 Light Meter. Purchased online from Amazon for under $20.

(From George Pearl.)

MAKE A RECIPE OF THE SCENE BRIGHTNESS

A comparison can be used in front of a jury when explaining how the photos match the scene luminance: "Everyone should be familiar with McDonalds restaurants. There is a reason why you can go into a McDonalds in Atlanta, Miami, or Las Vegas and order a Big Mac your sandwich will be exactly the same in ingredients, the manner of cooking, taste and even looks regardless of the location they are prepared."

The forensic photographer must follow a recipe of the scene brightness when the photos are exposed so the images produced may match what he or she saw when the photos were taken. The first step is to make certain the scene to be photographed has significantly the same illumination as what it was at the time of the incident. If certain streetlights were inoperative on that incident night, they need to be turned out on the night of the re-creation. This requires the cooperation of city or state engineers to do the extinguishing. The engineers and/or the local police department must also be on hand for traffic control. If there was a full moon that night, it is a good idea for the moon to be full again, even though it makes very little difference in the exposures. Include a photo of the moon on the night the images are taken to prove it was there.

If you are photographing from a vehicle, make certain the vehicle has a windshield in as close to the same condition of the subject vehicle at the time of the incident. If the information on cleanliness is not available, make the windshield as clean and clear as possible and have it stand as a best-case scenario. Also check to see if the subject vehicle has the same window tint as the exemplar. The exemplar should have enough gas to run the duration of the reconstruction, a good battery, and operative aligned headlights. If a proper matching exemplar vehicle cannot be found for the reconstruction, use a vehicle as close to the original as possible. Many vehicles from the same manufacturer and the same year have the same basic design and wheel base, so one can be substituted for another. The "Sisters and Clones" database for crash reconstruction can provide alternative vehicle options.

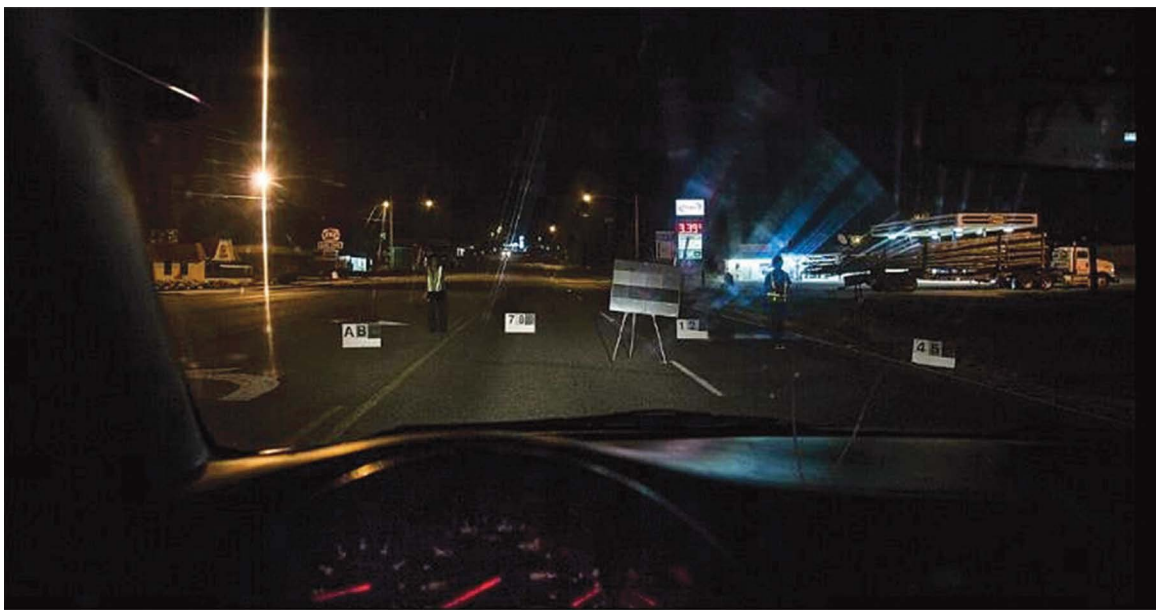


FIGURE 10.15 One effective way to properly document a scene visually is to place contrast control boards into the scene first. These are simply nonreflective photo boards made up with different shades of white to black squares and/or numbers and letters.

NOTE:

If the city or state is not party to the legal action, their participation may be an extremely expensive component to the planning and staffing of the project. If this is a roadway photo documentation, there needs to be as many police units as necessary to block and direct traffic, so your work does not cause another accident. It is a distinct possibility that the roadway in question will not be available for very long. The police will always want to close the road after full darkness and then reopen prior to morning rush hours. If you are not prepared in every possible way for photographing the reconstruction, chances are good the project will be a failure. Forensically sound practices dictate thoroughly documenting the existing light conditions and photography process so another photographer can duplicate them who has never been there. If your images cannot be reproduced using the steps you outline, your images may not be allowed into evidence.

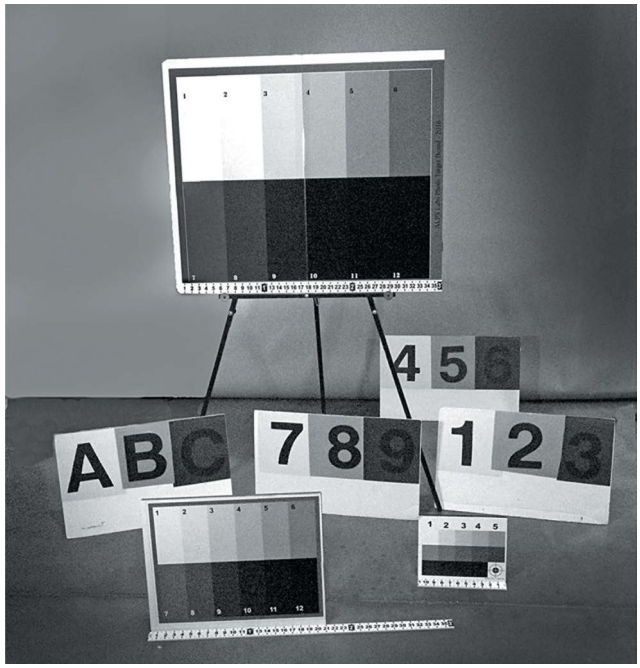
Many different sizes and shapes of control boards are required to fit the situations encountered in a documentation. Here is a sampling of some of the sizes and design boards made and used successfully over the years. They are printed photographs with numbers and shade gradations on them made for evaluation under various lighting conditions. These boards can be made simply with a number of commonly available software programs. The boards must be made in varying sizes to fit a multitude of situations.

What contrast control boards are made of is not as important as what they allow to be done. Once placed around a scene to be photographed, the photographer looks carefully at the control boards and writes notes about what can be seen or not seen on each board. Any photograph you produce as accurately representing the conditions you observed should effectively mirror your written observations. This is the only way that a scene can be effectively duplicated by another photographer checking your work.

IMPORTANT:

A normal eye exam is not going to test the photographer for low-light visual acuity. What one person may see could be totally different from another. It is critical to record as many factors regarding the subject viewer/photographer as possible, including their:

- Health
- Age
- Sobriety
- Visual health (i.e., glaucoma, eye glass prescription and tint, etc.)
- Most importantly, how long they have been away from a brightly lit place and in the darkness





FIGURES 10.16 AND 10.17 Contrast board samples and contrast boards in use.

(From George Pearl.)

Sometimes a letter or number seen against a darker background may be at a threshold for barely being seen or identified at all. You may find blocks of contrast seen as just one solid black or white long block instead of separate identifiable blocks of contrasting shades. Take good notes about this for your report. Also, try to always have some people standing in the control area. The human form is more identifiable to humans than any other form. Take notes about the details of the people in the picture. Can you see their face to identify them? Can you see variations in hair or just a solid color? Is the hair discernable from the face? Does their clothing stand out or fade into the background? Take note if a tree line is visible against the sky or otherwise invisible—can you see detail of tree leaves or grass and any other details in the scene? Take accurate notes about these things. Perhaps you can use the following chart to describe

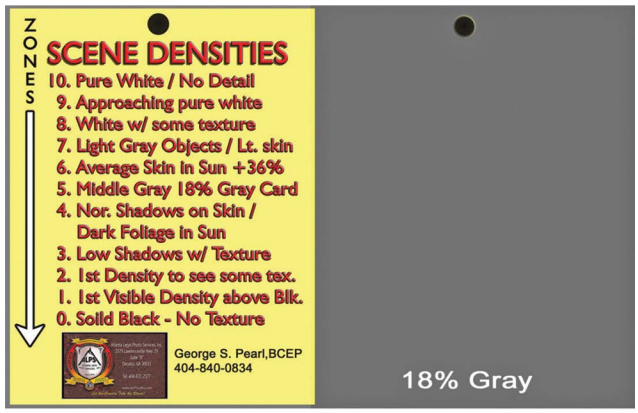


FIGURE 10.18 This chart of reference contrast areas goes back to the zone system developed by Ansel Adams. Adams claimed that by using the zone system, he could capture and print in his black-and-white photos, ten zones of luminance. The human eye can differentiate approximately 13.5 zones of contrast from black to white.

(From George Pearl.)

the density ranges visible. The chart offers specific criteria for judgement and comparison of tonal ranges.

Some professional digital single-lens reflex (DSLR) cameras are capable, in their inherent contrast density ranges, of providing the imagery we require. Pearl prints court exhibits with pigment inkjet printers now with good results. During photo processing, to image a wide range of densities, some compression may occur in the image contrast to represent a wide zone range. This is not necessarily something bad, as people just work to produce prints that fairly and accurately represent a scene.

NOTE:

Pigment-based printers are designed for fade resistance and long image life. Pigment printers typically have at least 6 and as many as 12 color cartridges, including multiple black and gray shades. Dye-based inks are more commonly home- and office-type color printers which can fade more quickly. The paper type used and how an image is displayed are important. Dye-based printers are limited to a maximum of four colors.

Using the number values from the scene density chart in Figure 10.8, observe different areas or objects in the scene and then assign a tonal number on them in your notes. When a print is made to replicate the observed scene conditions with the control boards pictured and using your notes of what the objects in the scene looked like at the time of exposure, you will then use a foot candle light meter to measure the scene luminance.

If a night visibility image is viewed under low light, fewer details will be visible than if viewed under bright light. More is visible in the light than in the dark. The recipe requires the viewing light of the prints to be under the same set foot candle illumination as the exposure was when capturing the images. Make lighter and darker test prints with contrast adjustments until the control boards under the precise foot candle viewing illumination appear as close as possible to the way they looked at the scene. Other noted areas should also match. Record all your postprocessing image adjustments just as you recorded your scene observations. Once you have matched the lighting levels, it is nearly time to make the scene prints of your vision study. Make enough prints for all parties involved.

PERSPECTIVE

Now you must decide the best image print size. Perspective is the size-to-distance relationship for viewed objects. With normal vision, a person should see a relationship of 1:1 between a viewed object and the object itself. We see about 1:1, since our eyes do not magnify or reduce the size of the objects we see. When a photo is made in a camera, the lens may be a wide angle, telephoto, or anything in between. Lens choice can magnify or reduce object size within the image. Wide-angle lenses squeeze more into the same area of the sensor and tend to reduce the sizes of the objects in the photo. A telephoto lens does the opposite. An adjustment must be made to have the objects in the photo reproduce the same relative sizes as we saw them when we took the photo.

PERSPECTIVE CORRECTION

When reading or viewing objects held in the hand, the average person, according to standard ophthalmological tests, holds the material about 14 to 15 inches from his or her eyes. Therefore, 14 to 15 inches is an accepted normal viewing distance. Larger viewing distances will dictate different size prints. Always enlarge the entire picture area with no cropping. To make the optical magnification of our photos match what is seen by the eye, we can adjust any differences between the camera, lens, or photo print enlargement by using this simple formula or a variation:

$$VD = M \times FL$$

where:
VD = Viewing distance in inches from the photo to our eyes,

M = The magnification of the sensor size image to produce the print. (To find the magnification, measure one side of the sensor, usually the long side, in inches and then divide into the dimension in inches the same long side of the enlarged photo, TV screen, monitor, or print desired.)

FL = The focal length in inches of the lens that took the picture or video.

For example, if you want to know the degree of enlargement, *M*, or how large to project an image or how large to print a photograph for viewing under a certain condition, work the formula as:

$$M = VD \div FL$$

If the full-frame sensor size is 36 mm wide, divide that by 25.4 = 1.42 inches.
If the camera lens was 50 mm, the focal length is 1.97 inches.

For a desired viewing distance of 14 inches, divide 14 inches by 1.97 inches to arrive at a magnification (*M*) of 7.11. We enlarge the image 7.11 times the width of the sensor to give the image width at 14 inches, for example, 7.11 × 1.42 equals a 10.1-inch printed image width. The vertical full-frame image also matches the magnification value of 7.11, or 24 mm divided by 25.4 equals 0.944, which is then multiplied by 7.11 to give an image height of 6.71 inches. Therefore, the correct image perspective print size for a 50mm lens on a full-frame camera would be 6.7 inches by 10.1 inches when viewed at 14 inches. If you were to change the viewing distance to 6 feet or 72 inches, the magnification factor would change to 36.5 and the resulting image print would be 34.5 by 51.8 inches.

This formula works on all imaging devices, still cameras and video. Unless the magnification is correctly adjusted for the desired viewing distance, scene perspective will be misrepresented. A photographer must be prepared to fully document in a report, and later testify, how the images accurately represent the scene, including the mathematical process used in making the images.

Do not think it is necessary to only use a "normal" lens for evidence photography. If you adhere to this magnification calculation formula, you will be able to use any lens and indicate the correct viewing distance of the resultant image to roughly match that to the eye's perspective. Pearl uses a 24 mm wide or greater angle lens on a full-frame digital camera to show the full view a person had. The wider angle is necessary to show the viewer of the photo what the subject may have seen around them. The prints may get large, but when viewed correctly they feel like "you are there." In fact, if the prints were carried back to the scene and viewed from the position photographed, the image on the print will overlay the scene! Even panoramic photographs covering over 180 degrees of view may be viewed successfully if blown up to the correct size and bent to be seen in an arc around the head of the viewer.

Another fact about perspective is that if the camera stays in the same spot, every photo taken, regardless of the lens used, will have the same perspective. The only way to change perspective is to move to another location. Changing lenses or zooming does not change the perspective—just the angle of view will change.

CONCLUSION

Making the night, existing, or low-light print for evidentiary purposes, we have made the control board photos match the notes we took at the scene through making and viewing test prints, and we determined the correct size for viewing. Once we get the control photo correct to be viewed under the foot candles assigned to it, the rest of the photos taken under the same lighting conditions may be printed and viewed the same way. We will provide the client with a foot candle meter and instructions for the correct light level for viewing. He or she may then use that same meter to measure the light for correct viewing of the prints wherever he or she desires to review them.

When asked how you know the prints are correct, you must show you did validation testing. On many occasions, Pearl has made prints and gone back to the scene to compare the prints against the scene. Care must be taken that illumination is the same as when the photos were exposed. Next, view the photos under the correct foot candle illumination and viewing distance. When you do this, the prints may be raised up and down over the scene. If you have done your work correctly, the photos will overlay the scene in terms of brightness and perspective.

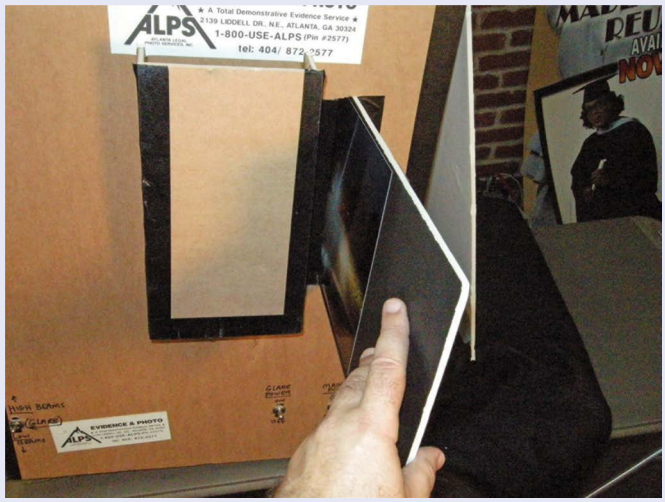
GLARE BOX

There is one more obstacle to discuss in this section. Glare from headlight beams or other light sources, including audience blinders from stage lighting, may be something requiring a demonstration. Glare does not happen inside a camera because cameras are built with black antiglare coating inside the mirror or prism box. Glare, however, does happen inside the eyes. It overloads the retina, cones, and rods of the eye. If the light is too intense, it becomes debilitating. Glare can destroy the image-forming ability of the eye, so portions or all the scene ahead becomes a whiteout.

CASE STUDY 10.3

The police stopped to talk to a dump truck driver on a two-lane highway at night. The police car pulled alongside the truck cab had its high beams on but not flashers. An oncoming driver was traveling at highway speed approaching the rear of the dump truck. The driver did not see and/or recognize the stopped dump truck in time to avoid the rear-end collision. The glare of the police headlights whited out the stopped truck. Pearl captured night photos of this scene from various distances, but when making the prints, none showed the high degree of glare in the driver's eyes. In order to demonstrate this glare, he created the glare box. The box allows prints to be viewed in the correct perspective and then to flip a switch and shine a spotlight into the viewer's eyes to demonstrate the high beam glare situation versus the low beams.



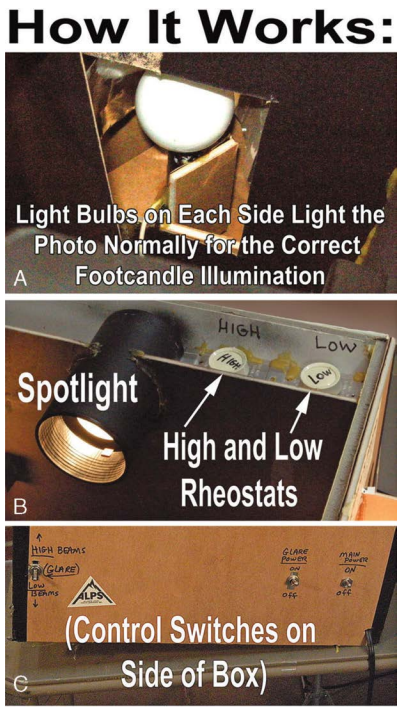




FIGURES 10.19 TO 10.21 Glare can only be truly demonstrated with a bright light shining into the eyes of the viewer. Figure 10.20 shows the mounted photo being inserted. This viewing box allows the viewer to see the image normally and then see the difference between high and low beams of an approaching vehicle.

(From George Pearl.)





FIGURES 10.22 TO 10.26 Glare box at work and inside design.

(From George Pearl.)

The mounted photos are inserted into the side of the view box onto an inside trough to guide them into the correct position. The image is lighted to the correct foot candle illumination with light bulbs on either side of the image inside the box. Additional lights aimed toward the viewer can be activated to demonstrate the glare effect.

In the digital age of photography, attorneys will ask for the digital files of your night visibility photos. It is best practice not to give those out, since the attorney has no way to accurately print them for correct viewing. You should provide enough final, printed images for all parties to an action with the explanation that they are specially prepared for the matter at hand. Any other pertinent case images can be delivered in electronic format provided image accuracy is not critical. Your strict formula for low light and night visibility prints will separate you from other photographers.

10A Existing Light Photography

Robert Wyman

AMBIENT LIGHT/VISUAL STUDY EXERCISE

The site in Figure 10.27 is a simulated crime scene location, with a concrete wall as a point of potential concealment, a parking lot with a nearby streetlamp, and a moderately dense landscaped area with both trees and shrubs.

The simulated assignment, in addition to normal "flash" and well-illuminated painting with light images of the area, is to document the actual lighting conditions at the time of the crime or incident.

To produce an accurate and indisputable view of the area, a series of exposures are completed from each vantage point of interest. Ideally, your images will be taken in the exact locations of any witness or participant to the event. This procedure expands upon the time-honored "bracketing" photographic procedure from the days of film, whereby a normal exposure would be supplemented by an overexposed version and an underexposed version, resulting in a narrow range of images by which to judge what looks best to the photographer.

In a forensic documentation environment, the photographer's opinion of the "best" or "most accurate" image is still important, but so, too, are the opinions of eyewitnesses and first responders more intimately acquainted with the incident. That is, the witnesses that observed the "live" event and lighting conditions at that exact point in time. The photographer, conversely, is recording the incident site minutes, hours, or even days later. Thus, the photographer has no independent knowledge or personal recollection of the actual lighting when the scene was fresh; the photographer can only select the best image for the time and conditions present at the time of the photography task.



FIGURE 10.27 This is a standard crime scene type photograph exposed by on-camera flash. The areas closest to the camera are well-lit, and the light intensity tapers off as distance increases. Notice also the bright reflection caused by something in the left center background in an otherwise dark area.

(From Robert Wyman.)

To provide a useful and objective photo documentation effort, a larger population of bracketed-style images are recorded, each with subtle exposure differences between the preceding and following images. The image exposure range is purposely varied from being abnormally dark to abnormally bright at any scene and vantage point, with several exposures falling between the overly dark and overly bright samples.

To this point, the overexposed and underexposed bracket images have not been directly addressed as to the amount of exposure change. In the section of Chapter 4 on HDR photography, the bracket amount was two stops over and under a normal exposure. Other situations may call for just one stop overexposure and underexposure. For the sample vision study images included here, the complete image series is available at www.forensicphoto.com/Vision-Study/Wyman-Images.html. There are 13 images plus a final image captured specifically because that one image matches the photographer's opinion of mirroring the exact lighting conditions. The only reason for the final image being taken is despite the group images allowing the actual witnesses to identify the lighting level as they recall it, the photographer is almost always asked which image matches his or her perception. All images were captured at ISO 100 and *f*/8 for consistent DoF with shutter speeds varying from 2 seconds to 30 seconds. Some of the images cannot be reproduced correctly in this text, but all are available for review on the web page.

The resulting population of images represents a distribution of exposures allowing viewers to independently select their choice of "best" or "most accurate," without the photographer's influence and without the limitations of a small sample size.

Within this range of sample exposures, witnesses can quickly dismiss images that are immediately discerned as too dark and too bright, then select one or more of the remaining images as the best example(s) of at-scene conditions. The photographer neither influences nor restricts these choices, as the large number of samples allow viewers to fine-tune their selections without compromising their choices, for example, by having to identify an image with the conclusion that "it's a little darker than this one" or "a little brighter than that one."

If the photographer wishes to provide a personal and professional opinion as to which image is the most accurate, I recommend the following protocol be applied to all images as a method to establish the photographer's choice:

1. Identify and observe the brightest part of the real-world scene which has been photographed in the range of images. This may be a bright light, bright reflection, or similarly light-colored area or object in the scene.
2. Next, identify and observe the darkest part of the real-world scene. This may be a dark shadow, a nonilluminated area, or similarly dark-colored area or object.
3. Within both the brightest and darkest parts of the scene, make note of the discernable colors, shadow tones, and object textures/details. Textures and details may be elements such as wall textures (concrete, brick, stone, wood, etc.), blades of grass, tree leaves, or other scene elements with a three-dimensional structure.
4. View the population of images in the camera or on a computer (if the images can be downloaded at the scene) and scrutinize the same points of brightness, darkness, color, and texture. Zoom in and magnify the recorded image to see more detail if needed.
5. Typically, one image will become apparent as the best match to the scene, with adjacent images being very close in accuracy as well. Other images will exhibit excessive brightness or darkness and loss of visible details. The photographer should complete the series of image exposures and then take one additional exposure that corresponds to his or her opinion of matching the scene lighting.
6. Some additional items should also be considered to enhance the accuracy of this procedure:
   a. Camera screen and computer screen brightness should be set at normal levels, without being overly dim or overly bright. This will facilitate the comparison between actual and recorded scene lighting conditions.
   b. Optionally, monitor screens can be calibrated for brightness, contrast, color, and sharpness via observational scrutiny, internal camera/computer settings, or external calibration hardware and software methods. Even without monitor calibration efforts, however, camera and computer screens with normal settings will provide enough visual information to make the needed comparisons.
   c. Note that colors may shift in some cameras and computers. This is a normal and predictable by-product of some imaging sensors, monitor screens, and lighting color temperatures. Sodium vapor streetlamps, for example, may appear yellow-orange to the naked eye, but exhibit more of an orange-brown coloration in the recorded image. In these circumstances, for comparison purposes, pay more attention to the overall scene brightness instead of the perceived color tones.
   d. While the photographer's intent should always be objective in terms of photo documentation, realize that certain subjective elements will always be present. Visual acuity is not consistent among all people, so the photographer's selection of the best photo will be influenced by this uniquely individual attribute. Similarly, not every camera brand and camera model will record a scene in exactly the same way. It should be extremely close among all of the high-quality, "name brand" cameras, but may not be exactly the same. These variations are minor and do not in any way invalidate the photographic effort or the comparison between images and real-world observations.
   e. To be clear, if two cameras (with similar sensor sizes and lens specifications) are used to record an ambient-light scene, camera settings selected for the best scene image from Camera A are typically exactly the same as comparative images from Camera B, with both cameras also properly illustrating the real-world scene. Exposure variations between cameras may be perceived in color tones or contrast, but the range of exposures will be similar. For cameras with different sensor sizes and lenses, any differences between each camera's recorded images can be precisely correlated; for example, Camera A's best image at 1/4 second shutter speed may correlate to Camera B's best image at 1/6 second shutter speed. Other images in each camera's exposure range will be similarly offset.

In the examples provided for this topic next, all exposures were recorded on a tripod-mounted camera with a constant aperture and ISO. The constant aperture maintains the same DoF for all images, while the constant ISO maintains the same noise level. Exposure difference therefore is controlled via shutter speed. The sample images were all recorded at *f*/8.0 and ISO 100. Shutter speeds ranged from 2 seconds for the darkest image to 30 seconds for the brightest image.

PHOTO MONTAGE



FIGURE 10.28 Shutter speed = 2 seconds.
(From Robert Wyman.)

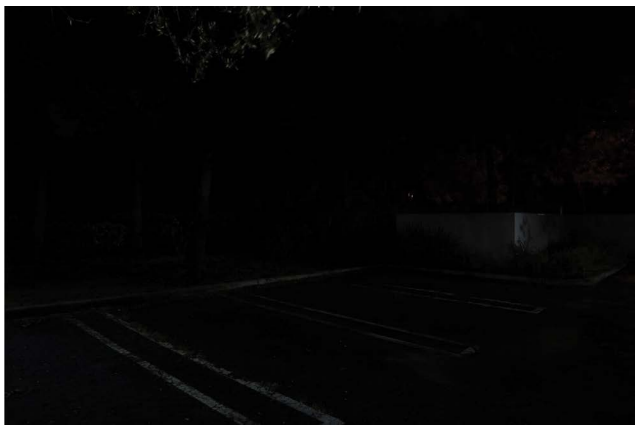


FIGURE 10.29 Shutter speed = 2.5 seconds.
(From Robert Wyman.)

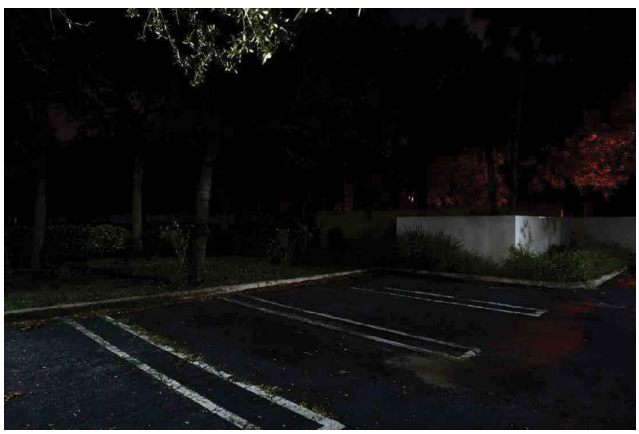


FIGURE 10.30 Shutter speed = 3.2 seconds.
(From Robert Wyman.)



FIGURE 10.31 Shutter speed = 4 seconds.
(From Robert Wyman.)

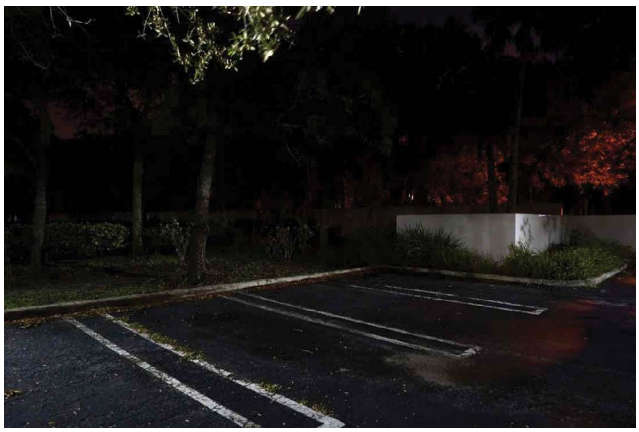


FIGURE 10.32 Shutter speed = 5 seconds.
(From Robert Wyman.)

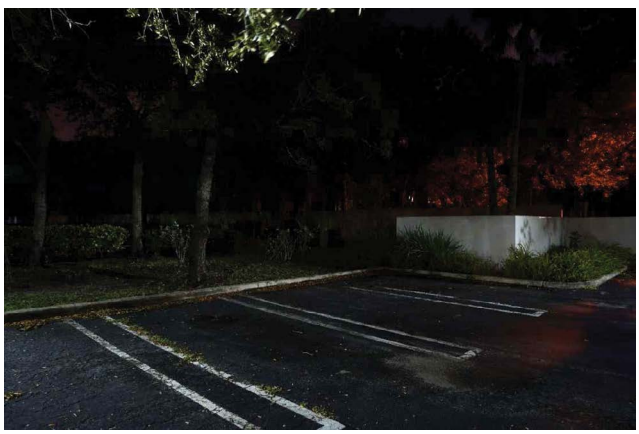


FIGURE 10.33 Shutter speed = 6 seconds.
(From Robert Wyman.)

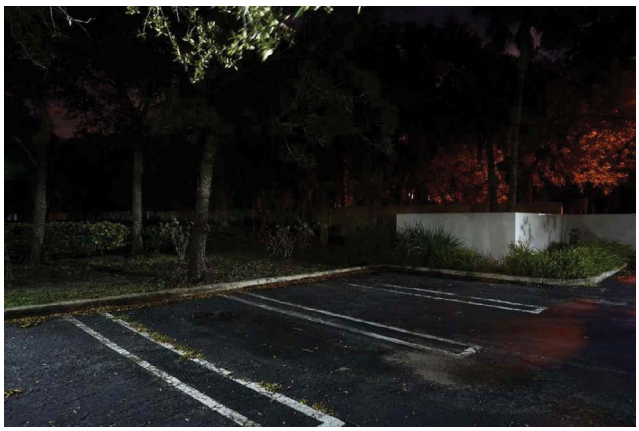


FIGURE 10.34 Shutter speed = 8 seconds.
(From Robert Wyman.)

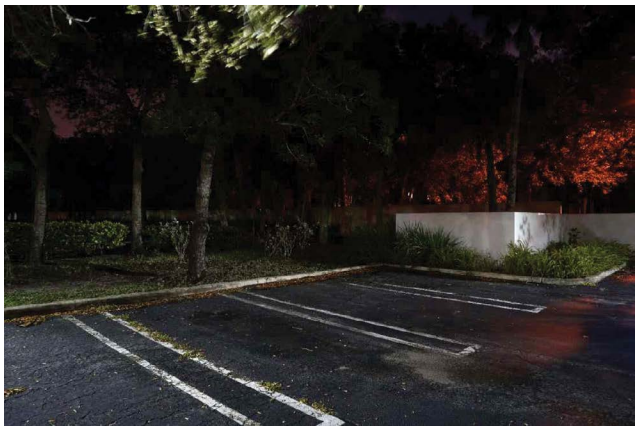


FIGURE 10.35 Shutter speed = 10 seconds.
(From Robert Wyman.)

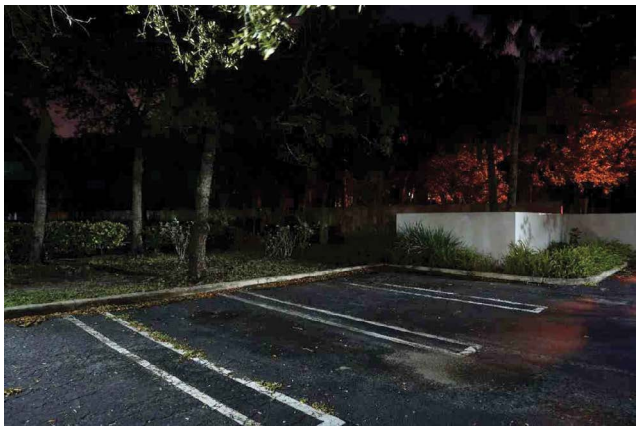


FIGURE 10.36 Shutter speed = 13 seconds.
(From Robert Wyman.)

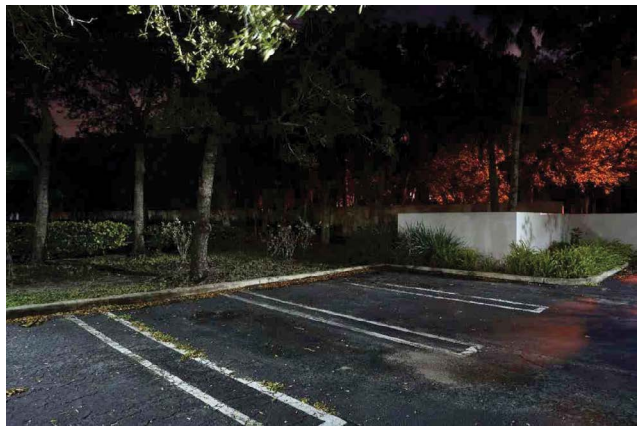


FIGURE 10.37 Shutter speed = 15 seconds.
(From Robert Wyman.)



FIGURE 10.38 Shutter speed = 20 seconds.
(From Robert Wyman.)



FIGURE 10.39 Shutter speed = 25 seconds.
(From Robert Wyman.)

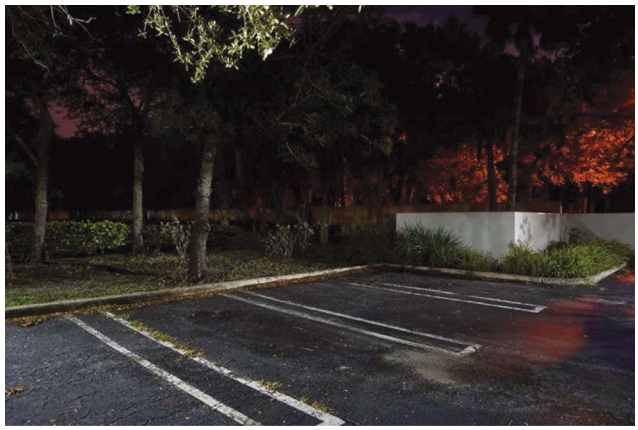


FIGURE 10.40 Shutter speed = 30 seconds.

(From Robert Wyman.)



FIGURE 10.41 Shutter speed = 6 seconds. The photographer's perceived matching image to the scene lighting.

(From Robert Wyman.)

10B Painting Evidence with Light

George S. Pearl

Of all the photographic techniques crime scene and accident photographers seem to have consistent difficulty with it is properly documenting scenes having low or no ambient light. Photographing scenes during the well-lighted daytime hours is a snap when lighted with the sun. The problem of lighting the scene comes when one is inside a huge warehouse with no power, or out on a dark stretch of roadway, or open field at night without any lights illuminating the area—you just can't see a thing in the dark. You can become overwhelmed by your need to show the overall large scene but not being able to light.

If you follow the suggestions in this section, you will have one of the most valued techniques of proper night scene photography available for your use the next time it presents itself. This type of photography is strictly for showing a darkened scene whereas it could not have been shown otherwise. As far as the image being a "fair and accurate representation of the scene as you saw it," this is a bit tricky. You will be able to say that you saw all the parts each lighted in a sequence and the resulting photograph is a fair and accurate *composition* of those parts as you saw them. This process is to show the evidence and not get all hung up on legal terms for the photo to be allowed in evidence. It should ultimately be allowed in for its value in the evidence being shown. As an example, x-rays are admitted into evidence in our courts every day, but no one saw inside the body when the picture was taken.

In a simple explanation what you will be able to do is to light up large areas of total darkness with just a single small electronic strobe light, a spotlight, or in some cases, even a good flashlight will work. This is called "painting with light" photography because you will be moving the light throughout the scene exposing one part at a time with your light while the camera lens and shutter are open the entire time. The idea is to paint all the areas of the scene that are dark with a light source and need to be shown as any lighted areas in your photograph.

To paint a scene with light, you will be walking all around in the photo you are taking! Don't worry about being seen because if you do this procedure correctly, you will not be seen in the resulting picture. This is because your body walking about will be darker than the lighted areas being exposed by your portable light. So, any ghosting darker image of you in the photo will be filled in with the brighter lighted scene from the strobe.

TIP:

Always keep moving and do not stand around for an extended time in one spot.

Painting with light requires a camera capable of full manual exposure for the aperture and the shutter speed to be able to set on "B" for bulb.

NOTE:

In the early days of photography, camera shutters were located inside the lens and operated by a small piston, driven by air pressure through a tube coming from a rubber bulb squeezed in the photographer's hand.

The shutter would be held open and the film exposed to light for as long as the photographer kept the rubber bulb compressed. Today we retain this "B" setting on our shutter speed dial to represent *bulb,* and the shutter remains open for as long as the shutter button is depressed. Modern DSLRs now use an electronic rather than a physical cable release. Most will allow you to open the shutter and lock it in the open position without touching the camera. Not touching the camera after you start your light painting is crucial, since you do not want to shake the camera during the long exposure time. Any camera movement will blur your image and make all your effort in painting the scene a waste.

You may find your camera has a shutter speed setting of "T." This "T" setting is for time exposure. the difference between "B" and "T" is that the first time you press the shutter button, the shutter will open and remain open until you push the shutter button again and then it will close to end the time exposure. The "T" setting may be more convenient to use than bulb.

You cannot use any automatic settings during a painting with light exposure. The camera needs to have focus, aperture, and ISO set manually. A digital or film camera does not matter. Today's digital cameras will display the finished image on their viewing screens after the exposure is complete, so that is a huge advantage over a film camera.

TIP:

Confirm that your camera battery has enough power prior to any long exposure sessions. Some film cameras will operate on "B" and several shutter speeds without a battery.

The next requirement is to always have and use a good sturdy tripod. Your camera must remain still while you paint with light because the total exposure time could easily run into several minutes. If the camera is moved during the exposure, it will smear the image, blurring it into an

unusable image (see Chapter 4A for more information on tripods).

A good handheld and hand-operated portable electronic strobe light is your next must-have requirement. The larger and more powerful the strobe light, the less total flashes and time will be required to cover the scene. A strobe that recycles fast is best, as well as one that will flash on full power many times before the batteries go dead. The strobe needs to be one that extra batteries can quickly be changed out and that you have fresh extra batteries handy before you attempt this kind of work.

In most cases, people will be waiting for you to take your images and get out of their way. Conversely, you will be holding up others working the scene because you cannot have them walking around shining their flashlights in the scene while you are exposing your picture. You need to operate as quickly as possible but don't become intimidated by anyone who just wants you to take some "snapshots" and move on. You must be in control of the scene to be able to produce this high-quality evidence.

In some situations, a drop light on a long extension cord or even a good high-powered flashlight can be used to paint an area or object. Even so, having a good portable strobe light that can be operated manually off the camera is a must in this business. A manual flash button on the strobe unit is also necessary.

Depending on the available light present, it may be best to cover up the lens with a dark 4″ × 6″ artboard in between flashes. This prevents strong lights in the scene from blooming out and overexposing the darker areas being painted or other important parts of the picture. Depending on the scene, you will quickly learn which scenes you can do by yourself (i.e., the totally dark ones) and which require the help of an assistant to fire the strobe. Voice or radio communication with an assistant is important for timing flashes and covering the lens. Keep your aperture set to a medium setting or smaller if you can while doing these pictures. This will help keep unwanted lights reduced and give you a greater DoF or sharpness throughout your shots.

The simple steps of the painting with light process are:

1. Place your camera on a tripod for stability.
2. Adjust the lens to cover and focus on the entire scene you will be painting.
3. Open the shutter on the bulb setting and lock it open until all flashes have been done.
4. You or an assistant directed by you flashes the strobe light set to manual full power output in sweeps walking from side to side in the scene.
   a. The person with the strobe will watch the EFU's ready light until it comes on.
   b. When the light comes on, aim the strobe and call out "READY!"
   c. When he calls out ready, remove the black card covering the lens.
   d. With the card removed, you will call back "FIRE!"
   e. Fire the strobe and quickly replace the black card over the lens and wait for the next "READY!" call.
5. Start from the most distant point of your scene and work your way back to the camera. Overlapping the light each time is preferred to give a more even lighting appearance. Each closer strobe illumination will cover over or negate any ghosting trace of the person firing the strobe light within the bounds of the picture.
6. Have the strobe pointing away from the camera overlapping the lighted areas each time



FIGURE 10.42 Painting with light.

(From George Pearl.)

If there are lights around the scene that could interfere with your production, you will need to somehow reduce their exposure time to prevent overexposure and blooming of the light ruining your picture. The easiest way would be to turn them off, but if that cannot be done, you will need another person to help you paint the scene. This helper will walk around firing the strobe light while you cover the camera lens with that black card during the time while there is no strobe flashing. Doing this allows



FIGURE 10.43 Same scene in daylight.

(From George Pearl.)

mostly just the controlled flash exposures to make up the photo instead of a very long time exposure of some light or lights in the scene that will become overexposed and ruin your shot.

The correct exposure for these painted shots can be somewhat determined by the flash exposure guide for your EFU's full power output. For example, your flash's owner's manual says the full power output for ISO 400 is *f*/16 at 20 feet. If you are shooting outdoors with no ceilings or walls for the strobe light to bounce off, try exposing at *f*/8.0 or *f*/11. This is a one- and two-stop increase in the amount of light getting to your sensor. You may also find that using the f-stop recommended by the flash gives the best results.

Do some quick tests and look at the results on your camera's viewing screen. Bracket your exposure with a couple of different runs to make sure you have found the correct exposure settings.

Painting with light indoors is the same, except the exposure may be different when there are ceilings and walls close enough for the strobe to bounce off from. You may find that this technique helpful to light up around an object or a body. Don't always think that this is only for large area scenes. Use painting with light whenever you desire to show something well lighted or even light shining from behind or through an object as well.

TIP:

Always practice special techniques before having to use them on an actual scene or job.

Being prepared and planning with the right equipment is useless unless you have the knowledge and experience to perform under pressure and time constraints. Practicing this type of photography with a friend or family member will seem game-like to them, but it is imperative for you to do this before you need to do it on the job. This may sound easy enough, but without prior practice and testing on your part, it can become a total failure and waste of everyone's time on a real scene. Prior practice and training with others that might be at your scene and showing them the end product image will encourage their support and assistance at a live scene. Painting with light is a slow process, but the efforts can be quite beneficial.

10C Dealing with Retroreflective Light

Robert Wyman

The solution is not in the camera settings, but in having a better understanding of light and those reflective signs and graphics. Modern signs and vehicle logos are much different than old-style devices.

OLD-STYLE REFLECTORS

As children growing up, each of us probably had a bicycle or toy with a "reflector" mounted on the device. Our parents explained to us, and perhaps demonstrated, how a car's headlamp would light up the reflector and make the bicycle easier to see at night.

These reflector styles, still used for bicycles, driveway markers, and similar delineators, have a flat mirrored surface, or a slightly curved, semi-parabolic mirrored surface, to direct incoming light back toward the light source. These mirrors are not glass but are instead a polished plastic or metal housing with either a foil sheet, chrome-plated base, or similar material used as the reflective surface. A tinted cover or lens introduces (typically) a clear/white, red, amber, or blue color to the reflector.

Enhanced reflector models utilize a faceted lens cover design, like a Fresnel lens, to further concentrate and direct the reflected light back toward the source. These designs are also used in stand-alone reflectors described earlier, as well as integrated within other lamp housings, such as taillamps of vehicles.

Reflectors are all limited in their reflective properties: a concentrated light beam, as from a vehicle headlamp, must hit the reflector in a perpendicular manner for that light beam to be reflected back toward the source.

These devices are called "retroreflective" along a *single* viewing angle.

For example, a red reflector mounted to the back of a bicycle must first be mounted so the lens is best oriented to reflect light from an oncoming car and headlamp.

- The lens must be mounted in a perfectly vertical orientation on the front-to-back or pitch axis, so the face of the lens is perpendicular to the ground.
- The lens must be also mounted in a perfectly horizontal orientation on the side-to-side or yaw axis, so the face of the lens is perpendicular to the bicycle frame and roadway lane, thus "facing" toward the rear centerline of the bicycle.

With this alignment, a headlamp beam originating from the center rear of the bicycle at or very near to the reflector's height above the road will produce a bright reflection from the bicycle. The light beam intersects the reflector in a perpendicular manner, returning on a reverse path toward the headlamp.

Headlamps mounted at particularly low or high elevations will not fully intersect the reflector and not return a bright spot of light from the bicycle. Other light beams aimed at the reflector but originating to the left or right of centerline also fail to intersect the reflector perpendicularly and will again not return a bright spot of light from the bike.

Of importance is how the light beam travels from the headlamp to the reflector and then from the reflector to the headlamp. The reflected light travels along a single axis, no matter if outbound from the headlamp or inbound to the headlamp.

As vehicle drivers, we see the maximum brightness of the reflector when approaching the bicycle because the headlamp beam is perpendicular to the bicycle's reflector, and our eye height (in most vehicles) is only slightly above the headlamp height.

TIP:

Walk around a bicycle or driveway marker reflector with a spot-beam flashlight placed next to your face, at eye height. Hold the flashlight at eye height, aimed directly forward, and keep your gaze directly forward as well. Walk around the reflector and gaze at the reflector from different angles and elevations (with the flashlight always next to your face, at eye height, and parallel to your gaze). The bicycle reflector will only provide its maximum reflective brightness when the flashlight (and your eyes) are precisely perpendicular to the reflector face and at the same elevation.

PHOTO TIP:

Instead of using a flashlight, photograph the reflector from various angles and heights with an on-camera flash (pop-up flash or external flash mounted to the hot-shoe). The reflector will again only provide its maximum reflective brightness when the camera is directly in line with the reflector, perpendicular, and at the same elevation. Like the vehicle driver seeing the maximum reflection because eye height is close to headlamp height, the camera will record the maximum reflection because the lens height is close to the flash height. An off-camera flash will not have this alignment and maximum brightness will not be recorded.

MODERN VEHICLE GRAPHICS AND TRAFFIC SIGNS

Police and fire logos, badges, and text banners on vehicles, as well as most traffic signs, are created from a self-adhesive material sheet in the colors and shapes desired by the local agency. The sheet includes reflective beads, microprisms, or tiny lenses embedded within the flexible material to make the resulting logo or sign retroreflective from almost all viewing angles. That is, unlike the older reflector devices detailed earlier, retroreflective sheeting will return a maximum reflection at any angle from which the source beam originates.

- The light source does not have to be perpendicular to the logo or sign, or at the same elevation.
- Our eyes (or cameras), however, still must be near the source lamp's angle for us to see the maximum reflective brightness of the logo or sign.

With these properties in mind, on-camera flash images of retroreflective sheeting will *always* return the maximum reflective brightness from the sheeting, no matter what angle the photographer is standing toward the logo or sign.

If the camera is set to any automatic or semi-automatic mode, with an on-camera flash, the resulting images will be abnormally bright (overexposed) at the logo sign or license plate and abnormally dark (underexposed) for all other areas in view. The flash or camera is reading the extreme brightness of the reflected light and cutting off the exposure prematurely for other elements in the scene (see Figure 10.46).

To solve the problem of having overexposed logos and signs with underexposed surrounding elements, a pop-up flash cannot be used and an external flash must be removed from the camera. The external flash can be minimally held at arm's length, but a better strategy is to separate the flash from the camera by several feet. The connection between the flash and camera can be wired or wireless, depending on the flash features available.

If the camera is on a tripod, a longer exposure can also be set, allowing the photographer to manually trigger the off-camera flash. A shutter speed of several seconds will allow the external flash to be aimed and manually triggered after the shutter button is pressed. Aperture and ISO should be set as needed to record the scene as desired.

PHOTO TIP:

Locate a suitable vehicle with retroreflective logos and graphics or a retroreflective traffic sign. Photograph the subject at different angles and heights with an on-camera flash. Each image will depict maximum reflective brightness, regardless of the shooting angle. Complete the series again using an off-camera flash and appropriate camera settings. The images will now have more evenly distributed illumination from the flash, without any "hot spots" generated from the retroreflective signage.



FIGURE 10.44 Typical AUTO setting where camera has chosen a high ISO that may be unacceptable for documentation of scene details. Overexposed retroreflective sheeting and underexposed scene. This is ISO 3200.

(From Robert Wyman.)



FIGURE 10.45 AUTO setting when photographer realizes the high ISO image is not desirable and dials in ISO 100 to minimize noise. Overexposed retroreflective sheeting and totally unacceptable scene elements.

(From Robert Wyman.)



FIGURE 10.46 Using a time-exposure with low ISO to better record actual lighting conditions. Five seconds at ISO 100. No flash. Good scene rendition but also somewhat dull.

(From Robert Wyman)

This can also happen in reverse. The photographer can use manual settings with ISO 100 to minimize noise but finds the scene too dark. The photographer then increases ISO dramatically, but at the expense of introducing noise.



FIGURE 10.47 Five seconds at ISO 100 with flash. Brighter image with an acceptable exposure on retroreflective surfaces.

(From Robert Wyman.)



FIGURE 10.48 Five seconds at ISO 100 with off-camera flash at arm's length. Best scene view with no retroreflective artifacts.

(From Robert Wyman.)

NOTES

1. Kayfetz, Paul, Is the Camera the Same as the Human Eye? *Advocate: Journal of Consumer Attorneys Associations for Southern California,* April 2015.
2. Ibid.
3. Harris Sr., James L., and Harris II, James L., Forensic Photography and Nighttime Visibility Issues, *Journal of Forensic Sciences* 37(4): 1992, pp. 1084–1095.
4. Phototopic vision is the sight under well-lit conditions.
5. Bomback, E.S., *Manual of Colour Photography,* South Brunswick, NJ, and New York, NY, A.S. Barnes & Co., 1966, p. 146.
6. Duckworth, John, *Forensic Photography,* Springfield, IL, Charles C Thomas, 1983, pp. 71–73.
7. Baker, J. Stannard, and Fricke, Lynn B., *The Traffic Accident Investigation Manual*, 9th Ed., Evanston, IL, Northwestern University Traffic Institute, 1986, pp. 36–23 through 36–25.
8. Ibid., pp. 36–25.
9. Hyzer, William G., An Extinction-Type Photometering Technique for Low-Light Luminance Measurements in Accident Investigations, *Journal of Forensic Sciences,* 33(2): 530–533.
10. In years past, a common collision cause or contributing factor was lack of visibility on the sides of commercial trucks and trains. The U.S. Department of Transportation now mandates red and white retroreflective tapes marking the sides of all trucks and yellow striping on the sides of rail cars. These markings have drastically reduced the frequency of these wrecks.
11. Holohan, Robert D., *Nighttime Photography: Show It Like It Is,* SAE Paper #890730, Warrendale, PA, 1989.
12. Holohan, *Nighttime Photography, Show It Like It Is.*
13. Klein, Ernest, and Stephens, Gregory, *Visibility Study: Methodologies and Reconstruction,* SAE Technical Paper Series #921575, Warrendale, PA, 1992.
14. Harris and Harris, Forensic Photography and Nighttime Visibility Issues, pp. 1084–1095.
15. Ibid.
16. Ibid.
17. Ibid.
18. Hyzer, W.G., The Eye, Brain, and Camera in Nighttime Accident Reconstruction, *Photo Electronic Imaging,* February 1993, 8–9.
19. Ibid.
20. Hyzer, The Eye, Brain, and Camera, pp. 8–9.
21. Ibid.
22. Ayres, T.J., Psychophysical Validation of Photographic Representation, Vol. 6, Safety Engineering and Risk Analysis, American Society of Mechanical Engineers, New York, 1996.
23. Ayres, Psychophysical Validation of Photographic Representation.
24. Ibid.
25. Baker and Fricke, *Traffic Accident Investigation Manual*, pp. 36–25.
26. Ibid.
27. Olson, Paul L., *Forensic Aspects of Driver Perception and Response,* Tucson, AZ, Lawyers & Judges Publishing, 1996, pp. 145–153.
28. Ibid.
29. Ibid.
30. Ibid.
31. Ibid.
32. Hyzer, J.B., Photographically Maximizing the Information Recorded in Forensic Images, Vol. 8 (paper presented at the Proceedings of the American Academy of Forensic Sciences, Atlanta, 2002).
33. Olson, Paul L., and Farber, Eugene, *Forensic Aspects of Driver Perception and Response*, 2nd Ed., Tucson, AZ, Lawyers & Judges Publishing, 2003, p. 298.
34. Alin, Boyd D., Isling, Kurt W., and King, David J., Digital Camera Calibration for Luminance Estimation in Nighttime Visibility Studies, SAE Paper #2007-01-0718 (paper presented at the 2007 World Congress, Detroit, Michigan, January 7, 2007).
35. Kayfetz, Is the Camera the Same as the Human Eye?

36. "Scotopic" from the Greek: "Skotos" meaning darkness and "opia" meaning a condition of sight.
37. Personal conversations between G. Pearl and Dr. H. Leibowitz and Herschel W. Leibowitz, C. L. Shupert and Robert B. Post, The Two Modes of Visual Processing: Implications for Spatial Orientation, retrieved from https://ntrs.nasa.gov/search.jsp?R=19850001740 2019-09-02T17:06:18+00:00Z on September 2, 2019.
38. For additional information see: J.W. Muttart, *Driver's Responses in Emergency Situations: A Quick Reference*, CollisionSafetSolutions.com.
39. Kayfetz, Is the Camera the Same as the Human Eye?
40. Green, Marc, Let's Get Real about Perception-Reaction Time, Human Factors, Tucson, VisualExpert.com, 2009.



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11 Macrophotography

Sanford L. Weiss and Robert Wyman

CONTENTS

Introduction 243
- Close-Up Lenses 244
- Extension Tubes 245
- Magnification 245
- Lens Extension: Reproduction Ratio: Magnification 246
- Extension Bellows 246
- Reversing Rings 248
- Macro Lenses 250
- Macrophotography Lighting 250
- Nikon SB-29S Speedlight 250
- Oblique Flash and Autoexposure 251
- Using a Built-In Flash and Autoexposure 254
- Axial Lighting 256
- Creating Axial Lighting 257
- Building an Axial Lighting Apparatus 257
- References and Scales in Macrophotography 259

Conclusion 265

11A Cellphone Forensic Photography 272

INTRODUCTION

Macrophotography is the type of close-up photography in which the final magnification of the image of the subject is anywhere from about .5× to about 25× of life size (1:1) on the image sensor. This type of photography is useful for the documentation of small objects and small parts of large objects requiring close inspection or ease of demonstration. Macrophotography fits the niche between normal photography and microphotography.

In forensic evidence documentation, it is often necessary to photograph subjects like tiny pieces of parts, sections of twisted metal, hunks of charred ash, or portions of broken bodies. The documentary images must be technically accurate but not necessarily aesthetically pleasing. To illustrate the characteristics of subjects, the forensic photographer must be able to create accurate representations of evidence by the selection and use of the most appropriate hardware and lighting, even if the finished photographs are not technically works of art. Macrophotography is often required to capture images of small scratches and other witness marks (gouges, imprints, or scratches used to position or locate a part in its proper spot) on shiny surfaces or in difficult locations where reflections are common and shadows from other parts of the subject are troublesome.

Every evidence photography project may require macrophotographs. Something small may need to be documented even in the largest disasters. Macrophotography may be performed in the field, where the evidence photographer must use close-up accessories and possibly an electronic flash unit (EFU) of one type or another to document the evidence in situ. In many cases, it is not appropriate to move the evidence until after it has been documented.

Sometimes macrophotography must be undertaken in a laboratory, studio, warehouse, morgue, home, or some other place to which the evidence has been located or moved. In these cases, the evidence must be properly protected but may be handled, set up, lit for proper exposure, put in front of a suitable background, and subjected to inspection and documentation, using all available equipment and techniques. Remember never to change the evidence by cleaning the surface. In any case, the photography may be tedious, exacting, and require all the possible skill and experience of the photographer.

Macro images may be the most important aspect of the documentation. Small marks and colorations may be the key to an incident reconstruction. Always have available and use the proper scales and references. The type of lighting used is extremely important, as well as how the lighting is utilized.

Working in the field is more difficult. With a minimum of accessories, the forensic evidence photographer must attempt to create accurate and properly detailed macrophotographs. If the subject is simple, lighting is sufficient, extreme depth of field (DoF) is not necessary, and high magnification is not required, the work should not be too complicated. However, "simple" subjects, conditions, and parameters do not normally exist.

The following are the greatest challenges in macrophotography:

- The inherent lack of DoF when the camera and lens are close to the subject
- Proper lighting to either avoid or create shadows

TIP:

At one-tenth life size (1:10) on the image sensor, an area about 7 by 10 inches imaged onto a Nikon DSLR sensor will have approximately:

- 1.5 inches of DoF at *f*/5.6 with a 35 mm focal length lens, or 6 inches at *f*/22.
- At life size (1:1), a subject 0.66-inch × 1 inch will have DoF less than 1 mm at *f*/5.6 or 3 mm at *f*/22.
- At 6× life size, DoF will be 0.25 mm at *f*/22.

TIP:

Due to the shallow DoF in macrophotography, the image sensor of the camera should always be as close as possible to parallel with the most predominant plane of the subject.

It is possible to utilize a variety of lighting techniques and formulas to properly illuminate macro subjects. Light must reflect off or pass through a subject to capture its image. In either case, the light must be controlled to limit shadows, emphasize textures and landmarks, and achieve proper exposure to supply the most accurate images.

Several kinds of equipment are commonly used for creating the required magnification and exposure, including the following:

- Close-up (diopter) lenses
- Extension tubes
- Bellows
- Reversing rings
- Macro lenses
- Appropriate lighting
- Appropriate references

TIP:

Focus the camera manually as often as possible when making macrophotographs.

Close-Up Lenses

Placing close-up (diopter) lenses in front of the camera's lens is a simple means to accomplish low magnification. Screw-in (see Figure 11.1) or slip-on lens attachments provide closer focusing at low cost. The quality is variable, with some diopter brands being better glass and therefore better for resolution. This type of equipment is a good close-up option for cameras with built-in and noninterchangeable lenses.

Screw-in lenses fit into the filter threads on the front of camera lenses and allow a reduction in the minimum lens-to-subject distance. The magnification of a close-up lens is specified in diopters, with higher numbers providing higher magnifications. The maximum focusing distance of the lens is reduced when diopter lenses are applied.

The lenses of digital cameras with small sensors may be shorter in focal length than those of the same purpose on 35 mm or full-frame sensor cameras and could need close-up lenses with higher numbers to accomplish the same magnification as they would on the cameras with larger sensors.

It is possible to use close-up lenses in combinations of two or three at a time. Always put the close-up lens with the highest number closer to the camera. Adding a +1 and a +2 lens yields the same magnification as a +3.

TIP:

When using close-up lenses in tandem, use the smallest possible lens aperture for the intensity of the lighting to minimize lens aberrations caused by possibly inferior diopter optics.



FIGURE 11.1 A screw-in close-up lens.

(From Sandy Weiss/Packer Engineering.)

Some advantages of close-up lenses include the following:

- They do not necessarily affect exposure.
- They do not make the image more difficult to see on the viewing screen.
- They do not interfere with autofocus.

Extension Tubes

Extension tubes (see Figure 11.2) are used on digital single-lens reflex (DSLR) cameras and are placed between the camera body and the objective lens to move and separate the lens farther from the sensor. With tubes attached, the camera and lens setup will focus at closer distances to the subject but will not at the same time focus to infinity. Extension tubes contain no optical elements, so they will not depreciate image resolution.

Extension tubes are available for every brand of DSLR (with interchangeable lenses). They may be used on lenses of any focal length but are recommended for normal and longer lens lengths. If a tube is used on a short focal-length lens, the minimum focal distance may be behind the front lens element rendering the setup ineffectual. To retain automatic operations of the camera, it is necessary to use tubes manufactured specifically for the brand of camera on which they are used. Many tubes will eliminate automatic focusing. Manual tubes will also and always cancel automatic metering.

Tubes can be used individually or in combination. The greater the extension used, the greater the magnification gained. Longer extensions require more light to create the same exposure. When using tubes, the subject image will appear darker in the viewfinder and/or on the viewing screen.

Extension tubes reduce the minimum focal distance of the lens and increase the lens magnification, which enlarges the size of the subject in the image. When using longer lenses with the same size tube, the tube will create less magnification. The longer the lens, the greater the minimum focusing distance from lens to subject. This may be useful in the odd case where the subject of the image is behind glass, like in a sealed beam headlamp, or even when working in a museum.



FIGURE 11.2 Set of extension tubes.

(From Sandy Weiss/Packer Engineering.)

REMEMBER:

DoF is reduced as the lens moves closer to the subject.

Magnification

Magnification (M) is the relationship of subject size to image size on the sensor and may be expressed in three ways:

1. As a *ratio,* image size to object size: for example, 2:1
2. As a *multiple:* for example, 4.0×, 1.0×, or 0.5× where the "×" replaces ":1".
3. As *lens-to-subject distance* (u) and lens-to-image distance (v): for example:

$$M = v/u = \text{image distance/subject distance}$$

$$1/u + 1/v = 1/F$$

where F is the focal length of the lens,
Or

$$v = (M+1)F$$

Magnification will change when the focal length of the lens or the lens-to-subject distance changes. Therefore, magnification can change by adding extension tubes or diopters.

TIP:

Using sufficient extension to raise the magnification to life size (1:1 magnification) requires two extra f-stops or four times the amount of light for a proper exposure.

TIP:

Magnification may be mathematically calculated by dividing the focal length of the lens into the length of the extension.

$$\text{Magnification} = \text{extension/focal length}$$

For example, when using a 50 mm lens on a 40 mm tube, the magnification will be 0.40/0.50 = 0.8× life size.

When adding close-up lenses/diopters to alter focal length:

$$\text{Magnification} = \text{focal length of lens/focal length of diopter}$$

$$\text{Reproduction Ratio}(RR) = \text{the size of the image/the size of the subject}$$

For example, if an image of a 4-inch subject is 0.5 inch on sensor, the RR is 1:8.

$$\text{RR} = 0.5 \text{ inch}/4 \text{ inch} = 1:8$$

If an image of a 0.5-inch subject is 0.5 inch on the sensor,

$$\text{RR} = 0.5 \text{ inch}/0.5 \text{ inch} = 1:1$$

$$\text{Scale} = \text{linear size of image/linear size of subject}$$

For example, if an image is 8 inches wide and the subject is 1 inch wide, the scale of the image is 8/1 = 8× = 8:1.

For another example, if an image is 1 inch wide and the subject is 1 mile wide, the scale of the image is 1 inch = 1 mile.

Lens Extension: Reproduction Ratio: Magnification

Magnification = extension/focal length

For example,

RR for a 50 mm lens and 10 mm extension is 10:50, or 1:5, or 0.2×
RR for a 50 mm lens and 20 mm extension is 1:2.5, or 0.4×
RR for a 50 mm lens and 50 mm extension is 1:1, or 1×

RR of 50 mm Lens with Close-Up Lenses

50 mm with +1 lens = 1:20
50 mm with +2 lens = 1:10
50 mm with +3 lens = 1:6
50 mm with +4 lens = 1:5

Exposure increase (EI) for lens extension

$$\text{EI} = \left((\text{lens focal length} + \text{extension})/\text{lens focal length}\right)^2$$

For example, a 50 mm lens with a 25 mm extension:

$$\text{EI} = \left((50 + 25)/50\right)^2$$

$$\text{EI} = (75/50)^2 = (1.5)^2 = 2.25$$

$$2.25 \times \text{E} = +1 - \tfrac{1}{3} \text{ f-stops increase}$$

$$1.4 \times \text{E} = +\tfrac{1}{2} \text{ f-stop}$$

$$2 \times \text{E} = +1 \text{ f-stop}$$

$$2.9 \times \text{E} = +1\tfrac{1}{2} \text{ f-stop}$$

$$4 \times \text{E} = +2 \text{ f-stop}$$

where E = Original or metered exposure value.



FIGURE 11.3 An extension bellows.

(From Sandy Weiss/Packer Engineering.)

Extension Bellows

Using extension bellows (Figure 11.3) between the camera body and the lens is another way to gain magnification by extending the distance between the lens and the sensor. Bellows are similar in purpose and operation to extension tubes, just much more versatile and far heavier.

Extension bellows attach to the camera between the body and the lens. Bellows provide variable extension and, therefore, variable magnification. They are available for most any interchangeable-lens DSLR camera. The minimum and maximum extensions are determined by the construction of the bellows. The magnification is computed by dividing the lens focal length into the extension length.

For example, if using a 50 mm lens on a 200 mm bellows, the magnification will be 4:1 on the image plane.

$$200/50 = 4$$

Special bellows lenses are available through some original equipment manufacturers (OEMs). Such lenses are designed for use only on a bellows and contain no built-in focusing mechanisms. They rely on the bellows, or a change of lens-to-subject distance, for focusing. Bellows lenses are available over a range of focal lengths between about 10 mm and 135 mm. Some contain automatic lens diaphragms, but most do not. Bellows lenses of some focal lengths will focus to infinity when on the bellows. (This is a very interesting concept for making images with both close-up capabilities and huge DoF when sufficient illumination exists.)

All lenses manufactured for use on photographic enlargers and many of the older interchangeable lenses manufactured for use on motion picture cameras provide excellent optics for macrophotography when used on a bellows. All these lenses have manual diaphragms. They are also usually designed to be flat field. This means they will produce images very sharp from corner to corner of whatever subject is being documented. Calculations of extension divided by focal length provide magnification figures. The advantages

of using these lenses for macrophotography are they are readily available, normally inexpensive, optically sound, and most importantly, physically small, so when close to the subject they do not block the illumination source.

It may be necessary to manufacture an appropriate lens mount adapter to affix the special lenses to the bellows or extension tubes. Camera body caps may often be milled to the proper size and then threaded to fit the lens. If threading is not possible, it may be possible to mill a hole and then glue or cement on a part already threaded to fit the lens.

TIP:

Use of a focal-length lens longer than considered normal for the image format will increase the working distance between the lens and the subject. This is useful when extra space between the camera and the subject is necessary.

Exposure must be adjusted for extension and magnification: the longer the extension, the more magnification and the more light is needed for a comparable exposure. When a camera's built-in light meter performs wide-aperture exposure metering, the lens aperture is not reduced to the size of its setting until the time of the exposure. When a camera's built-in light meter performs stopped-down mode exposure metering, the lens aperture is reduced to the size of its setting before the time of the exposure—while the photographer is viewing and composing the image. If the camera's built-in meter contains stopped-down metering capability, it may be possible to meter through the lens, even if the lens does not contain automatic meter-coupling system hardware. Some bellows have an integral focusing rail, so the magnification may be set at the desired ratio and the whole camera unit focused by moving closer and farther from the subject via the rail.

All the necessary parts are readily available for attaching an El-Nikkor enlarging lenses to a Nikon bellows. Steps to be followed to fit an enlarging lens onto a Nikon bellows:

1. Obtain a Nikkor or another brand of enlarging lens between 50 mm and 135 mm.
2. Purchase a 42 mm to 39 mm adapter ring and a 42 mm to Nikon bayonet adapter ring (many are available on the Internet). A 42 mm fits screw-mount Pentax lenses. A 39 mm fits the enlarging lens.
3. Attach the 42 mm to 39 mm ring onto the lens (see Figure 11.4).
4. Screw the lens and ring into the 42 mm to bayonet ring (see Figures 11.5 and 11.6).
5. Put the bayonet ring onto the bellows (see Figures 11.7 and 11.8).

These images illustrate the use of a Nikon bellows with an El-Nikkor 75 mm enlarging lens. Three EFUs are used for



FIGURE 11.4 A 42 mm to 39 mm adapter ring.

(From Sandy Weiss/Packer Engineering.)



FIGURE 11.5 A 42 mm to Nikon Bayonet adapter.

(From Sandy Weiss/Packer Engineering.)



FIGURE 11.6 An El-Nikkor lens with a Nikon bayonet.

(From Sandy Weiss/Packer Engineering.)

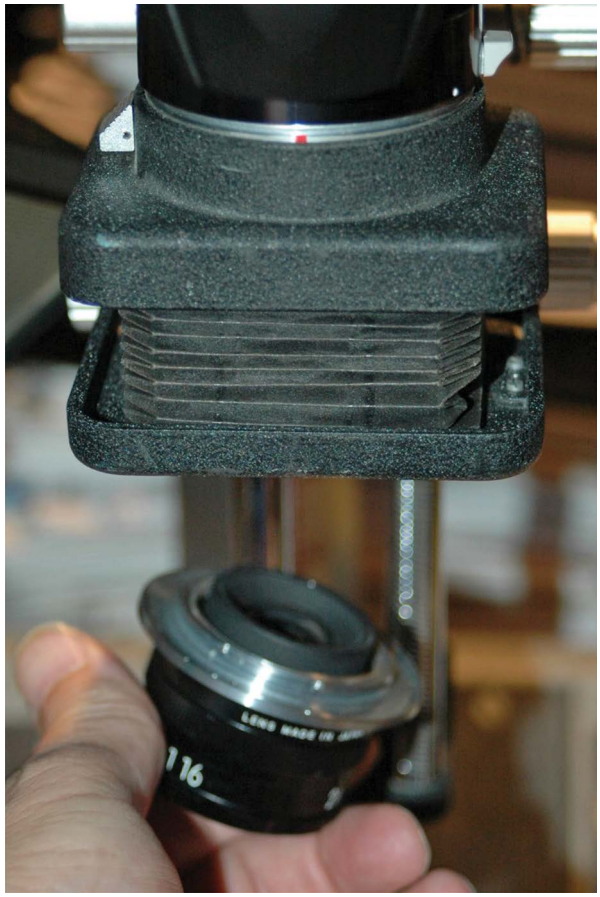


FIGURE 11.7 Connecting the bayonet to the bellows.

(From Sandy Weiss/Packer Engineering.)

sufficient illumination, and two are fired by photo-optical slaves. The subject is a 4-mm kidney stone. The stone is placed on an elevating stage, a U.S. nickel and stainless-steel mechanic's rule are used for scale. In this case, the copy stand is an old unit manufactured by Polaroid. It contains two fluorescent tubes to use for focusing lights (Figures 11.9 to 11.13).

Reversing Rings

Lenses intended for normal photography may provide increased resolution if mounted backward on the bellows with a reversing ring (see Figure 11.14). For best resolution, always focus the lens at infinity when mounted. Rings may produce magnifications up to 4× life size using normal lenses not designed for macrophotography.

IMPORTANT:

Very little additional magnification is gained by focusing the lens at any other distance.

Reversing rings attach to the filter thread on the front of a lens. (Remove all the filters unless working with an alternate light source and the filter is crucial.) The appropriate



FIGURE 11.8 Completed assembly for macrophotography with a digital camera, bellows, and enlarging lens.

(From Sandy Weiss/Packer Engineering.)

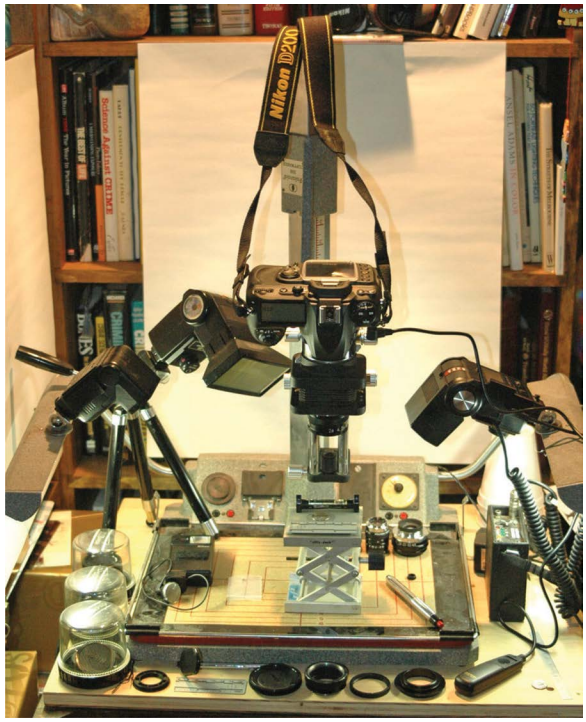


FIGURE 11.9 Nikon bellows with an El-Nikkor 75 mm enlarging lens and three EFUs in use for photography of a kidney stone.

(From Sandy Weiss/Packer Engineering.)



FIGURE 11.10 Side view of the Nikon bellows with an El-Nikkor 75 mm enlarging lens and three EFUs in use for photography of a kidney stone.

(From Sandy Weiss/Packer Engineering.)



FIGURE 11.11 Size comparison of a nickel and a kidney stone with appropriate scale.

(From Sandy Weiss/Packer Engineering.)



FIGURE 11.12 Nickel only to demonstrate the macro capability of a Nikon bellows with an El-Nikkor 75 mm enlarging lens.

(From Sandy Weiss/Packer Engineering.)



FIGURE 11.13 An image with extra extension of the kidney stone, 4.06 mm.

(From Sandy Weiss/Packer Engineering.)



FIGURE 11.14 Reversing ring adapter.

(From Sandy Weiss/Packer Engineering.)

mount for the camera lens is on the other side of the ring. This makes it possible to attach the lens to the camera body or tube or bellows backwards. The rear element of a normal lens is physically flatter in design than the front element. This is one factor in effect to make the reversed optics work well for macrophotos. Modern DSLR lenses often do not allow for manual aperture adjustment. Setting a reduced aperture on a reversed automatic lens requires tricky manipulations when removing the lens from the body or dedicated electronically connected reversing rings.

Macro Lenses

Macro lenses are specifically designed to have closer minimum focusing distances between the subject and the imaging sensor. This is so that the forensic objective of filling the frame with your subject is easier to accomplish. It should be plain that the subject of a macro photo is either small on its own or a critical section of a larger object as evidenced by the various figures in this book, e.g.,, coins stamps, signatures, flowers, insects, broken parts, bullets, and cartridge case headstamps).

"Commercial macro lenses can be found in "normal" (40-60mm), short telephoto (90-105mm) and medium telephoto (150-200mm) lengths. The variety of lengths relate to how close the camera the subject needs to be. Often this relates to whether the subject is alive and might be disturbed by the approach of a human with a camera.

"The second specific design feature of a macro lens relates to the curvature of field in the optical glass. Most consumer lenses are "curved field" with curved front element glass which produces an image with a sharp center area and softer edges. The edge softness may be reduced of eliminated with the use of smaller apertures but can only be confirmed by testing. Macro lenses are "flat field" in that the front lens element is less curved than a standard lens. This gives increased sharpness across the image at all apertures. A simple test is to photograph a newspaper page hanging on a wall and compare the sharpness and exposure of test images. (See Chapter 14 for more information on this topic.)

Macrophotography Lighting

Ring flashes are designed for photographing subjects in fine detail with (possibly) shadowless, low-contrast illumination. Ring flashes work well only at macro ranges out to a few feet. Many ring flashes have a full array of flash tubes arranged around the front of the lens. Some modern ring lights have white light-emitting diodes (LEDs) to provide continuous light sources for aiming and focusing.

Nikon SB-29S Speedlight

The Nikon SB-29S Speedlight (Figure 11.15) is a double flash designed specifically for macrophotography and is not actually a ring light. The two flashes are positioned on either side of the detachable lens mount unit. The SB-29S works with the through-the-lens exposure systems with Nikon film cameras but not Nikon DSLRs. Both or only one of the flashes may be fired for any particular exposure. The ring revolves around the front of the lens to enable the light to originate at any angle appropriate for the subject. The unit has a built-in modeling light to preview the lighting effect or to help focusing.



FIGURE 11.15 Nikon SB-29S.

(From Sandy Weiss/Packer Engineering.)

Nikon SB-R200 Remote Macro Flash

The Nikon SB-R200 Remote Macro Flash units are shown on each side of the lens in Figure 11.16. The flashes are wirelessly controlled, mastered by the built-in flash of some Nikon DSLRs or by an SU-800 remote commander. The flashes are adjustable in all directions from the optical axis. They contain white LEDs for accurate modeling and positioning. Up to four flash units may be used at once.

Sigma Macro Flash

One example of a non-OEM macro flash is Sigma Corporation's Electronic Macro Flash EM-140 DG (Figures 11.17 and 11.18). It works with autofocus 35 mm and DSLR cameras. It operates properly with all OEM-dedicated through the lens autoexposure systems. Its dual flash tubes may be fired simultaneously or separately. The guide number (GN) of the unit is 14 with an ISO sensitivity of 100. It has a built-in modeling light to check for reflections and shadows before exposing the flash image. The unit is supplied with 55 mm and 58 mm adapter



FIGURE 11.16 Nikon SB-R200 Remote Macro Flash on a camera.

(From Sandy Weiss/Packer Engineering.)



FIGURE 11.17 Sigma Electronic Macro Flash EM-140 DG.

(From Sandy Weiss/Packer Engineering.)



FIGURE 11.18 Sigma Electronic Macro Flash EM-140 DG on a Nikon camera.

(From Sandy Weiss/Packer Engineering.)

rings, and 52 mm, 62 mm, 67 mm, 72 mm, and 77 mm adapters are also available to adapt the flash to all lenses.

Oblique Flash and Autoexposure

In situations where the evidence photographer does not have a ring flash, it may be necessary to use a built-in or accessory EFU for macro lighting. If using the built-in flash and no diffuser, the lighting will illuminate the subject from the lens axis and may display bright reflections or deep shadows. If an accessory EFU is available, the most commonly used technique used for illuminating the subject is to hold the EFU off to the side of the camera and subject so the reflections will bounce past the camera and not be an issue. This technique is called oblique lighting. One EFU or continuous light source is held at about a 45-degree angle to the side of the subject. In macrophotography, it is critical to aim the flash directly at the subject. If the flash is set on automatic exposure and aimed anywhere but at the subject (see Figure 11.19), the image will be underexposed (see Figure 11.20).



FIGURE 11.19 Flash aimed too high.

(From Sandy Weiss/Packer Engineering.)

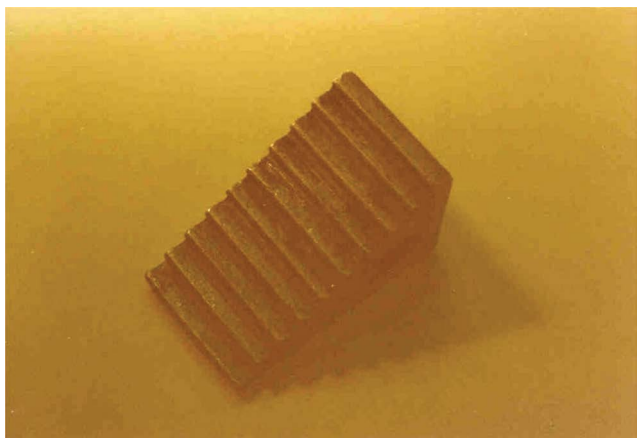


FIGURE 11.20 The image will be underexposed when the flash is aimed too high.

(From Sandy Weiss/Packer Engineering.)



FIGURE 11.21 Flash aimed at the right place.

(From Sandy Weiss/Packer Engineering.)



FIGURE 11.23 The subject is photographed against an 18% gray background.

(From Sandy Weiss/Packer Engineering.)

In Figure 11.21, the flash is aimed at the proper place and the subject will receive sufficient illumination. However, the subject is again underexposed because it was photographed against a white background (see Figure 11.22).

In Figure 11.23, the subject is placed on an 18% gray background and the flash is properly aimed. The resultant exposure is proper for the subject (see Figure 11.24).

In Figure 11.24, the exposure for the subject is correct; however, the front and right sides of the subject are underexposed because of the deep shadows. To reduce the density of the shadows, a reflector may be used.

In Figure 11.25, the front and right sides of the subject are illuminated by reflected light bouncing off the white card (the reverse of the 18% gray card) held to the right of the subject. This is a reasonable overall exposure of the subject (see Figure 11.26).

To eliminate the shadows from the front and right side of the subject in Figures 11.25 and 11.26, the subject may

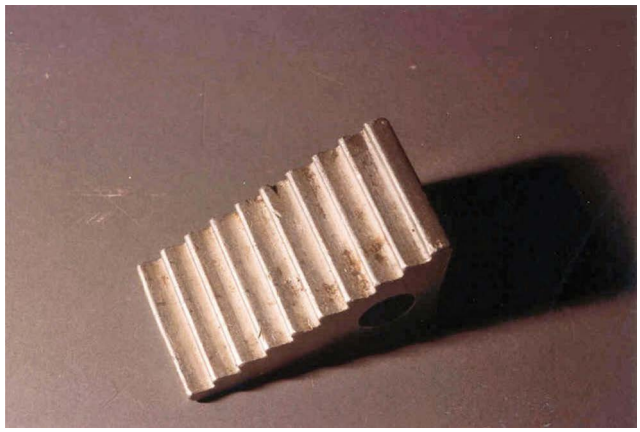


FIGURE 11.24 The exposure is correct for the subject due to the neutral background.

(From Sandy Weiss/Packer Engineering.)

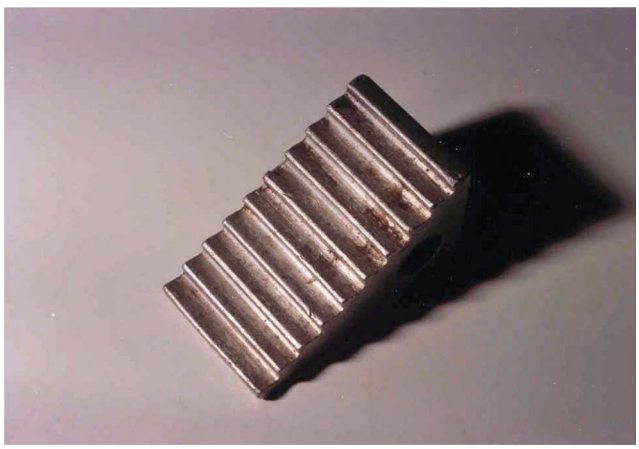


FIGURE 11.22 Subject underexposed because the background is too light.

(From Sandy Weiss/Packer Engineering.)

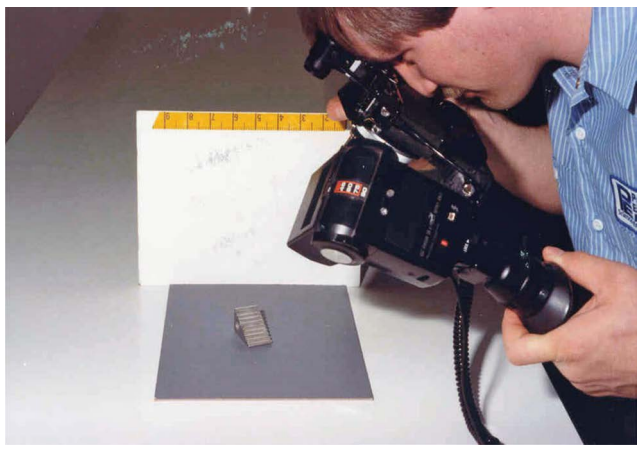


FIGURE 11.25 A white reflector illuminates the right and front sides of the subject.

(From Sandy Weiss/Packer Engineering.)

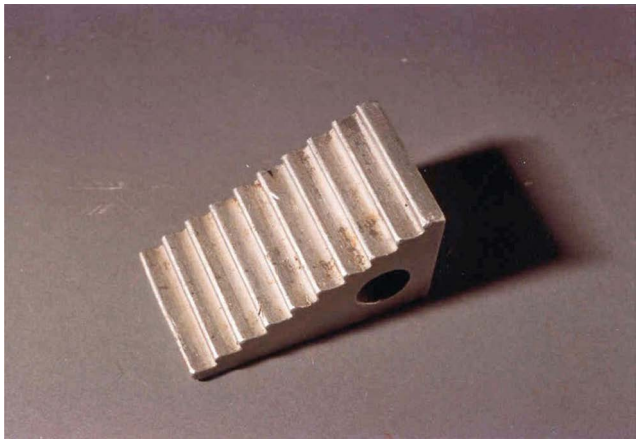


FIGURE 11.26 A properly exposed macrophotograph.

(From Sandy Weiss/Packer Engineering.)

be supported on a piece of glass with the 18% gray card beneath (see Figure 11.27). The shadows will appear far enough to the side of the subject to be separated. The subject appears suspended in space (see Figure 11.28), and the exposure of the subject remains correct.

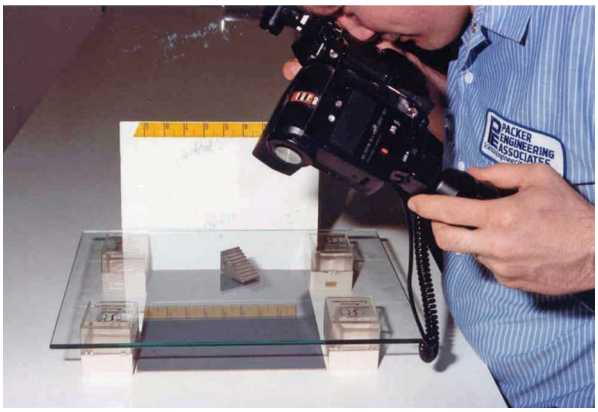


FIGURE 11.27 Subject supported on a glass stage.

(From Sandy Weiss/Packer Engineering.)

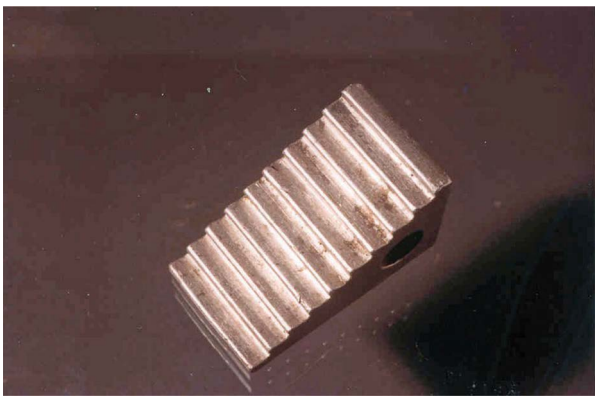


FIGURE 11.28 The shadows are separated from the subject.

(From Sandy Weiss/Packer Engineering.)



FIGURE 11.29 Using a brightly colored background for contrast.

(From Sandy Weiss/Packer Engineering.)

In Figure 11.29, the photographer used a background of a contrasting color so the subject would be rendered in higher contrast and stand out from the background. The yellow background provides some relief for the subject but also causes the color balance of the neutral metal subject to look excessively cool/blue in the resultant image (see Figure 11.30).

In Figure 11.31, the photographer used a black background behind the subject and under the glass. The subject is well exposed, but it is difficult to see where the subject stops and the background starts (see Figure 11.32), although the contrast is high between their tones.

When using an EFU on automatic exposure for macrophotography, it is advantageous to use reflectors or multiple flashes to evenly illuminate all sides of the subject. The use of neutral backgrounds of approximately 18% reflectance will promote proper exposures.

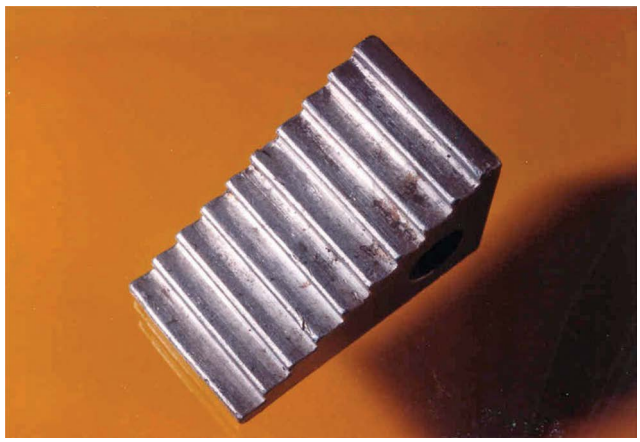


FIGURE 11.30 A yellow background gives the subject a cool blue appearance.

(From Sandy Weiss/Packer Engineering.)



FIGURE 11.31 A dark background can be used for contrast, but it may be difficult to see the boundaries between the subject and the background.

(From Sandy Weiss/Packer Engineering.)

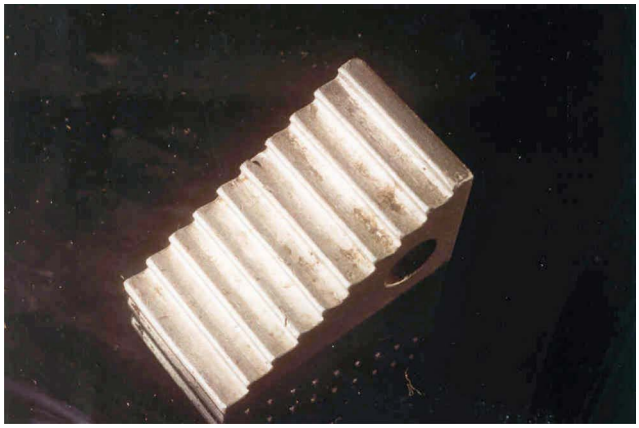


FIGURE 11.32 This well-exposed subject is difficult to differentiate from the background.

(From Sandy Weiss/Packer Engineering.)

Using a Built-In Flash and Autoexposure

When using only the built-in flash, some cameras will produce acceptable macrophotographs of small subjects. Figure 11.33 is an image of a U.S. quarter exposed with a point-and-shoot digital camera and a built-in flash.

The built-in flash used to photograph the U.S. quarter provides adequate lighting, but the flatness of the lighting produces an image with minimal relief contours (see Figure 11.34). It may not be possible to differentiate between raised and recessed features on the surface of the subject. In Figure 11.35, an accessory EFU held to the side at a 45-degree angle was triggered by the deflected illumination of the built-in flash. Note the shadow to the right side of the quarter. The shadow indicates the position of the main illumination. (See the explanation of flash deflectors in Chapter 8.) A small EFU was about 8 inches from the subject. In this image, the landmarks on the surface of the coin are easily identified as raised.



FIGURE 11.33 A U.S. quarter exposed with a point-and-shoot digital camera and a built-in flash.

(From Sandy Weiss/Packer Engineering.)



FIGURE 11.34 A close-up of a U.S. quarter exposed with a point-and-shoot digital camera and a built-in flash. It is difficult to differentiate between raised and recessed features on the subject.

(From Sandy Weiss/Packer Engineering.)



FIGURE 11.35 U.S. quarter exposed with a point-and-shoot digital camera and camera flash triggered by the built-in flash.

(From Sandy Weiss/Packer Engineering.)



FIGURE 11.36 Close-up of U.S. quarter exposed with a point-and-shoot digital camera and off-camera flash, showing the raised details of the subject.

(From Sandy Weiss/Packer Engineering.)



FIGURE 11.37 Fracture surface of a broken bolt exposed with built-in flash.

(From Sandy Weiss/Packer Engineering.)

In Figure 11.37 the fracture surface of a broken bolt was exposed with only a built-in flash. The image displays good quality and exposure, but the character of the fracture is impossible to analyze when the image is exposed with lighting from the axis of the lens. The same fracture surface exposed with oblique flash (see Figure 11.38) yields some information about the mechanics of the failure.

Proper Exposure of Small Subjects with Autoexposure EFU

When small objects are free standing in space and the flash is set for automatic exposure, the subject must be large enough to reflect sufficient light back to the flash and camera to prevent overexposure. If the free-standing subject is small, the subject (the top of the threaded rod in Figure 11.39, for example) will yield an image overexposed (see Figure 11.40).

An 18% gray card or another suitable object may be placed behind the subject to produce an image properly



FIGURE 11.38 Fracture surface of a broken bolt exposed with oblique flash.

(From Sandy Weiss/Packer Engineering.)

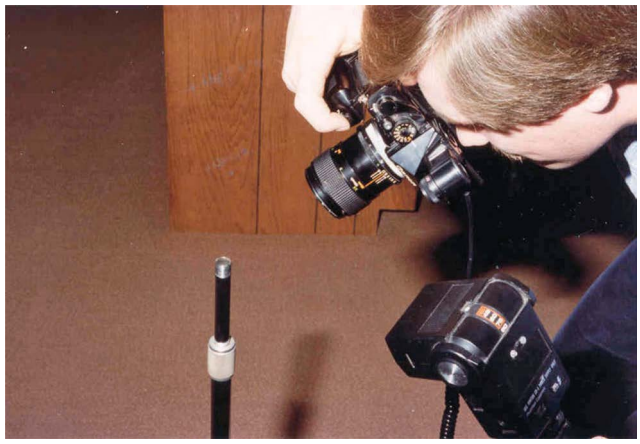


FIGURE 11.39 Flash exposure of a small, free-standing object.

(From Sandy Weiss/Packer Engineering.)



FIGURE 11.40 Overexposure of a small, free-standing object.

(From Sandy Weiss/Packer Engineering.)

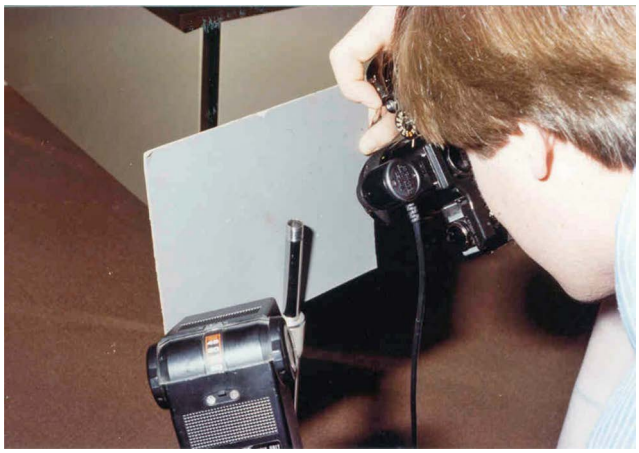


FIGURE 11.41 A gray card placed behind the subject for background.

(From Sandy Weiss/Packer Engineering.)

exposed (see Figure 11.41). The gray card reflects enough light back to the flash to allow a proper exposure (see Figure 11.42).

Axial Lighting

Direct lighting from an EFU creates an image high in contrast. When lower-contrast illumination is necessary due to the nature of the subject, axial lighting (see Figure 11.43) and tent lighting solutions may be used.

By definition, axial lighting is derived from a lighting formula used to provide illumination to the subject with the light emanating from the same axis as the lens of the camera. Ring and built-in flash are low contrast, but not truly axial, because they are offset slightly to the side of the lens. Axial lighting is achieved by bouncing the source light off a piece of glass and exposing the image through the same glass (see Figure 11.43). This lighting

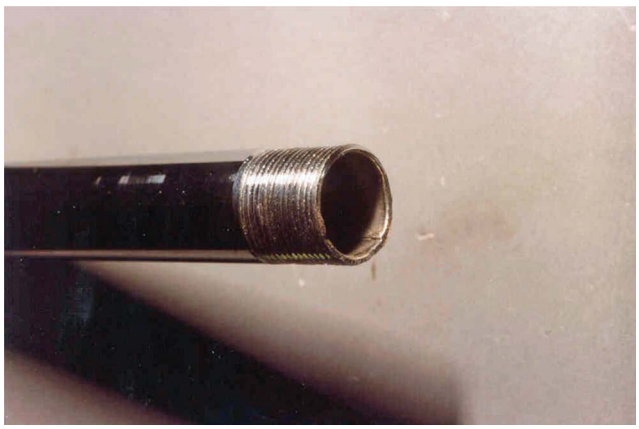


FIGURE 11.42 A gray card placed behind the free-standing subject results in proper exposure.

(From Sandy Weiss/Packer Engineering.)

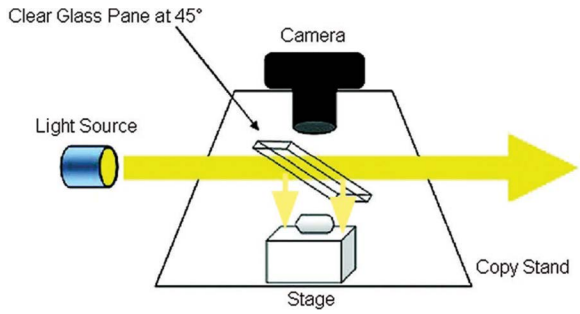


FIGURE 11.43 Axial lighting setup.

(From Sandy Weiss/Packer Engineering.)

solution is useful when photographing highly reflective surfaces or small objects with a high relief-to-size ratio (for example, printed circuit boards). A teleprompter mirror with 70% transparency and 30% reflectivity can effectively replace the angled glass in an axial photography setup.

All other types of lighting used for general macrophotography may cause unwanted reflections or deeper shadows (higher contrast) on parts of the subject. The reflections and shadows may necessitate exposing extra images of the same subject with lighting at various angles to capture all the aspects of the subject. The lower contrast of axial lighting allows wider latitude for exposure error.

The shell casing shown in Figure 11.44 is an easily photographed subject with any type of lighting. Oblique lighting will display surface landmarks but will also create dense shadows on one side. Axial lighting will display the surface characteristics and detail of the recessed surfaces in the same image.



FIGURE 11.44 Axially illuminated shell casing.

(From Sandy Weiss/Packer Engineering.)

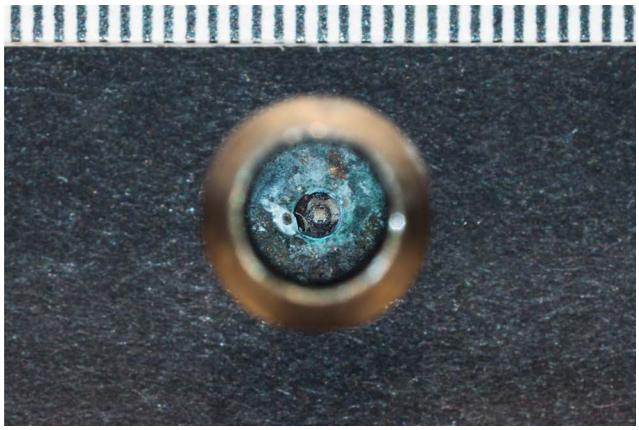


FIGURE 11.45 Axially illuminated interior of .223 REM cartridge case.

(From Eric Johnson.)

Creating Axial Lighting

It is often necessary to photograph details on shiny objects. Oblique lighting is practical, but the oblique lighting angle may create unwanted shadows. At high magnifications, if a shiny subject must be photographed at an angle to the lens axis, limited DoF may also be an issue. Axial lighting facilitates the imaging of shiny subjects without the problem of reflective highlights when the subjects are arranged in a parallel plane to the light sensor of the camera.

Figure 11.45 was exposed with an axial apparatus and a Nikon D1-X with a 60 mm Nikkor macro lens and a Vivitar 283 EFU. The sensitivity was set at ISO 100, the lens aperture at *f*/36, and the shutter speed at 1/400 second. The EFU was set on automatic exposure. The flash must always be left far enough outside the apparatus for the sensor to register the reflected light.

Trial and error is the best method for determining the proper exposure settings for axial lighting. Experience will eventually allow the photographer to select an exposure setting close to correct before exposing an image. When compared to a macro lens, the physical size of an enlarging lens makes it a practical choice for axial setups. *Remember:* It is important to factor for extra exposure when using a bellows or extension tubes.

Building an Axial Lighting Apparatus

For photographers who wish to save the money and build their own axial lighting kits, use the following instructions. You can vary the contrast of an axial lighting assembly by changing the color of the mirror chamber or the terminal wall. White provides the lowest-contrast light, brown/gray provides medium contrast, and black provides the highest contrast.

Instructions for Assembling an Axial Lighting Apparatus

To build your own axial lighting apparatus, gather the following supplies; the instructions follow (Figures 11.47 through 11.52).

Supplies

- Two sheets of thin 8½ × 11-inch white cardboard
- Scissors
- Razor knife
- Ruler
- Tape
- A piece of thin glass, like a Kodak projector slide cover glass 3¼ × 4 inches Optional: Sample size teleprompter mirror with 70% transparency and 30% reflective surface (available from twowaymirrors.com).

To assemble (see Figure 11.47), measure and cut a strip 2¼ × 8½ inches off the narrow side of one of the 8½ × 11-inch sheets of cardboard.

- Fold the remaining 8½ × 8¾-inch sheet into three sections: 2¾ × 3¼ × 2¾ × 8½ inches.

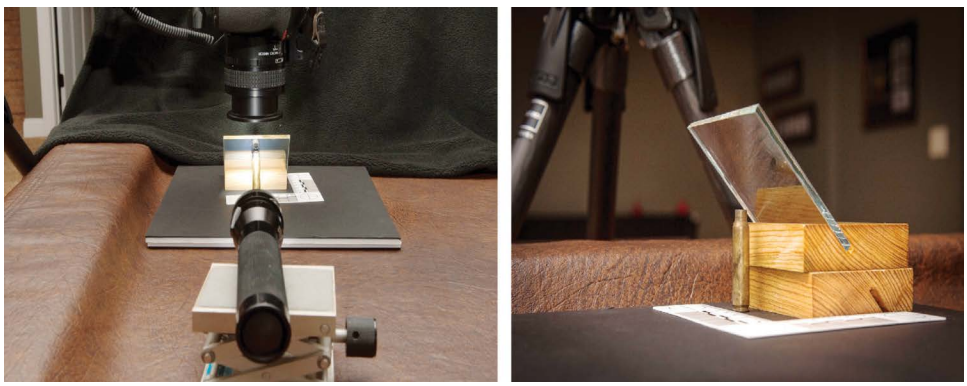


FIGURE 11.46 Simple axial lighting setup.

(From Eric Johnson.)

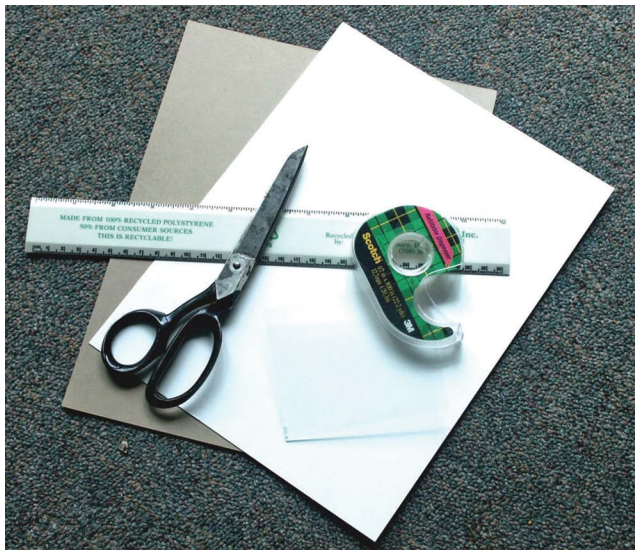


FIGURE 11.47 Supplies for building an axial lighting apparatus.

(From Sandy Weiss/Packer Engineering.)



FIGURE 11.49 Assembly of an axial lighting apparatus: partial assembly 1.

(From Sandy Weiss/Packer Engineering.)

- Mark a 2¼ × 2¾-inch rectangle on the 3¼-inch section, ¼ inch from the end.
- Cut and remove the section.
- Cut the 2¼ × 8½-inch section in half on the long end.
- Fold up the edges of the two small pieces, ½ inch from either end.
- Tape one small section on the end of the channel with the cutout.
- Tape the other section on top of the channel, 2¾ inches from the end with the cutout.
- Assemble a base by taking a full 8½ × 11-inch sheet and measuring 2½-inch, 3-inch, 2½-inch, and 3-inch divisions on the board. Cut four slits along the measured lines, 2½ inches into the board.
- Fold along lines into a rectangular box.
- Fold in and tape the flaps. Tape the channel to the box.
- Put the glass into the channel above the cutout so it is at a 45-degree angle when nested into the front guide and supported by the upper guide.

Tent Lighting

Some highly reflective objects are too large to be illuminated axially. Direct flash yields images with no surface

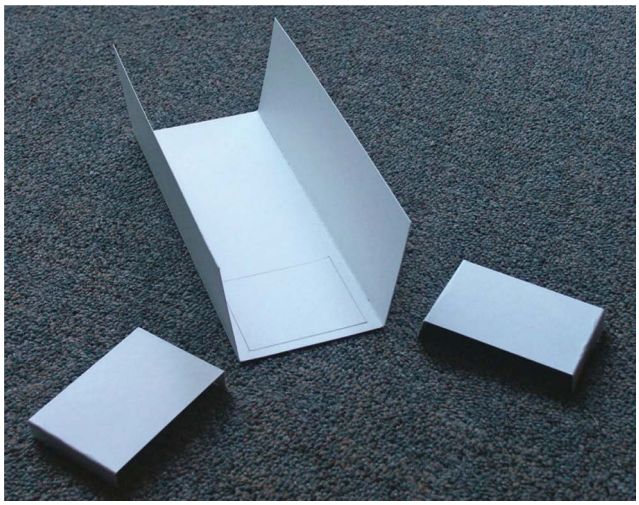


FIGURE 11.48 Assembly of an axial lighting apparatus: folded cardboard.

(From Sandy Weiss/Packer Engineering.)

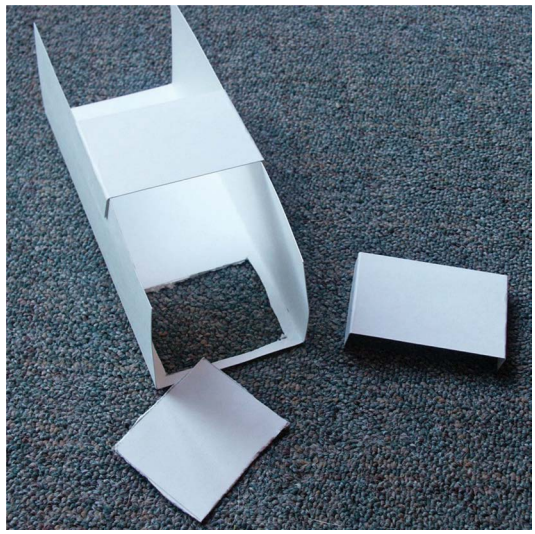


FIGURE 11.50 Assembly of an axial lighting apparatus: partial assembly 2.

(From Sandy Weiss/Packer Engineering.)

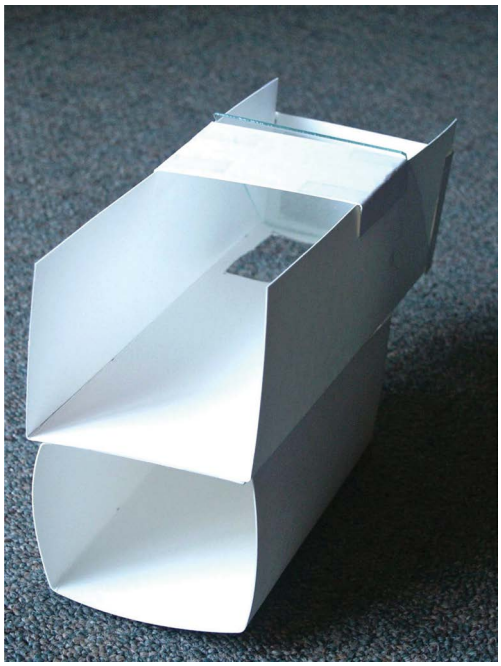


FIGURE 11.51 Assembly of an axial lighting apparatus: base assembly.

(From Sandy Weiss/Packer Engineering.)

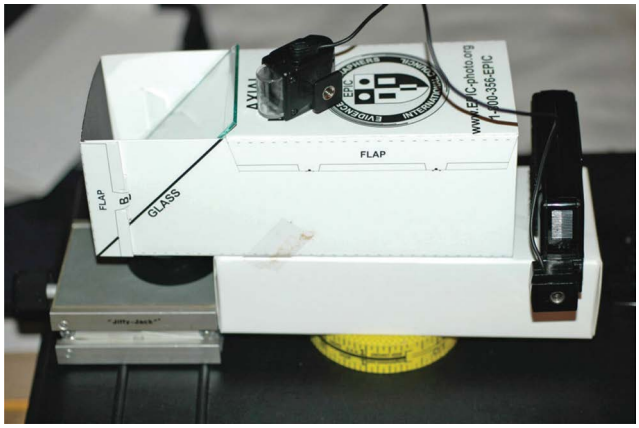


FIGURE 11.52 Assembly of an axial lighting apparatus: completed assembly in use to photograph a shell casing.

(From Sandy Weiss/Packer Engineering.)

detail (see Figure 11.53). Diffusing the light from an EFU is necessary to produce photographs where the objects exhibit their surface detail (see Figure 11.54). The lighting must be very low in contrast, so bare-bulb flash is not an option.

Bearings are difficult to photograph because they reflect the illumination back into the camera lens. They also reflect the camera, the photographer, the walls and ceilings of the room, and anything else around them. The bearing from an aircraft engine shown in Figure 11.54 shows banding caused by extreme heat during operation.



FIGURE 11.53 Direct lighting on a highly reflective bearing yields little surface detail.

(From Sandy Weiss/Packer Engineering.)

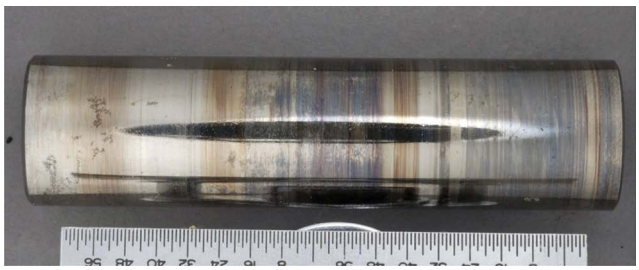


FIGURE 11.54 Diffuse lighting on a highly reflective bearing reveals banding.

(From Sandy Weiss/Packer Engineering.)

Figure 11.53 was exposed with a Vivitar 283 EFU set on automatic and held to the left of the subject at a 45-degree angle. The flash placement is inferred by the position of the shadow. The banding is barely visible through the reflections.

Figure 11.54 was exposed with the same camera, lens, and flash, except the bearing was encased by a foam coffee cup. The bottom of the cup was cut out to provide an opening for the camera to focus and expose through. The flash was aimed at the side of the cup. The dark oval on the bearing is the reflection of the opening in the cup. The flash was diffused by a tent of foam converting the image from dark to light and provided a better view of the banding.

If foam is not available or the subject is too large, you can roll semitransparent white material, such as thin white tracing paper or plastic milk carton, into a cylinder, fasten it with transparent tape, and place it around the subject. Use one or more EFUs flashed simultaneously at the cylinder for illumination. Evaluate exposure by trial and error.

References and Scales in Macrophotography

When exposing macrophotographs, it is often necessary to include an image scale for size reference.

THREE RULES OF SCALES

- Use a scale manufactured and confirmed to be accurate.
- Place the scale in the same plane as the subject, or part of the subject, being photographed.
- Include an image of the subject without the scale, so nothing in the image is hidden from view.

Use specific forensic or machinist-type scales whenever possible for the best accuracy. The most commonly used scale type and size for normal macrophotography are provided by a 6-inch straight scale (see Figure 11.55). If possible, use a scale with a dull gray or other neutral-colored finish.

The ABFO No. 2 Bite Mark Standard Reference Scale

The ABFO No. 2 is a standard scale of spatial reference designed by the American Board of Forensic Odontology (ABFO) for use with bite-mark photography. The scale has linear and circular graduations to satisfy the requirements of forensic odontologists (dentists who specialize in proper examination, handling, and presentation of dental evidence in a court of law) in the rectification and measurement of photographs of bite marks (see Chapter 32). Photographic distortion is shown when the scale's markings are not parallel or are not shaped uniformly. If the circles are ovals in the images, they must be rectified with a program like Photoshop to bring everything back into the proper size and angle.

Rectification of the photographed evidence, the process by which an image or grid is converted from image coordinates to real-world coordinates, is necessary for an accurate representation of the shape and dimension of the evidence. The ABFO's No. 2 L-shaped scale, or an adequate substitute, enables accurate measurements in two directions (planes) to facilitate the rectification of distortional errors created by oblique camera angles (see chapter 11B).

The scales shown in Figure 11.56 and many similar versions are commonly used by law enforcement photographers when measurements must be made from objects in evidence photographs (see Figure 11.57 and Chapter 12).

Forensic protocol demands a linear scale be placed next to the evidence during photography to enable an accurate size comparison. The ABFO No. 2 dimensional reference allows the photographer or investigator to re-create accurate life-size reproductions.

Photographic Protocol for Rectifying Distortion and Creating Life-Size Reproductions

Bite-mark evidence found with skin injuries or other objects is photographed for documentation, preservation, and analysis. Inaccurate positioning of the evidence, camera, or scale creates perspective and parallax distortion of the images. The distortion must be corrected to ensure reliable results are derived from comparison of the evidence and the image—for example, a suspect's teeth and a bite mark. Quantification of camera, evidence, and scale misalignment in evidence photographs is enabled by digital imaging techniques contained in recognized software. Adobe Photoshop

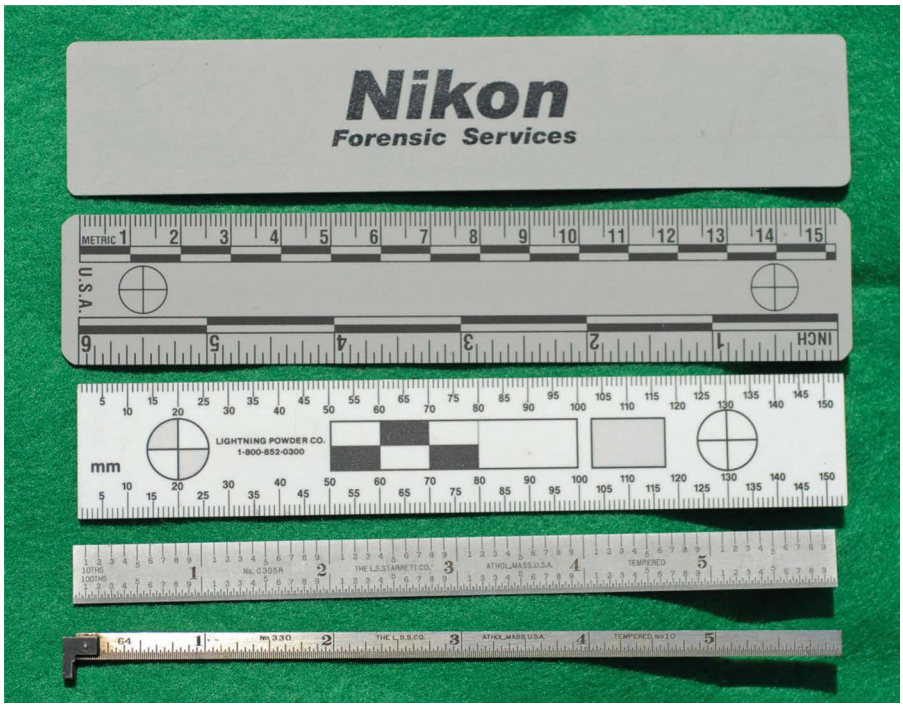


FIGURE 11.55 Samples of 6-inch scales for evidence photography.

(From Sandy Weiss/Packer Engineering.)

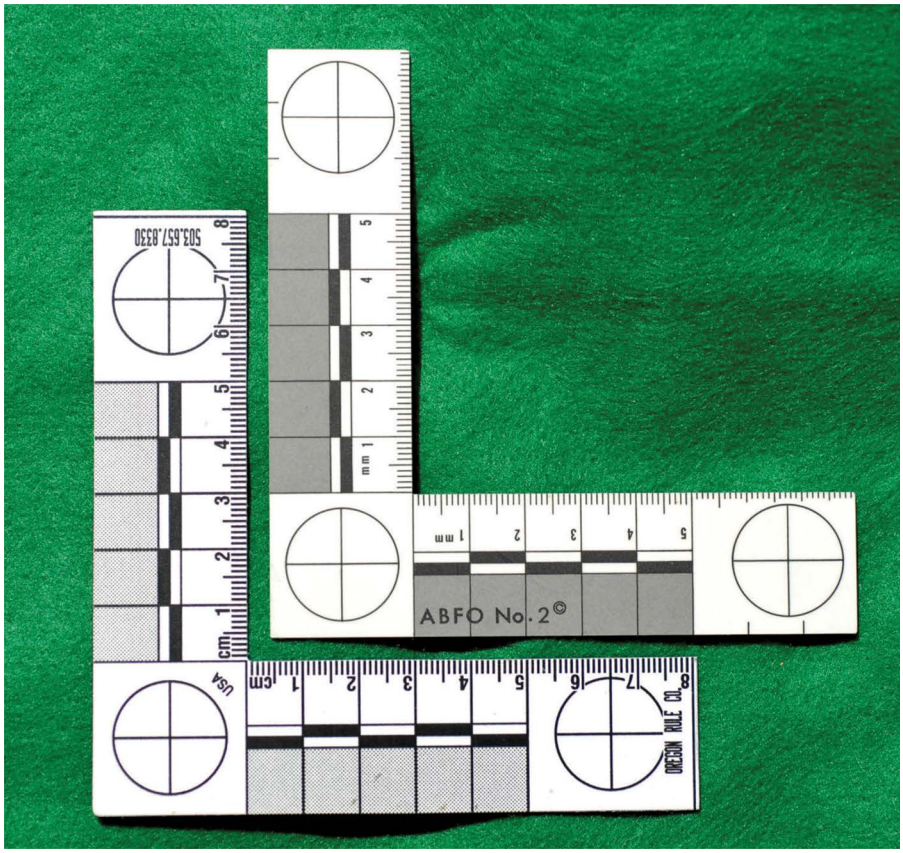


FIGURE 11.56 ABFO No. 2 Scales.

(From Sandy Weiss/Packer Engineering.)

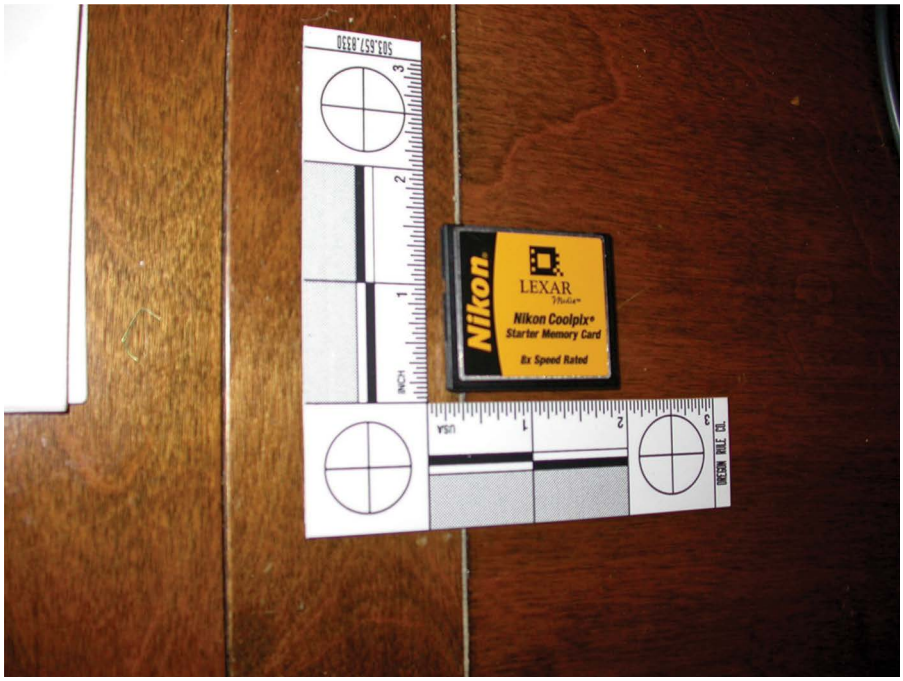


FIGURE 11.57 Scales are used for images needing rectification.

(From Sandy Weiss/Packer Engineering.)

is a valid software program to use to correct certain types of distortion.

Useful Scales for Evidence Photography

Calipers (see Figures 11.58 and 11.59) are used to measure the diameter of round objects, such as bolts and rods, and the depth of depressions and dents (see Figure 11.49). Machinist calipers may cost $80 to $100 for standard-size tools. It is not necessary to have a tool's accuracy certified. The use of plastic, $1-per-pair calipers requires the photographer to retain the tools with the photographs for subsequent comparison to the photographs. This will enable the accurate sizing of objects in images. Plastic tools are also useful because they easily pass through airport scanners.

In some cases, the use of a 6-inch scale is not possible because the scale must be placed into a position where 6 inches will not fit. Keep a selection of scales cut down from 6 inches to an inch or two (see Figure 11.60) to fit into small or confined spaces.

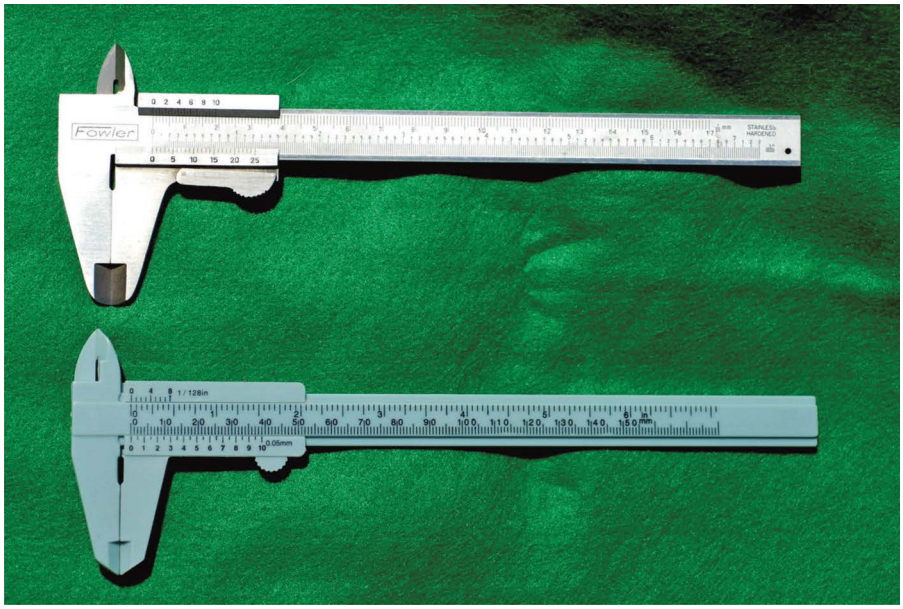


FIGURE 11.58 Large calipers.

(From Sandy Weiss/Packer Engineering.)

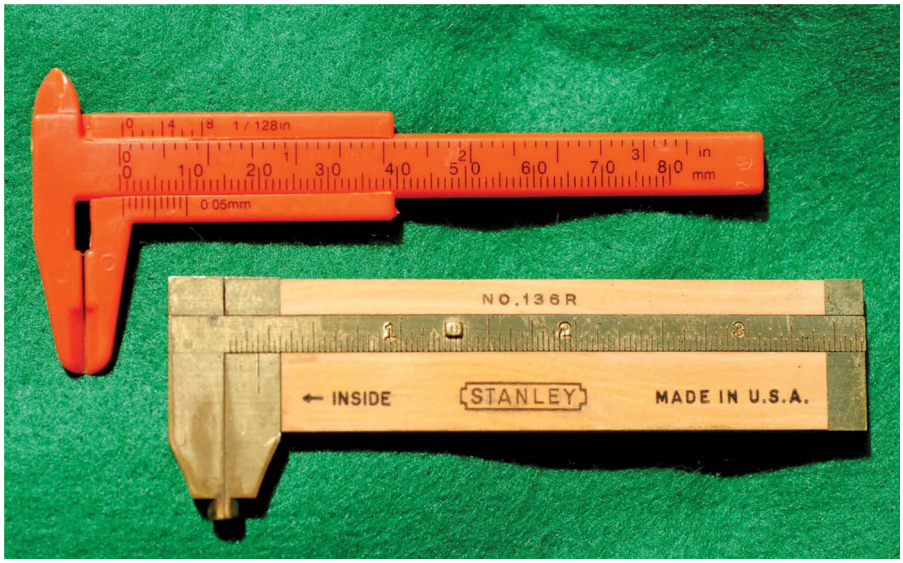


FIGURE 11.59 Small calipers.

(From Sandy Weiss/Packer Engineering.)

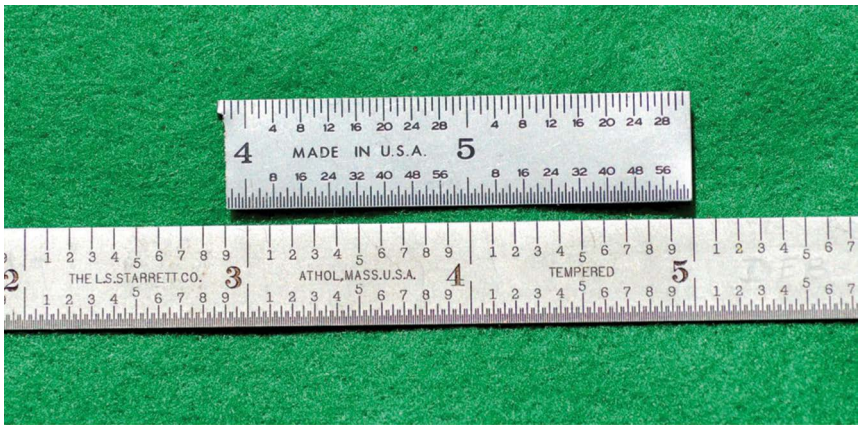


FIGURE 11.60 Small scales.

(From Sandy Weiss/Packer Engineering.)

Never trust or testify to a scale's accuracy until it is verified. The Home-Cad scale shown in Figure 11.61 was produced from dull aluminum with a cork backing and was intended for accurate sizing of drawings and plans. It was manufactured 1/16 inch too long over its 6-inch length.

The 12-inch green plastic school ruler shown in Figure 11.62 is an accurate scale. However, its markings are indistinct and its color distracting for a photographic reference. If such a ruler is used for photography, it must be retained and included in the case file for future verification.

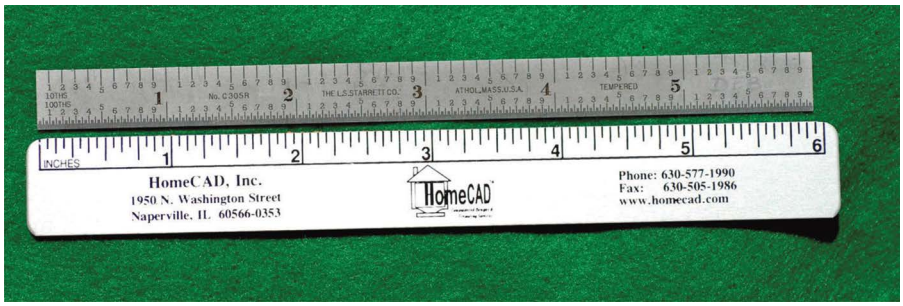


FIGURE 11.61 Inaccurate scale.

(From Sandy Weiss/Packer Engineering.)

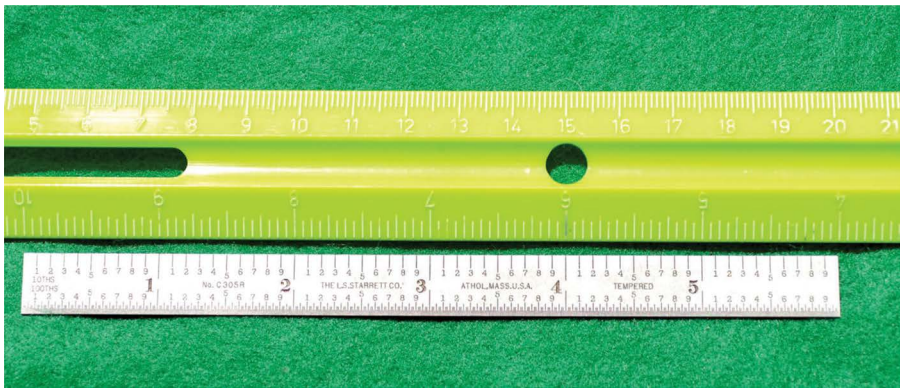


FIGURE 11.62 A common school ruler.

(From Sandy Weiss/Packer Engineering.)

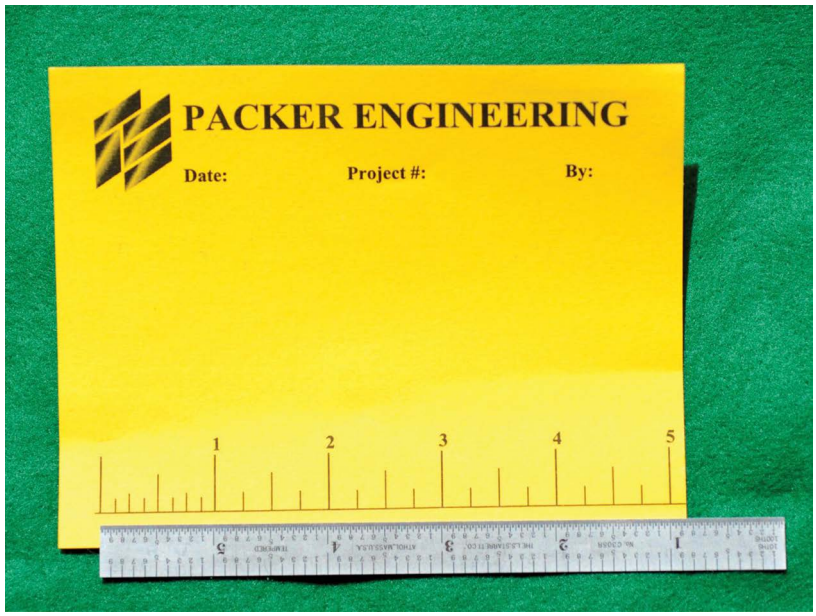


FIGURE 11.63 A color card with scale.

(From Sandy Weiss/Packer Engineering.)

Paper cards, like the one shown in Figure 11.63, were made specifically for tagging evidence. The size and color are good for inclusion in evidence photographs. They are also convenient and accurate.

Always place the scale in as close as possible to the same plane as the significant evidence (see Figure 11.64). Inaccurate positioning of the scale (see Figure 11.65) creates perspective and parallax distortion of the images. If the scale is misplaced, it is difficult to use for measurements from the images.

In Figure 11.65, the photographer put the scale behind the subject. From behind, the scale is out of the plane of focus and would require photogrammetric analysis to recover dimensions.

TIP:

Fill the frame! Use a scale! The photograph in Figure 11.66 looks amateur and is essentially useless for the retrieval of forensic evidence.

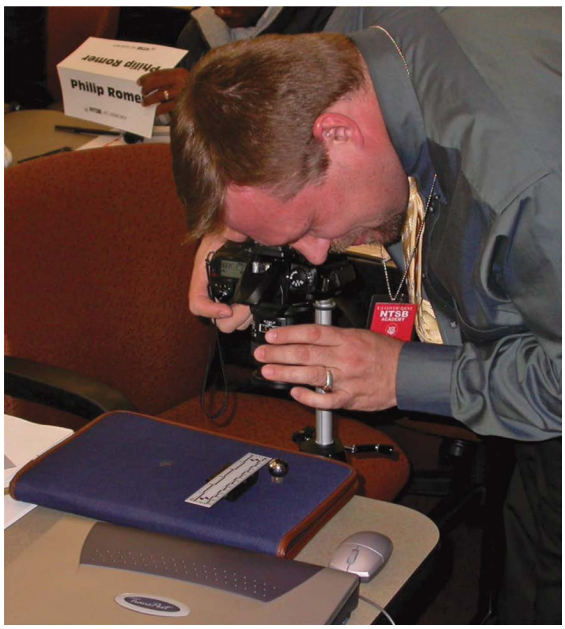


FIGURE 11.64 Proper use of a scale.

(From Sandy Weiss/Packer Engineering.)

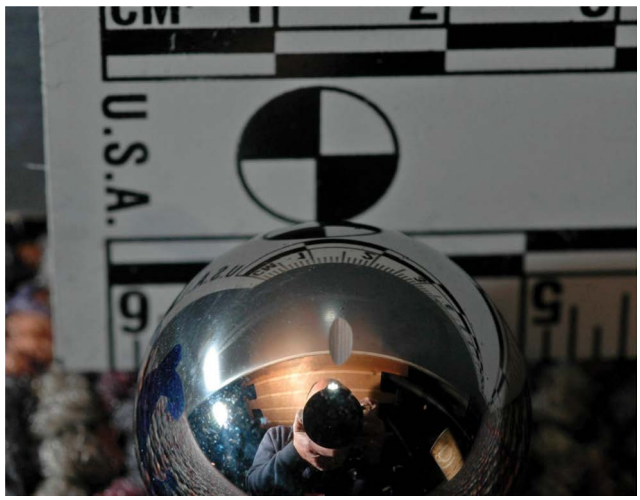


FIGURE 11.65 Improper use of a scale.

(From Sandy Weiss/Packer Engineering.)



FIGURE 11.66 Fill the frame.

(From Sandy Weiss/Packer Engineering.)



FIGURE 11.67 Focus carefully.

(From Sandy Weiss/Packer Engineering.)



FIGURE 11.68 Use a cable release if the camera is on a tripod.

(From Sandy Weiss/Packer Engineering.)

Focus carefully and fill the frame. The closer the camera and lens are to the subject, the shallower the DoF will be. The higher the magnification of the photograph, the easier it will be to move the camera, adding to bad focus issues during exposure. In macrophotography, use a tripod, cable release, and lens hood when possible (see Figures 11.66, 11.67, and 11.68).

REMEMBER:

Focus carefully. Fill the frame. Use a tripod, cable release, and lens hood when possible.

CONCLUSION

Macrophotography is a skill all forensic photographers must master. Every investigation probably will need photographs of small objects or small aspects of large objects.

The photographer must be prepared in the field and the lab with adequate hardware, lighting, and references to capture photographs to accurately tell the story of the evidence. The photographer must be able to determine the magnification of the finished photographs and correlate that to the evidence.

Modern cameras perform much of the focusing and metering automatically, even at macro distances. It remains important to be able to figure out what settings should be made manually to obtain proper focus and exposure. It is necessary to operate the camera properly to gain DoF through the use of the optimum lens apertures.

Many inexpensive gadgets may be used to aid in the practice of macrophotography. Do not be afraid to experiment. Be sure to practice sufficiently at home before working in the field. Create a go-kit sufficiently equipped to create any necessary images.

CASE STUDY 11.1: EXPLODED SHOTGUN

A shotgun exploded when fired. It severed some fingers from the hand of the man who pulled the trigger. He sued the manufacturer of the shotgun, claiming the weapon was defective. Packer Engineering was hired to investigate the accident. All the remaining pieces of the gun were inspected and photographed. The area of concentration for the investigation was the receiver, which on close examination was found to have the imprint of the back of a shell burned into it (see Figure 11.69).

No factory-loaded shell would burn with enough heat to transfer the printing. In the plaintiff's deposition, he admitted he customarily did his own reloading. Some of his other shells were inspected, and it was determined he was reloading with the wrong powder to increase the power of the shells. Through experimentation, the force and heat needed to destroy the subject weapon were duplicated under controlled conditions. The explosion was sufficiently violent to explode the metal used to manufacture the subject weapon. The explosion was not the fault of the shotgun manufacturer or the ammunition manufacturer—it was the fault of the overpowered shells constructed by the shooter.

A 6 × 7 Pentax with a Pentax auto-bellows and Pentax 6 × 7, 135 mm macro lens was used for the



FIGURE 11.69 Exploded shotgun receiver part and exemplar shell.

(From Sandy Weiss/Packer Engineering.)

photography. The photo depicted in Figure 11.69 was illuminated with a Novotron studio flash system and three flash heads. One flash head had a directional snout attachment. It was aimed at a low angle to the subject to make the faint lettering visible and legible in the final photograph. The other two flash heads were held farther from the subject and were used for fill lighting.

An undamaged shell casing was included in the photograph to allow the viewer to see exactly what was imprinted on a new shell and what was transferred in part to the receiver of the shotgun. The "ERS" and "GA" are easily recognizable on the gray metal.

CASE STUDY 11.2: HANDGUN CASING MARKINGS

Two small boys were playing with a semi-automatic handgun. When the weapon fired, one of the boys was fatally wounded by a gunshot to the head. The other boy testified that no magazine was in the weapon at the time of the incident, so he thought it was not loaded. The assignment was to fire the weapon with and without a magazine to inspect and photograph the markings left on the exemplar casings.

A Nikon DSLR and Micro Nikkor lens were used with an axial lighting setup to minimize reflections from the brass. The images were exposed with the axial lighting apparatus described in this chapter. In Figure 11.70, a dowel rod supports the shell casing. The rod fits loosely inside the casing and is also loosely taped to the top of the electronic flash. (It is important not to use a dowel too tightly fitting in



FIGURE 11.70 Axial photographic project with handgun shell casing.

(From Sandy Weiss/Packer Engineering.)

case markings inside the casing should ever become important to the case. If the dowel disturbed the markings during photography, the photographer would be in trouble for spoliation of evidence.) This enables the casing to revolve on the rod and under the lens. Notice the separation between the flash and the base of the axial apparatus. The flash must remain a few inches away from the light tunnel to allow sufficient bounced lighting to affect the flash sensor and turn off the flash after a small exposure. If the flash were slid forward into the light tunnel, the flash would fire as if it were set on manual exposure and would severely overexpose the subject. It is advisable to place a small gray card on top of the light tunnel to concentrate the light. It may also be necessary to position a neutral-colored umbrella over the whole setup during photography of very reflective subjects to eliminate reflections from ceiling illumination.

Figure 11.71 shows the mark left on the side of the casing when the weapon was fired without a

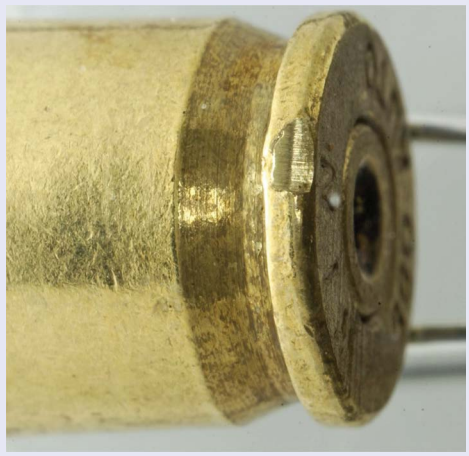


FIGURE 11.71 Ejector mark on the edge of the casing.

(From Sandy Weiss/Packer Engineering.)

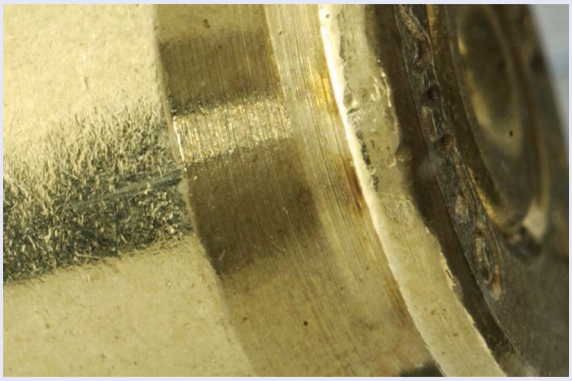


FIGURE 11.72 Markings left on an exemplar casing.

(From Sandy Weiss/Packer Engineering.)

magazine. The weapon was loaded by placing a round in the chamber. The casing was then fired and ejected. The mark is thus significant.

Figure 11.72 shows the markings left on an exemplar casing when the round was fired from a magazine and ejected. The rim was not significantly dented, and fine scratches can be seen down the side matching the condition of the subject casing (see Figure 11.72).



FIGURE 11.73 Subject casing: Fine scratches down the side match the condition of the exemplar casing.

(From Sandy Weiss/Packer Engineering.)

CASE STUDY 11.3: AIRCRAFT CRASH

A lawsuit was filed against the manufacturer of a small aircraft when the pilot was killed in a crash. After inspecting the wreckage, a plaintiff's expert testified that the throttle control cable displayed a fatigue fracture and broke when it was pulled by the pilot. This would have caused an out-of-control situation leading to the crash.

Packer Engineering represented the manufacturer of the aircraft and performed another inspection of the wreckage. The fractured throttle control cable would normally have been put into a scanning electron microscope (SEM) to inspect, characterize, and photograph the fracture surfaces of the individual wire elements. In this case, the cable was still attached to a large piece of wreckage (see Figure 11.74), making it too large to fit into the SEM vacuum chamber. By court order, destructive inspection was not allowed, so the cable could not be cut from the wreckage to reduce its size. An attempt was made to replicate the cable elements with plastic replica material, but the fractures were too fine to yield adequate replicas (0.015 inch in diameter).

The solution was to make photographs of the individual fractured wires to characterize the fractures. Ordinary low-magnification macrophotography was not appropriate. It was necessary to design a specific apparatus to achieve enough magnification for the study. A **Pentax 6 × 7** camera was used and attached to a Pentax auto-bellows. A custom-built Canon 35 mm adapter was attached to the front of the 6 × 7 bellows and a Canon 35 mm bellows was added for additional extension. Another custom adapter and a 1-inch C-mount cine-lens from a 16 mm movie

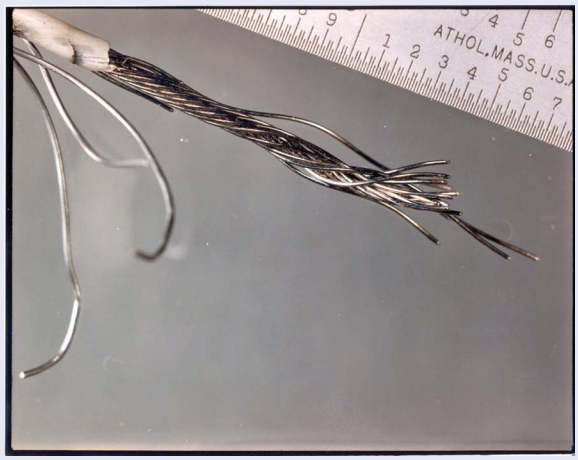


FIGURE 11.74 Throttle cable with fractured ends.

(From Sandy Weiss/Packer Engineering.)

camera was added to the front of the Canon bellows. The resultant magnification was about 25× at the film plane. The coverage of the lens, along with the length of the fully extended bellows, would not allow the 6 × 7 image area to be exposed without cutting off the corners of the image. The corners were not the area of main interest. An adjustable-height elevator with a fine thread was used to raise and lower the subject cable under the camera for focusing. Illumination of the subject was accomplished with a three-head Novotron studio flash system: one head with a snout for aiming the light at a specific area and the other two heads for fill. Exposure was done by trial and error due to the extreme length of extension from the camera body.

The photographs taken successfully show the deformation on the individual cable ends. They display the characteristic of a one-time ductile overload failure (see Figure 11.75). This type of failure would only be possible if the engine were ripped out of the plane on impact with the ground. The engine would have been thrown clear of the wreckage, and its weight would pull the cable apart, causing the overload. No human would have had sufficient strength to fracture the cable in the manner documented. The ductile fracture would not have been in evidence if the cable failed in fatigue. The evidence photographs were used to successfully characterize the failure and defend the manufacturer.



FIGURE 11.75 Macrophotograph of the throttle cable at 25× on film.

(From Sandy Weiss/Packer Engineering.)

CASE STUDY 11.4: BROKEN CHAIR

A cast-aluminum flange was used to attach the legs to a fiberglass chair (see Figure 11.76). The chair collapsed under the weight of a person, and the person



FIGURE 11.76 Flange from the bottom of the chair.

(From Sandy Weiss/Packer Engineering.)

was injured. The chair was brought to the laboratory for inspection and testing. One aspect of the study was to determine if the chair was assembled according to factory specifications and industry standards.

The specifications for the assembly of the chair stated a specific washer must be used under the head of the bolt. The washer was larger in diameter than the head of the bolt. Upon inspection, a witness mark left by a bolt head or washer was found on the surface of the aluminum flange. The photographic assignment was to document the mark on the flange with a scale, assess the diameter of the mark with accuracy, and determine if the mark was left by the washer or the bolt head.

A machinist scale graduated in hundredths of an inch was used in the images. The flange was placed parallel to the image plane of the camera. The scale was placed in precisely the same plane as the marking on the flange, so there would be no parallax issues and a size could be measured directly from the photographs if the flange were reproduced at life size in the images. Yellow cloth numbers were used to mark the position of the bolt hole on the flange.

Machinist scales are manufactured to precise tolerances, and their accuracy can be attested to in court. The diameter of the hole in the flange was precisely 0.25 inch. The diameter of the round mark around the hole was exactly the size it would have been if the washer were applied to the bolt during assembly.

CASE STUDY 11.5: SEALED BEAM

It is often necessary to determine if a head or tail lamp was lit at the time of a crash to reconstruct the event. A sealed beam headlight from the front of a light truck (see Figure 11.77) was inspected after the crash described in this case study.

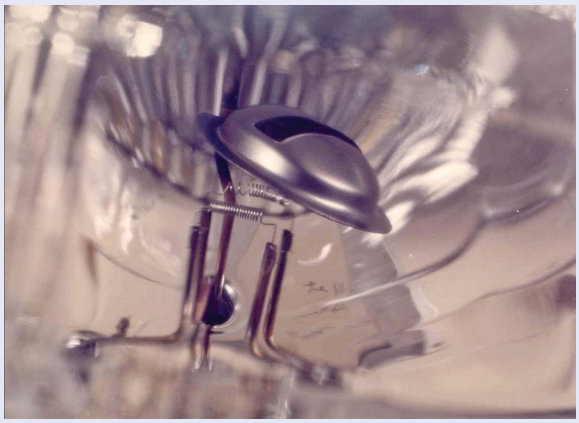


FIGURE 11.77 Sealed beam headlight filament.

(From Sandy Weiss/Packer Engineering.)

Bulb filaments are brittle when they are not powered up or are cold and will break upon impact. Warm filaments will distort at impact. In this case, the low beam was distorted and the high beam was not, indicating the low beam was on at the time of the vehicle crash.

The exterior glass of the sealed beam was not broken, so the image had to be exposed through the heavy glass. A 35 mm Canon F1 camera with a 50 mm Canon macro lens on a bellows were used for the exposure. The lens was fitted with a collapsible rubber hood to be placed directly onto the glass of the sealed beam. This kept the light from the flash illumination from creating a flare on the image during exposure. Illumination was from one Vivitar 283 EFU set on automatic exposure and its closest range. It was not possible or necessary to use a scale during the exposure.

CASE STUDY 11.6: AIRCRAFT OIL PUMP

An oil pump (see Figure 11.78) was recovered post-crash from a small aircraft. The plaintiff's expert contended the oil pump failed in flight, causing the engine to fail and the aircraft to crash. If the pump had failed in flight, the engine would have seized and the propeller would have ceased turning, or the propeller would have been turning powered only by air turbulence.

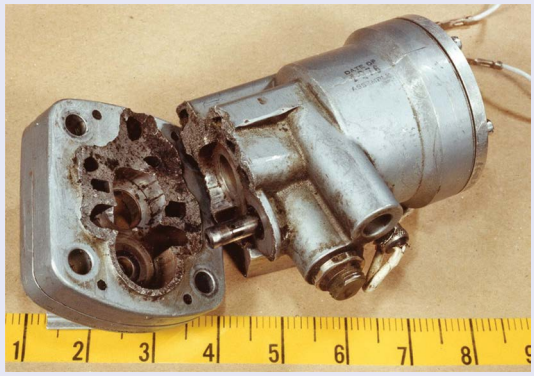


FIGURE 11.78 Oil pump.

(From Sandy Weiss/Packer Engineering.)

When the propeller is turning, the oil impeller is turning. Upon inspection, witness marks made by the oil impeller were found inside the circumference of the chamber in the middle of the flat broken section. These marks show the propeller was turning with great force at the moment the aircraft crashed and the impeller dug into the sides of the chamber, shaving off pieces of the aluminum.

Figure 11.78 shows the condition of the pump as it was received at the lab. The scale indicates the overall size of the unit. The pump was placed on a plain background of brown Kraft paper with about 18% reflectance. Yellow plastic inch-tape, graduated in inches like a ruler, is available in rolls from any forensic supply store. A piece of the tape was used in the overall image for scale because the size of the pump was not an issue.

The pump chamber measured about 1 inch in diameter. The area with the witness marks was too small to have a scale placed inside it for photography (see Figure 11.79). The size of the chamber was not

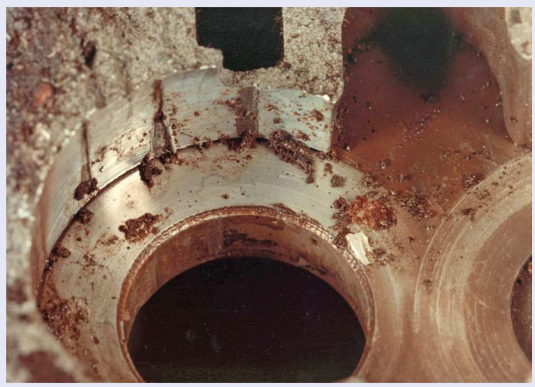


FIGURE 11.79 Oil pump macro.

(From Sandy Weiss/Packer Engineering.)

the issue. The flakes of aluminum dug out of the side of the chamber during the crash were the issue and were the obvious purpose of the photograph.

The camera was a 6 × 7 Pentax with a Pentax auto-bellows and 135 mm Pentax auto macro lens. A Novotron studio flash system with two heads provided lighting. One head had a snout to provide directional lighting onto the shaving, and the other head was diffused to provide background and fill illumination.

CASE STUDY 11.7: AIRCRAFT ENGINE DOCUMENTATION PROJECT

A small aircraft engine (described at the beginning of Chapter 5) was brought to the lab for the purpose of examining its wear and to determine its previous operating conditions. The engine had been used as a classroom demonstration project and was disassembled and reassembled, possibly more than once, at a local university.

It was disassembled in the lab down to individual components, with the intention of macrophotographic documentation. The wear patterns were closely examined and photographed to determine the wear of each component.

The spark plugs were unusual. One was missing entirely. Two were two-prong plugs, although the specifications called for three-prong plugs. The wear of aircraft spark plugs is demonstrated by a flattening of the material opposite the prongs. A Nikon D1-X camera with a 25 mm extension tube, a Nikon bellows, and a Nikkor 60 mm micro lens were used. Twin small EFUs were used, one to each side of the subject (see Figure 11.80). One was attached to the camera by a synchronization cable, and the other was fired photoelectrically as a slave.

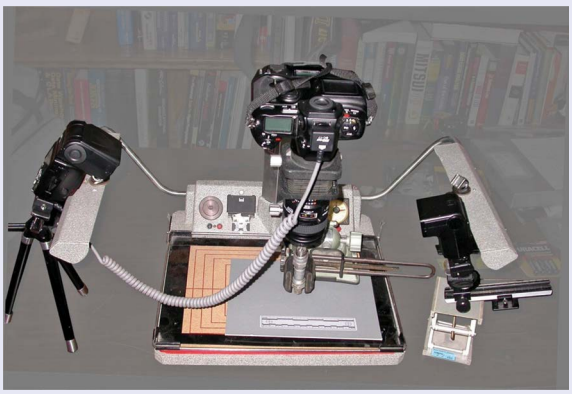


FIGURE 11.80 Macro setup with camera, extension tube, bellows, and micro lens.

(From Sandy Weiss/Packer Engineering.)



FIGURE 11.81 Two-prong spark plug.

(From Sandy Weiss/Packer Engineering.)

The images show the two-prong plugs were not worn (see Figure 11.81) and were probably not used in flight operation. The three-prong plugs displayed normal wear (see Figure 11.82).

The three-prong plugs were exposed with the same equipment and setup as the two-prong plugs. The camera was set on auto-white balance. A grayscale provided the camera with reference for color balance, and the color of the material was normal (see Figure 11.83).



FIGURE 11.82 Three-prong spark plug.

(From Sandy Weiss/Packer Engineering.)

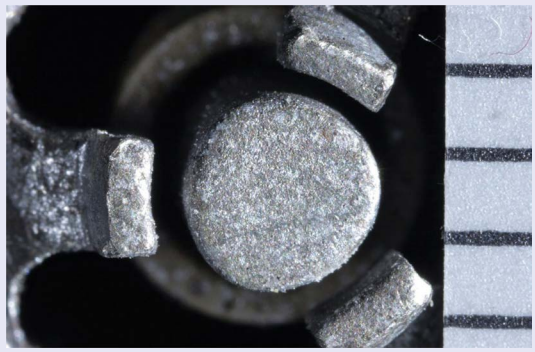


FIGURE 11.83 Spark plug and grayscale.

(From Sandy Weiss/Packer Engineering.)

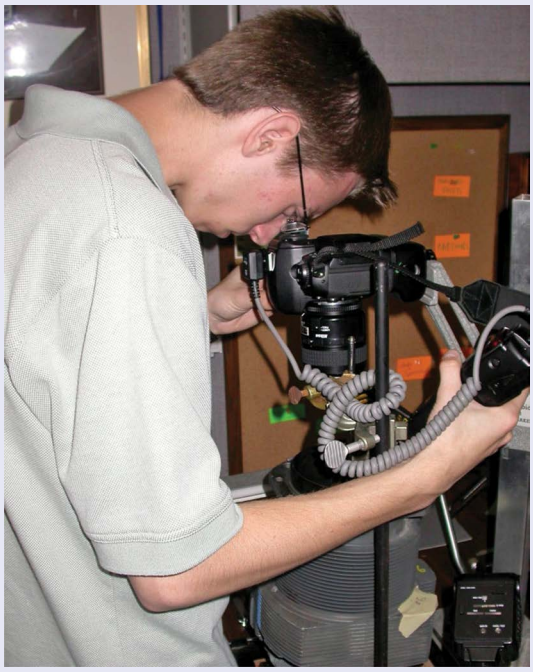


FIGURE 11.84 Making photographs of the inside of a cylinder.

(From Sandy Weiss/Packer Engineering.)

The engine cylinders were inspected individually. The machining lines on the inside walls of the cylinders started and stopped abruptly at the limits of the piston strokes.

It was important to document the texture of the metal on the insides of the cylinders to illustrate that particular wear aspect in the report, even though it is difficult to make photographs of the inside of a cylinder (see Figure 11.84). Because of the physical restrictions of the metal and because of the shiny surfaces, it is often necessary to expose the photographs off mirrors inserted into the space (see Figure 11.85),

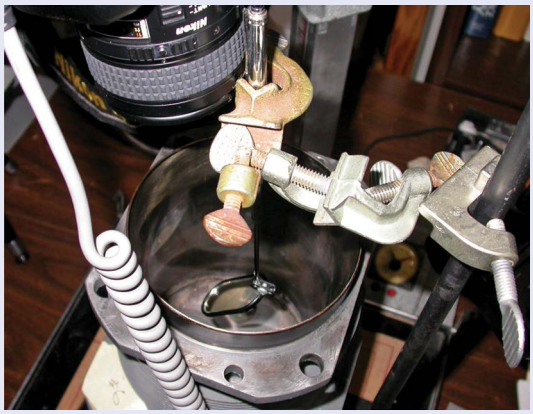


FIGURE 11.85 Cylinder photography using mirrors.

(From Sandy Weiss/Packer Engineering.)

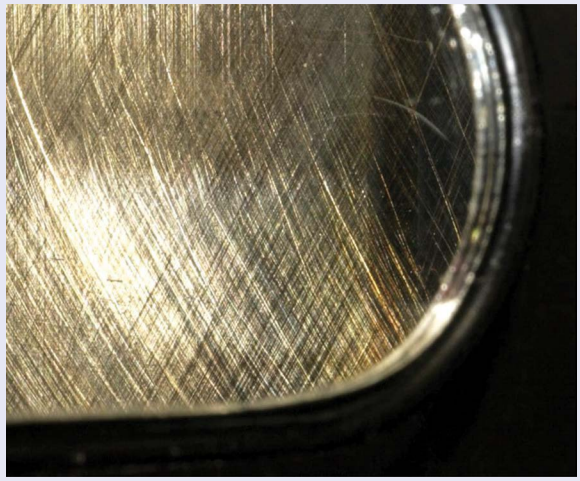


FIGURE 11.86 Rear-surfaced reflector.

(From Sandy Weiss/Packer Engineering.)

angled to bounce the light of the flash against the subject, and serving as a surface from which to expose the images. In this case the mirror is inside the cylinder and invisible in the overall photo.

Rear-surfaced mirrors have a reflective coating on the back surface of the glass. When rear-surfaced reflectors are used for photography, the images will be doubled due to one reflection from each surface of the glass being recorded (see Figure 11.86).

A hardware store automotive inspection mirror (see Figure 11.85) was used in this case. It is shown firmly attached to a test-tube stand and lowered into the circumference of the cylinder.

11A Cellphone Forensic Photography

Robert Wyman

Cellphone cameras are undeniably mainstream devices and essential "everyday carry" accessories. While early-model cellphone cameras were low-resolution designs and essentially a novelty feature, modern cellphone cameras are marvels of miniaturized technology. Cellphone cameras have also forced an evolution in the overall camera market, such that small "point-and-shoot" cameras now have a very minor market share.

For the forensic photographer, a cellphone camera is a valid additional tool in the evidence documentation toolbox, although many law enforcement agencies restrict or totally ban the use of such devices for official photography work. These restrictions are slowly being lifted, as this camera technology is a proven asset and the combination of portability, quality, and diversity of cellphone camera imaging cannot be matched by any other current devices.

The subject of standard operating procedures (SOPs) and the inclusion of all digital imaging devices (including cellphone cameras) in public agency or private business SOPs is covered in detail elsewhere in this book, along with issues regarding cellphone privacy and subpoenas for cellphone inspections. This chapter serves to identify the strengths of cellphone cameras as a replacement for point-and-shoot camera models or as a supplement to a practitioner's main evidence documentation camera system, with only a brief acknowledgement of this important SOP topic.

- To be clear, we are discussing the forensic photographer's utilization of a cellphone camera as a tool to record evidence and related casework elements; we are *not* discussing the search, seizure, and downloads from a cellphone belonging to a person of interest or a suspect in an investigation.

With regard to a law enforcement agency's approval of cellphone camera use, the oft-quoted concern about cellphones being subpoenaed for inspection can be answered with this question: "When was the last time your main camera was subpoenaed for inspection?" The answer is typically "never in my career," and that's because the camera is only a recording tool. The resulting images have evidentiary value, not the electrical-mechanical-optical appliance known as the camera, whether the camera is a stand-alone piece of equipment or is embedded within a communication device.

Departmental SOPs can identify this distinction and provide insulation toward unnecessary equipment inspections and privacy violations. Cellphones simply do not need to be inspected; cellphone images pertaining to casework should be downloaded and managed per SOP requirements and thus be available for future viewing as needed.

In adopting cellphone cameras for evidence documentation photography, one gains the immediate benefit of always having a camera on-hand and available for any time-critical photography tasks.

Examples include an investigator/forensic photographer arriving at the scene of an incident just to find a vehicle is being towed or traffic crash debris is being swept up for disposal; perhaps biological evidence is being removed by medical personnel; maybe the scene is being accessed and modified (or possibly contaminated) by other authorized agencies, investigators and technicians.

In each circumstance, the ability to rapidly record the scene and related activities via a cellphone camera may provide a series of photographs (or videos) never to be replicated. For rapidly occurring scene elements, the forensic photographer may also not have time to stage and deploy prime equipment from a vehicle or camera kit, but the cellphone camera is an adequate tool for this documentation.

Cellphone cameras are designed for quick and easy use by consumers. These are most often point-and-shoot photo opportunities, not technical or forensic imaging assignments. Nevertheless, a cellphone camera can easily be pressed into service for technical photography tasks.

- Exposure controls and on-board camera flash illumination may be adjusted by the photographer if automatic settings are inadequate.
- Many cellphones include lens magnification adjustments duplicating or simulating the similar wide-angle and telephoto lens options available with prime equipment.

The strength and unique capabilities of cellphone cameras, however, are rooted in the "apps" or optional application software used to enhance images or bring additional functionality to evidence documentation photos. Apps are diverse and ever-changing, with old apps being upgraded, replaced, or retired, while new apps become available almost every time a new cellphone or operating system is released.

Unlike their larger, "normal" camera counterparts, cellphone cameras and associated apps can be highly functional documentation tools, as outlined later. Some app examples may appeal to many forensic photographers, while other items may be more suited for specific target audiences, such as traffic crash or crime scene investigators, traffic crash or crime scene reconstructionists, or private investigators. Furthermore, some apps appeal more to first responders than to follow-up investigative personnel, such as insurance investigators, state attorney/district attorney investigators, or law firm personnel.

Note: As with all tools and equipment utilized in a forensic and legal environment, each forensic photographer is encouraged to vigorously test, evaluate, and document each cellphone photographic app and piece of equipment for compliance with SOPs, industry standards, and workflow.

- Apps and equipment providing output in terms of photographs and measurements should be tested in comparison to known and accepted tools and procedures.
- App output should be further analyzed, when possible, to determine error rates or other performance statistics possibly referenced in courtroom testimony, if needed.

Examples of built-in cellphone camera features suitable in forensic photography and evidence documentation include the following:

- With the cellphone's "location services" turned on, the cellphone will automatically record the global positioning system (GPS) coordinates of each image as long as the GPS signal can be obtained by the cellphone.
  - The approximate location of each photo at a scene is recorded without the need for further measurements, unless the precise camera location is desired by the photographer.
  - If the photographer is dispatched to multiple locations or scenes during a workday, each location's photos can be easily segregated via the GPS coordinates.

- Some cellphones can be remotely controlled by companion accessory equipment, such as "smartwatch" devices.
  - For confined-space photographic subjects, the cellphone camera can be placed at any needed location, distance, or angle to record the desired subject. The smartwatch can act as a live-view (viewfinder) accessory so the photographer can easily see the camera's exposure and field of view, control the camera, and review the resulting image.

- Conversely, some cellphones can act as remote controls for other camera devices via a wireless communication link between the phone and the stand-alone camera.
  - In this circumstance, the cellphone acts as a live-view accessory for the connected camera equipment, allowing for the utilization of specific lenses, lighting, or exposure techniques desired by the photographer.
  - Resulting images are typically saved on the camera in the resolution and quality level set by the photographer, as well as saved in the cellphone as a full-resolution or reduced-size/reduced-quality copy. This provides an instant backup for every image.
  - With remotely controlled photos being saved to the cellphone, these images are also immediately available for wireless distribution to other interested parties. For example, key photos of an active scene may be sent to supervisors or news media representatives for their immediate review.

Examples of optional cellphone camera apps suitable in forensic photography and evidence documentation include the following:

- Scene evidence marker apps provide electronic versions of paper or plastic evidence documentation cards or tents.
- Drug identification apps provide photo-based pill identification and prescription information.
- Scene measurement and diagramming apps utilize the cellphone's camera and built-in sensors to provide many unique measurement features.
  - Interior scene photogrammetry and building floor plans
  - Exterior scene photogrammetry and GPS surveying
  - Angular measurements
  - Specialized evidence measurements for items such as blood spatter
  - Double-exposure imaging to compare before and after views of the same scene or subject, such as for locating and measuring an item of evidence originally photographed but subsequently moved without complete documentation
  - Color-identification imaging (colorimeter)
  - Sunlight direction, shadows, and glare visualization
  - Moon phase and moonlight documentation

- Photo and video apps for high-speed photography, slow-shutter photography, panoramic photography, spherical photography, and photo/video editing.

Examples of optional cellphone camera hardware devices suitable in forensic photography and evidence documentation include the following:

- Elevated photography pole (alternative to low-altitude drone photography)
  - Telescopic extension poles for elevated photography from approximately 20' high to over 40' high. Shorter poles may be easily handheld while walking around a scene; longer units must be mounted to a vehicle trailer hitch or

specialized mounting harness on a car, SUV, truck, or small trailer.
    - For use with remote-controlled cameras placed on the elevated platform and controlled with the phone or tablet via a dedicated app.
    - A 20-foot-high camera platform with a standard camera and wide-angle lens provides a commanding view of exterior scenes. For interior scenes, the pole can be raised to a position just below the ceiling to provide a useful overview of a room or interior structure.

- Elevated photography tripod (alternative to low-altitude drone photography)
    - Extra-high, free-standing, elevated tripods are also available in 10-feet-plus and 20-feet-plus models. These are marketed as "stands" instead of camera tripods, but a camera with remote capabilities can still be mounted to the unit.

- Microscope cellphone camera attachment
    - Clip-on microscope lens attachment devices are placed over the cellphone camera lens to provide enhanced macroscopic and microscopic levels of magnification. Also available are stand-alone microscope devices wirelessly controlled by the cellphone. Some devices include a built-in ring light for shadow-free subject illumination.
    - Low-magnification models provide approximately 10× to 20× subject magnification, while high-magnification models may provide as much as 100× to 300× subject magnification.

- Thermal imaging (infrared) cellphone camera attachment
    - Clip-on infrared imager providing thermal imaging and noncontact, spot-meter heat temperature estimates with photo and video recording in standard, panorama, time lapse, and macro modes.
    - The imaging device operates in conjunction with a companion app.

- Photo lamp cellphone camera attachment
    - Accessory LED camera lamp provides additional subject or scene illumination.
    - One or more lamps can be mounted to the cellphone or used independently with wireless control.
    - The companion app can typically adjust light output and color temperature for each connected lamp.

- Accessory lens and filter cellphone camera attachments
    - Clip-on telephoto, wide-angle, and macro lens attachments are available.
    - Clip-on polarizing and ultraviolet (UV) filters are also available.

- Gyroscopic gimbal cellphone mounts
    - Three-axis, motorized gimbal cellphone mounts provide camera stabilization and smooth handheld pan, tilt, and roll controls for photos and videos.
    - Typically used for handheld photography when tripod use is undesirable due to the scene environment or other factors.
    - Motors are powered by standard batteries or a rechargeable battery pack.

- Cellphone tripod mounts, brackets, supports, and clamps
    - A wide variety of mounts, mini-tripods, monopods, dollies, slider rails, and other hardware devices are available for photo and video use.
    - Cellphone mounts provide solid support for low-light, nighttime, and inclement-weather photography, as well as for increasing the precision of measurement apps.

- Measuring device Cellphone Camera Attachments
    - Unique clip-on or wireless hardware devices, with companion apps, are available for viewing, measuring, and recording physical quantities.
    - Hardware and apps include small laser scanners for 3-D measurements that connect to cellphones or tablets; laser rangefinders for distance measurements; borescopes for tube, pipe, and confined-space imaging; thermometers; and industrial light meters (for foot candle and lux measurements) and photographic light meters (for aperture, shutter, and ISO image exposure measurements).

Cellphone cameras, either alone or with optional apps and devices, are extremely useful tools in the forensic photographer's arsenal of equipment. These items can produce unique photographic exhibits, provide noncontact photogrammetry or sensor-based scene measurements, and allow the forensic photographer to safely and accurately accomplish many tasks with minimal equipment.

Cellphones with new and upgraded features will certainly be produced, further enhancing the forensic photographer's toolkit and evidence documentation abilities.

12 Image Rectification and Angular Correction

Arthur Borchers

CONTENTS

Appendix: Verify 90-Degree Angle of Scale 280
Note 283
References 283

It has been stressed many places in this book for readers to take close-up evidence photos with a scale perpendicular to the object or surface. The reason for that emphasis is you may need to make precise measurements either of the object itself or the object in relation to something nearby. You rarely remember to take every necessary measurement while processing an active crime scene. The ability to take critical measurements from your photographs after the fact is highly valuable insurance. When the camera-to-subject angle is not perpendicular, the effects of perspective come into play. Edges are no longer parallel. Squares do not have four 90-degree corners—they become trapezoidal in shape. The following information is presented to allow you to confirm your photographs are perpendicular to the image plane. If the photographs are not at right angles, we explain how to modify them so they are.

There are many different designs of scales from small to large, but the most useful for evidence photography purposes is the ABFO No. 2 or similar variants providing scales in two directions at right angles to each other. The ABFO No. 2 provides millimeter scales demarcated into five 1-centimeter sections also extending to the ends of the legs; a photo-gray reference and three circles also included are useful in confirming perpendicularity. ABFO-style scales are produced by multiple manufacturers in both metric and imperial scales, in varying colors, on metal, plastic, magnetic, and/or paper substrates and in a variety of sizes, including some capable of footwear documentation or larger. A 50 mm macro lens or longer on a full frame image sensor is necessary to capture images without circular distortion found with wide-angle lenses. The macro feature is important to enable filling the image with as much detail as possible for future enlargement.

An immediate task is confirming your photographs were in fact taken perpendicular to the subject. This is handled simply by importing your image into a CAD or photo editing program where circles are drawn over the circles on the scale (Figure 12.1). The consistent alignment of the red circles with the scale's circles confirms perpendicularity. An image confirming this fact is saved with your investigative file.

The image in Figure 12.2 was taken at 10 degrees off angle and later imported into CAD and checked for perpendicularity. The green circle aligns with the top and bottom of the scale's circle, but the gaps at the left and right sides of the scale's black circle shows the captured image is an ellipse and not round. This makes the image a candidate for perspective correction, also called rectification, a procedure detailed later.

You will need a photo editing program with a "perspective warp" or "transform" function to be able to modify your images to accurately correct for perpendicularity. The following dicsussion focuses on the use of Adobe Photoshop and the tools contained within to perform the required editing steps. Other editors, including the free program GIMP (GNU Image Manipulation Program – www.gimp.org), are capable of performing similar modifications. As with all forensic image manipulation, careful notes of the changes should be maintained and kept on file.

This discusison is a step-by-step journey from an unknown-angle photograph to a perpendicular photograph suitable for further examination and analysis.

Figure 12.3 is our starting photograph. The first step is to open Photoshop and import a copy of the original image.

IMPORTANT:

If you open the image and then save your project as a .psd file, the original image file will remain intact and unmodified.

Once you have a photo imported, turn on Rulers (View > Rulers or Ctrl-R) and then right-click on the displayed ruler and change the units to pixels. Once this is on, you should never have to do it again.

Next you will add a visual grid to the image to help you align edges (View > New Guide Layout). The dialog box allows you to have as many guides and patterns as you like. You want to roughly duplicate the shape of the object that you are perspective correcting—in this case, the ABFO scale is close to a square in shape. The first information you need is the size of your original photo in pixels. This can be found at the bottom of the Windows Explorer view when you click on the file or by right-clicking on the file

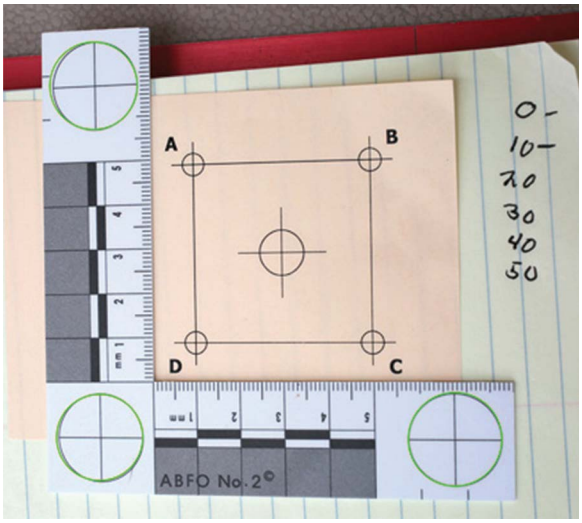


FIGURE 12.1 Perpendicularity confirmed with circles drawn over image circles.

(From A. Borchers.)

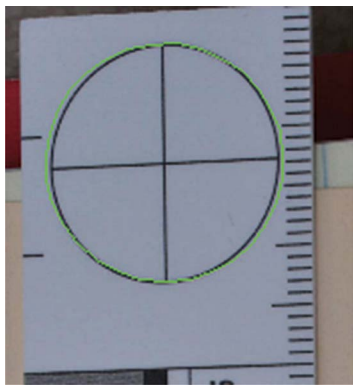


FIGURE 12.2 Circle comparison displays elliptical image shape.

(From A. Borchers.)

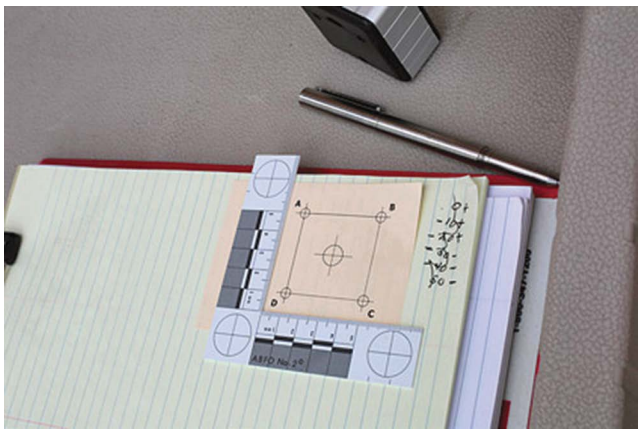


FIGURE 12.3 Starting image.

(From A. Borchers.)

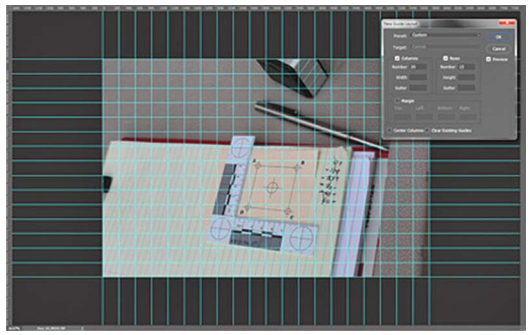


FIGURE 12.4 New Guide dialog and view.

(From A. Borchers.)

and viewing the properties. The original size of Figure 12.3 is 5720 × 3840, which reduces to an aspect ratio of exactly 3:2, carrying over from the 35 mm film size. Other common image ratios are 4:3, frequently refered to as four-thirds; 16:9 is a widescreen format; and finally you may be working with square images with an aspect ratio of 1:1. The number you choose to create your grid should be multiples of your aspect ratio. As shown, the 20 column wide by 15 row tall grid (Figure 12.4) will create medium-size squares.

Now you should align one edge of your image's scale to the grid. To do that, you will need to rotate your entire image (Image > Image Rotation Arbitrary). For Figure 12.5, the amount of rotation is about 8 degrees counterclockwise.

With one edge aligned to the grid, you can see in Figure 12.6 that the right angle of the bottom-left corner is visually incorrect. Your next step is to choose the Perspective Warp tool (Edit > Perspective Warp), and the cursor will visually change to a cross-hair–like appearance. Click on the scale's upper-left corner (Figure 12.7, #1). A warp grid layout will now appear with its toolbar at the top of the window. Drag the lower corners of the warp grid to the remaining corners of the scale (Figure 12.7, #2 and #3). When postioning the final corner of the warp grid, attention must be paid to aligning the edges of the warp grid to the ends of the scale legs so the lines are parallel to the projected edges (Figure 12.7, arrows). As you can

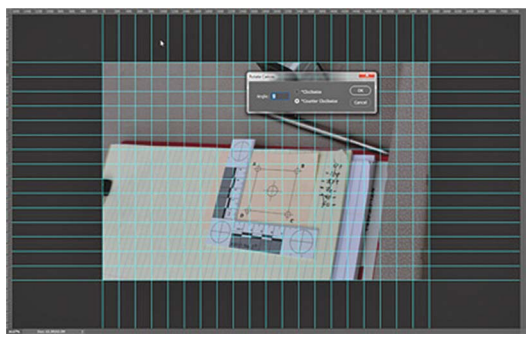


FIGURE 12.5 Rotate Image dialog.

(From A. Borchers.)

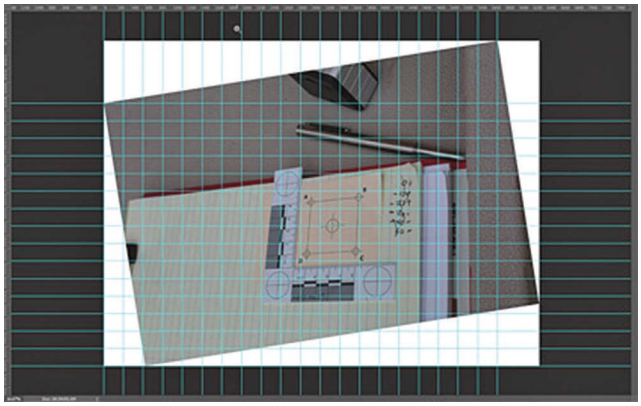


FIGURE 12.6 Rotate to align one edge.

(From A. Borchers.)

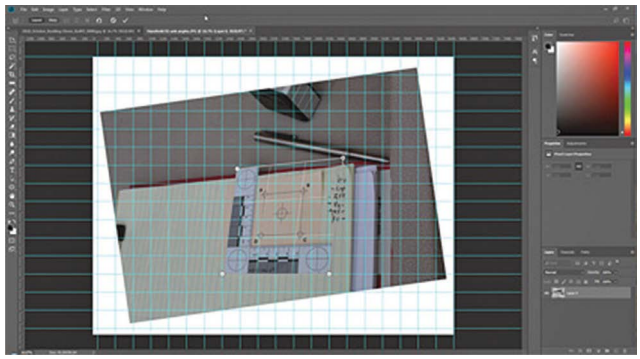


FIGURE 12.8 Place Perspective Warp grid.

(From A. Borchers.)



FIGURE 12.9 Perspective Warp toolbar.

(From A. Borchers.)

see in Figure 12.8, the remaining corner of the grid generally matches the projected lines in Figure 12.7. Once you have the warp grid positioned to your satisfaction, simply press the Enter key. The corners of the grid will change from light to dark.

The warp toolbar (Figure 12.9) will change the highlight from the "Layout" to "Warp." With this change, you can manually drag the corners to adjust the warp, but the easiest way is to click on the hashtag-shaped section of toolbar (#). That tool will align your grid to the vertical and horizontal axes, which is your goal, as shown in Figure 12.10. If you need to move any of the corners of the warp layout, you will find the guide alignment grid will help you by snapping your movements to the corners of the alignment grid. Be sure you maintain the squareness of the ABFO scale by ensuring the number of vertical and horizontal boxes are equal.

Your next step is to confirm the horizontal and vertical scales are equal. This is accomplished with the Measure tool, found by right-clicking on the Eyedropper tool (I) along the left side of the toolbar. When you select the Measure tool, its toolbar appears above the image window. The length of your measurement is displayed in pixels as the "L1" value ("D1" in older versions). It is recommended to measure a longer distance, such as the 5-cm line, rather than a shorter one. The values for the two distances should agree within a pixel or two over several measurement attempts. Using the longer distance over a shorter one

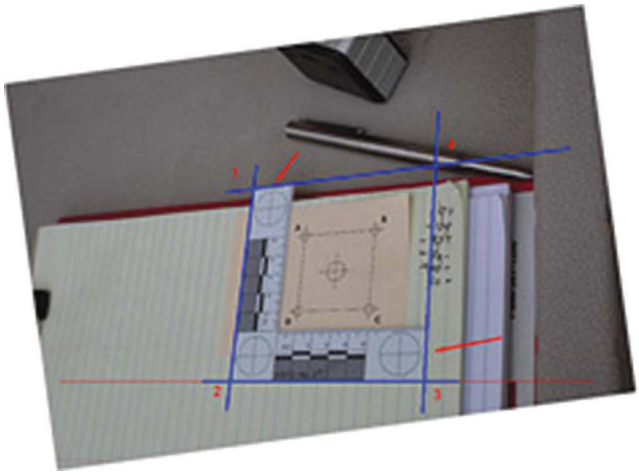


FIGURE 12.7 Perspective Warp tool alignment.

(From A. Borchers.)

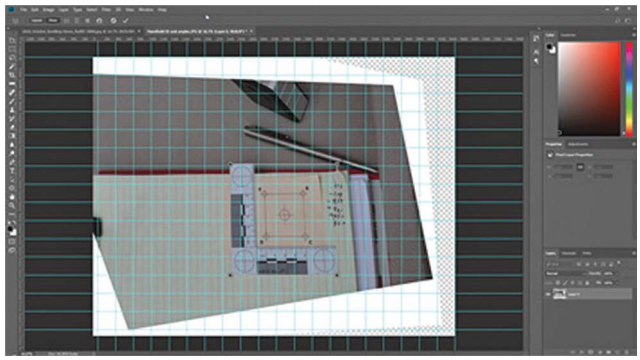


FIGURE 12.10 Perspective Warp vertical and horizontal adjustment.

(From A. Borchers.)



FIGURE 12.11 Measure toolbar with length displayed in pixels.

(From A. Borchers.)

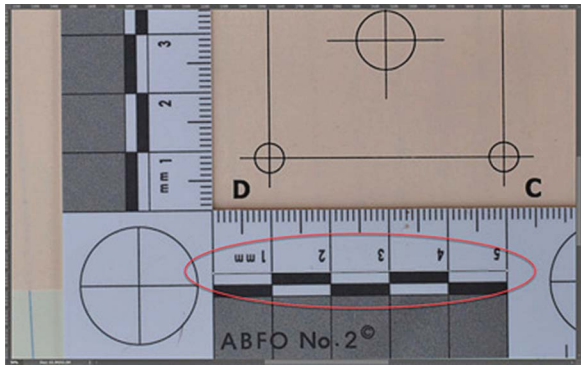


FIGURE 12.12 Measure the horizontal and vertical scales.

(From A. Borchers.)

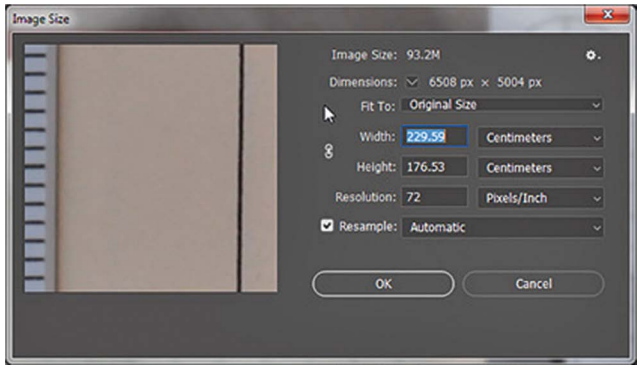


FIGURE 12.15 Image Size dialog.

(From A. Borchers.)

should account for any differences in your starting and ending locations (Figure 12.12).

If the measured values are not equal, the image scale or calibration can be easily adjusted. If, for example, your values are 952 pixels for the vertical distance and 970 pixels for the horizontal distance, your next step is to divide one value by the second value. If divided in the order given, the result is 0.981443. Should you divide 970 by 952, your result is 1.018907.

To fix your image scale, select Image Size (Edit > Transform > Scale), and the Scale Adjustment toolbar appears above your work window (Figure 12.13). Click on the link icon between the width and height percentage values so any highlight is turned off. This will allow image modification in only one axis. Please note, the Photoshop terms for horizontal and vertical dimension are width (W) and height (H) (see Figure 12.14).

Using the values obtained earlier, convert the ratio between the horizontal and vertical axes (0.981443) to a percentage by shifting the decimal point two places to the right, giving you a value of 98.1443%. If you were to do the same conversion with the second value (1.018907), your result would be 101.8907%. In our example, we want to reduce the horizontal width to 98.1443% of its original value without affecting the vertical size. Enter 98.1443% in the W box and press Tab. This should move your cursor to the H box but not change the value. If the value does change, click on the link icon to turn off the highlight and enter 100% in the H box and press Tab again. Verify your values are still what you want and then click the checkmark at the end of the toolbar to confirm your change. This will adjust only the width of your image to be approximately 1.8% smaller. Remeasure the pixel values of the scales to verify they are now reading the same or closely similar values.

Your next step will be to adjust the image size (Image > Image Size or Ctrl+Alt+I) to adjust your ability to print to scale.

Your first changes to the dialog box will be to uncheck the Resample box, then click on the link icon to the left of the width and height values and change the resolution scale to reflect the actual scale of your photographed measuring tool to either Pixels/Inch or Pixels/Centimeter. Next divide the pixel measurement you took earlier by the number of inch or centimeter segments and enter the value into the Resolution box. The width and height values will update as you type, but visually you will not see any change to your image when you click OK. When you print your file, however, it will print to the actual size of your pictured scale, allowing you to take direct measurements from objects (see Figure 12.16).



FIGURE 12.13 Scale Transform toolbar.

(From A. Borchers.)



FIGURE 12.14 Scale transform adjustment.

(From A. Borchers.)

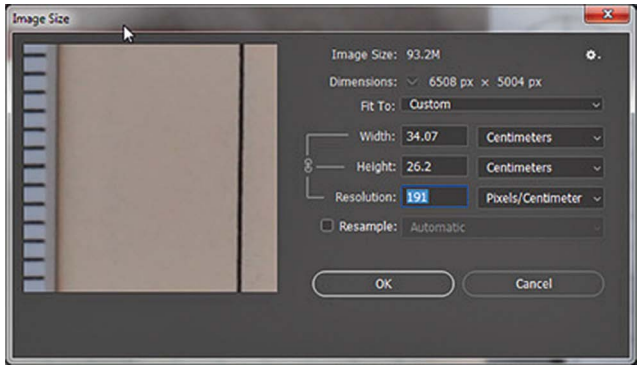


FIGURE 12.16 Image size adjustment.

(From A. Borchers.)

Your final step is the same as the first. You will need to verify the circles in your scale are in fact circular. This can be done in Photoshop using the Ellipse tool (U) near the bottom of the left toolbar. When you select Ellipse, click on the gear icon in the toolbar (Figure 12.17) and change the setting to match those below (Figure 12.18). When you draw your ellipse—now more accurately a circle—click on the intersecting lines in the center of the reference circle (Figure 12.19) and draw out to match the diameter. If the drawn circles accurately match the reference circles, you are done. Print a file copy and continue your case work. With practice, this process takes little time to accomplish and goes a long way to showing that your work is accurate.

Figures 12.20–12.23 depict actual image edits as examples.

Tammy Koelling obtained Figures 12.20 and 12.21 for publication through her account at depositphotos.com.

An additional rectification method is with EOS Systems Photomodeler photogrammetry program and the use of constraints. This method is highly dependent on the original working photograph having three or more lines defined



FIGURE 12.17 Ellipse toolbar.

(From A. Borchers.)

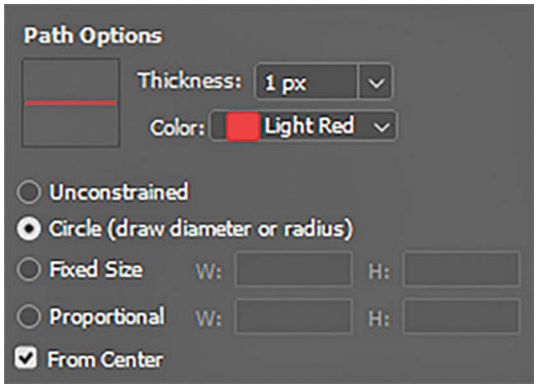


FIGURE 12.18 Ellipse tool settings.

(From A. Borchers.)

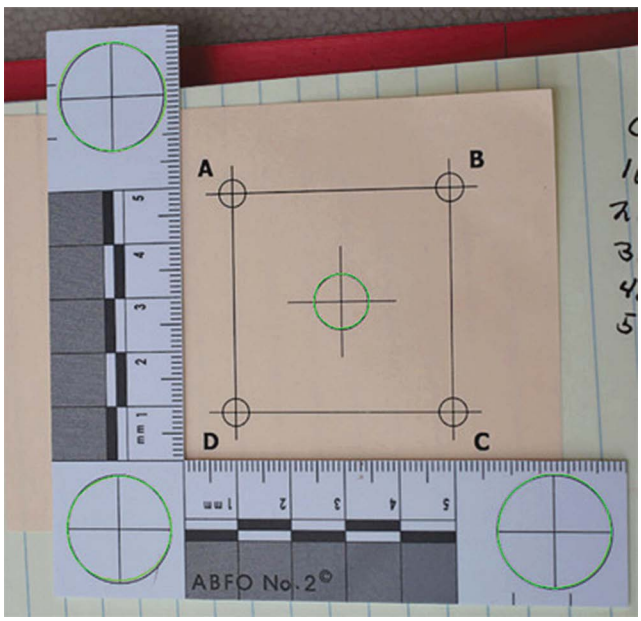


FIGURE 12.19 Perpendicularity confirmed by circles.

(From A. Borchers.)



FIGURE 12.20 Big Ben corrected photo.

(From A. Borchers.)



FIGURE 12.21 Big Ben file photo.

(From A. Borchers.)

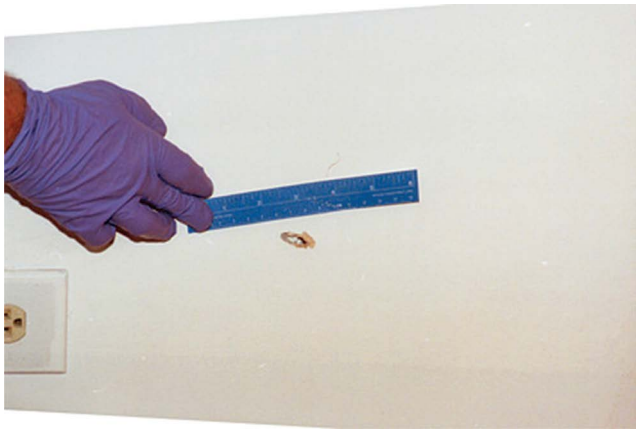


FIGURE 12.22 Bullet hole entry into wall as photographed.

(From A. Borchers.)



FIGURE 12.23 Perspective-corrected bullet hole to scale.

(From A. Borchers.)

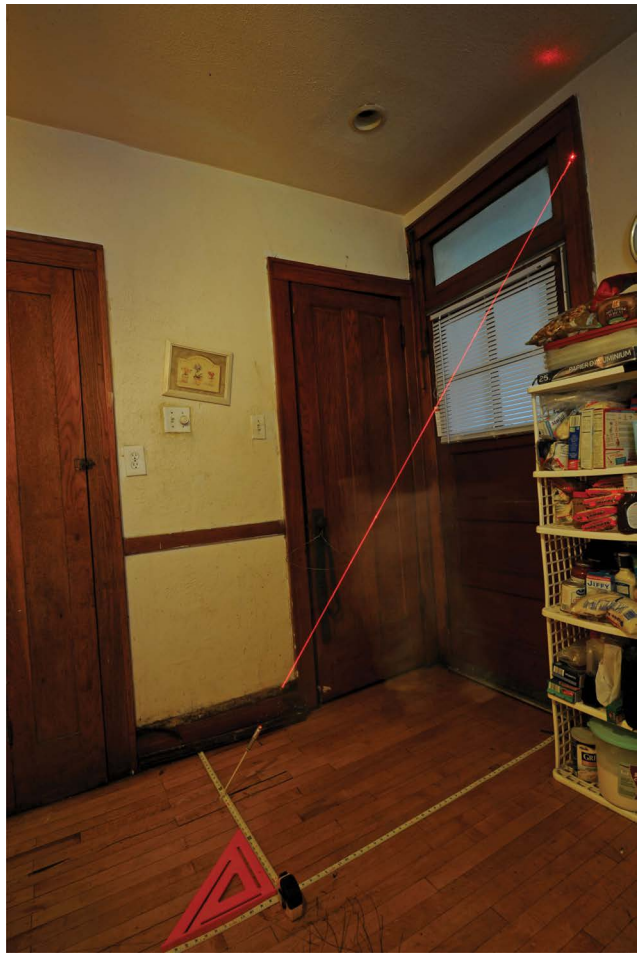


FIGURE 12.24 Original trajectory photo.

(From A. Borchers.)

as parallel. Figure 12.24 is an image from a shooting trajectory study with a laser placed in a bullet hole that went through the wooden floor.

The photograph was brought into Photomodeler, and five constraint lines were drawn on the image. One line is vertical from floor to ceiling in the corner of the room. Two lines outline the floor of the two walls intersecting with the line in the corner. The final two lines outline the ceiling and also intersect with the line in the corner. The lines on the left wall are defined as parallel to each other and being oriented left to right in the image. The lines on the right wall are also defined as being parallel to each other and oriented front to back in the image. The line in the corner is defined as being vertical. Surfaces for each wall, the floor, and the ceiling are defined with their texture or color information coming from the area of the photo covered by the defined surface. The project is solved, or processed, in Photomodeler, and the results can be viewed in relative 3-D (Figure 12.25). The 3-D image can be manipulated and rotated using the tools in the bottom-right corner of the 3-D viewer window.

Additionally, the calculated camera position can be displayed in the 3-D view (Figure 12.26).

A side-by-side comparison of rectified views of the one wall obtained with Photomodeler and Photoshop is provided in Figures 12.27 and 12.28, respectively.

APPENDIX: VERIFY 90-DEGREE ANGLE OF SCALE

When using an ABFO or similar scale, how do you know the manufacturer created an accurate 90-degree or right angle? Perhaps you are using a larger scale with a fixed pivot point joining two scales together you fold out to form a 90-degree angle, or you need to create a field expedient right-angle setup. How can you guarantee the angle is correct?

The answer to this question is about 2,500 years old and is known as the Pythagorean theorem. The theorem states that the square of the hypotenuse of a right triangle

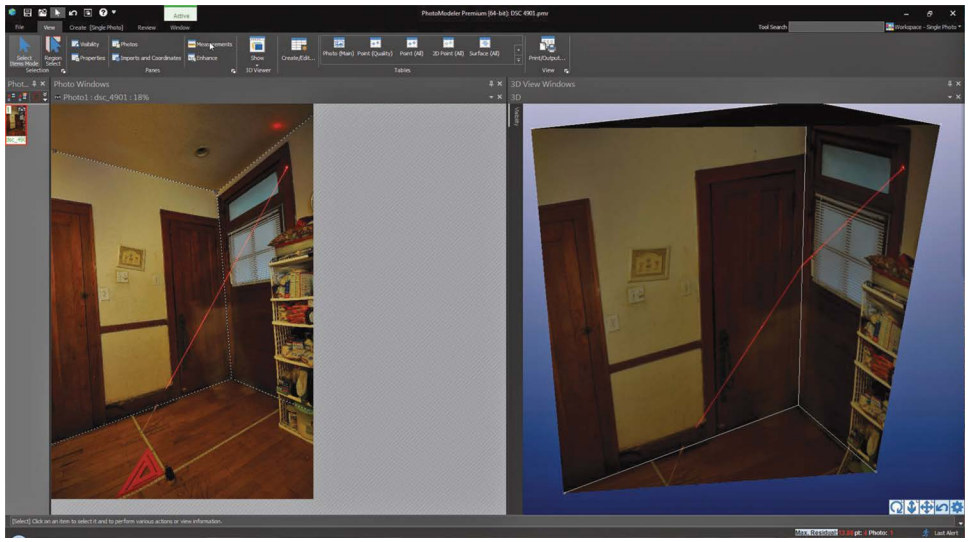


FIGURE 12.25 Original and 3-D views side by side.

(From A. Borchers.)



FIGURE 12.26 Calculated camera position displayed for original image.

(From A. Borchers.)



FIGURE 12.27 Perpendicular view of kitchen wall from Photomodeler.

(From A. Borchers.)

is equal to the sum of the squares of the other two sides. Referring to Figure 12.29, the theorem can be written as a mathematical equation relating the lengths of the triangle's three sides: *a, b,* and *c*. The equation is written as $a^2 + b^2 = c^2$. The hypotenuse, or long side, *c,* is opposite the right angle, while sides *a* and *b* are considered adjacent to the right angle and form the two legs seen in right-angle forensic scales.

Now I expect some readers are saying, "Ugh, math!" and are getting ready to turn the page. Wait! This process is simple and does not involve any math to verify accuracy. It is as simple as the numbers 3, 4, and 5!



FIGURE 12.28 Perpendicular view of kitchen wall from Photoshop.

(From A. Borchers.)



FIGURE 12.29 Sample right triangle.

(From A. Borchers.)

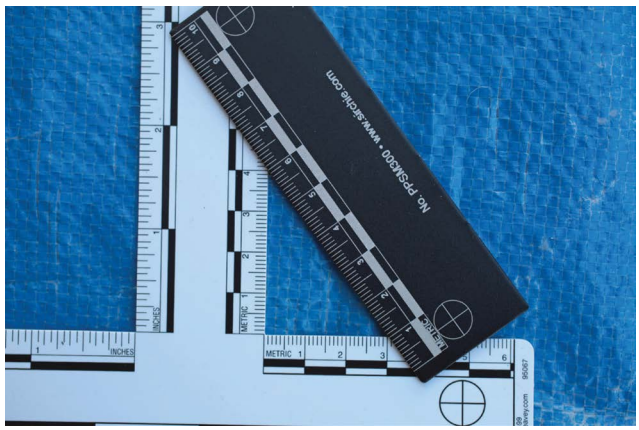


FIGURE 12.30 The 3-cm base, 4-cm height, and 5-cm hypotenuse confirm a 90-degree angle.

(From A. Borchers.)

Here is all you must do, refer to Figure 12.30 and do the same thing with your scales. Units of measurement are not important. You only need to use the same units throughout. Whether you use millimeters, centimeters, inches, feet, miles, or furlongs does not matter.

On one leg of your scale find a length of 3 units from the right angle. On the other leg of the scale find a length of 4 units from the corner. Now take a third scale and measure the length between the 3-unit point and the 4-unit point. The length should be exactly 5 units. If the measured length is more or less than 5 units, then your supposed 90-degree angle is not actually a right angle. If this scale is newly received from a vendor, send it back and demand a refund. If the scale has sat in your squad trunk kit all summer, it's time to replace some gear.

This technique is also used for setting a 90-degree angle on a pivoting scale set or setting two loose scales held together with a binder clip with only one small modification. After you find your 3-unit point and 4-unit point, use your third scale 5-unit point to adjust the legs so the adjustable angle is set to 90 degrees (see Figures 12.31 and 12.32). If you are running a long tape around a car, you can use this method to ensure square corners instead of needing to carry a large carpenter's square.

When it comes time to testify, take some time to review this section so you can explain the concepts to show the technique's long history is accurate and proven. A simple reference source, aside from any high school geometry book, is Wikipedia and their articles on the Pythagorean Theorem and Pythagorean Triples. If you refer to Table 12.1, you can see multiples of 3, 4, and 5 all work, and there are additional whole number values called *Pythagorean Triples* that function the same way.

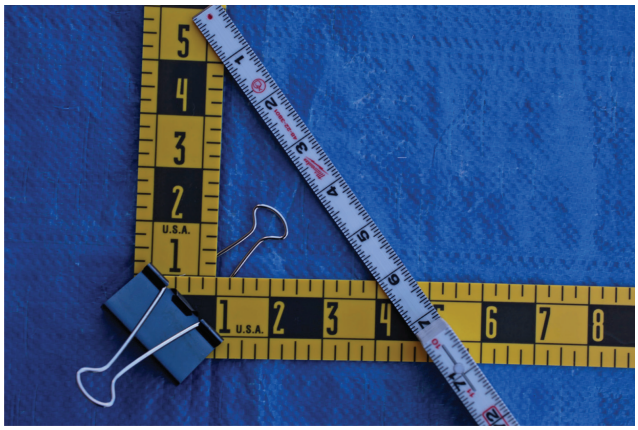


FIGURE 12.31 Field-expedient right-angle scales in use.

(From A. Borchers.)



FIGURE 12.32 Field-expedient scales, 90-degree angle verification.

(From A. Borchers.)

TABLE 12.1
Pythagorean Triples

x (x^2)	×2	×3	×10	Other Triple Number Sets		
3 (9)	6 (36)	9 (81)	30 (900)	5 (25)	48 (2,304)	60 (3,600)
4 (16)	8 (64)	12 (144)	40 (1,600)	12 (144)	55 (3,025)	91 (8,281)
5 (25)	10 (100)	15 (225)	50 (2,500)	13 (169)	73 (5,329)	109 (11,881)

Note: This chapter (not including the Appendix) is reproduced with permission from an article published in the Spring 2019 issue of Evidence Technology Magazine.

REFERENCES

1. Bowers C.M., and Johansen RJ, Photographic Evidence Protocol: The Use of Digital Imaging Methods to Rectify Angular Distortion and Create Life Size Reproductions of Bite Mark Evidence, *Journal of Forensic Science*, 2002, Vol. 47, No. 1, 178–185.
2. Pierce, Guy, Resizing Digital Images to Actual Size (1:1) Using Adobe® Photoshop®, *Journal of the Association for Crime Scene Reconstruction*, Spring 2009, Vol. 15, No. 1, 13–16.



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13 Firearms and Toolmarks

Carlo Rosatti and Marcelo Jost

CONTENTS

Firearms 285
Toolmarks 288
Impression 288
Striation/Scraping 288
National Integrated Ballistic Information Network (NIBIN) 289
Photography in Firearm and Toolmark Examinations 290
Scales and How to Use Them 290
Camera Stability 293
Framing, Focus, and Distance 293
Lights, Flashes, and Dispersed/Diffused Flashes 294
Digital Editing for (Better) Presentation 297
Special Topics in FATM Photography 298
Further Reading 303
Note 309
Further Reading 309
13A Bullet Trajectory Laser Photography 310

The field of firearms/toolmarks is utilized in most law enforcement agencies in the world, providing forensic and technical assistance to agencies involved in criminal investigations. Firearms/toolmarks has been a cornerstone in the forensic field, tracing its roots back to 1835. Physical evidence recovered in criminal cases and submitted to a laboratory undergoes macroscopic and microscopic examinations. Examiners of the crime laboratory document, process, and analyze this evidence, providing valuable—if not crucial—information to law enforcement agencies and case investigators in the field.

FIREARMS

The forensic study of firearms involves the identification of a bullet, cartridge case, or other ammunition component as having been fired by or in a particular firearm. The possibility of such an identification can be attributed to specific machining processes used in the manufacture of firearms. Manufacturers machine helical grooves known as rifling into the bore of a barrel of a firearm during production to increase the accuracy of that firearm. When a firearm is discharged, these grooves cause the bullet to rotate as it travels the length of the barrel, which imparts spin to stabilize the bullet during flight. The expansion of the fired cartridge and the high pressures propelling the bullet through the bore of the barrel press and scrape the bullet against the rifling as it heads toward the muzzle. The fired bullet will bear the negative impressions of the grooves in a rifled barrel. These marks are described by firearms examiners as land and groove impressions, or simply "lands and grooves."

The equipment used in the machining and finishing processes of firearms production is inherently imperfect at the microscopic level; a machined, rifled barrel will contain distinctive scratches, scrapes, and other minute nicks and flaws (toolmarks). These unique imperfections are exacerbated through the subsequent use and discharge of the firearm as further abrasion of the barrel occurs and because of wearing processes such as rusting and corrosion. Lead or jacketed bullets propelled by high pressures at great speed through the barrel of a firearm will have impressed on their surfaces not only the general rifling characteristics of that barrel but also microscopic marks unique to that barrel, marks not found in the barrel or rifling of any other firearm.

Several other impressions found on cartridge cases resulting from various machining processes are of great significance to firearms identification. Firing pin impressions, breechface marks, extractor marks, ejector marks, and chamber marks, when present and of enough quality, are all features used by firearms examiners in their analyses.

During the discharge of a firearm the firing pin strikes the primer of a cartridge, creating microscopic contact marks and unique indentations. The primer chemicals are a volatile mixture, and due to the sudden compression of the firing pin strike a spark is created, which ignites the propellent powder. The powder burns, albeit quite fast, but does not explode. An explosion is an instantaneous combustion event. The burning powder creates heated gas and expands exponentially, creating high pressure inside the cartridge case and expanding the case within the limits of the firearm's chamber(s). The heat and pressure increases are so great that the case conforms to any machining marks or defects in the steel chamber walls.

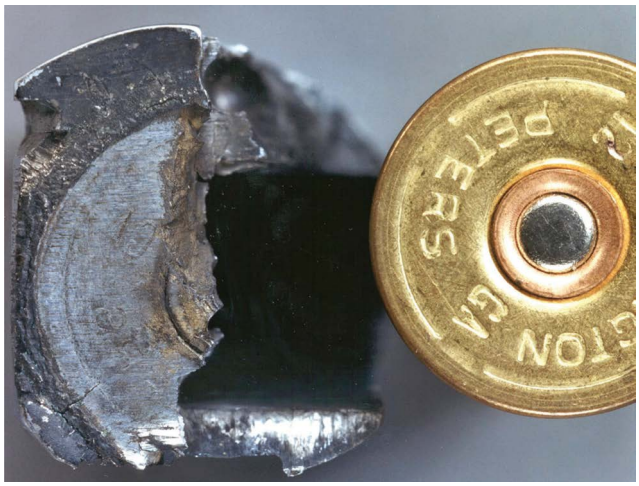


FIGURE 13.1 The cartridge case is propelled backwards against the breechface with enough force to be impressed with the characteristic microscopic features of that surface.

(From Sandy Weiss/Packer Engineering.)

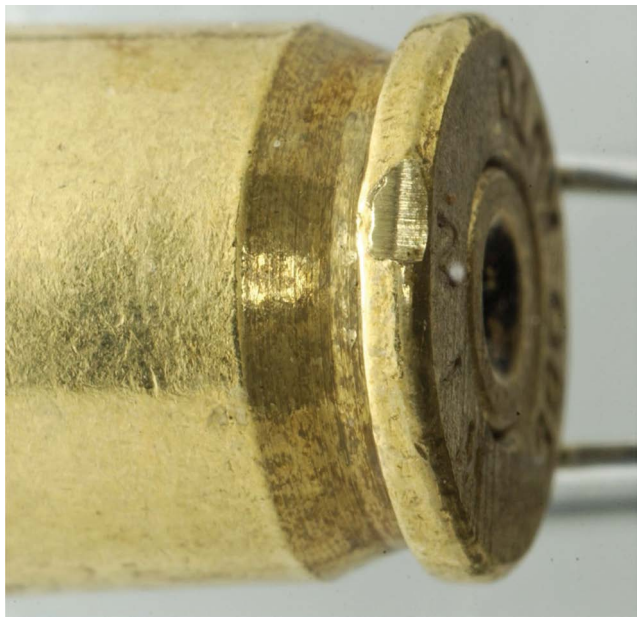


FIGURE 13.2 In a semi-automatic weapon, extractor and ejector marks are produced when the cartridge case is mechanically pulled from the chamber by the extractor and kicked out of the ejection port when the case head strikes the ejector pin.

(From Sandy Weiss/Packer Engineering.)

The weakest aspect of a loaded cartridge is the friction or pressed fit of the bullet into the mouth of the soft metal cartridge case. With the expansion of heated gas from the burning powder, the bullet is effectively pushed out of the case and into the barrel. The head of the cartridge case is pushed in the opposite direction, starting the process of recoil, when the case head impacts the breechface. The cartridge case is propelled backwards against the breechface with enough force to be impressed with the characteristic microscopic features of that surface.

In a semi-automatic weapon, extractor and ejector marks are produced when the cartridge case is mechanically pulled from the chamber by the extractor and kicked out of the ejection port when the case head strikes the ejector pin. These markings are visible as fine striations and gouged impressions on the rim and head of the case. Chamber marks, parallel striations on the cartridge case caused by contact with the walls of the chamber of the firearm, also occur at this time. All these potentially identifying features are produced because of the machining and finishing processes of firearms manufacture, which inevitably leave microscopically rough areas and edges on the parts of a given weapon. During discharge, these imperfections are transferred from the metal parts of the firearm to the bullet and cartridge case.

Firearm and toolmark examinations compare the physical and class characteristics of evidence items. An "association" conclusion is reached if the observable and measurable physical dimensions and design features of the two items agree or are "physically consistent." If these dimensions and features are clearly different, an "elimination" conclusion is reached. If there is a lack of observable design features or measurable dimensions, the result is "inconclusive." Association examinations are used to determine if two items are from a restricted group source and cannot be used to determine whether two items are from a unique source

The appropriate general rifling characteristics (GRC) measurements for an evidence bullet, including caliber or bore diameter, rifling twist direction, land and groove number, and dimensions, are entered in a database, which then returns a list of all firearms in the database with comparable GRCs. The GRC database contains information obtained from firearms at the Federal Bureau of Investigation (FBI) and other laboratories and from voluntary submissions of test-fired specimens from law enforcement agencies around the world. It is not a comprehensive list of all firearms and contains no information about the numbers of each type of firearm present in the general population. The firearms listed in the report are typically considered to be more common and are included at the discretion of the examiner authorizing the report.

Generally, bullets exhibit striated toolmarks produced when a bullet passes through the barrel of a firearm. Two bullets, either two evidence items or one evidence item and one bullet test-fired in the laboratory, undergo two stages of comparison. First, the bullets are examined to determine and compare their class characteristics. The class characteristics of fired bullets include diameter, number of land and groove impressions, direction of twist, and widths of the land and groove impressions. If the class characteristics of two bullets are not clearly different, the examination moves to a second stage using comparative microscopy. A microscopic comparison examination consists of a search of the striated marks

present on two bullets to determine if patterns of similarity exist.

Known test-fired specimens are compared to questioned evidence specimens using a trademark tool of the firearms examiner—the comparison microscope. Consisting of two separate microscopes joined by an optical bridge, this microscope allows the side-by-side observation and comparison of the microscopic characteristics present on different bullets or cartridge cases. A camera attached to this microscope provides photographic documentation of these specimen comparisons, which are conducted regarding class characteristics and individual characteristics. In firearms identification, class characteristics include number and direction of a barrel's rifling (e.g., four grooves, right twist, or six grooves, left twist), caliber or gauge, and the width of lands and grooves. Individual characteristics are distinct, unique marks produced during the manufacturing process and include signatures of damage and wear, such as the impression left by a deformed or broken firing pin or the unusual striations left on a bullet by a spur on a sawn barrel. These features, in combination with the microscopic marks left on bullets and cartridge cases as a product of the discharge of a firearm, enable an examiner to identify and classify ammunition components and firearms in relation to each other.

Firearms/toolmark identification relies on objective measurements and a subjective comparison of microscopic marks of value. Due to random changes in barrels, such as where corrosion and lead accumulations accrue, bullets fired from the same barrel are sometimes not identifiable as such. Additionally, some barrel manufacturing methods routinely produce barrels leaving limited microscopic marks of value on fired bullets. Damaged, corroded, or fragmented bullets may be of little or no value for comparison purposes.

Cartridge cases exhibit both striated and impression toolmarks from having been worked through the action or having been fired in a firearm. Two cartridge cases, either two evidence items or one evidence item and one cartridge case test fired in the laboratory, undergo two stages of comparison. First, the cartridge cases are examined to determine and compare their class characteristics. The class characteristics of fired cartridge cases include caliber, shape of firing pin impression, shape and orientation of breechface marks, and relative location of extractor and ejector marks. If the class characteristics of the two cartridge cases are not clearly different, the examination moves to a second stage using comparative microscopy.

Due to possible changes in firearm operating surfaces from wear, corrosion, damage, and differences in ammunition design and construction, cartridge cases fired in the same firearms are sometimes not identifiable as such. Additionally, some firearm manufacturing methods routinely produce working surfaces that leave limited microscopic marks of value on unfired cartridge cases.

Utilizing the various microscopic signatures created by a firearm during discharge, a forensic firearms examiner is charged with the task of comparing submitted bullets and ammunition components to each other, as well as to any number of firearms. Because a bullet, bullet jacket, or cartridge case cannot be directly compared to the rifling present in the barrel of a firearm or to the firearm's parts, the examiner will test-fire an incoming weapon into a water tank or cotton batting to produce known fired specimen bullets and cartridge cases for use in comparison with questioned (evidence) ammunition components. The capture medium slows a discharged bullet's flight with no damage or distortion to the projectile and the impressions it carries, thereby generating ideal samples for microscopic examination.

Following examination of case material, a firearms examiner will arrive at one of three conclusions: "identification," "exclusion," or "no conclusion." An "identification" signifies a match between two ammunition components or a match between an ammunition component and a firearm. An "exclusion" represents a nonmatch between the examined items of evidence—the possibility of an association between the items is excluded. "No conclusion" indicates that the ammunition components could neither be identified nor eliminated as having been fired by a particular weapon based on the quantity and quality of microscopic markings. In this instance the class characteristics of the evidence in question may agree, but the correspondence between individual characteristics or striations is insufficient or absent. This is not to say, however, that a given bullet could not have been fired by a submitted weapon or from the same firearm as another bullet, but rather that the markings present on the bullet are of insufficient character to draw any conclusion.

In instances of severe leading, mutilation, or corrosion of a recovered weapon, the unique microscopic markings normally present in the barrel and other portions of the firearm may be obscured or obliterated and thus may preclude identification. Conclusive identifications of bullets or other ammunition components are similarly impossible when the rifling impressions on these components match the rifling type of a given firearm but no other distinct, unique characteristics are present on the ammunition. In other words, a bullet may bear class characteristics like those produced by the barrel of a particular firearm model but may not be impressed with individual identifying characteristics to match it with a single specific firearm.

In addition to the preliminary examinations and research conducted by technicians and the microscopic analyses performed by examiners, evidence in the firearms/toolmarks section may undergo a variety of testing. Depending on the specifics of the case and the examinations requested by a contributor, an examiner-technician team might employ the following tests and procedures:

- Trigger pull tests, which determine the amount of force needed to discharge a firearm.
- Function tests, which determine whether a firearm is fully and normally operational in all its modes of fire and whether safeties are operating properly.

- Full-auto conversion tests, which determine whether a semi-automatic firearm has been modified to fire multiple rounds with a single trigger pull.
- Accidental discharge tests, which determine whether a firearm may fire without direct application of pressure on the trigger (e.g., drop from a height or an exposed hammer impact).
- Silencer testing, which determines whether certain muzzle attachments can be classified as sound suppressors.
- Gunshot residue examinations, which determine whether gunpowder or lead residues have been deposited on clothing and other items through physical and chemical examination.
- Shot pattern examinations, which assist in the determination of the distance of a shooter from a target through analysis of the change in spread of shot pellets following the discharge of a shotgun.
- Trajectory analysis examinations, which determine the angle and direction of fire and the location or positioning of a shooter through the geometric measurement and analysis of bullet holes.
- Serial number restorations, specialized toolmark examinations which assist in the observation of obliterated or altered serial number characters on firearms, vehicles, or other equipment through the application of chemical, thermal, and magnetic techniques to the altered surfaces.
- Toolmark examinations may also require an examiner to make casts of stamped numbers or impressions. These are made by creating a clay dam around the tool-marked area and pouring an epoxy or plastic casting material onto/into the isolated region. While some casts are made solely for reference purposes, the quality of detail obtained with this procedure is such that once the casting material has set and dried, it can be microscopically examined and compared with other toolmark casts and questioned tools.

TOOLMARKS

A toolmark is produced when two items, one not necessarily a tool, come into forcible contact with each other. Normally, one of the items is made of a material harder than the other, and when the two make contact, an abrasion and/or impression is left behind bearing microscopic marks suitable for comparison. Toolmarks are made by two distinct motions: impression and striation. Impression toolmarks occur when the tool comes into perpendicular contact with an object. The object is compressed and compacted or pushed out of the way. Striated toolmarks occur when the tool is moved across or through an item with enough force to produce scratch-type markings. Often, toolmarks are produced by the combination of the two motions and will exhibit microscopic characteristics of each.

Impression

Marks produced when a tool is placed against another object and enough force is applied to the tool so that it leaves an impression. The class characteristics (shape) can indicate the type of tool used to produce the mark. Examples include hammers, mallets, punches, number stamps, footwear, tire tread marks, etc.

Striation/Scraping

Marks produced when a tool is placed against another object and with pressure applied, the tool is moved across the object, producing a striated mark. *Friction marks, abrasion marks, and scratch marks* are terms commonly used when referring to striated marks. Examples include pry bars, chisels, screwdrivers, putty knives/scrapers, pliers, etc.

Toolmark examinations fall into two groups. The first group consists of those examinations where the investigator has no suspects and submits an item containing toolmarks for study to determine the type of tool used. Examinations of this type are based on a given tool type, which may leave characteristic impressions on an object upon which it was used. By measuring the size and noting the characteristic shape of the impression, as well as the nature of the material exhibiting the impression, identity of the type of tool involved may be determined. For example, an examination may reveal that a tool employing a cutting, shearing, pinching, or striking action was used: tools such as knives, razor blades, and axes may be said to employ a cutting action. Scissors and metal shears may be included in the types of tools employing a shearing action. Electrician's pliers and side-cutting pliers employ a pinching action. Hammers are included in the types of tools employing a striking action.

Pinching: Any opposed blade cutting tool, such as bolt cutters, wire cutters, etc.

Shearing: Any cutting tool where the blades bypass each other—one blade bites into the material being cut, while the other blade passes through when cutting, such as scissors, garden shears, etc.

Gripping: Any tool designed to grab an item with jaws for better leverage such as pliers, wrenches, vises, etc.

Single Blade/Slicing: A single-bladed tool can be a knife, axe, shovel, etc. Even multibladed tools will fall into this category if one of the blades is used independently from the others.

Fractures: Broken pieces of an item where a physical match of the items shows that these items were originally one continuous piece. Items can be compared based on surface characteristics (pattern, color), fracture topography (alignment of broken edges), and comparison of subcrystalline structure (material composition, wood grain). Examples include plastic car parts, paint chips, and broken glass.

Evidential toolmarks are primarily classified into two groups: general characteristics and individual characteristics. General characteristics are described as the class and subclass characteristics of the toolmark. General characteristics describe the type of action used to produce the toolmark and its dimensions. Class characteristics of a tool that are transferred within its toolmark become class characteristics of the toolmark. Individual characteristics are the unique microscopic striations found within the toolmark. It is these individual characteristics upon which identification is made.

Examination of this type will often aid in reducing the scope of the investigation by helping the investigator to eliminate certain tools, which may be recovered; eliminate certain suspects; or, in certain cases, through an analysis of the facts permit the investigator to close the investigation by showing the damage was accidentally produced rather than intentionally produced. For example, a macro/microscopic examination of a pair of wires believed to have been cut may show they broke apart because of stress or tension.

The second group of examinations consists of those where the toolmarks and tools are submitted for comparison and possible identification. Toolmark identification is like that employed in firearms comparisons. Just as guns leave their characteristic markings on bullets and cartridge cases fired in them, so, too, can tools often be identified as having produced an impression or set of markings on an object. Such identifications are based upon the accidental defects present in the striking force, cutting surface, or bite of the tool used. These defects may be produced in the manufacture of the tool as well as in the subsequent use of it.

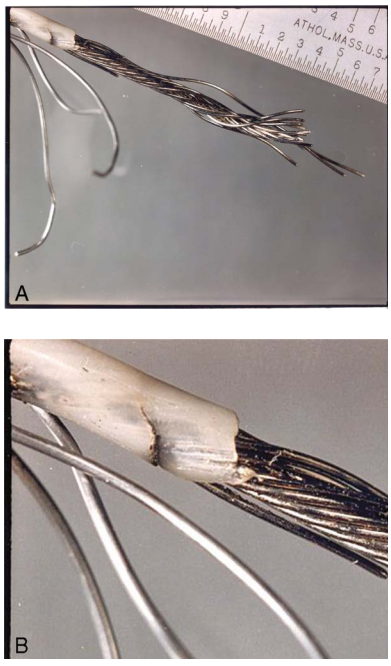


FIGURE 13.3 (a) Throttle cable with fractured ends. (b) From the upper left hand corner of 13-3a; what could have caused this damage to the insulation on the linkage cable?

(From Sandy Weiss/Packer Engineering.)



FIGURE 13.4 25× on film macrophotograph of wires from the throttle linkage of a small aircraft. The deformation on the individual cable ends show characteristics of a one-time ductile overload failure. No human would have had sufficient strength to pull the cable and fracture the wires in the manner documented. And the ductile fracture would not have been in evidence if the cable had failed in fatigue.

(From Sandy Weiss/Packer Engineering.)

The conclusions reached by examiners analyzing toolmark evidence are the same as those reached in firearms examinations: "identification," "exclusion," and "no conclusion." Regarding tools, "identification" signifies a match between two toolmarks or a match between a tool and evidence bearing toolmarks; "non-identification" denotes a lack of association between two items of evidence—the possibility that a tool produced a given mark or that the same tool produced two marks is excluded. A "no conclusion" result, as in the examination of firearms-related evidence, indicates insufficient corresponding microscopic characteristics and the consequent inability of the examiner to classify the evidence as either identification or exclusion.

NATIONAL INTEGRATED BALLISTIC INFORMATION NETWORK (NIBIN)

The newest technology is 3-D computer-based imaging. These database systems allow examiners across the country and throughout the world to compare and link evidence obtained during serial shooting investigations. After test-firing a weapon submitted as case evidence, an examiner or technician can digitally capture and store images of bullets and cartridge cases using the system. Operators can compare these images to thousands of other images of bullets and cartridge cases entered by category and classification into the database. "Hits" are made when a system

user finds a match between a specimen added into the database and a previously filed specimen. With 3-D imaging, crimes committed in one locale can be tied to crimes committed elsewhere, and investigators can access valuable forensic data.

PHOTOGRAPHY IN FIREARM AND TOOLMARK EXAMINATIONS

Photographic documentation is a very important process in any forensic procedure. Photography in firearm and toolmark (FATM) examinations has several specific demands. In the following topics there are tips and hints useful to the production of good-quality forensic photographs in the FATM field. It must be remembered, though, that the tips and hints are meant for the FATM expert when making his or her photographs in the lab or the field. In cases where the expert has the use of a forensic photographer untrained in the field of FATM, the expert in the field should work closely with the photographer to capture the images necessary to tell the WHOLE story of the case. It is unethical to not expose images of evidence that would be inconsistent with the story the evidence is trying to tell. As with any forensic investigation, NEVER go into the examination stage with a pre-existing idea of what was supposed to have happened.

Scales and How to Use Them

Perhaps the most important thing in forensic photography in general, and particularly in firearm examinations, is the use of a proper and convenient scale. Even a bad-quality photo with scale is better than a good-quality photo without one (within reason). Scales are used not only to determine the dimensions of the evidence but also the spatial relationship between several pieces of evidence in a crime scene and their mutual proportions. Basically, every time an evidence or crime scene photo is taken without scale and an accompanying image is not taken with scale, the expert is leaving information behind.

We will start with some bad examples, where the necessity of a scaled photo is exaggerated. An expert was asked for help identifying the caliber of a ricocheted bullet in a crime scene. He asked for a photo of the bullet and received the picture in Figure 13.5. It is out of focus, of low quality, and with poor lighting (more about this later). However, it could be useful had a proper scale been used. The lack of a scale rendered the photo essentially useless. It was taken solely for the caliber identification of the bullet. There is no way caliber can be determined from a scaleless photo.

Scales need to be correctly used to be useful. Positioning at right angles or in an orthogonal plane to the camera is a huge step in helping the examiner to later take measurements from the photo without much photogrammetric correction. In our example, the expert asked for a second photo, this time with better lighting and a scale.



FIGURE 13.5 An example of a forensic macrophoto lacking a scale.

(From M. Jost.)

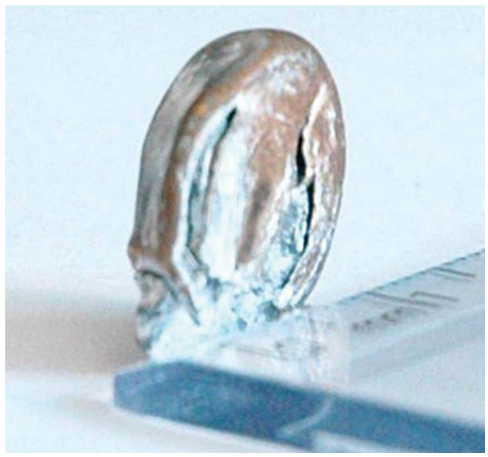


FIGURE 13.6 A poor use of a scale in a forensic photo.

(From M. Jost)

He received the photo in Figure 13.6. Although it is better lighted and a scale is present, the photo was taken from a very odd angle, and the scale is not able to provide any useful information except after extensive calculations. In other words, even with a scale, the photo does not provide useful information. A few months later it was found, when the bullet finally reached the expert, the caliber was a .380" auto.

NOTE:

In this text there are many references to making photos at a right angle to a subject. Other descriptions include perpendicular, at 90 degrees, orthogonal, vertical, plumb, straight-on, and normal.

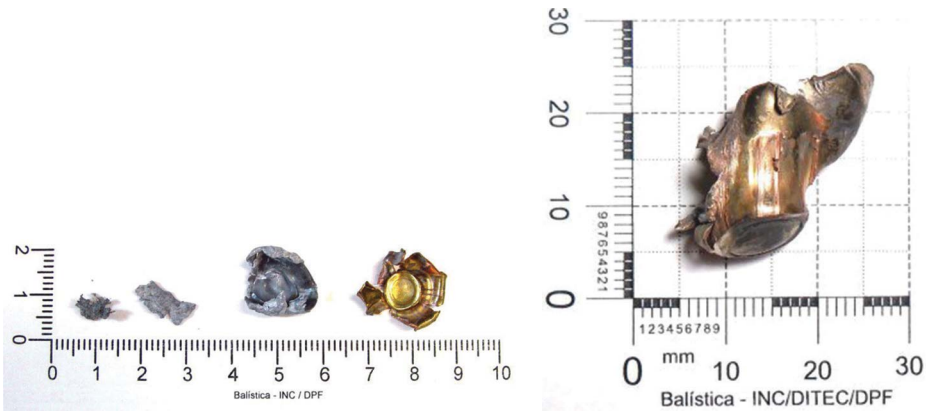


FIGURE 13.7 Related evidence in FATM examinations can be photographed together or alone. It is up to the expert to decide which way of documenting the evidence is better.

(From M. Jost.)

With that in mind, the tips for scale use in macrophotography are few and easy to follow:

1. Choose a scale graduated with increments useful to extract a good approximate size of the evidence.
2. Put the scale near the evidence or, better yet, if you can touch and move the evidence, rest the evidence on your scale. This works best if the evidence is relatively flat.
3. If the evidence is bulbous or has raised portions, it is best to raise the scale to a level where it is approximately halfway up the height of the material. This can be done by resting the scale atop washers or other solid items of the correct height and leaving enough space between the scale and the evidence to avoid one cutting off the other. Having the scale separate from the evidence also eliminates the need for images with and without scale.
4. High-magnification photographs will have increased distortion when the scale is in a different plane than the evidence.
5. Take the photos from above the scale and orthogonal/at right angles to it, so they are all framed with the scale and evidence correctly.

After choosing the proper scale, the expert can decide to put several pieces of evidence in the same photo or if it is better to take separate photos of each one. There are pros and cons on each process, and in the era of digital photography the expert can simply do both. The photos in Figure 13.7 show each case, first where several fragments of a single bullet were photographed together and another where one was photographed alone.

In both cases, the evidence was photographed with a scale. The second photo shows a more detailed scale, with several thin parallel lines in the X- and Y-axes that are very useful to measure tiny objects, such as fragments, gems, tiny components, and small evidentiary pieces. The grid can also identify lens distortion if the lines do not remain parallel across the image.

Many scales resemble a simple ruler. This allows the scale to be placed more conveniently when the evidence is larger or consists of several identical units. Later is a photo of magazines where this idea was applied. While the small scale fulfills its purpose, a larger scale would have been better in this instance.

Figure 13.9 shows a scaled photo of a plate from a ballistic vest. Sometimes you must pinpoint a feature in the evidence. This can be done by hand, as in the photo, or by something specifically made for this purpose, like paper or plastic arrows.



FIGURE 13.8 Sometimes the evidence is better photographed with a scale resembling a ruler, especially when one dimension is much more pronounced than the other, as with these pistol magazines.

(From M. Jost.)



FIGURE 13.9 Sometimes it is better to pinpoint what is important in the evidence with fingers than adding digital arrows afterwards. Paper arrows can be useful for this purpose.

(From M. Jost.)

It is better to do this directly with the evidence rather than adding something digitally afterwards. In the photo there were two bullet holes, indicated by pointing hands. There is a scale present, and the distance between the holes can be measured directly from the photo. The dimensions were measured directly from the plate, but the photo provides a means of repeating the process. This is a poor choice of scale and badly positioned relative to the size of the evidence.

Rulers can be used as scales, whether opaque or transparent, provided the numbers can be seen in the photographs and they are accurate. It is better to have a pair of scales to place at right angles in the image, so the expert has a way to extract information on both coordinate axes without much extra work. Foldable rulers used in masonry, in bright colors such as lemon green, orange, white, or yellow, may be preferable. They are inexpensive, can demonstrate a variety of lengths, and can be easily set to 90 degrees in any location or folded into squares and rectangles. All these features make them ideal field tools.

NOTE:

Calibrated scales or rulers are available and are generally more expensive than a standard ruler. Certified rules have a serial number and a certificate of calibration and state accuracy to within 0.005″ or better and follow American National Standards Institute (ANSI) or International Organization for Standardization (ISO) standards traceable to the National Institute of Standards and Technology (NIST). Commercially purchased scales and rulers should be compared to a certified scale by the vendor and the end user prior to use. The comparisons can be documented photographically and saved for later review. Scales or rulers that do not match up should not be accepted for use and should be destroyed.



FIGURE 13.10 A foldable masonry ruler is a very good instrument for instantly providing a convenient 1-D or 2-D scaling apparatus, as well as squares and rectangles to encompass many scaling needs of a FATM examiner. Yellow, orange, or lemon green rulers provide the best contrast.

(From M. Jost.)

TIP:

When placing two scales at right angles, the 90-degree angle can be confirmed by measuring the distance between 3 units on one scale and 4 units on the other. If the angle is correct, the distance should be exactly 5 units, thanks to Pythagoras ($a^2 + b^2 = c^2$ or $3^2 + 4^2 = 5^2$).

When using digital files with scales, for instance, a printed PDF file, the expert must double-check if the printed version has consistent and accurate measurements. Programs sometimes compress or enlarge the page so it fits onto another size of paper (i.e., A4 to letter or vice versa). This can distort the scales and print an inch scale that might be bigger or smaller than a real inch. Checking with a ruler solves the problem.

The only way an inch scale in an image can be an inch in dimension is if the photograph was exposed 1:1 and printed in such a way that the image is not spatially distorted. It is far easier to assume the sizes of the artifacts in the image are indeed distorted. If the artifacts are sized from the scale included in the image, only distortion in a direction not covered by an orthogonal scale is a worry. The circles on the axes of an American Board of Forensic Odontology (ABFO) and similar scales are useful in identifying and correcting perspective distortion.

One final question about scales: What must you do if you have nothing convenient to scale evidence? You improvise. Improvisation is better than nothing. Coins and national currency are good choices. They can be collected basically anywhere, are produced with high accuracy regarding dimensions, are opaque and unobtrusive, and can be chosen in several different sizes according to evidence size. Alternatively, the expert can pick anything else, provided he or she keeps what was used as a scale for later precise measurement: pens, pencils, pocketknives, bolts, ID, business or credit cards, etc. If the evidence is rather large, having a pocket foldable ruler, as noted earlier, or a measuring tape or big ruler would be a good choice.



FIGURE 13.11 A commercial pocket survey rod that pulls completely out of its plastic storage case is available in several measurement models.

(From M. Jost.)

Camera Stability

In the modern world of digital photography, camera stability should not be a problem but sometimes is. The main problem with stability arises when an existing-light picture is needed. Cameras and flash units will be discussed in detail in another chapter, but the expert must consider that very reflective surfaces on the evidence can blow out highlights that cannot be recovered with a digital editor. In these cases, a picture without flash must be taken, and for those, ideally a tripod should be used. If a tripod is not available, ideally the shutter speed should not be slower than one over the focal length of the lens (e.g., no slower than 1/60s with a 50 mm lens).

In the past, most tripods available were complex and heavy. Fortunately, they followed the advances of their digital imaging counterparts, and today's expert can find basically any tripod conceivable. For instance, a Gorilla Pod, which has magnetic feet, can hold basically any camera, exists in several different sizes, and can be contorted in any way the expert sees fit. It grips on branches, tubes, or whatever is available as an immovable base. Helping stabilize the camera is a good reason to always carry a portable, versatile, and light tripod. (Please see Chapter 4A for more information.)

In the absence of a tripod, however, the photographer can take other steps to improve the stability and enhance the sharpness of the images. One of the simplest ways is to brace the camera against a solid structure. Anything will do: a tree, a door, a chair, a table, a book, a car, or a wall. This way the expert can keep the camera relatively still while it exposes images. As mentioned elsewhere, increasing ISO will allow faster shutter speeds at the expense of image noise.

Framing, Focus, and Distance

Forensic photography is a means of documentation. Placing the evidence in the center of the photo is the accepted method of composition. The rule of thirds and the golden ratio of image composition must be put aside; the expert should concentrate on making sure what is important to show is in the center of the frame. This sounds easy, but sometimes it is not. If there are several important pieces of evidence making a dense cluster, especially in crime scenes, deciding how to document everything at once may be difficult. Making several overlapped photos could be a good solution in this case. Later it may be possible to digitally stitch together one larger image with all the elements put into one composition. In the FATM lab this is less of a problem because every single piece of evidence can be pictured alone.

Cameras with automatic focus are a big help in producing good-quality images of some subjects; but sometimes the focus system fixates on something slightly in front of or in the foreground of the evidence, making it difficult to focus exactly where needed. This is particularly true when imaging dark, round, perforated, or vertically lined surfaces. In these cases, some cameras have a half-pressed shutter release focus-locking function to hold the focus where the photographer wants while the camera is moved to a desired composition view. This can be used to place the plane of focus anywhere on the evidence. Holding the button half-pressed and then bringing the camera closer or farther from the evidence, until the focus is where it must be, is faster than switching the camera to manual focus. This could be used in situations where time or security is more important than consistent photographs. The results could be inaccurate, so several extra images should be captured to provide a higher probability of capturing exactly what the photographer is attempting to show. If time and/or security are not a problem, then perhaps putting the camera in manual focus would be the best solution. In this case, the expert has full control of the focusing process and having well-focused pictures should not be a problem.

TIP:

Just do not forget to put the camera back into autofocus after the assignment has been completed.

Sometimes the photographer can be working under one of two, or both, difficult lighting situations:

- If the ambient lighting of the shooting location is too dim to allow autofocus with the camera and supplementary lighting, like electronic flash, is not allowed or hazardous to use, a small flashlight can be shone on the evidence at an angle to show the most important areas.
- If the background on which the evidence is located has little or no pattern upon which the autofocus function of the camera may focus and the evidence is too small or irregular to allow the autofocus to lock in, manual focus and a supplemental light should be used.



FIGURE 13.12 A photo where the lens distortion was not corrected and could have been prevented by moving the camera away from the evidence and later cropping the photo.

(From M. Jost.)

Finally, there is the problem of the best distance, camera to subject, to expose the image of the evidence. Sometimes, to capture small detail which may require later software enhancement, the photographer should capture the image(s) as closely as possible to the evidence, filling the camera's frame. But poor lens choice may lead to distortion problems. Suddenly the shotgun once straight now appears to be slightly curved in the image. Distortion also leads to all sorts of difficulties with measurements taken from the images in the future. Figure 13.12 is an example of this problem. It was taken at a very close focal distance with a wide-angle lens. To eliminate distortion, the use of a normal lens, as defined elsewhere in this text, or a macro lens optimized for close-up use is critical.

The distortion effect can be more pronounced with some cameras/lenses than others. Depending on the size of the evidence, this method for exposing photographs may be more in the realm of macrophotography. In all aspects of this type of close-up exposures, the depth of field is very shallow. Close-range images may not show an entire subject with sharpness using one focus setting. One solution for these two situations might be quite simple:

- Move the camera away from the evidence, so the focal depth increases, and then zoom the lens to appear to bring the evidence closer.
- It is permissible to go as far from the evidence as the optical zoom can go and the camera can still focus. Remember, though, due to the rules of optics, the farther the camera is from the subject, the less inherent sharpness the figure will supply. This is because the farther away the camera is from the subject, the larger the pixels will be when visualizing a given area.
- Do not use a digital zoom feature, as once the maximum optical zoom is reached, the image is cropped in the camera to give the appearance of additional magnification with actual pixel size being increased.

By applying this zoom tip, you will still have evidence filling the camera frame, distortion will be reduced, and there is a good chance the entire evidence will be imaged in a single focal plane. While some editing software packages have a distortion correction tool, where the program makes the necessary corrections, if you can eliminate the distortion with your camera hardware, you will not need to waste time in the software.

Lights, Flashes, and Dispersed/Diffused Flashes

The purpose of this section is to provide some information on how to improve an evidence photo to be taken with or without flash in the lab.

The first option to be tested is:

1. Natural or supplemental dispersed/diffused lighting, which is present in most environments to some degree
   a. This kind of light source produces:
      i. Soft edges.
      ii. Casts less and softer shadows.
      iii. Illuminates the evidence in such a way that less editing may be necessary.
   b. The inconvenience of this method is:
      i. Sometimes the light intensity is insufficient and the shutter speed decreases to a point where blurred images result.
      ii. Sometimes, however, even with sufficient stabilization, the photos display poor quality due to JPG compression or insufficient sensor resolution. The use of a higher ISO, raw image format or exposure compensation likely offers a better solution.
      iii. An artificial light source or a flash is a final option.
   c. Another inconvenience to relying on ambient lighting is the fact that color temperature may not properly register with the camera.
      i. In this situation it is highly recommended to set the white balance in the camera to match the color temperature of the ambient illumination.
      ii. Remember to reset the color temperature of the sensor before you expose images under different lighting.

Light boxes allow reproducible illumination in both intensity and color. After a short period of experimentation, the expert can program their camera for the best interaction possible with the box. High-quality photos are taken easily, with results similar to each other, rendering precise photographic



FIGURE 13.13 If the physical lab structure allows for their use and the evidence is not too big, diffusing light boxes like the one pictured here come in multiple sizes and provide very good, all-around external illumination for evidence documentation. They are usually inexpensive, foldable, and unobtrusive when not in use, and some have their own power source and can be brought into the field.

(From M. Jost.)

documentation. Finally, different color backgrounds can be placed in the light box to enhance certain features of the evidence or for background erasing.

TIP:

It is always better to avoid background colors in the red group and/or other primaries. Many attorneys see red in photographs and refuse to allow them into evidence. Even though the primary colors are tempting to use for backgrounds, white, black, and neutral gray are always good choices. This is the same in any kind of macro-photography—the colors are boring but totally safe!

When a light box is not feasible or available, some sort of electronic flash must be used. Compact cameras usually have a small built-in flash. Reflex cameras have a hot shoe where different types of light devices can be attached. No matter the type or intensity, flashes are handy and sometimes the best option to illuminate the evidence. On the other hand, they can produce hard, high-contrast light that results in intense glare, shadows, and/or color shifts. The glare may occur in the exact spot that has something important to be seen. This is the primary reason to survey your exposures after the image is taken. If a highlight is included in an image that obscures an important aspect of the evidence, it should be retaken immediately. The necessity of a second photo session with that specific evidence is something that must be avoided and is usually impossible to arrange. Destructive testing of the evidence may be involved in the analysis and will permanently change its visual characteristics and render a reshoot impossible.

TIP:

When attaching a diffuser to the front of the flash, in situations when imaging larger pieces of evidence or where flash coverage needs to be increased, the flash power and aperture settings may need adjustment, or your images may be underexposed.

If glare from a camera flash is the problem, a simple shift in the camera-to-subject position may reduce and sometimes eliminate the hot spot. Since glare happens only when the flash's light is mirrored directly from the subject to the objective of the camera, capturing the image from another angle may cancel this effect. The examples pictured here and elsewhere in this book show this. They were taken with the same camera setups and at the same distance. However, the first picture was taken orthogonally to the evidence and the second one a bit off (~5 degrees) from that position. Notice how the glare almost vanished (see Figures 13.14 and 13.15). In rounded or curved surfaces, this trick is less efficient because there is always a part of the surface that points exactly back to the camera. Even then, it is worth trying to move the camera around to see how much improvement might be achieved.

TIP:

Do remember that if the camera is not orthogonal, the camera-to-subject distance for one part of the evidence will be slightly different from another. If a scale is in the photo, this difference will be evident when trying to read the scale accurately. As long as the angle is accounted for in the image notes, it can be fixed with software during image processing.

When the harsh direct flash glare cannot be eliminated, the best option is to disperse the light. There are several ways to achieve this. The simplest are commercially available devices attached directly in front of the flash. They often do a good job in rendering a more natural light than using the built-in flash alone and undiffused. More information can be found in Chapter 7.



FIGURE 13.14 Reflective surfaces, such as the stainless steel of this tool, produce a very harsh glare that obscures the surface of the evidence when photographed from directly above. A simple shift in the position of the camera solves this problem.

(From M. Jost.)



FIGURE 13.15 The same evidence as in the previous photo, now photographed from a small tilted angle from the vertical, presents no glare.

(From M. Jost.)

If a commercial device is not available, improvise. A piece of translucent plastic from a milk carton or similar object can be cut to size and used to disperse a flash. A single white sheet of paper like the one used in printers can be folded into most any shape to produce a good dispersive device. A bit of on-site experimentation can be done until the best setup is found. It is advisable to take several extra pictures with different setups and positions to ensure that a good image is captured.

The images in Figure 13.16 are examples of how effective this setup can be. They were taken with a very simple compact camera and one sheet of white paper as a diffuser. The subject was chosen as an example of what the expert often needs to capture: a polished stainless-steel scissor with matte black handles. It provides an ideal example of different surfaces with regard to the lighting.

The first photo was taken with a standard flash. Notice the glare in the polished metal surface extends to the background and the handles. Outside this glare area, the metal surface turns black, the shadows are very crisp and dark, and the whole image is difficult to balance with a photo editor. Some details in the pivot were lost in the glare. The correct dimensions of the handles are difficult to determine from the photograph because the shadows are nearly as dark as the black polymer handles themselves. The correct handle profile is difficult to determine, as they are indistinct from their shadows.



FIGURE 13.16 Evidence with different surfaces photographed without dispersing the flash. The glare in the center of the photo hides some areas of the object and should be avoided.

(From M. Jost.)



FIGURE 13.17 The same evidence photographed with a sheet of paper dispersing the flash. The overall result is better than bare light, but the angle of the scissor blades to the flash source now produces a long glare that should have vanished with the paper technique.

(From M. Jost.)

In Figure 13.17, the flash's light comes from the right to the left and is dispersed with a white paper held by hand in front of the light source. The paper does a fairly good job of dispersing the light, but the relative position of the scissors blades produces a significant glare now hiding detail in much of the metal surface instead of just a single reflective point. Considering this, the shadows are much softer, the metallic glare is not as harsh, the contrast in the handles is less pronounced, and the background shows no noticeable loss of detail. This image may be salvageable in a photo editor.

The third and final photo (Figure 13.18) shows why the photographer needs to do some experimentation when diffusing the flash. The camera used to create the images has a built-in offset flash relative to the lens's position. This is a very common feature in compact cameras. This may



FIGURE 13.18 Using the same paper diffusion system as the previous photo but rotating the camera 180 degrees (taking the photo upside down) has changed the angular relationship between the flash and the scissor blades, almost completely removing the glare. The expert should test different angles until the best photo is obtained.

(From M. Jost.)

not be a problem if the distance between the camera and the subject is large enough, but flash output may then be insufficient for proper subject exposure. In close-range photography, the asymmetrical light source may produce unexpected results.

Rotating the compact camera to capture an image upside down may make the dispersed flash light originate from the left instead of the right and make a significant difference in the results from the previous two images. The whole photograph has approximately the same level of illumination, and there is no obscuring glare making details more evident. This is perfectly workable material for the photo editor and should be the goal for every evidence photo.

As a final topic under the subject of lighting, it is sometimes necessary for the entire background to be removed in the digital editing phase. When required, the first and most important step is to select the background correctly. If the color of the background resembles the evidence in any way, the two will merge in the image, creating a difficult or impossible removal process. A smooth, preferably single-colored and visually different background should be used. Any hard shadow cast by the evidence onto the background will make the removal procedure more difficult. Therefore, it is good practice to reduce the shadow hardness. This is done using dispersed lighting and by increasing the distance between the evidence and the background. To increase the distance, standoffs are placed below the evidence with the intent that they do not appear in any photo. The images in Figure 13.19 show how simple the procedure can be.

While it is impossible to remove all shadows, the shadows in the photo in Figure 13.19 are very soft and there is a crisp edge between the evidence and the background. This makes the erasure procedure much easier. The distance between the evidence and the background was increased simply by laying the subject atop spent rifle cartridges, as shown in Figure 13.20.

Another process for imaging without shadows is to place the evidence onto a sheet of glass and suspend the glass sheet above the background with blocks or casings, as noted earlier. This may lead to minor reflections of the subject in the glass. A polarizing filter may be helpful in reducing glare or reflections.



FIGURE 13.19 Moving the evidence away from the background by even half an inch makes the shadows in the captured image more manageable.

(From M. Jost.)



FIGURE 13.20 To put a distance between the evidence and the background, anything that does not show in the final image can be used. In this case, the subject was placed on spent .223 REM cartridges to create a gap of almost 2 inches between the tool and the table. This makes the shadows much softer and easier to work with in a photo editor.

(From M. Jost.)

It is a good idea to keep sheets of glass on hand for these situations in sizes from 3 × 4 inches for things like bullets or casings up to 30 × 40 inches for long arms. With heavier subjects, the thickness of the glass must be increased. When the overall size and thickness of the glass increase, the color of the glass will become more noticeable in the final images. Also, with thicker glass, reflections can come from both faces of the material. It may be better to make a tabletop light box with daylight fluorescent or light-emitting diode (LED) illumination behind white plexiglass. Color-matched illumination or reflectors above the evidence may provide enough lighting. Experimentation is the best way to judge proper exposure.

TIP:

Never erase the images in the camera used to test the exposure. If images are missing in the final media submitted into evidence, it will raise red flags and cause unnecessary problems for the photographer!

Digital Editing for (Better) Presentation

Digitally enhanced photos are a logical next step for discussion after the original evidence photos are captured.

The first question is: Are digitally edited or enhanced photos in the report or the courtroom? Assuming the answer is "yes," the discussion here illustrates some ways of making changes to images to produce a higher-quality product. If the answer is "no," it becomes critical to be careful and thoughtful when exposing your original images of the evidence with the camera because your photos will be used as they were captured.

Before any thought of editing, it is critical to NEVER make changes to original camera images. Any changes to original images make it impossible to produce the image the way it was originally captured. In fact, it is crucial to adopt specific protocols, best practices, or standards for the downloading and processing of camera images to be followed with every active case. There is a chapter in this book

dealing with these types of handlings of image files, but in short:

1. After exposing all the images necessary to document your case, remove the memory media from the camera and place it into the proper container to send it to the image processing person or lab. if applicable, the photographer transfers copies of the images to the storage computer/server via a supplied cord or card reader.
   a. If possible, expose all the images for a given case on a single memory media.
   b. If there is no processing person or lab and you are both the photographer and the laboratory, it is less important to use a new media for each case. But a suitable way to differentiate between cases on the media itself must be set in your standard operating procedure (SOP) and followed.
   c. The simplest way is to use a new or freshly formatted memory card for each assignment and to photograph a card or sign before and after each case is completed. The card should contain pertinent case information, including:
      i. Name of the photographer, date of the project/case, and the case name or number.
      ii. Location or physical address of the assignment with images physically leading the viewer into the location. Whether the scene is indoors or outdoors, it is proper to capture street signs outside the location, roadways, alleys, doors, gates, and any possible means of egress or ingress to and from the scene to locate the images in space. This applies even where the camera records global positioning system (GPS) data on each image.
      iii. Someone should follow the photographer and record a log of the images as captured, or the photographer must create a log when back in the lab. It is more difficult and cumbersome to record the information in the field, but it is far easier than trying to remember what each image shows when reviewed.

TIP:

Consider using a tape or digital recorder while making the photographs to record your notes on the fly.

NOTE:

The camera brand and model, the lens brand and focal length, shutter speed, aperture, and ISO information will automatically be put into the EXIF data captured with the images.

2. Once the memory media is in the lab, the next step is to download the images onto a secure media—either a DVD or Blu-ray disc, or a dedicated computer system/server for the storage of original photo or video files.
   a. The transfer media must be something as close as can be to impossible to either delete the image files or in any way make changes. If using a DVD or similar media, record the serial number of the disk as part of the photo log file.
   b. All the written data from the ID cards at the beginning of each file on the memory media should be accessible when reviewing the images.
   c. Adding International Press Telecommunications Council (IPTC) data such as photographer, owner, and copyright information to the image file metadata during the transfer process is accepted practice and does not modify the actual image data. See Chapter 6 for further information.
3. Once the images from the camera have been successfully transferred onto secure media, it is okay to erase the original memory media and return it to the camera for the next use.
4. Only people with agency or firm approval have access to the saved files.
5. Duplicate disks may be created from the original for the use of investigators, report preparation, or court.
   a. Enhancement, enlargement, prints, crops, annotations, or other photographic processes can be done with copies of the image files as long as the process is repeatable and within the parameters of modern forensic applications.

Once the original files are stored securely, the original image files, if on a physical DVD or data disk, will never leave storage unless subpoenaed by the court. (See a discussion of an "original" file in Chapter 6.)

Special Topics in FATM Photography

Ballistic Comparison

There are three topics worthy of discussion here:

1. How to improve the quality of ballistic comparison photos from older microscopes
2. Capturing images of negative results
3. The importance of editing ballistic comparison photos to clarify the subject

Improving Photos from Older Microscopes

Most modern ballistic comparison microscopes come equipped with quality digital cameras. These cameras are

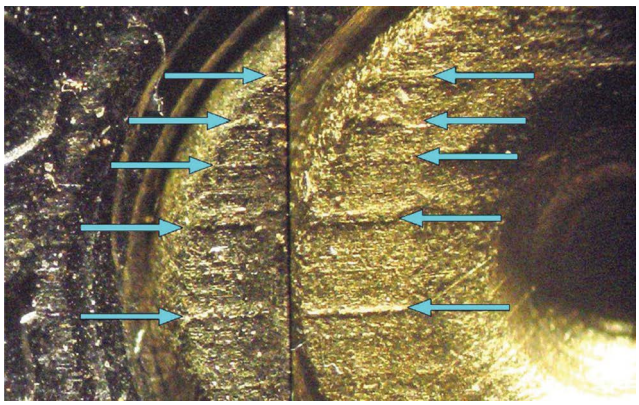


FIGURE 13.21 With older microscopes with poor (by 2018 standards) digital cameras or none, taking photographs through the ocular lens with a compact camera or cellphone can be a simple and low-cost solution. The image here shows an acceptable image of a positive comparison captured with a 5 MP compact camera. Current compact cameras and cellphone cameras in the 16 MP resolution range may capture even finer photos.

(From M. Jost.)

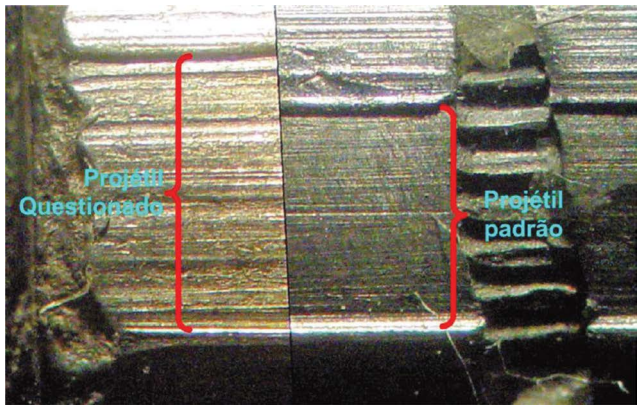


FIGURE 13.22 One of the only cases where a negative result in ballistic comparison is worth illustrating is when the bullets display different class rifling marks. In this case, many potential subject firearms might be eliminated from the crime scene investigation. Moreover, when a pair of rifling marks is photographed, there is the possibility of determining the twist rate between lands and grooves, which then provides information relative to the firearm manufacturer and model, potentially helping an investigation.

(From M. Jost.)

usually integrated with software that, within certain parameters, images captured with the microscope (including in between magnification and objective number) will provide a series of measurements from the subject evidence. For these, no special procedure is necessary when capturing images.

Older comparison microscopes with perfectly fine optics are still completely functional but have lesser-quality digital cameras (VGA output or lower) or have no digital cameras with no possibility of attaching one. The solution is simply to capture images through the ocular lens with a specialized digital camera. The focal distance of the ocular lens is like those used by cellphone cameras, so it is a matter of making the comparison by eye, choosing the best image, placing it in the middle of the microscope field, and then making an image through the ocular lens. Experimentation with the camera or cellphone allows the expert to pick the best combination of microscope magnification, camera position, and zooming to achieve the best result. The procedure is a straightforward and inexpensive solution to a difficult documentation problem.

Photos from Negative Results

When the ballistic comparison provides a negative result and the class characteristics are identical, it is usually pointless to capture microscopic images of the evidence against samples, especially with bullets. When the class characteristics are different, it may be useful to capture images illustrating how different they really are. Such photos provide a shortcut in any explanation of how different the actual evidence was from the samples. The photo in Figure 13.22 illustrates an example of where the class markings are different.

Editing Ballistic Comparison Photographs

Ballistic comparison examinations may sometimes produce cryptic photographic results. The field of view in the microscope is wider than the images presented in a report, and the expert can see much more than they were capable of imaging. When the expert has a certain amount of experience, he or she can easily see why a given photo is a positive comparison and why another is not. The public for whom the expert produces the photography does not have access to a microscope and lacks expertise in the subject; therefore, the public may not understand the information provided by the photos the expert may include in a report. The expert should strive toward instructive and convenient additions in the comparison photos so that the positive result is clearly shown and the result of the examination is clearly understood. For instance, the photo in Figure 13.23 shows positive results for breechmark comparisons on the bases of two cartridge cases. These are quite strong and provide convincing evidence to any FATM examiner.

However, after a simple graphic addition (Figure 13.24), the information is now clearer to a wider audience, despite being technically the same as before. Now the evidence is instructionally displayed in the photo, and the public can appreciate the information.

When the impression marks are scattered across the surface of the evidence, the editing process might be even more important and, hopefully, convincing. The photo in Figure 13.25 is one example where the expert needed extra time and study to understand why the marks provide a positive result. The circles and arrows, placed in the same

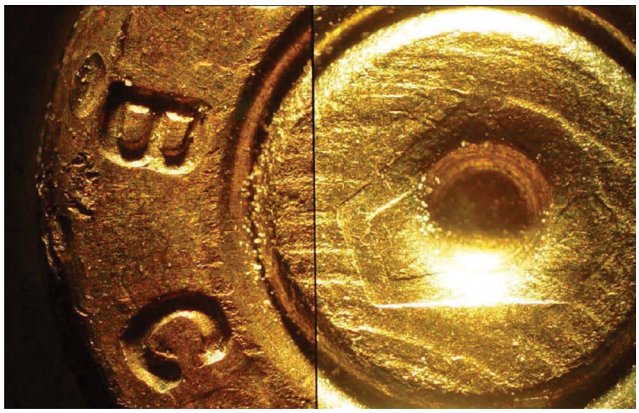


FIGURE 13.23 A positive ballistic comparison is shown. Since there are no indications about what evidence has led the expert to a positive conclusion, the picture does not fully inform the intended audience.

(From M. Jost.)



FIGURE 13.25 Where tiny impression marks are scattered about the surface of the evidence, it is even more important to pinpoint the positive result of the ballistic comparison. In the photo here, even an expert would take some time to find the positive correlations if they were not already identified and marked.

(From M. Jost.)

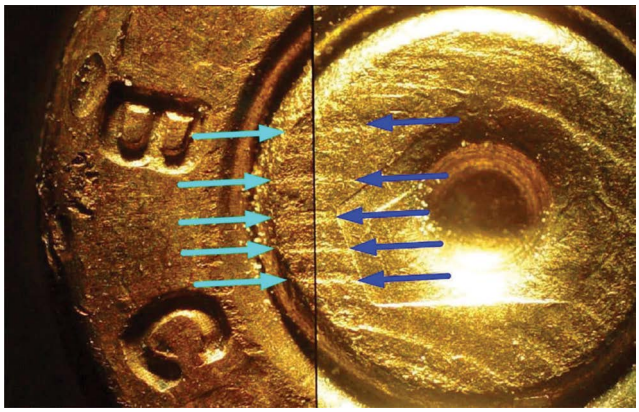


FIGURE 13.24 The same photo was digitally edited and now clearly indicates the breech impression marks that provided the evidence for the expert. This second photo can transmit the information found by the expert more clearly, reaching a broader audience.

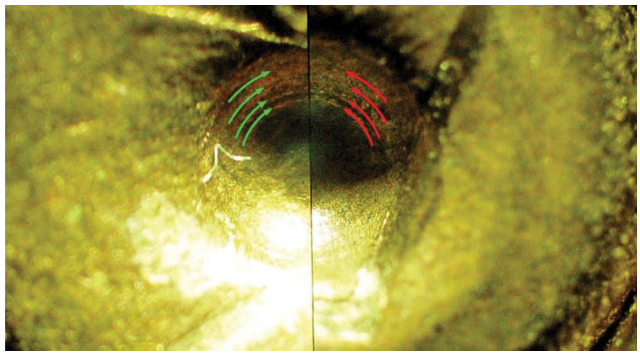


FIGURE 13.26 Firing pin markings are particularly difficult to photograph. When a report pivots around these markings, it is useful to edit the photos to visually aid toward a positive comparison.

(From M. Jost.)

relative locations and in the same orientation, help pass a clear message indicating the markings are the same on both casings.

When the result of the examination is due to firing pin marks, sometimes editing is very important, as in the photo in Figure 13.26, as these markings are usually very thin and difficult to photograph.

Even though the editing process can be more useful with impression marks than striation marks, striation marks in evidence may also benefit from editing. These photos are examples of such editing, showing the rifling marks on bullets (Figures 13.27 and 13.28).

For clarity of reporting, it may be best to include both the original and the edited images.

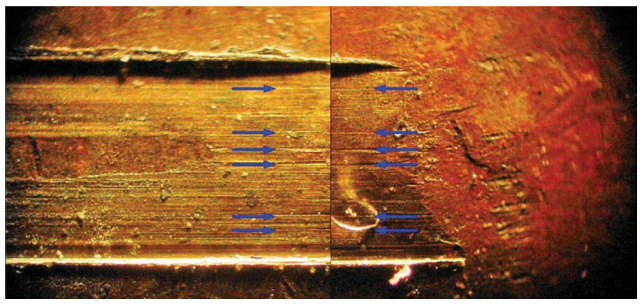


FIGURE 13.27 Although positive comparison with bullets is sometimes easier to illustrate as being positive, the stronger markings may enhance a report.

(From M. Jost.)

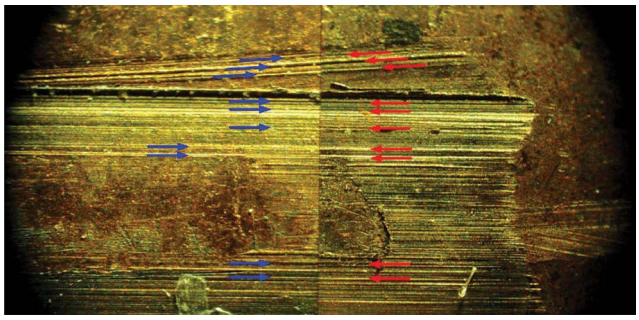


FIGURE 13.28 If a certain number of markings must be found and shown to indicate probable and reproduceable results in discussions, a large number may be shown.

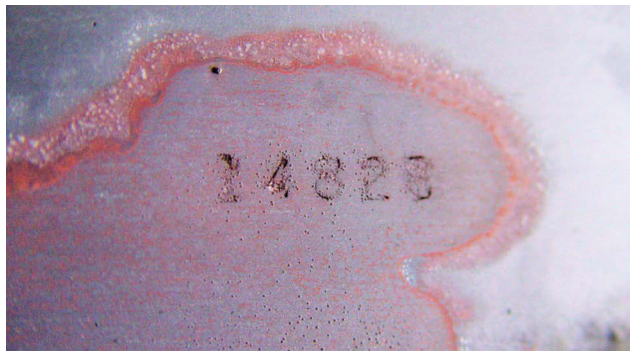


FIGURE 13.29 Serial number restoration imaged with the pickling solution still on the surface.

(From M. Jost.)

Serial Number Restoration

Photographic documentation of a serial number restoration process may be of extreme importance. Due to the chemistry used in this technique, the number restoration might be a temporary event, and the photographs exposed when the numbers are visible might be the only evidence of their existence.

The whole procedure of restoration should be documented, not only a final image, because the punching of the original numbers might differ in pressure from one number to the next, and this might result in the numbers being restored in different moments of the restoration procedure. For those firearms with the same serial number punched in different places, the whole sequence may not be revealed and can only be derived from series fragments obtained in different locations on the firearm.

Making quality images of serial number restorations is sometimes very difficult and frustrating. The human eye is often able to perceive nuances of color and shadow, very common in number restorations, but the camera finds it difficult due to dynamic range limitations. One thing is certain: if the numbers are visible, even for a brief time, the forensic photographer must be ready and able to expose images clearly showing the markings. What the eye can see, the camera can see, if the photographer has the talent and equipment.

Drying the surface to provide better results may worsen the problem. The interaction between a corroded metallic surface and the liquid layer above it intensifies the restored numbers, and the first photos should always be made with a liquid on the subject numbers. Gently removing the pickling solution from the metal surface and then rewetting it with water or oil may provide useful results. The restored numbers are usually very light and may demand some photographic ingenuity from the expert. The images in Figures 13.29 and 13.30 show different photographs taken from the same restoration process with different products on the metal surface, trying to discover the best combination of surface to liquid to produce the best report image. The first photo was taken with the pickling solution still on the surface.



FIGURE 13.30 Serial number restoration imaged after the pickling solution was removed and a few drops of water were dropped onto the surface. The brown color is due to the deposition of iron hydroxide. If the surface is lightly rubbed, this hydroxide may deposit itself in the corroded numbers, improving the contrast necessary for better photographs.

(From M. Jost.)

Next, the pickling solution was then removed, the surface lightly dabbed with paper towel, and a few drops of water added onto the surface. The water may accelerate the oxidation process at the surface, causing precipitating iron ions as iron hydroxide. This gives the brown tint to the photo in Figure 13.30. Since the iron hydroxide also deposits itself into the more deeply corroded numbers, it makes them darker than their surroundings. It may be a good idea to clean the pickled surface, add some water, and lightly rub it with a finger to augment the contrast between a number and the surface near it. The better the contrast appears, the better the photograph will be. The image in Figure 13.30 shows the surface after this rubbing procedure.

The surface was then cleaned with a paper towel and oil was sprayed onto it, resulting in the final photograph, which was used in the report (Figure 13.31).

When there are various serial numbers to restore on the same weapon, they can be used for cross-verifications, as in



FIGURE 13.31 Serial number restoration captured after the water was removed, the surface lightly rubbed with paper towel, and then wetted with transparent lubricant oil (WD-40). Dry surfaces do not often provide good photographs; therefore, taking the photographs with a wetted surface with pickling solution, water, or oil is often the best practice. In the case here, the contrast provided by the iron hydroxide inside the corroded numbers plus the oil on top provided the best overall image and the one used in the report.

(From M. Jost.)

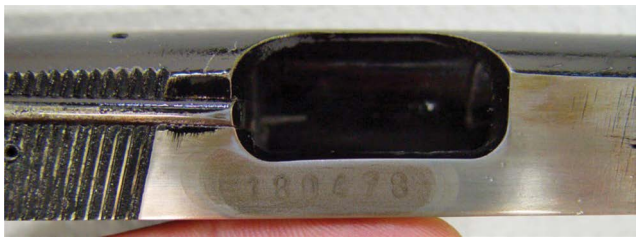


FIGURE 13.32 Serial number restoration done in the slide of a pistol. Notice the surface shining with oil. The numbers in this case were identical to the ones found on the barrel (see Figure 13.33), providing cross-reference evidence that both parts were from the same weapon.

(From M. Jost.)

the photos in Figure 13.32, taken from the serial numbers restored in the ejection port and slide of a pistol.

This process may be especially useful when none of the restoration sites provide the whole serial number, as in the photo in Figure 13.34. In this case, the assembly of the complete serial number was only possible after comparing and correlating the different number sequences in different locations on the pistol. The restored serial number on the slide is very light.

Depending on the way the original numbers were removed, sometimes it is only possible to produce a very light restoration. These are the worst-case scenarios in this kind of photography, as can be seen in the photos in Figure 13.35.

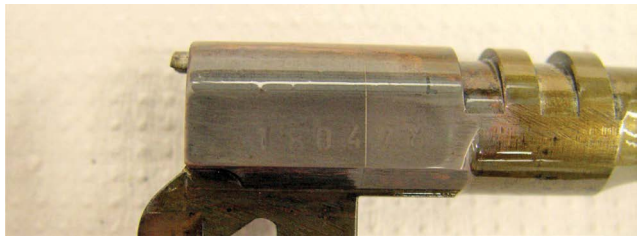


FIGURE 13.33 Serial number restoration done on the barrel of a pistol. Although lighter than the ones found on the slide, the numbers are the same.

(From M. Jost.)



FIGURE 13.34 None of the serial number restoration sites on this Glock could reveal the complete serial number. However, they were complementary and together were able to provide the complete sequence.

(From M. Jost.)



FIGURE 13.35 When the serial number removal procedure is more aggressive, sometimes the restoration process shows very light numbers, which are very difficult to photograph. In the case here, the numbers were ground off with a portable angle grinder. The depth of grinding and heat were such that only very light numbers were able to be restored (see Figure 13.36).

(From M. Jost.)



FIGURE 13.36 The restoration procedure on the gun in Figure 13.35 showing very light numbers.

(From M. Jost.)

FURTHER READING

Arrowood, M.C. (1992). *Toolmark Identification: Back to the Basics*, *Association of Firearm and Toolmark Examiners Journal*, Vol. 25, No. 3, pp. 197–198.

Arrowood, M.C., and Berglund, J. (1976). *Toolmark Identification in a Unique Shooting Case*, *Association of Firearm and Toolmark Examiners Journal*, Vol. 8, No. 2, p. 83.

Association of Firearm and Toolmark Examiners. (1986). *Association of Firearm and Toolmark Examiners Quality Assurance Program*, *Association of Firearm and Toolmark Examiners Journal*, Vol. 18, No. 3, p. 10.

Federal Bureau of Investigation (1988). *Firearms Toolmarks Unit Publication*, pp. 1–11.

Federal Bureau of Investigation (1958 [revised 1981]). *Firearms Training; Firearms* Toolmarks Unit Publication, pp. 1–10.

Federal Bureau of Investigation. (1950 [revised 1980]). *FBI Laboratory Makes Toolmark Examinations*, Firearms Toolmarks Unit Publication, pp. 1–6.

Gibson, W.M. (2001). *Toolmark Index Update*: *Association of Firearm and Toolmark Examiners Journal*, Vol. 33, No. 4, pp. 366–372.

Stone, R.S. (2003). *How Unique Are Impressed Toolmarks? Association of Firearm and Toolmark Examiners Journal*, Vol. 35, No. 4, pp. 376–383.

Thompson, E. (1998). *Individual Characteristics Criteria*, *Association of Firearm and Toolmark Examiners Journal*, Vol. 30, No. 2, pp. 276–279.

CASE STUDY 13.1: THE BOOTH DERRINGER

"A Genuine Artifact"

Carlo J. Rosati

The events surrounding the first assassination of an American president are extensively chronicled with regard to the cast of characters, social and political repercussions, and ultimate resolution, particularly as Lincoln's death occurred in the direct aftermath of the nation's greatest schism and would be a far-reaching factor in the future course of history. In the midst of these volumes of materials treating the Lincoln assassination, the focus of this section is not on the motives of John Wilkes Booth or on the response of the American people to the death of President Abraham Lincoln in Washington, DC, on April 15, 1865, but rather on the weapon that created the fatal ripple which is known as the Booth Derringer.

It was in 1806 that Henry Deringer Jr. established his firearms factory in Philadelphia, Pennsylvania, and began the manufacture of flintlock pistols, muskets, and later, percussion rifles for the U.S. Army. Though initially recognized as a supplier of long arms, Deringer gained renown with the production of percussion dueling pistols, which first appeared in 1825 and were primarily sought by military officers and political officials. The manufacture of a smaller version of the dueling pistol in the late 1840s and the pocket pistol in the early 1850s solidified Deringer's position as a manufacturer of quality firearms, all of which were handmade to order.

Notably, the use of the noun *Derringer* refers to a handgun manufactured by Henry Deringer, whereas the use of the noun derringer (sometimes spelled *deringer*) refers to a small pocket handgun of any make. Though seemingly redundant, the expression "a derringer" would accurately describe a concealable handgun manufactured by Henry Deringer.

The Derringer pocket pistol achieved its greatest popularity during the mid-1850s and was a favorite of civilians seeking a compact, easily concealed firearm for use in personal defense. Although the Derringer was somewhat limited by its single-shot capacity, its light weight and small size gave it a distinct advantage over bulkier, nonconcealable alternatives, and the limitations of its firing capacity could be circumvented by carrying two pistols, which were sold as pairs for approximately $25 in that time period. The Derringer pistol's success and infamy as a deadly weapon are apparent in the association with a number of prominent California murders, as well as its later use in the assassination of President Lincoln. The Lincoln homicide later ensured the permanent notoriety of the Derringer while simultaneously finalizing the incorporation of the word "derringer" into the American lexicon as a common noun denoting a concealable, short-barreled handgun.

Some copies of the Derringer can be distinguished from the genuine firearms by their solid steel barrels. Other copies, specifically those produced by Slotter

and Company, are identical in design, and the trademark stamp to the genuine Derringer's is too exact to be told apart from these.

A Derringer is typified by its small size and short-barrel, single-action percussion design. The barrel of this firearm can range in length from less than 1 inch to 4 or more inches and is made from wrought iron browned with a chemical solution that imparts copper-colored streaks to the barrel. Partially round and partially octagonal, the Derringer barrel is flattened and slotted on top to accept a blade-style front sight and is rifled with seven grooves, right twist. The grooves are beveled at the mouth of the barrel, and caliber varies from .33 to .51 inches. General attributes of a typical Derringer include a black walnut stock with a checkered grip, a checkered hammer thumb piece, and an S-shaped trigger guard. The mountings of the pistol are of engraved German silver; some specimens bear gold or gold-plated mountings. All mountings are attached to the stock with pins, with the exception of the side-plates and butt-plate, which are fixed with bolts or screws. The lock-plate and barrel are stamped with the trademark DERRINGER PHILADELA (on separate lines) and may bear an additional stamping on the top of the barrel indicating an agent's name and address. No serial numbers are present, but letters or digits may be stamped or punched on various parts of the pistol (e.g., barrel, lock-plate, breech-plug, wedge, and trigger) for use during assembly. The overall length of the Derringer pistols ranges from 3¾ to 9 inches.

The Civil War and the advent of breech-loading firearms and self-contained cartridges sharply declined the demand for Derringer pistols and other percussion weapons. In addition to its pending obsolescence as a percussion device, the Derringer's nonmartial status was underscored by the lack of a standardized caliber among handguns of its make. Because each paired set of Derringer pistols included a bullet mold specific to the caliber of the two matching pistols, loss of this mold virtually precluded the proper fit of ammunition for the paired set. The pre-war focus on definitively military weapons obviated the inadequacy of the Derringer pistols on the battlefield, and sales of the firearm during the war were low. Following the death of Henry Derringer in 1868, the market for pocket pistols opened to competitors eager to apply the breech-loading system to a concealable weapon.

However, many of the Derringer pistols were sold. One such owner was John Wilkes Booth. A man of means and one of the wealthiest actors of his era, John Wilkes Booth owned a silver-inlaid pocket Derringer. Five days after Confederate General Robert E. Lee surrendered to Union General Ulysses S. Grant at McLean's Courthouse in Appomattox, Virginia, John Wilkes Booth achieved historical immortality by firing one shot that claimed the life of President Abraham Lincoln. On April 14, 1865, the president, Mary Todd Lincoln, Major Henry Reed Rathbone, Rathbone's fiancée Clara Harris, and Rathbone's stepsister attended the performance of *Our American Cousin*, a play showing at Ford's Theatre in Washington, DC. At approximately 10:15 p.m., John Wilkes Booth made his way to the state box occupied by the president and his companions, entered the sitting area unchallenged, and, pointing the muzzle of his Derringer at the back of Abraham Lincoln's head, fired a single shot. The lead ball projectile entered the president's skull behind his left ear, creating a wound cavity through the brain and coming to rest behind the right eye. During the ensuing chaos, Booth dropped or threw down the Derringer, stabbed Major Rathbone in the arm with a 7¼-inch-long knife, vaulted over the railing of the state box to the stage, and escaped through the back of the theater to his horse. Though having broken the fibula of his left leg during his leap to the stage, Booth was otherwise uninjured and rode unpursued from the scene of the crime.

Abraham Lincoln was carried from Ford's Theatre on E Street to Petersen's House, a collection of boarding rooms located across the street from the theater. Surrounded by his family and political colleagues, Lincoln passed on the morning of April 15, 1865, approximately nine hours after receiving the fatal gunshot wound.

Of course, a number of artifacts related to this event in American history were recovered from various locations. Among them, the Derringer that Booth utilized to assassinate the president was recovered on the floor of the presidential box at the scene of the crime by a newspaper reporter covering the story. The lead projectile and several skull fragments were recovered by a local physician. For years after the assassination these artifacts and others were maintained by the War Department until 1940, when they were offered to the Department of the Interior. The Department of the Interior decided to display the Booth's Derringer, knife, and other artifacts related to the assassination at Ford's Theater, which is governed by the United States National Park Service. Artifacts such as the lead ball projectile and skull fragments were deemed to be too gruesome to be on display for the public at the Ford's Theater site and were kept from the public for some time. In 1956 they were returned to the army and are now on public display at the Armed Forces Institute of Pathology Museum in Washington, DC.

One hundred and thirty-two years after the death of Lincoln, the Booth Derringer was again an item of

interest in Washington, DC. In June 1997, the United States Park Police and the United States National Park Service contacted the FBI with a request for assistance in the examination of the Derringer used by John Wilkes Booth to ascertain beyond a reasonable doubt the authenticity of the exhibit. The authenticity of the Derringer, which had been displayed at the Ford's Theatre National Historic Site in Washington, DC, was drawn into question by officers who investigated a complex burglary ring that operated throughout the northeastern United States in the late 1960s through 1980s.

Officers discovered an informant, who told the story that while cleaning out his deceased mother's home he found some items he suspected were stolen. His brother was a member of the burglary ring, which had traveled to various museums along the Northeast stealing artifacts and sometimes replacing them with duplicates. According to this source one such item replaced was the original Booth Derringer in the late 1960s with a replica.

The officers questioned the incarcerated burglar, who insisted his story was true. His statement raised questions over a Derringer that some were laying claim to as being the Booth Derringer. Members of this burglary ring had allegedly replaced the original Booth Derringer with a replica in the late 1960s, at which time the security system in place at Ford's Theatre was much less sophisticated than that used today. Curatorial records of the Booth Derringer were unable to resolve the issue of authenticity. So, the United States Park Police and the United States National Park Service took the claim within the interest of national integrity.

The FBI laboratory was subsequently contacted to ascertain if a determination could be made to answer questions about this artifact. Carlo J. Rosati of the FBI Laboratory's Firearms-Toolmarks Unit was assigned to determine beyond a reasonable doubt whether the Derringer displayed at Ford's Theatre is the same Derringer pictured in historical photographs predating the late 1960s. Rosati headed a team of forensic specialists that included Charles S. DeFrance, Michael Van Arsdale from the Firearms/Toolmarks Unit (FTU), George Skaluba, William Peters, and George Savastano of the Special Photographic Unit. On July 28, 1997, the Booth Derringer was removed from its case in Ford's Theatre by Suzanne Kelley, United States National Park Service, and Captain William Lynch, United States Park Police, and hand-carried down 10th Street to the steps of the J. Edgar Hoover building where Carlo J. Rosati received the Derringer for examination.

Once in the possession of the FBI team, the Booth Derringer became the subject of a series of physical examinations that had not been conducted before. The FBI laboratory's Special Photographic Unit was requested to produce photographic superimpositions using the Booth Derringer and images of the pistol predating the 1960s.

The lead bullet extracted from Lincoln's brain during autopsy has been maintained by the Armed Forces Institute of Pathology as an exhibit that also features the skull fragments removed from President Lincoln during the probing of the wound by local physicians. The FBI FTU team traveled to the Armed Forces Institute of Pathology Museum to examine the lead ball projectile recovered from the skull of President Lincoln to ascertain if traditional firearms examinations were suitable.

This bullet had been previously reexamined on April 6, 1971, by Major John T. Legowik. It was noted that the surface was badly corroded and discolored. At this time the bullet weighed 97.44 grains. The examination conducted on July 2, 1997, found that the lead ball is now encapsulated in a clear plastic material to prevent additional oxidation. Although this encapsulation helps to preserve this artifact, it also prevented a more detailed examination of the specimen by Rosati. A microscopic examination determined this projectile lacks microscopic marks of value for comparison purposes. This is due to what appears to be lead carbonate and cement-like material on the surface of the bullet. It was noted in the 1971 report that a small hole was observed and is believed to represent a hole drilled to mount the bullet in the past. The examination conducted in 1997 agreed with Legowik's finding. In 1971 it was reported that the bullet is made of lead, not from Britannia bullion. A precise measurement of the encapsulated bullet could not be conducted, and the bullet was deformed, so the exact determination of the caliber could not be determined. The bullet is consistent with a .41 caliber lead ball, which was utilized in .44 caliber Derringers. These lead balls could be loaded into the Derringer with or without a tin cloth patch.

Returning to the FBI laboratory, Rosati conducted a series of physical examinations of the Booth Derringer. The specimen is depicted as a single-shot, muzzle-loading, percussion-cap-fired Derringer manufactured by/for the Henry Derringer Company of Philadelphia, Pennsylvania. Characteristics and markings included but were not limited to the black walnut stock with checkering, "S"-shaped trigger guard, hammer, and scroll work on the side-plates as well as the butt-plate, stock tip, wedge-plates, front sight, escutcheon, and flash-plate. The lock-plate and top of the breech plug each bear the trademark "Derringer Philadela." The letter "P" is stamped inside a sunburst as a proof mark on the left flat of the breech plug between two bands of

gold. The barrel itself is octagonal on the upper portion and round on the lower portion. Rosati's examinations characterized the Derringer with regard to all derringers of similar size and caliber. Measurements were made of the Derringer's overall length and height. In addition to the morphological examinations conducted by Rosati, which included standard forensic measurements, the FTU team made a cast of the interior of the barrel.

Utilizing dental casting material, the interior of the barrel, breech plug, and flash port were cast for examination and historic significance. From this cast the examination conducted determined that the barrel is rifled with seven grooves, left twist. This was determined to be in conflict with the printed literature, which states that the Derringers were produced with seven grooves, right twist. Various measurements from the derringer and the barrel cast were noted and included in the laboratory report.

Additional examinations included the Derringer being compared to the photographs supplied by the United States National Park Service. Having the Special Photographic Unit photograph the Derringer and produce prints and transparencies allowed Skaluba and Rosati to conduct overlaying examinations. Several differences stand out from the early photographs and the Derringer examined. In the photographs showing the right side of the Derringer, it is clearly evident that the hammer screw is missing, the stock is cracked, and a small piece of wood is missing, as are the gold nails that would hold the wedge plate attached to the stock. The screw used for replacement of the hammer screw is the wrong type of screw utilized by Henry Derringer Jr. when this Derringer was manufactured. The screw that should have been used would most likely have been a smaller head or a starburst head, as found on the left side of the Derringer. However, these differences are documented by the United States National Park Service as repairs to ensure the artifact's longevity. It was also noted that the left-side wedge-plate is missing from the Derringer, which is documented by early photographs of the Derringer.

Rosati and Skaluba compared the Derringer to several identifying characteristics that were noted. The Derringer's stock exhibits individual characteristics in the wood grain, which when compared through the overlaying examinations matched in size, shape, and direction (X, Y, and Z). Additional examinations noted impression toolmarks and cracks that were also present, including the S-shaped curved mark in the metal of the barrel, as well as impression marks, nicks, and scratches on several parts of the Derringer.

Through the use of overlaying forensic photographic examinations conducted in the FBI laboratory, Rosati and Skaluba rendered a conclusion that determined the Derringer currently on display in Ford's Theatre was the firearm depicted in previous photographs well before the date in question. This conclusion allows one to reach an additional conclusion which is beyond a reasonable doubt that this Derringer, which has been documented as in the control of the War Department or the National Park Service, was the Derringer used by John Wilkes Booth to assassinate President Abraham Lincoln on April 14, 1865.

Upon completion of the requested examinations, the Booth Derringer and photographs were returned to the United States National Park Service. In addition to the items supplied for examination, Rosati forwarded the complete cast of the interior of the barrel, breech plug, and flash port produced in the laboratory, as well as a set of photographs produced by the Special Photographic Unit. Rosati later supplied the National Park Service with a set of photographs documenting the examinations conducted in the FBI FTU.

Some historians and skeptics have asked questions for years and will continue to raise issues concerning this Derringer. The first of these concerns the distinguishing crack present in the stock of the Derringer, which most historians believe occurred when Booth dropped the Derringer to the floor in the state box after shooting President Lincoln. However, no one knows the history of the damage to the Derringer before or during Booth's ownership. The photographs predating the restoration of the Booth Derringer depict a damaged firearm. The Derringer exhibits nicks and scratches in the barrel, a cracked stock, a missing wedge-plate, and a sheared-off hammer screw. Perhaps an alternative theory asserts that the evidence predated the assassination and may actually have occurred while Booth, an avid horseman, was riding through Washington, DC, or some other city. The fall of the Derringer to a cobbled or brick-paved street from the pocket of a man on horseback would have involved a force capable of damaging the firearm in such a fashion.

Derringer pistols were distributed as a single items or in matched pairs, which sold for approximately $25 during the 1860s. These matched pairs were custom-made, high-quality firearms that often bore gold and silver inlays. Booth, as a prominent actor of his era, was a well-dressed man of means who would have been able to afford a set of derringers of the quality associated with the Derringer name. It is well documented that Booth did own at least one other Derringer, which is of a different design from the one Booth used to assassinate President Lincoln.

On April 15, 1865, somewhere backstage at Ford's Theater, a carpenter named James J. Gifford found

a second small Derringer, which when he examined it, he saw the engraved name J. Wilkes Booth on the butt-plate. Some have speculated that this was the Derringer that killed President Lincoln. However, that is highly unlikely. The second Derringer was recovered from the stage floor, unlike the first Booth Derringer, which was recovered from the floor of the presidential box where the fatal shooting occurred. Booth would have had one hand on the first Derringer and the second hand on the doorknob to enter the presidential box. After shooting the president, Booth would then quickly need his knife to fight off Major Rathbone. Witnesses have documented Booth's leap from the presidential box to the stage floor, which was a height of 11 feet. They also document Booth flashing his knife and quickly crossing the stage to exit out the back door of Ford's Theater. No one saw Booth holding or throwing down the second Derringer. Of course, that leap resulted in Booth suffering a broken leg, which while off balance could have also dislodged the second Derringer from a vest pocket, and then which slid across the stage.

No one knew of the second Booth Derringer for years. James J. Gifford feared he would be implicated in the plot to kill the president. He may have been right. Edrnan Spangler, who helped hold Booth's horse during the assassination, was sentenced to six years hard labor. Of course, if Gifford had turned the Derringer over to the War Department on the day he found it, authorities could have examined it to see if it had been fired. Instead, Gifford departed Ford's Theater and Washington, DC. In 1867 Gifford told George Goldwin, a co-owner of a theater in Philadelphia, about the Derringer he had recovered. Later that year Gifford gave the Derringer to Goldwin. The Derringer has now exchanged hands through several owners over the years.

Sure, chaos ruled that night in April 1865 and for some nights to come. It was a newspaper reporter who found the Derringer that killed the president. It was not photographed in place nor documented as a forensic team would do today. The same is true for a number of items related to this tragic event. We do have some photographs that were taken of several items together. However, these photographs are not to forensic exam quality. This leads us to a unique conclusion. We must give credit to the statements of the people who were able to place these artifacts in a particular time and place. Many of the questions can be answered by the statements of companions with the president, the newspaper reporter who found the first Booth Derringer, and the audience in Ford's Theater who witnessed the actions of Booth that night.

In 1865 the field of firearms identification was nonexistent as we know it today. No one knew that the Derringer could be examined to reach a conclusion if it had or had not been fired since last cleaned. The suspect Derringer could have been fired to recover test specimens for comparison purposes. Additional examinations could have determined the diameter of the bullet capable of being fired from the barrel of the second recovered Derringer. Gunshot residue examinations could have been conducted on President Lincoln's clothing, which would have established the muzzle-to-target distance for the fatal shot. One of the hardest things for any forensic examiner is to work a case that has been processed by someone else or a case that is dated. To reexamine a case that is well over 100 years old was the greatest challenge of any case that this author had ever worked on.

For anyone who loves history, we now know that the Derringer on display in Ford's Theater is a true American artifact. We also know what happened to the so-called second Booth Derringer. However, Booth also had two Colts, which were waiting along with his horse in the alley in back of Ford's Theater. Perhaps that will be the subject of an additional publication.



FIGURE 13.37 The John Wilkes Booth Derringer as photographed in the FBI Laboratory in 1997.

(From C. Rosati.)



FIGURE 13.38 Carlo J. Rosati in 1997 examines the John Wilkes Booth Derringer in the FBI Laboratory.

(From C. Rosati.)



FIGURE 13.39 The John Wilkes Booth Derringer and the Mikrosil cast produced from its barrel exhibiting seven grooves, left twist.

(From C. Rosati.)



FIGURE 13.40 This 1931 photograph shows the Derringer that killed President Lincoln, the 7¼-inch-long knife, and the boot John Wilkes Booth wore when he used the weapons to attack Major Rathbone. The assassin's boot exhibits the telltale signs caused by cutting the boot from his leg. Please note, the plank in this picture is not the one used by Booth to force the door to the presidential box in Ford's Theater.

(From C. Rosati.)



FIGURE 13.41 This photograph shows the Booth Derringer, bullet removed from the wound, the probe used by the physician, and fragments of Lincoln's skull, which were contained in the Lincoln Museum Study Collection. Please note the same imperfections noted in the examinations conducted in the FBI Laboratory.

(From C. Rosati.)

SPECIAL HISTORIC NOTES

An attempt on the life of President Abraham Lincoln was set for March 17, 1865, but when Lincoln changed his itinerary and did not pass by the Booth conspirators, the plot collapsed.

It is the belief of this author that the Booth conspirators may have been plotting an attempt on the life of Lincoln as far back as March 4, 1865, at his second inauguration. Photographic evidence shows several of these men at the inauguration, but the evidence shows they were too far away to make an effective attempt.

Robert Todd Lincoln, the president's oldest son, was summoned to Petersen's House, where President Lincoln had been taken, to see his father before he died.

On July 2, 1881, Robert Todd Lincoln was then secretary of war. He had traveled to Union Station in Washington, DC, where he was going to tell President Garfield that he could not accompany him to Elberon, New Jersey. When Lincoln arrived at the station, Garfield had just been shot by Charles J. Guiteau.

On September 6, 1901, Robert Todd Lincoln was invited to the Pan American Exposition by President William McKinley. When Lincoln arrived, he saw a group gathered about the president, McKinley, who had just been mortally wounded by Leon Czolgosz.

NOTE

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FURTHER READING

Cochvan, H., Booth's Other Pistol, *Civil War Times Illustrated*, January 1975, Vol. XIII, No. 9.

Kane, J.N. (1998). *Abraham Lincoln Presidential Fact Book*. New York: Random House.

Kunhardt, D.M., and Kunhardt, P.B. Jr. (1965). *Twenty Days: A Narrative in Text and Pictures of the Assassination of Lincoln*. New York: Harper & Row.

National Park Service (1999). U.S. Department of the Interior. *Ford's Theatre and the House Where Lincoln Died: Official Park Guide*. Washington, DC: Government Printing Office.

Parsons, J.E. (1952). *Henry Derringer's Pocket Pistol*. New York: William Morrow and Company.

Schehl, S.A., and Rosati, C.J. The Booth Derringer: Genuine Artifact or Replica? *Forensic Science Communications*, January 2001, Vol. 3, No. 1.

13A Bullet Trajectory Laser Photography

Arthur Borchers

Placement and utilization of trajectory rods are beyond the scope of this text. Photography of trajectory rods and attached lasers, however, is easily accomplished.

Recall the importance of overall and mid-range photographs, including scales, as well as orienting both the location of bullet impact points and the relationship between connecting locations by showing both perpendicular and angular views of walls, objects, and vehicles containing bullet trajectory evidence.

Physically locating bullet impact locations requires at least five measurements. In addition to X, Y, and Z measurements to a specific reference point, the horizontal and vertical angle of trajectory rods or the radial and calculated angle of a bullet hole are needed. If the impact surface is curved, like a car windshield or fender, additional angular measurements may be required. Close-up photographs of those measurements will provide clear documentation of the measurements themselves and how they were taken (see Figure 13.42 and 13.43). Additional measurements of the slope of a windshield or roof support should also be measured and documented with photographs.

Use of lasers attached to trajectory rods or an inert firearm provide clear graphic evidence of bullet path and potential shooter position in relation to the scene evidence.

Often a laser's beam is not plainly visible other than the beam's origin or terminus against some object. Therefore, longer-than-average photo exposure times are required, and compensation to obtain a normal-appearing image must be made while attempting to reveal and document the light beam. Detailed knowledge of manual operation of your camera is crucial to successful outcomes.

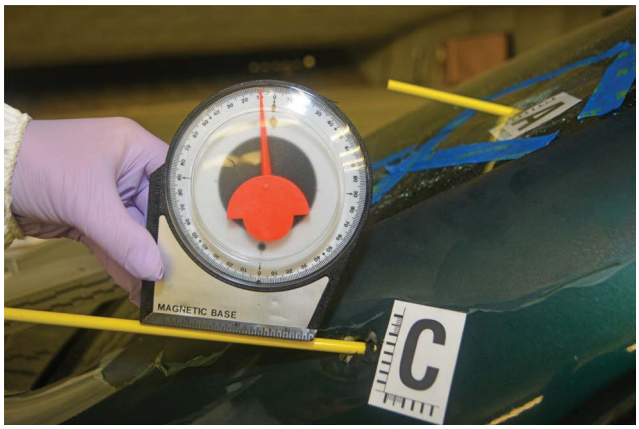


FIGURE 13.42 Measuring the downward bullet impact angle with an angle finder located on a trajectory rod placed through the "C" pillar of a vehicle.

(From A. Borchers.)

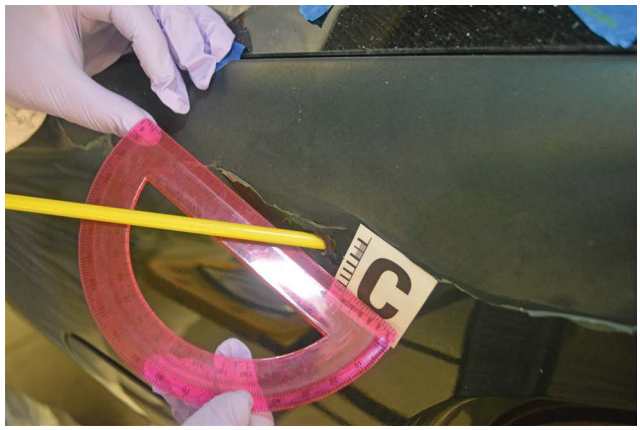


FIGURE 13.43 Measuring the horizontal bullet impact angle on a trajectory rod placed through the "C" pillar of a vehicle. The baseline should be held two different ways: one parallel to the closest axis (i.e., along the side of the vehicle) and second along the "flat" of the surface.

(From A. Borchers.)

Capturing the light from the laser will require a time exposure to properly highlight the beam. The long exposure time will also diminish the visibility of other movement through the image frame. While possible to accomplish unaided, an assistant is highly desirable.

In addition to a tripod, a cable release and a high-quality neutral density (ND) filter or variable neutral density (VND) filter are required. An ND filter has a fixed reduction in light transmission usually expressed in "stops" and may require more than one such filter be kept in your kit. Often these ND filters are square and will require a filter holder be attached to your camera's lens. The cost of square filters and holders can become a factor. While a large-diameter VND filter is not inexpensive, the versatility in light control and adaptability to multiple lenses justify the initial expense. A variable ND filter is round, and as its name implies, is adjustable for light transmission, usually between 2 and 8 stops of light reduction, when the filter ring is twisted like a circular polarizing filter (see Figure 13.44).

Advance experimentation and practice are key to successful image capture. Existing light techniques are core to proper image capture, as any benefit from electronic flash is negated by the ND filter. If an existing light exposure for your scene is 1/60 of a second at *f*/11 with ISO 400, the use of an 8-stop ND filter will change the exposure to 4 seconds at *f*/11. Adjusting the ISO to 100 will allow 2 additional stops of light compensation for a final shutter speed of 16 seconds. Bracketing exposures between 10 and 20 seconds may also be helpful.



FIGURE 13.44 77 mm and 82 mm variable neutral density filters with 2 to 8 and 4 to 11 stops of light reduction.

(From A. Borchers.)



FIGURE 13.45 Vello Shutterboss wired external interval and long exposure timer. A wireless version is also available.

(From A. Borchers.)

Depending on your camera, a 16-second shutter speed may exceed the internal camera setting options. Setting the camera to "Bulb" and using an external timer like the one in Figure 13.43 may be necessary. Some cameras and external camera control devices may connect to a smartphone application via a Bluetooth connection and provide additional exposure options. Even with a manual "bulb" setting and cable release, the image EXIF data will report the actual exposure settings.



FIGURE 13.46 An attempt to highlight the laser beam with a sheet of paper on a clipboard. Both the ghost image of the board and the person holding it are clearly visible in the background below the EXIT sign.

(From J.L. Larsen.)



FIGURE 13.47 Another attempt at highlighting the laser beam. This time the clipboard and person are much less visible but still detectable.

(From J.L. Larsen.)

Once the camera is positioned, the focus set, and initial exposure values determined, adjusted exposure values can be calculated and set according to the filter being attached to the camera. When the camera shutter is tripped, there are two common methods for highlighting the laser beam: first is the use of aerosol "fog" sold by various forensic and photography suppliers sprayed into the light path to reveal the beam in the ensuing haze (hair spray or atomized water can accomplish similar results); second is the use of a sheet of white paper walked carefully along and behind the length of the beam striking the paper.

Due to the time exposure, movement across the image area is less likely to be captured but is still possible (see Figures 13.47 and 13.48). Care must be taken not to obstruct the camera's view of the laser beam. Avoiding the beam is more easily accomplished by standing and moving on the far side of the beam, away from the camera. Multiple attempts to capture the complete beam path are often needed.

Figure 13.48 illustrates the use of two lasers: one red for the trajectory from a victim's head wound and the other green from the "unloaded" gun being handled and inadvertently discharged by the seated person. The use of two colors of laser highlights that the bullet path represented by both beams is colinear. The red laser terminus is visible on the hand of the "shooter." The green laser is visible striking both the laser and the chin area for the head wound trajectory path. A plain sheet of paper, without a clipboard, was used to highlight the beams striking each side of the paper. The reconstruction corresponds well with the shooter's initial statement to investigating officers that the shooting was unintentional.

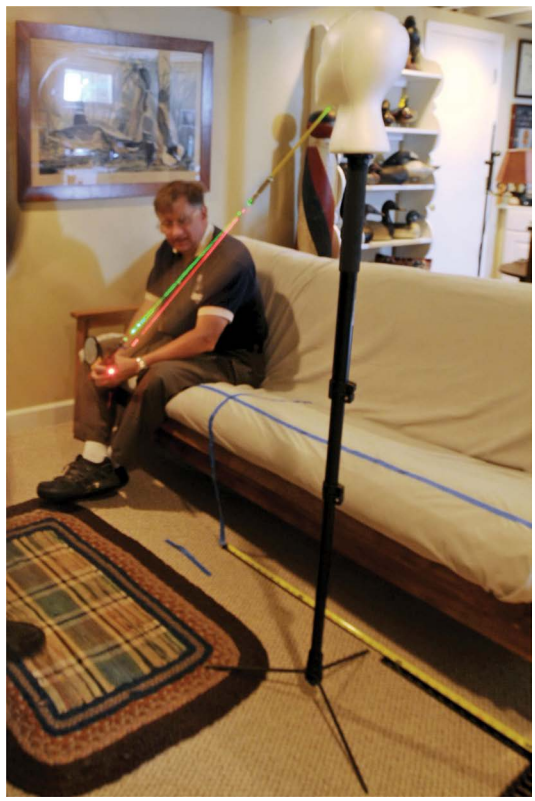


FIGURE 13.48 Highlighting the red laser from the victim's initial position and the approximate position of the "unloaded" pistol at the time the shot was fired. Ghosting of the person moving the paper is slightly visible.

(From J.L. Larsen.)

14 Questioned Documents

Emily J. Will and J. Wright Leonard

CONTENTS

Forensic Document Examination 313
Original Documents versus Nonoriginal Documents 313
Handwriting Photography 314
Macro Lens 314
Image Stabilizer 315
Large Copy Stand 315
Quadrapod Copy Stand 315
Fixed Lens Cameras: Point and Shoot 315
Scales 315
Lighting 316
Light Box 316
Photo Cube-Tent Box 316
Taking Pictures 316
14A Photography and Human Vision 317
Alternative Light Sources 317
"Light" versus Electromagnetic Wavelengths 317
Alternative Light Source Equipment 318
Alternative Light Sources in Casework 321
Photomicrography 323
Scanning 324
Conclusion 325
Appendix I: Digital Examination and Evaluation of Questioned Digital Documents 325
What's a PDF? 325
Is Printing Obsolete? 327
Detecting Alteration and Manipulation of Legal Documents 328
Tools Required for Digital Examination of Questioned Documents 328
Cut and Paste 329
Erasures 332
Creating Overlays 332
Conclusion 335
Note 336

FORENSIC DOCUMENT EXAMINATION

Forensic document examination (FDE) is a forensic specialty related to the examination of documents to answer questions posed regarding handwriting, printing processes, the materials of the document, and the chronology of the document. Typical questions would be: Did the correct person sign the document? Who wrote the anonymous note? Has the document been altered? Could pages have been substituted? What is under the obliteration on a document? Can the timeline of execution of the document be discerned? Is the passport a genuine passport?

Typically, a document is on paper, but it can be anything carrying a written message. So, for example, a document could be a last will and testament, an anonymous note, a message written with lipstick on a mirror, writing on a wall, a digital document with a signature written with a stylus on a digital pad or tablet, and more.

Original Documents versus Nonoriginal Documents

The current ability to reproduce (scan, copy, fax, photograph) documents is both a blessing and a curse. The original document always contains the highest level of detail in the writing line, and certain types of examinations (for example, indented writing) can only be performed on the original document. Therefore, the modern business practice of scanning originals and destroying them while retaining the scanned version can wreak havoc with the FDE's potential to conduct certain examinations. On the other hand, a good high-resolution grayscale or color photograph or scan or a high-quality copy

can be very useful during the examination process and in demonstrating observations for a report or testimony.

HANDWRITING PHOTOGRAPHY

In this chapter, many avenues of documenting handwriting and other features are discussed, including microscopy, ultraviolet (UV), infrared (IR), and various lighting techniques, such as for watermarks and holographs.

This chapter addresses getting the best digital photos of handwriting for reports, comparison charting, and exhibits, including the issue of documenting handwriting on unusual surfaces for submission to a document and handwriting examiner.

Consider what is to be done with the pictures you intend to take. Are they being sent to a document examiner who won't be able to see the actual original documents? Are they pictures of writing on paper or on an unusual surface, like a door or a wall? Will they be inserted in a forensic report or enlarged for court exhibits?

As an example, say a threat is handwritten on a door in a public place. The writing needs to be eliminated from the area. The best thing to do is take the door down and save it for the handwriting examiner so he or she can see and photograph the actual writing.

Unfortunately, this is usually not done, and the authorities take a picture of the writing and then paint the door (or the wall), eliminating the evidence. Most of the time these photos are not exposed close enough or with enough clarity or detail to be helpful to an examiner in determining the source hand.

It is the same with threats written on unusual surfaces, where the photos presented to the examiner are not exposed close enough, or not in macro, and therefore, don't display enough detail or clarity for examination and comparison to a suspected writer's genuine handwriting. All too often, a fingerprint exam will be conducted on a paper document before it is submitted to the handwriting examiner, and the chemicals used smear the writing, making an examination impossible (see Figure 14.1).



FIGURE 14.1 Fingerprint exam ruins handwriting.

In every case, the quality of the tools you are working with and your own skill at making photos with clarity and detail are critical.

Taking digital photographs of handwriting can be a complex process, but actually top-of-the line cameras with all the bells and whistles are not necessary to achieve perfectly clear and detailed results, documenting the handwritten evidence and suitable for enlarged court exhibits. Any decent digital camera with a remote flash and a close-up or macro lens should work just fine.

A document or handwriting examiner will ask to examine the original of the questioned writing, where there is ink on the paper or another surface, allowing greater clarity and detail to be seen, and will compare it side by side with the collection of comparison specimens. For the forensic examiner, the purpose of taking photos is to document the details of the writing revealed through the examination of the original document on site. These photographs will probably be used in any written report and enlarged for court exhibits.

In a forensic examination on site, one possibility is to take photographs with two cameras, one being the more sophisticated camera and the other being the backup in case there is an issue with the first camera through malfunction or loss. If you have two sets of images, you are more protected in the event of loss of images. However, this process is very slow going, and there are many instances when you just will not have the time. Keep a close eye toward the review screen and learn to be able to tell when the images look well exposed and sharp on the small review screen.

NOTE:

You will not always be using a flash to make macrophotographs of handwriting.

Macro Lens

A macro lens is necessary to capture 1:1 magnification—true macro. This means a subject ¼" long will also be ¼" long, or true-life size, on the camera's sensor. The lens specs will tell the achievable magnification ratio for that lens. Some manufacturers will advertise 1:2 as macro or sometimes a close-up lens. This means that the 1:2 lens is capable of projecting at one-half true life size. Macro lenses are available from 50 mm to 200 mm. An important consideration is the field of view using any of these lenses. You want to be able to take a photo of an entire signature in one frame and also have the capability of filling an entire frame with one letter or part of a letter. Equally important, you want the pictures to be crisp and clear.

To cover the same field of view on a document, you will find a shorter (50 mm) lens will allow a closer lens-to-subject working distance than a 200 mm lens. Both lenses could cover the same field of view, but you would be much farther away from the subject using a 200 mm lens. This may be important when using a tripod or in tight constraints. Think of photographing handwriting on the wall



FIGURE 14.2 A 55 mm macro lens.

of a bathroom stall. A 200 mm lens might require more distance than the stall makes available to capture the necessary images (see Figure 14.2).

In selecting a macro lens, remember you will generally need some sort of camera support when taking pictures for the best quality photos with the camera parallel to the document/writing, most particularly if there is no image stabilizer in the lens or the camera (see Figure 14.3).

Image Stabilizer

An image stabilizer is an important feature because it assists in minimizing the effects of any shake or movement of the camera. This helps to eliminate blurring of the picture. This image-stabilizing feature can be either in the camera or in the lens. This feature is critically important if you try to work without a copy stand, quadrapod, tripod, or other type of support.



FIGURE 14.3 Tripod with parallel ability.

Large Copy Stand

A **copy stand** is a piece of equipment used to adjust the height of the camera and keep it parallel to the subject being photographed. They often have various types of specialized lighting on each side. A large copy stand is usually thought of as an in-house or laboratory piece of equipment. Of course, the camera and lighting can be moved lower on the stand for close-up photos.

Quadrapod Copy Stand

The quadrapod is an example of a more versatile tripod in that it has telescoping adjustable tube legs and a frame supporting the camera and lens in a parallel position to the document. This allows you to get closer to the subject and perfectly eliminates all camera shake or movement. It is a more portable device than most tripods and stands.

Fixed Lens Cameras: Point and Shoot

Compact cameras can make good close-ups, and they are less expensive, but don't have the benefit of interchangeable lenses. (They are also mirrorless.) In selecting a camera to document handwriting, look especially for the minimum focus distance, optical zoom, and a macro mode.

Your compact camera should have the following to make good pictures of handwriting:

- Suggested at least 16 megapixels. Get the most you can on your budget.
- Minimum focus distance of 2 to 3 cm or less in macro.
- At least 12× or more optical zoom. Get the most you can on your budget.
- Autofocus Macro Mode (some also have Super Macro Mode).

Sometimes you are going to be working within a few inches of the handwriting, so a camera with a minimum focus distance of 6 or 8 feet in macro mode is not going to work. You often need to be closer to the subject than that. Some cameras have a minimum focus distance in macro of 1 cm, although you won't have to be exactly that close either. At the very least, if the camera has that capability, you will always be safe. Also, look for the greatest optical zoom: 5× optical zoom is not enough—having 12× or more is better for handwriting.

Scales

It's a good idea when taking photos of handwriting, both questioned and the comparison specimens, to use a scale below or with the writing for length comparison. It's best to

use a scale with metric measurement, both centimeters and millimeters. Clear see-through rulers are one good choice. Adhesive-backed photo evidence scales (rulers) are another choice. However, they should be used with caution. You don't want to damage the document.

These scales include measurements in inches and millimeters, up to 2 inches and 50 mm wide, and are printed on flat, pressure-sensitive label stock with a nonpermanent adhesive back. Handwriting and other document features are easily measured. The scales can be included in the photos for demonstration and can be carefully removed from the document without leaving residue behind.

Lighting

One of the most critical elements to making photos of handwriting is proper lighting. You want to have high magnification, but the closer you get to the subject, the less light you have to work with. Without question, the best lighting is natural light. Light is the most important tool used to reveal intricate details in the written strokes on paper, such as the twists of the ink lines.

TIP:

Moving the document to the natural light of a window and taking the picture at that point might be one way of solving the light problem.

In the absence of natural light, another consideration could be a ring light that attaches to the front of the camera lens. A ring light provides light from all sides at once and eliminates shadows. This is not used with the in-camera flash, since the in-camera flash will generally wash out the writing when you are shooting close up. A ring light provides soft, easily controlled light from all sides (see Figure 14.4).



FIGURE 14.4 Ring flash aperture.

(From Wikipedia used per CC 4.0. Uploaded by user: Jacek Halicki.)

You can also buy separate lighting systems from many sources—some that attach to the camera and some that attach to the tripod or copy stand you are using.

Light Box

Fluorescent lights, as in a light box for viewing x-rays, provide transmitted light when a document is placed above, allowing illumination from behind the document. This type of light is good when looking at erasures or obliterated or crossed-out or whited-out writing, or when other lighting is inadequate to take the photo.

Photo Cube-Tent Box

This is a portable folding square box, often made of white cardboard or foam board, which prevents shadows and reflections on the document and has interior lights from batteries. One side of the box is open. The subject writing is placed inside the box.

Taking Pictures

First, the autofocus setting will work just fine in a point-and-shoot camera. You are not taking a picture of a moving object. You are not taking a picture of an eyelash on a caterpillar. The subject is stationary and flat. You want sharp pictures of the handwriting, and you can get them with autofocus on the right camera in the macro setting.

IMPORTANT:

Put the autofocus area over a point of high contrast like a signature line. Otherwise, the camera may have a hard time focusing.

Use your copy stand or tripod, particularly with a DSLR where you will likely manually focus. You want zero handshake or movement. If you do not do this, you will quickly learn how important this is. You will be tempted to work without the stand or tripod because you will be exposing at different depths—from an image of a whole signature down to perhaps one letter or two letters. So, you will be moving the camera a lot. (This is where image stabilization becomes very important and desirable.)

- Make sure that the camera is parallel to the paper/writing.
- Make sure there is sufficient lighting.
- Take the pictures.
- Check them on the display screen.
- Enlarge them on the display screen for clarity, or transfer them to your photo software to check the results.

One requirement to making good photos of handwriting is patience while going through trial and error in perfecting your technique.

14A Photography and Human Vision

J. Wright Leonard

Photography is essential to the document examiner. Overall and close-up images and specific details can be recorded photographically for archival purposes and to help the examiner demonstrate observations in reports and testimony. Because people are familiar with handwriting, they want to see what the examiner has observed, not just read or hear about it. Photographs make it easier to describe observations and explain the analysis leading to an opinion. They also make it easier for the attorney/client/fact-finder to evaluate the report or testimony. The human eye and the camera are partners in the document examination process.

The human eye is capable of seeing light reflected from objects within a certain portion of the electromagnetic spectrum (EMS). Illumination from the sun contains all colors of light. When this light strikes an object, the object will absorb some of the light waves and transmit or reflect others. Each object has properties of reflection and absorption of various wavelengths of the EMS. For example, in the somewhat simplistic illustration in Figure 14.5, we see the apple absorbs all colors except red and reflects the red to be observed by the eye; therefore, the eye sees the apple as being red. The other colors of the visible spectrum are absorbed by the apple and are not visible to the eye. The eye sees only what is reflected. The camera responds similarly.

Many document examination cases can be solved with normal human vision in the visible light portion of the EMS. But other cases can only be solved when we can extend the capability of human vision into other areas of the EMS. This requires the use of alternative light sources. Fortunately, digital photography also works well in alternative light source conditions.

ALTERNATIVE LIGHT SOURCES

Visible light is just a small portion of the full EMS, which includes a range of frequencies of electromagnetic waves,

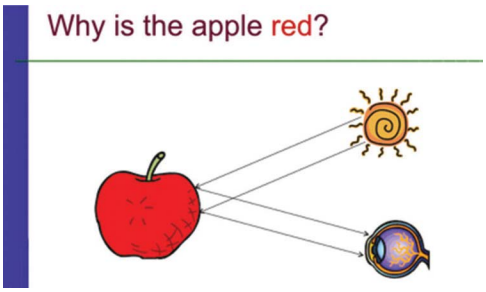


FIGURE 14.5 The sun's rays contain all visible colors, but the apple reflects only the red. Therefore, the eye can see only the red and the person sees the apple as being red.

(From J. Wright Leonard.)

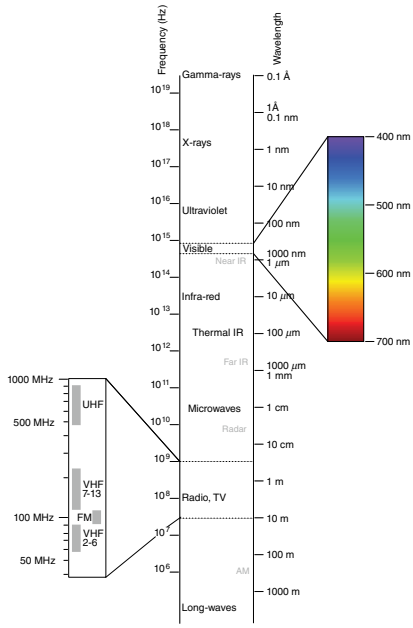


FIGURE 14.6 The electromagnetic spectrum (EMS) is made up of many wavelengths. The most useful to document examiners are ultraviolet, visible light, and infrared. Within visible light are all of the colors normal people see.

(From Original Penubag Vector Victor Blacus, CC BY-SA 3.0 httpscreativecommons.orglicensesby-sa3.0, via Wikimedia Commons.

including radio, IR, visible light, UV, x-rays, gamma rays, and cosmic waves (see Figure 14.6).

A wave is propagated through space or matter by the oscillating electric and magnetic fields generated by an oscillating electric charge. Think of dropping a stone in a pond. Ripples go out from the point where the stone entered the water (see Figure 4.7).

Wavelength is the distance between adjacent peaks. Portions of the EMS are defined by their wavelengths, which are measured in nanometers (nm). One nanometer equals one billionth (10^{-9}) of a meter. The most useful wavelengths for document examiners are long and short wave UV, visible light, and IR.

"LIGHT" VERSUS ELECTROMAGNETIC WAVELENGTHS

We commonly use the term "light" to refer to the wavelengths of the EMS acting upon the human eye to make sight possible. The term "light" is also applied in common usage regarding UV and IR. Technically, it is not proper to refer to UV and IR as "light." This gets confusing because the devices producing UV and IR are commonly referred

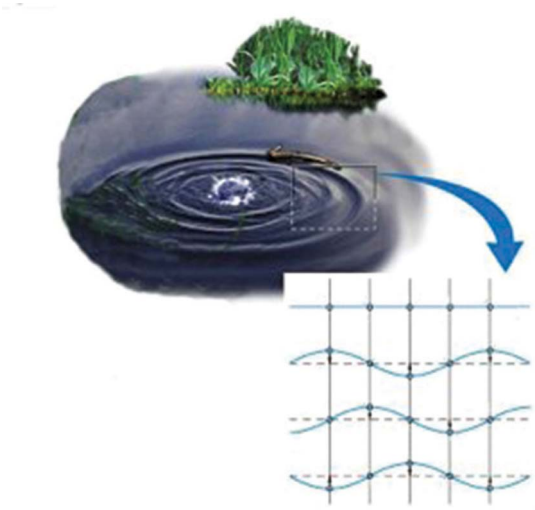


FIGURE 14.7 If you take a slice (cross section) of the ripples in a pond, the result will look like waves.

(From J. Wright Leonard.)

to as UV lights and IR lights. It is most correct to refer to UV and IR as electromagnetic waves, but if we slip and call them "light," as in common usage, at least we should be aware the term is not technically correct.

How is knowledge about the EMS useful to document examiners? As mentioned earlier, our eyes are limited in what they can see. There is more evidence available to us when we can extend our vision beyond visible light into other areas of the EMS. With alternate light sources and special sensing equipment, we can process evidence that becomes visible and can be photographed for use in reports and testimony. Let's look at some of the equipment used and then at some casework examples.

ALTERNATIVE LIGHT SOURCE EQUIPMENT

The reader might wonder why specialized lighting equipment is included in a book about forensic photography. The reason is that all the equipment described in this section relies upon general and normal cameras and principles of photography, even if the physical camera housing is not a typical camera body. As with most technologies, there are levels of appropriate equipment, with the more sophisticated units being more expensive and more capable in a wider range of examinations. Each option has pros and cons, but the ability to conduct some level of alternative light source examination with resulting photography is available to all forensic document examiners.

At the high ends of alternative lighting capabilities are laboratory desktop units made by companies such as Foster and Freeman (http://www.fosterfreeman.com), Projectina (http://www.projectina.ch), and Regula (https://regulaforensics.com/en/). The smaller units made by these companies and others such as Aco Electronics (http://www.acoelectronics.com/infrared-document-examination/) are suitable for the individual or small forensic laboratory. This is where the equipment cost and the types of examinations typically conducted are a good match for smaller units. For larger laboratories with wider-ranging requirements, larger and more complex units are available. A central element of these large and small units is a digital camera and optionally a computer connection for capture, annotation, and printing of photographs.

As an example, a smaller, transportable spectral comparator, the Foster and Freeman Video Spectral Comparator (VSC) series, offers infrared absorption/reflection, IR luminescence, UV, transmitted light, side lighting, and some coaxial lighting capabilities. All examinations are nondestructive, and the results of the examination are shown on the device's screen or on the monitor of an attached computer. The images on the screen can be saved, annotated, and printed.

In Figure 14.8, a black-inked obliteration is shown. Using a 780-nanometer filter in front of the VSC's camera, the obliterating ink layer is shown to have IR reflection properties and "appears to disappear," while the underlying ink absorbs the IR and can be seen on the monitor. The reason we can see the absorbing ink is it blocks the IR reflection of the paper itself, so the area of the writing does not reach the sensors. What we actually see on the screen is a lack of response of the camera sensors because they are not being activated by reflected IR in the area where the original writing occurred. All the other sensors are activated due to the IR reflection from the paper and the obliterating ink.

Smaller, less full-featured magnification and IR/UV examination devices are found in the MiScope series developed by Zarbeco (https://zarbeco.com). These handheld units are also built around a camera and attach via universal serial bus (USB) to any laptop or desktop computer. Depending on which device is used, there are differences in field of view, magnification, and IR/UV examination possibilities. Because the setup of the equipment is different (weaker illumination but closer to the document), the principles yielding the results are different from those of the larger devices. But in the range of illumination and filtering available in the unit, the images produced are comparable. Again, the images can be stored, annotated, and printed. In Figure 14.9, two views of the MiScope MP/IR are shown along with an image of a fluorescing fiber in the paper of a security document.

With the pieces of equipment described earlier, any document examiner can supply some level of IR examination capability. However, options are also available for unexpected or backup situations. Digital cameras, including those integral to iPhone and Android devices, often have the ability to respond to deep red and near-IR wavelengths. The setup for this type of examination includes excitation (illumination) of the document by a bright, full-spectrum light and blocking of the camera lens by filters in the 690-nm to 740-nm wavelength range. Experimentation is required to see what combination of lamp/filter/camera works best for your particular equipment.



FIGURE 14.8 This is the VSC 4c during the examination of a test obliteration. The obliteration (left) has been revealed (right) by the ability of the device to show on the screen the differences in the two inks' abilities to absorb or reflect IR wavelengths.

(From J. Wright Leonard.)

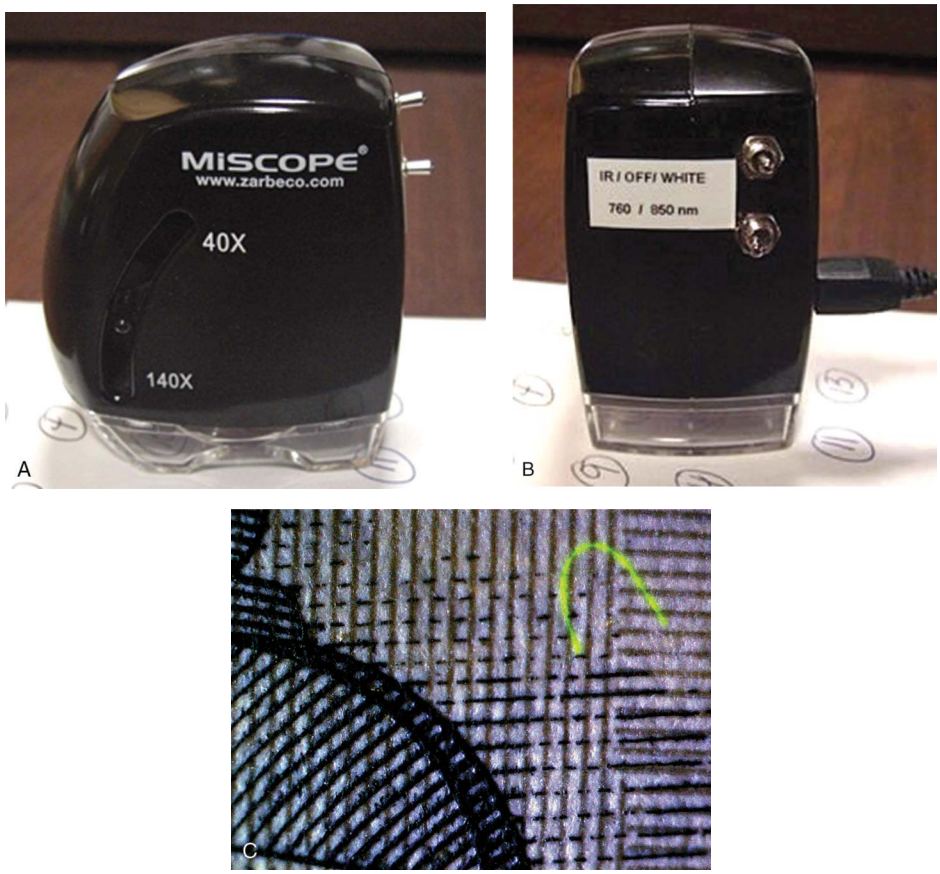


FIGURE 14.9 (A and B) Two views of the MiScope MP/IR. (C) An image showing a fluorescing fiber embedded in the paper of a security document.

(From J. Wright Leonard.)



FIGURE 14.10 Gel filter in holder (690–740 nm range) with illuminated halogen bulb magnifier.

(From J. Wright Leonard.)

Figure 14.10 shows one combination working well. The illumination is from a portable plug-in illuminated magnifier with a halogen bulb. Filters rated at 690, 720, and 740 nanometers work in this setup. The camera is an iPhone 8+ which must be supported at the free end, since the camera sensor is in one corner of the device. Figure 14.11 shows the test sample and images taken with the 690, 720, and 740 nm filters. The next filter on hand was a 790 nm, which proved to be too deep into the IR spectrum for any response from this particular camera. This simple and portable setup is capable of producing images of differences in inks.

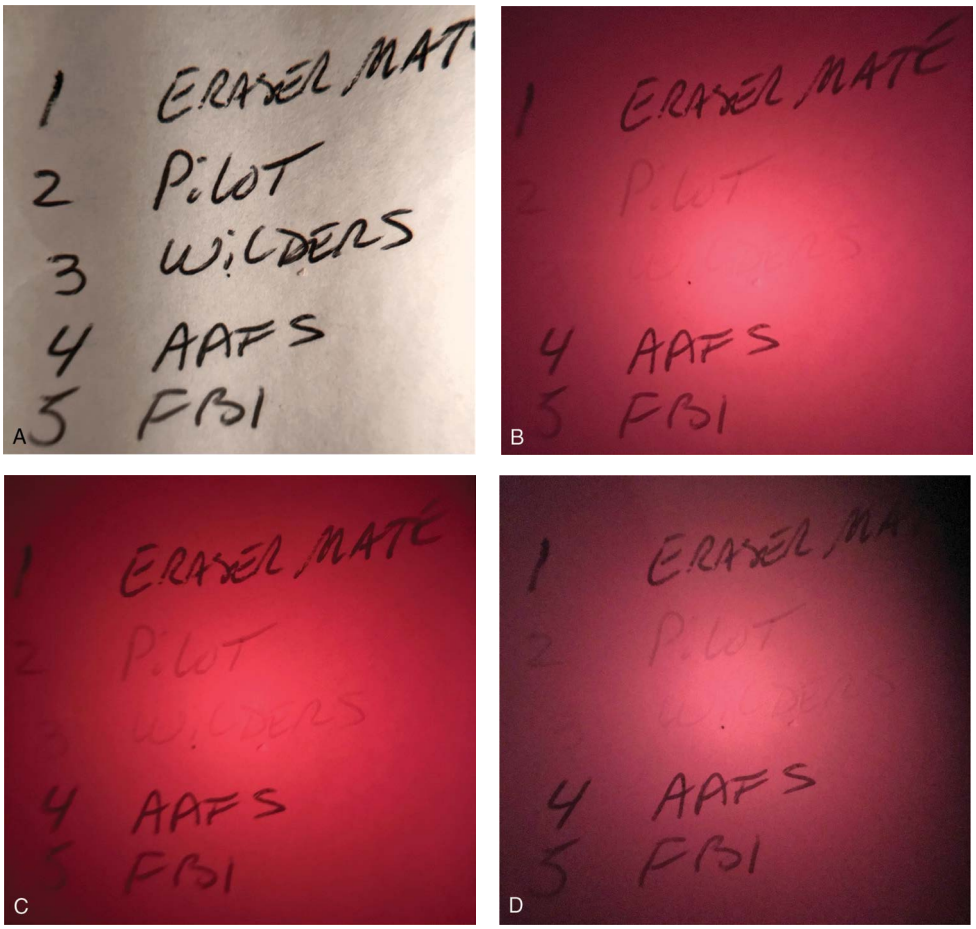


FIGURE 14.11 (A) The test sample. (B) Image using 690 nm filter. (C) Image using 720 nm filter. (D) Image using 740 nm filter.

(From J. Wright Leonard.)

ALTERNATIVE LIGHT SOURCES IN CASEWORK

CASE STUDY 14.1: CASE OF THE QUESTIONED TRAFFIC REPORT

In this case, a handwritten description of a traffic accident contained an obliteration. The question was, "What was written below the obliteration?" The original document was submitted for examination. The obliteration was quite heavy and made with a black ballpoint pen. The examination was conducted with a Foster and Freeman VSC (see Figure 14.12). The theory behind this type of examination is that just as the eye sees differences in visible colors reflected from objects, an IR viewer can see differences in IR wavelengths reflected from objects. The device's camera can then record an image showing the differences in inks not visible to the naked eye.

If the ink used to obliterate reflects or transmits IR, while the ink used for the original writing absorbs it, then it may be possible to see what was written below the obliteration. That is what happened in this case. The sensors of the IR device responded to the differences in absorption/reflection of the inks, and the examiner could see the results on the screen of the comparator and capture an image of the examination results. These images (Figure 14.9) are a re-creation of the actual document in this case.

If the IR-reflecting ink had been used for the original writing and the IR-absorbing ink had been used for the obliteration, this examination would not have revealed the original writing. It is important to understand that if differences are not observed in any IR examination by any method, this does NOT mean the inks are the same. "Sameness" cannot be proven by these imaging methods. Inks might respond the same way in IR examinations and still have different formulations, determinable by ink chemistry or other specialized testing.

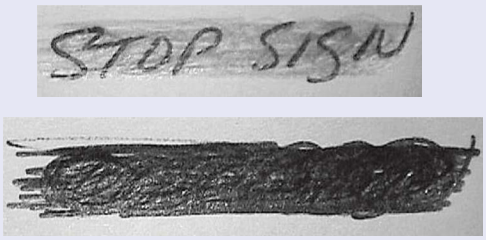


FIGURE 14.12 Images demonstrating the use of infrared absorption/reflection examination to reveal obliterated writing. The obliteration was revealed by the sensors of the infrared viewer and shown on the screen of the VSC.

(From J. Wright Leonard.)

CASE STUDY 14.2: CASE OF THE "RAISED" CHECK

In this case, the intended amount of a check was questioned. The result was determined using IR luminescence, which is an IR examination technique in which the document is illuminated with a narrow band of colored light, and various higher wavelength filters are placed in front of the device's camera lens. As you can see in Figure 14.13, the difference in inks can be seen by the lack of "glowing" (luminescence) of the alteration. The IR luminescence examination is accomplished with the specialized equipment discussed earlier. You cannot expect to get IR luminescence results with a simple digital camera.

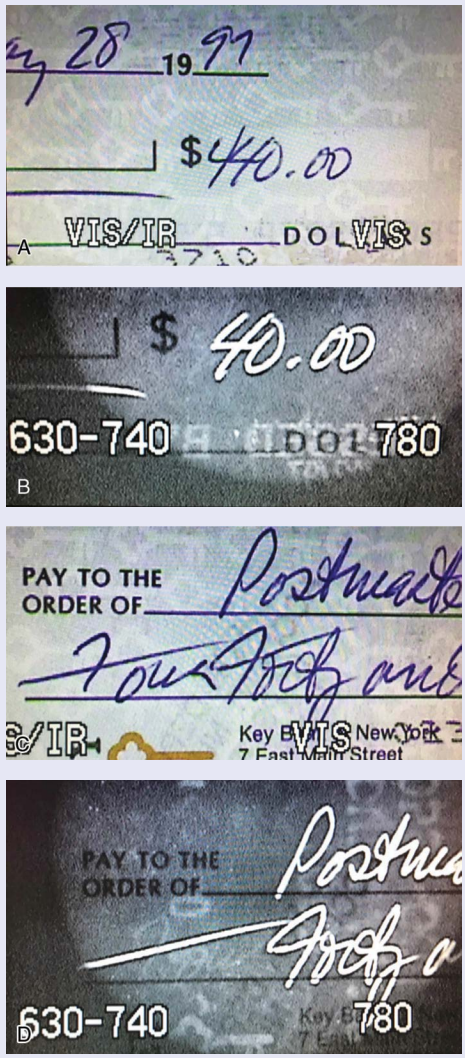


FIGURE 14.13 These four images show the two alterations in visible light (A) top left and (C) bottom left and with IR luminescence (B) top right and (D) bottom right. The settings of the VSC used in the examination are captured with the images.

(From J. Wright Leonard.)

The four images in Figure 14.13 show the numerical and written amounts for the check have been boosted from the original $40 to $440.00. The proof of the pudding comes using IR examination. The luminescing (glowing) ink was the original ink, and the alterations were added using a nonluminescing ink. Notice the perpetrator did two clever things to try to avoid detection. The long stroke that the writer placed to fill in the empty space in the written amount line as protection against tampering was used as part of the tampering. It became the cross-bar of the added "Four." And the cross bar of the "F" of "Forty" was extended so it would look similar in length to the alteration.

CASE STUDY 14.3: CASE OF THE ADDED NUMERALS

Sometimes the question about a document is simply whether the handwriting on it is "original" (written with ink) or has been copied or printed on to the document. The solution lies in microscopic examination of the writing line, and the answer can be demonstrated in various ways. The MiScope was used in this examination. Because the ink responded by reflecting IR wavelengths, the ink appeared to disappear, and the grooves left in the paper by the pen pressure of the writer could be seen and captured through the MiScope (see Figure 14.14).



FIGURE 14.14 The images captured through the MiScope digital microscope show the appearance of the blue ink on the document (top) and the indentation into the paper made by the pen (bottom), which can be seen when the blue ink seems to disappear during the IR reflection/absorption examination.

(From J. Wright Leonard.)

CASE STUDY 14.4: CASE OF THE ALTERED SCHEDULE A

There are times, especially in on-site examinations, when something unexpected arises. Having a backup capability is important in these situations. In this case, a handwriting authorship examination expanded when the examiner noticed some awkwardness in the handwriting. In Figure 14.15, you can see the list of personal property on a Schedule A document has been altered. Of course, there is no information about who did the alteration, or when it was done, but the fact that it occurred was reported along with the information about the handwriting requested by the client. The iPhone 8+, halogen magnifier, and 690 nm filter were used in this examination.

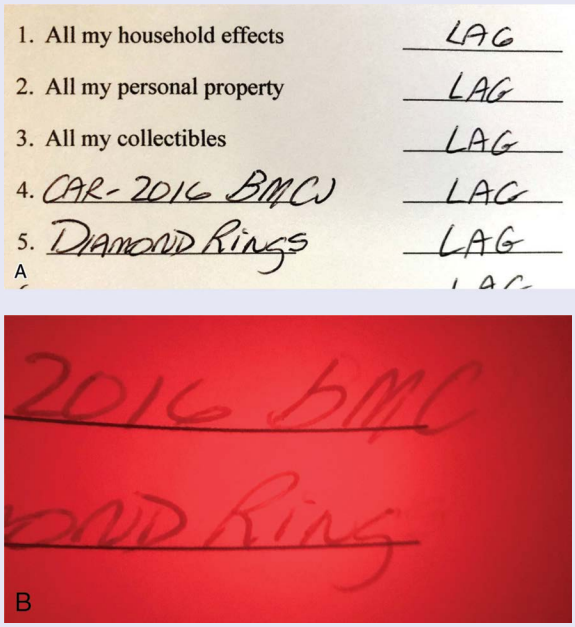


FIGURE 14.15 (A) Visible light. (B) Alterations "seem to disappear." On the top, the image is captured in visible light. On the bottom, a halogen magnifier and a 690 nm filter in front of the camera lens show there has been an alteration to the document. The curvature of the image on the bottom is due to photographing through a magnifier.

(From J. Wright Leonard.)

PHOTOMICROGRAPHY

Photomicrography is the process of capturing images through the eyepiece of an optical microscope. Such images are known as photomicrographs. This is sometimes confusing to people who think these images should be called microphotographs, but those would be tiny photographs, not photographs of tiny objects magnified by the microscope. (Refer back to Chapter 11.)

This type of photography is of particular interest to the document examiner who may need to record and demonstrate in reports or testimonies small features not easily captured as clearly in other ways.

One way to capture a photomicrograph is to use a trinocular microscope, which has a third viewing tube for the attachment of a digital camera, using a microscope as a camera adaptor. Adaptors are specific for each camera and microscope eye tube combination. The camera needs to have threads in front of the lens to accept the attachment, which slides into the eye tube of the microscope.

Photomicrographs can also be captured using a binocular microscope and digital camera with the correct adaptor. Figure 14.16 shows a typical setup. The microscope is a Bausch and Lomb Stereozoom 5. The camera is an older Nikon Coolpix 995. The adaptor is an Optem Digital Camera Coupler available at https://www.microscopeworld.com/camera_chart.aspx.

To take the photomicrograph, the eyepiece of the microscope is removed from the eye tube. The coupler is screwed on to the front of the camera. The other end of the coupler slides down into the eye tube in place of the microscope's eyepiece.

Using this setup, excellent images can be obtained for demonstration purposes. Small details are often critical to the examination of documents, and demonstrating these details exist is important.

In Figure 14.17, the final stroke of the "h" is shown to drag on the paper back in the direction of the "i-dot." In the formation of the i-dot the pen is in motion before the three heavier strokes of the i-dot are formed. These drag strokes are clues to the structure of the writing and the order in which various elements of the word were formed.

In Figure 14.18, the two "r"s, shown are just barely connected by a drag stroke. In some instances, drag strokes can be an indicator of natural writing. It is worth considering, if the documents in these images (14.18A,B) were photocopies rather than original documents, the drag strokes might have been "lost" in the copying process. Figures 14.17 and 14.18 show exactly that situation, with loss of clarity and detail in a poor-quality reproduction of the original document.

These images of "drag strokes" were captured with the setup shown in Figure 14.16.



FIGURE 14.16 This is a side view of a photomicrography setup. In this instance the microscope is on a travel stand but could just as well be on a boom stand in the laboratory.

(From J. Wright Leonard.)



FIGURE 14.17 Photomicrographs of an original document showing drag strokes at the end of the "h" and the beginning of the i-dot (top) and between two "r"s (bottom).



FIGURE 14.18 Photomicrograph showing the same areas of a copy. The amount of information available is considerably less.

Note how much more information is available on the images taken of the original as opposed to the images taken of a copy.

SCANNING

As in the case of specialized equipment, the reader might wonder why scanning is included in a book about forensic photography. The fact is that scanning is closely related to digital photography, and the result of both processes is a digital image. With a camera, the pixels on the sensor are essentially engaged at the same time (allowing for differences with time-lapse imaging), whereas with a scanner the sensor reads the image in sections moving across the bed of the scanner. Focus and maintaining a parallel plane with the document (paper) are straightforward with scanning.

Because most documents are paper and therefore flat, they are very compatible with flatbed and sheet-fed scanners. However, with a sheet-fed scanner there is the possibility of physical damage to the document due to jamming,

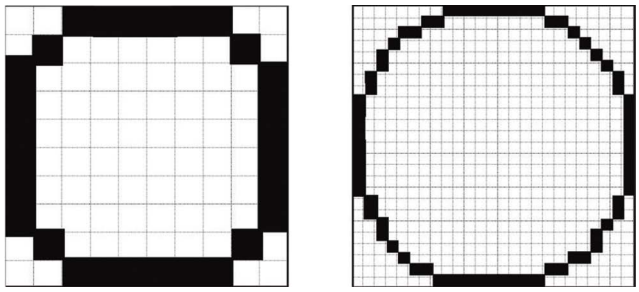


FIGURE 14.19 Which grid results in a smoother circle when it is created by filling in "pixels"? Fewer dots (pixels) per inch = rougher circle (left). More dots per inch = smoother circle (right).

(From J. Wright Leonard.)

misfeeding, poor alignment, or other problems. Therefore, most document examination scanning is accomplished with a flatbed scanner.

Scanner image quality is discussed in terms of resolution, typically measured in **dots per inch** (DPI). It makes sense that the more pixels (dots) per inch are captured, the finer the resolution of the image can be. Think of drawing a circle by filling in squares ("pixels") on the two grids shown in Figure 14.19. Which one would give a better result?

Clients and field officers often request to send scanned documents to the forensic document examiner. In cases where the document examiner agrees to work with scans, the quality of the scans is very important. All scans are not equally useful. To conserve on file size, it is acceptable to take higher-resolution scans (600 dpi) of areas of interest (such as a signature) and a lower-resolution scan (300 dpi) of the total document for archival purposes. Scans should be either grayscale or color to avoid forcing the scanner to select only black or white for each pixel (a 2-bit scan). When in doubt, there is no harm in selecting "color" even if the document contains no visible color. Scanned files should be saved as PDF files and named with a useful identifier, such as "Deed-March15_2015.pdf." The submitter should always contact the expert before sending files, and preferably before scanning files.

Canon manufactures a series of portable scanners that connect by USB cords to laptops and are powered by the same cord through which the information is transmitted. It is important to remember to lock and unlock the scanner (via a toggle, typically on the bottom of the scanner) when transporting it.

Figure 14.20 shows handwriting scanned at various settings. There are clear differences in detail

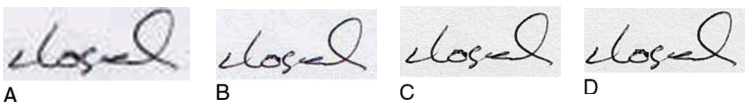


FIGURE 14.20 The same phrase has been scanned at four optical resolutions: (A) 75 dpi, (B) 150 dpi, (C) 300 dpi, and (D) 600 dpi.

(From J. Wright Leonard.)

available for examination. Both size and clarity are improved at higher resolutions. Poor-quality documents often lead to "qualified" or "no conclusion" opinions, which could have been avoided if better documents had been submitted.

CONCLUSION

In this chapter we have described and illustrated photography equipment and processes specific to the field of forensic document examination. In forensic work in general, description and illustration go hand in hand, which is one reason why forensic photography is important.

Photography is used to capture and archive images of handwriting when transportation of the original writing/document to the examiner is not possible. Image clarity is critical in these instances, and unusual substrates can pose interesting challenges to the photographer.

In forensic document examination, photographic processes also extend the expert's vision beyond the limits of human vision into part of the EMS, where important evidence is waiting to be discovered and illustrated. Also, judges and juries want to see what an expert is describing, rather than just hearing about it, and photography is the key to illustration. Photography is a real gift to the examiner in these document cases.

APPENDIX I: DIGITAL EXAMINATION AND EVALUATION OF QUESTIONED DIGITAL DOCUMENTS

David "Ski" Witzke

WHAT'S A PDF?

The information technology explosion of recent years is reshaping not only how we examine and evaluate questioned documents but how we authenticate questioned documents. The heart and soul of this technology is the Portable Document Format (PDF), created by Adobe Systems, Inc., and launched on June 15, 1993. The goal of this file format was to exchange and display documents accurately and reliably independent of hardware, software, or operating system.

But there is a critical problem with the PDF file format, which has a significant effect on the quality of documents created using this technology. To make matters worse, the majority of people who create, share, or use this technology are oblivious to the irreparable damage they can do to a legal document. For example, two functions are performed on any digital image (such as a signature, picture, etc.) embedded into a PDF file: (1) if the image has a resolution of greater than 225 pixels per inch (PPI), the image is downsampled to 150 PPI; and (2) then the downsampled image is compressed using medium JPG compression.

The purpose of these two functions is to reduce the size of the file, which is done at the expense of the quality (both in terms of resolution and clarity of detail). For example, a full page of text with a signature would require approximately 25 megabytes (MB) of storage if it were scanned using 24-bit color with a resolution of 300 PPI. This same page when saved and stored as a PDF using standard, default settings would be approximately 55 kilobytes (kb). In most environments, the single, noncompressed page could not be emailed due to file size limitations. If the document consisted of multiple pages, it could require hundreds of megabytes, if not multiple gigabytes, which far exceeds the limits of any email server.

It does not require a degree in computer science to figure out that most, if not all, information technology (IT) departments strictly enforce standards to reduce not only the size and the number of electronic files stored but the longevity for which they are stored. These three components directly affect an organization's entire computer infrastructure, including but not limited to internal and external network hardware and software, server (storage) size, Internet bandwidth, and other related technical areas.

As a result, the quality of the electronic documents preserved and maintained by large financial organizations, mortgage companies, title companies, registrars' offices (such as county clerks' offices, etc.), courts, lawyers' offices, so on has dropped below a threshold where many of the documents are no longer usable for analysis by questioned document examiners.

Adding to the need for this method of document preservation is the ever-increasing cost of real estate (buildings) for storing thousands of documents. And there is also the need to preserve, protect, and maintain copies of documents in the event of a catastrophic event, such as a fire, flood, or earthquake.

Some PDF creation applications provide an option to change the default settings to generate a higher-quality output, while other applications do not allow the user to change the default settings, which generates a lower-quality document.

It should also be noted that when a printed document is scanned using a flatbed scanner or a copy machine, the entire page is viewed as a single image (in other words, a layer) on a standard size page, such as a letter, legal, or other size page. In this case, the entire page is resampled and compressed using default PDF settings, which causes the text to be blended with the color of the background page.

While scanners and copy machines create a text image, applications such as Adobe Acrobat Pro and many others can create a PDF file directly from the application, or the PDF creator tool printer driver can be used to create an electronic file directly from word processing applications, such as Microsoft Word. In these instances, the text blocks are not handled as images, which means the text is not resampled and the text is not compressed, thus eliminating any of the JPG compression artifacts (see Figures 14.24, 14.25).



FIGURE 14.21 The illustration in box A shows an original, high-resolution signature; box B shows the same signature in which the resolution was resampled to 150 PPI, and box C shows the resampled resolution of the image in box B compressed using medium JPG compression.

(From David Witzke.)

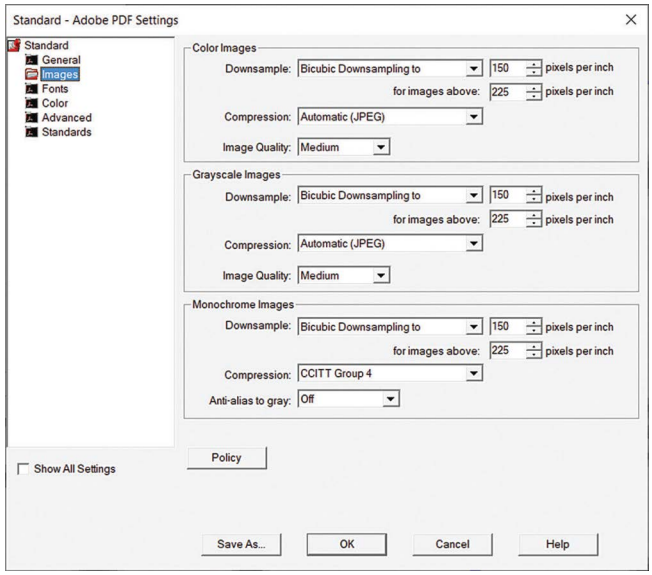


FIGURE 14.22 The standard, default Adobe PDF settings are configured to resample images using bicubic downsampling of images above 225 ppi to 150 ppi and then compress the image using automatic (JPEG) compression using medium image quality.

(From David Witzke.)

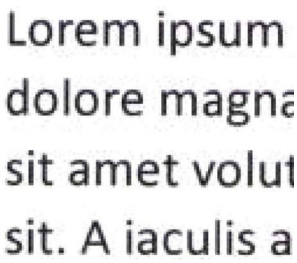


FIGURE 14.23 Flatbed scanners and copy machines create an "image" of the page, much like a digital camera would capture an image of a page. This text image is then treated like any other image, meaning it is first resampled and then compressed using medium JPG compression. The JPG blocking artifacts are clearly visible when the PDF document is enlarged on the screen.

(From David Witzke.)

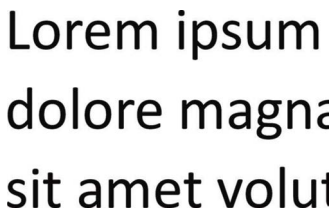


FIGURE 14.24 PDF creation applications can generate electronic documents in which the text is not compressed, but images, if any, embedded in the document are resampled and then compressed using medium JPG compression. The bottom line is that the text looks crisp and pristine (unaltered).

(From David Witzke.)



FIGURE 14.25 When the electronic file is printed on a laser printer, the original high-quality detail is lost because the text must be converted to a raster-based format (think of pixels), where each pixel is represented by a cluster of dots. As shown in this image, the sharpness of edges of the letters is lost.

(From David Witzke.)

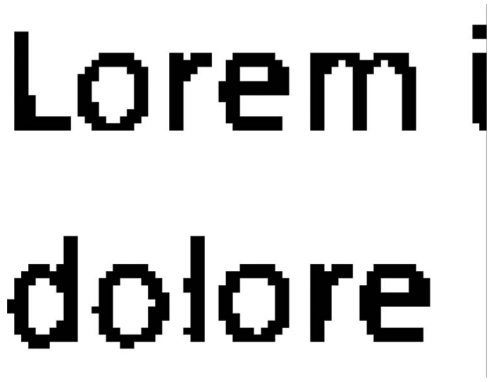


FIGURE 14.26 When the original document is printed and subsequently signed, the signed document is frequently scanned to create a new "original" document bearing the signature(s) of the party(ies) to the action. The new document is often scanned on a flatbed scanner or copy machine using a "black and white" document mode, which greatly deteriorates the quality of the document, rendering it of little or no use for analysis and comparison in the event the legitimacy of the document is challenged.

(From David Witzke.)

After the PDF document is printed and signed, in the case of an original, "wet-ink" document, the document is again scanned to create an electronic PDF copy of the signed original for purposes of memorializing the signed document. Regrettably, people are frequently not trained in the proper use of the equipment they use. Most copy machines provide two options for scanning printed (and signed) documents to create a "copy" of the original document. Figure 14.26 illustrates the effect of using a "black and white" document mode, and Figure 14.27 illustrates the effect of using a "grayscale" photo mode.

But even with all of the issues confronting questioned document examiners today with the multigenerational printing, copying, and creating of new PDF files, a wealth of information can still be obtained from reviewing the contents of the PDF file.

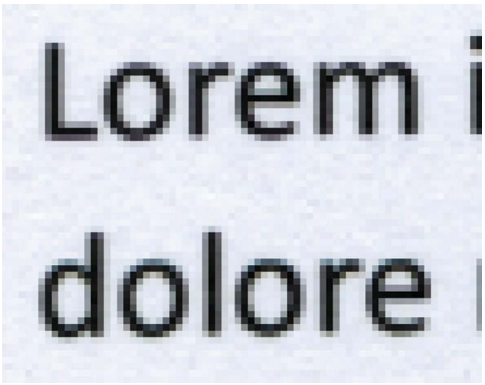


FIGURE 14.27 Typically, the original document is printed and subsequently signed, and the signed document is then scanned to create a new "original" document, which bears the signature(s) of the party(ies) to the action. Creating the new document using a flatbed scanner or copy machine with a "grayscale" photo mode is less destructive, but still deteriorates the quality of the document, diminishing the value of the new "original" for analysis and comparison if the veracity of the document is challenged.

(From David Witzke.)

IS PRINTING OBSOLETE?

Today, a wide range of PDF documents, such as those involved in real estate transactions as well as other legal matters, are being "signed" electronically using applications like DocuSign, AdobeSign, SignNow, SignEasy, PandaDoc, HelloSign, RightSign, etc. These "tools" allow organizations to prepare and manage documents electronically, as well as having individuals approve and sign documents electronically. While many people see this technology as a significant improvement in the signing, exchanging, and storage of documents, the technology provides a double-edged sword.

On one side, these technologies provide a fast, convenient way to approve and act upon legal matters. On the other side, these technologies eliminate the need for the individual's physical, "wet-ink" signature on the document, which can be used to authenticate that the document was signed by the actual party to the action. The question becomes, "How do I validate the identity of the person sitting behind the keyboard when the document is signed electronically?"

After a document is prepared, printed, and subsequently signed, caution must be used when a new "original" (PDF) document is created that includes the signature(s) of the party(ies) to the action. Obviously, additional printing of electronic documents should be considered obsolete. Not only is it unnecessary to print copies of the documents but the printed copies further deteriorate the quality of the document.

As mentioned, PDF documents created from a flatbed scanner or copy machine are "images" of a page or pages. All digital images are captured, stored, and displayed using picture elements (pixels). Using an 8-bit grayscale mode, a single pixel can be one of 256 possible shades of gray. If the image is in 24-bit color, each pixel can be one of

a combination of 256 possible shades of red, 256 possible shades of green, and 256 possible shades of blue or 16,777,216 possible color values (256 × 256 × 256).

When a pixel is printed, its grayscale/color value is represented by a cluster of dots. For example, consider a black-and-white laser printer, which has only one color of toner: black. In 8-bit grayscale, a pixel can be one of 256 possible shades of gray. Since there is only one color of toner, a group of dots are printed very close to each other to represent a dark shade, while a group of dots printed farther apart allow "white space" to be visible between the dots, tricking the eye into believing the value is a lighter shade of gray.

Based on a standard laser four-dot pitch grid, a square pixel value is represented by a grid that is four dots horizontally and four dots vertically, which yields a total of 17 shades of gray from white (empty grid) to black (a dot in all 16 spaces in the grid). Color laser printers can produce more detail because they have four different colors (cyan, magenta, yellow, and black [CMYK]) of dots to represent more color values.

Inkjet printers can provide a significantly better-quality image, depending upon the type of paper used. However, inkjet printers rarely are used for printing documents because of the speed at which they print and the cost of supplies (ink and paper).

It is this author's humble opinion that lawyers, questioned document examiners, the courts, etc., should consider printing of documents to be obsolete. A questioned document examiner should *never* print a hard copy of an electronically created and stored document. Not only does the number of colors of ink or toner affect the quality of the output but each printer manufacturer uses its proprietary printer driver (software tool that converts pixel values into dot values).

All PDF copies of questioned documents submitted to document examiners for analysis, comparison, and evaluation should be examined on a computer monitor where the page detail can be zoomed (enlarged) on-screen and examined more thoroughly and reliably. If an examiner prints copies of PDF documents for analysis, the examiner has committed a serious misstep in their analysis and evaluation.

Moreover, electronic PDF documents are often almost always submitted without any documentation of attribution, source, or origin, which should be provided for each file submitted. (In layman's terms, think chain of custody. Was the "original" created from one or more electronic copies of "other" documents, then printed and rescanned to hide the obvious artifacts?)

With more and more critical documents (such as mortgage documents, deeds, wills, and so forth) being stored using a PDF format, it is more important now than ever to know how to distinguish between a "wet-ink" original document, an original scan of a wet-ink original document, or a copy of a copy of a "supposed" wet-ink original document. It is also crucial for attorneys, financial institutions, the courts, and others to understand the continued denigration of image quality and integrity a document experiences each time it is printed and then rescanned to create a new PDF. Technology can be a great thing, but if used improperly, it can enable illicit corporations or greedy individuals to perpetrate fraud upon innocent, unsuspecting victims.

With the inadvertent loss or intentional destruction of originals after documents have been "preserved" electronically, it is incumbent upon every document examiner to fully comprehend and understand these issues, as well as be able to explain and illustrate these issues in their reports and in their testimony in court. Financial and other companies must also be knowledgeable about these issues as well as local, state, and federal registrars' (clerks') offices where "original" documents are preserved and recorded for legal purposes.

DETECTING ALTERATION AND MANIPULATION OF LEGAL DOCUMENTS

Not only is the alteration of documents becoming easier to do in today's digital environment, it is also becoming more prevalent. The most commonly used technique for manipulating or fabricating documents is copy and paste. Sometimes these alterations may be hidden from plain sight just by copying and resaving the manipulated document as a new PDF file. The good news is that while some individuals may try to hide their manipulation of documents, there are numerous "clues" for detecting if a document was altered or manipulated.

Tools Required for Digital Examination of Questioned Documents

To properly conduct an accurate, reliable digital examination of questioned documents, the examiner should use or have access to hardware and software that meets specific recommendations. These recommendations include but are not limited to:

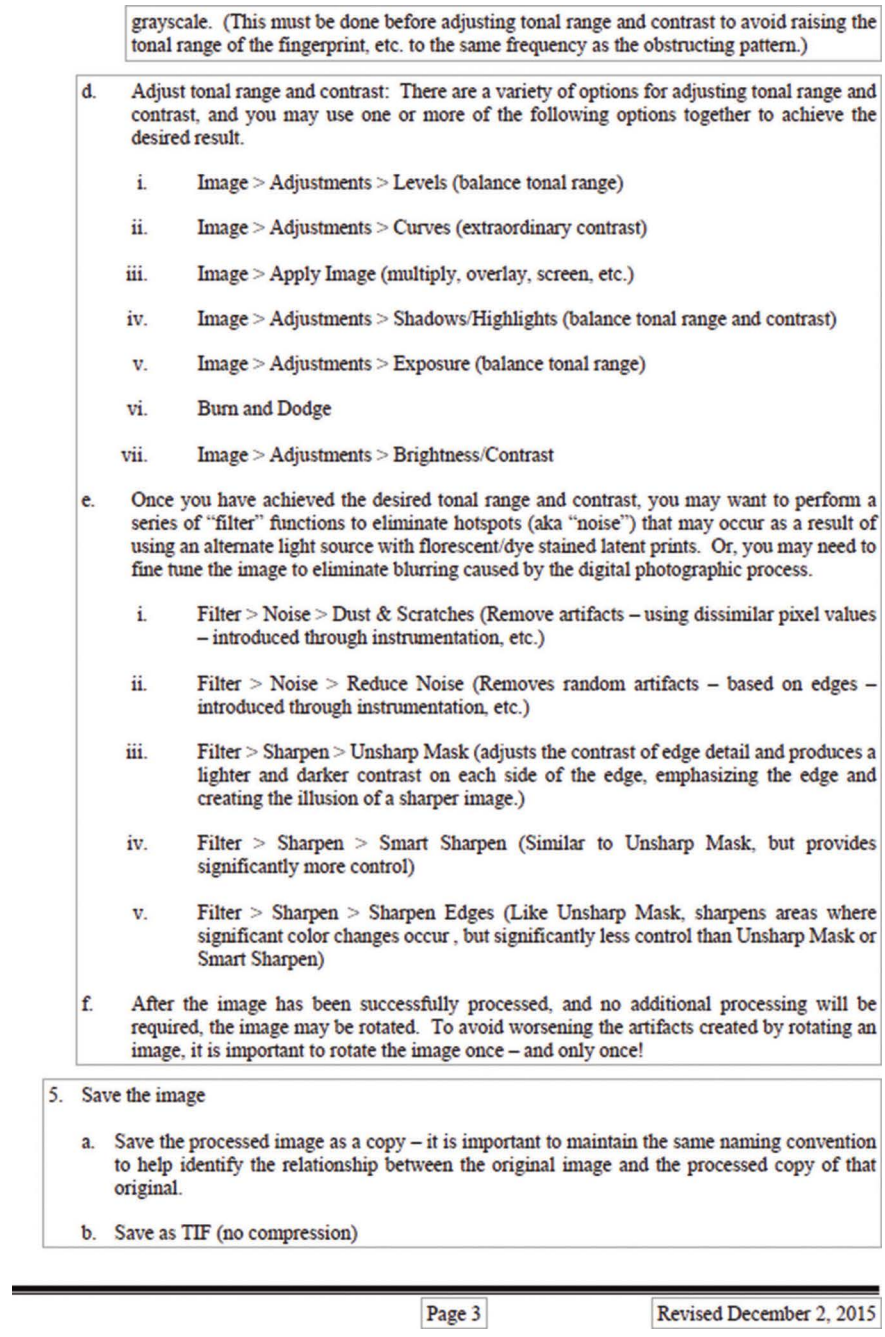
- Adobe Acrobat Pro DC Version 2019 or later (Acrobat Pro DC 2019 was released in August 2018).[1]
- Adobe Photoshop CC Version 2018 or later (Photoshop CC 2018 was released on October 18, 2017).
- An NVIDIA GeForce MX150 display adapter and Intel UHD Graphics 620 graphics driver with native support for a maximum resolution of 4096 pixels by 2304 pixels at 60-Hz frequency.
- An ultra-wide LED-lit monitor with ultra-high-definition resolution of 3440 pixels by 1440 pixels (or higher) connected via a High-Definition Multimedia Interface (HDMI) or video DisplayPort (DP) monitor port.
- High-resolution/high-dynamic-range flatbed scanner with an optical density (Dmax) of 4.0 (or higher) and with a native optical (hardware) resolution of 4800 PPI (or higher). (NOTE: This author recommends the Epson Perfection V800 Photo Color Scanner or the Epson Perfection V850 Pro Photo Scanner. These are the only two flatbed scanners currently available with a Dmax of 4.0.

While the Epson Perfection V550 Photo Color Scanner and Epson Perfection V600 Photo Scanner have a higher optical resolution [6400 PPI], these devices have a Dmax of 3.4.)

Cut and Paste

There is no set order of steps for conducting a digital examination of a PDF file. However, I believe that following a basic sequence of steps helps ensure all digital components are examined accurately, reliably, and consistently.

a. Open the PDF document in Adobe Acrobat Pro DC.
b. From the Tools menu, select Edit PDF.
c. Click on the first page of the document to display the bounding boxes for that page.
d. After reviewing the location and number of bounding boxes on that page, select the first



grayscale. (This must be done before adjusting tonal range and contrast to avoid raising the tonal range of the fingerprint, etc. to the same frequency as the obstructing pattern.)

d. Adjust tonal range and contrast: There are a variety of options for adjusting tonal range and contrast, and you may use one or more of the following options together to achieve the desired result.

i. Image > Adjustments > Levels (balance tonal range)

ii. Image > Adjustments > Curves (extraordinary contrast)

iii. Image > Apply Image (multiply, overlay, screen, etc.)

iv. Image > Adjustments > Shadows/Highlights (balance tonal range and contrast)

v. Image > Adjustments > Exposure (balance tonal range)

vi. Burn and Dodge

vii. Image > Adjustments > Brightness/Contrast

e. Once you have achieved the desired tonal range and contrast, you may want to perform a series of "filter" functions to eliminate hotspots (aka "noise") that may occur as a result of using an alternate light source with florescent/dye stained latent prints. Or, you may need to fine tune the image to eliminate blurring caused by the digital photographic process.

i. Filter > Noise > Dust & Scratches (Remove artifacts – using dissimilar pixel values – introduced through instrumentation, etc.)

ii. Filter > Noise > Reduce Noise (Removes random artifacts – based on edges – introduced through instrumentation, etc.)

iii. Filter > Sharpen > Unsharp Mask (adjusts the contrast of edge detail and produces a lighter and darker contrast on each side of the edge, emphasizing the edge and creating the illusion of a sharper image.)

iv. Filter > Sharpen > Smart Sharpen (Similar to Unsharp Mask, but provides significantly more control)

v. Filter > Sharpen > Sharpen Edges (Like Unsharp Mask, sharpens areas where significant color changes occur , but significantly less control than Unsharp Mask or Smart Sharpen)

f. After the image has been successfully processed, and no additional processing will be required, the image may be rotated. To avoid worsening the artifacts created by rotating an image, it is important to rotate the image once – and only once!

5. Save the image

a. Save the processed image as a copy – it is important to maintain the same naming convention to help identify the relationship between the original image and the processed copy of that original.

b. Save as TIF (no compression)

Page 3 Revised December 2, 2015

FIGURE 14.28 If the PDF document is created using a document editing application, such as Microsoft Word, Notepad, WordPad, etc., separate bounding boxes appear around paragraphs or groups of paragraphs using a similar format. The contents of each bounding box are treated as a separate entity and can be edited, deleted, or moved independently of the contents of the other bounding box.

(From David Witzke.)


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FIGURE 14.29 Depending upon the sophistication of the scanner or copy machine used to create a PDF document, the text and any images on a scanned page will appear as a single bounding box. In this illustration, the bounding box includes only the text. The margins of the page are not included in the bounding box. Using a less sophisticated scanner or copy machine, the bounding box would include the margins as well as the text.

(From David Witzke.)

bounding box and zoom in on the area covered by that box.

e. While focusing on the selected bounding box, move the bounding box off to the side of the screen to reveal the area hidden by the bounding box, or delete the contents of the bounding box.
f. Review the area exposed by the removal of the bounding box to see if any hidden information is now visible, such as deviation of pixel colors (such as pixilation or other compression-related blocking artifacts), difference in pixel sizes, etc.
g. If pixilation is visible, open the PDF file in Adobe Photoshop CC.
h. From the toolbar on the left side of the Photoshop window, select the Rectangular Marquee tool. With the tool, select a square/rectangular area that appears to have pixels of a different size.
i. Copy (Ctrl + C) the area inside the marching ants (the area selected with the Marquee tool).
j. Delete the marching ants (Ctrl + D).
k. Paste the copied area on top of the image. The copied area will be added to the document image as a new layer.
l. On the layer panel, select the Darken option. By default, the blending option is set to Normal. This blending option allows the white pixel values (highlights on the histogram) to become transparent/semi-transparent.
m. From the toolbar on the left side of the Photoshop window, select the Move tool.
n. Place the Move tool cursor on top of the newly added area (layer) on top of the image, click and hold the mouse button, and drag the area adjacent to an area where the pixels appear smaller or larger.

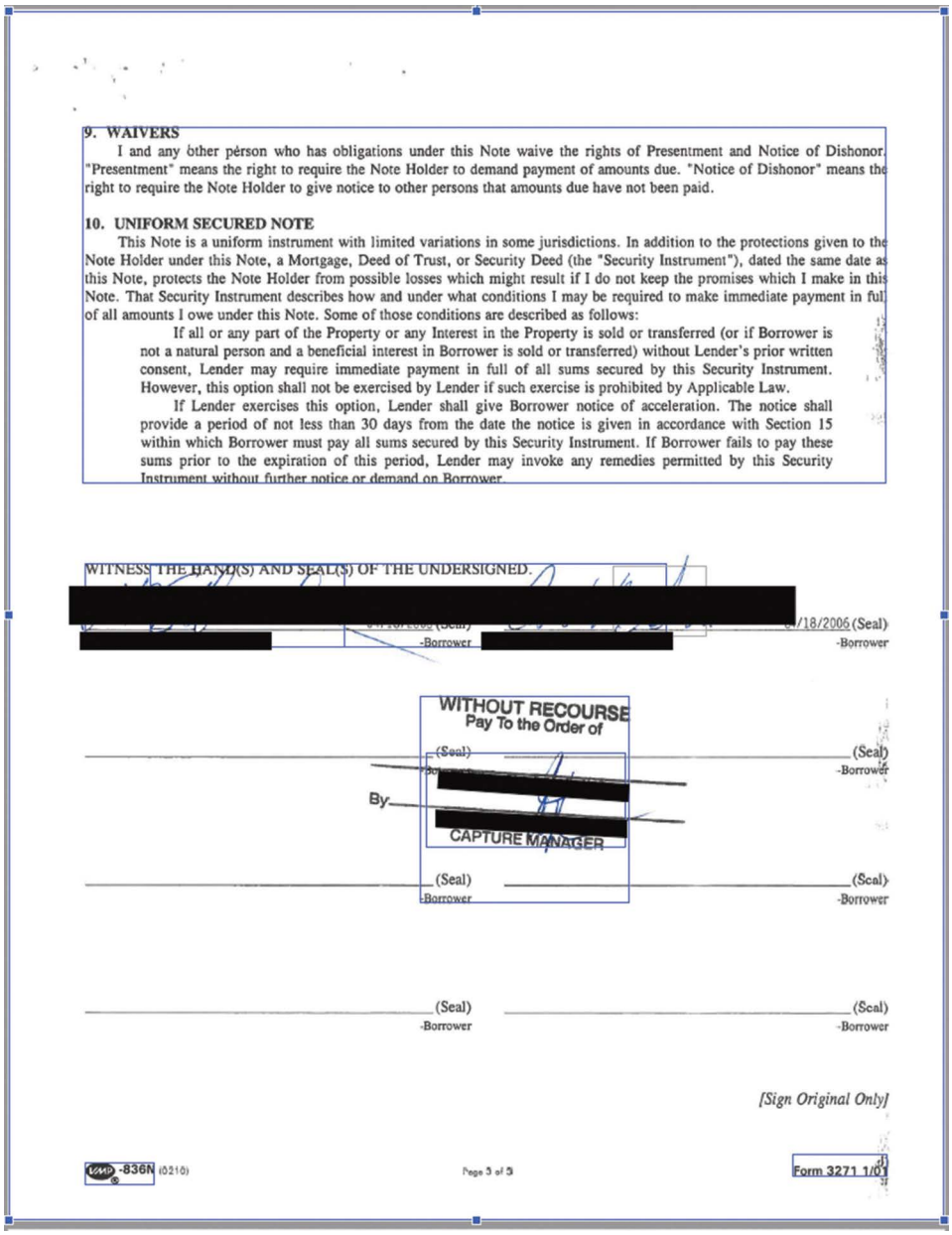


FIGURE 14.30 In situations where a PDF document has been altered, multiple bounding boxes will appear. In some instances, bounding boxes will appear on top of other bounding boxes (layers). The page illustrated here included 23 bounding boxes, many of which were created and placed on top of other layers to eliminate artifacts or to add missing details. (NOTE: The identity of the parties to this action have been redacted to protect their privacy.)

(From David Witzke.)

Upon a careful examination of the area shown in Figure 14.31, multiple artifacts are clearly visible. In the signature, the letter "W" contains color values that are consistent with image downsampling and blocking artifacts that are consistent with JPG compression. The letter "D" in the signature is a completely different shade of blue than is represented anywhere else in the signature. Further, there is no color aliasing as shown in the letter "W" or anywhere else in the original signature.

Also, notice the inconsistency in the white background along the signature line shown in Figure 14.32. The background is a solid white along the edge of the signature line and inside the enclosed loops. The background on the outside of the signature includes color aliasing consistent with resampling as well as blocking and other color artifacts consistent with JPG compression. Also, notice the difference in white pixel values inside the letter "D" below the signature line and the white pixels outside the letter "D."

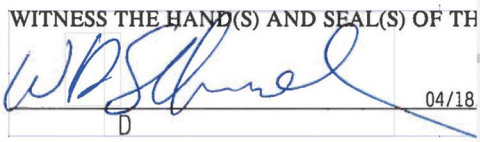


FIGURE 14.31 After removing the contents of multiple bounding boxes, more bounding boxes are revealed. With the removal of overlaying layers, cut and paste artifacts become clearly visible. (NOTE: The identity of the parties to this action have been redacted to protect their privacy.)

(From David Witzke.)

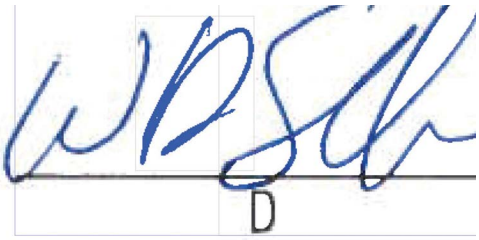


FIGURE 14.32 Signature line zoomed in more for detailed analysis and identification of artifacts consistent with image manipulation. Note the color inconsistencies of the signature as well as the color inconsistencies in enclosed areas, such as loops and the area between the signature line and the signature itself.

(From David Witzke.)



FIGURE 14.33 Upon closer examination (zooming in), the deviation in the size of pixels also becomes visible. Notice how the white pixels overlay the color pixels. As discussed earlier, images are downsampled to 150 ppi using the standard Adobe Acrobat settings. The standard default new image size for most, if not all, image editing software applications is 300 ppi.

(From David Witzke.)

Erasures

In addition to physical alterations, such as overlays, cut and paste can be used together with erasures to manipulate questioned documents. In this case, a signature appearing on another page or an entirely different document can be copied and pasted onto another page in the same or another document.

Using Adobe Photoshop CC, a signature can be copied from one page and overlaid on top of the signature on another page for comparison. During this process, it is very easy to see if the same signature was used on one or more documents. For example, if a signature line goes all the way across a page but there appears to be a distinct break in the line, it should be examined carefully.

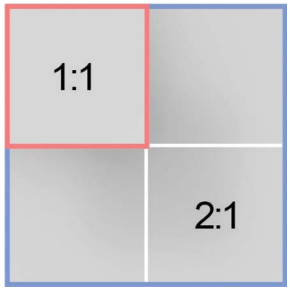


FIGURE 14.34 To resize the existing image, each existing pixel would be up-sampled using a 2:1 ratio for height and width. Therefore, a new pixel added to a resized image would be one-quarter the size of the original pixels.

(From David Witzke.)

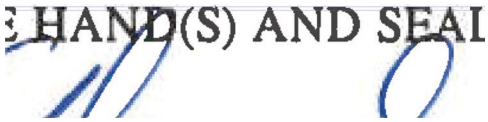


FIGURE 14.35 Also, be sure to review the text for inconsistencies. In this case, the letters H and N in HAND(S) and the letters "EA" in SEAL contain color artifacts consistent with image resizing and pixel blocking artifacts consistent with JPG compression. The other letters in the text do not contain these same artifacts; therefore, the letters could not have come from the same document.

(From David Witzke.)



FIGURE 14.36 By continuing to remove the overlaying layers, the final underlying layer reveals color artifacts consistent with image resizing and pixel blocking artifacts consistent with JPG compression. This proves that the underlying image (signature) existed on another page or within another document that had already been saved as a PDF (resampled and compressed) and that the image was cut and pasted into its current location on this page and then manipulated to appear as if it were an original signature without the preexisting artifacts.

(From David Witzke.)

CREATING OVERLAYS

The use of cut and paste for signatures on multiple documents can be demonstrated quickly and easily using an overlay function in Adobe Photoshop CC. The individual



FIGURE 14.37 On one page, there appears to be an erasure of the line and a portion of the background to accommodate the pasting of text or a signature. For example, start on the left side of the image and follow the line, and you can see where there is a trailing off (gradient) in the signature line.

(From David Witzke.)



FIGURE 14.38 On a separate document bearing a "wet-ink" signature, we find the signature that was used to cut and paste into Figure 14.37. In this image, the signature line starts above and to the left of the typed letter "D." Even though the image in Figure 14.37 has been resampled and compressed, the break in the ink between the letter "A" and the top of the letter "a" (on the right side of the image) is visible in both the original wet-ink signature and the copied and pasted signature.

(From David Witzke.)



FIGURE 14.39 After further enlargement of the signature line in Figure 14.37, it is easy to identify where the signature line was erased and the signature with its own line was copied and pasted into the document.

(From David Witzke.)

signatures are first colorized with different color values using Hue & Saturation and then the signatures are overlaid using a drag-and-drop technique.

a. To view the detail in the first signature when overlaying two signatures, change the color of the first signature to red.



FIGURE 14.40 The same signature used in Figure 14.37 appears again on another document. While this PDF document was created using a document mode (highest level of degradation), there are still characteristics that are clearly visible and can be compared in both signatures, such as the trailing tail on the back of the letter "D" and the break in the ink between the "D" and "a "of David and in the formation of the letter "i."

(From David Witzke.)

   i. From the Image menu, select Adjustments, and then select Hue/Saturation.
   ii. As shown in the Hue/Saturation window in Figure 14.41, enable the Colorize option on the right side of the dialog box. A checkmark should appear in the checkbox to the left of the Colorize option.
   iii. By default, the slider will appear on the left side of the Hue option, which is red.
   iv. Move the slider under Saturation to the far right, which will display 100.
   v. Move the slider under Lightness to the right, to 55.
   vi. Click OK in the upper-right corner to lock in the new color values.

b. Repeat step 1 with the second signature, colorizing the signature to green.
   i. From the Image menu, select Adjustments, and then select Hue/Saturation.
   ii. Enable the Colorize option on the right side of the dialog box. A checkmark should appear in the checkbox to the left of the Colorize option.
   iii. Move the slider under Hue to the right, to approximately 120.
   iv. Move the slider under Saturation to the far right, which will display 100.
   v. Move the slider under Lightness to the right, to 55.
   vi. Click OK in the upper-right corner to lock in the new color values.

c. Place the signatures side by side: from the Windows menu, select Arrange and then select 2-up Vertical, as shown in Figure 14.42.
d. Select the Move tool from the toolbar or type the letter V to enable the Move tool.
e. Move the cursor into the image window containing the questioned signature and click the left mouse button.

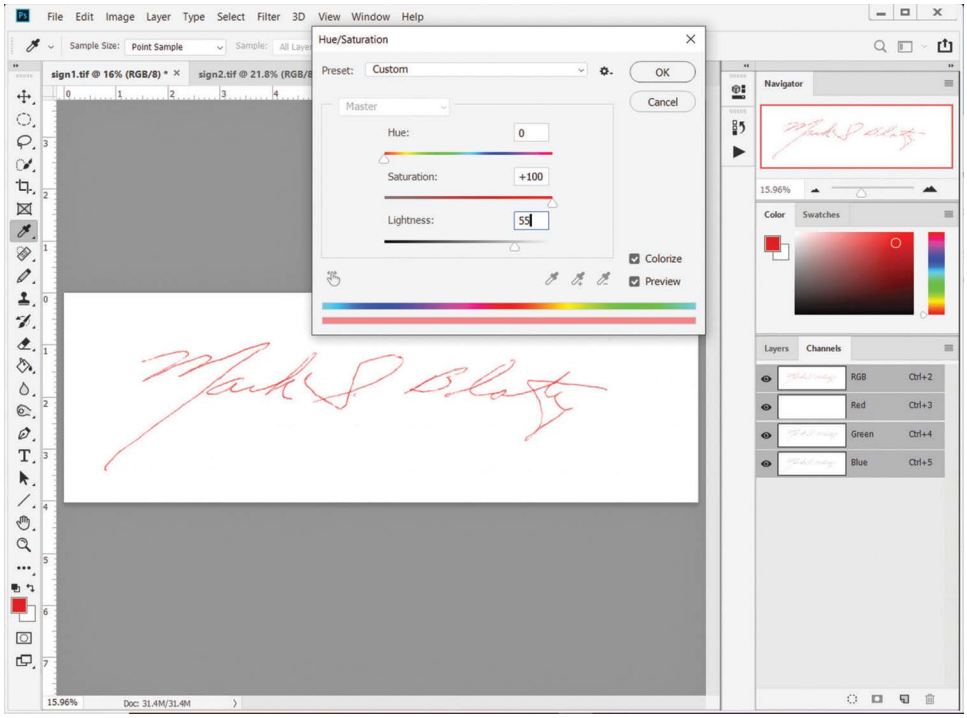
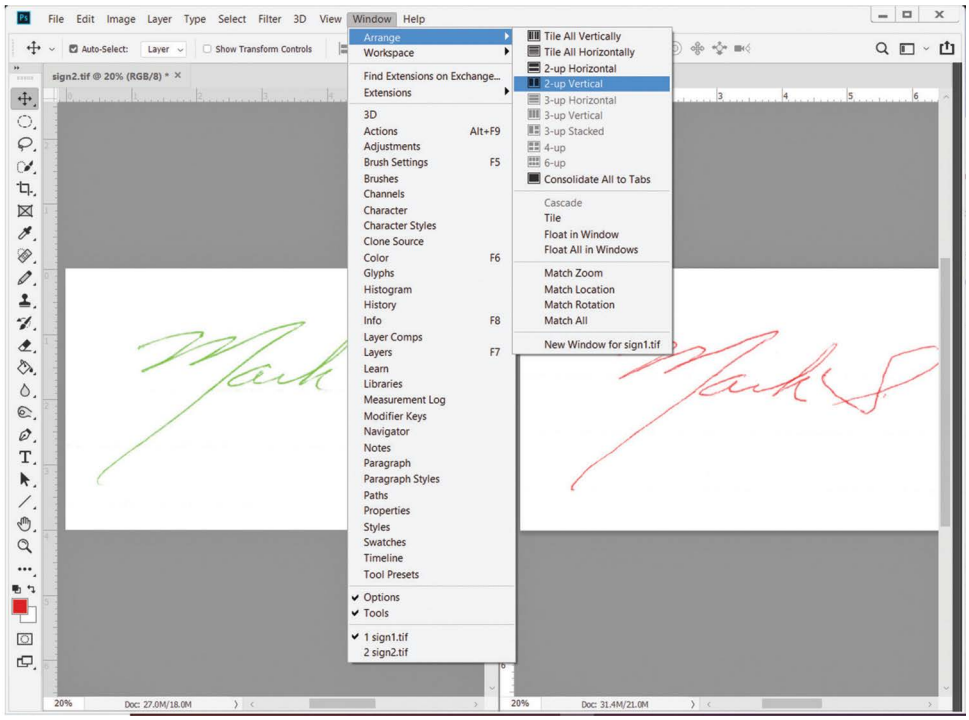


FIGURE 14.41 The Hue/Saturation window.

(From David Witzke.)



n.

FIGURE 14.42 Selecting 2-up Vertical.

(From David Witzke.)

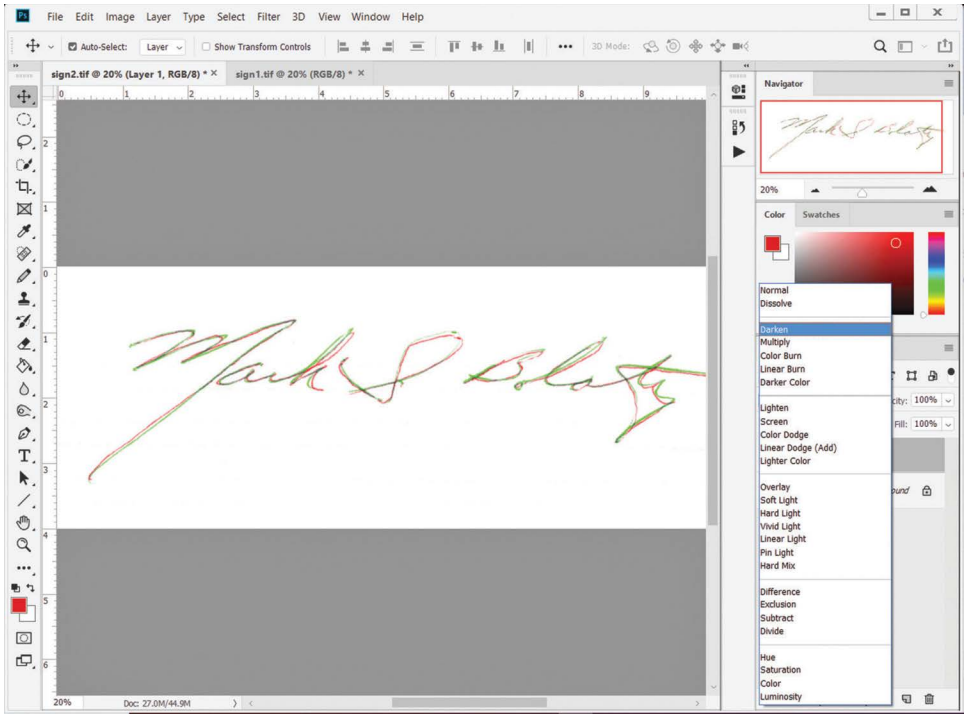


FIGURE 14.43 Displaying both signatures overlaid.

(From David Witzke.)

f. Place the tip of the arrow in the cursor on a characteristic that will be used for positioning the questioned signature on top of the standard in the other image window, as shown in Figure 14.42, and click and hold the left mouse button.
g. While continuing to hold down the left mouse button, drag the cursor into the other image window, and the cursor will change shape as it moves from one window into the other.
h. Position the tip of the arrow in the cursor on top of the corresponding position identified in step 16 earlier, as shown in the Figure 14.42, and release the left mouse button.
i. Now that both signatures appear in one window, side-by-side display can be dismissed. From the Window menu, select Arrange and then select Consolidate All to Tabs.
j. Click on the Layers tab in the Layers/Channels/Paths panel on the right side of the Photoshop window.
k. Beneath the menu bar for the Layer tab is a blending option selection box. The default option that appears in this box is Normal. Click the down arrow and choose the option Darken, as shown in Figure 14.43. The white background of the top signature will now be transparent, and both signatures will be visible.
l. Using the Move tool (aided by the left, right, up, and down arrow keys on your keyboard), you can align the signatures so that one signature is on top of the other.

OPTIONAL:

It may be necessary to use the Free Transform function (Ctrl + T) to adjust the vertical/horizontal orientation of the top layer to match the orientation of the underlying layer.

m. When the alignment and orientation of the images are satisfactory, save the overlay as a TIF file.

Once the images are aligned, the intensity of the red and green color values of the matching portions of the images will appear as dark shade of gray (black). In this instance, the signature was traced. The areas where the images do not match will be very noticeable because the visualization of the red and green color values will be very apparent.

CONCLUSION

This appendix does not intend in any way to instruct examiners in the examination, analysis, and comparison of questioned documents. The goal is to provide recommendations for the use of digital technologies in digital examination of questioned documents.

There are two critical components for conducting any type of digital examination in forensic sciences:

1. High resolution
2. High dynamic range

It is also critical to zoom in and carefully evaluate the minute detail contained within the image. Failure to zoom in on the document and view the enlarged detail may lead to missed indications of alteration or fabrication. High resolution is the key to analysis, comparison, and evaluation.

NOTE

1. Please be advised that Adobe Acrobat DC Pro has a default setting that is turned on (enabled) and it *must* be turned off (disabled) for any type of questioned document analysis! Under the Edit settings, there is an option for scanned documents. By default, the Recognize Text function is enabled (checkmark in the box). *This function must be disabled!*

The Recognize Text function is an optical character reader (OCR) function that automatically converts scanned documents into what it considers to be "editable" text blocks as well as editable graphics blocks. This process changes (alters) the rasterized (scanned) image data from bitmapped (pixel) graphics data into text data. The OCR software also tries to match the font type based on the pixel formation. (Beyond determining whether the font is a serif or san-serif font, this function is not very useful. You can override this function in the OCR software and enable the setting to use a regular system font.)

Another problem with the OCR function is that text may be included in graphic blocks, such as in a signature block. Since the OCR software cannot convert a signature to text, it converts the signature block as a "graphic" (pixel) format, which can result in misleading analysis. For example, text in a text block will appear vastly different than text in an image block.

15 Clandestine or Surveillance Photography

Patrick Linnenbank

CONTENTS

Fixed Location 339
Mobile or Vehicular 340
Walking Surveillance 342
What, Why, and How? 342
Further Reading 344

Since the first chapter list of this book was posted to our contributors, I have heard from various people with opinions regarding the subject of clandestine photography. In general, the comments have not been positive. The people who made the effort to bring their feelings forward said there is no place for the subject of clandestine surveillance photography in a text about forensic photography. Thus, this controversy.

What is clandestine photography? The best definition I have found is: The making of photographs of subjects in secrecy, unaware their photos are being captured. This applies to still or video images of people, objects, activities, animals, or a general area. Actually, anyone or anything may be the subject as long as the photography is accomplished from cover and the subjects do not realize it is taking place. It is nearly always something done at the behest and bankroll of a client. Photographs are made and submitted, untouched, by the photographer.

How indeed would this not qualify as a division of forensic photography? The only difference I can see between this work and any other part of forensic photography is the fact that the expert making the images is under cover. The subject of clandestine photography has existed since the camera became small enough to be portable and fast enough to stop the action. Law enforcement and private investigators were and are the groups using the discipline legally. It has always been necessary or opportune to catch people in the act of committing any sort of crime. How better than to have a qualified operative make photographs from a hidden location documenting the subject in the act? The photographers involved are legally qualified to be witnesses who can swear to the accuracy of the images. The operative sits in the witness chair and says, "This is what I saw" and "Here are the images to prove it!" At that moment, the subject is in deep trouble.

One more difference between this specific type of photography and the rest of the practice is that clandestine photography is the only branch using tradecraft to accomplish its goals. Defined by Wikipedia: "Tradecraft is, within the intelligence community, the techniques, methods and technologies used in modern espionage and generally, as part of the activity of intelligence. This includes general topics or techniques, or the specific techniques of a nation or organization."

What exactly is tradecraft to a forensic photographer? It is the same as the way a secret agent makes their living—anyone using the practice of photography with the express purpose of capturing images from cover proving someone is doing something they should not be doing.

The legality of this type of image capture must be highly stressed. In most, if not all, states in America, the performance of clandestine photography is legal only for law enforcement or licensed private investigators. In other parts of the world, consult with local law enforcement for the statutes in current use regarding the practice. Remember, if the person capturing the images is not properly credentialed for their purpose and location, opposing counsel will take only a few seconds to have the evidence dismissed.

Taken into a court of law, covert images may be a key part of the pieces of evidence putting the perpetrator(s) behind bars. There are several different types of surveillance operations:

1. **Fixed location**, where the operative waits for the subject to come into their view and the viewfinder of the camera.
2. **Mobile or vehicular**, where the subject is followed by a number of other vehicles, usually one to three, handing off the subject when necessary and working to avoid discovery. The cars or vans or trucks are equipped with clandestine features (like dashcams and/or bodycams, tinted windows to keep the subject from seeing inside, and possibly blackout curtains through which the operative is able to see but nobody is able to see in) allowing an operator to capture images without the subject being aware.



FIGURE 15.1 Fixed location surveillance waiting for the subject to return to their car.

(From Dr. Patrick Linnenbank.)

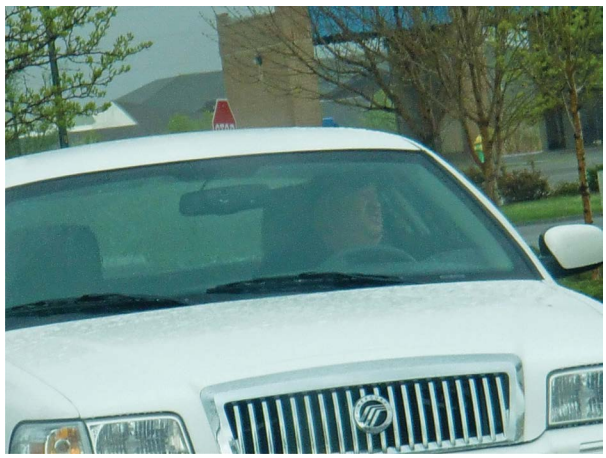


FIGURE 15.4 Mobile surveillance of a subject taken from a stationary van.

(From Dr. Patrick Linnenbank.)



FIGURE 15.2 Walking surveillance of two subjects using a hidden camera.

(From Dr. Patrick Linnenbank.)



FIGURE 15.5 Video surveillance of a subject carrying a covert camera.

(From Dr. Patrick Linnenbank.)



FIGURE 15.3 Mobile surveillance of two subjects after handoff to second follower.

(From Dr. Patrick Linnenbank.)

3. **Walking** is exactly the same procedure as vehicular. The operatives are mobile, in radio communication, and practiced in being invisible in plain sight. More on that later. But the followers work in tandem, handing off the subject as many times as necessary to assure the subject they are not being followed. Once the subject is comfortable, they are likely to do the act they are being followed for/about.
4. **Aerial** is a newer division of surveillance. The use of miniature drones is a growing technology. The machines are small, technically invisible, optically superb, and range in price from prosumer grade to very expensive. (Please see Chapter 23 for the proper use of drones for any photography.)
5. **Remote** is like fixed location, where equipment is left behind in the location suspected of being the site of a future event or operation. The operative sits at a computer monitor at a location around the corner or around the world. The images are



FIGURE 15.6 Remote surveillance using a hidden fixed camera.

(From Dr. Patrick Linnenbank.)



FIGURE 15.7 Covert camera image using a bodycam.

(From Dr. Patrick Linnenbank.)

transmitted on the Internet. The cameras may be ordinary CCTV equipment or small black boxes the size of a box of matches or up to the size of a box of Band-Aids. And sometimes, existing surveillance systems may be utilized. If placed and aimed in the right location, the necessary images should be captured. The setup of the equipment is something most any specialized electronics technician may do. The monitoring of the computer is a task left to qualified personnel only.

Today there exist cameras meant to be left behind in the woods to observe the movements of game animals. These cameras are movement activated and work well even in very dark conditions with infrared illumination and sensitivity. The newest ones are able to accept a copy of the owner's SIM card from their cellular phone and send the live feed of the view right to the owner's phone.

6. **Video surveillance** is where the subject is captured in movement by a type of video camera. This



FIGURE 15.8 Fixed-location image capture using a camera with a built-in motion detector.

(From Dr. Patrick Linnenbank.)

may be accomplished by a remote camera hidden in a specific location or by a covert camera carried in some way by an operative. However, the image capture is performed, it is usually images only to avoid extraneous sounds distracting from the images.

7. **Audio surveillance** is the capture of sound, not images, of hidden activities. Sadly perhaps, the use of audio surveillance only is illegal in America. Check with your local jurisdiction for the laws in your part of the world.

So, what is the real difference between overt and covert forensic photography? The things in common are:

- Same type of client
- Same type of deliverable
- Same type of authentication
- Same type of result

And, as mentioned before, what are the differences?

- Images captured from cover instead of in the open
- The photographer is a trained operative as well

Are these factors sufficient for disclaiming surveillance photography from the field of forensics? Is still camera or video surveillance any less or more different from forensic photography than laser scanning?

What type of photographic hardware/equipment should be used for this purpose?

FIXED LOCATION

The photographic hardware necessary for making images from a static location without the physical input of the photographer are of two kinds:

a. Closed-circuit television cameras (CCTV) are used. These cameras are short range, either hard wired or a local Wi-Fi or Internet-enabled system. The hard-wired system will have actual cable connectivity to a central console located somewhere near the cameras. The monitors can be one screen per camera or divided into up to four quarters of screens for four cameras. The cameras have automatic focusing and automatic metering capabilities. After dark they probably require an infrared light source to accompany the cameras, illuminating the area viewed. Sometimes the cables are not used because the cameras have Wi-Fi or Bluetooth capability. In either case, the cameras will be very similar, even though one is connected by cables and one is wireless. They both have connectivity to the central computer and monitors over a short distance.
b. Internet-enabled systems are similar in every way except the cameras are connected to the Internet and the person(s) monitoring the views can be across the street or across the world. These cameras work exactly the same as the short-range systems, except these are probably battery operated, while the short-range cameras are possibly powered physically by being connected to the system.
c. Some cameras meant for fixed-location image capture have built-in motion detectors. When motion is sensed and the detector is triggered, Wi-Fi cameras will send an alert to a smartphone and also possibly record a short clip of the event to the cloud.
d. The wireless cameras have up to a two-year battery life, powered by two AA lithium batteries, and the data is sent from IP-enabled cameras over Wi-Fi.

The cameras are being updated and changed in terms of capabilities in very rapid order, usually to be made physically smaller. When ready to purchase a system, shop online or at an electronics store and pick out the best you can afford. The resolution should be at the top end of possibility, so use that as the limiting factor for your choice.

MOBILE OR VEHICULAR

The hardware for these situations is chosen by budget and platform. Always buy the best cameras you can afford. As usual, the cameras come in multiple types, and it is up to the user and the situation to decide what to use. The best type of vehicle to use for mobile surveillance is a van. It should be a smaller van to be more or less invisible in traffic. Pick a dark color over a light color. Be certain to have the windows tinted. Then hang one-way curtains from the ceiling frame, surrounding all the windows except the windshield, to cover the user. The user can see out, but the subject cannot see in. The blinds still need to be raised physically to make the photographs.



FIGURE 15.9 Surveillance of two subjects from a bicycle. **(From Dr. Patrick Linnenbank.)**

There will also be the opportunity for the operative to surveille a subject from a bicycle, while wearing roller blades, or even a wheelchair. Never give up on the project just because you are forced to improvise.

a. Body-cams or dash-cams. These cameras are either mounted on the dashboard of a vehicle or worn physically on the body of the user. They are small and on the relatively inexpensive side.
b. One of the largest users of body-cams around the world is the law enforcement community. The cameras can be worn full-time.
c. The cameras automatically switch to night vision. An infrared light source projects the illumination up to 15 to 20 meters when the light level is too low for daylight exposure.
d. The cameras mostly record in full HD and carry an internal memory of up to 32 GB and include a built-in monitor for playback.
e. They are also fully weatherproof in case the operative is on foot in bad weather.
f. The cameras have sufficient resolution to capture and recognize the facial features of a subject at up to 15 to 20 meters away.
g. They are meant to collect video, audio, and still images of any personal action the user is seeing.
h. The screen displays the time and date directly onto the images and has the time, date, memory, resolution, battery life, and recording space available on the monitor at all times.
i. The price for these units is now under $150 each.
j. Exactly the same as the fixed-location equipment, some cameras have built in Wi-Fi connectivity, and the cameras will send an alert to a smartphone and also record a short clip of the event to the cloud.

k. The wireless cameras have up to a two-year battery life, powered by two AA lithium batteries, and the data is sent from IP cameras over Wi-Fi.

People will do certain things at any hour of the day or night. It is necessary to be able to make reasonable images in bright sunshine in the desert or on a rainy night in a dark alley in a city. Both of these environmental situations are reasonable for modern equipment, but the operative setting up the equipment must be a trained photographer to understand the proper ways of doing the job. Most modern cameras have a very high upper end for ISO, and some have larger maximum lens apertures for working in dark locations. But sometimes even these features are not enough, and the use of supplementary lighting is necessary.

A van is the preferred vehicle for going mobile because it is roomy and comfortable. There may be hours at a time when the operative has nothing to do but sit and watch a doorway for someone to enter or leave. If the van is equipped with coffee, please remember to include facilities for recycling as well. There are some extremely innovative and effective methods available now, at very low prices, for helping both males and females be more comfortable over hours of sitting and waiting.

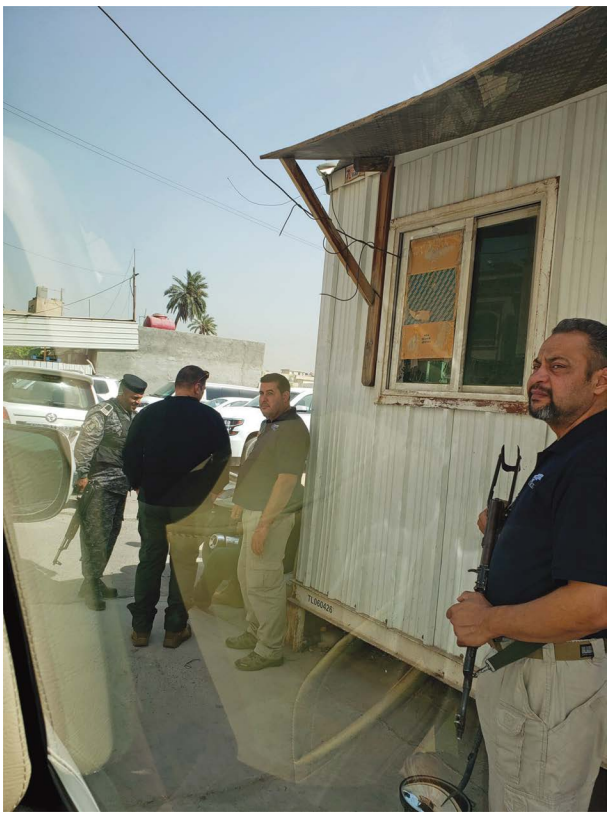


FIGURE 15.10 Vehicular surveillance in Baghdad through a tinted window.

(From Dr. Patrick Linnenbank.)

Equip the van with both a comfortable seat for the operative and a tripod for holding whatever camera is in use. Having the rear cargo bay empty at the start of being re-equipped is suggested, and then try to fasten one of the otherwise unused rear seats into the floor of the vehicle on a revolving platform so the user may see out of any window by turning the seat. It is best to carpet the floor so if anything drops from the hands, the sound is muffled on the outside. It is always best to have everyone think the van is uninhabited. If it is cold outside, a propane camp heater is a great choice. The only necessity then is to figure out a way to vent the fumes to the outside without making visual steam.

Besides the bodycams and dashcams, there is always the possibility the van will be parked at a reasonable distance from the suspected action, either because the best vantage point is not available closer or the location chosen is the closest possible place to park. That leaves two choices of hardware for the operation. Either a DSLR camera with a long-telephoto lens or a video camera with a very long zoom capability.

l. If a DSLR camera is in use, it should have either a very long fixed focal-length telephoto lens or a very long zoom telephoto lens. The zoom is always preferred in this case, because the subject may approach the vehicle the operative is in and the very long fixed-length lens may be ineffective when the subject is close. Longer lenses like these will often include a tripod mount on the lens itself. DO NOT think it is a good idea to attach the camera to the tripod anyway. If the lens comes with a tripod mount, USE IT. Just the vibration of the shutter activation will be sufficient to cause the images being captured to be blurry if the camera is attached to the tripod instead of the lens. Even cameras and/or lenses with image vibration dampening/suppression built in will not necessarily

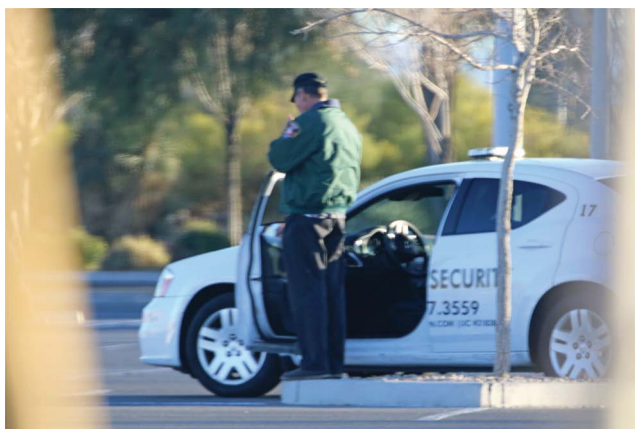


FIGURE 15.11 Long-lens surveillance using a tripod mount.

(From Dr. Patrick Linnenbank.)

overcome the issues of shutter vibration unless the system is properly anchored.

When shopping for a tripod, pick one in black or another dark color and paint all the chrome hardware in matte black. (See later for more information.)

Longer lenses may require extra light for proper exposure. It is strictly a factor of budget assumed by the camera or lens manufacturer. Some lenses may have a maximum aperture of *f*/5.6 or less. This is to keep the lens smaller and less expensive. Purchasing a lens with the same focal length but a faster maximum aperture of *f*/4 or possibly *f*/2.8 could make the difference of many thousands of dollars to the purchase price. When a lens of faster aperture is available, in less-than-optimum lighting a large aperture can be used, and the shutter speed can still be fast enough to stop the action. And the ISO can be kept low enough to eliminate some of the graininess created at higher numbers.

One last thing to mention: there may be the rare occurrence when photographs are taken in an overtly covert fashion. In other words, in the open when the subject should not notice what you are doing. There is a nice accessory to keep in your go-kit for these occasions: a right-angle lens hood. The hood screws onto the front of the lens, just the same as any other hood, but it has a 45-degree mirror built in to bounce the image onto the camera sensor from out the side of the hood. That way, from a distance, the subject will not be able to tell the camera is pointed in their direction. Of course, the images will be flipped from the actual view, and that is the way the originals should be saved. Then in any of the normal image processing programs, just flip the image back to the way it would have looked if the lens were pointed in the direction of the subject.

m. Video mobile surveillance. There will be projects where it is more important to capture the action of an event than the still image documentation. In these cases, the first thing to determine is the situation and then match the hardware to the situation. The full gamut of video hardware is listed and explained in Chapter 16, so it is not necessary to list it again here. The only thing I want to say is the equipment will most often be chosen by size. Cameras range in size from small to large. The small ones include the tiny video cams purchased at the camera or electronics shop and cellular phones. The large ones can go up to the size the television news crews use in the field. Each has its purpose: to capture movement in a format sufficient to replay and explain to witnesses and juries what occurred. The choice is up to the situation, budget, and personal preference.



FIGURE 15.12 Mobile surveillance using a dashcam.

(From Dr. Patrick Linnenbank.)

WALKING SURVEILLANCE

This is exactly the same procedure as vehicular, but without the vehicle. Everyone on the surveillance team should be equipped with some kind of image capture instrument. They should all be trained in the process of image capture. They should all be trained in being invisible in plain sight and remember to not make eye contact with the subject.

Since the operative is working without cover, chances are the opportunity for capturing the video will not be one where it is possible to stand and aim the camera at the subject. So, some sort of remote control for the camera will be used, and the operative will be experienced at aiming the camera by pointing the part of their body the camera is hidden in at the subject. It is not as easy as it may sound, and practice BEFORE need is highly recommended.

WHAT, WHY, AND HOW?

Hiding in plain sight, if that is what the project requires, is one of the most difficult things in the world to do. There are ways and means by which the operative will be successful or a failure. Why this is necessary should be perfectly obvious for everyone from the highly trained to the uninitiated.

The ways and means include the following:

- The subject of the project should never think they are being photographed. If the operative is caught pointing a camera in the direction of the subject, the case is known as "blown" in the vernacular of the operatives. What can happen to the project then? Probably, absolutely NOTHING!
- If the subject is being followed by any of the procedures indicated earlier, the operative(s) should be properly prepared mentally and physically for the challenge. They must know exactly what it is they are trying to accomplish and going to do, and they must know how they are prepared to do it before the necessity occurs. The use of hidden

cameras may look easy on television, but in real life, not so much. It takes training and practice.

- To be invisible in plain sight, the operative needs to blend into the background. The human eye (the eye of the subject, especially of the wary), will certainly be drawn to whatever seems changed from the days before and odd today over yesterday. Some of this reaction is instinctive and hereditary from the days of the hunters who lived in caves. Some people are able to FEEL when they are being observed. This is something the operative must be prepared to handle. If they think the subject is feeling them, it is time to hand off surveillance to the next operative or give up entirely for the day.
- The operative must never, ever make eye contact with the subject.
- There are ways to be disguised that will work and ways that will not. For example, an operative may stand on a street corner playing a violin or blowing a trumpet, while wearing fake facial hair (men only), fake glasses, and a pillow stuffed down the front of their shirt, wearing a backwards baseball cap, with the instrument case open to collect donations. They will be wearing a tiny two-way radio for communication with team members. Once the subject of the operation walks, rolls, or drives by, the musician tells the rest of the team what has occurred. After that, unless the musician ditches the instrument, completely changes clothes, and removes the fake facial hair and glasses, they are effectively out of the project except for the monitoring of covert cameras by computer in an enclosed van or other unlikely vehicle.
- The operative should dress very quietly and in a way to blend in with the majority of the people likely to be in the area. Wearing a tuxedo to an operation in a modest part of town is a bad idea, while wearing flannel and denim to a fancy country club dinner will not work either. The wearing of bright or light colors is too risky. They draw the eye of the subject and, quite possibly, seeing the same color once too often is something the subject will use, even if subconsciously, to warn themselves about something being very wrong, and that is not to be allowed.
- Do not keep the camera in a fake cast on an arm or leg either. How many casts does one see on the average day? Once seen, it will be remembered.
- Working alone from a vehicle is the most difficult of all surveillance techniques. If the subject is also in a vehicle, it is the only way to follow. But to follow alone, it is easy to be seen. You must stay far enough behind to be obscure, but being too far behind is a super simple way to get separated. You must obey the traffic laws. Running red lights is risky for you and the public. If the subject begins to perform anti-observance maneuvers, this is either because the subject feels they are being followed or it is something the subject normally does. Once this performance begins, if the surveillance cannot be safely continued, break off and go elsewhere.
- If working in tandem with a partner, inform them of your situation and see if you can hand off the subject to them or them to you.



FIGURE 15.13 Counter surveillance capture of a stalker. **(From Dr. Patrick Linnenbank.)**

Being able to perform the practice of clandestine photography, still or video, is not a project for the uninitiated. Sending the youngest or least experienced member(s) of a surveillance team out into the field because they have the lowest billable rate to bring back this type of image is a decision made by the foolhardy or inexperienced.

It takes time and effort to learn the ins and outs of the type of photography useful in tradecraft:

- Learn how to hide in plain sight. Take an acting class if this is too difficult for you to master otherwise.
- Of utmost importance is to learn how to avoid detection and to know when to call it a day when out on the job—when to just turn on your heel and say to yourself, "I will be blown if I continue. I will try again tomorrow."
- Having enough experience in the business to select an appropriate place to sit and wait for the subject to come by.
- Having enough experience to select proper ways to get away if detected and being able to anticipate the possible routes the subject will take if they sense they are being followed.
- At all times to remember to stay in character.
- Know what is happening around you at 360 degrees to keep yourself safe at all times.

- Do not forget your umbrella and a raincoat for your camera.
- You must research your subject thoroughly.
  - Know what they are likely to do before they do it.
  - Know everything possible about the person.
  - Learn their hobbies and personal habits.
  - Know where they are likely to be going.
  - Know what they do at certain times of the day.
  - Know how they normally dress.

The subject is more complex than one uninitiated is likely to imagine, and there is always room to grow into the project.

Experience and planning are necessary factors going into the placement of a static camera where it will not be noticed but where there is a better-than-average chance the necessary photographs may be captured. The camera may be triggered by motion or by a remote switch in the hands of the operative located in view of the action but invisible to the subject. The same skills used when planting the camera are necessary when attempting to leave the location of the planted camera without detection. One must collect the camera(s) left behind after the necessary images are captured and without leaving behind evidence of the surveillance operation.

The number-one consideration in any operation is the safety of the operative(s). If there is any danger about the subject being violent or being ready to kill or injure another person just for knowing the location of their lair, completely different tactics must be employed for the surveillance. The photographer must be just as wary, if not more, than the subject they are trying to observe. Sometimes when the subject is made aware of people following, they will lead the followers into danger. If this happens, the chances are excellent that the team will not only obtain no photographs but they also will be drawn into a fight or some other physical danger during the surveillance. The best people for this type of work are the skilled photographers who can see a vantage point for photography that is perfect for the job but still undetectable to the subject.

DEFINITION:

In law, the curtilage of a house or dwelling is the land immediately surrounding it, including any closely associated buildings and structures, but excluding any associated "open fields beyond" … Wikipedia

FURTHER READING

Defense and Security. (2014). *Defense, Homeland Security, and Law Enforcement; and Intelligence, Surveillance and Reconnaissance (CD-ROM)*. Baltimore: SPIE Press.

Fishbain, Barak. (2009) *Surveillance, Monitoring and Traffic Video Systems. Real Time Methods for Restoration, Enhancement and Analysis, VDM*. Verlag: Saarbrucken.

U.S. Air Force Doctrine Document (AFDD) 2-0. (2012). CreateSpace Independent Publishing Platform. *Global Integrated Intelligence, Surveillance, and Reconnaissance Operations.*

Dufour, Jean-Yves. (2015). *Intelligent Video Surveillance Systems*, London, England: Wiley-ISTE.

Jenkins, Peter. (2018). *Covert Surveillance: The Manual of Surveillance Training*. Englewood, NJ: Intel Publications.

Johnson, Emily M., and Rodriguez, Michael J. (Editors). (2013). *Legalities of GPS and Cell Phone Surveillance*. New York: Nova Novinka.

Siljander, Raymond P., and Juusola, Lance W. (2012). *Clandestine Photography – Basic to Advanced Daytime and Nighttime Manual Surveillance Photography Techniques – For Military Special Operations Forces, Law Enforcement, Intelligence Agencies and Investigators*. Springfield, IL: Charles C Thomas Publishers.

16 Videography

Kathryn McMillan

CONTENTS

Videography versus Video-Graphy 345
Video Admissibility 347
Video Hardware 348
    Manual Camcorder Controls 349
    Image Sensor Format 349
Cinema Video Cameras versus Camcorders versus Cellphones 352
The Cellphone 352
Protocol 353
Software 354
Video Depositions 355
Video Documentation 355
    The Equipment and Technical Aspects 355
    Problem Solving 355
    Filming Objects 356
Filming for the Re-Creation of Events 356
    Proper Perspective 356
    How Many Cameras 356
High-Speed Imaging 356
Video Surveillance 356
Covert Filming 356
    Low Light 356
Remote Filming 356
Postproduction 357
    Software 357

A disclaimer for this chapter is that it is the only one in the book written in first-person terms. Because it is the only chapter in the book covering an art/technology involving motion, I felt it matched the text if the author talked the reader through the techniques. If you do not agree with that theory, chances are you will at least find it a welcome break from all the chapters of lecture to one where we reset your attention clock. —*SW*

VIDEOGRAPHY VERSUS VIDEO-GRAPHY

The process of making video films or motion photography has many seemingly irrelevant aspects to use as a topic for a forensic photography book, but this choice wasn't without purpose. As with a cinematographer working on a large film set or a videographer on a small production, they both focus on the same qualities of making a compelling video. The forensic photographer using video as an evidence documentation tool uses the same methods, techniques, and necessary processes to get the job done as with a still camera. Video is just another medium or format to use successfully. Fortunately, I know, as I work in both fields—and especially behind the lens of a video camera.

Coming from a background in television and video production, breaking into the investigative world in 2001 was not so tough. I wasn't a novice at telling someone's story. I knew camera techniques to get a good photo, and I had an eye for detail. My career after college started out in local origination at a cable company, producing and directing TV programming and commercials, and later moving on to run my own production company. On September 11, 2001, I happened to be on location filming in Washington, DC, and although I had no desire to cover the devastating news stories, I did want to make a difference. This began my journey into the field of private investigations and evidence documentation.

My first day was on surveillance, as I sat quietly, eyes peeled to my surrounding area, looking for a car, a person, or an event, I realized patience was necessary. After 8 to 10 hours of just sitting, watching, and waiting, I was ready for action. But nothing happened. You would think this high-energy, chatty, quick-thinking creative soul would be bored out of her mind. I was not. I was fascinated. And



FIGURE 16.1 Professional film and video production.

even though I don't recall if there ever was action that long first day, I did remember seeing the sun rise, then daylight, then the moon. But I was still exhilarated.

After a trial period (I found this out later), my first supervisor told the "boss" I had an eagle eye, I wasn't annoying, didn't talk much, and when I asked questions, they were the right ones. Within six months I was asked to work on every case the agency brought in. That opened me up to learn another way to use the video camera. And I haven't shut up or stopped this type of videography since.

Working in two different careers as a videographer, I have to share how important the use of video really is to forensic photography and the documentation of evidence. And I really haven't found many creative or technical differences when using the video camera necessary to get both jobs done versus the use of still photography alone.

Videography is *the practice or art of recording images with a video camera,* according to the Merriam-Webster Dictionary. From my experience there are many different styles, forms, and genres. For example, live television is fast paced, one and done, then on to the next show's preproduction. Movie-making is slow and tedious, scene by scene, and usually out of order to boot. The creative process of other video productions is usually planned from the script, scheduled days of shooting on location, postproduction, then onto the next gig depending on the length of the project. Corporate films, wedding videos, web series, and other types fall into this creative genre in varying forms. Less creative videography begins with the news—told in short, rip-and-read segments—that either repeat what public information is given or report in short briefs commented by the newscaster on a topic the audience may be interested in. Docu-dramas and investigative journalism can be more artistic than the news in the way the story is told and shot, but documentary production most resembles evidence documentation videography. I am not talking about propaganda films; I am relating to actual old-school documentaries. Unbiased pieces of information uniquely told with the imagination of the filmmaker's eye, but just allowing life to happen in front of the lens, making sure the camera operator is there to capture it. And truly not manipulating the scene for the benefit of the story.

When I thought I had crossed some lines in between my creative video career and this evidence documentation stuff, I didn't realize at the time, but all my talents in the broadcast world were almost synonymous to investigative videography. Producing is gathering information, resourcing, and managing a developing project. Filmmaking is taking the initial story, writing a script, getting the proper clips, and then editing them together to tell the story in a way to which others can relate. An investigator takes in a case, gathers information, creates a plan, conducts research, gathers evidence, and writes a report. They really are similar to lines of discrete stages of filmmaking, leading to a finished product for someone else to review.

In my opinion, video surveillance and evidence documentation can be a cross between documentary-style filmmaking and watching paint dry. Seriously. But I am still excited each time I go out and capture the "shot," whichever career I am working on or in.

Thinking back to when I trudged through the doors of my new job at the first investigative agency, I was already considered the video expert. Although I was flattered by the title, it was notwithstanding that I knew more than how to program a VCR. It's amazing how much you can do if you read a manual, but before I digress, I really wasn't an expert at the time. I just knew technical aspects of cameras, lenses, f-stops, shutter speeds, depth of field, and other cinematography lingo and some basic nonlinear video editing skills. The luck that made my career proceed is I knew how to move with the action in front of the lens. I knew to always be prepared, to have the equipment batteries charged, not to film into the sun, and to line up the shot and have my camera ready at all times. I will share some of these habits in this chapter, as well as a few tips and tricks.

Today, I still work in both careers, and both professions have gone through numerous changes in just my 25 years. The most important change is that more people are documenting things with video than ever before. Due to the reach of a cellphone camera, huge amounts of evidence are being collected each second by the greater masses of society. It's not always a good thing, but evidence is out there. Everywhere.

Vital to the industry of or use of videography, whether it's civil evidence investigations or law enforcement work, I see the same issues keeping a potentially great shot from being captured or used at all. Admissibility, preservation, and authenticity, the same basic issues dealt with in forensic still photography. I hope my "expertise" in technique, style, and protocol will help you in your endeavor to learn more about this discipline and practice to gain the experience you need when **Video evidence is critical to your case!*

* Slogan for Evidence Video Investigations, Inc.

VIDEO ADMISSIBILITY

First of all, I must disclose that I am not an attorney and anything I discuss in this chapter is based on my humble opinion or was gained through my experience and discussions with my mentors.

Other chapters in this book may have each made points of reference to the laws and/or rules of evidence that vary from the state level to federal level. I've found video evidence usually falls under a certain rule number or code and may be titled under the entire "Admissibility of Digital Evidence or Recordings and Photographs" subsection. I suggest you read up on the Federal Rules of Evidence as well as the rules within the state statutes you are living and regulated by.

We've all seen the one popular movie scene that wins the case. The protagonist is just about to be sentenced to death or to life in prison when someone rushes into the courtroom, spouting in the final hour that the defendant should be set free and is innocent. The judge allows the smoking gun—a perfectly filmed video (including audio), and the real perpetrator is known and Mr. Hollywood gets off scot-free. Besides the customary practice of disclosing evidence in the discovery phase of a trial, in reality, this *My Cousin Vinny* moment rarely happens, or at least hasn't happened yet on any of my cases—not that I'm aware.

As you may have noticed, I have some issues I always must juxtapose. But as vague an idea, confusing, or tough as interpreting the law or a statute is, admissibility of video really just means I need to follow guidelines that won't get my great footage thrown out of court, or at least has a chance to get it in!

Of course, I may have provided the best video ever seen in the judge's chambers, but one of the lawyers will be arguing over whether there is a substantial need for it, if it's relevant, and if it can be authenticated.

To keep my side of the lens clean, I try to follow some wise do's and don'ts in gathering visual evidence. I don't have an exact science, but I know what evidence I provide can really be effective and do much damage in the legal processing of a respective case, so I keep in my frontal lobe that my video needs to be a fair and accurate representation of what I see and what is happening in front of my lens. The unsuspected danger of being accused or questioned if it is fake or real—and it's mind boggling all the technology out there to manipulate the footage—but I've never really been asked this question straight up. I usually am asked with the jury nearby, to get them to question the validity of my input (submission). Needless to say, my reputation, licensing, and financial status are way more important than any case I have worked or ever will, and frankly I answer to a higher entity than the laws on this earth. Point made. I am as real as my footage. Just enhanced.

Here are some of the questions that may be asked of you or your video evidence during the process of authenticating and what you should ask yourself before you film anything. Of course, if you are filming surveillance, you need to film what you see, so I am not stating to not film everything your subject is observed doing.

- Is it a fair and accurate representation of the subject of investigation?
  - Always ask yourself that! Does what I am videotaping represent reality?
- Does my video have value? Does it support the truth? Does it sway the truth?
  - Is the subject even in the film? Does what I am about to video add anything to the case or take anything away? Again, surveillance is different from evidence documentation of scenes.
  - I will talk later about protocol, but it's so important to keep all your evidence, whether a good or bad photo was taken from a technical point of view
- Where did the video come from? How was it recorded? Who recorded it? How was it gathered?
  - Know the chain of custody of the evidence and know your camera.
  - What is a handheld camcorder? A vehicle-mounted or dashboard-camera, or a covert camera?
  - Was there loss images, aka what frames per second recording? Drop frame?
  - Was it obtained lawfully?
- Is it made with the right perspective? What was the position or angle of the camera to subject when filming?
  - A low angle can make a person seem larger than life; overhead shots can make a person seem small.
  - Filming down the street can skew the perspective of the angle of view.
- Is it misleading?
  - Does it bring about the emotion directed?
  - Were filters used? Did it change the color of the scene or faces?
  - Does it show the person completely or only a face/headshot?
  - Just like still photos in a courtroom, the video needs to be in a generic documentary style—nothing dramatic, creative, or to skew the viewer's emotions or cloud their own judgement of the scene.
  - Did you film everything you saw? Did you leave anything out in the report because you didn't film it?
- Is it underexposed, overexposed, or noticeably bad lighting? Did you use supplementary lighting?
  - Does it bring foundation to the time of day it was shot?
  - Are you filming from inside a vehicle that has tint or outside, or in interior of a building? Is there tint on those windows?

- What is the perspective? Lens type?
- When was it taken relative to the case?
  - This depends mostly on the type of case, but is it new footage of an old scene? How long ago was it taken? Has the scene changed? Are trees overgrown or now cut down?
  - What was the weather when the crime or accident happened? What time of day? Were there road hazards or construction?
  - How has the scene changed since the accident or event?
  - Has the person changed? Is it really him or her or a relative?
- Was the original video submitted? How was it gathered? How was it transferred to the format it is in now?
- Was it edited? Did you enhance it on a computer? What software? What process?
- How is it being conserved? Conservation is as important as origination. How the original footage is being stored, maintained, and documented assists with the verification of genuine chain of custody.

As you can see, there are as many variables to video recording as there are in still photography of any evidence. Each of these questions could have an entire paragraph written about it, but although they may make the impression the questions are endless, your video could be the best footage ever, but these factors can make it go away from the case if you cannot explain some of these things! I've seen cases settled when lawyers will talk about how prejudicial evidence can unfairly bias a jury. The footage was so telling, but that isn't up to me to decide. I just try to first, get the video, which is a very valuable evidence tool. But so many factors go into its validity and relevance that the opposing counsel may try everything to suppress or quash it. I've not had that much experience at the courtroom level, testifying fewer than 10 times, so I haven't had to explain my footage too often. I think possibly because my part in the case is so small, I don't get invited to court to explain it. And other times, because my part was so useful to help settle a case outside of court. Nevertheless, I do my best on each and every case to shoot for the big one! Act as if everything I do will be seen and ripped apart by two teams of lawyers, a jury, a judge, the media, and even my peers. Then I know to always do everything in my power to gather and put the video together to not misrepresent anyone or anything.

VIDEO HARDWARE

I am going to break a number-one rule right now and presume something. For this section I am presuming you have a camera and one that takes/makes video. It may be a point-and-shoot still camera, digital single lens reflex (DSLR), or your cellphone you use to take photos/videos of your daily life. And to go even further in making presumptions, I will suppose it's probable you use or will be using a more professional camera in your actual line of work. When you leave the station or office, do you have a department-issued camera(s) in your gear bag? Or do you think it's a great idea to just use your cellphone when on a scene or on a case? I will not berate you for making these choices; my job here is just to educate you.

Since most cameras today have what is called video mode, they can all be considered video cameras. They are a lot smaller than my first one—the camera sat on my shoulder and the recording deck was tethered with a 1″ cable around my other shoulder and waist. But that's another line of work in a long-ago era. We are so lucky to have smaller equipment that runs cooler to touch, longer-life rechargeable batteries, and no wires! This is especially important for this profession of being discrete and professional or working in small crime scene spaces. Today the types of video cameras are as numerous as ever in history.

There are cameras from the top-of-the-line professional-grade broadcast and studio, digital cinema, industrial, point of view (POV), virtual reality (VR and 360 degrees), digital single lens, mirror lens, prosumer camcorder, action camera (GoPro), unmanned aerial vehicle camera (drone), point and shoot, single use (throw away), and most popular, the cellphone camera! The choice you make in buying a video camera depends on the needs of your case and type of work you perform.

Once a huge investment to buy or rent, today's prices for videography equipment are as inexpensive as $100 to $200 for a decent image-capture device, although I wouldn't suggest it for case work. Of course, the most used camera for many is already and always in your hand or in your pocket. I will touch on that topic in another section, but for the purpose of the remainder of this chapter, I will focus on using a basic National Television System Committee (NTSC) camcorder in the $500 to $1,500 price range.

High-priced cameras don't mean very much in basic evidence documentation because it's more important to focus on the features yours has than spending the most money for a camera. Sure, you get more bells and whistles in the higher-end camcorders ($1,500 to $3,800 price range), but you really don't need a 1000× digital zoom lens and in-camera editing or 4K video and so on for evidence documentation. Some may argue for the necessity for the 4K, but it's tedious to transfer, large to store, and difficult to play or edit on a computer unless you have a huge processor, and most do not. So, I will discuss high-definition (HD) 1920 × 1080 size frames. I will not talk about specific camera features, only the benefits of the main important aspects affecting the quality of the image. To me, the more important features are manual control, image size, resolution, optical lens, audio controls, viewfinder, and memory.

The top four to five brands in camcorders are still Sony, Canon, Panasonic, JVC, and a newer one called Blackmagic. A number of DSLRs are useful for videography, but it really depends on the type of case. Most need lots of light because of the specifications of the lens attached and do not offer an automatic setting for the times you need that option. And

many do not record time and date stamp options and may have focus issues too advanced for video but are great for still photography use.

Depending on your evidence documentation needs, you may want waterproof, live streaming, or Wi-Fi; handheld with a viewfinder, not just a viewing screen; infrared (IR); and night mode. These are my "wish list" features I do not go without:

Manual Camcorder Controls

If I cannot turn off the automatic exposure settings of lens focus and iris, then I don't have control over my scene and may only record poor-quality images. On many crime scenes or limited-access scenes, automatic settings will produce fine video, but when I have full access to what I am recording and can take my time, I like manual settings to get the correct images for the case.

A camera with image resolution of less than 720p horizontal at 1280 pixels, or larger at 1080i resolution of 1920 pixels by 1080 horizontal lines, is ideal for current evidence videography. Do not go lower because the comparison between these two interlaced frames are painted on the screen in two or more passes. This is important whether your final output is a DVD player on a TV or a digital MP4/MOV file to play on a computer screen. If you want the best, there is now 8k and higher coming out, but we barely have 4k in partial use. Just for the record, I will explain that 4K is ultra-high definition, almost 4000 horizontal pixels (actually 3840 × 2160, or 8-million pixels), which is four times the number and higher resolution than 1080p HD video.

Yes! That's a massively larger image size and way more detail it can record, which is good if you need to see detail farther away or magnify far-away objects, but I find storage space difficult when for client playback I end up downgrading to 1080p anyway. But this is a personal choice. If you want to future-proof your camera or just have several to choose from, you may go for the most resolution currently available.



FIGURE 16.2 Flip out LCD screen viewfinder camera with manual controls.



FIGURE 16.3 Camera sensor image resolution sizes in pixels.

Image Sensor Format

This is the shape and size of the camera's sensor that detects visible light and angle of view used to create the image. In the past, cameras have been sold on the number of megapixels (MP), but the size of the sensor frame is actually more important because that determines the quality of the image, since a larger surface area means more light hits and the better the details. In traditional 35 mm filmmaking, full-frame-format sensors are 36 × 24 mm and provide a broader dynamic range and are better in low light because the sensor gathers more information and allows for higher ISO performance. Additionally, there will be a shallower depth of field because the camera will need to be closer to the subject or use a longer focal length to fill the frame of the camera.

Today's popular-priced DSLRs and mirrorless video camera sensors are measured with APS-H, APS-C sensors (26 to 28 .1teamviewer), 1" or micro 4/3 sensors (17 to 21 mm), or less, and these are typically referred to as medium or standard format sensors. When a camera's sensor is smaller than a 35 mm camera, it is referred to as having a diagonal crop factor since it's essentially measuring less than 36 × 24 mm "full-frame." The smaller sensors will have lower-quality images with increased noise, less dynamic range, and increased depth of field but better for long zoom-range photos since the lens needs to be wider angle or be placed farther away from the subject in order to fill the frame.

The marketing of full-frame mirrorless cameras really made a hit in 2018, and although it can be important to match the 35 mm equivalent in television and big screen films to get better images, it's not for every videographer. Yes, they offer better image quality, but are bulkier and more expensive, and image detail is still dictated by the lens, so gear designed for cropped sensors can't be used or interchanged to their full potential.

As sensor technology changes replicating 35 mm cameras, two-fifths times as large as prosumer and consumer imaging devices, camera gear will become less bulky,

A few of my video cameras, such as my Sony FS700 with an Exmor Super35 CMOS sensor (25.5 mm × 15.6 mm), are considered equivalent to a 35 mm Hollywood full-frame

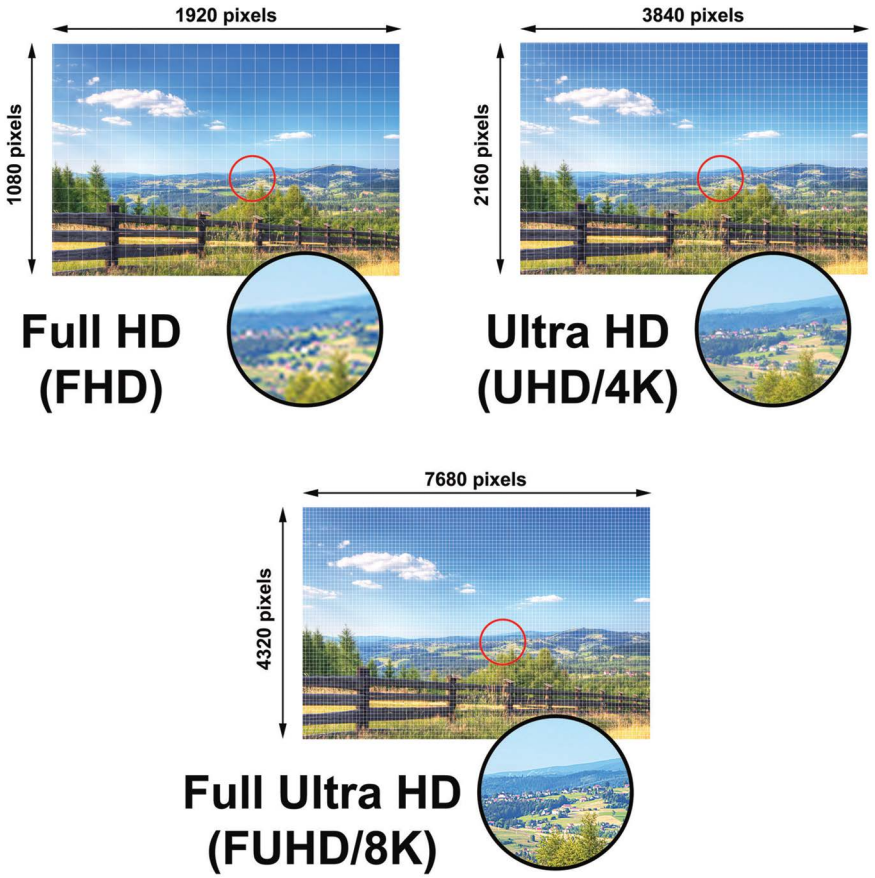


FIGURE 16.4 Image resolution samples.

camera, but it's closer to the APS sensor size. I get better light-gathering capabilities, higher resolution, and softer backgrounds because I can make full use of ISO and lenses to make this camera capture excellent images and even isolate a subject in focus whether it's macro video or interview-style framing.

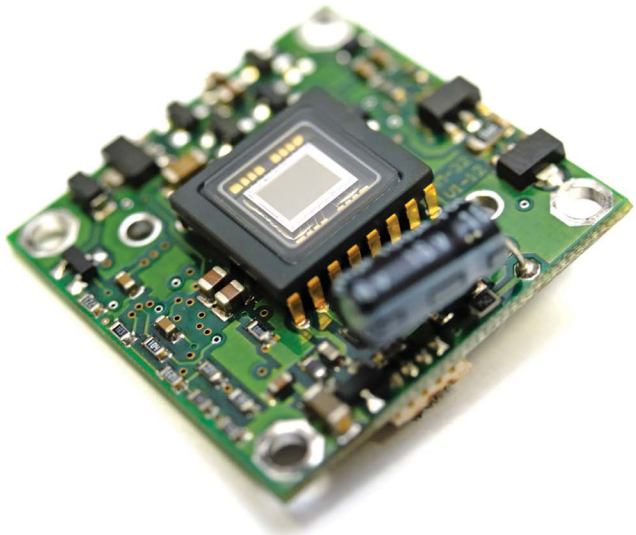


FIGURE 16.5 Camera sensor.

When I don't need to be extremely close and can move back or have a wider angle of view, I opt for my other smaller sensors, especially if I am filming surveillance footage. My other go-to cameras have 2/3-inch to 1/3-inch sensors, which most prosumer cameras have these days. My next camera to "add" to my arsenal will be a high-end full-frame mirrorless camera, as they are lighter, more compact, and better for 4k video than DSLR with more sensitive chips to suppress noise and use both phase and contrast detection. Although I am awaiting on increased available accessories and battery life, I can swap out lenses, they now offer speedy refined autofocus, more FPS, faster shutter speed options, steady image stability, and Wi-Fi.

Optical zoom is the lens's true zoom, and in my opinion one of the most important features to spend the extra cash on in a video camera for evidence videography work. The higher the number, the farther in and out the lens will zoom optically. Unless I can swap out lenses on the camera, and with most prosumer models you cannot, I only shop for a video camera with 25× or greater optically. Zoom lenses make it easier to frame your subject if you are farther away, but there can be issues such as needing additional lighting, a tripod for stabilization, and resolution quality that come with digital zoom.

You may think your cameras have 400× zoom capabilities, and you are smiling thinking you have me beat. Let me explain what this means. I want the best image possible and

control over the camera when recording video from farther away than can be zoomed in to the subject of investigation. Digital zoom is just an in-camera image processing for enlarging the area in the center of the frame, trimming outside edges away from the image. What you see are enlarged pixels and a reduction in resolution, ultimately crushing the details of the image quality! Don't do it! Turn off your digital zoom and buy a video camera with 25× to 60× optical zoom!

If you use a mirrorless DSLR and want to mount more/longer than your prime lens, you will have to adapt a telephoto or zoom lens onto it. Although there may be a larger full-frame sensor on your mirrorless camera, you will need lots of light to capture clean images and manual controls to change ISO sensitivity or speed to get usable shots in dim conditions. Many cameras already have in-camera "body" stabilization said to work on any mounted lens, but will work less efficiently with longer focal lengths. If you have a stabilized kit lens, having both may not be a good thing either, as they compete for the effect. Lens-based stabilization works by moving one thin and lightweight lens element or the necessary sensor movement required to compensate for shaking and scales with the focal length. Optical image stabilization versus digital image stabilization seems to correct part of the image on the sensor to make it seem like the subject and the camera are moving less. But if you are zooming in or using a telephone lens, the ultimate stabilizer is using a tripod!

Audio controls are imperative for the ability to turn off the in-camera microphone or plug it up during videography work. Unless I am conducting a video shoot needing audio, I turn it off. Some cameras have a jack/port to put a "line in" cable or manually control the audio levels to zero. In some cases, I need to record audio—for example, when I would include the documentation of an insurance adjuster or engineer inspection, deposition, interview, independent medical exam (IME), or a scene where sounds matter to the case. For surveillance and any similar video documentation purposes I turn off the audio. This is not always necessary or even wanted. But this protects me or a passing stranger from saying something irrelevant to a case while filming, and it minimizes distractions for the final audience.



FIGURE 16.6 Optical viewfinder with flip out LCD screen.

Optical viewfinders (OVFs) are more difficult to find on prosumer camcorders, as many are manufactured only with viewfinder screens. These electronic viewfinders (EVFs) allow great color preview of the image, simulated electronically onto the miniature display. To properly compose the shot, without bright sun glare on the viewfinder screen and less details for viewing, you really need to find one with a viewfinder, a separate viewing of the main optical system to help the shooter to focus, expose, and frame correctly. If you cannot see in the light of day and have to squint to even read the image on the screen, how focused do you think your lens really is? Plus, if you are doing covert work, the viewfinder screen can light up an entire room! There are positive attributes of the electronic viewfinder, including being able to see the time remaining or elapsed media, battery reserves, and color representation.

Memory is something I have taken for granted all my years, until now. Now I am talking about in-camera versus external memory options for a camcorder. This is where the recordings are physically stored once exposed. I doubt you are still using video tape. I will not judge you, because I know a few evidence videographers that use it for certain specific conditions. But with today's high tape prices, difficulty finding them, and low cost of new cameras, I strongly suggest you put that camera back in the closet for emergency needs. If your camera does not have a memory card slot, then it only has internal memory. How will you preserve the evidence? To me that type of system is basically useless if you cannot download the footage and conserve the evidence! If you cannot use a mini SD or SD removable memory card, then do not buy the camera. Just like when videotapes became cheaper with time (when they were popular), 8 to 16 GB or 32 to 64B memory cards have become cost-effective enough to use one time only per case to preserve the evidence and be able to answer chain-of-custody questions. Just enter the exposed card into the case file and forget about ever erasing it and using it again.

The time-date stamp is a foreign language when it comes to digital cameras of our era. Only a few camcorders can "burn in" time-date stamps, like the earlier analog cameras, but the process can be done in postproduction. This feature still remains of the utmost importance but remains a constant educational opportunity issue. In other words, most people just don't know how to approach getting the time-date stamp "off the camera." The answer is when it's not on the camera, it is in the metadata of the images captured! I know of only a few $3,000 range camcorders that "burn it in" to the image, but there is still an encoding process you must render once done filming. (More on that in the postproduction section). Do yourself a favor and learn how to export your footage from your camera with timecode or time-date stamp on it using a DVD recorder in analog mode. Additionally, learn how to use re-encoding software to show the subtitle or metadata of the time stamp, so you can testify to it in the courtroom.

CINEMA VIDEO CAMERAS VERSUS CAMCORDERS VERSUS CELLPHONES

Professional videographers use a professional camera for a multitude of reasons but mainly to get the best image possible for the project. The more sophisticated the camera, the more it can assist the videographer with the task of documentation. The smaller, inexpensive, $100 to $500 video cameras offered at large electronic stores don't have the features needed to capture good enough quality images for court. In addition to the earlier "wish list" of camera features, manual controls, viewfinder, image sensor, audio controls, etc., lower-end cameras don't have accessories to add to your tool kit. They are cheaply made and scream amateur to your client. Additionally, the low-end camera's battery life will be less than one hour due to the viewfinder screen always being on. Do you need to capture good audio? Why are you calling yourself a videographer? And what about the time and date stamp? Which leads me to what some colleagues have asked me: ***Why can't I just use my cellphone****?*

THE CELLPHONE

The biggest pet peeve of mine today is everyone thinks they are a videographer because they have a cellphone and it can produce and sometimes edit a movie. If you are in a "pinch" and only have your cellphone, should you use it to gather evidence? YES. Get the shot. And NO! Don't use your cellphone. In reality that entire phone can be called into evidence (but probably won't) when asked how you captured those images. Those other photos of your kids, dog, and whatever else you've been perusing on social media on the night shift that are on your phone will be obtained and could be incriminating you! The idea of the search of a personal cellphone used for evidentiary photographs has reached the level of urban legend. Any such use of personal equipment should be consistent with agency or firm policy and procedure. Images must be securely transferred from the device with metadata in a timely manner and appropriately documented in reports, notes, logs or memoranda. The likelihood of a judicially approved fishing expedition into all of a phone's content is unlikely to succeed without some proof of ill intent or malice. Digital multimedia is everywhere, and if professionals continue to cut corners, it will downgrade the industry's expectations of what a good-quality image really is. Do not hold the camera vertically! (See Figure 16.7).

Let's gamble: say I cannot miss the shot and have to use my phone to capture the evidence. I am not talking about witness photography evidence or about some types of cases when it may be okay to use, as mentioned by my friends in other chapters of this book. There are external lenses now available to get great macro and even telephoto shots. I also know people on YouTube who make entire low-budget films using a cellphone. But in general, cellphones are limited in what they can do. It may be artistic, but it's not art. It's evidence **WE** film, so handle this option with care.

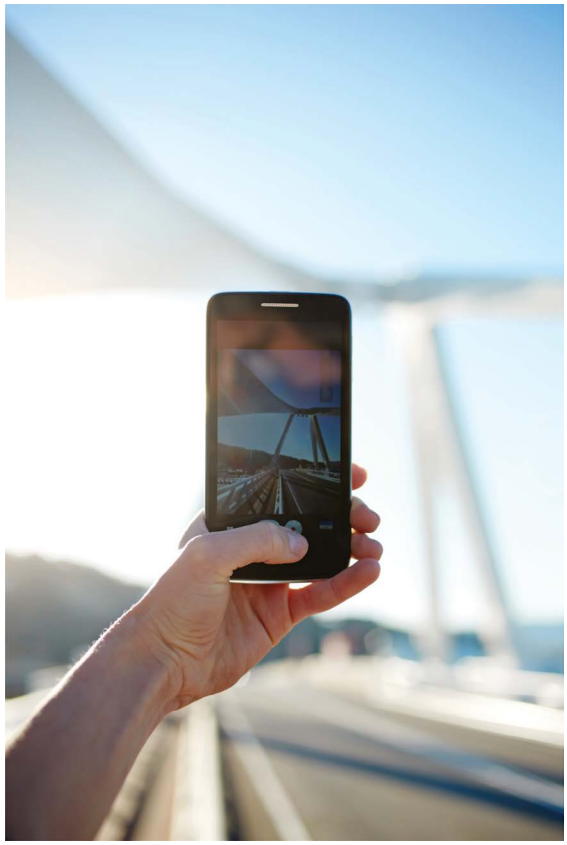


FIGURE 16.7 Vertical smartphone capture.

If your department purchased a smartphone for you to use during your job, then you may have more of a reason to use a cellphone camera than I have mentioned. If this is the case, then read up on your policy, procedures, and protocol, as well as the rules of evidence in your line of expertise. Then read the manual and get to know everything you can about the camera and options for accessories and software to help assist with your job.

I read *Evidence Technology Magazine* and have browsed a few articles about how certain applications are used to "record images, videos, witness statements, officer notes, drivers' licenses, evidence, and documents at the scene." These emerging technologies by proven companies are geared for someone to lighten the load and not have to "drag around cameras" and other devices, including their notebooks. It is awesome for one app to do it all, but the more we rely on only one single technological device, the more potential for trouble when the app crashes, or worse, the phone memory dies! We still have to back up our computers, and most of us who have learned lessons the hard way by losing information have several versions of our files stored in difference places. So, make sure to back up your phone too.

There are apps you can download to your phone to put a time and date stamp on camera recordings, actually burned into the photos and videos, that include global positioning system (GPS) coordinates. I have used that app on occasion when I have seen a subject of an investigation while not



FIGURE 16.8 Horizontal smartphone capture.

actively working a case and needed to just grab a photo. Again, a last-minute resource. Since even I don't always have a video camera with me and the rest of the time the camera I use has the memory card of the case I am currently working on, I can take a quick shot with this app so I don't use the same card in my camera on two different projects. Again, emergency use only. I go to that time-date stamp photo app—it opens up my camera with my watermark and GPS coordinates and takes an evidence photo, which I immediately offload to my case file once back to the office, since it also saves the information to your camera's gallery with the rest of your photos. The watermark function with GPS coordinates looks more professional than just a regular cellphone image because it does a little bit of separating from the other photos you may have taken. Cellphone camera image quality can be 4k and look great, but low-light video is impossible, or the flash may even come on by surprise when taking still photos.

The limitations of a cellphone and potential for it being used as evidence in its entirety make for a bad choice in cameras, at least not good for regular video documentation or videographing surveillance. It muddies the lines of preservation of authenticated evidence in my opinion. Again, if you now have a dedicated phone to use for evidence and have a written protocol, that may give you a different point of view. But I see so many other issues to address, like memory storage, preservation of evidence, how to authenticate the images, and security of evidence.

What about effects or photo enhancements in the camera? Did you tamper with it by the process of high dynamic range (HDR) imaging (see Chapter 7B)? That is a contrast enhancement between light and dark colors on the image, in the highlights and shadows, to process the images according to what the processor thinks the image should look like. That is not a fair and accurate representation. Just because you can, doesn't mean you should. At least in our profession. It is something which should be done only in postproduction—definitely not in-camera on your original footage.

If I have a choice, I want to capture and process an image the same way each time, using a professional camera that I can testify to about the process. We are professionals and should be using professional or at least prosumer-grade equipment specific to the line of our work. Equipment that can be verified, learned, and testified to in order to show anyone how it works. We should not only be as good as our tools, we should be the tools that were as good as our last job. We can always improve ourselves with technology but not rely on one device to do everything for us. Sure, it does make our lives easier, but we also still need to actually do the forensic scientific work ourselves.

PROTOCOL

My protocol is proprietary and I consider it my company's trade secret, but I will share a few things about having one. I consider it an internal guide to how I handle digital evidence from the gathering to the presentation in court. I think having a standard operating procedure is like following best practices and is always a work in progress, meaning it changes as the craft changes, like a police agency policy book. A protocol is different because it always stays the same. It's your own bible, if you will. It's my pre-collection and post-collection directive on how I specifically handle the entire process of evidence documentation, every single time I do it. Sure, cases are different, and my procedures can change, but when documenting evidence, it is very important for me to follow specific processes. They need to be in writing. I keep a notebook I can refer to when I need to follow the steps, ensuring I do exactly the same things in each case. It keeps me organized too.

The business of evidence documentation has taught me that although it may be part of my investigation, it is only part of it, so there is a protocol for my entire business as well. The major areas of importance relating to evidence documentation include the following:

- Preparation and planning
- Field practices/handling
- Guidelines for image capturing and documentation of image processing/titling
- Equipment
- Personnel
- Organizational chain of custody
- Filing: verification of original and processed images and raw set aside
- Archival (backup) and security
- Storage (NFPA 921, for example)
- Guidelines for software
- Compression and enhancement processes
- An authentication statement

Preparation and planning: I am a believer in prepare, prepare, and plan. Then plan for the plan to change. This includes everything from reading the case file; researching for old and new undiscovered information; viewing a map prior to arriving, even notating the date of the map; and making sure my equipment is cleaned, the camera battery is charged, I have extra batteries ready, lens cleaner,

reformatted or new memory cards, and equipment bags are organized. The list is actually way longer than that, but you get the point.

Field practices: This section discusses what I do when I get on scene, and depending on special circumstances, how I handle the job on site.

Image guidelines: What I do to get the shots. Which lenses and filters do I use for certain scenes, setups, etc. What camera angles do I set up and what framing do I get for each shot. What I name the files for each case and how I slate the project at the beginning.

Equipment: What equipment I use for specific cases. What accessories and also how I maintain them.

Personnel: Since it is mostly just me on my jobs, I don't have many things listed here, but this would be where I list who handles what tasks in the process and what information they would have access to.

Organization of images and chain of custody: I follow a GOLDEN RULE OF EVIDENCE: I ALWAYS keep the original video files, then transfer them to my computer backup system, make a copy of the entire folder, and use that copy folder for enhancing, editing, etc. I have listed the steps of how I capture images, how I offload them from the camera, whether onto DVD or a computer for editing, and how I get to the final deliverables with the time and date stamp.

One very important rule I follow that I haven't mentioned yet is when I am recording anything after my initial slate shot or location ID shot, I do not erase anything. I don't care if I videotaped the floor or my foot while walking onto a scene. It remains part of my evidence. It may be sloppy work on my part, accidentally recording my reflection in a mirror or leaving the camera on after the shoot is over, but I keep it all and it goes into the evidence case file. I just make a note in my footage log of the mistake, but I don't ever delete it. I don't delete anything. Ever. It would be considered tampering with evidence and not a good career move. I may sound dramatic but that is not my intention. We are professionals and must act accordingly; hence, I try to act like my camera is rolling all the time and just not do or say anything stupid if the microphone is on and try to keep the lens cap ON when the subject of my investigation is not in front of my lens.

Of equal importance is the chain of custody. In this section I have my directive on how I received outside footage or delivered my completed footage and what I did with it, where it is stored and who I gave it to, and so on.

Filing/storage/security: My protocol is changing in this section due to changes in technology, but the overall procedure remains the same. I return to my office and offload the SD card to a DVD drive with the analog time-date stamp. Then I offload the SD card into my computer, into two different folders, duplicate copies of the original files. One folder I title Original and the other Working copy. The working copy (whether video or photos) is the folder I use to extract the metadata when making the client copy of the evidence as my deliverable. I then have a backup system in place that secures the information and stores it in archives daily, weekly, and again once the case is over. I keep the storage for three years or until the hard drive becomes damaged, which is why I have two copies of the entire backup storage system, because electronics do fail eventually.

SOFTWARE

I have been working on Windows and Mac platforms for over 20 years, seeing firsthand how today it is easier than ever to enhance, edit, and re-encode video footage. If you are using a Windows-based PC then AVS Tools is a good option to obtain your time-date stamp metadata, and it's rather simple to use. If you are on a Mac computer, there are several options to use to convert your footage into a MP4 or MOV from the digital file on the SD card to show the meta data information as well. This includes Pinnacle and other all-in-one video converter software. Whichever software you use, make sure you write down the exact steps and processes you take in order to transfer your footage from the camera into the editing software and how you grab the subtitle tracks (or the metadata) from the images and then re-encode or convert into whatever format file to deliver to the client. Don't forget to include whether audio is rendered or not and, if so, what bit rate, sample rate, and encoder is used, and for video what frame rate, frames per second (FPS), resolution, and profile. I make sure I can answer how the original video was gathered, submitted, and transferred to the format it is in now.

Editing: Depending on what type of video you are producing, the deciding factor in editing software will be whether you use Apple-based Final Cut Pro or Adobe-based Premier Pro or Photoshop, or another photo enhancing or nonlinear video editing system. But nevertheless, you will again need to write out your protocol. I usually don't use any editing systems for video in evidence documentation, as I just transfer the footage as is into my converter software to get the video off the camera card into a digital file that I can upload to a client server. But all those steps are



FIGURE 16.9 File transfer and digital editing.

written in my protocol, how I do this, as well as if I did any photo enhancing in Photoshop or Lightroom programs.

Authentication: The protocol is necessary for having a disciplined system, where I don't let myself get lazy between cases. It's a checks and balances system to keep me in check gathering images that will be acceptable and authenticated in court.

I can't even entertain gathering video footage without knowing and following my protocol or standard operating procedures. They are that important. With years of experience, I can explain them in laymen's terms. I am able to articulate the discipline of evidence documentation to a judge or jury if necessary, in any case, whether it's civil, family, or criminal. Have that one process you do each and every time. If your protocol is rock solid and you follow it to the letter, nobody will be able to say your work product is out of line from being authentic. You should never produce things your clients do not need to pay for.

VIDEO DEPOSITIONS

I don't film video depositions anymore, but I had done so for a very short time in my career, so I still have a protocol in my file for this practice as well. Some states require a court reporter or notary to be present, but since this material has audio and video, the videographer should state at the beginning where he or she is, the time/date, who is being deposed, and who is present in the room. Equipment should include a higher-end professional video camera with the time-date stamp burnt in. There should be a microphone both on and off camera in front of all the people talking, and consider a medium-to-wide view with the camera zoom. Keep the tripod set to eye level of the deposed. I really think this can still be a lucrative business, although in my location, several court reporting agencies for hire have in-house rooms already set up for this type of videography. Make sure you read the rules of evidence, both federal and state, for video depositions.

VIDEO DOCUMENTATION

When it comes to evidence documentation, the methodology I follow is one of extreme preparation, the same way for either creative video or forensic video. I complete my research and checklist and then leave the office with case files and appropriate camera gear in hand. I arrive on scene and look for where to park, then take a moment to remind myself of my objective. I ask myself what I am there to accomplish. Then:

1. I make sure my camera time-date is correct according to the national time website or my cellphone, once refreshed.
2. I confirm my SD card is freshly formatted or the same card I began using last time on the same site.
3. I take either a photo of my business card or photo slate with internal and external case numbers.
4. I film a location identification shot, focusing on where I am, so the viewer will know where, including the address.
5. Then I start filming beginning with a wide-angle shot and then move in closer.
6. I work my way around in sections from right to left unless that is impossible.
7. As I move through the scene I don't talk. I listen. I watch. I observe.
8. I ask myself several questions:
   a. Am I being fair and accurate?
   b. Is my video telling the story?
   c. Will it make sense to the viewer?
   d. Am I missing anything?
   e. Then I go through my entire protocol and standard operating procedures.

The Equipment and Technical Aspects

- Am I using the right lens?
- Is my exposure correct?
- Are my camera angles correct?
- Am I creating a skewed perspective by an incorrect angle of view?
- Is it underexposed? Do I need to use a light or paint with light?
- Most times I use a tripod, so I ask myself should I try filming without one?
- Did I look up, down, and behind where I am standing? Can I move higher or get a lower angle? Am I too close? Too far?

Problem Solving

- Am I documenting everything in the scene?
- Am I legally allowed to be where I am?
- What was the weather like when the incident happened?
- What time of day is it?
- What has changed since the original accident or crime?
- Are trees overgrown or now cut down?
- Were there road hazards or construction?
- How has the scene changed since the accident or event?
- Has the person changed? Is it really him or her or a relative?
- Did I leave anything out?

Finally, as I am wrapping up, I ask myself if I missed anything that helps tell the story, was it a fair and accurate representation of the scene? I usually feel I could've gotten a better shot, a more creative way to tell the story, but although it may be entertaining, it's not entertainment. It's evidence.

Filming Objects

When video recording objects, the same methods apply:

- I slate the camera with case numbers.
- I photograph a wide shot.
- I then move in close, gathering all angles of the object.

This isn't always possible, as a recent case will demonstrate.

CASE STUDY 16.1

I was called to photograph a motorcycle in a mechanic's garage, tucked away behind many other bikes and unable to be accessed from 360 degrees of view. In this case I did my best to gather all the angles the engineer was inspecting. This was the second time I video-documented the inspection on this traffic homicide case due to the inspector wanting to relook at the headlight. I had previously videotaped the inspection, but there were additional questions the defendant's attorney had, and now the motorcycle was moved from the tow yard to the mechanic's location, and it was blocked in by several other motorcycles. I slated the camera and pressed record. The forensic engineer took the headlight apart and tested other electronic components with a field-test meter. I would zoom into the reading and then walk around the bike, since the engineer kept blocking my angle of view. There was little room to be able to see anything, so I ended up taking the camera off the tripod and using my strong standing position to cradle the camera tight in my arms to get a smooth shot.

FILMING FOR THE RE-CREATION OF EVENTS

Proper Perspective

Angle of view, standing position/eye height: Where do I set up? Whose view am I trying to duplicate? Is there a witness statement giving me the proper instructions for where to film? If not, where would be the logical place to watch from?

How Many Cameras

I have 10 cameras. How many to set up for any project is a simple choice. It depends upon if I am showing multiple witness viewpoints at the same time or if the viewpoints are each unique. For example, a vehicular incident occurs at an intersection. There are a total of three living witness statements concerning what happened. They all saw the event at the same time. In that case, I need three to four cameras. One would be for each witness and possibly a fourth for an overall view. Then I roll the footage from all the cameras at the same time. Possibly fire an electronic flash unit at the start of filming with the light visible from all the cameras. This will serve to synchronize all the cameras. If the driver(s) of the vehicle(s) survived, I may need at least one or two cameras inside each vehicle for the driver's viewpoint.

Conversely, there was an incident with no witnesses and no survivors—a single vehicle crash. If doing a walk-through of the scene, probably one or two cameras will be enough. One to show what the driver MIGHT have seen and another showing everywhere I go during the walk-through.

It is quite simple to figure out if you think about what you are trying to show, write down a formula, and set up accordingly.

HIGH-SPEED IMAGING

This is a specialized type of photography and really not considered videography. This is considered reconstruction for motion analysis and/or slow-motion photography. It requires expensive and specialized cameras. If you go into this line as well as videography, it will be like having two separate businesses. There are a number of references available for this type of work, and it is beyond the scope of this chapter.

VIDEO SURVEILLANCE

See Chapter 15 for more information. This is not CCTV footage. Ask yourself how was it recorded, documented, and transported and if it is reliable.

COVERT FILMING

Low Light

See Chapter 10A for low-light photography and techniques. But for video, it is a given that your camera will depend on lots of light unless you have a cinema camera that allows for adjustments to the ISO and shutter speed. If you need lighting, several camera-mountable/on-camera lights are available in today's equipment market, as well as professional lighting gear. I have cool lights for smaller scenes, including LCD 3200 to 5600K variable color temperature controls of 500 to 1,000 watts. This means I can quickly match ambient or artificial light balances. They are ideal for my location work, interviews, and small sets where color accuracy, control, and flicker-free output are of major importance.

REMOTE FILMING

If you are performing a video documentation project where you are doing the photography and someone is

watching over your shoulder from a different location, it is necessary to hook up your camera(s) to the Internet and give the viewer the URL where they can watch what is happening. This operation is getting far easier than it used to be. The important factor is obtaining an Internet-enabled camera. From there, the instructions come with the camera. Otherwise, the video capturing protocol is identical.

Originally, video remotes were used in the news world, where anchors would send their stories live as they were happening back to the television station. But with enhanced technology today, talk shows and even courtrooms are using this technique with just a camera and the Internet. Sometimes dangerous defendants are kept in jail and are able to see the judge without being in the same building. The term video conference is widely used in government and corporate business, but comes from the same terms as if you have an HDMI-to-USB convertible camera. You can connect to a smart TV and basically enhance your web camera experience. Think of your own YouTube channel, as many people are live-to-Web these days, utilizing this ever-enhancing technology. Cell towers are sending the same HD video feeds newscasters are using. These employ remotes through their cellphones connected to a video camera in the field to send live coverage to the television station without having to use a satellite truck. The quality isn't always great, especially in rural areas where signals can be intermittent, but this type of videography is very important and has been used over the last few years during storm disasters to have continued coverage nationwide.



FIGURE 16.10 Videoconferencing.

POSTPRODUCTION

Software

There are many types of professional editing software on the market, each with features and benefits keyed to a person's needs. For evidence documentation, the only software I use on a regular basis are conversion programs. Depending on your protocol and postproduction setup, you may be using a direct export to DVD or Blu-ray from the camera. If you do not use your analog RCA cables and go directly from the memory card to the media recorder, you probably will not capture the time and date stamp. Therefore, you must use the analog jacks or another type of interface to keep this metadata, taking it from the digital format to analog, to show up on the screen of the converter system if using direct to DVD.

If you want to use a computer to display the time/date information already within the metadata of the video, you have to use external software. To keep the court from questioning the authenticity of the video, please note we are *not* editing the video. We are merely displaying a subtrack of the internal date and time, so make sure you learn your camera and setup to state this correctly when testifying in court.

We use software like Pinnacle Editing for Mac or AVS Video Converter on Windows. Newer software is always gaining momentum on the market, but not all cameras can work with all systems Make sure you test with a trial version before purchasing it, as it can be costly. After I follow my protocol, I take the footage, import it into the timeline or viewer window, chose a codec format (MP4 or MOV) for output, turn off the audio track (if any and if unnecessary), and click on the "subtitle" button to be able to view the metadata for the time/date. Then I choose or make a new folder, name the file, and click the export or convert button—and then sit back, watching more paint dry. I have found additional tools of the trade but I use Mac and Windows. I am waiting for the next tablet to be able to handle Wi-Fi direct from camera into it so I can edit in the field, as I would really like to use my iPad in the field to export video with metadata to then upload to the client server for delivery of evidence. But as of this writing it's not here yet!

Videography to me is the same as photography, except you have to think about audio and movement affecting your image. Either the audio needs to be off or make sure it's not over modulated and peaking. The use of a tripod is more necessary when moving the camera than in still photos. Otherwise, if we correctly expose, have maximum depth of field, are free from distortion, and are in sharp focus, we did a swell job of documenting the evidence, one frame at a time. It takes time to become an expert. I look forward to it myself, maybe by the next issue of this book.



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17 Surveillance Videos Capture the Path of a Killer (Forensic Analysis)

Litigation Animation

CONTENTS

Further Readings 364
Note 365

Venice Beach, California, was founded in 1905 as a seaside resort town and remained independent until 1926. Today, Venice is a suburb of Los Angeles nestled between Santa Monica and Marina del Rey. Attracting a variety of eclectic people, Venice is known for having a carnival-like atmosphere. This iconic city with a 2½ mile pedestrian-only ocean front walk featuring mystics, musicians, artists, performers, vendors, restaurants, hotels, and, of course, the beautiful Pacific Ocean, attracts millions of tourists every year from all over the world wanting to experience this unique and eccentric vibe. Only Disneyland attracts more tourists to Southern California.

On August 3, 2013, Nathan Louis Campbell, a 38-year-old drifter with police records in multiple states, drove to the Venice Beach ocean front walk. He parked his 2008 Dodge Avenger on Dudley Avenue next to the Cadillac Hotel, within 30 feet of the boardwalk. At approximately 6 p.m., Mr. Campbell entered his vehicle, alleging that he had put the car in reverse and had become startled when the car accelerated forward. He steered the car onto the sidewalk, squeezing in between a wall and bollard. The vehicle had entered the pedestrian-only ocean front walk crowded with people. The vehicle continued accelerating, launching an ATM machine and a mannequin 40 feet across the boardwalk. The first person to be injured was a woman hit by the ATM machine. Mr. Campbell quickly turned the steering wheel hard to his left, away from the beach, aiming the car directly at the greatest concentration of people. In the ensuing chaos, people began screaming, yelling, and warning others of the oncoming vehicle. Mr. Campbell did not apply the brakes, honk the horn, flash the lights, or steer the vehicle off the boardwalk toward the beach, where the deep sand would have slowed or stopped the car. Mr. Campbell allegedly steered the vehicle back and forth in an S pattern to avoid hitting people; however, after 16 seconds he had struck a total of 17 people between Dudley Avenue and Sunset Avenue, where the last person was hit before he exited the boardwalk. If not for the people yelling warnings and the chaotic sounds created by the rampaging car, more pedestrians would have been injured or killed.

Nathan Campbell had traveled approximately 600 feet on the boardwalk, for an average speed of 24 mph. Of those 17 people injured, an Italian honeymooner, Alice Gruppioni, was killed. Mrs. Gruppioni was walking with her husband southeast on the boardwalk when the vehicle struck them from behind, violently knocking her husband down and carrying Alice away on the hood of the vehicle for approximately 130 feet until she fell. It was not clear from the video if Nathan Campbell provided steering input causing Mrs. Gruppioni to fall off the hood. Her injured husband looked on in horror as Alice lay dying. In less than a minute, the carnival-like atmosphere at Venice Beach was transformed into a nightmare. Two hours later an intoxicated Nathan Campbell went to the Santa Monica Police Department and said, "I am the one you are looking for." Nathan Louis Campbell was arrested and the vehicle impounded. The car was later inspected for mechanical problems; none were found. It is unknown whether he was intoxicated at the time of the incident. A witness stated that Nathan had paid approximately $35 dollars for drugs, and when the dealer did not return, Nathan told him that he was going to find the dealer and run him over. The Los Angeles Superior Court charged him with murder and assault on August 6, 2013.

One year later in July 2014, I was contacted by Los Angeles Deputy District Attorney (DDA) Victor Avila, who was prosecuting Nathan Louis Campbell for the murder of Alice Gruppioni and the assault of 16 others. Mr. Avila explained the case and that his detectives had retrieved surveillance camera footage from various shops along the ocean front walk. Each camera had captured a few seconds of the car from various angles as it traveled southeast down the boardwalk. He asked if the video and physical evidence could be used as the foundation for reconstructing the complete path of the vehicle to include any speed variations. Ultimately the DDA wanted to show the jury a 3-D animation of the vehicle on the boardwalk that clearly communicated Nathan Campbell's true intent that day. Before seeing the video, I had two questions in mind: Was there enough overlap between cameras to string together the complete path and, if not, would the physical evidence, such as tire friction marks and debris, fill those gaps?

We had our assignment and started with reviewing the surveillance videos, the physical evidence diagram,



FIGURE 17.1 Venice Beach pedestrian-only Ocean Front Walk.



FIGURE 17.2 Surveillance video sequence showing people running for cover as a vehicle drives on pedestrian-only ocean front walk.



FIGURE 17.3 Views from seven different surveillance cameras as the vehicle enters the frame.



FIGURE 17.4 Three-dimensional survey model of pedestrian-only ocean front walk.

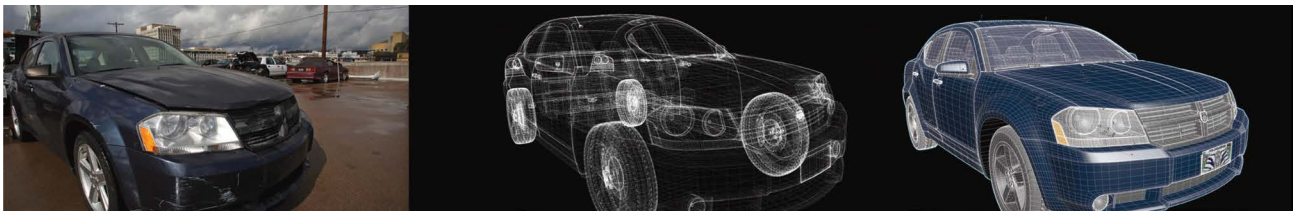


FIGURE 17.5 Three-dimensional model of 2008 Dodge Avenger developed from actual vehicle.

crime scene photos, and witness statements. However, we were missing two key pieces of information for the project to move forward: a 3-D survey of the ocean front walk and a 3-D model of the 2008 Dodge Avenger. We made arrangements and were soon escorted by LA detectives to the ocean front walk, where we surveyed the site from the air with a DJI drone.[1] Next, the detectives escorted us to the impounded vehicle, where we photographed and made measurements of the 2008 Dodge Avenger for construction of the 3-D model. After synchronizing the video sequences, it was revealed that most of the victims were hit within the first seven seconds, which was likely due to people being caught off guard. This observation was found to be consistent with the physical evidence diagram. Some people who were alerted had mere seconds to escape. The video showed visibly terrified people running, stumbling, falling to the ground, and into the shops; some grabbed children as they ran for cover.

In order to properly analyze the vehicle movement, we used a process called photogrammetry. This technique has been around since the 1950s and simply means making a measurement from a photo. In those early days, a 1-inch transparency of the image was created outlining key features, then placed in the viewfinder of a modified film camera. The photogrammetry expert would then take that modified camera to the actual scene and by viewing the scene with the outlined overlay, he was able to determine the perspective, position, and orientation of the actual camera that took the original image. At that point measurements were made.

The concept of photogrammetry has been in existence even before the invention of the camera. In 1480 Leonardo da Vinci described the process in his writings on perspective.[2] "Perspective is nothing else than the seeing of an object behind a sheet of glass, smooth and quite transparent, on the surface of which all the things may be marked that are behind this glass. All things transmit their images to the eye by pyramidal lines, and these pyramids are cut by the said glass. The nearer to the eye these are intersected, the smaller the image of their cause will appear."

A simpler form of photogrammetry approximates a measurement by having two objects on the same image plane perpendicular to the camera and knowing the dimensions of one of those objects. Allow me to explain with two examples: Imagine a photo where a father and son are standing next to each other on the same plane. You know the father is 6 feet, and visually you observe that his son is half his father's height. It is reasonable to approximate the son's height at 3 feet. During surf competitions, wave heights are routinely estimated by referencing the surfer to the wave. The genius Leonardo da Vinci was known for driving science with art and art with science. Today, photogrammetry is a perfect example of that philosophy.

A more sophisticated and precise form of photogrammetry takes advantage of drone survey technology, 3-D animation software, photogrammetry algorithms, and high-resolution digital cameras that not only record an image but also the longitude-latitude and altitude from where it was taken. Surveys created optically by a drone compare favorably with ground-based laser scans. We have done field testing comparing both techniques and presented the results to the Society of Forensic Engineers and Scientists.[3] Photogrammetry algorithms are constantly being improved upon, resulting in greater accuracy and efficiency. We used high-resolution 4K monitors (the bigger the better) to review



FIIGURE 17.6 Three-dimensional point cloud of pedestrian-only ocean front walk.

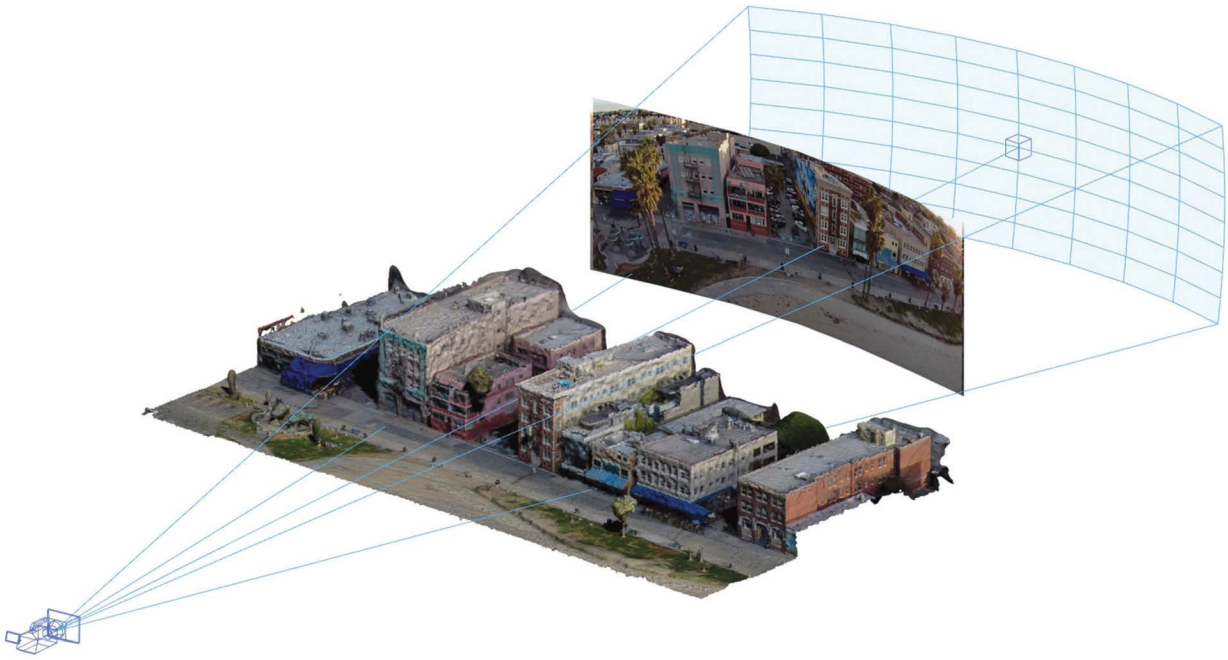


FIGURE 17.7 Three-dimensional model of photogrammetric process showing virtual camera, survey, and surveillance image.

and analyze the video and still images because they behave like a large magnifying glass, revealing greater detail down to the pixel level.

For this complex assignment, we used 3-D Studio Max software[4] for modeling, animation, and photogrammetric analysis; Pix4D aerial survey software[5] to autonomously fly the drone over the ocean front walk; and Adobe Photoshop[6] to analyze the crime photos and the physical evidence diagram. 3-D Studio Max has virtual reality (VR) cameras that can be accurately translated and rotated in 3-D space. These VR cameras also have the ability to simulate perspective and lens distortion, which were crucial for the analysis. The photogrammetric technique used on this assignment is known in the scientific community as reverse projection photogrammetry.[7] This is how it works. From within the simulated environment of 3-D Studio Max, the 3-D survey was brought in and locked into place. Next, the seven video sequences were imported as background plates and seven VR cameras created for each of the seven real-world surveillance cameras. Each video's frame rate, image aspect ratio, and pixels aspect ratio, either square or rectangular, were properly set. Within this virtual world the VR cameras were then positioned on the 3-D survey at the approximate 3-D location and orientation as their corresponding real-world surveillance camera. The general locations of the seven surveillance cameras had previously been measured at the boardwalk.

We now entered the simulated world of Venice Beach contained within 3-D Studio Max and selected VR camera number one to view the corresponding surveillance video background plate (Figure 17.7). The survey (wireframe model) appeared overlaid on the video background plate and out of alignment with corresponding features due to



FIGURE 17.8 3-D Studio Max Virtual Camera views showing vehicle trajectory placement on survey with surveillance video in background.

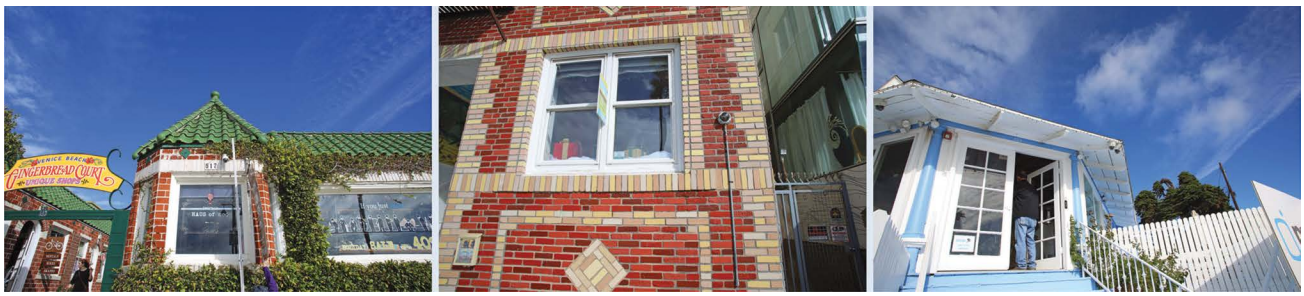


FIGURE 17.9 Images showing three surveillance cameras.

lens distortion and the approximate placement of the VR camera. The perspective and lens distortion for that VR camera were then adjusted to match the video background plate, while simultaneously changing the position and orientation of that VR camera. Continued adjustments were made to achieve satisfactory registration between the survey and the video background plate; then that VR camera was locked into position. The process was repeated for each of the remaining cameras.

This process can be time consuming if the edge features and perspective lines are not easily identified or the lens distortion is significant. It is important to compare the real-world camera properties to the VR camera. The accuracy of the analysis is influenced by three factors: the quality of the footage (resolution and lens distortion), the subject's distance and orientation relative to the camera, and finally, how well the perspective lines are defined in the image. A photogrammetrically analyzed image may contain features that decrease in accuracy as the distance from the camera increases. Here is why: objects in the foreground are defined by a greater number of pixels (high resolution), and objects in the background are represented by fewer pixels (low resolution). For example, imagine that you are standing on the railroad tracks taking a picture of an oncoming train. As the perspective lines converge to the vanishing point in the distance, the train appears small and may be represented in the image by a small number of pixels resulting in a poorly defined train. As the train has now moved to the foreground, that same train appears larger and may be represented by a greater number of pixels providing higher level of detail and resulting in much more accurate measurements. Our final results were checked qualitatively by inspecting the survey/video alignment and quantitatively by comparing the 3-D cameras' position and lens specification.

After matching all seven VR cameras and locking them into place, we then turned our attention to the movement of the vehicle. The 3-D vehicle was imported and positioned onto the survey. Then the video background plate advanced one frame at a time until the real-world car appeared. At this point, the 3-D vehicle was repositioned on the survey to match the video (Figure 17.8). We continued matching the vehicle movement video until the vehicle went out of frame. Moving on to the next VR camera, the process was repeated until the complete trajectory was established, creating a 480-frame animation (Figure 17.11). There was sufficient overlap as the vehicle moved between the VR cameras. The first two cameras were the most difficult when tracking the car due to the greater number of people in the foreground. The final result matched well with the



FIGURE 17.10 Aerial view demonstrating vehicle trajectory.



FIGURE 17.11 Southeast view of vehicle path.

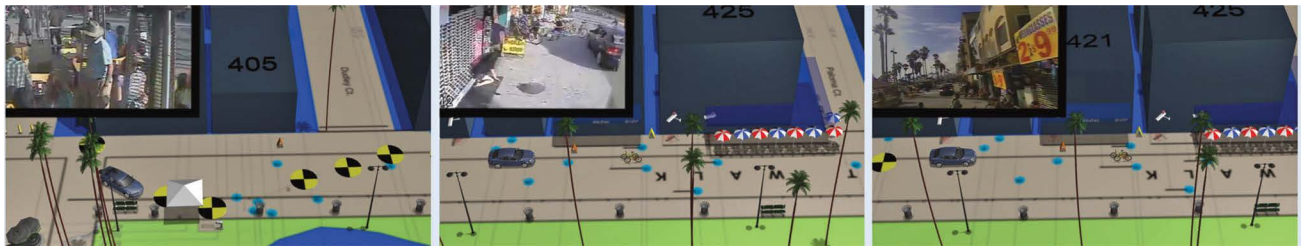


FIGURE 17.12 View of vehicle trajectory composited over physical evidence diagram.

physical evidence diagram, specifically the tire friction marks. The entire vehicle path was animated on the ocean-front walk, and we were able to calculate the velocity at any point in time.

The final 16-second animation showed that the vehicle traveled between 20 mph and 35 mph on the pedestrian-only ocean-front walk between Dudley Avenue and Sunset Avenue. The animation was composited over the crime scene diagram and surveillance video to demonstrate correspondence (Figure 17.12). The final work product clearly showed that people were struck and ran for their lives as Nathan Louis Campbell tried to run them down. Nathan Louis Campbell was convicted of second-degree murder and charged with 17 counts of felony hit and run and 10 counts of leaving the scene of an accident. The techniques described in this criminal case are identical to those we use in civil litigation. In May 2015 I presented the animation at trial. One of the questions asked by the defense attorney that stands out is, "What was the speed of the vehicle?" My response was, "At what point?" The fact that Nathan Louis Campbell's vehicle speed varied, clearly demonstrated that he was pressing on the gas and not the brake. Nathan Louis Campbell was sentenced to 42 years to life in state prison.

FURTHER READINGS

1. DJI is a Chinese technology company that manufactures drones for aerial applications. Their Mavic Air is wonderfully portable and houses a three-axis mechanical gimbal. Its angular vibration range is reduced to 0.005 degrees. The gimbal dampeners are set in a triangular formation. The built-in 32 MP camera makes horizontal, vertical, and 180-degree panoramas. It can stitch 25 images together in under eight seconds to create 32 MP sphere panoramas. They may be viewed from an immersive perspective with DJI Goggles.
2. History of Photogrammetry by the Center for Photogrammetric Training.
3. Society of Forensic Engineers and Scientist (SFES).
4. **Autodesk 3ds Max**, formerly **3-D Studio**, then **3-D Studio Max** is a professional 3-D computer graphics program for making 3-D animations, models, games, and images.
5. **Pix4D** is a suite of software products that use photogrammetry and computer vision algorithms to transform both RGB and multispectral images into 3-D maps and models.
6. Adobe Photoshop is a raster graphics editor developed and published by Adobe Systems for macOS and Windows.
7. SAE 1999-01-0093 Using Computer Reverse Projection Photogrammetry to Analyze an Animation — David J. Massa (Sigma Animation, Inc.).

NOTE



For over 24 years, Jorge and Donna Mendoza have operated Litigation Animation, Inc., a consulting firm with offices in San Jose and San Francisco, California, specializing in laser and optical scanning, animation, photo/surveillance video analysis, and day/night visibility studies. Jorge and Donna are both FAA licensed drone pilots with experience in optical scanning of accident sites from the air for greater coverage and cost benefit. Jorge has a BS in mechanical engineering and Donna has a BS in medical technology. Both are members of the Society of Forensic Engineers and Scientists (SFES). Paul Enrique Mendoza is a recent addition to their team. Their work can be viewed at www.litigationanimation.com. E-mails: litamation4297@gmail.com and litamation@yahoo.com.



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18 Working the Field/Accident Scene

Robert Wyman

CONTENTS

Photographic Projects Concerning Accidents, Traffic Crashes, and Other Civil or Criminal Incidents 367
Personal Injuries from Slips, Trips, and Falls 368
Incident Site Photography 369
Traffic Crash Photography 369
    Camera Equipment 370
    Safety Equipment 370
    Location Identification and Measurement Equipment 370
Environmental Documentation at a Traffic Crash 370
Scene Photographic Documentation 371
Overall Views 372
Mid-Range Views 372
Close-Up Views 372
Macro Views 372
Vehicle Photographic Documentation 372
Traffic Crash Reconstruction Photography 373
Mass Casualty Incident/Multicasualty Incident Photography 374
Housings for DSLR Cameras 376
GoPro 376
Details of the Investigation 380
    Victim Recovery, Examination, and Identification 380
Conclusion 385
Further Readings 385

PHOTOGRAPHIC PROJECTS CONCERNING ACCIDENTS, TRAFFIC CRASHES, AND OTHER CIVIL OR CRIMINAL INCIDENTS

Photographic documentation of accident sites, victims, and peripheral evidence is a mainstay of forensic photography. Before leaving for the site, certain mental preparations should be considered and physical preparations made. The following questionnaire is a recommended example of the thought and actual processes to be followed, and the questions to be asked, at the commencement of an assignment.

Who is commissioning the assignment?

TIP:

The following also applies to inspections and documentation surveys meant to prevent accidents.

- In the private sector, clients may include property owners, risk managers, fleet managers, insurance adjusters, private investigators, expert witnesses, attorneys (criminal defense or civil plaintiff and defense attorneys), and accident victims themselves.
- In the public sector, those needing photographic documentation may include prosecutors, office of the public defenders, attorneys or representatives of individual public agencies and third party investigators (risk management department, office of the inspector general, etc.).
- Of course, appropriate law enforcement agency employees will also be tasked with photo documentation assignments on an almost daily basis.

What is the purpose of the images?

- Are the photos for a criminal or civil legal proceeding?
- An insurance or safety survey?
- An academic or demonstrative exercise?

Who is going to be seeing and using the images?

- Legal team or other professional practitioners?
- Accident/incident victim or witnesses?
- Students, other citizens, or news media representatives?

What is the scope of use?

- Is a declaration of permitted or restricted uses of images needed?
- Should the photographer consider potential copyright, trademark, and intellectual property issues regarding the ownership of the images?
- Who will have authority to copy, modify, transmit, publish, and archive the images?

What are the delivery deadline and preferred transmittal mechanism?

- Is there a fixed or variable deadline for the output, media delivery or report?
- How will the photos be conveyed to the client or entity responsible for this assignment (printed or electronic output)?

In addition to the subjects of site location, description, and documentation required, will any pre-photography planning be required?

- A walk-through of the project site may be prudent to identify specific photo locations and subjects, observe the lighting conditions for photography, look for potential safety hazards, determine where parking will be provided, etc.
  - Environmental conditions such as the weather forecast, including the potential for inclement weather, may affect the photo schedule.
  - Time-of-day issues may be important, as natural light direction and intensity may adversely affect photography tasks, including sunrise, sunset, shadows, glare, and reflections. For interior and exterior locations, the presence of automatically operating streetlamps or interior lamps should also be considered.
  - Date and day-of-week issues may also be part of the planning process. Site photography can be severely affected by adjacent roadway traffic volumes and traffic patterns, nearby roadway or building construction zones, and local special events (parades, festivals, concerts, sporting events, traffic detours, etc.).
- A pre-photography checklist and/or sketch may be prudent to streamline the photography workflow, ensure that all intended photographs have been completed, and provide an illustration of the photo points around the site.
- A written authorization, via letter or email, may be prudent to verify the photographer's authority to access the site should there be a challenge to such authority.
  - No matter if the site is on public or private property, police employees will typically be immune to any challenge while processing a scene.
  - Private practitioners, however, may be quickly challenged and threatened with a trespass violation if site access has not been previously approved. Some sites may require the purchase of a permit for access generally or photography specifically, with related site liability insurance also required well in advance of the scheduled assignment. Sites may also require the photographer to be escorted through the assignment by facility security or property management personnel.
- Expanding on the subject of site safety, especially for private practitioners, planning may include the determination if special personal protective equipment (PPE) is required, including local requirements for hard hats, safety glasses, hearing protection, safety shoes, etc.

PERSONAL INJURIES FROM SLIPS, TRIPS, AND FALLS

Slip, trip, and fall incidents resulting in personal injuries are common. Pedestrians who fall may experience a wide range of injuries, from only minor scrapes and bruises to internal injuries or even death. A pedestrian with pre-existing health problems may be at increased risk for serious or fatal injuries by a severe fall.

Site documentation is typically required for slip/trip/fall locations, with pedestrian injury photography also desirable for severe incidents.

- Slip incidents are due to insufficient surface friction specifications for the walking surface. Surface friction specifications are known and measurable quantities for any surface (the "coefficient of friction"), although special equipment is needed to perform friction tests. Local municipal codes and/or state building codes usually address minimum surface friction standards for walking surfaces used by the public. Interior walking surfaces may have different minimum standards than outdoor surfaces.
  - Examples
    - "Traffic polished" walking surfaces. Similar to roadway traffic–polished surfaces, a poorly maintained floor with years of pedestrian traffic may become extremely slippery. Areas such as decades-old train stations, subways, bridges, and similar facilities can experience this condition.
    - Painted or coated walking surfaces. When a walking surface is painted instead of being left in its originally constructed surface finish, paint must be maintained and

reapplied on a regular basis. Specifications exist for pedestrian-safe paints and coatings, with sufficient slip-resistance additives giving a texture to the paint or coating. When unsafe paints are applied, or when previously applied paints have outlived their original specifications, the walking surface can become extremely slippery. A particularly severe hazard is a noncompliant outdoor walking surface in inclement weather. This surface may be safe to walk on when dry, but when wet may exhibit the same surface friction as an ice rink.

- Pooled or flowing liquid across a walking surface. Water, oil, or other liquid contaminants can easily become slip hazards for a walking or running pedestrian. Clear liquids may be unseen by the pedestrian and unavoidable until they have already taken a step toward the liquid or are already within the hazard zone caused by the liquid.

- Trip incidents are due to a "tripping mechanism" being present but unseen by the pedestrian. Often the result of poor floor, walkway, or sidewalk maintenance, tripping mechanisms are hazards to pedestrians often easily remedied, but also easily overlooked until a severe incident occurs.
  - Examples
    - Uneven wooden floor or deck planks.
    - Wooden floor or deck planks with decorative gaps or drainage gaps.
    - Uneven floor tile or grout seams.
    - Poorly formed concrete walkways, with hazardous surface irregularities such as depressions (dips or indentations at an elevation below the surrounding walking surface) or projections (bumps or bulges raised above the surrounding walking surface).
    - Poorly maintained municipal sidewalks, with raised or lowered concrete panels and exposed "lips" due to tree roots, soil erosion, or similar instances.
    - Walkway structural failures, cracks, displaced segments, or collapsed segments.
    - Walkway edge drop-offs, erosion, and similar damage.
    - Walkway potholes or similar damage.
    - Stairway irregularities in surface composition or dimensions.
    - Ramp irregularities in surface slope specifications or dimensions.
    - Doorway threshold irregularities regarding improper threshold hardware or installation specifications.
  - Not to be overlooked is the possibility of the pedestrian slipping or tripping due their own negligence or physical condition.
    - A pedestrian may trip and fall on their own clothing with loose-fitting pants or skirts.
    - A pedestrian may slip or trip and fall with ill-fitting shoes or shoe designs inappropriate for the walking surface, such as the use of high-heel shoes on a wood-plank deck with drainage slots.
    - A pedestrian may fall due to a medical condition or ailment affecting balance and mobility.
  - Finally, a walkway or stairway may be structurally sound and otherwise safe as a walking surface but deficient in other items required by municipal codes, building codes, architectural plans, or other standards.
    - Walkway and stairway interior lighting may be required, including minimum lighting standards for brightness and the type of lamps.
    - Handrails may be required, including specific handrail locations, heights, designs, and materials.

INCIDENT SITE PHOTOGRAPHY

Slip/trip/fall site photography is often presented as a photo essay, beginning at a significant point in the pedestrian's walking route, prior to encountering the hazardous area. Photos are captured of the overall area where the pedestrian has walked, progressing along the pedestrian's path until the hazard location is reached.

Images recorded at the pedestrian's standing or running height may be necessary to accommodate this variable and guard against any photo inaccuracy claims due to incorrect photo heights and perspectives. That is, if a small-stature child or adult is a slip/trip/fall victim, a 6-foot tall photographer with a camera at eye height will not produce the same photos as recorded at the pedestrian's actual eye height.

At the hazard location, overall, mid-range, close-up, and perhaps macrophotographs are completed of the incident site. For semi-permanent hazards not yet repaired, such as walkway structural irregularities, hazards can be photographed and measured to great detail just as any other point of evidence.

Consult Chapter 10 for suggestions on how to properly photograph the scene in low light if darkness or shadows are a factor.

TRAFFIC CRASH PHOTOGRAPHY

Law enforcement and other emergency personnel photographing traffic crashes have a unique documentation assignment. Roadway scenes may require partial or full road closures, resulting in traffic detours, roadway congestion, travel time delays, and often the creation of other hazards, as approaching traffic must rapidly brake, slow down,

change lanes, merge traffic streams, and maybe drive on shoulders or medians to get around the crash site.

The photographer is often pressured by supervisors, news media representatives, and the public to complete the documentation assignment as soon as possible so the road can be reopened. Local politicians may also enter the fray as constituent complaints start being received at their offices.

While the photographer's intent may be to complete the assignment quickly, other workers are also on scene, each with their own assignments. Personnel, vehicles, and equipment from law enforcement and fire-rescue, plus ambulances, tow trucks, news media, and others may have also responded to the scene to do their jobs, with each entity occupying space near the crash site. Each person, vehicle, and piece of equipment may obstruct the photographer's assignment.

Since the scene is often dynamic, with multiple activities occurring simultaneously, the photographer may have to prioritize the photo subjects or call for assistance to divide the scene documentation task with another photographer.

For first responders primarily, but also for private practitioners who may visit the crash site after the initial response, a well-stocked crash documentation kit contains many more items than just a camera bag. Each item is directly related to successfully completing the photo documentation task:

Camera Equipment

- One or more cameras
- One or more lenses
- High-output electronic flash unit (EFU)
- Memory cards
- Tripod
- Extension pole ("selfie stick") for slightly elevated photos and low-angle, confined-space, vehicle undercarriage photos
- Elevated photography pole or drone for medium to high elevation scene photos
- Wired or wireless remote shutter release



FIGURE 18.1 Vehicle crash.



FIGURE 18.2 Measuring wheel.

- Camera and EFU batteries
- Inclement weather camera sleeve (for light precipitation) or housing (complete enclosure for waterproof/dustproof camera operation)

Safety Equipment

- Traffic vests
- Traffic cones
- Vehicular emergency beacons (if allowed by state and local laws)
- Personnel emergency beacons
- Flashlights and batteries
- Portable wide-area floodlights

Location Identification and Measurement Equipment

- High-quality compass to identify roadway directional properties when no physical landmarks are present
- Global positioning system (GPS) to identify site coordinates when no physical landmarks are present
- Site surveying instruments (survey-quality GPS, total station, laser scanner, photogrammetry kit, etc.)
- Handheld measurement devices (laser rangefinder, walking wheel, tapes and scales, plumb bob, etc.)

ENVIRONMENTAL DOCUMENTATION AT A TRAFFIC CRASH

In many forensic photography assignments, inclement weather or outdoor site illumination has little or nothing to do with the incident. For traffic crashes, the environment is both a documentation subject and an operational condition for the assignment's completion.

As a point of documentation, inclement weather is an important photo subject. In testimony or report writing, a photographer may have difficulty articulating the severity of a storm and surface conditions of the road. Statements like "it was raining heavy" or "the snow was blowing hard" may not paint an accurate mental picture of environmental conditions. Photographs, on the other hand, fully illustrate the conditions encountered at the scene. Roadway visibility and roadway surface conditions are immediately recorded and preserved through accurate site photography.

- Rain, snow, smoke, and windblown dust may be photographed with ambient (existing) light, an EFU mounted on-camera, an EFU or other camera lamp positioned off-camera, or vehicular headlamps or spot-lamps.
  - Various lighting techniques should be used, with the results evaluated for the selection of the best representative images.
  - Images exposed using an EFU may result in very bright or overexposed airborne elements, with very dark and underexposed backgrounds.
- Regarding focus settings, the camera may have to be set to manual focus and prefocused on a desired nearby point to obtain a sharp and properly exposed photograph of airborne liquids and particulates.
- Regarding shutter speed settings, photos of rain and snow, more so than smoke and dust, may require a high shutter speed to negate the movement of these elements and produce sharp views of the precipitation. Conversely, slow shutter speeds may also be of value, as heavy precipitation will be recorded as dense streaks of rain or snow. This, too, may have value in describing the scene.

The environment is also an operational condition. Scene documentation must often progress regardless of the environment, even if a return site visit is planned once weather conditions improve. Preplanning for inclement weather and practicing photographic techniques during inclement weather are keys to a successful assignment.

Nighttime photography, mentioned at various times throughout this book, presents other challenges in all weather conditions.

- Nighttime and cold weather photography will consume camera and EFU batteries significantly faster than in more normal conditions.
- When the view toward parked police and fire vehicles is unavoidable in a nighttime scene, the retro-reflective graphics and logos applied to these vehicles, as well as retro-reflective traffic signs near the scene, will produce intense reflections back to the camera when an on-camera EFU is utilized. These reflections will affect image exposures, with the logos and signs appearing overexposed, while surrounding areas are underexposed. See Chapter 10C for the technique to use an EFU but avoid these logo reflections.
- For long traffic crash scenes, an EFU may not be adequate to illuminate the entire scene. Consult Chapter 10 for a review of painting with light. This may be the only option for the photography of an extensive nighttime scene.

SCENE PHOTOGRAPHIC DOCUMENTATION

Many traffic crash scenes benefit from photographs primarily aligned parallel or perpendicular to the traffic lanes and related roadway landmarks, with secondary photographs completed at other angular views toward the scene. The locations and spatial relationships of evidence such as vehicle positions, skid marks, gouge marks, fluid spills, debris patterns, and biological evidence are more easily understood when roadway lane pavement markings, traffic signs, or other roadway design elements are included in the photographic view.

In coordination with evidence measurements and diagrams, a well-planned and well-executed photo documentation assignment will logically lead the viewer of the photos though the scene from beginning to end.

- Parallel photographs illustrate each vehicle's location or other point of evidence within or outside of the travel lane(s). These views establish whether a vehicle or evidence point is centered within a lane, offset in a lane, crossing into an adjacent lane, on the shoulder, etc.
- Parallel photographs also illustrate the orientation of a vehicle or evidence point, such as whether the item is pointing to or aligned with a certain compass direction that may be different from the roadway lane direction.
- Perpendicular photographs may help to establish evidence point locations along the roadway length when roadside landmarks are present. Traffic signs, utility poles, landscaping, buildings or other objects on the road, shoulders, or adjacent properties are examples of nearby items that may be useful in scene documentation. These items may be in alignment with evidence points, making the description of such points easier in a photo essay or report.
  - For example, a photograph depicting a pedestrian victim's shoe in alignment with an intersecting sidewalk may be critical to an investigation.
  - As another example, a photograph illustrating the beginning of a skid mark in alignment with house number 123 Main Street's east driveway edge may be an excellent reference if a future crash reconstruction is needed.
- When the roadside is void of unique landmarks and visual cues, perpendicular photographs may

require measurement tools to document where each point of evidence is located. One hundred-foot or 300-foot tapes can be used to establish a linear measurement reference along the roadway edge, and a GPS can be used to establish one or more coordinate points when no other reference points are available.

OVERALL VIEWS

Scene documentation starts with overall views approaching the crash scene. Roadway elements perhaps having contributed to the crash, such as curves, hills, traffic signs, speed limit signs, or other pre-crash roadway or traffic control elements, should be photographed. Overall views depict what each driver may have seen (and perhaps reacted to) prior to the crash. Inclement weather conditions can also be documented within overall or mid-range views. For east–west roads, sunlight glare, reflections, and shadows may also be apparent.

MID-RANGE VIEWS

Moving closer to the beginning of the crash scene, mid-range photos establish the basic points of the investigation. Subjects such as the number of vehicles involved, locations of each vehicle, locations of other points of evidence, and roadway environmental conditions are all photographed. The aforementioned parallel and perpendicular photos will best place each item in a grid-style view of the scene, and angular photos will provide views of the spatial relationships between evidence points.

CLOSE-UP VIEWS

At each point of evidence, close-up views provide enhanced details of the crash. Metal, plastic, glass, and biological evidence on the road are subjects of documentation. Tire marks, including skid marks and yaw marks, are also photographed.

Close-up views should not be "orphan" images, meaning they should not be recorded without additional wide-angle views in the mid-range category. The location of the evidence is established in the mid-range view, while the detail of the evidence is recorded in the close-up view. An orphan image may provide excellent close-up detail, but it's worthless without knowing where it is in the scene.

MACRO VIEWS

Scene elements requiring extreme magnification for photography will be additionally documented with macro settings and equipment.

VEHICLE PHOTOGRAPHIC DOCUMENTATION

Continuing with the procedure of overall, mid-range, close-up, and macrophotos, each vehicle or mechanism involved in the crash is similarly documented. Consistency in the procedure will lead to an efficient workflow without omitting any subjects.

Overall photos can proceed clockwise around the vehicle, perpendicular to each of the four sides and at each of the four corners. An eye-height series around the vehicle as well as a waist-height series around the vehicle may be useful. The overall photos provide a view of damage locations and severity.

Mid-range and close-up photos next document vehicle and owner identification information, including the license plate; dashboard vehicle identification number (VIN) plate; driver's door VIN/manufacturing plate; and vehicle make, model, and trim level body emblems.

Mid-range and close-up photographs continue in a clockwise pattern around the vehicle, with an emphasis on damage areas, intrusion angles, crush depth, component failures, paint transfer, and any other significant items observed during the assignment. Photographs of each tire's brand, model, size and manufacturing information are also completed.

Interior views are next, again starting with overall images of the interior layout, airbag deployments (if applicable), interior damage, and points of evidence.

Interior close-up views can document mechanical switch positions, seatbelt positions (extended or retracted), and biological evidence locations.

Macro views can finalize the vehicle documentation effort. Exterior points of interest may include:

- Contact points and paint transfer photographed with macro techniques.
- Specific components, such as bulb filaments, are also inspected and photographed if applicable to the crash. Bulb filament examinations may determine if a headlamp, taillamp, or supplemental lamp was illuminated at the time of the crash.



FIGURE 18.3 Vehicle accident with two trucks.



FIGURE 18.4 Vehicle accident with two trucks, second photograph.



FIGURE 18.5 Jib arm.

Interior macro subjects may include:

- Seatbelt webbing examinations to identify seatbelt utilization at the time of the crash
- Windshield head-strike biological evidence
- Fingerprint evidence to determine occupant seating locations, if questioned
- Other biological, chemical, fabric, or trace evidence as needed for the case

TRAFFIC CRASH RECONSTRUCTION PHOTOGRAPHY

In addition to the photographic subjects presented earlier, a traffic crash reconstruction effort combines at-scene photographs, at-scene measurements, environmental documentation, vehicle performance specifications, traffic control device information, and related subjects into a complete analysis of the crash sequence. Reconstruction tasks may be completed shortly after a crash or sometimes many months or years later due to legal proceedings and court calendars. Expanded photography subjects may include:

- Detailed photographs of each driver or pedestrian's line of sight and field of view toward the unfolding crash scene
- Detailed photographs of vehicle mechanisms and components during inspections, such as event data recorder (EDR) and crash data retrieval (CDR) downloads, brake inspections, lamp inspections, and other vehicular system examinations
- Incident simulations conducted with the actual crash vehicles being placed together at their maximum intrusion angles in an effort to match damage components and visualize damage patterns
- Incident simulations utilizing exemplar vehicles for visibility, acceleration, braking, and other performance testing
- Simulations may also include revisiting the crash site within a few days or on a specific anniversary date to obtain photos of the exact sun position or moon phase as had occurred on the original crash date and time

An extension arm/camera boom for/as the tripod is a useful accessory for high-aspect photography.



FIGURE 18.6 Camera (selfie) stick.



FIGURE 18.7 Overall boat damage.



FIGURE 18.8 Mid-range boat damage.



FIGURE 18.9 Overall side damage view at tow yard inspection.

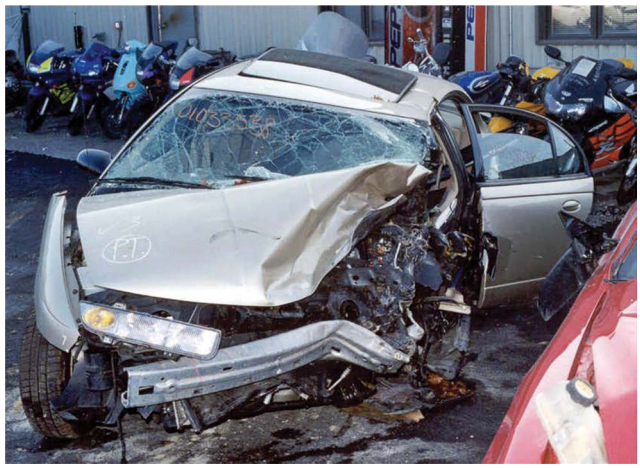


FIGURE 18.10 Overall frontal crash damage.

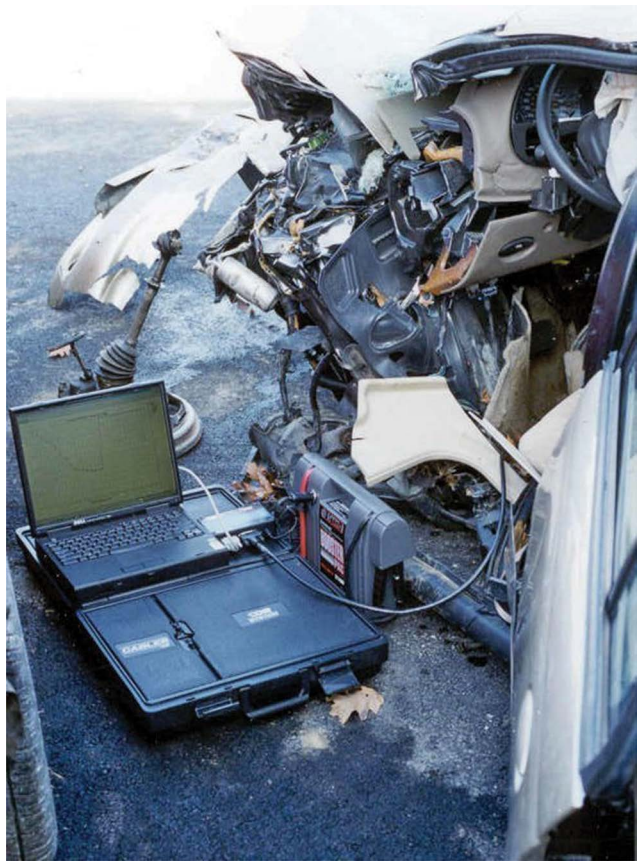


FIGURE 18.11 Downloading vehicle control module.

MASS CASUALTY INCIDENT/MULTICASUALTY INCIDENT PHOTOGRAPHY

Mass casualty incident (MCI) photography is very specialized, and photographers assigned to such incidents will have specific access clearances. MCI photography may also be completed in teams for large incidents, with defined photo locations or photo subjects being assigned to each team.

MCI events often involve dynamic and unstable scenes: dynamic because scene elements and evidence may be developing well beyond the initial response period, and unstable because the scene itself may contain dangerous structures, hazardous materials, leaking fuel, and other impediments to a normal photography assignment.

Although an MCI event can include just a few people, most involve dozens, hundreds, or even thousands of casualties or fatalities, such as:

- Terrorist actions
- Industrial explosions and fires
- Institutional and residential fires
- Floods
- Earthquakes
- Hurricanes, tornadoes, and severe storms
- Building and bridge collapses
- Transportation incidents involving aircraft, maritime vessels, buses, and trains
- Electrical grid failures

In the United States and elsewhere, MCI events are the subject of detailed plans, deployment procedures, supply caches, equipment inventories, and constant personnel training for incident rescue, recovery, and analysis.

Photographers assigned to these response groups or task forces are typically cross-trained to encounter extraordinary working conditions, including:

- Photography while utilizing PPE, including decontamination procedures
- Photography in extreme temperature conditions (heat or cold)
- Photography in extreme outdoor environments, from swamps to mountaintops
- Photography within a hazardous materials environment, including operating camera equipment in a flammable atmosphere
- Photography in confined-space conditions
- Photography with limited resources for recharging batteries and downloading images to a computer or off-site archive

MCI photo assignments are planned, controlled, and executed with personnel safety being the first priority. The resulting photos may be critically important, but no photographic image is worth an injury or fatality to the photographer.



FIGURE 18.12 Documenting hurricane damage.



FIGURE 18.13 Re-creation of train/bus collision.



FIGURE 18.14 Debris removal at explosion/fire site.



FIGURE 18.15 Examples of personal protective equipment.



FIGURE 18.16 High aerial view of the ground.

HOUSINGS FOR DSLR CAMERAS

If you need a camera that will function properly underwater or in hazmat conditions without risking damage, there are great housings made by multiple manufacturers to fit their own specific cameras. Some come with leak detection systems and dual optical fiber ports for viewing and exposing images. Housings are made from a combination of polycarbonate, steel, and glass. They come with positive buoyancy—so much that you need to use the strap included in the package. You also get a shoulder strap and external threads for application of appropriate filters. They are normally verified for pressures to 195 feet under water.

GOPRO

GoPro offers a line of still and motion picture cameras for use in underwater or hazmat conditions.

Aerial Scene

There is just so much of an accident/crime scene that can be photographed from the ground. When an intersection or group of buildings needs to be documented in total, or an incident requires a large area for a question of line of sight, it is common to have the scene documented from the air. See Chapters 22 and 23 for further information.

CASE STUDY 18.1

Adjacent to a public building, a section of walkway with a variation in surface levels between sections was the site and alleged cause of a trip and fall incident involving a plaintiff who sustained personal injury. An attorney contracted a forensic photographer to document the site.

The incident occurred at night, but the claim was not vision related, so the documentation was undertaken on a bright sunny morning. The walkway was in the same condition as at the time of the incident, but the property owner had placed three 5-gallon plastic pails of water on the walkway at the point of the incident to discourage subsequent foot traffic.

The go-kit used for this documentation consisted of:

- Digital camera
- Metal ruler of sufficient length to measure the width of the walkway
- Plastic triangle for a square
- Profilometer to accurately document the disparity between the adjacent sections of the walkway
- Paper and pen
- Caliper to measure on-site the same disparity
- Rigid plastic sections to place on the rough concrete for use with the caliper
- Smart level with digital readout for measuring inclination

Other optional accessories that were available but not used included:

- Reflective cones to warn traffic and pedestrians
- Personal protective devices, including gloves and knee pads
- Tape recorder to document the proceedings

The documentation proceeded in a logical manner.



FIGURE 18.17 Forensic photographer gear load out.

1. All necessary tools were made ready to use.



FIGURE 18.18 Figure 18.19 photographer position illustration.



FIGURE 18.19 Front overall view.

2. Overall images of the building, walkway, and surrounding area were exposed (see Figures 18.18 to 18.22).



FIGURE 18.20 Photographer placing measuring tape.

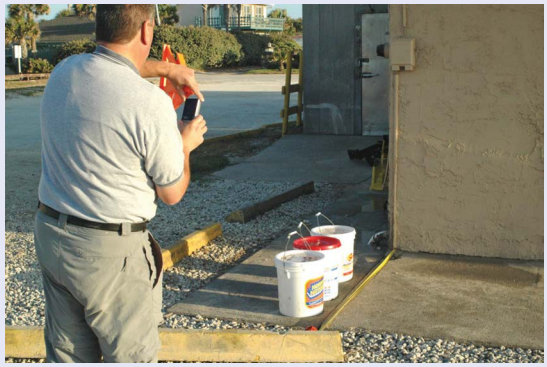


FIGURE 18.21 Figure 18.22 photographer position illustration.



FIGURE 18.22 Side overall view.



FIGURE 18.23 Close up view of tape measure showing sidewalk width.

3. A metal ruler was placed across the walkway to document its width. Photographs were exposed to demonstrate the width of the pavement (see Figures 18.22 and 18.23).



FIGURE 18.24 Moving barricades for photography purposes.

4. The plastic buckets were moved out of the way (see Figure 18.24).



FIGURE 18.25 Positioning scale and level to demonstrate uneven surface levels.



FIGURE 18.26 Mid-range side view of scale and level showing uneven sidewalk levels.

5. A plastic triangle was placed on the lower section and a level parallel on the upper section to enable visualization of the disparity.



FIGURE 18.27 Capturing Figure 18.28.



FIGURE 18.28 Close up of scales demonstrating the sidewalk height difference.

6. The disparity was photographed (see Figures 18.26 and 18.28).

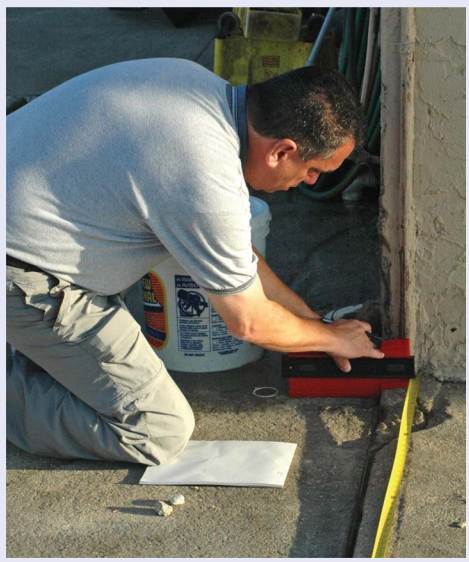


FIGURE 18.29 Using a profile gauge to capture the actual height disparity.



FIGURE 18.30 Close up view of profile gauge near building.

7. A profilometer/contour gauge was used to document the contour of the disparity at five locations across the pavement, starting at the side closest to the building (see Figures 18.29 and 18.30).



FIGURE 18.31 Transferring captured profile to graph paper.

8. The contour taken at each position was permanently recorded on paper (see Figure 18.31 to 18.33).



FIGURE 18.32 Capturing profile at middle of sidewalk.



FIGURE 18.33 Transferring outside edge profile to graph paper.

9. Position 3 The outside edge of the sidewalk profile was captured and recorded.



FIGURE 18.34 Recording the lateral slope angle of the sidewalk.

10. A smart level was used to document the pitch of the concrete, perpendicular to and on both sides of the disparity, and parallel to the disparity (see Figure 18.34).

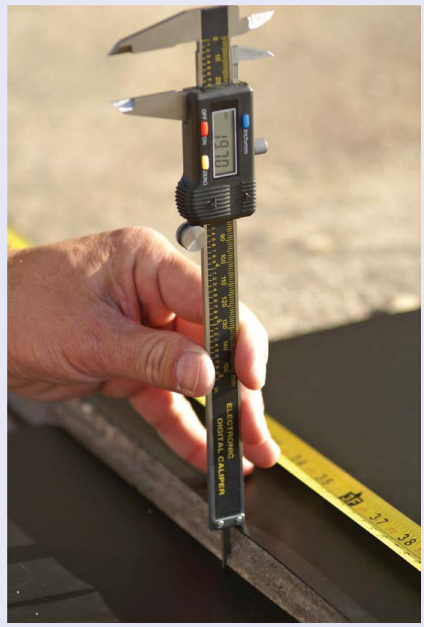


FIGURE 18.35 Capturing precise level difference with digital calipers.

11. A digital caliper was used to take detailed measurements of the disparity to double-check the measurements derived from the contours. Sheets of rigid plastic were placed on both surfaces to allow extra accuracy of readings.

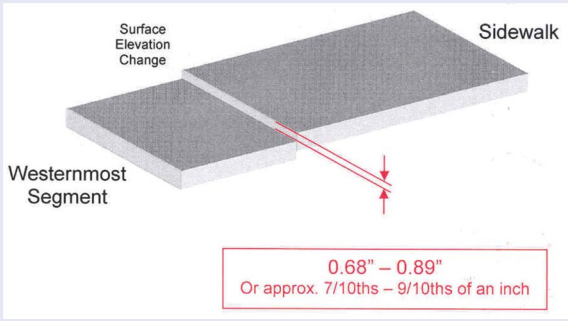


FIGURE 18.36 Completed CAD drawing of sidewalk conditions.

12. The drawings made of the contours were used in a computer-assisted drawing (CAD) application to construct a 3-D model of the walkway (see Figure 18.36).

The images were used to document the findings of the inspection and to substantiate the report furnished by the reconstructionist. The finished report was sent to the attorney who contracted the project, and it was used as an exhibit at trial.

SUMMARY

The average vertical displacement of 0.78 inches of the westernmost section of the walkway exceeds the vertical elevation change allowable by the Americans with Disabilities Act (ADA) and possibly the Florida Building Code.[1]

CASE STUDY 18.2

The Accident: DCA-96-MA-070
Location: Atlantic Ocean at 72:37.46 North Latitude, 40:39.52 West Longitude, near East Moriches, New York
Equipment: Boeing 747-131, N93 119
Operator: Trans World Airlines, Inc.
Date: July 17, 1996
Time: 2031 Eastern Daylight Time (EDT)



FIGURE 18.37 TWA 800.

SUMMARY

On July 17, 1996, at 2031 EDT a Boeing 747-131, registration number N93 119, operated by Trans World Airlines, Inc. (TWA) as TWA Flight 800 was en route from John F. Kennedy International Airport (JFK), New York, New York, to Charles De Gaulle International Airport, Paris, France. Shortly after departure from JFK and while climbing near the southern coast of Long Island, New York, the aircraft exploded and broke up in flight and crashed into the Atlantic Ocean near East Moriches, New York. Flight 800 was a scheduled air carrier flight, operated and conducted under Title 14, Code of Federal Regulations (CFR), Part 121. Visual meteorological conditions prevailed at the time, and an instrument flight rules (IFR) plan had been filed. The 18 crew members and 212 passengers aboard Flight 800 were fatally injured and the airplane was destroyed.[2]

DETAILS OF THE INVESTIGATION

Victim Recovery, Examination, and Identification

The remains of all 230 victims aboard the airplane were recovered and identified. The remains were recovered at sea and brought to a temporary morgue at the Coast Guard station at East Moriches, New York. The first 99 bodies were found floating on the surface of the ocean and were recovered by various civilian, military, and police vessels during the night of July 17, 1996, and throughout the day of July 18, 1996. The majority of the remaining victims were recovered by U.S. Navy divers and local police divers during the next 96 days. Contract trawling operations were subsequently utilized for the recovery of additional wreckage and remains until April 30, 1997. The last remains that were identified were recovered by a fishing trawler on May 22, 1997.



FIGURE 18.38 Academy sign.



FIGURE 18.39 Seating.



FIGURE 18.40 Seating, second photograph.



FIGURE 18.41 Belly.

The outline, Mass Casualty Incident in this chapter, (see Chapter 20 and other resources for more detailed information). The seats were recovered, examined, and photographed. The victims were photographed for injuries and burns, etc., after recovery. The location of each victim was carefully documented and was cross-checked against the seating assignment. The pattern of the explosion, break up, and eventual crash as documented by the damages to the seats, location of recovery, and injuries to the victims established the series of events of the accident.

The accident was attributed to the explosion of fumes collected in the nearly empty center-wing fuel tank as a result of a long wait on the tarmac prior to takeoff. With the engines running on a hot day, the heat from the cabin air-conditioning unit below the tank vaporized the fuel, and a very small discharge from electric wiring in the area was the ignition source. The explosion blew out the skin of the aircraft, causing a catastrophic in-flight separation and crash.

The photographs of the recovered seats and victims pinpointed the origin, direction, and severity of the explosion, and the location of recovery data was used to reconstruct the sequence of events.

A large number of eyewitnesses to the crash stated that they thought they saw a missile come up from the ground, impact the aircraft, and cause the explosion and crash. The wreckage did not support those observations. To properly illustrate the reasons for the crash, the recovered wreckage of the 747 was reconstructed to visually demonstrate the location and deformation to the skin of the aircraft. The reconstruction is now located in the hangar at the NTSB Academy building in Virginia.

CASE STUDY 18.3



FIGURE 18.42 Hurricane Andrew, aftermath image 1.

Hurricane Andrew, a Category 5 storm, made U.S. landfall as the first named storm of the 1992 Atlantic hurricane season. Andrew hit southern Florida around Homestead and southwest Louisiana around Morgan City. Andrew caused $26.5 billion in damages, mostly in south Florida and was the most crippling natural disaster in U.S. history until Hurricane Katrina in 2005.[3]

Andrew recorded average winds of 142 mph with a peak gust of 177 mph. The storm destroyed most of the Homestead area. The storm damaged or destroyed every building in its path. In Dade County 90% of homes had major roof damage, and 117,000 had major damage or were totally destroyed.



FIGURE 18.43 Hurricane Andrew aftermath image 2.

Insurance claims in the wake of the storm caused the bankruptcy of 11 insurance companies and seriously strained 30 more. After the closures, nearly 1,000,000 homes were no longer eligible for coverage by any insurance. Homeowners and officials criticized developers and contractors for inadequate building practices and lax building codes. An inquiry after the storm concluded that there were probably some construction flaws in some buildings. The state of Florida had enforced stricter building codes since 1986, but they were either overlooked or ignored.



FIGURE 18.44 Hurricane Andrew aftermath image 3.

The photographic documentation of the damaged residences after the storm was an enormous undertaking. The photographs served multiple purposes:

- Documented the residential damages for a decision about whether the structure was a total loss or could/should be repaired.
- Documented any obvious remaining building code violations so the contractor/builder could be held responsible for some of the damage.

The region was a disaster area. Road signs were primarily nonexistent. The destroyed structures held little clues as to their identification. Government agencies went through and spray-painted addresses on the structures still standing. When hired by an insurance company to assess hundreds of homes in the area, a major part of the project was in finding the structures at all. The police were on the lookout for looters, and proper identification had to be prominently displayed on clothing and vehicles.

Each structure was photographed systematically:

- Identification by address
- All sides of the exterior
- If walls still stood, each room of the interior
- Details within the rooms
- Services (gas, electric, etc.)
- Any obvious building faults

Sorting and archiving the images was also a huge chore. The whole job had a project number. Each structure was a distinct file within the file. Each photograph had a negative number within the structure file, within the project file.

Teamwork and communications kept the same structure from being inspected more than once. Hazmat precautions were unnecessary in general because of the lack of victims.

Thankfully, the death toll was far lower than Katrina and there was no issue of standing water after the storm subsided.

CASE STUDY 18.4[6]

Very similar to accident scene/evidence photography is the documentation of inspections for the purpose of accident prevention and/or insurance claims, studies, research, or future reference.

In this case, the device involved was a large rock-crushing apparatus used by a firm dealing with quarry stone, crushed rock, and concrete. A sealed, pressurized gear chamber transfers energy from a horizontal pinion gear to a vertical shaft. The issue was that pressure and friction sensors indicated abnormalities in the pinion gear rotation, and the firm believed these were due to manufacturing defects and not wear and tear. The pinion gear was new at the time.

The difficult part of the assignment was to physically insert a camera into the chamber. The chamber mechanism was halted, and the chamber depressurized. Close-up photos of the pinion gear teeth were needed for the engineers to determine if wear patterns were indeed abnormal.

Figure 18.46 was taken through the inspection port and exposed with off-camera flash aimed through the port. The images were taken during a walk-though and familiarization/evaluation visit prior to acquisition of the actual assignment. The company required verification that the proposed technique would fulfill their requirements.



FIGURE 18.45 Stone quarry.



FIGURE 18.46 Opening port.

A monopod was used to elevate the camera above the pinion gear and around various other parts of the mechanism, some of which obstructed a direct view of the gear from the inspection port.

The yellow-orange and red-orange liquids and droplets are condensed lubricant. During use, the entire chamber is pressurized with a lubricant mist atmosphere to reduce friction and heat.

The chamber is about 12 feet in diameter. The pinion gear is about 4 feet in diameter and also

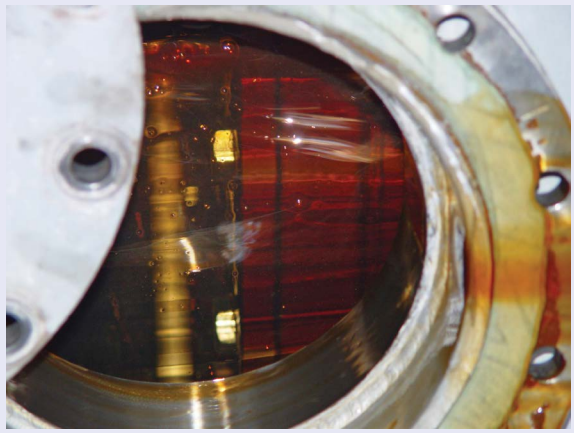


FIGURE 18.47 Through the port.

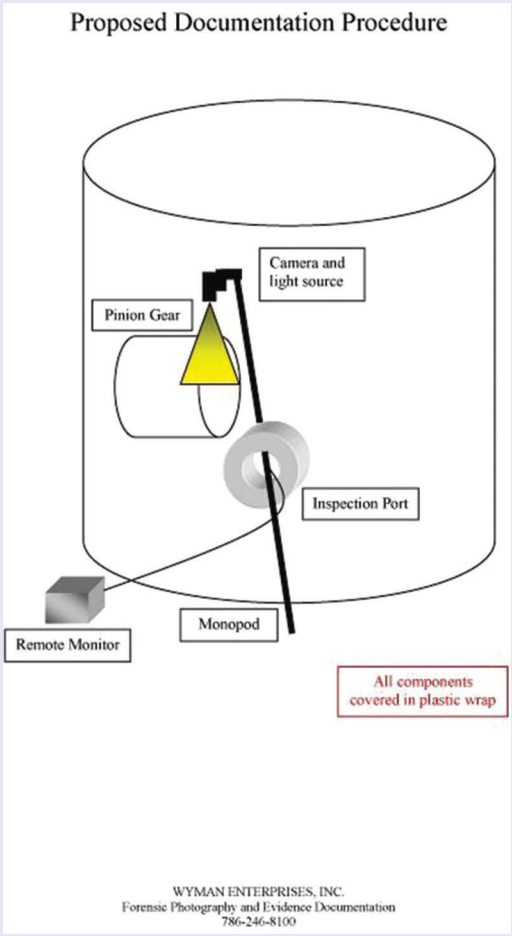


FIGURE 18.48 Apparatus.



FIGURE 18.49 Gear.



FIGURE 18.50 Gear, second photograph.



FIGURE 18.51 Gear close-up.

about 4 feet in length. The inspection port was about 18 inches in diameter.

Inside the chamber, looking down at slight downward angles toward the pinion gear, the camera and flash were mounted to a 10-foot monopod and held, rotated, and angled through the inspection port. The entire camera (except the lens) and the flash (except the output window) and the monopod were covered in Saran Wrap due to the dripping lubricant throughout the chamber. The camera had to be held in a lens-downward attitude to avoid ruining the lens and contaminating the camera with the lubricant dripping down from the ceiling of the chamber.

Since the monopod was fed towards the pinion at an angle from the port, there was little that could be done to "square up" the images along the length or width of the gear. The monopod head was adjusted by sight estimate and then fed into the chamber. Once the Saran Wrap was on the system and the camera was placed, there was no ability to change the mounting angle. The whole system was covered in lubricant from the second it entered the chamber.

Upon finishing the assignment, it took 30 minutes to unwrap the messy Saran Wrap and discard it without contaminating the equipment or the photographer.

The system worked perfectly. There was no damage to the photographic equipment, and the images were used to evaluate the gear.

CONCLUSION

The documentation of incident scenes is another challenging aspect of forensic photography. Criminal incidents, vehicle crashes, and accidents can be as small as a cut finger or as large as an airliner crash or hurricane that devastates an entire region. Each photographic assignment is a matter of telling as much of the incident's story as possible.

The incident will often eventually involve litigation, so accuracy in the courtroom is essential. Proper equipment and training must be available to the photographer before the incident, not after, in order to properly complete the photographic task.

FURTHER READINGS

1. All images for this study were taken and furnished by Mr. Robert Wyman, Wyman Enterprises, Inc., Coral Springs, Florida, and Ms. Kathryn McMillan, Evidence Video Investigations, Daytona Beach, Florida. The 3-D CAD model and the conclusions were also furnished by Mr. Wyman.
2. National Transportation Safety Board, Office of Aviation Safety, Washington, DC, 20594, October 17, 1997, Medical/Forensic Group Chairman's Factual Report of Investigation.
3. http://en.wikipedia.org/wiki/Hurricane_Andrew
4. www.nps.gov/vick/eduguide/chp_7/cwterms.htm
5. en.wikipedia.org/wiki/Casting
6. This case study was submitted by Robert Wyman, Wyman Enterprises.



Taylor & Francis
Taylor & Francis Group
http://taylorandfrancis.com

19 Laser Scanning

Ryan Hacker

CONTENTS

Laser Scanning 388
What Is Light? 389
The Maser: First Step to the Laser 390
Who Took It from Maser to Laser? 390
Several Companies Tried to Build the Laser 390
    Westinghouse Research Laboratories 390
IBM 390
    Bell Labs 391
    Hughes Aircraft Co. Laboratories 391
The First Laser 391
How Does a Laser Work? 391
Laser Uses 391
Technologies 391
Military 392
Professional Uses of Laser Scanning 392
    Laser Scanning and 3-D Modeling 392
    Motion Detectors 393
Point Cloud and Imagery Acquisition 395
    X,Y,Z Points 395
    Color Imagery 396
    Black-and-White Imagery 396
    Leica P-40 Scanstation 397
    3-D Reverse Engineering 397

MESSAGE FROM THE EDITOR

While designing this book, it was necessary to make decisions about everything from who, what, when, and how it was to be done. Some of the most difficult decisions were regarding content. I worked on the outline endlessly, planning the numerical order, adding material here and subtracting there. Three chapters of the many gave me the most food for thought: Surveillance, Videography, and Laser Scanning. It was the same when I was designing the first book. These decisions are not made lightly.

For surveillance, I kept thinking of my dear friend, now deceased, Gene Robertson. He was a retired DEA agent who spent the rest of his years as a private investigator, specializing in surveillance projects. Surveillance is definitely photography based—it is performed for clients who pay good money for the deliverable. Gene spent countless hours in a van watching for his photo ops and then countless hours in court testifying about his work. He taught the subject to everyone from the local police to the FBI and clients overseas. He even made educational videos on the subject that were sold worldwide. If anyone ever said to Gene that surveillance was not a part of forensic photography, I would not want to see his reaction. So, in honor of Gene's memory, the chapter stayed as a prime part of this book's content.

For videography, I kept thinking about my friend Kathryn McMillan. She has made a living for herself and provided the means of making a living for her employees for many years. She performs the work, she teaches the subject, and she is the best forensic videographer I have ever known. The only difference between what she does and what I did is the type of cameras we used. I exposed still photographs of evidence, and she exposes moving ones. Her deliverable is of the same type as the rest of us, and she goes to court and testifies regarding what she has done.

I do not think it would be possible to argue Kathryn out of the fact that what she does should be called forensic photography as well as videography.

That brings us to laser scanning. Of the three subjects, this one is the least mainstream as a branch of forensic photography.

Or is it?

The work is often requested by clients trying to reconstruct an accident or a crime by seeking forensic imaging. There are also architectural aspects of the work, inspection for the auditing of conditions, research and development, design, reverse engineering, medical, forensic anthropology and archaeology, and applications we have not even begun to imagine. The deliverable is essentially the same as the rest of the field of forensic photography, and the competent laser scanning company will have people ready to testify regarding the work products of their efforts. So, what is the major difference between photography and laser scanning? One uses a camera and one uses a scanner. This is reminiscent of the differences between videography and photography. Should the difference in hardware disqualify laser scanning from its rightful place in this book? I truly do not think so. In fact, I think laser scanning is the future of forensic photography. I think hardware is going to continue becoming smaller and less expensive. I see no reason not to believe, in a few years from now, the process will be something people may do with attachments for cellular phones.

So, all three of the chapters stayed as parts of this book about forensic photography for the preservation of evidence. —*SW*

LASER SCANNING

By definition, photography is the process of producing an image from radiant energy, most often light from the visible spectrum, transmitted or reflected, onto a light-sensitive receptor like a digital sensor. Photography was first used as a means of capturing images on sensitive material in 1839.

Radiant energy is the energy of electromagnetic waves. The intensity and degree of these waves are what may describe the brightness of lighting. Electromagnetic waves as a term is also used in the field of telecommunications. Radiometry is the branch of science dealing with the detection and measurement of radiant electromagnetic energy.

An electromagnetic wave is a wave that exists and travels due to the power of electric and magnetic fields. In other words, a wave propagated either through space or matter by oscillating electric and magnetic fields. In a vacuum, the wave travels at the speed of light.

The electromagnetic spectrum is the full range of frequencies of electromagnetic radiation and their respective wavelengths and light energies (Figure 19.1).

Electromagnetic radiation is all the various types of radiation, in which electric and magnetic fields vary simultaneously within portions of the electromagnetic spectrum. The word light usually implies visible light, which is a part or possibly all of the visible spectrum at various times.

The full electromagnetic spectrum is a range of electromagnetic waves with frequencies from below 1 Hz (1 Hz is equivalent to the frequency of once per second) to above 1025 Hz. That frequency range includes wavelengths from greater than 10^3 kilometers to less than the size of atoms.

The hertz is a unit of time for measuring frequency. The range of frequencies is divided into separate bands, and the electromagnetic waves within each frequency band are called by different names; beginning at the high frequency, or short wavelength end of the spectrum, are:

The shortest wavelengths have the highest frequency!

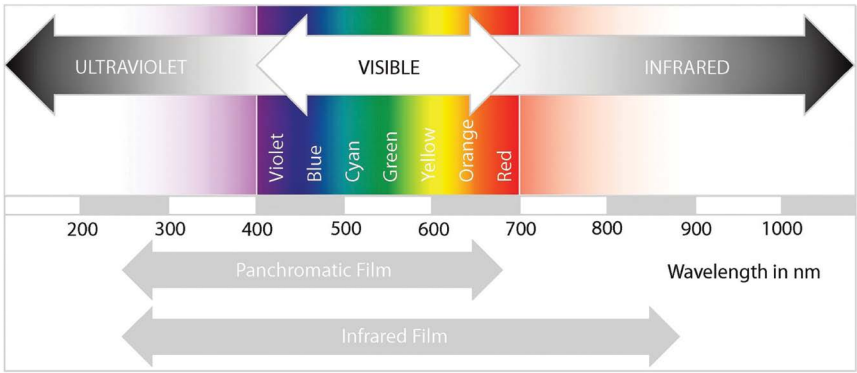


FIGURE 19.1 Electromagnetic spectrum.

(From Sandy Weiss.)

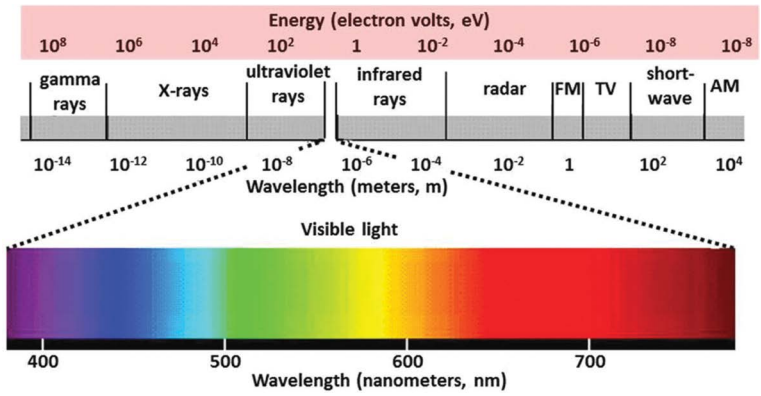


FIGURE 19.2 Visible light spectrum.

(From Sandy Weiss.)

Gamma rays – Gamma rays have the shortest wavelengths, $<10^{-2}$ nanometers (about the size of an atomic nucleus). This is the highest-frequency region of the electromagnetic spectrum.

X-rays – Wavelengths in the range of 0.01 to 10 nanometers, corresponding to frequencies in the range from 30 petahertz to 30 exahertz (3×10^{16} Hz to 3×10^{19} Hz).

Ultraviolet – Has frequencies of about 8×10^{14} to 3×10^{16} Hz and wavelengths of about 100 to 400 nanometers (1.5×10^{-5} inches) to about 10 nm (4×10^{-7} inches).

Visible light – The normal, healthy, young human eye is able to see wavelengths from about 380 to 740 nanometers (Figure 19.2).

Infrared – Range from approximately 300 GHz. The gigahertz is also a unit for the measurement of alternating current (AC) or electromagnetic (EM) wave frequencies equal to 1,000,000,000 Hz to 30 THz (terahertz—1 mm to 750 nm [one nanometer = one billionth of a meter]) (1 mm to 10 µm—the Greek letter µ for micro is a unit prefix in the metric system for a factor of 10^{-6} (one millionth) to 400 THz.

Far-infrared – From 300 GHz.

Microwaves – Wavelengths in the range of approximately 30 cm (= 1 GHz) to 1 mm ($= 3 \times 10^2$ GHz).

Radio waves – Frequencies from 300 GHz (1 mm) to as low as 3 kHz (100 km).

The electromagnetic waves in each band have different characteristics, including how they are produced, how they interact with matter, and their various uses. Gamma rays, x-rays, and high ultraviolet rays are dangerous and are called ionizing radiation because their photons have enough energy to ionize some atoms, causing chemical reactions. Exposure to these rays may be a health hazard to animals and humans, causing problems including radiation sickness, DNA damage, and possibly even cancer. Radiation from the wavelengths of visible light and lower are nonionizing and are not normally a health hazard.

Spectroscopy is used to study the interactions of electromagnetic waves with matter. In most of the frequency bands, spectroscopy can be used to physically separate waves of different frequencies, producing a partial and possibly unique spectrum showing the constituent frequencies.

WHAT IS LIGHT?

In ancient Egypt, people worshipped the sun. They believed the sun was the god of light and life to everything in the universe. Due to the climate, the sun almost always shone there. The sun was an unblinking, all-seeing eye. There was a strong and eternal connection of light with enlightenment, meaning the sun was the source of wisdom. The sun's rays had special powers then in a far different way than they do now.

Interest in the various types of radiation increased markedly around the start of the 20th century, with the discovery of radio waves, x-rays, and radioactivity. Scientists discovered light waves were the same type of electromagnetic waves as radio waves, just with shorter wavelengths. A whole new spectrum of radiation opened for study, having electromagnetic waves with wavelengths longer and/or shorter than visible light. Research into these types of radiation could possibly develop new uses in medicine, communications, scientific research, and possibly even warfare.

The use for radio was found quite quickly, but the same techniques did not work with radiation of shorter wavelengths. A method for amplifying light was theorized by Einstein in 1916. He said: "Rays can stimulate atoms to emit more rays of the same wavelength." But the engineers of the day had little idea how to manipulate atoms, and for many years the theory lay dormant.

Scientists and engineers worked on the problem and eventually discovered some ways to make radio techniques work with shorter wavelengths. In the 1930s they attempted to create a "death ray" for use on the battlefield and to aim at aircraft in flight. That did not work out, but

the experience led to something better: radar. By 1940, a new blockbuster invention, a device made in America, could generate rays with wavelengths of a centimeter or less (the cavity magnetron). These parts were used in radar to detect enemy aircraft and helped greatly to win the Battle of Britain. Scientists say radar won the war and the atomic bomb ended it.

A spectrum chart shows the various forms of electromagnetic radiation. The only difference between one ray and another is the length of its wave. The spectrum is designed to show the wavelength is reduced by a large factor at each major division. Thus, visible light rays are approximately $1/10^5$ the length of the "microwave" rays commonly used for radar. Rays with shorter wavelengths can carry more information and more energy.

As the Cold War against the Soviet Union started, the U.S. government put more money into basic and applied research. With the possibility of applications for the military/industrial complex, corporations and entrepreneurs threw more money onto the table. The Soviet Union launched the first satellite in 1957, so the U.S. government increased its funding for research again. Industrial and university laboratories sprouted like weeds around the country. From this fertile development, **the laser was invented**.

THE MASER: FIRST STEP TO THE LASER

In the 1930s, scientists could have built a laser. They had the optical techniques and the theoretical knowledge, but nobody put the two ideas together. Scientists showed in 1947 that sending a bolt of electricity through a gas could put a set of atoms in a special "excited" state, which could yield the result Einstein predicted: the "stimulated emission" of radiation. Scientists at Columbia Radiation Laboratory developed a new understanding of quantum electrodynamics. However, they did not work at amplifying the bolt of electric radiation.

The breakthrough happened around 1950. Short-wavelength radio waves, called microwaves, could make a cluster of atoms vibrate in interesting ways. Leftover radar equipment from World War II was redesigned and utilized to provide the necessary radiation. Some of the world's top physicists worked on new methods to study systems of molecules by striking them with radiation.

Under the right conditions, inside a resonating cavity magnetron, like the one used to generate radar waves, the right collection of molecules might generate radiation all on its own. By 1954 a working device was made. It was called a MASER, an acronym for microwave amplification by stimulated emission of radiation. A meaningful and useful property was predicted for the resultant radiation from the device. It would be at a single frequency. The high degree of order in such radiation would give the maser, and later the **laser**, important practical uses.

WHO TOOK IT FROM MASER TO LASER?

Physicists worked diligently at finding methods for utilizing and controlling shorter wavelengths. After radio waves, measured in meters, and radar waves measured in centimeters, the next logical step would be going down to the far-infrared waves. Masers had been somewhat useful for scientific research. Only a few scientists thought an infrared maser might be important and pondered how to make one. Infrared rays could not be manipulated like radar rays, and indeed were difficult to manage at all. In 1957, from the equations for amplifying radiation, it was theorized that it might be easier to use very short waves than far-infrared waves. They jumped across the far-infrared region altogether and decided to use techniques known for manipulating ordinary light.

The key was to put the atoms to stimulate in a long, narrow cavity with mirrors at each end. The rays would then move back and forth inside, and there would be more chances for the stimulated atoms to radiate. One of the mirrors would be only partly silvered so some of the rays could leak out. This arrangement had been used for decades of research.

A graduate student at Columbia University speculated about all the things that could be done with a concentrated beam of light. He named the not-yet-invented device a laser, for light amplification by stimulated emission of radiation.

Some of the ideas about energizing atoms to higher states to emit light, and thus how to build a laser, were already available. Physicists worked out ideas for pumping energy into atoms and molecules in gases and solid crystals.

SEVERAL COMPANIES TRIED TO BUILD THE LASER

Westinghouse Research Laboratories

Masers were made from crystals of synthetic ruby. Westinghouse thought a crystal might be stimulated to emit visible light. They tried pumping energy into a ruby, using a tungsten lamp. The system was inefficient, and they could not get enough energy into the atoms to make a laser.

IBM

At IBM it was realized that mirrors were not needed if crystal with the right properties was used. Calcium fluoride crystals were polished into squares. A ray striking an edge at a 45-degree angle would be reflected towards the next edge and continue to go around and around the inside. By including uranium atoms inside the crystal, it could act like a gas in a cavity. But they could not develop the amplification of light to make a laser.

Bell Labs

Bell Labs had the necessary rubies for maser research, but some of their people preferred the medium of a gas. They settled for a combination of helium and neon in a long glass tube. An electric discharge through the gas should energize the helium, and collisions could transfer the energy to the neon. They still could not achieve laser action.

Hughes Aircraft Co. Laboratories

Hughes Aircraft was first started by Howard Hughes, the man who was very controversial in his day. He was perhaps an eccentric genius, but his eccentricity was overpowering to the contemporary public.

At the beginning of World War II his company had only four full-time employees, but by the end of the war had 80,000. Hughes Aircraft was one of many aerospace and defense companies to flourish in Southern California during and after World War II. American physicist Richard Feynman is best known for his work in quantum mechanics and particle physics. While working on his PhD from Princeton, he was part of the Manhattan Project and helped in the development of the atomic bomb. He was also one of the people who participated in the development of Hughes Aircraft.

During the war, the company built struts for B-25 bombers, centrifugal cannons, and machine gun feed chutes. The company is currently co-owned by General Motors Corporation and Boeing Aerospace. Workers at Boeing built passenger planes, helicopters, fighter planes and missiles, satellites and spacecraft. They sent astronauts to the moon and the International Space Station. Their inventions were key for today's new technologies.

THE FIRST LASER

Theodore Maiman made calculations and measurements convincing him it was possible to get enough energy into a ruby. But he would need a very bright light energy source. Maiman believed the source did not have to shine continuously. He decided to try using a flash lamp. He bought a very bright and powerful electronic flash with a helical-shaped glass flash element into which it was possible to insert a ruby. He assembled the components and on May 16, 1960, observed pulses of red light. It was the world's first laser.

The ruby crystal (aluminum oxide with traces of chromium) used had both ends silvered. When the atoms lost their energy, if one ray moved along the crystal axis, it would bounce back and forth between the mirrors and possibly stimulate other atoms to emit more rays. One end was only partly silvered to let some of the rays escape.

Meanwhile, back at Bell Labs, they continued on their original path, and in December of the same year produced a continuous beam of infrared rays: the first gas laser. By the end of 1960 three different types of lasers of different designs were working.

HOW DOES A LASER WORK?

Light travels in waves, and the distance between the peaks of a wave is called the wavelength.

Each color of light has a different wavelength. For example, blue light has a shorter wavelength than red light. Sunlight—and the typical light from a lightbulb—is composed of light with many different wavelengths. When all the different wavelengths (colors) come together, our eyes see the mixture as white light.

Lasers are different. Lasers do not occur in nature. Lasers are narrow beams of light where all the light waves have similar wavelengths. The laser's light waves travel together with their peaks lined up, or in phase. This is why laser beams are very narrow, very bright, and can be focused onto a very tiny spot.

Because laser light stays focused and does not spread, laser beams can travel long distances. They can also concentrate a lot of energy onto a very small area. This is called coherent light, or a beam of photons all having the same frequency. A laser produces coherent light by stimulated emission. Laser light occurs as the result of spontaneous emission of a photon by an electron undergoing a transition in an atom.

LASER USES

Lasers have many uses. They are used in precision tools for cutting materials like hard metal and even diamonds. Remember the famous scene in the 1964 film, *Goldfinger*, where the villain puts James Bond (Sean Connery) on a slab of gold with a laser beam crawling ominously up between James's legs? The beams can also be used in delicate operations like LASIK eye surgery. Lasers are used for recording and retrieving information. They are used in communications and in carrying TV and Internet signals, in laser printers, barcode scanners, and DVD players. They also help to make parts for computers and other electronics. In manufacturing, lasers are used for cutting, engraving, drilling, and marking a broad range of materials. Lasers are also used in spectrometers to help scientists and engineers determine the composition of materials.

There are many different types of lasers. The laser medium can be a solid, gas, liquid, or semiconductor. Lasers are commonly designated by the type of lasing material employed: solid-state lasers have lasing material distributed in a solid matrix, like a ruby.

TECHNOLOGIES

Time of flight – This measures the time taken for a light pulse to travel to a target and back. The speed of light is a known constant: include an accurate measurement of the time taken, and the distance

can be calculated. Many pulses are fired sequentially, and the average response is most commonly used. This technique requires very accurate sub-nanosecond timing capabilities.

Multiple frequency phase shift – This measures the phase shift of multiple frequencies on reflection from a surface, then solves simultaneous equations to give a final distance measurement. Phase shift is how far the wave amplitude is shifted horizontally from its usual position. Vertical shift is how far the wave amplitude is shifted vertically above its usual position. The easiest way to determine horizontal shift is to determine by how many units the "starting point" (0,0) of a standard sine curve, y = sin(x), has moved to the right or left, and vertical shift is computed the same way.

Interferometry – This is the most accurate and most useful technique for measuring changes in distance rather than absolute distances. Systems can measure absolute distances of up to 300 mm with an uncertainty of one micro-meter (1×10^{-6} meter), within a timeframe of 40 seconds. The system uses a Michelson interferometer (a beam-splitter), a tunable laser, a wavelength meter, and a computer for performing its analysis. Many developments in tunable laser technology have been made over the last 10 years. Widely applied tunable laser sources include biomedical applications of fiber lasers and ultrashort pulsed lasers, as well as laser isotope separation and cancer photodynamic therapy.

One of the many applications for laser technology includes laser range finding (RF).

MILITARY

Rangefinders provide an excellent approximation of the distance to targets for various weapons, including sniper rifles and artillery. Handheld military rangefinders operate through ranges of about 2 km to 25 km and are often combined with binoculars and/or monoculars. When the rangefinder is equipped with a digital magnetic compass and an inclinometer, it is capable of providing magnetic azimuth, inclination, and height or length of targets. Some rangefinders can also measure a target's speed of motion relative to the observer. Some rangefinders have wireless interfaces to transfer their measurement data to other military equipment, including fire control computers. Some models also have night vision technology and thermal imaging capabilities.

These devices are now available to most any country, so our armed forces need to cover many military targets, including aircraft, with laser-absorbing paint and/or coatings to make laser rangefinders and laser-guided weapons less useful and less deadly against them. Radiation-absorbent material (RAM) is a specially designed material shaped to absorb incident range-finding radiation from as many different incident directions as possible. The more effective the RAM, the lower the resulting level of reflected range-finding radiation. Stealth technology, sometimes called low observable technology (LO technology), is a discipline of military tactics, of passive or active electronic countermeasures, used with personnel, aircraft, surface ships, submarines, missiles, satellites, and some ground vehicles to make them less visible to radar, infrared, sonar, and other detection methods. It is actually military camouflage (multispectral camouflage) within the utilized parts of the electromagnetic spectrum.

PROFESSIONAL USES OF LASER SCANNING

Laser Scanning and 3-D Modeling

Laser scanning as a technology began in the 1960s. The laser in a scanner generates a beam of intense coherent monochromatic light by the stimulated emission of photons from excited atoms or molecules. LiDAR (light detection and ranging) is a surveying method for measuring distance to a target by illuminating targets with pulsed laser light and measuring the reflected light pulses coming back to the scanner. A LiDAR scanner may be used to scan buildings, rock formations, factories, facilities, cities, etc., to produce 3-D computer models. LiDAR can aim its laser beam in a wide range—its head rotates horizontally and a mirror flips vertically for sending light. The laser beam is used to measure the distance to the first object in its path.

In the last 10 years, leaps and bounds is the only way to describe the progress made in the technology of laser scanning. Scanners are now faster, smaller, provide more information in the same time, and produce full 360-degree scans in a minute or so. For example, Leica Manufacturing produces great, top-of-the-line scanning systems and software. Newer computers are also faster at processing vast quantities of data. Newly designed software handles detailed point clouds and ties all the scans together into a seamless view. Autodesk also manufactures software, and laser scanning is now most of their business.

In the 1990s, the practice began to be useful for engineering applications, as well as military and scientific uses. Cyra Technologies was founded in 1993 and produced one of the first scanners used by surveyors and engineers. Then in 2001, Cyra was purchased by Leica Geosystems, the company that is still the industry leader in 3-D laser scanning software and hardware.

If anyone wants to get into the business of laser scanning today, they will find the equipment a bit expensive. Leica markets their scanners at about $250,000, and then you still need to add peripherals like software. Other manufacturers, like Faro, make lower-end, long-range scanners that cost about $30,000 to $40,000. Faro also makes Faro Arms, etc., which are short-range scanners with a high level of accuracy (for reverse engineering and other short-range scanner applications).

Law enforcement in some jurisdictions are able to purchase equipment with grant money. It is an interesting concept for them to feel it sufficiently important to spend a total like that on one aspect of their hardware and software budget. For law enforcement, there is special forensic software for reconstruction of crimes and accidents. It reconstructs the trajectories of bullets and vehicles, etc.

Training is always with the manufacturer after purchase. They hold seminars in centralized locations at certain times of year to hopefully enable all operators to take advantage.

Leica Geosystems LiDAR sensors are used for architecture, engineering, and construction (AEC) and any other conceivable use people want to attempt. Airborne topographic LiDAR sensors are used for area mapping of large regions or small landforms.

Laser rangefinders are used for 3-D object recognition, 3-D object modelling, and many computer vision–related fields. This technology is used for time-of-flight 3-D scanners. In contrast to the military instruments described earlier, laser rangefinders offer high-precision scanning abilities, with either single-face or 360-degree scanning modes.

A number of algorithms have been developed to merge the range data retrieved from multiple angles of a single object to produce complete 3-D models with little error. One of the advantages laser rangefinders offer over stereoscopic methods of computer vision is the computer does not need to correlate features from two images to determine depth information.

Laser rangefinders used in computer vision applications often have depth resolutions of tenths of millimeters or less. This can be achieved by using triangulation or refraction measurement techniques as opposed to the time-of-flight techniques used in LIDAR.

A laser rangefinder uses a laser beam to determine the distance to an object. The most common form of laser rangefinder operates on the time-of-flight principle by sending a laser pulse in a narrow beam towards the object and measuring the time taken by the pulse to be reflected off the target and returned to the sender. Due to the high speed of light, this technique is not appropriate for high-precision sub-millimeter measurements, where triangulation and other techniques are often used.

Leica terrestrial LiDAR scanners (TLS) may be used to scan buildings, rock formations, etc., to produce 3-D models. The TLS can aim its laser beam in a wide range: its head rotates horizontally and a mirror flips vertically. The laser beam is used to measure the distance to the first object in its path (Figure 19.3).

Laser scanning could not advance until bandwidth and memory increased and became more economical. Even now, scan data (point clouds) are typically delivered on external hard drives or thumb drives because the files are too large to email or even utilize File Transfer Protocol (FTP).

Laser scanning started out much the same as global positioning system (GPS). In the early days of GPS, only military personnel, surveyors, pilots, and boaters ever heard of GPS. Now GPS is incorporated into millions of devices, including our computers, cars, boats, aircraft, and cellular phones. Today, surveyors, engineers, architects, and even law enforcement use 3-D laser scanning, and its popularity is ever widening.

A new Leica laser scanner is able to capture 2 million measurements per second with a 10-lb machine. Ten years ago, a scanner weighed about 80 lb and took at least two men to get it onto a tripod. Most scanners have a built-in camera, and it ties the point cloud together with a still image.

It is possible to scan objects as well as areas. Any three-dimensional solid object is possible to scan, from something as large as a petrochemical refining facility to the lobe of someone's ear. A handheld scanner is used for scanning small objects like faces and skeletons. They are a short-range, 5- to 6-lb machine with two lenses. Some require the application of reference targets to the object being scanned. They usually cost between $15,000 and $65,000. They provide both a point cloud and a mesh. The better the scanner, the finer the mesh, and the more resolution (Figure 19.4).

Motion Detectors

A motion detector is a device for detecting moving objects, particularly people. Such a device is often integrated as a component of a system to automatically perform a task or alert a user of motion in an area. Motion-sensing capability is a critical aspect in the gaming industry, with systems like Wii and Kinect. "Xbox Kinect" is a form of laser scanning. The game scans the players in real time, recording their size, shape, and movements, and from this information creates a virtual reality. One of the exciting key aspects of Kinect is its promotion of the natural user interface (NUI) paradigm, which in many ways is the successor to the traditional graphical user interface (GUI) and command-line interface (CLI) paradigms for human–computer interaction. Microsoft's approach to Kinect is highly focused on the utilization and modernization of NUI, and there is a vision for Kinect going far beyond gaming. Microsoft recently stated that the "computing interface is evolving from something we drive personally to something that's more like us." The search continues for applications for NUI, while Kinect and its capabilities show where motion-sensing technology may be headed in the next decade.

Leica CloudWorx CAD plugins allow users to work with the resultant large point clouds directly inside their chosen computer-assisted design (CAD) system. They can use existing CAD tools and commands and the entire set of specialized point cloud commands provided by CloudWorx.

CloudWorx adds simple tools for viewing and working with slices of point cloud data to:

- Increase the rapidity of 2-D drawing creation
- 3-D object and object surface modeling
- Increase the accuracy of as-built modeling in architecture



FIGURES 19.3 Leica P-40 Scanner used to map an industrial site.

(From Ryan Hacker.)



FIGURES 19.4 Leica P-40 scanner capturing rebar, post-tension cabling and sleeves prior to pouring concrete slab.

(From Ryan Hacker.)



FIGURE 19.5 Colorized point cloud (raw scan data) of edge of slab after pour to verify it was poured to the design-intent specifications.

(From Ryan Hacker.)

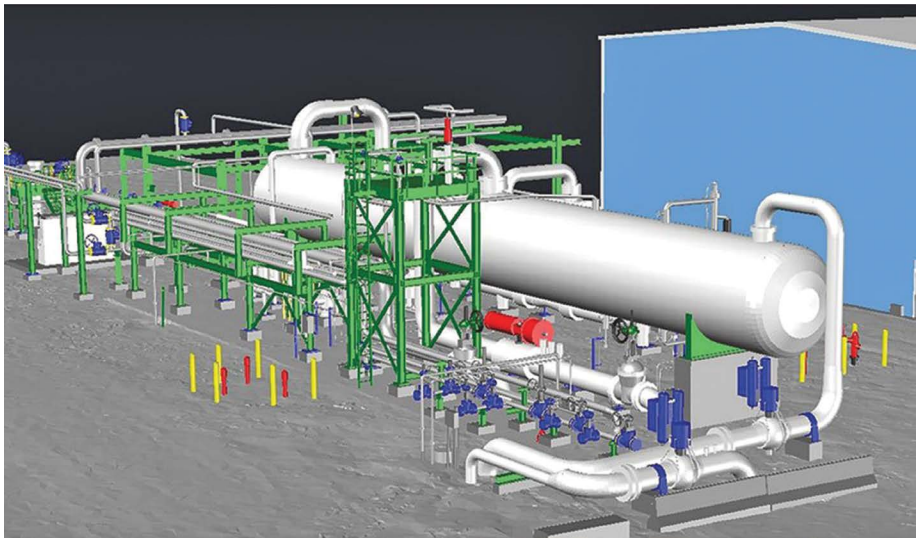


FIGURE 19.6 3-D solids model of an industrial site created from point cloud data created from a 3-D laser scanner.

(From Ryan Hacker.)

The end product of 3-D scanning is the deliverable. The point cloud looks great in its native scanning software; however, upon delivery to clients, it is mostly unreadable because of its huge file size.

A typical point cloud can be anywhere from 10 GB to terabytes in size, making most CAD programs completely inoperable. The deliverable must be moved on external hard drives. The real power of scanning is when you can utilize the point cloud and the as-built model derived from the point cloud in whatever software system is needed (Figures 19.5 and 19.6).

The benefit of being able to visualize both the point cloud and the as-built model is to maximize the ability to conduct proper and accurate clash detection: the effective identification, inspection, and reporting of interferences in a 3-D project model.

POINT CLOUD AND IMAGERY ACQUISITION

X,Y,Z Points

The most widely known products of laser scanning are the X,Y,Z points of the target, also known as the point cloud. The X,Y,Z coordinates are the mathematical three-dimensional coordinate system, where X and Y define the depth and width of the horizontal plane and Z defines the height of the vertical plane. The problem with point clouds is, until very recently, user-friendly software did not exist to utilize the point cloud data. This data was far too large to import into standard CAD programs. Recently that has changed, but large clouds are still unusable to many clients.

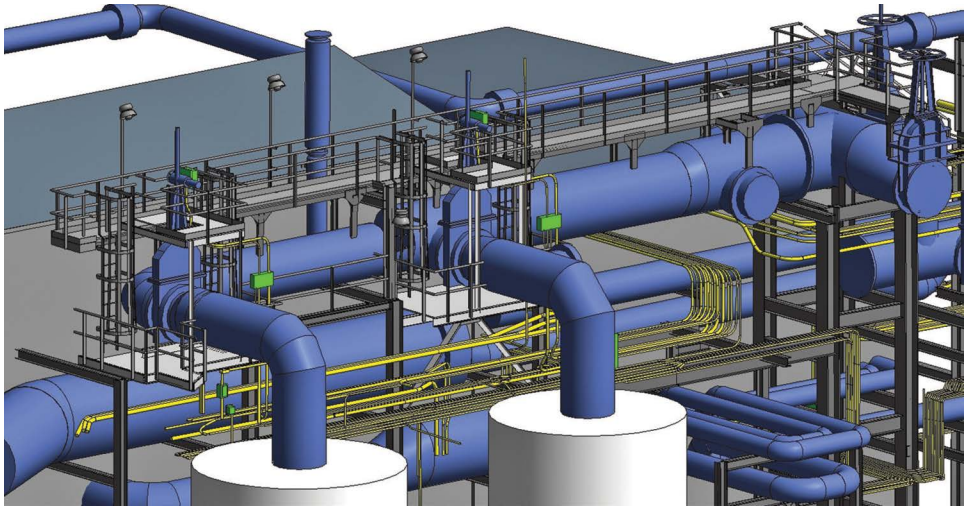


FIGURE 19.7 Using a 3-D laser scanner to capture up to 2,000,000 measurements per second, this 3-D model was created from the raw scan data (point cloud) produced by the laser scanner.

(From Ryan Hacker.)

Color Imagery

The by-product of many of today's laser scanners is 360-degree high-definition imagery (Figure 19.7). The imagery can essentially be fit onto the point cloud like a coating to bring color onto it. The best use of this imagery is for the benefit of the client, allowing them to relate the point cloud or model to the real world. The client can view the imagery and compare it to the point cloud and model in real time, looking for clarification of the point cloud or model. The high-definition imagery also captures the site in a moment of time. A client can go back to the cloud and imagery years after the fact to see the conditions at the time of the scan. The only downside to the color imagery is it takes two to three minutes per scan.

Black-and-White Imagery

Black-and-white imagery is an alternative to color imagery when time is short. There is no additional time required for black-and-white imagery, and it shows the same level of detail, without the color (Figure 19.8).

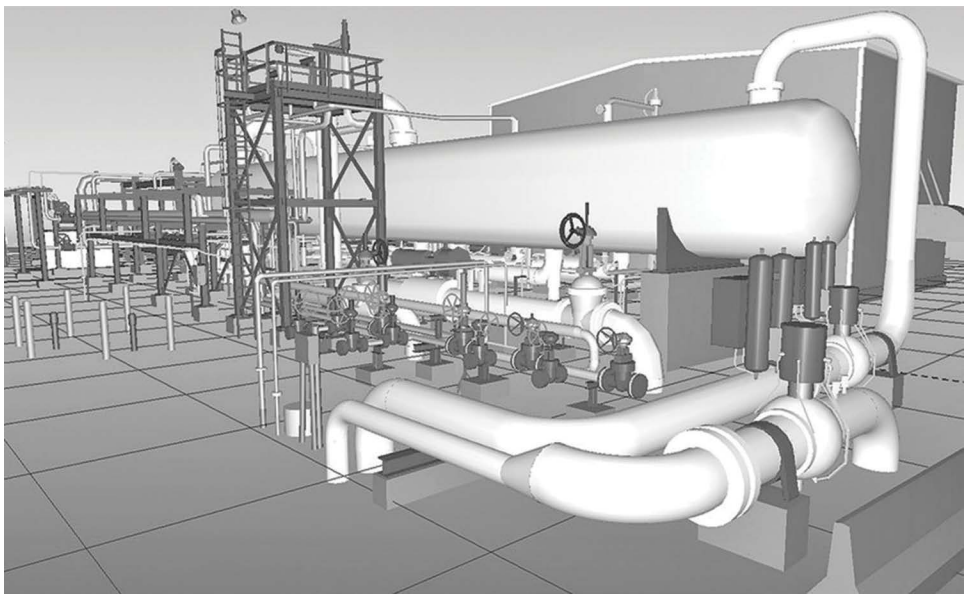


FIGURE 19.8 A black-and-white version of the Figure 19.7 project.



FIGURE 19.9 A Leica terrestrial-based laser scanner (TLS) capturing the as-built conditions of a demolished interior space prior to construction completion.

(From Ryan Hacker.)

Leica P-40 Scanstation

The Leica Scanstation is the 2019 version of a "time of flight" scanner for long-range point cloud acquisition, utilized on projects where data needs to be acquired from a distance of over 250 feet (Figure 19.9). It acquires point data at approximately 1,000,000 points per second at a range up to approximately 1000 feet. The new Leica RTC 360 captures 2,000,000 points per second. Typical uses include large buildings, bridges, towers, or in general, structures where the scanner cannot occupy a location close to the structure. One problem with scanning from 1000 feet is the scanner's perspective becomes very narrow.

Some new scanners can be lowered into a manhole. It is just necessary to have line of sight, not visible light. The scanner can be used on top of buildings, etc., as long as there is not any movement. A dual-axis compensator monitors the scan in real time, and if there is any movement in the scanner, within reason, it will adjust the cloud.

It is possible to do floor flatness and floor levelness investigations with a survey-grade scanner like the Leica RTC 360.

3-D Reverse Engineering

Reverse engineering is a term used for design and engineering applications. If there is a part existing today without CAD drawings, a laser scanner is able to capture the part in 3-D and create a new and relatively exact copy of the part, except if it has multiple pieces. The scanner cannot see into the interior of anything.

Uses for the technology are:

- Product design and manufacturing
- Part repair and re-manufacturing
- Documentation and archiving
- Product redesign
- Defect/deterioration documentation

What about the weather? The scanner is water resistant, but some people will not work in the rain or snow because the scanner will pick up the snowflakes or raindrops in the scan data, causing excessive extraneous noise in the scan.

There have been no issues to date with the admissibility of laser scanner product. But the client is always to maintain chain of custody, etc. It is always necessary to have NIST-certified targets, and the equipment is NIST certified.

There are standards and best practices for laser scanning, but they are kept and used by each individual client. There is a society, but there are no recognized industry standards or forensic associations.



Taylor & Francis
Taylor & Francis Group
http://taylorandfrancis.com

20 Large Scene Investigation

John L. Larsen

CONTENT

Conclusion 404

This chapter outlines and provides a set of guidelines to enable the photographer of a mass disaster scene to successfully generate quality photographs and documentation.

When initially confronted with a mass disaster scene, the photographer should expect to be overwhelmed with the depth and scope of the project. I have found through experience to approach these scenes as if working a single homicide. The photographic procedures do not change. When possible, everything within and surrounding the scene is photographed in place before anything is disturbed. There are instances where search and recovery operations will affect and disturb structures in attempts to recover survivors and remains of victims within the area. The movement of evidentiary items (exhibits) before they are photographed needs to be memorialized at least in written format. These areas need to be documented as soon as possible via still photography and/or video.

Aerial photographs of the scene should be taken as soon as possible. Aerial photographs provide an overview of the scene and allow investigators to make determinations regarding establishing zones of operations, required specialized equipment, decontamination area(s), staging, food service, and rest areas and to provide realistic ingress and egress avenues to conduct the search operations. See Day 1 of search aerial photo in Figure 20.1.

The platform for this aerial photograph was a Pennsylvania State Police helicopter. The FBI evidence response team (ERT) photographer used a Nikon N90 with a 28-106 mm AF Nikkor lens, ISO 400 color film, set on shutter speed priority with the focus set on infinity (∞). Shutter priority is used because a very fast shutter speed, like 1/1000 of a second, is necessary to overcome the vibration of the aircraft. If the camera was set on auto or program, the images might all be fuzzy because of camera shake, which may not be apparent to the photographer at the time. If a manned aircraft is not on-site, images captured from a drone will do nicely.

The examples I utilize throughout this chapter come from the September 11, 2001, United Airlines Flight 93 crash site at Shanksville, Pennsylvania. When being assigned to such a scene the photographer should understand the scene will take between two and three weeks to process. The photographer will be part of an ERT. As part of a team the photographer will work with a photographic log keeper. In turn the photo team will be assigned to a search team to provide photo documentation of a specific search area. As with the United Flight 93 site, there are numerous photographic teams. The photo teams were assigned specific search sites, as well as special photographic assignments, that is, aerial photograph (which was carried out at scheduled times twice a day) and public relations photographs to be disseminated to the news media and governmental agencies daily (i.e., Justice Department, White House, etc.).

The skill sets for the photo units to be used cover a wide range of photographic disciplines from basic crime scene photography to advanced photography dealing with aerial, infrared (IR), reflective ultraviolet imaging system (RUVIS), and alternate light source (ALS).

A photographer who believes all is needed is a digital camera and the willingness to go into harm's way will be ill-prepared to work the scene. Preparation is a key factor in successful documentation.

Preparation is built on having:

1. **Personal safety equipment**
   a. Safety boots with steel soles and toes (i.e., Caterpillar construction boots)
   b. Hooded Tyvek; breather and mask(s) (i.e. HEPA filter, dust filter vapor filter, etc.)
   c. Construction-grade helmet (mountaineering helmets with chin strap are best suited for this type of operation)
   d. Safety gloves
   e. Knee pads

All this personal safety gear should be stored in watertight containers (i.e., Pelican Cases).

2. **Camera and kit**
   a. Digital camera
   b. Various lenses to include: 60 mm macro lens, 35 to 70 mm zoom lens, and 28 to 106 mm zoom lens
   c. Tripod with adjustable head
   d. Independent flash unit with external battery pack
   e. Lens filters (i.e., UV optical filter, polarizing filter, etc.)

(These are the pieces of equipment I prefer. Other kits are fine too if preferred by the individual and appropriate for



FIGURE 20.1 Day 1 United 93 crash site aerial view.

(From J.L. Larsen.)

the project.) The photographer should be comfortable with their camera and supportive equipment.

3. **Photographic protocol and/or guidelines for scene conduct:** As a photographer, I consider this preparation step critical. Its makeup provides the foundation for which the photo team will conduct its operations in the field. The elements of these guidelines are as follows. (Some of the guidelines are protocols and are strictly followed by crime scene photographers throughout the world. These protocol elements are highlighted in **bold** type.)
   a. **Safety consideration first:** Be aware and know what environment you are walking into.

The United Flight 93 crash site was fraught with numerous dangers. These dangers covered a wide range of safety issues including torn airframe hanging from the forest canopy, fires in sublayers of the forest floor, mangled debris and vegetation, and massive coating of biohazard materials (blood mixed with aviation fluid and human remains) were just some of the considerations (see Figure 20.1). Weather considerations for an outdoor scene can be critical. Based on conditions, hydration breaks every hour become a protocol issue.

FBI Chicago ERT's 8 a.m. entry through the final checkpoint (see Figure 20.2). The author is to the immediate left of the state trooper. Notice multiple glove layers being put on by search members.

a. Photo teams wore two nitrile glove layers.
b. Photographers and photo log keepers were not allowed to handle any evidence in the field.



FIGURE 20.2 Security check point for scene entry manned 24/7 by Pennsylvania State Police Troopers.

(From J.L. Larsen.)

It was assumed that all surfaces within the search zone were covered with biomaterial and aviation fluids. Word of caution: If you observe no insect activity, especially flies, you and your team are in danger and need to be in protective clothing and wearing breathing filters.

The photo team, once assigned to a zone, should coordinate their photo activities with the search team leader (STL) and the total station team leader/coordinator. This information is critical. Please remember the photo team is not at the highest level of the investigation. The photo team is there to be told what area to cover, and in some cases, what types of materials to be documented.

a. The photo team will conduct their own site survey of the zone to be searched at the beginning of each search day.
b. Once a zone of responsibility is established, the photo team will photograph the area in detail.

The initial photographs are orientation photographs of the overall zone and then orientation photographs of the specific area to be searched that day.

The STL will literally mark out an area to be searched on that day by the team. The search boundaries were marked using yellow evidence ribbon tape and/or colored surveyor's twine (see Figure 20.3).

a. At the end of the day the photographer will generate a chain of custody to accompany the day's memory media. A photographic log of the day's photo shoot will also be generated. These items will be turned over to the STL, who will disseminate the chain of custody and evidence and photographic logs to the overall command senior evidence recovery team leader.
b. The log keeper has the job of providing written documentation on every photograph taken.



FIGURE 20.3 FBI/ATF team working within yellow bordered area in Zone C.

c. Each day the log keeper will start the photo process by generating a photo identification placard (face-sheet).
d. The photographer and log keeper move as one. The placard is imaged in the first exposure on a memory media. That way, if the memory should be mixed up for any reason, the analysts may easily identify which memory card is which.
e. A pattern/orientation is established for each photo. (The whole function of this operation is to allow an investigator/prosecutor at a later date to bring the images into a trial setting and tell a story.)
f. Images must be generated in such a way to enable the viewer at a different time and place to know what they are looking at.
g. There must be something in the frame to denote direction.
h. Much camera and exposure information may be recovered from the Exchangeable Image File Format (EXIF) data attached to each frame.

Modern digital cameras record metadata right into the photographs. These settings can later be used to organize a set of photographs, perform searches, and provide important information to photo analysts about the way a particular photograph was captured. EXIF data is a range of settings including ISO speed, shutter speed, aperture, white balance, camera model and make, date and time of exposure, lens type, focal length, etc.

a. The area covered by a group of photos is suggested by the GPS coordinates generated by the camera at the time of exposure. Once the overall/orientation photographs are taken, the search team will conduct the detailed search.
b. Items of possible evidentiary value are marked using colored plastic surveyor flags. On the flags (colors established at the outset) general items will be marked with notations in black indelible ink: date, zone, general description, and initialed by a search team member writing the flag.
c. The photo team will then initiate another series of photographs of the exhibits flagged. This operation is started by a group member while the search team takes its 15-minute hydration break at the end of the hour.
d. Orientation photographs are first taken back to an identifiable and locatable point in the search area, of the flagged items followed by mid-range photographs, and finally close-ups of the exhibit and marking flag (descriptors on the flag). It is the photo log keeper's job to document the notations on the flags. The photo team does not terminate its operation until all the flags/exhibits are documented for the day. Expect this process to be time-consuming. Red flags are used to

document human remains. Once a human remain is documented, it is placed in a red biohazard bag, collected, and turned over to the STL. At lunch break and the closing of search activities, 5:00 p.m., the bioexhibits are turned over to a carrier to bring to the disaster mortuary operational response team [DMORT] for processing and storage. (Please refer to Chapter 29 for complete information about the documentation and identification of disaster victims.) The red flags stay in place until, at such time, the total station (surveying) team uploads the location data and identifiers into the total station.

The total station team will document where the flags were located and where the item(s) were recovered. Once the item has been entered into the total station, the flag is removed.

a. After all exhibits and markers have been removed the photo team takes closing photographs, terminating the search activities in that zone for that day.
b. The photo log keeper generates a log identifying case number, date, search zone/grid, photographer's name, log keeper's name, type of camera, and lens used, as well as frame number, description of subject matter, and use of photo scale(s).

The photo log keeper is responsible for writing and submitting a photo log at the close of each search day. These photo logs are to be typed. The photo log is turned in before the photo team signs out at the end of the day. The photographer is the liaison between the STL and total station senior operator.

Specialized photography issues inside as well as outside the scene perimeters include the following:

Initially the aerial photographs should include the surrounding areas bordering the outer perimeters of the scene (see Figure 20.4).

Aerial platforms can include everything from a fire engine ladder truck, cherry-picker boom trucks, to single-engine planes, helicopters, satellites, and/or drones. The list is open to creative possibility.

Ground photographs pertaining to the support efforts are taken independent of the scene. The photo team may be tasked with taking historic operational photographs. The cameras used in these instances are isolated and stand-alone units. It should be remembered that every photograph taken within the scene has the potential to become evidence. (The photographs within this chapter were taken by an assigned member of the Chicago ERT with permission of the acting FBI ERT unit on-scene supervisor to be used in training, not only by ERT but also state and local law enforcement.)

This type of historic documentation, if executed properly, provides a pictorial timeline of events. Some of the photo subjects were:

- First security checkpoint (turnaround point for anyone not authorized to be within the general perimeter)
- Secondary security checkpoint where individuals sign in to a general log book and are given further access into the outfitting and staging area (see Figure 20.4)
- Volunteer food services (i.e., Salvation Army and Red Cross mobile canteens)



FIGURE 20.4 Staging area and the entry of heavy equipment into Zone A to begin recovery of the aircraft frame.



FIGURE 20.5 Decontamination and staging area.

(From J.L. Larsen.)

- Search team(s) staging and equipment (personal safety)
- Briefing area handled by each zone team leader
- Inner security area where suited ERTs enter the actual crime scene (processing area); ERT members sign in to and out of this checkpoint at the start of the daily operation and at the completion of the daily operation
- Decontamination station (local volunteer firefighters maintain this critical site) (see Figure 20.5)
- Port-a-potties and break area within the scene processing area
- Inner meeting and lunch tent (within innermost secure area)
- Total station platforms



FIGURE 20.7 Sifting operations.

(From J.L. Larsen.)



FIGURE 20.8 Airframe storage and collection for Zone C.

(From J.L. Larsen.)



FIGURE 20.6 Ancillary personnel (i.e., heavy construction equipment and operators) working on impact crater.

- Anything of a special nature used in the recovery operation, including heavy machinery
- Photographs of search personnel performing specific search skills (i.e., human remains recovery operations)
- Safety operations
- Any unusual exhibit and/or action that in the future may come into question

CONCLUSION

In summary the photo team (photographer and photographic log keeper) have critical roles within the ERT processing and documenting any incident for both criminal and accident mass disaster scenes. Administrators should allow the photo team to have free run and responsibility within a specific search zone and/or grid throughout the search. The submission of digital memory cards and photo logs is generated at the end of each day by every team working the incident site.

These roles provide investigators the tools for prosecutors to develop and define the modus operandi of a crime and/or the evidence left behind after a mass disaster.

21 Photographing Crime Scenes

Sanford L. Weiss and Robert Wyman

CONTENTS

Photographs as Evidence 406
Metadata 406
Federal Evidence Rules 901 and 1001 407
Original Files 407
Crime Scene Imaging Sequence 407
Scientific Method 408
Scientific Crime Scene Processing 408
Types of Scenes 410
Types of Evidence 410
- Shoeprints 410
- Tire Tracks 412

Processing a Homicide Scene 412
- Photography of the Corpse 413
- Evidence Collection 414
- Trace Evidence 414
- Body Fluids 414
- Fingerprints at a Crime Scene 414
- Fingerprint Development 415

Types of Prints 415
- Latent 415
- Patent 415
- Plastic or Molded 415
- Search for Prints 415
- Print Development 415
- Print Fuming 416
- Print Documentation 416
- Print Collection 416
- Mobile Fingerprint Scanner 416
- Print Identification 416

Blood Evidence 416
- Blood Visualization 417
- Blood Photography 417
- Collection of Blood Evidence 418
- Dried Bloodstains 418
- Wet Bloodstains 418

The Crime 419
The Confession 419
Gasoline Purchase 419
Physical Evidence 419
Sentence and Appeals 420
The Hearing 420
Pardon 421
Appendix I 421

21A Public and Private Scene Investigations: Fire, Crash, and Crime Scenes 423

21B Crime Scene Photogrammetry 435
The 3-D Model Creation Process 436

Photogrammetry Photo Planning and Capture 436
Scaling and Reference Measurements 440
Photographic Considerations for a 3-D Model Creation 440
Overlap and Perspective 440
Distance to Object 440
Blurring 442
Depth of Field 442
Random Textures 442
Contrast 442
Focal Length (i.e., Zoom Setting) 442
Capture at High Resolution 442
Turn Off Any Image Stabilization 442
Glossary 443
21C Single-Photo Perspective Photogrammetry 444
Notes 451

Crime scene photography is an integral part of crime scene investigation and documentation. Although the photography is important, and at sometimes critical to a case, it is not close to the whole act of investigating. In this chapter, the practice of forensic photography of crime scenes is the intended subject. However, one cannot discuss that subject without getting into the investigation part too. For the people who are here to learn about crime scene investigation, there are several other excellent books on the market to educate on that subject. However, those books may be lacking in information regarding the proper practice of forensic photography. If you are here to learn about crime scene photography, you are in the right place.

Crime scene photographs are intended to accurately and systematically document the scene and evidence of a crime. Physical evidence has the potential to play a key role in the overall investigation and resolution of a suspected criminal act.[1] Photographs taken at a crime scene are critical to the investigation and critical to the resolution of the case.

PHOTOGRAPHS AS EVIDENCE

When photographs are judged as fair and accurate representations of evidence, they are admissible in evidence for a variety of purposes, including:

- The identification and documentation of:
  - Persons
  - Places
  - Things
- The relative locations or objects
- Better or clearer understanding of testimony
- The detection of forgeries
- To represent documents where the original cannot be readily produced[2]

In some cases, crime photographs may be considered primary evidence. Three examples include:

- When a suspect is arrested for creating and/or selling pornographic photographs[3]
- A burglar breaks and enters a residence and steals a valuable photograph hanging on a wall
- The original evidence is no longer in existence and only the photographs remain[4]

In these particular cases, the photographs ARE the evidence.

In most other cases, when photographs are captured of primary evidence and if the photographs are used at trial, the photographs are secondary or supporting evidence. A person may use photographs as exhibits in testimony, but only the testimony is primary evidence.

The testifier must substantiate exhibit photographs as accurate representations of the evidence, within the limitations of the media. A judge decides if the photographs are fair and admissible. The testifier may or may not be the person who exposed the photographs.[5] If the testifier understands how the photographs were made and can testify the photographs have not been altered and the images are not inflammatory, the photographs will usually be allowed. If the image involves specialized techniques or enhancement, the photographer or technician will likely need to attest to the validity and acceptance of the technique or process used within the scientific community. The competency of the photographer may be questioned at trial, and the perceived accuracy of the photographs as representations of the evidence will depend on the skills and qualifications of the photographer.

Before photographs can be introduced in evidence, they must be properly identified.[6] The use of an imaging standard operating procedure (SOP) is important for the testifier. The judge must rely on the character of the testifier to relate the circumstances of the documentation in order to pass judgment on image admissibility.

METADATA

The metadata stored in JPEG and raw photographic files includes:

- Date and time of exposure information
- Camera settings
- Camera model and make
- Aperture

- Shutter speed
- Focal length
- Metering mode
- ISO speed
- Descriptions and copyright information

FEDERAL EVIDENCE RULES 901 AND 1001

Under Evidence Rule 901 and its state analogues, photographs are typically admitted as secondary evidence to support testimony. Videos are authenticated in the same manner as still photographs.[7]

Under Federal Evidence Rules 1001 through 1004 (see the Appendix), original documents (including photographs) are required to prove the truth of the facts for which the documents are offered. Duplicates, including electronically made prints or digitally identical electronic files, are also admissible to the same degree as originals, unless the duplicate is inaccurate or unfair.

IMPORTANT:

The inherent inaccuracies of photographs do not necessarily lead to their inadmissibility, as long as they are explainable.[8]

The Federal Rules require all discoverable electronic information to be produced upon request in the native format. Production of photographic images must include digitally identical copies of original raw, JPEG, or other format files.

The Federal Rules may also require the production of the metadata of image files. Metadata is the electronic information about the creation of the image. All native format files will include accurate metadata unless it has been intentionally altered or removed. The importance of accurate metadata stresses the importance of proper setting up of the camera. ALWAYS make sure the camera is set for the correct time, day, and date, and adjust for Daylight Saving Time, leap years, etc.

ORIGINAL FILES

RULE:

Keep each original photograph in its unaltered state. Never modify an original file. Make any corrections and/or adjustments to copies of the originals.

TIP:

Most digital cameras sequentially number each photograph. Deleting images on memory media will result in numbering gaps. Gaps may cause problems in court. It is always best to retain all exposures and, if necessary, classify any mistakes as photographer error.

In many jurisdictions, SOP requires a case identifier (see Figure 21.1) and photo log (see Figure 21.2) to accompany images because:

- Case identifiers provide correlation between the image files and the case in question.
- The time lag between the documentation and the trial may be prolonged.
- Written information accompanying the photographs may aid the testifier.
- The person who exposed the photographs may not necessarily be the person presenting them in court.
- Having the written documentation of the images may enhance their admissibility.

It is normal to record the time, date, location, photographer, and other pertinent information into the case report. The information in and with the photographs should match the report for continuity.

The absence of a case identifier or log document will not necessarily lead to inadmissibility. It is likely the evidence photographer will make errors when completing the log. The most that should be required is the best possible effort to remain complete and accurate. However, the image metadata will include most, if not all, of the pertinent information for each and every image.

CRIME SCENE IMAGING SEQUENCE

Each image should be exposed in a systematic, methodical, and logical manner. Each photograph should be substantiated by its predecessor. A logical sequence of images at a scene may include:

- Location in the world
  - Establishing photograph of a recognizable and immovable landmark
- Overall images showing where the evidence lies within the scene

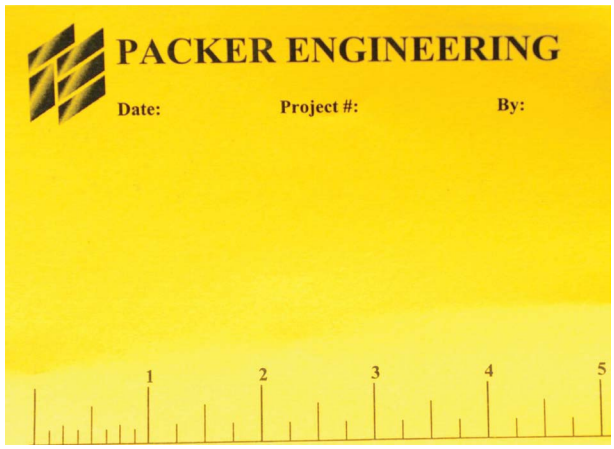


FIGURE 21.1 Case/project photo identifier.

(From Sandy Weiss/Solution Engineering.)

Photo Sheet Site _____

Date _____ Job _____ Roll letter _____ Person _____

Photo	Location	Description
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		

FIGURE 21.2 Photo log sheet.

(From Sandy Weiss/Solution Engineering.)

- Mid-range images to identify the evidence and relationships within the scene
- Close-up images to characterize the evidence

It is necessary for the testifier to establish there was no material change in the scene of an accident or crime during the interval that elapsed between the time of the event and the time of the documentation.[9] If the incident occurred at night and the photography occurred after sunrise, the obvious difference in the scene should be noted in the report. If more images are needed after sunset on a subsequent day, any differences should be noted again and the photography undertaken accordingly.

SCIENTIFIC METHOD

When using the scientific method for crime scene organization and documentation,[10] never assume. Keep an open mind and attempt to tell every possible story with the photographs.

Timing is crucial. Photography should begin as soon as possible after arrival at the scene, even if it is still active



FIGURE 21.3 SRT training.

(From Christopher Cali, Crime Scene Investigator, City of Naperville, Illinois, Police Department.)

(see Figure 21.3). Fragile evidence should be documented first, because it may be destroyed unintentionally over time. Use a systematic approach in the documentation to keep the story of the photographs cohesive and logical. The photographs must be accurate representations of the conditions and locations of the evidence as it was found. Nothing should be touched, moved, or added into the scene until it has been thoroughly photographed.

IMPORTANT:

Photographs are critical to record the condition of the scene and the scene evidence as closely as possible to their original condition at the time of the crime.

IMPORTANT:

Organize the photography to correspond with and complement the sketch and notes.

TIP:

Do not place your camera bag or evidence kit where it will appear in subsequent photographs.

SCIENTIFIC CRIME SCENE PROCESSING

Crime scene processing is a multitask function involving, at a minimum, the following:

1. Interviews to develop a hypothesis of the case and determine if any changes have been made to the scene before your arrival. This includes opening/

closing doors and/or windows, turning on lights, and/or approaching the victim(s) to check for life signs
   a. Witnesses
   b. Suspects
   c. Victim
   d. First responder(s)
2. Examine the scene
   a. Assess the size and nature of the scene
   b. Create initial processing plan
3. Photograph the scene and the evidence
   a. Photograph the entire scene
   b. Tell a story with the images
   c. Examine and photograph the evidence on the floor/ground around victim(s)
   d. Use a systematic search and documentation method
      i. Photograph overall images of the scene from the corners at the 12, 3, 6, and 9 o'clock positions
      ii. Photograph from the outisde in overall images of the scene, working from a stationary landmark into the evidence
      iii. Overlap photographs when possible to allow the photographs to be assembled into a panorama or montage
   e. The scene is three-dimensional
      i. The layout/grid of a scene is like a 3-D chessboard
      ii. Divide the floor/ground into ranks and files numbered 1 to 8
      iii. Walk from A1 to A8, then turn around and walk from B8 to B1, and turn around and work from C1 to C8 and so on until the whole board has been covered
         1. This works for circular scenes as well. Either truncate the number of grid squares or shrink their dimensions as required
      iv. The X-Y plane is only part of the job. Once the X-Y is covered photographically, cover the Z plane at any square reference where an item of interest is found.
      v. Or cover the Z plane at the same time as the other two. Do whatever works for you and is understandable and documentable
         1. The notes for the photography should be sequenced by stating the grid square or column where the images were taken
         2. For any piece of evidence, besides the grid square, capture an overall, a mid-range, and a close-up image of anything of interest
   f. Photograph with and without scales (see Figure 21.4)
   g. Document all footprints and tire tracks



FIGURE 21.4 Use of 2-D scale.

(From Christopher Cali, Crime Scene Investigator, City of Naperville, Illinois, Police Department.)

4. Sketch
   a. The scene to document the layout
   b. To identify the position of evidence and/or victims within the scene
      i. Document only essential elements
      ii. Include name, date, location, compass direction, landmarks, scale, legend, and color references
      iii. Use the same system of designation of evidence in all documentation
      iv. Use appropriate forms
      v. Use templates for shapes and curves
5. Process
   a. The scene for evidence
      i. Identify
      ii. Document
      iii. Collect subject evidence[11]
         1. Keep complete inventory
         2. Chain of custody
      iv. Collect exemplar evidence
         1. From environment (vegetation, soil)
         2. From structure (carpet fibers, paint, fibers, other)
         3. From vehicle (carpet fibers, seat fibers, tires)
         4. From animals (hairs, bedding)
         5. Blood samples from victim[11a]
         6. Fingernail clippings
         7. Swab bite-mark areas
         8. Exemplar hairs
   b. Follow local, state, and federal laws for collection and admissibility
      1. Physical
      2. Testimonial

TYPES OF SCENES

Scenes can be classified by type of crime, including:

- Homicide
- Assault
- Rape and sexual assault
- Arson/bombing
- Robbery
- Cyber crimes

Scenes are also classified as primary or secondary. A primary scene is where the crime occurred or the victim was found. Secondary scenes include the victim or suspect's home or vehicle and any other related indoor or outdoor area. Most secondary scenes are not processed as thoroughly as primary scenes, unless peripheral reasons are discovered.



FIGURE 21.5 Muddy suspect shoeprint on wooden floor with scale.

(From Aric Dutelle, University of Wisconsin – Platteville.)

TYPES OF EVIDENCE

Shoeprints

Shoeprint identification is a widely accepted practice in forensic investigation. It is a technique requiring specialized training and has been the subject of many studies in forensic literature. The subject is covered here in basic form. For more extensive instructions, search the literature by situation and specialty.

The basic steps for the processing of shoeprint evidence include:

- Examination
- Recovery
- Identification

In many criminal investigations, it may be necessary to determine if a particular person was present at the scene at some time. Shoeprints exist at most crime scenes but may easily be overlooked. The prints are among the most fragile types of evidence and may be obliterated by subsequent traffic. The prints may be crucial to an investigation, demanding specific criteria for accuracy in their inspection and photographic documentation (see Figures 21.5 to 21.8).

Shoeprint evidence may reveal:

- Brand of shoes
- Type of sole
- Wear patterns
- Approximate shoe size
- Size and weight of person(s)
- Number of persons at the scene
- Paths of travel
- Sequence of events

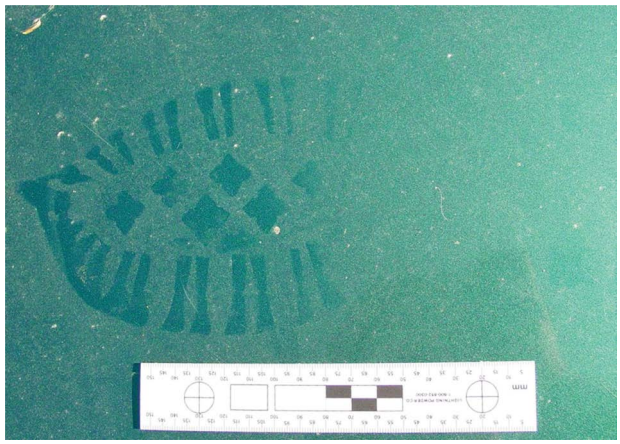


FIGURE 21.6 Suspect shoeprint in the dust on a tile floor, with scale.

(From Aric Dutelle, University of Wisconsin – Platteville.)



FIGURE 21.7 Suspect shoeprint in soft dirt, with scale.

(From Aric Dutelle, University of Wisconsin – Platteville.)



FIGURE 21.8 Suspect shoeprint in hardened mud, with L-shaped, 2-D scale.

(From Aric Dutelle, University of Wisconsin – Platteville.)

After the processing of any victims, conduct a complete search and marking for shoeprints within a logical perimeter. The documentation and collection of the prints should be completed after the search and marking are completed (see Figure 21.9). Once a location is marked, remember to correlate it to the scene and to the other prints through a logical and systematic set of consecutive images.

If the scene is complex or requires extensive foot traffic from emergency medical services (EMS) personnel, protection may be placed over the shoeprints (cardboard box, cone, bag, or so on) until the scene is available for processing. Investigators and EMS personnel should always mark their shoes for easy identification and elimination from the subject evidence. Common methods of shoe identification include the use of disposable shoe covers or to wrap rubber bands around them, top to bottom. If there are multiple people, use different numbers of bands.

The weather conditions at an outdoor scene are always a factor but should not rule out the search for shoeprints. Snow, rain, ice, and fire after the event may obliterate the markings.



FIGURE 21.9 Evidence markers.

(From Sandy Weiss/Solution Engineering.)



FIGURE 21.10 Right-angle 2-D scale manufactured in the proper size for ease in documentation of shoeprints.

(From Sandy Weiss/Solution Engineering.)

Steps for shoeprint photography include:

- Set the camera for sufficient image resolution.
- Use a camera and lens with macro capabilities.
- Use an appropriate scale, next to and on the same plane as the evidence. Right-angle scales (see Figure 21.10) are recommended to enable the successful rectification of the image to life-size during image processing.
- Focus the camera on the evidence, not the scale.
- Photograph each shoeprint with a positional reference.
- Position the camera directly over the print with the image sensor as close as possible to parallel to the evidence.
- Use a tripod if one is available.
- Crop the image in the camera view finder to include only the evidence, scale, and label.
- Use a flash and position it obliquely to the print.
- Photograph each shoeprint with the flash set at various aspects to the evidence.
- It may be necessary to bracket exposures if the substrate of the shoeprint is very dark or very light.
- Block distracting ambient illumination.

The flash will be more effective if taken off of the camera. The flash should be positioned obliquely, to the side of the subject. Experiment by moving the flash to various sides of the shoeprint to capture optimum detail. Areas shadowed in one image may be visible in another. When the prints are on reflective surfaces, a top-mounted or built-in flash may cause reflections or uneven exposures hindering visibility. If the shoeprints are three-dimensional, they should be cast as well as photographed.

When shoeprints are located on smooth interior surfaces like linoleum and tile, they may be difficult to find and see. If possible, darken the room and use a directional light source, like a flashlight, from a very low angle to illuminate and inspect the suspected surfaces. If a print is found, for

best results, use the same angle of directional lighting that made the print visible to the eye for the camera exposure.

TIP:

Expose shoeprint photographs with and without scales, and possibly with and without flash.

TIP:

ALS (alternate light sources) may be useful to bring out the contrast of shoeprints on hard, shiny surfaces.

Even when it is not possible to definitively match a suspect to a shoeprint, the evidence is admissible under the guidelines established by the Supreme Court in *Daubert v. Merrell Dow Pharmaceuticals*, 509 U.S. 579 (1993).

Tire Tracks

A suspect may be associated with a crime scene by the impressions left by vehicle tires. This is another area heavily documented in the forensic literature, if the information included here is found to be too limited.

Steps for tire track photography:

1. If possible, mount the camera on a tripod.
2. Adjust the camera to bring the image plane into a parallel orientation with the marking. If the track is on an inclined surface, the camera should be adjusted to the same angle.
3. Expose photographs with a detached electronic flash unit (EFU) placed about 45 degrees obliquely to the track and from both sides.
4. Vary the angle of the EFU to create the most usable relief view of the markings (see Figure 21.11).
5. Use a scale next to the marking and in the same plane.
6. Continue to make exposures until one complete circumference of the tire has been captured, IF POSSIBLE. The circumference of a tire depends upon the size of the tire. For example, a 21-inch tire would have a circumference of 2 π R or 2 × 3.14 × 10.5—about 66 inches.
7. Overlap the images sufficiently so they can be successfully stitched together into a montage.
8. Concentrate on specific characteristics that make the tire unique.

As with footprint evidence, overall photographs should be taken using a macro lens, showing the impressions in relation to the other features of the scene.[12] Take physical measurements of the dimensions of the tracks and the separation in between.



FIGURE 21.11 Tire track on soft dirt.

(From Aric Dutelle, University of Wisconsin – Platteville.)

A vehicle's track width is the distance between the center of the tire of one side of the vehicle to the center of the tire on the opposite side. Front and rear track width may be different on some vehicles. The measured track width may be used to provide a list of possible vehicles matching the tire impressions.

The wheelbase of a vehicle is the measured distance between the center of the front axle and the center of the rear axle. This is a useful measurement, but it is often difficult to compute from tire tracks.

PROCESSING A HOMICIDE SCENE

After it is established that the victim is deceased, a perimeter should be taped off around the extent of the scene. The perimeter should be placed at the outer location of any likely evidence pertinent to the crime. This may be extremely difficult to establish, so it is better to err on the side of too large rather than too small. The perimeter should not be entered by anyone but the investigator/photographer until the scene has been properly processed for evidence. Scene security and an entry/exit log must be maintained by personnel other than individuals processing the scene.

In an archaeological situation, where a corpse has been discovered after an extended period, the scene processing should include the following:

- Identify and mark the perimeter (see Figure 21.12)
- Wear proper personal protective equipment (PPE) for the situation. At minimum, gloves, masks and shoe covers should be worn. Various Tyvek (TM) suits may be necessary or full HAZMAT equipment. (see Figure 21.13)
- Photograph the evidence with and without scales and references
- Work in layers, making photographs at logical intervals (see Figure 21.14)
- Always look for insect activity and document accordingly (see Chapter 30)



FIGURE 21.12 Gravesite with perimeter locators.

(From Aric Dutelle, University of Wisconsin – Platteville.)



FIGURE 21.13 Investigators in appropriate PPE, excavating gravesite.

(From Aric Dutelle, University of Wisconsin – Platteville.)



FIGURE 21.14 Photography of the gravesite in logical layers.

(From Aric Dutelle, University of Wisconsin – Platteville.)



FIGURE 21.15 Sifting the soil at the gravesite.

(From Aric Dutelle, University of Wisconsin – Platteville.)

- Sift all removed soil for small evidence (see Figure 21.15)
- Measure the depth and record the three-dimensional location of everything involved in the scene

Photography of the Corpse

In the field, the corpse should be documented in a systematic and logical manner, including:

- Locate trauma
- Document trauma with and without scales and references
- The series of images should include:
  - Overalls of the body
    - Head to feet
    - Right side
    - Feet to head (see Figure 21.16)
    - Left side
    - From above (overall if possible, or in sections)
  - Mid-range, starting at the head and working down
  - Close-ups of all unusual evidence

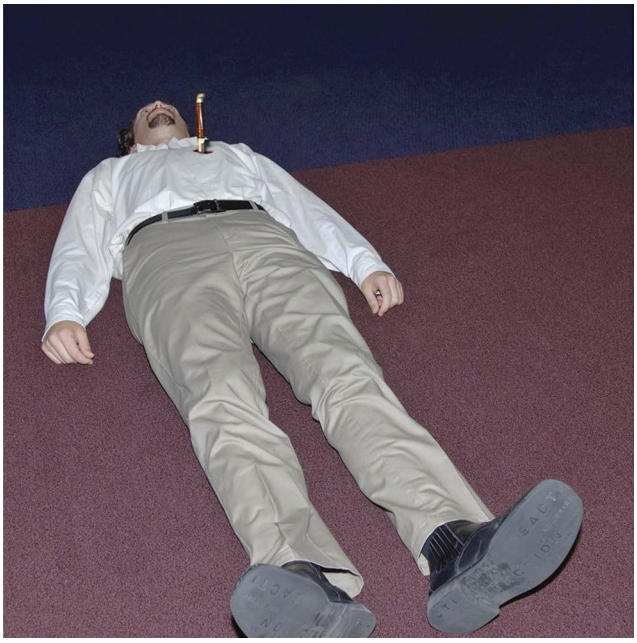


FIGURE 21.16 Deceased, stabbed in the heart, overall photograph, feet to head, but what else should be done for overall images?

(From Sandy Weiss/Solution Engineering.)

Evidence Collection

Document, collect, and document again:

- Trace evidence, including:
  - Hairs
  - Fibers
  - Fingerprints, if possible
  - Body fluids
  - Insect activity

Trace Evidence

Follow specific departmental SOP or protocol or the *FBI Evidence Manual* for the proper methods of collection and packaging. Always wear gloves and any other necessary PPE. The tools for the collection of trace evidence include but are not limited to:[12a]

- Tweezers
- Surgical instruments (see Figure 21.17)
- Pet hair rollers
- Brushes
- Combs
- Vacuum

Body Fluids

If areas of the victim are found to have unusual fluids or dried residues, they must be documented and collected. Body fluids are collected by swabbing or scraping (see Figure 21.18).

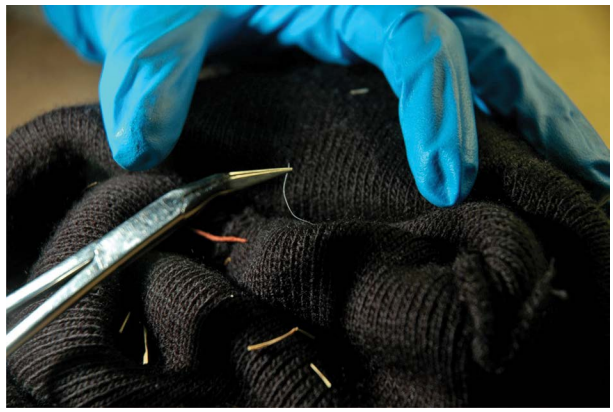


FIGURE 21.17 Collection of a hair from the inside of a knit cap.

(From Aric Dutelle, University of Wisconsin – Platteville.)

Fingerprints at a Crime Scene

Fingerprints are imprints made by the ridges on the pads of human fingers. The prints are often left on objects at a crime scene and are used in forensic science to identify victims and suspects. Fingerprints are believed to be unique for every person, even identical twins (see Chapter 6 for more information).

The fingerprint objectives of the crime scene investigator are:

- Search
  - Discovery
  - Recognition
- Development
- Documentation
- Collection

It will be necessary to collect fingerprints of the victim and any left by a suspect on the corpse. Recovering latent prints

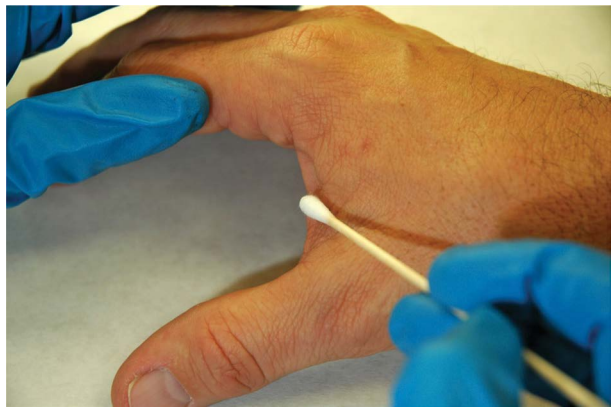


FIGURE 21.18 Collection of body fluid by swabbing.

(From Aric Dutelle, University of Wisconsin – Platteville.)

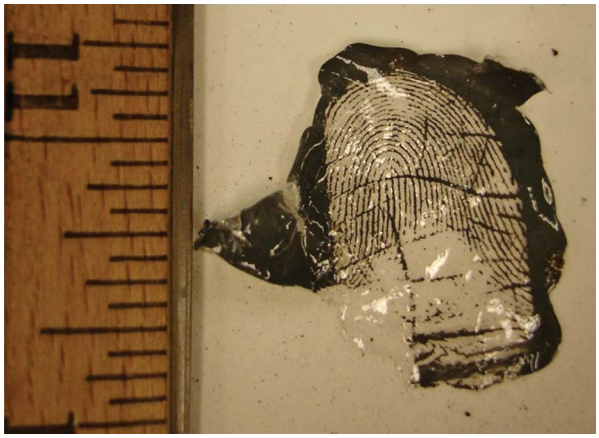


FIGURE 21.19 Fingerprint lifted from a surface with special tape.

(From Aric Dutelle, University of Wisconsin – Platteville.)

from human skin is a specialty that should be studied in the course of becoming an experienced investigator. In all fingerprint recoveries, the investigator requires:

- Information about the surface the print is on
- Information about possible recovery methods
- Instructions for developing and recovering latent prints

Fingerprint Development

- Direct lifting (see Figure 21.19)
- Super Glue fuming
- Direct application of fingerprint powders

Experience and study are the best teachers about which method will be most effective. Always document the recovered prints in a logical method for later correlation.



FIGURE 21.20 Fingerprint visualized on the door of a car by the application of fingerprint powder.

(From Aric Dutelle, University of Wisconsin – Platteville.)

TYPES OF PRINTS

Useful print impressions are made by fingers, palms, toes, feet, and even ears. The types are the same, no matter which body part made the impression(s). The documentation and collection of any prints are similar to the steps for fingerprints. The databases used for comparison and identification vary in size and source.

Latent

Latent fingerprints are invisible impressions left by the friction ridge of fingers on a surface. Latent prints may be visible or invisible. There are electronic, chemical, and physical processing techniques to enable the visualization of invisible latent prints.

The prints may include a complete or partial section of the surface of the finger. They may be smudged, distorted, or both, depending on how they were created.

Patent

Patent prints are friction ridge impressions visible to the human eye. They are caused by the transfer of a foreign substance on the finger(s) and then onto another surface. They may need no enhancement for proper viewing and documentation. They are always photographed with and without scale before collection.

Plastic or Molded

A plastic print is an impression made in a material that retains the shape of the ridge detail. This type of print may be left in wax, window putty, grease, and any type of moldable material. These prints are readily visible and will usually require no enhancement before being photographed.

Search for Prints

The search for fingerprint evidence covers all areas of the scene. The investigator will usually have a SOP for the search pattern. Primary and secondary locations are inspected. Pay special attention to logical items that may have been touched, moved, or look out of place. Oblique lighting, ALSs and lasers are often utilized in the search, as well as powders.

Print Development

Special powders are applied to nonporous surfaces with a soft brush in areas of possible fingerprint locations. The particles of powder will adhere to the substances contained in the print. A variety of chemicals are produced to react with prints deposited on porous and absorbent surfaces, including paper, untreated wood, skin, and so on.

Print Fuming

Super Glue (cyanoacrylate ester) creates a vapor that reacts with water in a latent impression and forms a residue from the materials contained in latent print deposits. The fumes are dangerous to humans, and a fuming chamber or PPE must be used. Once the print(s) is developed, it should be properly documented before collection.

Print Documentation

Photography is performed to document the location and material of the print(s). Accurate documentation of prints is critical in case the print is damaged or lost during collection. Follow all the basic steps and suggestions for macrophotography in the documentation of any type of fingerprint. Follow all suggested SOPs and protocols.

Print Collection

Fingerprint collection differs in SOP and method, depending on the type of print and the type of material upon which it is located. Always develop and document the prints before any collection process begins. After collection, place prints on rigid backing cards with a contrasting color background. The recovery data should be noted on the back of the card, along with all pertinent case information. Follow agency chain of custody procedures.

Mobile Fingerprint Scanner

Wireless, digital fingerprint scanners and printers are used by law enforcement and security agencies. These devices may be used in any field location to scan, collect, and verify a subject's fingerprints. Scanned fingerprints may be used for database comparison to possibly extract a person's ID profile. Using the Automated Fingerprint Identification System, the profile can then be sent to wireless devices, including computers, phones, and personal digital assistants (PDAs). This system may determine the identity of an individual in real time.

There are a number of ways to collect the print images. The most common method in use today is optical scanning. An optical scanner (see Figure 21.21) uses an imaging sensor like a charge coupled device (CCD), the same as in digital cameras and camcorders. The scanning process starts when a finger is placed on a glass plate and a CCD camera captures an image. The scanner has a built-in light source, usually an array of light-emitting diodes (LEDs), to illuminate the ridges of the finger. The system generates a negative or inverted image of the print. The darker areas, ridges, reflect more light, and the lighter areas, between the ridges, reflect less.

If the scanner is satisfied with the quality of the image, it is retained. If the scanner is online with print databases, the print may be compared with others on file. Inked fingerprints may be less likely to experience optical distortion and contain more information and higher resolution than scanned images, making the older-fashioned technology worth retaining.



FIGURE 21.21 Fingerprint scanner.

(From Constance Rohrer, Forensic Photographer.)

Print Identification

The fingerprints from a scene are sent to a fingerprint examiner for identification. It is determined by SOP whether the investigator or the examiner is responsible for the rectification of the image of a print to life-size for comparison to prints in established databases.

BLOOD EVIDENCE

Blood evidence is often essential to the solution of crimes. It is essential to correctly document, collect, and preserve all blood evidence (see Figure 21.22). DNA analysis is used to characterize bloodstains and may connect the blood to a unique individual or a very small group.



FIGURE 21.22 Blood pattern at scene of a suicide.

(From Dodge County, Wisconsin, Medical Examiner's Office, P.J. Schoebel.)

Blood evidence may tie suspects and victims together in various ways, including:

- Finding blood with a victim's genetic markers, ABO blood type, and DNA profile:
  - On a suspect
  - On something owned by a suspect
  - On something associated with a suspect
- Finding blood with a suspect's genetic markers:
  - On a victim
  - On something owned by a victim
  - On something associated with a victim
- Blood spatter and/or blood location information (see Chapter 21B for more information)

Types of blood evidence include:

1. Bloodstains and/or spatter found at the primary scene
2. Bloodstains and/or spatter found away from the primary scene
3. Blood spatter patterns that indicate how a crime occurred or a sequence of events
4. Blood trails leading away from a scene

Blood Visualization

Chemicals are used to enhance the visualization of bloodstains at a scene. Luminol and Bluestar™ will cause bloodstains, old or new, to glow in the dark. It is not a foolproof method but may be useful as a locator for a blood deposit that may then be characterized in other ways. The use of chemicals, including Luminol, may contaminate bloodstains and eliminate the possibility of further analysis.

A variety of fluids may be found at crime scenes. Presumptive testing may be performed to determine if a fluid or stain is indeed human blood.

Luminol may react with opper, iron, and cobalt and some dyes and bleaches to give false-positives for blood.[13]

Blood Photography

Use high-intensity oblique lighting (see Figure 21.23) to search a scene for blood evidence. This type of lighting will enhance bloodstain visualization. Use the same type of light source for blood stain and spatter photography. Remember that blood spatter may be very fine and located in unusual places. The suspect of a crime may have attempted to clean the crime scene and have succeeded in removing the blood from the obvious places. Look behind, under, and above objects. Every scene is three-dimensional, and many forensic photographers forget to look for stains on ceilings, etc.

Photograph the scene in a logical and systematic manner to show the relationship of blood spatters to the various objects and structures at the scene. If the crime occurred indoors, the photographs should show how various areas are connected. This is particularly valuable when recording peripheral bloodstains found in other rooms.

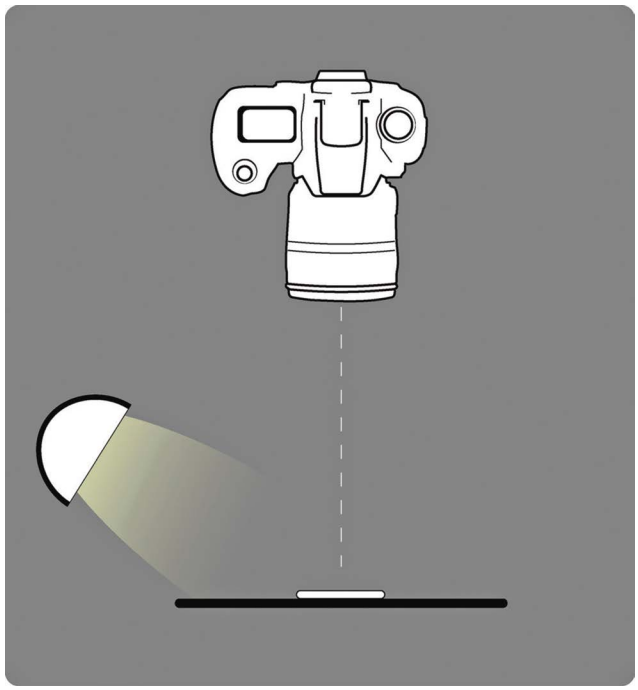


FIGURE 21.23 Oblique lighting for inspection and photography. **(From Jessica Weiss.)**

Record overall, mid-range, and close-up images. Use of the proper scale is mandatory. Use a 2-D scale with stains and spatters covering large areas. Use larger scales, like yard sticks or pocket rods (see Figure 21.24), for even larger areas.

The photographic image may later be projected for analysis. Match the scale of the image to an actual scale, and the image will then be nearly 1:1 size of the original. The perspective of the image and optical problems with the camera equipment must be calculated if the stain/spatter analysis is to be exactly 1:1. In overall images, place the scales parallel and perpendicular to the floor to enable simpler calculations. If the perspective of the image is oblique to the subject, it will be impossible to match the size of both scales to the projected image. One of the sticks or rods will be shortened compared to the other. When this occurs, it is permissible to change the projector-to-screen angle. Projection at an angle to the screen will enable matching of the image to both scales. Measurements and vectors from projections may be used to determine the direction and points of origin of blood spatter evidence.[14]

One drawback of the analysis of 2-D photographs captured of 3-D objects is the difficulty involved in accurate analysis of the information contained in the image. If bloodstain or spatter is on a 3-D object, remember the possibility



FIGURE 21.24 Pocket rod for high-visibility photography of large areas.

(From Sandy Weiss/Solution Engineering.)

of creating 3-D photographs. (Refer to Chapters 9, 10, and 20 for application instructions.)

The International Association of Bloodstain Pattern Analysts has created a special glossary of terms used in the description of blood spatters (see Figure 21.25). This glossary is downloadable from http://www.iabpa.org.



FIGURE 21.25 Blood spatter testing.

(From Aric Dutelle, University of Wisconsin – Platteville.)

Collection of Blood Evidence

After the locations of blood evidence have been noted, tagged, and documented, the collection process may begin. Collection should be performed using a logical and systematic sequence, following the same route as the walk-through and documentation of the scene. Photographs should be made of the collection process and then re-taken if layers of evidence not previously visible and/or documented are then uncovered. Follow departmental or FBI protocols for the proper collection and preservation of blood evidence.

Always use appropriate safety precautions when handling biological evidence. Be sure to wear PPE, including gloves, masks, and/or eye protection, as the situation warrants.

Dried Bloodstains

If the bloodstained item is small and transportable, package it in a paper bag or envelope. If the bloodstained item is large or not easily transported:

1. Cut out a piece of the substrate
2. Tape-lift a sample
3. Scrape a sample into an envelope
4. Absorb a sample onto a wet, clean, white cotton thread or square
5. Consider the removal and retention of the entire surface, wall, floor, ceiling, or other area

If possible, the investigator should also collect samples from unstained areas of the item for negative controls.

Wet Bloodstains

If the item is small and transportable, package it in a paper bag or envelope or VERY temporarily in a plastic bag to prevent contamination of other objects. Remove the object from the plastic bag as soon as it arrives at the lab.

If the bloodstained item is large or not easily transported, absorb the stain onto a 1" × 1" cotton square as described for dried bloodstains.

CASE STUDY 21.1 DEATH ROW FOR ARSON AND MURDER

This case study is a perfect example of how photographs may mean the difference between life and death in a criminal investigation.

Mr. Madison Hobley had been on death row for 15 years before Packer Engineering became involved in his case. The original scene was no longer in a suitable state to be inspected for new evidence. A gasoline can found at the scene was still preserved

in evidence and was available, as were all of the photographs taken by the officers at the scene. By court order, the photographic exhibits could not be taken from Cook County Jail in Chicago. A portable copy arrangement was assembled, and the exhibits were copied photographically at the jail library, under police supervision. By detailed study of the copied images and the physical evidence, Packer engineers were able to bring forth an opinion influential in releasing Mr. Hobley from custody.

THE CRIME

Mr. Hobley had been sentenced to death, primarily based on alleged confessions obtained by a group of Chicago police officers.

Four officers claimed Hobley admitted setting a fire that claimed the lives of his wife, infant son, and five other persons early the morning of January 6, 1987, at an apartment building in the 1100 block of East 82nd Street in Chicago (see Figure 21.26).

When the fire broke out, Mr. Hobley, then 26, escaped from the scene wearing only his underwear. He repeatedly swore his innocence, alleging the officers tortured him and, when that failed, they fabricated his confession.

THE CONFESSION

The morning after the fire, Mr. Hobley was placed under arrest and was taken to police headquarters where the alleged confession took place. According to the police, Mr. Hobley said he went to a filling station with a gas can, bought $1 of gasoline, went home, emptied the can into the hallway outside his third-floor apartment and down the stairwell, ignited the gasoline with a match, and threw the can down into the second-floor hallway (see Figure 21.27).

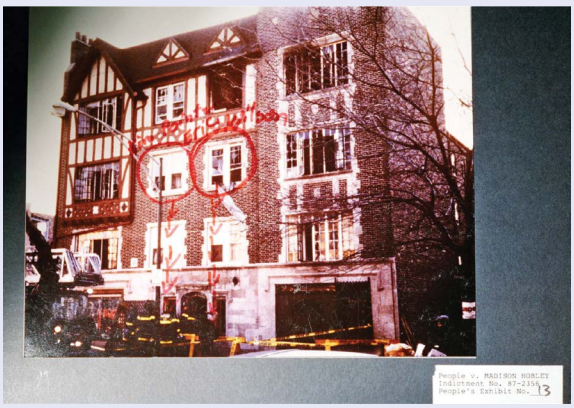


FIGURE 21.26 Outside of arson scene, copy.

(From Sandy Weiss/Packer Engineering.)

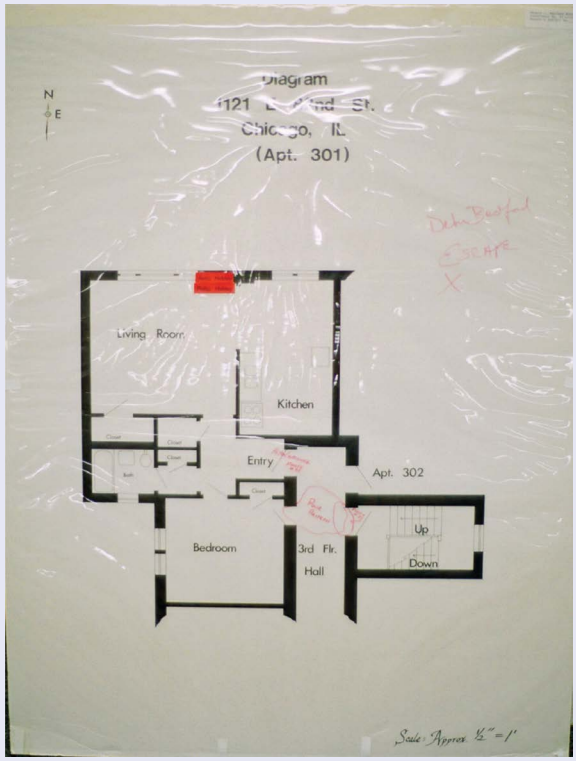


FIGURE 21.27 Plan of structure, copy.

(From Sandy Weiss/Packer Engineering.)

The police said he did this so that he might start a new life with a woman with whom he had recently had an affair.

GASOLINE PURCHASE

Two eyewitnesses identified Mr. Hobley and linked him to the purchase of the gasoline at an Amoco station less than an hour before the fire. The witnesses were also present at the fire scene and testified they saw the same man who purchased the gasoline watching the fire.

PHYSICAL EVIDENCE

Police officers introduced a 2-gallon gasoline can into evidence that another officer testified he discovered at the fire scene.

A Chicago police detective testified as an arson expert for the prosecution. He told the jury a burn pattern on the floor in front of the Hobley apartment (see Figure 21.28) indicated gasoline had been poured there. He acknowledged subsequent tests showed no traces of gasoline in the area but claimed it must have been washed away by water the firefighters used to extinguish the fire.



FIGURE 21.28 Floor and gas can, copy.

(From Sandy Weiss/Packer Engineering.)



FIGURE 21.29 Gas can in evidence.

(From Sandy Weiss/Packer Engineering.)

SENTENCE AND APPEALS

The jury found nothing in the evidence and testimony to preclude the imposition of the death penalty. The judge sentenced Mr. Hobley to death in 1994. The Illinois Supreme Court upheld Mr. Hobley's conviction and death sentence, calling the evidence "overwhelming."[15]

In 1995, Mr. Hobley's appellate attorneys filed a petition for post-conviction relief in the circuit court, alleging the authorities had illegally withheld a forensic report from the trial. The report stated the gasoline can in evidence had been examined for fingerprints and Mr. Hobley's were not on it.

It was also alleged that authorities withheld reports showing the police had recovered a second gasoline can at the scene of the fire and had destroyed it. The implication of these reports was that the fire had been set by someone other than Mr. Hobley and the can introduced into evidence at the trial had been planted to corroborate Mr. Hobley's confession.

In 1998, the Supreme Court found the new evidence sufficient to remand the case for an evidentiary hearing. The court stated that "at the defendant's trial, the defense theory was that another person had started the fire. The lack of fingerprints and the existence of a second gasoline can found at the fire scene, would have offered concrete evidentiary support to that defense theory."[16]

THE HEARING

Russell A. Ogle, PhD, PE, CSP, of Packer Engineering, Inc., testified that the gas can (see Figure 21.29) showed no signs of exposure to the extreme heat that had destroyed other items in the area where the can was found. The plastic cap on the can had not been damaged (see Figure 21.30).

Dr. Ogle also testified that in contradiction to the prosecution expert's contention at Mr. Hobley's trial, there was no evidence of burn patterns on the third floor of the building. Dr. Ogle said the fire started in a stairwell lower in the building (see Figure 21.31).

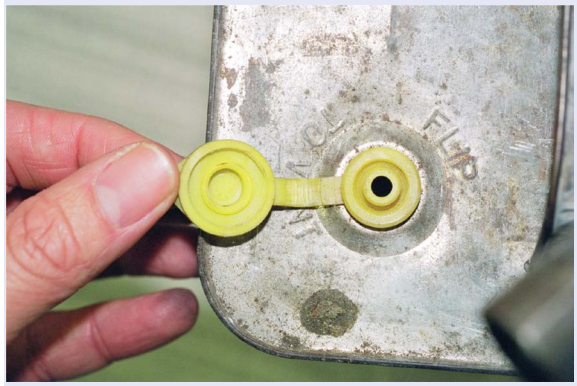


FIGURE 21.30 Undamaged plastic vent.

(From Sandy Weiss/Packer Engineering.)



FIGURE 21.31 Lower stairwell, copy.

(From Sandy Weiss/Solution Engineering.)

PARDON

On January 9, 2003, Illinois Governor George H. Ryan granted Mr. Hobley a pardon. The governor stated Mr. Hobley was convicted on the basis of flawed evidence and the jury did not have the benefit of all the existing evidence. The photographic and physical evidence from the scene was influential in the pardon of Mr. Hobley.

Some of the details in this summary were prepared by Rob Warden, executive director of the Center on Wrongful Convictions. Northwestern University School of Law, Center on Wrongful Convictions, 357 East Chicago Avenue, Chicago, IL 60611, (312) 503-3100. It is reprinted with appropriate attribution.

APPENDIX I

Federal Rules of Evidence

ARTICLE IX AUTHENTICATION AND IDENTIFICATION

Rule 901 Requirement of Authentication or Identification

(a) General provision.
The requirement of authentication or identification as a condition precedent to admissibility is satisfied by evidence sufficient to support a finding that the matter in question is what its proponent claims.

(b) Illustrations.
By way of illustration only, and not by way of limitation, the following are examples of authentication or identification conforming with the requirements of this Rule:

(1) Testimony of witness with knowledge. Testimony that a matter is what it is claimed to be.

(2) Non-expert opinion on handwriting. Non-expert opinion as to the genuineness of handwriting, based upon familiarity not acquired for purposes of the litigation.

(3) Comparison by trier or expert witness. Comparison by the trier of fact or by expert witnesses with specimens which have been authenticated.

(4) Distinctive characteristics and the like. Appearance, contents, substance, internal patterns, or other distinctive characteristics, taken in conjunction with circumstances.

(5) Voice identification. Identification of a voice, whether heard firsthand or through mechanical or electronic transmission or recording, by opinion based upon hearing the voice at any time under circumstances connecting it with the alleged speaker.

(6) Telephone conversations. Telephone conversations, by evidence that a call was made to the number assigned at the time by the telephone company to a particular person or business, if (A) in the case of a person, circumstances, including self-identification, show the person answering to be the one called, or (B) in the case of a business, the call was made to a place of business and the conversation related to business reasonably transacted over the telephone.

(7) Public records or reports. Evidence that a writing authorized by law to be recorded or filed and in fact recorded or filed in a public office, or a purported public record, report, statement, or data compilation, in any form, is from the public office where items of this nature are kept.

(8) Ancient documents or data compilation. Evidence that a document or data compilation, in any form, (A) is in such condition as to create no suspicion concerning its authenticity, (B) was in a place where it, if authentic, would likely be, and (C) has been in existence 20 years or more at the time it is offered.

(9) Process or system. Evidence describing a process or system used to produce a result and showing that the process or system produces an accurate result.

(10) Methods provided by statute or rule. Any method of authentication or identification provided by Act of Congress or by other rules prescribed by the Supreme Court pursuant to statutory authority.

ARTICLE X. CONTENTS OF WRITINGS, RECORDINGS, AND PHOTOGRAPHS

Rule 1001. Definitions

For purposes of this article the following definitions are applicable:

(1) Writings and recordings. "Writings" and "recordings" consist of letters, words, or numbers, or their equivalent, set down by handwriting, typewriting, printing, photo-stating, photographing, magnetic impulse, mechanical or electronic recording, or other form of data compilation.

(2) Photographs. "Photographs" include still photographs, X-ray films, video tapes, and motion pictures.

(3) Original. An "original" of a writing or recording is the writing or recording itself or any counterpart intended to have the same effect by a person executing or issuing it. An "original" of a photograph includes the negative or any print therefrom. If data are stored in a computer or similar device, any

printout or other output readable by sight, shown to reflect the data accurately, is an "original".

(4) Duplicate. A "duplicate" is a counterpart produced by the same impression as the original, or from the same matrix, or by means of photography, including enlargements and miniatures, or by mechanical or electronic re-recording, or by chemical reproduction, or by other equivalent techniques which accurately reproduces the original.

Rule 1002. Requirement of Original

To prove the content of a writing, recording, or photograph, the original writing, recording, or photograph is required, except as otherwise provided in these rules or by Act of Congress.

Rule 1003. Admissibility of Duplicates

A duplicate is admissible to the same extent as an original unless (1) a genuine question is raised as to the authenticity of the original or (2) in the circumstances it would be unfair to admit the duplicate in lieu of the original.

Rule 1004. Admissibility of Other Evidence of Contents

The original is not required, and other evidence of the contents of a writing, recording, or photograph is admissible if—

(1) Originals lost or destroyed. All originals are lost or have been destroyed, unless the proponent lost or destroyed them in bad faith; or
(2) Original not obtainable. No original can be obtained by any available judicial process or procedure; or
(3) Original in possession of opponent. At a time when an original was under the control of the party against whom offered, that party was put on notice, by the pleadings or otherwise, that the contents would be a subject of proof at the hearing, and that party does not produce the original at the hearing; or
(4) Collateral matters. The writing, recording, or photograph is not closely related to a controlling issue.

21A Public and Private Scene Investigations: Fire, Crash, and Crime Scenes

Arthur Borchers

A forensic investigation is a search for the answers to the age-old questions of who, what, where, when, how, and why an event or incident occurred, with a view toward presenting the results before a trier of fact. An examination by a public or government agency is normally conducted with the purpose of determining if there is any criminal liability associated with the event or a danger to the public at large. A private examination of an incident is usually related to civil torts where monetary damages may be assessed against one party in a dispute or incident.

An investigation begins with the arrival of the first responder and continues long after a scene is released. It is never known what might be critical evidence or inconsequential. One latent fingerprint in an unusual location or a cigarette butt crushed out on the floor might be a decisive connection between a suspect and a scene.

The public agency response, in the form of law enforcement or fire services, normally occurs immediately after an incident is first discovered and reported. There is frequently a degree of immediate danger to public safety or the possibility of bodily harm at the location. Access to the area until the danger has passed or been controlled is but one primary concern of any response. Any subsequent public or private examination rarely has the same ability to control access to, or over, a scene.

Police or fire department access after the initial emergency is contained is entirely dependent on one of the following criteria:

1. They have consent, preferably written from the owner or legal designee of the property, to be present in or on a given location.
2. The location is a public street, field, or park.
3. The investigating authorities have obtained a warrant to search for evidence of a crime in or at the private structure, location, or vehicle involved.

Once the emergency has passed and a crime scene completed or a fire struck out, or victims, suspects, and witnesses have all been removed from a scene, there is nothing precluding the police or fire department from restricting all access until valid permission or a warrant is obtained to complete their investigation. Contrary to some still existing belief, there is no crime scene exception to the rules of search and seizure.[16] A crime scene search is exactly what the name implies: a search for evidence and instruments of a crime. Whether a suspect is known or unknown, he or she has constitutionally protected rights, including protection from illegal searches and seizures. The issue boils down to whether an individual/suspect has a reasonable expectation of privacy at a location or vehicle and whether the government's investigators are operating within the law.

For example, Subject A enters a store where he shoots and kills the owner and sole proprietor. Subject A then takes cash or property before leaving. Police respond, enter, determine a crime has occurred, arrange emergency medical care for the injured party, and verify no one else is present. With the immediate danger past, the police begin to process the scene for evidence. During the search, the police discover Subject A's wallet on the floor of the store. A bit of investigation into Subject A reveals a feud with the now-deceased store owner, and Subject A's fingerprints are found on a counter in the store. Subject A is not an owner or employee, so he does not have a reasonable expectation of privacy at the store. Therefore, Subject A has no standing to object to a crime scene search that discovers evidence against him and was made without a warrant. If, however, Subject A was a business partner having equal access to the location and was attempting to mask his involvement by creating the appearance of a robbery, any evidence located during a crime scene search without a warrant or written consent would likely be ruled inadmissible.

In another example, police and fire personnel are called to a private home where a husband reports his wife is inside the burning home. Once the fire is extinguished, the wife is found to be deceased. Firefighters report an odor of gasoline and seeing oddly colored flames in the bedroom during the fire. A charred accelerant pour pattern is visible on a stairway and the floor leading into the bedroom. The husband's initial claims about the fire are clearly contradicted by the initial evidence and witnesses. The husband has an expectation of privacy in his own home. Any continued crime scene and fire investigation without a search warrant would violate the husband's rights and all evidence subsequently recovered would be suppressed. Therefore, the police and fire investigators should stop any processing, secure the area, and then maintain complete custody of the scene while obtaining a search warrant. The information and any images obtained during the initial response can be used to support the warrant, as both the police and fire personnel had a right to be at the location due to the emergency response. Anything they observed, and statements recorded by body-worn cameras, was in plain view and noncustodial in nature. Once the search warrant has been obtained, investigators may reenter the location and process the scene following standard procedures.

In the case of a motor vehicle collision, some evidence may be collected from inside a car because it is on a public

road, in plain view from outside the car and because an officer has a legal right to be where he observes the evidence. Further, due to the mobile nature of vehicles, an officer needs probable cause to believe a person in the car is involved in criminal activity before a search can be conducted. The search must be related to the arrest offense. Following an arrest for driving under the influence of alcohol or drugs, an officer may search for evidence related to the offense. A general search for other contraband is not allowed. However, the electronic information stored by modern airbag and engine control systems is a matter of much dispute over the "ownership" of the data and the "privacy" of the driver. Any data collection is best obtained and legally preserved by obtaining a search warrant or the written consent of the titled owner at the time of the collision or at collection.

A private or civil response and investigation of an incident is rarely as immediate as that of the police or fire services. A government agency concerned with a potential defect in a car's mechanical system may not learn of an incident until months afterward. While the same agency may learn of a high-profile transportation event due to the evening news, they may only have personnel available to investigate the following day. The scene, once the initial police and fire response is complete, will be cleaned up and returned to "normal." Any attempt to reconstruct or recreate the incident will never be as accurate, faithful, or complete as the original scene.

Any follow-up investigator, government or civil, may also need a court order, like a search warrant, for access to evidence or a location. Subsequent investigation is highly dependent upon the work of the police and fire personnel who investigated and documented the initial incident. The quality of the initial response and investigative actions are crucial to all subsequent inquiries and reconstruction efforts. Each group, however, may have different objectives in their investigation, but all are attempting to reconstruct the event to differing extents.

The fire department will attempt to determine the cause and origin of the fire: bad wiring, improper storage of flammable materials, and/or was the fire intentionally set? The police will be looking at the cause and manner of a death to see if it was natural, an accident, a suicide, or a homicide. If an unattended death is found to be natural, there is no further need for official involvement. The other three manners of death must be investigated to determine if there is a danger to public safety or potential criminal activity involved. A death from carbon monoxide in/from a running vehicle may be an accident or a suicide. The same carbon monoxide death in a home may be traced back to a defective water heater or intentional tampering with the heating system. The trajectory of bullets may be determined to see who fired first and from where. The glass in a window where a homeowner reports a firebomb was thrown may have to be meticulously pieced back together to see if it was broken from the inside or the outside.

For purposes of this discussion, the collision between two motor vehicles or a vehicle and another object like a tree, light pole, or pedestrian will be referred to as a traffic crash or traffic collision. The nominal description as an "accident" is not accurate. A "traffic accident" does not meet the standard definition of a foreseen event, an unplanned event, or a circumstance. Most motor vehicle collisions involve some carelessness, ignorance, or violation of the law involved up to and including intentional homicide. With the potential criminal aspect involved, there are more similarities than differences with crime scene and traffic crash photography. For that reason, they will be discussed together with any specific considerations addressed separately.

Scenes are broadly broken into two categories: indoor or outdoor. Indoor scenes rarely extend outside the walls of the structure. Outdoor scenes can be virtually unlimited in size. Manpower considerations are not limited to the personnel needed to process the scene but must include staffing for securing the area for the entire time necessary to complete the assignment. Scene security must be in place even when processing personnel are not. Once the scene is no longer controlled, a property owner can start to clean up after whatever event occurred and potentially destroy any evidence not found and collected. If not monitored, a landlord might scrub a building hallway where one living victim was found while crime scene personnel are working in an adjacent apartment with a second but deceased victim.

First responders have a multitude of factors to consider: scene size and quantity, injured person(s), identifying victim(s), suspect(s) or witness(s), weapons, hazardous materials including blood-borne pathogens, flammable or dangerous vapors, liquids or chemicals, and the structural integrity of the location—all in addition to their legal authority to be present and continue working along with the physical security and protection of personnel present at the scene. Most of these topics far exceed the photography purpose of this book but must be considered as vitally important to the eventual legal admissibility of the photographs documenting the work. Recalling that "forensic" means belonging to legal or court use, it would be a shame that, after hours of detailed effort, the work was wasted due to lack of authority to investigate.

Photographs can be primary evidence of a crime such as images of child pornography or the security video of a burglary or shooting, but typically, photographs are secondary or supporting evidence: exhibits that show a piece of evidence as it was found and supports the testimony of the individual who discovered it.

Photographs have been used as evidence in the United States since the 1860s. The law regarding their admissibility has always been such that photos are required to be true and accurate representations of the evidence or scene within the limitations of the type of media involved. A trial judge decides if the photos are fair and admissible. A given scene may contain a large quantity of blood, and so photos may be limited to black-and-white images so as not to overly shock or inflame persons viewing them.

TIP:

With any type of color photography, black-and-white images of a colorful scene can be produced from the same original images. It is not necessary to expose separate color and black-and-white media at the scene.

The person testifying to the accuracy of the photographs may or may not be the person who captured the images but was a detective or someone else who was present and saw the scene as depicted. However, someone who takes an original image and modifies, enhances, or uses it in some advanced way will likely be called upon to explain the process used, its foundation, and its general acceptance within the scientific community. Therefore, an SOP, department or agency policy, or rules must be in place to govern the entire workflow from scene capture to storage and through to eventual distribution or dissemination. (See Chapter 3 for detailed information on SOPs.)

Photographs of a crash or crime scene are important to accurately and systematically document an incident; the spatial relationships between objects; the identification of persons, places, and things; and give a better and clearer understanding of testimony. The photographer should be attempting to tell the story of the event: How did the cars come to be where they are? How did the offender enter, move through, and leave a structure? How did a fire start?

Maintaining a written log of photographs exposed during the assignment is tedious but important documentation of the image subject. What may appear to be a dashboard image captured in error and overlooked by a viewer may be found later to be an intentional image showing the headlight switch in the off position. A photo of a cigarette butt only becomes important when contrasted with no ashtrays being present and the investigation revealing the burglary victim is a nonsmoker.

Examine a scene and compare to what first responders tell you. Always ask yourself, "Does this make sense?" Seek answers to anomalies. Track all changes to the scene. Have doors been opened or closed? Have lights been turned on or off? What is the indoor temperature compared to outdoor? Document any changes made by first responders or follow-up personnel.

Create and follow a general plan of action for your scene. Update the plan as necessary and check that everything has been completed before you leave. While scenes are typically classified by the type of crime involved (i.e., homicide, burglary, arson, domestic battery/abuse), the process to work each scene should fundamentally be the same. Realistically, the scene itself dictates the amount and type of work required. The location where a person was shot will require more effort to document than the car that drove him to the hospital.

Some processing decisions will be limited by the available resources. Access to photogrammetry tools, as detailed in Chapter 21B, will provide options in addition to dental stone casting of shoeprints and tire tracks. Access to a drone may preclude or supplement a scene map. Use of a 3-D laser scanner will drastically simplify scene measuring efforts. However, lack of advanced technologies does not preclude a proper scene investigation. The technologies only enhance a proper investigation.

TIP:

Take closing photographs to document the scene as you left it. This will protect you and your agency from accusations of unnecessary damage or outright theft.

Photos can reveal hidden detail to document alterations or isolate a fingerprint hidden in a background pattern.

Photos can bring a damaged car into a courtroom where the actual physical object cannot, for obvious reasons.

Photographic equipment considerations:

1. Standard camera with normal, wide-angle, and short telephoto lenses or comparable zoom and macro lenses
2. Medium to strong external flash (either hot shoe or bracket mount)
3. Memory cards
4. Gray cards/color standards
5. Circular polarizing, ultraviolet (UV), infrared (IR), and neutral density (ND) filters for lenses with step-up or step-down rings as needed
6. Flash extension cords, tripods, batteries, tape measures, rules and scales (large and small)
7. Magnetic compass for north or bearing determination
8. Data transfer cords and memory card readers should **not** be brought to the scene

IMPORTANT:

Before every photo assignment begins, verify the camera's date and time settings are correct.

TIP:

Compare all rules and scales to multiple standards to ensure accuracy when new supplies are received. Periodically check cloth tapes and wheel measures against a steel tape to prevent errors due to stretching or damage. Document your testing at least annually and retain the report or memo in a permanent file.

TIP:

Multiple smaller-capacity memory cards (e.g., 8 GB) are preferable to one large card in the event of a card malfunction or loss.

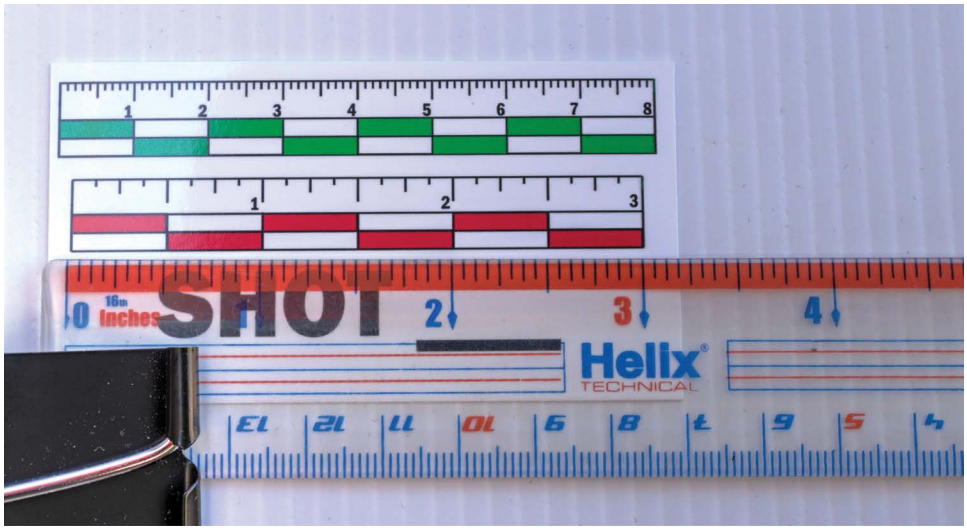


FIGURE 21.32 Comparison of photo scale to commercially manufactured scale.

(From A. Borchers.)

Unless circumstances require otherwise, the first and last photo of any assignment should be an identification card, written to include at least the following information:

1. Case name or crime
2. Case number
3. Date
4. Time (incident time, assignment start and ending time)
5. Location
6. Photographer information along with any assisting personnel
7. Color reference and/or gray card for eventual proper white balance setting or adjustment

TIP:

For an outdoor scene, an additional identification frame could include a photo of a smartphone app displaying GPS data of the location if your camera is not equipped to record GPS information. For a large open area, this may be the best way to locate your scene. An alternative is to take at least three compass headings to fixed landmarks. A surveyor's Mag Nail can be used to mark reference points on a street.

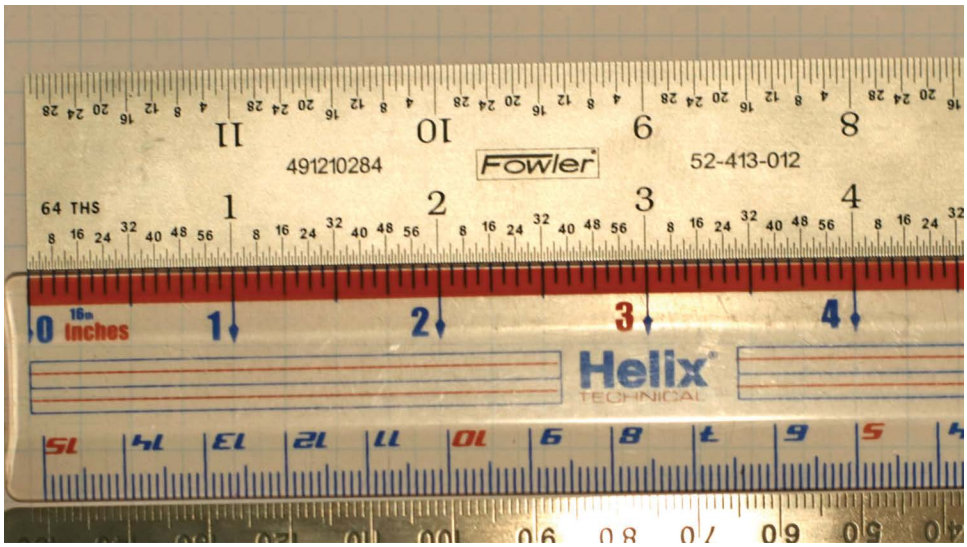


FIGURE 21.33 A commercial scale next to a certified scale.

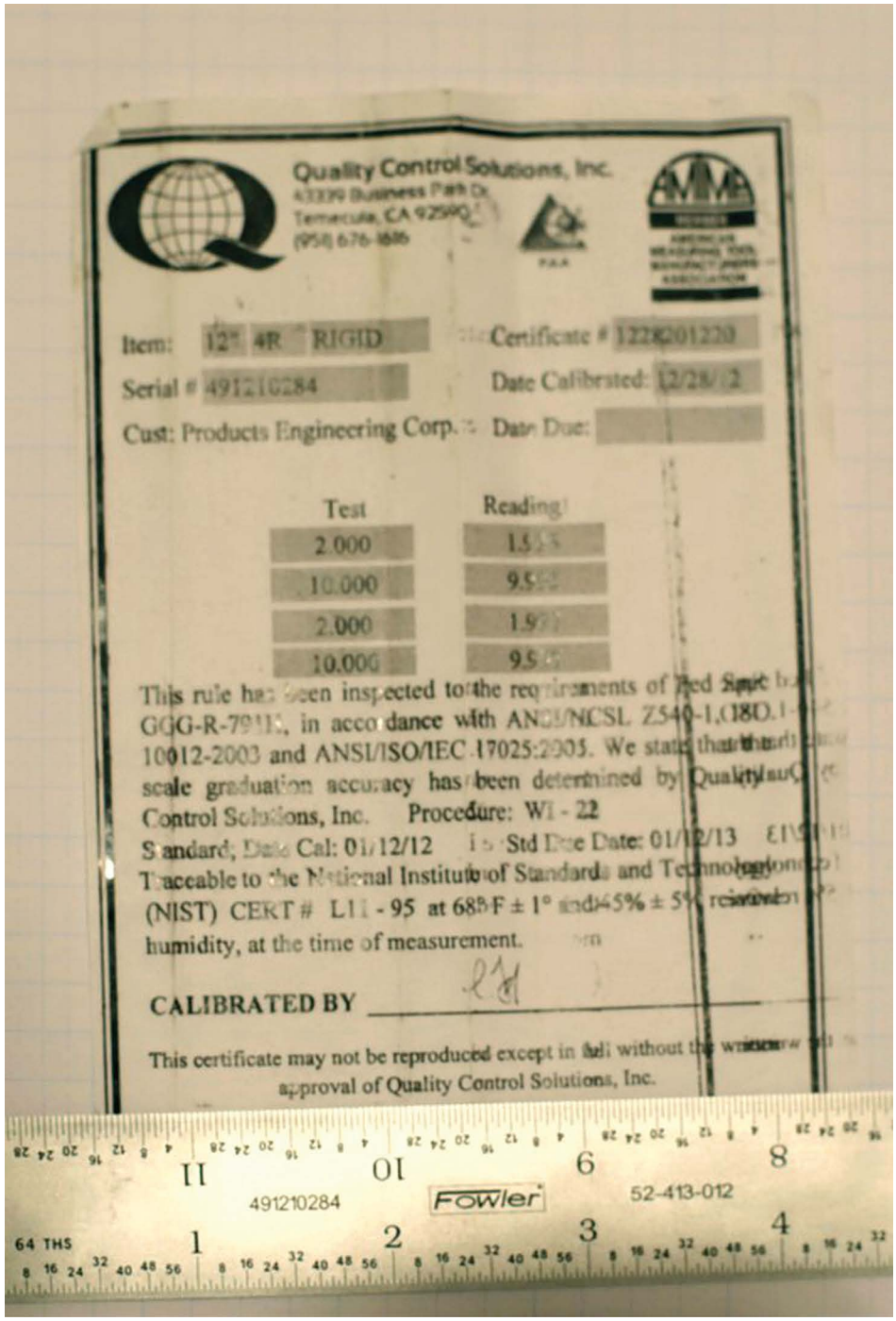


FIGURE 21.34 A certified and serial numbered scale with its calibration certificate.

(From A. Borchers.)

TIP:

Check your camera's menu settings regarding numbering. If possible, reset numbering when inserting and formatting a memory card before each assignment. Your photo sequence numbers will start at 1 and ensure that the card is working properly.

TIP:

When inserting and removing a memory card, wait until the camera is finished writing or accessing information, as indicated by a small flashing light located on the camera back near the card access door. Even if turned off, the camera will attempt to read and write to a card when a memory card is inserted.

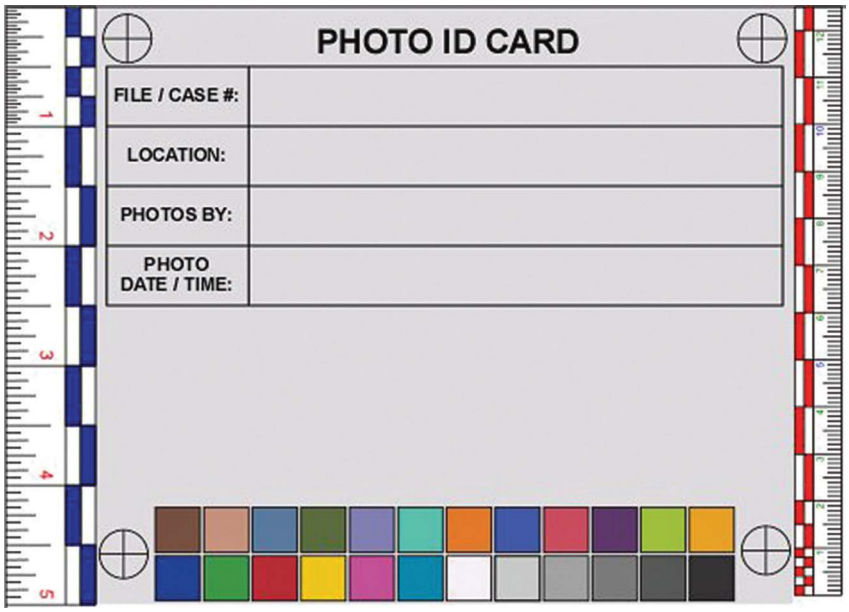


FIGURE 21.35 A case identifier, scale, and color reference.

(From A. Borchers.)

The scene and incident shall dictate the order and content of any photographic documentation. EMS response to injured persons may require photos showing the positions of persons as found in a scene while treatment or extrication efforts are in progress. While photos of firefighters cutting back the roof of a vehicle may be cluttered and disorganized, they are vastly preferable to photos only showing a rescue ravaged car.

The first photos captured after an identification frame should be of the overall area or exterior of a house or business with some attempt to localize the photos by including nearby street signs, businesses, or address numbers, but the priorities of the scene will dictate the actual order. The full exterior of buildings should be recorded. In a vehicular incident, the approach paths of vehicles to an impact site should be recorded back to a reasonable distance from the incident. Perishable evidence, including impact debris, fluid drainage, blood, cartridge casings, etc., should be recorded before they are swept up, washed away, kicked, or trampled. While evidence marker tents should be placed after the initial photos, it may be necessary to mark small

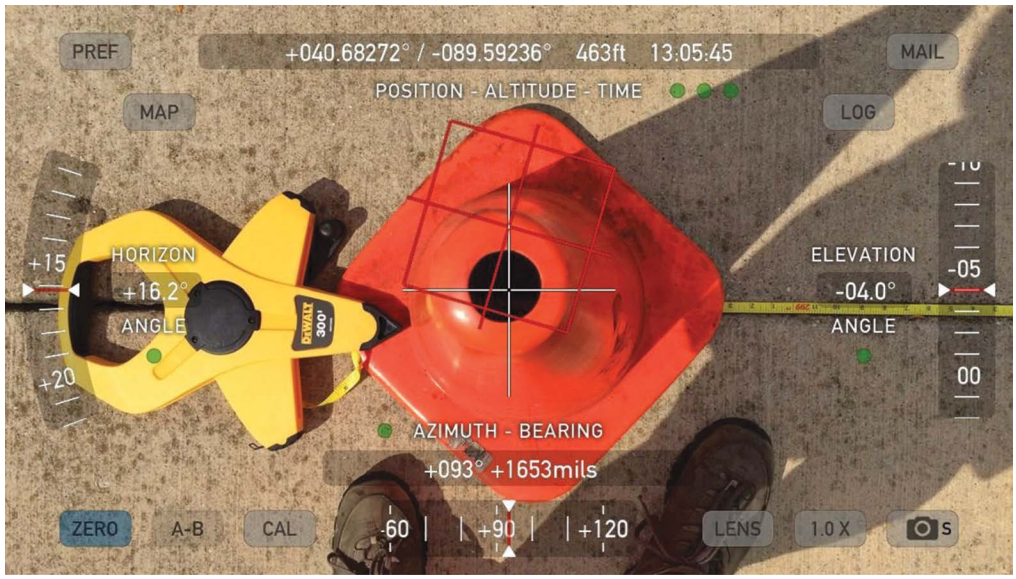


FIGURE 21.36 Smartphone image of GPS information to locate scene location. Anyone viewing this image can then locate and return to the same position at a later date.

(From A. Borchers.)

items before any photos are exposed to protect the integrity of the scene. Some large police agencies' policy is for initial response personnel to cordon off the area and mark small or fragile evidence items to better protect the scene from destruction or alteration (e.g., cartridge cases, bullets, and guns) as soon as possible, likely even before crime scene personnel are notified or arrive. The evidence markers may be in the form of folded and hand-numbered index cards that will be documented and replaced with more traditional tent markers.

In the first minutes, an active crime or crash scene can be adrenaline-filled chaos. It is critical for the initial responding personnel, supervisors, and crime scene responders to bring stability, calm, and organization as soon as possible. Once the initial emergency is resolved, the rest of the work should begin with an experienced sense of organization.

TIP:

One easy way to control a scene is with the use of a crime scene log. Documenting every person going in and out of a scene and their reason for being inside the barrier tape should curtail the entry of those who do not belong.

The general rules for scenes are:

1. Photograph the most fragile things first.
2. Take the overall images from multiple angles starting with larger items and moving to smaller items.
3. Move from the outside into the center of the scene.
4. If not already marked, expose a photograph, place an evidence marker, and then expose another photo showing the marker in place.
5. Use a tripod to expose photos of impression evidence, including fingerprints and footprints in their entirety. The camera should always be perpendicular to the evidence, if possible, to not introduce any angular distortion.
6. Include a scale on/in the same plane as the impression in a second photo.
7. Take interior photos in portrait or vertical orientation to show the full vertical length of walls, to include sections of both floor and ceiling. (Be careful to hold the camera with a wide-angle lens perpendicular to the subject wall and level with the floor to eliminate angular distortion in the finished photographs.)
8. Include ceiling images to verify lack of evidence.

Overall photos should attempt to show:

1. The area around an incident from the perimeter, including:
   a. Building exteriors with identifiable address information
   b. Vehicles from all sides
   c. Entry and exit doors or windows from both sides, including apartment numbers
   d. Bystanders, potential witnesses, or suspects remaining in the area
2. Fire hotspots or flame color
3. Consider taking room photos from the corner looking into and across the room and from the center of the room looking out

Document any changes made to the scene as it was found:

1. Lights turned on/off
2. Windows opened/closed
3. Weapons picked up to avoid loss or further use
4. Furniture, objects, or victims moved during EMS response
5. EMS response debris
6. Victims removed
7. Cars damaged by rescue personnel efforts

Use flash with existing light even in daylight conditions:

1. Fill flash will increase the lighting intensity in damaged/darkened areas, in deep shadows, and in fire scenes (this is a useful purpose for the small pop-up flash on some digital single-lens reflex [DSLRs])
2. Existing light at night to demonstrate road lighting conditions (see Chapter 10)
3. Camera-mounted, direct flash is appropriate for most situations; however, side or oblique flash lighting will highlight details, textures, and tool marks or reduce glare from a polished or reflective surface when necessary. A brand dedicated flash extension cord can maintain accurate off-camera exposure values.

TIP:

Learn how to keep the camera in one spot and move the flash to another.

A factor to keep in mind when trying to photograph reflective and retro-reflective surfaces (e.g., license plates, uniform accessories, and police car/fire truck markings) is the reflected light often fools the automatic settings of electronic flash units into underexposing images. The simplest solution is to move about 10 degrees off perpendicular and repeat an exposure or repeat the image using manual flash settings and allow the reflective surface to be overexposed. An alternative is using a manual flash setting to properly expose the scene and let the reflective material be overexposed.

To maximize depth of field, focus one-third of the way into an image. (Depth of field or the area of apparent focus is reduced when closer to the actual camera focal point and greater behind the focal point.) Use of smaller apertures



FIGURE 21.37 Reflections from license plates and other reflective surfaces can cause an image to be underexposed. The stop sign is approximately 300 feet from the photographer but is more clearly visible than the car in the center of the image.

(From A. Borchers.)

(i.e., a higher numbered f-stop), while increasing the depth of field may cause a loss of sharpness due to lens diffraction.

Digital cameras have on-demand adjustable ISO values. A modern trend offering wider exposure options, depending on your camera to take advantage of ISO adjustability, is manually setting both the shutter speed and aperture (i.e., 1/125 second and F/11) and then allowing the camera to automatically choose the appropriate ISO for any lighting condition. This may help prevent camera shake or image blurring while resulting in a deeper depth of field, while the ISO automatically adjusts to ensure proper exposure.

An ongoing log of photographs taken is important to acknowledge the intended subject of each photo. The log also accounts for known poor exposures or flash failures. A digital voice recorder can be used to dictate the photo log as images are taken.

RULE:

It may be tempting to delete a bad exposure, but in forensic practice, no image should ever be deleted! In the discovery process or at the end of an assignment, every image is turned over. This simple rule can save hours of embarrassing testimony later.

Once overall photos are taken, the process of narrowing in on specific subjects and items begins with medium-range exposures followed by close-up images. If necessary, even macrophotos of tool marks, blood spatter, lamp filaments, or fingerprints can be captured. Photographs of fingerprints in dust may be the only record of their existence.

Mid-range photos help in establishing the visual and spatial relationship of objects to one another—for example, the ejection patterns of fired cartridge cases on a floor. Close-up photos should be taken of each casing by its evidence marker. For more information on close-up and macrophotography, see Chapter 11.

RULE:

Keep the original image files in their unaltered state. Never modify an original image; make a copy of the file and adjust that file. Save and document your work.

Some subjects require more specific images. A deceased victim should be photographed from multiple angles. These include having the photographer at a standing position, then laterally parallel to the floor or bed surface, without altering the body position. Position and condition of the deceased's hands and feet should be recorded. Visible wounds must be shown with and without sizing scales. Oblique lighting may be required for showing best detail. When a body is turned or moved, the once-hidden side and revealed surfaces must be documented. Photos after the body is removed from the scene are also necessary because what is beneath the body may be valuable evidence.

Transient evidence such as drinking glasses with melting ice or the evidence of hot food, out-of-place smoking materials, or drug paraphernalia must be documented promptly. Other police and EMS actions may need to be shown, including the emptying of a bathtub, medical debris left behind, or the moving of furniture to improve access so as not to be confused with evidence of a struggle. Close-up photos require a scale on the same image plane and 90 degrees to the subject. Multiple lighting angles may be required, as well as restricting ambient lighting. With close-up images, direction of north or up should be included for reference. Scales should be sized appropriately to the evidence. A 2-inch scale next to a vehicle tire or a 6-inch scale next to a ¼-inch blood droplet are not effectively used.

Close-up photos of serial numbers on weapons and vehicles will support written records.

When photographing vehicles:

1. The first images should be the front, back and sides.
2. Secondary images should be the four corners showing two sides together.
3. This is followed by close-up photos of the license plate and the vehicle identification number either on the driver's dash or the driver's door frame sticker.
4. Specific images showing damage movement direction of large parts and assemblies can then be captured.
5. Images taken looking down the side of a vehicle may better portray lateral movement or crush.
6. Fill flash may be exceptionally helpful to show deep damage areas.
7. Photos of the vehicle interior can show:
   a. Structural intrusion
   b. Occupant movement and contact points
   c. Seatbelt use or lack thereof
   d. Airbag transfer
   e. Evidence of alcohol and drug use

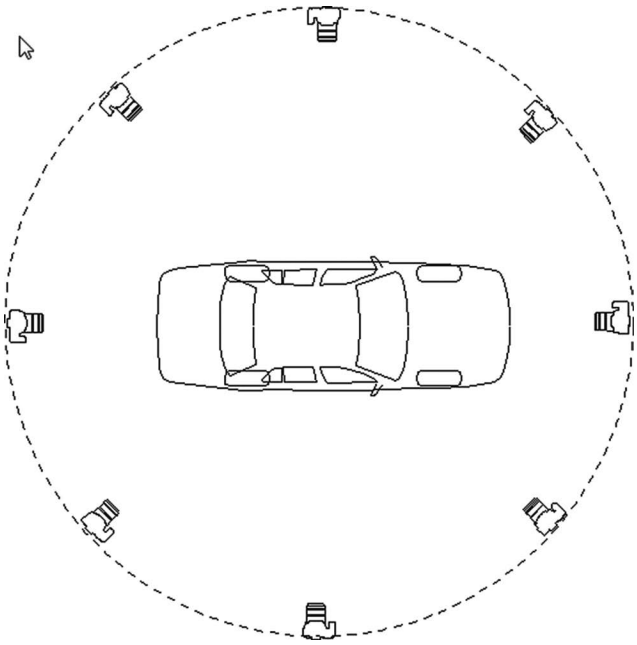


FIGURE 21.38 Standard eight views around a vehicle.

(From A. Borchers.)

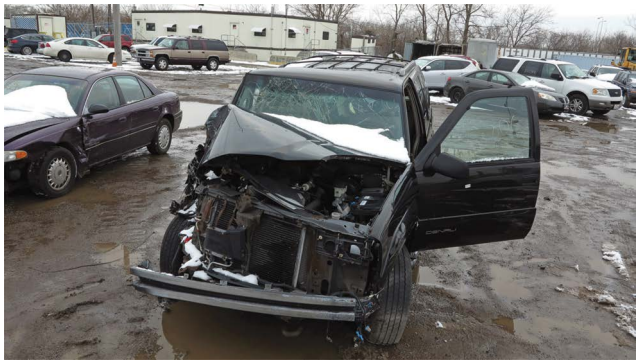


FIGURE 21.39 Front view of a crash-damaged vehicle.

(From A. Borchers.)

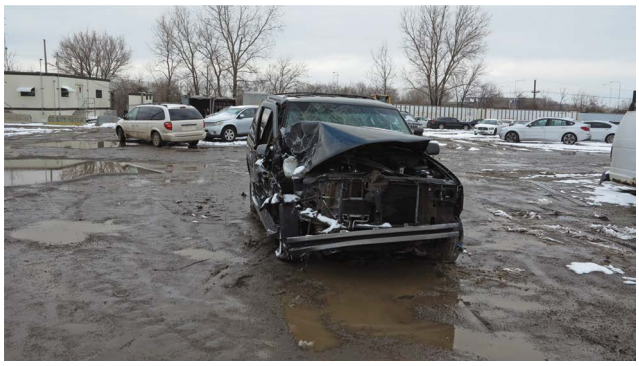


FIGURE 21.40 Front passenger side of a crash-damaged vehicle demonstrating little lateral displacement indicating a principal direction of force along the side of the vehicle.

(From A. Borchers.)



FIGURE 21.41 Continuing the 360-degree images around the vehicle, the displacement of the right front wheel to the rear becomes clear.

(From A. Borchers.)



FIGURE 21.42 The amount of displacement of the right front wheel can be seen.

(From A. Borchers.)



FIGURE 21.43 Full passenger side view of the vehicle.

(From A. Borchers.)



FIGURE 21.44 Right rear view.

(From A. Borchers.)



FIGURE 21.45 Rear view.

(From A. Borchers.)



FIGURE 21.46 Left rear view.

(From A. Borchers.)



FIGURE 21.47 Driver side view.

(From A. Borchers.)



FIGURE 21.48 Left front view. Note deep shadow under the damaged hood.

(From A. Borchers.)



FIGURE 21.49 Fill flash reveals area under the hood.

(From A. Borchers.)

TIP:

It is also advisable to take photographs of important sections from different heights besides standing with the camera at eye height. Climb onto something to get high-angle images and lie down to get low-angle images. There is always something you can see in these you could not in the standard photos.

Evidence on the pavement can include:

1. Tire marks, including:
   a. Skid marks
   b. Critical speed yaw
   c. Rolling tire impressions
2. Chips, gouges, and scrapes
3. Fluid and debris can help identify impact areas and travel paths after impact.

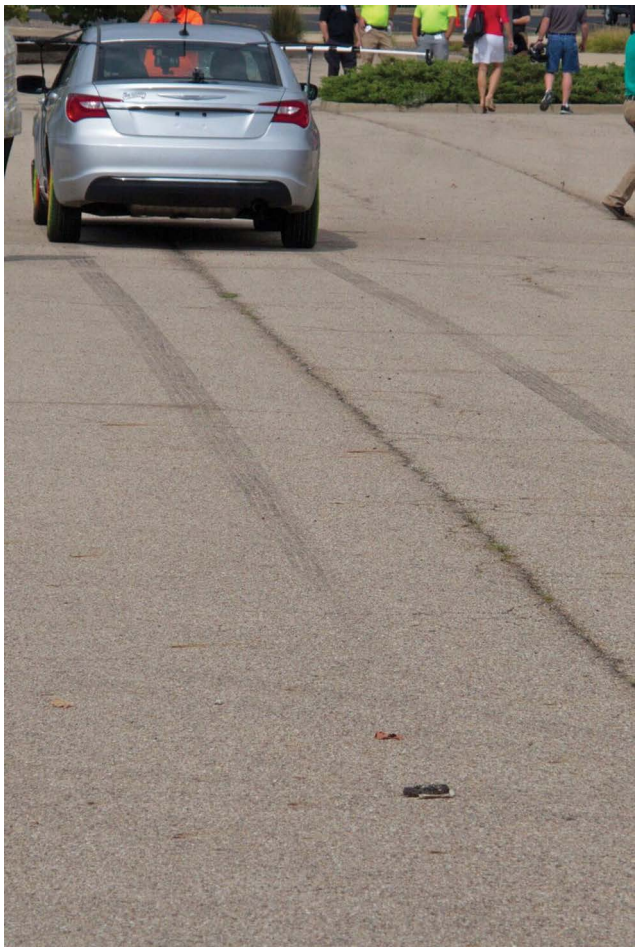


FIGURE 21.50 Skidding tire marks. Note that the grooves in the tires can leave void lines. Cars with anti-lock braking systems may leave little to no visible evidence or erasure on the pavement.

(From A. Borchers.)



FIGURE 21.51 Curving critical speed yaw tire marks left by a tire that is both sliding and rotating. Note the striations in the center mark.

(From A. Borchers.)



FIGURE 21.52 The combined tire marks, gouges, and scrapes at a scene can be a jumbled combination of marks that are difficult to interpret.

(From A. Borchers.)

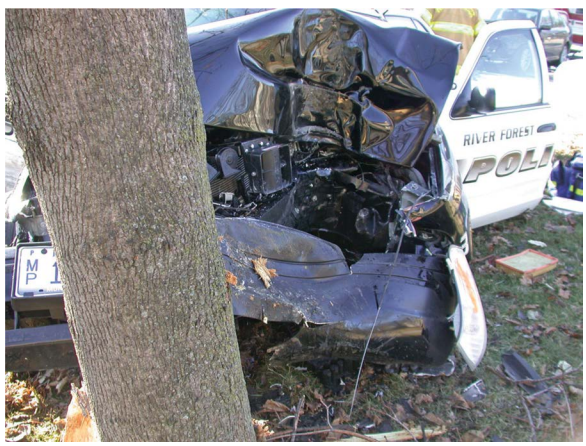


FIGURE 21.53 Narrow object impact is evident, but actual depth is unclear.

(From A. Borchers.)

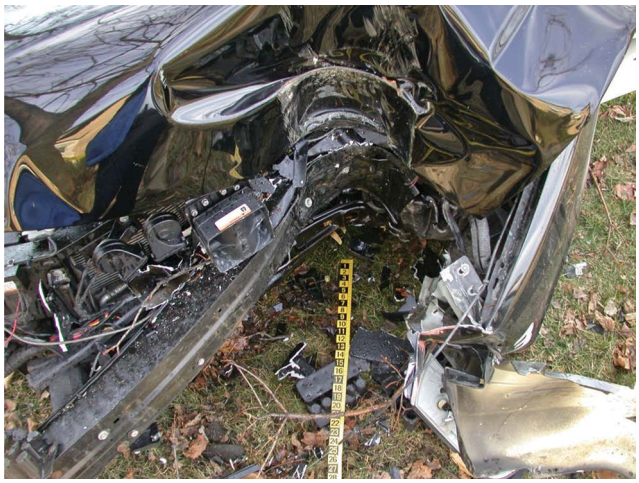


FIGURE 21.54 Scales can assist in visualizing crush depth when photographed from a better angle.

(From A. Borchers.)



FIGURE 21.55 Scrapes left on a road surface.

(From A. Borchers.)

Crash scene photos can:

1. Identify and document the presence or lack of visual obstructions
2. Preserve the overall lighting conditions found by the first responder
3. Demonstrate traffic signal operation
4. Multiple photos can later be used to measure crush with photogrammetry

The final step of the photographer's investigation is preparing a comprehensive report. Whether the report attempts to reconstruct the incident with the use of other evidence or just document the steps taken by the individual involved is immaterial. The adage "If it's not in the report, it didn't happen" has been proven time and again on the stand at trial. Notes taken during the processing of a scene and used in preparing a report must be kept. Whether they are filed as a supplement to the report or inventoried as evidence will be controlled by agency or firm SOP.

21B Crime Scene Photogrammetry

Eugene Liscio

Photogrammetry has a long history in the fields of surveying and aerial mapping, outdating many of the modern-day forensic disciplines. Shortly after the first forms of cameras were produced, it was discovered that cameras could be used to obtain measurements for topographic mapping, among other uses. Although quite primitive in its origins, the push and development of photogrammetry came about from two world wars, analytical advancements, and then a digital revolution. It would be very difficult to cover all aspects of photogrammetry in one chapter, and even the *Manual of Photogrammetry* itself, produced by the American Society of Photogrammetry and Remote Sensing (ASPRS), has well over 1,000 pages, covering various aspects of the practice. However, at its roots, photogrammetry is about obtaining measurements from photographs. The word itself, "photogrammetry," comes from three Greek words, which when loosely translated mean "measurements from a light drawing." Skipping past the many advancements from manual geometric methods to analog and then digital methods, the most recent forms of photogrammetry allow for full 3-D model creation which are true to form and incredibly photorealistic. Hence, this chapter aims to look at some of the opportunities that may present themselves to people working in the areas of crime scene or collision investigation and what kinds of things can be done on scene with a simple camera in hand. Due to their omnipresent nature, mobile phones and DSLR cameras are the most common equipment to document crime and accident scenes. Most crime scene investigators now have a mobile phone, tablet, or digital camera within arm's reach, and this means the equipment to document and record 3-D evidence is readily available for use. Video is also quite ubiquitous, and as body-worn cameras become adopted by more agencies, the opportunity to obtain images from an officer-involved event is more likely to occur. The source of the digital images is not all that important. In many cases, even low-cost or lower-resolution images can produce a decent 3-D model, so long as the quality and quantity of images are sufficient. In some cases, creating a full 3-D model is not possible simply due to the nature of the environment. However, in almost all cases, geometric information about objects in a scene can be obtained using more comprehensive photogrammetry software programs. Granted, the process is not as simple as creating a fully automated 3-D model, but at least the information is locked away if needed. All that is required is a little bit of knowledge on how to capture the photographs so 3-D information is recorded.

The basic purpose of 3-D model creation from photogrammetry would be to generate metric (i.e., measurable) data for a scene or piece of evidence. This can be accomplished by using a comprehensive photogrammetry software package in more than one way, and the results may be applied to different areas in forensics. Measurements from photographs can be obtained from one of the following methods:

1. Multiple overlapping images with a scale reference in at least one of the images. This allows for full model creation or full measurements in 3-D.
2. Single image with many references or controls as seen in the image. The reference measurements or controls can be obtained by many hand measurements, total station, or laser scanner of the same area as seen in the single image. This allows for measurements of objects on planes and from one perspective.
3. A single image with surfaces that can be assumed to have known geometric properties or "constraints," such as a corner room where the floor and walls are perpendicular to one another. This allows for correcting perspective distortion, and measurements may be obtained so long as there is a known reference measurement in the images.

The applications of the three methods are numerous. Some examples of where these can be applied include but are not limited to:

- Reconstruction of clandestine graves
- Bullet trajectory documentation to obtain position and impact angles
- Suspect height analysis



FIGURE 21.56 3-D model of a section of a tire made using multiple overlapping images. This 3-D model can be used for making comparisons to tire tread impressions found at a crime scene.

(From Eugene Liscio.)

- Bloodstain pattern analysis to determine the impact angles and directionality of bloodstains
- Vehicle crush measurements
- Reconstruction of shoe and tire impressions
- Shooting reconstructions to determine shooter position and pose

THE 3-D MODEL CREATION PROCESS

In general, almost all photogrammetry software for creating high-resolution 3-D models use the same general process. Although much effort is put into refining and optimizing the algorithms that process through the images, the basic process is similar in almost all cases. Much of this would go unnoticed to the casual user, as in many cases the model creation all happens automatically.

Taking photographs is in fact the first crucial step, but this portion of the process will be treated in a separate section of this book. Taking photographs for photogrammetry requires the photographer to be in a different frame of mind, since the photographs are being used for 3-D model creation and not for direct measurement or for the purposes of an investigator or juror to understand the context of a crime scene or accident. In fact, a photographer would never take photos in the same manner in general as when reconstructing a 3-D model from photographs, since much of the time, the way the images are framed break some common rules of forensic photography.

PHOTOGRAMMETRY PHOTO PLANNING AND CAPTURE

Like other photography applications, images destined for a photogrammetry project require planning and have a specific objective. The first major difference between crime scene images and photogrammetry images is that you will take a significantly larger number of images for a single photogrammetry project with relatively little change between each image.

There are some general guidelines for capturing photogrammetry images:

- Maximize your *f*/ number to increase depth of field. Depth of field is very important in the point matching process.
- Use a tripod or monopod to support the camera. Turn off lens or camera body stabilization.
- Aim for a well-balanced overall exposure. Blown-out highlights and deep shadows are to be avoided. HDR images can be helpful.
- Maximize your subject within your images. Fill roughly 60% to 80% of the center of the frame with the subject. Overlap 50% to 75% of the subject from one frame to the next. The same portions of the subject should appear in at least three images.
- Panorama-type images from a fixed pivot position should not be used (see Figure 21.57).

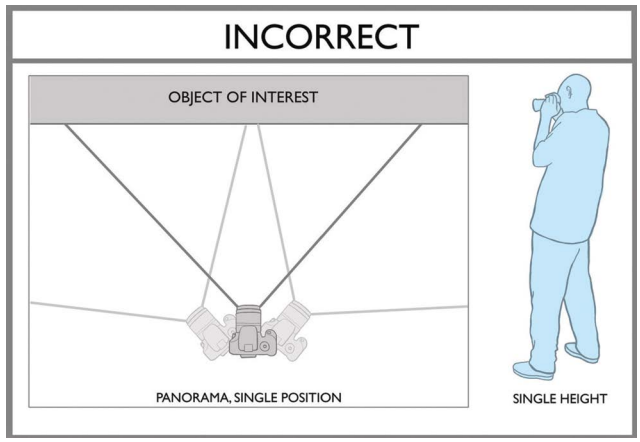


FIGURE 21.57 Panoramic style from fixed pivot point. **(From Amy Wedge.)**

- Find ways to avoid plain, monotonous, glittering, glass, or transparent surfaces. Texture is what ties the images together. Glare can be reduced with a circular polarizing filter.
- Find a way to include an appropriate size scale for the subject (see Figure 21.56).
- If top and bottom views of an object are important, be sure there are enough details in both sets of images to allow for joining or merging the top and bottom view projects.
- If a section of a subject is highly detailed, take additional photos at closer range while dividing up and overlapping the views (see Figure 21.58).
- Consider your subject when taking your images. For a relatively flat surface, such as a building façade or a footwear impression on the ground, take your images with the camera sensor parallel to the subject surface and move laterally across the area of interest (see Figure 21.58).
- If the subject is round, take images around it in about 5- to 15-degree intervals. Repeat the photo series at several heights and, if possible, include images going over the top of the object (see Figure 21.59).
- Inside a room, maximize distance to the object or wall. Take photographs in portrait orientation to capture the floor-to-ceiling view (see Figure 21.62).

Thus, assuming the photographs have all been taken, the first phase of the image processing involves identifying and matching features in an image set. Often referred to as scale invariant feature matching (SIFT), this implementation revolutionized photogrammetry due to its ability to automatically find features in an image and then subsequently find matching images. These are images which contain the same objects or environment from a slightly different perspective. However, SIFT has its roots in computer vision and not directly in photogrammetry. First developed by David Lowe at the

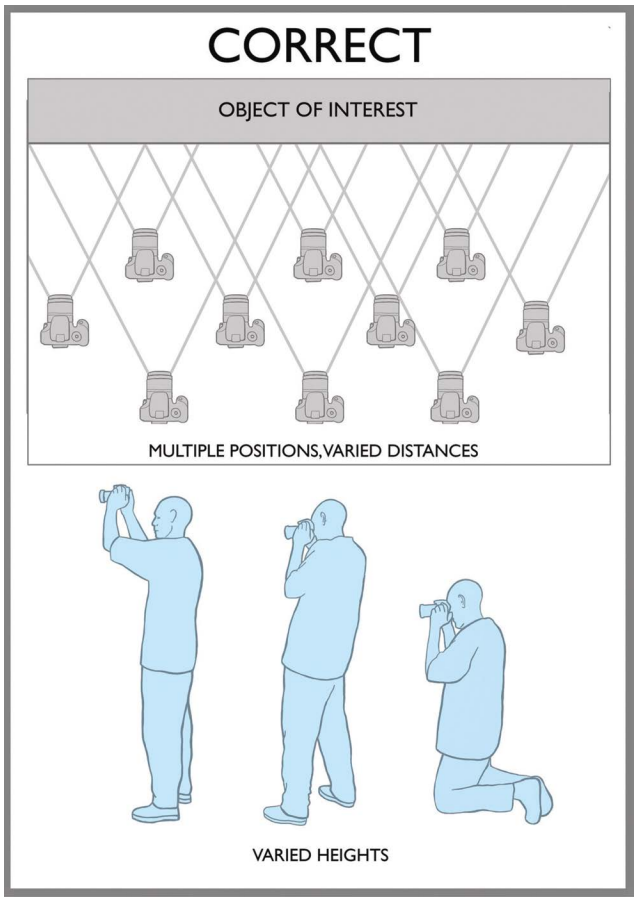


FIGURE 21.58 Overlapping images across the face of the subject with varied height.

(From Amy Wedge.)

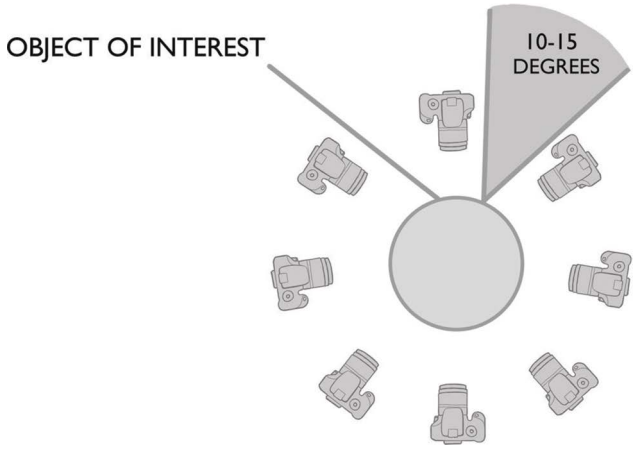


FIGURE 21.59 10- to 15-degree incremental images spaced around the subject.

(From Amy Wedge.)

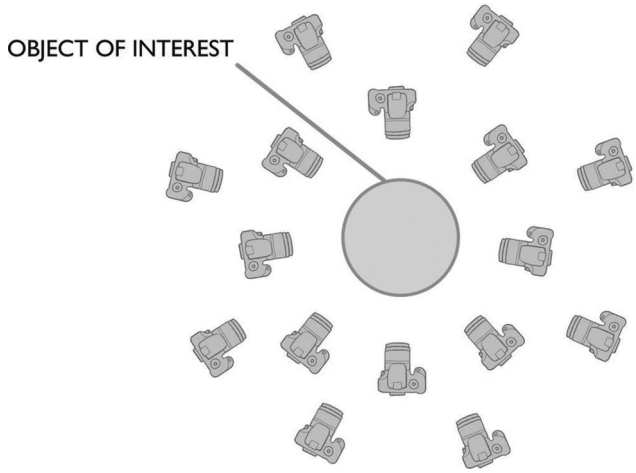


FIGURE 21.60 Overlapping images surrounding the object of interest.

(From Amy Wedge.)

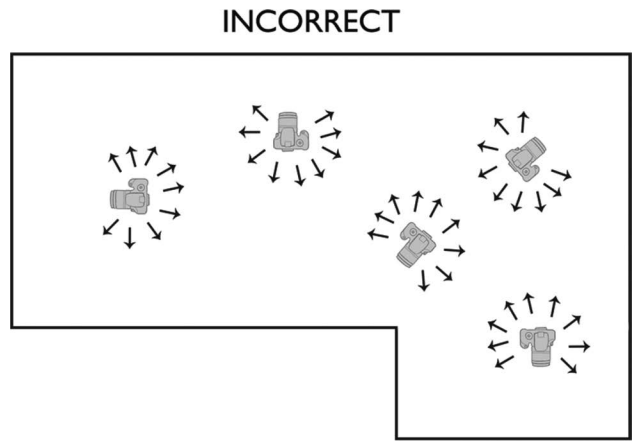


FIGURE 21.61 Panoramic style from fixed points limits visibility within a room.

(From Amy Wedge.)

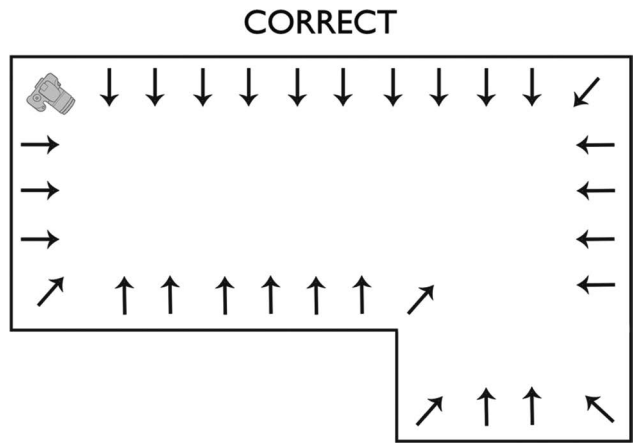


FIGURE 21.62 Maximized distance and overlap perpendicular to subject.

(From Amy Wedge.)

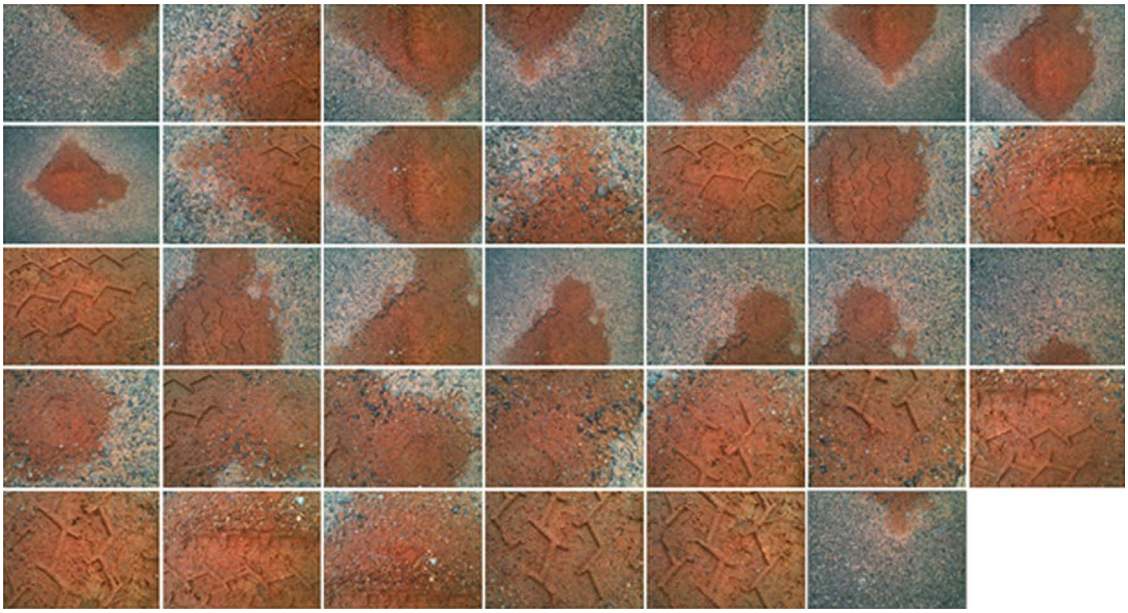


FIGURE 21.63 Series of images taken of a tire impression in a patch of mud. Notice the photographs are captured as wide angle and then overlapping close-up images.

(From Eugene Liscio.)

University of British Columbia around 1999, it is astonishing how robust this algorithm is when comparing a set of photographs for common features. Even when the features in the photograph, like the camera's perspective, angle, lighting, and other features, have changed to some degree, a positive correlation can still be made between images. Aside from its robust nature, the SIFT matching process is highly efficient on large image sets and, in most cases, removes the need for a human to automatically mark similar points between photographs, which would undoubtedly take an enormous effort over dozens of photographs.

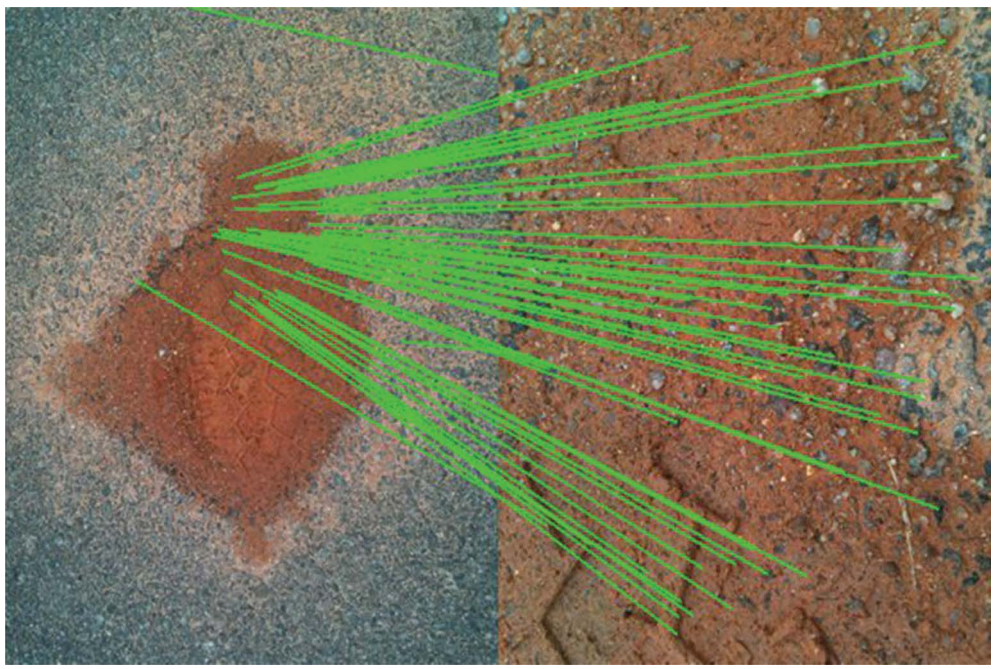


FIGURE 21.64 Matched images of a tire impression, showing common features in two images with great differences in camera-to-subject distance.

(From Eugene Liscio.)

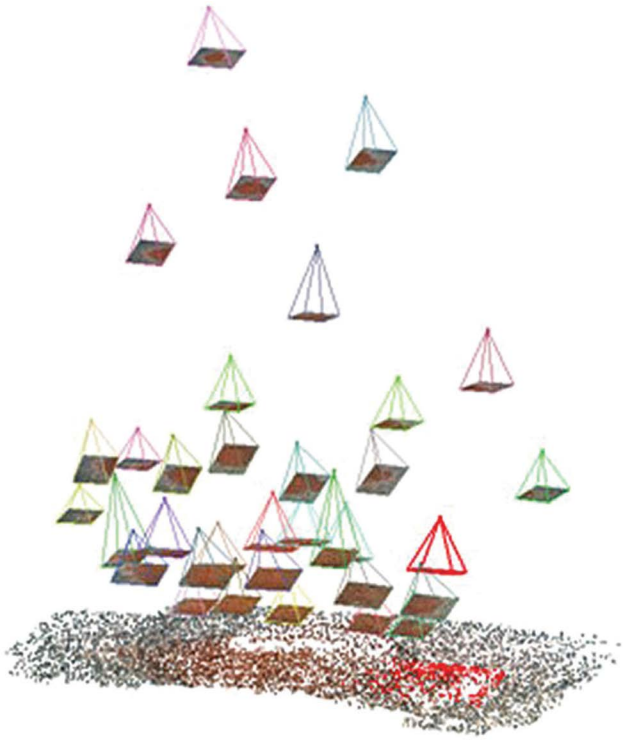


FIGURE 21.65 Sparse reconstruction showing matched 3-D points and calculated camera positions.

(From Eugene Liscio.)

Once enough images have been matched with common points, it is possible to run a "sparse reconstruction," which calculates the relative location of the matched points in the images, along with the position and orientation of each camera that captured the photographs. The sparse reconstruction is a direct contribution from the photogrammetric world and allows the basic setup to be forwarded for further processing to create a dense point cloud.

Since there are millions of pixels in a high-resolution image, it is theoretically possible to create a 3-D point for every pixel in a photograph. However, processing full-resolution images can be a time-intensive process, and thus many photogrammetry software packages allow for a scaling factor to be used to save time while still producing enough detail for the task at hand. Often, the scaling or densities of reconstruction are simply labelled low, medium, high, ultra-high, or similar. Choosing the right density of point cloud is often difficult to quantify, although a general rule of thumb would be to consider if the object in question has unique and detailed geometry.

RULE:

The smaller, more frequent, and greater the geometry appears to be, the more detail is required to define an accurate model.

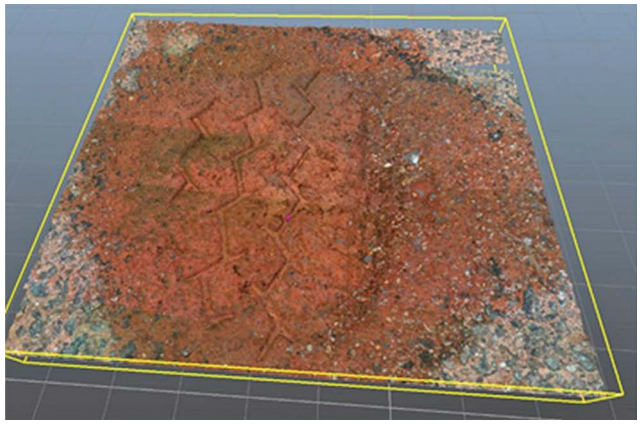


FIGURE 21.66 Dense point cloud of tire impression in mud created from multiple overlapping photographs.

(From Eugene Liscio.)

This is, of course, a general rule and without a doubt, trial and error often becomes the best way to resolve this choice.

Although many would be happy with a dense point cloud, this is not the most optimal format to work with on the generated data. Point clouds can be especially massive and contain tens or hundreds of millions of points, making loading and working with the data on most computers especially taxing and with inferior performance. In addition, not all software can handle working with point clouds, and in some cases require special software or plugins just to load the data. Hence, it is up to the user whether they wish to proceed to the next phase of model creation, which is the mesh creation stage.

Creating meshed models has some advantages when working with point clouds. Meshed models are more universally accepted in most 3-D software programs, and it is possible to convert them to one format or another, including formats easily posted online. Perhaps the main advantage of the meshed model is it can approximate the surface geometry rather well by using a lattice of "patches" or polygons connected to vertices. These patches are at a minimum triangular, with three sides, but can be four-sided (or more) depending on the meshing algorithm. Meshing can be imagined as draping a sheet over a dense set of points, where the sheet conforms to the shape of the object rather well. In flatter areas with less complex geometry, the shape can be approximated by removing many of the vertices or underlying points. This form of adaptive meshing allows for the 3-D object to retain its shape without the need for an overly dense model.

In general, the color of a 3-D photogrammetric model is often much more photorealistic when compared to other sources of 3-D data, including terrestrial laser scanners. 3-D models created from a high-quality camera benefit from the quality of colors and look more pleasing to the eye. However, for the best-quality 3-D model, it is necessary to create "textures" from the original images. Taking a step back to

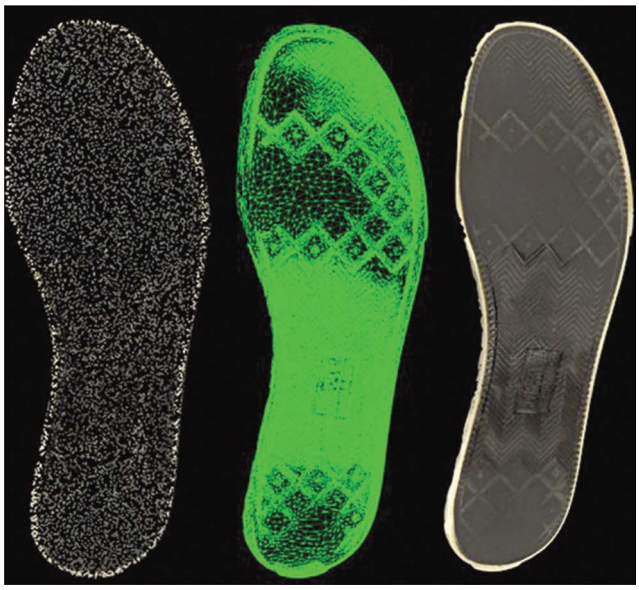


FIGURE 21.67 Sole of a shoe shown from left to right as first a set of points, then a meshed object, and finally a textured mesh.

(From Eugene Liscio.)

the dense point cloud creation stage, it is important to understand the red, green, blue (RGB) colors for each generated point obtained from the respective pixel. Unless the generated point cloud is extremely dense, some space will always exist between adjacent points. Stepping forward to the mesh creation stage, the RGB values from the points are initially transferred to the mesh. However, this is less than the full pixel density of the original photograph and is why it is necessary to produce a "texture" from the original photographs to make the model more photorealistic. Like other stages of processing, the texturing stage is highly automated and has choices for the quality of the texture applied to the meshed model. Once complete, the meshed model may be exported in various common formats, with or without color, including OBJ, VRML, STL, and DXF, to name a few.

SCALING AND REFERENCE MEASUREMENTS

Of foremost importance in forensics is the inherent scale of the created models used to ensure they are true to form. A downside of using any form of digital camera is we are taking light rays in the 3-D world and projecting them onto a 2-D sensor. As a result, we lose depth and scale in the process. The 3-D geometry can be recovered by using multiple images with the process previously described. But without the introduction of some scale or reference measurement, the created model has an arbitrary size assigned to it. Almost all photogrammetry packages allow for scaling of generated point clouds and 3-D models. In its simplest implementation, the scaling process requires the user to click on two points in the model to specify the real-world distance between the points. In addition, some photogrammetry packages allow for error checking when specifying a list of distances on known coordinates. Scaling can also be performed once the model is exported to another 3-D software program.

PHOTOGRAPHIC CONSIDERATIONS FOR A 3-D MODEL CREATION

Since photogrammetry is heavily dependent on the use of a digital camera, the use of good photographic principles applies. There are many techniques and practices a forensic photographer would undergo in difficult photographic situations where lighting, space, scale, etc., may be problematic. In general, knowledge of these principles and techniques is helpful, although creating a 3-D model from images has some different requirements. Some of the most important factors and common issues are discussed next.

Overlap and Perspective

When photographing evidence like shoe impressions, bullet impacts, etc., it is often imperative that the photographer frame the image perpendicular to the evidence. This avoids most perspective distortion, and when a reference scale is included in the photographs alongside the evidence, measurements can be gathered in a single plane. However, images for photogrammetry require varying angles and perspectives to build a successful 3-D model. A technique used by many when photographing smaller evidence (i.e., on the order of 10 cm to 2 m) is to move around the subject in a "ring-like" fashion. Each photograph should have an angle of separation from the previous image of roughly 15 degrees but more or less coverage is often acceptable as well. The amount of overlap should be on the order of roughly 80% if possible, but in some cases, due to the nature of the evidence, it may be less. Taking too large a "jump" between photographs means there is less information to feature match and subsequently less to create a dense point cloud. Thus, keeping the incremental steps between photographs small ensures the best possibility of strong feature matches, and the capture of a few extra photographs should be of little concern.

Distance to Object

A common mistake people new to photogrammetry make is to take photographs placing the evidence in the entire frame of the image. This may be useful to give an overall perspective, but from a photogrammetric point of view, the reconstruction can benefit from having images closer to the object.

RULE:

One common mistake in image capture is to adjust the zoom/focal length of the camera while documenting the same evidence. Fix zoom ring in place with a piece of colored electrical or gaff tape.



FIGURES 21.68 TO 21.71 Subset of images from a larger set showing good angles of separation and overlap.

(From Eugene Liscio.)

This should be avoided at all costs, and it is better to just vary the camera-to-object distance. A good rule of thumb is to photograph the evidence in thirds or quarters and then take the photographs close-up with the previously recommended amount of overlap. Combining wide images with evidence in full-frame and also the close-up images means details are captured with greater clarity and minute details of geometry can be reconstructed with greater accuracy.



FIGURES 21.72 TO 21.75 Series of images showing close-up photographs with portions of the skeleton out of view. These close-up images will result in better details in the photogrammetric reconstruction.

(From Eugene Liscio.)

Blurring

Blurring causes aberrations and distorts the locations of pixels, making it unclear where the position of an object may be. Although an object may be generally in focus, the software looking at these images on the pixel level must decide where the point exists in a discrete location. Blurring may be caused by an object in motion, but in most forensic situations, the culprit is the photographer, whose movement of the camera is the cause of the motion. A simple solution is to use a tripod, especially in situations where lighting is poor and extended exposure times are required.

Depth of Field

When trying to reconstruct smaller objects or pieces of evidence, it is often difficult to ensure the entire object is within the depth of field, meaning part of an object is in focus while another part, further or closer to the camera, is out of focus. Focus has similar challenges as blurring and causes "noise" in the reconstruction. In this case, using higher f-stop numbers and smaller apertures can help increase the depth of field. The downside is higher f-stop numbers allow less light to enter the aperture, and as a result, prolonged exposure times with a tripod may be necessary.

Random Textures

It is not always possible to produce a full 3-D model from still images, and in some cases, it can be rather frustrating when one's expectations are high. Knowing what kind of scene is suitable for a photogrammetric reconstruction helps to avoid disappointment and sometimes embarrassment down the line. Of key importance in a scene strongly suited for a photogrammetric reconstruction is **random texture**. Good examples of this are to think of a pile of dirt or rocks, tree bark, old asphalt roads, sidewalks, etc. Items that appear "dirty" or lack any kind of reflective surface or shine are usually good candidates. On the contrary, surfaces like flat white walls, repeating patterns, windows with reflections, and bodies of water will not provide a good reconstruction simply because it is extremely difficult to find matching features in the images.



FIGURE 21.76 Two images showing the increase in depth of field when changing the f-stop number.

(From Eugene Liscio.)



FIGURE 21.77 High-contrast images cause problems with photogrammetric reconstructions, since the dark areas have very few distinguishable features.

(From Eugene Liscio.)

Contrast

Photographs with a combination of very bright and very dark areas are difficult to capture properly. One area will usually be either too "washed out" or simply too dark to distinguish any features. Using a flash to brighten darker areas is helpful, although it may introduce other challenges. In areas where lighting can be controlled, block out any harsh lighting so the environment is more evenly lit or diffuse (see Chapter 7).

Focal Length (i.e., Zoom Setting)

Although it is possible to photograph with varying zoom settings, the most accurate projects are done with only one focal length when taking photos. When it is required to get closer to an object, it is better to physically locate yourself closer to the object and not use the zoom. Changing the focal length of the camera creates more complex reconstructions in photogrammetry software and often breaks the consistency of the project. In fact, the best way to avoid this is to use a lens with a fixed focal length. In some situations where a zoom lens on a DSLR camera could move slightly, either because of the weight of the lens or through other movement, it is recommended to fix the lens with some tape to ensure no movement is possible.

Capture at High Resolution

The size/resolution of an image will influence the accuracy and quality, since you have more pixels covering the same area and less pixilation occurs.

Turn Off Any Image Stabilization

Image stabilization works by utilizing some moving components in the lens. Since we are concerned with matching

objects and points in each image, we don't want to introduce anything that could change the relationship or positioning of these points between each respective photo.

GLOSSARY

Angle of separation: The distance between photographs. For lateral surfaces, depending on distance to the subject, lateral distance change may be inches or several feet. For circular subjects, capturing images at 5- to 15-degree intervals will produce enough difference between images.

Mesh creation: An extension of the point cloud where the points are connected to create a relatively smooth representation of the surfaces.

Overlap: Depending on application or subject, the amount of common image information carried over from the prior photograph. For panoramic images, 25% overlap from one image to the next is enough to tie images together. For photogrammetry purposes, 60% to 80% overlap will allow the same information to appear in at least three sequential photographs.

Point cloud: A set of data points in space. A total station mapping system may be used to capture distance, radial angle, declination, and other data at a scene to create a 3-D map of up to several hundred points. A 3-D scanner will capture similar data on the order of millions of points and record the color of the object at that point in space. Depending on instrument or software settings, the relative spacing between the points can be considered sparse or dense. With the appropriate viewer, the point cloud can appear highly realistic. Point clouds generated from photographs will require accurate scale to be set based on the captured information.

Prime lens: A fixed focal-length lens as opposed to a zoom lens. For this application, the fixed focal length assures consistency between captured images.

Random texture: Introducing a random texture on monotonous or reflective surfaces will improve reconstruction results because the changes in surface texture or coloring are more detectible in the feature detection process.

Ring method: Capturing images around an object like a tree or statute by circling around a fixed object and capturing images at 5- to 15-degree increments to guarantee enough overlap between images.

Scale invariant feature transform (SIFT): A feature detection algorithm in computer vision to detect local features in pictures. A computer application of point matching objects common in two or more photos that is more efficient than human processes.

Structure from motion: An automated process that mimics the human ability to see depth through stereo vision by using multiple photographs taken from multiple locations around or across an object of interest.

Texture: A varied nonreflective surface will give better results.

21C Single-Photo Perspective Photogrammetry

Arthur Borchers

Several methods of photogrammetry are discussed within this book. Some are new and highly accurate using laser measuring and sensing techniques resulting in highly detailed point clouds of data, but the systems involved can sometimes be prohibitively expensive. The perspective method discussed here is older, decidedly low-tech, and a reasonable-cost to no-cost alternative.

Processing evidence from a crime or crash scene requires detailed notes, extensive photographs, numerous measurements, and multiple sketches, leading to a final scale drawing. The minutia of a scene practically guarantees some detail will be missed. Tire marks, liquid trails, broken auto parts debris, glass fragments, scrapes, scratches, gouges, blood spatter, and shell casings defy complete recording. After the fact, any one item may be found to have importance and be improperly documented. Evidence may be lost due to changing weather conditions or the result of rescue or EMS activity.

Manpower issues may limit the time or ability to process an incident. The initial severity of the incident may change when a victim unexpectedly dies, turning a "minor" incident into a "major" crime. The location of an incident may preclude restricting access for an extended period, such as an interstate highway. Most jurisdictions have a limited amount of time available for closure of arterial roadways before reopening of the roadway becomes necessary. These factors and others increase the necessity of complete and thorough photo documentation. The potential value of a few additional "just-in-case" images cannot be overstressed. While measuring scene evidence from photographs is more frequently applicable to crash scenes, these techniques also apply to crime scenes.

Look-down images from drones, elevated ladders, tall buildings, or pole-mounted cameras provide more map-like images, but those resources may not be available or feasible on a given scene. Standard eye-level images are perfectly satisfactory given the right camera positioning. An officer standing in the middle of a traffic lane documents a scene in a way not significantly different from the iconic perspective illustration of a pair of railroad tracks leading off into the distance and appearing to merge into a single point/track at the horizon. Images with two-point perspective can also be used effectively. Merriam-Webster defines two-point perspective as "linear perspective in which parallel lines along the width and depth of an object are represented as meeting at two separate points on the horizon, 90 degrees apart as measured from the common intersection of the lines of projection."

In the past, single-photo perspective measurements were accomplished with large printed evidence images and hand drawing tools. Now all the work can be done in a computer-aided design (CAD) program. That alone is a monetary savings where correcting a marking error only requires a few mouse clicks instead of starting over on a new printed photograph.

There are three types of perspective-based photogrammetry: perspective grid, perspective disc, and natural grid. Two of the three require minimal additional equipment for recording images. That equipment has simple requirements and is easily made by hand. Targets must weigh enough to stay where they are placed and be visually different from the image background. Targets should be relatively impervious to damage from the weather or other liquids common to crash and crime scenes or be disposable if contaminated. While corrugated plastic can work well, the simplest perspective grids are twelve-inch vinyl floor tiles.[16,17] Perspective discs can be made by cutting tiles into 12-inch-diameter circles. Light color tiles can be left in their natural state or be painted for additional variety.

The targets can also have contrasting color edges, lines, and center markings. Scenes can use one grid tile or up to four aligned in a 2-foot square. The disc method requires three discs laid out in a rough triangular pattern. (See Figures 21.78 and 21.79 for examples.)

Drawing the perspective lines in a perspective disc image is accomplished by drawing lines tangent to the disc edges and extending to their intersection at the horizon line. Lines parallel to the horizon line are then drawn at the top and bottom of the foreground circle. The horizontal and vertical lines form the initial rectangle from which all additional drawing is based.[18]



FIGURE 21.78 Perspective grid samples.

(From A. Borchers.)

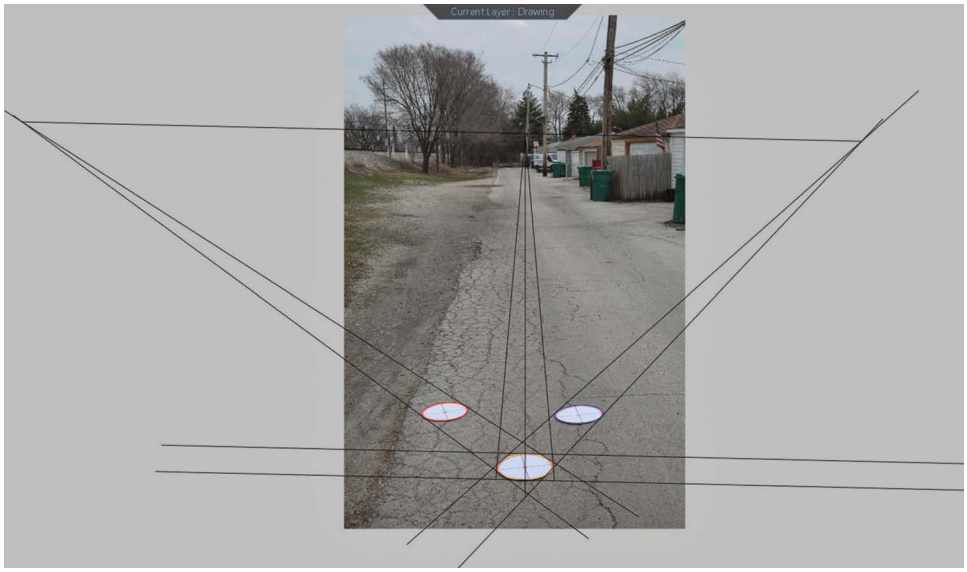


FIGURE 21.79 Perspective disc samples.

(From A. Borchers.)

Both methods require the targets be laid out in the near foreground of each image. The photographer should place himself or herself perpendicular to the targets, but that is not an absolute requirement, as will be demonstrated in the case study. A small lens aperture should be used to give even depth of field across the image.

The physical location of a corner of the grid square or the center of the disc within the scene must be known, as well as another orienting object or location within the image to correlate any derived positions to the actual scene.

In some instances, you may be called upon to work with older photos, where you must rely on natural features present in the scene rather than specifically placed targets. The value of any naturally present grids, rectangles, or squares will then come into play. You may need to revisit the scene and locate features to correlate with the evidence image.

Figure 21.80 originally appeared *Forensic Photography: The Importance of Accuracy*. Examination of the photo indicates it was originally made around 1980. After a search, the location of the photo was found, and Figure 21.81 shows the scene as it was in 2018. There is enough detail remaining for existing details to be used for obtaining measurements from the original image.

The precision of any measurements obtained with these techniques are not on par with a 3-D laser scan or a total station, but the measurement accuracy illustrated in Table 21.1 compares favorably with results extracted from Figure 21.82 on the location of the same evidence items. When those measurements are converted into a scale diagram, the differences are negligible.



FIGURE 21.80 1980s photogrammetry project by Roger Spiegler.

(From Sandy Weiss/Packer Engineering.)



FIGURE 21.81 2018 view of Figure 21.80 by Steven Applebaum.

(From Steven Applebaum.)

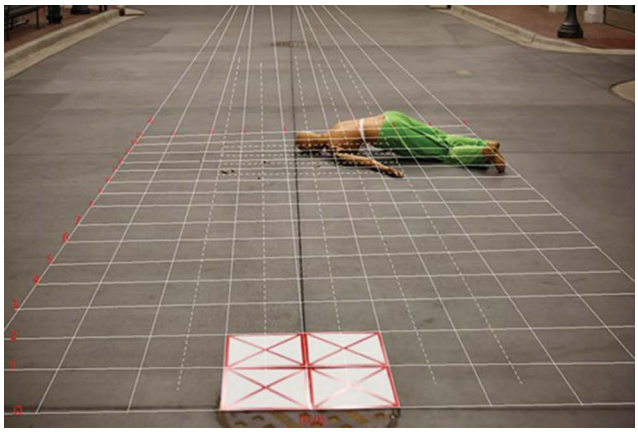
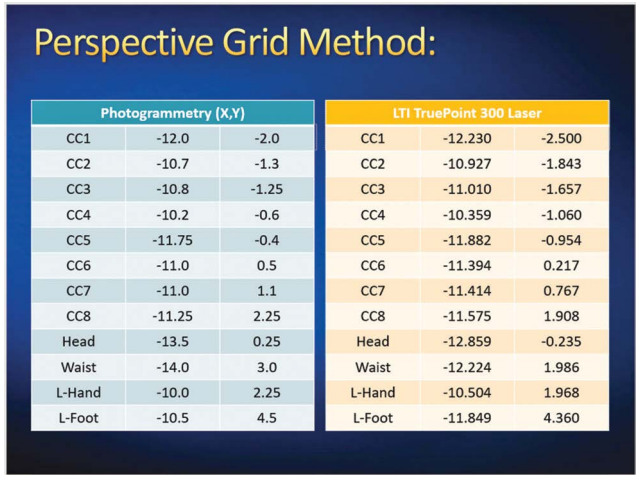


FIGURE 21.82 Test crime scene.

(From A. Borchers.)



Photogrammetry (X,Y)		
CC1	-12.0	-2.0
CC2	-10.7	-1.3
CC3	-10.8	-1.25
CC4	-10.2	-0.6
CC5	-11.75	-0.4
CC6	-11.0	0.5
CC7	-11.0	1.1
CC8	-11.25	2.25
Head	-13.5	0.25
Waist	-14.0	3.0
L-Hand	-10.0	2.25
L-Foot	-10.5	4.5

LTI TruePoint 300 Laser		
CC1	-12.230	-2.500
CC2	-10.927	-1.843
CC3	-11.010	-1.657
CC4	-10.359	-1.060
CC5	-11.882	-0.954
CC6	-11.394	0.217
CC7	-11.414	0.767
CC8	-11.575	1.908
Head	-12.859	-0.235
Waist	-12.224	1.986
L-Hand	-10.504	1.968
L-Foot	-11.849	4.360

FIGURE 21.83 Measurement method comparison (distances in feet).

(From A. Borchers.)

CASE STUDY 21.2

You are assigned to conduct a follow-up investigation of a traffic crash having occurred the previous Saturday night on a parkway-like road, with four traffic lanes and a 45-mph speed limit. The initial scene investigation revealed a white minivan had been rear-ended by a black SUV.

The scene photos reveal multiple tire marks, impact debris, and fluid trails tending to indicate the collision took place in the far-right lane. The lone occupant of the minivan was transported from the scene in cardiac arrest. The driver of the SUV had a strong odor of alcoholic beverage on his breath. The single witness to the crash states the SUV was traveling at an estimated 85 mph at the time of impact. The initial officers handling the scene made a few measurements, marked the start of a couple of tire marks with paint, and recorded the rest locations of two tires on each vehicle along with exposing many photographs.

The driver of the minivan was taken off life support and passed away. The family of the minivan's driver reported they were on the telephone with her at the time of the crash because her vehicle had broken down, leaving her stranded on the parkway. The driver of the SUV was given a blood test at the hospital during treatment for minor injuries, showing a blood alcohol level nearly twice the legal limit.

The roadway is an alternative route for a nearby interstate highway and carries hundreds of cars past the scene every hour. The scene examination shows rain and traffic have washed away all the debris and tire marks visible in the scene photos. The road surface is concrete, and there are regular cuts to allow thermal expansion. A good number of the cuts are visible in the scene photographs. Measurements of the pavement cuts will allow a scene reconstruction and the creation of a scale diagram to document the tire marks, debris, and approximate impact location.

The process of extracting measurements from just one image is shown in Figures 21.84 to 21.91. The software used to draw the lines using the natural grid method is FARO Zone 3-D, but other CAD programs can perform the same function. The drawing process is relatively basic, but it requires tedious effort to determine locations within the image and to translate those locations into real-world two-dimensional X,Y coordinates. In this case study, this same analysis was completed on a total of seven images documenting impact location and other tire marks.

The first step is to import the digital image(s) into the CAD program and place it in its own layer. Create at least two additional layers, and mark points of evidence and interest with contrasting varicolored lines, circles, or other marks. Lock both the image and evidence layers. In Figure 21.84, the original image, you see yaw tire marks and the perimeters of two natural grids in the pavement. The tire mark from the vehicle's right tire is on the left in the image and is dark; the right tire mark is effectively an erasure mark and may be difficult to discern. In Figure 21.85, you see the tire marks highlighted in green and the natural gridlines highlighted in red.



FIGURE 21.84 Original scene image.

(From A. Borchers.)

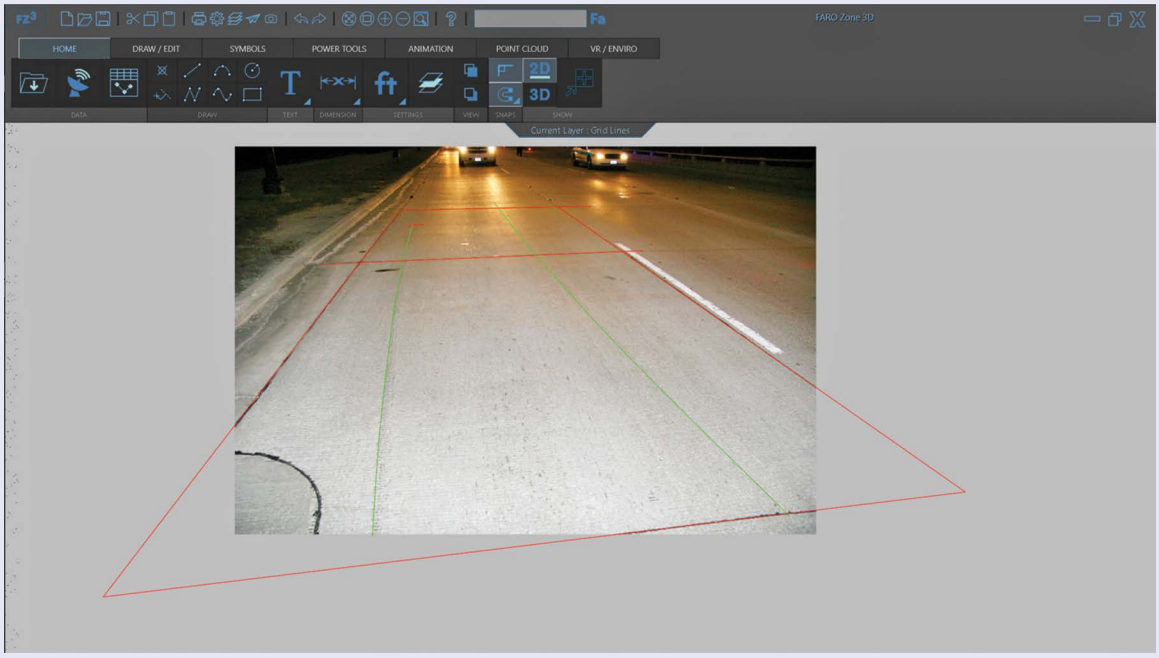


FIGURE 21.85 Yaw tire marks and two natural grids in pavement.

(From A. Borchers.)

Ideally, the horizontal lines are parallel because the photographer aimed the camera perpendicular to the lines, but in this case, the horizontal lines as well as the vertical lines closely converge outside the image (see Figures 21.86 and 21.87). If you connect the convergence points you find a line corresponding to the natural horizon of the image had it been exposed at the time.

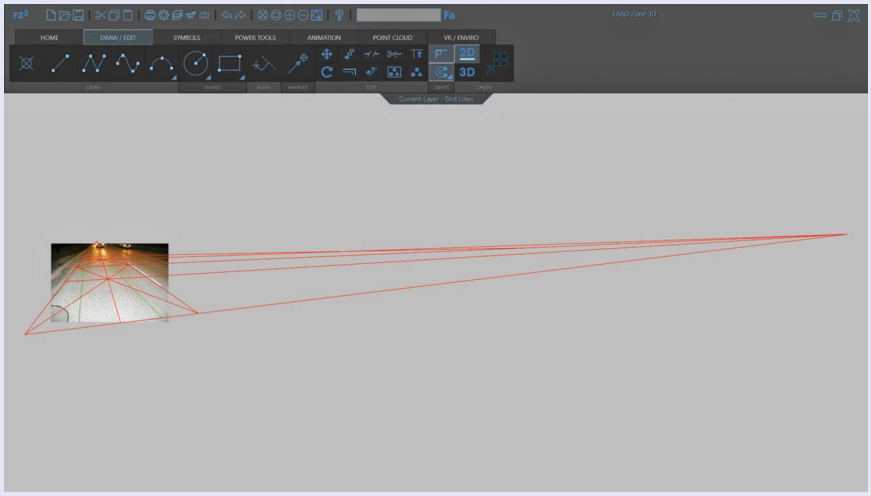


FIGURE 21.86 Horizontal line convergence.

(From A. Borchers.)

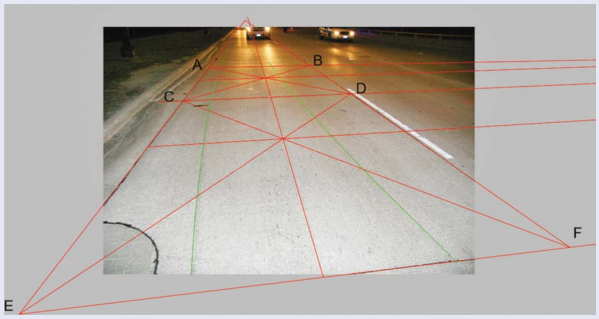


FIGURE 21.87 Vertical line convergence.

(From A. Borchers.)

Six points, the corners of the two rectangles, labeled A–F in Figure 21.87, are known X,Y coordinates measured specifically for the reconstruction. The distances between the points are also known. These six points create two rectangles that are approximately 11 feet by 15 feet.

The next step is to draw diagonal lines between the corners, followed by a line horizontally dividing the rectangle through the diagonal intersection and connecting to the right convergence point. Had the horizontal lines been parallel, the cross line would also be parallel.

Now diagonal lines are drawn between the midpoints of the sides of the original rectangles creating both a diamond shape (orange in Figure 21.88) and a bicolored "X" in each of the four subrectangles.

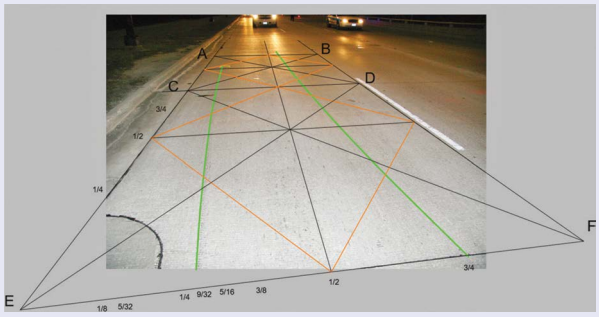


FIGURE 21.88 Additional diagonal lines added in orange.

(From A. Borchers.)

The process of adding subrectangles, making smaller and smaller rectangles, will close in on the evidence locations (see Figures 21.89 to 21.91).

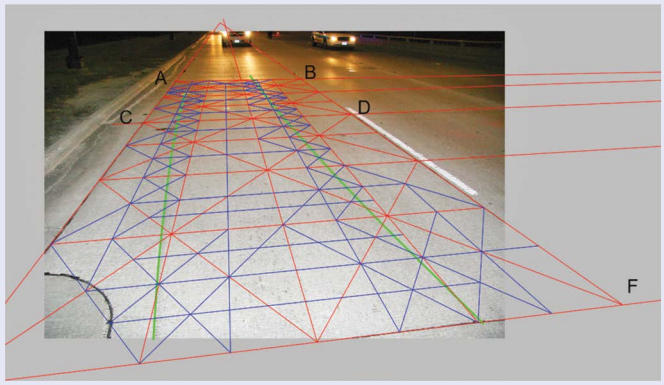


FIGURE 21.89 Alternating colors assist in closing in on evidence locations.

(From A. Borchers.)

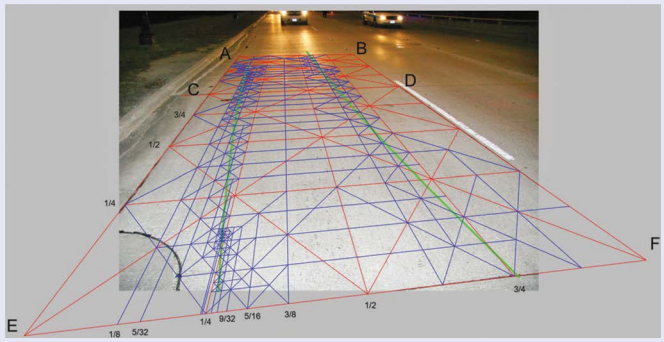


FIGURE 21.90 Smaller and smaller rectangles increase accuracy in locating evidence.

(From A. Borchers.)

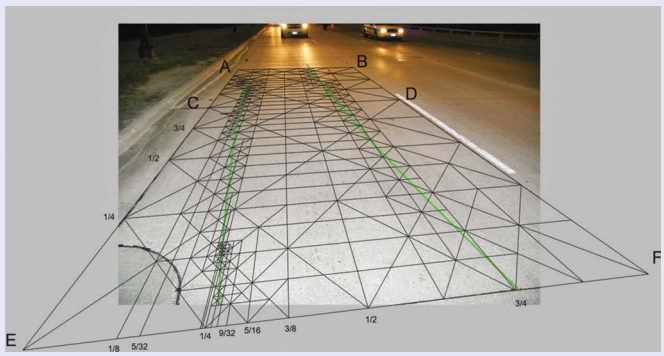


FIGURE 21.91 A final grid can be printed as part of the evidence file, documenting the localization process.

(From A. Borchers.)

When using the natural grid method, the actual length of the sides becomes important, in that the distances must be calculated. In Figure 21.92, fractions of distance on Line EF and CE are marked. The right tire mark crosses Line EF at approximately three-fourths of the width of the line. Knowing the length of that line and multiplying it by 0.750 gives the approximate distance the mark is from Point E. If this were the only photograph being examined with this process, the Y value of Line CE could be given the value of 0. When using perspective grids, the base unit is the dimension of the grid you added to the scene. That grid can be subdivided into halves and quarters, which for a 1- or 2-foot grid translates to 12, 6, and 3 inches—relatively easy dimensions to work with and calculate.

The natural grids used here are easily subdivided up to seven times when working with a computer screen (e.g., 1/2, 1/4, 1/8, 1/16, 1/32, 1/64, and 1/128, or 0.0078 of the grid side). For a 15-foot rectangle side, that equates to approximately 0.11 feet. Recall that 1 inch is approximately 0.083 feet, so this method is reasonably close to within inches. With the traditional method of printing a photo and working with a pencil and ruler, the photo would need to be quite large to achieve the same precision. Given the number of photos involved in this case requiring analysis and the number of points to be determined, a spreadsheet was created for each photo to calculate the coordinates of each point in relation to known positions within the scene.

However, this is a large scene, and Point E is nearly 80 feet south of the reference point (R/P) identified by the original responding officers. Therefore, this project uses a large negative Y value for Point E. The reference point or measurement origin is a survey mark imprinted in the concrete (202 + 100) near the rest positions of both vehicles. Normally, a reference point can be the intersection of extended curb lines, a relatively permanent feature like a power pole, light pole, fire hydrant, or sewer/utility/manhole cover that is unlikely to change and can be relocated easily should future measurements be needed.

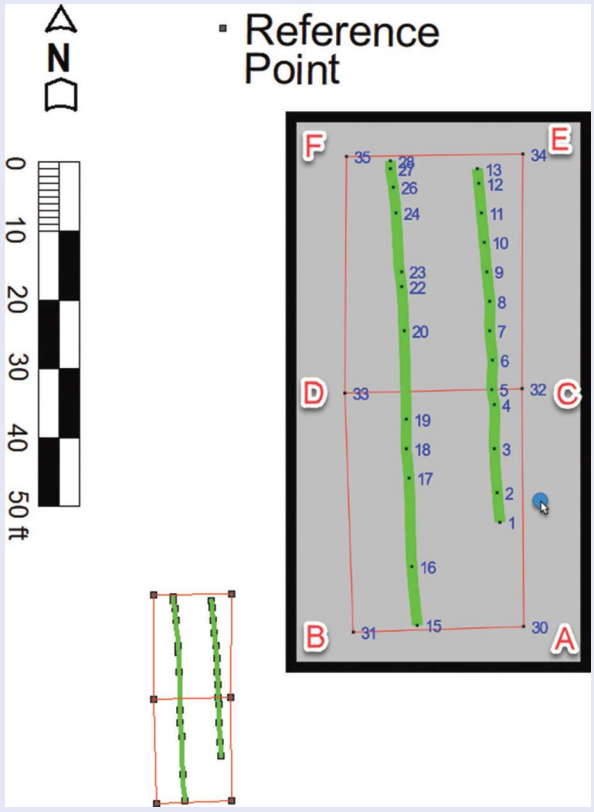


FIGURE 21.92 CAD plotted tire mark points to scale with close-up inset (red natural grid outline.) Points 1–13 and 15–28 are the tire-mark points calculated from the photographs. Points 30–35 represent the known locations A–F.

(From A. Borchers.)

A minimum of 10 coordinate points for each tire mark were located and calculated for this image and added to a scale diagram (Figure 21.92). While potentially not as accurate as measurements taken during an original scene investigation, they are sufficiently precise for reconstruction purposes. The start of the left tire mark was

documented by the initial investigators as being (–3.25, –106) with respect to the curb. The location as calculated in this process is (–0.19, –105.5) with respect to the AC gridline. These points correspond well enough to one another to be considered accurate.

When the photograph analysis is complete and the approximate impact location determined, the post-impact vehicle travel distances can be calculated, as well as the initial post-impact speeds for each vehicle. Using conservation of linear momentum and cross-checked with crush and kinetic energy calculations, the speed of the SUV at impact was found to be approximately 45 mph, the roadway speed limit. Further interviews with the witness revealed that his statement was based only on his seeing a small part of the collision and making incorrect assumptions of what happened. With recklessness on the part of the SUV driver ruled out, only the fact that he was driving while intoxicated remained. This significant detail still merited a prison sentence, albeit one less severe than for reckless homicide.

NOTES

1. Technical Working Group on Crime Scene Investigation, *Crime Scene Investigation, A Guide for Law Enforcement*, U.S. Department of Justice, Washington, DC, 20531, Jan 2000, p. 1.
2. *State v. Miller*, 43 Oregon 325.
3. *People v. Muller*, 32 Hun 209; *Barnes v. Ingalls*, 39 Ala.
4. Ill. App. 398; 31 Wis. 512; 32 NY. Supp. 702.
5. *United States v. Clayton*, 643 F.2d 1071, 1074 (C.A. 5, 1981).
6. *Green v. Terwilliger*, 56 Fed. Rep. 384; *Locke v. Sioux City, etc., R. Co.,* 46 Iowa, 109; *Goldsboro v. Central R. Co.,* 60 N.J. Law, 49; *Crane v. Horton*, 5 Wash. 479, *Bruce v. Beall*, 99 Tenn. 303; 81 Cal. 408; 83 N.Y. 464.
7. *Saturn Manufacturing, Inc. v. Williams Patent Crusher and Pulverizer Company*, 713 F.2d 1347, 1357 (C.A. 8, 1983).
8. *Riksem v. Hollister*, 96 Idaho 15, 523 P. 2d 1361 (1974) and *Southeastern Engineering & Mfg Co v. Lyda*, 100 Ga. App. 208, 110 S.E.2d 550 (1959).
9. *Keyes v. State*, 122 Ind. 527; *Blair v. Pelham*, 118 Mass. 420; *Cowley v. People*, 83 N.Y. 464.
10. Swanson, Charles, Chamelin, Neil C., and Territo, Leonard, *Criminal Investigation*, 5th ed., New York, NY: McGraw-Hill, 1992.
11. *FBI Handbook of Forensic Services.* https://www.fbi.gov/file-repository/handbook-of-forensic-services-pdf.pdf/view accessed on March 25, 2021.

11a. Deceased victim standards are obtained at the postmortem examination. Living victim standards should be collected by a medical professional in a proper setting.

12. California Department of Justice, Documentation of Shoe and Tire Impression Evidence. Physical Evidence Bulletin, PEB 23 (Rev. '98) http://files.crimescenedb.com/pdf/CAimpression.pdf accessed March 25, 2021.

12a. With the sensitivity of current DNA analysis, tools used should be new, individually cleaned and sterilized before use.

13. Lee, H.C., "Identification and Grouping of Bloodstains," in *Forensic Science Handbook*, ed. R. Saferstein, Englewood Cliffs, NJ: Prentice Hall, 1982.
14. Scott, S. Elaine, "Bloodstain Pattern Analysis – Five Years Later," juried paper presented at the Southern Association of Forensic Scientists, September 18, 1987, Atlanta, Georgia.
15. *People v. Hobley*, 159 Ill 2d 272 (1994).
16. Baker, J. Stannard, Perspective Grid for Photographic Mapping of Evidence, Traffic Institute, Northwestern University, Evanston, Illinois 1977.
17. Hyzer, William G., "Perspective Grid Photogrammetry, Photomethods, Vol. 25, No. 7, July 1982, p. 14.
18. Hyzer, William G., "The use of Circular Scales in the Perspective Grid Technique of Making Photographic Measurements," Journal of Forensic Sciences, JFSCA, Vol. 31, No. 1, Jan. 1986, pp. 20–26.



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22 Aerial Coverage from Light Planes and Helicopters

Robert Feuerstein

CONTENTS

Aerial Photography 453
Clothing to Wear 453
Time of Day and Weather Conditions 455
Determine What Angles to Work from Before Takeoff 455
Look Out for Rotor Blades in Photographs 457
General Camera Settings 457
What Camera Equipment Is Required? 457
Batteries and Memory Cards 457
Using Video 457
Make 3-D Displays 457
Orienting the Photographs 458
Using a Helicopter for Surveillance Photos 458
Photos for Court 458
Notes 458

AERIAL PHOTOGRAPHY

Aerial photography is useful for both surveillance and for court evidence. It can be photos taken from a helicopter, a small fixed-wing aircraft, or a cherry picker or even from a tall building. (Drones are also discussed in Chapter 23.) A helicopter is most often the best choice for capturing handheld aerial photos and videos, but other options will allow the necessary work without the expense of helicopter rental.

In a case I photographed for the Los Angeles, San Fernando Valley Courthouse, two gangs had fought and killed each other at two major roadway intersections. I used a cherry picker instead of a helicopter to capture the photographs necessary for the attorney's use for documentation. He used them in court to ask the eyewitnesses to point out where they thought the incidents occurred.

Much of the following information covers helicopter photography and assumes the reader has the necessary basic photographic skills. However, it is also applicable to any type of aerial photography.

To prepare for photographing from a helicopter, there are several necessary things to consider in addition to the choice of photographic equipment, including:

1. Wearing appropriate clothing
2. The time of day for capture
   a. Is it important to capture the documentary images at the same time of day as the incident in question was supposed to have occurred? Shadows on the ground captured from an aerial platform will hide important landforms on a sunny day
3. Weather conditions (consider local weather patterns and be cognizant of expectations)

Clothing to Wear

While working for the Los Angeles County District Attorney's office, I was asked to capture aerial photographs of two home locations, one in the San Fernando Valley and the other in Beverly Hills. They were the houses of Joseph Lyle Menéndez and Erik Galen Menéndez, brothers from Beverly Hills who were later convicted in a high-profile criminal trial in 1994 for the 1989 murder of their wealthy parents. The day before the scheduled flight, I contacted the sheriff's Aero Bureau to discuss the upcoming weather and if I would be able to fly the mission with or without the doors closed or removed on my side of the helicopter. The flight was a go, and I wondered if it would be advisable for me to wear a windbreaker, as the doors would be off. The temperature at 2000 feet differs markedly from ground-level temperature. With two locations to document, I needed to consider the difference between Beverly Hills and San Fernando Valley temperatures. I decided I did indeed need the windbreaker (see Figure 22.1).

When taking a flight, you have many choices of clothing, including but not limited to:

1. Jumpsuits
2. Heavy jackets
3. Lightweight jackets
4. No jacket
5. Pants with lots of pockets (cargo pants)
6. Photography vests with lots of pockets



FIGURE 22.1 This photo shows how quickly and how short a distance it takes to go a couple of thousand feet in the air with a helicopter.



FIGURE 22.2 Two gangs had fought and killed each other at two major roadway intersections.



FIGURE 22.3 Determine the time of day necessary for the project before hiring the aircraft!

You must be able to quickly and easily access any needed equipment while belted into a restricted area. Consider the weight of clothing and its design because you do not want your clothing too loose and flapping in the wind when there are no doors on the helicopter or aircraft.

Remember you will probably be wearing a hat, headphones, and possibly sunglasses while capturing the images. If the camera to use is not convenient under those circumstances, it may be best to change to different equipment.

Depending on where you work and the time of year, as well as the specific location of the shoot, it is wise to check with your pilot or ground crew the day before the flight about your choices of necessary clothing.

Time of Day and Weather Conditions

In the case of the Menéndez brothers, the house in Beverly Hills sat at an elevation of 259 feet,[1] and smog or haze could be expected at that location, time of year, and altitude. To proceed to the other location in the San Fernando Valley, we would be flying over Mount Lee, where the "Hollywood" sign is located, at an elevation of 1708 feet.[2] At the area of the house in the San Fernando Valley, elevation varies from 600 to 1200 feet.[3] Because the mountain range separates the two locations, the expected weather patterns are very different. The haze or fog in Beverly Hills usually occurs early morning up to 11:00 a.m., and the haze in the San Fernando Valley is usually late afternoon, after 4:00 p.m. at that time of year.

The time of day and the sun position are important factors to consider when attempting the capture of ground details requiring shadows to be seen or not. For example, capturing images of tire tracks from directly overhead (90 degrees) with the sun overhead will not allow the necessary detail. The angle of the light needs to be planned, and the angle of the image is then necessary to be captured from an appropriate aircraft to ground angle to bring out the detail, usually somewhere about 35 to 45 degrees.

Because haze or fog causes contrast and clarity issues at any altitude, they need to be considered along with time of day and angle of light. It could be necessary to reschedule the flight depending on the weather and impending need (see Figure 22.3).

Determine What Angles to Work from Before Takeoff

The two angles used most often in any aerial photography are:

1. A mostly straight-down view—90 degrees—like looking at a map where the pilot flies a tight radius
2. A more level view to the horizon with an angle of a wider orbit around the subject—35 to 45 degrees

When photographing through an aircraft or crane window, you will need to be cognizant of the reflections from the other windows in the aircraft or platform and their color tint. If those are not taken into consideration, it may ruin the images. It may be advisable to limit angles and use white balance procedures for proper color balance. In the case of

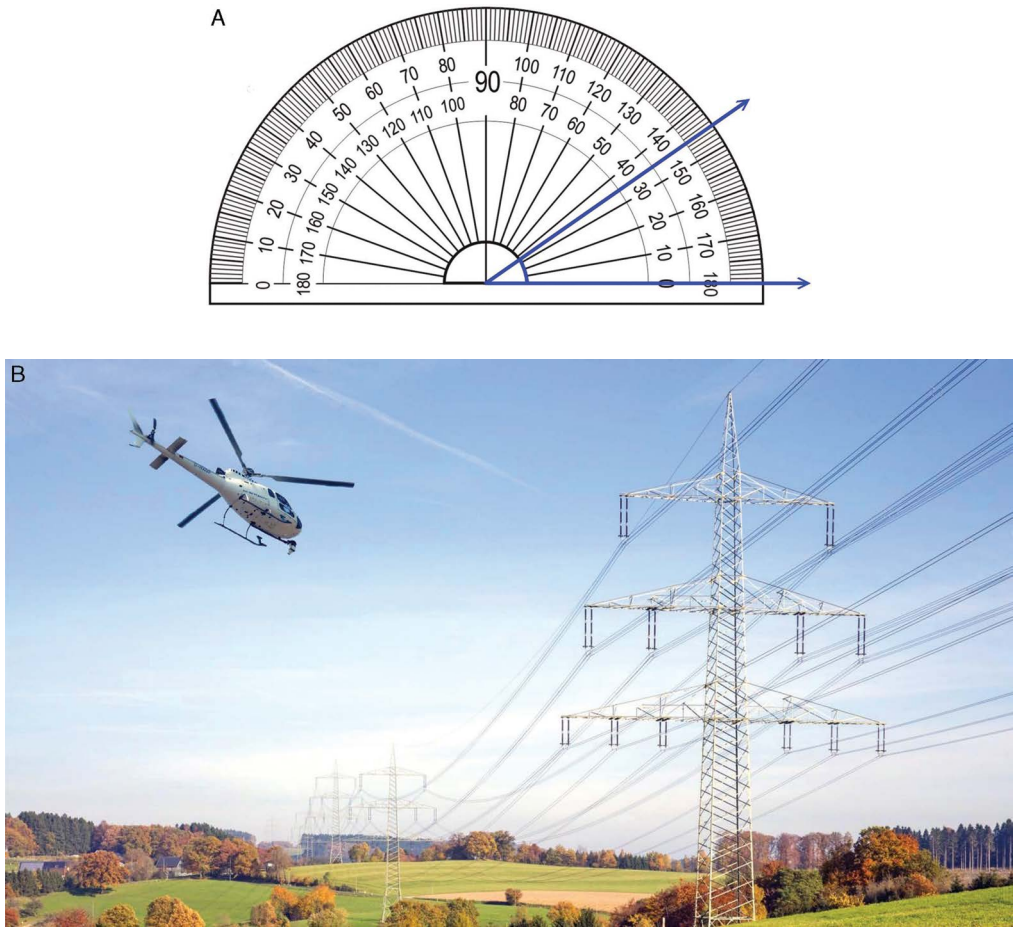


FIGURE 22.4 (A and B) Determine the appropriate angle.

the homes in Beverly Hills, it was necessary to use a tight orbit—90 degrees—with no door. That made worry about color tinting or reflections unnecessary.

TIP:

Use a rubber lens hood on your camera when taking photographs through a window in the interior of an aircraft. This accomplishes two goals. First, if one holds the lens hood against the window when taking images, the reflections from other windows are immaterial. It is protection for the plastic material of the windows. If one holds a serrated filter against the plastic window material and focuses the lens, the serrations will leave scratches in the window that can never be removed. Second, if one is certain the rubber of the hood is held firmly against the plastic window, it means the camera is as close as possible to the window material. This will do the best job of minimizing the distortion caused by photographing through window material at severe angles.

It is critically important to go over the police report or other background material with the attorney or supervisor before leaving for the project and be clear about what images are needed. Use a map or take a ground recon to locate the best angles for the subjects necessary to capture. Any information learned about the area in advance will always be helpful. Most helicopters now include global positioning system (GPS) capabilities, which will assist in finding a specific address or location. Have a plan of action ready before takeoff, as flying time is expensive and limited (see Figure 22.2).

Because of expense, the use of a zoom lens on the camera is often helpful by allowing the pilot to change helicopter altitude less and thus to stay more consistent with the captured images. Staying at constant altitude also uses less flying time and less fuel. Take into consideration the normal viewing of aerial maps. Most people are accustomed to north being at the top, so the captured images should contain landforms referring to specific points of the compass to the north, south, east, and west directions, making it very clear and comfortable for the viewer.

If it is not necessary for the photographs to be used for mapping or location, imaging may be done from any

altitude or direction. But how often does that happen? On some occasions, for instance, for the justification of a search warrant, the need will be to show the scene from all points of the compass: imaging behind buildings, backyard dogs, other obstacles, or dangerous items including hazardous chemicals.

Photographing a chase that covered many blocks, I asked the pilot to do a slip maneuver, flying sideways, so the route was directly below the open helicopter door and flying at a lower altitude starting farther out and ending farther out (overlapping the scene) taking photos of the complete chase.

LOOK OUT FOR ROTOR BLADES IN PHOTOGRAPHS

When photographing from a helicopter you need to consider whether rotor blades will help your photo. You can use a lens angle to never include them in the images, or if the rotor blades become part of the image but they are not necessary, you may simply crop them out. Always refer to the rules in Chapter 6 for the cropping of images. The original images must be kept safe and in the exact way they were first exposed.

GENERAL CAMERA SETTINGS

Use as low an ISO as possible to avoid excessive noise in the photographs. Increase the ISO if necessary to ensure image stability. You may use auto-ISO on most recent cameras and simply set a maximum range. Do not use auto-ISO on an older camera without the ability to set a maximum, as it may increase the ISO to a point where the images are out of focus and unusable. Avoid going higher than ISO 12,500 because most cameras cannot handle the higher ISO well. It will depend on the camera.

For image quality, it is best not to go lower than *f*/8 on the aperture setting because *f*/8 is normally near the sharpest point in a lens and it yields images with a decent approximation of human visual depth of field. On a bright day you may go higher than *f*/8, up to *f*/11 or even higher. To prevent motion blur in the images, due to platform movement or movement of the ground, a faster shutter speed at or above 1/1000 sec is normally required. That is a relatively safe speed to eliminate motion blur, including the whirling rotor blades or the movement of the helicopter in relation to the ground. A general rule with zoom lenses for handheld photography is the shutter speed must be set at a minimum of 2× the focal length. In a helicopter, up to 3× shutter speed may be necessary (3 × 500 mm = 1/1500 shutter speed).

Take a few test photos while still on the ground before going up in the air and then follow up on the settings each time the amount of sky in proportion to the ground changes. Be aware of how much ground or sky is in the viewfinder, because an image with only ground and no sky will need a different exposure setting, as will one with only sky.

What Camera Equipment Is Required?

It is always best to use a digital single-lens reflex (DSLR) or a professional-level mirrorless camera that supports the necessary adjustments for this type of work. Select a camera preferably with at least an ISO range up to 12,500. Then mount a lens with a zoom range of 28 mm to 300 mm. A camera body with a full-frame digital sensor is becoming the standard for this type of work. The use of a zoom lens allows the pilot room for unnecessary altitude adjustments. If necessary, use the zoom and crop in the air for close-ups or wider angles to capture the best image area and the best clarity. It will also save processing time when working on the images later.

Batteries and Memory Cards

Always be aware of the specifications of the camera in use and remember the battery life so you know if you will need extra batteries. Bring as many extra batteries as necessary for any possible occurrence.

Carry at least two extra blank memory cards to separate capture locations or just in case one card is inoperative. Some cameras today have two memory card slots built in and can be used to set up one for video and the other for still images, or both can be used for the same format for more storage space.

Using Video

Most current DSLRs have the ability to capture video[4] as well as still images. There are advantages to using video, including capturing video and frame-grabs from the series while having the pilot perform a slip technique. By flying sideways, so the open door of the helicopter or aircraft stays above the direct line you need to follow, such as a road, the camera movement will be limited. Use this technique for a long police chase, as it yields more comprehensive images than a series of still photos. One of the disadvantages of using video in the helicopter is the movement, making the viewer feel motion sickness. One solution to this problem is to use a stabilized camera system. Also, some helicopters have built-in video systems with stabilization that can be used instead of a handheld camera.

MAKE 3-D DISPLAYS

When the images and video are viewed from the capture in the aircraft, they are going to be strictly 2-D. This shows the viewer the landscape, but not the landforms. If the edge of the roadway drops off steeply or there is a dip in the highway surface, it will be impossible to see in the raw images. However, when capturing the images along a straight line above the scene, every consecutive image will create a stereo pair by using it and the one before or the one after. All that is necessary to view the scene in 3-D is to print

the image pairs and set them up under a 3-D print viewer. This way the landforms are immediately visible.

Orienting the Photographs

Different types of photographs are used at trial. For opening and closing statements or just general information photographs, images captured in any direction may be usable. Photos used for directional orientation in a courtroom need compass points included. Because of the way the photos will be used in the courtroom, specific directions need to be built in to the photographs. Sometimes it is easier for the jury to visualize what is happening by using a map with the photographs inserted and arrows added to point to the visualized location. It is important for court testimony to capture the photographic directions clearly. It is always necessary for the images to be oriented with the map.

Using a Helicopter for Surveillance Photos

See Chapter 15 for more information on this topic. However, there are different types of surveillance photographs. One type shows the judge what is going on at a property for probable cause (in one case, for example, looking for 50-gallon drums holding stolen gasoline). The same photos may be used at a briefing to show the officer team what they are looking for and what they can expect to see. For equipment, use a long lens, 300 mm or 500 mm, and a fast shutter speed. The minimum speed should be 3× the focal length of the lens. This allows flying at higher altitudes without being obviously noticeable. Do not photograph in an orbital pattern because someone might surely spot what you are doing. Do not fly across the property more than twice.

Photos for Court

Aerial photos are used for court in many different scenarios, perhaps a police chase, an auto accident, or the distance between two locations. Before conducting the photo assignment, ask the attorney or officer for the intended image purpose. Are they for a warrant, for background in an opening statement, presenting material facts or closing summation.

In the beginning of the case, photographs are used to illustrate what they want to present in the case. In the middle of the case, photographs are used to show what took place at the time. At the end of the case, they may be used to point out important facts as a review for the judge and/or jury in a very long or complex case. In the Lincoln Savings and Loan Association case,[5] the lawyer asked for the photographer to visit several locations in Orange County and Los Angeles County to photograph where people sat to sign documents. Before each person went into the courtroom to testify, the photographer captured a head and shoulders photo of each of them. These photographs were then used to remind the jury of what each person said and where they sat, because the trial went on for a very long time and there were many witnesses.

NOTES

1. https://en.wikipedia.org/wiki/Beverly_Hills,_California
2. https://en.wikipedia.org/wiki/Mount_Lee
3. https://en.wikipedia.org/wiki/San_Fernando_Valley
4. https://en.wikipedia.org/wiki/Digital_single-lens_reflex_camera
5. https://en.wikipedia.org/wiki/Lincoln_Savings_and_Loan_Association

23 Drone Photography

Abbe L. Lyle and Mark Johnson

CONTENTS

Practical Considerations for becoming a Forensic Drone Pilot 459
Understanding the Rules of Engagement 459
FAA Requirements for Commercial Operation of Unmanned Aircraft Systems 460
Learning to Fly a Drone Safely 464
Drone Photography and Videography Considerations for Forensics 468
23A Forensic Aerial Imagery and Drone Photogrammetry 474
The History of Aerial Imagery 474
Internet Resources for Aerial Imagery 474
Commercial Aerial Image Providers 475
Drone Imaging 475

PRACTICAL CONSIDERATIONS FOR BECOMING A FORENSIC DRONE PILOT

The concept of capturing images from the sky is nothing new. Aerial imaging has been a huge boon in many industries for decades. However, the ability to generate photogrammetric maps using small drones is a fairly recent phenomenon. Other chapters have described the utilization of such information. Prior to addressing any further relevance to forensics, this chapter will first attempt to explain the process allowing individuals to fly a drone professionally to capture images or video. It is important to understand the responsibility of the drone operator. Each country has a different set of rules, and for the purposes of this book, I am concentrating on America. However, once the fundamentals are understood, it is a simple task to check the differing regulations of your specific region of the globe.

UNDERSTANDING THE RULES OF ENGAGEMENT

One only has to put five simple words into a Google search—"how to fly a drone"—and a multitude of options offering differing advice (much of the website order dictated by search engine optimization [SEO] rather than credibility) are instantly available. While the Federal Aviation Authority (FAA) will not be able to teach you how to fly, it has created a useful starting point listing the rules and the reasons behind the rules. My humble advice is this is an excellent launching point. Next, I would suggest adopting the mind-set of a pilot (as opposed to a remote pilot) when you begin studying and then employing your new knowledge as you perfect your flying skills.

Drones, or unmanned aerial vehicles (UAVs), are sharing the airspace with piloted aircraft, and therefore full knowledge of the rules of the sky is essential—moreover, it is the law. Clearly, this book caters to individuals who are extremely knowledgeable in their forensic fields, and I would not presume to sound facile; however, this relatively new technology comes with metaphorical, if not actual, strings attached.

The FAA states (and I will frequently quote from the FAA website) that any aircraft operation in the national airspace (NAS) requires a certified and registered aircraft, a licensed pilot, and operational approval. It is hard for the casual observer to make the leap from a drone that can be bought off the shelf from many popular locations to an airplane, but there it is. In fact, many who should know better break the rules set by the FAA on a daily basis. Approval from a police unit responsible for a case you may be working on does not override the rules set out by the FAA. Rather, the organization has to demonstrate to you that they have the necessary clearance allowing you to fly.

Adequate training requires far-reaching knowledge and not only involves safe drone operation but considerations including location, emergency procedures, and when and where to obtain authorization. I shall make the assumption that if you are reading this chapter, you have either already added a drone to your professional forensic toolbox or are looking into what is involved. I will therefore not cover the differences between commercial and recreational use. The FAA does further dissimilate use between government and civil operations, so there are occasions where your forensic exploits may involve helping law enforcement and working under their Certificate of Waiver or Authorization (COA)—more about this later. As I have mentioned, it is vital to understand that even first responders or organizations aiding with natural disasters or other emergency situations still require clearance. In these situations, approval can often be expedited through the FAA's Special Governmental (SGI) process. Regardless, you must be an existing certified remote pilot.

When it comes to authorization to fly, the Small UAS Rule (14 CFR part 107) is only applicable to drones weighing less

than 55 pounds at takeoff. There is a further requirement for flying unmanned aircraft weighing 55 pounds or more. Operators need to apply for an exemption under the Special Authority for Certain Unmanned Systems. In the early days, this exemption was known as a Section 333 exemption. The FAA website states that the Special Authority for Certain Unmanned Systems (49 U.S.C. § 44807) grants the secretary of transportation the authority to use a risk-based approach to determine whether an airworthiness certificate is required for a drone to operate safely in the NAS. Under this authority, the secretary may grant exemptions to the applicable operating rules, aircraft requirements, and pilot requirements for a specific operation on a case-by-case basis. The Special Authority for Certain Unmanned Systems grants UAS operators safe and legal entry into the NAS, thus discouraging illegal operations and improving safety. It is anticipated that this activity will result in significant economic benefits, and the FAA administrator has identified this as a high-priority project to address demand for civil operation of drones for commercial purposes.

For any type of serious utilization and significant image or video capture, this type of exemption was vital only a few years ago. However, technology has leaped forward, and some of the most useful drones, specifically in our field of interest, are now below the weight limit requirement. Heavier is not always better in this context. The ability to set up in a matter of minutes and capture what is required with the minimum of fuss is certainly a plus in the forensics field. We will cover the technology later, once I have firmly established the importance of obeying the rules!

On that note, it would be difficult to produce a concrete set of rules, as the industry is constantly evolving and new legislation is regularly adopted. I shall attempt to cover the fundamental requirements as set out currently by the FAA and explain why they are so important. There is clear evidence that using drones in your workflow can be extremely useful. However, as I have already mentioned, there are many factors to consider. Trying to obtain a concise understanding of the learning curve and rules allowing and inhibiting flight can be quite challenging. I refer back to the FAA that keeps the drone pilot apprised of current rules and regulations, but many states and local government organizations are making it increasingly difficult for UAS operations.

It is important to remember that the FAA holds exclusive authority for regulating aviation safety. However, cities and municipalities may determine the location of aircraft landing sites, which is where the complications can arise. The Department of Transportation has established a specific UAS Integration Pilot Program (IPP) currently working with the FAA to find optimum ways to involve local jurisdictions in the integration of UAS into the airspace. Unfortunately, the privacy battle continues in America. The Uniform Law Commission (ULC) continues to push for a Tort Law Relating to Drones Act. Without getting into the weeds, state laws could end up seriously complicating commercial operations. However, the involvement of the FAA in administering guidelines has been a huge help when it comes to understanding what is and is not allowed. Indeed, the FAA does not wish to stand in the way of UAS operations and understands these operations can frequently provide critical information for first responders and law enforcement agencies in their discovery process. Perhaps it would be beneficial to examine these requirements.

FAA REQUIREMENTS FOR COMMERCIAL OPERATION OF UNMANNED AIRCRAFT SYSTEMS

First, let's explain the verbiage. The drones to which we are referring are machines capable of taking flight without a pilot strapped to a cockpit seat. In terms of the FAA, these drones are classified as an aircraft. This has many consequences for those wishing to fly. The drone is operated remotely, and many can be preprogrammed for autonomous flight, but there must always be a qualified remote pilot capable of manipulating the controls should a failure occur. For commercial purposes, the pilot must be a certified remote pilot, as defined under 14 CFR Part 107 of the FAA regulations. Every UAS must be registered if it weighs over 55 pounds, regardless of recreational or professional use (see Figure 23.1).

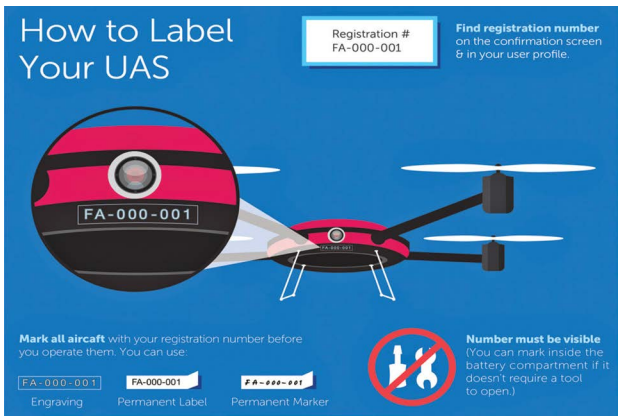


FIGURE 23.1 Instructions on how to register can be found at: www.faa.gov/uas/getting_started/register_drone/.

(Image courtesy of FAA.gov.)

You may hear the terms UAV and UAS. The difference between the two is simple. The registration number must be in plain sight and cannot be hidden in the battery compartment of the drone.

Unmanned Aerial Vehicle (UAV): A remotely operated aerial vehicle. A UAV is simply the vehicle and not the system operating the vehicle.

Unmanned Aircraft System (UAS): Refers to the complete system allowing operation of the UAV. This includes the controller, the UAV, and the complex system allowing communication between the UAV and the controller.

The required test, presented in multiple choice format and timed, is not as arduous as the one for general aviation, but does involve an extensive understanding of ground school, similar to the test taken by individuals wanting to fly a fixed-wing airplane. At present, a practical test is not required, but would be favored by this author. It is incredible to me that an individual is able to obtain a remote pilot certificate without having once flown the UAS.

If you are operating in the NAS under any circumstances, but especially as forensic scientists, I think it important to embrace and accept the language and fully understand the gravity of your undertaking. It is common to hear people reference themselves as Part 107 pilots. Once you hold your certificate, you are considered a remote pilot and not a Part 107 pilot. You do not hear many manned pilots refer to themselves, for example, as 14 CFR Part 61 pilots or operators. This terminology is more than a matter of semantics—it is setting the standard moving forward and separates the professional from the amateur.

As I have already mentioned, the process is not as complicated as it may seem. Presently, the following requirements must be met. I have abbreviated many of them, but the full details can be found on the FAA.gov website appertaining to UAV use (https://www.faa.gov/uas/).

To become a remote pilot, you must:

- Be at least 16 years old; be able to read, speak, write, and understand English; and be in a physical and mental condition to safely operate a small UAS.
- Pass the initial aeronautical knowledge exam at an FAA-approved knowledge-testing center. The certificate must be easily accessible by the remote pilot during all UAS operations. Certificate holders must pass a recurrent knowledge test every two years.

This chapter is not designed as a study guide for the test, but rather a synopsis of what you will be expected to understand. The initial aeronautical knowledge test requires specific study in the following areas:

a. *Applicable regulations relating to UAS rating privileges, limitations, and flight operation*. This relates specifically to what is and is not allowed under Part 107 rules when you are flying for commercial purposes. These rules are critical. They can be downloaded in PDF form directly from the FAA website. I will also cover these in a little more detail later.
b. *Airspace classification and operating requirements and flight restrictions affecting UAV operation*. Airspace classification is one of the hardest areas of study for those with no knowledge of the topic. Grasping the idea that airspace is regulatory and nonregulatory and then controlled, uncontrolled, special use, and other airspace rather crushes the concept of the great wide open. Once you begin to delve into airspace, it may still take a while to make sense! Certainly, understanding the importance of airspace surrounding busy airports is a relative no-brainer, but it becomes a little more complex when you introduce the idea of uncontrolled airspace, where it may seem logical it would be safe to fly your drone. I am scratching the surface but trying to indicate the subject is fraught with potential dangers—its importance cannot be emphasized enough. While we are considering this section, it may take a while to get to grips with reading an aeronautical chart. There will be many questions on this topic. The recurrent test may have fewer questions but does drill down on the ability to read an aeronautical chart to answer a question. For practical purposes, always check the airspace surrounding your proposed operation. There are several mobile apps for help with this.
c. *Aviation weather sources and effects of weather on UAV performance*. Weather is a pretty hefty chapter in any study guide, and there are a few concepts to struggle with, such as reading weather reports. One important practical consideration is the role weather plays on general drone performance. Many a new drone pilot has run out of battery power over water because of lack of attention to wind direction and speed. Moderate to strong winds can affect the speed and flight path. As you learn the material the FAA wishes you to cover, it may cross your mind that a lot of this information concerns aircraft flying considerably higher than the drone, but awareness of weather and performance cannot be emphasized enough.
d. *Small unmanned aircraft loading and performance*. It is helpful to understand the relationship between load and performance. The section also covers load factors and density altitude.
e. *Emergency procedures*. This topic may seem self-explanatory but applies to specific requirements, such as preflight inspections and the knowledge that as the pilot in command (PIC) during an emergency, you are permitted to deviate from any part of 14 CFR Part 107. If asked by the FAA, it is necessary to report any emergency.

f. *Crew resource management (CRM).* While there is clearly not a flight crew onboard, remote operation for commercial purposes often requires a team of individuals. In 1979, NASA established the necessity of CRM in analyzing and detecting reasons for air traffic incidents. The FAA takes CRM very seriously, and there are often several questions on the topic. This topic is extremely helpful out in the field. Aeronautical decision-making and good judgment are certainly relevant for remote pilots.
g. *Radio communication procedures.* The required knowledge goes far beyond a civilian understanding of radio communication. You will be required to know best operating practices and procedures for use when aircraft are approaching or departing airports without an operating control tower, broadcast procedures, and the correct International Civil Aviation Organization (ICAO) phonetic alphabet.
h. *Determining the performance of small unmanned aircraft.* The FAA considers it vital that you understand the UAV's capabilities and limitations. Further knowledge of the effect of humidity and temperature on density is required.
i. *Physiological effects of drugs and alcohol on pilot performance.* The study section is surprisingly long and detailed, but provides a healthy revision on how drugs and alcohol can affect your decision-making process.
j. *Aeronautical decision-making (ADM) and judgment.* ADM and CRM (see earlier) are vital every time you go out to fly a mission. ADM covers good pilot judgment and the personal attitudes critical to safe flight. The risk management process is also a useful tool when going out to fly on critical forensic missions. Often, as remote pilots, we are flying on our own, so single-pilot resource management may be more relevant and is also covered.
k. *Airport operations* may seem unnecessary but if you are planning on flying near an airport (with sufficient clearance), it is important to understand how airports operate. This section also covers latitude and longitude.
l. *Maintenance and preflight inspection procedures.*

Once you pass, a Transportation Security Administration (TSA) background test will be performed. It is necessary to complete FAA Form 8710-13 for a remote pilot certificate (FAA Airman Certificate and/or Rating Application) using the electronic FAA Integrated Airman Certificate and/or Rating Application system (IACRA). Once the background check is completed, instructions will be sent via email from IACRA for printing a copy of the temporary remote pilot certificate. A permanent remote pilot certificate will be sent via USPS mail once all other FAA-internal processing is complete.

Manned pilots follow a simpler route and require study in the following areas:

a. Applicable regulations relating to small UAS rating privileges, limitations, and flight operation
b. Effects of weather on small unmanned aircraft performance
c. Small unmanned aircraft loading and performance
d. Emergency procedures
e. CRM
f. Determining the performance of small unmanned aircraft
g. Maintenance and preflight inspection procedures

They must also complete FAA Form 8710-13 (FAA Airman Certificate and/or Rating Application for a remote pilot certificate). Once the applicant's identity is validated via the local Flight Standards District Office (FSDO), a temporary airman certificate will be issued. A permanent remote pilot certificate will be sent via mail once all other FAA-internal processing is complete.

Remote pilots are required to complete a recurrent training course or pass a recurrent knowledge test within 24 calendar months to continue to exercise the privileges of their remote pilot certificates.

If you are a drone and manned pilot (Part 61 qualified) you can either:

1. Retake the recurrent Part 107 knowledge test at a testing facility
2. Take an online training course on the FAA Safety Team (FAAST) team website
    - If you are a drone pilot and do not hold a Part 61 (manned pilot) qualification, you must take the initial or recurrent Part 107 knowledge test at a testing facility. The difference between the initial and recurrent knowledge test/online training course is the length. Both versions meet the requirements to maintain your remote pilot certificate. However, you will not be issued a new certificate and will need to keep the recurrent paperwork with your initial certificate and have it available upon request.

I cannot stress enough the benefit of referring to the official FAA website. A Google search can also lead you down a few rabbit holes here. Make sure the website you click on takes you to a .gov site. Since most people are aware of the fact that .com is not going to take you to the source, some companies have taken up the .org domain, and it can be misleading. There is *never* a requirement to pay for the study guides on the government site. Since many companies have surfaced offering not only ground school but also flight training, I believe it is helpful to establish exactly what you need to know from the source. The FAA provides helpful free links to study guides for the exam. I would highly recommend taking a course from a ground school

catering to those wanting to fly fixed-wing aircraft or from a professional pilot offering training. Some of the content is overwhelming if you are coming at it with little or no knowledge at all.

The specific UAS rules, or Part 107 FAA regulations, can often create challenges in the forensics field in particular. Documenting a scene in an area where flight is not permitted without a waiver can be extremely frustrating, and there can be a temptation to ignore the regulations. The good news is that as the waiver process becomes more automated, it is simpler for qualified remote pilots to conduct business.

I promised to go into a little more depth regarding Part 107 as it stands at the time of this publication. As I have frequently mentioned, the full operating requirements under the rule can be found on the FAA website. These rules will obviously need to be second nature prior to conducting any type of commercial operation, but in broad terms, they can be broken up into two sections. It is imperative you review the full documentation, as I am simply providing a synopsis.

Operational limitations

- Unmanned aircraft must weigh less than 55 pounds
- Visual line-of-sight (VLOS) only—may also use a visual observer
- No operation over people not directly participating
- Daylight operations or civil twilight with anticollision lighting
- Yield right of way to other aircraft
- "First Person View (FPV)" cannot satisfy the "see and avoid" requirement
- Maximum ground speed of 100 mph (87 knots)
- Maximum altitude of 400 feet above ground level (AGL), or if operating around a structure higher than 400 feet AGL, remain within 400 feet horizontally and above the structure
- Minimum weather visibility of 3 miles from control station
- Operations in Class B, C, D, and E airspace are allowed with the required air traffic control (ATC) permission
- Operations in Class G airspace are allowed without ATC permission
- No person may act as an Remote Pilot in Command (RPC) or Visual Observer (VO) for more than one unmanned operation at one time
- No operations from a moving aircraft
- No operations from a moving vehicle unless the operation is over a sparsely populated area
- No careless or reckless operations
- No carriage of hazardous materials
- Preflight inspection required by the RPC
- No operation if there is any indication of an operator mental or physical condition that might interfere with the safe operation of the small UAS
- Foreign registered small unmanned aircraft are allowed to operate under Part 107 if they satisfy the requirements of Part 375
- External load operations are allowed if the object being carried by the unmanned aircraft is securely attached and does not adversely affect the flight characteristics or controllability of the aircraft

It is worth noting that many of the restrictions can be lifted if the applicant demonstrates the operation can be safely conducted under the terms of a certificate of waiver.

Remote PIC certification and responsibilities:

- Establishes a remote PIC position
- Holds a remote pilot airman certificate with a small UAS rating or is under the supervision of a person holding said certificate
- Fulfills the qualifications necessary to obtain certification (we have covered these earlier)
- Until international standards are developed, foreign certified UAS pilots will be required to obtain an FAA-issued remote pilot certificate with a small UAS rating
- A remote PIC must:
  - Make available to the FAA, upon request, the small UAS for inspection
  - Report to the FAA within 10 days of any operation that results in at least serious injury, loss of consciousness, or property damage of at least $500
  - Conduct a preflight inspection. FAA airworthiness certification is not required
  - Ensure the small unmanned aircraft complies with registration requirements
  - A remote PIC may deviate from the requirements of this rule in response to an in-flight emergency

Going beyond the basics, once you have truly earned your wings, new challenges need to be addressed. The small UAS rule (14 CFR Part 107) clearly defines the legalities. I promised to cover the use of waivers in more detail. Your operations may frequently require the use of a waiver to deviate from certain rules. The FAA waiver will allow UAS operation to take place in the following circumstances if a waiver is granted and the operation is deemed to be safe:

- Operation from a moving vehicle or aircraft (§ 107.25)
- Daylight operation (§ 107.29)
- VLOS aircraft operation (§ 107.31)
- Visual observer (§ 107.33)
- Operation of multiple small UASs (§ 107.35)
- Yielding the right of way (§ 107.37(a))
- Operation over people (§ 107.39)
- Operation in certain airspace (§ 107.41)
- Operating limitations for small unmanned aircraft (§ 107.51)

The past few years have clearly been challenging for drone operators in our field in terms of the amount of time it can potentially take to be granted either a one-time use or blanket waiver, but the process is more straightforward than it used to be. The FAA is aware of the need to process waivers quickly for emergency operations and has an SGI process for the following situations:

- Firefighting
- Search and rescue
- Law enforcement
- Utility or other critical infrastructure restoration
- incident awareness and analysis
- Damage assessments supporting disaster recovery–related insurance claims
- Media coverage providing crucial information to the public

These special waivers may be granted within an hour or sooner. All of the required forms can be found on the FAA.gov/UAS website. Government entities are also able to either fly under the small UAS rule or obtain a blanket public COA. More details can be found on the website also.

The FAA has also set up the UAS Data Exchange. The agency aims to support multiple partnerships regarding airspace moving forward. It is beginning with the Low Altitude Authorization and Notification Capability (LAANC). LAANC provides "access to controlled airspace near airports through near real-time processing of authorizations below approved altitudes in controlled airspace." At the time of writing, only a handful of LAANC UAS service suppliers have been approved, but as the program gains momentum, the prediction is this number will grow. The data exchange website (https://www.faa.gov/uas/programs_partnerships/data_exchange/) provides detailed information as well as current UAS facility maps.

So, I hope I have, with the help of the FAA, left you with an understanding as to why so much training and knowledge are required. I first learned of the importance of airspace when I decided to become a private pilot back in 2001. I remember being overwhelmed by the necessary rules and regulations. I learned only too well how it can go horribly awry when I approached the flight school preparing for a lesson, only to learn of the horrific terrorist attacks that would change our forays into the sky forever, as a passenger or pilot. Once I began my instrument rating, the depth of knowledge necessary to fly using nothing but the available instruments on my panel (and a shield disabling my view of the sky) was, frankly, staggering. Having to read back to the control tower detailed instructions and speak clearly, accurately, and quickly without taking up too much time on the airwaves made me break out into a cold sweat. The mere idea that I may be interrupting the "heavies" as they announced their intent certainly drummed home the concept of the vast highway in the sky. Remember, all these manned aircraft have to land, and by necessity, fly low enough to potentially encounter problems with the small, mostly plastic computers we are launching in the sky.

Each day individuals purchase drones and attempt to fly without even so much as glancing at the manual. Pictures are posted clearly violating many laws, and frustration abounds for those who understand the gravity of the undertaking. Even those who read the manual are only getting a thumbnail sketch of the information required to fly responsibly and reduce the risks of pilot error caused by ignorance. The good news is commercial use is moving beyond the early adoption phase. There is a more widespread understanding about the rules of engagement. The year 2018 saw a marked increase in the number of FAA-certified remote pilots. But the number is still relatively low at around 120,000.

LEARNING TO FLY A DRONE SAFELY

As commercial users, we must be educated and knowledgeable about how our drone operates. Let me take a few paragraphs to explain how the system works, why updates are vital, and why things can go wrong. A colleague of mine frequently opens his presentations with a quote from Stanley Kubrick's science fiction film, *2001: A Space Odyssey*. The character David Bowman requests that HAL, the computer on the U.S. spacecraft Discovery One, open the pod bay doors, to which the computer replies. "I'm sorry, Dave. I'm afraid I can't do that." You may not understand the inference here, but this is a witty and correct analogy of what can go wrong once you have launched your airborne computer. We are reliant upon technology, and we all know technology can go wrong. Even as I sit at this computer and type my words, I am conscious of the need to back everything up in order not to lose my work. Drone technology is progressing at an unbelievable rate and enables us to conduct our forensic work in ways we never thought imaginable. But a fundamental understanding of operation is absolutely vital if we are to even begin to comprehend what could potentially be going awry with the system as we launch into the sky.

In order for these fabulous flying computers to operate as perfectly as they can, the inertial measurement unit (IMU), gyroscopic stabilization, and flight controller technologies are essential. The equipment we favor has three-axis attitude control (pitch, yaw, and roll), as well as a positional hold to help keep the UAV in position anywhere in 3-D space. Gyro stabilization technology is one of the most important components, allowing the drone to fly extremely smoothly, even in strong winds and gusts. Moreover, the built-in global positioning system (GPS) tracks the drone spatially. Flight stabilization, along with waypoint navigation, is extremely useful and allows us to produce top-quality 2-D and 3-D photogrammetry. The gimbal stabilization unit attached to the camera greatly reduces vibration. The stabilization quality is remarkable, allowing long exposures and considerably smoother aerial video.

Movement of the remote-control sticks sends signals to the central flight controller (CFC), which then delivers

instructions to the electronic speed controllers (ESCs) for each motor, directing each motor to increase or decrease speed. Additionally, the CFC takes information from the IMU, gyroscope, GPS modules, and on some drones, obstacle detection sensors to stabilize flight, log positions, and attitude and avoid obstacles when so equipped. Most flight controllers encompass the IMU, GPS, and gyroscope (and other features) to control flight and stability. Often there are dual IMUs for a crude form of redundancy and even safety features like a return to home button, which I would suggest you do not rely upon. The accelerometers detect the current rate of acceleration by sensing the acceleration of gravity using the same technology behind gyroscopes. The gyroscopes detect changes in rotation. Some IMUs have a magnetometer to help prevent the drone from drifting. In strong wind, some drifting will inevitably occur, which is another reason why you need to fly the drone and not let the drone fly you!

A bit about the ESCs—the ESC circuit in the motor is used to vary speed, direction, and braking. Each brushless motor attached to the propeller in each arm of the drone is dependent upon an ESC. The ESCs take instructions from the flight controller and use battery power to make each brushless motor spin. The drone is dependent upon the variable speed of the motors driving the propellers. The wide variation of thrust and control in motor/prop speed allows the drone to fly.

All our drones use brushless electric motors. This efficient motor allows for less battery drain and therefore more flying time, as well as being much less prone to moisture and wear. Most important, though, is the stability. I cannot emphasize enough how the relentless push for stability has been a game changer for all of us. These brushless motors, along with the gimbal stabilization unit attached to the camera gimbal, greatly help reduce vibration as they generate much less oscillation than the original belt-driven gimbal.

Understanding how the drone flies is a somewhat complicated undertaking, but a little study goes a long way. Similarly, it is vital to understand fully the flight application you use to control your drone and to monitor imagery during flight, as well as any software used to work with or produce work product from the imagery taken. For example, there will be times when your video feed may drop and your screen goes blank, but this does not mean you have lost control of the drone. Possible application software glitches caused us to make a company-wide decision to fly most of our missions manually. We do not want to rely upon an algorithm suggesting the number of images needed to complete a mapping mission (even though there is some room for user input). For instance, we can choose to have much greater overlap for portions of an image, rather than a uniform number over the whole mission. Also, we are able to wait for traffic to clear so we can capture roadway images with the minimum amount of cleanup necessary and make sure important landmarks or physical evidence is not obscured or blurred by passing traffic. Similarly, we do not set our cameras on auto if we really know what we are doing. When software engineers set out to enable a drone to fly an autonomous flight, do you think they took every possible wind condition into account? If autonomous flight is attempted, it is important you know exactly how to take over control of your drone to mitigate any type of disaster.

If you want to get up to speed quickly and be in a position to start using this technology for work, I strongly suggest taking a course combining ground school with practical flying lessons. Integrating your ground school knowledge with flying time is an ideal way to become immersed in this technology. You will establish your limits extremely quickly and learn if you need to hire a professional to fly your missions or if this is something you want to do yourself. This may seem an odd statement, but during my time as an instructor, I have had many accomplished photographers, including a few from National Geographic who were keen to fly drones in remote areas. Some found out fairly quickly that while they knew how to set their cameras, they were not cut out for the practical flying part of the operation. There is no judgment from me. I am a self-professed careful flyer who will not push myself beyond the boundaries of my comfort and ability. I frequently have others fly missions I personally feel present potential dangers and are pushing the boundaries. When flying over a traffic accident or crime scene, there is a lot going on. This can also be true of a busy intersection you may be flying after the fact. It is easy to get caught up in the operation and not stop to evaluate all the potential hazards. I would be lying if I said I had never had an incident or had to land because I felt my drone was operating less than optimally. We tend to take two or three drones with us to cover this possibility.

The appearance of many UAVs on the market can be deceptive, akin to a wolf in sheep's clothing. Don't let appearances fool you. These small flying computers offer great opportunity, but also have the potential to get you into a lot of hot water. The small but effective digital cameras attached to the UAV give us the opportunity to view our surroundings from a few to several hundred feet off the ground with relative ease, and a relatively small capital investment. However, inherent risks are involved and careful risk assessment is vital.

When flying a plane or driving a car, we know we need specific training in order to be successful and not put any lives at risk. I spent many an hour in deserted parking lots teaching my progeny how to conduct a three-point turn or parallel park. Similarly, it is useful to take your UAV out to a deserted spot where onlookers will not pester you and practice your standard maneuvers. For the purpose of practicing, I would also recommend paying no attention to your camera, but rather concentrating on how you see your UAV responding to the instructions from the controller. This skill will prove extremely useful should you find yourself unsure of how your UAV is reacting to a command. Once you have a feel for flight, it is then time to pay attention to the camera and combine the two abilities. More importantly,

concentrating on watching the drone in real time rather than on the screen means you will remember to look up and be aware of the location of your drone in relation to you.

Unlike my children, when I learned to drive in the UK, I learned on a manual transmission automobile. After a few lessons, it became second nature to depress the clutch with my left foot while using my right foot for the brake or gas. I knew to shift the gear up as necessary to maintain a smooth ride, save on fuel, and not overtax the engine. I also learned that overacceleration with the clutch partially engaged would take me nowhere fast and wear out the engine. I painfully remember the grinding sound when my car was not in gear. I do have a point to make here! In the early days we would teach our students to fly a drone in manual mode while tethered to an instructor. Manual mode means you really have to learn to fly. The drone will not automatically hover in place and will start falling or drifting with the wind. We do this less and less as the drones become more advanced, but if you really want to be proficient, I highly recommend this type of flight training. Modern systems make it much easier to press a button and engage the drone in "return to home" state, but this "easy" button is not always going to work. It is vital for a professional remote pilot to understand how the drone flies and how to mitigate potentially dangerous scenarios. Understanding the different flight modes and when to use them could get you out of a scrape or two.

Flying a drone would not seem to be particularly tricky. However, flying safely with a full understanding of what you and the drone are capable of is another matter entirely. There is a reason the FAA requires a study of pilot attitudes. As an instructor, I have witnessed many states of dangerous attitudes in pilots. In most instances I have been able to highlight the behavior, but sometimes there is denial, or even anger, that I am questioning the ability of the PIC. These students make the most dangerous pilots. While they are capable of passing a test, they are incapable of admitting they are unaware of what went wrong and where the drone is located. If you are aware you display these tendencies when flying, try to correct them and remove your ego from the situation. Conversely, don't give up when you feel as though you have lost control. This is another pilot attitude that can get you into trouble.

This section is not intended to be a manual on how to fly, but rather point you in the right direction (forgive the pun). There are plenty of places to go for help. What I will mention are the main areas tending to present challenges. I will make the assumption that you are acquainted with the controls and know which stick operates which action. I have compiled the following areas of challenge from the countless hours I have spent teaching. On a personal note, when it comes to stick control, I recount this story for my students. My father was a major player in the aviation industry in the United Kingdom, and he received a CBE from the queen for his services to the airlines. He learned to fly on a Tiger Moth, was a bomber pilot during WW2, and flew during the Berlin Airlift. He was truly my hero, and nothing gave me more pleasure than learning to fly so I could take him flying. When I went for my first flying lesson, he imparted a small but useful thought I shall never forget and that I pass on to all my students. The yoke is the instrument used in many fixed-wing aircraft to control the attitude in both pitch and roll. He said "Abbe, treat the yoke like you are milking a mouse, no sudden or vigorous movement is needed." Whether you pinch or thumb your control sticks, think of them like the yoke of a plane and heed my father's advice!

A large challenge for all of us is depth perception. This issue does not go away—you simply learn skills to help evaluate your distance from potential obstacles. It is simple to check your distance and height from the controller, but what is a good rule of thumb for your distance from those wires or trees or buildings? I can give you a few pointers, but nothing replaces stick time. You often hear of people flying into buildings or hitting trees. I guarantee, most of these instances were due to pilot error and not some sudden problem in communication between the UAV and the controller. The distance from you to your drone is obvious as you take off and hover for a moment, but once you are farther away, it is not so simple. I often have my students fly over bright cones. This is a great exercise to try with a partner. Do not rely upon the image on your screen; rather, estimate when you are positioned over the top of the cone. Get your partner to go and look, and I guarantee you will still have some distance to cover. Once you have practiced a few times, point the camera of your drone straight down and hover once you are directly over the cone.

TIP:

Always make sure you can see sky between the object below and your drone. While you will have to keep looking up to check, as you get farther away, this is a good indication you are clear of the obstacle. Keep looking and checking as your distance increases.



FIGURE 23.2 UAV flight instruction and mentoring.

(Image courtesy of Abbe Lyle.)

I have noticed the tendency for those new to the sticks to actually concentrate so hard, they slightly rotate the orientation of the drone. This goes back to milking the mouse! However, once the drone is slightly turned around, your controls will not work as you expect them to. Where you think you should be flying straight ahead, you are suddenly flying to the right or left. I get many an adamant response that there was absolutely no input from the operator, but the drone was acting up! You will learn very quickly if this is a tendency and the sooner you correct it, the better. Flying with the drone battery pointed toward you will mean the controls react as you expect them to. As soon as you turn 180 degrees, the controls will be counterintuitive or reversed. Practicing the simple squares, circles, and figures of eight will help with smooth maneuvers and will help you considerably out in the field. The good news is that in basic terms, the GPS positioning (when you are not flying in manual mode) will prevent your drone from falling out of the sky, and if you feel out of control, release your tight hold on the sticks and allow your drone to hover until you are once again in control and aware of your position. Generally speaking, if you are in doubt, punch your drone up in the sky to give you time and distance from any possible obstacle.

Many years ago, when I first started working in Photoshop, I accepted the settings presented to me without question. Now I have my own workspace set allowing me to work optimally. I would suggest you spend a good deal of time exploring the settings for your drone and adapting them according to your needs. Most of the drones you will be considering arrive in beginner mode, which is great for learning, but very quickly you will want to override the manufacturer's suggestions and fine-tune your settings.

Remember to always check the weather and site safety when you arrive at the scene. Our practice is to always wear bright protective clothing and hard hats when necessary. Placing yourself in a position of authority stops random questions and allows you to get on with the mission. We bring cones out with us too, which also discourage onlookers from approaching. We go through a rigorous preflight check, as though we are strapped to the drone. This simple task will make sure no part of preflight planning is ignored. Don't forget to include establishing an emergency landing area and announcing to everyone where this will be. If something goes awry, it only takes a verbal cue to let everyone know you will be starting emergency procedures. I am still caught off guard when I am teaching. Recently, I was powered down but a little distracted as I watched my students land in wind. As I was about to take the propellers off the UAV, the wind caught one side, and I cut my finger. Admittedly, it was incredibly windy, but don't underestimate the power of plastic in the wind! Imagine what would happen to your fingers if the props were actually turning. It is sometimes the small details that are missed and this is when mishaps take place.

The other practice I adopt in my routine at a scene or when flying a mission is I give myself preparation time prior to actually placing my drone in the position I need to be to start mapping, making images, or videoing. I hover for a few seconds to make sure my drone is reacting correctly, and then I perform a quick pitch, roll, and yaw test. I check for any warnings on my controller and generally make sure l am 100% comfortable before proceeding with the flight mission. It is easy to get turned around when concentrating on flying a mission. It is important to keep an eye on your UAV and constantly monitor the software on your controller to make sure you are always aware of your position.

As we witness autonomous flight for scenarios such as mapping missions, it is easy to assume that ultimately, we will not need such skill sets. However, human intervention is still necessary today when autonomous systems fail. Not only this, if we wish to fully capture a scene, additional images become incredibly helpful to fill in the gaps of an accurate photogrammetric image. One way of improving footage is through a fully immersive experience with first-person view (FPV) through a virtual reality (VR) display. Currently it is necessary to be able to also view the drone, and this combination is always best with the help of a visual observer. The FPV experience can also help greatly with the issue of depth perception.

Finally, I would like to finish this section with the importance of retaining knowledge and relevant information from your test. I promise, some of those facts that seemed irrelevant will be useful down the road. We may be on a steep invention curve, but the effects of weather, for example, will not change. Here are a few thoughts on this subject. You have studied and learned the regulations and passed your test. You will remember that you must remain 500 feet below and 2000 feet away from clouds, maintain visibility for 3 miles, and operate under VLOS. Let's think about the potential safety hazards that may present themselves on a beautiful, clear, sunny day. Glare may be your first challenge, so be aware of the position of the sun, and

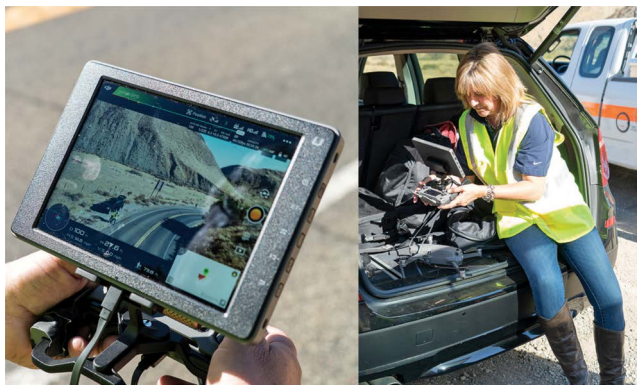


FIGURE 23.3 DJI CrystalSky monitor and preparation for a mission.

(Image courtesy of Visual Law Group.)

although you must keep your drone within VLOS, take a moment to plan the flight so you are not looking directly into the sun. The sun is not your friend when it comes to overpowering the brightness of your liquid crystal display (LCD) screen. Make sure you can either shield your screen from the glare of the sun or buy a backlit monitor. The DJI CrystalSky high brightness monitor may seem like an unnecessary and costly purchase, but we would not fly without one.

That wind I mentioned earlier can be a serious issue. Wind can affect the speed and flight path of your drone. If the wind speed surpasses the maximum speed of your drone, you are going to be in trouble, no matter how adept you are on the sticks. Both headwinds and tailwinds can pose a threat. How great it is to get to the destination of your mission quickly, how miserable to try and fly back against the wind when your battery is running low and the 25-mph wind blowing against your drone is negating your 25-mph speed! Similarly, a crosswind will alter your desired heading. If you are successfully fighting wind and seemingly winning, remember the excess current draw from your battery (or batteries in some cases). Increasing thrust will drain your batteries faster than normal.

Think about aerodynamic performance. There was a reason for learning about air temperature and density. The rules applying to larger aircraft also apply to the smaller drones. Anything that can damage the electronics, such as precipitation, should be taken into consideration. As more and more waivers are granted to allow operators to fly beyond VLOS, it is important you really know how to fly. I sound like a broken record, but it would be devastating to lose the amazing benefits of this unique tool due to a catastrophe caused by insufficient training and ignorance.

DRONE PHOTOGRAPHY AND VIDEOGRAPHY CONSIDERATIONS FOR FORENSICS

The importance of photographic accuracy has been well established throughout this book. Mark Johnson's chapter 23A demonstrates the ability to accurately create photogrammetric 3-D maps and orthographic and topographic images utilizing drone technology. Our work in this area, combining drone technology with other solutions, is demonstrated in Figures 23.4 to 23.6.

Mr. Johnson establishes a solid case for drones in forensics. He and I refer to similar cases. To find out more, please refer to his chapter on forensic aerial imagery and drone photogrammetry. I would like to step back and consider the simpler benefits for those not ready to jump so deeply into the topic but wanting to explore some more basic drone techniques. The simplest application would obviously be the ability to capture the global scene from the sky or, in some cases, from the ceiling. In the instances where the

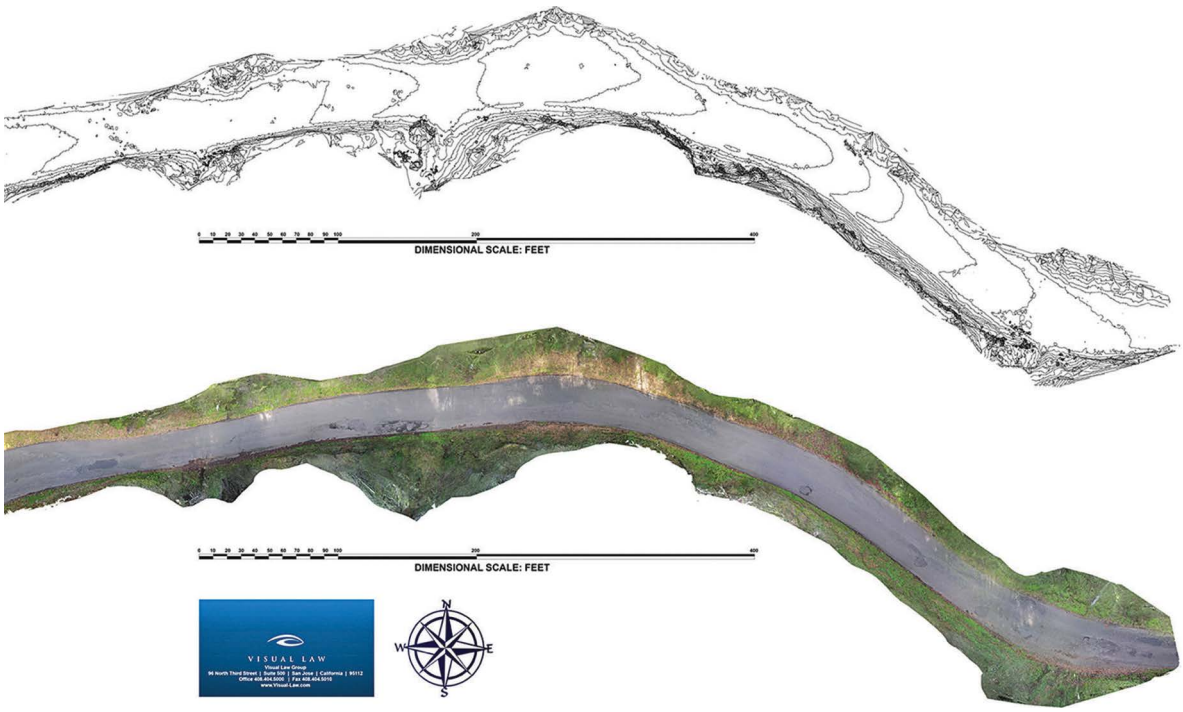


FIGURE 23.4 Flying the drone and processing the topographic map using Pix4D software created the large-scale detail on this topographic map. This was of specific relevance in a case involving the camber of the road. We were able to use the map to show the exact angle of the collision.

(Image courtesy of Visual Law.)



FIGURE 23.5 Combining a 3-D photogrammetric map with Google Maps allows you to show a much larger area in context. We can now zoom into the significant area and demonstrate exactly what took place.

team and I go out on a mapping mission, we will start by taking a bird's-eye establishing image.

This image is the basis of our more detailed foray into photogrammetry, but it certainly provides a starting point. The processed orthographic image looks similar but allows for more accurate measurement once we begin to build a 3-D animation.

These images also help detectives with their investigations. For example, in November 2018, Chris Watts was sentenced in the murder of his pregnant wife and two little girls. Authorities investigating the case in Colorado used drones to help locate the bodies, which were buried near a remote oilfield. Without having to use sophisticated software, these small cameras on their virtual tripods in the sky can save time and money with a simple flight, hover, and click of the shutter. Until fairly recently, the ability to capture a useful and detailed aerial photograph was limited to manned aviation. A small drone can be easily launched, is cost-effective, and can capture detailed, high resolution images in a matter of minutes.



FIGURE 23.6 The photogrammetric mesh generated through Pix4d from a drone mission gives us the base topography for placing a 3-D replication of the wreck in the scene.

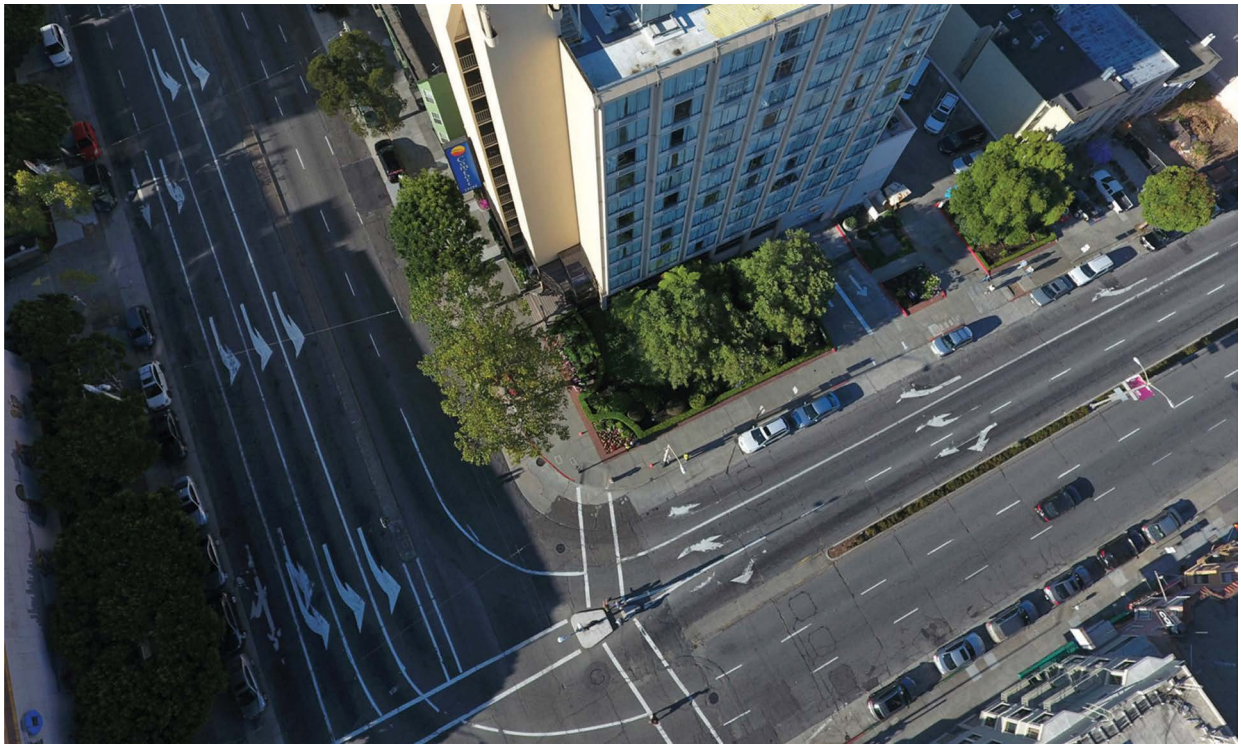


FIGURE 23.7 Single aerial establishing image.
(Courtesy of Visual Law.)



FIGURE 23.8 Ortho-image.
(Courtesy of Visual Law.)



FIGURE 23.9 This image was taken in Maine while I was teaching basic drone photography. The car has been in the quarry for a long time, but it is a prime example of how one image can aid first responders.

From our experience in the field, I can number several instances where the accident occurred in a remote location. While our work usually takes place quite some time after the fact, when the first responders have a drone readily available, they are able to conduct a quick evaluation of the scene. These initial images offer immediate feedback as to the severity of the situation. They can also provide vital information regarding the best access route. Immediately, the UAV becomes an invaluable tool. Preserving evidence and minimizing scene contamination are so vital that that ability to document hard-to-access areas could make the difference in the overall outcome of the investigation. It is worth mentioning that UAVs are also capable of carrying LiDAR equipment as well as infrared and thermal sensors. Thermal imaging cameras on drones can aid in many different scenarios, but for our purposes, we will examine forensic capabilities such as detecting minute differences in heat. The capability of seeing through dust and smoke means heat energy can be detected in most environmental conditions. Aerial thermal imaging kits can be added to drones, enabling a variety of enormous benefits to the forensic toolbox. Several options are available at the time of writing, but options are progressing at an unbelievable rate. It is now possible to produce thermal 3-D photogrammetric models.

Analysis after the fact is just one factor—the ability to use a drone with advanced functions to transmit images for immediate viewing can potentially speed up the process of analysis. High-quality aerial images of collision scenes allow for immediate analysis of entry and exit points of automobiles and show skid marks and debris prior to any type of scene contamination. Once these images are captured, there is the possibility of opening roads sooner and hastening the cleanup process.

It is worth noting that some law enforcement units are choosing what they believe to be the better high-tech expensive options allowing fully automated flight (as I mentioned earlier, this does not negate the need for a qualified RPC), and I would opine this is often overkill for the purpose of capturing images and video. These large and bulky options generally come with a hefty price tag and training, but they are much harder to deploy, are easier to crash, and the end result may not justify the cost. Add to that the need for a more detailed waiver from the FAA, and the resulting question is whether the cost justifies the end result.

In a recent case, we were able to find a way to solve one of the biggest questions needing an answer by flying a drone. The fatal accident occurred after a small Cessna crashed into high-tension wires. Using the high-resolution video on the camera of the UAV, we were able to position the UAV right up to the wire and fly backwards at various heights along the known flight path of the aircraft. Once the video was reversed and retimed to match the plane's precollision velocity, we could replicate the view of the pilot as he approached the wires and were able to assess there was no possibility he would have seen them until it was too late. Images captured from the video show the wires were not visible until less than a half-second before impact.

This type of test would have been impossible without the use of a drone. In this case we were able to use the drone for the video footage, for a 3-D photogrammetric replica of the crash site, and for an orthographic image of the airplane.

Data from the drone can either be stored in the drone's internal memory or a memory card and can be uploaded from the field or later transferred upon returning to the office. Ensuring the integrity of the original data would be no different from other forms of digital forensics, so should not be seen as an obstacle. However, employing a standard operating procedure for image capture is important. To limit the possibility of losing vital data, we take several memory cards to the mission. Once one battery is flown, we land and take out the memory card and copy the files onto a hard drive on-site. A new card is deployed, and we follow the same process for each flight.



FIGURE 23.10 (A and B) Image without the wires and image showing the wires.

Seemingly, as each month progresses, we are able to purchase new drones uniquely capable of extremely specific applications. The technology is progressing at an incredible rate, so much so that I do not believe it would be much help to extoll the virtues of any specific drone. I can mention that we currently favor the DJI Mavic 2 Pro for image quality and ease of flight. Software companies are developing and constantly updating new applications to aid in the conversion of photographic and video footage captured from our drones. Since we are dealing with forensic use in this book, I will not expand on many of these applications, but other chapters have covered many of the applications germane to this field.

As I have touched upon earlier, there is often the assumption that bigger is better. The truth is that we all get caught up in the quality of data we can capture and then need huge processing power to achieve our end goal. The more portable drones are easy to deploy and offer the operator a

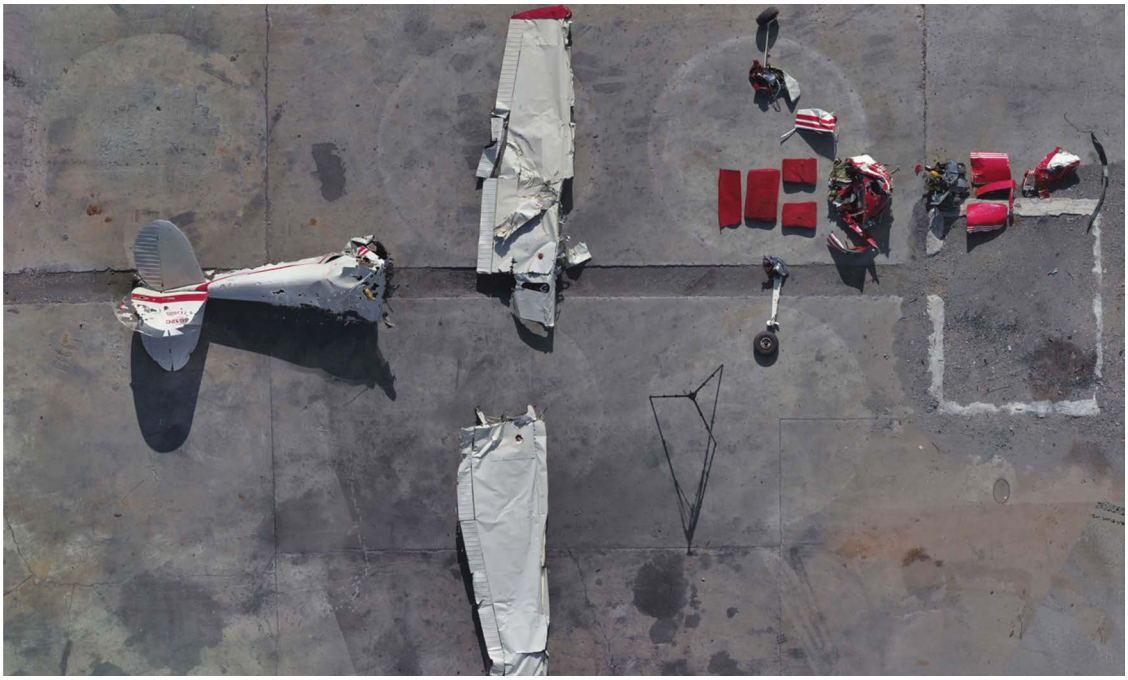


FIGURE 23.11 Utilizing a drone for the video footage, for a 3-D photogrammetric replica of the crash site, and for an orthographic image of the airplane.

variety of choices when it comes to image or video quality. If the drone is too small, there can also be issues; it is hard to see once airborne; therefore, the operator will experience limitations in both VLOS and depth perception. However, the larger and more complex drones often purchased by first responder teams and companies wanting to provide a specialist service are harder to operate and therefore more prone to operator error. One should also consider the safety aspect. If, with proper clearance, you are attempting to map an accident over a busy intersection, you want to keep the possibility of damage from a malfunctioning UAV to a minimum. The ability to capture the data needed for a mapping mission from a small drone is astonishing. There are other elements that come into play when government organizations are considering which drone to purchase, but that is an element needing to be sorted out between the drone manufacturer and the organization. These considerations surround the security of the data capture. This is a much-debated issue and not for this segment, but it is good to be aware of all the considerations when contemplating such a purchase.

In summary, with the correct permission and the right qualifications, we are already capable of utilizing the drone for data collection of both still images and video for forensic scene data and help in animation. Simple video or still images can aid in search and rescue, fire damage assessment, crash scene footage from above, disaster relief efforts, construction safety, and monitoring, to name but a few. There are still many myths and misunderstandings surrounding drones. The multitudes of public forums address some of these issues, but often information of any import gets buried in the morass of individual opinion and emotion. The controversy surrounding drone use will most likely continue as more advanced, specialist drones take to the skies. However, as this technology is integrated specifically into the field of digital forensics, we will witness increased dependency and value in this field.

23A Forensic Aerial Imagery and Drone Photogrammetry

Mark Johnson

THE HISTORY OF AERIAL IMAGERY

Aerial photography was born in France in 1858 when balloonist Gaspard-Felix Tournachon took images over Paris from a tethered balloon. In the United States, one of the most successful early practitioners of aerial photography was George R. Lawrence who began specializing in taking photographs from high ladders, poles, balloons, and kites in 1895. His photographs of San Francisco showing the devastation after the 1906 earthquake became famous worldwide and propelled him to a successful career in photography, until he decided to switch to aviation design in 1910 (Figure 23A.1).

Since those early efforts, aerial imaging has matured into an important tool for many industries and scientific disciplines. As flight became common and controllable, all major urban areas began to be systematically documented through aerial photography, so libraries of historical images became available for commercial use by the 1940s. In the decades following, high-altitude photography and *satellite imagery* became available worldwide and the use of *aerial imagery* as a forensic tool became commonplace. Today, aerial imaging plays a major part in both civil and criminal trials.

INTERNET RESOURCES FOR AERIAL IMAGERY

The massive *Google aerial databases* available free through *Google Earth Pro* and *Google Maps* are truly an extraordinary resource for litigators and forensic technicians. Google Earth Pro has a historical imagery option that will display images collected over time. I have found this feature extremely valuable forensically on many occasions. A related feature is available through Google Maps where the "*street view*" will display historical images as well. Using these applications together will give you historical views from the air and at street level for most public roadways within urban areas, nationwide and around the world.

In addition to options for identifying landmarks, roads, boundaries, and other features, *Google Earth Pro* includes tools to measure distances and areas, often helpful for forensic analysis. There are other useful online resources for imagery, like Microsoft's BING map/aerial database. The United States Geological Survey also has extensive data and resources, including aerial imagery and topographic datasets. Furthermore, there are commercial resources online, such as www.TerraServer.com, providing aerial photography and USGS topographic maps for a fee.

While many attorneys are familiar with these online tools for personal use, few have attempted to lay a foundation for admitting Google imagery as a substantive exhibit at trial. Nevertheless, with a little planning, this evidence can be usable in court. One simple method for admitting online imagery relies upon having a witness authenticates the image(s) as being a true and accurate depiction of the conditions shown. Another approach is to submit requests for admission requiring the opposition to admit or deny the images accurately depict the scene at the relevant time. If opposing counsel does not object, the imagery will be deemed admissible.



FIGURE 23A.1 Photograph of San Francisco in ruins from Lawrence Captive Airship, 2000 feet above San Francisco Bay; 1906. (From: Geo. R. Lawrence Co. gelatin silver print; 18 x 48 in. LOT 5785, no. 15 (OSF) P&P.)

It is also possible to *subpoena the records custodian for Google* or any other domestic online service provider *to authenticate the imagery in question*. For Google, subpoenas must be issued to Google Inc., 1600 Amphitheater Parkway, Mountain View, California 94043. Google typically files a pro-forma objection to any subpoenas received as a method to control the volume of requests they must deal with. Nevertheless, if you persist you will receive a Certificate of Authenticity from the Google Custodian of Records, foundationally sufficient to admit the imagery as an official record and as an exception to the hearsay rule.

COMMERCIAL AERIAL IMAGE PROVIDERS

Every urban area will have one or more aviation companies specializing in aerial images. Likewise, you will find aerial image libraries that keep historical aerials for property within their area of collection. Frankly, these libraries are generally superseded in terms of resolution and coverage by Google and the other online resources referred to above. Nevertheless, in cases where a specific condition on a given date becomes important, these resources can make a real difference in a case.

DRONE IMAGING

The availability of inexpensive unmanned drones equipped with high-quality cameras has truly revolutionized forensic photography today. The benefits of this technology are extraordinary in several key areas:

High-Resolution Photography: As noted above, aerial imagery has been an important factor in forensic analysis for decades. Nevertheless, until recently, available aerial data was almost always limited to higher altitudes and manned aircraft, which necessarily reduces the resolution for the acquired image and elevates the cost of the mission. Today, drones carry high-resolution cameras that operate at low altitude (0–400 feet) and the total cost for a complete system will typically be between $1,000 and $3,000. As a result, ultra-high-resolution aerial photographs can be acquired for a crime scene or the site of a transportation disaster, on demand. The significance of this development cannot be overstated for the forensic field.

Photogrammetric Drone Mapping: In 1993 EOS Systems released its first beta version of a software application called *Photo Modeler*, designed to create three-dimensional (3-D) computer models from analyzing a series of overlapping photographs. After release of the full version in 1994, Photo Modeler became a prominent tool for forensic technicians and accident reconstruction engineers, due to its ability to extract accurate dimensions from photographs of crime scenes, collision sites, and post-collision vehicles.

After Photo Modeler was released to great success, several developers brought competing products to market and practical reconstruction of 3-D scenes from photographs improved considerably as software improved and users became more familiar with the techniques required to achieve good results. However, the real power of this technology did not fully blossom until GPS-controllable drones with stabilized cameras began proliferating after 2010. These *Unmanned Aerial Vehicles* (UAVs) quickly became recognized as ideal platforms for acquiring an overlapping grid of photographs above a fixed area of ground, from which accurate 3-D data could be constructed using photogrammetric software.

GPS-based control meant developers were able to create applications to run on a laptop or smartphone in the field, from which the drone could be controlled according to preplanned flight missions. Additionally, by 2010, most drone manufacturers were offering cameras using stabilized mounts called "*gimbals*", relying upon brushless motors to precisely counteract the craft's yaw, pitch, and roll. Gimbal-equipped cameras eliminate vibration and motion so well, high-quality still images and video are achieved during flight. Thus, the drone was transformed into a "tripod in the sky", is so stable, relatively long exposures may be taken without blur.

In 2011, the Swiss company Pix4D released its first version of Pix4D Mapper, which autonomously controls consumer-grade drones to fly a "grid" mission over a user-selected boundary area, to achieve survey-quality results after processing. An application on the drone pilot's smartphone displays the surrounding geography and shows the drone's position on a map. The user simply draws a polygon around the area to be flown and chooses the flight altitude (which determines the final resolution of the data to be acquired).

Photogrammetry relies upon image overlap to successfully create a map. If an object is present in the overlapping portion of at least three photographs, its relative position in 3-D space can be calculated. As the same object is photographed from slightly different camera positions, its relationship to surrounding landmarks will change accordingly. Photogrammetry software uses powerful algorithms to calculate an object's position based on comparing its position in multiple photographs.

The GPS systems used in drones do not operate with high precision. Thus, the absolute position of the drone may vary by a few feet from where the system claims to be. Despite this inherent limitation of GPS accuracy, the software can achieve impressive results in terms of relative accuracy, since the use of multiple overlapping photographs

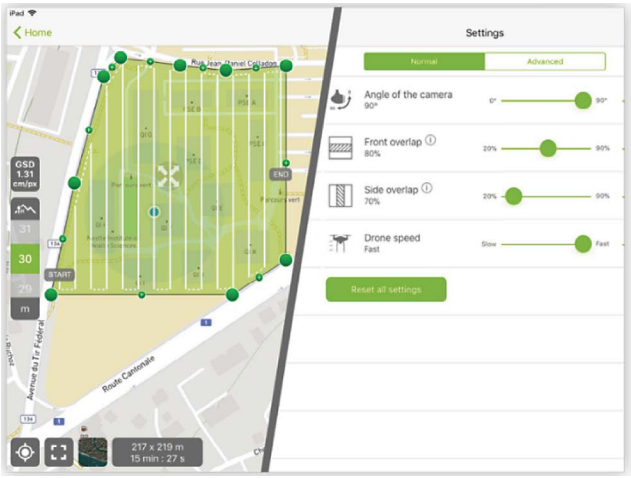


FIGURE 23A.2 The smartphone screen for Pix4D Mapper.

provides error correction allowing the software to calculate the actual position of the camera for each photograph taken in relation to all other shutter points. Therefore, relative scale within the completed orthographic image will be quite good without any further rectification.

Within the field of forensic accident reconstruction, absolute accuracy with respect to latitude/longitude is usually not critical, while relative accuracy within the scene itself is quite important. Verification of scale for a given scene can be easily achieved by either measuring distances between a few landmarks visible from the air (lane markers or curb lines work well for this). We often place a large metal carpenter's rule on the roadway and use it for scale verification in the completed orthographic imagery.

Figure 23A.2 shows a screenshot from the Pix4D smartphone application. The smartphone flies the drone along the programmed route as the user monitors its progress on the displayed map. Upon completion of the mission, the application lands the drone and the user has the option of either uploading the acquired photographs via the cloud, or manually downloading the images from the drone's memory card after returning to the office. In either method, the grid of overlapping photographs is processed to produce any of several data options:

Orthographic Imagery: One of the most valuable products generated by drone-based photogrammetric mapping is the creation of high-resolution *orthographic aerial images* for the area flown. Today, these survey-grade maps can be created by a single operator who may spend less than an hour in the field. Processing the imagery can be done in a matter of hours so the client can have the finished work product in less than 24 hours.

Prior to the past decade, the gold standard for forensic scene mapping required a day's work by a survey crew operating a total station in the field. The recorded data would then be converted to a scale line drawing diagram, the accuracy of which depended upon the survey crew measuring each object of interest. All too often, certain physical features or landmarks at the scene would later become important to a case that had not been recognized as significant when the site survey was done. A drone-based photogrammetric orthographic image has the distinct advantage of recording *all* physical features and forensic evidence in the camera's view.

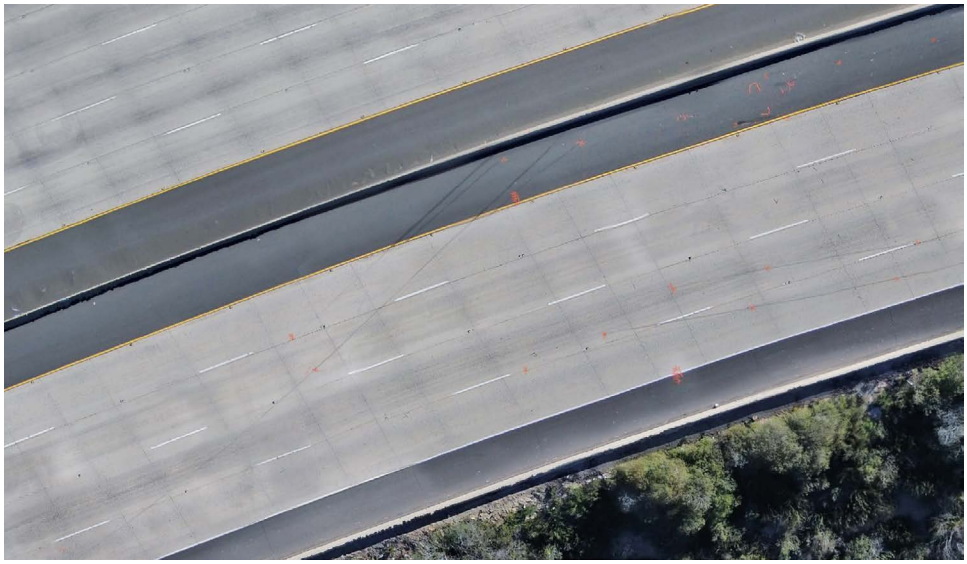


FIGURE 23A.3 Orthographic image of freeway collision site showing physical evidence.

Figure 23A.3 is an excerpt from an orthographic image flown at the site of a collision that took place on the Glendale Freeway in Los Angeles a week after the site had been documented by the California Highway Patrol. The highway patrol had the advantage of being able to close the roadway to obtain measurements of the evidence at the scene. That option was not available by the time Visual Law was retained by one of the parties. Drone photogrammetry allowed us to document the scene with equivalent accuracy to the total station used by the CHP. You will note the orthographic image clearly records not only the physical tire skid marks, but also the orange spray paint markings left by the original team investigating the collision.

The image in Figure 23A.3 is more than an aerial photograph. As a true orthoimage, the accident reconstruction engineers can take measurements from the photograph, accurate in any direction along the plane of the roadway surface. Moreover, this was accomplished by one pilot operating safely away from the freeway, in 45 minutes without anyone being aware he or the drone was present.

Topographic (Contour) Maps: In addition to orthographic imagery, Pix4D can generate accurate topographic or contour maps showing the elevation of the selected surface. Each line on the map represents an elevation, which allows an observer to interpret slope on the 2D map. Figure 23A.4 is a topographic (sometimes called topo) map of a mountain roadway where a collision occurred between a truck and bicycle. The roadway is perched on a hillside and you easily see the relatively flat roadway where the lines are broadly separated. In contrast, the sharp hillside slope is evident from the tightly spaced lines on either side of the roadway.

The photogrammetric application allows the user to specify what units of measurement are to be used (imperial versus metric) and the user may choose the elevation interval to be applied for each contour line. When producing topographic maps from drone data it is important to make certain your elevation data is oriented correctly to the vertical axis. The best way to accomplish this is to acquire four accurate points of measurement around the perimeter of the area being mapped. These so-called "*ground control points (GCP)*", will automatically rectify your data once they are entered as part of the photogrammetric processing parameters. Many operators use a *total station* to measure ground control points in the field, but you also have the alternative of using Google Earth Pro or other online resources to extract elevation data for a given map. Of course, total station-based elevation data will be more accurate than online sources. Nevertheless, we've found that GCPs derived from Google Earth Pro are adequate for almost all of our forensic work.

Although terrain surfaces are the most common subject for topographic maps, drone-based photogrammetry permits an operator to generate contour lines over any surface having changes in elevation. For instance, Figure 23A.5 shows a topographic map generated from an industrial building roof using Pix4D Mapper software. At a glance you can see the roof is crowned to allow water runoff away from the center to the sides where drains are placed at intervals. Being able to accurately visualize elevation changes has many uses in forensic work.



FIGURE 23A.4 Contour map of roadway surface.



FIGURE 23A.5 Contour map of roof surface generated with Pix4D Mapper.

Three-Dimensional Point Clouds and Mesh Files: Another valuable output from the same grid of overlapping photographs is the creation of a *3-D Point Cloud*. To make a 3-D Point Cloud, the photogrammetric software places a single point at every measured distance computed from the overlapping photographs. This results in a collection of millions of points (often tens or hundreds of millions) so the entire surface can be visualized in three dimensions. Seen from a distance, a point cloud appears to be a solid surface (much the way a newspaper photograph is made up of individual dots of ink that become visible when using a magnifying glass).

Figure 23A.6A shows a point cloud viewed from a moderate altitude on a computer screen. As a 3-D object, the point cloud can be manipulated to be viewed from any angle or vantage point. From this distance, the point cloud appears to be a solid surface. However, Figure 23A.6B shows zoomed-in view of the same point cloud with the virtual camera positioned just over the painted "STOP" at the intersection. At this close distance you can see the individual points making up the 3-D scene.



FIGURE 23A.6A 3-D point cloud of a collision scene.

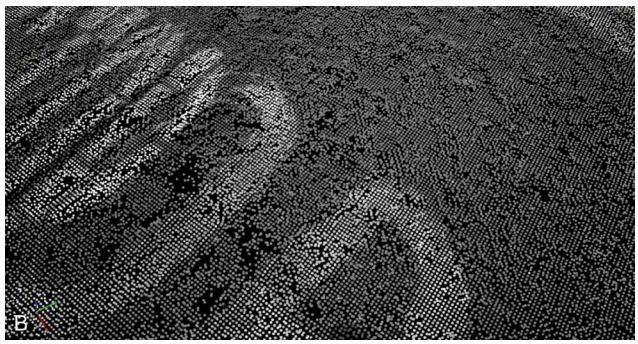


FIGURE 23A.6B Enlarged view of point cloud shown in Figure 23A.6A.

3-D Point Clouds have the disadvantage of being extremely large in terms of file size, due to the sheer number of individual points making up the scene, while also requiring considerable processing power to work with such a large dataset.

Pix4D and other photogrammetric applications can convert the massive point clouds into a much more efficient format called a *3-D mesh surface*. A 3-D mesh model replaces the point could with simple polygon surfaces requiring far less processing power to manipulate. The polygon mesh also has the benefit of being a continuous "watertight" surface, eliminating the pointillist appearance inherent in close-up views of a point cloud.

Figure 23A.7 depicts a 3-D mesh model of a terrain near Gilroy, California. This model represents about 2.5 square miles in area and was flown by Visual Law Group using two separate teams whose images were combined to generate the single dataset shown. Unlike 3-D point clouds, 3-D mesh models can be rendered with lighting and shadows, adding

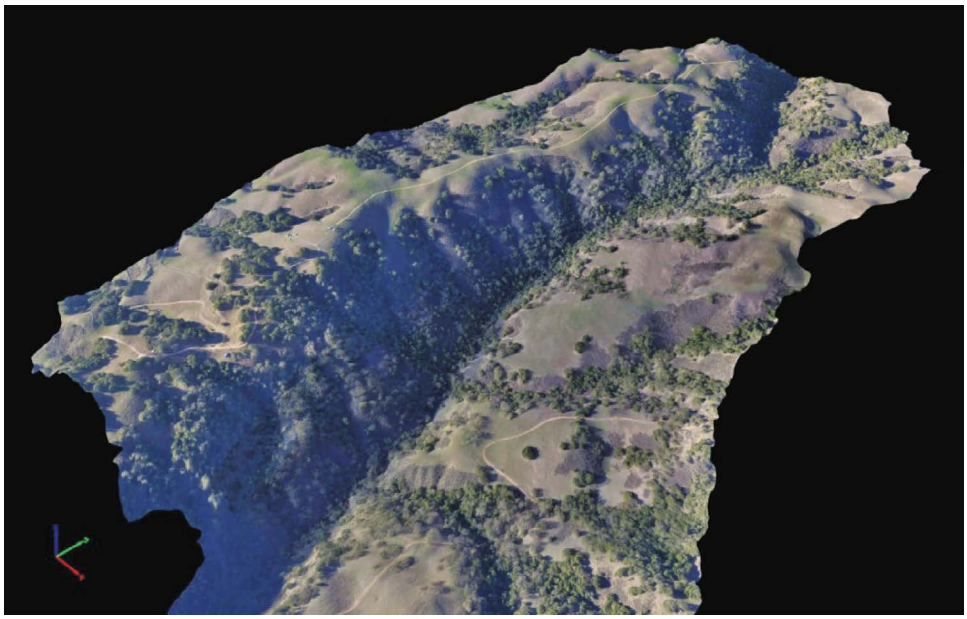


FIGURE 23A.7 3-D mesh terrain model created with Pix4D Mapper.

realism to the finished view. This model was used to study and animate the crash of a small Cessna airplane.

Figure 23A.8 shows one frame from the forensic animation produced using the 3-D mesh file discussed earlier. An accurately scaled model of the Cessna 140 airplane was used to depict the relationship between the airplane and the unmarked high-tension power lines strung across the valley. The 3-D mesh model of the terrain permitted the aviation experts to measure lines of sight for the approaching pilot, convincingly explaining why the support towers were not visible at any point prior to his collision with the wires.

Speaking as a forensic animator, I can honestly say, drone technology and photogrammetry represent a revolution eclipsing other advances in our everyday work. We use drones in most of our cases involving outdoor events. The capability of acquiring an accurate 3-D model of a terrain or building with a few hours work, borders on magic when I look back on our former workflow. When combined with terrestrial laser scanning, UAV photogrammetry gives today's forensic technicians, photographers, and civil engineers an extraordinary opportunity to provide valuable evidence to their clients.



FIGURE 23A.8 Forensic animation produced using 3-D mesh terrain generated photogrammetrically from drone imagery.



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24 Inspection for Auditing Conditions

Sanford L. Weiss

In all situations, there are two different occasions upon which a structure of any type will be audited for its condition. The first is when it is being inspected by engineers for a change of ownership or if there is a worry about its soundness. The second is after an event where the structure in some way failed. The photography and demands upon the photographer for either audit are essentially the same, but with one major difference. Where they are the same is the photographs will include images of all parts of the structure (concentrating upon the failure in the second case), especially the parts where failure is likely to occur.

The image project begins at the point of ingress into the structure in the case of a building or crane. In the cases of a roadway or bridge, it begins at a point recognizable and static at one end, documented by a fixed landmark like a hydrant, manhole, light standard, or survey marker to put the photographic project into its correct and unchangeable location in the universe. Once the permanent location is documented, the rest of the images on the project should follow logically around the location in a clockwise orientation. This will provide documentation in the X-Y plane. For the Z plane, a photographer in a light plane or helicopter will be able to make the necessary images, or more likely today, a camera in a drone operated by a certified pilot.

All the variables involved in the completion of such a documentary project are mentioned in other chapters or sections. They are, for example, weather, time of day and/or year, and safety for the photographer from dangerous debris or location. The four case studies that follow are actual cases I worked on during the process of my career as an engineering forensic photographer. Of course, variables will be involved in every scenario undertaken in the real world of today. But the real world has not changed sufficiently from the recent past to cause significant differences between what I did and what you are about to do.

These four cases were undertaken after significant disasters. That is the more difficult side of the coin in auditing conditions and requires the most photographs and care. If you are a home or building inspector, chances are you may never be called upon to document the failure of a structure, except post-fire, as written in Chapter 26. If you work for an insurance company or law firm, the opportunities for this type of work are far more frequent. If you work for a manufacturer or civil engineering company, you have the most opportunities for failure projects.

Always remember, **SAFETY FIRST!** You do not want to be the forensic photographer who became injured or dead while undertaking a documentation project. In the 30 years I worked in the field, I only felt threatened by the situation a few times. The times where the danger was and is the most palpable are the ones where the subject of the documentation failed by fire, explosion, or collapse and the world continued to operate around the scene as if nothing had ever happened. In the case of a highway re-creation, you may be standing within 3 feet of automobiles zooming past at 70+ miles per hour. Feeling the wind of their passing is completely daunting, not to mention adding difficulty to the technical aspects of the project. You are essentially putting your life into the hands and wheels of every motorist passing your location during the fulfillment of your obligations. Hanging from a damaged crane, bridge, or other structure and not being totally certain of the integrity of the location is even more dangerous. Always opt for the use of every available piece of safety gear. I am certain every reader of these words understands the point I am trying to make. Work with your head and not with your ego.

CASE STUDY 24.1: CRANE FAILURE

Early one cold, snowy, windy, winter morning, a phone call was received at Packer Engineering informing of a crane failure in the middle of the Loop, in downtown Chicago. Traffic was snarled for miles after the police blocked the street where parts of the evidence landed. The police wanted an investigative team on site immediately to document the artifacts in situ, so the surrounding streets could be reopened for rush-hour traffic (see Figure 24.1). Two engineers, a technologist, and a photographer were dispatched in all possible haste. Considering we were 35 miles away and needed to prepare and outfit as quickly as possible and then drive to the scene through snarled traffic, it was difficult and impressive to arrive on the scene within 90 minutes.



FIGURE 24.1 Inspecting the crane failure.

(From Sandy Weiss/Packer Engineering.)

Upon arrival, we found the accident scene was distributed into four distinct zones. Pieces of the crane were located across the street, in the street, hanging onto the front of the building, and on the highest existing (8th and 9th) floors of the building under construction. Everything was covered with snow.

Triage was obvious; the parts in the street needed to be documented and moved so traffic could be allowed to resume normally. The police allowed us 30 minutes to accomplish all the street photography. Knowing an accident reconstruction would be needed, it was important to determine the exact final resting location for each of the pieces. We made sketches, and measurements were taken. Photographs of the pieces were made as they were found, if possible, and before they were moved. More detailed photographs were exposed of each piece after they were shipped back to the lab. Further documentation of their new resting places with regard to the initial failure was not possible due to the impatience of the police.

The fractured bolts from the crane turntable were the most difficult items to find. The catastrophic failure of that part of the crane launched the head and body sections of most of the bolts to places beyond where our search could cover. Most were never found. That made the fracture surfaces of the parts of the bolts remaining in the turntable doubly important to be well documented. It should be and was possible to determine from the fractures the type and sequence of their failures.

From the street, the on-site documentation moved to the top of the building, the eighth and ninth floors of the construction. All of the necessary photographic equipment had to be carried manually up to those floors because the building had not yet been fitted with a working elevator. The turntable had landed upside down on a concrete surface and had also broken through it. Thus, the turntable parts were partially on the ninth and also the eighth floors of the construction. It was perched at about a 45-degree angle, with the bolt fracture surfaces on the face underneath. The concrete surface was not stable on the ninth floor, and the turntable needed to be approached with great care for study. A medium wide-angle lens, 35 mm on a 35mm film camera, was used for the overall documentary images. Light was not a problem, but metering in the snow can always be challenging if certain rules are not followed. If the camera was allowed to meter snow scenes in an automatic setting, the snow would appear approximately 18% gray in the resultant images. To bypass that possibility, one of two means could be utilized. Either the ambient light could be measured by an incident light meter and the camera set accordingly, or the exposure could be set by metering with the camera or a spot meter off of an 18% gray card once in every location, and then the exposure settings maintained on the camera until the location changed. A normal focal-length macro lens of 50 mm was used for the mid-range images. A telephoto macro lens was utilized to acquire the necessary bolt images.

There were 36 fractured bolts needing to be documented before the turntable was moved. This was necessary because any of the bolts could be lost or damaged when the turntable was lifted out by another crane. If enough of the bolt parts were displaced or lost, the root cause of the crane failure might never be able to be determined.



FIGURE 24.2 View from the ninth floor and down to the street.

(From Sandy Weiss/Packer Engineering.)

The most difficult part of the project was dealing with the snowmelt on the top surface of the metal turntable. The temperature had risen above freezing, as can be seen in the photo taken from the ninth floor looking down at the street (see Figure 24.2).

The water was dripping down in a torrent from the top to the bottom of the turntable and interfered a great deal with the photo equipment. In addition, a lot of rubble on the eighth floor was in the way, so it was a project in itself to set up for every one of the fracture photos. Many needed to be exposed off of mirrors. Many of the fractures were recessed into the metal of the turntable. In most of the photos, the photographer had to be on his back, in the rubble, in the torrent of dripping water, and in an overall dangerous environment.

The boom was not photographed in detail until it was removed from the edge of the building.

The fracture surfaces of the bolts were the most important evidence for telling the story of this accident visually. It would have been much easier to expose the images early, before the snow started to melt. But in this case, triage of the accident prevented the photographs from being made in the most expeditious manner. The police needed the street reopened, and it was critical to document the pieces before they were moved. As long as the whole story was told, however, the documentation was a success.

It is not always possible to take all the photographs in what would be considered a logical order. It is also not possible sometimes for the photographer to have the subject of the documentation brought to a place with a controlled environment and lighting. This type of work is very difficult and requires the photographer to be ingenious and flexible. It is also of extreme importance to carry a field go-kit at all times with enough gadgets to be able to perform this type of complex documentation. A complex project might sometimes need to be undertaken with just what you have with you, not just what you may be able to get if you have the time.

CASE STUDY 24.2: BUILDING COLLAPSE

In a foundry (a facility where iron and steel are made into useable items) on the west side of Chicago, a roof collapsed over a production area. The collapse was due to the weight of sand, which had leaked out onto the roof of the building over time. One worker was killed; he was working directly under the part of the roof that collapsed.

In some foundries, molten iron is formed into a casting, a process by which the molten material is introduced into a sand mold (see Figure 24.3), allowed to solidify in the shape of the inside of the mold, and then removed. Sand casting produces rough metal castings using a mold usually made from sand and formed around a replica of the object to be cast. Castings made by this process are then further refined by peripheral processes (see Figure 24.4).

The cast is filled around the model in the mold with properly prepared casting sand or green sand, a slightly moist mixture of sand and clay. The sand is packed into the mold by vibration. Sand may also be bonded with chemicals,



FIGURE 24.3 Pouring parts for the Wright Flyer engine.

(From Sandy Weiss/Packer Engineering.)



FIGURE 24.4 A rough casting out of the mold and a coin for scale.

(From Sandy Weiss/Packer Engineering.)

including resins. Foundries purchase sand in large quantities and store it in tall elevated tanks (see Figure 24.5). The sand is fed through a system of pipes lying on top, across, through, and under the ceilings of the foundry buildings. Each position in the foundry requiring sand has an outlet from the feed system.

The photographic project included documentation of the complete sand feed system (see Figure 24.6) from the storage tank to the collapsed building. Special attention was directed to leaks. The amount of sand at any of the leaking locations could determine how long the sand had been leaking and who was to blame for the leaks.

The photographs were assembled into a long montage of images, showing every foot of the pipe run. The project was complicated by the route of the piping. In some places it was outside, on top of the roof. In some places it was inside, hung from the roof. When it was inside, it was crisscrossed with air ducting, electrical service, sprinkler piping, and lighting. To document the full run in a way allowing all the photos to fit together, the magnification of all the photos needed to be essentially the same. Some of the photos were exposed from the ground, looking up, and some from the roof, looking down. The buildings had 16-foot-tall ceilings. Lenses were interchanged, depending on the camera-to-subject distance, to create images with constant pipe dimensions (see Figure 24.7).



FIGURE 24.5 Sand storage.

(From Sandy Weiss/Packer Engineering.)



FIGURE 24.6 Sand system piping.

(From Sandy Weiss/Packer Engineering.)

Telephoto lenses were used in images made from the floor. Wide-angle lenses were used on the roof. Some of the angles were nearly impossible to document due to obstructions (see Figure 24.8). Heavy bags of equipment were carried up ladders to roofs. The length of the run was over 200 yards. Eventually, all the images were made.

One particular image turned out to be a key. On top of the collapsed building, a 6-foot-tall mulberry tree was growing out of the sand (see Figure 24.9). Of course, nobody planted it there as a roof-sapling. It grew there from a seed and into a tree. This clue demonstrated the leaked sand on that roof was not a new issue.



FIGURE 24.7 Vertical run of sand system.

(From Sandy Weiss/Packer Engineering.)



FIGURE 24.8 Mulberry tree growing out of the sand on the roof.

(From Sandy Weiss/Packer Engineering.)

TIP:

Clean all safety equipment, including shoes, after use and before storage. Contact with chemicals may cause serious deterioration of the equipment. When I was walking from the scene to my car after completion of the project, the soles of my safety shoes completely separated from the shoes. They were new shoes. Obviously, I had walked through something corrosive at some location in the foundry. No, I did not have a spare pair of safety shoes. What would I have done if the soles came off when I was only halfway done?

CASE STUDY 24.3: BRIDGE PHOTOGRAPHY

The outside (both northbound and southbound) lanes of the I-294 bridge over the Cal-Sag Channel near Alsip, Illinois, were under construction for many months. This caused extreme traffic congestion, but sadly, the construction was done improperly. Packer Engineering was called and contracted to photographically document the bridge problems made evident by the structural sagging near the supports. The new construction, having cost many millions of dollars, was going to be completely removed and redone, but the state of Illinois wanted documentary images captured before demolition began. Demolition was scheduled to begin at 6:30 a.m. on the day we were contacted, so it was necessary to arrive at the



FIGURE 24.9 This photo was exposed without a tripod and with the camera pointing NNW along the west side of the southbound lanes. Bridge photograph with flash.

(From Sandy Weiss/Packer Engineering.)

site before dawn (officially 6:09 a.m.) to wait for the sun to rise and supply the illumination necessary for photography. Obviously, it was also necessary to document the proper images on the first try. The bridge would not be there tomorrow.

The state requested the images be captured on film rather than digitally. Three different focal-length lenses were used (50, 200, and 500 mm) to document the appropriate parts of the bridge, using a conventional film camera, backed up by digital images documenting appropriate parts of the bridge. In all cases, the official camera was on a heavy tripod, leveled using a bullet level in the tripod head for side-to-side orientation, and a torpedo level on the camera for the proper vertical orientation (X-Y-Z planes).

The sky was light before sunrise, but there was no direct lighting on the bridge until after official sunrise. After sunrise, the sun shone brighter on the east side (northbound lanes) than on the west side of the bridge. Because of this high contrast, for a photographer to set the camera using automatic light metering would be an error.

In this case, and for the sake of a teaching exercise, both properly and improperly exposed digital photographs were knowingly made with a second camera set on variables of automatic operation to illustrate the possible problems associated with automatic metering under these conditions. As intended, the digital images were created and also used as insurance in case anything went amiss with the film images.

The photos included here appear "as-exposed," not adjusted for brightness, contrast, or sharpness (see Figure 24.10).



FIGURE 24.10 This photo was exposed with the flash turned off but with the camera set on fully automatic exposure. Bridge photograph underexposed due to meter error.

(From Sandy Weiss/Packer Engineering.)



FIGURE 24.11 Bridge photograph taken without flash.

(From Sandy Weiss/Packer Engineering.)

The camera was fitted with a 200 mm lens and set on fully automatic exposure. The built-in flash fired, and the camera chose an appropriate exposure for flash under the ambient lighting conditions. Outdoor firing of a built-in flash on this particular camera covers a maximum distance of 12 to 20 feet. The wooden barrier with the orange paint in the lower-left corner of the frame is approximately 20 feet from the camera. The image is nearly properly exposed because the ambient lighting and the exposure-for-flash setting were approximately the same. The image lacks overall sharpness and has insufficient depth of field, evidenced by the lack of sharpness in the green tie-rods along the pavement.

When using a fully automatic camera in this type of marginal lighting, the built-in flash will always fire unless it is purposely turned off. If the flash is allowed to fire, the camera circuitry will set the internal exposure systems as if the flash would be sufficient to illuminate the entire scene. The outcome is a photo exposed at a shutter speed too fast for adequate overall exposure, too slow for handheld sharpness, and with an aperture too large for adequate depth-of-field.

Figure 24.11 was exposed shortly after Figure 24.10. Bridge photograph without flash.

The camera was set on manual, and the flash was turned off (see Figure 24.12). In this case, a small lens aperture was chosen to supply adequate depth of field for front-to-back sharpness and a slow shutter speed to supply adequate

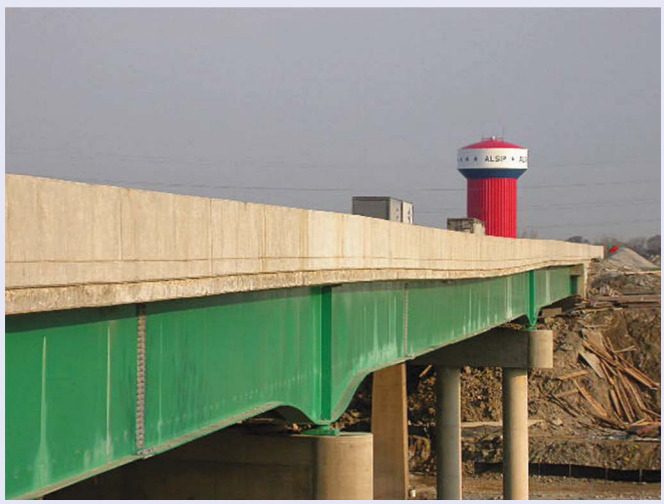


FIGURE 24.12 This photo was exposed with the flash turned off but with the camera set on fully automatic exposure. Bridge photograph under-exposed due to meter error.

(From Sandy Weiss/Packer Engineering.)

exposure. The camera was not on a tripod, and therefore the images suffered from camera movement during the long exposure. The traffic was moving slowly, but the headlights are still blurred. This setting still did not allow sufficient exposure, extended depth of field, or maximum detail in the shadows.

Inclusion of the sunrise-bright sky in the image caused the camera to compute the scene as brighter than would be appropriate for a proper exposure of the side of the bridge. Composing the image at a physically lower point of view and eliminating most of the sky from the composition would have resulted in a better exposure. The image is not usable even if printed lighter, as it is unsharp and missing information in the shadows due to underexposure. The shutter speed and lens aperture picked by the camera are not appropriate in this image for stopping motion or capturing sufficient depth of field.

The camera was again set on fully automatic with the flash turned off. This image exhibits the most appropriate of the auto-exposures. The visible part of the sky and the bridge are both subject to the same intensity of illumination from the rising sun. The dynamic range (contrast) of the scene is somewhat wider than the capabilities of the camera to handle at the default settings, but in this case the area under the bridge is not the area in question. A layered image would certainly help in these situations. Please see Section 7B about HDR photography.

Automatic exposure and no flash produced a finished image (see Figure 24.13) with good contrast and density, but the autofocus reacted to the closer parts of the bridge, and the large lens aperture necessary for proper exposure limited the depth of field.

In ALL cases, following standard procedures, multiple combinations of shutter speeds and lens apertures resulted in proper exposure for the final images. In many cases, a specific part of the resultant photograph is the area needed for documentation. For optimum sharpness and contrast in difficult lighting situations, it is advisable to manually determine the intensity of the light reflected from, or falling upon, the subject area and to set the camera accordingly to the best speed/aperture combination to either stop the action or supply sufficient depth of field, or if necessary and possible, both.

Multiple photographs and views were recorded because in many cases, a specific part of a photograph was the area needed for documentation.



FIGURE 24.13 This photo was actually the first frame exposed in this project. It displays the sagging concrete between the supports under the structure. (The sag is easy to see about halfway down the right side.) The bridge could not be used in this condition and needed to be totally torn down and redone. Properly exposed photograph of the east side of the bridge.

(From Sandy Weiss/Packer Engineering.)

CASE STUDY 24.4: ROADWAY ACCIDENT

On a freeway outside Newark, New Jersey, a semi-tractor and trailer became disabled and the driver parked the rig on the right shoulder of the road, approaching but not yet on an off ramp (see Figure 24.14). A woman with her two children in a car drove into the back of the trailer at high speed, injuring her and one of the children severely and killing the other child. A lawsuit was filed against the trucking company and the state of New Jersey.

Packer Engineering was hired to investigate the accident and to determine how far back from the parked truck the initial point of visibility should have been for the driver of the car and at what point she should have been able to tell the truck was not moving. The re-creation took place several years to the date after the subject accident.

In any scene reconstruction involving a vision issue, it may be important to proceed on as close as possible to the day of the year of the original occurrence. Even working on the same calendar date is not perfect, but is as good as can be. Try for as close as possible to the subject weather conditions. If there was snow or rain on the day of the occurrence, it would not be as good to re-create the scene on a dry day, or vice versa. It is essential to procure proper vehicles as close as possible in color and condition to the subject vehicles. Make every attempt to document the subject vehicle's cleanliness of headlights, windshield, and mirrors and the condition, adjustment, and position of the driver's seat before assembling the re-creation.

Many factors were involved in the visual analysis of this case. The truck had been disabled and on the side of the road for some time. A state trooper came to the driver's aid, let him into his cruiser, and drove him to an automotive supply store nearby to purchase repair parts for the truck. The trucker was thus not present at the time of the accident. The truck driver did claim to have put out the required orange reflective triangles in the positions indicated by the Department of Transportation (DOT) codes, signaling to approaching traffic the truck was disabled. The presence or lack of triangles at the time of the accident was never verified.

At the time of the accident there was an overhead sign at the location of the parked truck, but that had since been removed and there was no way to substitute a temporary sign during the re-creation of the accident. There were also more trees growing close to the road at this location at the time of the accident, but they had since been trimmed.

Both the plaintiff and an eyewitness who was walking over a nearby bridge allege there were no triangles visible at the time of the accident. Police photos were taken at the scene, and measurements from the accident report and the scene photos were used to position the truck for our re-creation. Paint marks applied to the roadway at the time of the accident were naturally obliterated over the elapsed time. The place where the truck was parked was just west of an exit ramp, and the ramp was indicated by appropriate signs. Placement for the re-creation was measured from the recorded distance of the next overpass and the trailer position and footage markers placed accordingly.

The subject trailer had been repaired and in use since the accident, but then taken off-line and stored for an extended time. It was available to use for testing. The re-creation was documented with both still photographs and video. An exemplar subject car was purchased in Illinois and prepped before taking it to Newark. It was the same make, model, and color as the subject vehicle. The car was outfitted with custom-built camera mounts inside the

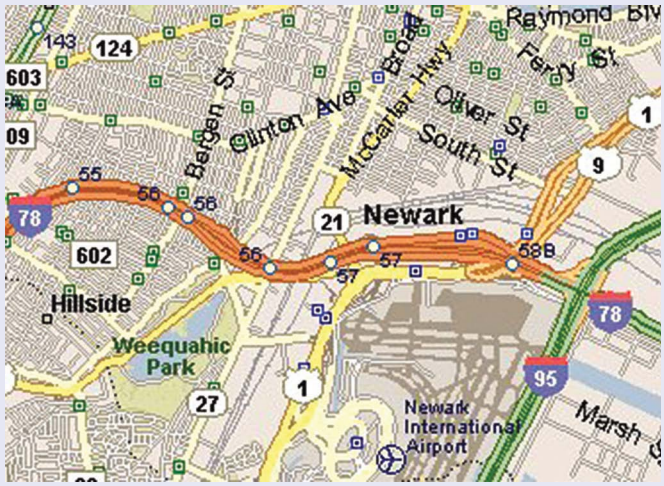


FIGURE 24.14 Map of the location.

(From Sandy Weiss/Packer Engineering.)

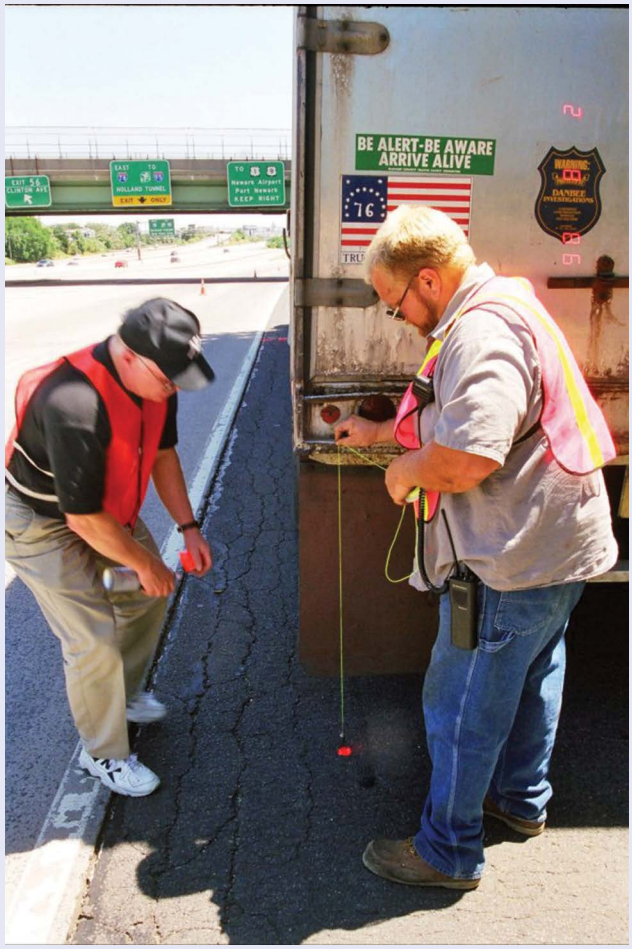


FIGURE 24.15 Using field notes to pinpoint the location of the truck on the roadway.

(From Sandy Weiss/Packer Engineering.)

passenger compartment so the video camera could be mounted to physically record the footage markers during the drive-through re-creation from just next to the driver's eye position.

The car was brought to the scene on a flatbed so there was small chance of damage to it on the trip. The state police did close off the outside lane of the freeway for a period of one hour at a non-rush time for the testing. The cars going by at 65 to 80 mph in the next lane were too close for comfort and were a detriment to the photography due to the wind from their motion. Some of the police photos were exposed from the center of the outer lane, and the re-creation photographs were required to be made from exactly the same height and angle, so the tripod leg was very close to the passing cars during some of the exposures. The wind shook the tripod so much it had to be weighted with sandbags before each image could be exposed. There were six accident scene photographs needing to be duplicated as closely as possible.

Making photographs to duplicate other photographs is one of the most difficult tasks ever posed to a forensic photographer. A technique was once developed where a viewfinder-sized overlay of the image to be duplicated was inserted into the focusing screen inside the removable viewfinder of a high-end still camera. Even then the task was difficult unless the new photos were exposed with the same camera and lens as the first set. It is conceivable for the same technique to work with a digital camera by making a viewing screen-sized and very thinly exposed overlay to fit onto the monitor/viewing screen of the camera. If the overlay is thin enough, with only several fixed reference points showing, the technique may work. Otherwise, just showing up at the scene with the original photograph and your camera, you are in for a significant amount of walking up and back, side to side, and possibly positioning the camera on a tripod to attempt a match. Depending upon the period of time between the two images, especially in cases where there is greenery, the task can seem nearly impossible due to the growth of the plant life or trees. Just remember to be prepared for a difficult task before you if you need to match scene photos in a subsequent year.



FIGURE 24.16 Location of subject truck on the roadway from the west.

(From Sandy Weiss/Packer Engineering.)

After the stills were made in this case (see Figures 24.16 and 24.17), the video drive-throughs were done. For the videos, a high-resolution camera was used as the fixed camera on the bracket inside the car to include the footage markers on the side of the road. A helmet mounted ultra-mini-camera was used to record what the driver might see, including the head movements the driver might make. The fixed camera was mounted on a bracket directly over the driver's right ear and focused out through the windshield of the car.

Positions were marked on the side of the road in 50-foot increments on signs large enough to be legible in the videos (see Figure 24.18). Orange reflective triangles required by DOT were included, even though they may not have been present at the time of the accident.



FIGURE 24.17 Location of subject truck on the roadway from the east.

(From Sandy Weiss/Packer Engineering.)

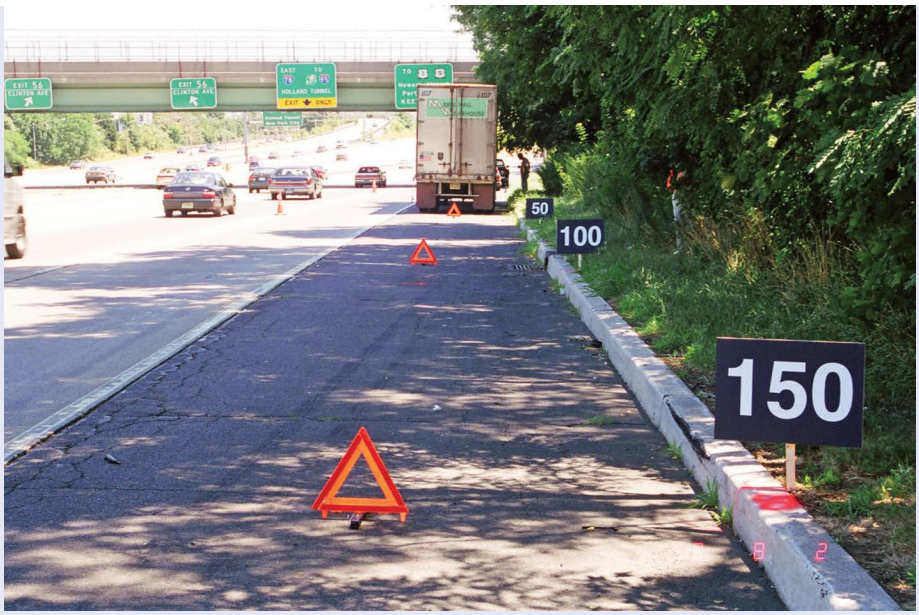


FIGURE 24.18 Orange triangles on the roadway.

(From Sandy Weiss/Packer Engineering.)

For the videos, the car was backed to the west, past the 350-foot sign, then accelerated forward to the speed limit; the cameras started and recorded the drive-through and then the tape was reviewed on a monitor in the car before repeating.

The weather conditions were not duplicated in this re-creation. The day of the accident was overcast, and the day of the re-creation was sunny with deep shadows. The engineers decided to go ahead with the re-creation anyway because the shadows provided a worst-case scenario. In other words, it would be easier to see the parked truck on a cloudy day, so the sunny-day shadows would supply conditions making visibility/conspicuity even more difficult (see Figure 24.19).



FIGURE 24.19 Truck sitting in the shadows.

(From Sandy Weiss/Packer Engineering.)

The still camera was loaded with 400 ASA color film in order to afford maximum depth of field for the images and to duplicate the sensitivity of the 400 ASA black-and-white film exposed by law enforcement at the time of the accident. Due to the sunny conditions and the inherent higher contrast of 400 ASA film, the resultant contrast was somewhat high in the finished images.

In conclusion, we determined the truck became visible at a distance of 325 feet to the west after the plaintiff's car came out of a slight curve in the road. That distance is more than sufficient for the car to come to a stop before impact if it had been traveling at the posted speed limit. It was also found the truck was obscured by the shadows of the overhanging trees and the reflective triangles were also shaded by the trees and not highly conspicuous on the roadway.

25 Water and Underwater Photography

Jennifer Idol

CONTENTS

Learning Objectives 495
Building a Dive Team 495
- Team Roles and Duties 495
- Safety Concerns 497
- Training 497

Diving Environments 497
- Water Conditions: Currents, Tides, and Weather 497
- Working at Depth 498
- Contaminated Water 498
- Cold Water 498
- Low Visibility 499

Equipment Needs 499
- Scuba Equipment 499
- Photo and Video Equipment 500
- Choosing Equipment 500
- Equipment Maintenance 503

Creating Successful Images 503
- Identifying Subjects 503
- Composing Images 504
- Shooting in Low Visibility 504
- Shooting Video 504
- Lighting 504

Conclusion 504
Key Terms 505
Exercises 506

LEARNING OBJECTIVES

The following learning objectives outline methods for the successful completion of underwater documentation. Each element contributes to this mission. Documenting forensic evidence underwater can contribute significantly to the information available in an investigation. It can show how discarded weapons lay and inform of body disposal or vehicle abandonment. In some cases, documentation can reveal details relating to how an accident or crime occurred. Documentation can also be helpful when trying to locate subjects underwater.

Building a dive team capable of documenting evidence underwater is an investment in equipment, training, and talent for a unique and uncommon working environment. The value a dive team brings to its local community depends on recovery success and communication. Sometimes, a dive team brings closure to families through recovery efforts.

1. **Building a dive team**
   Learn what qualities help a dive team operate efficiently and safely.
2. **Diving environments**
   Understand variables contributing to dive plans and equipment choices.
3. **Equipment needs**
   Use the right equipment for your budget, goals, and environment.
4. **Shooting effectively**
   Learn methods for creating useful documentation.

BUILDING A DIVE TEAM

Team Roles and Duties

The success of a mission depends on the cooperation of each member in an effective dive team. While recovery operations are typically not constrained by time, preparedness and timeliness are important so the team operates as a group and is prepared for any situation that may occur with a team member.

Environmental situations change the roles required. A 5-person team provides enough minimum resources to complete safe and successful tasks, but a 10-person team is

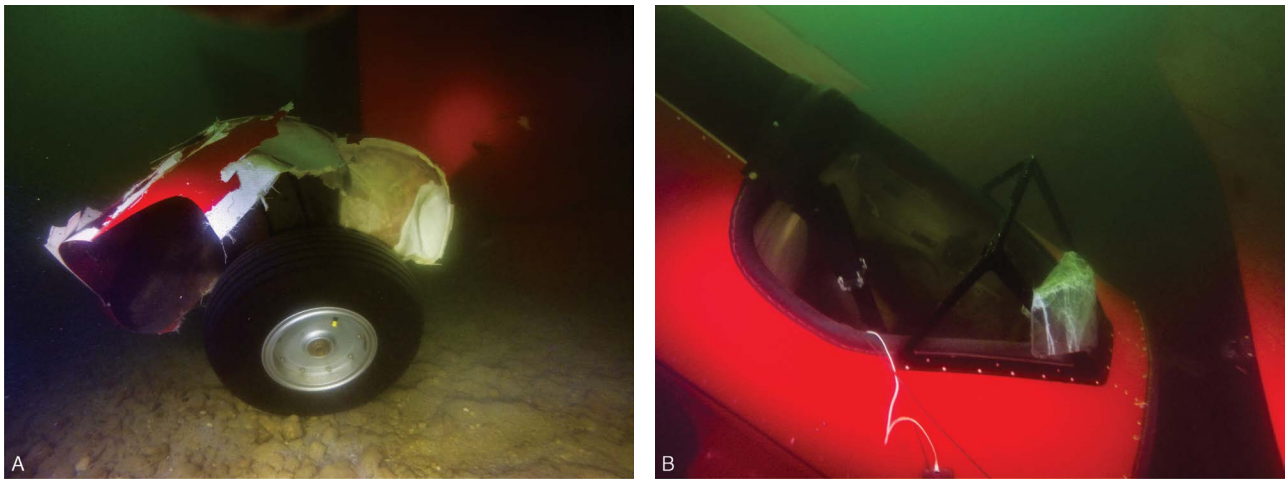


FIGURE 25.1 (A and B) Footage on a plane wreck that was obtained by the first divers on the scene without touching any part of the aircraft.

more ideal. Not every person will be available for a call, so maintaining a team of 10 to 12 helps ensure enough divers will be able to respond.

Solo diving is not advised. Diving with a buddy provides a second brain to work through situations. Buddies can also assist with reducing disruption of a scene by maintaining situational awareness and helping their buddy navigate the scene.

Recommended roles are as follows:

- Team leader (boat captain)
- Divemaster (surface manager)
- Two active divers (support and documentation)
- Comms operator
- Tenders for each diver
- Safety diver

The boat captain focuses on weather conditions and navigation of the vessel. The boat captain leads the team to the destination and directs entry and exit procedures. In the event a dive is conducted from shore, the captain acts as the team leader for the dive.

Surface managers maintain a list of the divers in the water, as well as their entry and exit times. They also document the gas (air) supply for divers. They assist with emergent gear failures and coordinate activities of the team members. The documentation they create can be useful for evaluating team effectiveness.

Two divers descend as a buddy pair, each maintaining their dive profile. However, the task loading required by the primary person responsible for documentation necessitates a buddy to be alert for safety concerns, time limits, and depth limits of each dive. Identify a supporting and documenting diver. The supporting diver is also useful for



FIGURE 25.2 Briefings before and after dives help coordinate activities.

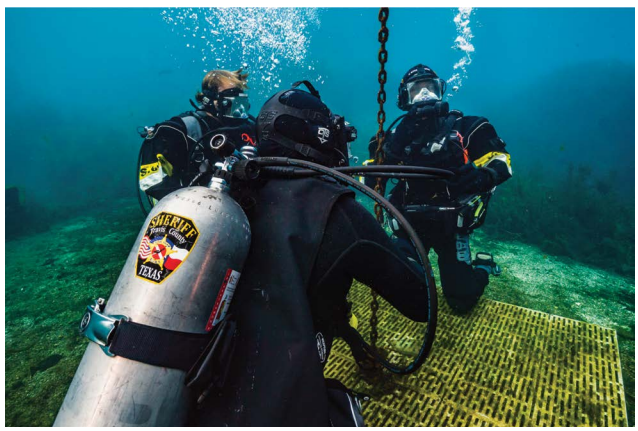


FIGURE 25.3 While as few as three team members could be deemed adequate in certain situations, redundancy helps address failures with equipment, hostile environments, and taxing physical conditions. No matter the makeup of the team, all roles should be clearly identified and understood.



FIGURE 25.4 Safety divers inspect other divers from head to toe.

equipment redundancy and the ability to assist with tasks such as lighting objects or holding equipment.

A safety diver is available to provide in-water or surface assistance with any emergencies that may arise and reviews each diver head to toe before he or she enters the water. They should be prepared to enter the water as a diver at any time. They may be required to assist with lost buddy situations, helping divers emerge from the water, water tows, and delivering rescue breaths.

Safety Concerns

The success of documenting a scene requires the safety of all team members. Keep safety first and live to dive another day. Physical conditions, environmental factors, and equipment failures are points of safety. The wellness of divers is important for task management. Fatigue and dehydration contribute to the physical wellness of divers.

Injuries

Create an emergency action plan to handle injuries. Divers are susceptible to injuries ranging from first-aid wounds to decompression illness, lung overexpansion injury, and oxygen toxicity.

Bring a maintained emergency oxygen kit to each dive site with a safety diver trained in the deployment of oxygen in the case of a decompression-related injury. Oxygen is the primary treatment for decompression sickness. Contact emergency services if required. The Dive Alert Network (DAN) is a specialized diving insurance provider that can mobilize decompression chamber services if required. Learn the location of the closest chamber to the dive site.



FIGURE 25.5 All divers should be trained to deploy emergency oxygen, the primary treatment for decompression illness.

An effective dive plan that calculates no-decompression limits and oxygen loading should prevent decompression-related injuries. For planned decompression dives, calculate lost gas and time limit scenarios. For all dives, calculate the minimum surface intervals to plan for safe gas loading.

Entanglements

Dangers such as sharp objects and entanglements are present in underwater environments. Carry appropriate cutting devices such as dive knives, z-cutters, or medical shears and know how to deploy them to help cut divers from entanglements. Low visibility may obstruct entanglement hazards, especially in overhead environments where mobility is restricted.

Training

Divers should undergo regular dive training to advance skills, and practice dive drills regularly to be prepared for planned dives. Muscle memory develops from repeated training. All underwater skills, including camera use, should be practiced on land before used underwater.

Professionals such as Andera Zaferas and Butch Hendrick provide hands-on training around the country for public safety diving and homicidal drowning investigation. The Professional Association of Diving Instructors (PADI) has also developed courses specialized in public safety diving.

DIVING ENVIRONMENTS

Water Conditions: Currents, Tides, and Weather

Equipment choices and diving safety depend on environmental situations. Learn the conditions relevant to possible dive sites. Rivers, caves, oceans, and lakes all present very different diving conditions. Fresh water requires less weight to achieve neutral buoyancy than salt water. Salt water corrodes metals and deposits salt on equipment.



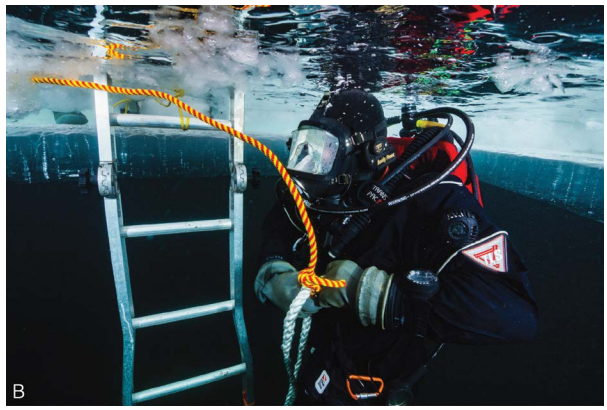


FIGURE 25.6 (A and B) Overhead and extreme environments such as ice diving require additional training and safety considerations such as additional surface support.

Currents create challenges for navigation and diving procedures. They may necessitate additional equipment such as jon lines for ascents and descents, tools to hold divers in place on the bottom, or tethers. Currents can contribute to navigational difficulty when searching for a scene and move divers away from the intended site. They can change suddenly and may differ at the surface, on the bottom, or change direction during the dive. Dive captains determine if currents are unsafe for diving and consider how to safely navigate around divers needing to emerge. Signs of heavy current include leaning buoys, debris flowing with water, and heavy winds.

Tides are significant for knowing when to enter and exit dive sites. They may make boats inaccessible from docks or control the flow of water. High tide is often ideal for dive times because it causes incoming water to slow currents. Not all sites are tidal dependent. Areas in the north require tidal consideration, whereas it is less significant for southern states. Tides also change perceived depths of sites and are a navigational consideration. Know how long a dive is safe to conduct in a tidally dependent area.

Weather can make a difficult dive easy or an easy dive difficult. Rain reduces visibility both above and below water. Wind can make a lake seem oceanic. Lightning is a serious risk in water and should be avoided in obvious ways.



FIGURE 25.7 Plan regular underwater training exercises.

Working at Depth

Tasks underwater are always more difficult than on land. By dividing tasks across an entire team, each diver is able to keep tasks simpler. This helps each diver think clearly with as little confusion from fatigue and stress as possible. Narcosis is a condition at depth that can impair divers similar to the effects of alcohol. Depth, dehydration, stress, visibility, and cold may influence a diver's susceptibility to narcosis. Plan dives ahead of time and know all actions before executing them underwater.

Contaminated Water

Wear appropriate suits to protect from contaminated water and follow post-dive clean procedures to prevent contact with skin. Vulcanized rubber dry suits may be necessary equipment to keep divers safe from contaminated water. Full face masks or diving helmets, hoods, and gloves may also be necessary equipment for protection.

Camera equipment is sensitive to contamination, particularly if the contaminant(s) react with the silicon lubed O-rings that keep equipment from flooding. Sufficiently rinse all gear in fresh water post-dive.

Cold Water

All water below human body temperature cools divers. Length of exposure to cold and the temperature itself influence the effects of cold water. Cold water dives are generally shorter than those in warm environments and must be planned efficiently if all documentation is to be completed.

Plan cold water dives for emergency situations where a diver may need to survive if thermal protection floods and a diver comes in direct contact with the water. Cold water slows thinking in divers. It may also cause cramping and stiff hands and contribute to narcosis.

Batteries drain faster in cold water than in air or warm water. Bring backup batteries and fully charge all batteries before a day of diving.

Low Visibility

Not only does low visibility reduce the ability to document effectively, it also causes safety concerns. It can obstruct hazards from view, contribute to lost buddies, and compromise navigation.

Maintain physical contact with your buddy in low visibility and use touch communication. Touch communication varies and ranges from feeling the hands of your buddy to identify a hand signal or a series of one, two, and three arm squeeze notifications to indicate stop, start, and emergency. Pull back twice on a diver's elbow to indicate move backwards and push forward to indicate move forward. Squeeze multiple times to indicate an emergency or entanglement. Whatever method of communication is chosen should be agreed upon before commencing dives.

Creating images in low visibility is difficult. Consider shooting video as well or instead of stills and learn strobe positioning to avoid backscatter in images.

EQUIPMENT NEEDS

Scuba Equipment

Maintain all equipment regularly to avoid failures. As a group, it can be beneficial to schedule regular full gear reviews on land. This will identify worn, broken, or missing equipment, which can be replaced or added to a budgetary needs list.

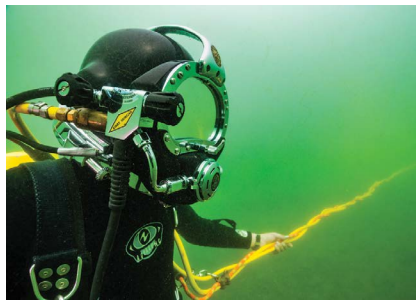
Developing gear failure is inevitable, so whenever possible, carry backup equipment. Common failures include hoses leaking, regulators leaking, batteries dying in cameras and dive computers, dry suits leaking, dry suit seals tearing, mask and fin straps breaking, power inflators failing, and cylinders (tanks) leaking from the neck or valve.



FIGURE 25.8 Inspect equipment regularly for damage such as dry rot, tears, and functionality.

Regulators require annual service. Cylinders require an annual visual inspection and a hydrostatic inspection every five years.





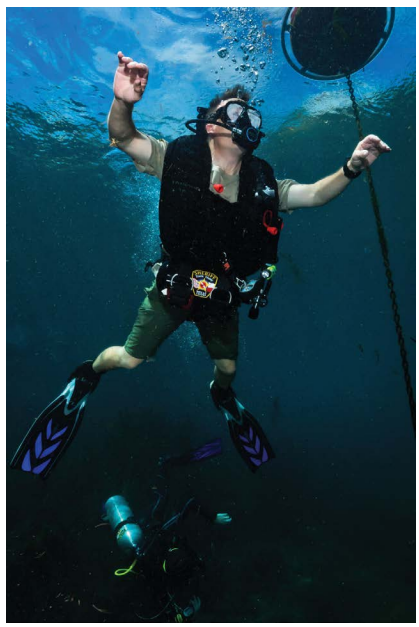


FIGURE 25.9 (A, B, and C) Full face masks and dive helmets can be equipment with comm systems so that divers and the surface crew can communicate with one another.



FIGURE 25.10 GoPros are small, versatile cameras that can be mounted onto masks.



FIGURE 25.11 Professional cameras can be housed in aluminum housings. Two INON strobes and a steady video SOLA light are mounted to this camera.

Surface-supplied air works for some contaminated environments and can be equipped for comms, but may pose an entanglement hazard due to the umbilical cord supplying air.

Alternative small-scale systems may be used for reconnaissance recovery dives.

Choose equipment matching your dive environment. Surface-supplied air, open-circuit dive equipment, closed-circuit dive equipment, dry suits, vulcanized rubber dry suits, hoods, gloves, dry gloves, back-mount configuration, and side-mount configuration may be considerations.

Closed-circuit rebreather dive equipment (CCR) is usually not advisable for public safety diving situations. Since the system creates no bubbles, it can be difficult for captains to locate divers. While CCRs extend bottom time, they are expensive and require diligent training and equipment management.

Photo and Video Equipment

Camera equipment has become more affordable for dive teams and may be as simple as a GoPro or as complicated as a professional digital single-lens reflex (DSLR) or dedicated video camera. GoPros can be mounted to masks or lights and can provide hands-free operation.

Choosing Equipment

Determine whether still images or video is the priority for documentation. All modern documentation is created with digital cameras. Resolution is greatest in a dedicated professional DSLR or mirrorless camera, but a GoPro may be sufficient. Budget may contribute to equipment choice. While still images can be taken from video, the sharpness, framing, and resolution are less than with a dedicated still camera.

Lights

Color and brightness diminish with depth underwater. To restore both, bring an artificial light source such as strobes or continuous lights. Video operates only with continuous lights, whereas still cameras can use both.

Choose lights that fit the required budget, amount of light, and length of time on full power (burn time). Video lights are specially designed to distribute light evenly across broad areas, whereas dive lights are designed to shine a continuous beam of piercing light for navigation.

Consider the size of lights and output when choosing a product. Small lights fit into smaller spaces and maneuver more easily, which reduces task loading. They can be mounted to a helmet or mask.

INON strobes are compact professional lights that provide all the power ever needed for any environment. Ikelite strobes are large lights that are less expensive but also produce less output. INON strobes with fresh rechargeable

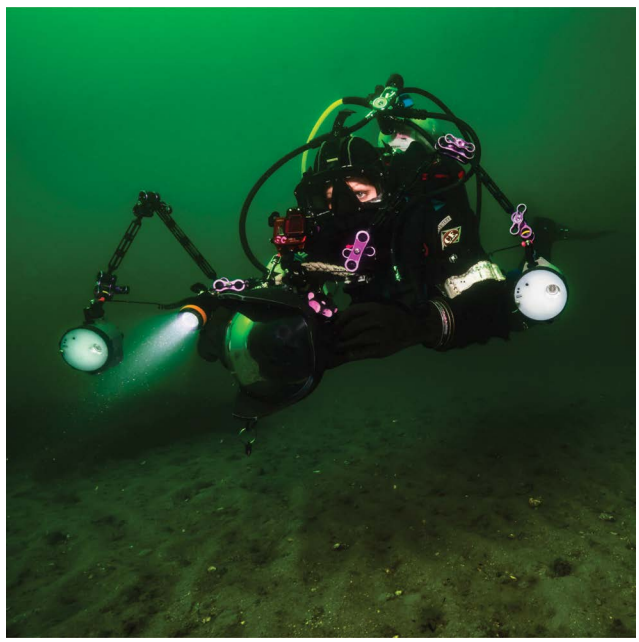


FIGURE 25.12 Strobes in low visibility are angled slightly away from the subject to avoid backscatter.

AA Tenergy or Eneloop batteries will last an entire day. To fire, strobes must be connected to the camera with a cable. Fiber-optic cables are preferred over sync cords because fiber optics can't flood, whereas the sync cord can flood. Sync cords can fire faster, but this is not necessary for recovery dives.

Light and Motion and OrcaTorch produce a series of underwater lights designed for either SCUBA or video. The video lights are more expensive but distribute light evenly. Light and Motion SOLA lights are slightly less expensive than professional lights but operate with reduced battery life. Big Blue and Keldan lights are among the best professional continuous light sources available—with strong battery life, bright output, and small size. Light Monkey also produces video lights with long battery life. Whatever manufacturer is available to your team, ensure that lights are light-emitting diodes (LEDs) and not high-intensity discharge (HID). HID lights break easily, whereas LED lights are more durable.

Affordable Options

GoPro offers the widest platform support and cost-effectiveness of any manufacturer for small, high-resolution cameras. If there is a problem with or missing piece of equipment, GoPro offers good service for replacing items free of cost. For underwater housings, be sure to order the deep diving housing and not just the waterproof housing.

GoPros continues to develop their hardware and do have screen previews available for newer models. However, the preview function severely limits battery longevity. Without the screen preview, it can be difficult to see what is being captured. It is also difficult to determine if a GoPro mounted on a helmet or mask is recording. Buddies should verify the GoPro is operating if they are mounted on a diver's head.

Small systems, such as those produced by SeaLife, are budget friendly. SeaLife is one of the few systems designed for underwater use that does not require the purchase of a housing to be used underwater.

Even today's iPhones and Android devices can be placed inside a waterproof housing and used to create high-quality images or video, though they can't create raw footage.

Professional Imaging Equipment

Cropped sensor, full-frame DSLRs, and mirrorless cameras require dedicated housings to go underwater. Mirrorless systems are smaller than DSLRs. Higher-end mirrorless cameras can match DSLR quality. These camera systems require training to use proficiently.

Professional cameras can create both raw and JPG file types. Raw files can be important for creating legally binding files because they cannot be altered. Professional cameras allow data to be stored directly on files in metadata.

Professional DSLRs offer many benefits, such as media redundancy. An automatic backup is made on a matching memory card within the camera during shooting. While these systems are more expensive initially, the redundant file system can save considerable cost. If files become corrupted, overwritten, or lost, the cost of the dive increases if it needs to be repeated, if even possible. Sometimes, the dive cannot be repeated due to artifact retrieval or dive conditions. One solution could be to run two or more less expensive cameras underwater.

These cameras all utilize interchangeable lenses. For nearly all applications, wide-angle lenses will be required underwater to sufficiently document subjects.

Housings are produced in two materials: acrylic and aluminum. Aluminum housings are more durable, but acrylic housings are cheaper and more visible. The camera cannot be seen in its entirety inside an aluminum housing. An aluminum housing is heavier than an acrylic housing, which may require additional weight added to make the camera neutrally buoyant.



FIGURE 25.13 Even an iPhone can be used to create images with an underwater housing.



FIGURE 25.14 A mirrorless camera sits opposite a full-frame DSLR, showing the huge size difference between cameras.

Underwater Remotely Operated Vehicles (ROVs)

Drones are to the air what an underwater ROV is to water. Divers offer the most flexibility for decision-making, but underwater ROVs can reach dangerous or difficult locations remotely. A trained pilot needs to manage the ROV. Surface conditions also limit the range of ROVs. Strong current and entanglement hazards can make ROV use impossible. ROVs tend to cost more than other professional imaging systems.

Peripheral Equipment

In addition to dive training, personnel, dive equipment, and camera equipment, peripheral equipment determines the total cost of underwater documentation. Peripheral equipment, including computers, software, and media storage, is essential to managing digital documentation.

Media Storage

Media refers to the digital storage for both cameras and the saved files after they are downloaded from cameras.

Memory cards have become more affordable and varied. GoPros use micro SD cards, while most DSLRs use SD cards. Some cameras use Sony's proprietary XQD cards. Some professional DSLRs also still use CompactFlash Cards. Purchase memory cards that are rated for professional level.

Cards are rated by quality and speed, with speed class, minimum sequential writing speed, and/or Ultra High Speed (UHS) speed class. These ratings are important for determining how quickly digital media can be saved to a card before another image is captured. The ratings also determine a camera's ability to record video.

Always format cards before each use to prevent file corruption, among other problems mentioned elsewhere in this book.

Exterior hard drives have also improved. They have become more affordable, become smaller, and have increased capacity. Store all media on external drives and never on internal computer hard drives. Back up all media regularly on separate external drives.

Western Digital, Seagate, G-Technology, and LaCie produce portable hard drives with ongoing development for greater capacity. A minimum of 4 TB is recommended for storage. Hard drives typically last five years because they become unstable after that time due to mechanical fatigue. Plan for obsolescence or unreliability beyond that time. Some agencies may offer external storage through a server environment with daily backups.

Software Editing Tools

This unmodified photo (Figure 25.16) is less clear than the adjusted image, but can be showed as a before and after to highlight image details. Uneven light from divers bleeds from the bottom and was corrected with editing software.



FIGURE 25.15 External hard drives are essential to storing footage and should be marked with tape to identify the date of purchase, owner, and contents.

While only the original files preferred in court, editing and managing files can help improve an image by adjusting the color balance, contrast, sharpness, and exposure. Documenting all changes and enhancements to original images will increase their admissibility potential. Blurry or bad images cannot be improved.

IMPORTANT:

Always edit a duplicate of the original file and never the original itself when software other than Lightroom is being used!

Adobe sells software available as monthly subscriptions through their Adobe Cloud interface. Lightroom, Photoshop, Bridge, and Premier are essential professional editing tools included with some of the Adobe subscriptions.

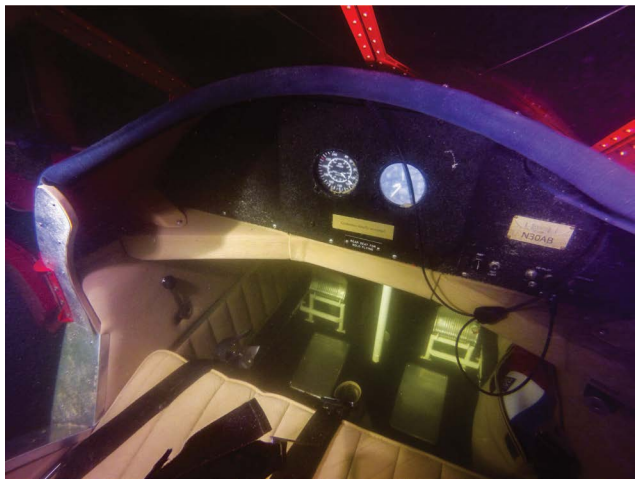


FIGURE 25.16 Damage to the plane was documented before the plane was to be retrieved and evaluated for insurance purposes.

This software requires training for use. Vivid Color-Pix is an alternative affordable underwater editing software.

Lightroom is an important piece of software because it preserves the original image when edits are made. The software imports the original image. Changes applied to the image are saved in a separate XMP file. To save an image with changes applied, export the adjusted image. Lightroom also edits large sets of images quickly. Adjustments to images can be applied across image groups. Photoshop edits one photo at a time and changes the original image—if you save changes instead of saving a new file.

Bridge is a file management program that comes with an Adobe subscription and is used to preview images. It is a memory-intensive program, however.

Premier and Final Cut Pro are professional video editing software. Other editing software such as DaVinci Resolve, iMovie (Mac platform only), and GoPro (GoPro footage only) are free video editing tools.

Most software can be learned through lynda.com with a membership.

Equipment Maintenance

Underwater housings are made waterproof through a system of lubricated O-rings. Some are required to be lubricated and cleaned of dust by the user. Others must be maintained periodically by either the manufacturer or an underwater camera company such as Reef & Photo. Only use the correct manufacturer silicone lubricant on O-rings.

Before every day of diving, clean and lubricate available O-rings. Replace O-rings that appear crushed (oval in shape) or have tears, gashes, or pot marks. Check the inside of all lens components for dust and hairs. Remove with a camera cloth or lens pen. Do not remove with fingers because fingernails scratch acrylic.

Rinse equipment externally after every dive. A fresh water bucket may be necessary to bring on boats to rinse equipment used in salt water.

CREATING SUCCESSFUL IMAGES

Test footage before arriving at a dive scene with a test shot or short clip taken with the camera fully assembled. Many professional housing units come with a vacuum test to ensure the housing is waterproof. This should be set before the dive.

Turn on the camera at the surface of the water. If filming with a GoPro, begin video footage at the surface and check the camera indicator light. Camera problems such as low batteries, dust on the lens or housing, no memory card, or lens caps on inside the housing cannot be fixed once the camera is in the water.

Identifying Subjects

Locate and identify the subject you need to document. Consider if the subject would be best captured through still, video, or both formats. When you approach a subject, also determine what angle of capture will create the most recognizable images of the object in question. As a diver, you have access to any angle imaginable.

The most important key to documenting a subject is good buoyancy. Avoid disturbing silt at all costs and know where your fins are placed. A great diver should be able to hover without moving fins or hands. Swim with fins and use hands only for operating equipment or signaling, not for swimming. Divers should also swim horizontally and not vertically.

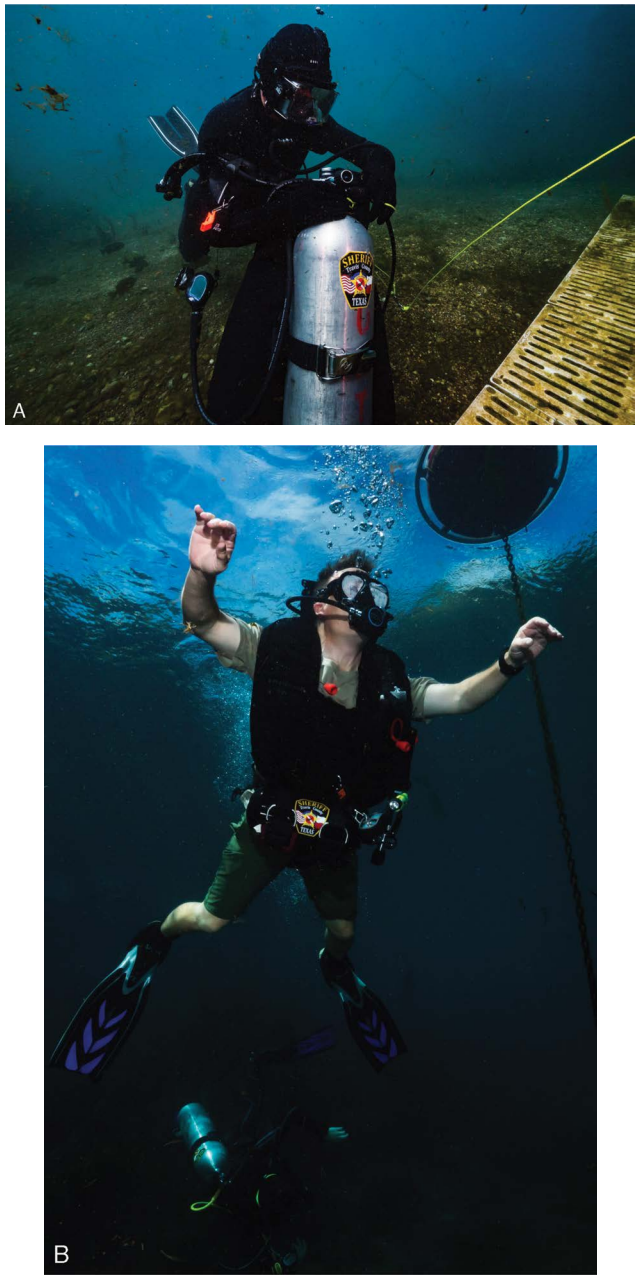


FIGURE 25.17 (A) Divers practice switching between their primary and backup gas supplies. Sometimes, doubles, side-mount, or gas block configurations are used. (B) Underwater environments contain entanglement hazards and often are covered with silt. Visibility can be good until divers disturb silt unless good buoyancy is practiced.

TIP:

Create more images than you think necessary to accurately capture the subject.

Composing Images

Consider the edges when framing an image. Underwater, you need to get as close as possible to a subject to reduce the amount of water between the camera and the subject. This increases sharpness as much as possible. If the photo is created too far from the subject, details will be lost.

Try to contain the subject within the frame and avoid cropping the subject badly. Some subjects are too large to capture in one frame. Create images of sections but ensure they are identifiable.

Shooting in Low Visibility

Shoot video when possible to add context in low-visibility environments. For still photos, position strobes so the faces of the strobes are parallel with the back of the camera. Constant video lights may also illuminate particulate in the water if placed near the camera.

Shooting Video

Set cameras to the highest resolution and frame rate as possible. High-speed footage such as 60 fps can be slowed down with more resolution than slower footage of 30 fps.

Hold cameras as steadily as possible to avoid shaky footage. Shaky footage will be difficult to interpret. Good buoyancy will help create useful footage.

Think about the direction you move when shooting video. Video shows movement through time and determine what is shown first, second, and last.

Lighting

Light subjects as evenly as possible. Strobes produce a bright flash from one direction. Buddies can hold continuous video lights from additional angles to illuminate more of the scene.

Backscatter is caused when the angle of light from strobes fires at a subject and reflects back into the sensor of the camera. Strobes fire at an angle toward a subject. To prevent backscatter, position the strobes so they are not angled directly toward the subject, but instead flat or slightly away from the subject. The farther they are from the camera, the less they will interfere with the image.



FIGURE 25.18 Review gear as a team to solve problems and ensure dive preparedness.

CONCLUSION

Underwater documentation is an investment that requires personnel, training, dive equipment, camera equipment, and peripheral equipment. Used well, the documentation supports cases, illuminates events and leads to incidents, or describes its effects.



FIGURE 25.19 The author fully geared up.

CASE STUDY 25.1

In May 2018, a young female recreational boater fell overboard on Lake Travis in Texas. No one claimed to observe her fall overboard. Alcohol was consumed on the recreational boat, so judgement was impaired by all aboard. No one wore life jackets.

The dive team was called to the scene and given a search area based on the last boat position in the water. Depths in the area reached 100 feet, and unusual rains diminished visibility. The team conducted dives for two weeks with U search patterns. Additional loss of visibility occurred due to fin movement. They did not find the missing woman.

Dives continued periodically while the team marked their search areas. Eventually, conditions improved. There was some disbelief by other personnel that the body would be found. With no current in the lake, the body should have sunk and not moved. People erroneously believe bodies hover midwater rather than sink or float up and sink due to body composition and gut contents.

Six months later in October, the team again conducted dives. This time, their search pattern showed a white object at a distance. The body was found within 20 feet of the expected location in 100 feet of water resting on top of the silt—and in good condition. Only her eyes and lips were missing. The team was able to recover the body and bring closure to the family. All activities were preserved with GoPro cameras mounted on masks. The footage was reviewed later to investigate the death and used to prove the viability of searches.

Search patterns and good visibility were key to locating this body and to helping with the investigation afterward. The divers acted as a persistent team to reach a successful conclusion and proved that bodies can be recovered.

KEY TERMS

Backscatter – When light flashes directly onto particles in the water and reflects back into the camera as large spots.

Decompression chamber – Medical facility that pressurizes a confined space to treat injuries such as decompression illness. This returns divers to the depths they were exposed to and slowly decreases the pressure in a controlled environment to allow bubbles in the blood to off-gas comfortably.

Decompression illness (DCI) – Both decompression sickness (DCS), known as the bends, and arterial gas embolism (AGE) comprise DCI. Both receive the same treatment and involve bubbles entering the bloodstream or lungs and cause tissue damage that results in a variety of symptoms and possibly death.

Dive profile – The planned times and depths for divers helps manage search times and keep divers within safe operating limits.

Hydrostatic inspection – SCUBA cylinders (tanks) must undergo pressurized testing from a qualified company and receive a stamp indicating a passing performance every five years.

INON strobe – Strobes are waterproof flashes and are manufactured by a number of companies. Although no company is endorsed in this text, brands like INON are mentioned because of quality performance.

Jon line – Static jon lines typically consist of 6 feet of nylon webbing with a clip at the end to tie divers to mooring lines during ascents and descents in high currents.

Lost gas – Equipment failure can cause gas to escape from a cylinder through the low-pressure inflator valve, the regulator, the Buoyancy Compensator Device (BCD), the neck of a SCUBA cylinder, the valve, dry suit inflator hoses, or gauges. Overbreathing can also cause gas to deplete quickly. In the case of a decompression dive, additional cylinders are calculated into the total gas supply for a dive. In the event that one cylinder has emptied or cannot be reached, it is important to determine how much gas can be lost and allow for a safe diver exit from a dive.

Lung overexpansion injury – Gas expands during ascent and increases in volume. When a diver holds their breath during ascent, their lungs can overinflate and tear, even from depths as shallow as 15 feet.

Narcosis – At depth, gases interact with the physiology of divers and can cause conditions such as narcosis. When nitrogen found in air is inhaled at depths typically below 100 feet, the physiological effect can impair a diver by slowing reaction times and even altering consciousness.

No-decompression limit – Decompression refers to the period of time at depth during which bubbles formed during a dive leave the tissues of a diver. To ascend safely without needing to stop for predetermined depths and times during ascent, a diver plans dive depths and times within limits that do not require these stops.

Oxygen loading – At depth, divers absorb gases into their tissues, including oxygen. Over time, oxygen and other gases are stored, or loaded, into the tissues.

Oxygen toxicity – Too much oxygen can cause convulsions and drowning of divers. Since the effects of gases multiply at depth. Diving with too much oxygen at certain depths can cause this toxicity.

Post-dive clean procedures – For hazardous and contaminated water or water in which invasive species predominate, procedures should be in place to rinse gear so that it will not contaminate other bodies of water. Often, vinegar mixes are used to clean gear.

Raw file – Cameras can be set to create uncompressed images that are like undeveloped film. These digital raw files cannot be altered.

Rescue breath – Cardiopulmonary resuscitation (CPR) cannot be performed in water, but during rescue diver training, rescue breaths are taught as a way to supply oxygen to unresponsive divers.

Surface interval – The time between dives is known as the surface interval and is calculated as part of the off-gassing process.

U search pattern – Several search methods are used to locate subjects underwater, particularly in low-visibility environments. The U search pattern involves kicking a predetermined distance and then turning around like a U before kicking back the same distance. Circular search patterns involve tying a line to one end and then rotating in a circle with the line, moving outward with each circle. This pattern can snag on objects on the bottom.

Visibility – How far a person can see in water.

Water tow – Tired or unresponsive divers may need assistance reaching an exit point and must be pulled through the water, usually on their backs at the surface.

Z-cutter – Several cutting devices help remove entanglements. The Z-cutter is named for its shape and unlike a knife does not have an exposed blade on the outside of the metal. Instead, the sharpened portion is inside the Z shape.

EXERCISES

Q1. Create an underwater scene on land and document the area with a dive team using cameras. Communicate as you would during the dive. Use hand signals for simulated underwater communication.

Q2. Create an underwater scene in a pool and document the area. Plan the dive as a team and discuss team member roles. Discuss what went well and what changes could improve the outcome.

Q3. Create an underwater scene at a local training dive site. Plan the dive as a team and document the scene. Plan for one diver to simulate a dive emergency or equipment failure. Direct divers to choose from a flooded camera, out of air, or lost diver scenario. Discuss reactions and procedures following the drill.

26 Forensic Fire and Explosion Photography

Noah Ryder

CONTENTS

Introduction and Need 507
- Role of Photography in Documentation 507
- Basics of Fire 508

Documentation during the Fire Event 509
- National Fire Protection Association (NFPA) Standard 921 509

Recommended Equipment 509
- Lenses 509
- Cameras 510

Field Photography 510
- Overview of the Process 510
- Interior 512

Specialty Photographs 514
- Panoramic and 360 514
- Black-and-White, Tinted, or Temperature-Adjusted Photographs 514

Vehicles 514
Explosions 515
- Types of Explosions 515

Note 516

> *It is a capital mistake to theorize before one has data. Insensibly, one begins to twist facts to suit theories instead of theories to suit facts.*
>
> **—Sherlock Holmes, "A Study in Scarlet," by Sir Arthur Conan Doyle**

A word of caution: Fire is destructive and thus fire scenes by their nature may not be in a safe state. Structures may be destroyed or weakened, hazardous materials may be present, sharp objects and nails may be hidden in debris, and electrical hazards may be present. Whenever attending a fire scene, take the necessary precautions to minimize exposure to hazards by ensuring safety is a priority and ensure that proper personal protective equipment (PPE) is worn at all times.

INTRODUCTION AND NEED

Role of Photography in Documentation

While other chapters of this book have discussed the importance of photography, and it is the main focus of this book, its importance cannot be overstated when it comes to fire investigations. Fire scenes can be far ranging with potentially hundreds or even thousands of items of interest, which may provide data necessary for the investigation. Many of these items may be impractical to collect as evidence (beams, columns, large appliances, etc.), especially if they are not potentially associated with the origin or cause or are major contributors to the fire spread, but remain materially relevant to the investigation. In this case the only means an investigator has to support their conclusions may be based on the photographs taken of the scene. For fire investigations it is not uncommon to have cases ongoing for years after the event, and thus any and all information possibly necessary, regardless of the direction of the case, must be gathered during the course of the initial investigation.

Photographs serve as triggers to remind the investigator of the specifics of the investigation and can help inform and tell the story of the incident to other parties, who likely have not seen the site in person and may never have seen a fire scene before at all. Furthermore, a photograph's ability to provide a pictorial representation of what took place and to inform its audience can support the investigator's analysis, help to refute alternative hypotheses, and ultimately demonstrate the investigator's knowledge of not just the scene itself but of forensic reconstruction.

The photographic process itself should be aligned with the objectives of the investigation, which should always be understood prior to undertaking the project. While the initial

objectives (i.e., determine the origin and cause of the fire) may be known, care must be taken to also capture as many photographs as may be necessary to ensure sufficient information is available should the scope and objectives change. Thus, while there is some discussion of the technical aspects of forensic fire scene photography in this chapter, most of the chapter is focused on the purpose of the photographs and thus is more about what to image rather than how. For those unfamiliar with fire scene investigation, a brief bit of material is provided on the basics of fire, but for those familiar with the subject, it can be skipped. In the end, in order for the photograph(s) to be accepted in a court of law, and all photographs should be made with the understanding they might be needed for this purpose, the photograph(s) must be a *fair and accurate* representation of what was observed.

Basics of Fire

Controlled fire has remained one of man's greatest inventions and has enabled us to stay warm, to feed ourselves, and to mold steel into structures reaching for the sky. Uncontrolled fire, on the other hand, remains one of man's greatest nemeses, one that kills thousands and costs billions per year. As a result, it is important to have a brief understanding of what exactly a fire "is" and what it is we are looking to photograph.

Fire is quite simply a chemical reaction of a fuel source (it may be gaseous, liquid, or solid) resulting in the release of heat, light, and products of combustion (smoke). In order for this to occur, three components are necessary: oxygen, a heat source (ignition source), and fuel (see Figure 26.1).

The amount of heat or energy produced from a fire is referred to as the heat release rate (HRR) and indicates the rate at which heat is produced. It is important to note that this is rarely a constant value and will change during the course of the fire as it grows and declines. The determination of the HRR is difficult and for our purposes isn't strictly necessary. However, what physically manifests itself as a result of the HRR is of great importance.

As mentioned earlier, fire produces light, heat, and smoke, and these may leave evidence in the form of burn patterns, soot staining, and other physical features, possibly visible and suitable for documentation. These can provide great insight into where, how, and even when the fire may have occurred and where it spread. Of particular note is one of the key challenges with forensic fire photography is fire is destructive by nature, and therefore oftentimes key evidence has been consumed and the investigator is left trying to complete a puzzle, some of the pieces of which have been destroyed. Exacerbating this may be the effects of fire personnel during the course of their normal efforts to rescue, suppress the fire, or overhaul the scene.

As a result, the investigator must be able to extract information on the fire initiation, development, and eventual extinguishment from the scene by observing not only what is present and visibly damaged but also what has been consumed completely or remains intact. In fact, oftentimes the documentation of what has been untouched by fire yet is in close proximity to areas or items damaged and thus can serve to inform the investigator significantly about the fire, as it acts as a sort of threshold or boundary delineating the effects of the fire.

Thus, the investigator should take a holistic view, taking into account the environment around the incident, narrowing the focus to the incident scene, and continuing to refine the focus to the area and potential cause of origin, similar to a scientist increasing the magnification of a microscope.



FIGURE 26.1 Fire triangle, showing the necessary components to sustain a fire. (If any of these are not present, a fire will be unable to start or to continue. If these are present in sufficient quantities, then a fire is possible and will develop based on its surroundings, the available air, and available fuel.)





FIGURES 26.2 AND 26.3 Burn and smoke damage.

DOCUMENTATION DURING THE FIRE EVENT

While the investigator is rarely on-site during a fire event, the potential for video or photographs of the fire in progress is greatly increased from times past and continues to increase. The rise of smartphones, security cameras, hobby drones, and the 24-hour news cycle almost guarantees some documentation of the fire in progress will be available. While the overall usefulness of the photos may be limited, if nothing else they can provide insight into the timeline of the event, and the investigator should seek them out to incorporate as necessary into their analysis. Similarly, fire department reports can also be useful, as they may provide information about when and where firefighters took actions, and this can be tied to photos of the event when available.

National Fire Protection Association (NFPA) Standard 921

Our advice regarding the information found in NFPA 921 regarding fire photography is this: Be careful to take the information as advice only. NFPA 921 is published only every few years, and the information contained may be out of date, even in the newest edition. Also, the information found there is only basic and goes into detail about nothing photographic. Use the information contained in the standard to craft your agency or firm SOP.

RECOMMENDED EQUIPMENT

A good forensic photography kit will likely be suitable for fire scenes; however, there are a few unique features of fire scenes that may necessitate additional equipment. In particular, fire scenes are typically relatively dark, as power is usually disconnected to the structure; the smoke, char, and residual from the fire is made of carbon, providing little contrast; tight confines and restricted access and mobility may come into play; and finally, the environment itself may be hazardous, requiring the cleaning or potentially the post-use disposal of equipment. Thus, prior to going on-site, it is important to understand to the extent possible what the nature of the scene may be and to plan equipment accordingly. The following section provides some brief supplemental information to that provided earlier in Chapter 7 of this book.

Lenses

A series of good lenses with high-quality optics are arguably the most important part of a fire camera kit. Many 4/3, macro, or "point-and-shoot" cameras are significantly limited in terms of lens selection, and they may not support additional lenses at all. As a result, the selection of lenses available should influence the choice of camera, especially when dealing with cameras that have reduced image sensors (Figure 26.4).

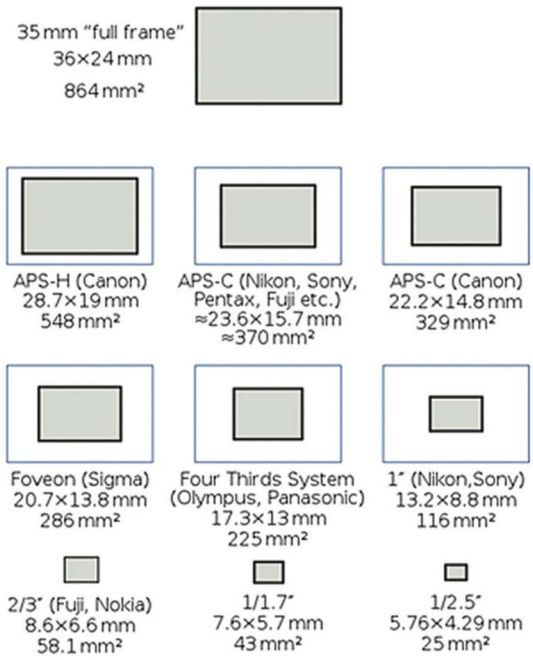


FIGURE 26.4 Comparison of sensor sizes in relation to a standard 35 mm frame.

Zoom Lens

A "zoom" lens allows for the focal length to be changed and is thus very versatile. The downside to a zoom lens is they tend to be larger and heavier, and as the range of focal lengths increases, this only gets worse. A prime lens tends to be lighter and less expensive but may be reduced in terms of flexibility. However, they tend to have a larger maximum aperture and thus are better suited for the low-light conditions often encountered at a fire scene. The limited focal length means any change in "focal length" must be achieved by relocating yourself relative to the subject of interest.

Macro Lens

A macro lens generically means the lens enables a photograph to be exposed in close proximity to the subject and is similar in reproduction size to real life. Macro lenses are



FIGURE 26.5 A short zoom lens.



FIGURES 26.6 Macro image of the inside of a conduit showing strands of electrical cable after a fire event.

typically used to detail small objects such as fusible links, glass bulbs, horns on smoke detectors, electronic components, etc., of interest to the case.

Cameras

DSLR or Equivalent

A good camera with a wide range of potential lens selections is vital to successful photography at a fire scene. The ability to change lenses is key. A digital single-lens reflex (DSLR) is still the preferred "go-to" camera for investigators due to the relative familiarity of operation, the general interchangeability with 35 mm lenses and accessories, and the overall quality of the images produced.

Rugged Camera

While an interchangeable lens camera system will be the primary camera for most investigations, a "rugged" camera is an invaluable part of any camera kit. First and foremost, a backup camera is always in order, and ruggedized cameras expose quality photographs and offer macro features too. A ruggedized camera is perfect, as it can stand being dropped, banged, and otherwise getting dirty. When all is said and done, a good rinse in the sink and the camera is good as new.

FIELD PHOTOGRAPHY

Overview of the Process

The goal of the photographer should be to gather and provide data on the scene in such a way that information about relevant data points can be conveyed to observers of the photographs in a clear and logical manner. As such, the photographic process usually consists of the following basic categories of photographs,[1] each of which is discussed in the following sections:

- Title
- White card
- Exterior photographs/surroundings
- Interior photographs
- Evidence collection
- Victim photographs

Title

The beginning of any good photo project should include a title image to provide information about the photographs following. When necessary a secondary title can be included to clearly indicate a different "scene" about to be photographed. This, along with the photographic field notes (see Figure 26.7), regarding individual photographs, will ensure the investigator is able to clearly present his or her work to those who may be reviewing it, as well as to act as a mental trigger for himself or herself.

The title image should include the following:

- Unique number/descriptor of the incident/project
- Date/time of incident
- Location of incident
- Photographer name and affiliation
- Date of photographs

Exterior

Documenting the exterior of a structure and/or the surroundings of an incident provides context to the overall scene and the conditions during the investigation. The purpose of the

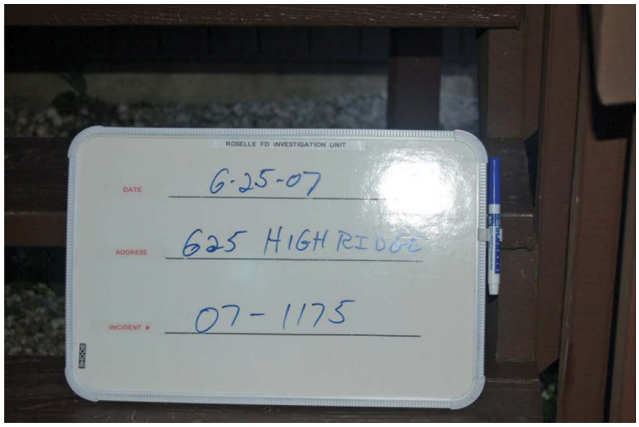


FIGURE 26.7 A title card. This one is reusable. Wipe off the writing, and it is ready for the next case.

exterior photographs is to enable a viewer of the photographs to understand what surrounds the incident, the extent of the incident relative to its surroundings, and how, if at all, the surroundings may have affected the incident timeline or outcome. As most fires of interest involve a structure of some kind, the following is framed from that perspective; however, the same approach should be taken when photographing pieces of equipment, wildfires, or other scenes in which a structure may not be directly involved.

Fire personnel in most areas refer to structures as having sides A, B, C, and D, which refer to the front of the structure and then rotating clockwise, as shown in Figure 26.8. Along with this designation will be a north arrow.

Exterior images should be exposed first and, if possible, provide an aerial view of the site, orienting the viewer to the overall environment. This may be done using a drone or in the event one is not available or permitted, typically a satellite image may suffice. The first photograph should always be of the property address, if possible, to demonstrate the photos following are associated with that unit. While this may sound like common sense, in large fires involving multiple properties, especially those of similar design, it can

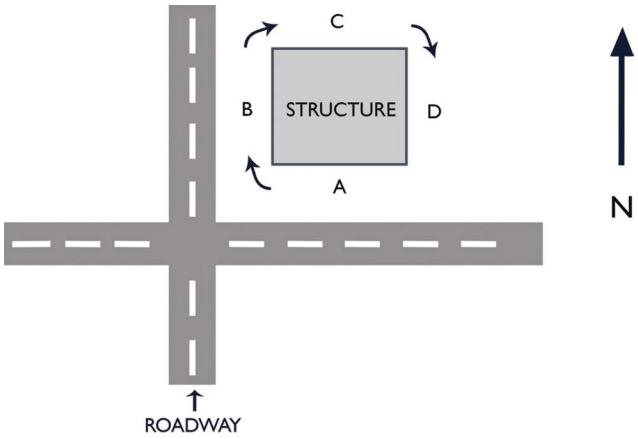


FIGURE 26.8 Orientation and reference for scene photography.





FIGURES 26.9 AND 26.10 These are both the same church. The interior burned completely, but the front wall remained standing, almost intact.

be easy to lose track of what photograph belongs to what property. Once the address photograph is exposed, the exterior photographs should then start at the front of the structure, A, and if possible, move in a clockwise direction around the structure until you arrive back at the starting point. Photographs of each face, as well as the corners of the structure, should be made to ensure continuity from one frame to the next. While often only one quality photograph of each may be necessary, depending on the extent of the fire, should there be a need for visual evidence of fire effects, more detailed photographs should be made to adequately enhance the data.

As fire scenes can be busy places with many investigators on-site, it may not be possible to begin photography at side A or rotate in the desired direction. Regardless, wherever photography starts, the direction of travel should be consistent throughout until all exterior photographs have been made. If upon review or observation additional exterior photographs are necessary (for instance, slight soot staining at a vent is observed), it is recommended that a full-frame exposure of the area be exposed again for context, and then closer photographs highlighting the area of interest may then be completed. When exposing the exterior photographs, particular attention should be paid to any observed damage or lack of damage.

Key Identifiers, Utilities, and Access

While exposing exterior images, any key features or identifiers of the structure or surroundings should be documented to provide context. This includes house/building numbers, street signs, mailboxes, and mailbox numbers. These can be particularly useful in situations where properties are similar in visual appearance or are part of a larger complex.

Most structures will have means for utilities to be provided to them. It is important, prior to ever stepping foot inside, to identify what utilities were provided and the state they are in. Overhead electric drops, gas and electric meters, gas or propane tanks, and other specialized utilities may be provided to the structure. Each may pose a hazard once onsite and may have been involved in the fire event. Each item should be documented and its state confirmed prior to entry. Ideally, confirmation will be provided for all electric and gas having been shut off to the structure and thus the risk will be minimized. Documentation of the utilities, in addition to ensuring safety, will also provide useful information about potential fuel loads and may indicate if there was a problem with the utility or one of its components.

While most times it is not an issue, fire department and emergency response access is critical to the outcome of the event. Should a first responder be hindered in access due to the facility layout or exposure, it may affect the suppression and rescue efforts. Any access restrictions such as narrow or unpaved roadways, low overhangs or lack of clearance, downed power or utility wires, or other hindrances should be thoroughly documented.

Doors, Windows, and Vents

Doors, windows, and vents are key items to document on the exterior of a property. These are the paths for air to enter into the structure and also a primary means for smoke and flame to escape and/or spread. Plumes exiting from windows, doors, and balconies leaving physical evidence can be used to determine estimates of heat release rates; thus, documentation and good photographs are key. Furthermore, evidence of smoke and heat damage (Figure 27.11) removed from the "involved" area may indicate openings, penetrations, or other pathways for the movement of smoke and heat that are present but not readily visible without destructive examination.



FIGURE 26.11 Heat and smoke damage visible on roof soffit, showing evidence of smoke spread through attic space and exiting on noninvolved side of the house.

(From N. Ryder.)

Doors and windows are also of interest, as they are potential means of escape for people from a fire, especially those on the ground floor. The condition, dimensions, and any security measures present should be documented. In particular, anything that might hinder escape or shows damage (i.e., window breakage) should be documented as it relates to the timeline of the event.

Interior

The documentation of the interior should follow the same general process as the exterior. Overall photos should be exposed and then gradually work in to the subject of interest. In general, photos should be sequenced from areas of least damage to the area most damaged. In this way the context of the overall scene and extent of damage can be documented in a logical way.

Architectural, Structural, and Design Features

Key architectural, structural, and/or design features that may have affected the path of travel of smoke, fire plumes, or the fire itself should be documented in detail. Aspects like vaulted ceilings, beams, cloud ceilings, etc., will all affect the flow of gases and thus may affect the activation of smoke detectors, heat detectors, or sprinklers, if present. Ceilings may often be damaged directly from the fire or via the firefighter overhaul process, so it is important to document the damaged areas, but also to document similar undamaged areas, if available, for comparison. Wall and ceiling coverings can also affect the spread of fire, as can curtains and other similar types of hangings.

Fire is largely a buoyancy-driven event; thus, anything affecting the buoyant flows or ceiling jets will affect the spread of smoke and heat and may affect the fire growth and spread. Heating, ventilation, and air conditioning (HVAC) systems and exhaust fans in particular are important, as they move air around and can transport smoke to other areas of the structure where people remote from the fire may be exposed. Similarly, devices such as smoke detectors may not be exposed if smoke is removed from the area, which can result in delayed activation.

Fire Detection and Protection Systems

While the range of fire detection and protection systems varies from structure to structure, the details should be understood and photographed thoroughly throughout. Notification devices (horns, speakers, strobes, etc.), exit signage, smoke and heat detectors, and automatic suppression systems (sprinklers, dry chemical, etc.) should be documented both in the area affected by the fire and in those areas where



FIGURE 26.12 Close-up of a fusible link for a self-closing fire shutter after activation.

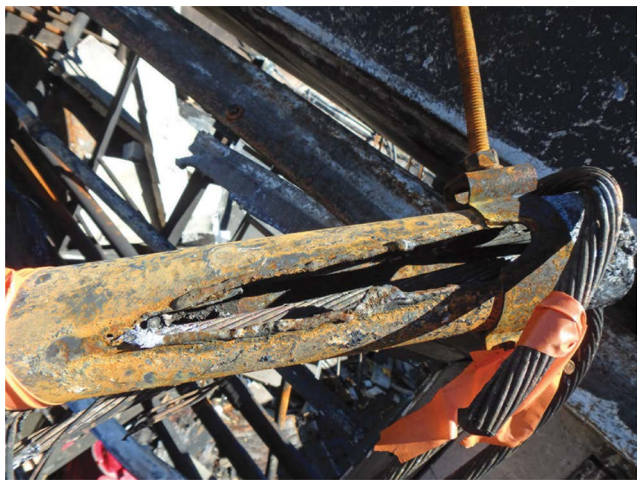


FIGURE 26.14 Photo showing arcing of electrical cable and damage to conduit from arcing.

example systems can be examined and documented to illustrate the pre-fire conditions.

Devices activated during the fire, or that potentially should have been, should be thoroughly photographed to make sure the make, model, serial number, etc., are documented, in situ if possible.

Electrical Components, Wiring, and Arc Mapping

When heat or flames come in contact with electrical wires and cabling, the insulation may begin to thermally degrade. For most insulative materials, this thermal degradation can result in the formation of char, which is conductive. Char may also contribute to increased resistance in the cable, which in turn causes more heat and insulative failures. This condition, or direct exposure, can cause wire to melt and "bead," thus closing the electrical loop and breaking the path of the current downstream of the bead. By examining wiring, it may be possible to determine where the fire was located first and then where it spread. This process is known as arc mapping and requires detailed documentation and photographs to show where beads formed and where they stopped. This process can be very painstaking, as it requires careful tracing of each circuit to determine the source of the energy. Also, the type and location of each failure must be identified.

Contents

The contents of a fire scene, relative level of damage and "patterns" observed can be quite meaningful, both to illustrate what was damaged and what wasn't. Based on the level and type of damage observed, conclusions may be made on the potential magnitude and length of exposure. Figure 26.16 shows multiple identical drums that were all exposed and yielded different levels of damage. Based on this we can ascertain that the drums towards the right side of the picture were subjected to a more intense exposure and potentially for a longer duration. This in turn can

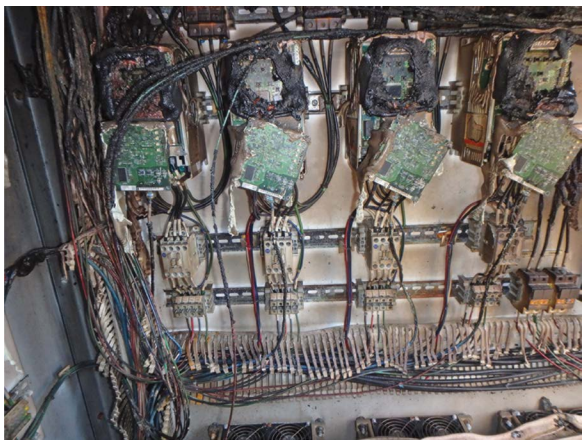


FIGURE 26.13 Photograph of electrical cabinet exposed to fire from the outside. Damage from heat can be observed on wiring, plastic housings, and components. The limit and type of damage make it clear the damage was due to external fire exposure.



FIGURE 26.15 Kitchen ductwork showing heat damage as a result of a hood fire.



FIGURE 26.16 Identical drums illustrating different levels of damage due to exposure to heat flux. Those farther to the right show greater damage, while those to the left show less, with those towards the rear showing no damage.

(From N. Ryder.)

provide insight into where the fire was located. Furthermore, by knowing what material the drums are made of, we can estimate the amount of heat possibly required to cause the observed levels of damage. The photograph enables and supports this analysis.

SPECIALTY PHOTOGRAPHS

Panoramic and 360

Panoramic and 360-degree images can be very useful for setting the context of more detailed images and can help provide a greater understanding of the surroundings. While virtual reality or augmented reality is not in widespread use, it is expected to make its way into the forensic field, and forensics may in fact be a perfect application for the technology.

The prevalence of low-cost panoramic photography capability (nearly every smartphone enables an average user to make high-resolution panoramic images) and specialized apps, such as "360," which allows a smartphone to create 360-degree panoramic photos and automatically stitches the images together, greatly enhance what can be provided visually.

As an example, 15 years ago in order to create a 360-degree photograph, a tripod had to be set up with a camera and exacting photos spaced out every 5 degrees horizontally and vertically. These photographs were then taken back to the "shop" and were manually stitched together using specialized software. This process was cumbersome and expensive. Now in the matter of 2 minutes in the field the same output can be generated and instantly transmitted (see Figure 26.17).

While not highly detailed close-ups, these kinds of images can orient the viewer and provide a level of interactivity not possible with a still photograph, and when users are presented with a number of these, they can grasp the full context of what the scene looked like.



FIGURE 26.17 "Flattened" 360-degree panoramic photograph of fire scene.

(From http://360.io/Q6acdQ and N. Ryder.)

Black-and-White, Tinted, or Temperature-Adjusted Photographs

While infrequently used these days, black-and-white photographs, though usually still exposed with a color camera, can provide more contrast, possibly enhancing contrast. They also can help to focus a viewer on the intended subject, as the colors are removed and not a distraction. It must be clearly stated that it is a black-and-white image, and then the photographs can be useful. If the texture, form, or light levels of the subject are more important than hues, a black-and-white photograph may be in order or may be useful to highlight an area of interest.

VEHICLES

In the United States, fire departments respond to nearly 300,000 vehicle fires per year. While the approach to photographing a vehicle is largely the same as that of a building, there are a number of systems and components typically existing requiring documentation and that may not be readily recognizable for many individuals. Fires in vehicles normally initiate in one of two locations: under the hood/portion of the fuel system or in the passenger compartment. Many times, a fire in one area may not readily spread into the adjacent area based on the construction of the vehicle and fire stops possibly present.

In general, vehicles will have a fuel system composed of fuel tank(s), fuel pumps, fuel lines and injection systems, and potentially a carburetor. Each of these components carries fuel, often at elevated temperatures and pressures; thus, the conditions are ripe for a fire in the event of an accident or leakage. Also, the electrical systems of vehicles may fail in similar ways to those in structures and similarly may cause a fire. With the rise in electric and hybrid vehicles and the integration of more electronic components into vehicles, more electrical failures will be expected and the important features of vehicles may change. As a result, the photographing of a vehicle must ensure the main systems are documented, providing details on the observed damage, the systems affected, and other pertinent details, regardless of the method of propulsion.



FIGURE 26.18 (A, B, and C) Comparison of color, black-and-white, and color temperature-adjusted photographs. **(From N. Ryder.)**

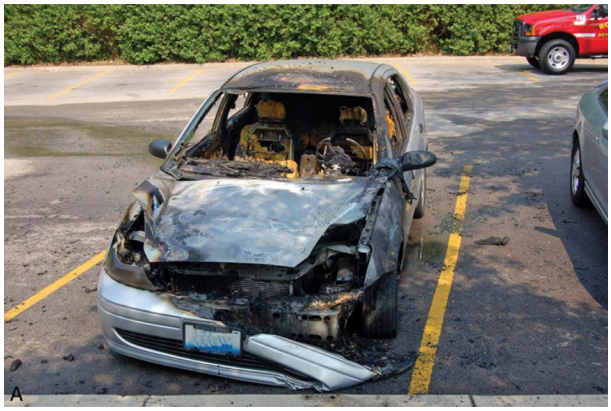






FIGURE 26.19 (A, B, and C) An automobile consumed by a fire starting under the hood.

EXPLOSIONS

The documentation of explosion scenes shares many of the same characteristics and techniques as that of fires, combined with structural and mechanical failures. The one major difference needing to be kept in mind is the process of an explosion will often result in evidence or artifacts being distributed over a significant area, possibly well outside the area in which the explosion originated. As a result, the area of documentation will be significantly larger and may be much more challenging; however, it must be performed well, as the distance traveled and size of a fragment can provide valuable information about the size and nature of the explosions.

While the basic equipment required is the same as that discussed earlier, it may also be very helpful to use a drone or aerial photography to provide an overview of the scene and extent of the damage. It is also helpful to have a camera or standalone global positioning system (GPS) unit to provide accurate GPS coordinates of evidence and artifacts, especially when the scene is large and may cover acres or even miles (such as airplane incidents). Most important is to understand the types of explosions you may encounter and how they may affect photography.

Types of Explosions

Fundamentally an explosion is defined by an increase in pressure—without an increase in pressure, there is no explosion. There are two categories of explosions: deflagrations and detonations. A deflagration is an explosion in which the pressure wave is expanding slower than the speed of sound, while a detonation exceeds the speed of sound. Most accidental explosions involving gases (such as methane, propane, or natural gas) will be deflagrations; however, some accidents can be detonations, including fireworks or factories making energetic materials.

This brings us to the three main types of fuels that can result in an explosion. The first is a gas, the second is a dust, and the last is termed a condensed phase explosive (i.e., TNT or similar). The importance of the type of fuel leading to the explosion is for a dust or gas, the fuel able to participate in the explosion may be spread out (imagine a cloud of gas being ignited), while for a condensed phase explosive like TNT, the fuel is located in a single place. This arrangement

matters, as the pressure waves will differ in form for a gaseous/dust explosion versus a condensed phase explosion. Gaseous and dust explosions may increase and build in pressure as they move outwards from the ignition source, while a condensed phase explosion will reach peak pressure at or near the point of ignition and then dissipate.

Obviously, this difference in behavior will affect what the damage patterns look like and how far and severe the damage may be and therefore what areas will require documentation. As a result, it is critical for this basic information to be understood with regard to explosions. Once the basic behavior is understood, the actual photographic process is similar to a fire, structural collapse, or other mechanical issue. In many ways, the aspects when photographing a fire scene (i.e., low contrast) are ameliorated for an explosion scene.

PHOTOGRAPH DESCRIPTION		Card No.	File/Project
Field Notes			
Picture #	Description	Picture #	Description
1		26	
2		27	
3		28	
4		29	
5		30	
6		31	
7		32	
8		33	
9		34	
10		35	
11		36	
12		37	
13		38	
14		39	
15		40	
16		41	
17		42	
18		43	
19		44	
20		45	
21		46	
22		47	
23		48	
24		49	
25		50	

FIGURE 26.20 Sample field photo log.

NOTE

1. While the "usual" steps are preferred, there may be occasions where the order of photographs must be changed due to environmental, structural, evidential, or other reasons. In this case, it is particularly important to tie in the remainder of the photographs and to note what was done and why, so the information is preserved and clear for use in the future.

27 Injury Photography

Eric Johnson

CONTENTS

Part One: Initial Documentation 518
- Challenges 518
- Camera Settings and Controls 518
- Best Practices 520
- Exposure Basics 524
- Lighting Basics 525
- Know Your Equipment 526
- Lighting Techniques 529
- Proper Techniques 532
- Putting It All Together 534

Part Two: Advanced Techniques 535
- Required Equipment 535
- The Basics 535
- Using What's in Your Bag 546

Part Three: Testing Your Equipment 546
- ISO Noise 548
- Accurate Viewer Perspective 549
- Minimum Focus Distance 550
- Color Balance aka White Balance 550
- Depth of Field 551

Notes 553

Photographs of injuries are used for many purposes: criminal prosecution, civil litigation, documentation of recovery progress, etc. The one thing that all these photos should have in common is accuracy.

This chapter will discuss how to ensure the highest level of accuracy is achieved by using proper camera settings, experimenting with various lighting techniques, learning how to obtain accurate color, learning how to properly compose an image, and ensuring that images are sharp and reveal an accurate perspective. Learning and using these principals together will ensure the five following components of a great image are met:

1. Proper lighting
2. Proper exposure
3. Accurate color
4. Proper composition
5. "Sharp"—meaning nothing is blurry, out of focus, or noisy from using a high ISO

Information on these five components, as well as camera settings, ISO, and other controls will be addressed throughout this chapter.

Becoming a good injury photographer is not a matter of simply reading this chapter and applying the described techniques. That would be like reading a chapter on how to shoot a firearm, and then expecting to be proficient without practice. Instead this chapter will be discussing various scenarios and options the photographer will have to experiment with to understand how everything works.

While digital cameras may seem similar, they can be quite different; there are different types and sizes, they have different settings, different modes, and different capabilities. If you were taking one of my workshops, we would zero-in on the specific camera you were bringing and discover its capabilities for best capturing injury photographs. Since there is no way for me to know what camera you are using, throughout this chapter I will be recommending tests and experiments for you to conduct yourself to fully realize the potential of your equipment.

For purposes of organization this chapter is divided into the following three parts:

- Part One is written for the benefit of the first responder or investigator needing to document the extent of an injury or injuries for possible criminal prosecution.
- Part Two is written for the more advanced photographer and explores some advanced techniques. It will also address the specific challenges of documenting the extent of an injury many months or sometimes years after the injury occurred, generally directed at the forensic photographer in a civil proceeding.

- Part Three contains a description of how to conduct five important tests to become familiar with and know how to get the best images using your equipment.

PART ONE: INITIAL DOCUMENTATION

First responders will generally be the ones seeing and documenting an injury shortly after it has occurred. If possible, injuries should always be photographed twice: (1) as first observed, and (2) after the injury has been cleaned-up but before bandaging. Circumstances will always play a role, of course. The type of incident, such as a domestic assault or in-home/work accident, may provide more opportunities for photographers than a felonious assault or traffic crash victim. Regardless of circumstances, once the scene is secure and the threat no longer exists, it is time to get the camera and begin the documentation process.

The initial injury can often be very graphic, with the presence of blood, bone fragments, torn tissue, severe distortion, and other anomalies caused by trauma to the victim. There is always value to this documentation, even though on occasion these photographs will not be used because of their graphic nature and a fear of prejudice in a court proceeding. In a civil case, the appearance of the initial injury usually has no bearing on the long-term effects of the injury, so the value is limited. Still, taking photographs of an injury before treatment should always be done if possible.

Challenges

The first responder will almost always face challenges when needing to document an injury on-scene; variables of weather, subject condition and temperament, lighting at the scene, and even bystanders or family members can all have an impact. Other factors that may not seem evident at the time include distractions in the photographs such as subject clothing, busy or confusing backgrounds, and unwanted reflections and color casts to name a few.

Any experienced police officer knows first-hand that the scene of a domestic incident, particularly if injuries result, can be emotional and complex. It has always been important to separate the participants and isolate them from each other—and the same is true when it is time to take photographs.

Whenever possible, photographs should be taken removed from all distractions, regardless of the circumstances. Consideration should be given to the background that will appear in the photographs; taking photos with a cluttered background, with a mirror or window in the background, with people in the background—anything nonrelevant to the purpose of the photographs should not be in the image.

I have seen photographs of victims and their injuries taken in front of a big screen television that had been left on and inadvertently captured an inappropriate moment from a broadcast. I have seen photographs of victims and their injuries taken with their backs to a large picture window with lights from emergency vehicles predominant in the background. I have seen backgrounds so distracting with people and clutter and "things" more interesting than the victim and the injury that the impact of the actual injury was diminished.

With a little planning and effort, the victim can be photographed without these distractions; every photograph should be free of everything but what is important to show: the injury.

Camera Settings and Controls

Although this chapter is not about basic camera settings or controls, a quick review is necessary to ensure an understanding of the suggestions made throughout this chapter. Even if you think you know all about camera settings and controls, I encourage you to take a few extra minutes to review this topic.

Before describing the relevant camera settings and controls, it is important to first understand the meaning of the term depth-of-field (DoF). There is no term more important, especially in a law-enforcement application. In fact, the end goal of learning how to properly use the camera settings and controls described in the section is to achieve the necessary DoF.

DoF is the area within your photograph that shows your subject matter in sharp focus, from the closest to the farthest point in the photograph. With two exceptions, your goal should always be to ensure everything in the photograph will be sharp. The first exception is when you need to isolate a piece of evidence to separate it from a distracting background. The other exception is when you need to emphasize an injury mark or scar in a close-up photograph. In both cases, however, you should always have a medium view photograph showing the subject matter in sharp focus.

The following camera controls and settings when properly combined will serve the purpose of achieving the best possible photograph of your subject matter—and will ensure you have adequate DoF.

Aperture, or f-stop, is a hole that allows light into the camera. The larger the hole, the more light is let in. However, the size of the hole will also determine DoF. A large hole has less DoF than a small hole. Large holes have lower numbers, like *f*/2.8, *f*/4.0, *f*/5.6, *f*/8.0, etc. Small holes have larger numbers, like *f*/11, *f*/16, *f*/22, etc. Many are confused by the concept that the larger hole has the smaller number. An easy way to remember is to visualize a "1" instead of the "f" and think in terms of a fraction. Instead of *f*/4.0, read it as 1/4.0. Instead of *f*/22, read it as 1/22. 1/4th of a whole is much larger than 1/22nd of a whole.

Shutter speed is like a window shade. Shutter speed can be very fast or very slow; the biggest concern for the forensic photographer is that a slow shutter speed will result in soft or blurry photographs from either camera or

subject movement. In most law enforcement applications, the speed of the shutter is not important since the subject matter is usually stationary and not moving. However, slow shutter speeds require a tripod or other stable surface, as well as a method to release the shutter without touching the camera.

ISO[1] is a camera setting that determines light sensitivity. Low numbers are used when there is a lot of light, like 64, 100, and 200. Higher numbers are used when there is reduced light, like 400, 800, 1600, and 3200. The problem with high numbers is that "noise" starts to appear on the photograph. A very high ISO will have substantial noise that will also reduce the sharpness of an image (Figure 27.1). However, the noise from a high ISO in a bright scene is much less noticeable than the noise from a high ISO in a dark scene. In addition, not all cameras are equal when it comes to noise. Some cameras have quite low noise at higher ISOs, and other cameras have a lot of noise even at low ISOs. It is important to test the camera you use to determine where it becomes a problem. There is a suggested method to test the ISO noise levels in your camera in Part Three of this chapter.

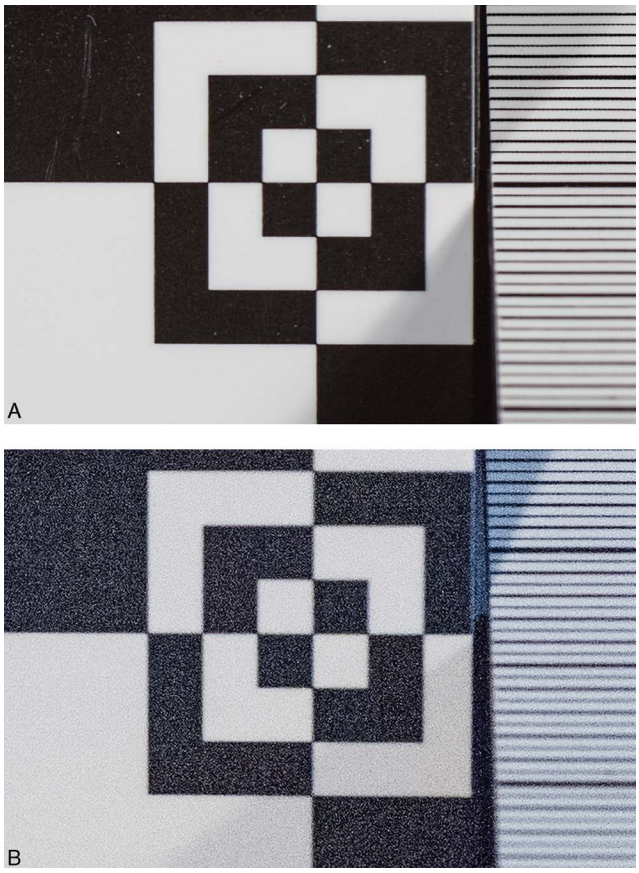


FIGURE 27.1 Low- and high-noise examples. (a) A low-noise example of ISO 100 on a full frame camera. (b) This is a high noise example that is typical of ISO 400 for a cellphone camera, ISO 800 for a point-and-shoot camera, or as high as ISO 6400 for a full frame camera.

Camera shooting modes allow a choice of varying levels of control providing a photographer the ability to prioritize their needs. The following five basic modes are:

1. Automatic
2. Program
3. Aperture Priority: "A" on Nikon, Sony, and most other cameras, and "Av" (aperture value) on a Canon
4. Shutter Priority: "S" on Nikon, Sony, and most other cameras, and "Tv" (time value) on a Canon
5. Manual

In the **Automatic mode**, sometimes referred to as the "green mode,"[2] the camera makes all the decisions. There is a computer module in the camera that is programmed to respond to thousands of lighting scenarios. If the scene is dark, the internal or pop-up flash will be activated, even if the subject matter is out of range for the flash.[3] The photographer has no control over shutter speed, f-stop, or ISO. This is NOT the mode to use for injury photography, nor other law enforcement applications; you have no control over DoF.

The **Program mode** is quite similar to the automatic mode, in that it uses preprogramming to determine correct exposures. In this mode, however, the photographer can adjust the f-stop or shutter speed, and the function not changed will automatically be adjusted in the opposite direction in order to keep an accurate exposure. This uses the principals of exposure more fully described in the upcoming exposure section. The advantage this mode has over the automatic mode is that the photographer can adjust to obtain a specific f-stop or shutter speed to best capture the image. Still, this is not an ideal mode for law enforcement use.

The **Aperture Priority mode** is a favorite among many experienced photographers. This mode allows you to set your desired f-stop, and the shutter will then automatically be adjusted based on the amount of light in the scene. This is an excellent way to prioritize DoF and is also a preferred method of exposure when using an external flash in the TTL[4] flash mode.

The **Shutter Priority mode** is a favorite among photographers that shoot action subjects, like sports or wildlife. The shutter is set at a speed required to stop the action, and the aperture is then automatically adjusted to provide the proper exposure.

The **Manual mode** is typically used only by experienced photographers; this mode allows you to be in total control. You set the aperture and shutter speed manually and adjust whichever is more important for the particular subject matter you are photographing. Many "casual photographers" are afraid to use the manual mode—mostly because they feel it is complicated. It is not. Cameras that offer this option also include a meter that indicates a proper exposure based on the lighting of the scene. The meter can be viewed through the viewfinder or on a display on the top or back of the camera (Figure 27.2). You simply adjust aperture, shutter speed, or ISO to center the meter on "0" indicating a

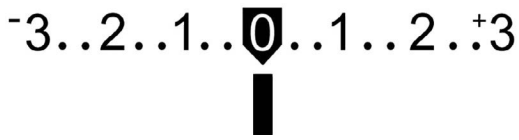


FIGURE 27.2 The meter centered on "0" indicating a proper exposure.

proper exposure. In forensic photography, you set the aperture needed for the required DoF, and make other adjustments as appropriate, described later in this chapter.

The one commonality when discussing each of the above modes is that the camera's internal meter is used to determine the proper exposure. However, most cameras have several metering modes that will read the scene quite differently and provide very different results. In order to get a proper exposure, the camera metering mode selected must match the type of scene and the lighting conditions within that scene.

Camera metering modes allow adjustments based on lighting conditions that have a direct impact on the accuracy of an exposure. Most cameras have three metering modes: evaluative (Canon) or matrix (Nikon), center, and spot. Canon also includes a partial metering mode on some of their cameras. Each of these modes measures the amount of light being reflected through the lens to the camera at different locations within a scene. As the name infers, a "spot" mode measures reflected light from the location you have placed the spot in the viewfinder. A very dark object in the center of the scene, when the rest of the scene is well lit, will provide an improper exposure if the camera is left set in the spot mode and the lens is focused on the object in the middle. Thus, using the spot mode in that circumstance would be improper and inaccurate. Refer to your camera manual for additional information about selecting metering modes.

For any photography, injury included, you should be filling the frame with your subject matter, regardless if it is an overall view, medium view, or close-up view. As such, the matrix or evaluative mode will generally provide an accurate exposure. However, the camera meter isn't infallible. It finds an area within your frame that it wants to convert to 18% gray. If taking photographs of a very light-skinned person, or a very dark-skinned person, the exposure the camera calculates may not be correct. Again, one advantage of digital is the ability to review your images to ensure they are sharp and have the proper exposure. However, you cannot always trust what you are looking at on the camera monitor.

TIP:

Your camera meter is easily fooled. In some instances, the only way to obtain an accurate exposure is to use the manual mode and set your exposure by metering off a gray card.[5]

Image review can sometimes be difficult, especially on bright sunny days. The camera monitor can become almost

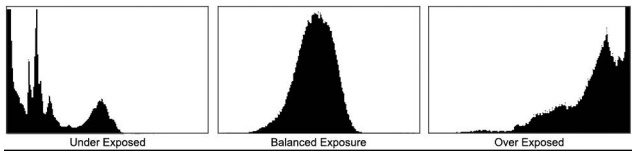


FIGURE 27.3 Seeing if an image is underexposed, properly exposed, or overexposed.

unreadable,[6] and you cannot determine if you have a proper exposure. A tool found on nearly every digital camera is the histogram readout, which will reveal the accuracy of exposure. This tool will show if an image is underexposed, properly exposed, or overexposed (Figure 27.3). Refer to your camera manual to learn how to display the image histogram. I was surprised very recently to find a camera in a class I was teaching that had no histogram. This tool is so important that I would avoid purchasing a camera that does not offer a histogram, regardless of the other wonderful features it has.

Best Practices

Some techniques covered in this chapter evolved from trial and error, but many have become best practices based on the experiences of law enforcement officers, forensic photographers, and others working in the field of forensics. All have one very important element: the ability to validate these techniques in a courtroom setting. Most of these are techniques subscribed to by the Forensic Photography and Electronic Imaging Science and Practice Subcommittee of the International Association for Identification (IAI). These are also techniques required for those seeking certification by the IAI Forensic Photography & Imaging Certification Board.

Four Levels or Views

The process of documenting an injury is no different than what has been referenced elsewhere in this book. Whenever photographing a crime or accident scene, specific items of evidence, or persons that have suffered an accidental or intentional injury, the following four levels, or "views," should always be included:

1. Overall, or "overview" photographs
2. Mid-range, or "medium view" photographs
3. Close-up photographs
4. Close-up photographs including a forensic scale[7]

Overall Photographs

For the first responder or investigator, overall photographs of the victim can become an important part of the investigation. Overall means a photograph of the subject from head to toes, from the front, the back, and each side of the victim. Minimally, and depending on the extent of injury, these photos are taken after the victim has been treated

and cleaned-up, but on occasion there may also be value to overall photos of the victim before being treated.

TIP:

Develop a protocol to be followed regardless of the situation. If the overall front view is captured first, the rest of the views should follow logically in the image set. This will be easier for a viewer to follow and may keep the photographer from forgetting to capture any necessary views.

While logic may seem to dictate photographs are required only of the obvious injury or injuries, these overall photographs will not only establish the location of the injury or injuries but also document the absence or presence of other injuries or marks that may or may not be related to this incident. This is a critical step that can either validate future claims about another injury that may have been unknown or invalidate a claim for an injury that was unrelated to the incident.

Mid-Range Photographs

Following the overall views, mid-range photographs must be captured. A mid-range photograph serves the purpose of establishing a closer view of the injury in relation to a part of the body that is recognizable; it locates the injury. A mid-range photograph of an injury to the right forearm, for example, should reveal enough of the arm to determine the injury is on the right arm, and what side of the arm (Figure 27.4). A close-up of an injury to a body part that has no mid-range reference makes it difficult, and sometimes impossible, to determine the location of the injury.[8] Any other marks or injuries that were revealed in the overall photographs, related to this incident or not, should be photographed in the same manner and noted accordingly.

Close-Up Photographs

The first close-up photographs of an injury are typically taken before clean-up or treatment. After clean-up, these photographs can be the most important. These are the photographs that will reveal the true extent of the injury or injuries. Having only photos before cleaning the injury and surrounding areas could likely result in a photograph that misrepresents the actual seriousness of the injury. This could make it seem more serious than it actually is. This is especially true of head injuries, where there is often a lot of blood due to the high number of blood vessels near the surface of the skin. These photographs are typically done at the hospital or medical center, which will provide a more controlled environment to work in.

Finally, additional close-up photographs of the injury should then be taken with a forensic scale.[9] Using a scale provides a meaningful reference to the size of the injury and should be composed in the same manner as the close-up photograph without the scale. In my workflow, I compose a photograph of an injury with the scale, take at least two and sometimes three shots, and then without moving the camera, I remove the scale and take at least two more shots (Figures 27.5 and 27.6). Multiple shots are taken to ensure at least one with and one without the scale are sharp; DoF is limited, especially when taking close-up shots. The mere



FIGURE 27.4 Identifiable as the right arm.



FIGURE 27.5 Without a mid-range photo (Figure 27.4), this body part would be difficult to identify.

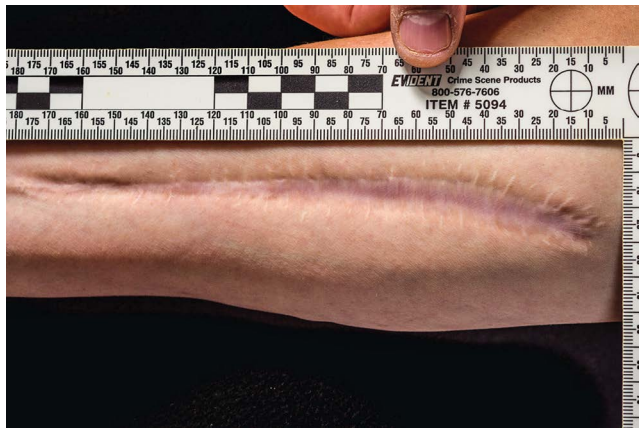


FIGURE 27.6 A close-up image of arm with a forensic scale.

act of you or your subject breathing can throw the injury out of focus. This will be covered in more detail later in this chapter.

I also recommend you use a scale only after the injury has been cleaned-up; it will provide a more accurate and unobstructed view of the actual injury and will also avoid unnecessary contamination of the scale. You should always clean the scale with a sterile wipe before touching it on the victim—and do it in a manner that they see you do it. You should then clean the scale once again when you have completed taking photographs.

Proper Composition

Nearly all cameras capture images in rectangular format; the most common aspect ratio is 3:2 and is the default setting for the majority of cameras. A 12-megapixel camera, for example, would have 4000 pixels across the top of the frame (horizontal), and 3000 pixels along the side (vertical). Some cameras, including cellphone cameras, allow the user to change the 3:2 format to something different. However, changing from 3:2 to something else is there for the purpose of allowing the photographer to be creative—which is not our purpose. The standard 3:2 format is recommended for law enforcement applications.

Too often the composition of a photograph is not even a consideration. I've been told by first responders that they don't have time to worry about composition. In actuality, it doesn't take any more time to properly compose a shot than to improperly compose a shot. In addition, filling the frame with the subject matter should always be a priority.

For example, overall photographs of a person standing should be taken in a vertical position, not a horizontal one. A person lying on a bed or on the floor is in a horizontal position, not a vertical one; the orientation of the camera should be horizontal, not vertical.

Since mid-range photos are oriented in a manner that show the injury in relation to a recognizable part of the body, close-up photos should orient the injury in a manner that matches the shape of the injury to the format of the camera. Figure 27.7 is improperly oriented; this is a vertical composition for a horizontal injury. It wastes pixels and shows irrelevant details. Figure 27.8 is correctly oriented and the item of interest, the injury, fills the frame. No pixels are wasted, and the viewers' attention is drawn to just the injury, not to other irrelevant areas.

Filling the Frame

Part of proper composition is filling the frame with your subject matter, which is important for several reasons. First, you want the viewer to understand what they are looking at. Filling the frame with the relevant detail avoids any possible confusion with things in the photograph that are not relevant. Second, filling the frame with the important and relevant subject matter will also ensure that your camera meter is recommending an exposure based on exactly what is important. Third, a digital camera only has "x" number of pixels. The more pixels in a photograph, generally the better the quality will be—especially if made into a large print or projected on a screen. If the relevant subject matter in the frame uses only one-tenth of the available pixels, all the other pixels are wasted. In essence, at best you are using only 10% of the available quality.



FIGURE 27.7 Incorrect orientation fails to fill the frame with the subject matter.

Do not waste pixels!

Accurate Viewer Perspective

Accurate viewer perspective[10] is the photographic reproduction of an object or scene that closely resembles what the



FIGURE 27.8 Correct orientation. The subject of the image fills the majority of the frame.

eye sees. It is important in injury photography, as well as all law enforcement applications, to take photographs that represent what you could see at that time. Cameras today offer lenses that can severely distort the subject matter. While providing an accurate viewer perspective is a best practice, the specifics on how to do so will be discussed in the section *Know Your Equipment*.

Stability

Over the years I have viewed hundreds of photographs taken by police officers of victim injuries (as well as other subject matter), and the photographs were "soft." Soft is another term for a blurry photograph due to a slow shutter speed combined with camera or subject movement when the shutter was released. This is most often the result of slow shutter speeds due to low light levels. Even though the images can be viewed on the camera's built-in rear monitor, it is not obvious the image is soft until zooming-in on the photo or enlarging it on a computer monitor as previously referenced. There is no way to properly "fix" a soft image.

Stability is the most critical factor that will help ensure you get a sharp photo. Even a slow shutter speed used on a stationary subject can produce a sharp image if the camera is on a stable surface. The use of a tripod is always the best option; there are also various types of "mini-pods" (Figure 27.9) that are inexpensive and are useful to have in your kit. In fact, a mini-pod is almost a necessity if using a point-and-shoot or cellphone camera.

If a tripod or mini-pod is not available, you can use any number of things to stabilize the camera—limited only by your imagination. You can set your camera on a table, a stool or chair, or a stack of books (Figure 27.10). You can even use a vehicle, but make sure the engine is not running or the vibration will cause movement and blurry images, which leads to one of the most important aspects of stability. As much as you practice, no matter how stable the surface, and no matter how careful you are, it is virtually impossible to press the shutter on any kind of camera and not cause camera movement. This is especially noticeable when using slow shutter speeds.

Using a cable or remote shutter release to activate the shutter is a technique used for as long as cameras have been in existence and is essential when using slow shutter speeds. Unfortunately, there are no shutter release accessories made for point-and-shoot or cellphone cameras.



FIGURE 27.9 Mini-pods.



FIGURE 27.10 Camera stabilized on books.

However, there is a feature built-in to nearly every camera on the market today, including cellphone cameras, that provides a near-perfect substitute: a timer. The timer can usually be set to release after 2, 5, or 10 seconds. The camera is placed on a tripod or other stable surface, the shutter is activated, and the countdown begins. Some cameras will even let you program them to release the shutter every "x" number of seconds for as many times as you wish.

In a law-enforcement application, such as taking injury photos, finding a stable surface and then releasing the camera's shutter using the timer will prevent any camera movement. However, your victim must not move when the shutter is released, or that will also result in a soft image.

Even though it may seem awkward, it is usually possible to position your victim in such a manner as to minimize their movement, and then position the camera to properly compose the injury. It may require some creativity on your part, but it can be done. Another challenge in this scenario is the potential of your victim being intoxicated or traumatized to the extent they simply cannot hold still for a photograph. In those cases, you will need to revert to higher shutter speeds that will require more light—and sometimes a higher ISO setting.

Is a tripod or stable surface always necessary? The short answer is no. Using a flash will freeze subject movement at the moment of the flash. However, if the shutter speed is even a little slow in order to take advantage of ambient light, movement by you or your subject will appear as a "ghost" outline around the image frozen by the flash.[11]

Using a flash for injury photography is not always the best option. The limitations of a flash, and why it may not be appropriate for the camera you are using, will be discussed in the *Lighting Techniques* section.

Cellphone Cameras

The convenience of having a camera in a cellphone is undisputed; nearly everyone today is carrying a camera with them all the time. And, the best camera to have is always the one you have with you. However, using the camera in

your cellphone to document any type of subject matter that could ultimately result in a criminal action is unwise and not recommended.

Cellphone cameras are fine for taking a quick shot of a driver license or a plate or something that you wish to remember in order to complete a report; those are images that typically have no value in a courtroom proceeding. However, using a personal cellphone camera to collect potential evidence becomes problematic in that images have now crossed-over into being located on your personal property. Not only does that become a chain-of-evidence issue, but you also could find your cellphone being subpoenaed and made available for forensic examination by opposing counsel. The last thing an investigator would want is their personal cellphone being secured in an evidence room until the case is settled. Remember too that everything on the phone now becomes available for others to see.

If you were to find yourself in a position where there were no other options, however, using a personal cellphone camera is better than not taking any photographs. Just be aware of the potential consequences; let your prosecutor or district attorney know immediately and follow their advice regarding a recommended protocol. At a minimum, in the presence of a supervisor you should upload the photographs into a secure storage media at your worksite as would be done with a department camera. Also, in the presence of a supervisor the images should then be deleted from your cellphone camera, with all the steps documented in your report. Still, doing so will likely not prevent attempts to obtain your phone for analysis and review.

Exposure Basics

A basic knowledge of exposure principles is required to ensure the first two of the five components of a great image are met:

1. Proper lighting
2. Proper exposure

Exposure Values

My goal is to not become too technical in this chapter, but some aspects of photography must be understood in order to understand some of the principles that will be discussed in this section.

An exposure value (EV) describes an equivalent of one "stop" of light, and how we can mathematically determine exposure—ergo "exposure value." A full stop of light is either twice as much or half as much light as the adjacent full stop. This applies to aperture values, shutter speed, and ISO settings. Most cameras today are set-up to measure light in one-third stop increments.[12] Using the f-stop as an example, *f*/5.6 is one stop more than *f*/4 and requires twice as much light as *f*/4. *f*/5.6 is one stop less than *f*/8, so requires only half as much light as *f*/8. Full stop increments are shown in Table 27.1.

TABLE 27.1
Full-Stop Increments

F-stop	*f*/2.8	*f*/4.0	*f*/5.6	*f*/8	*f*/11	*f*/16	*f*/22
Shutter speed	1/500th	1/250th	1/125th	1/60th	1/30th	1/15th	1/8th
ISO	100	200	400	800	1600	3200	6400

Each step up requires twice as much light, and each step down requires half as much light. The next section about the exposure triangle will help show how these three controls work together.

Exposure Triangle

There are three previously described functions on a camera that can be adjusted by the photographer to best use the amount of light available: f-stop (aperture), shutter speed, and light sensitivity (ISO). These three functions must work together and are best illustrated by an exposure triangle (Figure 27.11).

The function at the top of the exposure triangle represents the most important function, and the lower left corner of the triangle is the secondary priority. The lower right corner is the ISO and represents the function that should be changed as a last resort. In all scenarios, ISO should be changed only if the other two settings cannot provide the correct exposure, since the increased ISO will result in noise and a resulting reduced sharpness.

For injury photography—or any image taken to document evidence—the most important function is the aperture setting, or f-stop.[13] This is the primary method to control DoF,[14] which helps to ensure a sharp photograph. So, the f-stop is placed at the top of the triangle, and shutter speed is of secondary importance. This underscores the need to use a tripod or other stable surface. In order to get the required DoF, a slow shutter may be required—which shouldn't matter when shooting a stationary subject. Although, as previously stated, your victim must remain still, or the slow shutter will result in a soft, blurry image.

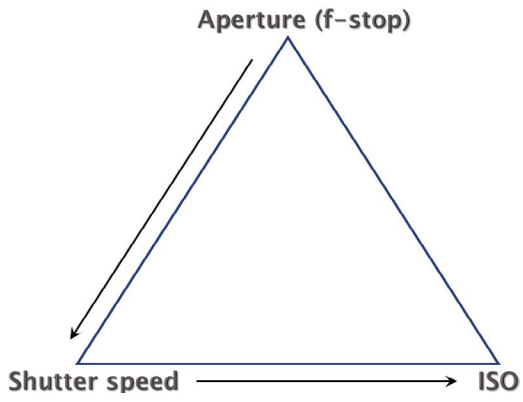


FIGURE 27.11 Exposure triangle. The most important priority, Aperture, is at the top of the triangle. The second priority, Shutter Speed is at the bottom left. The lowest priority is at the bottom right, ISO.

What is important to remember is that if the value in one corner of the triangle is changed, there must be an equal change in one of the other corners. If you change the value in the top corner, then a value needs to be changed in another corner in an equal amount in the opposite direction.

Lighting Basics

Light is the single most important element required to take an acceptable photograph. The amount of light will determine the shutter speed and ISO you will need to use after determining the DoF. Usually, the more light you have, the better the photo will be.[15] Unfortunately, we don't always have an adequate amount of light, so there are various controls in our cameras that will help compensate for varying light levels. These controls will enable us to get the shot but require a sacrifice to either your shutter speed or ISO setting.

For the most part, point-and-shoot cameras and cellphone cameras are designed to work best on a bright, sunny day. In the world of law enforcement, however, when we need to use our cameras, most often it is anything but bright and sunny. There are numerous ways to achieve what some may consider acceptable results, but most of those ways are built in to specific modes on the camera that sacrifice quality by either slowing the shutter speed below the recommended hand-holding amount, or by increasing the ISO.

How Much Light Is Enough?

While many digital cameras are similar, there are more cameras that are totally different. One of the biggest differences in cameras and camera and lens combinations is the amount of light they require to obtain an acceptable forensic photograph. This is the reason why the exposure triangle is so important, and also the reason you must test every camera you plan to use for injury photography—or any evidentiary photography. This is particularly true with point-and-shoot and cellphone cameras.

How much light is enough depends on your camera and lens combination. Some lenses are large and let-in a lot of light. Many lenses are very small and can gather only a small amount of light. And, the size of the lens must be matched to the size and quality of the image sensor.[16] In addition, very small sensors will tend to be much noisier than large sensors, although in cellphone cameras internal processing takes place that will attempt to reduce the noise. When looking at those images on your cellphone screen, and sometimes even a computer monitor, they may look fine. Still, when enlarging or projecting those images, they will likely be soft and/or noisy creating an almost muddy appearance.

Unless shooting a moving subject, shutter speed is the least important of the three corners of the exposure triangle. As previously noted, the aperture is the most important, as this is the primary way to ensure your images are in sharp focus by using a good DoF. On a stationary subject, a slow shutter speed and proper aperture will result in a sharp image. It is the third component that starts to degrade the image at a higher threshold, ISO. Cameras with very small sensors do not do well with high ISOs for a very simple reason: the sensor isn't large enough to capture enough light.

Too Much Light

At the other end of the challenges encountered with digital cameras is too much light. Too much light can result in an overexposed image, and overexposed images are typically difficult if not impossible to fix during post processing.[17] With injury photography, it is best to use a secondary light source to cross-light the injury that is brighter than the ambient light (cross-lighting will be explained in the upcoming section on Lighting Techniques). When trying to balance the natural light, the brighter light source used to highlight the injury can result in an overexposed image.

The best fix for too much light from your secondary light is to diffuse the brighter light using a white handkerchief, tissue, or even white paper. Shoot through the diffuser, and the light will be cut down substantially. If it is still too much, add another layer. You can also diffuse the light when bouncing into a bounce card. Just be sure to not diffuse the light to the same level as the primary (ambient) light, as you will lose the effect of cross-lighting.

Another common problem is a portion of the scene being much brighter than the overall scene, or a bright light in the scene. The ability of a camera to capture bright areas and dark areas in a scene at the same time is known as dynamic range. Although the dynamic range of cameras is getting better all the time, it is not uncommon to have a "hot spot" or "blown-out highlights" in an image that would otherwise be properly exposed. Although this is not usually a problem in injury photography, it is important to be aware of.

Fixing a hot spot is best done by recomposing the shot to not include the bright light causing the problem. And sometimes it doesn't need to be fixed as long as (1) there is nothing in that area of importance, and (2) it doesn't distract from what you are trying to show.

Types of Lighting

Daylight, of course, is the most obvious preferred choice of lighting for most kinds of photography. When we have it, there is plenty of it. It comes in many forms: bright sunlight, light overcast, dark overcast, and "golden hour" light at daybreak and dusk, which is preferred by many professionals for the beautiful warm light it creates to illuminate the subject matter. Each has its own distinct advantage or disadvantage.

For law enforcement applications, however, we cannot always control when or where we will be taking photographs, or what the subject matter will be. We must learn to adapt to whatever natural light is available at the time, if any, and then supplement that light with the artificial light we bring to the scene. We must also be aware of the many different colors of light and learn how what we use will interact with available light at the scene, whether it is natural light or another form of artificial light. More about colors of light will be addressed in the later part of this chapter.

The most common artificial light used in photography is light from a flash that is color balanced to closely match daylight. Since the introduction of light emitting diode (LED) lights, however, I've had photographers tell me they prefer a continuous light source like they get with LED lights, especially for injury photography; it's easy to see how the injury will look when using a continuous light source. In fact, I've seen some very fine injury photography done with LED lights. But I've also seen some very poor injury photography done with LED lights, almost always caused by subject movement.

Because DoF is critical, and slow shutter speeds can result in soft images from subject movement, I prefer to use a flash as opposed to a continuous light source. Using a flash will freeze movement. Furthermore, the brief intensity of a flash will provide much more light, resulting in the ability to use a lower ISO, as well as a smaller f-stop with the resultant increased DoF.

I still remember family functions as a young boy when the Super-8 movie camera came out, accompanied by a bank of three super-bright lights that were uncomfortable to look at and were very, very hot. They had to be carefully set down in a safe place after being turned off so they could cool. Continuous light sources, at least for portable and consumer applications, were abandoned many years ago for those reasons. Heat from incandescent or quartz or halogen light bulbs can be both uncomfortable and dangerous, causing severe burns if touched, fires if tipped-over, and storage problems due to required cooling-off periods.

Continuous light sources like LED lights lack one of the problems we had with the older lights: heat. LED lights are much cooler, so the danger of the burning hot lights is gone. However, most LED lights will still generally require slower shutter speeds or a higher ISO. That's not to say bright LED lights are not available, but the intensity or power of the light needed to achieve the same result as a flash can be uncomfortably bright to both the victim and the photographer.

So, I don't discount LED lights completely. But the first time you need to take photographs of an injured, squirming, screaming child, you will appreciate the power of a flash to stop motion and to provide a better DoF. You can't see the light in advance, but you can quickly learn the proper placement to get the results you need. Besides, you can always check your image and just do it again if the light isn't placed just right.

Color Accuracy

A photograph that has a strange color cast is difficult to be viewed as credible. And, when you show the photograph of an injury, you want the viewer to focus on that injury and see just that. If the color is terrible, that will become the point of focus.

It is important to realize that all sources of visible light have a "color temperature." Our eyes and brain work together to see things as the same even though different light sources cast a different color. The technical term for this is *chromatic adaptation*. When looking at a piece of paper we believe to be white, our brain will tell us it is white regardless if it is illuminated by the sun, if it is illuminated by an incandescent light bulb, or if it is illuminated by a fluorescent light. In actuality each of those light sources has a quite different color temperature and produces various shades of color on that white piece of paper. But our brain tells us it is white.

Cameras have an automatic white balance setting—which is how it ships from the manufacturer. The automatic white balance setting is a computer trying to duplicate what our eyes and brain tell us. Sometimes it works very well, and sometimes it doesn't.

The most accurate way to capture correct color for the casual user is to use a setting in the camera known as a "white balance setting."[18] The color temperature for various lighting scenarios is matched to scenes and objects illuminated by sunlight, photographs taken in the shade, and photographs illuminated by incandescent bulbs, fluorescent bulbs, or halogen bulbs. Some cameras even have other options in addition to the ability to customize the color balance to a color temperature of your choosing.

Having a correct color balance in a legal application—in-particular injury photography—is important for several reasons. The auto white-balance setting may or may not be accurate, but if you unknowingly select a color balance setting that is different from the light source you are using, the photographs will have a terrible color cast that will call into question the accuracy of the photos, as well as the ability of the photographer. As stated previously, it just doesn't look credible. Even more important is that injuries often are best illustrated by capturing what are sometimes subtle color variations, especially with bruising.

This is another situation where experimenting will help you understand the importance of color balance when trying to obtain accurate photos. Using a single light source, such as an incandescent bulb, take the same photograph of the same subject without moving your camera, changing only the color balance setting between shots. You will notice that some will be very similar, but some will be quite different—and very inaccurate.

If you are fortunate enough to work for an agency that allows you to shoot raw images and/or will allow post processing, the use of a gray card, or an even better, a color checker is the best way to ensure accurate color. More on this technique will be covered in Part Two of this chapter.

Know Your Equipment

First responders most often will be using equipment provided to them by their department. In some cases, the camera is a point-and-shoot camera; in other cases, it may be a digital single lens reflex (DSLR) or mirrorless camera, and in some cases in may be a cellphone camera. As previously discussed, using a personal cellphone should be avoided, but there could be an occasion when that is the only option.

Although some cameras are more desirable than others, most of today's cameras have the technology to accurately document an injury if used properly. One of the obvious advantages with using a digital camera is the ability to immediately review the image and then take it again if the results are not satisfactory. However, the resolution on a camera screen rarely can match the resolution of the actual photo, which often will look just fine at first glance.

When reviewing the image on a camera screen, always zoom-in on the actual injury to ensure it is sharp—and don't be surprised if it isn't. Zooming-in on the screen to examine the details will provide a more accurate idea of what that image will look like on a computer monitor or when printed or projected.

Another often overlooked advantage with a digital camera is that you can experiment and become familiar with what your camera is capable of and how to best use it based on the circumstance at hand—and all it costs is your time. Some important things to learn include:

- Every camera has a minimum focus distance for the lens or lens setting being used. Most are different. How close can you focus with your camera and lens combination?
- Most cameras have a zoom lens today; at what setting do your images become distorted?
- Some cameras will take a photo even if it is not in-focus, and others will not. Will yours?
- Many cameras have difficulty autofocusing on skin. Do you have a work-around?
- ISO settings produce more noise as the ISO gets higher. Sometimes you can actually see the noise marks, and sometimes the higher noise is more evident by resulting in a soft photo.[19] Different cameras have different thresholds. How high can you go with your camera before it is unacceptable?

At the end of this chapter are five exercises that will help you determine the best settings for your camera in these areas. Knowing the limitations of your camera and how to adjust your settings to compensate for those limitations should be as familiar as shooting your weapon. That familiarity can only be obtained in one way—experiment and practice.

Point-and-shoot, DSLR, and mirrorless cameras, as well as some cellphone cameras, have a myriad of options and shooting modes. These options and modes are designed by the camera manufacturer to serve as a convenience to the casual shooter, and almost always consider slow shutter speeds or noisy images to be acceptable. While this can result in "getting the shot" that may be pleasing to the eye at first glance, when enlarging the image to a size usable for courtroom display, it will not have the sharp, noiseless image important in forensic photography.

I have tested and used hundreds of cameras and have yet to find a camera with a built-in "law enforcement mode," or even a mode that prioritizes the settings important in law enforcement when documenting crime or accident scenes, injuries, or other items that could be potential evidence in a criminal prosecution. A law-enforcement mode would ensure that every image met the previously referenced five components of a great image:

1. Proper lighting
2. Proper exposure
3. Accurate color
4. Proper composition
5. "Sharp" (meaning nothing is blurry, out of focus, or noisy from using a high ISO)

More information on these five criteria, as well as camera settings, ISO, and other controls will be addressed throughout this chapter.

With a little research and experimentation, you will find there are ways to use whatever camera you have in a manner to ensure you can meet these five criteria. Proper lighting can be accomplished using a flash, a flashlight, ambient light, or a combination of all three. Proper exposure can be achieved by taking the time to ensure your camera settings are correct. Providing accurate color can be achieved by using a proper white balance setting or a color chart. Keeping a low ISO can be achieved by having proper lighting combined with proper camera settings. Having a sharp image can be achieved with low ISO, proper focus, and ensuring that both your camera and your subject are stable.

Focus

Focusing on an injury can be difficult; skin has little contrast, and unless the focus point is on a very distinct mark, the camera may "hunt" for the focus. And often proper composition of the injury will not align it with the focus point in the camera—especially when there are multiple marks on the skin in a small area. Also remember that some cameras will take the photograph even if the object is not in focus.

Another big issue with focusing on injuries, or any law-enforcement application, is that many cameras default to a "smart focus;" the camera finds something in the scene it interprets to be the right target and focuses on that object. Face detection is very popular, and camera systems are getting better and better at finding the correct target. Still, this type of focus should not be used in a law-enforcement application. You must always control the focus. You decide what is important, and then ensure the focus point in the camera locks-on to that object or spot.

There are several work-arounds for both of these issues. First, look in your camera manual and find where you can turn off the auto-area focus. If there is an option for a single-point focus, that is what you want to use—always. There will be a dot or other indicator in your viewfinder that will show you precisely what you are focusing on. Some cameras will allow you to move that focus point within the viewfinder; I recommend you place it in the center of the viewfinder and leave it there.

When composing for an injury photo, you place the focus point over the injury, press the shutter halfway down to lock the focus, then move the camera into a position to properly

compose the photograph. Again, be careful, because some cameras will take the photo even if it failed to obtain a focus. The majority of cameras, except cellphone cameras, will have an indicator light that will turn a solid color when the camera is in focus. Look for it in the lower left or right portion of the viewfinder—refer to your camera manual for an exact location.

If the camera just can't achieve a focus due to a lack of contrast, use a scale or another very flat object to focus on. Lock the focus-in, then remove that object and take the photograph. I especially like using a dollar bill when photographing injuries of children; I then let them have it as a reward for being a good model. However, if photographing an open wound, a piece of currency is not very sanitary. Use the scale after you've cleaned it.

Using the Right Focal Length

As referenced in the section on best practices, accurate viewer perspective is the photographic reproduction of an object or scene that closely resembles what the eye sees. It is important to know that a camera with a built-in zoom lens will default to a wide-angle view when first powered-on. This is true for point-and-shoot cameras, some mirrorless cameras, and cellphone cameras. In fact, any camera I've owned, used, or tested that does not have the ability to use interchangeable lenses defaults to a wide angle setting when first powered-on. Although this default lens setting allows you to capture more of the scene, a wide-angle view makes objects appear farther away than they really are and will also result in barrel distortion (Figure 27.12).[20]

Particularly in a law-enforcement application, whether it is taking photographs of an injury—photographs of a traffic crash scene, or photographs of a crime scene—the goal should always be to capture an accurate viewer perspective. In order for you to know how to accurately document an injury, or any other subject matter, you must experiment and learn where your lens needs to be set to avoid this unwanted distortion.

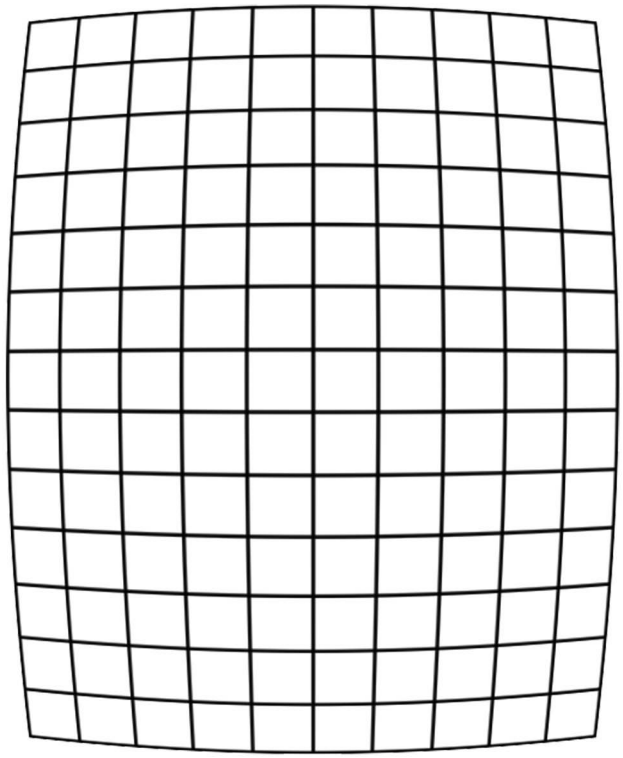


FIGURE 27.12 Barrel distortion.

Figure 27.13 shows the distortion from the default lens setting on a point-and-shoot camera. Note the size of the nose and ear compared to Figure 27.14, which has no distortion.

Unlike crash or crime scene documentation, however, using a longer focal-length setting is perfectly acceptable to document an injury. For scene documentation, the photographer must be aware-of and avoid scene compression, which occurs when using a telephoto lens setting. Because



FIGURE 27.13 Distortion.



FIGURE 27.14 No distortion.

documenting an injury is confined to a shorter distance, a long focal length is perfectly acceptable.

The universally accepted standard to capture accurate viewer perspective is to always use a "normal" focal length when documenting anything for legal purposes. In the old film days, that focal length was identified as a 50-mm lens. However, today there are many variables that make this no longer accurate, particularly in the modern camera world where technology plays a much bigger role in how a photograph is captured. In addition, depending on the camera you are using, the actual number assigned to a focal length to obtain an accurate viewer perspective could vary widely. The only way to know what setting on the camera you are using will result in an accurate viewer perspective is to test it.

Testing Viewer Perspective

One of the most important tests you can make is to determine accurate viewer perspective with your camera and lens combination. Before reading on, please refer to Part Three of this chapter and conduct the test on accurate viewer perspective.

Lighting Techniques

The best way to light an injury is to use multiple light sources, which is where the importance of understanding color balance becomes clearer. If an incandescent flashlight is used in conjunction with a flash, and the camera white balance is set to flash, the flashlight will cause a yellow streak in the photograph. However, if you use an LED flashlight, the difference in color temperatures will be less noticeable, if at all.[21] Again, experiment in advance with your own equipment to learn what you can use with acceptable results.

Controlling the intensity and direction of light is a much simpler matter than color balance. Any light source can be used to illuminate an injury, and you can position either the light source or the victim in such a manner that it falls across the injury, not at the injury (Figure 27.15). This is no different than using your flashlight to discover patent prints or shoe impressions or tire impressions; you direct your flashlight *across*, not *at*, the area where the suspected impression is located so that ridge structure and other details can be seen. This is known as "cross-lighting."

Lighting an overall view of a subject will be quite different than lighting a close-up photograph of an injury. To be able to light your subject in a manner that provides the most accurate information about their condition and specific injury or injuries, however, there are some basic principles of light that must be understood.

Inverse Square Law

One topic that strikes fear in some casual photographers is the term "*inverse square law*." At the same time, many photographers are baffled by how easily moving a short distance will result in an underexposed photograph. These two things are very closely related and can be explained in very simple terms.

When using a light source such as a flash or flashlight and you obtain a proper exposure using that light at a given distance, if you double the distance you will need four times as much light for the same exposure. If you double that distance again, you will need four times as much light as was needed for the second distance or 16 times as much light as you needed at the original distance. You can also always adjust your exposure instead of adding more light. Either way, you can see how an increase in the distance of the light source causes a disproportional loss in exposure. One important

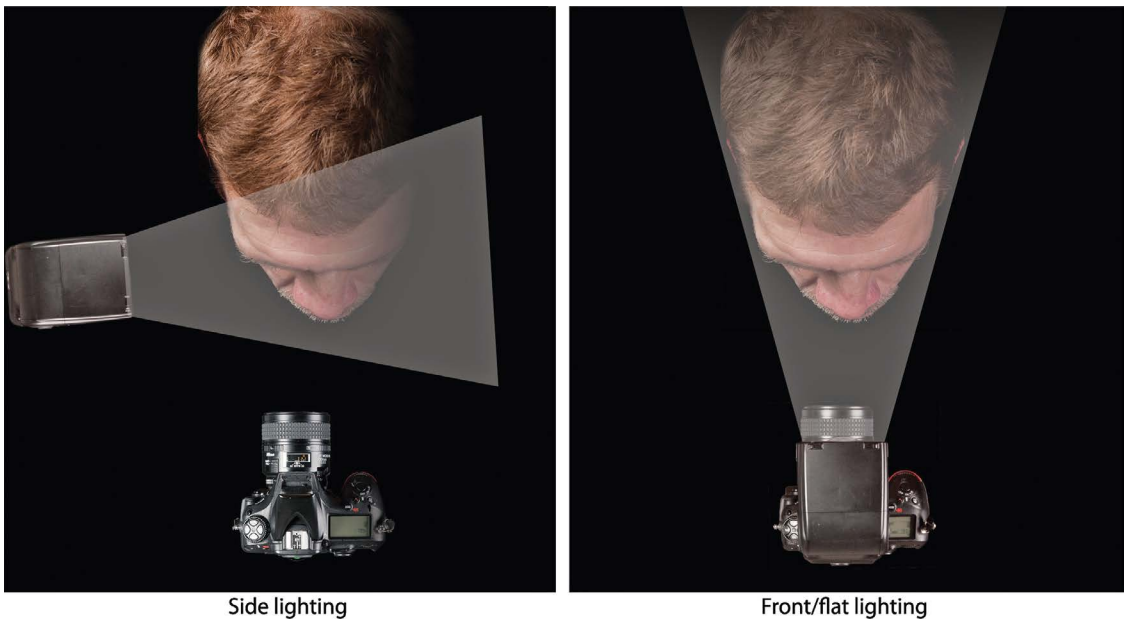


FIGURE 27.15 Side lighting versus front/flat lighting.

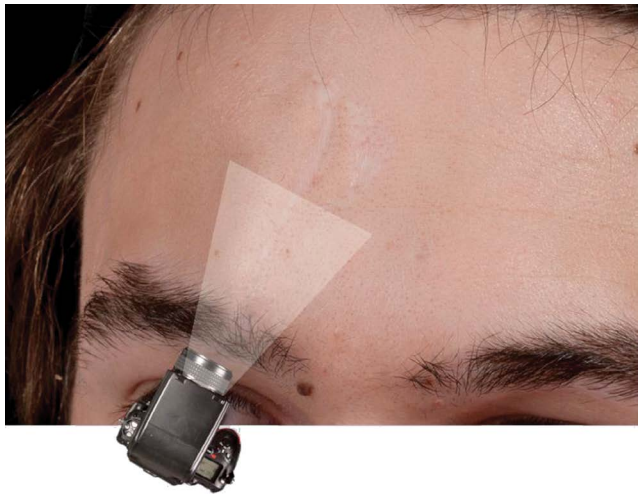


FIGURE 27.16 Flat lighting.

note: the loss of light due to the inverse square law is affected by the distance of the light source from the subject, NOT the distance of the camera. So, the most obvious solution is to use a light source that is not connected to the camera. More on this in the later part of this chapter.

Flat Lighting

The primary goal of this chapter is to help you take better injury photos, and the first best step is to learn how to not use flat lighting. Flat lighting is a term that describes subject matter lit from one direction only, typically from the front (Figure 27.16). In addition, flat lighting is often very harsh lighting, leaving dark shadows that are anything but natural. This is the most common lighting and is the result of using a pop-up flash or external flash attached to the top of the camera. And, that's the way the CSI photographers do it on television. This is NOT the best way to light an injury—or much of anything, for that matter.

This doesn't mean that a flat-lit photo of an injury is not acceptable. Any photo that is sharp, properly exposed, properly color balanced, and properly composed is a *good* photograph. If the detail of the injury can be seen, mission accomplished. However, remember there is another component to a *great* photograph, and that is properly lit. When properly lit, there is a dimension to a photograph; shadows are controlled in a manner that provide depth and directionality but aren't dark and distracting.

So, if a flat-lit photograph can be acceptable, why take this extra step? Two reasons: (1) The technique of using a pop-up flash or external flash mounted to the top of a camera often results in an improper exposure, especially for close-up photographs. Most often, a close-up photograph will be overexposed. This is simply a limitation of many camera systems, although some are better than others. (2) The best photograph is one that looks natural, and there is nothing natural about flat lighting. A person viewing a photograph that looks natural is more likely to accept that photograph as credible and accurate. After all, that is how we see things with our eyes. A photograph with flat lighting, even if properly exposed, just doesn't look right. It shows the injury, but the question is likely to come up: Is this an accurate representation of the injury, or has the injury been inaccurately represented due to the harsh light?

Most injuries involve damage to the skin: cuts, tears, holes, scrapes, bite marks, or bruising. Other injuries may be from broken bones, with deformities sometimes obvious, and other times evidenced only by swelling and discoloration. While flat lighting will still show some of those injuries, moving the light to the side will make the injury more apparent, and can reveal more detail about the actual damage to the skin or area of injury (Figures 27.17 and 27.18).

In injury photography, flat lighting seldom will show the true extent of the injury. In fact, flat lighting will sometimes even make an injury difficult to see. Using the built-in flash on a camera will always result in flat lighting. In addition, the useable distance is very limited; if you are too close, the photograph will be "blown-out," meaning the important area of the injury will be overexposed, totally obscuring the injury. In addition, anything farther than 10–12 feet, which is needed for overall views, will result in an underexposed photograph. In fact, if your camera has a built-in flash,



FIGURE 27.17 An illustration of flat lighting.



FIGURE 27.18 Moving the light source to the side will make the injury more apparent.

I suggest you not use it for injury photography unless supplementing it with another light source. Incidentally, for those using an automatic mode on their camera, the built-in flash will automatically pop-up and fire—which is another reason to not use the automatic mode.

Best Alternatives: Internal Flash Cameras

Point-and-shoot and cellphone cameras typically only offer the option of using the built-in or pop-up flash. This is the time to find the flash control in your camera and turn it off. However, I've encountered at least a couple of cameras that don't have that option; you get a flash whether you want it or not. That's when you obtain a small piece of gaffer[22] or duct tape and place it over the flash, which will solve that problem.

After disabling your flash, position your subject so they are evenly lit with ambient light. This could be natural window light during the daytime, or an incandescent light or overhead light. Of course, you may also be able to move the light source itself to the correct position. Either way, change your white balance setting to match that of the ambient light, which we will refer to as the "fill light." Take the overall views and medium views if the light is adequate.

The close-up views are the really important ones. This is when you should add another light, what we will refer to as the "main light," to emphasize the injury. The light from a flashlight or light from a cellphone camera may provide just enough additional light to cross-light and highlight the injury even more. Be careful of a light that is too bright and harsh; a reminder that you can diffuse the main light by placing a handkerchief or tissue over the strobe lens. You can also bounce the main light into a white piece of paper or another object that will not cause a color cast to your subject, which is the method I prefer. The next section on external flash lighting shows examples of using a small pad of paper to bounce the light onto.

So, how to hold the light in one place and the camera in another place at the same time when you're by yourself? This is where the tripod or stable surface becomes an important tool. You compose your shot, asking your subject to hold very still. If using your flashlight, find the location you need to hold it. Using the timer on the camera to release the shutter, you then return to the light position you found best showed the injury.

This is a technique you need to practice. Try it with different light sources and different color balance settings. Try it in your squad room with overhead room lighting by positioning a test subject (what are partners for?) in a manner that a simulated injury is well lit. Most of the squad rooms I've been in are illuminated with fluorescent light fixtures. Change the white balance on your camera to fluorescent and check the color cast. Then, add a main light using your flashlight, both diffused and not diffused. Now try a different color balance setting.

At a residential scene, most often you will encounter incandescent bulbs, which have a yellow cast. Many people are converting their homes to LED lights, which are available in numerous color temperatures, but most often are not as yellow, and sometimes are almost blue.

What you will find is that many color temperatures don't mix well. Try the auto-white balance—but don't expect great results. Trying mixing daylight with fluorescent or daylight with your flashlight. There will be a difference if your flashlight has an incandescent bulb or an LED bulb. If the colors don't look natural, don't give up! Colored "gels" (pieces of plastic) can be placed over the head of your flashlight or other light source that will help get the colors more compatible. Experiment!

One innovative officer I know purchased an LED light bulb for a standard light fixture that he carries with him on patrol in his patrol bag. And, he purchased that LED light bulb with a color temperature that closely matched his LED flashlight, which is also close to daylight.[23] When he needs to light an injury at a location where there is a light fixture, he uses his bulb and then uses a diffused beam from his flashlight to highlight the injury. He can also use that bulb in conjunction with daylight coming-in from a window.

Since this is the section on lighting techniques, I am only discussing ways to use lighting. A bit later in this chapter I will be combining the suggested lighting techniques with the other principles discussed in order to get great results.

Best Alternatives: External Flash Cameras

Many DSLR and mirrorless cameras have a pop-up flash, but also have a hot-shoe on the top of the camera that allows them to be used with an external flash. Mounting an external flash on the camera and pointing it directly at your subject will still cause flat lighting just like a pop-up or internal flash, even though the light is being directed from a higher angle. The main difference is that external flashes usually are much more powerful and the TTL ability more accurate. Still, a direct, head-on flash is not natural, and will cause harsh shadows as well as possibly areas of overexposure.

Most external flash units have a head that tilts and rotates. Tilting the flash head either up or rotating it to the side allows you to bounce the light off the ceiling, a wall, or bounce card that creates a more natural look (Figure 27.19). An even better option is to remove the flash from the camera and bounce the light from a side angle to your subject, as opposed to straight at your subject. Removing your flash from the camera requires the use of an external flash cord, or, some cameras can activate the flash using the pop-up flash as a trigger—which is the best of all worlds. Check your camera manual for availability and instructions.

Three things need to be remembered when bouncing light: (1) The color of the light will reflect the color on the surface of whatever you are bouncing it on. Even a white ceiling that is in the home of someone who smokes will reflect a dingy, yellowish cast from the smoke stains on the ceiling. (2) Bouncing light from a ceiling can result in dark shadows in and under the eyes. (3) The inverse square law becomes a major factor.

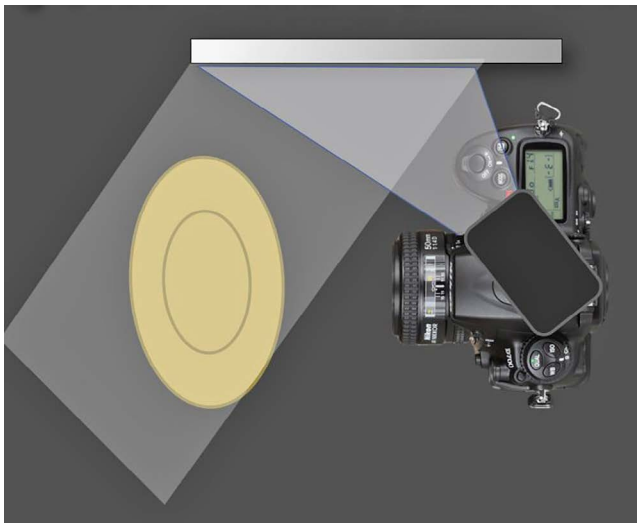


FIGURE 27.19 Using a bounce card or wall.

Remember that if you double the distance, you need four times as much light; the distance is measured from the flash head to the bounce surface, then back down again to your subject, which almost always will double the usable distance in a room with a standard 8-foot ceiling. Or, you can change your exposure. As discussed in the section on EVs, if you need *f*/11 to get the DoF, you would need to change your aperture two stops to *f*/5.6 to get a proper exposure—which has a much smaller DoF than *f*/11.

When I bounce my flash to obtain a more natural lighting effect, my preference is to bounce the flash into a white bounce "card," which could be a pad of white paper. I always try to use white, as it will not cause a color shift and provides the highest reflectivity (Figure 27.20). In addition, the bounce card is placed directly over the flash, so the inverse square law is not an issue. Still, whenever bouncing, expect that you will lose some light—at least one stop. If your flash is powerful enough, you may be able to keep your aperture at *f*/11. If not, dropping to *f*/8 is not as drastic as dropping to *f*/5.6. Finally, when bouncing the light into a card located at the flash head the dark shadows in and under the eyes will be less likely.



FIGURE 27.20 Handheld external flash bounced into tablet of paper.

Proper Techniques

Although some of the following techniques are not specific to lighting and the technical aspects of using your camera, these things are just as important—and I would be remiss not to mention them.

Putting Your Subject at Ease

Photographing injuries can be a very stressful process to the victim. Many factors can turn into challenges. Pain or discomfort, being distraught, angry, or upset: these and other factors require someone to bring a sense of assurance and calm. That is your job.

In addition, injuries often occur in places on the body that are very private and difficult for the victim to reveal to a stranger. Injuries to genitalia are common, and awkward when taking photographs. While it is ideal to have a person of the same sex taking the photographs, that is not always possible. In that case, politely explain why you need to take photographs. During the process, explain what you need to do before doing it, and ask permission.

Always consider what the victim is going through and how you would feel if in their place. If you act shy and uncomfortable, they will feel uncomfortable. Be confident in what you do and say, and always remain respectful. Never touch them without first asking permission and explain why you need to do so—even if it is moving a piece of hair away from their face. Ask permission to move a piece of clothing or better yet, ask someone else present that the victim trusts to do so.

I always let them know that I've been doing this a long time, and there really isn't much I haven't seen. Somehow that seems to help put them at ease. Respect the victim's privacy and show only what needs to be shown in the photograph by covering adjacent body parts that should be kept private. Remember that many people will be looking at these photographs in the months or sometimes years to come.

This is a good time to point-out that trying to put your victim at ease is *not* the time to be fumbling with your camera controls or lighting. It's hard to instill confidence if it appears you don't know what you're doing. Know what you are doing. Practice first.

Always Have Another Person in the Room

You should always, always have another person in the room if photographing the opposite sex or a child. The choice of who that will be can sometimes be difficult, depending on

circumstances. In a domestic situation, it can be especially problematic. However, it is better to wait for someone than to later be accused of inappropriate conduct.

My first choice is to have someone like a family member or friend present in the room. If they are not available, a police officer, nurse, or other person must be present—again preferably of the same sex of the victim. Be sure to document who was there for later reference.

This is the same requirement whether it is a law-enforcement matter or a civil matter. When doing civil cases, I am always very clear in advance that someone must accompany the victim when I am taking photographs.

Using an SOP

No matter if you are conducting a field sobriety test, arresting someone, or taking photographs, you should have a standard operating procedure (SOP) that you follow every time. That is the only way to ensure you don't miss anything, and it also serves a value when being cross-examined in a courtroom setting.

I first use a checklist to ensure my camera is set-up properly (Figure 27.21), then I set-up the lights, and establish color balance. I then systematically take photographs as described in the next section.

Workflow

After the first photo of the victim, which is typically a head shot to establish identity, I then will do the overall photos if involved in a criminal matter.[24] Minimal clothing is worn; a full overview of the front, then the back, and then each side of the victim is taken. Be sure to have the arms positioned in a manner that shows the front and back of the arms and hands when doing the front and back photos. When doing the side photos, the arms should be extended slightly in front of the body so as not to obstruct a full view of each side of the body.

D810 Checklist

1 Battery
2 Memory Cards
3 Mode: Manual
4 Exp. Comp. Off
5 Bracketing: Off
6 Quality: RAW
7 ISO: 64
8 Auto ISO: Off
9 WB: Flash
10 Drive: Single shot
11 Auto focus: S, S
12 Monitor brightness: -3
13 Shutter speed: 1/200th
14 Shutter speed lock: ON
15 Aperture: f/11

FIGURE 27.21 An example checklist.

This is also the time to remember DoF which is particularly important when taking overall views to ensure everything is in sharp focus on all parts of the body. One advantage you have when taking overall views is that your lens-to-subject distance is greater, which provides a greater DoF. How much depends on your camera and your focal length setting. Experiment in advance so you know.

Mid-range views then establish the location of the injury to another part of the body. In my workflow, I start at the top and work down. A head injury, for example, would have a mid-range view to help establish the precise location of the injury on the head, with a close-up view of the injury to follow. If the injury has been cleaned-up, or is a scar or other mark, I will first include a scale with the close-up. I include the scale first because I know I can get a focus on the scale, and as mentioned previously, focus on skin can be difficult. Without moving the camera, I then remove the scale and take another photograph. By doing so, the last two of the four required views are completed in a simple, efficient manner.

When using a scale, be sure to position the camera so the injury and scale are properly oriented, and that the scale is parallel with the frame (Figure 27.22).

In a complex situation that has many marks and scars, having this workflow will help you systematically capture every detail without the fear of missing something. Even then I've found sometimes I second-guess myself, especially when those marks and scars are on the front, sides, and back of arms, legs, and torso. I have to rely on the



FIGURE 27.22 Correctly placed scale parallel to the wound.

medium views to stay oriented. This is especially difficult when photographing burn injuries.

Putting It All Together

Each aspect of what it takes to produce a great photograph of an injury has now been reviewed; putting it all together is the next step. Please be sure to read through all of the following steps before implementing:

1. First, know your equipment and how you intend to light the injury. Set your camera to provide the best image possible based on tests you've made.
2. Place your subject in a location that has no distractions; stay away from windows, television screens, or anything that is busy and will take away from the injury photos. Dark backgrounds are always best, if available. I prefer black.
3. When placing your subject into position, do so with available light falling evenly on your subject to ensure they are well-lit. Otherwise, move your light source to their location.
4. If using a point-and-shoot or cellphone camera, make sure the internal flash is off and prepare a suitable light as previously described that adequately lights the subject. Adjust the focal length on your lens so that it will not capture a distorted wide-angle view. This will vary by camera, but you should know the correct position after testing.
5. For point-and-shoot and cellphone cameras, your ISO should be no higher than 100, and the camera should be in the *aperture priority mode*, set on no less than *f*/8 for the close-up photographs. If you have a lot of light, *f*/11 is an even better choice.
6. If using a DSLR or mirrorless camera and place it in the *manual mode*, use the meter in your camera to set your exposure for the ambient light in the room as it is falling on your subject.[25]

   The preferred ISO is 100,[26] and use an f-stop of *f*/5.6 for the overall views. You should use an f-stop of *f*/8 or *f*/11 for medium views, and an f-stop of *f*/11 or *f*/16 for close-up views.[27]

   The only adjustment you should make is to your shutter speed, which may be slow. If the shutter is less than 1/60th of a second, you should have your camera on a tripod or other stable surface. Even when using a tripod, if the shutter speed is less than half a second, your subject must remain very still. If needed, you can increase your ISO in this circumstance. Remember where the ISO noise is noticeable on your camera.
7. Make sure your flash is in the TTL mode. All flashes have a readout on the back that will read TTL, TTL/BL (backlight), or other variations (Figure 27.23). Use your flash in the bounce position to reflect a natural, not harsh, light on your subject. A bounce card or pad of paper is preferred over bouncing off the ceiling or walls.
8. For all cameras, take the overall and medium views of the subject.
9. For all cameras, take close-up photos of the injury after first ensuring your subject is stabilized; if a head injury, have them sit near and lean their head onto a wall if needed. If a hand, arm, or leg injury, have them lay it on a stable surface. If needed, you can zoom-in to fill the frame with the injury, depending on the minimum focus distance that you have determined by testing.
10. For a point-and-shoot or cellphone camera, use a main light source, such as a flashlight, to cross-light the actual injury. Diffuse the light so that it creates a non-harsh, natural looking light, and that there are no dark shadows.
11. No matter what kind of camera you are using, remember to check the small light in the viewfinder that indicates if you have a good focus. If it is not solid, use one of the techniques previously described.
12. For a DSLR or mirrorless camera, bounce the flash in a manner to cross-light the injury. This is best done if you can remove the flash from the camera, which will require a remote flash cord. If unable to remove the flash from the camera, use a flashlight as previously described.
13. For all cameras, make sure to stabilize the camera by using a tripod or mini-pod or another stationary surface.
14. For point-and-shoot or cellphone cameras, release the shutter by using the internal timer, being sure to tell your subject to not move. I often have them take a deep breath, then exhale half and wait for the shutter.
15. For DSLR or mirrorless cameras, use a remote shutter release to release the shutter. If you don't have a remote shutter release, use the timer to release the shutter.

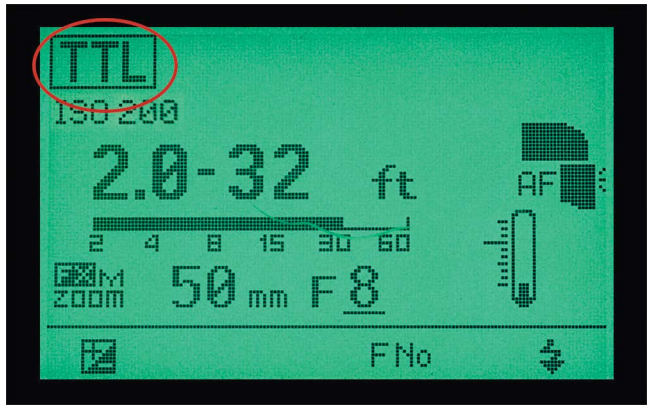


FIGURE 27.23 Look for "TTL" on the flash panel.

16. For all cameras, review the image for sharpness, exposure, and color accuracy by zooming-in on the camera's LCD monitor.

PART TWO: ADVANCED TECHNIQUES

This section is written with the assumption that the photographs are being taken well-after the initial injury has been documented. This could be many months or even years after the injury occurred. While it is almost a certainty that the documentation of an injury after the fact will be in a much more controlled setting, there are potential challenges that are no different than the original; subject clothing, distracting backgrounds, unwanted reflections, and possible distractions from persons present at the time of the photographs.

These advanced techniques are being written with the assumption the photographer is more advanced, using more advanced equipment, and is post processing their own images. It is also written with the expectation that most of your subjects will be photographed at a location where you have complete control over lighting.

Required Equipment

For the most part, more advanced techniques require more advanced equipment. This section is written for the photographer with, at a minimum, a DSLR or mirrorless camera with interchangeable lens ability and an external flash. The actual equipment you need will depend on the amount of injury photography you expect to do. For the motivated photographer who wants to do the best job possible with a good quality camera and lens, the following equipment should be considered minimum:

- Quality DSLR or mirrorless camera with interchangeable lens ability
- Either a "normal" lens for the camera,[28] or a lens capable of macro photography
- At least one quality external flash (two is better)
- An external flash cord that allows the use of the flash off the camera
- A gray card or color checker (preferred)
- A stable, quality tripod
- A remote shutter release
- A flashlight, preferably with an LED bulb balanced to simulate daylight
- A computer with an image processing program

A step up from this would be a photographer whose business is documenting injury photography for medical or legal purposes. In addition to the equipment noted earlier, the photographer would be wise to invest in a portable flash lighting set or kit, similar to what is used in portrait photography. A lighting kit will also require the use of light modifiers that will diffuse the very powerful light that falls on your subject. Through experimentation, my personal preference is a pair of soft boxes, or a soft box, and a parabolic light attachment (Figures 27.24 and 27.25).

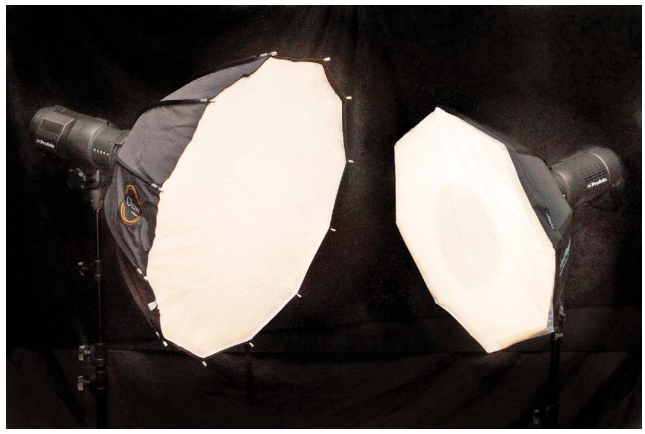


FIGURE 27.24 A pair of soft boxes.



FIGURE 27.25 A soft box and a parabolic light.

The Basics

Composition and Views

The rules of composition are exactly the same as described in Part One of this chapter. However, the need to photograph four levels or views will not be required unless the injuries encompass the entire body. Typically, overall views are not required: only mid-range photographs to orient the location of the injury and close-up views with and without a forensic scale.

Post Processing

The preferred way to capture injury photos is in a camera raw format,[29] with each image being adjusted for clarity when post processing the images. Raw images take-up a great deal of file space, and I've found several agencies that do not allow raw images for that reason. The benefits of shooting in raw are many: Raw files cannot be changed; raw files capture substantially more color information than a JPEG file; and you can make much greater and more precise adjustments during post processing to a raw file than a JPEG file.

If you are working for yourself or have influence with the decision makers for those you work for, I encourage you to capture images in raw format whenever possible. Besides, file storage solutions are much less expensive than

they were just a few years ago. The benefits of raw far outweigh the cost for additional file storage.

Whether you are shooting in raw, or are required to shoot in JPEG, processing standards[30] allow for adjustments to brightness, contrast, color, dodging or burning,[31] and cropping. These standards also require that any and all processing steps are documented and are repeatable. Image processing software like Photoshop's Adobe Camera Raw (ACR) has a history log[32] that will embed each processing step within the image metadata.[33]

Image manipulation is easier today than ever before, so you must be prepared for the challenge that your images were manipulated or altered. Words like image "enhancement" or "modification" may throw-up a red-flag unless those terms are clearly understood to mean enhancements done within allowable guidelines.

When I describe processing, I prefer to use the term "clarification." Processing an image is doing nothing more than what you do when you turn on a light switch in a dark room. You are not adding, deleting, or altering anything; everything you see in the room was there already. You just had to turn-on the lights to see clearly what is in that room.

IMPORTANT:

Be sure that when you work on your images, you work only on copies of the originals.

The originals should be untouched and secured in a location with controlled access. By retaining the original, untouched images, you can provide definitive proof that no alterations were made to the image outside accepted processing guidelines. So, be mindful that upcoming references to post processing in this chapter will be with the assumption you are making adjustments to a copy of an image, not the original.

Controlling the Background

Using a non-distracting background is always important. My preference is a black background; a black towel is inexpensive, readily available, and will work perfectly for both the mid-range and close-up views. For those photographers who do a lot of injury photography on a wide variety of subjects, you may wish to invest in a larger background. I've experimented with many different materials, and have found black fleece material is inexpensive, absorbs the light, cleans easily, and is fairly lightweight to carry. I carry two; one that measures 4″ × 10″, and a smaller piece that measures 3″× 5″. Using a black background removes all distractions and makes it look like there is no background (Figure 27.26).

Controlling the Color

The goal of accuracy is always paramount; reproducing accurate color can be difficult without the proper tools. This is an important concept for many of the reasons previously noted. While changing the white balance in the camera to try and match the light source used at the time of capture



FIGURE 27.26 Medium view on a black background.

is always a good option, those images still may not look exactly right on your computer monitor, or, they might not print as you might expect on your printer.

Differences in skin color may sometimes be the only evidence of an injury. Bruising on a recent injury may have distinct color patterns and differences that should be captured; bruising can even be evident many months after the initial injury.

What We See

A recent experience with a cataract in one of my eyes taught me how differently people can see colors; the color cast in my clear eye was totally different than the eye with the cataract. I was fascinated to learn when they replaced the lens in my bad eye, they did so with a lens that had a slightly yellow color cast to make things seem a bit "warmer" and more pleasing.

In addition, computer monitors can show color quite differently. Old monitors versus new monitors, different brands of monitors, and different brands of graphics cards all create a myriad of possible variations on the photographs you are trying to make accurate. And, when printing, different color printers will not produce identical results. In fact, it is not uncommon for a typical consumer printer to print colors differently from one day to the next as the ink gets older and the print head becomes worn and dirty.

So, accurate color is subjective, at best. Setting all that aside, your goal should be to reproduce the colors as you saw them. Theoretically, if you do so, others looking at the photograph(s) will see what they would have seen when the photographs were taken, as well.

Color Management

The only sure method to produce accurate color with your photographs is to use a color management system, the heart of which is a calibration process. When you consider that we view and work on a back-lit image on our computer monitor, and, if printed, we then view the print on paper that is lit by front lighting; it is easier to understand why it is necessary to go through this process.

There are three steps to properly managing color: (1) calibrating the monitor, (2) using a color checker when shooting, and (3) using a printer profile so what you see on your

monitor will match what is printed. Unfortunately, there is no way to calibrate monitors for those that may be viewing the photographs in their own offices, nor is it possible for you to control what the colors will look like if printed on someone else's printer. All you can control is your monitor and the printer you use.

In the civil world, I rarely have anything printed unless it goes to trial. Most cases reach a settlement, and my photographs are either viewed on a computer monitor or printed on an in-house printer at the law firm. I have always been very careful to point-out there will likely be color differences in either case, and the only way to ensure accuracy is for me to provide the finished prints.

When I am asked to provide prints for trial, I prefer to use a professional lab[34] to print my photographs. By using a professional lab, I don't have to worry about print heads failing, inks fading, or colors shifting. A good color lab ensures their printers and other equipment are properly calibrated on a daily basis. They will also provide you with their ICC[35] printer profile, along with instructions on installing that profile, followed by some actual test prints to ensure everything is profiled and calibrated properly.

Calibrating your computer monitor is a fairly simple process if using the right tools. Doing so involves the use of a colorimeter, which is readily available and is not expensive. I use a system by X-Rite. Another popular brand is made by Data color and serves the same function. These meters come with software you can install and use in your workflow to ensure the colors you are seeing on your monitor will be accurate and will match what you saw in-person.

You still need to ensure that what you capture in a photograph, especially under varying lighting conditions, will provide the computer with enough information to ensure accurate color in the end product. This very important step involves the use of a "color checker" (Figure 27.27). The color patches on a color checker are individually painted to very exacting standards and are used to calibrate your images to your computer monitor. My very first image when doing injury photography is a photograph of the color checker card using the same lighting used to illuminate the subject. Once I've uploaded the images to my computer, I then use the photograph of that card with the software that came with the colorimeter to calibrate the colors with my monitor.



FIGURE 27.27 Color checker card for accurate color rendition.

White Balance

The last step in processing injury photos and obtaining accurate color involves setting the correct white balance. You may have done so in the camera as suggested earlier in this chapter. However, the white balance settings in the camera are fixed to a very specific color temperature, and by processing your own images you can fine-tune that color to be even more accurate.

Once you've used the color checker and software to calibrate your monitor, you need to select a white balance that is the same as recorded in your image. One of the color swatches on the color checker card will be 18% gray. The one illustrated in Figure 27.27 is on the bottom row, second from the left. You use that swatch to set the color balance in your imaging software, and then apply the color profile and white balance to all your images.

Sometimes it is difficult to trust the results. As previously noted, everyone sees things differently, especially when it comes to color. In fact, if I cover one eye, the colors look different than when I cover the other eye—thanks to another cataract. Unless an image has been corrected for being way underexposed or way overexposed,[36] I've concluded the best thing to do is to trust my color management system instead of my eyes.

Unwanted Colors

Another very important aspect of color control is the reflection of unwanted colors. Reflection of color can come from the clothing being worn by your subject, the color of the walls where you are taking the photographs, and the color of the clothing you are wearing. If you are wearing a brightly colored shirt, all the color control and white balance tools at your disposal will not be able to correct the color that reflects from your flash to you and then on to your subject. If your subject is wearing brightly colored clothing, which is common with children, the light reflected on their skin will be nearly impossible to correct.

When possible, I always ask those being photographed to not wear anything brightly colored. And, I have certain shirts that I wear, as well. Grays, blacks, dark blue—nothing that will reflect a color. My wife tells me I have a boring wardrobe. And she is correct. It is that way for a reason.

Earlier in this section I described the two black fleece pieces of material I carry. The larger one is used as a backdrop for the purpose of eliminating distractions, and doubles to help with unwanted color reflections from the walls. The smaller piece is used to drape over the subject if they wear something that has a "busy" pattern or is reflecting colors. Sometimes I will use the smaller piece to just isolate an arm or a leg.

Identifying distractions is a relatively simple matter; I have a quick test that I learned years ago when I was doing outside portrait photography. I call it the "squint" test.

Look at your subject (or scene) and squint your eyes. If what you see is other than what you want to show, it is a distraction.

This is another area that you should test. I think you will be surprised how much light is reflected if you are wearing a bright red, yellow, or blue shirt. Use a color checker or a gray card and see how successful you are in getting the correct color.

Controlling the Perspective

Accurate viewer perspective occurs when you capture an image that looks the same as what you see with your eyes. In Part One, the use of a proper focal length was discussed. Capturing a distorted image is the last thing an injury photographer should do. By testing your camera and lens combination, you should know what lens setting is needed to avoid barrel distortion, which is caused by being too close due to the use of a wide-angle lens setting.

I use a 60-mm macro lens with a full-frame camera, so getting close to the injury is not difficult. However, if you are using a point-and-shoot camera, a cellphone, or a DSLR or mirrorless camera with a kit lens, you may not be able to get as close to the injury as you need in order to fill the frame with the injury. It is perfectly acceptable to use your zoom lens to zoom-in on the injury even though long focal lengths should not be used when documenting a scene. Unlike a scene, there is very little depth when photographing injuries, so compression is not an issue.

You may find the minimum focus distance for your zoom lens will still prevent you from getting close enough to fill the frame with the injury. In that case, it is acceptable to crop the image during post processing so the composition properly shows only the area of interest.

Again, you must test your camera so that you know what to expect in advance. Part Three of this chapter describes one method to determine your minimum focus distance.

Controlling the Light

The ability to control the light to achieve the best results will require experimentation and patience. The time to experiment, however, is not when you are photographing your subject, but prior to doing so. One suggestion is to experiment with different options just prior to the actual photographic session. If you know you will be photographing a facial injury, experiment with another person or an object that will represent a head. If photographing scars on an arm, first experiment with a person or object that will represent an arm. And so on …

Single Light Source

Many photographers think in terms of having only one light source, which may be just the flash they have on their camera. However, wherever you go, there will always be a second light source available. Using multiple light sources is the best way to obtain good injury photographs. But that becomes a bit more complex and requires experimentation and practice.

If you must use just the flash on your camera, remember from Part One that there are ways to diffuse the light to create a more natural-looking photograph. Bouncing the flash into a bounce card is probably the easiest method, but that will not always light the injury properly to show the extent of the injury. Using a direct flash on your camera will result in harsh shadows and will likely overexpose the actual injury in close-up photographs.

It is my hope that you are reading this chapter to learn better ways to photograph injuries than using a single light source. Still, there may be occasions when you don't have much choice.

Multiple Light Sources

As mentioned earlier, even if you have only a flash on your camera, there will be two light sources whenever you photograph your subject. During the day you will have natural window light; remember the color temperature of natural light is very close to what your flash will produce. During hours of darkness you will have room lighting, although the color temperature of the light can vary a great deal. There are several ways to compensate for the difference in color and prevent an unwanted color cast to your photographs.

Many external flashes will come with an assortment of filters that you can place over the lens of the flash (Figure 27.28). If you are at a location that is illuminated with incandescent lighting, you simply place an orange filter over the camera flash. In an area illuminated by fluorescent lighting, you would use a green filter. You then set your camera white balance to the appropriate lighting. Again, this is where you need to experiment in advance so you know what will work, and what will not.

Another option is to use a colored gel to cover the light source. Gels are inexpensive and easy to carry. They are available in a variety of different sized sheets and look like a piece of very thin colored film. They can be purchased to convert incandescent bulbs, fluorescent lighting, and a variety of other color temperatures to a daylight color temperature. They are typically heat resistant, so you can wrap them around an incandescent bulb, or otherwise place them between the light source and your subject. Although I've

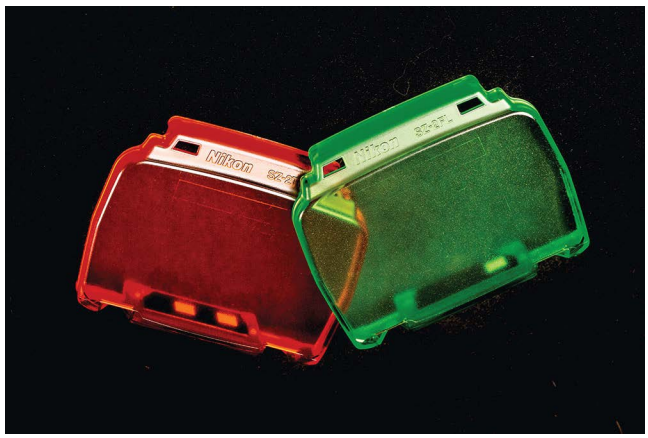


FIGURE 27.28 Flash color filters.

not used colored gels in an injury application, I have used them to balance room and accent lighting with my flash system in a portrait setting.

An even better solution is to purchase a daylight-balanced LED light bulb or two to carry with you. You can then place your bulbs in an existing lamp or other light fixture. It is then a relatively simple matter to balance your flash intensity with the intensity of the LED light source.

Light Intensity

To be able to create a photograph with the dimensionality discussed in Part One, shadows are required, but are controlled by the intensity of light. Again, for the purpose of clarity, I will refer to the ambient light where you photograph the subject to be "fill" light, and the light you bring to be the "main" light. The intensity of each light source will determine how much dimension, or modeling, you will have in your photographs.

Keeping in mind the color balance challenges referred to in Part One of this chapter, position your subject so the fill light falls evenly on your subject. The main light source is then used from a different direction to provide more light on your subject than the fill light—typically one or two stops more light than the fill light. Again, you will need to experiment to determine the best ratio.

Sounds complicated, but it really isn't, and it will be explained in more detail shortly.

Flash Modes

Most external flashes have a variety of modes. Some photographers prefer the manual mode on a flash and determine proper exposure based on the distance scale that appears on the flash readout in conjunction with their f-stop. With the advantage of being able to immediately review your images in our digital world, it doesn't take long to tweak the power of the flash to obtain the desired results. However, two things need to be present in order for this system to work. First, the flash must have variable power on manual. Some flashes set to manual will use full output only, meaning they will give a full power dump every time the flash is fired. Unless you are using a battery pack or AC to power the flash, the batteries inside will die quickly.

My preference is the TTL mode, although there are times when metering through the lens is fooled by the subject matter, resulting in an underexposed or overexposed image. In that event, switching to the manual mode makes a lot of sense. Typically for injury photography, however, the TTL mode works fine.

The following discussion regarding using camera flash is based on the use of the TTL mode.

On-Camera Flash

If you are using an external flash, you need to get the flash off the camera so you can position it at different angles. But, if you do not have a remote flash cord, or a system that allows you to trigger the flash with the internal flash, the next best option is to bounce your flash into a white reflector that will then redirect the light from an angle.

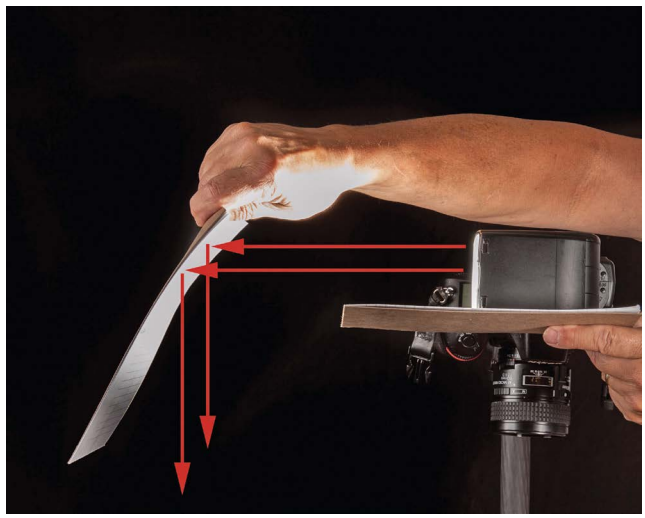


FIGURE 27.29 Overhead view of using a bounce technique to redirect the light at an angle.

With your camera on the tripod, angle your flash to the side that you wish to be the main light, and then use a bounce card to redirect the light from the proper angle. The bounce also has the benefit of softening the light. Be aware that some light from the flash will "spill" to the front and may result in unwanted shadows or glare. In that case, use a piece of white cardboard—or even the back side of your gray card or color checker, as an improvised "scrim," which will block the spill. Since you will have both hands busy, this is an occasion where you use the timer to release the shutter on the camera.

Figures 27.29 and 27.30 are two examples of bouncing the light at an angle to your subject when your flash is mounted on a camera.



FIGURE 27.30 Front view of using a bounce technique to redirect the light at an angle.



FIGURE 27.31 IR panel over pop-up flash.

Off-Camera Flash

Moving the main flash off the camera simplifies everything. This can be done either by using a remote flash cord, or by using the internal or pop-up flash on your camera to trigger an external flash. This latter method is available on many cameras today, so consult your camera manual. Nikon offers an infrared (IR) panel that fits in the hot shoe and can then be used to block the visible light from the pop-up flash—but will still trigger the main flash (Figure 27.31).

By getting the flash off the camera you now have the ability to position your main light at extreme angles. Sometimes you need to have that light nearly behind the subject; there are some examples in the section on light direction.

Knowing where to position the flash can sometimes be a bit difficult, but you can use your flashlight to simulate what you will get with the flash. By moving the light around the injury, generally from the side, and sometimes even behind the subject, you will find a position that best cross-lights the injury. You then hold your flash in that position and trigger the camera using the remote shutter release. Remember to soften the light by either placing a diffusing material in front of the flash or by bouncing the flash into a white bounce card (Figure 27.32).

Multiple Flashes

If you have more than one flash, even more opportunities for light control become available. As previously mentioned, some cameras have the ability to use the pop-up flash to trigger an external flash when it is not mounted to the camera. The amount of power the pop-up flash has is limited, but is often enough to provide the fill light, replacing the need to use the ambient fill light source. Controls in your camera will allow you to set the power output of the pop-up flash to provide an equal amount of light as the remote flash, or less, or more. If there is good ambient light, I will generally set the pop-up flash to its minimum power, which then provides nothing more than a trigger for the main flash and adds a nice catch light in the eyes if doing a face photo.



FIGURE 27.32 Bounce into pad of paper.

A second external flash unit can be fired simultaneously with some camera systems, such as with Nikon's Creative Lighting System. If you are fortunate enough to have that kind of equipment, you can use your second flash as the fill light. It is best to bounce your fill flash into either a white card, onto the ceiling, or off a wall to provide the fill light. Don't forget the potential of color casts from a ceiling or wall. Set the power on that flash at least one stop less than your main flash. This will be your fill light for softening shadows from your main flash, creating the dimensionality previously described. Again, experiment in advance so you know what settings work best.

Light Direction

The direction of the light and intensity of each light works closely together to determine how well you are able to show the injury. The direction of your fill light source is the easy part: you just position your subject and the light so there is even illumination on your subject. Directing the main light so it best illustrates the injury is the part that takes a lot of practice. A properly directed main light is one of the more important steps.

The main light is the light that does all the work, and its position is critical to capture the details of an injury or scar. Even if you've practiced your light set-up in advance, every case will be different and may require some experimentation and fine-tuning at the time of the session to best illustrate the injury. Subtle differences in your main light position can make a substantial difference in the end result. Even though the image in Figure 27.33 (left side) clearly shows the severity of this injury, the image on the right side more accurately portrays the extent of the injury.

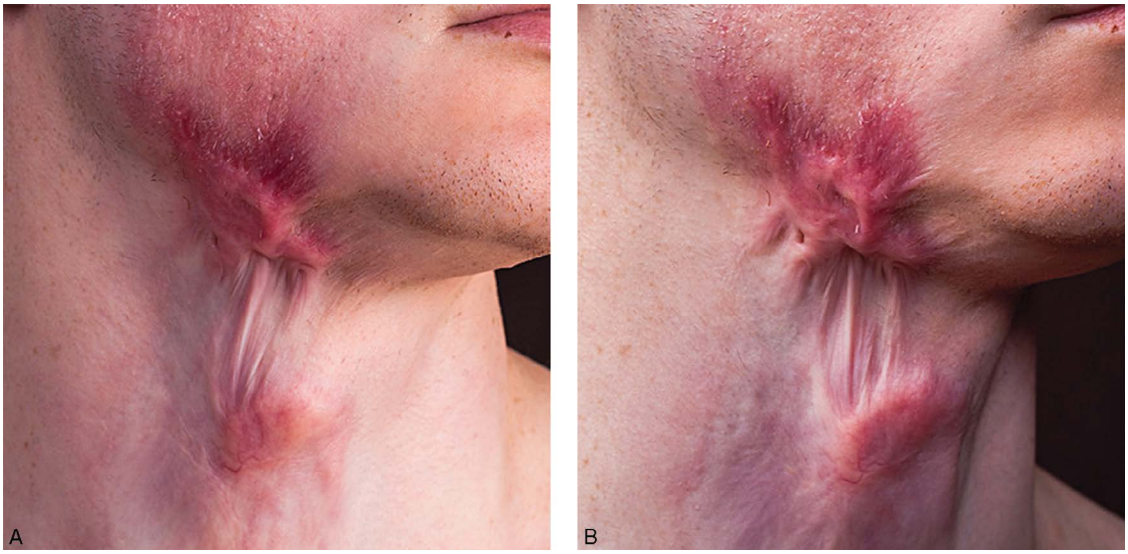


FIGURE 27.33 Cross lighting. (A) Good cross lighting. (B) Better cross lighting.

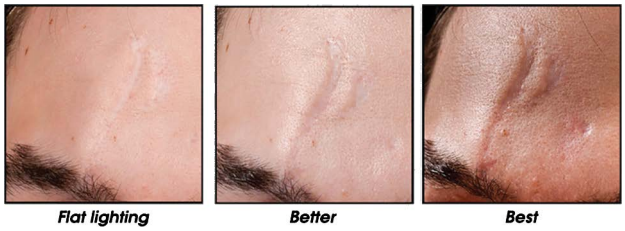


FIGURE 27.34 Extreme angle light placement.

The subject in Figure 27.34 required the light to be placed over his right shoulder firing forward in order capture detail of the scar. When shooting an extreme angle like this, always be careful to not allow the light from the flash to strike your lens, or you will get unwanted flare. You should always use a lens hood, which is particularly critical in this lighting scenario.

Figures 27.35 to 27.37 show the light placement for each of these three photographs.

When learning proper placement of multiple light sources and the correct position of the main light, you will find the use of a tripod is necessary, as well as a remote shutter release. By using both, you can concentrate on the light direction, and remotely release the shutter when you find the right placement. I also suggest that you pre-focus the camera and tell the subject to sit still.

Controlling Depth-of-Field

Over the years I've heard many people talk about the need to increase DoF, but when I ask how much DoF they actually have at certain f-stops, it usually results in a blank stare. For those that have studied photography, generally all we've learned is that a smaller f-stop (higher number) will give us a better DoF. Except that isn't always true.

Three things affect DoF: (1) f-stop, (2) lens focal length, and (3) lens-to-subject distance. In order to understand how much DoF you need for an injury photo—or any photo for that matter—you need to know what does what and how much.

The most common thought regarding DoF and injury photographs is that a cut or wound is relatively flat and doesn't require much DoF. Except, that also isn't necessarily true. I've taken injury close-up photos on a man's arm that had a lot of hair, and found the autofocus focused on the hair, not the skin. The hair was tack-sharp. But when I am doing scar photographs, I judge sharpness by the ability to see the pores of the skin. With a better DoF, both can be sharp.

I use a full-frame camera and nearly always use a 60-mm macro lens when I take injury photographs. When I am doing a close-up photograph of an injury, I have only 1.59 mm DoF at 9½ inches. That is 1/16th of an inch. If hand-holding the camera, the mere act of breathing can take you outside that range and result in a soft image. And you may be surprised to learn that the depth-of-field doesn't change if I "stop-down" (make my aperture smaller). In fact, my DoF is exactly the same if I use *f*/8, *f*/11, *f*/16, *f*/22, or *f*/32. How do I know? I tested it. That is a characteristic of that lens at that distance (Figure 27.38).

If I need more DoF, I simply move back so I am not as close. At 18 inches, my DoF ranges from nine sixteenths of an inch at *f*/8, to one and nine sixteenths of an inch at *f*/22. I will then crop in post processing to fill the frame with the subject matter.

After hours of testing different lenses at different settings and different distances, it occurred to me that I had seen DoF charts somewhere. So, I pulled-out my lens manuals and there they were! It was interesting to compare my testing to the charts; I found my testing was very close, and a bit more conservative than the numbers on the charts. If nothing more, the charts validated my testing. And, I still test even though the chart is available. When being cross-examined on the stand, explaining that you read something doesn't carry as much weight as if you tested it.



FIGURE 27.35 Don't position the light source so it shines at the injury.



FIGURE 27.36 A better angle.



FIGURE 27.37 The best angle.

Inch	f/8	f/11	f/16	f/22	f/32
8 ¾"	1.59 mm	1.59 mm	1.59 mm	1.59 mm	1.59 mm
9"	1.59 mm	1.59 mm	1.59 mm	1.59 mm	1.59 mm
9 ¼"	1.59 mm	1.59 mm	1.59 mm	1.59 mm	1.59 mm
9 ½"	1.59 mm	1.59 mm	1.59 mm	1.59 mm	1.59 mm
10"	1.59 mm	1.59 mm	1.59 mm	1.59 mm	4.76 mm
12"	1.59 mm	4.76 mm	4.76 mm	7.94 mm	11.11 mm
15"	7.94 mm	9.53 mm	15.88 mm	22.23 mm	31.75 mm
18"	14.29 mm	20.64 mm	28.58 mm	39.69 mm	57.15 mm

FIGURE 27.38 Depth of field table; Nikon 60 mm lens.

The DoF with your camera and lens may be similar to mine, or it could be quite different. The smaller the sensor, the greater the DoF. Cellphone cameras have tiny sensors, so while they are not good at gathering a lot of light, most everything in your image will appear in-focus. The same is true with point-and-shoot cameras. Many mirrorless cameras and DSLR cameras have smaller sensors and a greater DoF than full-frame[37] cameras; however, a higher quality camera with a larger sensor will provide more control over the DoF.

When doing injury photography, you need to know your DoF ranges and limitations. I can't remember them all, so I've created pages with that information in One Note that I can refer to on my smartphone (what I now refer to as my brain). I encourage you to do the same. Look-up the DoF tables for the camera and lens you are using and keep that information readily available. And for the common ranges in which you find yourself shooting injury photographs, test that data, and know what you can expect before you have an actual case.

There are a number of free and paid apps available that can be installed on a smartphone, which calculate DoF after you enter the information about the camera and lens being used. I've experimented with and used many of these apps, and while they are helpful, it is noteworthy that no two apps provide the same information when inputting identical camera and lens information. So, my conclusion is they are helpful to give you an idea about your DoF, but you are still wise to test each lens with the camera you are using.

Controlling Exposure

The final step in this process is to control your exposure. In order to control the exposures for both the fill light and the main light, you will need to switch to the camera's manual mode. If you are using two off-camera flash heads, as previously referenced, you may be able to use the flash's TTL mode with your camera in the aperture priority mode. Still, not all systems work the same. Test it both ways.

When you are making adjustments to your camera settings, remember the most important consideration is your DoF. So, you first set the desired aperture to obtain the needed DoF. The second most important consideration is having low noise and maximum sharpness; your ISO should be set at 100. Can you use a higher ISO? Of course. But test it. Know at what ISO setting your camera starts getting noisy and soft. You can never go wrong with an ISO of 100.

If you are using two flashes in the TTL mode, and your camera in the aperture priority mode, and you can balance the output of each flash to best show the injury with dimension, you are fortunate. You are good-to-go. However, if you are using just one external flash and ambient light for the fill light, the following paragraph is what will bring this all together.

If using a single off-camera flash with ambient light as the fill light, place your camera in the manual mode and then meter for the ambient light that is falling on your subject[38] using the f-stop you've selected. Since you are using a tripod and a remote shutter release, the shutter speed doesn't matter. Forget about the flash for now. You control your exposure by adjusting your shutter speed to match the ambient light. Chances are the amount of light will result in a shutter speed that will be slow enough that any subject movement will result in a soft image, so ensure your subject is in a stable position and coach your subject accordingly. Telling an adult to hold still usually works pretty well. With children, not so much.

You now have controlled every aspect of the exposure triangle; by using the manual mode, you have defined the level of ambient light (aka fill light) with your shutter speed, and your f-stop will control the output of your flash, which becomes the main light in the TTL mode. When you place your flash in the position to capture the injury, you will find the additive nature of light will result in the direction of the flash providing the depth and dimension that will clearly illustrate the injury. If you require more direction to achieve your desired result, you then simply increase your shutter speed to allow less ambient light to fall on your subject. By doing so, you are reducing just the fill light, not the flash.

Setting your controls as described here may require some tweaking. Experiment with different settings so you know in advance what works best. Tweaking when on location is always okay. Learning how to do it when on location is not. Again, experiment, experiment, experiment—in advance! Learn your equipment.

Specular Highlights

Specular highlights are areas on the skin where light is reflecting, causing glare in the image. This glare can easily hide what you are trying to show. So, you reposition your light so that the glare doesn't cover the injury. Still, and especially with oily skinned persons, the glare can be distracting. And sometimes the injury is large enough it is nearly impossible to get all the glare away from the injury.

I spent countless hours testing different light modifiers and light positions and filters and gels and combinations of all these things trying to solve this problem. In fact, being somewhat of a perfectionist, this became an obsession for me that lasted several years. And then one day I had an epiphany.

Cross-Polarization

A common process used when photographing paintings and artwork, as well as a process being used in some medical examiners offices to photograph human organs, is cross-polarization. I decided to order a sheet of polarizing film[39] that I could place over my soft boxes. I cut the film to size, attached the film to my soft boxes with Velcro, and began testing with a circular polarizing filter. I also conducted these same tests with a linear polarizing filter.

I'm no scientist, and certainly not an expert in light transmission and frequencies and all the things that make this work, but it does. And it works beautifully. Make no mistake. This will require you to invest in the materials, and to invest a great deal of time finding what works and what doesn't. But the results are amazing.

Things I've Learned

No two pieces of equipment are the same, so what I am going to share about what I've learned will hopefully help you get where you need to be a little faster. You will still need to set-up and test your equipment using this method. First a bit about polarization.

Of all the explanations I read on how polarization works, the one I found easiest to grasp was a description of how light waves actually vibrate and do so in both a vertical and horizontal direction.[40] Polarized light is when you see the waves vibrating in only the vertical or horizontal plane. So, a polarizing filter is designed to block light vibration in one plane or the other—which is why you must rotate a polarizing filter on your camera lens to see the results. Simple.

When using polarization for injury photography, it is important to calibrate all the filters so that they work together, which can be a bit tricky. Following are some of the tips and things that I've learned:

1. Polarizing film cannot be placed inside a soft box or inside a flash lens cover; the polarizing film must be the last thing the light passes through. And as I thought about it, that made sense. Initially I had hoped I could put the film in front of the flash tube and diffuse the polarized light from there. The problem was that as soon as the light passed through the diffuser, it was no longer polarized. So much for saving money on polarizing film!
2. Polarizing film on two lights need to be at the same plane to work. I set-up my fill light and then rotate the polarizing filter on my camera until the specular highlights disappear. But when adding the main light to emphasize the injury, the glare will likely be back where the main light falls—unless you are lucky enough to just have it in the right position. Never happens for me, though. So, you must calibrate each light so that they are on the same plain.
3. Calibrating with two lights can be difficult, especially since you must look through your camera lens

and rotate the lens filter to find the correct position. My arms aren't long enough to do so at the same time I am rotating the film on a light source, and I don't have enough arms to do so on both lights and the camera at the same time.

4. So, I took a business card and placed it on an adhesive piece of mount board, leaving an area around the card so that I could then place and adhere a piece of polarizing film on. You hold the card in front of one light source and rotate the film on that source until the card turns dark, making sure the second light source is either not on or turned-away. You then repeat the process with the other light source. Then, aim both light sources at the card, and the card should remain dark. Leaving the card in place, look through the viewfinder of the camera and rotate the filter until it turns completely dark (Figure 27.39).
5. I experimented with numerous angles. Theoretically the light with a polarizing filter should be angled 45 degrees at your target. But I found it didn't really make all that much difference. I just slightly adjusted the polarizing filter on my camera lens and got the same or similar result.
6. Even if I had both lights balanced with my camera filter, as soon as I started moving one of the lights around to the side, back, etc., I had to readjust all over again.
7. I also found that a circular polarizing lens filter and a linear polarizing lens filter work about the same. For years I read that a linear polarizer filter would not autofocus, and would not provide a proper exposure. However, I found that to not be the case. I should mention that I am using a very good quality linear polarizing filter[41] and haven't tested an inexpensive consumer filter. And, my preference is the linear filter, mostly because it has a scale that I can preset.
8. To save time, I placed a mark on the top of each polarizing film so that when I attach the film to my soft boxes, the vertical and horizontal planes are properly aligned. Using the scale on my linear polarizing lens filter, I know where that needs to be to get the best results. I still test it with my card though.
9. Repeated testing and practice are really important when attempting cross-polarization.
10. A good friend and fellow forensic photographer told me that he thought the polarized images had the appearance of being soft. I examined them closely and could see what he was referring to. They weren't soft but gave that appearance because of the way the polarized light was not reflecting off the skin. Depending on the case I am working on, I will often take one frame fully polarized, and then a frame just partially polarized by turning my lens filter slightly off axis. I then decide in post processing which shows the injury better. And, sometimes I select the one that isn't fully polarized. The most important thing is that the glare is not covering up the injury, and it has been dramatically reduced so that it isn't distracting.

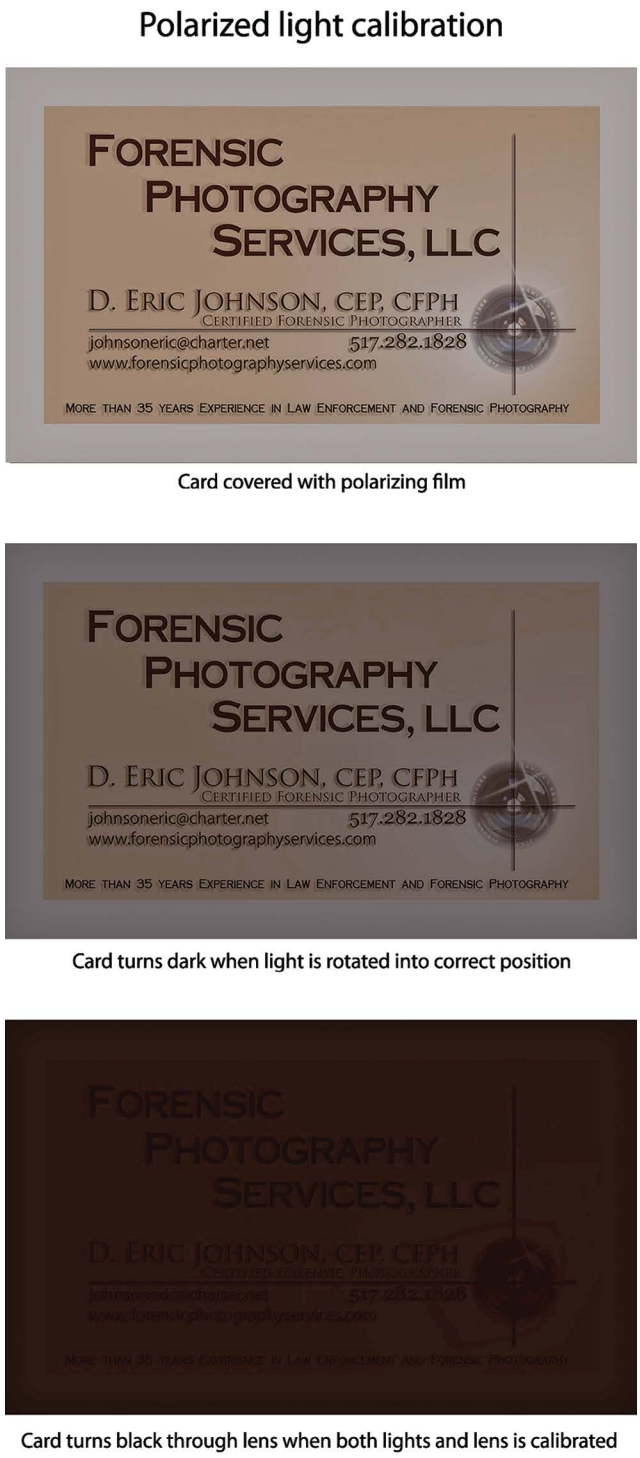


FIGURE 27.39 Calibrating the lens with two lights.

Figures 27.40 to 27.43 show specular highlights, and then those highlights being corrected by cross-polarization.



FIGURE 27.40 An example of corrected highlights using cross-polarization. (a) Non-polarized. (b) Polarized.

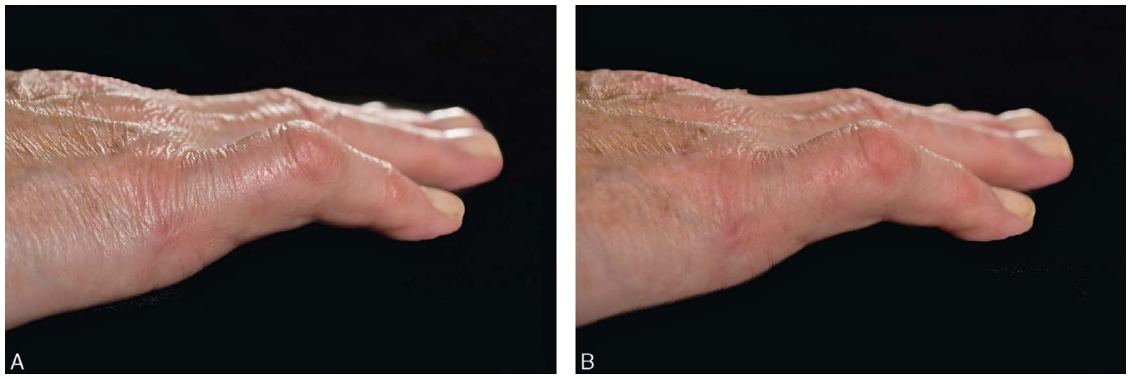


FIGURE 27.41 Another example of corrected highlights using cross-polarization. (a) Non-polarized. (b) Polarized.

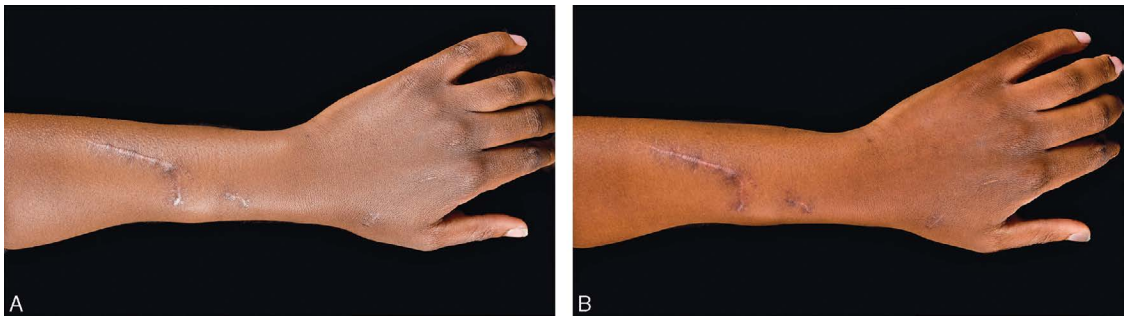


FIGURE 27.42 Another example of corrected highlights using cross-polarization. (a) Non-polarized. (b) Polarized.

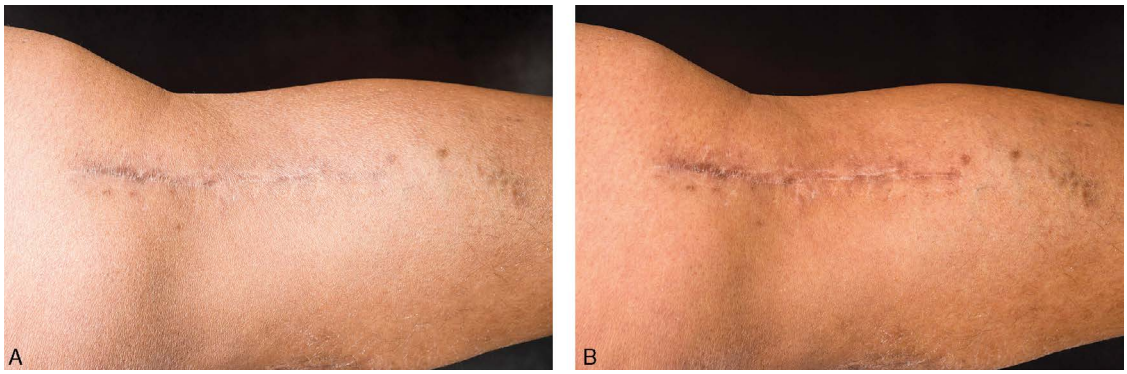


FIGURE 27.43 Yet another example of corrected highlights using cross-polarization. (a) Non-polarized. (b) Polarized.

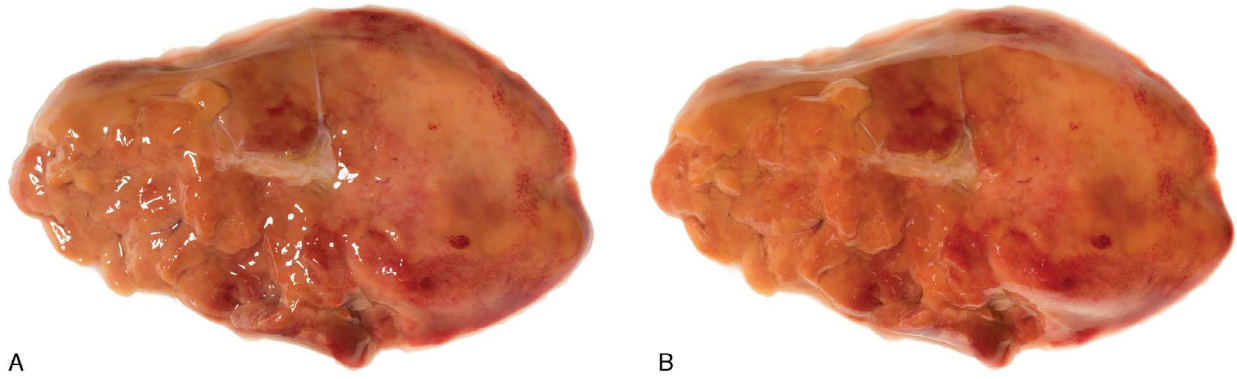


FIGURE 27.44 A final example of corrected highlights using cross-polarization.

Testing Ideas

There is probably no surface that will produce specular highlights as much as body organs. So, I purchased a whole chicken, and removed the heart, gizzard, liver, and whatever else there was. I stored those parts in a plastic bag in the freezer until I was ready to do additional tests. Usually they thaw-out pretty quickly, but one time I didn't plan ahead and made the mistake of putting them in the microwave. That is the eleventh thing I learned. Not a good idea.

When they are fresh, or after they thaw the old-fashioned way, put those shiny body parts on a neutral surface and start with no polarization. Then just add the camera polarizing filter and see if you can eliminate the glare that way. Now place a polarizing film over one light source and rotate your lens filter until the entire glare is gone (Figure 27.44). Place your light source at difference angles, and note differences, if any. Shoot from different angles and note the differences. Be sure to control your camera position by using a tripod—and take notes so you can remember what did what.

Now add the polarizing film to your second light source. Rotate, move, and try different angles with the second light source, adjusting to eliminate glare—then move your first light source. Plan to spend some time on this. It will be worth it.

Using What's in Your Bag

I am often asked what equipment I use. Because I do a great deal of injury photography, and most of it is on-location, I recently tested six different portable flashes or monolights before I decided to purchase a pair of Profoto B1X monolights. But everyone's needs—and budget—are different. You don't need a set of Profoto lights to achieve good results.

I use a Nikon full-frame camera with either a 60-mm macro or 105-mm lens, depending on the subject matter and required DoF. But it doesn't matter if you use a Nikon or a Canon or a Sony or an Olympus or whatever camera system. Test your equipment as I've suggested, master some of these techniques, and your results will be outstanding. The camera brand doesn't matter.

A few years ago, I presented a workshop on injury photography and decided to title it *Using What's in Your Bag*. I wanted to demonstrate that excellent results can be achieved without having expensive equipment and fancy lighting. Just a few weeks after I agreed to do the workshop, my wife and I were traveling, and one of my clients called and asked what it would cost to travel to a town in another state for an injury documentation. As it so happened, we were in a position to easily reroute our return trip home and travel through that city. I didn't have my forensic camera kit, and I didn't have my lights. But I had a camera, a macro lens, a tripod, a shutter release, and a single flash. Everything my workshop was designed to cover.

Using the techniques described in the first part of this section, I used ambient window light as my fill light, I used my pop-up flash to trigger my main light source, which also provided a little fill and catch lights in the subject's eyes, and a pad of paper that I had in my vehicle to bounce my main light source or external flash in to. Since I didn't have a black background with me, we stopped at a Walmart store and purchased a black bath towel for around $5 USD.

Figure 27.45 shows the subject illuminated only by ambient light. Figure 27.46 then shows how the subject was illuminated using an external flash as the main light, bouncing it into a pad of paper. Figure 27.47 shows the pop-up flash being used to add a bit more fill light.

Using the three light sources, Figure 27.48 shows the final result, and Figure 27.49 shows a close-up of the scar near the left eye using the same lighting. For anyone having doubts about how this lighting was accomplished, I have also included a close-up of the subject's eye in Figure 27.50. The eye is cropped from the image in Figure 27.48, and you can clearly see the window light, the pop-up flash, and the external flash being handheld.

PART THREE: TESTING YOUR EQUIPMENT

Testing your equipment is important regardless of the type of camera you are using. You need to know your camera's strengths, weaknesses, and limitations. In order to get the most from these tests, conduct all of the following

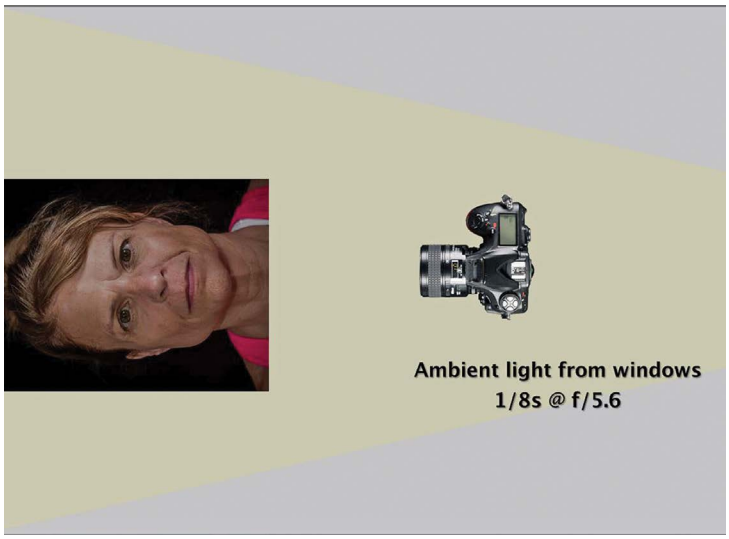


FIGURE 27.45 Photograph with only ambient light.

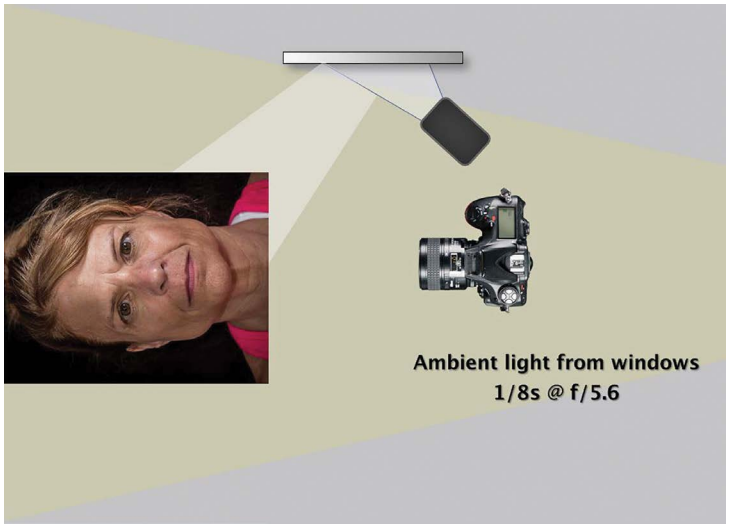


FIGURE 27.46 The same photo using an external flash as the main light, bouncing it into a pad of paper.

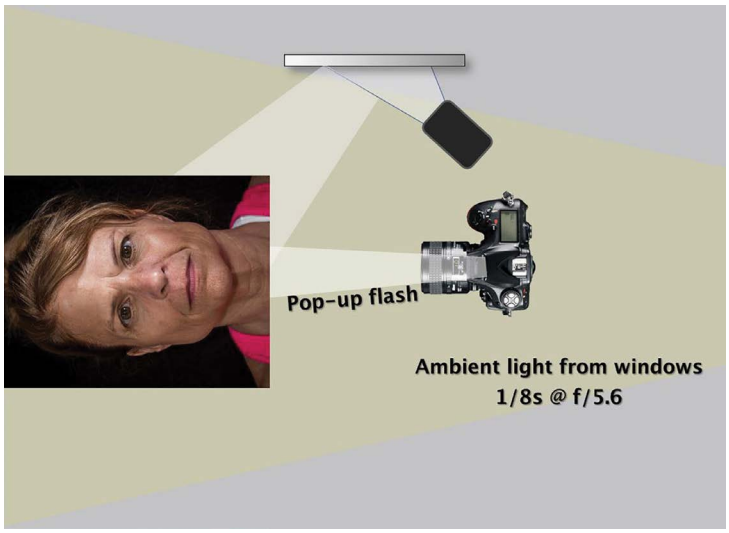
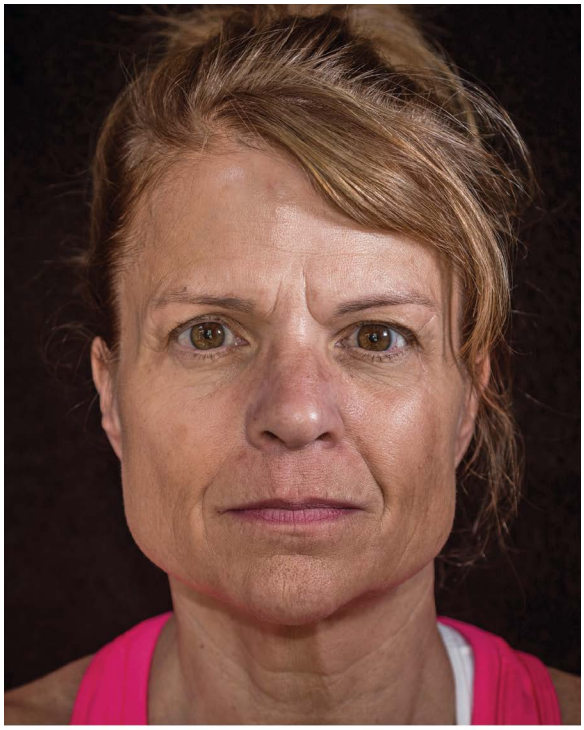


FIGURE 27.47 The same photo with the addition of pop-up flash being used to add a bit more fill light.



Documentation portrait using ambient light and pop-up flash as fill, and a hand-held external flash bounced into a pad of paper. The external flash was triggered by the pop-up flash.

FIGURE 27.48 The photo using three light sources.

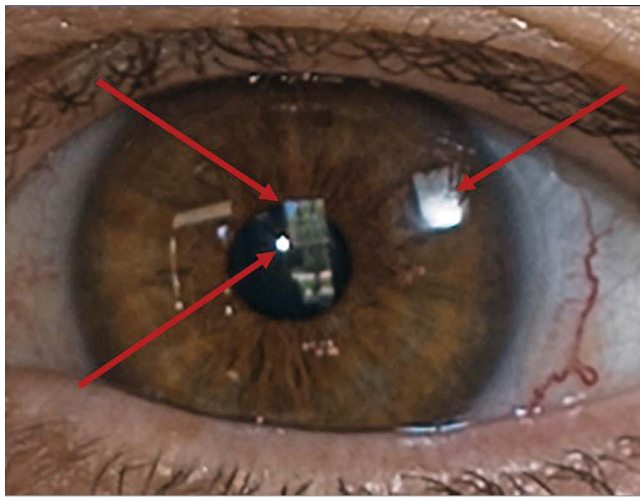


Close-up of scar



Close-up of scar with a scale

FIGURE 27.49 A close-up of the scar near the left eye using the same lighting.



The enlargement of the eye clearly shows the window (top arrow) the pop-up flash (left arrow) and the hand-held external flash (right arrow)

FIGURE 27.50 A close-up of the subject's eye.

while using: (1) a tripod (or stable surface), (2) a shutter release or timer, and (3) the aperture priority mode, unless instructed otherwise.

ISO Noise

With injury photography, good DoF and low noise are a necessity. When using a camera in the automatic mode, the camera will often slow the shutter, increase the ISO, or both. The extent of these adjustments will often cause a shallow DoF, a blurry photo due to slow shutter speed, and noise in the image reducing the sharpness of the photograph.

Some point-and-shoot cameras do not allow changes to any or all of these controls. More advanced cameras, including mirrorless and DSLR cameras, limit the amount of control based on the mode they are in. Typically, even in more advanced cameras the auto or green mode or program mode will not allow changes to ISO. I suggest you conduct these tests in the aperture priority mode.

The following steps will help you determine when the ISO noise becomes unacceptable for your camera:

1. Select a target with both a light and very dark area on it.
2. Obtain a focus on your target; if the camera has difficulty focusing because of lack of contrast, place a dollar bill or another flat object on your target, manually focus, and remove the object. Be sure to leave the autofocus turned-off for the remaining steps.
3. Provide a constant light source, but not too bright a light source, falling evenly on your target. The typical amount of light used to illuminate a room is adequate.
4. Adjust your color balance to match the light source.

5. Place your camera on a tripod and attach a shutter release. If you don't have a shutter release, put the camera in the self-timer release mode.
6. Place your camera in the aperture priority mode, and the ISO on its lowest setting, typically ISO 100.
7. Take your first shot and listen to how long the shutter remains open.
8. Change your ISO to the next higher EV of ISO 200. That will usually be three clicks on your dial.
9. Release the shutter and listen to the shutter time.
10. Set your camera to the next ISO EV, which would be ISO 400, and repeat.
11. Now set your camera to ISO 800 and take another shot. Notice how the shutter is operating faster and faster as you increase the ISO.
12. Next use ISO 1600, then ISO 3200, then ISO 6400 if your camera goes that high.

Using the image preview feature on your camera, go to the image you made at ISO 100. Be sure to zoom-in on your monitor so you can see a portion of the dark side of the target. While you are zoomed-in, advance to the next frame using your command dial. Then the next, and so on. At one point you will begin noticing noise in the image. The higher the ISO, the noisier it looks. When the noise becomes objectionable, mentally note what ISO you were using, and remember that should be your maximum threshold.

Do the same procedure reviewing the light portion of the images. The noise will be more difficult to see, but at some point, it will also become objectionable. Note the ISO level for future reference as noted earlier.

For even better results, review your images on a computer monitor. Closely examine the dark object within the image, looking for random colored dots or specs (aka noise) at each ISO. Using your computer software, now increase the brightness of the dark object, and observe how details of the object are affected. Where that noise becomes unacceptable will vary by the camera you are using.



FIGURE 27.51 Note focal lengths of 18, 24, 35, 45, and 55.

Accurate Viewer Perspective

On some cameras, primarily those with built-in zoom lenses, including point-and-shoot and cellphone cameras, it is difficult to determine a focal length setting. On other cameras, especially those with interchangeable lenses, the focal length is clearly marked on the lens barrel (Figure 27.51). No matter what kind of camera and lens combination you are using, you can conduct a simple test to learn where the distortion is and where it goes away.

Using a beverage can, position your camera so you are shooting directly into the center of the can (Figure 27.52); be sure to fill the frame with the can from top to bottom, as shown in Figure 27.53.

If using a camera with a built-in zoom lens, take the first shot with the lens at the default focal length—which is the way the camera powers-on. Then zoom-in slightly (longer focal length) and move back so that the can continues to fill the frame from top to bottom and take another shot. Repeat this process until you have zoomed-out to the maximum, using a minimum of four lens settings.

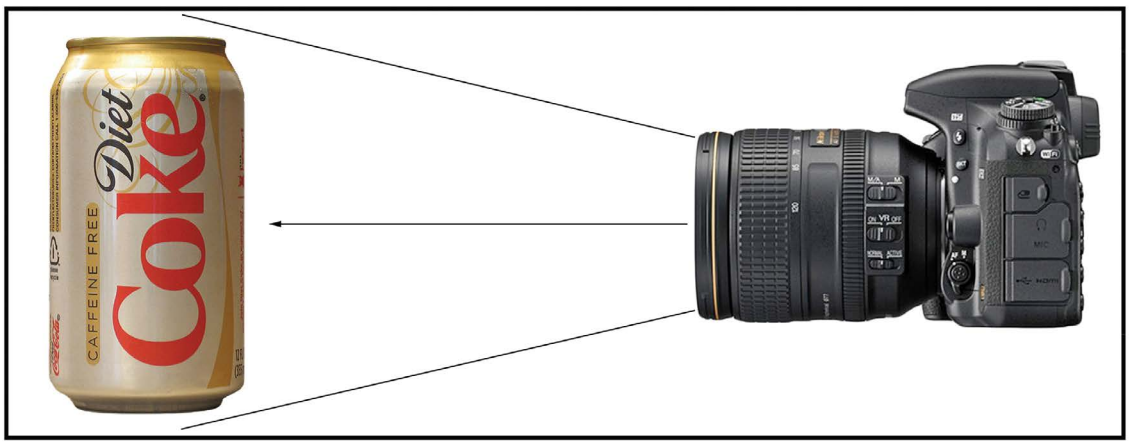


FIGURE 27.52 Shoot directly at the center of the can.



FIGURE 27.53 Filling the frame.

If using a camera with interchangeable lenses, as mentioned previously, the lens will have a focal length setting marked on the barrel. The most common DSLR cameras at the time of this writing come with a "kit lens" that typically will be marked 18 mm, 24 mm, 35 mm, and 55 mm or something similar as shown in Figure 27.51. Start by setting the lens on the lowest number and take the shot. Then rotate the lens barrel to the next higher (longer) focal length number and move the camera back to again fill the frame. Repeat this process until you have zoomed-out to the maximum, using a minimum of four lens settings.

As you review your results, you will see the top of the can go from curved to nearly flat. You will also notice two other things: the sides of the can also go from curved to flat, and less of the background will show due to the narrowing of the lens field of view (Figure 27.54). Whatever camera and lens you are using, you should set your lens at the focal length or longer where the flattening occurs whenever shooting an injury photo—or any photo where you want to minimize the distortion caused by the lens focal length setting.[42]

Minimum Focus Distance

First, find an object with good contrast for focusing purposes, and after obtaining a focus, look for the small circular focusing aid in the viewfinder that has a solid light. If you move the camera, the light will flash. Sometimes there will be up and down arrows that will blink. Some cameras will also emit a beep when you achieve focus. If unsure of what aid you have, refer to your camera manual to learn what you need to look for to confirm correct focus.



FIGURE 27.54 Note the top of the can going from curved to nearly flat. The sides of the can also go from curved to flat. Lastly less of the background will show due to the narrowing of the lens field of view.

If using a zoom lens with a focal-length indicator, change the focal length to the widest setting. So, if using an 18–55 mm kit lens, set it at 18 mm. Using the same target object with high contrast, move within about 6 inches and try to get a focus. Watch for the solid light in the viewfinder. If you cannot get a solid light, move back an inch and try again. Repeat that process until you are able to get a focus as indicated by the solid light. Make note of the distance, by not only taking a measurement, but also by using your extended fingers and arm; note at what point on your arm is the minimum focus distance. This will enable you to quickly determine where you need to be when working on a case.

Without moving the camera from that position, zoom-in (using a longer focal length) to the target. On good-quality lenses, I've found it should be able to focus at that focal length, as well.

If using a camera with a zoom lens that has no focal length indicators, like a point-and-shoot or cellphone camera, you may find the zoom will occur in increments. Point-and-shoot cameras, for example, typically have a zoom lever. Each short press of the lever will move the focal length the same amount each time. Starting at the widest focal length, which is how that camera turns-on, move back as described in the earlier process. Then zoom-in by increment to determine if you can focus with the longer focal lengths at that same distance.

For those using a fixed focal length lens, the process is the same. Start at 6 inches and keep moving back until you can achieve a focus.

For those that are using what I consider an extreme zoom lens, like the common 35–105 mm lens, you will find the minimum focus distance will be around 2½–3 feet, and not the best choice for injury photography. And, that's why I test everything.

Color Balance aka White Balance

The color balance set-up will be similar to the ISO test set-up. Using an object that has multiple colors, and a light

source of your choosing, set the camera on a tripod, place it into the aperture priority mode at ISO 100, and place your white balance on auto. Take your first shot.

Now change only the white balance setting to whatever is next on your camera. Take another shot and repeat until you've used all the white balance settings. Now review your images and note the color cast in many of the images. Change your light source and do the same test using every white balance setting. Then use a combination of light sources with different color temperatures and go through the process again.

The benefits to this test are several. Not only does it show you the extreme differences in color shifts, but it will also help you identify what setting to use in your camera with various light sources. It will also help you identify how things change when you use multiple light sources with different color temperatures in the same photograph.

If you post process your images, I encourage you to take this one step further. Include a gray card in some or all of these photographs, and then attempt to color correct in post. Do this in both the raw and JPEG formats. Try to do the post processing soon after you take the photographs so you can remember how it looked, and then compare your results with what you remember to be accurate. Taking all these steps will help you learn what settings and tools you need to use in order to achieve the highest level of accuracy. At the same time, you may find it will simplify, not complicate, your workflow in your quest to achieve color accuracy.

Depth of Field

There are many ways to test DoF, but for the purposes of this text I will describe a fairly simple method that you can use as a starting point to understand the concept. Fine-tuning DoF can then be done using a variety of readily available tools.[43] For a recent class, I constructed a method to test using a piece of paper and a lightweight forensic scale. There are also a number of useful tools that can be ordered online, similar to the one in Figure 27.55.

For this test you will need your camera, a tripod, and a shutter release. If using a zoom lens, with a focal length scale, set the focal length on not less than 50 mm.[44] If using a camera without a scale, zoom all the way out, and zoom back one position. Set your ISO at 100 and place your camera in the aperture priority mode.

This test involves the use of four soda cans or something similar. Place those four cans spaced at approximately 6 inches apart on center and in a straight line (Figure 27.56). Position your camera at an angle to the cans that allows you to see the front can in either the front or left side of your viewfinder, and the back can in the other side of your viewfinder. Fill the frame as much as possible with the cans by moving your camera. Your focus point should be in the center of your viewfinder and should fall on the second can. See Figure 27.57 for proper camera placement, and Figure 27.58 for what it should look like through your viewfinder.



FIGURE 27.55 Depth of field tester.

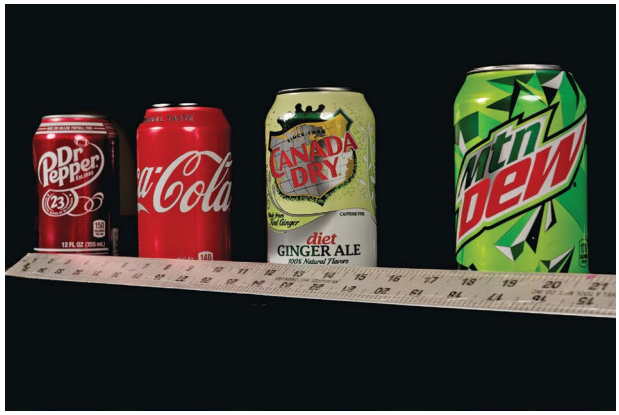


FIGURE 27.56 Four cans spaced at approximately 6 inches apart on center and in a straight line.

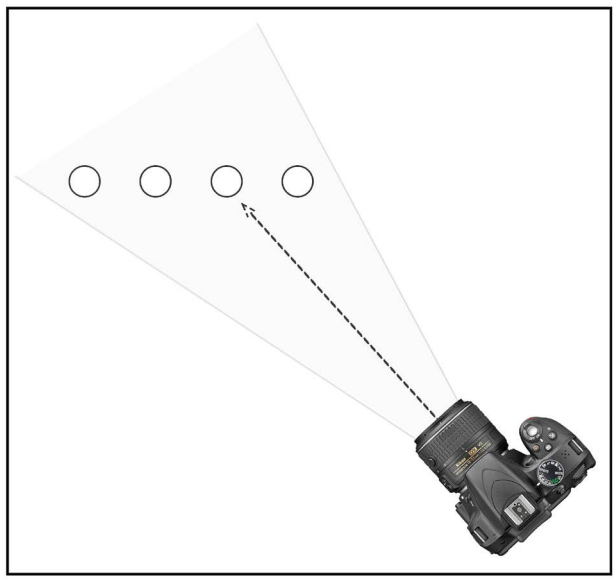


FIGURE 27.57 Focusing on the second can.



FIGURE 27.58 What it will look like through the viewfinder.

Once you have the proper camera position, open your aperture as wide as possible; the widest aperture will depend on the lens you are using. A standard 18–55 mm kit lens will typically have the widest aperture of *f*/3.5 to *f*/4.0 or even *f*/5.6, depending on how much zoom you are using. Ensure your focus point is on the second can and take your first shot. The spot you are focusing on is called the "point of critical focus" (PCF). Now, verify your focus by reviewing the image in the camera monitor by zooming-in to ensure you have a sharp image. Without moving your camera, change your f-stop to the next full EV. Take a photograph at each of the following f-stops:

Widest	*f*/5.6	*f*/8	*f*/11	*f*/16	*f*/22

When you have all your shots, go back to the first image and review on your camera monitor by zooming-in on the second can. Now scroll your review screen so you can see the front can, which will be blurry and out of focus. Many cameras allow you to move from frame to frame during the review process without changing your zoom-in position. Please consult your camera manual so you know how to do so, as that is an important aspect of the next steps.

Without changing your zoom, advance to the next frame leaving the close-up on the first can. You will see a slight shift of focus. Without changing anything, advance from frame to frame, and you will see the front can start to come into focus. By the time you review the image taken at *f*/22, the front can will be as in-focus as the second can was in the beginning. Now scroll past the first can, then the third can, and then to the can in the back; they should all be in focus (Figure 27.59)!

What you have just observed is what is known as the one third–two-thirds rule. As you increased your DoF by using a smaller f-stop, areas will start coming into focus almost equally from one third in front of your PCF to two-thirds behind the PCF. However, it is important to note that



FIGURE 27.59 Illustrating the use of f-stop to keep all cans in focus.

when you start getting closer than 3 feet, the one third–two-thirds shifts substantially. Depending on the lens you are using, and the actual distance to your target, the focus will become equal on both sides of the PCF. In fact, at one point the focus will not extend past the PCF no matter how small your aperture.

Try this same test using different focal lengths on your camera lens. Always fill the frame as much as possible with the four cans, so at your widest setting you will be very close, and at the longest setting you will be much farther away. Note the difference in the change of DoF depending on how close you are.

This is another area that you really need to test, particularly at distances closer than 3 feet. When focusing at close distances, fine-tuning that focus becomes more important as you get closer and closer. Using the tools previously referenced, I encourage you to test your lenses and develop a system that you can use to determine lens placement and aperture setting based on the needed DoF.

Remember that your DoF is based on three factors: (1) f-stop, (2) focal length, and (3) lens-to-subject distance.

The only way you will learn to master DoF is to test and practice not just one, but all of these factors combined. And, there is nothing more important in injury photography than sharp photos, much of which comes from your DoF.

NOTES

1. ISO is an abbreviation for the International Organization for Standardization; it is *not* an acronym. It is pronounced "eye sew," not I. S. O.
2. The mode dial on most popular cameras will have a green rectangle or icon that represents automatic mode.
3. Internal or pop-up flashes will cause very flat lighting and are only good for a range of 2–12 feet, depending on the camera make and model.
4. TTL (flash mode) is an acronym for through the lens metering.
5. Gray cards, or grey cards, are available in many forms and sizes. These are available at most camera stores and online suppliers. I prefer an 8" × 10" size that has been certified to be "accurate to within 1%."
6. Camera monitors can be adjusted for brightness to enable viewing an image in bright conditions; however, what you view will not necessarily be accurate to the actual exposure.
7. These are often referred to as "examination quality" images.
8. Some may argue that an accompanying report will suffice by describing the location of the injury. However, there is great value to providing photographs that visually can stand on their own.
9. A forensic scale is one that can be obtained through various evidence equipment suppliers; use of a common ruler, measuring tape, or other device may give inaccurate results. The inaccuracy of rulers and non-forensic scales is common.
10. There are several other terms that are sometimes used with the same meaning: "natural perspective," or "true perspective," or "normal view," or "normal reproduction."
11. This is something I encourage you to experiment with in order to see the effect: slow shutter speed and flash with a moving subject.
12. Menu settings in most cameras allow changing from one-third stop increments to one-half stop increments, based on personal preference.
13. If you were doing sports or wildlife photography, which involve fast moving subjects, shutter speed would be at the top and DoF would be secondary.
14. Depth of field is controlled by three things: (1) aperture, (2) lens-to-subject distance, and (3) lens focal length.
15. Too much light can be a problem when (1) only a small area of the photo has a light or is lit much brighter than the overall scene, resulting in blown-out highlights, and (2) the exposure is not adjusted for the intensity of the light, resulting in an overexposed image.
16. The most important component in a camera is the sensor. This is part of the camera that collects the information that is ultimately converted to a photograph—information collected by light. Sensors range in size from 2 mm diagonal (Sony) to very large "medium format" sensors measuring up to 67.2 mm (Phase One).
17. Post processing is the process of examining the images captured from the camera, and then making adjustments in color and density to produce an accurate photograph. Post processing is required when shooting raw images. JPEG images are first processed in the camera, but adjustments can also be made after being uploaded.
18. If there is a potential to do post processing, the use of a color chart or an 18% gray card is always the preferred method to obtain accurate color.
19. Noise is most evident in darker portions of the image; in well-lit images, the noise dots or marks may not be as evident but can result in a soft image.
20. The term for distortion caused from a wide-angle lens is "barrel" distortion. This effect is actually caused by being too close to an object. A perfect rectangle will appear more like a barrel, ergo the term.
21. LED bulbs are available in various color temperatures, which is usually indicated when purchasing.
22. Gaffer's tape is especially designed for use in photography. It not only has a strong adhesive quality but, more importantly, it doesn't leave a sticky residue like duct tape.
23. Light is measured in a "Kelvin" (K) temperature scale; daylight is in the range of 5000–6500 K. Incandescent lighting is mostly used in homes, and is considered to be warm and inviting, and is around 2700–3000 K. LED lights are typically available in a range between 3000 K and 5000 K.
24. Overall photographs are rarely used in a civil matter; the injury claim is usually specific to a certain part of the body.
25. Always use a gray card if you have one available; hold the gray card at the same location the light is falling on your subject and take your meter reading off the card. Be sure to fill the frame with the gray card.
26. ISO 100 is always preferred. However, if there is simply not enough light, and you find your shutter speed is slower than half a second, then change the ISO to 200. If there still is not enough light, you can go as high as ISO 400—but this is not recommended.
27. These are suggested starting points. As you become familiar with your equipment and learn how to control DoF, you may find other settings will work just as well.
28. A "normal" lens focal length will vary based on the size of the sensor.
29. Camera raw is a file that contains only raw data, exactly as captured. When reviewing the image seen in the camera LCD monitor, you are seeing an interpretation of how that image "should" look, much like the corrections made in-camera to produce a JPEG file.
30. Accepted processing standards were established by the Scientific Working Group on Imaging Technologies (SWGIT) in Section 5 of their published guidelines.
31. Dodging or burning is the same as making an adjustment to brightness, except that adjustment is done to a specific area within the image instead of the entire image.
32. The history log is not on by default; it must be selected in the preferences menu.
33. Metadata is data found within each electronic image and contains data about that image.
34. I have used Miller's Professional Imaging located in Columbia, Missouri, for nearly 30 years.
35. ICC is an acronym for International Color Consortium.
36. When attempts are made to correct badly exposed images in post processing, they will exhibit a color shift away from the white balance settings.
37. A full-frame camera has a sensor size equivalent to a 35-mm negative. APSC cameras have sensors that are roughly two-thirds the size of a 35-mm negative.

38. Metering off a gray card is the most accurate way to get a meter reading.
39. American polarizers at https://www.apioptics.com/ offer an excellent selection.
40. https://www.physicsclassroom.com/class/light/Lesson-1/Polarization
41. I purchased a Heliopan Linear Polarizer Filter.
42. Distortion is actually caused by the closeness of the camera to the subject matter. For the purposes of this text, we will refer to it as lens setting.
43. Some tools designed for testing focus accuracy can also be used for determining depth of field, like the DSLRKIT Lens Focus Calibration Tool Alignment Ruler Folding Card, the Datacolor SpyderLensCal SLC100, or the LensAlign MkII Focus Calibration System.
44. The use of a 50-mm lens for this test is applicable to either an APSC or full frame sensor.

28 Documenting Findings in Interpersonal Violence

William M. Green

CONTENT

Appendix I: Medical Consent Form 568

Interpersonal violence is an unfortunate reality in every society and culture. This violence affects not only the individuals involved but also frequently affects the healthcare, criminal justice, and social services systems. Violent and nonconsensual contact often creates visible findings. Many of these findings are injuries. Any type of injury is possible, but the majority of visible injuries will be superficial blunt-force trauma mechanisms that create redness, bruises, abrasions, and lacerations (cuts or tears).

Penetrating trauma mechanisms occur less frequently and include gunshots and sharp-force injuries (stab wounds and incised wounds caused by pointed or sharp-edged objects). Burns (thermal, chemical, or electrical) intentionally inflicted may also be encountered. In addition to injuries, interpersonal violent encounters may leave other visible evidence. Trace evidence (e.g., fibers, hairs, vegetation, debris, paint residue, makeup, etc.) may be very important to establish contact between or among the crime scene, victim, and assailant (associative evidence). Biological evidence left by the assailant may be visible as wet or dry stains from blood or semen. Any of these findings may inform medical decision-making regarding evaluation or treatment and may influence social service activity related to investigative issues and custody determinations. The greatest impact of all the visible findings following interpersonal violence falls on the criminal justice system. Inflicted violence with resultant physical findings always raise the possibility of a crime. That crime must be investigated and potentially prosecuted. Meticulous documentation of all visible findings is critical to the criminal justice process. High-quality forensic imaging is the path to that objective.

Serious traumatic injuries will be documented in the resuscitation suite, the radiology department, or the operating room. Fatal injuries will be documented at the autopsy. The focus of this chapter is on the vast majority of interpersonal violence situations that do not produce medically serious injury but whose visible findings must be carefully documented to facilitate the proper criminal justice outcome. These common situations include general assault, sexual assault, domestic violence, child physical and sexual abuse, and abuse of the elderly and the disabled. Unfortunately, this is a huge number of victims all needing high-quality documentation of their visible injuries and evidence findings.

Ideally, every victim injury and evidence finding should be documented by a trained, experienced forensic photographer using professional equipment and techniques. The reality on the ground is quite different. The responsibility for the forensic imaging of most victims of interpersonal violence falls to two disciplines. The first is law enforcement, both first responders ("patrol") and investigators ("detectives"). Their equipment will range from cellphones to point-and shoot cameras, and a few will have more sophisticated digital single-lens reflex (DSLR)-macro systems. Their training will likely be proportional to their equipment, with the majority having at least rudimentary forensic photographic instruction. The second discipline is forensic medical examiners (mainly forensic nurses primarily trained to evaluate sexual assault patients). The scope of practice for sexual assault nurse examiners (SANEs) continues to grow and includes forensic documentation (written and photographic) on other categories of interpersonal violence victims. Most forensic medical examiners will have had some basic forensic photographic training and will have a point-and-shoot camera or an entry-level DSLR system.

The apparent challenge is concerning. A very large number of victims, whose welfare and hope for justice may pivot on the quality of the images documenting their injuries and evidence findings, must rely on a forensic photographic workforce with variable training, potentially limited experience, and a spectrum of equipment. The mitigation of this problem is provided by the basic photographic objective for this type of forensic imaging. All required of the image of a visible physical finding is it must fairly and accurately represent what the photographer's eyes and brain saw at the time the image was exposed. It must be of sufficient quality for the photographer and expert witnesses to review and properly interpret the findings depicted on the image. This objective should be achievable with basic forensic photographic training and a basic, but good-quality, imaging system.

Besides this primary objective of fair and accurate documentation of the visible finding for the criminal justice process, forensic images have many other practical uses. (See Table 28.1)

TABLE 28.1
Utility of Forensic Images

- Accurate documentation of visible physical findings for the criminal justice system (investigation and prosecution)
- Immediate review and comparison of the image to the actual finding on the victim to ensure accuracy
- Consultation and second opinion regarding interpretation and significance
- Measurements for size perspective and pattern finding analysis
- Comparison of the finding to published literature
- Standard for subsequent or follow-up evaluation
- Review for testimony preparation
- Presentation during testimony
- Training
- Research and publication

A good digital image "stops the clock" and provides a precise "image in time" for detailed evaluation later. This is especially helpful, since many of the items being documented are perishable (injuries, stains, trace evidence, etc.). Digital imaging allows the photographer to immediately assess the image for technical accuracy and composition. If the image is not ideal, the victim is still present and can be rephotographed and the next image reassessed, corrections made, and so on until the optimum image is created. It is quite helpful for investigators and experts to review the images and discuss the interpretation and significance of the documented findings in the context of the other case materials. Proper use of scales allows accurate measurements of the findings for size context and comparison with the injuring object for analysis of "patterning." A pattern finding is one in which the appearance of the finding gives information about how it was caused.

If the finding in question is to be analyzed in comparison to published scientific literature, a fair and accurate image is essential. If the interpretation of the finding is uncertain or the injury is evolving, the original image is invaluable for comparison to the appearance at the follow-up evaluation (where physical examination and imaging should be repeated). Reviewing all the images along with the other case materials is essential preparation for testimony. For juries, "a picture is worth a thousand words," and the photographer or expert using the images has the responsibility to clearly analyze and explain the documented finding. Training others, both about photographic technique and the interpretation of findings, would be almost impossible without a robust image bank. Scientific inquiry and publication are well served by illustrating concepts and details with high-quality images.

The term "forensic" implies the application of scientific principles to the legal process. The context of interpersonal violence adds "forensic medicine," focusing on the interface between medicine and the law. Before the first image is captured, the forensic photographer responsible for documenting visible findings after interpersonal violence must thoroughly understand and strictly adhere to a set of legal and procedural principles (see Table 28.2).

TABLE 28.2
Basic Legal Issues Related to the Forensic Photographic Documentation of Interpersonal Violence Findings

- Consent to be photographed (see Appendix I)
- Identification of the subject
- Chain of custody of the images
- Admissibility of the images
- Relevance and authentication
- Enhancing digital images for accuracy
- Standard operating procedure (SOP) and consistent workflow

Statutes will vary by state or federal jurisdiction, and standard practice will vary by locale, but it is always prudent to obtain specific, written consent from the individual who is being photographed. Personal privacy law is constantly evolving, variable by jurisdiction, and always complex. Because the images under discussion in this chapter involve body photographs of injuries, laws pertaining to personal health information (PHI) and Health Insurance Portability and Accountability Act (HIPAA) may come into play. The consent process goes far beyond simply making the image. How the images will be used, who has access to the images, how and where the images will be stored, the circumstances of image duplication, and transfer and security measures to protect the images at every step are all elements potentially related to the "consent to be photographed" issue. Because of so many local variables, every forensic photographer who intends to make the kind of images discussed in this chapter must work in the context of a specific written policy developed and vetted by local legal authorities.

In some situations, this type of photographic protocol is already established and in place. For example, in California, the California Office of Emergency Services 2-923 Protocol for the Forensic Medical Report for the Acute Adult/Adolescent Sexual Assault Examination includes a specific, written patient consent for forensic photographs that document physical findings. The details of this protocol also limit and specify access to these images.

It is critical that every forensic image be reliably linked to the individual being photographed and to the specific time and circumstance for which the images are generated. The emergence of digital imaging significantly facilitated this objective with the introduction of EXIF digital data embedded in every image. This information includes the date and time of capture (assuming the camera is correctly set!), the camera used, and many camera settings. Other common techniques include having the first and last image of every project/case be specific subject identification information. In a hospital exam setting, it is standard practice to use a hospital "patient sticker," which includes the date of exam, patient name and date of birth, and patient medical record number. These stickers are routinely generated for every patient and used to label laboratory specimens and patient documents.

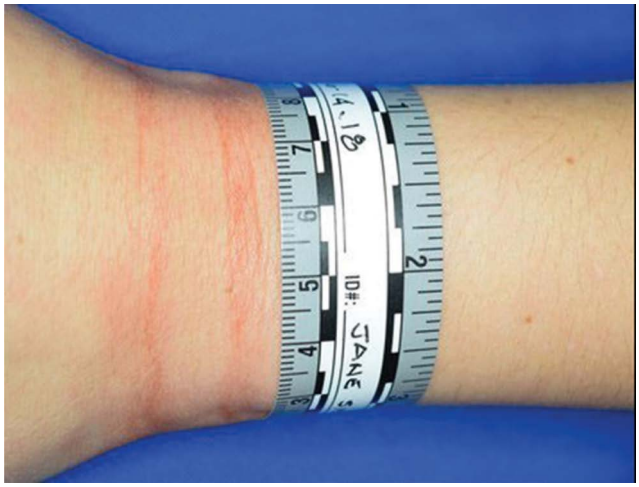


FIGURE 28.1 A hospital "patient sticker," including date of exam, patient name and date of birth, and patient medical record number.

Another common technique to link the images to the individual is to put the subject's name and date (and perhaps the law enforcement case number) on the scale when it is used for the forensic images.

If prints are generated from the digital images for investigative or courtroom purposes, subject identification information should be on each print. Some prosecutors and law enforcement personnel advocate for a frontal facial view of the subject also be used at the beginning and end of each session (only for identification purposes, not to document injuries). This practice is controversial and should be thoroughly discussed locally.

Forensic images are likely to be legal evidence. Chain of custody is a foundational legal principle controlling the documentation of the location and transfer of evidence. This documentation provides a written record of the sequential accountability of everyone who handled the evidence from the time of collection or image capture. Every time evidence is transferred, the record indicates the date of the transfer (often the time as well), who is releasing the evidence, and who is receiving it. The record also documents the location of the evidence at all times. This sequential accountability record is always attached to the piece of evidence itself or to the container holding the evidence. This procedure is designed to ensure there has been no tampering, alteration, or loss of evidence prior to trial. Any break in the chain or irregularity of the documentation will come under intense legal scrutiny and could result in the exclusion of that piece of evidence or those images.



FIGURE 28.2 Put the subject's name and date (and perhaps the law enforcement case number) on the scale.

Admissibility is the judicial process by which the judge determines whether a given piece of evidence can be used in a legal proceeding. The general approach to admissibility of any evidence is applicable to forensic images offered as evidence. First, the judge must determine the relevance of the images. This basically tests whether this evidence is necessary or helpful to prove something in the particular case at hand. Part of this test requires the judge to determine if this evidence's probative value (potential usefulness) outweighs any prejudicial effect (typically, an emotional response to the images that could create bias against one party despite the accuracy of the images).

The second judicial test for admissibility of forensic images is authentication. The standard here is the image must fairly and accurately present what it purports to be. More precisely, the image must be an accurate representation of what the photographer's eyes and brain saw at the time the image was captured. The authentication determination will rest on the testimony of the photographer who attests to the fact that the image portrays exactly what was seen at capture.

When digital photographic technology first emerged, there was considerable legal challenge to the admissibility of digital images for fear of alteration, which could change the image and consequently affect the interpretation and create prejudice or bias. Since then, considerable case law and numerous evidence code statutes have developed, ensuring the admissibility of digital images as evidence so long as some basic rules are followed. Never delete an image (even bad ones). Digital images are numbered, and a break in sequence may suggest the photographer is biased and intentionally hiding probative evidence. Keep every original image from a case in a dedicated file and back it up securely. Never do anything to original images until they are filed and backed up. Even rotating an image may be considered "alteration." The photographer must be able to testify that the file of original images is free from any deletion or alteration. Courts now routinely recognize prints or copies made from the original images as equivalent to the original. The actual "original" must always be available for review.

Alteration or manipulation of an original digital image is never permitted, since this process may add or remove digital information and create an image that is not a fair and accurate representation of the original scene. Enhancing a digital image (a copy of the original) is permissible so long as the objective is to improve the

TABLE 28.3
Elements of the Standard Operating Procedure (SOP)

- Consent to photograph policy
- Ensure proper identity of all images
- Chain-of-custody documentation policy
- Image enhancement policy
- Define and specify consistent workflow
- Specific written policies and procedures for
  - Image storage and cataloging
  - Searching and image retrieval
  - Image duplication and end-user products (e.g., prints)
  - Image access and transfer
  - System and component backup
  - Security precautions
- Clearly identified custodian of images

appearance of the image, so it more accurately portrays the original scene. Enhancement is done in postproduction and typically includes adjusting brightness (exposure), contrast, and color balance. These changes may be global or local (e.g., dodging or burning). Rotation or cropping is also acceptable to improve the appearance while maintaining accuracy. It is important to document all steps taken for the enhancement (most modern software does this automatically), and, as always, the original must be readily available for comparison. The photographer must be prepared to testify about what was done to the image and say the resultant "new" image is a better (compared to the original), more accurate representation of what was seen at capture.

The document specifying and codifying the essential rules and policies regarding the handling of forensic images is the SOP. In addition to the elements already discussed, the SOP defines the workflow path(s) of the images from capture to end-user application. The exact details will be different from one jurisdiction to another (see Table 28.3) but the prevailing local system should be well known and followed precisely.

The SOP document should contain specific written instructions regarding how images are handled at each step in the process, and, again, strict knowledge and compliance are essential to ensure the security and legal integrity of the images. There should also be an individual designated as "custodian of images" who is accountable for the functioning and oversight of the imaging system.

Setting up a forensic camera outfit for documenting the findings after interpersonal violence is straightforward and does not have to cost a fortune. Cameras in the zone from mid-range point-and-shoot to entry-level DSLR with a basic kit lens or inexpensive macro lens will be more than adequate. Given the criminal justice end-use applications, 6 megapixels and above is all you need. Macro (close-up) capability is necessary, and vibration reduction/image stabilization is strongly recommended. An optical viewfinder is helpful if working environments will include glare. Spot metering and spot focus are very helpful for

TABLE 28.4
Creating Forensic Images: Fundamental Issues

- Equipment
  - Essential
  - Optional
- Understand the fundamental and technical objectives for imaging interpersonal violence findings
  - Image review, assessment, and correction
- Preparation and the pre-shoot checklist
- Fidelity to the scene
- Basic compositional principles
- The forensic series of images
- Using scales
  - Measuring
  - Color
- Imaging challenges
  - Curved surfaces
  - Body cavities
- Indications for follow-up forensic imaging

imaging small details and body cavities (mouth, vagina, rectal cavity).

Basic support equipment includes:

- Plenty of back-up batteries
- Blank media cards
- Measurement and color scales
- Stickers or labels for subject identification purposes
- Camera cleaning supplies
- Camera manual

IMPORTANT:

A media card reader and the basic computer setup to support digital photography are mandatory but are not necessarily brought into the field.

Additional items useful in some situations are:

- A tripod (or monopod) with an external shutter release mechanism
- A small light-emitting diode (LED) flashlight is handy to provide tangential or side lighting to better illustrate the three-dimensional nature of an evidentiary image

In the context of interpersonal violence, the forensic images should complement the written record and visually help "tell the story" about what happened (see Table 28.4). As discussed earlier, every image must be a fair and accurate representation of the scene; it must be realistic. Ideally, the series of case images should stand alone without captions or narration. One huge advantage of digital over film-based imaging is cost per image. There really is no cost penalty with digital images, and the more images (and the more variations in view and perspective), the better.

Realism of the image starts with the technical objective of sharpness. Every image should be "tack sharp" or perfectly focused. This is important for overall image analysis and must also allow for magnification or "zooming in" to assess fine detail. A blurred image cannot be adequately corrected after capture. As briefly discussed earlier, the best practice is to immediately examine each image after capture, magnify it on the liquid crystal display (LCD) screen, and navigate to all pertinent areas of the image to assess critical sharpness. If any important area falls short, recapture and reassess, and repeat as indicated for optimum clarity. If achieving sharpness is difficult, other accommodations may help. First, make sure image stabilization/vibration reduction is on. Reduce camera motion by holding or stabilizing the camera properly.

A tripod or monopod may be necessary if shutter speeds are of necessity slow. Increasing the light (ambient or off-camera) or using a wider aperture will allow a faster shutter speed. Using spot focus and spot metering for fine detail may improve sharpness. Manual focusing is always an option too. Obviously, the immediate review process can also allow for correction of any other photographic issues.

Another technical component of realism is exposure (image brightness). This is easily assessed on image review and may be adjusted by altering the light source and adjusting shutter speed, aperture, ISO sensitivity, or (if a consistent error) exposure compensation. Exposure can also be corrected in postproduction as an enhancement.

The third main technical contribution to realism is color. This is controlled by adjusting the white balance. A common strategy is to start with the default "auto–white balance" and assess the image. If not perfect, adjust the white balance to the specific light source being used (daylight for flash, tungsten, fluorescent, etc.). Be prepared to experiment with other light source choices on the white balance menu to achieve the most realistic color. Color can also be adjusted later as an enhancement.

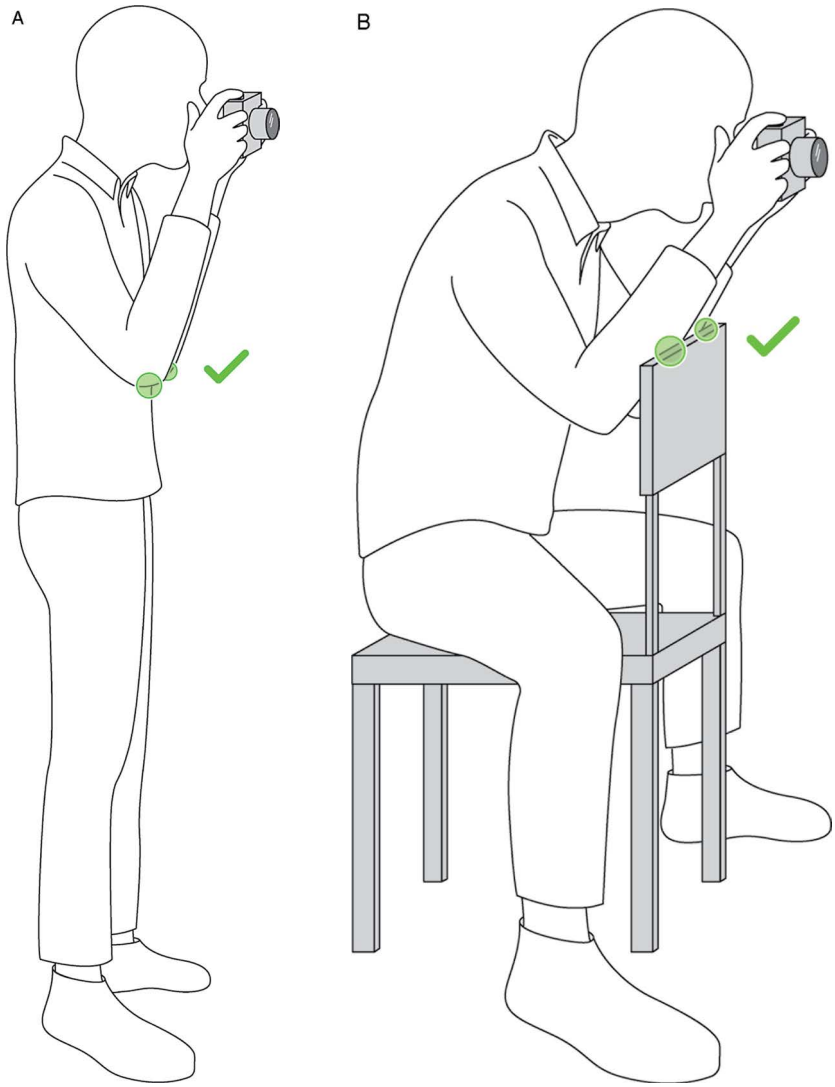


FIGURE 28.3 (A) The images are "Elbow Stabilization." While standing and holding the camera, "lock" the elbows against the body or a solid surface. (B) The photographer may also rest the thumbs against the face and/or the forearms against a solid object, like a chair. These maneuvers should help reduce camera motion.

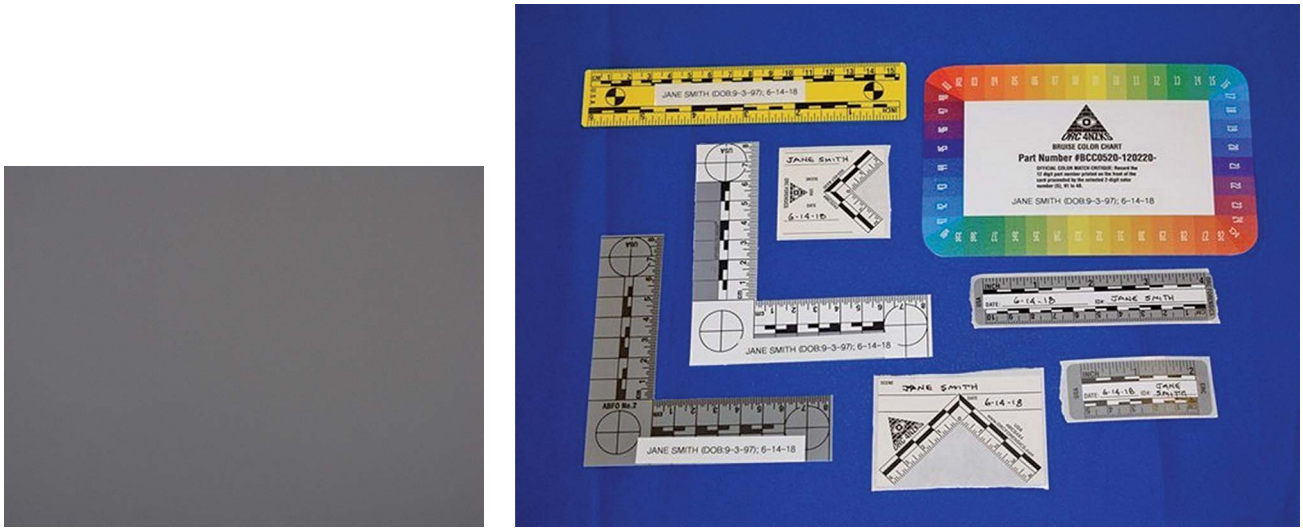


FIGURE 28.4 A color reference card (18% gray or other color swatch) can be used to match the reference color on the card to the actual finding. There are many types of color card, as well as scales with color patches included. Including images of one or more of these in the photo sequence allows for more accurate color reproduction.

Before starting a new project, a little preparation can pay significant dividends. Read your camera manual and understand the basic settings and adjustments. Plan ahead and have all necessary equipment and supplies. Clean the lens, LCD, and viewfinder. Protect your camera and equipment, and don't subject your camera to environmental extremes (especially the trunk of your car in summer!). Develop and always run through a "preshoot checklist." The specific items and settings will vary by camera make and model and by the preferences and experience of the photographer. An example is provided in Table 28.5.

A fundamental forensic principle is "Don't disturb the crime scene until photographically documented." In the context of interpersonal violence, the "crime scene" is the victim's body and clothing. The basic principle applies. The "when first encountered" appearance of the victim should be imaged before anything is removed, cleaned, or disturbed. After anything is changed, the area should be imaged again. This technique will accurately document the appearance of the victim crime scene from first presentation through processing to final appearance.

Composition in artistic photography is complex and very subjective. Compositional principles for interpersonal violence finding documentation are simple, straightforward, objective, and planned.

To ensure appropriate focus by the viewer, the photographer should take steps to eliminate distracting background clutter. It may be necessary to move or reposition the victim; for smaller subjects of interest, draping adjacent parts



FIGURE 28.5 The subject of interest goes in the exact center of the image.

TABLE 28.5
Example of a Pre-Project Checklist

- Check media card for prior case images (if images are present, save that card and start with a blank card)
- Format blank media card
- Check battery status (and have extra batteries)
- Check current date and time (reset if necessary)
- Confirm (and reset if needed) anticipated baseline settings
  - Shooting mode: programmed (P); macro for close-ups or aperture priority or variable ISO for more experienced photographers
  - File format: JPEG or raw for images with more capabilities
  - Image size: large
  - Compression: superfine
  - Autofocus frame: center weighted (spot for macro)
  - Focus mode: autofocus or manual in specific circumstances
  - Shutter release: single
  - ISO: auto
  - White balance: auto
  - Flash mode: auto or off
- Clean all optical surfaces
- Use an ultraviolet (UV) filter for lens protection

of the victim's body may eliminate distractions. Only if appropriate for the subject, choosing a wide-open aperture will narrow the depth of field and keep sharp focus on the finding while blurring the unimportant background by creating "bokeh." Before releasing the shutter, the last activity should be scanning the entire potential image (viewfinder screen) to assess the planned composition and identify clutter and distracting elements.

The primary analytical focus on any visible finding after interpersonal violence will be its proper identification (What is it?), its general significance (What does it mean?), and its specific interpretation in the case at hand. For proper overall interpretation, the finding must be evaluated in consideration of its size, its orientation, and the specific anatomic location on the body. To accomplish all the necessary contextual documentation, every visible-finding image should be part of a forensic series. The series starts with an overview image documenting the location of the finding in a body region.



FIGURE 28.6 A forensic series. This series shows the potential injuring object superimposed to suggest patterning. If color standardization is indicated, a close-up with a color scale should be included.

At least two obvious anatomic landmarks should be seen. This image will provide little detail regarding the specific finding. If there are multiple distinct findings in the region, one overview will suffice as the overview for multiple forensic series. Next is the mid-range image, which is taken closer to the finding and shows more detail and orientation. The mid-range image should show at least one anatomic landmark for regional confirmation. The final images in the series are close-ups, which provide the best detail. Multiple images may be required to provide optimum detail. At least one of the close-up images should include a properly positioned measuring scale to facilitate accurate determination of dimensions.

Since close-ups do not usually include anatomic landmarks, the associated overview and mid-range images are essential to confirm location. Every distinct finding should be included in a forensic series. The examiner/photographer will determine when a finding is distinct (requiring its own close-ups) or when the findings are a cluster of similar items possibly documented as a group. In either situation, overview and mid-range images must provide anatomic context.

This material assumes the photographer and the examiner are the same person. If they are separate people, the examiner is the one to decide what is necessary to image and what is not.

Photographing scales placed adjacent to findings provides accurate, reproducible data regarding the finding. The most common scale is a measuring rule that provides accurate size documentation. Most popular is the L-shaped ABFO No. 2 developed by the American Board of Forensic Odontology (see Figure 28.7). This scale is available in inches or centimeters, includes 18% gray areas, and has circles for identifying distortion from the plane of the camera sensor. For measurements to be accurate, the scale must be parallel to the plane of the camera sensor, parallel to the plane of the finding being photographed, and in the exact plane of the finding (see Figure 28.8).

The second drawing ("plane-incorrect") shows the three scenarios of incorrect placements leading to distortion (see Figure 28.9).

1. First, the scale and subject are in the same plane, but the camera sensor is tilted out of parallel with the other two.
2. The next frame shows the camera sensor and scale parallel, but the subject is not parallel.
3. The third frame shows all three planes parallel, but the scale and image are not in the same plane.



FIGURE 28.7 A series showing the potential injuring object super-imposed to suggest patterning.

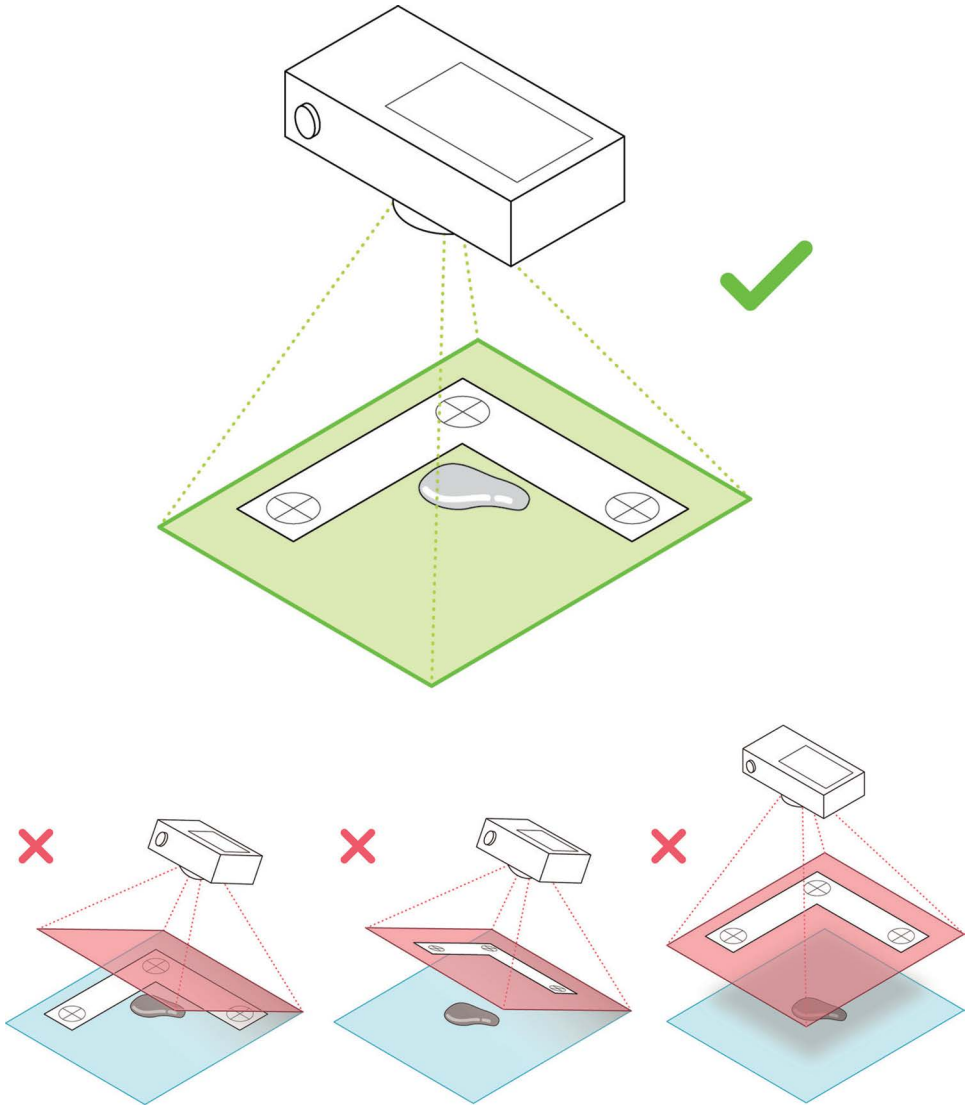


FIGURE 28.8 The first drawing is "Plane-Correct" and shows all three planes (camera sensor, subject and measuring scale) in parallel with the subject and the scale in the same plane. The second drawing ("Plane-Incorrect") shows the three scenarios of incorrect placements leading to distortion.

Any failure in these parameters will invalidate the measurements without sophisticated computer photogrammetry processes. To assess if the planes are parallel, focus on the circles on the scale. The circles should be precisely round. If the circles appear to be elliptical, the planes are not parallel (see Section 21C).

TIP:

One way to determine if the plane of the scale is in the plane of the finding is to look at the edge of the measuring scale next to the skin. If any shadow appears along the interface of the scale and skin, the planes are different.

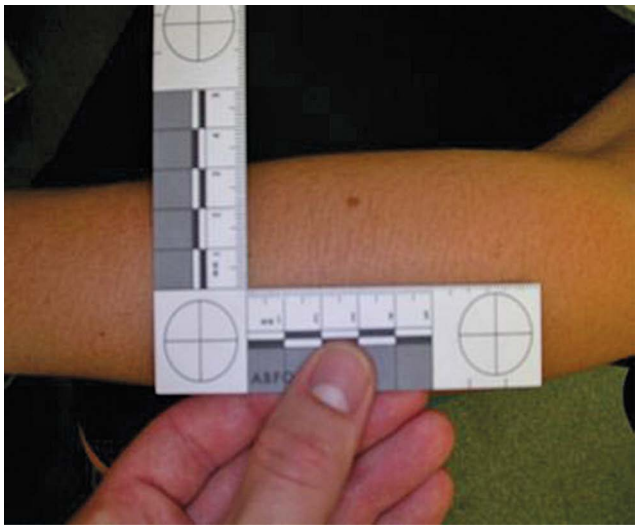
TIP:

For accurate measurements, the measurement markings on the scale must be as close to the finding as possible without covering the finding.

NOTE:

All areas underneath any scale must be accurately documented in other close-up images to avoid any challenge of "hiding" information.

A color scale can provide objective, reproducible color documentation of a finding (see Figure 28.11).



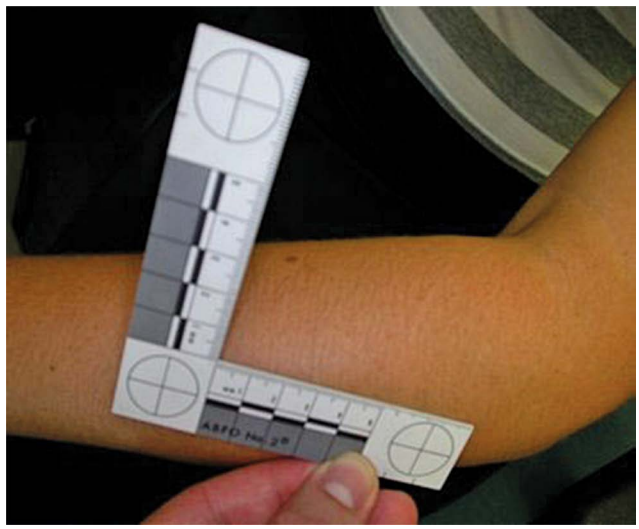


FIGURE 28.9 Right-wrong examples.

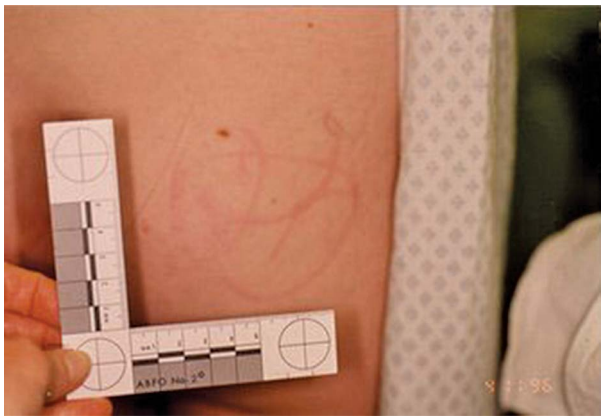




FIGURE 28.10 Both wrong!





FIGURE 28.11 A color scale can provide objective, reproducible color documentation of a finding.

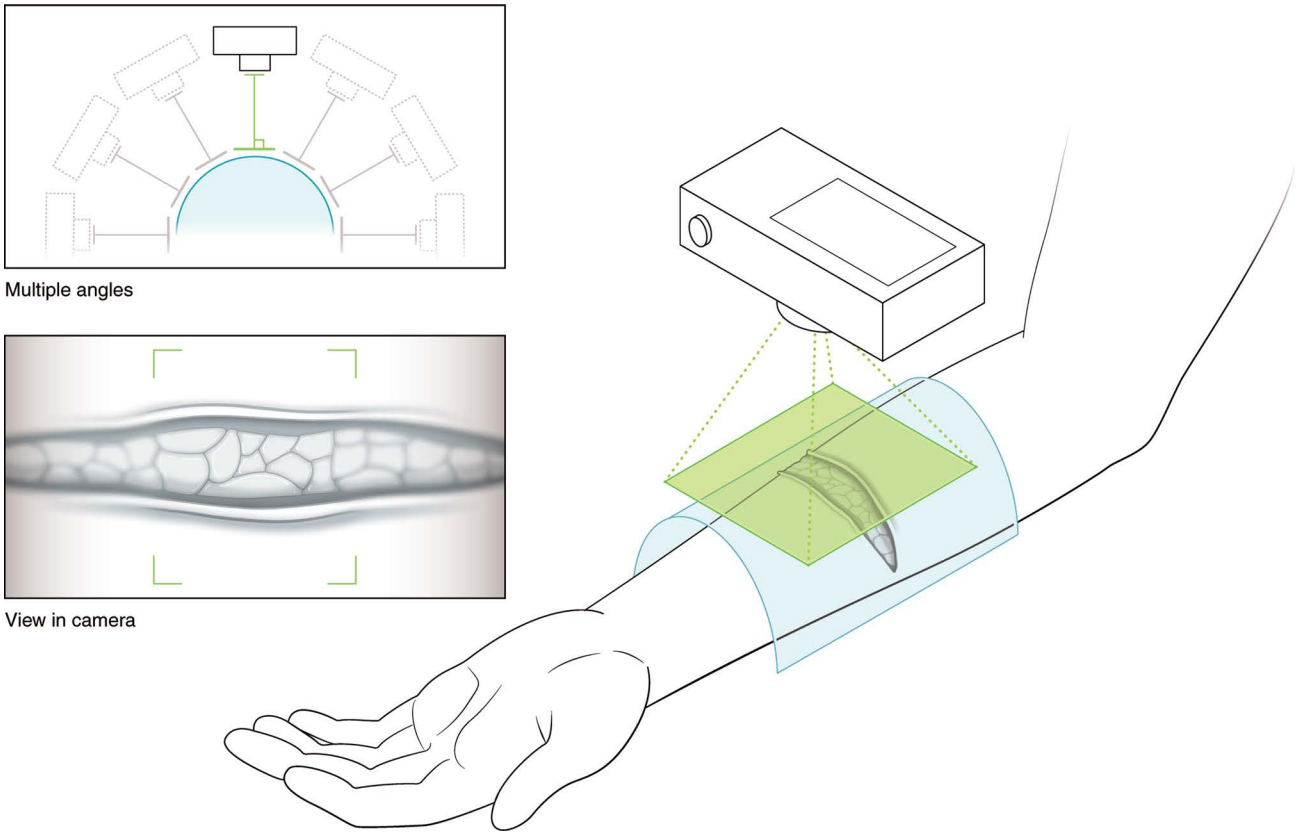


FIGURE 28.12 Drawing "Plane-Curve" illustrates the need for multiple images of a finding that follows a curved surface. Note that each image will only show a portion of the total finding in sharp focus. A curved adhesive scale should be on the skin surface next to the entire length of the finding.

Typically, a color scale will have multiple color boxes around the edges of the scale, and each color will have an arbitrary number. The colors are in the spectrum of tones commonly found in bruises and other traumatic injuries. The photographer selects the color box that most closely matches the color of the finding, places that box next to the finding, and captures an image (which includes that color box's number). When that documented finding is analyzed, the color card can be compared to the print or digital image in order to ensure accurate color reproduction. These cards may be purchased from any scientific or forensic supply company.

The body is not a monochromic, flat surface. It is a diffuse landscape with variable colors, curves, contours, shadows, and cavities. Findings can occur anywhere and often traverse different parts of that landscape. Findings on curved surfaces are common. Capturing high-quality images of the entire finding requires multiple shots around the curved surface so every aspect of the finding has a sharply focused image. Only that portion of the finding parallel to the camera sensor will be sharp. The size of the finding and the degree of curvature involved will determine how many images are required.

Providing accurate measurements of curved findings is challenging with a flat scale like the ABFO No. 2. An alternative is to use an adhesive paper scale applied directly to the skin adjacent to the finding.



FIGURE 28.13 Adhesive inch-tape.

In this scenario, the camera is moved multiple times, while the scale remains stable and, because it is adhesive, is in the plane of the finding.

Small adhesive paper scales may be used, but accurate measurement is always difficult with multiple small contours.

Imaging body cavities (mouth, nose, ear canals, vagina, and rectum) creates special challenges. Adequate lighting is difficult and usually requires a dedicated light source. A ring light and macro lens are usually required for the larger cavities (which may be held open by medical instruments).

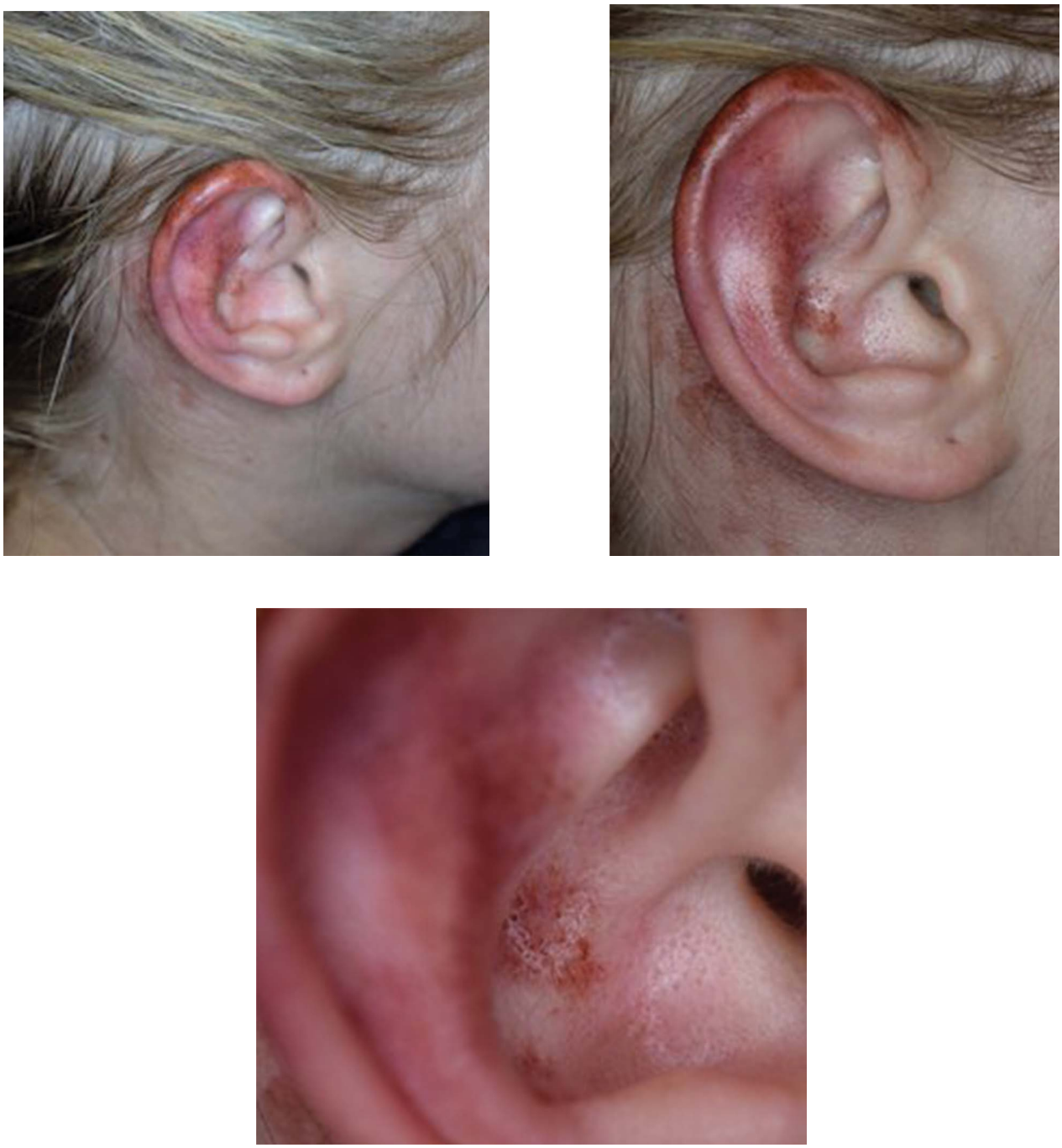


FIGURE 28.14 Highly contoured areas (like the ear) require multiple images and will also need multiple adjustments of the light source for adequate visualization and sharp focus.

Spot focus and spot metering will facilitate better images. Specialized medical diagnostic tools (e.g., colposcope, digital otoscope, etc.) may provide the best cavity images, especially for small cavities, but will only be available in medical settings and require a trained health professional.

There are two medical forensic situations for which follow-up examination and imaging may be helpful. The first is the presence of a nonspecific finding like redness (erythema). Redness may be caused by trauma and should be documented after interpersonal violence. But the problem is the interpretation of that redness. Redness may be caused by many other mechanisms besides trauma, including infection, inflammation, allergic reaction, thermal injury, and neurologic dysfunction, and may be normal for that patient. The follow-up exam should include medical information (detailed medical history, palpation for tenderness, and potentially medical testing) and repeat imaging. Redness that is a normal variant in that patient, at that location, will be unchanged at follow-up and clearly eliminates trauma as the cause.

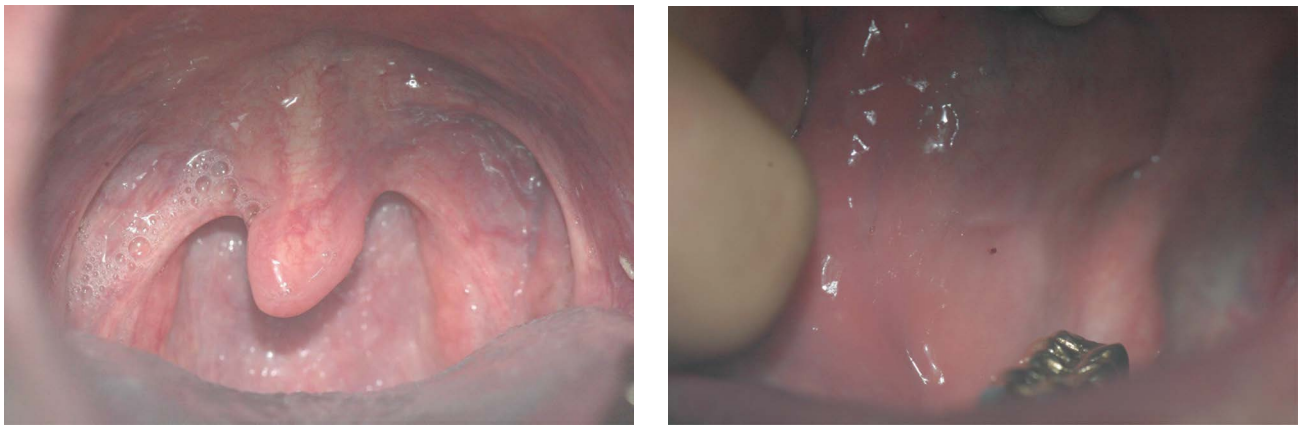


FIGURE 28.15 Images inside the mouth exposed with a homemade colposcope attachment. For detailed instructions on making one, please contact the author.

The second indication for follow-up imaging is for evolving injuries. Blunt-force trauma can damage tissue and create bleeding under the surface of the skin that just after the injury is barely visible or not visible at all. For bleeding under the skin to be visible, the blood from tissue damage must be within about 3 millimeters of the skin surface. If the blood is deeper, it will not be seen on the surface. Clinical clues to the presence of such an unseen or poorly seen injury are the patient's history of what happened (description of the mechanism of injury) and the presence of tenderness (pain upon touching the area of subsurface damage). Over hours to a few days the blood may migrate closer to the surface, eventually revealing a bruise. This sequence of changing findings should be photographically documented to confirm the initial suspicion of soft tissue injury (see Figure 28.16).

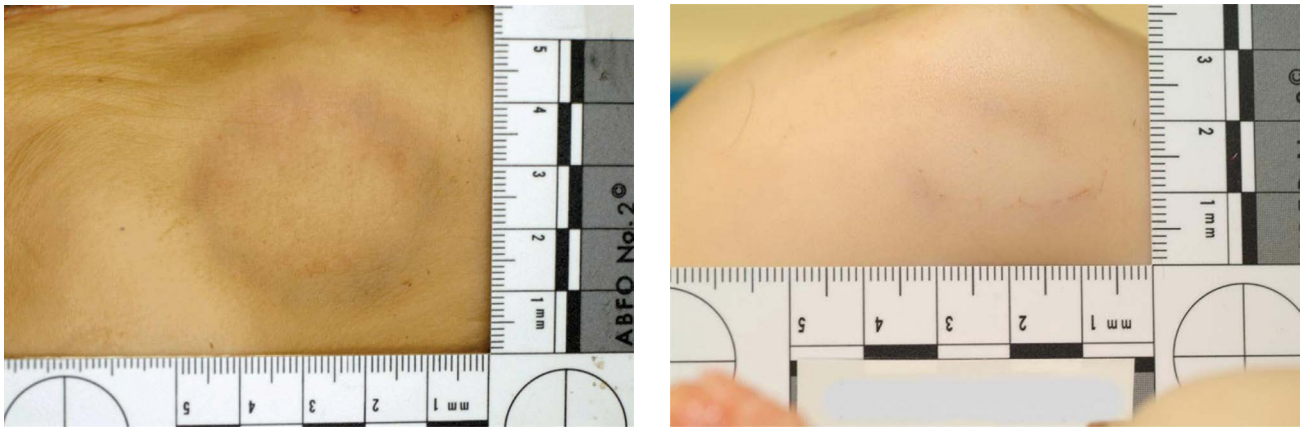


FIGURE 28.16 Evolving injuries: Image on the right exposed 10 days later.

APPENDIX I: MEDICAL CONSENT FORM

FORENSIC MEDICAL REPORT: ACUTE (<120 HOURS)
ADULT/ADOLESCENT SEXUAL ASSAULT EXAMINATION

STATE OF CALIFORNIA
Governor's Office of Emergency Services

Cal OES 2-923

Confidential Document

Patient Identification

A. GENERAL INFORMATION (print or type) | **Name of medical facility:**

1. Name of patient | **Patient ID number**

2. Address | **City** | **County** | **State** | **Telephone** (C) (W)

3. Age	DOB	Gender M F	Ethnicity	Arrival date	Arrival time	Discharge date	Discharge time

B. REPORTING AND AUTHORIZATION | **Jurisdiction (❒ City ❒ County ❒ Other):**

1. Telephone report made to law enforcement agency | **Reported by:**

Name of Officer | Agency | ID Number | Telephone | Name | Date | Time

2. Responding Officer | **Agency** | **ID Number** | **Telephone**

3. I request a forensic medical examination for suspected sexual assault at public expense.

TELEPHONE AUTHORIZATION
Agency:
Authorizing party:
ID number:
Date/Time:

Law Enforcement Officer | ID Number | Agency

Telephone | Date | Time | Case Number

C. PATIENT INFORMATION

I understand that hospitals and health care professionals are required by Penal Code a sections 11160–11161 to report to law enforcement authorities cases in which medical care is sought when injuries have been inflicted upon any person in violation of any state penal law. The report must state the name of the injured person, current whereabouts, and the type and extent of injuries. _____(initial)

D. PATIENT CONSENT

Minors: Family Code Section 6927 permits minors (12 to 17 years of age) to consent to medical examination, treatment, and evidence collection for sexual assault without parental consent. See instructions for parental notification requirements for minors.

- I understand that a forensic medical examination for evidence of sexual assault at public expense can, with my consent, be conducted by a health care professional to discover and preserve evidence of the assault. If conducted, the report of the examination and any evidence obtained will be released to law enforcement authorities. I understand that the examination may include the collection of reference specimens at the time of the examination or at a later date. I understand that I may withdraw consent at any time for any portion of the examination. _____(initial)
- I understand that collection of evidence may include photographing injuries and that these photographs may include the genital area. _____(initial)
- I hereby consent to a forensic medical examination for evidence of sexual assault. _____(initial)
- I understand that data without patient identity may be collected from this report for health and forensic purposes and may be provided to health authorities and other qualified persons with a valid educational or scientific interest for demographic or epidemiological studies. _____(initial)

Signature _____ ❒ Patient ❒ Parent ❒ Guardian

DISTRIBUTION OF CAL OES 2-923

❒ Original–Law Enforcement ❒ Copy within Evidence Kit–Crime Lab ❒ Copy–Child Protective Services (if patient is a minor) ❒ Copy–Medical Facility Records

29 Autopsy Photography

Sanford L. Weiss and P.J. Schoebel

CONTENTS

Forensic Autopsy Objectives 569
Fatalities and Injuries at a Fire Scene 569
Manner of Death 570
Natural Death 570
Accidental 570
Homicide 570
Suicide 570
Undetermined Manner of Death 570
Cause of Death 570
Mechanism of Death 572
Burn Injuries 572
The Normal Autopsy 573
The Process 573
External Examination of the Body 573
Internal Examination 575
Skull and Brain Examination 576
Neck Organs and Tongue 579
Individual Organs 579
Conclusion 579

In the case of autopsies, the terms medicolegal and forensic pertain to the legal aspects of the medical practice of pathology dealing with the investigation of the dead. The goal of the forensic autopsy is to determine the cause of death of the decedent by the use of investigative procedures least likely to be challenged in court.

The photography of autopsies presents a unique set of challenges to the practitioner or photographer working in a morgue. The subject matter, even for the experienced, is often emotionally disturbing, especially when the subjects are young or extensively traumatized. The presence of diseases and decomposition further adds to the difficulties. These issues may be minimized through planning and the use of a methodical approach to the documentation of the entire autopsy process.

FORENSIC AUTOPSY OBJECTIVES

The autopsy is a detailed external and internal examination of the decedent conducted by a forensic pathologist. Although there are no accepted, standard protocols from one jurisdiction to another in the United States that outline the autopsy process itself, the photographic imaging of the procedure and the physical evidence should always meet accepted photographic standards for accuracy. The pathologist will examine, describe, and document any natural and traumatic conditions.

FATALITIES AND INJURIES AT A FIRE SCENE

Fatalities at a fire scene are a good example to use for stating the value of the forensic autopsy. There are many examples of murderers attempting to cover up their crime by incinerating the body in an inferno. The problem is that for the murderer, the normal inferno fails to totally destroy the body. There is frequently enough of the body remaining after the fire suppression to determine the cause and manner of death.

This is also the case in all the other methods criminals use to dispose of bodies. If the body is found, in most any condition, at most any time, there can be enough evidence left on the tissues or bones to give clues as to the way the person died.

The job of the forensic photographer is to watch and listen to the pathologist and make photographs of any and all important findings. Normally the person performing the autopsy will inform you what to photograph. If they do not do that, use your own initiative and reason to determine what things to document. Your training should kick in as soon as the project begins.

When the fire scene involves the recovery of human remains, a team of specialists may be required. The team may include the following:

- First responder
- Crime scene investigator
- Coroner/medical examiner
- Forensic pathologist
- Photographer

When they are available, consult other specialists, including the following:

- Forensic anthropologist
- Forensic entomologist
- Forensic odontologist
- Surveyor

MANNER OF DEATH

The manner of death explains how the death occurred. For example, was it a natural death or a violent death? Natural deaths are caused by disease or old age, rather than an accident or act of violence. An injury may cause or contribute to death. In that case, the fatality will be classified as non-natural. The following are subclasses of the manner of death:

- Natural
- Accident
- Homicide
- Suicide
- Undetermined

Forensic pathologists investigate the manner of death through an autopsy. The information found during an autopsy may reveal the following, within a reasonable certainty:

- Cause of death
  - How
  - When
  - Where
- Manner of death

NATURAL DEATH

The mechanisms of natural death include these:

- Heart failure
- Disease
- Death while sleeping
- Brain death

The autopsy should reveal if death was sudden or unexpected or if the person was ill.

ACCIDENTAL

Accidental death occurs resulting from injury sufficient to end life during an accident.

The mechanisms of accidental death include but are not limited to:

- Vehicle crashes
- Falls
- Fires
- Drowning

HOMICIDE

Homicide is the killing of one human by another. Some examples include these:

- Shooting (gunshot wound [GSW])
- Stabbing
- Strangling
- Bludgeoning
- Burning

All murders are homicides, but not all homicides are murders. Murder is the unlawful taking of one human life by another. This may include premeditation. If a police officer takes a life in the line of duty, it is homicide, not murder.

Every type of weapon leaves distinct marks on a corpse. A pathologist may be able to identify whether an injury was caused by a certain type of weapon.

SUICIDE

When a person terminates their own life, it is called suicide. The manners of death by suicide include but are not limited to:

- Gunshot
- Stabbing
- Incision
- Poisoning
- Hanging
- Falls
- Entrance into a nonsurvivable situation

UNDETERMINED MANNER OF DEATH

The manner of death is undetermined when the conclusion concerning a particular manner of death cannot be determined after all the available information has been considered.

CAUSE OF DEATH

National mortality statistics are gathered by classifying each and every death as due to one specific condition. This is based on the information reported on the death certificate and using international rules for categorizing the cause of death from reported conditions. The International



FIGURE 29.1 Observable injuries documented during the postmortem examination to include gunshot wounds, recovered bullets, contact gunshot wounds, puncture and stab wounds, lacerations, abrasions and scratches.

Statistical Classification of Diseases and Related Health Problems (ICD-10) is used for coding the cause of death.

MECHANISM OF DEATH

The mechanism of death consists of the physiological or biochemical events that end life. The mechanism is determined by the cause—for example, cardiac arrest or respiratory arrest—due to, but not limited to, any of the following:

- GSWs
- Stabbing
- Smoke inhalation
- Assault
- Arson
- Vehicular accident

BURN INJURIES

The investigator may determine information about various aspects of the fire by examining the effects of fire on a victim's body. The injuries may also help to develop the timeline of the fire. This information may be crucial to the determination of the origin and cause. The injuries may also provide information regarding the occurrence of arson.

Many deaths and injuries are caused by fire, heat, and smoke. Burn injuries occur when the skin of a victim receives more heat than can be absorbed by the body. The common types of burns include the following:

- Thermal, from high temperatures
- Flame, from direct contact with fire
- Radiation, from close exposure to heat or radiation
- Scalds, from hot liquids or steam
- Contact, from touching hot objects
- Chemical, from contact with corrosive chemicals
- Ultraviolet, from overexposure to solar radiation or sun lamps
- Electrical, from contact with live conductors

Burns are seen in the following types of crime scenes:

- Arson
- Insurance fraud
- Drug abuse
- Child/elder abuse
- Domestic violence
- Suicide
- Homicide

Failure to use proper standard operating procedures (SOPs) when examining and processing burn victim evidence may compromise the admissibility of the evidence at trial. It may also lead to inaccurate conclusions regarding the origin and cause of the burns and the possibility of arson. It is critical to process fire victims properly to preserve any evidence of value.

Use the same SOPs, if possible, with living victims at the scene, following these steps:

- Collect clothing, shoes, and personal effects
- Collect other evidence
- Document injuries
- Record your observations of present medical personnel

Regardless of whether the victim is alive or deceased, fire suppression activities should have been minimized at their location. It is SOP to use the minimum of destructive procedures during fire suppression in the location of victims. Excess water may wash away evidence. Use the utmost care and common sense to preserve the scene. As soon as it is safe to enter the area where the victim is located, that area should be given the highest priority for investigation and documentation. Foot traffic in the area should be minimized until after documentation is completed.

TIP:

The position and condition of the body may supply the medical examiner and fire investigator with crucial information. The body should not be moved until it has been fully documented in writing, sketches, and photographs. In most jurisdictions the medical examiner or coroner has complete legal control over the deceased. No body may be touched, moved, or examined absent exigent circumstances without their explicit permission.

When exposing photographs, strive to answer the following questions:

- Who is the victim?
- What are the cause and manner of death?
- What injuries did the victim sustain?
- Was the victim alive or conscious at the time of the fire?
- Much can be determined by the position of the body when discovered post-fire.
- What is the victim's relationship to the scene?
- What is the timeline of the fire events?
- Much can also be determined by the condition of the corpse's lungs during autopsy.
  - It often takes more than a normal fire to destroy the corpse enough to eliminate the examination of the inside of the lungs and other respiratory passages. Clean tissue inside the lungs indicates the decedent was dead when the fire began.
  - Sooty tissue inside the lungs indicates the decedent was alive during the fire.
  - It is exactly the same situation with drowning. Water inside the lungs indicates the person was alive at entry into the water. Dry inside the lungs indicates the person was already dead when entering the water.
  - These autopsy results go a long way towards determining the cause and manner of death.

THE NORMAL AUTOPSY

In general, the evidence collected during the autopsy includes samples of:

- Biological specimens, such as blood, urine, and vitreous fluid
- Foreign material, such as wood, metal, fiber, and glass

Images will include overall and close-up views of the corpse and the collected evidence, with and without appropriate references for scale and color. In all types of technical photography, the conversion of three-dimensional objects to two-dimensional images causes certain inherent problems. The human brain easily accounts and compensates for problems in perspective, exposure, color, and dimensionality in general photographs—but only up to a certain point. In projects such as autopsies, where it is possible for minor optical issues to cause major problems, it is best to use extreme caution in all aspects of the photographic process. This will make it far simpler for the pathologist to explain—and for the judge and jury to correctly understand—the images when they are presented in court.

THE PROCESS

Human tissue—both interior and exterior—is highly reflective. Therefore, great care should be taken to eliminate flash flare in all exposures. This is most easily performed by having the flash set at an oblique angle to the subject (usually from 30 to 45 degrees). See Figures 29.2 and 29.3. Special flash brackets are made for holding the flash off to the side of the camera lens. These help eliminate the flare caused by having the flash aimed directly at the subject. In many cases the flash can be triggered by a cord connected from the camera to the flash or by an electric eye, where the smaller, lower-intensity, top-mounted camera flash will trigger both simultaneously.

If this setup is not possible, use a neutral-colored, semitransparent type of material to place over the lens of the flash to diffuse the light sufficiently to help reduce reflection and maintain detail in the image highlights. Try a piece of waxed paper or clear bubble wrap with the smaller bubbles for diffusion if an original equipment manufacturer (OEM) flash diffuser is not available. Do not forget that if you diffuse the light emission from the electronic flash unit (EFU), it will cause the images to be underexposed unless the output discrepancy is compensated for in the exposure.

When using a digital single-lens reflex (DSLR) camera, use these general equipment guidelines:

- Use a macro lens of 50 to 60 mm in focal length.
- Use a supplementary flash.

If using a digital point-and-shoot camera, use these equipment guidelines:

- Use a consistent focal length from one image to another for the overall views.
- Switch to macro focusing when applicable.
- Use a supplementary flash if possible, or diffuse the built-in flash and compensate for the exposure.

Appropriate scales and references for both size and color are available from medical supply companies and should be certified specifically for forensic photographic use. See Chapters 7, 11, 28 and 31 for more information about scales.

EXTERNAL EXAMINATION OF THE BODY

The photographic portion of the autopsy begins with capturing images to document the integrity of the body as evidence, including:

- A planned and methodical approach to make photographing a difficult subject far easier. Have a PLAN!
- The unopened, sealed body bag with the body inside.
- A close-up image of the intact body-bag seal and serial number.

If the body is clothed, it is necessary to perform a detailed external examination with written and photographic documentation before the clothing is removed. The images should be exposed while the body is still in the body bag and before trace evidence collection, with and without scales. Images should include:

- An overlapping series of anterior (front) images of the body

Morgue ceilings are usually too low for overall images of the anterior to be exposed without the use of a wide-angle lens or an oblique angle from behind the head or in front of the feet of the body (see Figure 29.2). Both of these procedures will result in unusually foreshortened perspectives and, possibly, images with limited detail. Instead, it is best to expose a series of overlapping images from directly above the body. This is often accomplished by standing on a ladder placed next to the table. Keep moving the ladder to a new position matching the portion of the object being photographed. If you just change the camera angle for each image from on the ladder, the foreshortening and distortion caused by the varying camera positions will make the overlapping series of images almost useless for future stitching into a collage (see Figures 21.57 and 21.58). Using a ladder as a tool may require one to be brought by the photographer.



FIGURE 29.2 Top: Improper foreshortened perspective by image taken from feet. Bottom: Correct image taken from directly above.

This situation will be found in both the morgue and a mortuary on occasion.

Be sure to include sufficient overlap from image to image so the series may be stitched together into a continuous montage if necessary. If using a flash, be sure the flash-to-subject angle does not vary from image to image. If the flash angle changes, the exposure on the subject will also change, damaging a possible collage. If using an autofocus camera, be sure to disable the autofocus system before starting to expose the series, so the camera does not refocus between exposures and create images of different sizes and magnifications. Also, if the camera has a zoom lens, be certain to keep the lens at the same focal length for all the exposures. This is especially important for cameras with lenses that push in and pull out to zoom. Sometimes these lenses have a tendency to zoom themselves because of gravity when the camera is pointed directly down. If necessary, use a piece of tape to secure the zoom feature. It is absolutely the same with the focusing



FIGURE 29.3 Lividity on the back.

feature. Once a focus is determined for the first exposure, tape the focus of the lens in that position and move the camera in or out to focus successive images.

- An overlapping series of both lateral surfaces (sides) of the corpse

Consider the background to be seen in the photographs. Care should be taken to avoid images of other bodies and personnel in the lab during the exposure of the lateral images. If it is impossible to exclude these distracting objects, consider placing a neutral-colored screen behind the subject while photographs are being taken or selective large aperture to render the background out of focus.

Photographic documentation should also include:

- An overlapping series of the posterior surface of the body.
- A series of the front, top, both sides, and back of the head.
- Dorsal and palmar aspects of both hands. If the hands have been put into paper bags, photograph the bags and then the hands after the pathologist removes the bags.
- Macrophotographs of any trace evidence spotted during the examination.
- Clothing, jewelry, personal possessions, and all other items removed from the decedent.
- Any pathology, trauma, postmortem artifacts, or items of interest as indicated by the pathologist.

Following the initial clothed corpse examination, the subject's clothes are removed. The clothing should be laid out on clean white or brown paper and photographed at the same focus scale as the body in case injuries to the body need to be matched to damage in the clothing. The pathologist will methodically assess the body for signs of trauma and disease and identify evidence adhering to the body. It is not necessary to follow a specific order for this examination, but it is normal to begin the examination with the top of the head and work down to the feet.

Injuries and evidence adhering to the body should be photographed prior to the corpse being washed in order to document the original condition of the anomalies. If possible, this set of photographs should be exposed in the body

bag and prior to cleaning and trace evidence collection, with and without scale, including:

- An overlapping series of the anterior surface.
- An overlapping series of both lateral surfaces.
- An overlapping series of the posterior surface.
- A series of the front, top, both sides, and back of the head.
- Dorsal and palmar aspects of both hands.
- Tattoos, piercings, and other body art. In some cases, alternative lighting may be useful in bringing out the design of age-faded tattoos.
- Scars.
- Macrophotographs of any trace evidence spotted during examination.
- Any pathology, trauma, postmortem artifacts, or items of interest as indicated by the pathologist.

After all evidence has been collected and the pathologist has completed the initial examination of the decedent, the body will be removed from the bag and cleaned of any loose materials, blood, and other debris. Another series of photographs of the decedent should be taken at this time, with and without scales and references, including:

- An overlapping series of the anterior surface
- An overlapping series of both lateral surfaces
- An overlapping series of the posterior surfaces
- Dorsal and palmar aspects of both hands
- A series of the front, top, both sides, and back of the head
- Any pathology, trauma, postmortem artifacts, or items of interest as indicated by the pathologist



FIGURE 29.4 A tattoo would be considered an item of interest.

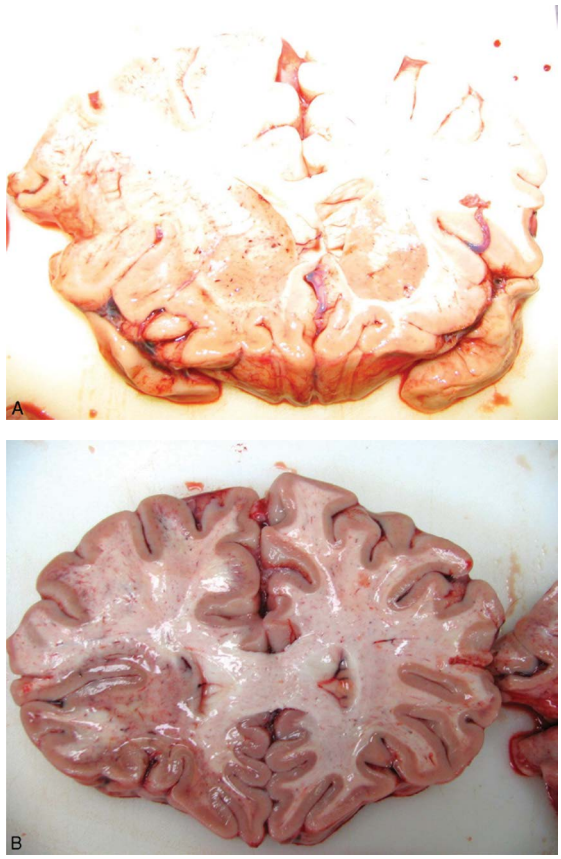


FIGURE 29.5 (A) The highly reflective nature of human tissue poses a challenge for the forensic photographer (left). Using a direct flash, as shown here, will tend to create troublesome flash flare, obscuring important details. (B) To avoid this problem, hold the flash at an oblique angle to the subject or diffuse the flash.

INTERNAL EXAMINATION

The autopsy proceeds when the pathologist makes a thoracoabdominal incision (commonly called a Y-shaped incision) extending roughly from each of the shoulders to a point at the middle of the sternum and then continues along a single line to just above the pubic bone. This incision allows the pathologist to expose the rib cage, which protects the thoracic organs and, when removed, exposes them. The incision also exposes the abdominal organs for documentation.

Body with chest plate removed — During the autopsy, the pathologist will make a thoracoabdominal incision in order to expose the rib cage and abdominal organs. Be sure to position the camera directly above the area of interest and photograph straight down with a 50 to 60 mm lens.

As the autopsy proceeds, expose photographs with and without the appropriate scales and references in order to document the condition of the body, including:

- The exposed rib cage and abdominal organs
- The **rib cage removed** to expose the thoracic organs (Figure 29.6)
- The condition of the thoracic and particular abdominal organs

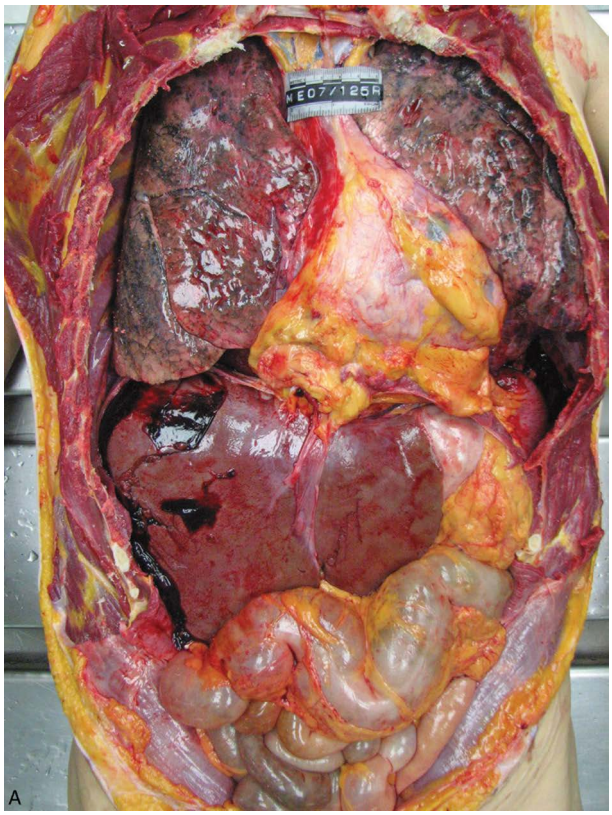




FIGURE 29.6 (A and B) Documenting the abdominal organs.

There are two accepted techniques used by pathologists to remove the organs from the body. The pathologist will have a personal preference. Both techniques require the same type of photographic documentation.

Rokitansky method—In this technique, the tissues connecting the thoracic and abdominal organs of the body to the whole are cut and the organs removed as a block. The pathologist can then dissect each individual organ—heart, lungs, spleen, liver, stomach, intestines, and pancreas—from the block. Some pathologists prefer the Rokitansky technique, particularly when examining traumatic injuries, including GSWs. It may allow for easier tracking of the bullet trajectory through the organs.

When photographing an autopsy in which the pathologist is performing a Rokitansky technique, photograph both the anterior and posterior surface of the organ block, and then capture individual images of each organ after dissection has taken place.

Virchow method — The other common method of removing organs is the Virchow technique. In this technique, the thoracic and abdominal organs are individually removed from the body cavity. When photographing autopsies in which the pathologist prefers the Virchow technique, photograph each organ as it is dissected and laid out by the pathologist.

Skull and Brain Examination

Prior to any incision of the head, a series of photographs should be exposed, both with and without reference scales. This series of photographs will include:

- Left lateral, right lateral, and top of the head
- Pathology, trauma, and any other items indicated by the pathologist

Examination of the skull is accomplished after one incision, beginning behind one ear, extending across the top of the head, and ending behind the opposite ear. (An incision performed in this manner should not be visible during funeral services.)

The scalp is then reflected forward and backward, exposing the skull. If any injuries or defects are present on the external surface of the skull, or if any are found later, a complete series of documentation photographs from external to internal is made to show the extent of the injuries.

The second set of photographs should include:

- Left lateral, right lateral, and top of skull (Figure 29.8) prior to removal of residual tissue and blood
- Left lateral, right lateral, and top of skull following removal of residual tissue and blood
- Pathology, trauma, and any other items as indicated by the pathologist

Every stage of the autopsy should be carefully documented with a standard set of photographs. Here, the autopsy photographer documents the top of the skull after the pathologist

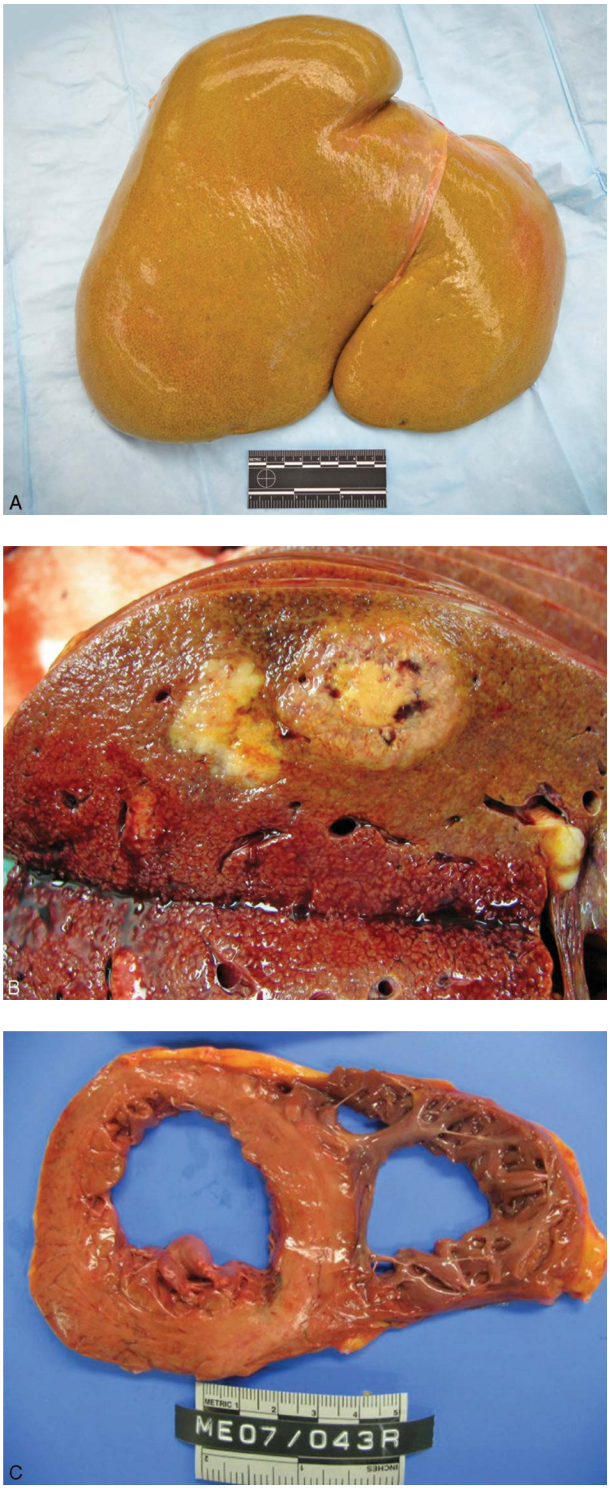


FIGURE 29.7 (A) Liver cirrhosis. (B) Malignancy. (C) Heart section.

has removed the scalp, plus the residual tissue and blood. Each detail is documented for future evaluation if necessary.

The skull cap is then removed using a Stryker saw, exposing the brain. To show continuity of injuries and defects, continue taking photographs in the manner previously described: Begin with the left lateral, then the right lateral, and then the top of the brain in situ (see Figure 29.9).

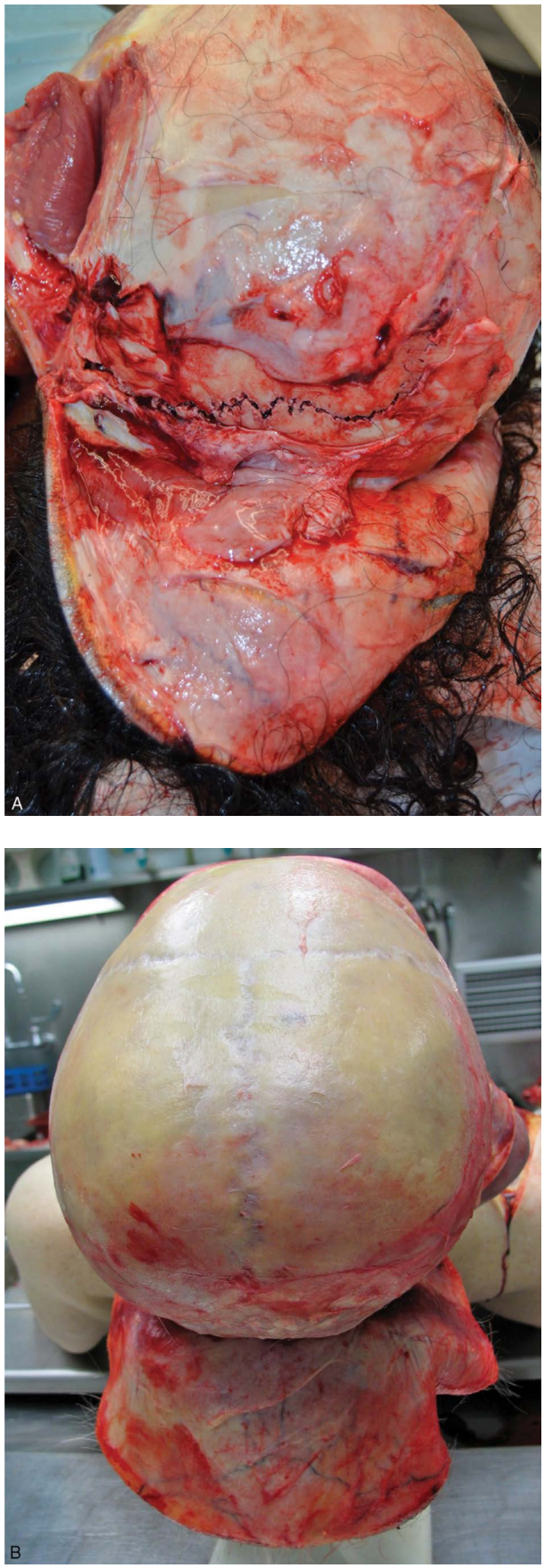


FIGURE 29.8 (A and B) Skull fracture.

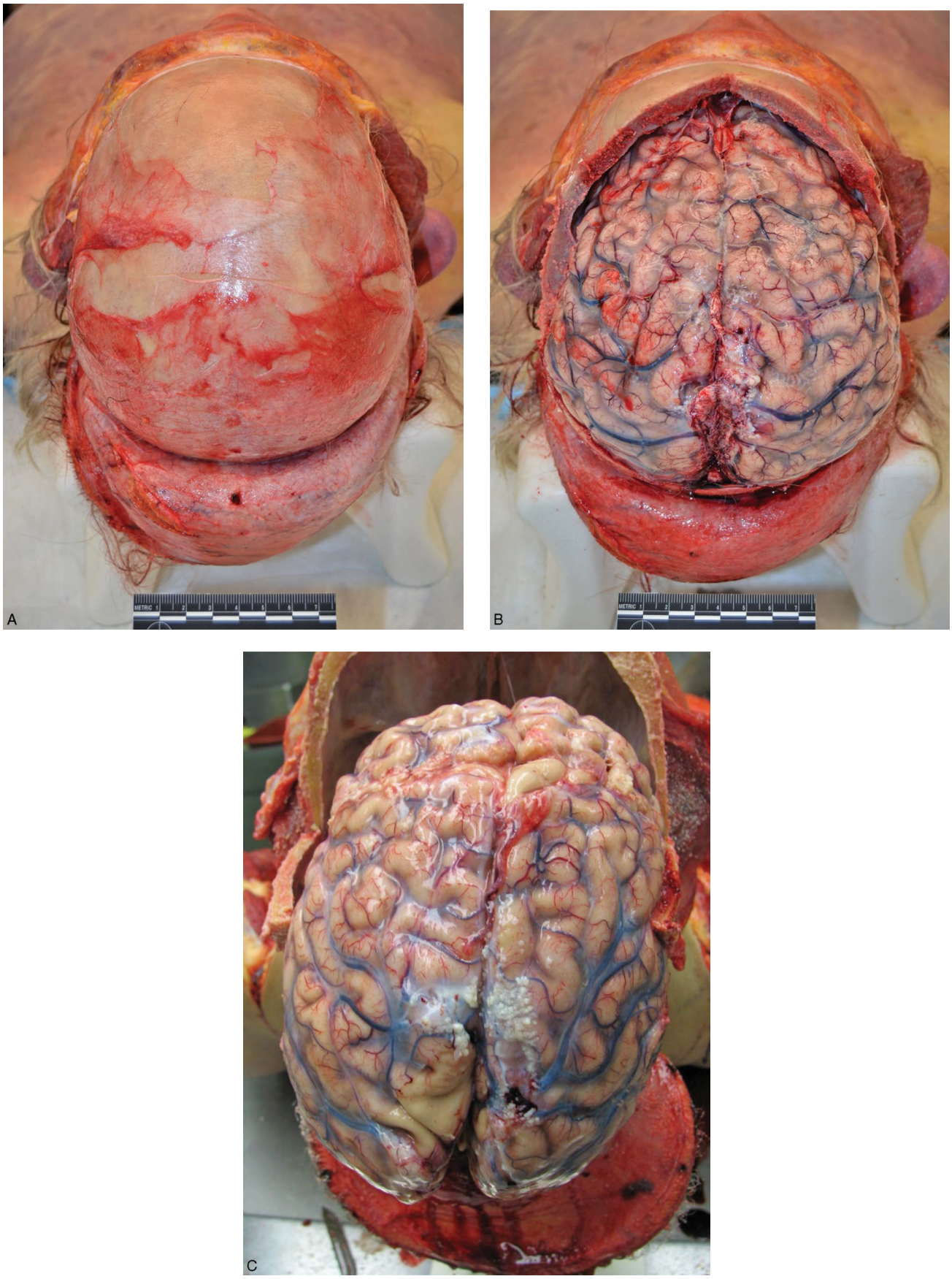


FIGURE 29.9 Image series showing (A) the opening of the skull, (B) the brain in situ, and (C) the brain being removed.

After the brain is removed, there will be a coating of dura mater inside the skull. Dura mater is the outermost, toughest, and most fibrous of the three membranes covering the brain and spinal cord.

Following a discovery/examination process, photographs should be taken of the:

- Interior of the skull and skull cap with dura mater in situ
- Interior of the skull and skull cap following removal of the dura mater

Neck Organs and Tongue

The neck's organs and the tongue are usually removed next in the process and examined separately. The organs are placed on a clean surface and photographed, anterior and posterior.

Fractures, bite marks on the tongue, or other pathology should receive special consideration, and detailed photographs should be taken as directed by the pathologist.

Individual Organs

All organs should be photographed whole prior to their sectioning by the pathologist (Figure 29.11). Each organ will then be cut in order to ascertain the extent of the disease process or injury affecting the decedent. Macrophotographs should be taken of the cut sections. To reduce glare, organs may be soaked in a 10% formalin solution for 10 to 15 minutes prior to photographing.



FIGURE 29.10 After organs such as the brain are removed from the body by the pathologist, each should be placed whole on a clean surface and photographed, anterior and posterior.

CONCLUSION

Use of a simple, organized, and thoughtful approach to this difficult task will limit mistakes and help the practitioner eliminate unnecessary stress and wasted energy possibly used more efficiently to concentrate on the job at hand.



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30 Entomological Photograph Protocols

Neal H. Haskell, Leon G. Higley, and Pat Cicero

CONTENTS

The Needs of the Forensic Entomologist from the Scene and Autopsy 583
Blow Flies' and Other Insect Groups' Development and Life Cycles 587
The Blow Fly Life Cycle 588
Distinguishing Insects from Noninsects: The Dust Bunny Case 591
Using Scales in Crime Scene Photographs 592
Use Macrophotography for Specific Groups of Insects or Specific Individual Specimens 592
Documenting Specific Temperatures When Investigating Indoor Cases 595
Presenting the Photographic and Tabular Evidence in Court 595
Status Today 597
Answer to the Question in Figures 30.2 and 30.3 597
Notes 597
References 597

The famous Locard's principle, the idea stating that a perpetrator always brings to and leaves with evidence at a crime scene, contributes to the recognition that anything at a scene might be evidence. Of equal importance are how potential evidence is arranged and its condition at the time of its discovery. Hence, sketches, photographs, videos, and other means of recording details of a scene are almost as important as the evidence itself. In fact, when primary evidence is not collected or changes after the crime—both key issues with insects—the photos and videos become the evidence.

When dealing with murder cases, natural death, suicide, accidental, or undetermined situations, as well as nonlethal attacks, fraud, assault, breaking and entering, and a host of other types of crime, there are many excellent texts found in the crime scene investigation science literature, training manuals, and police protocols detailing general overviews of crime scene investigations (e.g., Gebreth 2015, Saferstien 2017, Spitz and Spitz 2006, Wecht 1983). These references include information on general principles of forensic photography, videography, and other techniques in scene documentation. General photography references are excellent forensic resources, having the great advantage of offering information on new advances and techniques, such as high dynamic range (HDR)—a method for combining exposures for bright and dark portions of an image (see Chapter 7B)—or focus stacking—a method for increasing depth of field, that is, the portion of a photo in focus) (e.g., Kelby 2013, Northrup 2012).

Forensic photography has never had a time of greater changes and opportunities. This revolution started with the transition to digital photography from film. Now the growth of digital videography, the increasing quality of cellphone cameras, low-cost drones, and increasingly powerful photo and video editing software all provide novel approaches in documenting and evaluating crime scenes and evidence. However, the basic principles and requirements in forensic photography have not changed (e.g., Dutelle 2016, Mancini and Sidoriak 2017). Moreover, each specific forensic science area requires its own detailed photos be collected, with certain protocols and sequences necessary for that science. This is especially true in forensic entomology, where photos or video may be the only evidence available.

You might suppose photography for forensic entomology requires special macro lenses and training in insect photography, but that is not the case. Actually, the only instances we know of insect macrophotography being used at a crime scene are when entomologists have been at the scene with CSI technicians (e.g., Figure 30.1).

But there are special considerations in photographing evidence from a forensic entomologists' perspective, some which apply broadly to forensic photography and some of which are unique.

For example, specific time sequence details while photographing a scene can be helpful to capture critical evidence, especially the state of remains or insects at an exact time. Such time estimates often are crucial in determining the possible sequence having taken place, but it is the combination of photos with other evidence that becomes most useful—photos alone can be deceiving for the untrained or unwary (for instance, look at the same body in Figures 30.2 and 30.3 and guess the difference in time between the photos [answer at the end of the chapter]).

Also, in nonfatal assaults, it is imperative that recording of injuries be documented as soon as possible—usually once the victim is medically stabilized. Healing of the victim begins immediately, and within a few hours obvious change may have dramatically taken place. Critical



FIGURE 30.1 A macrophotograph of a blister beetle at a death scene. Because disturbing these beetles causes the release of a blistering chemical, they could potentially incriminate a suspect with unexplained blisters.

(From L. Higley.)





FIGURES 30.2 AND 30.3 Bodies found after death. Can you tell how much time has elapsed between these images?

(From N. Haskell.)



FIGURE 30.4 Crime scene photograph.

(Courtesy of Putnam County Coroner, Indiana.)

evidence may disappear and be lost during the progression of the body's healing process (e.g., bruising, swelling of tissues, and other physiological changes).

The necessity of photographing at crime scenes is one of but many ways of documenting what has transpired over a period of time. It begins the moment the investigation is initiated, through the time when the police investigators release the scene. Always remember, if exposing still photographs, the images portray but one instant in time. When capturing video, the images portray an extended instant, but still not a very long period.

Some of the various methods of crime scene documentation can include drawings and sketches, as well as photographs (Figures 30.4 and 30.5).

Sketches let a technician log measurement of distances to known specific pieces of evidence, thus setting up spatial understanding of relative distances of different evidence between each other and the environment where the crime was committed. Always keep an open mind regarding the spatial location of the evidence as found and the world in general. It is always possible the evidence has been moved from where the crime was enacted, and things are not always what they appear. Only a proper investigation will tell whether the evidence was discovered at the actual scene of the crime. In addition, never forget the importance of collecting:

1. Videos
2. Written notes taken by investigators on different aspects of the investigation
3. Recorded or written interviews of witnesses
4. Measurements from a datum point providing compass direction and distances
5. Other verifiable facts pertaining to the investigation

By using multiple techniques, a much better understanding of the scene and its interactions with any and all evidence may be better understood.

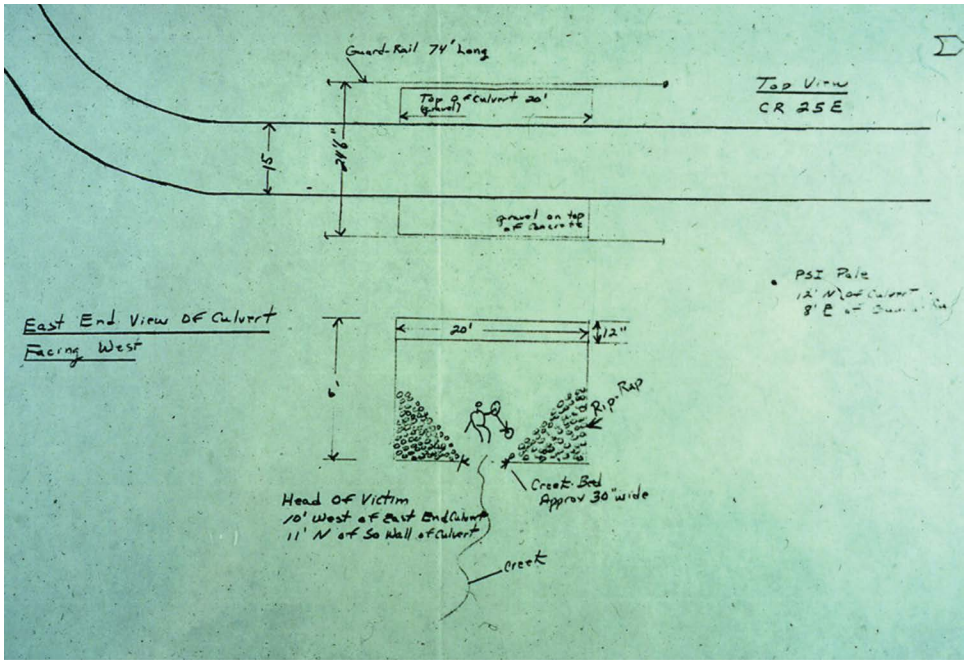


FIGURE 30.5 Sketch associated with scene in Figure 30.4, illustrating the spatial relationship of evidence and importance of measurements.

(Courtesy of Putnam County Coroner, Indiana.)

I (Haskell) have had the opportunity of testifying in many states solely by the use of photos and video tapes and had drawings or diagrams provided to give reference of the remains at the scene. These records were all helpful, but when possible, I usually like to be taken to the scene before I testify to gain additional perspective of the environmental interactions that may have influenced decomposition of the remains. While not changing my final opinion, being present at the scene provides greater understanding of directions and distances, and the items of physical evidence provide additional reliability when answering under oath. Often, there are unknown interactions not shown by the videos, photographs, or sketches if used singly. Thus, additional knowledge is available to the entomologist by using everything together rather than one piece alone. However, there are times when observing the scene is not possible before testifying.

When I first started in this work, we only had 35 mm single-lens reflex (SLR) film cameras (as the best tools to record the scene at the time of recovery) and beta and VHS for video. When video from the field first made its appearance, many of us thought the video recording would be much more precise than the SLR. After a few cases, we discovered the shortcomings of video over SLR. The video tapes provide an "overview" of the scene and its relationship to the environment, but they lacked the detail necessary when looking at and showing insects on the body. I liked both formats because they would show a relation to the scene, but SLRs provided much more detail, especially for the insect evidence possibly present.

Today, there are a multitude of types of photographic equipment, lenses, and digital devices available to the crime scene investigators with costs of the products ranging into the thousands of dollars. The technicians are extensively trained in the techniques necessary to retrieve the needed photos to provide a visual record of the visual portion of the evidence. The high costs involved, and the training required for their use, have let me personally concentrate on the entomology and rely on the crime techs for the photographic records. A simple request for a photo or a series of photos from the crime scene usually will accomplish my needs with specific or unique exposures. Therefore, I rely heavily on the crime techs for my bug photographs.

However, in jurisdictions without trained crime technicians, especially in smaller towns and cities or rural areas where violent crime is uncommon, photos and videos may be made by officers who have little or no training in forensic photography. Here, very simple issues—focus, proper exposure, distance to subject, coverage of the scene—can present challenges in making entomological determinations.

THE NEEDS OF THE FORENSIC ENTOMOLOGIST FROM THE SCENE AND AUTOPSY

When the forensic entomologist (FE) is involved directly in a case where he or she has been requested by the overriding authority, the FE must follow accepted standards,



FIGURE 30.6 Illustration of fly (likely ***Rhagoletis cerasi***, the European cherry fruit fly) life cycle on a cherry from Francesco Redi's 1668 book ***Experiments on the Generation of Insects***. Clockwise from top, maggot in cherry, third-stage maggot, puparium with end cap (called an operculum) after emergence of the adult, and the adult fly.

(From Redi 1668.)

techniques, protocols, and procedures. These standard techniques are usually methods used for hundreds of years in procuring and handling entomology specimens. This is why the FE has little problem establishing forensic entomology is not a new or novel science. Since I established precedence in a number of states from a ruling by the Indiana court, all I do is cite the first true experiment of Francesco Redi (1668) (Figure 30.6) on insect development (disproving spontaneous generation of life) and then refer to centuries of entomological research to establish how maggot growth on a body relates to time of death.

The judges understand this is not new or novel information, but merely calculating insect:

- Growth
- Development
- Behavior
- Distribution (both seasonal and geographic)
- Insect identification
- Many other entomological factors used every day in the field of entomology

For instance, during one of my first trials in Indiana, my testimony was challenged to the Indiana Supreme Court. The jurists reasoned that forensic entomology is not a new or novel science, the capturing and preservation techniques were standard within the science, and Neal H. Haskell was an expert in the field of forensic entomology (Supreme Court of Indiana 1990). This was a major ruling and an important aspect for entomological evidence coming into courts very early in my career and set strong precedents in other states as to the uses of forensic entomology.

The following general procedures, shown here in a series of steps, should be followed by any crime technician, coroner, medical examiner, or entomologist during the investigation of a scene involving an insect population. While all steps are not necessary in all cases, the general steps are as follows:

a. Observation and recording of the overall aspects of the scene environment reported by accepted primary methods of making that record (e.g., sketches, videos, photographs, and diagrams). These are obtained by starting at the outer corners of the designated area thought to contain every element of the crime. This may be an extensive area containing square miles or may be as small as a few square feet.

   With the onset of drone technology and modern high-definition videography, law enforcement agencies have greatly enhanced their documentation capabilities in large outdoor scenes. Drone documentation not only allows an overall aerial view of the scene, but it can also provide 90-degree mid-range and sometimes close-up documentation.

   As it pertains to still digital photography, the investigator will eventually capture overall photographs of the scene, concentrating on utilizing the four-corner method. Once the overall exposures are complete, the investigation should physically move inward to the center, while continuing to photograph the scene and altering exposure angles.

   Also, the investigator will need to be observant and document items he or she happens across, which may potentially be elements of the crime. (This record is usually accomplished by still camera or video and possibly sketches.) After this is completed, an extensive search is begun, using standard search techniques, looking for pieces of specific evidence, including clothing, a possible murder weapon, evidence left by the perpetrator, tire tracks, footprints, even an area where a fight had taken place, etc.

   In a number of entomology cases, "elbow and belly" searches have been used, with the investigators crawling along slowly, searching for very small insect evidence. Often, evidence a previous search group overlooked can be found, given the sizes of the specific evidence. In one case from Indianapolis, a few very small .22-caliber empty shell cases were found by an entomologist at a ¾-inch depth of "stinker juice" (this is composed of fluid purging from the natural body openings and additional fluids created by the maggots as they break down the soft tissues of the remains) totally covering a tile kitchen floor. These spent cases provided evidence regarding the firing pin strikes on the cases recovered (this case will be covered in detail later in the chapter). All these small pieces of evidence should be marked, photographed, and if moving, should be quickly collected. If this

evidence is biological, it may be necessary to collect and preserve it immediately, especially if these are maggots. Work in accordance with the entomological protocols as the best training dictates. Again, overall, mid-range and close-up photographs, taken in sequence, are the best method to record the insect activity and other evidence.

b. The person in charge of the scene must coordinate the needs of the specialist and will provide everything needed for processing the remains in logical order.

It can take time, waiting on stand-by for the preliminary steps of the scene processing to be completed. This can be the time needed to discuss with other investigators the specifics of the entomological needs as the investigation moves in towards the body. Most often, if adult flies are present (Figure 30.7), they will be disturbed if techs move in towards the remains too closely/quickly.

This is all right as long as the body is not yet moved and the flies have a chance to settle back down to laying their eggs or feeding on the fluids purging from the body. For entomological photographic work, direct the photographer to capture images covering the overall aspects of the remains, and then have him or her move in closer to marks that may be from insects or other trauma. After overall photographs of the decedent's location are completed, the investigator should alter the exposure angles and take 90-degree mid-range and close-up exposures, focusing in on the areas of colonization (maggot masses), whether only eggs, different sizes of larvae, and different sizes of maggots. Along with the close-up photography, it is highly recommended that the photographer routinely introduce a disposable millimeter scale into the appropriate location, especially when photographing eggs and larvae. Other marks on the body should also be documented with these referenced photos. These insect stages may suggest egg laying over a period of time, or they may be from a different species of insects. Good depth of field in the photographs is important because when the images are put on a monitor or screen, the viewer can increase magnification and observe much more detail than with a one-to-one image. While the identification of larval species may not be possible with these techniques, the general taxa (a group of insects of similar likeness) of the fly may often be revealed. Depending on the geographic location of the death, this could eliminate potential species down to three or four possibilities. Often within the same genera, developmental differences may be similar to one another, and a reliable range of time of death may not be a problem since all are about the same age.

c. Upon moving the remains (usually rolling the body on its side) there is a likelihood that the different insect taxa may have moved to feed on the underside of the body. These will generally be of the beetle species, so prepare to capture them quickly (these are "fast movers"). Any delay in capture may result in the loss and escape of some of the nascent species, because many species move quickly into other vegetation and become lost.

There may be different fly species under the remains in contrast to those feeding on the uppermost surface of the body. Have the photographer ready to obtain close-up exposures of these fast movers, because the photos taken may be the only record of their occurrence at the scene (Figure 30.8).



FIGURE 30.7 Dead pig with flies and eggs.

(From N. Haskell.)

TIP:

It is necessary for photographers to adjust their shutter speed or use a flash while maintaining proper exposure with the lens aperture or the ISO when photographing fast-moving insects.

d. Searching in the surrounding area when the remains have been removed can yield additional evidence found in the plant material and detritus from under and in close proximity to where the body had lain.

This is where some scraping and digging can be used in conjunction with sieves of different-sized wire screening. By sifting through sieves, many additional specimens can be discovered. When excavating an old surface deposit or when removing a buried body, the sifting causes most immature insects and maturely developed adult insects to be recovered. Close-up and macrophotos may reveal insects large enough to make a positive identification (Figure 30.9).



FIGURE 30.8 An example of a fast-moving carrion beetle (order: Coleoptera, family: Silphidae) associated with remains.

(From L. Higley.)

e. In forensic entomology, searching at distances from the remains is a very important necessity and may range out from 3 feet to 100 yards or more. This is because in most blow fly species' life cycles (Calliphoridae), they will leave their food source and move off and away from the food, going into the migratory or post-feeding larval stage. Obtaining records of migration by photographs, sketches, and videos, with stated distances and compass headings, provides the stories of additional hours and sometimes days in the flies' life cycles (Figure 30.10).
f. Although documenting details on a body, like wounds and bruising, is sometimes thought to be the responsibility of the forensic pathologist, photographs of this evidence can be of crucial importance for entomological interpretations too. For example, Figure 30.11 shows lesions on a body initially misinterpreted as symptoms of a bacterial infection.

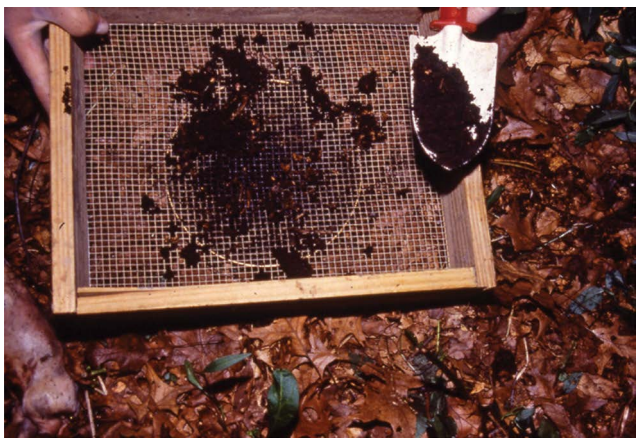


FIGURE 30.9 Sieving soil for recovery of larvae, pupae, insect fragments, and empty puparia.

(From N. Haskell.)



FIGURE 30.10 Migration of maggots off body at Anthropology Research Facility.

(From N. Haskell.)

However, when I saw this photograph, I immediately knew there was a different cause. This is a typical pattern of cockroach feeding on human skin, and I asked



FIGURE 30.11 Lesions on a 3-year-old child from cockroach feeding.

(Courtesy of Marion Police Department, Indiana.)

the crime scene tech if there were cockroaches. He said, "Hell yes, there were so many cockroaches we didn't even want to get on the floor to collect the evidence." Besides being important for avoiding misinterpretations, cockroach feeding on humans is powerful evidence in severe abuse and neglect cases. Other types of insect feeding, especially from ants, can often be determined using good photographs.

Well-trained CSIs usually do an outstanding job capturing the important details of a scene by using the many state-of-the-art techniques at their disposal. A tech with experience in the recovery of data and the documentation of the exact relationships and interactions between the various items of evidence will do well at the proper processing of a scene. There are special needs for photography in entomological recovery, but they are not out of line with the specific needs necessary in normal crime scene photography. The special techniques can be learned best when working with an experienced forensic entomologist. They look for very small bits of partial insects or whole insects (both can be very important in some cases). Also, noninsect evidence, which can be small and mixed in the fluids purged from a body, are often found by the entomologist at a scene. These types of evidence will have a bearing on the investigation.

An early case from the late 1980s illustrates this point. A man was shot three times with a small-caliber handgun in a house on the north side of Indianapolis. The projectiles were damaged, so it was impossible to match them to each other or a specific firearm. The police had a suspect in custody, but no match of the gun to the killing. My team went to Indianapolis about a week after the scene had been released because we were learning about what a forensic pathologist examines during autopsies. We were discussing the current murder and requested a look in the house.

The dead man had been found on the linoleum tile (about 12′ × 12′) covering the kitchen floor. The crime scene tech unsealed the house, and we entered the dwelling. Normally, once a scene is released, chain of custody of the scene is broken. However, in this case there was at least a 1" depth of decompositional, purged fluid covering the entire kitchen floor. The last tech out of the house entered first and immediately observed new disturbances present on the floor. My team searched for migrating larvae and puparium, either hatched or unhatched, which could narrow the postmortem interval. We searched along the wall and floor molding because this is where the wandering larvae move when in a confined structure with walls. If the larvae are lucky enough to find the door opening, they will continue until their bodies reach their development threshold, and they will change by halting migration, shortening, and becoming thicker, and the outside exoskeleton will begin to harden. After about 30 hours, they will darken and arrive at the puparial stage. Of course, we found puparium scattered in the goop and around the border of the kitchen walls. One of the team continued to search in the kitchen, and the rest of us moved through the opening into the living room. Suddenly, the person in the kitchen gave a yell. We all dashed into the kitchen to see what was happening. On the far side of the kitchen she was kneeling and picking up a few very small cylinders (three empty .22-caliber shell cases), which contained the firing pin striker marks. Once we returned to the crime lab, the firearms examiner was able to confirm these cases had been fired through the subject firearm. By digging through stinking decomposing material, the entomologist may find additional evidence. They often recover additional items if able to enter the scene. When the FE cannot gain access, they must rely on others' photographs to help tell the story.

BLOW FLIES' AND OTHER INSECT GROUPS' DEVELOPMENT AND LIFE CYCLES

When a vertebrate organism (and even some invertebrates) dies, decomposition begins during the first second after death. Obviously, during cold weather this phenomenon is altered considerably by freezing of the remains; thus, changes take place more slowly. During a normal weather period (70° F to 100° F), insect attraction is in an optimum range, and it can be assumed adult insects (blow flies) will be attracted to the odors given off by the progression of decomposition and are usually expected within the first hour. However, a number of situations can alter the events and change how quickly or slowly insect colonization will take place, including but not limited to if the remains are:

- Tightly covered
- Buried
- Enclosed
- In darkness

These situations should be verified and given by the crime tech to the FE.

Upon the commission of egg deposition, odors from the female blow flies will attract more female blow flies, and soon there will be a large number of female flies at the food source. Within a three- to six-hour period, tens of thousands of eggs may be deposited. It should be noted that even with optimum temperatures, egg laying has not been seen during nighttime (unless by a streetlight) except on one occasion (a case from Chicago). Thus, a person can be murdered during darkness, but fly colonization will not be seen until after sunrise the following morning. Female flies will continue to fly in and place their eggs in masses for additional days following the subject death. Once the attractive odor production ends, the blow flies will reduce in numbers and other insect species will take over, establishing their new colonies due to biochemical changes in the decomposition odor progression.

THE BLOW FLY LIFE CYCLE

egg
first-stage larvae
second-stage larvae
third-stage feeding larvae
third-stage post-feeding larvae
puparia
newly hatched adults (male and female)

See Figure 30.12 for more details.

The eggs will incubate for a number of hours to a few days (depending on species and temperatures) and then hatch and become first-stage larvae. Upon hatching, they will range in size from about 1.5 mm to 3.0 mm depending on the species. Green bottle flies and screwworm flies, both within the blow fly family, are smaller than members of the blue blow fly group. In addition, the green bottle flies and screwworm flies are known as warm weather flies, while the blue bottle flies are known as cool or cold weather flies.

If ambient temperatures are above ca. 60° F for the period of time in question, the warm weather flies will usually be the species present. If temperatures are 55° F or below, the blue bottle flies should be found in most abundance. However, several species can be present in combination. Of course, a number of variables can alter this sequence, particularly if large ranges of temperature are occurring day to day during the decomposition progression.

Again, depending on temperatures, the first-stage larvae will grow and develop into second-stage larvae in two days or more. These larvae will end the second stage very quickly (18 to 36 hours) if temperatures are in the optimum ranges and more slowly if temperatures are lower. Their sizes will range from ca. 5.0 mm to 7.5 mm if supplied with an abundance of tissue to feed upon, but can be shorter if supplies of food are not fully available. The life cycle can also be completed during times when food is limited. This applies through the three feeding stages. However, if the maggots have developed into the migration phase or the puparial stage, they will complete their life cycles without further feeding.

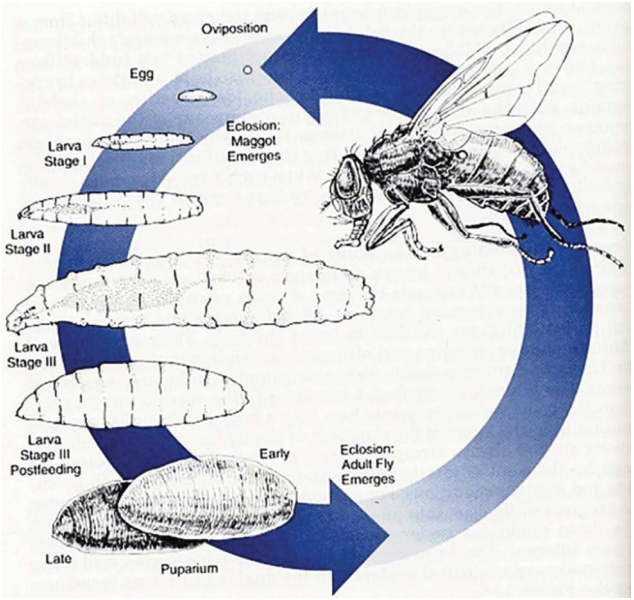


FIGURE 30.12 Typical blowfly (order: Diptera, family, Calliphoridae) life cycle.

(From Haskell and Williams 2008.)



FIGURE 30.13 Pig 10 minutes postmortem.

(From N. Haskell.)

The third stage of the life cycle is where masses of soft tissue are removed from the dead carcass. In Figures 30.13 to 30.17, it was very warm, temperatures in the 90s, and shaded by the overstory of trees in a wood lot.

These four photographs were taken at approximately 24-hour intervals. Figure 30.13 was taken 10 minutes after death. Figure 30.14 was taken ca. 24 hours after death.

Notice that even the first photo shows a few adult blow flies, while the photo at 24 hours shows tens of thousands of unhatched eggs and eggs that had hatched, and the maggots have moved to the eyes, nose, and mouth to feed on



FIGURE 30.14 Pig 24 hours postmortem.

(From N. Haskell.)



FIGURE 30.15 Pig 48 hours postmortem.

(From N. Haskell.)



FIGURE 30.17 Pig 96 hours postmortem.

(From N. Haskell.)

epithelial tissues in the nasal, visual, and oral cavities. These early larvae do not feed deeply but stay superficially on the outer layer of the epithelial tissues. The 48-hour photos (Figure 30.15) depict little change in the carcass.

Even though bloating is occurring, the smaller and larger larvae, second-stage larvae, are maturing and new eggs are still being laid. In Figure 30.16 (72 hours), the most larvae are in the third stage and, due to shading, show maggots totally covering the pig carcass.

This large quantity of larvae was totally unexpected, and I sat observing them for several hours. You could actually watch the tissue disappearing. When the maggots came to a bone, they fed around the bone until it became loosened and then as a group they move the bone off to the side of the carcass.

The next day (day 4), again at the 24-hour interval, the maggots had removed most of the soft tissue and moved away from the food source at anywhere from 2 to 3 feet out into the leaf detritus and up to 25 feet or more (Figure 30.17).

In this pig experiment, dispersion appeared to be somewhat uniform. However, in cases where there is a slope or stones or a barrier, they tend to take the least obstructed route away from the food.



FIGURE 30.16 Pig 72 hours postmortem.

(From N. Haskell.)

During this migration phase, they move away from the source of food and search for soft earth or other nonrestrictive materials to find a place where they are protected from the elements and disguised from predators. They burrow down to between one and two inches. This is when they will move into the puparial stage and are totally defenseless. This is also where the major change of form, or metamorphosis, takes place. The maggots will not move again until they hatch out of the puparia as adults. They will take a couple of hours to dry while their outer covering is hardening and then move off to find their first meal of carbohydrates and protein. The males and females will require about four days to mature sexually, and then they go off in search of new carrion. After mating and egg development, they get ready to lay the next generation of eggs.

The pig in Figure 30.13 initially weighted ca. 50 pounds, and it is not until the third photo (Figure 30.16) that ca. 200,000 larvae are present. By day four (Figure 30.17), the maggots have completed their feeding and moved away from the carcass, and within 96 hours, the pig has lost 32 pounds of total soft tissue weight. Only bones and dried skin remained. The conditions are now ready for other flies and beetles to move onto the carcass and continue to feed on this biochemically changed food source. Often, adult beetles can be identified in photographs if the photos are clear and the close-up capabilities are sufficient. Note that the timing of these events depends upon temperature, and at lower temperatures, the sequence could be grossly extended.

The life cycle described here applies to the taxonomic group, Family Calliphoridae, the blow flies. Most other fly taxa found on carrion will demonstrate the nonfeeding egg stage, three feeding stages, the migration phase, and the puparial stages. While the sizes will vary among the species, ca. 2.5 mm up to 20 mm, most of these different stages are present and can be found during decomposition as the biochemistry of the corpse changes with the stages of

decomposition. There are usually exceptions to the standard life cycles. Flesh flies (Sarcophagidae) directly deposit larvae on the corpse and skip the egg-laying stage by holding the eggs in their abdomens until they hatch. This reduces predation because the larvae are mobile and can move away from threats quickly.

There are a number of beetles and a few other insects possibly found associated with a decomposing body. These insects, including the fly groups, will behave differently under differing environments. Therefore, get in close to the insect evidence to capture the desired photos.

Often, when specimens are not collected, or even if they are collected, photographing what is found can be the key to essential questions needing answers in court. In a case from White Plains, New York, the insects were properly collected and preserved. The majority of flies were from two groups of very tiny fly species (the coffin fly, Phoridae family, and sepsid flies, Sepsidae family). This was the first case in New York where a caregiver (the son) was going to be charged with murder under the statutes instead of merely with lack of care of the victim. The victim died from dehydration, malnutrition, and lack of hygienic care. The invalid elderly woman was dead on her couch, covered with a blanket. Under the blanket tens of thousands of multiple puparia, dead hatched adults, and a variety of different-sized larvae were discovered. This death had taken many days for all of these different life stages to grow, mature, and then fly off the victim. For part of the time she had been in this position, she had literally been eaten alive. Multiple life cycles were involved, from tiny flies to new life cycles continuing to develop. The treatment of the victim demanded harsher punishment than a misdemeanor for improperly caring for a family member.

All we really needed to do was show the photographs to the jury and the trial would be over. However, the judge ruled the photos were so horrible they could not be shown to the jury because of the major bias the photos would raise. I was one of the last witnesses to testify, and we had been given an opening to enter the photos of the very high numbers of the multiple life cycles of flies and other insect groups on the victim and the blanket. I was on direct questioning for about 90 minutes. I described the combination of urine, feces, old insect specimens, and new ones still feeding on the decomposing remains. The defense was trying to make a point that there were only a few little larvae feeding in a small lesion on her thigh. The photo was taken while at autopsy, and the victim was cleaned up with most of the insect specimens washed off. I responded to his question of my overstating the infestation with, "No, no, no, I have photos showing the full extent of the infestation." The prosecutor jumped on the question by offering all the photos previously suppressed from the jury. The jury audibly gasped upon seeing these horrible photos from the crime scene. Had the defense attorney been a little more cautious and not tried to minimize the facts, the jury would never have viewed the photos.



FIGURE 30.18 Dead phorid flies (order: Diptera, family: Phoridae) collected from the death scene.

(From N. Haskell.)

I had the insect collection, the necessary temperature data, and multiple specimens properly preserved, but had we not had the photographs depicting what was occurring at the scene, we may not have had enough evidence to obtain a conviction for murder. I was not able to retain the scene photos, but I did take photos of the hatched-out and dead flies found on the floor and on the blanket (Figure 30.18)

In yet another case very early in my career, photographs were extremely helpful in the total time interval of the case. A middle-aged man had committed suicide inside his car in a closed garage. It was during the summer, and temperatures were hot (highs in the 90s to lows in the mid-70s). The larvae and other insects were collected properly and sent to my lab. Photos were to come in a couple of days with other documentation regarding the case. I had worked up the postmortem interval (PMI) by using mature third-stage larvae collected from the body and surrounding area.

When the additional photos and documentation finally arrived (Figure 30.19), I was surprised to observe photos taken from the accumulated trash on the floor of the back seat.



FIGURE 30.19 Photos of blow fly puparia along the bottom of the door panel inside the victim's car.

(Courtesy of Ft. Wayne Police Department, Indiana.)

The crime techs were documenting anything possibly relevant to the scene and details pertaining to the suicide. Photographed was a sack of empty beer cans and other trash on the floor of the auto. What was also recorded were a number of little football-shaped, small, hard, round-ended cylindrical objects ca. 1.50 mm to 2.5 mm in width and about 6.5 mm to 7.5 mm in length that could have been mistaken for little plant seeds. They were reddish to brownish in color, with several visual segments. Given the temperatures and the large larvae, I had concluded the body had been dead for about three to five days. After seeing these puparia present, I expanded the original PMI out to five to seven days postmortem.

Often, the puparia are not recognized as part of the stages of the insect's life cycle and are not collected, but often end up seen in the photographs. These puparia were actually large when compared to other puparium, such as the coffin flies (Phoridae) and other tiny carrion colonizing species from the group Diptera (all flies) and many small beetles from the order Coleoptera. By knowing puparia were present, and thus expanding the time since death, a more reliable time of death could be concluded.

These types of mistakes are understandable for those who have never been to a qualified maggot school. Once one has witnessed a huge maggot mass on decomposing carrion and the mounds of puparia eventually developing from a source of carrion, they will not overlook these different life stages again.

DISTINGUISHING INSECTS FROM NONINSECTS: THE DUST BUNNY CASE

As stated earlier, crime scene photographs are always informative for the work of an FE, even when actual insects have also been collected from a scene. For example, the locations and densities of insects are crucial for associating insects with a body and for distinguishing insects of potential or no forensic importance. So, it is not surprising that when insects are not collected at a scene, the photographs of the insects are of utmost importance. What may be less obvious is that when insects or certain insect stages are not at a scene, photographs can be equally important.

One of us (Higley) testified for the prosecution in a capital murder case in which the defendant had an alibi (being in jail) for some days after the victim was last seen alive. Thus, the PMI was crucial. Unfortunately, although the murder scene was identified as the victim's home and some maggots were collected, the body had been moved to a forest sometime after death and was not found. Nevertheless, it was possible to estimate the PMI from the maggots collected, indicating the murder occurred outside the time frame of the defendant's alibi.

In response, the defense claimed one of the crime scene photographs (Figure 30.20) showed an uncollected fly puparium.[1]



FIGURE 30.20 Crime scene photograph showing purported "puparium" at the top of the image.

(Courtesy of Emily Ortolano, Lake County Sheriff's Department, Florida.)

If the image did show a blow fly puparium, it could suggest an earlier time of death and would exonerate the defendant.

Two issues were pertinent here: first, if the image did show a puparium, was there any evidence to link it to the location of the body; and second, did the image actually show a puparium? The first point is important: not all insects collected at a scene or in a house are likely to be of forensic importance. Thus, photography establishing the location of the sample relative to the body is crucial. In this instance the purported "puparium" was in the track of a sliding door, distant from the location of other insect samples and the presumed murder site. Ordinarily, this distance would preclude the "puparium" as being of significance, but the defense argued it was near a location where the body was moved and might have fallen off the body. So, the location of the "puparium" was subject to interpretation.

Consequently, the second issue: did the image actually show a puparium, became crucial. A blow fly puparium is barrel-shaped and dark-colored and has distinct lines around its circumference (the segment lines of the maggot from which the puparium is formed). Given the resolution of the crime scene photograph, it was impossible to see details confirming this was an insect puparium. However, it WAS possible to confirm it could not be a puparium. How? By increasing the magnification of the item to the level of individual pixels (Figure 30.21), it was possible to see the colors and edge pattern of the item in question.

Both variations in color of the pixels and the uneven edges of this item were completely inconsistent with how an actual insect puparium would look at this level of magnification (which would have uniform coloration and a distinctly sharp edge). With these observations, the obvious conclusion was that a dust bunny is not an insect puparium.



FIGURE 30.21 Magnification (700%) of "puparium" in Figure 30.20 showing irregular coloration and uneven edges demonstrating this is not a puparium.

(Courtesy of Emily Ortolano, Lake County Sheriff's Department, Florida.)

USING SCALES IN CRIME SCENE PHOTOGRAPHS

It is very important to have reference points when mapping out the scene. Therefore, when making a scaled drawing of a scene, make sure to have a stationary starting point. If inside a dwelling or building, pick a corner and take measurements from a datum point somewhere in the confines of the room or rooms. The coordinate method is another option when measuring and mapping indoor scenes. If you are processing a case with outside components, use a tree, a utility pole, rocks, or other well-placed and stationary reference points. Often, utility structures will have numbers or letters on them referencing that particular building, pole, or other structure. In instances where there are no structures or stationary reference points, investigators could create their own datum point utilizing a metal surveyor spike or by pounding a piece of rebar into the ground. After establishing the datum location, the investigators should obtain global positioning system (GPS) coordinates for the datum location in the event there is a need to return to the scene and locate the datum. Remember to take initial photos without a scale and then take additional photos including the scale. This is to prevent the defense from stating your scale in the photo is covering some item of evidence.

It is possible several hours may pass before the FE has clearance to enter the scene. Use this time to question investigators not at the scene at present in order to learn as much as possible about the body, the environment, and the overall aspects of the scene. The crime techs will be measuring; estimating compass directions; and documenting temperatures, wind speed and direction, and distances from other structures or other stationary objects.

TIP:

It is amazing how fast time passes when you are busy collecting data.

When permission is granted to enter the scene itself, advise the team member in charge of the scene as to your exact needs for searching and your methods. These may be crucial to the collection of the necessary specimens. The basic procedures are enumerated in other texts, so review them elsewhere. Inform the photographer what you need for documentation of the bugs. It is preferable to slowly move into the scene to observe if any insects are moving away from the food source. They may have begun migration by that point, and having photos of that stage will help determine the correct time interval for the case.

Many times in case photographs, a scale is not present in any of the images. This may be rectified partially by measuring unique items in the scene to determine the relationship in size of the insects to a known-sized object. If the known-size object is unique to the scene, do not forget to collect that object with the rest of the evidence. If the known-size object is a floor tile, a piece of molding, or another object attached to the scene, make images of a scale with the object being measured, even if it is necessary to return to the scene afterwards to capture the necessary images. With close-up exposures, I have used the total length of an average human canine tooth, the average width of a nasal opening, the width of a normal eye socket (observed from individuals in the images, if possible), or even a coin in the photo to scale the images. If the photographer used a zoom lens to capture the images, it should be obvious by judging the size of the same object in two or more photos. If this is the case, the known-size image scaling technique is no longer valid. It needs an image postprocessing specialist to either reduce or enlarge some of the images to the scale of the one image chosen to be the standard. A specialist may also revolve an angular image around its axis to transform the photo into a directly perpendicular position and then scale it with the standard image from the case. Though there are alternative methods to provide scale, the best method is always to place on-scene a known manufacturer millimeter disposable scale into several images exposed at the same magnification.

TIP:

Always remember to use the scale in a photo and then take additional photos without the scale. YOU CAN NEVER TAKE ENOUGH PHOTOS FROM A CRIME SCENE!

USE MACROPHOTOGRAPHY FOR SPECIFIC GROUPS OF INSECTS OR SPECIFIC INDIVIDUAL SPECIMENS

When documenting the specific areas of colonization on the corpse, expose overall images first and then move in closer to mid-range exposures with a sequence of alternating angle exposures while coming closer to the insect mass or individual you are documenting and/or capturing in the field. When perpendicular close-up exposures have been exposed, repeat the same sequence from a side angle.

This is because the high-contrast lighting from a flash may cause shadows and highlights to either obscure or reveal additional items of evidence that could be lost in available-light images.

When working cases in full or partial sunlight, it is often necessary to use electronic flash for fill lighting. In one example, the crime techs were documenting a body resting beside a car. It was a bright sunny day, but the area next to the car was well shaded. One of the techs prepared to photograph under the car. The tech attached his flash to the camera, while some of the other techs at the scene harassed him about using a flash on the camera during a bright sunny day. He ignored them because he had just returned from a photographic workshop where he had learned about using flash for fill when it is very bright outside and exposing images in shadows or heavily shaded areas. Guess what? Even though you couldn't see the items under the car in normal light, a screwdriver and gloves were shown in the photos because of the flash attachment.

When closing in on a maggot mass (Figure 30.22), obtain photographs straight on and at an angle, as discussed earlier.

If different individual specimens stand out, take a number of exposures of the interesting specimen. Most crime scene techs think a maggot is a maggot. However, there can be some maggots involved from a totally different species. They may not behave in the same manner as the rest of the maggots. Capture images of different maggots doing different things. Some may still be feeding while others are preparing to leave the food source and crawl away. A situation like this can either indicate a second species is present or more than two hatches are being deposited over two or more days. Multiple insect clutches are not different generations, but indicate an additional time when a female fly has deposited new eggs on the food—usually two to four days will span this interval. It is possible these different specimens may not be collected. Without the photos documenting the different individuals exhibiting different behavior, there would be no evidence to support the observation. This difference could indicate from one to three days of differing maturity.



FIGURE 30.22 Maggot mass on a pig.

(From L. Higley.)



FIGURE 30.23 Maggot mass on murder victim.

(From L. Higley.)

Figure 30.23 illustrates the variety of information possible to discern from photographs of maggot masses on a body. Here, the pattern of maggot mass location initially seems normal, from the head to the torso. Because blow flies only lay eggs at openings in a body, usually maggots are associated with the head, which has seven openings (two ears, two eyes, two nares, and one mouth). That is true in Figure 30.23, but there also are maggot masses in unexpected locations—off the body and in a small patch on the torso. The maggots on the torso reflect an opening, in this case a knife wound, which is a potential cause of death. The unusually large group of maggots beside the body also is an indicator of cause of death: multiple stab wounds on the back of the victim caused blood and decompositional fluid to pool beside the victim.

As the larvae grow and become more mature, they shorten a few millimeters and increase their girth. A few extra days may separate the feeding versus the migration phase, which would alter the ages of the larvae greatly. Always make a point to capture images with sufficient depth of field to sharply document the majority of the individual insects. If there is a line of maggots migrating, following one another, photograph the leading edge of the migration and measure how far away from the food source it is and what compass direction it is taking. Collect a sample of specimens (both alive and dead) and submit them as a properly labeled sample.

These migration trails may extend tens, if not hundreds, of feet from the food source (see Figure 30.24).

Follow the trail by documenting it with photos, and collect specimens until the farthest point of the migration away from the carcass is reached. Dig down a few inches too, as the larvae will not burrow down more than three inches. If not collecting specimens, you can dig down through this shallow layer of soil and photograph the puparia with a scale in the photo for accurate measurements of their size. If collecting these specimens, collect them dry and place them in a maggot motel (Figure 30.25) and keep them at around 70° F.



FIGURE 30.24 Maggot migration up a tree. Maggots are not supposed to climb trees, but these never read the book!

(From N. Haskell.)

Record the time and date and observe the insects morning and evening. At the end of their puparial stage they will hatch into adult specimens. You now have specimens that can be identified in terms of species and the total time (or energy) needed to bring them to full development. You may want to photograph their hatching with date and time on the photographs. Once they have hatched, the tech can photograph through a binocular dissecting microscope the definitive characteristics of that particular species. If the reared specimens are not blow flies, the specific species can be determined and the appropriate data growth table for that species consulted. The table shows the different time limits for a number of species recorded for further case work. This adds to the accuracy of the overall data expansion. There can be a difference in comparative data sets, allowing for the extent in the manner and range of data found under a specific experimental data set. The individual researcher will need to make the decision about which data set they prefer to follow.

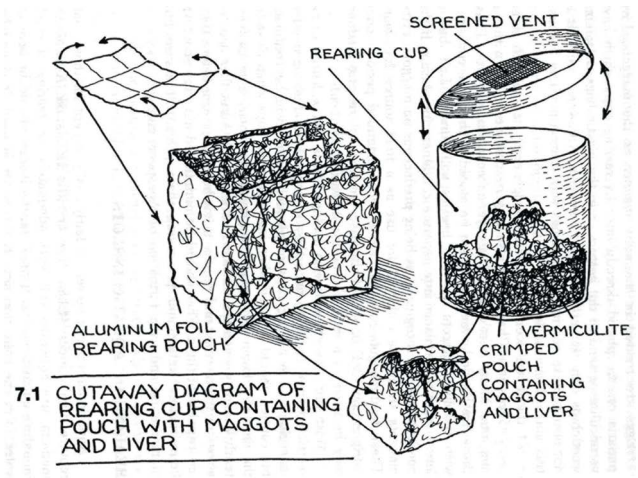


FIGURE 30.25 Maggot motel. A maggot motel is nothing more than a manmade environment in which the immature insects will be content to continue their development into adult insects. A motel may be an old Styrofoam or plastic cup with a lid. Sand, soil, or detritus make a decent layer between the plastic or Styrofoam and the insects. Place an appropriate animal food source contained and closed on a large piece of aluminum foil inside the motel. Collect some of the immature insects in question and place them into the enclosure with the food. Close the foil around the food and insects and wait until they have developed from pupae into adults. Once the insects are adults, they may be collected and identified.

(From Haskell and Williams 2008.)



FIGURE 30.26 Dr. Huntington moving in a culvert following potential blow fly migration and the high-water line from a heavy rainfall the previous fall.

(From L. Higley.)

The importance of looking for and photographing evidence of migrating maggots is illustrated by a death investigation Higley and his graduate student Dr. Tim Huntington conducted. The body of a 26-year-old woman was found in the remains stage (bones and dry tissue) at the side of a country road, approximately nine months after her disappearance in the fall. No insects were found with the body. We went to the scene and looked for possible locations where migrating maggots might have gone to pupate. There were trees on the opposite side of the road and a dry culvert under the road. Tim crawled in, noticed a high-water line (Figure 30.26), and on the other side found part of a blow fly puparium (Figure 30.27) fixed above the water mark.



FIGURE 30.27 Blow fly puparium on wall by a culvert, above the water line, 28 feet from the location of the victim.

(From L. Higley.)

After reviewing weather data,[2] we found there was only one heavy rainfall in the previous fall, about one week after the victim's disappearance. Consequently, we could reliably conclude the victim was killed within a day of her disappearance, given that blow flies from her body had migrated only a week after she vanished.

DOCUMENTING SPECIFIC TEMPERATURES WHEN INVESTIGATING INDOOR CASES

The documentation of temperatures within confined structures, including for example, rock cuts in cliff faces, inside culverts (larger—from two to six feet), and other situations where there are barriers to air circulation, present a problem for temperature estimation. Make sure you note whether an air conditioner (AC) is/was running and cooling the space. If the AC is on, take a photograph of the thermostat as soon as the tech enters the structure. This is going to be nasty to your senses but obtain this temperature before doors or windows are opened to hopefully reduce the overpowering smell. This will provide a known temperature, which will then coincide with what the remains experienced. At colder times of year, check to see if there is heating on and where the thermostat is set and what temperature is stable in the confines of the room, house, or other structure. Temperatures inside structures have a tendency to reach a stable range. On warm days, the highs of the day will be considerably lower than the ambient temperature outside. Likewise, on colder days, the daily lows will be higher than the outside temperature. It is important to record the temperature, by photograph, throughout the day to track the influence of the heating or cooling within the dwelling where the remains have lain.

Obtain the readings at ca. four to five feet above the flooring where the victim was located. Under some circumstances, it may be necessary to query the local weather station nearby to supply historic temperatures recorded during the days in question near the scene. Crime scene texts explain how anyone performs this procedure. In short, at a given time and date, soon after the remains are recovered, ask the National Weather Service about the hourly temperature at the specific date and time and for the days before, back to the estimated interval. At the same time, document using an accurate and calibrated thermometer the reading at the scene about 6 inches above where the remains were found. Next, run a graph of the Weather Service temperature on the X-axis against the scene temperature on the Y-axis. This will show if there are differences in temperature on the X-axis with regression on the Y-axis. A regression is normally used to understand the relationship between several data inputs and one data output. This Y-axis will provide a slope of the regression line, and a formula may be calculated. Once you have the equation to the line, you substitute in the X value to the equation and solve for Y. With this equation, you can create a total database of temperatures using the X-axis to calculate what the temperature of the scene (Y) actually was with regard to the X value. There are other ways of evaluating the X to the Y slopes, but this method (which should be left to the FE) is sound and will provide what is necessary for the calculation of energy units needed to reach a specific larvae age.

PRESENTING THE PHOTOGRAPHIC AND TABULAR EVIDENCE IN COURT

When it is time to testify, either in deposition or in court, it is critical to learn if you are going in opposed by testimony from another FE. Often, you are going to be the only expert witness in the area of forensic entomology. This can be deceptive in nature from the opposition, not knowing if the other side has actually contacted another entomologist to aid in your examination. You will probably be advised someone is assisting on the other side but is not listed as a witness. In other circumstances, the opposition will not even have a consulting opposition witness, or there will be a designated FE, whom you may know. With any of these situations, it is best to keep things simple. You must point out errors of the opposition to your attorney, usually from his report, hit him in cross-examination with his errors while under oath, or use his publications in cross-examination while on the stand. It is the attorney who will call him to task. You will not have to speak a critical word about the differences of philosophies between the two of you. If the expert has published a quantity of writings in the literature, this can present you with contradictions between earlier writings versus what he is stating 20 years later.

This is where photographs or the computer can be used expeditiously—when you throw his thoughts from a decade earlier against what he is stating today. There are several FEs who have totally changed their philosophies over the years, and this may help to impeach the opposition witness. Using photographs from the other expert's books or other published sources, it can be fun when you have their old text supporting the position your side is suggesting now and the position of the expert has totally changed over the years (of course, without justification).

In a case from Coeur d'Alene, Idaho, a female torso was found floating with legs and feet on a slight incline of sand along the shore (Figure 30.28).

The torso was floating about 6 inches out of the water. I had worked with these techs for over a decade, and they knew the drill. Once the documents arrived, I called the lead technician and asked him when the insect evidence was coming. He said there were only tiny maggots, so he decided not to collect then. I asked him if he was "nuts"; he said "more stupid than nuts." He kept apologizing and I said, "OK, I forgive you this once," but he had sent several hundred photos, and I thought I could sort it out.

There seemed to be a major confounding issue. The little lake was very shallow and had major clumps of grass across the body of water. The grass was shedding its seeds, and they were all over the place (Figure 30.29).

They looked like midsized larvae and were floating on the water's surface. He had also photographed the areas



FIGURE 30.28 Death scene in shallow lake near Coeur d'Alene, Idaho, with the body partially in water and surrounded grasses shedding seeds.

(Courtesy of Kootenai County Sheriff's Department, Idaho.)

(the chaffing) where the perpetrator had bound her ankles together (Figure 30.30).

He had also taken many photographs chronologically, so I concentrated on the larvae actually making headway in the water. These were very small larvae, still in the first stage. After much study, I found no larvae larger than late first stage. There were a small amount of eggs and larvae up on her left shoulder (Figure 30.31)

I had the opportunity to explain to the two prosecutors with whom I was working that I could narrow down the species to about three or four possibilities and all four species were fairly close in their development times. This made an estimate of the PMI readily reliable. Once my report had been reviewed by the opposition's forensic entomology expert, he wrote a three-page report refuting all my conclusions and their rationale. The opening of his report stated there were 33 species of blow flies in Idaho and it was impossible to determine any 4 as being the most likely. He also stated any entomologist could, through deductive reasoning, come up with three



FIGURE 30.29 Grass seeds resembling maggots, floating in lake.

(Courtesy of Kootenai County Sheriff's Department, Idaho.)



FIGURE 30.30 Victim ankle ligature.

(Courtesy of Kootenai County Sheriff's Department, Idaho).

or four species that would be present in Coeur d'Alene, Idaho, and this had never been used in any case in North America. One of my opposition's last sentences was "Dr. Haskell's conclusions were merely the guesswork of a vivid imagination and thus only the speculations of an inventive mind." My two prosecutors really didn't like the opposition doctor's reasoning. Thus, we started off on a funny and challenging course of counteracting, digging through the literature, and a thought process of taking down the opposing expert.

The murder victim was found during the second week in June. The investigator was feeling badly about not collecting the specimens, as proved by him apologizing every time I talked to him. I finally convinced him he had done such a great job photographing the scene that it was all going to be fine. A fact by which the opposing FE had done me a favor, sending me a 2009 paper about which species of



FIGURE 30.31 Victim's neck and left shoulder with blow fly egg masses (center of image) and first-stage maggots visible. In contrast, the bottom of the image shows grass seeds that can be confused with maggots.

(Courtesy of Kootenai County Sheriff's Department, Idaho.)

blow flies were found in Idaho. This saved me a lot of extra work. Also, I consulted the hourly temperature data from Coeur d'Alene for the period in question and calculated the energy units for the flies found during this time of year and the period of time in the case (late springtime, which was critical). I began going through the list of species, eliminating those species that would not be found on humans or present when temperatures were in the 80° F range.

What I found was very detailed data for species occurrences:

1. Thirteen species only colonized nestling birds.
2. Eight species fed and ate earthworms.
3. There was one species with only adults found on golden eagles.
4. Six species were cold weather blow flies not found this time of year.
5. One species didn't show up until October.
6. Five species were present during this time of year. All five species had very similar developmental times, with one of these not being found until late in the season (September).

One more thing—I had just completed a maggot school at the end of May and into June of that year, 20 miles east of Spokane, Washington, which is 25 miles west of Coeur d'Alene. I knew exactly which species would be there.

I asked my attorneys to do a literature research, and they found an interesting citation. There was a multipage article about how you can actually determine species from a photograph—authored by none other than my opposing forensic entomologist. My attorney was really annoyed by the fact that the opposing expert had actually lied in his report regarding this case. We worked on our line of cross-examination and were going to put his feet to the fire. Two days before I was to board a plane from Chicago to Spokane, the defendant decided to settle with a plea bargain. That saved me from traveling to Coeur d'Alene. Sadly, it does take a long time to reach the West Coast, and I charge for travel time.

Thank God for all the photographs!

STATUS TODAY

In a number of cases the insects are not collected and I am left with only the photographs. This is occurring with more frequency than it did 8 to 10 years ago. This is likely the influence of budget cuts in most police jurisdictions for training in crime scene processing and the pressure of the financial budgets demanding cutting across all criminal justice areas. For the previous 20 years of training, case evaluations, case requests for assistance, and appearances in courts for providing testimony, it was usually the norm to help with the investigation by at least sending the insect(s) for evaluation. Sometimes, this occurred without a report being rendered. Many of my crime techs were regular clients, and this enhanced the quality of collections, gaining additional knowledge of what were forensically important insects and where to find them. As time progressed and the financial downturn hit, previous students retired, moved up in seniority, or died, so my forensic entomology business declined. We now have a new set of crime techs who have never trained in forensic entomology, not knowing what or where to retrieve insect specimens. However, with the upturn in the economy, some police investigators, coroners, prosecutors, defense attorneys, and even judges are requesting initial training in forensic entomology (maggot wrangling). Our team is preparing to meet this renewed interest.

ANSWER TO THE QUESTION IN FIGURES 30.2 AND 30.3

From the Anthropology Research Facility, University of Tennessee. The individual died on July 11 and was placed in a cooler. The body was placed in the field at ARF on July 13. The photo in Figure 30.2 was taken on July 21, 1989, after eight days of exposure. The second photo, Figure 30.3, was taken on August 15, 1989, after 31 days of exposure. So, the photos show a difference of 23 days of exposure with temperatures in the 90s.

NOTES

1. Similar to a cocoon, the puparium is the structure in which the maggot becomes a pupa and later emerges from it as an adult fly.
2. In the US, the National Weather Service or www.weather.gov

REFERENCES

Dutelle, A.W., *Basic Crime Scene Photography*, 2nd Ed, Create Space (Amazon), 2016.

Geberth, V.J., *Practical Homicide Investigation: Tactics, Procedures, and Forensic Techniques*, 5th Ed, Boca Raton, FL, CRC Press, 2015.

Haskell, N., and Williams, R., *Entomology and Death: A Procedural Guide*, 2nd Ed, Clemson, East Park Printing, 2015.

Kelby, S., *The Digital Photography Book: Part 1*. San Francisco, Peachpit Press, 2013.

Mancini, K., and Sidoriak, J. *Fundamentals of Forensic Photography: Practical Techniques for Evidence Documentation on Location and in the Laboratory* (Applications in Scientific Photography). New York, Routledge, 2017.

Northrup, T. *Stunning Digital Photography*. Waterford, CT, Mason Press, 2012.

Redi of Arezzo, F., Mab Bigelow (translation and notes), ed. *Experiments on the Generation of Insects*. Chicago, Open Court, 1668 (1909).

Saferstein, R. *Criminalistics: An Introduction to Forensic Science*, 12th Ed, Boston, Pearson Education, 2017.

Spitz, W.U., and Spitz, D.J. (eds.), *Spitz and Fisher's Medicolegal Investigation of Death: Guidelines for the Application of Pathology to Crime Investigation*, 4th Ed, Springfield, Charles C, Thomas Publisher, 2006.

Supreme Court of Indiana 1990; opinion, *State of Indiana v. Cephis E. Pasco* 563 N.E.2d 587.

Wecht, C.H. (ed.), *Forensic Sciences* (in five volumes), New York, Matthew Bender Elite Products, 1983, with annual revisions through 2018.



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31 Forensic Odontology

Denise Murmann

CONTENTS

Antemortem Records 599
Equipment Needed 599
Digital Camera 599
Electronic Flash 600
ABFO No. 2 Scale 601
Cheek Retractors 601
Dental Photography Mirrors 601
Types of Resection 602
Photographs That Should Be Made 602
Back Up Your Data 602

The word "forensic" is often used but rarely understood. It means "having to do with a court of law." So, by definition, forensic dentistry is the application of dental knowledge to legal matters. There are a few areas that fall under the auspices of forensic odontology: human identification, age assessment, bite-mark evaluation, human abuse, and civil/malpractice cases. The most common usage area of this forensic science is human identification, which is what we will discuss here. The legal end result we are working toward is a death certificate. The decedent's burial, the awarding of life insurance to the survivors, and closure for the family are all dependent upon this legal document. It is not the forensic dentist that makes the identification, but the coroner or medical examiner. The forensic dentist gives their opinion in a report the coroner or medical examiner uses with other reports and evidence to make their final conclusion.

Photography and radiography (x-rays) are the two main tools used in dental identification. They document the decedent in an objective and scientific way. Photographs document the teeth present—they can capture what fillings are present and give details about what materials the restorations are made of. For example, full gold crowns and zirconium crowns look the same on an x-ray but appear very different when photographed (see Figures 31.1 and 31.2).

Additionally, very small composite fillings may be difficult to see during the visual examination with no magnification. However, when photographed in macro, in the close-up view, they may be easier detect and document. X-rays are two-dimensional, so you cannot always tell what surface a filling is on, or even if the filling is there (see the case study later in this chapter). In the x-ray of tooth #30, it looks like there is only one filling because they are superimposed. In the photograph, you can see there are two fillings, where they are located, and what materials they are made of (see Figures 31.3 and 31.4).

In some cases, there are no antemortem (before death) dental records to compare to. In that circumstance, postmortem photographs of the front teeth can be compared to antemortem photographs to make a dental identification.

Documentation is also necessary if the case is to go to court in the future. Five years after the dental postmortem examination, very little may be remembered about a particular case. The photographs will be invaluable to document how you came to your conclusions.

Perhaps most importantly, the remains of the decedent most likely will be unavailable to the forensic odontologist in the future. If buried, it is expensive to have the body exhumed. If cremated, the dental evidence will be gone.

ANTEMORTEM RECORDS

Digital dental records are becoming more standard, including in forensic odontology. Digital x-rays and charts can be emailed by an antemortem dentist to the coroner's/medical examiner's office, which in turn can be sent to the forensic odontologist very quickly. However, we still occasionally receive analog x-rays and paper charts from antemortem dentists. The most efficient way to digitize physical film is to place the x-rays on a view box and make digital copies by capturing macrophotographs of them. Antemortem written records can also be digitized by making photographs of them.

Good photography is critical for dental identification and documentation.

EQUIPMENT NEEDED

Digital Camera

It will need to have:

1. A sensor with at least 8 megapixels to be able to enlarge photos to court display size.
2. Macro setting to zoom in on small details needing to be documented.

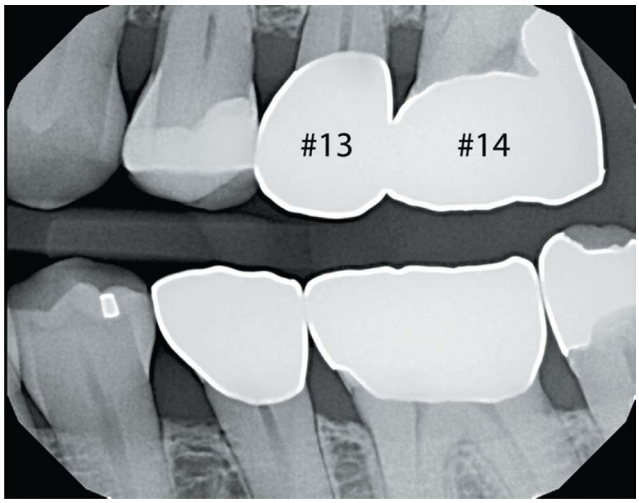


FIGURE 31.1 The upper two back teeth, #13 and #14, both have large restorations that look very similar on the x-ray.

3. An external/interchangeable macro lens. The American Society of Forensic Odontology (ASFO) Manual 5th Ed, page 275, advises an aperture range of *f*/2.8 to *f*/32 and a focal range with continuous focusing capability from 1:1 (life-size) or 1:2 (half life-size) to infinity. Many macro lenses do not focus to 1:1 without extension tubes or some other physical device but that does not render then unusable without the need for adapters.

Helpful additions:

1. Hot shoe for external flash attachment
2. Moveable liquid crystal display (LCD) screen to be able to photograph from a higher position than the line of sight. Without it, you would more often need to climb a ladder to take photographs from above a gurney.
3. Extra batteries for your camera, the external flash, and anything else that might need them.
4. Extra memory cards. Assume something will not work. If you have duplicates, you will save yourself time and embarrassment.



FIGURE 31.2 Photography shows tooth #13 has a zirconia (white ceramic) crown and tooth #14 has a gold crown.

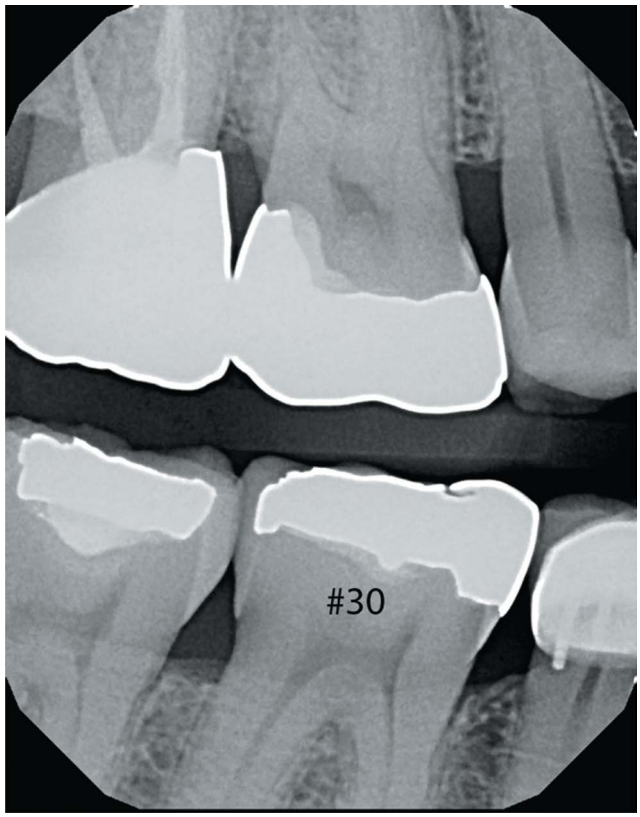


FIGURE 31.3 The lower molar, tooth #30, has restorations, but on the x-ray, it looks like there is only one.

Electronic Flash

A single point integral flash that usually comes built into a camera will do the job, but a ring or dual flash will give more control over the amount and direction of the light, resulting in better photographs. If you get a ring flash, choose one that will allow you to use the right or left side separately, as well as together. No matter what type of flash you use, make sure the teeth are dry when photographing them to avoid reflective areas that will lose detail.



FIGURE 31.4 The photograph shows there are two restorations: a large gold inlay and a small amalgam filling (indicated by the arrow).

ABFO No. 2 Scale

This scale was designed by William Hyzer, an engineer, and Thomas Krauss, a forensic dentist. Krauss was a diplomate of the American Board of Forensic Odontology (ABFO) and this was their second design, thus the name of the scale.

- It is L-shaped to document two directions of measurement.
- It is marked with centimeters and millimeters, with the lines long enough to be used to grid the photograph.
- The legs of the scale are 1 inch (2.54 cm) wide, giving a reference in the imperial system if needed.
- The circular reference shapes allow the determination of angular distortion from when the photograph was made. If the photograph shows an ellipse instead of a circle in that area, the photograph is distorted. This is because the camera was held at an oblique angle in relation to the scale. This can be rectified with the proper software. (See Chapter 12.)
- The scale is 1 mm thick to make it extra rigid and prevent bending and distortion of the scale.
- There are gray areas on the scale with 18% reflectance to be used as a control for the reproduction of color more accurately in the final photograph.
- The black and white bands are 1 cm each and alternate, so if a photograph is overexposed or underexposed, making the small lines invisible, the photograph can still be used to measure in centimeter increments.

The scale is most useful in bite-mark documentation, but in the *ABFO Diplomate Reference Manual*, in the Body Identification Guidelines, Section IV, page 37, it is recommended the ABFO No. 2 scale be used. It makes a convenient site to place the case number and the date in the photographs, as is also recommended.

Cheek Retractors

If the jaws are not resected, cheek retractors will allow for a better view of the teeth, as they will hold the soft tissues back during the examination.

Dental Photography Mirrors

If the jaws are not resected, these mirrors assist with better documentation of the occlusal (chewing) surfaces of the teeth.

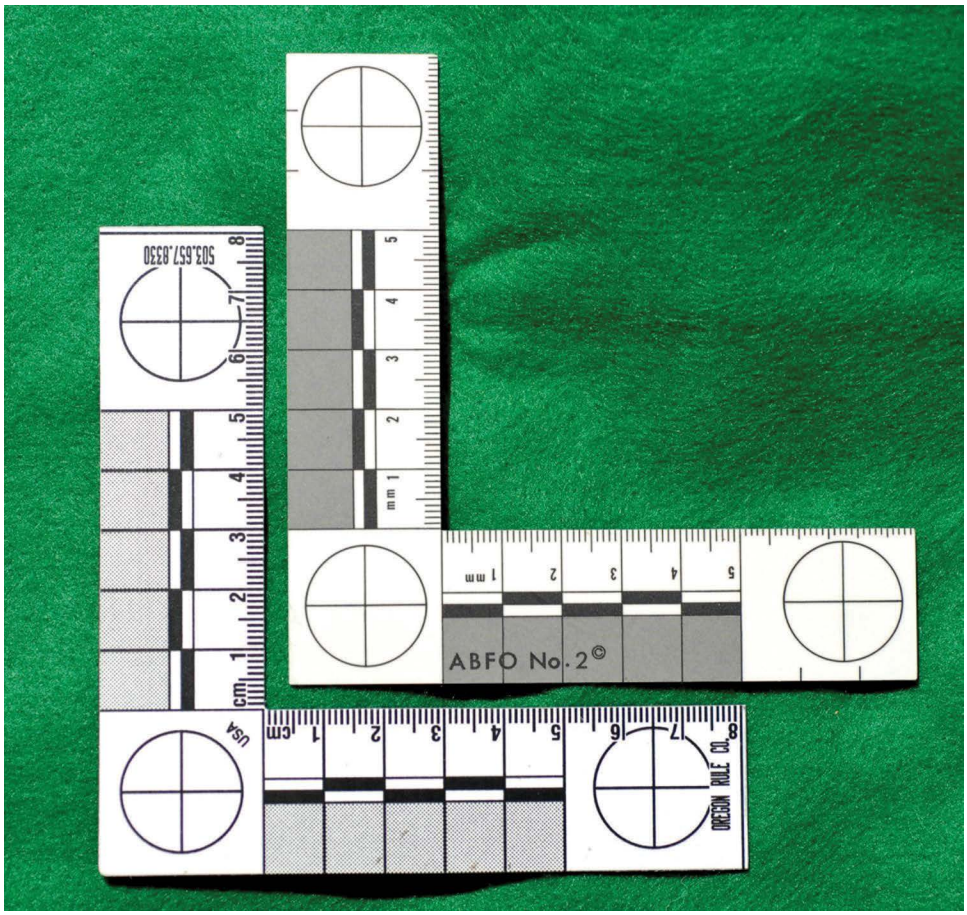


FIGURE 31.5 ABFO No. 2 scale.



FIGURE 31.6 Use of a dental mirror.



FIGURE 31.7 Unusual marks on the lower two front teeth that would need to be documented.

Types of Resection

Resections should never be done without the express permission of the coroner or medical examiner.

No Resection – If the body is intended for viewing. Cheek retractors and dental photography mirrors will be necessary to document the dental structures.

Soft Tissue Resection – Used in multiple fatality incidents (MFIs) where the soft tissue is cut and pulled back to expose the dental structures completely, but no tissue is removed from the body. This eliminates the possibility of any tissue being separated from the body in a disaster situation.

Full Resection – The jaws are completely removed from the body, allowing the dental structures to be more easily documented.

PHOTOGRAPHS THAT SHOULD BE MADE

a. Case packaging/body bag
b. Morgue ID tag
c. Full face
d. Full face with lips retracted (if jaws not resected)
e. Overview of the teeth/jaws (if jaws have been resected)

   Make D and/or E twice: the first time to document the condition of the teeth as you have received them. Make them again after the teeth have been cleaned and dried. Then move on to the close-up photos (F–J)

f. Occlusal (chewing surface) of upper and lower teeth
g. Buccal (cheek side)
   1. Right posterior
   2. Canine area, right
   3. Anterior
   4. Canine area, left
   5. Left posterior
h. Lingual (tongue side)
   1. Right posterior
   2. Canine area, right
   3. Anterior
   4. Canine area, left
   5. Left posterior
i. With jaws in occlusion, if possible. This will be used to compare to other photographs and to document any cross-bites
   1. Right posterior
   2. Canine area, right
   3. Anterior
   4. Canine area, left
   5. Left posterior
j. Special view photographs, which can mimic any antemortem photographs available or document something unusual (see later)

Within all of the photograph categories, make two separate photographs of each view. Refocus each time and do not just take multiple versions of the same photograph. Here, too, duplication will save time and embarrassment. When you review the photographs enlarged on a computer screen, often one photograph will be better than the other. Remember you will most likely not have the opportunity to make the photographs again. This will ensure that what you do have is of evidentiary value.

BACK UP YOUR DATA

Make sure to transfer the photographs from the memory card to a secure computer as soon as possible. Check to make sure all of the photographs transferred successfully. Then delete the photographs from the memory card. Memory cards are small and can be lost. Not only will your data be lost then, but there is the horrifying possibility that someone else will find the card and your photographs who should not have them. Protecting the data protects the privacy of the decedents we serve.

Finally, make sure you back up the data on your secure computer. If the computer crashes, you still will have access to the photographs made. Once again, duplication will save you time and embarrassment.

CASE STUDY 31.1

The skulls of the dinosaur species Tyrannosaurus rex have holes or defects in them. Various theories have been suggested as to their cause, such as a protozoan infection or bite marks. I have had the wonderful opportunity to examine some of these fossils in an ongoing study (thus no results yet) with a group of experts to find out more about the defects. One of the goals of documenting each skull is a three-dimensional digital scan. In addition, documentation of the skulls and the defects was accomplished with photography.



FIGURE 31.8 Overview photograph of the skull of Sue (FMNH PR 2081) at the Field Museum of Natural History in Chicago, with the 3-D scan.



FIGURE 31.9 Mid-range photograph of the left side of the lower jaw of Sue (FMNH PR 2081).



FIGURE 31.10 Close-up of one of the defects on Sue with an ABFO No. 2 scale for reference (FMNH PR 2081).

32 Photography and Forensic Archaeology

Karl Harrison

CONTENTS

The Challenges of Photography in Forensic Archaeology 605
Outdoor Crime Scenes 605
Large-Scale Searches 607
Excavation 607
Photographing into the Grave 607
Visualizing Distinctions between Different Colors of Soil 608
Glare and Flash Burn on Damp Objects 609
Body Recovery 609
Formal Exhumation 609
Darkness 610
Neighboring Graves 610
Notes 610
References 610

Forensic archaeology has been defined in a UK context as being "the application of archaeological methods and theories in a criminal framework; integrating those methods and theories … with those of forensic science and criminalistics" (Powers and Sibun, 2014) and in a continental European context as being "a forensic discipline that uses archaeological theories, methods and techniques in a legal context" (Groen et al., 2015). In North America it is sometimes presented as being a subdiscipline of "body recovery" under the wider field of forensic anthropology (Steadman & Haglund, 2005), but this remains a bone of contention (Tuller, 2012).

While much has been written on the methods of forensic archaeology, relatively little attention has been paid to the photography of forensic archaeological sites, the assumption being that such skills would be provided as part of "core" crime scene investigation (CSI) support. The term "album" has been used throughout this chapter to refer to a photographic output used for either briefing purposes or for presentation in court. Given the potential to present photographic images via television or computer screens, this need not now be a paper album of developed and printed photographs.

The expertise of the forensic archaeologist is used to communicate an understanding of a context of deposition. These contexts are often understood as makeshift clandestine graves within which the remains of a murder victim have been concealed. But it could be any scene in which stratification—where layers of material or objects offer the opportunity to unpick a chronology to material deposition—is important to an investigation. As a result, formal exhumations from cemeteries, buried arms caches, collapsed buildings, and deep fire debris can and have been subject to examination by forensic archaeologists.

Archaeologists develop an understanding of stratigraphy of any given site through a process of excavation and recording. As with many aspects of crime scene investigation, this process is largely unrepeatable, as the act of excavation destroys the stratigraphic relationships being investigated. This places a critical onus on recording of such scenes, and clear photographic recording is essential.

THE CHALLENGES OF PHOTOGRAPHY IN FORENSIC ARCHAEOLOGY

The forensic photographer faces a range of challenges when working with a forensic archaeologist to record a stratified excavation in a systematic manner. Some of these are complications shared with other outdoor scenes, whereas others are more specific in nature.

Outdoor Crime Scenes

Clandestine graves are frequently located in remote areas, and the act of locating them can entail an extensive search that may require the extensive disruption of the scene, such as the trimming of vegetation, removal of trees, or the removal of soil with a backhoe. This can bring about a range of challenges for the photographer, including:

- **Disorientation:** An outdoor location can be difficult to understand from a photographic album alone (see Figure 32.1). Large extended scenes with repetitive, nondescript vegetation (coniferous woods, cereal crops, or meadowland, for instance) present few visual orientation cues to the viewer who has not attended the scene in person. A poorly thought-out and constructed set of locating



FIGURE 32.1 (A–C) Two trial pig graves are hard to visualize when located in a disorientating landscape.

(Courtesy of the RAF CSI Section.)

photographs risks leaving the viewer confused as to the location of a grave in a landscape.

- There are several solutions to disorientation the photographer can adopt:
  - Plan a series of images in advance of taking them. For example, if a large area of woodland has been searched resulting in the location of three separate suspicious sites to be searched more closely by the forensic archaeologist, choose a common starting point (a car park or staff rendezvous point) and expose images of the approach to each of the three sites from this common point.
  - Add reverse-angle shots when exposing images of your approach to document the view 180 degrees behind the photographer, showing where investigators have come from and how far.[1]
  - Consider the positioning of landmarks when composing your photographs. A large tree in the distance of one photo can move into the foreground of view as you proceed into the scene and then be featured in the reverse-angle photos as you pass it by.
  - When you reach the point of interest, quarter photographs in four directions, hopefully overlapping, around the point of interest your narrative of scene approach has led up to.
- **Visualizing targets:** The search phase of an archaeological examination generally seeks to identify anomalous characteristics indicative of a hidden burial. These characteristics might be topographical (a subtle slump or rise in ground level) or environmental (alterations in vegetation colonization) in nature. Or the characteristics might be wholly invisible on the ground surface, such as an indication provided by a cadaver dog, or a change in subsurface response detected by a geophysical search technique, or intelligence provided by a witness to a crime identifying a deposition site (see Figure 32.2).
  - Once identified, targets of the search should be numbered in sequence to allow all scene



FIGURE 32.2 Electrical resistance survey in progress, but photography can be just as powerful in capturing subsurface features, such as the buried cable trench behind the searchers.

(Courtesy of the RAF CSI Section.)

personnel to reference them without confusion. Crime scene investigation number boards can then be used as visual identifiers in the photo. If the physical parameters of the target can be estimated, such as the length or breadth of the feature, then these can be illustrated with the use of search flags or marker pegs. In addition, the introduction of an appropriately placed high-visibility north arrow and scale further improves the recording of the scene.[2]

Large-Scale Searches

Under certain conditions, archaeological searches may be forced to abandon targeted searching of anomalous targets in favor of widespread machine stripping with a backhoe. This can rapidly alter the landscape of a scene beyond easy recognition, causing potential confusion for album viewers. The recording of such scenes is best managed by the division of the area into numbered grids or sectors, and these numbers should then be visible in scene photographs. Any system of grid numbering put in place should be clearly differentiated from sequential exhibit or target numbering to avoid duplication or confusion.

Large-scale searches can progress over days or weeks. To record these changes, in addition to "standard" scene photographs, opening and closing images of the scene in its entirety should be captured at the beginning and end of every day of operation to assist in documenting the progress of the search, no matter the size of the project.

Excavation

The actions of an archaeological search are generally followed by excavation—by hand or by machine—to determine if any of the indications of target sites feature the subject of the search. Excavated areas require careful photography and benefit from the photographer having a deep understanding of the methods of the archaeologist. A good description of the role of the photographer in forensic excavations has been provided by Hunter et al. (1995).

Whatever system of excavation the archaeologist uses, one of their aims is the identification and recording of the grave as it was originally dug by the offender. This serves the dual purpose of revealing the grave as it was originally prepared by the offender and of allowing the identification of evidence associated with the act of burial, whether items associated with the victim or left by the offender or toolmarks and associated paint flecks in the grave sides/edges.

The systematic removal of fill from the grave is normally undertaken from the top down and requires regular and systematic photography to track the progress through the excavation. Where possible, the photographer should take up a fixed shooting position or set of positions by the graveside, allowing the construction of a record of the excavation in the clearest way possible. Unless space is unavoidably limited, very wide-angle lenses that will distort the proportions of the grave should be avoided.

Excavation inevitably requires various hand tools: trowels, buckets, spades, shovels, and the like. Although at times arduous, care should be taken to remove these items from the frame. Likewise, excavation generates disturbed soil, or "loose," which must be cleaned and removed before taking photographs.

One of the perennial problems of all photography of archaeological excavation has been how to capture with a camera distinctions in the ground that can be seen with the archaeologist's eyes or felt with the trowel. The fill of a clandestine grave dug hastily by an offender is likely to show little, if any, visible distinction, yet the distinction between grave sides and fill is a vital one in describing the nature of the grave and its contents.

Archaeological understanding of an excavation is formed visually by an understanding of the extent of the features of the grave in the top-down plan and by the chronological sequence of layer superimposed on layer visible side-on in chapters (see Figures 32.3 and 32.4).

Items or body parts located during the excavation should, where possible, be carefully cleaned in situ by the archaeologist before being photographed in detail. Such photography should follow a sequence like that given in Table 32.1.

Photographing into the Grave

Photographing down into a hole in the ground from the surface can present a range of challenges of contrast on a bright day. As the grave excavation proceeds to deeper and deeper



FIGURE 32.3 An archaeological skeleton investigated by police as unexplained. The plan view shows how complex the surrounding archaeology is.



FIGURE 32.4 Section view of the burial in Figure 32.3 showing successive layers of material on top of the burial.

levels, sharply defined shadows are likely to obscure the lower portions of the grave. There are numerous techniques to assist with image capture:

- Erect a scene tent. In addition to providing protection from the elements, a white scene tent will act as a large diffuser, softening the contrast caused by bright sunlight (see Figure 32.5).
- Use a balanced fill flash technique to smooth out contrast. Balance the camera's exposure for the lit areas of the photo using a meter or redirecting the lens temporarily for through the lens exposure systems. Expose the image directing a synchronized speedlight flash angled on an extender cable into the darker areas of the scene. Try to ensure that the flash thyristor is not triggered by flash light bouncing back off brighter surfaces.
- Use a pop-up reflector to redirect daylight or strong torchlight into the darker parts of your image.
- Under extremely dark lighting conditions, set up a timed exposure photo allowing you time to paint light into the darkest parts of the image.



FIGURE 32.5 (a and b) Little things mean a lot. The image of the excavated pig to the left loses detail due to the burn from directional sun. Readjusting the scene tent balances the exposure in the image on the right.

(Courtesy of the RAF CSI Section.)

TABLE 32.1
Process of Photographing Items and Body Parts Located in a Grave

1. Item or body part first becomes visible during excavation. Initial uncleaned photos taken by photographer to give location of find within grave.
2. Cleaning around the item or body part completed by the archaeologist. Archaeologist ascertains whether the item is in isolation or part of a larger buried whole (such as the limb of an intact body).
3. Locating long shots of the item or body part, clearly indicating where in the grave it/they are located.
4. Repeat the locating shots with scale, north arrow, and number board as appropriate.
5. Mid-range images of item/body part, unscaled and then scaled.
6. If the item/body part is isolated and can be removed from the grave, it should be placed onto clean forensic packaging and detailed photos completed again with a scale. This allows items to be photographed from all perspectives; where present, labels, writing, "best before" dates on food packaging, and similar details can be photographed with a macro function.

Visualizing Distinctions between Different Colors of Soil

Very fine distinctions of brown, orange, and gray present important observations for the archaeologist and can present significant challenges for the photographer. Powerful direct sunlight will reduce the observer's color vision sensitivity, and the evaporation of moisture locked in the ground surface will act to further bleach out color differentiation (see Figure 32.6). These effects can be minimized with the use of a scene tent over the area of interest and in avoiding significant delays between the archaeologist finishing a given area of work and the record photographs being taken.



FIGURE 32.6 Trick of the light. The subtly darker soil to the top center of the image is the fill of the practice grave, while the dark area to the bottom center is an artifact of a camera-mounted flash striking the lens hood.

(Courtesy RAF CSI Section.)

If it does not impede the progress of the scene examination, clean and dry areas of the excavation can be photographed again early the following morning. Condensing dew will restore color to exposed soils in all but the most arid of conditions.

This effect can be further enhanced by loosely covering the area of interest with plastic membrane or a tarp overnight, increasing the capture of condensation beneath it.

Under very dry conditions a pump-driven water mister can be used to introduce moisture to the ground surface. Note: This should only be done in agreement with the forensic strategy. The authors would suggest a new mister filled with clean, potable water from which a control sample could be taken to avoid any suggestions of potential contamination.

Archaeological distinctions in the ground can be further enhanced by brushing where time and conditions do not permit the passive modification of conditions to optimize photography. Note that because the following method affects the material appearance of the archaeological layers, they should be photographed prior to enhancement. Following these initial photographs, the archaeologist can delineate changes they see in the archaeology with the point of a trowel, or they can increase the visual distinction between two adjacent layers of archaeological material by brushing them in different directions to enhance the contrast between them (Simmons, 1969, 51).

Glare and Flash Burn on Damp Objects

Graves are frequently damp environments, with groundwater and pooled body fats gathering at the base. This can create problems for the photographer regarding the level of "bounce back" of flash light back into the camera. Cameras with fixed-position flashes set close to the lens aperture are particularly prone to glare and flash burn. This effect can be minimized by shooting from a tripod with a camera that has an association to a remotely triggered flash (linked to the camera by either a flash extension cable or a Bluetooth connection or remote sensor). When held out at an oblique angle to the subject, this should minimize the glare received by the camera.

Wet items requiring close-up detailed photography but not being considered for further forensic analysis can be gently dried with a sterile swab or gauze.

BODY RECOVERY

In many instances, the successful conclusion of a forensic archaeology–led search and excavation is the discovery and recovery of a body concealed within a clandestine grave. Clearly this aspect of the examination process requires careful photographic recording, which should pay close consideration to the following:

- The position the body was found in, with detailed photos of the head, hands, and feet, as well as any trauma evident on uncovering the body.
- Any elements of the grave removed to allow access to the body and its subsequent recovery should be fully photographed before removal.
- Where elements of the body are protected as part of the recovery (such as the bagging of head, hands, and feet), they should be photographed before and after the addition of any protective measures.
- The body should be photographed immediately before recovery and then again following recovery when resting on a body sheet or inside an open body bag. These images are designed to illustrate the level of disturbance the remains were subjected to during recovery.
- Where disarticulated skeletal remains are recovered, these should ideally be arranged in an anatomical order on the body sheet or open body bag to illustrate the completeness of recovery.
- The final photographs of body recovery should include detailed photos of the numbered zip seal of the body bag to provide continuity with the opening images of any postmortem examination (which should ideally begin with the same numbered seal on the bag).

Following the recovery of the body, the photographer's attention should then return to the work of the archaeologist, who will be engaged in the final clearance and recording of the grave base and sides. The successful completion of the recovery should alleviate time pressures associated with the investigation and focus the attention of investigating detectives elsewhere, giving the archaeologist and photographer time and space to capture the most considered images of the recovery.

FORMAL EXHUMATION

Exhumation refers to the preplanned removal of human remains from a formal place of burial or interment. Many of the challenges faced by the photographer are like those described earlier, with some additions:

Darkness

Formal exhumations frequently begin under cover of darkness or at first light to minimize public and press interest and disturbance to the cemetery's normal activity. Under such circumstances, handheld, single-flash photography will create harsh shadows in the grave as the excavation proceeds. Photography from a tripod is always best practice, but here it is essential and should be used in combination with open shutter, multiple-flash, and/or light painting techniques of exposure.

Neighboring Graves

In some legislations (the UK being one), it is strongly advised that the names of deceased unconnected with the enquiry are not captured in the photographic record of the exhumation. This can be achieved with the addition of bubble wrap or large paper sacks wrapped around neighboring gravestones before initial opening photography. This measure also helps to protect the neighboring gravestones from incidental damage during the examination.

NOTES

1. Some viewers find a mixed album of forward/reverse/forward/reverse images to be disorienting. If a mixed set of forward and reverse-angle photos are being shown in a jury bundle, it may be worth considering splitting these two sets of images into a "forward" and a "reverse" narrative and introducing them separately.
2. As always when introducing visual aids into a shot, the forensic photographer must consider the potential criticism about their aids obscuring features of the scene. Always capture an initial sequence of photographs without any introduced aids before doing a repeated sequence with the introduced aids.

REFERENCES

Groen, M., Márquez-Grant, N., and Janaway, R., *Forensic Archaeology: A Global Perspective*, Chichester, Wiley-Blackwell, 2015.

Hunter, J., Roberts, C., and Martin, A., *Studies in Crime: An Introduction to Forensic Archaeology*, London, Routledge, 1995.

Powers, N., and Sibun, L., *Standards and Guidance for Forensic Archaeologists*. Chartered Institute for Archaeologists, 2014.

Simmons, H.C., *Archaeological Photography*, London, University of London Press, 1969.

Steadman, D.W., and Haglund, W.D., The Scope of Anthropological Contributions to Human Rights Investigations. *Journal of Forensic Science*, 2005, Vol. 50, No. 1, pp. 23–30.

Tuller, H., "Mass Graves and Human Rights: Latest Developments, Methods and Lessons Learned," in *A Companion to Forensic Anthropology*, ed. D. Dirkmaat, Chichester, Wiley-Blackwell, 2012.

33 Forensic Anthropology and Photography

Özgür Bulut and Amy Wedge

CONTENTS

33A Forensic Facial Analysis 612
Introduction 612
Morphological Analysis 612
Anthropometrical Analysis 613
33B Forensic Age Progression 619
Introduction 619
The Human Face 619
Facial Structure 619
Facial Head Forms 620
Craniofacial Growth and Development 620
Basic Growth Concepts 620
Bolton Standards 623
Facial Aging 623
Basic Concepts of Aging 623
Intrinsic and Extrinsic Aging 623
Age-Related Facial Changes 624
Forensic Art 627
Age Progression 627
References 628
33C Forensic Facial Reconstruction and Postmortem Depiction 632
Introduction 632
Postmortem Depiction 632
Overview 632
Photographing the Dead 632
Basic Enhancements 632
Correcting Facial Injury 632
Finishing Touches 633
3-D Forensic Facial Reconstruction 633
Overview 633
Assessment of the Remains 633
Photographic Documentation of the Skull 633
Positioning the Skull 634
Backdrops 634
Lighting 634
Avoiding Distortion 634
Reproducing the Skull 634
Digital 3-D Facial Reconstruction 635
Tissue Depth Markers 635
The Manchester Method 635
Finishing Touches (Clay) 636
Finishing Touches (Digital) 636
Photographing the Final Reconstruction 636
2-D Approach to Forensic Facial Reconstruction 637
Summary 637
References 637
Further Readings 638

33A Forensic Facial Analysis

Özgür Bulut

INTRODUCTION

Forensic science is the application of scientific techniques to legal issues and is used in the judicial process. Forensic experts analyze various types of findings during the forensic investigation, which is the collection and examination phase of physical findings in order to enlighten the criminal event.

Evidence is central to a forensic investigation because it can provide sufficient cause for an indictment.[1] There are two kinds of evidence: biological and peripheral. Teeth, bones, blood, and saliva are some examples of biological evidence, which consists of solid and liquid components of the body, whereas peripheral evidence is anything having a causal and circumstantial connection to the forensic case, suspect, victim, or crime scene. It might not only be photographs, radiologic data, clothes, or any other personal belongings of a victim but also images or closed-circuit television (CCTV) footage recording the crime scene.[2] According to Klasén,[3] visual evidence is a primary type of evidence and has been instrumental in identifying all aspects of criminality.

Photographic comparisons are becoming significantly important. The number of requests for this type of forensic analysis has risen drastically since the late 1980s. The increase in the number of installations of CCTV cameras worldwide has led to an enormous growing demand for photographic facial analysis in recent years.[2,4–6] Forensic facial analysis is the technique of comparing photographs of an offender with images of a suspect.[7]

In the 1990s no standard procedures had been developed for forensic facial analysis. Each expert followed his own method and he was defending his decision based on his own technique. However, The Facial Identification Scientific Working Group (FISWG) and the Digital Imaging Working Group (DIWG) are organizations focusing on forensic facial analysis and identification. They perform joint research on facial identification and organize meetings and trainings to share new knowledge and construct validated standards for facial identification.

Forensic facial comparison is the process of analyzing visual information and comparing the images of a criminal with target images based on the methods of morphological analyses, craniofacial superimposition, and anthropometric measurements of the facial landmarks.[8,9] Among these analyses, forensic facial analysis plays an important role in forensic investigations in order to confirm or exclude identity from video recordings or/and photographs.[10]

The power of comparison is directly related to the quality of the images. In forensic cases where the quality of the image records is high, the facial comparison can be regarded as primary evidence by the court,[7] whereas it is accepted as supporting evidence when there is a lack of scientific validation, which are low-quality images.[5]

In terms of forensic facial analysis, images can be divided into three categories:[10]

1. *Category 1:* **Objective evidence**. Objective evidence is independently measurable and verifiable and thus suitable for scientific comparison. Superimpositions and photogrammetric measurement come into this category.
2. *Category 2:* **Subjective evidence**. Subjective evidence is personally observable and demonstrable but not necessarily independently measurable.
3. *Category 3:* No credible evidence.

MORPHOLOGICAL ANALYSIS

The human face has the characteristics of recognizing the people we know and distinguishing them from others.[11] The face is the most identifiable part of the human body. Each face has its own morphological features, and these characteristics include significant details that make the face unique.[12] Anthropological nomenclature and anatomical terms are used to analyze the facial features (Figure 33.1).

Morphological analysis is the comparison of the characteristic features and the anatomical structures of the face (Table 33.1) and identifying the differences and similarities. These characteristics and structures are evaluated in two different components (Table 33.2).

Before starting with the detailed morphological examination (component I and component II), the individuals in the photographs to be compared are examined in terms of their gender, biological appearance, body type (somatotype) properties, and skin color compatibility.

Component I: This is the characteristic features of the face (Figure 33.2). These are:

- Scar
- Mole
- Dimple
- Birthmark

Wounds, cuts, perforations, and abrasions leave traces after the healing process on the skin. A scar can be caused by trauma, surgery, burns, and some skin infections.

Component II: In morphological examinations, a holistic evaluation is first performed to compare the general anatomical structure of the head and the shape and form of the face. Then the face, which is divided into parts and the parts are categorized into types (Table 33.2), is subjected to a detailed feature-by-feature examination.[5,13,14] The

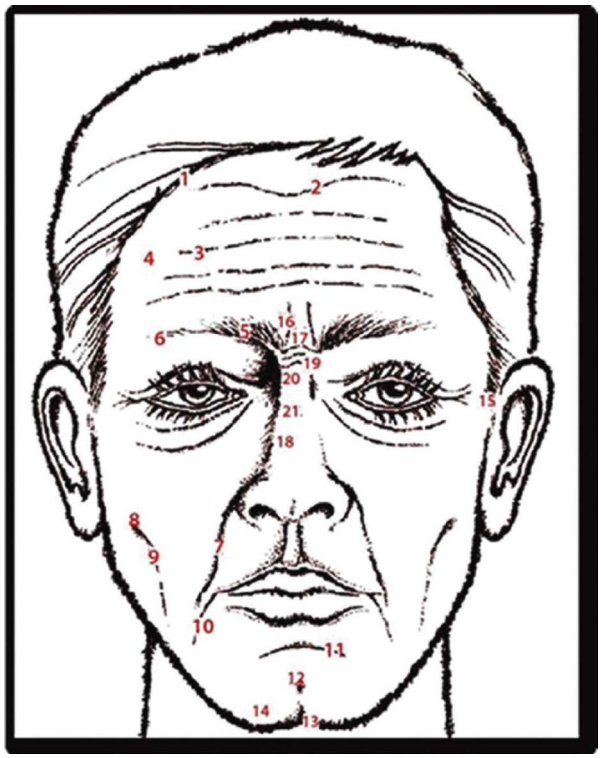


FIGURE 33.1 Anatomical nomenclature of the face.

1 Hairline; 2 Upper forehead crease; 3 Forehead creases; 4 Forehead; 5 Eyebrow; 6 Supraorbital margin; 7 Nasolabial crease; 8 Buccal pit; 9 Buccomandibular groove; 10 Marionette line; 11 Mental crease; 12 Mental pit; 13 Median chin crease; 14 Chin; 15 Sideburn; 16 Vertical glabellar lines; 17 Glabella; 18 External nose; 19 Transverse nasal grooves; 20 Nasal root; 21 Nasal bridge.

(Modified from Dunn and Harrison, 1997.)[19]

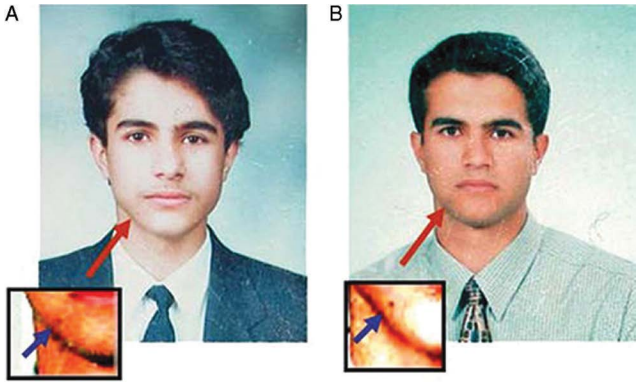


FIGURE 33.2 (A and B) Depiction of a mole on the face in two photographs.

comparison scale (Table 33.2) needs to be filled out according to the expert's examination on the characteristics and structure of the face.

ANTHROPOMETRICAL ANALYSIS

Anthropometry is a specific subfield of anthropological science that basically deals with the dimensions, landmarks, and angles of the human body in order to quantify facial structures and proportions. Craniofacial photoanthropometry, as an important part of facial identification, is a metric method applied in face mapping. In photoanthropometric facial comparison, facial soft tissue landmarks are placed on the face (Figures 33.3 and 33.4) and distances between the landmarks are measured (Figure 33.5). Then normalized proportionality indices (PIs) are calculated for each measurement, taking each measurement as a percentage of the largest available measurement.[4,15]

TABLE 33.1
Comparison Scale for Morphological Analysis

		SAME		NO CONCLUSION			DIFFERENT	
	COMPARISON CRITERIA	VERY STRONG	SUPPORT	WEAK SUPPORT	NO SUPPORT	WEAK SUPPORT	SUPPORT	VERY STRONG
COMPONENT I	COMPONENT I							
	Characteristic Traits (Mole/Pigment/Sulcus/Line/Scar)							
COMPONENT II	Head Form							
	Hair							
	Forehead (Shape, Size, Glabella, Tüber)							
	Eyebrow shape/density							
	Eye (Shape, Size, Color)							
	Nose (Ala Nasi, Apex Nasi, Shape, Size)							
	Cheeks (Zygomatic Bone, Shape, Size)							
	Ear (Helix, Antihelix, Ear Lobe, Shape, Size)							
	Mouth (Philtrum, Lips, Size)							
	Chin (Shape, Size)							
Conclusion								

TABLE 33.2
Facial Components

Facial Forms
Elliptical
Round
Oval
Pentagonal
Rhomboid
Square
Trapezoid
Wedge-shaped
Double concave
Asymmetrical

Eye folds
Absent
Internal
Slight
Average
Developed
Median
Slight
Average
Developed
External
Slight
Average
Developed

Alveolar prognathism
Absent
Slight
Medium
Pronounced

Chin projection
Negative
Neutral
Slight
Forward
Protruding

Chin type
Median
Triangle
Bilateral
Forward
Protruding

Chin shape
Dimple
Cleft
Double chin

Hair Form
Straight
Low waves
Deep waves
Curly
Frizzy
Woolly

Palpebral slit
Down
Horizontal
Up slight
Up moderate
Up extreme

Philtrum size
Small
Wide

Philtrum shape
Flat
Deep
Sides parallel
Sides divergent

Lip thickness
Very thin
Thin
Average
Thick

Upper lip notch
Absent
Wavy
V-shape
Thick

Mouth corner
Straight
Upturn
Downturn

Ear size
Small
Medium
Large

Ear projection
Slight
Medium
Large

Forehead Height
Low
Medium
High

Forehead width
Small
Medium
Broad

Eyebrow thickness
Slight
Small
Average
Large

Eyebrow density
Sparse
Thick
Bushy

Eyebrow shape
Straight
Wavy
Arched

Nostril visibility
Lateral
None
Slight
Medium
Visible

Frontal
None
Slight
Medium
Visible

Bony profile
Pointed
Concave
Wavy
Convex

Lobe
None
Soldered
Attached
Free
Long and free

Baldness
Absent
Slight
Advanced
Complete

Beard quantity
Very little
Small
Average
Hairy

Nasion depression
Trace
Slight
Average
Deep

Nose tip shape
Straight
Bilobed
Angular
Rounded

Nasal alae
Compressed
Slight
Flaring
Extended

Nostril form
Slit
Ellipse
Intermediate
Round

Septum tilt
Up
Up slight
Horizontal
Down
Down slight

Helix
Flat
Slight roll
Average
Very rolled

Antihelix
Slight
Medium
Developed

Source: Modified from Hammer, H.J., "Körperliche Merkmale," in H. Hunger and D. Leopold, eds., *Identifikation*. Leipzig: Barth, 1978, pp. 391–404.

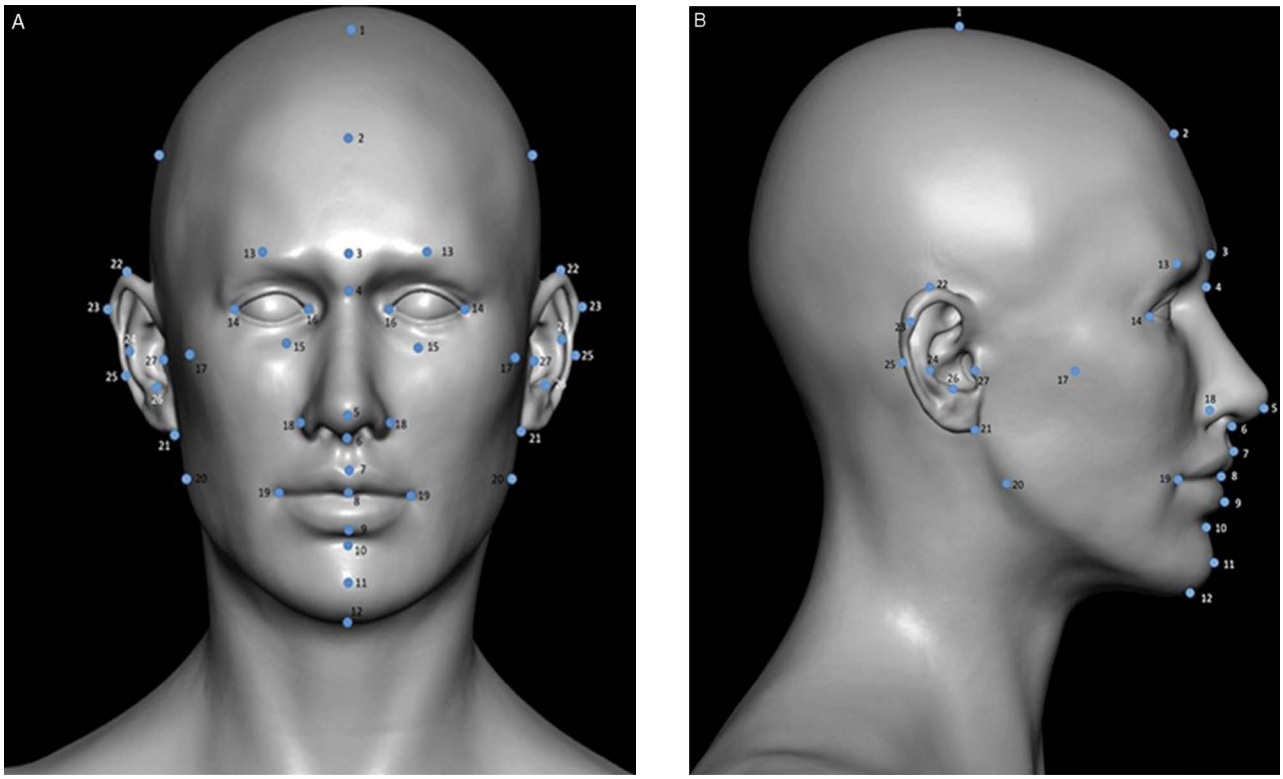


FIGURE 33.3 (A) Facial landmarks located on the frontal image. (B) Facial landmarks located on the lateral image.

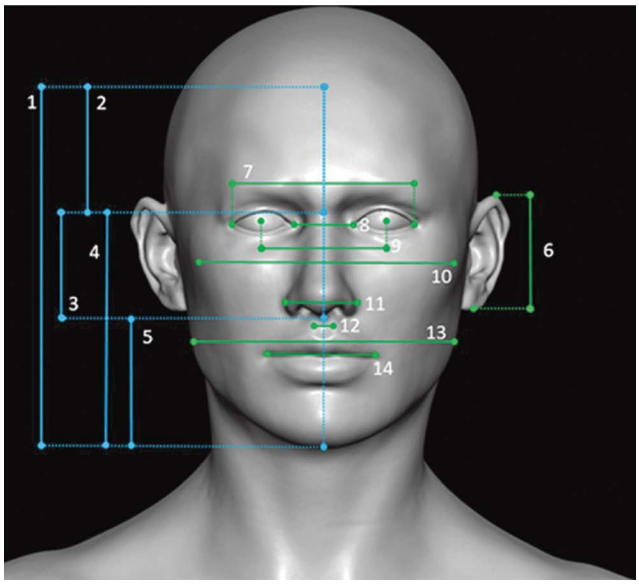


FIGURE 33.4 Measurements on the lateral and frontal aspect of the face.

1 Physiognomical face height; 2 Forehead height; 3 Nose height; 4 Morphological face height; 5 Lower face height; 6 Ear height; 7 Outer eye distance; 8 Inner eye distance; 9 Interpupil distance; 10 Maximum facial breadth; 11 Nose width; 12 Philtrum width; 13 Bigonial breadth; 14 Mouth width.

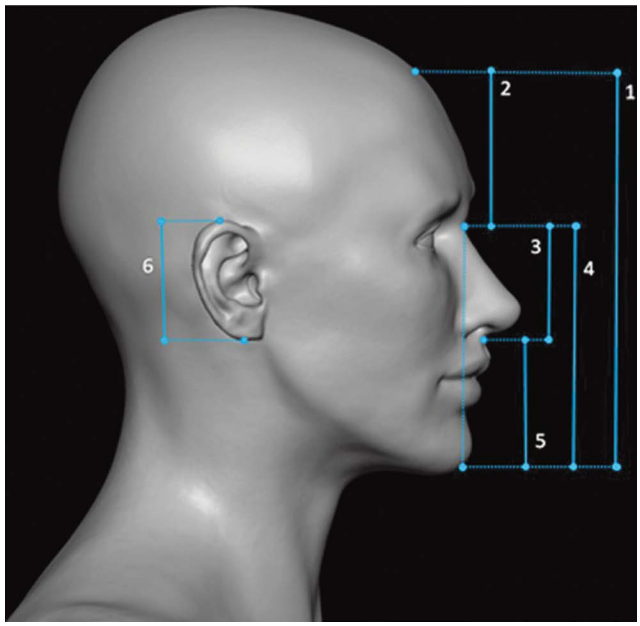


FIGURE 33.5 Ratios of the vertical and horizontal distances between the facial landmarks.

Measurement operations can be done using measuring tools of forensic image processing programs. In order to make anthropometric comparisons and analyze the ratios of the distances between the landmarks (Table 33.3) on the photographs, the photographs need to be brought to the same size (Figure 33.6). In order to calibrate the facial photographs to the same size, the distance between the pupils or the inner canthal points of the eyes can be considered as the standard reference measurement value.

For index calculations, the measured values are compared with the other measured values taken by the same method. In index calculations, the smaller measured value is multiplied by 100 and then divided by the larger measured value, which is considered to be the comparative (Table 33.4). Therefore, index calculation is indicated as the percentage ratio of the smaller measured value to the larger value.

Photoanthropometry is considered a less reliable method than morphological analysis in terms of facial comparison. It quantifies the image comparison process, which has a lot of subjectivity. On the other hand, the method, being highly dependent on the external factors, decreases its reliability (FISWG, 2012).



FIGURE 33.6 Ratios overlaid on photos.

TABLE 33.3
Definition of Facial Landmarks

Nr	Landmark	Definition
1	Vertex	The highest point of the head
2	Trichion	Midpoint of the hairline
3	Glabella	The most prominent midline point between the eyebrows
4	Nasion	The midline point of the nasal root
5	Pronasale	The most anterior midpoint of the nasal tip
6	Subnasale	The midpoint of the columella base below the nasal spine
7	Labiale superius	The midpoint of the upper vermilion line of the upper lip
8	Stomion	The midpoint located at each labial commissure
9	Labiale inferius	The midpoint of the vermilion line of the lower lip
10	Labiomental	The midpoint of the labiomental groove
11	Pogonion	The most anterior midpoint of the chin
12	Gnathion	The most inferior midpoint on the soft tissue contour of the chin
13	Supraorbital	The highest point on the upper margin of the orbi
14	Exocanthion	Outer corner of the eye
15	Infraorbital	The lowest point on the lower margin of the orbit
16	Endocanthion	Inner corner of the eye
17	Zygion	The most lateral point on the soft tissue contour of each zygomatic arch
18	Alare	The most lateral point on each alar contour
19	Chelion	The corner of the mouth fissure
20	Gonion	The most lateral point on the soft tissue contour of the mandibular angle
21	Subaurale	The lowest point on the free margin of the earlobe
22	Superaurale	The most superior point on the helix of the ear
23	Darwin's tubercle	Posterosuperior point of the concave edge of the helix
24	Antihelix	The most posterior point on the antihelix curve
25	Helix	The most posterior point on the free margin of the ear
26	Antitragion	The apex of the antitragus
27	Tragion	Upper margin of the tragus

TABLE 33.4
Facial Indices

Index	Classifications
Forehead size index (100 g-tr/gn-v)	(1) Low <21.9; (2) intermediate 22–28; (3) high ≥28.1
Facial index (100 gn-n/zy-zy)	(1) Short, wide ≤78.9; (2) intermediate 79–92.9; (3) long, narrow ≥93
Intercanthal index (100 en-en/ex-ex)	(1) Close ≤36.9; (2) intermediate 37–46; (3) far apart ≥46.1
Nasal index (100al-al/n-sn)	(1) Narrow ≤54.9; (2) intermediate 55–99.9; (3) wide ≥100
Nasofacial index (100n-sn/gn-n)	(1) Short ≤37.9; (2) intermediate 38–46; (3) long ≥46.1
Nose–face width index (100al-al/zy-zy)	(1) Narrow ≤31.9; (2) intermediate 32–36; (3) wide ≥36.1
Lip index (100ls-li/ch-ch)	(1) Thin ≤34.9; (2) intermediate 35–44.9; (3) thick ≥45
Vertical mouth height index (100ls-li/gn-n)	(1) Low, thin ≤15.9; (2) intermediate 16–22; (3) high, thick ≥22.1
Upper lip thickness index (100ls-sto/ls-li)	(1) Thin ≤31.9; (2) intermediate 32–44; (3) thick ≥44.1
Lower lip thickness index (100li-sto/ls-li)	(1) Thin ≤51.9; (2) intermediate 52–62; (3) thick ≥62.1
Mouth width index (100ch-ch/ex-ex)	(1) Narrow ≤54.9; (2) intermediate 55–66; (3) wide ≥66.1
Chin size index (100li-gn/gn-n)	(1) Short ≤19.9; (2) intermediate 20–29; (3) long ≥29.1

Superimposition

One of the methods used for identification purposes is superimposition. In the superimposition method, one of the two images is made transparent and superimposed onto another for visual inspection of the combined image to identify similarities or differences. Furthermore, it is also possible to employ vertical, horizontal, and diagonal wipes on one of the images to check the matching of the facial parts of each other (Figure 33.7).

Vanezis and Brierley[18] proposed the technique is most useful for the matching of facial marks such as scars, moles, or ear structures on two photos of the same person. In order to apply the superimposition technique, photographs must be taken from the same angle (viewpoint)



FIGURE 33.7 The two images (A and B) are compared. Vertical, horizontal, and diagonal wipes are employed.

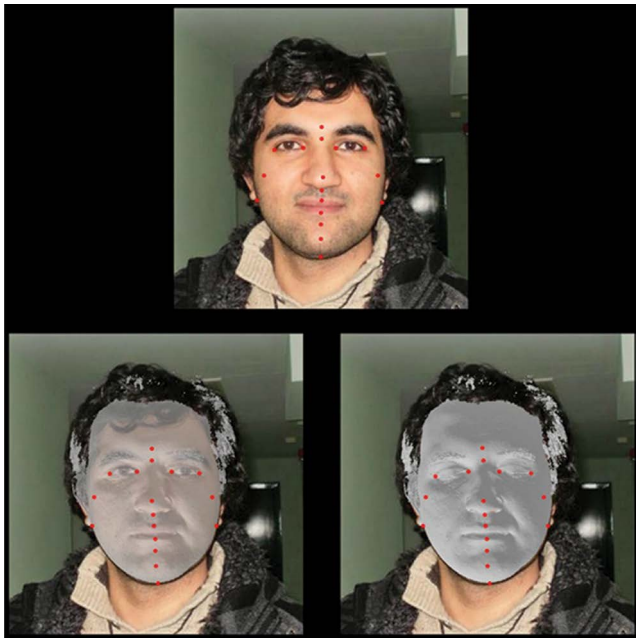


FIGURE 33.8 3-D scan and 2-D image are viewed on the screen for morphological analysis using 3-D software.

and the photographs must be brought to the same size. Interpupillary distance is the most preferred distance for calibration of the two photographs.

Apart from the 2-D/2-D superimposition technique, forensic facial experts are employing a 3-D/2-D superimposition technique to evaluate and compare the facial structures (Figure 33.8). The 2-D/3-D superimposition technique was aimed at eliminating the problems of head orientations between the facial comparison images. In this technique, 3-D surface data of the face of the individual is acquired using 3-D scanners (e.g., Polhemus Fastscan, Artec Spider, Gom Atos 3-D scanner) and then imported into a 3-D software (e.g., Geomagic Freeform, 3D-Rugle3VR). So, forensic experts are able to rotate and position the 3-D scan of a suspect in the same orientation as the subject in the 2-D image or CCTV footage. Several research studies have demonstrated that using 3-D data is more objective than 2-D morphometric and anthropometric analysis.

33B Forensic Age Progression

Özgür Bulut

INTRODUCTION

Every year, thousands of individuals, including abducted children, adults, seniors, and even criminals, are reported missing. The extension of these forensic cases over long periods of time are among the main difficulties in finding missing persons and fugitives (Taister et al., 2000). Dramatic changes in their facial appearance based on craniofacial growth and development, natural aging processes, and other factors as they age hamper attempts to find them (McQueen, 1989).

In terms of aiding in the identification of the victims or criminals, forensic art techniques are preferred by law enforcement agencies. Forensic art is accepted as a field of forensic science (Taylor, 2001), a multidisciplinary study growing daily in depth and scope used to help the judicial system (Gialamas, 2000; Bell, 2008).

Forensic age progression, one of the fields of forensic art, plays a significant role in the identification of a suspect or victim of a forensic case (Michalis, 2004). It is most commonly used specifically in missing children cases (Lampinen et al., 2008) as, sadly, thousands of missing children cases have occurred in recent years (Horace, 1996).

Forensic artists use several methods of age progression, not only traditional methods but also computer-aided techniques developed over the years with new technology (Taylor, 2001; Mullins, In press; Gibson et al., 2009; Horace, 1996).

THE HUMAN FACE

Each face is unique (Wilkinson, 2004; Taylor, 2001; Panfilov, 2007a). There are roughly 6 billion living individuals on earth, and no two faces, even mono-ovular twins, are completely the same (Enlow & Hans, 1996; Panfilov, 2007b; Wilkinson, 2004). Every face has several characteristic features with significant details that make each face different from all the others.

The face reflects the details not only of the biological profiles, including sex, race, and age, but also health and emotional state (Wilkinson, 2004; Taylor, 2001). The face also plays a significant role in communication, interpersonal relations, and social interaction (Wilkinson, 2004).

Artists, philosophers, and scientists have been studying the human face for a very long time. Panfilov (2007c) states that the Chinese have been studying prosopology, the study of facial features, to understand the human face, for 3,500 years.

Physiognomy, the evaluation of an individual's character from his facial appearance, has been studied since ancient times (Taylor, 2001). Aristotle (384–322 BC), who is thought to be the first to apply physiognomy, suggested some relationships between character and facial morphology. These include "a large forehead suggested slowness of movement, a small forehead suggested fickleness, a broad forehead suggested a tendency to be distraught and a rounded forehead suggested a quick temper" (Wilkinson, 2004; 8).

At the end of the 19th century, in addition to physiognomy and phrenology, criminal anthropology, or anthropological criminology, became a field of criminal profiling. Cesare Lombroso (1836–1909) studied criminals by observing and measuring their facial features (Taylor, 2001; Panfilov, 2007c). He claimed that certain criminal types, known as "Lombroso's criminal types," have more abnormalities physically and mentally than the rest of the population (Panfilov, 2007c; Wilkinson, 2004).

Determination of an individual's character through examination of his or her face, however, is not based on a generally accepted scientific hypothesis and/or methodology. Physiognomy, phrenology, and criminal anthropology are today generally considered pseudo-sciences, rather than real sciences because of their subjective explanations and lack of accepted evidential proof and their inability to satisfy empirical requirements.

In the 1880s, Alphonse Bertillon (1853–1954) developed an identification system based on anthropometric measurements and evaluation of facial features (Taylor, 2001). In his system, 11 anthropometric measurements from the body and head, morphological features, and the photographs of criminals, taken in frontal and profile views, were all included in a record file (Wilkinson, 2004).

Today, the face is being discussed in different fields of study, including physical anthropology, forensic anthropology, facial anthropology, archeology, forensic art, medical art, anatomy, craniofacial identification, forensic science, and dentistry.

Facial Structure

"The head is the superior part of the body that is attached to the trunk by the neck" (Moore & Dalley, 2006; 887). It is composed of hard and soft tissues, including the cranial cavity, two ears, two orbits, two nasal cavities, and an oral cavity (Drake et al., 2005).

The skull is the skeleton and fundamental structure of the head (Kahler, 2003; Moore & Dalley, 2006), has the greatest impact on the face (Wilkinson, 2004), and is the most complex part of the skeleton (White & Folkens, 2005).

The skull (Figure 33.9) consists of 22 bones, 14 of them being facial and 8 of them cranial (Table 33.5). Considerable

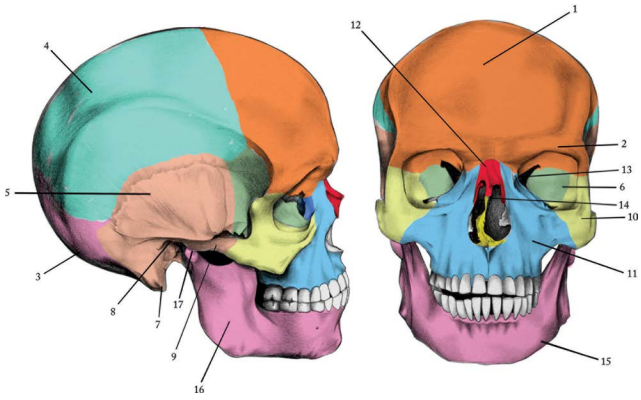


FIGURE 33.9 Human skull, front and side views.

1 frontal bone
2 supraorbital ridge
3 occipital bone
4 parietal bone
5 temporal bone
6 sphenoid bone
7 mastoid process
8 ear hole
9 zygoma
10 zygomatic bone
11 maxilla
12 nasal bone
13 lacrimal bone
14 ethmoid bone
15 mandible
16 ramus
17 temporomandibular joint

(From Sobotta, 2001.)

variation among skulls is brought about by the complex structures of these bones (Wilkinson, 2004).

The muscles of the face (Figure 33.10), lying between the skin and the skull, are grouped into two categories: the muscles of mastication and the muscles of expression (Kahler, 2003; Taylor, 2001).

The muscles of mastication, which are the masseter, temporalis, medial pterygoid, and lateral pterygoid, are responsible for the activity of mastication. The masseter is a very strong and bulky muscle, rectangular in shape, which runs diagonally across the cheek. Its origin lies along the lower margin of the zygomatic arch, and it inserts at the angle of the jaw. The temporalis is a fan-shaped muscle covering the side of the head. It originates from the inferior temporal line at the side of the skull, goes through the zygomatic arch, and inserts at the coronoid process of the mandible. The functions of the masseter and temporalis muscles are to elevate the mandible. The medial pterygoid muscle also elevates the mandible. The lateral pterygoid muscle protrudes the mandible, which allows the teeth to grind food (Wilkinson, 2004; Taylor, 2001; Kahler, 2003).

TABLE 33.5
Bones of the Skull

	BONES of the SKULL
8 Cranial Bones	1 × Ethmoid Bone
	1 × Frontal Bone
	1 × Occipital Bone
	2 × Parietal Bones
	1 × Sphenoid Bone
	2 × Temporal Bones
14 Facial Bones	2 × Inferior Nasal Conchae
	2 × Lacrimal Bones
	1 × Mandible
	2 × Maxillae (pl.); Maxilla (sing.)
	2 × Nasal Bones
	2 × Palatine Bones
	1 × Vomer
	2 × Zygomatic Bones
TOTAL: 22 BONES	

Facial Head Forms

The head shape is classified into two main groups, dolichocephalic and brachycephalic (Enlow & Hans, 1996) (Figure 33.11).

The dolichocephalic head form is described as a thinner and longer face, having a more sloping forehead, less prominent cheekbones, and deep-set eyes. The brachycephalic head form is a broader and shorter face, more upright profile, and the nose has a more rounded tip, leading to a concave profile (Enlow & Hans, 1996; Wilkinson, 2004; Taylor, 2001; Feik & Glover, 1998). In addition, there is another head form called mesocephalic. This head form is described as a medium or intermediate facial form, more likely to fall between dolichocephalic and brachycephalic head forms (Wilkinson, 2004; Taylor, 2001; Feik & Glover, 1998).

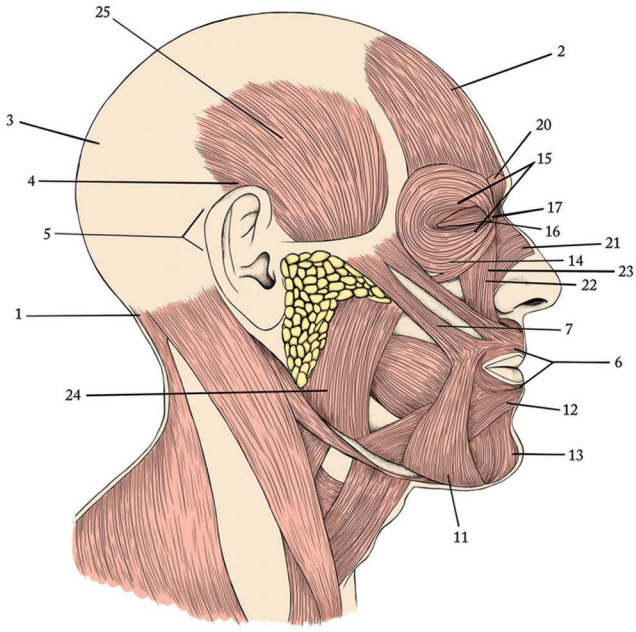
In terms of geographic distribution range of the head forms, it is suggested (Enlow & Hans, 1996) that the dolichocephalic head form is more likely to be seen in England, Scotland, Scandinavia, Northern Africa, and some Middle Eastern countries. The brachycephalic head form, on the other hand, is more likely to be seen in Central Europe and the Far East.

CRANIOFACIAL GROWTH AND DEVELOPMENT

Basic Growth Concepts

The terms "growth" and "development" have different meanings, although they are related. This phenomenon may cause difficulties in understanding. According to the Cambridge Dictionary (2010), growth is defined as "the process of increasing in size," whereas development is defined as "changing and becoming more advanced." In this chapter, the term growth usually refers to an increase in size and the term development refers to an increase in complexity (Proffit and Fields, 2000).

In human growth and development, proportional changes occur throughout the body. Figure 33.12 shows the alterations of the body during the period of growth and development. After the third month of fetal life, the size of the head and the face proportionally reduces compared to the total body size. Furthermore, proportional comparison between a newborn infant and an adult shows the infant's



Scalp
1 occipitalis
2 frontalis
3 epicranial aponeurosis
4 temporoparietalis
5 auricularis

mouth
6 orbicularis oris
7 zygomaticus major
8 risorius
9 levator anguli oris
10 triangularis
11 mentalis
12 depressor labii inferioris
13 mentalis

eyelid
14 o.oculi.p.orbitalis
15 o.oculi.p. palpebralis
16 palpebral ligament
17 depressor supercilii
18 corrugator supercilii

Neck
19 platysma

nose
20 procerus
21 nasalis
22 levator labii superioris
23 l. Labii sup. alaeque nasi

m. of mastication
24 masseter
25 temporalis

FIGURE 33.10 Facial muscles, side view.

(From Sobotta, 2001.)

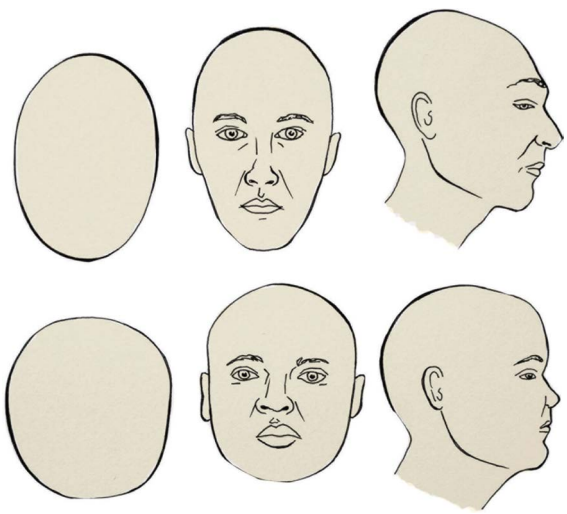


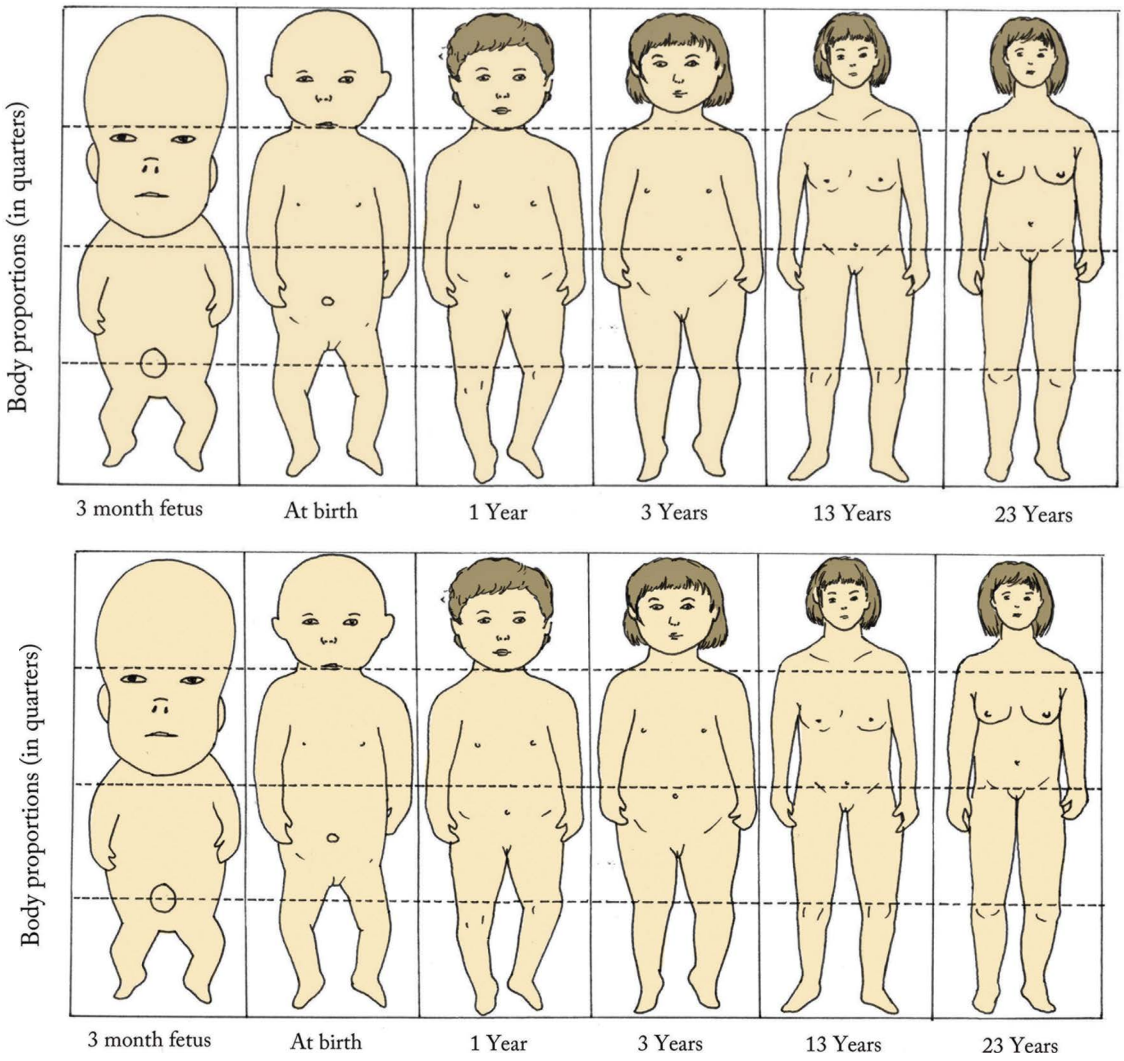
FIGURE 33.11 Facial head forms.

cranium is larger than the adult's cranium, whereas the infant has a relatively smaller face than an adult face. The proportion between the head and face changes drastically (Figure 33.13) during the period of growth and development (Proffit and Fields, 2000).

It is possible to reach a conclusion from Robbins's (1928) research that the head takes up almost 50% of the total body length in the second month of fetal life, 30% at the time of birth, and 12% of the total body length at the beginning of the adult period. According to Wilkinson (2004), an infant's head forms one-quarter of its total body length.

Growth and development can be regarded as a kind of energy (Arat et al., 2001). Human growth and development is a highly complicated process, affected by external and internal (genetic) factors, extending to 20 years of age (Cameron, 2002; Carter, 2001).

Growth of bone is a complex process, representing a disproportionate enlargement. During the process of remodeling,



FIGURES 33.12 AND 33.13 Changes in overall body proportions during normal growth and development.

(From Singh and Juneja, 2007.)

surfaces of the bone do not enlarge uniformly (Enlow, 1968). The facial skeleton increases in all three planes—height, width and depth—but it grows at different times and at different rates (see Figure 33.14) (Sarnat, 1963).

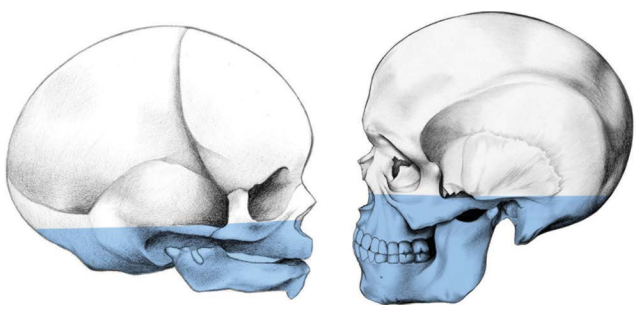


FIGURE 33.14 Growth of facial skeleton affects the proportions of the head and face between an infant and an adult.

(From Proffit and Fields, 2000; 26 and from Lowery, 1973.)

During the process of craniofacial growth, there is a close relationship between the soft and hard tissue parts (Enlow and Hans, 1996). Gordon (1986) states that in the early years the upper and lower jaws enlarge and change rapidly in size and form. Drastic enlargement and changes in the lower face are the main factor for children's faces elongating downward and forward. Taylor (2001) tried to explain through an illustration (Figure 33.15) displaying a fetal skull and adult skull that the lower part of the face changes radically and proportionally over time.

One of the significant factors affecting the designation of the head form and characteristic features of the facial type is the formation of the neurocranium, which is the template of the facial growth field. Anteroposteriorly and vertically elongated patterns and mandibular retrusion are common features of the dolichocephalic facial type, whereas the brachycephalic facial type has a wider midface (nasomaxillary) with a rounder lower part of the face (Enlow and Hans, 1996).

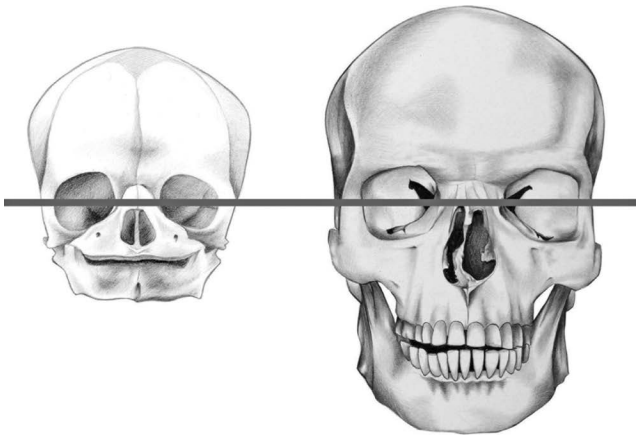


FIGURE 33.15 Proportional comparison of the fetal skull and the adult skull.

(From Taylor, 2001.)

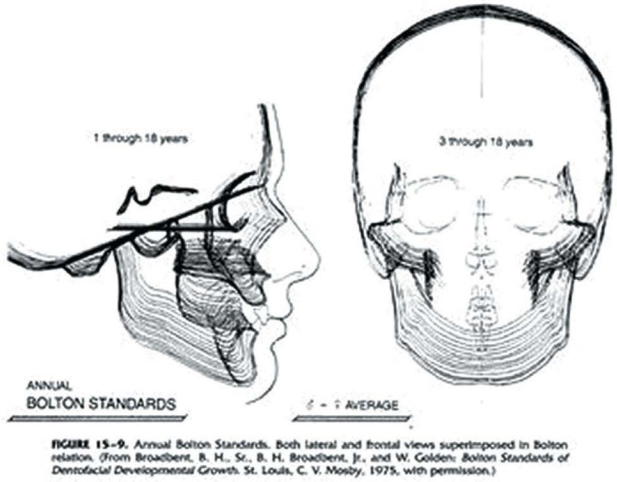


FIGURE 15–9. Annual Bolton Standards. Both lateral and frontal views superimposed in Bolton relation. (From Broadbent, B. H., Sr., B. H. Broadbent, Jr., and W. Golden: *Bolton Standards of Dentofacial Developmental Growth*. St. Louis, C. V. Mosby, 1975, with permission.)

FIGURE 33.16 Annual Bolton cephalometric standards. Superimposition of lateral and frontal views in the Bolton relation.

(From Broadbent et al., 1975.)

Bolton Standards

Cephalometrics is a technique used in anthropological studies to make head measurements. This method is utilized in clinical and research orthodontics, particularly in craniofacial growth and development, with relation to specific reference points (Broadbent et al., 1996).

The Bolton standards, based on 22,000 recordings on over 5,000 children, present the optimum craniofacial developmental growth. These standards are used in a very wide field of study. Maxillary surgery, oral surgery, and orthodontic treatment are examples of the clinical uses of the Bolton standards. They may also be used in conducting studies on craniofacial growth and developmental abnormalities. Normal and abnormal craniofacial growth processes can be demonstrated with the use of Bolton standards as a comparative reference (Broadbent et al., 1975).

The Bolton standards, which are one of the largest longitudinal studies ever conducted, include annual lateral transparencies (Figure 33.16) from 1 to 18 years of age with coordinated frontal standards from 3 to 19 years, for both males and females (Broadbent, 1996).

FACIAL AGING

Basic Concepts of Aging

Human beings are mortal, as are all organisms. Over a finite life span, we are born and we die (Featherstone and Wernick, 1995).

Scientists have been investigating the aging process to gain an understanding of how aging occurs and the reasons why. They are also trying to give a scientific explanation of the question "Why does it happen?" (Gavrilov and Gavrilova, 2006).

Knowledge about aging in medical, biological, and social sciences is advancing at an incredibly rapid pace (Schulz, 2006). According to Brownell et al. (2006; 44), using the Google search engine in 2004, there were 8,520,000 links to websites that included references to "aging" and 985,000 just to images of aging. Today, in 2018, using the Google search engine, there are 52,400,000 links to websites that include references to aging and 18,000,000 just to images of aging.

Aging is a complex phenomenon (Sehl and Yates, 2001; Taister et al., 2000). It is widely known to be an irreversible and uniform process of cumulative decline (Cole et al., 1993) that is widespread and universal to humankind (Fry, 2006). According to the Cambridge Dictionary (2010), aging is defined as "relating to getting older." Webster's Dictionary (2010) has a slightly different definition of aging, being the "organic process of growing older and showing the effects of increasing age."

In terms of biological aging, Giacomoni (2006) defines aging as the accumulation of molecular damage. As the life course progresses, organisms produce fewer cells (Gosden, 1985; Herndon et al., 2002). Strehler (1977) summarizes aging as intrinsicality, universality, progressivity, irreversibility, and genetically programmed.

From another aspect of the term aging, it is a process that begins with birth (Rubinstein and Canham, 2008). Accordingly, Costa and McCrae (1995) explained aging with an evaluation of what happens to an organism within a defined time period. Masoro (2006; 44) discusses this time period in three main parts. First, is "no change with time," second is "beneficial changes with time" (physiological processes during development), and third is "deteriorative changes with time" (such as those that occur with advancing adult age).

Intrinsic and Extrinsic Aging

Aging is the consequence of a genetic program and of cumulative environmental damage (Chung and Cho, 2004; Finch and Tanzi, 1997). There are a number of factors affecting the aging process that result in functional and aesthetic changes in the superficial texture of the skin, soft

tissue, and skeletal supportive structures of the human face (Sadick et al., 2009; Coleman and Grover, 2006).

Aging, which occurs at different rates from individual to individual, is derived from an interaction between internal and external factors, and these can be divided into two main categories: genetic (intrinsic) and environmental (extrinsic) aging (Vasto et al., 2007; Tzaphlidou, 2004; Treacy, 2009; Krutman and Gilchrest, 2006).

Intrinsic aging is caused by the genetic background, structural, functional, metabolic, and hormonal changes. Intrinsic aging is a continuous process occurring naturally over time within the face. Intrinsic aging results from a gradual thinning of the skin, loss of tissue elasticity, shrinking of fat, and alteration in facial volume and muscle underneath the skin (Henry and Costa, 2000; Coleman and Grover, 2006).

The signs of intrinsic aging are:

- Thin, less elastic skin and wrinkled with age because of decreased fiber production
- Loss of underlying fat (leading to hollowed cheeks and eye sockets)
- Bone and muscle loss and decrease in size
- Dry skin and a decrease in sweat glands
- Hair loss and a decrease in hair pigments, graying hair

These changes cause sagging skin (Benjamin et al., 1997; Wilson, 2008).

Extrinsic facial aging is caused by a variety of external sources, such as sun ultraviolet radiation (photoaging), smoking, arid weather, drug use, and stress (Albert et al., 2007).

According to Krutman and Gilchrest (2006), Henry and Costa (2000), and Sadick et al. (2008), ultraviolet radiation, which is called photoaging, is the primary and the most important factor leading to extrinsic aging.

Photoaging can cause wrinkles and sagging and a rough, dry, inelastic skin texture (Uiotto 1997; Uiotto et al., 1989). Furthermore, uneven skin tone, which is hypopigmentation (loss of color), hyperpigmentation (darkened color), or a combination of the two, is a common result of photoaging (Henry and Costa 2000).

A number of studies have shown that there is a close relationship between smoking and facial aging (Daniell, 1971; Kadunce et al., 1991; Ernster et al., 1995; Leung and Harvey, 2002; Koh et al., 2002; Aizen and Gilhar, 2001) and it accelerates aging and the formation of wrinkles (Nicita-Mauro, 1990; Boyd et al., 1999; Novick, 1988).

In his research, Aizen (2001) studied smoking's effect on skin wrinkling. Eighty aged volunteers were included in the study. He concluded that prominent facial wrinkling was more common among smokers no matter their age. Koh et al. (2002) found a similar result in their study, comprising 360 individuals, including current smokers, nonsmokers, and past smokers; the smokers had more facial wrinkles than nonsmokers and past smokers.

Doshi and his colleagues (2007) studied twins who lived in the same geographic location. They had the same education, same type of job, and similar sun exposure. They differed, however, in their smoking history. The study showed that the twin who smokes has more severe skin aging than the nonsmoking twin.

Age-Related Facial Changes

Facial Changes in Juveniles

Children grow and change over time. In terms of facial proportions, there is an enormous change between babyhood and maturity (Feik and Glover, 1998). Due to these drastic changes of the face, it is hardly possible to recognize an infant if not seen even for a few months (Y'Edynak and Iscan, 1993).

In the period of time from birth to adulthood, the inevitable changes in our facial appearance are led by the growth of the skull over time (Wilkinson, 2004) (Figure 33.17).

The parts of the skull do not grow at the same rate. These differences in the rate and timing of growth therefore lead to changes in cranial form (Feik and Glover, 1998). Having a vertically short face is because of the diminutive nasal and oral regions of the infant face that developed relatively late related to the body and lung size (Enlow, 1982).

Soft tissues have an important role in a child's changing appearance (Feik and Glover, 1998). The baby's nose, which is small and concave, differs markedly from that of an adult (Ligget, 1974). Wilkinson (2004; 222) states that "regardless of sex, the child's face has a short, pug like nose with low nasal bridge and concave profile."

Farkas et al. (1992a) studied age-related craniofacial growth changes in 1,593 North American Caucasian individuals between the ages of 1 and 18 years who were involved in this study. It is shown that at 1 year, the nose height reaches 59% of an adult size. At 5 years of age, it reaches 80% of an adult size. At 1 year, the width of the nose reaches 79.5% of an adult size, and it reaches 87% by 5 years. The fully developed nose height and width are reached by the age of 12 in females and 14 to 15 in males (Table 33.6).

Kreutz and Verhoff (2002) describe the characteristics of the child's face as (in Kreutz and Verhoff, 2007):

- Disproportionately large eyes
- Pudgy, plump cheeks
- Soft, unmarked skin
- Small nose
- Small teeth and jaws

Having larger buccal fat pads than an adult leads to smoother skin and the round-cheeked appearance of a child (Wilkinson, 2004). When discussing the chin, Prahl-Andersen et al. (1995) state that soft tissue depth of the chin increases with growth.

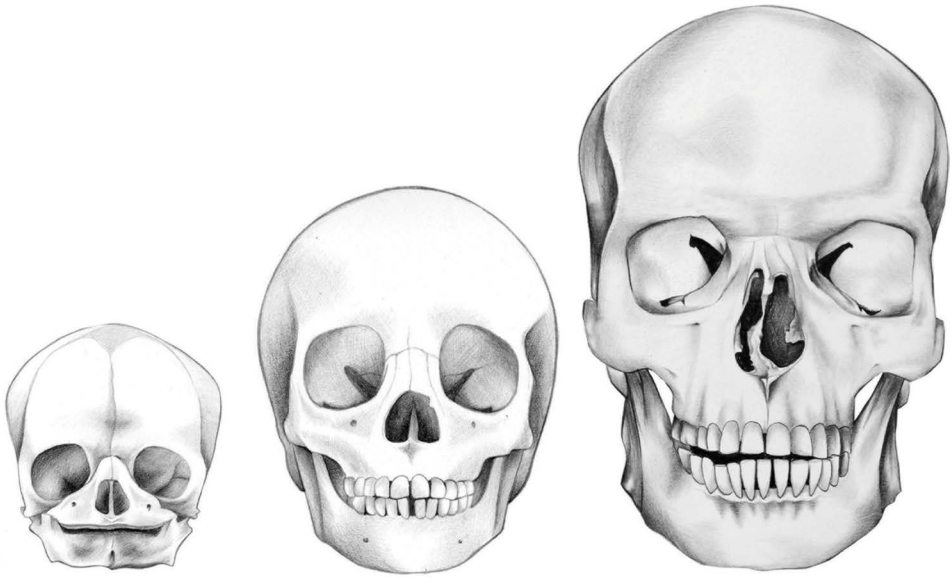


FIGURE 33.17 Series of skulls are different ages.

(From Schaefer et al., 2009.)

The chin develops and becomes squarer with age. Development of the chin, eruption of the teeth, and enlargement of the ramus of the mandible lead to the whole lower face taking on a more U-shaped appearance (Wilkinson, 2004).

In early childhood, the width of the ear is more developed than its length. At the age of 1, ear width reaches 93.5% of adult size, whereas ear length reaches only 76.4% of adult size. At the age of 5, ear width reaches 96.7% and ear length reaches 86.6% of adult size. Ear width reaches its fully developed size at 7 years in males and at 6 years in females. Ear length fully develops at 13 years in males and at 12 years in females (Table 33.7) (Farkas et al., 1992b).

The child's forehead is bulbous and upright; however, it slopes more with age (Wilkinson, 2004). The child has relatively large eyes compared to the proportions of the whole face (Kreutz and Verhoff, 2002; Wilkinson, 2004). Farkas et al. (2002c) studied the age-related changes in the orbital region by analyzing the intercanthal (en-en) and binocular (ex-ex) widths obtained from 1,594 North American Caucasian individuals between the ages of 1 and 18 years. This showed that the development of the intercanthal width is 84.1% and that of the binocular width is 85.9% of adults, in both sexes. At the age of 5, the intercanthal width reaches 93.3% and binocular width reaches 88.1% of adult size in both sexes. Full maturation of the intercanthal width is reached at the age of 8 in females and 11 in males, and binocular width at 13 years in females and 15 years in males (Table 33.8).

TABLE 33.6
Full Maturation of the Nasal Measurements

Measurement	Sex	Age of Maturation
Nose height *(n-sn)*	Male	**15**
	Female	**12**
Nose width *(al-al)*	Male	**14**
	Female	**12**

Source: Farkas et al., 1992a.

TABLE 33.7
Full Maturation of the Ear Measurements

Measurement	Sex	Age of Maturation
Ear width *(pra-pa)*	Male	**7**
	Female	**6**
Ear length *(sa-sba)*	Male	**13**
	Female	**12**

Source: Farkas et al., 1992b.

TABLE 33.8
Full Maturation of the Orbital Measurements

Measurement	Sex	Age of Maturation
Intercanthal width *(en-en)*	Male	**11**
	Female	**8**
Binocular width *(ex-ex)*	Male	**15**
	Female	**13**

Source: Farkas et al., 2002c.

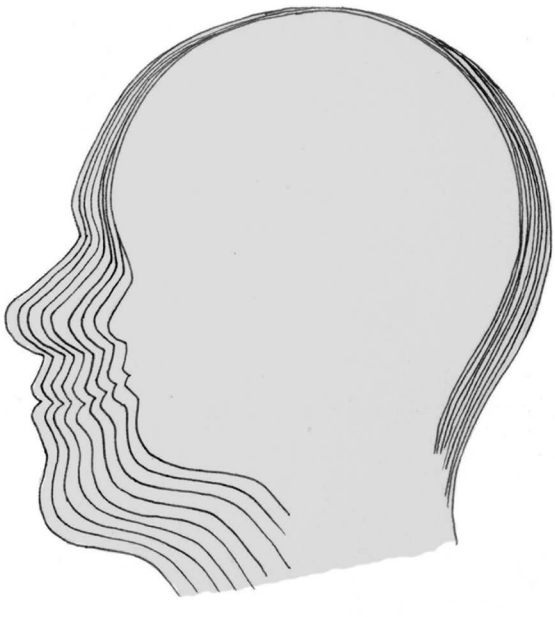


FIGURE 33.18 Craniometric growth of an infant (innermost profile) to adulthood (outermost profile).

(Modified from Todd et al., 1980).

When comparing a child's face with an adult face, Wilkinson (2004) states that the child's face differs significantly from the adult face. As illustrated in Figure 33.18, "the adult face is longer, more sloping, the face is proportionally bigger relative to the head and the general appearance is more dolichocephalic" (Wilkinson, 2004; 225).

Farkas and Posnick (1992d) concluded from their research that "the face reaches maturity by about 10 to 13 years in girls, and 12 to 15 years in boys" (in Wilkinson, 2004; 225).

Facial Changes in Adulthood

Facial aging is the outcome of the skin, soft tissue (subcutaneous fat, muscle, and fascia), and hard tissue (bone and teeth) changes (Coleman and Grover, 2006). Wilkinson (2004) states that skin and soft tissue changes appear to be more noticeable than hard tissue changes.

When discussing craniofacial aging, Bartlett et al. (1992) insist it is the result of bone atrophy, bone expansion, and bone loss. Thus, the shape and the proportions of the head are affected by these factors. Tooth loss causes the mandible and maxilla to become smaller. Resorption of the alveolar ridge and change in the chin shape, which are caused by having a reduced number of teeth, result in changes in the soft tissue and facial proportions (Neave, 1998; Coleman and Grover, 2006). Changes in these structural components lead to a reduction in facial height and an increase in facial width and depth (Coleman and Grover, 2006).

Changes such as "loss of soft tissue in certain areas (periorbital, forehead, malar, temporal, mandibular, mental, glabellar, and perioral sites)" (Coleman and Grover, 2006; S5) and "loss of skin elasticity, formation of wrinkles, sagging of flesh, loss of adipose tissue, blurring of the iris detail, increased prominence of facial lines and hair loss are the noticeable external age related signs" (Wilkinson, 2004; 76).

Adulthood Periods in Facial Aging

Young Adulthood

In the twenties, the skin is fresh, smooth, and elastic (Neave, 1998). There is no sagging of soft tissue in the face (Henry and Costa, 2000). Nonetheless, fine facial lines begin to appear horizontally across the forehead and between the eyebrows vertically (vertical glabellar lines) and around the outer corner of the eyes (lateral orbital lines) (Albert et al., 2007; Taylor, 2001).

Noticeable changes can be observed in the thirties (Neave, 1998). This period is the beginning of the malar fat pad descent (Treacy, 2009). Vertical glabellar lines and lateral orbital lines continue to deepen. Nasolabial lines develop and become noticeable (Neave, 1998; Albert et al., 2007; Taylor, 2001). In this age period, there is a "change in skin texture from smooth to uneven" (Neave, 1998) and the face does not look as fresh as it once did (Henry and Costa, 2000).

Adulthood (Middle Age)

During the forties, significant changes occur in the appearance of the face. Eyebrows and upper eyelids may descend, the lips may thin out, and an inferior orbital groove may develop and become noticeable (Albert et al., 2007; Taylor, 2001). Malar fat pad descent and the nasolabial groove become noticeable (Treacy, 2009). Depending on the structure of the face, oromental and mentolabial grooves may become apparent (Taylor, 2001). Hair loss in males and dispigmentation of the hair both in males and females can be seen (Neave, 1998). Circumoral striae (lines around the mouth) may develop and become apparent (Taister et al., 2000; Albert et al., 2007).

In the forties, the skin texture becomes coarser and less elastic compared to that of previous age periods (Henry and Costa, 2000).

Later Adulthood

In the fifties, it can be observed that there is an increase in hair loss in males and loss of hair pigmentation in both males and females (Neave, 1998). Existing creases and grooves, such as the inferior orbital groove, nasolabial groove, and mentolabial groove, deepen (Albert et al., 2007; Taylor, 2001; Neave, 1998).

The density and thickness of the facial bones decreases, which causes changes in facial proportions (Taylor, 2001). Tooth loss may be seen in this period of life. If this occurs, it leads to accelerated bone resorption—the lower third of the face becomes shorter (Neave, 1998) and the cheeks can appear hollow (Albert et al., 2007). The lips become thinner, and jowls and a double chin appear (Albert et al., 2007, Taylor, 2001; Treacy, 2009).

TABLE 33.9
Hard and Soft Tissue Age-Related Changes

Approximate Age Range (Years)	Likely Bony Change	Probable Soft Tissue or Facial Appearance Effect
20–30	• Slight craniofacial skeletal growth. • Slight anterior (mostly lower) face height increase. • Mandibular length increase.	• Upper eyelid drooping begins. • Eyes appear smaller. • Nasolabial lines begin to form. • Lateral orbital lines begin to form. • Upper lip retrusion begins in females.
30–40	• Maxillary retrusion progressing, contributing to nasolabial folds • Dentoalveolar regression suggesting eruptive movement of teeth. • Mandibular length increase.	• Circumoral striae begin to form. • Lines begin to form from lateral edges of nose to lateral edges of mouth. • Upper lip thickness decreasing.
40–50	• Craniofacial skeletal remodeling progresses. • Dental alveolar regression and dental eruption progressing. • Maxillary and mandibular dental arch lengths decreasing.	• Facial lines and folds continue to increase in depth. • Nose and chin positioning affected as dental arch lengths decrease. • Most profound morphological changes of the head, face, and neck are evident.
50–60	• Craniofacial remodeling continues. • Cranial thickness likely unchanging	• Facial lines and folds continue to increase in depth. • Protuberance of nose and ears due to greater craniofacial convexity.
>60	• Alveolar bone remodeling. • Possible dental attrition affecting vertical face height. • Decrease in craniofacial size. • Greater craniofacial convexity (excluding maxilla and mandible). • Possible temporomandibular joint arthritis and joint flattening. • Alveolar bone remodeling continues.	• Protuberance of nose and ears continues. • Concave appearance in cheek hollows due to alveolar bone remodeling. • Diminished jaws.

Source: Albert et al., 2007.

Old Age

All existing lines and furrows, which cover most of the facial surface, are exaggerated (Albert et al., 2007; Taylor, 2001; Neave, 1998). The authors (Albert et al., 2007; Taylor, 2001; Neave, 1998) all agree that there is a loss of skin elasticity and significant sagging of soft tissues after 60 years of age.

The ears appear longer and the nose is getting wider and flattened (Albert et al., 2007; Taylor, 2001; Neave, 1998). Neave (1998) states that "the upper lip frequently becomes quite thin, and the lower lip has a tendency to protrude forwards." He also agrees that upper eyelid hooding becomes noticeable, which is a significant feature of older faces. Skin pigment cells, which occur as brown spots on the face, increase in number and size (Treacy, 2009).

Albert et al. (2007) indicates the main age-related soft tissue and hard tissue changes on the face (Table 33.9).

FORENSIC ART

In order to have an understanding of forensic art, above all else forensic science should be comprehended. Forensic science is the application of science to law (Saferstein, 2004). It is defined in the Forensic Science Glossary (Brenner, 1997; 62) as "The application of scientific facts to legal problems. The field of science used in the judicial process."

Forensic science is a multidisciplinary study (Gialamas, 2000). According to Inman and Rudin (2001; 3), judicial authorities may benefit from "any profession, discipline, craft, or art." One of the fields in forensic science is forensic art. Taylor (2001; 3) opines that "forensic art is any art that aids in the identification, apprehension, or conviction of criminal offenders, or that aids in the location of victims or identification of unknown deceased persons."

Forensic art is a relatively new and rapidly growing field of study (Gibson, 2008); however, it is related to many other disciplines. Forensic artists work closely with forensic photographers, forensic anthropologists, medical artists, forensic odontologists, and pathologist and crime scene examiners to assist in forensic investigations.

Taylor (2001) categorized forensic art into four subcategories. These are composite imagery, image modification and image identification, demonstrative evidence, and reconstruction and postmortem identification aids.

Age Progression

Image modification, one of the subfields of forensic art, aims to modify the photograph and generate a new portrait for the purposes of age progression and age regression (Taylor, 2001; Michaelis, 2004). Age progression, a useful method in forensic applications, can be applied to missing



FIGURE 33.19 Age progression: an individual at ~20 years of age (upper left), ~30 years (upper center), ~40 years (upper right), ~50 years (lower left), ~60 years (lower center), and ~70 years (lower right).

persons cases (Manhein et al., 2008). It also plays a significant role in identifying a suspect or a victim of a forensic case (Michalis, 2004).

Future facial appearance of an individual can be predicted by the application of the age progression method (Figure 33.19). Basically, there are two age progression categories: juvenile age progression and adult age progression. Juvenile age progression is generated for law enforcement units to help in finding abducted and missing children, whereas adult age progression is commonly requested for updating fugitive images (Mullins, in press).

Traditionally, there are two methods of age progression: hand drawn and computer assisted using photo-editing packages (Taylor, 2001; Michaelis, 2004; Gibson, 2008). Whether hand drawn or computer assisted, the age progression specialist must obtain knowledge of craniofacial growth, dentition, facial anatomy and structure, and age-related soft and hard tissue changes (Taylor, 2001); otherwise, the reliability of the age progression work of the practitioner will be questioned. In his paper, Michaelis (2004) specifies that working with a forensic anthropologist authenticates the age progression work of the practitioner if he does not have knowledge of facial growth and aging processes.

Determining the methodology of age progression mostly depends on the quality of the photograph and angle of the view of the individual. If the photograph is of high quality and the appropriate angle of the view is suitable, the computer-assisted method will be chosen; otherwise, the hand-drawn method would be the optimal choice (Taylor, 2001).

At present, photographs may be of high quality because of the available hi-tech cameras. Furthermore, computer-assisted software packages offer powerful tools to manipulate the images. Thus, the computer-assisted age progression method is generally preferred by forensic artists and forensic anthropologists (e.g., Joe Mollins, Eileen Barrow, Caroline Wilkinson, and Charlaine Michaelis in the UK and Manhein et al., 2008; Thomas, 2003; and Michalis, 2004 in the United States).

In the computer-assisted age progression method, the last known photograph of the missing person is scanned and manipulated to generate an age-appropriate image. The photographs of the parents and bloodline relatives are also included into the work, either being used as guidance or merged with the photograph of the missing person (Gibson et al., 2009; Manhein et al., 2008; Thomas, 2003).

REFERENCES

Aging (2010) In Merriam-Webster Online Dictionary, [Online]. Available: http://www.merriam-webster.com/dictionary/aging [01 June 2010].

Aging (2010) In Cambridge Online Dictionary, [Online]. Available: http://dictionary.cambridge.org/dictionary/british/ageing#ageing__3 [01 June 2010].

Aizen E, Gilhar A (2001) "Smoking effect on skin wrinkling in the aged population." *Int J Dermatol* 40:431–3.

Albert AM, Ricanek K, Patterson E (2007) "A review of the literature on the aging adult skull and face: Implications for forensic science research and applications." *Forensic Science International* 172: 1–9.

Bartlett SP, Grossman R, Whitaker LA (1992) "Age-related changes of the craniofacial skeleton: an anthropomorphic and histologic analysis." *Plast Reconstr. Surg* 90:592–600.
Bell S (2008) *Encyclopedia of Forensic Science*. New York: Facts on File Inc.
Benjamin CL, Garman GR, Funston JH (1997) *Human Biology*. USA: McGraw-Hill Companies.
Bishara ES, Ferguson D (2001) Introduction to the Growth of the Face. In: Bishara ES (ed) *Textbook of Orthodontist*. Philadelphia: W.B Saunders company. Ch.4.
Bishara ES ed., (2001) *Textbook of Orthodontist*. Philadelphia: W.B Saunders company.
Boyd AS, Strasko T, King LE, Cameron GS, Pearse AD, Gaskell SA (1999) "Cigarette smoking-associated elastotic changes in the skin." *Journal of the American Academy of Dermatology* 41:23–26.
Brenner JC (1997) *Forensic Science Glossary*. Florida: CRC Press.
Broadbent BH, Broadbent BH, Golden WH (1975) *Bolton Standards of Dentofacial Developmental Growth*. Saint Louis: The C.V. Mosby Company.
Broadbent BH (1996) Cephalometrics in: Enlow DH, Hans MG (eds) *Essentials of Facial Growth*. Philadelphia: W.B. Saunders Company.
Brownell W, Mundorf N, Mundorf J (2006) Aging, Images Of. In: Schulz R (ed) *The Encyclopedia of Aging*, Fourth Edition. New York: Springer Publishing Company.
Cameron N (2002) *Human Growth and Development*. California: Academic Press.
Carter NE (2001) Facial growth in Laura M (ed) *An Introduction to Orthodontics*. 2nd Edition. Oxford University Press.
Chung J, Cho S (2004) Why Does the Skin Age? In: RigeI DS, Weiss RA, Lim HW, Dover JS (eds) *Photoaging*. New York: Marcel Dekker, Nc.
Cole TR, Achenbaum AW, Jakobi P, Kastenbaum R (1993) *Voices and visions in aging: Toward a critical gerontology*. New York: Springer Publishing.
Coleman SR, Grover R (2006) "The Anatomy of the Aging Face: Volume Loss and Changes in 3-Dimensional Topography." *Aesthetic Surg J* 26 (suppl):S4–S9.
Coleman SR (2004) *Structural Fat Grafting*. St. Louis, MO: Quality Medical Publishing.
Costa PT, McCrae RR (1995) Design and analysis of aging studies. In: E. J. Masoro (Ed.), *Handbook of physiology*. New York: Oxford University Press, pp. 25–36.
Daniell HW (1971) "Smoker's wrinkles. A study in the epidemiology of ''crow's feet.'' *Ann Intern Med* 75:873–80.
Development (2010) In Cambridge Online Dictionary, [Online]. [Online]. Available: http://dictionary.cambridge.org/dictionary/british/development_1 [01 June 2010].
Doshi DN et al. (2007) "Smoking and Aging in Identical Twins". *Arch Dermatol*; 143(12):1543–1546.
Drake RL, Vogl AW, Mitchell AWM (2005) *Gray's Anatomy for Students*. 2nd Ed., Edinburg-London-Melbourne-New York: Churchill Livingstone.
Enlow DH (1968) *The Human Face*. New York: Harper & Row Publishers.
Enlow DH, Hans MG (1996) *Essentials of Facial Growth*. Philadelphia: W.B. Saunders Company.
Enlow DH (1982) *Handbook of Facial Growth*, 2nd edition. Philadelphia: W.B. Saunders.
Ernster VL, Grady D, Miike R, et al. (1995) "Facial wrinkling in men and women, by smoking status." *Am J Public Health* 85:78–82.
Farkas LG, Posnick JC, Hreczko TM, Pron GE (1992a) "Growth Patterns of the Nasolabial Region: A Morphometric Study." *The Cleft Palate-Craniofacial Journal*: 29(4): 318–324.
Farkas LG, Posnick JC, Hreczko TM (1992b) "Anthropometric Growth Study of the Ear." *The Cleft Palate-Craniofacial Journal* 29(4): 324–329.
Farkas LG, Posnick JC, Hreczko TM, Pron GE (1992c) "Growth Patterns in the Orbital Region: A Morphometric Study." *The Cleft Palate-Craniofacial Journal* 29(4): 315–318.
Farkas LG, Posnick JC (1992d) "Growth and Development of the Head." *The Cleft Palate-Craniofacial Journal* 29: 301–329.
Farkas LG (1995) *Anthropometry of the Head and Face*. 2nd edition. New York: Raven Press.
Featherstone M, Wernick A (1995) Imaging the Aging Body. In: Featherstone M, Wernick A (Eds.), *Images of Aging*, New York: Routledge.
Feik SA, Glover JE (1998) Growth of children's faces. In: Clement JG and Ranson DL (eds.) *Craniofacial Identification in Forensic Medicine*. New York: Oxford University Press, pp. 204–224.
Finch CE, Tanzi R (1997) "Genetics of aging." *Science* 278:407–411.
Fry CL (2006) Cross-Cultural Research. In: Schulz R (ed) *The Encyclopedia of Aging*, Fourth Edition. New York: Springer Publishing Company.
Gavrilov LA, Gavrilova NS (2006) Reliability Theory of Aging and Longevity. In: Masoro EJ, Austad SN (eds) *Handbook of the Biology of Aging*, Sixth Edition. Burlington: Academic Press.
George RM, Singer R (1993) "The lines and grooves of the face: A suggested nomenclature." *Plast Reconstr Surg* 92: 540–2.
Giacomoni PU (2006) Aging of Human Skin. In: Conn PM (ed) *Handbook of Models for Human Aging*, Burlington: Elsevier Academic Press.
Gialamas DM (2000) Criminalistics. In: Siegel J, Knupfer G and Saukko P (eds.) *Encyclopedia of Forensic Sciences*. San Diego: Academic Press, pp. 64–68.
Gibson L (2008) *Forensic Art Essentials*. 2008. California: Academic Press.
Gibson SJ, Scandrett CM, Solomon CJ, Maylin MIS, Wilkinson CM (2009) "Computer assisted age progression." *Forensic Sci Med Pathol* 5:174–181.
Gordon L (1986) *How to Draw the Human Head*. New York: Penguin Books.
Gosden RG (1985) *The biology of menopause: the cause and consequence of ovarian aging*. San Diego: Academic Press.
Graber (1972) *TM: Orthodontics*, third edition, Philadelphia: WB, Saunders.
Growth (2010) In Cambridge Online Dictionary, [Online]. [Online]. Available: http://dictionary.cambridge.org/search/british/?q=growth [01 June 2010].
Henry KA, Costa M (2000) *The Face-lift Sourcebook*. Illinois: NTC Contemporary Publishing Group.
Herndon LA, Schmeissner PJ, Dudaronek JM, Brown PA, Listner K M, Sakano Y, Paupard MC, Hall DH, Driscoll M (2002) "Stochastic and genetic factors influence tissue-specific decline in ageing C. elegans." *Nature* 419: 808–814.
Hill P (1998) *Bone Remodeling. "British Journal of Orthodontics*" Vol 25:101–107.
Horace H (1996) "Age-progression technology and its application to law enforcement." *Proceedings of SPIE - The International Society for Optical Engineering*. 2645: 49–55.
Inman K, Rudin N (2001) *Principles and practices of criminalistics: the profession of forensic science*. New York: CRC Press.
Kachlik D, Baca V, Bozdechova I, Cech P, Musil V (2008) "Anatomical terminology and nomenclature: past, present and highlights." *Surg. Radiol. Anat*. 30:459–466.

Kadunce DP, Burr R, Gress R, et al. (1991) "Cigarette smoking: risk factor for premature facial wrinkling." *Ann Intern Med* 114:840–4.

Kahler K (2003) A head model with anatomical structure for facial modelling and animation. PhD Thesis, Saarbrücken: Saarland University.

Knott VB (1971) "Changes in cranial base measures of human males and females from age 6 years to early adulthood." *Growth* 35:145–158.

Koh JS, Kang H, Choi SW, et al. (2002) "Cigarette smoking associated with premature facial wrinkling; image analysis of facial skin replicas." *Int J Dermatol* 41:21–7.

Kreutz K, Verhoff MA (2002) *Forensische Anthropologie*. Berlin: Lehmanns Media.

Kreutz K, Verhoff MA (2007) "Facial Identification of Children Regarding Age Dependent Changes of The Human Face and Their Influence On Individual Identification." Anil Aggrawal's *Internet Journal of Forensic Medicine and Toxicology* [serial online] Vol. 8, No. 2. Available from http://geradts.com/anil/ij/vol_008_no_002/papers/paper003.html. (Accessed: June 15, 2010).

Krutman J, Gilchrest BA (2006) PhotoAging of Skin. In: Gilchrest BA, Krutman J (eds) *Skin Aging*. Berlin: Springer-Verlag.

Lampinen JM, Arnal JD, Hicks JL (2008) Prospective person memory. In M. Kelley (Ed.) *Applied Memory*. Hauppauge, NY: Nova Science Publishers

Lanitis A (2008a) "Comparative evaluation of automatic age-progression methodologies." *EURASIP J Advances Signal Processing*, doi:10.1155/2008/239480.

Lanitis A (2008b) Computer-Based Age Progression Methodologies. In: Dayan N (ed) *Skin Aging Handbook*, Norwich: William Andrew Inc. Ch.3.

Lanitis A, Taylor CJ, Cootes TF (2002) "Toward automatic simulation of aging effects on face images." *IEEE Transactions on Pattern Analysis and Machine Intelligence* 24(4):442–455.

Lee WS, Wu Y, Magnenat-Thalmann N (1999) Cloning and aging in a VR family. in *Proceedings of IEEE Virtual Reality (VR '99)*, Houston, pp. 61–68.

Leung WC, Harvey I (2002) "Is skin ageing in the elderly caused by sun exposure or smoking?" *Br J Dermatol* 147:1187–91.

Ligget J (1974) *The Human Face*. London: Constable.

Lowery GH (1973) *Growth and Development of Children. ed 6*. Chicago: Mosby Inc.

Manhein MH, Barrow NE, Listi GA (2008) The Louisiana State University (LSU) Forensic Anthropology and Computer Enhancement Services (FACES) Laboratory. In: Warren MW, Walsh-Haney HA, Freas LE (eds). *The Forensic Anthropology Laboratory*. New York: CRC Press Taylor & Francis Group. Ch.9

Masoro EJ (2006) Are Age-Associated Diseases an Integral Part of Aging? In: Masoro EJ, Austad SN (eds) *Handbook of the Biology of Aging*, Sixth Edition. Burlington: Academic Press.

McQueen I (1989) "Computer Age." *Police 33-34*, 42–43.

Michaelis C (2004) Forensic Art and Age Progression. International Center for Unidentified & Missing Persons [Online] Available at: http://www.doenetwork.org/media/news61.html [Accessed 4 June 2010].

Moyers RE, Enlow DH (1988) Growth of the Craniofacial Skeleton. In: Moyers RE (ed) *Handbook of Orthodontics*, 4th edition, Chicago: YearBook Medical Publishers, Inc.

Moore KL, Dalley AF (2006) *Clinically Oriented Anatomy*. 5th ED. Philadelphia: Lippincott Williams & Wilkins.

Mullins J (in press) *Facial Identification*. Cambridge: Cambridge University Press.

Neave R (1998) Age Changes to the face in Adulthood. In: J. G. Clement and D. L. Ranson, (eds.) *Craniofacial Identification in Forensic Medicine*. New York: Oxford University Press, pp. 225–231.

Nicita-Mauro V (1990) "Smoking, calcium, calcium antagonists, and aging." *Exp. Gerontol* 25: 393–399. Novick NL (1988) Super Skin. New York: Clarkson N. Potter.

Panfilov DE (2007a) The Face as a Dynamic Mosaic work – Prosopoplasty. In: Panfilov DE (ed) *Aesthetic Surgery of the Facial Mosaic*. Berlin: Springer-Verlag, Ch.1.

Panfilov DE (2007b) Fourth Dimension of the Face. In: Panfilov DE (ed) *Aesthetic Surgery of the Facial Mosaic*. Berlin: Springer-Verlag, Ch.10.

Panfilov DE (2007c) Facial Expression. In: Panfilov DE (ed) *Aesthetic Surgery of the Facial Mosaic*. Berlin: Springer-Verlag, Ch.4.

Prahl-Andersen B, Ligthelm-Bakker AS, Wattel E, Nanda R (1995) "*Adolescent growth changes in soft tissue profile*." *American Journal of Orthodontics And Dentofacial Orthopedics*. 107(5): 476–83.

Proffit WR, Fields HW (2000) *Contemporary Orthodontics*. 3rd edition, St. Louis: Mosby Inc.

Ranly DM (1980) *A synopsis of craniofacial growth*. New York: Appleton-Century-Crofts(ACC) Prentice Hall, Inc.

Robbins WJ, et al. (1928) *Growth*. New Haven: Yale University Press.

Rubinstein RL, Canham S (2008) Aging Skin in Sociocultural Perspective. In: Dayan N (ed) *Skin Aging Handbook*, Norwich: William Andrew Inc.

Sadick NS, Karcher C, Palmisano L (2009) "Cosmetic dermatology of the aging face." *Clinics in Dermatology* 27: S3–S12.

Saferstein R (2004) *Criminalistics Introduction to Forensic Science*, New Jersey: Prentice Hall.

Sarnat BG (1963) "Postnatal Growth of the Upper Face: Some Experimental Considerations." *The Angle Orthodontist* 33(3):139–161.

Schaefer M, Black S, Scheuer L (2009) *Juvenile Osteology: A laboratory and field Manual*. Burlington: Academic Press

Sehl ME, Yates FE (2001) "Kinetics of human aging: I. Rates of senescence between ages 30 and 70 years in healthy people." *Journal of Gerontology: Biological Sciences*, 56A, B198–B208.

Singh G (2007) Postnatal Growth of the Craniofacial Complex. In: Singh G (ed) *Textbook of Orthodontics*, 2nd Edition, New Delhi: JPBMP Ltd.

Singh G (2007) Postnatal Growth of the Craniofacial Complex. In: Singh G (ed) *Textbook of Orthodontics*, 2nd Edition, New Delhi: JPBMP Ltd.

Singh N and Juneja T (2007) Basic Principles of Growth. In: Singh G (ed) *Textbook of Orthodontics*, 2nd Edition New Delhi: JPBMP Ltd.

Sobotta J (2001) Atlas of Human Anatomy, 13th English edition, Volume 1: *Head, Neck, Upper Limb*. Philadelphia: Lippincot Williams & Wilkins.

Sperber GH (2001) *Craniofacial Development*. London: BC Decker Inc.

Standring S (2005) *Gray's Anatomy. The Anatomical Basis of Clinical Practice*. 39th ed. Philadelphia: Elsevier Churchill Livingstone.

Stamrud L (1959) "External and internal cranial base." *Acta. Odontol. Scand*. I7:239–266.

Strehler BL (1977) *Time, cells and aging*. 2nd edition. New York: Academic Press.

Taister MA, Holliday SD, Borrman HIM (2000) "Comments on Facial Aging in Law Enforcement Investigation." *Forensic Science Communications* Volume 2, Number 2.

Taylor KT (2001) *Forensic Art and Illustration*. New York: CRC Press.

Thomas P (2003) *Forensic anthropology: the growing science of talking bones*. New York: Facts on file, Inc.

Todd JT, Mark LS, Shaw RE, Pittenger JB (1980) "The perception of Human Growth" *Sci. Am* 242(2):132–144.

Treacy P (2009) "The Science of Facial Aging". PRLog.Org - Global Press Release Distribution. Available at: http://www.prlog.org/10299776-the-science-of-facialaging.html.

Tzaphlidou M (2004) "Morphological and functional changes in aging skin." *Micron* 35:153.

Uiotto J (1997) "Understanding premature skin aging" *New England Journal of Medicine* 337:1463–1465.

Uitto J, Fazio MJ, Olsen DR (1989) "Molecular mechanisms of cutaneous aging: Age associated mechanisms of cutaneous aging." *Journal of the American Academy of Dermatology* 21:614–622.

Vasto S, Candore G, Balistreri CR, Caruso M, Colonna-Romano G, Grimaldi MP, Listi F, Nuzzo D, Lio D, Caruso C (2007) "Inflammatory networks in ageing, age-related diseases and longevity." *Mech Ageing Dev* 128:83–91.

Weinmann JP, Sicher H (1955) *Bone and Bones*, ed. 2, St. Louis: The C. V. Mosby Company.

White TD and Folkens PA (2005) *The Human Bone Manual*. Amsterdam: Academic Press.

Wilkinson C (2004) *Forensic Facial Reconstruction*. Cambridge: Cambridge University Press.

Wilson K (2008) Market Evolution of Topical Anti-aging Treatments. In: Dayan N (ed) *Skin Aging Handbook*, Norwich: William Andrew Inc.

Y'Edynak GJ and İşcan MY (1993) Craniofacial evolution and growth. In: İşcan MY and Helmer RP (eds). *Forensic Analysis of the Skull: Craniofacial Analysis, Reconstruction, and Identification*, New York: John Wiley, pp. 1127.

33C Forensic Facial Reconstruction and Postmortem Depiction

Amy Wedge

INTRODUCTION

In the United States, approximately 4,400 unidentified bodies are recovered every year, and a quarter of them remain without identity after one year (National Institute of Justice, 2018). In many cases the remains of these individuals are decomposed beyond recognition and DNA results have not yielded any answers. It is in these circumstances that a forensic facial reconstruction or postmortem depiction may be carried out by a forensic artist to help generate new leads as well as bringing public attention to a case.

Forensic art is a varied field attracting professionals from a wide range of backgrounds, such as anatomy, forensic anthropology, art, and photography. They may specialize in one aspect of forensic art or several. This chapter will focus on 3-D and 2-D forensic facial reconstruction as well as postmortem depiction. It will discuss the role of photography in these practices and explain how to capture images appropriate for use by the artist.

POSTMORTEM DEPICTION

Overview

Postmortem depiction is the process of artistically rendering the face of a deceased individual to see its face as it would have appeared in life. The circumstances around postmortem depiction often involve mass disasters where identification by means of investigative or dental records is not possible. For example, in 2004 the Indian Ocean tsunami claimed the lives of approximately 230,000 people. For religious, familial grieving, and legal reasons, obtaining a positive identification on the remains is crucial. The physical effects of the decomposition process, often meaning the release of an image of the individual as is, is not appropriate, as it could cause psychological distress to family members as well as potentially resulting in a false identification. It is therefore necessary to create a version of the postmortem photographs suitable for release to the general public.

Photographing the Dead

Photographs of the victim's face are commonly provided to a forensic artist by a medical examiner/coroner or police department, and these images will form the basis of the postmortem depiction. It is therefore important the images be of high quality, with correct lighting and taken from appropriate angles. Where possible, any dirt, blood, or fluids should be cleaned from the face to provide the clearest view of the facial features. This helps to improve both the accuracy of the depiction and the time required to carry out the art process. A mortuary head block is recommended to position the head and hold the neck in place. These will also allow for a clear, unobstructed frontal view of the face. As with standard portrait photography, setting the focal length to short telephoto will help prevent distortion. Lighting should be even, with a flash being avoided, as flash contrast can distort the appearance of depth and bleach out subtle facial contours. Excellent guidelines for producing photographs suitable for postmortem depiction can be found in Wilkinson and Rynn (2012) and in Chapter 30.

Basic Enhancements

Before any adjustments can be made to the image, a few basic enhancements take place. It is important for every enhancement and adjustment made to the postmortem photographs be noted and later written up formally in a postmortem depiction report. Most artists choose to work in grayscale when producing a postmortem depiction. This takes unwanted color distraction away and makes evening out patches of skin discoloration easier. Creating a black-and-white image removes concern about guessing eye and hair color as well. In Adobe Photoshop, color is removed in the Hue/Saturation panel by dragging down the saturation levels. This is often done before any other changes are made. If a wide-angle lens has been used, image barreling may occur; this is where the photograph becomes distorted with straight lines appearing to curve inwards, mimicking the shape of a barrel. This should be corrected at this stage and any histogram alterations made. Histogram alterations refer to the brightness levels of the image; the overall tone can be adjusted to make the image darker or lighter (see Figure 33.20).

Correcting Facial Injury

In an image, the head can be selected using either the Lasso, Quick Selection, or Marquee tool, copied, and then pasted onto a new background layer of either white or light gray. This removes any background detritus or mortuary tables from the frame.



FIGURE 33.20 Left, overexposed. Middle, correct exposure. Right, underexposed. The histogram can be used to adjust the brightness levels of the image.

Tools can then be used to begin cleaning the face, concealing cuts, bruises, and any remaining dirt. The choice of tool will depend on the artist's personal preference and the size and nature of the injuries. The clone stamp is good for dealing with larger areas requiring correction. An area of undamaged skin can be sampled and used to paint over the area(s) of imperfection. For smaller injuries, the healing brush tool is very useful. It is commonly used for covering blemishes in portrait photography. This tool can remove small contusions, cuts, and flecks of blood/dirt from the face rather successfully. Distortion tools can be used to adjust minor facial deformations. The Liquify tool is particularly good for pushing and pulling parts of the image into place. For more drastic distortion or large areas of trauma unable to be corrected with any of the tools noted here, photographs from an image bank of portraits can be imported and an appropriate matching feature can be copied, pasted, and blended in.

Most postmortem images are captured with the victim's eyes closed. However, it is preferred for postmortem depiction renderings to show the individual with open eyes. It is therefore often necessary to select a suitable replacement from the image bank and copy, paste, and blend them in. Working in grayscale reduces the issue of unknown eye color. A mid-tone should be used if the color is not known.

Finishing Touches

When reaching the final stages, the Photoshop file will have multiple layers containing cut and pasted facial features, skin patches, and smaller corrections. Before merging the layers, it is advised to check the blending, ensuring the tones of the pasted areas match the original image and, if not, adjust accordingly. Another element to check is the resolution of the sections pasted from the image bank in comparison with the resolution of the original photograph. If these do not closely match, the resulting depiction will appear disjointed. This can be corrected by slightly blurring any layers appearing too sharp with the Gaussian Blur tool until evenly matched. Another way would be to adjust the resolutions of all the layers so they match.

3-D FORENSIC FACIAL RECONSTRUCTION

Overview

Although the concept of facial reconstruction may be perceived as a modern scientific method, it has in fact been carried out for over a century. The first scientifically recognized facial reconstruction was attempted by Kollman and Buchly in the late 19th century (Kollman, 1898), and subsequent anthropologists, artists, and archaeologists explored the practice and improved upon the methods. It is, however, still a controversial technique with greatly disputed accuracy. Ultimately the quality of the reconstruction is reliant upon the skills and experience of the forensic artist, as well as the accuracy of information provided to them, including photographic material and anthropological assessment.

Assessment of the Remains

The reconstruction process first begins with an assessment of the remains by a medical examiner, coroner, or forensic anthropologist. At this stage they will attempt to determine the sex and ancestry of the individual and estimate an approximate age. This is ascertained by careful examination of the bony features of the skull and the postcranial skeleton. The skull is of particular interest due to the uniqueness of its complex structures. The development and growth of the cranial and facial bones vary significantly from person to person and form the basis of an individual's unique facial characteristics.

Photographic Documentation of the Skull

In most cases, remains requiring reconstruction will be skeletal, but it is possible soft tissue may still be present. If this is the case, it is important to photograph and record anything significant possibly providing information relating to the individual's facial features. If hair is present, color and texture should be noted and documented, as this will further assist the accuracy of the final reconstruction. Residual soft tissue is typically removed before the skull is presented to a forensic artist, so the onus is on

the medical examiner to correctly photograph anything of importance.

Photographing the skull before the reconstruction begins greatly aids in the initial planning stages of the sculpture, allowing the artist to familiarize themselves with the subtle bony features and textural characteristics of the individual. A common mistake for novice forensic artists is losing track of the underlying skull once they begin applying the clay. Physical, one-to-one scale printouts of the images should be made and kept as a reference throughout the reconstruction process to prevent this from occurring.

Positioning the Skull

The Frankfort Horizontal Plane is the standard anatomical position in which a skull should be placed to achieve accurate horizontal alignment for photographing. Merriam-Webster describes the position of this plane as being "the highest point on the upper margin of the opening of each external auditory canal and the low point on the lower margin of the left orbit" (Merriam-Webster, 2018). Figure 33.21 demonstrates the correct alignment. The cranium and mandible should be assembled and photographed together if both are present. Attention should be paid to ensure correct positioning of these two skeletal elements. If the skull is too unstable to stand freely, a cloth can be used to help stabilize it. It is important to check that the cloth does not obscure any parts of the skull when framing the photograph.

Backdrops

When photographing forensic or archeological remains, there are two standard backdrop options: either blue or black cloth. The color of bones varies depending upon burial conditions. Some may be considerably lighter than others, and the backdrop material should be selected in accordance with the bone color. A nonreflective material should always be used. Velvet or cotton is recommended for successful results. Any cloth used to support the positioning of the skull should be the same color and material as the backdrop.

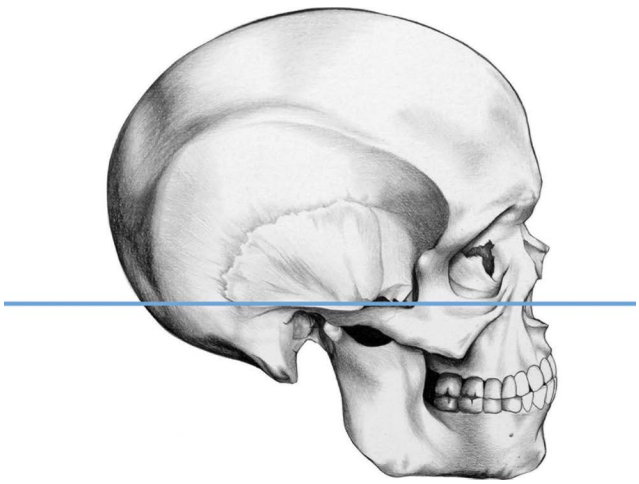


FIGURE 33.21 The Frankfort Horizontal Plane, correct alignment indicated by positioning of the blue line.

Lighting

It is likely that most photography of human remains will take place in a lab setting, and it is fair to assume the lighting will be adequate under these conditions. However, if the lighting is too harsh it may create shadows obscuring details of the skull. A macro ring-flash may be used to achieve more controlled, even lighting and prevent unwanted shadows or blown-out images. To check for blown out highlights, file information can be accessed on the camera display using the playback option and selecting Highlights. Different cameras will, of course, have different ways of viewing this. When the Highlights option is selected, highlight warnings will appear on any overexposed areas. Another way is to check the image histogram to determine if the white values are in contact with the Y-axis of the graph.

AVOIDING DISTORTION

The small, intricate details of a skull provide the unique characteristics of an individual. Minor distortion of these features in the photographic process can have a significant impact upon the completed reconstruction if the images are relied upon to inform the sculpture. It is therefore important to avoid any level of distortion by correctly setting up and positioning the camera. Placing the camera too close to the subject will result in a barrel distortion, as previously described. It is preferable therefore to select or zoom a lens to short telephoto and move the camera farther away from the skull to reduce this effect. The recommended focal length for portrait photography depends upon the size of the image sensor, but approximately 1.5× the "normal" lens focal length should be enough to minimize distortion. This is also applicable for photographing the skull. Once the photographs have been made, reviewed, and any minor enhancements made, the images can be scaled and printed, ready for the next stage of the reconstruction process.

Reproducing the Skull

Originally, facial reconstructions would be carried out by applying clay directly onto the unidentified individual's skull. This approach was problematic in that damage could occur to the skull during the process of either applying the clay or later removing it. Reconstructing the skull onto a cast then became the preferred method. Modern technology allows remains to be accurately scanned using a 3-D scanner and 3-D printed in plastic, thus precisely reproducing the texture and structure of the bones in a manner nondamaging to the remains. Nowadays 3-D printing is relatively easy, fast, and inexpensive. An object such as a skull

can be scanned and replicated by means of a 3-D scanner and printer within several hours. Printing multiple copies of the skull is quick and easy and gives the artist the advantage of having a second replica on hand to refer to throughout the reconstruction.

Digital 3-D Facial Reconstruction

3-D scanning of the skull allows forensic artists the option of reconstructing the face digitally using sculpting software such as Freeform with a haptic stylus; haptic input devices allow the artist to physically feel the shape of the object they are sculpting. A haptic stylus is a digital sculpting tool shaped like a pen and fixed to a movable arm, allowing a sculptor to interact with a computerized 3-D object on the screen as if they were touching the real object. The arm attached to the pen provides resistance, creating the illusion of touching the object, and the ability to sculpt with the pen in a software program in a similar manner to sculpting a physical block of clay. The downside to these devices is the high cost of the hardware and training time required to learn the software successfully. The ability to send 3-D bone scans and reconstructions via email or text opens up the option of instantly sharing files across the world, giving police departments the opportunity to work with artists globally. The following steps described for carrying out a clay reconstruction are similar to the digital process. The main differences arise towards the end of the reconstruction and relate to texturing/finishing.

Tissue Depth Markers

Tissue depth refers to the combined thickness of the soft tissues, muscles, fat, and glands. Tissue depth is calculated based on sex, age, and ancestry; a person's weight will also affect their tissue depth; however, this can be difficult to estimate if no soft tissue is present. Signs of chronic anorexia or obesity may be seen on the bones, and this information can be used to aid in the determination of tissue depth. Charts listing average tissue depths can be found in *Forensic Facial Reconstruction* (Wilkinson, 2004). Wooden pegs are cut to the appropriate length to match the depth and fixed to the skull at designated points. Figure 33.22 demonstrates the positioning of the tissue depth markers.

The Manchester Method

The Manchester method is one of the two main methods of facial reconstruction, and the American method is the other. The difference between the two approaches is the Manchester method requires the sculpting of individual muscles and glands, whereas with the American method, the clay is applied in strips without the underlying anatomical detail. Figure 33.23 shows the comparison between the two.

Most artists choose to begin sculpting the neck to provide a stable base for the rest of the sculpture. The facial

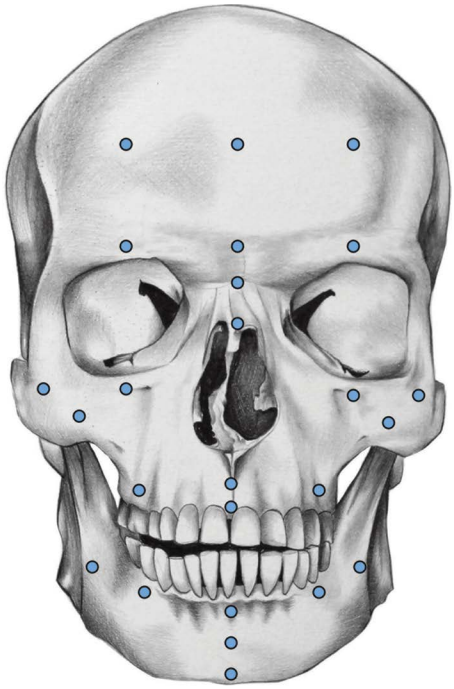


FIGURE 33.22 Tissue depth markers. Blue circles indicate standard placement points for wooden tissue depth markers.

muscles are then shaped and applied to the skull in the following order:

- Temporalis
- Masseter
- Buccinator
- Orbicularis oris
- Mentalis
- Depressor labii inferioris
- Depressor anguli oris
- Orbicularis oculi

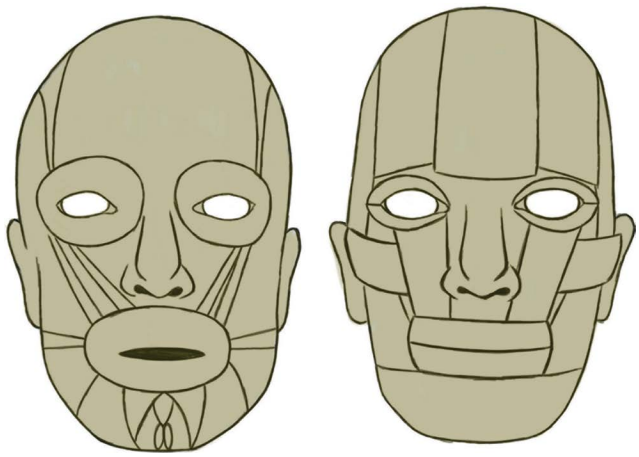


FIGURE 33.23 Left, Manchester method. Right, American method. Illustrations show the basic structural differences between the two approaches.



FIGURE 33.24 Basic sculpting process using the Manchester method. Application of clay muscles, followed by glands, fat, and a skin layer.

- Levator labii superioris alaeque nasi
- Nasalis
- Levator anguli oris
- Levator labii superioris
- Zygomaticus major and minor
- Corrugator supercilii
- Procerus
- Occipitofrontalis
- Parotid gland
- Risorius

Figure 33.24 illustrates some of these stages. Once all muscles and glands have been applied, a skin layer of approximately 8.5 mm can be rolled out in clay and carefully placed over the top of the muscles, with particular attention paid to ensure the pegs are covered, but not deeply.

Ears and Nose

Ear size and shape are dependent upon the development level of the supramastoid crest. This will indicate either upper or lower protrusion of the ear. The directional position of the mastoid processes while the skull is positioned in the Frankfort Horizontal Plane determines whether the lobes are adherent or nonadherent. A downward-pointing process is indicative of adherent lobes, and forward-pointing processes suggest nonadherent lobes.

The methods of calculating the nasal profile, width, and projection are slightly more complex. One-to-one scale printouts of the skull photographs previously taken will be of use at this stage, as it often helps to draw out the nasal shape before sculpting it.

Finishing Touches (Clay)

The skin layer is smoothed, and textural detail is applied. The age estimate will provide a guide to the condition of the skin in terms of wrinkles and elasticity. When adding the final details, caution should be taken that the artist does not embellish elements to create a more realistic portrait deviating from the known information. That is:

- Skin texture
- Pores
- Facial hair

These may make for a more lifelike sculpture but could detract from the accuracy of the reconstruction. If no information is known about hair color or length, a best guess can be used. Ancestry statistics for hair color and texture may help in this, and an appropriate and subtle style should be chosen to minimize distraction from the facial features.

Finishing Touches (Digital)

Once the digital sculpture is completed, it can be textured in 2-D by layering photographs. This is achieved by taking a high-resolution screenshot of the reconstruction in portrait position (mode) and exporting it into Photoshop. Forensic artists who routinely carry out digital reconstructions typically have large image banks of high-quality portrait photographs, displaying different facial features and characteristics. The composite image is then assembled by considering each individual feature, sourcing a matching photograph from the bank, and then superimposing and blending the image over that. Converting the image to black and white is a common practice. This not only helps with blending the superimposed images but also prevents attention being drawn to eye and hair color if those details are unknown and turn out to be wrong.

PHOTOGRAPHING THE FINAL RECONSTRUCTION

At this stage the completed reconstruction is ready to be photographed and released to the press, to hopefully gain new leads and possibly identify the individual. As with the skull photography, even-textured lighting and correct camera setup are vital to ensure the quality of the images. The same rules apply as previously described under backdrop, lighting, and avoiding distortion. Final adjustments will be

made to the image in postproduction. Typically, this will involve converting the image to black and white. If eye color and hair color are unknown, it is recommended to release only a black-and-white image of the sculpture, as guessing these features may lead to someone ruling out the identity of a friend or family member based on these details.

2-D Approach to Forensic Facial Reconstruction

The principles of 2-D facial reconstruction are similar to that of 3-D reconstruction. The benefit of this method is the lower cost and shorter time it takes to produce an image, although there is debate over the accuracy of the results compared to working in 3-D. *Forensic Art and Illustration* (Taylor, 2000) describes the process in detail and demonstrates successful applications of this method.

Forensic photography is an important element of 2-D reconstruction. Unlike in 3-D reconstruction, the artist may not have access to the skull or a copy of the skull and is therefore reliant on the quality of the extant photography to produce the drawing. The success of facial reconstruction is dependent upon the artist identifying the subtle bony features of the skull and using this information to determine the individual's facial characteristics. Deformation in the photography stage due to incorrectly setting up the camera, poor lighting, or inappropriate positioning of the cranium and mandible will have a detrimental effect on the finished reconstruction. The same basic photography rules regarding lighting, backdrops, and avoiding distortion, as previously mentioned, apply for 2-D reconstruction reference images also.

SUMMARY

Forensic photography plays a critical role in the success of both facial reconstruction and postmortem depiction. It is therefore of use to law enforcement, medical examiners, and any other professionals working with a forensic artist to have a basic concept of the processes involved. Errors occurring at the initial photography stages will have a detrimental effect on the outcome of the sculpture or drawing, potentially leading to a misidentification. Understanding how the artist creates a reconstruction or depiction will help those working with them to provide the best quality photographic material.

REFERENCES

1. Houck M. (2007). *Forensic Science Modern Methods of Solving Crime*, Westport: Praeger Publishers.
2. İscan MY. (1993), Craniofacial Image Analysis and Reconstruction, in *Forensic Analysis of the Skull,* Willey-Liss, New York.
3. Klasén L. (2002). Image Sequence Analysis of Complex Objects, Unpublished master's thesis, Department of Electrical Engineering, Linköping University, Linköping, Sweden.
4. Moreton R. and Morley J. (2011). Investigation into the use of photoanthropometry in facial image comparison. *Forensic Science International*, 212(1–3), pp. 231–237.
5. Steyn M, Pretorius M, Briers N, Bacci N, Johnson A and Houlton TMR (2018). Forensic facial comparison in South Africa: State of the science. *Forensic Science International*, 287:190–194.
6. Bulut Ö. and Sevim A. (2013). The Efficiency of Anthropological Examinations in Forensic Facial Analysis. *Turkish Journal of Police Studies/Polis Bilimleri Dergisi*, 15(1).
7. Bromby M. (2003). "At Face Value? The Use of Facial Mapping and CCTV", *New Law Journal: Expert Witness Supplement*, February 153(7069):302–304.
8. Porter G, Doran G. (2000). An anatomical and photographic technique for forensic facial identification. *Forensic Science International*, 13;114(2):97–105.
9. Wilkinson C, Evans R. (2009). Are facial image analysis experts any better than the general public at identifying individuals from CCTV images? *Science & Justice*, 1;49(3):191–6.
10. Evison MP, Bruegge RW. (2016). editors. *Computer-aided forensic facial comparison*. Boca Raton, FL, CRC Press.
11. Oxlee G. (2007). Facial recognition and imagery analysis. *Forensic Human Identification: An Introduction. Taylor & Francis, Boca Raton, FL*, pp. 257–70.
12. Tistarelli M, Bicego M, Grosso E. (2009). Dynamic face recognition: From human to machine vision. *Image and Vision Computing*, 2;27(3):222–32.
13. Bulut O. (2010). Blind Study of Age Regression Evaluation. Unpublished MSc Dissertation, Centre for Anatomy and Human Identification, University of Dundee, UK.
14. Hammer HJ, Körperliche M. (1978). In H Hunger and D Leopold (eds): Identifikation. *Leipzig:Barth*, pp 391–404.
15. Roelofse MM, Steyn M, Becker PJ. (2008), Photo identification: facial metrical and morphological features in South African males. *Forensic Science International*. 20;177(2-3):168–75.
16. Kleinberg KF, Vanezis P, Burton AM. (2007). Failure of anthropometry as a facial identification technique using high-quality photographs. *Journal of Forensic Sciences*, 52(4):779–83.
17. FISWG (2012). Guidelines for Facial Comparison Methods. Accessed on: November 13, 2018. https://www.fiswg.org/FISWG_GuidelinesforFacialComparisonMethods_v1.0_2012_02_02.pdf
18. Iscan MY. (1993). Introduction of techniques for photographic comparison: potential and problems. *Forensic Analysis of the Skull*. 1993, pp. 57–70, Willey-Liss, New York, USA.
19. Vanezis P, Brierley C. (1996). Facial image comparison of crime suspects using video superimposition. *Science & Justice*, 36, 27–33.
20. Dunn K, Harrison RK. (1997). "Naming of parts: a presentation of facial surface anatomical terms." *British Journal of Plastic Surgery*, 50, pp. 584–589.
21. Yoshino M, Matsuda H, Kubota S, Imaizumi K, Miyasaka S. (2000), Computer-assisted facial image identification system using a 3-D physiognomic range finder. *Forensic Science International*, 109(3):225–237.
22. Yoshino M, Matsuda H, Kubota, S, Imaizumi K, Miyasaka S. (2000), Assessment of computer-assisted comparison between 3-D and 2-D facial images. *Japanese Journal of Science and Technology for Identification*, 5(1):9–15.
23. Yoshino M, Noguchi K, Atsuchi M, Kubota S, Imaizumi K, Thomas CDL, Clement, JG. (2002). Individual identification of disguised faces by morphometrical matching. *Forensic Science International*, 127(1–2):97–103.

24. Yoshino M. (2005). Facial image identification system based on 3D physiognomic data. *Computer-Graphic Facial Reconstruction*, pp. 347–362.
25. De Angelis D, Sala R, Cantatore A, Grandi M, Cattaneo, C. (2009). A new computer-assisted technique to aid personal identification. *International Journal of Legal Medicine*, 123(4):351–356.
26. Goos MI, Alberink, IB, Ruifrok AC. (2006). 2D/3D image (facial) comparison using camera matching. *Forensic Science International*, 163(1-2):10–17.
27. Mullins J. (2012). Age progression and regression. *Craniofacial Identification*, pp. 68–75.
28. Gibson L. (2010). *Forensic Art Essentials: A Manual for Law Enforcement Artists*. Academic Press.
29. Gibson S. (2012). Computer-assisted age progression. In: Wilkinson C, Rynn C, editors. *Craniofacial Identification*. Cambridge: Cambridge University Press. pp. 76–85.
30. Stephan CN, Caple, JM, Guyomarc'h, P, Claes, P. (2018). An overview of the latest developments in facial imaging. *Forensic Sciences Research*, pp. 1–19.

FURTHER READINGS

Christensen A, Bartelink E, Passalacqua N. (2014). *Forensic anthropology*. Oxford: Academic Press.

Collier J. and Collier M. (1986). *Visual anthropology*. Albuquerque, New Mexico: University of New Mexico.

de Meijer P, Karlsson J, LaPrade R, Verhaar J, Wijdicks C. (2012). A guideline to medical photography: a perspective on digital photography in an orthopaedic setting. *Knee Surgery, Sports Traumatology, Arthroscopy*, 20(12): 2606–2611.

Dirkmaat D. (2015). *A companion to forensic anthropology*. Malden (MA): Wiley Blackwell.

Edwards E. (2016). *Photography, Anthropology and History*. [S.l.]: Routledge.

Gatliff B.P. (1984). Facial Sculpture on the Skull for Identification. *American Journal of Forensic Medicine and Pathology*, 5(4):327–332.

Gilbert W. and Richards G. (2000). Digital imaging of bone and tooth modification. *Anatomical Record*, 261(6):237–246.

Guan Y. (2009). Unsupervised human height estimation from a single image. *Journal of Biomedical Science and Engineering*, 02(06):425–430.

Kollman J.A. *Die Persistenz der Rassen und die Reconstruction der Physiognomie Prahistorischer Schadel*. Archiv fur Anthropologie, 1898.

Mann R., Hunt D, Lozanoff S. (2016). *Photographic Regional Atlas of Non-metric Traits and Anatomical Variants in the Human Skeleton*. Spingfield: Charles C. Thomas Publisher.

Merriam-Webster. *Frankfort Horizontal Plane*. https://www.merriam-webster.com/medical/Frankfort%20horizontal%20plane. 2018.

Miranda G, Melani R, Francisquini Júnior L, Daruge Júnior E. (2017). Use of an Alternate Light Source to Detect Tooth and Bone. *Brazilian Dental Journal*, 28(1):78–81.

National Institute of Justice. *About NAMUS*. https://www.namus.gov/About. 2018.

Neave R., Prag J. *Making Faces: Using Forensic and Archaeological Evidence*. British Museum Press, 1997.

Taylor, K. *Forensic Art and Illustration*. CRC Press, Boca Raton, FL, 2000.

Thurner P, Erickson B, Schriock Z, Langan J, Scott J, Zhao M, Weaver J, Fantner G, Turner P, Kindt J, Schitter G, Morse D and Hansma P. (2006). High-speed photography of the development of microdamage in trabecular bone during compression. *Journal of Materials Research*, 21(05): 1093–1100.

Weiss E. (2015). The surface of bones: methods of recording entheseal changes. *Surface Topography: Metrology and Properties*, 3(3), p.034003.

White T, Folkens P. (2005). *The Human Bone Manual*. Oxford: Academic.

Wilkinson C., "Facial Tissue Depth Measurement," in. C. Wilkinson, ed., *Forensic Facial Reconstruction*, Cambridge, UK: Cambridge University Press, 2004, pp. 126–140.

34 Photography for Publication

Mark R. Feil

CONTENTS

Introduction 639
Image File Formats 639
JPEG (or JPG) 639
GIF 640
PNG 640
TIFF 640
Raw 640
PDF 640
Creating Print-Ready Files 641
Note 641

INTRODUCTION

If you are reading this chapter, you have taken photographs and you probably have a good idea of what you want to do with those images. There are a number of important distinctions and details to keep in mind, depending on the type of files your photographs are in and how you want to use them. Forensic photographs are typically destined for one of the following: the Web, a presentation, publication in a journal or a book, or a poster to be displayed at a conference or in court. Depending on the type of file in which your individual image is saved, how you want to use it will determine how much work is ahead of you.

Digital images can be saved in ways including JPG, GIF, TIFF, PDF, PNG, and raw. Each has its own advantages and disadvantages. However, before we explore the characteristics of each, we should mention the different types of digital images: raster and vector.

A raster image is one represented by information that translates into pixels on a screen. Together these points of color form an image. Each pixel is assigned a color, and this type of file uses the red, green, and blue (RGB) color system on your computer screen. Examples of files that are raster images include GIF, PNG, TIFF, raw, and JPEG. Images in these formats should be captured and processed at the highest possible and practical resolution. Adobe Photoshop and other image editing software can save raster images in both RGB and CYMK (cyan, yellow, magenta, black) color formats. This is very important and will be discussed further later.

A vector image is a special type of file using a mathematical formula to construct the image. Each pixel, line, and shape has its own formula. Because the formula is easily scaled, this type of image can be enlarged and still have smooth edges and not appear blurry or jagged. The best-known file of this type is PDF.

In addition, different file types require different amounts of space on a hard drive or other storage media. To get around issues with large image sizes, graphic files can be compressed, but not always without penalty. If a graphic file can be compressed, then restored, and every single bit of data is intact afterwards, it is termed a lossless format. An example of this is a TIFF file. On the other hand, certain types of files will lose some of their original data upon being restored to their original size. This will result in a permanent loss of image features and quality. These types of files are called lossy. The best-known example of this format is JPEG.

Finally, consider resolution. If an image on a web page looks reasonably sharp on a computer screen, chances are it will look bad when printed. That is because images on the screen only need to be 72 dots per inch (dpi). For a graphic or a photograph to look good when printed, it should be at least 300 dpi across the whole size of the print. Higher resolution requires larger file sizes, and because web pages need to load quickly, lower-resolution images are often used.

IMAGE FILE FORMATS

JPEG (OR JPG)

This common file format was developed by the Joint Photographic Experts Group and is the graphic file type people are most familiar with. All digital cameras use this file type primarily, and the photographers can set and choose from a number of different resolutions. High-resolution JPEG photos can often be breathtaking. However, JPEG files are a lossy raster format that can be compressed a great deal to reduce file storage size. As file size decreases so does the quality of the image. However, this file type will still look good compressed, which is why JPEGs are usually used for websites and email where small file size makes speed of transit and reconstruction shorter.

Use: JPEG when you need to share a compressed image online, like on a web page, or when you have a

high-resolution file you want to edit and print on a printer or upload to a printing service like those found in drug stores.

Do not use: JPEG if you need a web graphic with transparency, or you need a layered image to edit. Also, the more times you open, edit, and save a JPEG, the more you MAY degrade its quality. This will not be noticeable if you only do it a couple times, but after 10 or 12 sessions, you may begin to observe the quality suffering.

GIF

GIF (pronounced "Jiff" like the peanut butter) is a lossless raster format that stands for Graphics Interchange Format. These types of files can be compressed to a very small size and are ideal if you want to create a web animation. However, they are restricted to 256 colors, which excludes them from producing photographic-quality images.

Use: GIF if you need a small file or transparency, or if you want to create an animation for a web page.

Do not use: GIF if you need high image quality, because it is restricted to 256 colors, or if you need to print an image.

PNG

PNG stands for Portable Network Graphics. This file type is a lossless raster format and can be considered GIF on steroids, because it can display more than 256 colors, it has transparency, and it can be highly compressed for websites. While it is lossless, it is also a low-resolution file type. This makes it ideal for the Web, but unsuitable for photos needing higher quality.

TIFF

TIFF stands for Tagged Image File Format. These very high-quality files are lossless and can be saved in a variety of color formats and degrees of compression. However, these types of files are usually much larger than other types. Many digital cameras will allow the option of saving photographs as TIFFs, but they will take up more room in storage media than JPEGs and take longer for the camera to save this kind of file onto the media.

Use: TIFF when you want high-quality images that will not degrade no matter how many times they are edited, saved, compressed, and repeated.

Do not use: TIFF if you are creating web pages because of the larger sized files, which will take longer to load on a browser.

Raw

Many digital cameras allow the option of saving captured images in raw format. These contain ALL the information the camera captured. Raw images store the processed and unprocessed data in separate files so the highest-quality image is then possible that can be edited nondestructively. However, raw files are not for sharing on the Web or printing—if you want to do that, you will have to use the paired JPEG or possibly TIFF. Raw is a proprietary format: every camera manufacturer has their own, and those formats change over time. Thus, it may become more difficult to read today's raw files 10 years from now.[1] The smart thing to do is to create a TIFF or JPEG file along with the raw file for archival storage.

Use: Raw when you want very high-quality images and broader editing capabilities after converting the raw file to JPEG or TIFF.

If shot in raw, the camera sensor is for capture, not editing, giving the photographer control of the finished image.

Raw files need to be imported into a computer program like Adobe Lightroom or Adobe Camera raw and then exported as JPEGs. Or they can be perfected by editing according to the photographer's vision for the specific image and *then* exported as a JPEG or another printer-friendly format

A raw file is not an "image." It is information gathered by the sensor and delivered on a memory card. It is then the photographer's job to do what they want with that information before compressing it into an "image."

Do not use: Raw when you're working with web pages. When you want to use your raw photos on a web page, convert to a JPEG first and then compress it by saving it as a smaller-sized file.

PDF

Adobe created the Portable Document Format and it is found everywhere files are found, both textual and photographs. PDFs are lossless vector files, which means they can be compressed and they can also be enlarged without becoming blurry or jagged.

There are two main ways to create PDFs. The first is to save your image file as a PDF from your editing program. The resulting file can be compressed, scaled, and placed on a web page, emailed, or printed at your desk. It can also be sent to an editor who will lay it out in an article or book. Unfortunately, PDFs are difficult to edit. Your editor might prefer to receive a JPEG that he or she can edit. When the entire article or book has been laid out, it will ultimately be sent to the printer as a PDF.

The second way to create a PDF is to edit your photograph and then save it as a JPEG or TIFF to be laid out using Adobe InDesign, Photoshop, or Illustrator. Also, no commercial printer will accept a JPEG or TIFF file for printing. They only accept PDF files. After your graphic file has been laid out, you will export the entire file as a PDF, which a commercial printer will use to make your finished product. You would do this if you wanted to enlarge your photograph for a presentation or a courtroom. (Please check with your particular professional printer for their requirements about file designations. It is all up to the printer's preferences. Once you have a relationship with a printer, you will know what formats to use from job to job.)

Unfortunately, when you export a PDF to send to a commercial printer, there are a number of very important settings you must pay attention to. Some involve resolution, some involve quality settings, and others involved bleed and trim marks and CMYK. When you are ready to talk to a commercial printer, call and ask to speak to someone in the pre-press department. They will walk you through all the settings you will need for a great product.

CREATING PRINT-READY FILES

Besides the Adobe software mentioned earlier, Acrobat DC is a program to help you create high-resolution, print-ready PDFs. All of them export a file in CMYK format, which are the colors used by printers. The colors you see on your screen are RGB, so what you print and what you're looking at will have subtle differences.

If you have a photograph you want to print, make sure it's in CMYK format and 300 dpi. if you're not concerned about space, save it as a TIFF; if you are concerned, save it as a JPEG, but don't compress it until you're done editing it.

If you want to use your photograph for something displayed on a computer screen like a web page or a PowerPoint presentation, feel free to compress your JPEG file because you only need 72 dpi.

NOTE

1. A preventive solution of future raw incompatibility is the Adobe Digital Negative (DNG) format. When your raw file is imported from a memory card, the raw file can be converted to a DNG file containing all of the original proprietary raw data but is now in a non-proprietary archival file format. The DNG converter is a free download from www.adobe.com.



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35 The Role of the Forensic Scientist as Expert Witness in Court

Julia Garcia de Leon

CONTENTS

Who Is an Expert Witness? 643
Legal Framework and the *Daubert* Standard 643
Giving Testimony 644
Ethical Considerations 646
The Expert Witness and the Attorney 646
The Use of Technology in the Courtroom 647
The Forensic Photographer as an Expert Witness 648
Conclusion 648
References 648

> "It is the job of the law, and not science, to determine how science is to be used in the courts. But in another sense, our passivity has served both ourselves and the legal system poorly. It is the job of science, and not of law, to determine what is good science and what is not."
>
> **— Thornton (1994)**

Expert witness testimony is a crucial and challenging aspect of a forensic scientist's job. It constitutes the pinnacle of the scientist's efforts—the obtention of degrees, continued training, meticulously documented crime scene, and laboratory reports, as well as commitment to ethical principles. At best, expert witness testimony allows the judge and jury to make an informed verdict in the service of justice; at worst, it may cause irreparable damage to a scientist's reputation, as well as undermining the hard work of every professional involved in the law enforcement process. Understanding how to be a successful expert witness is an integral part of a forensic scientist's training, yet many scientists are not fully aware of the variables affecting their perception in a juror's mind. The present chapter will explore the various aspects of expert witness testimony in court—who qualifies as an expert witness, what they should and should not do, and why are experts required to testify in the first place.

WHO IS AN EXPERT WITNESS?

An expert witness, in general terms, is a person who has achieved a level of knowledge in a specific discipline—be it by means of education, training, and/or experience—separating them from a layperson. The main role of an expert witness, whether he or she may be testifying in criminal or civil court, is to explain to the jury the facts involved in the case as they relate to their particular discipline and their assigned role in the investigation. For the forensic scientist, this role is twofold: first of all, they must undertake the scientific activity of collecting, testing, and evaluating evidence, so it may be analyzed and an opinion derived from it; second, the scientist must have the ability to communicate their opinion to a jury in a clear, concise, comprehensible manner. It is the judge's role to decide whether or not a given professional is qualified to fulfill the duty of expert witness, a decision usually taken during the pre-trial stage of a court case. According to Pyrek (2007:382).

> Four criteria are used to generally qualify an individual as an expert witness: educational degrees received, number of years of occupational experience in the field, membership in professional organizations, and professional articles or books published.

The expert witness is called upon to support the jury in their role of determining the facts of the case, as well as which evidence should be accepted in order to assess whether or not the prosecution—or civil case plaintiff—has proven its case.

Thus, it is important that the expert is able to explain to the jury, in layman's terms, the results of their findings during the investigative process, so the jury may understand the relevance of evidence and how it fits into the investigation as a whole. An effective expert witness must be able to teach and persuade the jury without resorting to advocacy, as well as be able to successfully withstand cross-examination at the hands of the opposing team. A credible expert witness must also be personable, well prepared, and demonstrate a general and great competence in their chosen discipline.

LEGAL FRAMEWORK AND THE *DAUBERT* STANDARD

The need for expert witness testimony in a court of law is generally established in the Confrontation Clause of the Sixth Amendment to the U.S. Constitution, which grants

the defendant in a criminal prosecution the right to face their accusers, with the specific purpose of allowing cross-examination to take place (Confrontation Clause, n.d.).

Although the validity and admissibility of expert witness testimony may vary from court to court, testimony is currently deemed admissible only if it is based on sound scientific evidence, the definition of which has varied depending on the way judges and lawyers interpret legislation on the subject. While the modern expert witness emerged during the 18th century, it wasn't until the 20th century that an expert was required to provide proof of their expertise. This process began with the court ruling of *United States v. Frye*, also known as the *Frye* or General Acceptance test (Houck, 2008:5–6). The ruling states that evidence and expert testimony presented to the court must be based on procedures, techniques, and methods using established principles widely accepted by the scientific community. This means that at times, advances in techniques and scientific methods may not be considered legally admissible in court if they have not yet gained general acceptance in their field.

Between 1993 and 1999, the Supreme Court made landmark rulings—known as the *Daubert* trilogy of opinions, or the *Daubert* standard—which further refined the requirements for admissibility of expert testimony (Bernstein, 2013:28; R. V. Mohan, 1994 CanLII 80, 2 SCR 9, is the similar ruling case in Canada).

Alternatively, a court may rely on Rule 702 of the Federal Rules of Evidence (National Court Rules Committee, 2019) to determine the admissibility of evidence and expert testimony in court. The rule states:

> A witness who is qualified as an expert by knowledge, skill, experience, training, or education may testify in the form of an opinion or otherwise if:
> a. The expert's scientific, technical, or other specialized knowledge will help the trier of fact to understand the evidence or to determine a fact in issue;
> b. The testimony is based on sufficient facts or data;
> c. The testimony is the product of reliable principles and methods; and
> d. The expert has reliably applied the principles and methods to the facts of the case.

Rule 702 puts the onus on the courts and the judges to determine the specifics as to, for example, what constitutes "scientific, technical, or other specialized knowledge" (Houck, 2008:6).

Currently, the *Daubert* standard has replaced the *Frye* test in federal court, although a version of the *Frye* test is still in use in many courts at the state level (Hagy, 2007:37).

The existing legislation on expert testimony admissibility is not, however, without its flaws. Ideally, the *Daubert* standards should act as a vaccine against junk science in the courtroom. However, as Edmond and Roach (2011) point out, these guidelines have often been applied unreliably, with expert evidence presented in civil court generally being held to a higher standard compared to expert evidence presented by the state in criminal proceedings. This has often resulted in factually innocent persons being convicted of serious criminal offenses (Edmond and Roach, 2011:359). Furthermore, the 2009 National Academy of Science (NAS) report reached the conclusion that most forensic evidence—except single-sample nuclear DNA—lacks scientific rigor and quality control (National Research Council, 2009). In the last decade, attention has also been drawn to the role of bias in the forensic scientist's decision-making process (e.g., Dror, Charlton, and Péron, 2006; Dror and Charlton, 2006; Dror et al., 2017; Dror et al., 2018). Edmond and Roach (2011:349) suggest that state institutions and private consultants hired by the state should be given incentives to devote more resources for the purpose of refining scientific techniques and putting appropriate quality assurance methods in place. Edmond and Roach (2011:393–397) suggest that rather than focusing on "idealized versions of science" as interpreted through the *Daubert* standards, admissibility decisions should primarily be shaped by legal principle and criminal justice values, as well as take contextual considerations into account. This, they suggest, may be done by focusing attention on the demonstrable reliability of evidence; by being aware there is no simple way to define science or to identify reliable knowledge; by being aware of insights wrongful convictions provide about the limitations of the law enforcement process; by keeping in mind judges have been too lenient with incriminating expert evidence. As they rightly state (Edmond and Roach, 2011:349),

> Our proposed approach to admissibility is informed not only by the values and context of criminal justice but also by the content of the particular form of expertise offered as testimony. This means judges and lawyers must not rely solely on the idealized and abstract vision of proper science implicit in *Daubert* but should also attend to the limitations of techniques and the controversies in the particular field from which the expert evidence derives. Such an approach imposes formidable burdens on lawyers and judges, again reaffirming our position, they must be given the necessary tools to conduct such analysis and it would be dangerous to rely solely or primarily on judicial reform of the forensic sciences. That said, the complicity of the legal system in the dismal state of much forensic science and medicine can no longer be ignored.

GIVING TESTIMONY

Oral testimony begins with an expert's report, which should be written in a clear manner and should avoid jargon; it is, after all, meant to be read not only by fellow scientists but by lawyers, judges, and/or law enforcement personnel. An expert witness's testimony and all related documents, including case notes and diagrams, are made available to both defense and prosecution during the discovery process of a trial.

Houck (2008:51–52) notes that expert testimony may be one of the most difficult forms of spoken communication humans conduct for three reasons:

1. Expert testimony requires a simplification of very technical information to an audience who does not necessarily have any knowledge of the topic.

2. The rules governing testimony are layered and intricate, spanning English grammar and vocabulary through scientific methodology and into federal, state, or local laws, and even "house rules" of particular judges or jurisdictions.
3. The question-and-answer format is done in an adversarial setting; even if the attorney asking you the questions is the one who called you to testify, opposing counsel is listening and looking for openings and missteps.

General guidelines exhort the expert witness to prepare for testimony ahead of time and suggest a familiarization with the courtroom environment. Additionally, the expert is advised to comprehend the case's general legal context and prepare a three-sentence summary of their testimony that is both understandable and persuasive (Brodsky and Neal, 2013:604–608; Houck, 2008:56–59). There are many opinions on the type of clothing an expert should wear to court, but the general rule of thumb is to dress professionally but comfortably and to avoid items of clothing likely to distract the audience from the expert's testimony.

Testimony in court is divided into three main phases:

1. *Voir dire* – A vetting process where the witness's qualifications and expertise are established.
2. Direct examination – The expert is questioned regarding his or her analyses, methods, and conclusions.
3. Cross-examination – The expert is subjected to examination at the hands of the opposing counsel.

The ultimate goal of undergoing these phases is to establish an expert witness's credibility. Credibility of a witness is measured in four major aspects: witness likability, level of knowledge, confidence, and trustworthiness (Neal and Kovera, 2015).

According to Petty and Cacioppo (1986), there are two paths leading to persuasion in an individual, that is, two paths by which a juror will decide whether or not an expert witness is credible: central processing and peripheral processing. Central processing is defined by "a person's thoughtful and careful consideration of the strengths of an argument," while peripheral processing is based on "a superficial assessment of cues unrelated to the quality of the evidence" (Neal and Kovera, 2015). In other words, central processing is up to the expert witness: it is based on a compelling, well-founded argument. Meanwhile, peripheral processing is a way for jurors to create a snap judgement based on cues not directly related to an argument, such as an expert's perceived level of confidence, their clothing, nonverbal language, or even how fellow jurors react to the witness's statements. Peripheral processing is dependent less on the quality of the statement and more on its delivery.

The goal for the expert witness is to prevent the audience from forming an opinion based on peripheral cues when possible, which is why the use of professional but plain clothing is one of the most common suggestions when preparing for courtroom appearances. However, there are other variables besides fashion choices to be taken into account. Previous studies have attempted to find causal relationships between various other peripheral cues (e.g., perceived confidence, likability, the gender of the witness, complexity of the testimony; see Brodsky et al., 2009; Couch and Sigler, 2002; Cramer, Brodsky, and DeCoster, 2009; Levet and Kovera, 2008; McQuiston-Surrett and Saks, 2009; Neal et al., 2012; Schuller, Terry, and McKimmie, 2005), with illuminating results.

Data gathered by Schuller, Terry, and McKimmie (2005) suggest that despite theoretical literature on gender-role stereotyping, an expert's sex is not directly correlated to their perceived credibility; instead, they found jurors were more likely to consider gender as a factor only when the testimony was difficult to understand. In other words, if a juror finds testimony difficult to process, he or she is more likely to depend on peripheral cues (such as gender) in order to assess the credibility of a witness on the stand. This is also supported by Neal and Kovera (2015), who stress the importance of using layman's terms in court in order to avoid this very issue. Interestingly, Schuller, Terry, and McKimmie (2005) did find some evidence about the perceived gendering of a witness's area of expertise, which may play a part in whether they are deemed competent or not: a female expert may be seen as more capable than her male counterpart if their discipline is female-dominated. While research suggests no clear-cut rules regarding the effect of gender stereotypes on perception, an easy recommendation is for expert witnesses to take care in presenting the testimony in terms a lay person will understand, so as to avoid having their credibility depend on peripheral cues.

A high level of likability or a high level of knowledge (or better yet, both) were found by Neal et al. (2012) to be significant factors in determining a witness's credibility. They, too, found evidence suggesting the discipline's perceived maleness or femaleness is a factor affecting credibility assessments: once the occupational domain was removed, the data suggested, male and female experts were evaluated similarly (Neal et al., 2012:495).

A preference for moderate amounts of confidence (i.e., avoiding being perceived as arrogant) is also supported by the data. Cramer, Brodsky, and De Coster (2009) found that moderate levels of confidence and extroversion reflect positively in the minds of the jurors.

Furthermore, Levet and Kovera (2008) evaluated the effectiveness of opposing expert witness testimony in educating jurors about unreliable expert evidence. The point of having an opposing expert witness is, the courts would argue, to educate jurors and better enable them to accurately weigh the evidence. However, Levet and Kovera (2008) found the presence of an opposing witness results in a skepticism effect, in which jurors become skeptical of all testimony rather than becoming sensitized to flaws in the opposition's methods and conclusions. Overall, it seems the data does not support the use of opposing expert witnesses in helping prevent junk science in the courtroom,

and judges and lawyers are advised against their presence in the courtroom at the time of testimony.

Levet and Kovera (2008) also found evidence suggesting average individuals usually can't evaluate statistics and methodologies very well. Neal and Kovera (2015) suggest experts should try to link relevant research to the specific facts of the case in which they are testifying, since simply providing information and hoping the jurors will be able to visualize the link between one piece of evidence and the other is not an effective strategy.

In conjunction, data from these studies results in specific, practical tips to help experts be perceived as having a high degree of credibility, which are summarized as follows:

- Be confident but avoid arrogance.
- Avoid jargon; do not let the jury be confused by your testimony, or they will rely on peripheral cues outside your control in order to assess whether or not they find you credible.
- Be likable, well mannered, respectful, and pleasant.
- Keep appropriate eye contact with lawyers and jurors.
- Employ a stable tone of voice and a moderate pace of speech.
- Take special care to appear competent and knowledgeable; provide details regarding your training, certifications, places of study, publications, etc.

ETHICAL CONSIDERATIONS

There are a variety of discipline-specific organizations acting as watchdogs and promoting ethical behavior within their ranks. A general set of guidelines is available online courtesy of the Forensic Expert Witness Association (FEWA), a nonprofit professional membership association of consultants providing forensic services, with chapters across the United States (Forensic Expert Witness Association, 2018). In summary, FEWA's ethics code warns against engaging in conduct or practice possibly discrediting the association, untruthfully criticizing or misrepresenting the services of others, misrepresenting credentials and/or qualifications for the purpose of self-aggrandizement, becoming compromised by conflicts of interest with clients, or allowing the influence of others to override their objectivity.

Perhaps the key aspect in which an expert witness can engage in unethical behavior is to misrepresent the extent of their knowledge. Sanders (2007) explains that in order for something to count as knowledge, three requirements must be met: the expert must believe something to be true, the thing believed to be true must in fact be true, and the expert's belief that something is true must be justified. Sanders summarizes this idea as follows: if the expert doesn't believe something to be true, it is ignorance; if that something is not true, it is an error; if the expert does not have appropriate justification for believing that something is true, it is mere opinion (Sanders, 2007:1541).

In a practical sense, an expert witness should limit himself or herself to four answers to the question of whether A is associated with B (Sanders, 2007:1551; Cohen, 2003:950–951):

- No
- Yes
- The evidence suggests yes, but it could be an artifact of chance
- The evidence suggests no, but the existing evidence is limited in its ability to detect an effect

Despite the fact that attorneys often demand clear-cut, yes-or-no answers, sometimes the right thing to do, when confronted with a lack of evidence or a lack of sufficient time to examine all possible available evidence, is to provide a caveat or simply state the answer is not known.

There are two roles an expert witness may adopt during testimony: scientist-educator (the expert conveys the knowledge of his or her field so the fact finder may understand the strengths and weaknesses of the parties' arguments) or party advocate (the expert is part of the team that hired him or her and takes that team's side, erring on the side of advocacy) (Sanders, 2007:1559–1561). The topic of advocacy will be explored in more detail in the section "The Expert Witness and the Attorney." It bears underlining, for now, that the most ethical role of the expert witness is understood to be one of the scientist-educator.

There are a number of ways an expert witness may incur sanctions if engaged in unethical behavior. According to Sanders (2007), sanctions may be dealt by the parties to the litigator, by lawyers declining to hire unethical experts, by professional organizations when justification for an expert's opinion is deemed inadequate, by judges via contempt holdings and sanctions against the party, and by juries if the expert's testimony is deemed to have resulted in an adverse trial outcome at a post-trial juror interview. However, Sanders (2007:1572) states that the most effective sanctions come during *Daubert* and *Frye* hearings, where findings point the finger at the testimony of certain experts.

Engaging in unethical testimony is a serious offense going against the prime objective of the testimony itself: it undermines the ability for judge and jury to come to a verdict in pursuit of justice by obfuscating the facts and evidence surrounding a case.

THE EXPERT WITNESS AND THE ATTORNEY

Effective communication between attorneys and expert witnesses working together on a case is key, as is discussing the case ahead of time. Both the attorney and the expert should be aware of the topics to be covered during examination, as well as the answers to be provided. It should be noted that preparing a predetermined set of questions with their corresponding answers is a part of expert witness preparation before trial and does not constitute unethical behavior, assuming they were derived from the expert's

own statements and reports and they are congruent with the expert's testimony. Preparing such a script is a standard and expected part of the process.

As has been stated, effective communication between expert witnesses and attorneys is key in excelling in courtroom testimony. Unfortunately, effective communication can sometimes be hindered. Some common issues in communication between attorneys and experts have been pointed out by Prichard (2005), including the following:

- A lack of time to discuss a case with the expert witness
- Unfamiliarity with technical language on both sides
- A failure on the lawyer's part to listen to the expert witness
- Contacting the expert at the last minute
- A possible aggressive and adversarial stance on the part of the lawyer

It is crucial for expert witnesses to be given time enough to prepare their testimony. Practicing examination and cross-examination in front of a video camera also helps the expert become aware of how he or she may be perceived by jurors, and thus is a highly recommended step in preparing for trial.

As was mentioned earlier, an expert may adopt the role of a scientist-educator or a party advocate, with the former being the preferable choice. This is because the key role difference between the attorney and the expert witness is that while the attorney acts as an advocate for his or her client, an expert witness must remain objective and limit the nature of their testimony to statements supported by their findings as presented in their expert report. It is very important for a call of persuasiveness in testimony not to be mistaken as a call for advocacy. Persuasiveness is required to put the jury at ease and convince them the expert is competent and their analyses are valid. However, the expert falls in the trap of advocacy when he or she adopts a position regarding the defendant's culpability or lack thereof. This presents a significant obstacle not just for the expert witness but for others involved in the process. For example, a study based on surveys given to federal judges and attorneys between 1991 and 1998 found one of the most frequent problems encountered with expert witnesses was their tendency to act as advocates. This highlights the importance of not taking sides in the argument during trial, but rather presenting findings in a clear and concise manner (Krafka et al., 2002).

THE USE OF TECHNOLOGY IN THE COURTROOM

Another consideration in preparing as an expert witness in trial deals with the equipment made available in the specific courtroom the expert will be using. Extra attention should be given to both the type and state of the equipment itself (e.g., Is it present but broken? Is it incompatible with the expert's computer or tablet? Does the expert have the right adapter to connect a computer to a projector?). Additionally, Thomas (2014) strongly suggests having a spare copy of the videos, documents, photographs, and other presentation materials the expert will need during testimony. He also suggests using strong passwords to protect data gathered for trial, as well as taking advantage of cloud-based storage services in order to keep all documents synchronized across multiple devices so they can be accessed for use as an alternative if needed.

Presently, most courtrooms in the United States are equipped with basic technology necessary for in-courtroom presentations, either in the form of portable equipment assigned as needed or equipment already installed in the room (Dixon, 2017:36), although, at certain times it might be necessary for the expert to provide the specific equipment he or she needs for their testimony when it goes beyond what is deemed basic (computer, projector, microphone, speakers). Dixon and Unger (2018) provide excellent practical tips, summarized here:

- Standard laptop computer speakers may not be enough to amplify sound (especially in large rooms), so experts should test their sound system beforehand.
- A laptop is preferable to a desktop computer due to the ease with which laptops can be transported.
- The use of a non-infrared-based mouse with reception of at least 50 feet is highly recommended.
- Wasting money on individual monitors for jurors and/or other people in the room is not recommended; while it may sometimes be necessary to place a few monitors in key areas, most of the time a single 7- to 10-foot screen is enough. Individual monitors for jurors should only be used when absolutely required, since they steal attention from the expert giving testimony.
- Use PowerPoint wisely: don't overuse graphics, use plain English in your speech and graphics, do not overuse bullet points, avoid animations and flashy backgrounds because they are distracting, use colorblind-friendly slides, and avoid white backgrounds as they make the text more difficult to read. PowerPoint is a valuable tool when used correctly.
- Get approval from the court in advance and make sure you consult the judge, bailiff, court reporter, court clerk, or other people who use the courtroom as an office on a daily basis before installing any new equipment.

Keep in mind that the use of technology in the courtroom should be guided primarily by a desire to effectively communicate your message to the judge and jury, with Fitzgerald, Anderson, and Lovy (2016) advising against using technology for the sake of shock and awe. Instead, they suggest taking the juror demographics into account:

older jurors retain and understand information more easily if they can physically touch it (e.g., printed documents), while younger jurors are likely quite accustomed to getting their information from a screen (Fitzgerald, Anderson, and Lovy, 2016:2339).

THE FORENSIC PHOTOGRAPHER AS AN EXPERT WITNESS

Some guidelines tailored towards forensic photography expert witnesses, found in Weiss (2009:496–498), are summarized here:

- Images may include captions, arrows, and other aids to help illustrate pertinent findings, but all annotations must be added to duplicates of the image and not the original file.
- Exhibit boards are usually around 24 × 30 inches in dimension, provided that the images are of a good enough resolution to be displayed at that size (the minimum is 6 MP).
- Every PowerPoint slide should include the case number, departmental logo, and copyright notice, unobtrusively.
- Expect to testify to the degree of accuracy of the images or models being presented in court.
- If using PowerPoint slides to follow a storyline, insert the elapsed time in plain sight. Be sure to use compass headings, global positioning system (GPS) numbers, or other references when they will help the audience understand the slide.

Keep in mind that in order for photographs to be admissible in a medicolegal context, they should be an accurate representation of the evidence and conditions existing at the time the photographs were captured (Weiss, 2009:496).

CONCLUSION

For all of its regulations and potential downfalls, expert witness testimony is a very rewarding part of a forensic scientist's job. It helps form a juror's understanding of the facts surrounding a case and explains how a piece of evidence fits within the overall puzzle. Providing expert witness testimony also satisfies a defendant's inalienable right to face their accuser in a court of law.

General guidelines can be adopted in order to become a better expert witness and are summarized as follows. The chance of a juror using peripheral cues to assess a witness's credibility is greatly lessened by simply making testimony accessible language-wise. An expert will ideally take care to present themselves as likeable and avoid arrogance but will not shy away from stating relevant credentials since they provide justification for their presence in the courtroom. There are four general answers available to the expert: yes, no, evidence suggests yes but it may be a matter of chance, and evidence suggests no but the existing evidence is limited in its ability to detect an effect. An expert should be wary of allowing the sometimes adversarial role of the cross-examiner to pressure them into giving a yes or no answer—it is acceptable to give caveats and to state something is unknown or beyond the realm of expertise. The relationship between an attorney and an expert witness is an important one; without proper communication between the two parties, it is not possible to give effective testimony in court. The expert should take great care in ensuring the testimony provided fits ethical guidelines both general and discipline-specific. All technological considerations should be planned for before the day when testimony is due in order to ensure a hassle-free experience.

Finally, a word of caution: under the current adversarial judicial system, it is the law undertaking the role of gatekeeper of forensic science testimony. It is the pivotal job of the forensic scientist to help fill in the research gaps in the disciplines covered by the NAS 2009 report so the issue of wrongful convictions may be addressed and junk science may be kept out of the courtroom.

REFERENCES

Bernstein, D.E., The Misbegotten Judicial Resistance to the Daubert Revolution, *Notre Dame Law Review*, 2013, Vol. 89, No. 1, pp. 27–70.

Brodsky, S.L., Neal, T.M.S., Cramer, R.J., and Ziemke, M.H., Credibility in the Courtroom: How Likeable Should an Expert Witness Be? *Journal of the American Academy of Psychiatry and the Law*, 2009, Vol. 37, No. 4, pp. 525–532.

Cramer, R.J., Brodsky, S.L., and DeCoster, J., Expert Witness Confidence and Juror Personality: Their Impact on Credibility and Persuasion in the Courtroom, *Journal of the American Academy of Psychiatry and the Law*, 2009, Vol. 37, No. 1, pp. 63–74.

Cohen, N.B., The Gatekeeping Role in Civil Litigation and the Abdication of Legal Values in Favor of Scientific Values, *Seton Hall Law Review*, 2003, Vol. 33, pp. 943–965.

Confrontation Clause, https://www.merriam-webster.com/legal/confrontation%20clause

Couch, J.V., and Sigler, J.N., Gender of an Expert Witness and the Jury Verdict, *Psychological Record*, 2002, Vol. 52, pp. 281–287.

Dixon Jr., H.B., The Basics of a Technology-Enhanced Courtroom, *Judge's Journal*, 2017, Vol. 56, No. 4, pp. 36–39.

Dixon Jr., H.B., and Unger, P.J., The Fundamentals of Today's Technology-Enhanced Courtroom, presented at the American Bar Association Tech-show on March 8, 2018, https://www.americanbar.org/content/dam/aba/events/law_practice_management/techshow/2018/Fundamentals%20of%20Today's%20Technology-Enhanced%20Courtroom%20Final2.pdf.

Dror, I.E., and Charlton, D., Why Experts Make Errors, *Journal of Forensic Identification*, 2006, Vol. 56, No. 4, pp. 600–616.

Dror, I.E., Charlton, D., and Peron, A.E. Contextual Information Renders Experts Vulnerable to Making Erroneous Identifications, *Forensic Science International*, 2006, Vol. 156, pp. 74–78.

Dror, I.E., Morgan, R.M., Rando, C., and Nakhaeizadeh, S., Letter to the Editor—The Bias Snowball and the Bias Cascade Effects: Two Distinct Biases That May Impact Forensic Decision Making, *Journal of Forensic Sciences*, 2017, Vol. 62, No. 3, pp. 832–833.

Dror, I.E., Kukucka, J., Kassin, S.M., Zapf, P.A., No One Is Immune to Contextual Bias—Not Even Forensic Pathologists, *Journal of Applied Research in Memory and Cognition*, 2018, Vol. 7, No. 2, pp. 316–317.

Edmond, G., and Roach, K., A Contextual Approach to the Admissibility of the State's Forensic Science and Medical Evidence, *University of Toronto Law Journal*, 2011, Vol. 61, pp. 343–409.

Forensic Expert Witness Association, Code of Ethics, 2018, https://forensic.org/about/code-of-ethics/.

Fitzgerald, C., Anderson, C., and Lovy, D., A Few Thoughts on Technology in the Courtroom, *Oklahoma Bar Journal*, 2016, Vol. 87, No. 30, p. 2339.

Hagy, D.W., *Digital Evidence in the Courtroom: A Guide for Law Enforcement and Prosecutors*. Washington, DC, National Institute of Justice, 2007.

Houck, M.M., *Feder's Succeeding as an Expert Witness*, 4th Ed, CRC Press, 2008.

Krafka, C., Dunn, M.A., Treadway Johnson, M., Cecil, J.S., and Miletich, D., Judge and Attorney Experiences, Practices, and Concerns Regarding Expert Testimony in Federal Civil Trials, *Psychology, Public Policy, and Law*, 2002, Vol. 8, No. 3, pp. 309–332.

Levet, L.M., and Kovera, M.B., The Effectiveness of Opposing Expert Witnesses for Educating Jurors about Unreliable Expert Evidence, *Law and Human Behavior*, 2008, Vol. 32, pp. 363–374.

McQuiston-Surrett, D., and Saks, M.J., The Testimony of Forensic Identification Science: What Expert Witnesses Say and What Factfinders Hear, *Law and Human Behavior*, 2009, Vol. 33, pp. 436–453.

National Court Rules Committee, Rule 702, *Federal Rules of Evidence*, *2019 Edition*, https://www.rulesofevidence.org/article-vii/rule-702/

National Research Council, *Strengthening Forensic Science in the United States: A Path Forward*. Washington, DC: National Academies Press, 2009.

Neal, T.M.S., and Kovera, M.B, Harnessing the Science of Persuasion for Expert Witness Testimony, presented at the American Bar Association 2015 Section of Litigation Annual Conference, https://www.americanbar.org/content/dam/aba/administrative/litigation/materials/2015-sac/written_materials/32_1_harnessing_the_science_of_persuasion.pdf

Neal, T.M.S., Guadagno, R.E., Eno, C.A., and Brodsky, S.L., Warmth and Competence on the Witness Stand: Implications for the Credibility of Male and Female Expert Witnesses, *Journal of the American Academy of Psychiatry and the Law*, 2012, Vol. 40, pp. 488–497.

Petty, R.E., and Cacioppo, J.T., The Elaboration Likelihood Model of Persuasion, *Advances in Experimental Social Psychology*, 1986, Vol. 19, pp. 123–205.

Prichard, F., *Experts in Civil Cases: An Inside View*, New York, LFB Scholarly Publishing, 2005.

Pyrek, K., Chapter 13, in *Forensic Science under Siege: The Challenges of Forensic Laboratories and the Medico-Legal Investigation System*. Burlington, MA, Elsevier, 2007, p. 382.

Sanders, J., Expert Witness Ethics, *Fordham Law Review*, 2007, Vol. 76, No. 3, pp. 1539–1584.

Schuller, R.A., Terry, D., and McKimmie, B., The Impact of Expert Testimony on Jurors' Decisions: Gender of the Expert and Testimony Complexity, *Journal of Applied Social Psychology*, 2005, Vol. 35, No. 6, pp. 1266–1280.

Thornton, J., Courts of Law v. Courts of Science: A Forensic Scientist's Reaction to *Daubert*, *Shepard's Expert and Scientific Evidence Quarterly*, 1994, Vol. 3, pp. 475–485.

Weiss, S.L., Chapter 17, in *Forensic Photography: Importance of Accuracy*. Upper Saddle River, NJ, Pearson/Prentice Hall, 2009, pp. 496–498.



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36 Technology for Courtroom Displays and Demonstrative Presentations

Mark Johnson

CONTENTS

Physical Prints and Trial Boards 651
Evidence Camera Systems 652
Digital Projectors 653
Wired versus Wireless 653
LED, LCD, or DLP? 653
Courtroom Video Monitors 653
Three-Dimensional Imaging 654
CAD-Based 3-D Modeling and Animation 654
Laser Scanning Technology 657
Notes 658

The accelerating pace of technology through the end of the 20th century has seen marked changes in the way juries receive evidence in courtroom trials. The Federal Judicial Center conducted a comprehensive survey[1] of federal courts in 2002 and 2003, finding 93% of federal courtrooms accommodated the use of laptop computers for displaying evidence and 77% had video monitors installed outside the jury box. Today the use of presentation hardware in both state and federal courts is ubiquitous. In those rare occasions where monitors are not available on portable stands or built into the courtroom, attorneys can always commission one of several companies who specialize in providing presentation hardware for trial. "Trial tech" is a growing field with vendors in every major urban area who have developed portable systems to be delivered into any courtroom.

Traditional photography has evolved into a multitude of imaging technologies, and the presentation of this evidence requires an understanding of the advantages and limitations of both the media and the hardware used to convey the evidence to judges, attorneys, and jurors in the courtroom. In the case of photographic or video evidence used to represent what a party or witness could see, it is important to consider both the camera used to acquire the imagery and the means by which the evidence is presented in court. This chapter will look at the primary categories of demonstrative evidence and the major means through which attorneys may choose to present their proof to a jury.

PHYSICAL PRINTS AND TRIAL BOARDS

The convenience of projection technology is undeniable, and it certainly is possible to present all documentary and visual evidence through one global system using monitors in the courtroom for the court and jury to view. Nevertheless, experienced trial lawyers recognize the importance of using physical representations of significant pieces of evidence, and most trials include electronic presentations alongside traditional methods such as the use of mounted enlargements or trial boards. In former days, trial attorneys made do with physical exhibits and, perhaps, a large pad and easel to draw upon. Today much of the evidence jurors see is projected or displayed, and jurors come to the courtroom with suppositions based upon impressions created from film and television representations of courtroom dramas. More recently, the proliferation of popular television programs devoted to forensic science and cold cases has given jurors expectations about the evidence they will receive—particularly in criminal trials—and what used to be called a high-tech courtroom has become the norm.

Researchers have coined the term "the CSI effect" to describe the phenomenon resulting from viewing forensic and crime-based television shows. A 2015 study conducted at San Jose State University revealed that laypersons following such programming often have unrealistic presumptions of forensic science and when called to be jurors they may be biased in favor of the defense.[2] Research also showed the influence of CSI-like programs has caused major players in the criminal justice system to change tactics in order to give the appearance of having more forensic or laboratory testing as a means to persuade jurors.

One way to counter the CSI effect is to involve the jury in the trial rather than treating the panel as being mere passive observers. For instance, an attorney may elect to pass a photograph to the jury for each to study individually before passing the photo to his or her neighbor rather than simply projecting the image to the courtroom at large. The simple act of having each juror physically engage with the exhibit heightens their connection to the case and their

role as participants, rather than as observers. Some counsel will elect to provide individual copies of photographs for all jurors rather than having a single exhibit passed among them. But the main point is for the jurors to become active participators rather than seeing everything on a monitor or projection screen.

While the science of persuasion is beyond the scope of this chapter, it is worth pointing out that *how* evidence is presented does affect the way jurors perceive and consider a case.

Whether you are a forensic technician, expert witness, attorney, or jurist, the time spent reading Thomas Mauet's *Fundamentals of Trial Techniques* will be well spent.[3] Mauet emphasizes that visual information is retained exponentially more than aural evidence. An enlarged physical manifestation of an exhibit (the trial board) has the advantage of commanding attention in the courtroom even when the projection system has moved to another exhibit. I have often participated in trials where an enlarged aerial photograph or a scene diagram will remain on display on an easel near the jury to be an orientation tool for reference to as needed.

Astute counsel will mark and admit individual trial boards as exhibits so they will be collected and delivered to the jury room with the other exhibits during deliberation. No matter how effective an image appears in the courtroom on a projection screen or video monitor, having a huge mounted enlargement in the jury room will assure the jury pays attention to that evidence. I am reminded of an older trial attorney who told me he made it a practice to always turn the opposition's trial boards around or cover them up before he commenced his own examination of a witness to avoid having the jury look at the opposition evidence while he or she was at the podium. For enlarged trial boards, I recommend using the standard size of 30 × 40 inches, as this size is the largest that can be shipped via standard rates and it also will fit in most full-size vehicles with a rear hatch. Printing resolution is not as critical as many attorneys assume, given the way boards are used in the courtroom (typically on an easel away from the jury). If you specify at least 120 dpi for printing resolution, the results will be fine for courtroom display. I also recommend matte finish for photographic enlargements, although I do have some clients who feel glossy boards "look" more polished. For the mounting substrate, foam core has become standard due to its light weight and decent rigidity. A foldable easel can be purchased from any office supply store and should be standard equipment in the courtroom kit for every trial.

Physical courtroom models are an option many attorneys overlook but can be extremely useful for the jury. We recently were commissioned to produce a three-dimensional scene in both computer form and as a physical model for a prosecution in a criminal trial. Many companies specialize in architectural models, and producing an accurate physical model of a building can be quite cost-effective. Furthermore, 3-D printing technology has improved vastly in the past few years so full-color physical models of terrains and structures are now possible.

EVIDENCE CAMERA SYSTEMS

Both WolfVision and ELMO introduced sophisticated document camera systems at the 1988 Photokina exhibition in Japan.[4] The use of so-called evidence cameras in court exploded, and by the mid-1990s most trial attorneys referred to these evidence projection systems generically as ELMOs even though several manufacturers were producing competitive systems. These systems are essentially a live video camera mounted on a stand over a lighted display area. The live video feed is projected to a large monitor, so the jury and court sees whatever document or physical exhibit is placed under the camera. The 2003 Federal Judicial Center Survey found that fully 97% of federal courtrooms were equipped with evidence camera systems at that time (see Figure 36.1).

These systems have the advantage of allowing the jury to see any document, as well as physical objects. Simple controls permit the operator to magnify and highlight any portion of a document. Today, the use of evidence camera systems has decreased since photographs and documentary evidence are now almost always available in a digital format and can simply be projected from a laptop. Nevertheless, in the event a document gets marked up during trial, or when a photograph or document hasn't been digitized, the use of an evidence camera can be critical. Today several companies market systems sometimes called



FIGURE 36.1 Visual Presenter.

(Photograph courtesy of ELMO USA Corp.)

"visualizers" or "presenters," and all integrate easily with the more common digital projection systems connected to a laptop.

DIGITAL PROJECTORS

Projection systems are now more common than video monitors as a built-in courtroom tool. Moreover, high-illumination projection systems are both compact and inexpensive to the point that their use in court is the rule rather than the exception. Nevertheless, all projectors are not created equal, and doing justice to the evidence presented will hinge upon a few important specifications.

Of course, if the system in question is built into the courtroom (as is increasingly the case), you can generally be confident it will perform adequately for the task. If you are bringing your own hardware, however, the following are important considerations.

Wired versus Wireless

In theory, both systems will work, and a wireless system eliminates having cords draped over tables or on the floor. In practice, the risk of signal interference or drop-outs makes wired systems preferable, given the mission-critical character of courtroom presentations. A roll of wide, removable tape will corral the cables and you will have the confidence that your imagery will display every time on command.

LED, LCD, or DLP?

The various acronyms accompanying digital projectors can be confusing. It is important to understand there are only TWO main components of digital projectors: the lighting component and the imaging component. Traditionally, lighting was provided by lamp technology, and the bulb improved substantially over time from old metal halide bulbs to ultra-high-pressure mercury lamps used in projectors today. More recently, the industry developed a new lighting technology based on light-emitting diodes (LEDs). While LED sources are more expensive initially, they typically have a longer lifespan—up to 20,000 hours in comparison to mercury vapor bulbs—and are environmentally safer. Additionally, LED-based projectors cannot match the brightest lamp-based ones, which can be a problem in courtrooms with large windows that cannot be easily covered.

On the imaging side, there are basically two choices: liquid crystal display (LCD) and digital light processing (DLP). The DLP systems use a single chip to create an image and are generally smaller and thinner than the LCD devices (see Figure 36.2). Moreover, LCD devices are subject to dust infiltration and must have their filters cleaned regularly or the image will begin appearing degraded within a few years of use.

Brightness – The brightness of a digital projector is probably its most important specification, but the degree of brightness required will differ depending upon the environment. In a completely dark room, a projector rated at 1300 lumens will be fine, but it will be washed out in a bright environment. As a rule, choose at least 3000 lumens for a courtroom with moderate ambient lighting during the presentation.



FIGURE 36.2 DLP Digital Projector.

(Photo courtesy of Epson Corp.)

Throw Ratio – Every projector has a throw ratio. This represents the size of the image the projector creates for a given distance. You can calculate the image size by dividing the distance between the screen or wall and projector by the specified throw ratio of the projector. Most projectors today have a zoom lens allowing you to adjust the image size. Thus, if your projector has a throw ratio of 1.8 to 2.22, it will produce an image between 54 and 66 inches when projecting on a screen or wall 10 feet away. Ideally, the jury should be sitting at a distance more than twice the width of the image.

If the projector does not have a favorable throw ratio, it will be limited in the size of the projected image in very small courtrooms. In those instances, it makes sense to rent a projector designed for small rooms in order to give the jury an adequately sized image to view during trial.

Screen versus Wall – A white wall will do in a pinch, but a screen will usually be smoother than a wall, and because of its specially designed surface, offer higher luminance and more even reflectance. Most courtrooms today have a screen built into a wall or will have a portable screen available for use. The most valuable advice I can give is to always visit the courtroom at least a week in advance and test whatever technology you will be using to make certain the images shown will be easily seen by the jury.

COURTROOM VIDEO MONITORS

Many courtrooms have built in monitors or projection systems so it may not be necessary to cart in your own system. Nevertheless, older courtrooms often operate with legacy systems not ideal for the presentation of important evidence, so it may make sense to bring in a more suitable monitor system. Today bright flat-screen monitors are inexpensive and lightweight, so arranging for the temporary use of a large monitor is an easy task. I recommend that counsel or the presentation technician take time to do

critical viewing from the jury box prior to trial in order to decide whether any system in place is of high enough quality for the evidence to be displayed. If possible, plan your visit during daylight hours to assess how much illumination comes in through courtroom windows and whether it may be blocked with curtains or blinds. If the available system is not up to par, you will have the choice of bringing in a digital projector and screen, as described earlier. Alternatively, you may choose to bring in a large flat-screen monitor that can be positioned optimally for the jury's view. I cannot stress enough the importance of conveying evidence to the jury efficiently. It is worth the extra expense and hassle of renting a system if the available hardware does not permit viewing a large, sharp, and bright image. The following are elements that should be considered for a primary viewing monitor in the courtroom.

Multiple Jury Monitors – As technology began to be incorporated into courtrooms, some designers installed small monitors in the jury box for each juror or occasionally between jurors for shared viewing. This approach is not ideal, as it hampers the ability of the attorney to control the focus of the jury. The best arrangement provides a line of sight from the jury box that matches the witness and the attorney on a horizontal line. If the juror must look down to a monitor during testimony, it will limit their attention span. Judge Herbert Dixon Jr. recently discussed this issue in an ABA Technology White Paper:

> If there are individual monitors in the jury box, jurors tend to prefer their personal monitor to review the exhibit and are rarely inclined to look away from the monitor toward the presenter. In the view of many lawyers, this results in a loss of connection with the individual jurors. In addition, jurors may be absorbed with their own thoughts concerning what they consider important about the image they are viewing on their personal or shared monitor.[5]

Monitor Size – A single large monitor is the best choice for jury viewing, but it raises the question of how big should the monitor be? As a rule, larger is better, but the extreme difference in size and configuration makes the choice highly dependent on each courtroom space. In practice, a monitor on a rolling stand that can be positioned in front of the jury box will often be the best choice. Otherwise, it may be best to use a projector and screen, as described in the previous section, in order to have a large enough viewing surface.

Monitor Resolution – Just as a larger size is preferable, a higher monitor resolution is desirable as well. Although there are 8K resolution monitors coming to market, there is no good reason to choose one for a courtroom monitor today. In truth, good-quality high-definition (HD) monitors are quite cheap and will provide enough resolution for courtroom use. The highest resolution I would recommend is 4K, and there are many models available from many manufacturers if you choose to use a higher resolution screen.

THREE-DIMENSIONAL IMAGING

This chapter has discussed the hardware used to present video, photographs, and other demonstrative evidence at trial. Given the explosion of 3-D technology over the past two decades, it is worth taking time to discuss how three-dimensional imaging is presently being used in the courtroom. This discussion is apropos for a textbook devoted to forensic photography because the creation and presentation of 3-D evidence will share many considerations in common with photographic evidence. For instance, 3-D computer animation and virtual reality (VR) technology rely upon the use of "virtual" cameras that behave identically to physical cameras in terms of focal length and, in some instances, exposure. Most 3-D scenes created for the courtroom require the use of virtual sunlight or virtual luminaires that behave according to the physical characteristics of illumination familiar to professional photographers. In fact, I would stress that a forensic photographer is ideally suited to advise his or her client regarding the deficiencies of a 3-D animation presented by the opposing side. The science of photography is the gold standard for judging whether a 3-D animation depicts a scene with "reasonable accuracy." All the considerations that apply to video or photographic depictions of a driver's viewpoint or a witness's point of view will apply to a 3-D animation as well (i.e., field of view and focal length).

It should be noted that "reasonable accuracy" for purposes of admissibility in court is a sliding index that varies depending upon what the evidence is being used for. For example, cases involving sun glare or nighttime visibility are often problematic for 3-D computer animation because of the difficulty in replicating how human eyes behave under those conditions.

Forensic photographers are very aware of the complications involved when replicating driver or witness views, and the difficulty is compounded for 3-D animation. On the other hand, if visibility is not an issue and the primary purpose of a 3-D animation is to simply show relative velocity or vehicle positions, illumination does not have to match real-world conditions precisely.

The remainder of this chapter will discuss the major areas of 3-D visualization and how this new technology is being used in court.

CAD-BASED 3-D MODELING AND ANIMATION

When attorneys discuss "computer animation," they are almost always referring to motion videos created with computer-aided design (CAD) software. This is the same technology driving the video game industry, which is projected to reach 180 billion dollars of revenue by 2021.[6]

Concomitantly, the motion picture industry continues to see exponential growth in feature films utilizing CAD-based 3-D animation, as well as CAD-based 3-D special effects.[7] These major markets are propelling phenomenal technological developments that also benefit those who

create and use 3-D animation for forensic purposes. The same tools that make possible the astounding visual effects seen at the cinema are being used to create the forensic animations shown in court.

The quality of forensic animation has improved dramatically from 1993, when the first 3-D computer animation was admitted in a criminal trial. The case involved a sensational murder case involving the Mitchell brothers who operated a small pornography and strip club empire in San Francisco. The prosecution hired Jason Alexander to produce a 3-D animation that showed bullet trajectories and the positions of the persons present when the shooting occurred. Although the quality of the polygonal animation in the Mitchell brothers' trial appears somewhat coarse in comparison with current 3-D character animation, the animation demonstrates how valuable it can be to visualize complex events in an understandable fashion. The trial was held in Marin County, with the jury returning a verdict for conviction and credit being given to the effectiveness of the animation in showing the prosecution's theory of the case.

Accordingly, news of the trial's success is widely considered to have accelerated the use of 3-D animation in courtrooms across the country for both civil and criminal trials (Figure 36.3).

My company, Visual Law Group, uses a variety of software applications to produce 3-D forensic animation for litigators handling both criminal and civil trials. Figure 36.4 shows two excerpts from a 3-D kinematic animation explaining how a worker's repetitive use of a sledgehammer caused orthopedic injuries to his cervical spine.

Today, commercially available software allows forensic animators to re-create lighting and weather conditions, as well as dynamic natural effects, such as wave motion (Figure 36.5). Skilled forensic animators can create photorealistic scenes that can come close to replicating photographic imagery.

Attorneys and expert witnesses agree that the use of 3-D computer animation in court has become common over the past two decades. Recently, the California Supreme Court endorsed the admissibility of computer animation, provided counsel sufficiently proves it to be "a fair and accurate representation of the evidence to which it relates."[8] This liberal approach will assure that even more 3-D animation will be used at trial, and it also reflects the approach being taken by the federal judiciary.[9]

Although 3-D animation has become almost routine in major cases, there has been surprisingly little study of the effect computer animation has on influencing or persuading a jury. Almost 25 years ago, John Selbak wrote a provocative article for the *Berkeley Technology Law Journal* warning that computer animation may give an unfair advantage to an opponent who arrives for trial without an opposing animation.[10] The article concludes with a warning that advances in computer animation poses a risk of making jurors "fact investigators" rather than "fact determiners."[11] It is fair to conclude that Mr. Selbak's fears were overstated and that the law has proven more than capable of managing issues of admissibility for computer animation.

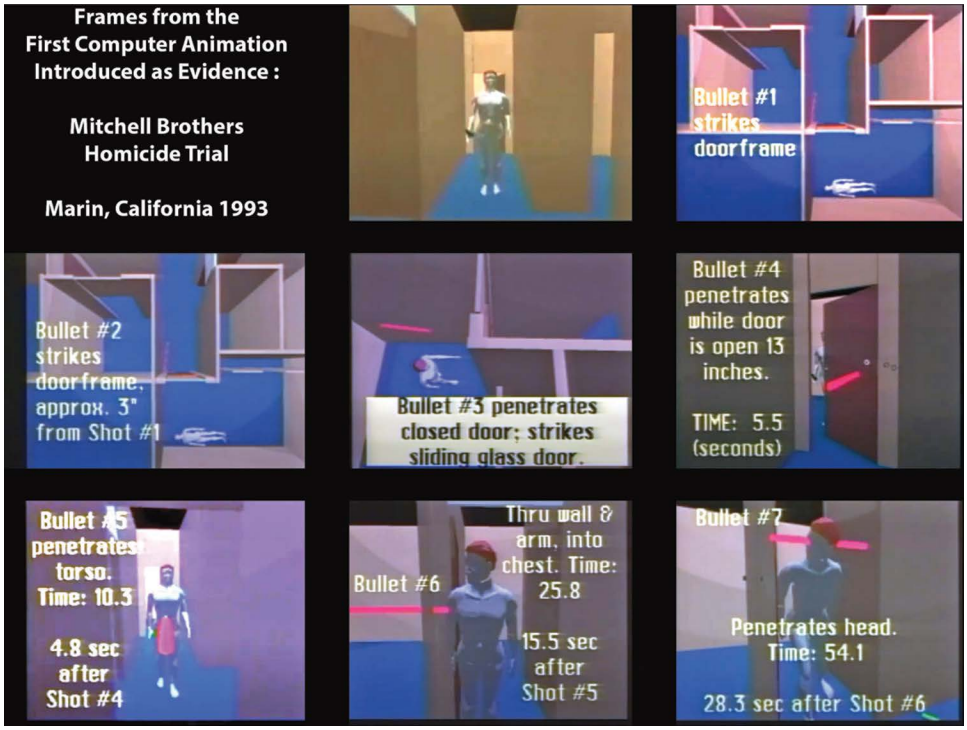


FIGURE 36.3 Frames from Mitchell brothers' homicide trial animation.

(Courtesy of Jason Alexander; http://www.alexanderjason.com/forensic-computer-animation.)

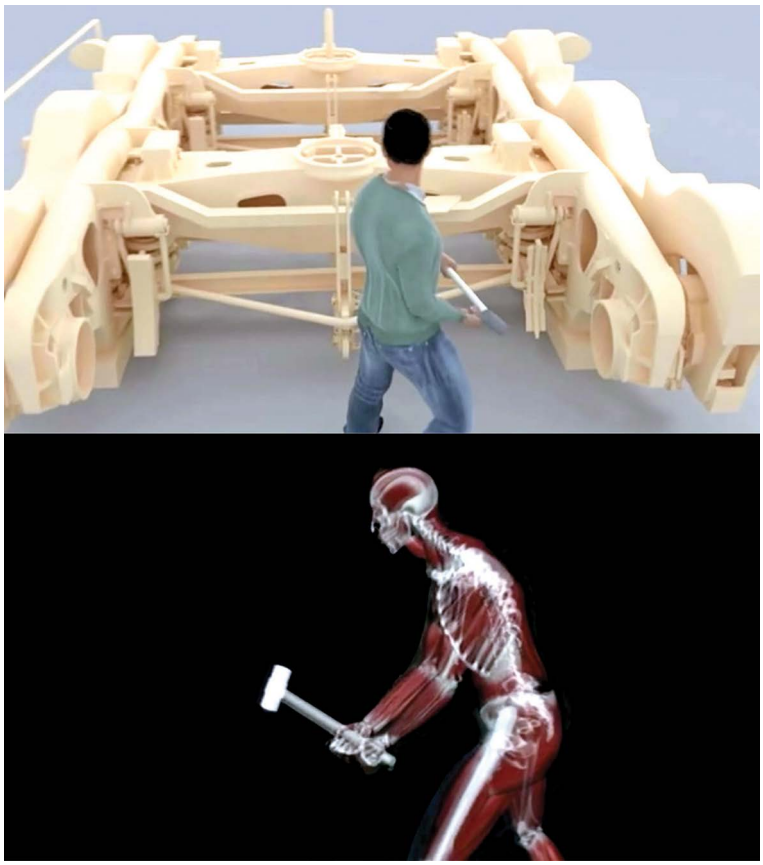


FIGURE 36.4 Frames from 3-D Kinematic Animation.

(Courtesy of Visual Law Group.)



FIGURE 36.5 Frame from animation produced for maritime case depicting wave conditions during storm at Molokini Crater, Maui, Hawaii.

(Courtesy of Visual Law Group.)

The bigger question remains as to how effective computer animation is as a persuasive tool. One study in 2002 attempted to answer the question by using control groups to measure how significant computer animation was to the deliberative process of mock juries.[12] The study concluded that computer animation did not have a significant effect on influencing decision-making. Speaking as a forensic animator, I would recommend taking those findings with a grain of salt, given the inherent difficulty in measuring subjective factors such as persuasion between two groups.

Moreover, having observed hundreds of forensic animations produced by various companies over the course of almost three decades, I can state emphatically that the quality of 3-D animation covers a very wide spectrum and that, frankly, many examples are simply not terribly good when compared with the work of the leading providers in the field. I would want to critically examine the animation used in any study to assess the persuasive elements and quality of the animation being studied.

Anecdotally, I can certainly report numerous conversations with jurors and judges who have expressed favorable opinions regarding the impact of some of our animated sequences. I've also observed occasions when a 3-D animation depicts an event so dramatically that audible gasps have come from the jury box.[13] I don't claim my experience to be equivalent to a carefully constructed study, but I am convinced that well-crafted forensic animations are among the most powerful weapons in a trial lawyer's arsenal.

LASER SCANNING TECHNOLOGY

Since 2000 the use of 3-D laser scanning has proliferated to the point that, in many cases, it has supplanted the use of traditional survey techniques. Since about 2010 the laser scanner began to be accepted by law enforcement agencies as a tool for documenting crime and collision scenes. Predictably, evidence collected by laser scanning now has become common in both civil and criminal courts.

A laser scanner—often referred to as a LiDAR scanner—is an instrument that operates on a tripod to shoot a pulsing laser that reflects off the ground, buildings, foliage, and any other solid objects in the scene. The laser typically operates in a 360-degree sweep capturing everything within the range of the laser around the tripod. The operator can also limit the sweep of the laser to a predefined arc if a specific object is the desired target, rather than the entire scene.

When the scan is completed, a three-dimensional "point cloud" is generated that accurately locates the vast collection of points into a 3-D representation of the scene. When the objective is a single object, such as a damaged vehicle, the laser scanner is positioned at separate stations around the target and the multiple point clouds are merged to create a 360-degree representation of the object (Figure 36.6). The point cloud can be viewed from any angle and can be used to take accurate measurements of the object itself. In the past, forensic work had to be completed at the scene, and taking a series of discrete measurements of the vehicle typically approximated measurements of vehicle crush. Now, an accident reconstruction expert can use the point cloud to develop extremely accurate measurements in the office rather than being limited to the work accomplished in the field.

Laser scanning has become almost a standard requirement for major crime scenes occurring in interior spaces because the technology can capture the location of physical evidence and the position of objects without any human intervention, other than positioning the scanner and turning it on.

After a laser scanning point cloud is acquired, it can be projected on a large screen in court as counsel or the witness navigates the scene using a mouse or joystick. FARO Technologies, a leading manufacturer of forensic scanning instruments, has incorporated VR capabilities into its software product suite. Thus, users of FARO scanners can now view 3-D point clouds using commercially available VR headsets such as the OCULUS or HTC VIVE. Most attorneys and judges agree it is likely that VR will be used in the courtroom soon. Visual Law Group recently worked with FARO Technologies to present a VR crime scene at a conference attended by FBI and law enforcement personnel. Using an HTC VIVE headset, members of the audience were invited to walk through a crime scene and make measurements using digital measuring tools while wearing the headset. The audience saw what the user was experiencing via a large projection screen, and the consensus opinion of attendees was that the tool would be valuable both as a forensic tool and as a presentation tool in court.



FIGURE 36.6 Post-collision vehicle at scene (top) and two views of the point cloud created by a FARO FOCUS laser scanner.

(Courtesy of Visual Law Group.)

Clearly, presentation technology will continue to be refined, and three-dimensional imaging will become more and more a part of courtroom presentations and our lives in general. We are seeing elements of augmented reality (AR) becoming more common whereby smartphones can project virtual products or characters within the camera's live view. Virtual projection of high-resolution objects would allow juries to see important evidence three-dimensionally in circumstances where it would be impossible to bring the object or scene into the courtroom.



FIGURE 36.7 Forensic technician analyzes blood splatter with the assistance of a FARO laser scanner.

(Photo courtesy of FARO Technologies.)

Current developments in the film industry and computer gaming fields prove that 3-D experiences and VR are advancing rapidly, and the use of such technology in the courtroom is virtually inevitable (pun intended).

NOTES

1. Wiggins, Elizabeth C., Dunn, Meghan A., and Cort, George, *Federal Judicial Center Survey on Courtroom Technology, December 2003*. Federal Judicial Center, Washington, DC, 2003. 2
2. Alldredge, John, The 'CSI Effect' and Its Potential Impact on Juror Decisions, *Themis: Research Journal of Justice Studies and Forensic Science*, 2015, Vol. 3, pp. 114–126, Article 6.
3. Mauet, Eichelbaum, *Mauet's Fundamentals of Trial Techniques*, 4th Ed, Auckland, Law Book Co. of Australasia, 2018.
4. New Technology Japan, Volume 16, Tokyo, Japan External Trade Organization, Machinery and Technology Dept., Japan, 1988.
5. Dixon Jr., Herbert B., The Basics of a Technology – Enhanced Courtroom, *American Bar Association Judges Journal*, 2017. https://www.americanbar.org/content/dam/aba/publications/judges_journal/vol56no4-jj2017-tech.pdf
6. Newzoo Computer Game Analysis, April 2018; https://newzoo.com/key-numbers/
7. VFXV, Fall 2017; http://vfxvoice.com/the-future-of-vfx-industry-leaders-look-ahead/
8. *People v. Duenas* 74 Cal.App.2d 846 (Cal.2012) p. 20.
9. *United States v. Mohney* (6th Cir. 1991 949 F.2d 1397, 1405), see also *United States v. Beckford* (4th Cir. 2000) 211 F.3d 1266, where computer-generated animations were illustrative for discussion of opinions of ballistics expert).
10. Selback, John, Digital Litigation: The Prejudicial Effects of Computer-Generated Animation in the Courtroom, *Berkeley Technology Law Journal*, 1994, Vol. 9, No. 2, pp. 337–367.
11. Id., p. 367.
12. Dunn, Meghan, Federal Judicial Center, Technology in the Courtroom: An Examination of the Effects of Computer Animation, presented at the Law and Society Association Conference, 2002.
13. In 2002 I participated in a trial in which we depicted a driver's approach to a railroad crossing where a train had collided with and killed all the occupants. We set up a large projection screen in front of the jury that effectively put them in the driver's position. The lead trial attorney played the video three times with no train in view as he discussed the foliage, signage, and other landmarks of the railroad crossing. On the fourth playing of the video, he substituted, without comment, a version we had created with a 3-D computer-generated train bearing down on the car at 50 mph (the speed of the locomotive in question). Startled, a juror in the back row shouted an expletive, which disrupted the proceedings but clearly demonstrated the effectiveness of the presentation.

37 Teaching Forensic Photography in the 21st Century

Sarah Graham

CONTENTS

A Summary: What Is Forensic Photography and Why Is It Important? 659
What Is It Like to Take Forensic Photographs? 660
How to Teach a Class in Forensic Photography Today 661
Photography Subjects 662
Can This Be Online? 663
Other Forms of Scene Recording 663

A SUMMARY: WHAT IS FORENSIC PHOTOGRAPHY AND WHY IS IT IMPORTANT?

This is more than just crime scene photography, and more than even crime scene photography is often thought to be. According to the Oxford Dictionary, forensic is defined as "relating to or denoting the application of scientific methods and techniques to the investigation of crime."

Photography is an important and integral tool throughout the investigative process, starting from the crime scene and ending in the courtroom. It relates to many fields and disciplines and is one of the most important ways of recording evidence.

Photographs are crucial to a forensic investigation. Unlike evidence recovery such as fingerprint powders or chemical treatments, you get multiple attempts to take a photo. They show evidence as it truly is, and they don't affect the subject. It is also the one constant. Forensic investigations are varied and involve many specialties, personnel, and agencies. Photographs, no matter the camera, provide a consistent documentation for investigators, judges, jury members, and anyone else involved.

Forensic photography is a way of providing a permanent, visual record of forensic evidence or a crime scene. A crime scene can be a location, but it can also be a vehicle, item, or person. The photographs taken provide a permanent and reliable record of the way evidence was observed. Crime scenes vary widely and so can the associated evidence. One of the main aspects of crime scene investigation is to record the evidence while preserving its integrity. Photography allows us to capture evidence throughout its journey from crime scene to court and within various forensic specialties. It allows us to tell a story and is an impartial representation.

One of the basic elements of photography is that it is a form of continuity. No matter the evidence types or the photographer, a picture shows how the evidence was found and can be used to record all actions completed. For instance, photographs are taken during a body recovery to ensure the pathologist can gain an accurate view of the condition of the body at the crime scene if they have not attended. This photography then continues throughout the postmortem. Photography not only shows the evidence in a case but also provides context to these items and where they were recovered. It also allows us to identify all exhibits and where they were recovered.

Photographs are often used as exhibits themselves. This is especially true of fingerprints and footwear patterns. These are used in comparison to reference profiles taken from those involved in a case. For these, precise photographic skills and procedures are needed.

In conjunction with other forms of evidence recording such as diagrams, it allows us to record the exact location and relationships between pieces of evidence and the surroundings. This gives context to the evidence and allows for items to be put back should a reconstruction be necessary and analysis to be done on the scene after scene closure.

Photography gives another visual element to evidence documentation. This shows an item more clearly than a description could and is not subjective. Where people use different words and descriptions, this isn't a factor. Even a color description is not infallible, as our perceptions of color can vary; therefore, a proper evidence photo is more accurate and less subjective. It also provides a permanent record of conditions otherwise not easily recorded in notes such as weather at a crime scene or condition of an item.

These aspects also make it ideal for use with other people working on a case. This can be for briefings with police officers or for passing information to the laboratory for analysis. One of the key areas is use in court. Not only are photographs used to show evidence to the courtroom but they are also an important aide-memoire for those presenting evidence they may have dealt with months or even years prior.

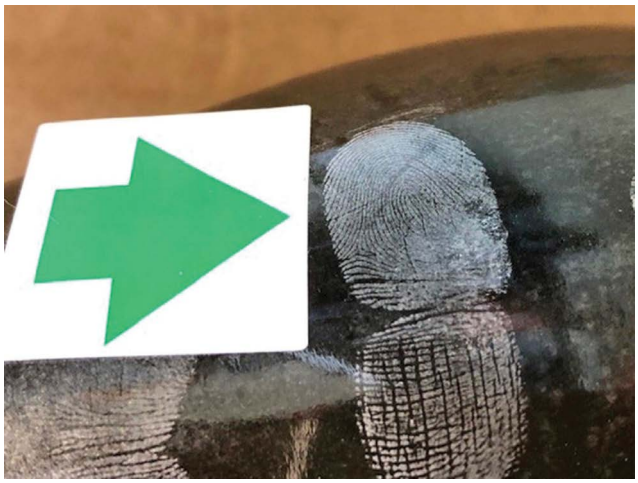


FIGURE 37.1 A fingerprint.



FIGURE 37.2 A crime scene.



FIGURE 37.3 Evidence at the crime scene.



FIGURE 37.4 Associated evidence.



FIGURE 37.5 A bright sunny day.

WHAT IS IT LIKE TO TAKE FORENSIC PHOTOGRAPHS?

Although evidence collection is completed after the crime, it doesn't mean the job of taking photographs is an easy or straightforward one. Crime scenes relate not just to contained, indoor, well-lit areas. They can be outside, at night, in busy or dangerous areas. They can relate to people, both living and deceased. Evidence isn't always easy to work with and is constantly changing. No two cases are exactly the same, and there can be no set process that will work for everything; therefore, part of teaching photography is providing a toolkit from which the examiner can select the best procedure to capture the evidence. Plus, although photography is important,

it is just one aspect of the work being undertaken. No matter who the photographer—CSI technician, police officer, or forensic scientist—they have many duties alongside this. Anyone completing forensic photography must be competent in this area to not only take the best possible photos but also manage this with their other tasks.

HOW TO TEACH A CLASS IN FORENSIC PHOTOGRAPHY TODAY

Although crime scene investigation as a subject has become more academic than before, with students learning the basic science behind the techniques, it still requires extensive practical work. No matter the equipment—basic cameras to top of the range—photography input is essential.

For anyone taking forensic photographs, training is needed. However, how much will vary depending on:

- The type of work they do: crime scene or lab.
- The environment they encounter. For instance, a lab will stay consistent but crime scenes vary.
- The equipment used.

For anyone using photography as part of their work, some areas stay the same in teaching. There are basic principles to be conveyed to everyone:

Practice and get to know your camera. Feeling confident and comfortable goes a long way to getting the best photograph.

Take your time. Photography is a nondestructive recovery type. Unlike some forms of evidence recovery such as fingerprint enhancement or footwear pattern casting, you can have repeated attempts to take a photograph. By getting this part right, any work completed after this can be done with the reassurance that the initial evidence has been captured.



FIGURE 37.6 A training situation.

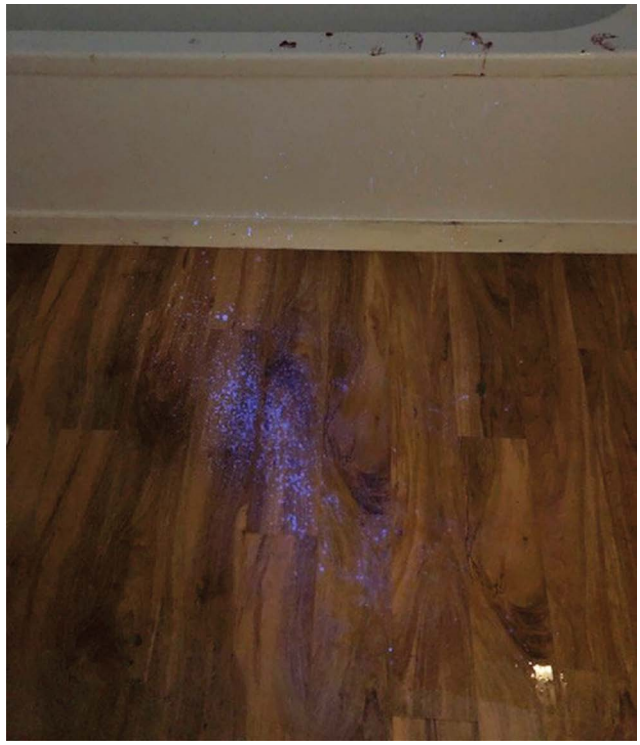


FIGURE 37.7 A difficult image to properly capture.

Review your photography. We work with digital devices now. Unlike the previous cameras that used film, we can review the photos! We don't have to take a photo and hope for the best. By reviewing photos and considering how they are to be used and that they provide all the information for the evidence, we ensure we have captured the evidence to the best of our ability.

Those working in crime scene investigation typically receive the most training. Photography is crucial to the role. There are often scenes where photography is the only form of evidence recovery.

For foundation-level CSIs, nearly the whole first week of a five-week course is on photography. This is then incorporated throughout the course. For each forensic recovery method, the photography is taught alongside this. This includes evidential photographs such as fingerprints. Students produce a portfolio of photographs by the end of the course. This is then continued in the posting, with a mentor.

For more advanced CSIs, the advanced subjects require equally advanced photographic methods. They will be required to attend major scenes and serious crimes. These can include places that are more difficult to capture, such as burned-out buildings, or more complicated scenes with lots of evidence or information to capture.

For those who will undertake forensic photography, especially those using more advanced cameras that have a variety of settings, they will need a solid base in photography. Many police forces now ask their photographic

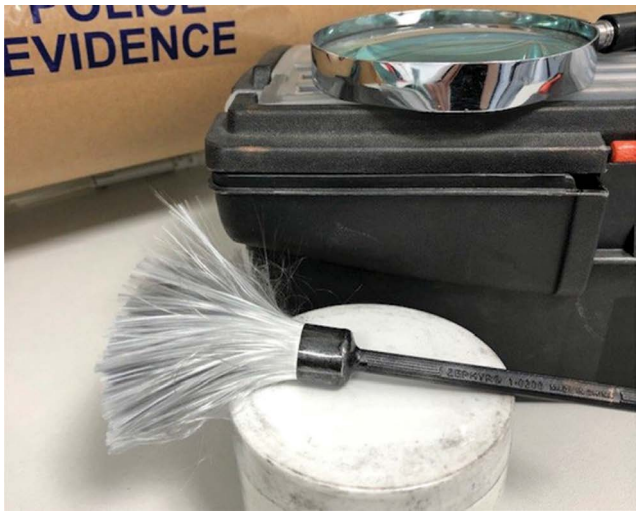


FIGURE 37.8 A training photograph.



FIGURE 37.10 Is this a good evidence photograph?

department to take more photos, typically, injury photography and at postmortems. For these personnel we have taught them the same skills as the crime scene investigators. They also use the same camera equipment. As they receive the photographs taken by the CSIs, it is also important for them to know crime scene photography, as they are aware of the challenges faced in the field and they can assist with troubleshooting problematic situations.

However, it is not just CSIs or police staff photographers who are recording evidence this way; we are more commonly seeing police officers being tasked to record the work they do. These evidential types include digital recovery, scene work, and firearms analysis. For these sessions we utilize the work presented in the longer photography courses, which can be altered depending on the equipment available. This may be quite similar for the officers who are given good cameras. For these we can provide the basics of camera work: getting to know your camera, aperture, etc. For others, they may have more simple cameras: the "point-and-shoot" types. For these it is the composition and end result we emphasize more, as there are limited changes to settings. There are some areas now where tablets are used for photography, commonly in fixed locations such as the lab, where they will encounter similar items and the photography is mainly for continuity purposes.

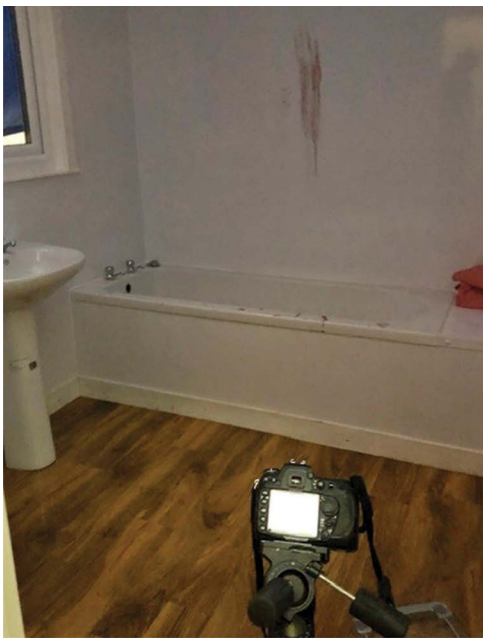


FIGURE 37.9 An image at an actual scene.

Basic equipment needed for teaching photography:

- Camera.
- Associated lenses, depending on the specific subject. For instance, polarized lenses for working with reflective surfaces.
- Flash. Especially for dark subjects or locations.
- Tripod. For evidential photography, fingerprint and footwear photography requires specific settings. It is important that students feel confident using these.
- Remote trigger. Vital for changes in shutter speed.
- Computer access and way of transferring photos to the computer.

PHOTOGRAPHY SUBJECTS

The basic subjects to teach are:

- Introduction to cameras, including the various functions and settings
- Aperture and depth of field
- Shutter speed
- ISO
- White balance
- Low-light and flash photography

The first step for a photography course is for the students to get know their camera and its settings. Knowing how to change these and return to normal settings introduces confidence with the camera. This is then continued with the main subjects in photography. For all these, theory work (often using PowerPoint) is combined with short exercises. Some of these are very basic exercises to practice the skill, while others are fun, for instance, practicing nighttime photography in a new, exciting location. These elements aim to make a student feel more relaxed using their camera and practice moving the settings around. The theory and practical exercises should allow the student to feel confident with their camera and know how to work with each new situation.

Photography is one of the constants in all forensic work, and will be the constant throughout an investigator's specific area. It is important therefore that students can complete this aspect with ease. This then influences the rest of their examination.

More specific, advanced subjects are:

- Scene and evidential photography
- Injury photography
- Ultraviolet (UV) and infrared (IR) photography
- Postmortem photography
- Specific scenes: Blood pattern analysis, fire, and firearms

For those working in the field, any course should be followed up with mentoring.

Photographs can be submitted electronically or on a file. These need to be kept for a prescribed number of years in case they need to be referred to.

Feedback can be given by reviewing the photos taken of practical sessions or by reviewing students' photos in class, using metadata. This can be beneficial for all students.

CAN THIS BE ONLINE?

Online courses can be delivered in a similar way. The theory elements such as presentations, instructions, and exercises can all be made available on a website or computer package. Though these may need more information supplied, as obviously students are without an instructor to add in information. Online courses can be helpful for those who cannot be made available for a residential course or who may not be near a location for short sessions. For these it is important for the student to complete all work and submit this for grading. The photographs can be uploaded for feedback. Tutorials should be made available for more specific help.

OTHER FORMS OF SCENE RECORDING

Along with cameras there are increasingly other ways of recording the crime scene. These are constantly changing with technology. These can be in conjunction with classic photography and in some cases instead of this.

Given the built-in cameras in tablets, these are becoming more common, particularly in cases where interpretation is less of a factor and photographs are primarily used for continuity.

Crime scene video work is still taught, as this can often be quite difficult. It adds context to a scene but is a long process to complete. This is much less common due to new technology—for example, 360-degree cameras and 360-degree scanners are more commonly used to record a scene as a whole, acting as both a video and scene diagram in one. These can be useful for the court to replace walkthroughs at a crime scene.

Body-cam footage is becoming a common way for officers to record scenes and evidence as they walk around a location or talk to individuals. In some cases, this has been valuable evidence, and at times when a scene has been released in error, can sometimes be the only evidence. It is important that anyone recording with this understands the principles and objectives of this area.

Drones are currently being assessed for their use in crime scene photography. Though there are risks and concerns of how disruptive they may be, they can capture evidence from large or potentially dangerous scenes. Work in this area continues, but skill in utilizing this form of photography should be developed.



Taylor & Francis
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http://taylorandfrancis.com

Glossary

18% Gray / Gray card: A neutral gray card that reflects 18% of the visible light falling upon it and absorbs 82%. It is the color all photographic light meters are calibrated to. Gray areas on a scale with 18% reflectance are to be used as a control for the reproduction of color more accurately in the final photograph. It is the "mid-point between black and white on a logarithmic or exponential curve." 18% gray cards have been used for decades as a tool onto which photographers could aim a spot meter and use the brightness as the exposure of the scene. Always use an 18% gray card if you have one available; hold the gray card at the same location the light is falling on your subject, and take your meter reading off the card. Be sure to fill the frame with the gray card. https://en.wikipedia.org/wiki/Gray_card

3-D Models: Three-dimensional survey model.

6 × 7 Camera (2.25 × 2.75 in): A camera using 120/220 film or a 2.25 × 2.75 in digital back for exposures.

ABFO#2 scale: A special 90-degree scale developed by the American Board of Forensic Odontology originally used only for the photography of bite marks. The scale design became so popular, it is used now for general use in macrophotography where size in two dimensions is required to be documented. Designed by William Hyzer, an engineer, and Thomas Krauss, a forensic dentist. Krauss was a diplomate of the American Board of Forensic Sciences (ABFO), and this was their second design, thus the name of the scale.

Abstract: Dealing with a subject in the abstract without practical purpose or intention; "abstract reasoning"; "abstract science." wordnet.princeton.edu/perl/webwn

Acceptance angle: The maximum cone half-angle for which incident light is captured by and will travel through the optical fiber. If the acceptance angle is q, then the acceptance cone is defined by a solid cone of 2q.

Accreditation standards: Accreditation is a process of review allowing organizations to demonstrate their ability to meet regulatory requirements and standards established by a recognized accreditation organization.

Accuracy: The degree of conformity of an indicated value to an accepted standard value, or ideal value. www.novalynx.com/glossary.html

Acrobat software (format): Adobe Acrobat is a family of application software and web services developed by Adobe, Inc., to view, create, manipulate, print, and manage files in Portable Document Format. The family comprises Acrobat Reader, Acrobat, and Acrobat.com. https://en.wikipedia.org/wiki/Adobe_Acrobat

Adaptation: The ability of the eye to adjust to various levels of darkness and light.

Adaptive meshing: When meshing a 3-D model, the flatter areas of the subject can be meshed with fewer vertices and underlying points, thus making the size of the finished point cloud smaller and easier to work with. (See Meshed model.)

Admissible/admissibility: Pertinent and proper to be considered in reaching a decision. Refers to the evidence considered in determining the issues to be decided in any judicial proceeding. www.courts.state.va.us/glossary_of_court_terms.html

Aerial imagery: Photographs from an aircraft or other flying object. Mounted cameras may be triggered remotely or automatically; handheld photographs may be taken by a photographer. Aerial photography is the taking of photographs of the ground from an elevated/direct-down position. https://openei.org/wiki/Definition:Aerial_Photography

Aesthetic: Having to do with beauty in both form and appearance. An aesthetic procedure is one in which the principal purpose is to improve the appearance. www.spafinder.com/spas/medical/glossary.jsp

Airy disc: Due to the wave nature of light, light passing through apertures is diffracted, and the diffraction increases with decreasing aperture size. The airy disk is the best focused circle of light with the given aperture. Rings around the disk, formed by light diffraction, form the Airy Pattern.

Age progression: A useful method in forensic applications; can be applied to missing children and adult cases. Age progression is the process of modifying a photograph of a person to represent the effect of aging on their appearance. Digital image processing is the most common technique today, although sometimes artists' drawings are used. Age progression is most often used as a forensics tool by law enforcement. https://en.wikipedia.org/wiki/Age_progression

Age regression: These are conducted in a similar fashion as age progressions, yet in these scenarios, the clock is turned back to exhibit the appearance of a subject at an earlier age. https://mcforensicart.com/ageprogressions

Aging, environmental (extrinsic): A continuous process occurring naturally over time within the face. Intrinsic aging results from a gradual thinning of the skin, loss of tissue elasticity, shrinking of fat, and alteration in facial volume and muscle underneath the skin. Factors include the sun's ultraviolet radiation (photoaging), smoking, arid weather, drug use, stress, etc. Prominent facial wrinkling was more common among smokers no matter their age period.

Aging, genetic (intrinsic): Caused by the genetic background, structural, functional, metabolic, and hormonal changes.

Aliasing: In computer graphics, the process by which smooth curves and other lines become jagged because the resolution of the graphics device or file is not high enough to represent a smooth curve. Smoothing and anti-aliasing techniques can reduce the effect of aliasing.

Alteration of evidence: A closely related concept to spoliation of evidence is tampering with evidence, which is usually the criminal-law version of the same concept, namely when a person alters, conceals, falsifies, or destroys evidence in an investigation by law enforcement or by a regulatory authority. https://www.law.cornell.edu › … › Chapter 73. OBSTRUCTION OF JUSTICE

Alternative light sources: The full electromagnetic spectrum includes a range of frequencies of electromagnetic waves including radio, infrared, visible light, ultraviolet, x-ray, gamma ray, and cosmic waves. Alternative light sources (ALSs) are invaluable for detecting substances (forensic trace) at a crime scene such as body fluids (semen, urine, saliva, vaginal fluids, blood, sweat etc.), bruising, hair, fibers, footprints, fingerprints, etc. (see Infrared imager and Ultraviolet lighting). www.advanced-ndt.co.uk/als_forensic_lighting.htm

Ambient lighting: The light already present in a scene before any additional lighting is added. It usually refers to natural light, either outdoors or coming through windows, etc. It can also mean artificial lights such as normal room lights. https://www.mediacollege.com/lighting/ambient/

Angle of separation: A technique used by many when photographing smaller evidence (i.e., on the order of 10 cm to 2 m) is to move around the subject in a "ring-like" fashion. Each photograph should have an angle of separation from the previous image of roughly 15 degrees.

Angle of view: Describes the angular extent of a given scene imaged by a camera. It is used interchangeably with the more general term field of view. https://en.wikipedia.org/wiki/Angle_of_view

Angular size: A measurement of how large or small something is using rotational measurement (degrees of arc, arc-minutes, and arc-seconds); useful for measuring things that are so far away they appear two-dimensional.

Antemortem records: Records of forensic significance among edentulous individuals. The identification of edentulous individuals is problematic due to poor provision of labeled dental prostheses. Dental records may still provide useful information for odontologists in the comparative identification process. Edentulous comes from the Latin prefix e-, meaning "missing" or "absent," and the Latin root dent-, meaning "tooth." https://www.dictionary.com/browse/edentulous

Anthropological nomenclature: Anatomical terms are used to analyze facial features.

Anthropometric measurements: Systematic measurements of the size, shape and composition of the human body. For example, body mass index (BMI) is a measurement of a person's weight-to-height ratio, and waist-to-hip ratio is a measure of the waist circumference divided by the hip circumference. https://study.com/…/what-is-anthropometric-measurement-tools-purpose-methods.html

Anthropometry: A specific subfield of anthropological science that basically deals with the dimensions, landmarks, and angles of the human body in order to quantify facial structures and proportions. In order to calibrate facial photographs to the same size, the distance between the pupils or the inner canthal points of the eyes can be considered as the standard reference measurement value.

Anthropomorphic: Attributing human-like characteristics to something not human. www.mnh.si.edu/arctic/html/resources_glossary.html

Aperture, lens: Aperture refers to the opening of a lens's diaphragm through which light passes. It is calibrated in *f*/stops and is generally written as numbers such as 1.4, 2, 2.8, 4, 5.6, 8, 11, and 16. https://www.nikonusa.com/en/learn-and-explore/a/tips-and-techniques/understanding-maximum-aperture.html

Aperture priority: A mode in which a desired lens opening (f-stop) is manually selected and locked in; the camera then chooses an appropriate shutter speed for proper exposure. Used primarily to control DoF (the range of sharpness) in front of or behind a subject or object.

Application software (apps): Computer functions used to enhance cellular phone camera images or bring additional functionality to the hardware.

Arc mapping: By examining wiring, it may be possible to determine where a fire was located first and then where it spread. This process requires detailed documentation and photographs to show where beads formed and where they stopped.

Art form: An artist's practice or in the development of an artistic genre. www.canadacouncil.ca/help/lj127228791697343750.htm

Artificial intelligence: Typically, neural networks.

Assault: The crime of violence against another person. In some jurisdictions, assault is used to refer to the actual violence, while in other jurisdictions (in the United States, England, and Wales), assault refers only to the threat of violence, while the actual violence is battery. Simple assaults do not involve weapons; aggravated assaults do.

Association conclusion: If the observable and measurable physical dimensions and design features of the two items agree or are "physically consistent." (See Elimination conclusion.)

Associative evidence: Associative evidence can be used to provide links between evidence and individuals involved in a crime. In some cases, the associative evidence (e.g., fingerprints or DNA) may be sufficient to prove the contact. https://projects.nfstc.org/firearms/module06/fir_m06_t05_01.htm

Authenticity: Undisputed credibility. wordnet.princeton.edu/perl/webwn

Autofocus: System by which the camera lens automatically focuses the image of a selected part of the picture.

Autopsy, clinical (medical): The postmortem examination of the decedent to determine the cause of death. Please note, the definitions for the terms involved with the autopsy are shown in Chapter 29.

Autopsy, forensic: The medicolegal or forensic autopsy is performed at the request of police, prosecutor, or court by a forensic pathologist—usually in unnatural (violent) deaths, in otherwise sudden unexpected deaths, and in some unwitnessed deaths.

Axis X, Y, and Z: Define virtual three-dimensional space with a center (zero) point known as the origin. This is the point where the three major axes (XYZ) intersect. https://web.calpoly.edu/~elovagli/HTML/concepts_01.htm

Axial lighting: Axial lighting is derived from a lighting formula used to provide illumination to the subject, with the light emanating from the same axis as the lens of the camera.

Axonometric: A drawing technique devised to represent three-dimensional objects on flat paper. Verticals are drawn to scale, but diagonal dimensions are distorted. www.archiseek.com/guides/glossary/a.html

Azimuth: The horizontal angle or direction of a compass bearing; the horizontal angle is measured clockwise from any fixed reference plane. https://en.wikipedia.org/wiki/Azimuth

Bayer filter array: A Bayer filter mosaic is a color filter array (CFA) for arranging RGB color filters on a square grid of photosensors. Its particular arrangement of color filters is used in most single-chip digital image sensors used in digital cameras, camcorders, and scanners to create a color image. https://en.wikipedia.org/wiki/Bayer_filter

Beam splitter: An optical component that can split the power contained in one beam of light into two or more beams. www.point-source.com/glossary.asp

Bellows: An accordionlike, light-tight camera accessory that fits between the lens and camera body. Enables closer focus of a subject and may achieve greater-than-life-size magnification on a sensor.

Binocular: The simultaneous use of the two eyes in the act of vision to produce one image. www.eyecaretyler.com/knowmore.htm

Biological evidence: Evidence that is commonly recovered from crime scenes. Such evidence is in the form of blood, saliva, sperm, hair, tissue, bones, teeth, blood, or other bodily fluids. https://definitions.uslegal.com/b/biological-evidence/

Blurring: Blurring may be caused by an object in motion, but in most forensic situations, the culprit is often the photographer, whose movement of the camera during the exposure is the cause of motion. It is recommended to use a tripod when the shutter speed of the camera is slow enough to possibly cause a blur.

Bodycam or Dashcam: Cameras are either mounted on the dashboard of a vehicle or worn physically on the body of the user.

Blackbody radiator: The thermal electromagnetic radiation within or surrounding a body in thermodynamic equilibrium with its environment, emitted by a black body (an idealized opaque, nonreflective body). It has a specific spectrum and intensity that depends only on the body's temperature, which is assumed for the sake of calculations and theory to be uniform and constant. https://en.wikipedia.org/wiki/Black-body_radiation

Blood spatter: Blood spatter, or bloodstain pattern interpretation, is a technique that seeks to piece together the events that caused bleeding. In the actual spatter analysis, a forensic investigator determines the trajectory of the blood (where the blood came from and how it spread over the surface). https://www.encyclopedia.com/science/encyclopedias-almanacs…and…/blood-spatter

Bluetooth connection: Before you can use a Bluetooth device like a mouse or a headset, you first need to connect your computer to the device. This is also called pairing the Bluetooth. https://help.gnome.org/users/gnome-help/stable/bluetooth-connect-device.html.en

Body type (somatotype): William H. Sheldon, PhD, MD, introduced the concept of body types, or somatotypes, in the 1940s. Most people are unique combinations of the three body types: ectomorph, mesomorph, and endomorph. www.uh.edu/fitness/comm_educators/3_somatotypesNEW.htm

Bolton standards: The overall ratio known to be 91.3%. The anterior analysis measures the sum of the

mesiodistal width of the front six mandibular teeth and compares them to maxillary teeth. Having a different ratio than normal is referred to as a Bolton discrepancy. A standard deviation of more than 2 yields a significant discrepancy. https://en.wikipedia.org/wiki/Bolton_analysis

Bombing: A bomb is an explosive device, usually some kind of container filled with explosive material, designed to cause destruction when used. The explosion of the bomb must be triggered, usually by a clock, a remote control, or some kind of sensor.

Borescope: An instrument used to inspect the inside of a structure through a small hole. https://en.wikipedia.org/wiki/Borescope

Bounce back: Light, in the form of reflection, which bounces back into the camera lens and leads to a bad exposure. The term means a lot of different things depending upon the context of the conversation. Cameras with fixed-position flashes set close to the lens aperture are particularly prone to glare and flash burn.

Brightness: Brightness is an attribute of visual perception in which a source appears to emit a given amount of light. In other words, brightness is the perception elicited by the luminance of a visual target. en.wikipedia.org/wiki/Brightness

Bruise: A bruise, or contusion, or ecchymosis is a kind of injury, usually caused by blunt impact, in which the capillaries are damaged, allowing blood to seep into the surrounding tissue. Normally minor but painful, bruises can be serious, leading to hematoma, or can be associated with serious injuries, including fractures and internal bleeding. Minor bruises are recognized by their characteristic blue or purple color in the days following the injury.

Bulb setting: This means the camera will the shutter open until your finger comes off the shutter button. Bulb mode is mostly used for long exposures at night. The main advantage is that it allows the photographer to achieve shutter speeds longer than the 30 seconds (displayed 30″ on the camera) that is allowed on most DSLRs. https://improvephotography.com/958/bulb-mode-photography-long-exposure-night/

Burns, intentionally inflicted (thermal, chemical or electrical): A burn injury often results from an energy transfer to the body. There are many types of burns caused by thermal, radiation, chemical, or electrical contact, or friction: thermal burns, hot metals, scalding liquids, steam, and flames, when coming in contact with the skin, can cause thermal burns. https://www.urmc.rochester.edu/encyclopedia/content.aspx?ContentTypeID=90

Camera: A lightproof box fitted with a lens though which the image of an object is recorded on a material sensitive to light.

Camera metering modes: Allow adjustments based on lighting conditions which have a direct impact on the accuracy of an exposure. Most cameras have three metering modes: evaluative (Canon) or matrix (Nikon), center, and spot.

Camera raw format: A camera raw image file contains minimally processed data from the image sensor of either a digital camera, a motion picture film scanner, or other image scanner. raw files are named so because they are not yet processed and therefore are not ready to be printed or edited with a bitmap graphics editor. https://en.wikipedia.org/wiki/raw_image_format

Candela (cd): Standard unit of luminous intensity in the International System of Units (SI: Le Système International d'Unité); formally defined as the magnitude of an electromagnetic field, in a specified direction, that has a power level of 1/683 watt (1.46 × 10–3 W) per steradian at a frequency of 540 terahertz (540 THz or 5.40 × 1014 Hz).

Candle (standard): Basic unit of luminous intensity adopted under the International System of Units (SI: Le Système International d'Unité); equal to 1/60 of the luminous intensity per square centimeter of a blackbody radiating at the temperature of 2,046 Kelvin.

Candle power: Luminous intensity of a source of light expressed in candelas.

Cavity magnetron: A high-powered vacuum tube used to generate microwaves using the interaction of a stream of electrons with a magnetic field while moving past a series of open metal cavities (cavity resonators). This is the integral piece in improving radar so it could detect enemy aircraft from long distances.

Cephalometrics: The study and measurement of the head, usually the human head, especially by medical imaging such as radiography. Craniometry, the measurement of the cranium (skull), is a large subset of cephalometry. https://en.wikipedia.org/wiki/Cephalometry

CGS system: System of units of measurement based on the metric system and having the centimeter of length, the gram of mass, and the second of time as its fundamental units. Other CGS units are the dyne of force and the erg of work or energy.

Chain of custody: Once evidence is gathered, there must be documentation, in writing, for everyone who touches it and whenever it is moved from one place to another. Special forms are normally prepared by individual departments for the written documentation. There is no particular standard.

Characteristic curve: A curve (of a film) showing the relationship between the common logarithm of exposure, log K, and the optical density, D; also called the D-logE curve or the H and D curve.

Characteristic impressions: These are based on a given tool type, which may leave characteristic impressions on an object upon which it was used.

Circle of confusion (CoC): An optical spot caused by a cone of light rays from a lens not coming to a perfect focus when imaging a point source. It is also known as disk of confusion, circle of indistinctness, blur circle, or blur spot. https://en.wikipedia.org/wiki/Circle_of_confusion

Clandestine surveillance photography: The making of photographs of subjects in secrecy, unaware their images are being captured.

Clash detection: The effective identification, inspection, and reporting of interferences in a 3-D project model.

Class characteristics of fired bullets: Include diameter/caliber, shape of firing pin impression, number of land and groove impressions, widths of the land and groove impressions, shape and orientation of breechface marks, direction of twist, and the relative location of extractor and ejector marks.

Clipping: A result of oversaturation (too bright) or undersaturation (too dark) in an image. If the video image contains grayscale values outside the image processor's upper and lower limits for the grayscale range, pixels exceeding the limits are set to the highest or lowest values possible.

Closed-circuit television camera (CCTV): Also known as video surveillance, the use of video cameras to transmit a signal to a specific place, on a limited set of monitors. CCTV systems may operate continuously or only as required to monitor a particular event. https://en.wikipedia.org/wiki/Closed-circuit_television

Close-up lens: In photography, a close-up lens (sometimes referred to as a close-up filter or a macro filter) is a simple secondary lens used to enable macrophotography without requiring a specialized primary lens. They work like reading glasses, allowing a primary lens to focus more closely. (See Diopter.) https://en.wikipedia.org/wiki/Close-up_lens

Cloud: A virtual private cloud (VPC) is an on-demand configurable pool of shared computing resources allocated within a public cloud environment, providing a certain level of isolation between the different organizations using the resources. (See Virtual cloud.) https://en.wikipedia.org/wiki/Virtual_private_cloud

CMOS imaging sensor: A CMOS sensor is an electronic chip that converts photons to electrons for digital processing. CMOS (complementary metal oxide semiconductor) sensors are used to create images in digital cameras, digital video cameras, and digital CCTV cameras. https://whatis.techtarget.com/definition/CMOS-sensor

Code of Federal Regulations (CFR): The codification of the general and permanent rules published in the Federal Register by the executive departments and agencies of the federal government, divided into 50 titles that represent broad areas subject to federal regulation, with each volume of the CFR updated once each calendar year and issued quarterly. www.dlis.dla.mil/EPp/acronyms/default.asp

Coefficient of friction: The ratio between the force necessary to move one surface horizontally over another and the pressure between the two surfaces. https://simple.wikipedia.org/wiki/Coefficient_of_friction

Color: A visual attribute of things resulting from the light they emit or transmit or reflect; "a white color is made up of many different wavelengths of light."

Color balance: In photography and image processing, color balance is the global adjustment of the intensities of the colors (typically red, green, and blue primary colors). An important goal of this adjustment is to render specific colors—particularly neutral colors—correctly. https://en.wikipedia.org/wiki/Color_balance

Color fidelity: The degree to which a device (such as a CD player, radio, or television) correctly reproduces sounds, pictures, music, etc., with much higher fidelity. For example, a printer with outstanding color fidelity is a printer that produces very accurate colors. www.learnersdictionary.com/definition/fidelity

Color management: The only sure method to produce accurate color with your photographs is to use a color management system, the heart of which is a calibration process. There are three steps to properly managing color: (1) calibrating the monitor, (2) using a color checker when shooting, and (3) using a printer profile so what you see on your monitor will match what is printed.

Color rendition: A color rendering index (CRI) is a quantitative measure of the ability of a light source to reveal the colors of various objects faithfully in comparison with an ideal or natural light source. Light sources with a high CRI are desirable in color-critical applications such as neonatal care and art restoration. https://en.wikipedia.org/wiki/Color_rendering_index

Color temperature: Light is measured in a Kelvin (K) temperature scale; daylight is in the range of 5000 K to 6500 K. Incandescent lighting is mostly used in homes, and is considered to be warm and inviting, and is around 2700 K to 3000 K. LED lights are typically available in a range between 3000 K and 5000 K.

CompactFlash (CF) memory card: A type of flash memory mass-storage device used by most portable digital electronic devices. The first CF was developed and manufactured in 1994 by SanDisk. Over the years CompactFlash has become useful and has surpassed other storage media devices such as SmartMedia and Miniature Card. https://

www.cleverfiles.com/howto/what-is-compact-flash.html

Comparative microscopy: A microscopic comparison examination consisting of a search of the striated marks present on two bullets to determine if patterns of similarity exist.

Comparison microscope: The instrument used to perform comparative microscopy. A device used to analyze side-by-side specimens. Two microscopes are connected by an optical bridge, resulting in a split-view window enabling two separate objects to be viewed simultaneously. https://en.wikipedia.org/wiki/Comparison_microscope

Composition: Composition is the plan, placement, or arrangement of the elements of art in a work. The general goal is to select and place appropriate elements within the work in order to communicate ideas and feelings with the viewer. https://en.wikipedia.org/wiki/Composition_(visual_arts)

Computational photography: Refers to digital image capture and processing techniques that use digital computation instead of optical processes. https://en.wikipedia.org/wiki/Computational_photography

Condensed phase explosion: Deflagration or detonation of a solid or liquid substance or mixture of substances. https://wikips.tamu.edu/condensed-phase-explosion/

Cone cells and rod cells: Cone cells, or cones, are photoreceptor cells in the retinas of vertebrate eyes (e.g., the human eye). They respond differently to light of different wavelengths and are thus responsible for color vision and function best in relatively bright light, as opposed to rod cells, which work better in dim light. https://en.wikipedia.org/wiki/Cone_cell

Cone of visual attention: The area of main human vision. The rest of what we see is peripheral vision. Studies have measured the cone of visual attention and found it to be about 55 degrees wide. http://www.photosig.com/articles/585/article

Conflict of interest: A situation in which a person has a duty to more than one person or organization but cannot do justice to the actual or potentially adverse interests of both parties. https://legal-dictionary.thefreedictionary.com/conflict+of+interest

Conspicuity: The quality of being conspicuous; obviousness.

Consent to be photographed: The best way to protect oneself from being sued for invading someone's privacy is to obtain his or her permission to be photographed. https://www.photovideoedu.com/Learn/…/the-role-of-permission-in-photography.asp

Consumer market: A consumer market is a marketplace consisting of household consumers who buy goods for individual or family consumption. It is different from a business market, in which businesses sell goods and services to other companies. https://bizfluent.com/facts-6022096-definition-consumer-market.html

Contrast: In visual perception, contrast is the difference in visual properties making an object (or its representation in an image) distinguishable from other objects and the background. en.wikipedia.org/wiki/Contrast

Contrast sensitivity: A very important measure of visual function, especially in situations of low light, fog, or glare, when the contrast between objects and their background often is reduced. https://www.allaboutvision.com/eye-exam/contrast-sensitivity.htm

Copy stand: A vertical rail with a camera adapter to raise and lower the camera for making images of different sizes and magnifications. There are also usually a set of lights, one or two on both sides of the platform at the base of the rail, for the illumination of the material to be copied.

Craniofacial photoanthropometry: A metric method applied in facial mapping. In photoanthropometric facial comparison, facial soft tissue landmarks are placed on the face and interdistances between the landmarks are measured.

Craniofacial superimposition: Craniofacial superimposition is a forensic process where photographs or video shots of a missing person are compared with a model of a skull that is found, projecting one above the other (skull-face overlay). www.human-competitive.org/sites/default/files/ibanez-slides.pdf

Crime scene investigation: A forensic science applied to answer questions that are of interest to the legal system as well as social sciences such as archaeology.

Criminal liability: In criminal law, strict liability is liability for which *mens rea* (Latin for "guilty mind") does not have to be proven in relation to one or more elements comprising the *actus reus* (Latin for "guilty act") although intention, recklessness, or knowledge may be required in relation to other elements of the offense. https://en.wikipedia.org/wiki/Strict_liability_(criminal)

Crop factor: The ratio of a camera sensor's size to a 35-mm-size full frame. (See Focal length multiplier.) https://www.photographymad.com/pages/view/crop-factor-explained

Crush depth: The depth of intrusion of one vehicle or structure into another is used to calculate the impact speed of the two bodies.

Curtilage: Of a house or dwelling and is the land immediately surrounding it, including any closely associated buildings and structures, but excluding any associated open fields beyond.

Cyanoacrylate ester: Cyanoacrylate glues are the proper name for a type of glue commonly known as Super

Glue. Their name derives from the strong bond they can form with any surface in the presence of moisture. https://www.hotmelt.com/blogs/blog/what-is-cyanoacrylate-glue

Data authentication: Merriam-Webster defines authentication as "an act, process, or method of showing something (such as an identity, a piece of art, or a financial transaction) to be real, true, or genuine; the act or process of authenticating something."

Data integrity: A process that ensures "the information presented is complete and unaltered from the time of acquisition until its final disposition." *SWGIT Guidelines, Section 13 - Best Practices for Maintaining the Integrity of Digital Images and Digital Video.*

Death ray: Scientists and engineers of the 1930s attempted to create a beam for use on the battlefield and to aim at aircraft in flight. (See Radar.)

Decomposition: Decomposition is the process of decaying or rotting. https://www.vocabulary.com/dictionary/decomposition

Default settings: In computer science, refers to the pre-existing value of a user-configurable setting that is assigned to a software application, computer program, or device. In many devices, the user has the option to restore these default settings for one or all options. https://en.wikipedia.org/wiki/Default_(computer_science)

Deflagration: A deflagration is an explosion in which the pressure wave is expanding slower than the speed of sound

Dense point cloud: A useful starting point for 3-D modeling and can be helpful in positioning 3-D objects into a scene. A dense point cloud is made based on the information generated by a software camera and uses the points to create a 3-D mesh of 2-D images.

Densitometer, reflective color: An instrument for measuring the photographic density of an image on a film or photographic print. https://en.wikipedia.org/wiki/Densitometer

Density: The degree of tone, weight of darkness, or color within a photo or reproduction; measurable by the densitometer. www.dataprintonline.com/resources/glossary.html

Depth clues (cues)/depth perception: Depth perception is the visual ability to perceive the world in three dimensions and the distance of an object. Binocular cues include stereopsis, eye convergence, disparity, and yielding depth from binocular vision through exploitation of parallax. https://en.wikipedia.org/wiki/Depth_perception

Depth of field: The zone of acceptable sharpness within a photo that will appear in focus. Using higher f-stop numbers and thus smaller apertures can help increase the depth of field. https://digital-photography-school.com/understanding-depth-field-beginners/

Depth of focus (DoF): Depends upon the numerical aperture, as well as the magnification, and is inversely proportional to both: the higher the magnification, the shorter the depth of focus for any given numerical aperture.

Detonation: A detonation is an explosion in which the pressure wave is expanding faster than the speed of sound

Diagonal crop factor: When a camera's sensor is smaller than 35 mm it is referred to as having a diagonal crop factor since it's essentially measured as less than 36 × 24 mm "full frame."

Diaphragm: A ring or plate with a hole in the center that controls the amount of light entering the camera. An adjustable diaphragm in a lens controls the size of the hole, or aperture, thereby permitting more or less light to pass through the lens to the film.

Diffraction: The tendency of waves to bend around corners. The diffraction of light establishes its nature as a wave.

Diffuser, flash: A flash diffuser is a simple light modifier that attaches to the upper part of an external flash unit. It's used to soften or spread the harsh, concentrated light that bursts out of the flash, creating a more even and flattering light on the subject. The larger the diffuser, the softer the light will be. https://www.adorama.com

Digital camera: A camera that records and stores photographic images in digital form. https://searchmobilecomputing.techtarget.com/definition/digital-camera

Digital evidence: Digital evidence or electronic evidence is any probative information stored or transmitted in digital form that a party to a court case may use at trial. As such, some courts have sometimes treated digital evidence differently for purposes of authentication, hearsay, the best evidence rule, and privilege. https://en.wikipedia.org/wiki/Digital_evidence

Digital magnetic compass: Solid-state microelectromechanical system compass. https://en.m.wikipedia.org/wiki/Digital_compass

Digital photograph: Digital photography, as opposed to film photography, uses an electronic sensor to record the image as a piece of electronic data rather than as chemical changes on film. Since 2005, digital cameras have outsold film cameras, and they include features not found in film cameras, such as the ability to shoot video and record audio. Some other devices, such as mobile phones, now include digital photography features.

Digital photography: Taking pictures with a digital camera and storing and printing them on digital devices. The "digital film" comprising flash memory modules, or CD-Rs, can be transferred to a computer for printing, or can be uploaded to a website for

viewing and printing. www.bradycommunications.com/perspectives/glossary.aspx

Digital zoom: An in-camera image processing for enlarging the area in the center of the frame, trimming outside edges away from the image.

Diopter: A unit of focusing power of a lens that fits on the front of a camera lens, allowing photography at closer distances than normal for that lens.

Direct export: Sending data to DVD or Blu-ray right from the camera.

Disorientation: The condition of having lost one's sense of direction, occurring when insufficient fixed references are offered to the viewer of the photos. https://dictionary.cambridge.org/us/dictionary/english/disoriented

Display device: An output device for the presentation of information in visual or tactile form (the latter is used, for example, in tactile electronic displays for blind people). When the input information that is supplied has an electrical signal, the display is called an electronic display. https://en.wikipedia.org/wiki/Display_device

Distort: To deliberately exaggerate or manipulate an image to the extreme. www.brigantine.atlnet.org/GigapaletteGALLERY/websites/ARTiculationFinal/MainPages/A-DVocabulary.htm

Distortion: Warp, twist, contortion, bend, buckle, deformation, deformity, curve, curvature, malformation, disfigurement, crookedness; gnarl, knot, "strain on the muscles of the eye leading to a distortion in shape or structure." https://www.merriam-webster.com/dictionary/distortion

D logE curve: The film precursor of the digital image histogram. It required a densitometer to measure the dark and light areas of a processed negative. When all the measurements were completed, they were graphed. They showed the exposure/processing possibilities for a given film and developer combination. (See Characteristic curve.)

DMORT (Disaster Mortuary Operational Response Team): Activated in response to large-scale disasters in the United States to assist in the identification of deceased individuals and storage of the bodies pending the bodies being claimed. https://en.wikipedia.org/wiki/Disaster_Mortuary_Operational_Response_Team

DNA: Deoxyribonucleic acid or deoxyribose nucleic acid is a nucleic acid that contains the genetic instructions specifying the biological development of all cellular forms of life (and many viruses). DNA is often referred to as the molecule of heredity, as it is responsible for the genetic propagation of most inherited traits. During reproduction, DNA is replicated and transmitted to the offspring.

Document or handwriting examiner: A person who examines disputed documents and signatures within the legal system.

Dots per inch: The resolution of output of a flatbed scanner.

Drones: Unmanned aerial vehicles (UAVs).

DSLR: Denoting or relating to a camera that combines the optics and mechanisms of a single-lens reflex camera with a digital imaging sensor, rather than photographic film. https://www.pcmag.com/encyclopedia/term/42047/dslr

Dual-axis compensator: Monitors a 3-D scan in real time, and if there is any movement in the scanner, within reason, it will adjust the cloud.

DX format: The Nikon DX format is an alternative name used by Nikon Corporation for the APS-C image sensor format, being approximately 24 × 16 mm. Its dimensions are about two-thirds (29 mm vs. 43 mm diagonal, approx.) those of the 35 mm format. https://en.wikipedia.org/wiki/Nikon_DX_format

Dynamic: Changeable. Normally used to refer to elements that can change. www.machinima.com/article.php

Dynamic range: Dynamic range in photography describes the ratio between the maximum and minimum measurable light intensities (white and black, respectively). In the real world, one never encounters true white or black—only varying degrees of light source intensity and subject reflectivity. Therefore, the concept of dynamic range becomes more complicated and depends on whether you are describing a capture device (such as a camera or scanner), a display device (such as a print or computer display), or the subject itself. https://www.cambridgeincolour.com/tutorials/dynamic-range.htm

Ecchymosis: A discoloration of the skin resulting from bleeding underneath, typically caused by bruising. https://www.medicalnewstoday.com/articles/321943.php

Edge distortion: In geometric optics, distortion is a deviation from rectilinear projection. https://en.wikipedia.org/wiki/Distortion

Ektachrome SO366: Kodak has several slide duplication films. The most common ones are the SO-366 and the 5071. The SO-366 is a daylight film; the 5071 is balanced for tungsten (3200 K). http://www.erwinvoogt.com/SO366/so366.html

Electrical resistance survey: Resistivity is a form of geophysical survey where electrical current is passed through the ground at regular points on a survey grid. Electrical resistance in the soil varies and is affected by the presence of archaeological features. The patterns of resistance in the soil are recorded, plotted, and interpreted. www.pastperfect.org.uk/archaeology/resistivity.html

Electromagnetic field: Physical field produced by electrically charged objects affecting the behavior of charged objects in the vicinity of the field.

Electromagnetic radiation: A kind of radiation including visible light, radio waves, gamma rays, and x-rays, in which electric and magnetic fields vary simultaneously. In physics, electromagnetic radiation (EM radiation or EMR) refers to the waves

(or their quanta, photons) of the electromagnetic field, propagating (radiating) through space, carrying electromagnetic radiant energy. https://en.wikipedia.org/wiki/Electromagnetic_radiation

Electromagnetic spectrum (EMS): The full range of frequencies of electromagnetic radiation and their respective wavelengths and light energies. The range of electromagnetic waves is frequencies from below 1 hertz (Hz) to above 1025 Hz (1 hertz is equivalent to the frequency of once per second).

Electronic flash: A flash is a device used in photography producing a flash of artificial light at a color temperature of about 5500 K. https://en.wikipedia.org/wiki/Flash_(photography)

Electronic viewfinder (EVF): A camera with a viewing screen and sometimes a viewfinder too for focusing and composition. (See Optical viewfinder.)

Elevating stage: A device of variable sizes to raise and/or lower a small subject for macrophotography under a perpendicular camera.

Elimination conclusion: There is a lack of observable design features or measurable dimensions; the result is "inconclusive." (See Association conclusion.)

Enhance: To make better or more attractive.

Epidermis: The outer layer of skin, which is made up of the horny layer, squamous cells, and basal cells.

Ethics/ethical: The study of fundamental principles defining values and determining moral duty and obligation. www.science.psu.edu/alert/frontiers/Glossary1-2001.htm

Event data recorder (EDR) and crash data retrieval (CDR): The on-board computers built into modern vehicles. The black box data or vehicle event data recorders are used in all passenger vehicles manufactured after 2014, and some vehicles were equipped with black box data recorders starting in 1994. During the occurrence of a car accident, the event data recorder or black box archives five seconds of data prior to the impact, provided the collision is strong enough to "wake up" the system. The information can be read using the proper equipment and software program. The black box data is always there, as long as it is captured within a certain amount of time. https://atslab.com/forensic-services/black-box-data

Evidence: Testimony, records, documents, material objects, or other things presented at a trial to prove the existence or nonexistence of a fact. www.utcourts.gov/resources/glossary.htm

Evidence response team (ERT): The field and laboratory professionals who collect evidence from crime and/or accident scenes and analyze it using a variety of sophisticated techniques and tools. ERTs are usually composed of special agents, mechanical engineers, forensic specialists, forensic canine operators, and management and program analysts. https://www.fbiagentedu.org/careers/criminal-investigation/evidence-response-team/

Evidence spoliation: Lawyers and courts use the term spoliation to refer to the withholding, hiding, or destruction of evidence relevant to a legal proceeding. It is a criminal act in the United States under federal and most state law.

Evidential toolmarks: Two groups: (1) general characteristics and (2) individual characteristics. General characteristics describe the type of action used to produce a toolmark and its dimensions. Individual characteristics are the unique microscopic striations found within the toolmark.

Evolving injury: The original image is invaluable for comparison to the appearance at the follow-up evaluation (where physical examination and imaging are repeated).

Exchangeable Image File Format (EXIF) metadata: A standard means of tagging digital image files with metadata, or additional information about the image. The word "EXIF" is based on the Exchangeable Image File Format standard. https://techterms.com/definition/exif

Excitation: Illumination of a document or another subject by a bright, full-spectrum light and blocking of the camera lens by filters in the 690 nm to 740 nm wavelength range.

Exclusion, in firearms examinations: Means two pieces of evidence definitely DO NOT come from the same weapon. (See Identification.)

Exhibit: An object or statement produced before a court of law and referred to while giving evidence.

Exhumation: The preplanned removal of human remains from a formal place of burial or interment. The action of digging up something buried, especially a corpse. https://www.dictionary.com/browse/exhumation

Existing light exposure: An exposure made using only the light available at the time and in the place of the scene or object.

Exitance: The total light coming off a surface; dependent upon the illuminance on and the reflectance of the surface.

Exposure value (EV): The EV system, which originated in Germany in the 1950s, was created to be a simple-to-use substitute for the shutter speed/aperture combination, using a single number instead of two. Abbreviated EV (always with a plus or minus number attached), it indicates the degree of exposure change with exposure compensation or backlight compensation—for example, +1.5 EV, –0.5 EV.

Extension tube, lens extension tube: Metal cylinder(s) placed between the camera body and the lens. Shortens the focusing distance. Designated according to the reproduction ratio they afford (image/subject ratio) (e.g., 1:3, 1:2, 1:1, 2:1).

Exoskeleton: A rigid external covering for the body in some invertebrate animals, especially arthropods,

providing both support and protection. https://dictionary.cambridge.org/us/dictionary/english/exoskeleton

Expanded tonal range: The tonal range is the range of tones between the lightest and darkest areas of an image. An image with a wide tonal range will have both very dark (black) and very light (white) elements within the photograph. https://photographyicon.com/tonalrange/

Expert: An expert is someone capable of assisting the trier of fact in a legal proceeding to understand the nature and meaning of specialized information that is outside the normal understanding of a layperson.

Expert witness: Someone who is "qualified" (in a specific case) as an expert by knowledge, skill, experience, training, or education and may testify in the form of an opinion or otherwise. Qualified; officially recognized as being trained to perform a particular job; certified. https://www.thesaurus.com/browse/qualified

Exposure: In photography, exposure is the total amount of light allowed to fall on the sensor (or film) during the process of taking a photograph. https://en.wikipedia.org/wiki/Exposure_(photography)

Exposure meter: An instrument (also known as a light meter) containing a light-sensitive cell used to measure the amount of light reflected from or falling on a subject. The measurement is usually expressed in shutter speed and aperture combinations that will render an acceptable exposure.

Exposure triangle: The exposure triangle is a common way of associating the three variables that determine the exposure of a photograph: aperture, shutter speed, and ISO. The function at the top of the exposure triangle represents the most important function, and the lower-left corner of the triangle is the secondary priority. The lower-right corner is the ISO and represents the function, which should be changed as a last resort. https://photographylife.com/what-is-exposure-triangle

Extension bellows: A bellows system works exactly the same way as extension tubes, but by a different design. The collapsible, light-proof bellows is mounted between the camera and the lens and allows the photographer to move the lens even farther from the camera than several extension tubes would. https://www.bhphotovideo.com/explora/photography/buying-guide/macro-photography-gear-bellows-reversal-rings-macro-couplers-and-focusing

Extinction: Loss of light from an object as a consequence of absorption or scattering by an intervening medium.

Extinction meter: Early type of exposure calculator requiring the use of the human eye for quantification.

Extravasation: The leakage of intravenously (IV) infused, and potentially damaging, medications into the extravascular tissue around the site of infusion. The leakage can occur through brittle veins in the elderly, through previous venipuncture access, or through direct leakage from wrongly positioned venous access devices. When the leakage is not of harmful consequence it is known as infiltration. Extravasation of medication during intravenous therapy is an adverse event related to therapy that, depending on the medication, amount of exposure, and location, can potentially cause serious injury and permanent harm, such as tissue necrosis. https://en.wikipedia.org/wiki/Extravasation_(intravenous)

F-stop: The f-number (focal ratio) expresses the diameter of the diaphragm aperture in terms of the effective focal length of the lens. For example, *f*/16 represents a diaphragm aperture diameter that is 1/16th the focal length (or the focal length is 16 times the aperture).

Fair and accurate representation: Free from favoritism or self-interest or bias or deception; or conforming to established standards or rules. The degree of conformity of an indicated value to an accepted standard value, or ideal value.

Federal Rules of Evidence: Evidence law governing the use of testimony (e.g., oral or written statements, such as an affidavit), exhibits (e.g., physical objects), documentary material, or demonstrative evidence, which is admissible (i.e., allowed to be considered by the trier of fact, such as jury) in a judicial or administrative proceeding. https://en.m.wikipedia.org/wiki/Evidence_(law)

Field of view: The width of the angle of an observer's unimpeded, possible visual field of view of a scene at any one moment. It can be the full field of possibility of a person's binocular vision from an unobstructed viewpoint, or it can be partially blocked, for example, by the A-pillar of a vehicle when the person is in the driver's seat. The full field of view of a person or a camera and lens is the maximum possible angle they can capture or see at any one time without moving laterally or vertically. https://whatis.techtarget.com/definition/field-of-view-FOV

Field training officer (FTO): An experienced or senior member of an organization who is responsible for the training and evaluation of a junior or probationary-level member. The role is used extensively in law enforcement, fire departments, and emergency medical services. https://en.wikipedia.org/wiki/Field_training_officer

Field training program: The Field Training and Evaluation Program (FTEP), also known as the Field Training Officer Program (FTOP or FTP), was first designed by the San Jose California Police Department. Over the years this program has evolved and changed as other departments adopted it. https://en.wikipedia.org/wiki/Field_training_program

File Transfer Protocol (FTP): A standard network protocol used for the transfer of computer files between a client and server on a computer network. FTP is built on a client–server model architecture using separate control and data connections between the client and the server.

Fill lighting: A form of supplementary light mainly used to lighten shadows in an image. https://www.cambridgeincolour.com/tutorials/portrait-fill-light.htm

Filters (neutral density): Neutral density filters (commonly referred to as ND filters) are filters placed in front of the lens to reduce the amount of light entering the camera. This allows the photographer to use a slow shutter speed to create motion blur and/or create a shallower depth of field. https://www.capturelandscapes.com/neutral-density-filters-will-improve-photography/

Filters (UV haze, skylight, and polarizing): A filter is a camera accessory consisting of an optical filter that can be inserted into the optical path and changes the properties of the light passing through. The filter can be of a square or oblong shape and mounted in a holder accessory, or, more commonly, a glass or plastic disk in a metal or plastic ring frame, which can be screwed into the front of or clipped onto the camera lens. https://en.wikipedia.org/wiki/Photographic_filter

Fingerprint: Physical evidence consisting of an impression made by the friction ridges of human skin, most commonly the fingers.

Fire: A chemical reaction of a fuel source (it may be gaseous, liquid, or solid) resulting in the release of heat, light, and products of combustion (smoke).

Fire control computer: A fire-control system is a number of components working together, usually a gun data computer, a director, and radar, designed to assist a weapon system in targeting, tracking and hitting its target. It performs the same task as a human gunner firing a weapon but attempts to do so faster and more accurately. https://en.wikipedia.org/wiki/Weapon_system

Firearms/toolmark identification: Objective measurements and a subjective comparison of microscopic marks of value.

Flash diffuser: A lens attached to the front of the flash, over the flash tube, to both diffuse the light and increase the angle of coverage. These attachments normally decrease the power of the emanated light output, so the chart on the flash or the auto-flash function of the flash will not properly work, leading to underexposure. The only system where the image will avoid underexposure is where the flash and camera communicate through a TTL metering system.

Flat field: Will produce images very sharp from corner to corner of whatever subject is being documented.

Flat lighting: A term that describes subject matter lit from one direction only, typically from the front.

Flatbed scanning: Making a copy of text or images with a flatbed scanner.

Focal length: The distance between the film plane and the optical center of the lens when the lens is focused at infinity. The focal length of the lens is marked in millimeters on the lens mount. The principal focal point is the position of best focus for infinity.

Focal length multiplier: The ratio of the dimensions of a camera's imaging area compared to a reference format; most often, this term is applied to digital cameras relative to 35mm film format as a reference size. (See: Crop factor.) https://en.wikipedia.org/wiki/Crop_factor

Focus (manual/automatic/phase detection/contrast detection): In photography, it's practically married to sharpness. An image that is completely sharp is said to be in focus. An image that's completely blurry is said to be unfocused. In order for a camera to create a focused image, it takes light and runs it through a lens, concentrating the rays on the image sensor inside. www.digital-photo-secrets.com/tip/2210/understanding-focus/

Focusing rail: Magnification may be set at the desired ratio and the whole camera unit focused by moving closer and farther from the subject via the rail.

Foot candle: The total intensity of light falling upon a 1-square-foot surface placed 1 foot away from a point source of light equals 1 candle power.

Foot-lambert (fL): The luma (brightness) resulting from a surface emitting a luma flux of 1 lumen per square foot. The luma of a perfectly reflecting surface receiving an illumination of 1 foot-candle.

Footprint/footwear impression: Footwear evidence is often the most abundant form of evidence at a crime scene and in some cases can prove to be as specific as a fingerprint. Initially investigators will look to identify the make and model of the shoe that made an impression. https://en.wikipedia.org/wiki/Forensic_footwear_evidence

Forensic: Relating to the use of science or technology in the investigation and establishment of facts or evidence in a court of law. www.emaglink.com/terms.htm

Forensic age progression: Age progressions of adults are done in cases of endangered missing adults as well as fugitives, all in the hopes of generating renewed public interest and fresh leads for investigators. https://www.askaforensicartist.com/age-progression

Forensic anthropology: The application of the anatomical science of anthropology and its various subfields, including forensic archaeology and forensic taphonomy, in a legal setting. A forensic anthropologist can assist in the identification of deceased individuals whose remains are decomposed, burned, mutilated, or otherwise unrecognizable, as might happen in a plane crash. Forensic anthropologists

are also instrumental to the investigation and documentation of genocide and mass graves. Along with forensic pathologists, forensic dentists, and homicide investigators, forensic anthropologists commonly testify in court as expert witnesses. Using physical markers present on a skeleton, a forensic anthropologist can potentially determine a victim's age, sex, stature, and ancestry. In addition to identifying physical characteristics of the individual, forensic anthropologists can use skeletal abnormalities to potentially determine cause of death, past trauma such as broken bones or medical procedures, and diseases such as bone cancer. https://en.wikipedia.org/wiki/Forensic_anthropology

Forensic archaeology: The application of archaeological methods and theories in a criminal framework; integrating those methods and theories with those of forensic science and criminalistics.

Forensic art: A forensic artist, also commonly referred to as a sketch artist, is a graphic artist that renders free-hand or computerized drawings, enhancements, and reconstructions. Forensic art is defined as an artistic technique used for identification, apprehension, or conviction purposes. Forensic art is divided into four subcategories: composite imagery, image modification and image identification, demonstrative evidence, and reconstruction and postmortem identification aids. https://www.crimesceneinvestigatoredu.org/forensic-artist/

Forensic entomology (FE): Forensic entomology is the use of the insects, and their arthropod relatives that inhabit decomposing remains, to aid legal investigations. The broad field of forensic entomology is commonly broken down into three general areas: medicolegal, urban, and stored product pests. https://www.forensic-entomology.com/definition/

Forensic facial analysis: Facial recognition has played an essential role in digital forensics due to the widespread use of digital technology such as CCTV, mobile phones, and digital video. https://www.sciencedirect.com/science/article/pii/S1742287618301841

Forensic facial reconstruction: Forensic facial reconstruction (or forensic facial approximation) is the process of re-creating the face of an individual (whose identity is often not known) from their skeletal remains through an amalgamation of artistry, anthropology, osteology, and anatomy. https://en.wikipedia.org/wiki/Forensic_facial_reconstruction

Forensic medicine: Focuses on the interface between medicine and the law. The application of medical knowledge to the investigation of crime, particularly in establishing the causes of injury or death. https://www.merriam-webster.com/medical/forensic%20medicine

Forensic odontology: Encompasses human identification, age assessment, bite-mark evaluation, human abuse, civil/malpractice cases, etc.

Forensic photography: Forensic photography, also referred to as crime scene photography, is an activity that records the initial appearance of the crime scene and physical evidence in order to provide a permanent record for the courts. It is the basic tenet of why crime scenes should be investigated. https://en.wikipedia.org/wiki/Forensic_photography

Fovea: A small depression in the retina of the eye where visual acuity is highest. The center of the field of vision is focused in this region, where retinal cones are particularly concentrated. https://www.merriam-webster.com/dictionary/fovea

Fractography: Descriptive treatment of fracture, especially in metals, with specific reference to photographs of the fracture surface. Macro-fractography involves photographs at low magnification (<25×); micro-fractography involves photographs at high magnification (>25×). www.corrosionsource.com/handbook/glossary/f_glos.htm

Fracture surface: A fracture is the separation of an object or material into two or more pieces under the action of stress. The fracture of a solid usually occurs due to the development of certain displacement discontinuity surfaces within the solid. https://en.wikipedia.org/wiki/Fracture

Frankfort horizontal plane: Because animals can change orientation with respect to their environment, and because appendages (arms, legs, tentacles, etc.) can change position with respect to the main body, it is important that anatomical terms of location refer to the organism when it is in its standard anatomical position. https://en.wikipedia.org/wiki/Standard_anatomical_position

Frequency: The rate at which something occurs or is repeated over a particular period of time or in a given sample. https://www.merriam-webster.com/dictionary/frequency

Frequency range: The radio spectrum refers to the section of the electromagnetic spectrum that holds all possible radio frequencies ranging from 3 kHz to 300 GHz. Radio frequency is used for radio communication technology, wireless networks, and telecommunication systems. https://www.amphenolrf.com/frequency-range-chart/

Full-frame sensor: A full-frame camera uses a sensor that's the same size as a single frame of traditional 35mm film, measuring 36 × 24 mm. The more popular APS-C sensor size found in most DSLRs and mirrorless cameras measuring 22 × 15 mm. This means a full-frame sensor has more than 2.5 times the surface area of an APS-C sensor. https://en.wikipedia.org/wiki/Full-frame_digital_SLR

Galvanometer: An instrument that measures small electrical currents by means of deflecting magnetic coils.

General rifling characteristics (GRCs): Measurements for an evidence bullet, including caliber or bore diameter, rifling twist direction, and land and groove number and dimensions, are entered in a database, which then returns a list of all firearms in the database with comparable GRCs.

Ghosting: Evidence of visible movement or blurring within a still image.

Gimbals: Rely upon brushless motors to precisely counteract a UAV's yaw, pitch, and roll. Gimbal-equipped cameras eliminate vibration and motion so high-quality still images and video are achieved during flight. https://www.bhphotovideo.com/c/buy/brushless-gimbal-stabilizers/ci/28767/N/3717223530

Global or local (e.g., dodging or burning): Changes to a digital image may be global, meaning they affect the whole image, like changing contrast. Or the changes can be local, where they are like burning and/or dodging.

Go-kit: Specialized knowledge and equipment are the tools of any go team. As may be expected, the equipment cache is usually referred to as the "go-kit," whether a small belt-pouch, a contractor-size toolbox, a wheeled case, a large aircraft-style cargo pallet, or even an entire truck full of equipment. See Chapter 4 for more information.

Golden ratio: A ratio between two numbers that equals approximately 1.618, also called ITAL Phi /ITAL. In art, the proportions of the face are aesthetically pleasing because the ratio between the height and width are equal to 1.618.

Google Earth Engine: Combines a multi-petabyte catalog of satellite imagery and geospatial datasets with planetary-scale analysis capabilities and makes it available for scientists, researchers, and developers to detect changes, map trends, and quantify differences on the Earth's surface. https://earthengine.google.com/

Google Earth Maps: Find locations with Earth View, Street Views, and Satellite Maps. Go can also get driving directions and street maps. www.mapstrek.com/EarthMaps/StreetView

Google Earth Pro: Includes tools to measure distances and areas, often helpful for forensic analysis. https://www.google.com/earth/

Google, records custodian: If you issue a subpoena to authenticate the imagery in question, you will receive a certificate of authenticity from the Google custodian of records that is foundationally sufficient to admit the imagery as an official record and as an exception to the hearsay rule.

Go team: Emergency response team, special response team, special operations group, multidisciplinary investigation team, the ubiquitous Special Weapons and Tactics (SWAT) team, or anything else, this unit represents a focused approach to problem-solving and situational response.

GPS (Global Positioning System): A global public service brought to the public by the U.S. government used to locate the global position from which an image was captured with a cellular camera. The accuracy commitments do not apply to GPS devices, but rather to the signals transmitted in/from space. For example, the government commits to broadcasting the GPS signal in space with a global average user range error (URE) of ≤7.8 m (25.6 ft.), with 95% probability. Actual performance exceeds the specification. On May 11, 2016, the global average URE was ≤0.715 m (2.3 ft.) 95% of the time. GPS is operated and maintained by the U.S. Air Force. GPS.gov is maintained by the National Coordination Office for Space-Based Positioning, Navigation, and Timing.

Grayscale: In digital photography, computer-generated imagery, and colorimetry, a grayscale image is one in which the value of each pixel is a single sample representing only an amount of light, that is, it carries only intensity information. Grayscale images, a kind of black-and-white or gray monochrome, are composed exclusively of shades of gray. The contrast ranges from black at the weakest intensity to white at the strongest. https://en.wikipedia.org/wiki/Grayscale

Ground control points (GCPs): Marked points on the ground that have a known geographic location. In aerial surveying, a drone can be used to autonomously collect photos of the survey area. If used, GCPs must be visible in these aerial photos. The photos are then processed in the cloud using drone mapping software. For aerial survey applications GCPs, are typically required, as they can enhance the positioning and accuracy of the mapping outputs. To do this correctly, the GCPs and desired mapping outputs must use the same ESPG code. https://www.groundcontrolpoints.com/

Halation: Blurred effect at the edges of a highlighted area of a photograph caused by reflection of light that passed through the film. The light is reflected from either the surface of the film or the camera back.

Hazard zone: A hazard zone is one of the four levels of hazards (Hazard Zones A through D) assigned to gases and liquids that are poisonous when inhaled. A hazard zone is based on the LC50 value for acute inhalation and toxicity of gases and vapors. Hazardous materials assigned a hazard zone are nonmailable. Hazard class means the nature of the physical, health, or environmental hazard (e.g., flammable solid carcinogen, oral acute toxicity).

Hazmat: Any substance that is explosive, flammable, poisonous, corrosive, irritating, or otherwise harmful and is likely to cause injury or death. Hazmat is short for the words "hazardous materials."

Hazmat-related signs usually pertain to truck and train restrictions through tunnels or a heavily populated area where a hazmat-related accident or spill would be detrimental to the immediate surroundings. Shields are in place now for hazmat preferred routes and banned routes. The signage is a white square with the letters HC in a green circle. www.aaroads.com/glossary.html

HDR photography: High-dynamic-range imaging (HDRI) is a high-dynamic range (HDR) technique used in imaging and photography to reproduce a greater dynamic range of luminosity than is possible with standard digital imaging or photographic techniques. https://en.wikipedia.org/wiki/High-dynamic-range_imaging

Hiding in plain sight: Operative needs to blend into the background/be unnoticeable by staying visible in a setting that masks his or her presence. https://www.yourdictionary.com/hide-in-plain-sight

High-speed imaging: High-speed photography is the science of taking pictures of very fast phenomena and making it possible to analyze events that occur in an instant by exposing a great many images very quickly. https://www.techimaging.com/applications/high-speed-imaging

Histogram: Graph of the dynamic range of the photograph. A histogram is a display of statistical information that uses rectangles to show the frequency of data items in successive numerical intervals of equal size. Some histograms are presented with the independent variable along the vertical axis and the dependent variable along the horizontal axis. https://searchsoftwarequality.techtarget.com/definition/histogram

Histogram alterations: There are multiple types of histograms—it will depend upon what you are trying to accomplish to determine which histogram you need to use. Typically, the default will be either the RGB (red, green, blue) or CMYK (cyan, magenta, yellow, black). https://www.picturecorrect.com/tips/how-to-edit-photos-using-the-histograms-in-photoshop/

Historic operational photographs: Photographs documenting the historic timeline of events of any particular aspect of the project. https://www.energy.gov/management/office…/operational…/history/historical-resource.

Homicide: The killing of another human being by one or more others. In contrast, suicide is the self-killing of a human being. The deliberate and unlawful killing of one person by another is murder. https://criminal.findlaw.com/criminal-charges/homicide-definition.html

Horizontal field of view/horizontal: Horizontal is an orientation relating to, or in parallel with the horizon, and the opposite of vertical. A horizontal line goes from left to right (or vice versa), whereas a vertical line goes from top to bottom. https://en.wikipedia.org/wiki/Horizontal

Horizontal shift: The easiest way to determine horizontal shift is to determine by how many units the "starting point" (0,0) of a standard sine curve, $y = \sin(x)$, has moved to the right or left, and vertical shift is computed the same way.

Hospital patient wristband: The bracelet the hospital puts on the wrist of every patient being examined or admitted for care in the facility—used 100% for identification and tracking.

Hughes Aircraft: First started by Howard Hughes. His company at the beginning of World War II had only 4 full-time employees, but by the end had 80,000. American physicist Richard Feynman, best known for his work in quantum mechanics and particle physics, was part of the Manhattan Project and helped in the development of the atomic bomb. He was also one of the people who participated in the development of Hughes Aircraft.

Hyperfocal distance: Assuming a permissible circle of confusion, the distance from the lens of the nearest object that is in focus when the lens is focused on infinity. If a lens is focused on the hyperfocal distance, then all points are within the range covered by the DoF, from infinity down to half the hyperfocal distance. The hyperfocal distance depends upon the lens focal length and aperture.

Hyperfocal focus: The hyperfocal distance of a lens is the distance from the camera lens to an optimal point of focus that maximizes the depth of field in the image. By focusing on this optimal point—the hyperfocal point—as much of the scene as is possible for that lens and aperture setting will be in acceptable focus from near to far. https://photography.tutsplus.com/…/focal-length-and-hyper-focal-distances–cms-27007

Hertz (Hz): A unit of time for measuring the frequency of electromagnetic waves. The range of frequencies is divided into separate bands, and the electromagnetic waves within each frequency band are called by different names that frequency range includes wavelengths from greater than 103 kilometers to less than the size of atoms.

Identification, in firearms: When two pieces of evidence, such as bullets or casings, come from the same weapon. (See Nonidentification.)

Identification, in toolmarks: Signifies a match between two toolmarks or a match between a tool and evidence bearing toolmarks. (See Nonidentification.)

Illuminance: The density of luminous flux incident upon a surface. Measured in foot-candles (lumens/square foot) or lux (lumens/square meter); 1 foot-candle equals 10.76 lux.

Image: A visual representation of something, such as ISO speed, shutter speed, aperture, white balance, camera model and make, date and time, lens type, focal

length, and much more. https://www.merriam-webster.com/dictionary/image

Image contrast: The difference in luminance or color that makes an object(s) (or representation in an image or display) distinguishable. https://en.wikipedia.org/wiki/Contrast_(vision)

Image resolution: Image resolution is the level of detail an image holds. The term applies to raster digital images, film images, and other types of images. Higher resolution means more image detail. Image resolution can be measured in various ways. Photographic lens and film resolution are most often quoted in line pairs per millimeter. https://en.wikipedia.org/wiki/Image_resolution

Image review: This can sometimes be difficult, especially on bright sunny days. The camera monitor can become almost unreadable, and you cannot determine if you have a proper exposure.

Image sensor: An image sensor is an electronic device that converts an optical image into an electronic signal. It is used in digital cameras and imaging devices to convert the light received on the camera or imaging device lens into a digital image. https://www.techopedia.com/definition/30413/image-sensor

Image set: Often referred to as SIFT (scale invariant feature matching), this implementation revolutionized photogrammetry for its ability to automatically find features in an image and then subsequently find matching images.

Image stabilizer/stabilization (IS): Assists in minimizing the effects of any shake or movement of the camera. A feature used in some digital cameras to reduce blurring of images due to vibration while taking pictures.

Imaging chain: The process by which an image is formed, processed, and displayed can be conceptualized as a chain of physical events called the imaging chain. By mathematically modeling the imaging chain, we can gain insight into the relationship between the camera design parameters and the resulting image quality. www.gbv.de/dms/ilmenau/toc/636650820.PDF

Immersive: A story or visual presentation that enables the player to convincingly enter and participate in a virtual world. www.igda.org/writing/WritersGlossary.htm

Impression and pattern evidence: Impression toolmarks occur when the tool comes into perpendicular contact with an object. Striated toolmarks occur when the tool is moved across or through an item with enough force to produce scratch-type markings.

Incident light: The light actually falling on a subject, which may not be the same as the amount of light being reflected by the subject.

Incident simulation: A re-creation of an event using exemplar vehicles or other machines or structures as identical as the subject ones as possible. Some people use the term re-creation when they should say simulation.

Inclinometer: A device for measuring the angle of inclination of something, especially from the horizontal. An instrument used for measuring angles of slope (or tilt), elevation, or depression of an object with respect to gravity's direction. https://www.merriam-webster.com/dictionary/inclinometer

Individuation: The process by which an individual or a piece of evidence becomes distinct and different from everything else. The word individual is a good clue to the meaning of individuation, which is how a being or thing becomes an independent, separate entity. https://www.vocabulary.com/dictionary/individuation

Inductive reasoning: A process where a premise based on a sample leads to a prediction or conclusion about a population. https://en.wikipedia.org/wiki/Inductive_reasoning

Infer: To infer is to take the results from a small sample and generalize them to be representative of a larger population. www.ablongman.com/html/abrami/glossary/glossary.html

Infinity: (1) Time or space that has no end. (2) A place that is so far away that it cannot be reached. (3) A number that is larger than all other numbers. https://dictionary.cambridge.org/us/dictionary/english/infinity

Infrared imaging: Thermal imaging is a method of improving the visibility of objects in a dark environment by detecting the objects' infrared radiation and creating an image based on that information. Thermal imaging, near-infrared illumination, and low-light imaging are the three most commonly used night vision technologies. (See Alternative lighting.) https://whatis.techtarget.com/definition/thermal-imaging

Infrared (IR) luminescence: An IR examination in which a document is illuminated with a narrow band of colored light, and various higher wavelength filters are placed in front of the device's camera lens.

Insecta taxa: A taxonomic category, as a species or genus. https://www.dictionary.com/browse/taxa

Insects/Insecta: Insects or Insecta are hexapod invertebrates and the largest group within the arthropod phylum. Definitions and circumscriptions vary; usually, insects comprise a class within the phylum Arthropoda. As used here, the term Insecta is synonymous with Ectognatha.

Intense coherent monochromatic light: A device that generates an intense beam of coherent monochromatic light (or other electromagnetic radiation) by stimulated emission of photons from excited atoms or molecules is a laser. https://en.oxforddictionaries.com/definition/laser

Intensity: The relative purity or saturation of a hue (color) on a scale from bright (pure) to dull (mixed with another hue or a neutral. Also called chroma. www.ackland.org/tours/classes/glossary.html

Interferences: The combination of two or more electromagnetic waveforms to form a resultant wave in which the displacement is either reinforced or canceled. https://www.merriam-webster.com/dictionary/interference

Interferometry: The most accurate and most useful technique for measuring changes in distance rather than absolute distances. Systems can measure absolute distances of up to 300 mm with an uncertainty of one micro-meter (1×10^{-6} meter) within a time frame of 40 seconds. The system uses a Michelson interferometer (a beam splitter), a tunable laser, a wavelength meter, and a computer for performing its analysis.

International Association of Identification: The International Association for Identification (IAI) is the largest forensic organization in the world. It was originally formed as the International Association for Criminal Identification in October 1915. Through the years it has grown into an educational and certification body with over 6,000 members worldwide. https://en.wikipedia.org/wiki/International_Association_for_Identification

International System of Units (SI): A system of physical units (SI units) based on the meter, kilogram, second, ampere, Kelvin, candela, and mole, together with a set of prefixes to indicate multiplication or division by a power of ten. https://en.wikipedia.org/wiki/International_System_of_Units

Interpersonal violence (IPV): The intentional use of physical force or power, threatened or actual, against a person or group that results in or has a high likelihood of resulting in injury, death, psychological harm, maldevelopment, or deprivation. https://ipv.appstate.edu/definitions-of-interpersonal-violence

Interpolation: In the mathematical field of numerical analysis, interpolation is a method of constructing new data points within the range of a discrete set of known data points. It is often required to interpolate (i.e., estimate) the value of that function for an intermediate value of the independent variable. https://en.wikipedia.org/wiki/Interpolation

Intrusion angles: Beginning with one of the original straight lines of a vehicle, the angle of intrusion, or the impact angle, can be calculated by using a protractor of sufficient size to measure the angle from which the vehicle was impacted by another vehicle or structure.

Inverse square law: When using a light source such as a flash or flashlight and you obtain a proper exposure using that light at a given distance, if you double the distance you will need four times as much light for the same exposure.

Investigation: A systematic, minute, and thorough attempt to ascertain the facts about something complex or hidden. It is often formal and official. www.fsmpublicauditor.fm/hotline/glossary.htm

Investigator: Takes in a case, gathers information, creates a plan, conducts research, gathers evidence, and writes a report based on the facts discovered.

ISO/ISO rules: International Organization for Standardization. The ISO works with standards institutes from over 150 countries to develop technology and product standards. These standards lead to a more efficient, safer, and cleaner development of products. In photography, the standards relate to the specific sensitivity of media with respect to differing levels of light. https://techterms.com/definition/iso

JPG (Joint Photographic Experts Group): An ISO/IEC group of experts that develops and maintains standards for a suite of compression algorithms for computer image files. JPEG is a popular image file format. It is commonly used by digital cameras to store photos since it supports 224 or 16,777,216 colors. Still, the compression algorithm is lossy, meaning some image quality is lost during the compression process.

Junk science: Untested or unproven theories when presented as scientific fact, especially in a court of law. https://en.wikipedia.org/wiki/Junk_science

Land and groove impressions: The negative impressions left on a fired bullet by the grooves in a rifled barrel.

Laser: A laser is a device emitting light through a process of optical amplification based on the stimulated emission of electromagnetic radiation. Lasers are narrow beams of light where the light waves have similar wavelengths. The term laser originated as an acronym for light amplification by stimulated emission of radiation. The first laser was built in 1960.

Laser range finding: A laser rangefinder uses a laser beam to determine the distance to an object. The most common form of laser rangefinder operates on the time of flight principle by sending a laser pulse in a narrow beam towards the object and measuring the time taken by the pulse to be reflected off the target and returned to the sender. Due to the high speed of light, this technique is not appropriate for high precision sub-millimeter measurements, where triangulation and other techniques are often used. A long-range laser rangefinder is capable of measuring distances up to 20 km. The resulting system also provides azimuth and elevation measurements.

Laser scanning: In modern surveying, the general meaning of laser scanning is the controlled deflection of laser beams, visible or invisible. (Marshall, Gerald F., *Handbook of Optical and Laser Scanning*, Boca Raton, Marcel Dekker, 2004.)

Latent print: Any chance or accidental impression left by friction ridge skin on a surface that is generally invisible at the time of deposition and must be processed in some manner to be seen.

LCD display/LCD projector: An electronic video projector for displaying video and computer images on a large projection screen. www.tvsaudiovisual.com/glossary.htm

Leading: In firearms, leading refers to the buildup of elemental lead (Pb) in the barrel or cylinder of a weapon. In trajectory studies, the dark circle around a bullet hole.

Leica CloudWorx CAD plugins: Allow users to work with the resultant large point clouds directly inside their chosen CAD system. CloudWorx adds simple tools for viewing and working with slices of point cloud data.

Lens aberration: In optics, aberration is a property of optical systems such as lenses that causes light to be spread out over some region of space rather than focused to a point. Aberrations cause the image formed by a lens to be blurred or distorted, with the nature of the distortion depending on the type of aberration. The failure of rays to converge at one focus because of limitations or defects in a lens or mirror; refraction of light by a convex lens. The rays passing through different parts of the lens are brought to a focus at slightly different distances (*spherical aberration*); at the same time, the colored rays are separated by the prismatic action of the lens and likewise brought to a focus at different distances (*chromatic aberration*). https://www.dictionary.com/browse/aberration https://en.wikipedia.org/wiki/Optical_aberration

Lens hood: In photography, a lens hood or lens shade is a device used on the front end of a lens to block the sun or other light source(s) to prevent glare and lens flare. https://en.wikipedia.org/wiki/Lens_hood

Lens profile: Adobe Photoshop, Lightroom, and Camera raw plugins include numerous lens profiles, which you can use to correct common lens aberrations such as barrel and pincushion geometric distortion. Most lens profiles also correct for vignettes, where the corners of an image appear darker than the rest of an image. https://helpx.adobe.com/x-productkb/multi/lens-profile-support.html

LiDAR: A surveying method for measuring distance to a target by illuminating targets with pulsed laser light and measuring the reflected light pulses coming back to the scanner. A detection system that works on the principle of radar but uses light from a laser. https://en.wikipedia.org/wiki/Lidar

LiDAR sensor: Leica Geosystems LiDAR sensors are used for architecture, engineering and construction (AEC) and any other conceivable use people want to attempt with it. Airborne topographic LiDAR sensors are used for area mapping of large regions or small landforms.

Life size: The actual size of a piece of material, as opposed to its size in a representation.

Light: The portion of the electromagnetic spectrum producing stimulation of the optic nerves and images of everything humans can see. Visible light wavelengths range from 380 to 720 nanometers.

Lighting: The devices or techniques used for illumination, usually referring to artificial light sources, such as lamps or flashlights. Creates a real-world environment by allowing the rendering of different grades of darkness and brightness of an object's appearance to make the object look solid.

Light intensity: In photometry, luminous intensity is a measure of the wavelength-weighted power emitted by a light source in a particular direction per unit solid angle, based on the luminosity function, a standardized model of the sensitivity of the human eye. The SI unit of luminous intensity is the candela (cd), an SI base unit. https://en.wikipedia.org/wiki/Luminous_intensity

Light meter/light measurement: An instrument used to measure the amount of light reflected from or falling on a subject. The measurement is usually expressed in shutter speed and aperture combinations, which will render an acceptable exposure. Also known as an exposure meter. photography-tips.com/page.cfm/2038

Line-of-sight: An imaginary straight line along which an observer looks. wordnet.princeton.edu/perl/webwn

Line pairs: A line pair in image processing is this: on a test pattern consisting of closely spaced black parallel lines on a white background, a line pair is two black lines together with the white space on either side and in between. The lines get closer and closer together and finer and finer. The closest together they can get and still show as two lines is the highest resolution of the camera and lens. https://en.wikipedia.org/wiki/Line_pair

Linearity: Linearity is the behavior of a circuit, particularly an amplifier, in which the output signal strength varies in direct proportion to the input signal strength. Both amplifiers are linear within the input-signal strength range shown, because both lines in the graph are straight. https://whatis.techtarget.com/definition/linearity

Lithograph: Prints taken from a drawing done from a polished limestone or zinc or aluminum plates. The drawing is done with greasy crayons, pens, or pencils. A solution containing gum arabic and dilute nitric acid is washed on the stone (or plate). This solution fixes the design in place. The entire plate surface is washed with water and then inked. Print paper is applied and sent through a press, transferring the image of the stone (or plate) to the paper. www.ahpcs.org/Library/diction-ta.htm

Locard's exchange principle: States that with contact between two items, there will be an exchange.

Lumen: The quantity of luminous flux emitted within a unit solid angle (1 steradian) by a point source with 1 candela intensity in all directions.

Luminance: The specific light that comes off the surface, whether off a filament, lightbulb, lens, louver, tabletop, etc. Varies with both the direction at which the surface is viewed and its gloss characteristics; measured in candela per square foot.

Luminol: A chemical used by forensic investigators to detect residual blood.

Luminosity function: A standard function established by the Commission Internationale de l'Éclairage (CIE) to account for the variable sensitivity of the human eye to radiation at different wavelengths; converts radiant energy into luminous (visible) energy.

Luminous emittance: It is a measure of how much the incident light illuminates the surface wavelength-weighted by the luminosity function to correlate with human brightness perception. Similarly, luminous emittance is the luminous flux per unit area emitted from a surface. https://en.wikipedia.org/wiki/Illuminance

Luminous exitance: The ability of a surface to emit light expressed as the luminous flux per unit area at a specified point on the surface. https://www.collinsdictionary.com/us/dictionary/english/luminous-exitance

Luminous flux: The flux of visible radiation so weighted as to account for the manner in which the response of the human eye varies with the wavelength of radiation. Basic unit of measurement is the lumen (lm).

Luminous intensity: The intensity (flux per unit solid angle) of visible radiation weighted to take into account the variable response of the human eye as a function of the wavelength of light. Usually expressed in candles. In photometry, luminous intensity is a measure of the wavelength-weighted power emitted by a light source in a particular direction per unit solid angle, based on the luminosity function, a standardized model of the sensitivity of the human eye. https://en.wikipedia.org/wiki/Luminous_intensity

Lux: The metric measure for light level; 1 lux equals the total intensity of light falling on a 1-square-meter surface that is placed 1 meter away from a point source of light that equals 1 candle power.

Macro: The ability of a lens to focus just inches away from an object or subject so as to produce big close-ups, sometimes even larger-than-life size. www.dpcorner.com/all_about/terms.shtml

Maggot masses: Areas of maggot colonization.

Maggot motel: A maggot motel is nothing more than a manmade environment in which the immature insects will be content to continue their development into adult insects after collection at a scene while awaiting forensic examination. See Chapter 30 for more information.

Maggot school: A maggot is the larva of a fly (order Diptera); it is applied in particular to the larvae of Brachycera flies, such as houseflies, cheese flies, and blowflies. Qualified instructors hold classes where people learn a plethora of information about maggots. https://en.wikipedia.org/wiki/Maggot

Magnification: The relationship of subject size to its image size on the sensor.

Manhattan Project: The unofficial designation for the U.S. War Department's secret program, organized in 1942, to explore the isolation of radioactive isotopes and the production of an atomic bomb. The initial research was conducted at Columbia University in Manhattan. https://www.dictionary.com/browse/manhattan-project

Manipulate: To change the form or picture of a part of a negative. library.thinkquest.org/6275/Glossary.html

Manual focus: Adjustment of the focus of a lens by hand. https://en.wikipedia.org/wiki/Manual_focus

MASER: An acronym for microwave amplification by stimulated emission of radiation. Forerunner of the laser.

Matrix metering: When a digital camera has to set the exposure automatically (the aperture and shutter speed), it often uses matrix metering. A set of areas, or spots, in the picture that the camera looks at and averages to decide on aperture and shutter speed settings—the exposure settings. Sometimes this is "center weighted," meaning that most of the spots are in the center of the frame, and sometimes it is bottom weighted.

Mechanic's rule: Basically, a ruler for including in the field of macrophotographs as an indication of size of the subject. These scales are normally very accurate and have been pre-certified for accuracy at the factory of their manufacture.

Media: Materials such as VHS, DVDs, films, audiotapes, and CDs, requiring special equipment to be used. www.library.appstate.edu/tutorial/glossary/glossary.html

Megapixel (MP): One million pixels. (See Pixel.)

Memory: Any physical device capable of storing information temporarily like RAM (random access memory) or permanently like ROM (read-only memory). Memory devices utilize integrated circuits and are used by operating systems, software, and hardware. https://www.computerhope.com/jargon/m/memory.htm

Mensuration: The branch of geometry that deals with the measurement of length, area, or volume. https://www.dictionary.com/browse/mensuration

Meshed models: Perhaps the main advantage of the meshed model in 3-D model building is it can approximate the surface geometry of the subject rather well by

using a lattice of "patches" or polygons connected to vertices. Meshing can be imagined as draping a thin sheet over a dense set of points, where the sheet conforms to the shape of the scanned object rather well. (See Adaptive meshing.)

Mesopic vision: Occurs in intermediate lighting (luminance level 10^{-2} to 1 cd/m^2) and is a combination of scotopic and photopic vision.

Metadata: A set of data that describes and gives information about other data. https://en.wikipedia.org/wiki/Metadata

Metering: Metering works in conjunction with the exposure systems of digital cameras. It measures the amount of light and works out for the photographer the optimum exposure for the image. Some cameras have auto-metering, whereas others offer a metering mode option. A few different metering modes are center-weighted average metering (probably the most common), spot (partial) metering, and matrix or evaluative metering.

Michelson interferometer: A beam splitter where light from a light source is split into two parts. One part of the light travels a different path length than the other. www.physics.iitm.ac.in/~ph5060/manuals/Michelson.pdf

Micro-contrast: Micro-contrast is the ability of the lens to communicate the richness and vibrancy of the intertonal shifts between the brighter to darker part of a very same color onto the sensor. A lens with great micro-contrast has much richer colors and tone transitions compared to a weaker one. www.dslrbodies.com/lenses/lens-articles/what-is-micro-contrast.html

Microphotograph: Photographs made using a microscope to capture magnifications much larger than real life.

Microscopic magnification: Magnification is "a measure of the ability of a lens or other optical instrument to magnify, expressed as the ratio of the size of the image to that of the object." Microscopic magnification is determined by the power of the optics of the instrument. Microphotographs normally exist in between the powers of 25× and 1000×. The maximum magnification of an objective is about 100× and of an eyepiece is about 10×, giving total maximum magnification of a light microscope to be 10 × 100 = 1000×. The wavelengths of visible light ranges from 350nm to 700nm and is the theoretical limit for the power of a light microscope, if optics could be made to perform in such a way. It is truly not necessary to try, because the electron microscope routinely supersedes the wavelength of visible light.

Microscopic signatures: Created by a firearm during discharge, a forensic firearms examiner is charged with the task of comparing submitted bullets and ammunition components to each other, as well as to any number of firearms. The examiner will test-fire an incoming weapon into a water tank or cotton batting to produce known fired specimen bullets and cartridge cases for use in comparison with questioned (evidence) ammunition components.

Microwaves: Short-wavelength radio waves, called microwaves, could make a cluster of atoms vibrate in interesting ways, leading to the invention of the laser.

Migration: Seasonal or developmental movement of animals from one region to another. https://en.oxforddictionaries.com/definition/migration

Military camouflage (multispectral camouflage): Traditional military camouflage attempts to hide an object in the visible spectrum. Multispectral camouflage also tries to simultaneously hide objects from detection methods such as infrared, radar, and millimeter-wave radar imaging. https://en.wikipedia.org/wiki/Multi-spectral_camouflage

Minilab: A computer printer that uses traditional chemical photographic processes to make prints of digital images. Photographs are input to the digital minilab using a built-in image scanner, a kiosk that accepts CD-ROMs or memory cards from a digital camera, or a website that accepts uploads. The operator can make minor corrections, such as brightness or color saturation.

Mirror lock-up: Often abbreviated MLU, this is a feature employed in many single-lens reflex (SLR) cameras. It allows the operator to reduce vibration-induced motion blur during exposure. It also allows the mounting of lenses which extend into the SLR's mirror box when mounted. https://en.wikipedia.org/wiki/Mirror_lock-up

Mirrorless photography: Mirrorless cameras (also known as CSCs or compact system cameras) allow you to change lenses, but as the name might suggest, they don't feature a complex internal mirror system like DSLRs do. https://www.techradar.com/news/mirrorless-vs-dslr-cameras

Modeling light: Modeling light allows you to preview the effect of the flash. https://www.adorama.com

Monochrome: A single color; usually refers to a black-and-white image; also referred to as line art or bitmap mode (Adobe Photoshop).

Monocular: Refers to only one eye. www.eyecaretyler.com/knowmore.htm

Morphological analyses: Morphological analysis is the analysis of morphology in various fields. Morphological analysis (problem-solving) or general morphological analysis, a method for exploring all possible solutions to a multidimensional, nonquantified problems. Also, the comparison of the characteristic features and the anatomical structure of the face and to identify the differences and similarities. https://en.wikipedia.org/wiki/Morphological_analysis

Mortuary head block: Six curvatures from hyperbolic to parabolic to elevated are available. The products give a range of control over heads of different sizes and heads at different elevations. Lightweight and durable. Chemically resistant and strong for repeated use. https://www.lynchsupply.com/HEAD_BLOCK_MULTI_POSITION_PLASTIC_p/hbl910216.htm

Motion detector: A device for detecting moving objects, particularly people.

Multiple frequency phase-shift: Measures the phase shift of multiple frequencies on reflection from a surface, then solves simultaneous equations to give a final distance measurement.

Municipal codes/building codes: A building code (also building control or building regulation) is a set of rules specifying the standards for constructed objects such as buildings and nonbuilding structures. Buildings must conform to the code to obtain planning permission, usually from a local council.

Muscles of expression: The muscles of facial expression are located in the subcutaneous tissue, originating from bone or fascia, and inserting onto the skin. https://teachmeanatomy.info/head/muscles/facial-expression/

Muscles of mastication: During mastication, three muscles of mastication (musculi masticatorii) are responsible for adduction of the jaw, and one (the lateral pterygoid) helps to abduct it. All four move the jaw laterally. https://en.wikipedia.org/wiki/Muscles_of_mastication

MUTCD compliant: Manual on Uniform Traffic Control Devices, Federal Highway Administration, http://mutcd.fhwa.dot.gov

Native format: For photographic images means the format they were exposed in by the camera at the time they were created.

Natural or supplemental dispersed/diffused lighting: Ambient available lighting, possibly with a reflector.

Natural user interface (NUI) paradigm: The successor to the traditional graphical user interface (GUI) and command-line interface (CLI) paradigms for human–computer interaction.

Negative control: A control sample where a negative result is expected to help correlate a positive result with the variable being tested. Example: a section of unburned flooring is compared to a section of burned flooring to determine if an accelerant was used to start a suspicious fire.

Neural network: A computer system modeled on the human brain and nervous system. https://skymind.ai/wiki/neural-network

Neutral density filter (ND): A lens device with a fixed reduction in light transmission usually expressed in "stops."

NFPA 921: NFPA 921, *Guide for Fire and Explosion Investigations*, is published only every few years by the National Fire Protection Association, and the information contained may be out of date, even in the newest edition. Also, the information found there is only basic and goes into detail about nothing photographic.

Night visibility: Compared with daytime, a larger proportion of road accidents happens during nighttime. The altered visibility for drivers partially explains this situation due to difference in contrast between visible objects. https://www.wmo.int/pages/prog/www/IMOP/meetings/CB/Ed…/EdBd-2_P-I_Ch-9.doc

Night vision: The ability to see in low-light conditions. Whether by biological or technological means, night vision is made possible by a combination of two approaches: sufficient spectral range and sufficient intensity range.

NIST: The National Institute of Standards and Technology, a unit of the U.S. Commerce Department. Formerly known as the National Bureau of Standards, NIST promotes and maintains measurement standards. https://searchsoftwarequality.techtarget.com/definition/NIST

No conclusion, in firearms examinations: Indicates insufficient corresponding microscopic characteristics and the consequent inability of the examiner to classify the evidence as either identification or exclusion.

No conclusion, in toolmark examinations: Indicates insufficient corresponding microscopic characteristics and the consequent inability of the examiner to classify the evidence as either identification or exclusion.

Nonidentification, in toolmark examinations: Denotes a lack of association between two items of evidence—the possibility a tool produced a given mark or the same tool produced two marks is excluded. (See Identification.)

Normal lens: A normal lens is a lens with a focal length approximately equal to the diagonal of the film format or of a digital camera's image sensor. A scene viewed through a normal lens appears to have the same perspective as the way your eye sees it. https://shuttermuse.com/glossary/normal-lens/

Normal viewing distance: The viewing distance of a print is somewhat subjective. Common theory dictates that the optimal viewing distance for a print is between 1.5 and 2 times the diagonal length of the print. Example: for a $4 \times 6''$ image print, the normal viewing distance is approximately 10 to 14 inches. https://martinbaileyphotography.com/…/print-viewing-distances-and-print-resolution-.

NTSC (National Television System Committee): The television broadcasting system used in North America and Japan. https://en.wikipedia.org/wiki/NTSC

Objective evidence: Independently measurable and verifiable and thus suitable for scientific comparison. Superimpositions and photogrammetric measurement come into this category.

Oblique, slanting: Sculptured other than axially, radially, or concentrically (i.e., other than parallel or perpendicular to a growing edge).

Odontology/forensic odontology: A branch of forensic medicine dealing with the proper examination, handling, and presentation of dental evidence in a court of law. The work of a forensic odontologist includes identification of bite marks on the victims of attack; comparison of bite marks with the teeth of a suspect and presentation of this evidence in court as an expert witness; identification of bite marks in other substances such as wood, leather, and foodstuffs; identification of unknown bodies through dental records; and age estimations and identification of skeletal remains. A forensic odontologist often works with a forensic pathologist or forensic anthropologist.

OEM: Original equipment manufacturer; for example, using an OEM Nikon Flash on a Nikon DSLR.

Onboard computer: The onboard computer, or OBC, more commonly refers to the computer of a vehicle's avionic subsystem (i.e., the unit where the onboard software runs). https://www.esa.int/Our_Activities/…/Onboard_Computer_and…/Onboard_Computers

Optical center: The point on a lens through which light passes unrefracted; the thickest point of a plus lens or the thinnest point of a minus lens.

Optical distortion: In geometric optics, distortion is a deviation from rectilinear projection; a projection in which straight lines in a scene remain straight in an image. It is a form of optical aberration. https://en.wikipedia.org/wiki/Distortion_(optics)

Optical viewfinder (OVF): DSLRs have an optical viewfinder. It's what makes them a DSLR. The "SLR" bit of their name means "single-lens reflex" and is the mechanism by which light is directed from the lens to the viewfinder using mirrors and a prism. When you press the shutter button, the mirror lifts out of the way and the light hits the sensor instead so it can record an image. Electronic viewfinders (EVFs) are found on some mirrorless cameras. They're more likely to be standard on higher-end models but may be an optional extra on entry-level models. Rather than use a mirror to give you a preview of what you're shooting, the digital sensor is always active and displays what it detects on a small electronic view screen where an optical viewfinder would be. Removing the mirror is a large part of what makes mirrorless cameras significantly smaller than DSLRs. (See Electronic viewfinder.) https://www.howtogeek.com/what's-the-difference-between-an-optical-and-electronic

Optical zoom: The higher the number, the farther in and out the lens will zoom optically.

Optics: The branch of physics that studies the physical properties of light. wordnet.princeton.edu/perl/webwn

Original: Original documents (including photographs) are required to prove the truth of the facts for which the documents are offered. *Federal Evidence Rules 1001 through 1004*

Orthogonal plane: At right angles or perpendicular to the subject.

Orthographic aerial image: An orthophoto, orthophotograph, or orthoimage is an aerial photograph or satellite imagery Orthographic views project at a right angle to the data plane. https://en.wikipedia.org/wiki/Orthophoto

OSHA: The Occupational Safety and Health Administration. It is the branch of the U.S. government that sets and enforces occupational health and safety regulations. For example, OSHA sets the legal exposure limits in the United States, which are called Permissible Exposure Limits (PELs). OSHA also specifies what information must be given on labels and Material Safety Data Sheets for materials that have been classified as hazardous using their criteria. ccinfoweb.ccohs.ca/help/msds/msdstermse.html

Overlap: When photographing a subject with the intention of creating a photo montage, each image should be on the order of 80%, if possible, at least 10% on each side of the image to overlap to allow for good stitching capability. But in some cases, due to the nature of the evidence, it may be less. Taking too large a "jump" between photographs means there is less to feature match and subsequently less to create any dense point cloud.

Painting with light: Moving the light throughout the scene exposing one part at a time with your light source while the camera lens and shutter is open the entire time. See Chapter 10 for more information.

Panorama: A series of photographs taken from a point to cover 360 degrees around that point. history.nasa.gov/EP-95/glossary.htm

Parallel: Given distinct lines in the plane that are infinite in both directions, the lines are parallel if they never meet. Two distinct lines in the coordinate plane are parallel if and only if they have the same slope. csmp.ucop.edu/cmp/resources/glossary.html

Passive autofocus: Commonly found on digital single-lens reflex (DSLR) auto-focus cameras, determines the distance to the subject by computer analysis of the image itself. https://electronics.howstuffworks.com/autofocus3.htm

Patent prints: Contaminated with foreign matter, often containing dust, grease, or blood. These prints occur when fingers are pressed in a thin layer of contaminant and some sticks on the friction ridges.

When the finger touches something else, a visible print is deposited.

Patterning: A pattern finding is one in which the appearance of the finding gives information about how it was caused.

Penetrating trauma mechanism: An injury caused by a foreign object piercing the skin, which damages the underlying tissues and results in an open wound. The most common causes of such trauma are gunshots and stab wounds. https://www.amboss.com/us/knowledge/Penetrating_trauma

Pentaprism: A five-sided prism with two silvered surfaces giving a constant deviation of all rays of light through 90 degrees, used chiefly in the viewfinders of single-lens reflex cameras. https://www.dictionary.com/browse/pentaprism

Perimortem: Taking place at or around the time of death. https://www.merriam-webster.com/medical/perimortem

Peripheral evidence: Anything having a causal and circumstantial connection to the forensic case, suspect, victim, or crime scene. It might not only be photographs, radiologic data, clothes, or any other personal belongings of a victim but also images or CCTV footage recording the crime scene.

Peripheral vision: The areas just outside the cone of main vision.

Perspective: In photography it is defined as the spatial relationship between objects as they relate to one another in an image. It is also the difference between an image made perpendicular to a subject and one made from an angle. The appearance of things relative to one another as determined by their distance from the viewer. wordnet.princeton.edu/perl/webwn

Perspective distortion: A warping or transformation of an object and its surrounding area differing significantly from what the object would look like with a normal focal length, due to the relative scale of nearby and distant features. https://en.wikipedia.org/wiki/Perspective_distortion_(photography)

Phase shift: The phase shift is how far the function is shifted horizontally from the usual position. (See Horizontal shift and Vertical shift.)

Phot: A photometric unit of illuminance, or luminous flux through an area; not a metric (SI) unit; equal to 1 lumen per square centimeter; 10,000 phots equal 1 lux.

Photoanthropometry: It is a metric-based facial image comparison technique using photography as an anthropometric tool. https://www.ncbi.nlm.nih.gov/pubmed/21802228

Photogrammetry: The use of photography in surveying and mapping to measure distances between objects. https://en.wikipedia.org/wiki/Photogrammetry

Photograph: An image (often just called a photo), or a representation of an image, such as one printed on plain paper, created by collecting and focusing reflected electromagnetic radiation. The most common photographs are those created of reflected visible wavelengths, producing permanent records of what the human eye can see.

Photographic facial analysis: To obtain objective average measurements of the profile and frontal facial soft tissue to be used as a guide for aesthetic treatment. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4598381/

Photography: It is the process of making pictures by means of the action of light. It involves recording light patterns, as reflected from objects, onto a sensitive medium through a timed exposure. The process is done through mechanical, chemical, or digital devices commonly known as cameras. en.wikipedia.org/wiki/Photography_as_an_art_form

Photomacrography, scanning or deep field, and zero-perspective imaging: Scanning light photography (SLP), also known as photomacrography, provides a solution to several of the most limiting problems associated with more conventional close-up techniques. As implied by its alternate name, deep-field photomacrography, subjects recorded using this method will be rendered in focus from the details nearest to the lens to those at the farthest limit. Using conventional techniques, only a part of the subject can be in acceptable focus when recorded at magnifications high enough to resolve fine detail. Using SLP, subjects can be photographed with the kind of depth of field commonly associated with scanning electron microscopy (SEM). http://kazilek.com/pages/slp.htm

Photometric: Photometry is the science of the measurement of light in terms of its perceived brightness to the human eye. It is distinct from radiometry, which is the science of measurement of radiant energy (including light) in terms of absolute power. https://en.wikipedia.org/wiki/Photometry_(optics)

Photometry: Deals with light energy of wavelengths that can cause visual sensation. Human visual range is typically from 380 nanometers to 780 nanometers. Wavelengths outside this range do very little to stimulate the human eye.

Photomicrography: The process of capturing images through the eyepiece of an optical microscope.

Photomodeler: Software for generating 3-D data, measurements, and models of the real world using just a camera; designed to create three-dimensional computer models from analyzing a series of overlapping photographs.

Photo montage: A collage can be about the complete disarray of the images in the work. The layout is more artful than logical. A multi-image picture created

in overlapping layers by a photographic or digital process is a photo montage. The definitive difference between a photo collage and photo montage is the method of creation.

Photon: The quantum of electromagnetic energy, generally regarded as a discrete particle having zero mass, no electric charge, and an indefinitely long lifetime.

Photo-optical slaves: Triggering manual flash mode requires either sync cords, radio triggers, or optical slave triggers on each light. An optical slave trigger is a light-sensitive sensor at each remote flash, which triggers the flash in sync when it sees the flash of another manual flash unit. https://www.scantips.com/lights/slaves.html

Photorealistic/photorealism: A genre of art that encompasses painting, drawing, and other graphic media, in which an artist studies a photograph and then attempts to reproduce the image as realistically as possible in another medium. https://en.wikipedia.org/wiki/Photorealism

Photopic vision: What occurs in normal light (luminance level 1 to 106 cd/m^2); color discrimination is optimum.

Photosensitivity: The amount to which an object reacts upon receiving photons of light. Devices that are photosensitive include the human retina and photographic film. Film is photosensitive because a chemical reaction occurs on it when struck by light. The same process is used in the electronic device known as a photocathode, which is a surface that emits electrons when struck by light.

Photoshop, Adobe System: The most powerful image editing software for web, desktop, and mobile applications.

Photovoltaic (PV): Converting light into electricity. Photo means "light"; voltaic means "electric." Commonly referred to as "solar electric."

Phrenology: The detailed study of the shape and size of the cranium as a supposed indication of character and mental abilities. https://www.dictionary.com/browse/phrenology

Physics of optics: It is the branch of physics that studies the behaviour and properties of light, including its interactions with matter and the construction of instruments that use or detect it.

Physiognomy: A person's facial features or expression, especially when regarded as indicative of character or ethnic origin. https://www.merriam-webster.com/dictionary/physiognomy

Picture elements or pixels: Any of the small discrete elements that together constitute an image. (See Megapixel.)

Plastic prints: Occur when the finger touches or presses against a deformable material in such a way that a negative impression of the friction ridge is produced. These types of prints are generally found in places like a newly painted object, wax from candles or sealants, in the gum on envelopes and stamps, and on substances that melt easily or soften when they are held in the hand. An example of this would be chocolate.

Pocket rod: A 6-1/2–foot vertical-reading leveling rod or grading rod is packed compactly like a tape measure. It's ideal for checking a grade without having to carry a full-size rod. Great for foundation work, grading, swimming pools, and construction photo records. Easy-to-read numbers are printed on both sides. https://www.amazon.com/Keson-PR618-Builders-Pocket-Units/dp/B000KL6LOI

Point cloud: A point cloud is a collection of data points defined by a given coordinate system. Point clouds are generated by 3-D scanners or 3-D laser/LiDAR scanners, which measure a large number of points on the external surfaces of objects. The 3-D scanners gather point measurements from real-world objects or photos for a point cloud then translated to a 3-D mesh or CAD model. https://whatis.techtarget.com/definition/point-cloud

Point of view: The position from which something or someone is observed. https://literarydevices.net/point-of-view/

Polaroid: An instant camera that uses self-developing film to create a chemically developed print shortly after taking the picture. Polaroid Corporation pioneered (and patented) consumer-friendly instant cameras and film and were followed by various other manufacturers. https://en.wikipedia.org/wiki/Instant_camera

Personal protection equipment (PPE): Hard hats, safety glasses, hearing protection, safety shoes, etc.

Postmortem: Occurring or performed after death. https://www.dictionary.com/browse/postmortem

Postmortem depiction: The recognition of a decedent by a family member is often employed as identity confirmation. However, misidentification from facial recognition is also common, and faces of the dead may be extremely difficult to recognize due to decomposition or external damage. The depiction of faces of the dead can be a useful tool for recognition leading to identification, and postmortem facial depiction is described as the interpretation of human remains in order to suggest the living appearance of an individual. https://www.ncbi.nlm.nih.gov/pubmed/25447181

Postprocessing: The process of examining the images captured from the camera and then making adjustments in color and density to produce an accurate photograph. Postprocessing is required when shooting raw images. JPEG images are first processed in the camera, but adjustments can also be made after being uploaded.

PPI (pixels per inch): Resolution of a printer.

Precision: A measure of how consistently the result is determined by repeated determinations without reference to any "true" value. www.racteam.com/LANLRisk/Glossary.htm

Previsualization: The art of concentrating or imagining something very strongly, usually as a visual image.

Prejudicial effect: When the evidence is called by the defense, the balance between probative value and prejudicial effect is weighed further in the side of admission. A judge should only exclude evidence where the prejudicial effect "substantially outweighs" the probative value. https://en.m.wikibooks.org/wiki/Canadian_Criminal…/Acceptance_of_Evidence

Primary evidence: When what you have in your hand IS the evidence. (See Supporting evidence.)

Prime lens: A fixed focal-length lens as opposed to a zoom lens. For this application, the fixed focal length assures size consistency between captured images.

Private examination: Usually related to civil torts where monetary damages may be assessed against one party in a dispute or incident.

Probative value: Evidence that is sufficiently useful to prove something important in a trial. However, probative value of proposed evidence must be weighed by the trial judge against prejudicing in the minds of jurors toward the opposing party or criminal defendant. https://www.law.cornell.edu/wex/probative_value

Program exposure: An exposure mode on an automatic or auto-focus camera that automatically sets both the aperture and the shutter speed for proper exposure.

Prosopology: The scientific study of the countenance; physiognomy. The Chinese have been studying prosopology, the study of facial features, to understand the human face, for 3,500 years. http://thebigdictionary.com/prosopology/

Prosumer: Type of electronic product that straddles the professional and consumer markets, or one who uses such a product. Refers to more expensive semiprofessional digital cameras aimed at the consumer market.

Pseudoscience: A collection of beliefs or practices mistakenly regarded as being based on scientific method. https://www.merriam-webster.com/dictionary/pseudoscience

Puparial stage: The life stage of some insects undergoing transformation between immature and mature stages. The pupal stage is found only in holometabolous insects, those that undergo a complete metamorphosis, with four life stages: egg, larva, pupa, and imago. The processes of entering and completing the pupal stage are controlled by the insect's hormones, especially juvenile hormone, prothoracicotropic hormone, and ecdysone. https://en.wikipedia.org/wiki/Pupa

Qualitative: (1) Referring only to the characteristics of something being described, rather than exact numerical measurement. (2) Indicative only of relative sizes or magnitudes, rather than their numerical values. www-personal.umich.edu/~alandear/glossary/q.html

Quality: Quality refers to the inherent or distinctive characteristics or properties of a person, object, process, or other thing. En.wikipedia.org/wiki/Quality

Quality of light: Relates to the color of the light sources (color temperature reading in degrees Kelvin). For example, noon sun on a clear day would be the ideal condition for photography. The Kelvin reading would be approximately 6500 K (U.S. broadcast standard).

Quantitative: Involving the measurement of quantity or amount. www.nmlites.org/standards/science/glossary_5.htm

Quantity of light: Defined as a measure of a certain light source or area. Can be applied in a variety of ways, from compliance with OSHA safety requirements in a factory to light-level measurement around a bank ATM machine (for security reasons) to a Hollywood studio film set. Light is measured in foot-candles (English measurement) or lux (metric measurement).

Radar: A system for detecting the presence, direction, distance, and speed of aircraft, ships, and other objects, by sending out pulses of high-frequency electromagnetic waves that are reflected off the object back to the source. By 1940 a new blockbuster invention, made in America, could generate rays with wavelengths of a centimeter or less and was used to detect enemy aircraft in flight, from long distances and helped to win the Battle of Britain. "Radar" was coined from the phrase "Radio Detection and Ranging." (See Cavity magnetron.) https://en.wikipedia.org/wiki/Radar

Radiation-absorbent material: Usually known as RAM, this is a material that has been specially designed and shaped to absorb incident RF radiation (also known as nonionizing radiation), as effectively as possible, from as many incident directions as possible. (See Stealth technology.) https://en.wikipedia.org/wiki/Radiation-absorbent_material

Radiant electromagnetic energy: Radiant energy is energy that travels by waves or particles, particularly electromagnetic radiation such as heat or x-rays. An example of radiant energy is the source of energy used in radiation therapy. https://www.yourdictionary.com/radiant-energy

Radiant flux: Radiant flux (also referred to as "radiant power") is the radiant energy emitted, reflected, transmitted, or received, per unit time, and spectral flux or spectral power is the radiant flux per unit frequency or

wavelength, depending on whether the spectrum is taken as a function of frequency or of wavelength. https://www.sweetwater.com/insync/radiant-flux/

Radiograph: A radiograph (also known commonly as an x-ray) is an image obtained by shining high-energy light or x-rays through the body to a detector, which is normally a photosensitive plate. The body or structure absorbs different amounts of radiation depending on the density of the tissue or materials contained. Dense tissues such as bone absorb more radiation and appear light, and less dense tissues such as lung absorb less radiation and appear dark. www.mdia.com/medterm.html

Radiometer: Measures radiance, the energy emitted or reflected by a source.

Radiometry: The measurement of optical radiation power and the detection and measurement of radiant electromagnetic energy.

Reality: Reality in everyday usage means "everything that exists." The term "reality," in its most liberal sense, includes everything, whether or not it is observable, accessible, or understandable by science, philosophy, theology, or any other system of analysis. https://en.wikipedia.org/wiki/Reality

Reciprocity failure: Occurs when a film's speed cannot be relied upon for proper exposure at slow shutter speeds; a shift in the color balance or the darkness of an image caused by very long or very short exposures.

Rectification: The process by which an image or grid is converted from image coordinates to real-world coordinates. Rectification typically involves rotation and scaling of grid cells, and thus requires resampling of values.

Reference: Any object used in an image to demonstrate the color of something known in relation to something unknown. (See Scales and references.)

Reference point: When an object changes position compared to a reference point. A fixed reference point is an object in a field, which has very low likelihood of ever moving. Objects we call stationary—such as a tree, a sign, or a building—make good fixed reference points. http://www.goodrichscience.com/8-a-reference-point.html

Reflected light: Light bounced off a subject, not falling on it.

Reflective ultraviolet imaging system (RUVIS): RUVIS UHD uses intensified UV reflectance instead of fluorescence as in forensic light sources. The system can detect fingerprints on most nonporous surfaces prior to any treatment or after a cyanoacrylate (Super Glue) fuming. https://spexforensics.com/products/ruvis

Reflector: Any device used to reflect light onto a subject.

Refraction: The fact or phenomenon of light, radio waves, etc., being deflected in passing obliquely through the interface between one medium and another or through a medium of varying density. The measurement of the diffraction defines the materials through which the light is passing.

Regression: A measure of the relation between the mean value of one variable (e.g., output) and corresponding values of other variables (e.g., time and cost). https://www.merriam-webster.com/dictionary/regression

Relevance: The quality or state of being closely connected or appropriate. https://www.merriam-webster.com/dictionary/relevance

Relief: The difference in elevation between high and low points of a surface. www.nps.gov/cave/glossary.htm

Replica: A close reproduction of the original.

Representation: The formulation or view of a problem. Developed so the problem will be easier to solve. dssresources.com/glossary/dssglossary1999.html

Reproduce: Make a copy or equivalent. wordnet.princeton.edu/perl/webwn

Reproduction ratio (RR): Indicates the magnification of a subject for macrophotography—specifically, the size of the image recorded on a sensor divided by the actual size of the subject. For example, if the image on film is the same size as the subject, the reproduction ratio is written as 1:1 or 1×.

Resolution: Measured in pixels per inch (PPI). Can be defined as the number of pixels in the image. The more pixels in the image, the higher the resolution and larger the size of the file. For example, a 1-inch square of an image scanned at 72 PPI contains 5184 pixels (72 × 72) and has a file size of 6K; if the same file is scanned at 144 PPI, it will contain 20,736 pixels (144 × 144) and a file size of 21K.

Resolve: Make clearly visible. wordnet.princeton.edu/perl/webwn

Retina: A layer at the back of the eyeball containing cells that are sensitive to light and that trigger nerve impulses that pass via the optic nerve to the brain, where a visual image is formed. https://www.allaboutvision.com/resources/retina.htm

Retroreflective light: A retroreflector (sometimes called a retroflector or cataphote) is a device or surface that reflects radiation (light, usually) back to its source with a minimum of scattering. Being directed, the retroflector's reflection is brighter than that of a diffuse reflector. https://en.wikipedia.org/wiki/Retroreflector

Reverse engineering: With an older object or device, the mechanical drawings and material specifications used for initial manufacture may not be available in order to make more. Then new drawings and specifications are made from the old piece, and the new documentation is used to manufacture modern copies.

Reversal ring: Photographic hardware made to allow the lens in use on a digital camera to be taken off and mounted in reverse. This orientation allows the camera to focus much closer than when the lens is mounted normally. https://expertphotography.com/reversing-rings-macro-photography/

Rifling: Helical grooves machined into the bore of a barrel of a firearm during production to increase the accuracy of that firearm by imparting spin to the projectile.

Rifling type: Conclusive identifications of bullets or other ammunition components are impossible when the rifling impressions on these components match the rifling type of a given firearm but no other distinct, unique characteristics are present on the ammunition. In other words, a bullet may bear class characteristics like those produced by the barrel of a particular firearm model but may not be impressed with individual identifying characteristics to match it with a single specific firearm.

Ring flash: Attached to the front of the lens and designed for photographing subjects in fine detail with (possibly) shadow-less, low-contrast illumination.

Ring method: Capturing images around an object like a tree or statue by circling around a fixed object and capturing images at 5- to 15-degree increments to guarantee enough overlap between images.

Robbery: The crime of seizing property through violence or intimidation. Because violence is an ingredient of most robberies, they sometimes result in bodily harm or murder of their victims.

Root cause: The real cause or origin of a problem. www.industryforum.co.uk/glossary.htm

RS-232: A standard interface between a computer input/output port and a peripheral device. Signal properties, including time duration, voltage, and current, are specified by the Electronic Industries Association.

Rule of thirds and the golden ratio: Two rules of image composition for most types of artistic endeavors that are not appropriate or necessary aspects of forensic photography.

Satellite imagery: Also Earth observation imagery or spaceborne photography, these are images of Earth or other planets collected by imaging satellites operated by governments and businesses around the world. https://en.wikipedia.org/wiki/Satellite_imagery

Scales and references: Scale = linear size of image/linear size of subject. Reference = any object used in an image to demonstrate the color or size of something known in relation to something unknown.

Scale invariant feature matching (SIFT): A feature detection algorithm in computer vision to detect and describe local features in images. https://en.wikipedia.org/wiki/Scale-invariant_feature_transform

Scaled images: Point cloud densities are labeled low, medium, high, ultra-high, or similar from the original point cloud, which is too many points to work with easily in some software. Of foremost importance in forensics is the scale of the created models to ensure they are true to form. A downside of using any form of digital camera (except using two cameras at once—see Chapter 9) is we are taking light rays in the 3-D world and projecting them onto a two-dimensional (2-D) sensor. Almost all photogrammetry packages allow for scaling of generated point clouds and 3-D models.

Scalp reflection: Peeling the scalp back to uncover the skull during autopsy.

Scanning electron microscope (SEM): An electron beam–based microscope used to examine, in a three-dimensional screen image, the surface structure of prepared specimens. www.fao.org/docrep/003/X3910E/X3910E22.htm

Scar: Can be caused by trauma, surgery, a burn, and some skin infections. A mark left on the skin or within body tissue where a wound, burn, or sore has not healed completely and fibrous connective tissue has developed. https://www.merriam-webster.com/dictionary/scar

Scientific method: A process that is the basis for scientific inquiry. H. G. Wells said, "For the true Scientific Method is this: to trust no statements without verification, to test all things as rigorously as possible, to keep no secrets, to attempt no monopolies, to give out one's best modestly and plainly, serving no other end but knowledge."

Scientific Working Group on Imaging Technology (SWGIT): The mission of the Scientific Working Group on Imaging Technology (SWGIT) was to facilitate the integration of imaging technologies and systems within the criminal justice system (CJS) by providing best practices and guidelines for the capture, storage, processing, analysis, transmission, output of image, and archiving. https://www.swgit.org/

Scientific Working Group for Shoeprint and Tire Tread Evidence (SWGTREAD): The Scientific Working Group on Shoeprint and Tire Tread Evidence (SWGTREAD) has a published standard that discusses the minimum qualifications and training for footwear/tire track examiners. www.forensicsciencesimplified.org/fwtt/how.html

Scotopic vision: Monochromatic vision of the human eyes in dim light.

Scrim: Some light from the flash will "spill" to the front and may result in unwanted shadows or glare. In that case, use a piece of cardboard—or even your graycard or color checker—as an improvised "scrim," which will block the spill.

Sealed beam: A type of lamp that includes a reflector and filament as a single assembly, over which a front cover (lens), usually of clear glass, is permanently attached.

Secure Digital (SD) memory cards: An SD card is a very small flash memory card. SD cards are used in smartphones, digital cameras, e-books, and car navigation systems. https://searchstorage.techtarget.com/definition/Secure-Digital-card

Sexual assault nurse examiners (SANEs): Health professional trained to conduct forensic documentation (written, photographic, and evidence collection) examinations of interpersonal violence victims.

Screenshot: Also called screen capture or screen grab, this is a digital image of what should be visible on a computer monitor, television, or other visual output device. https://en.wikipedia.org/wiki/Screenshot

Shutter priority: A mode in which a desired shutter speed is manually selected and locked in; the camera then chooses an appropriate lens opening (f-stop) for proper exposure. Used primarily to prevent motion blur in fast-moving subjects or objects.

Shutter release focus locking function: Press down partway to lock focus.

SI: The International System of Units (abbreviated SI from the French, Le Système international d'unités) is the modern metric system.

Silver: Silver is a chemical element in the periodic table with the symbol Ag (from the traditional abbreviation from the Latin *argentum*) and atomic number 47. A soft, white, lustrous transition metal, silver has the highest electrical and thermal conductivity of any metal and occurs in minerals and in free form. This metal is used in coins, jewelry, tableware, and photography. https://en.wikipedia.org/wiki/Silver

Single-lens reflex (SLR): A camera with one lens only for both viewing and taking pictures. The image is reflected onto a viewing screen by a moveable mirror in the camera. The mirror flips out of the way just before the shutter opens, permitting light to strike the film. www.photographytips.com/page.cfm/2088

Situational analysis: An in-depth process to develop understanding of the needs of specific audiences in a specific setting. It involves a combination of data-gathering techniques conducted from a variety of perspectives (soial, economic, environmental, and political, etc.).

Slow-speed lens: A lens with a relatively narrow maximum aperture—*f*/8, for example.

Sparse reconstruction: Calculates the relative location of the matched points in the images, along with the position and orientation of each camera that took the photographs. The sparse reconstruction is a direct contribution from the photogrammetry world and allows the basic setup to be forwarded for further processing to create a dense point cloud.

Spatial relationship of objects: A spatial relation specifies how some object is located in space in relation to some reference object. When the reference object is much bigger than the object to locate, the latter is often represented by a point. Commonly used types of spatial relations are topological, directional, and distance relations. https://en.wikipedia.org/wiki/Spatial_relation

Spectral comparator: An infrared viewer that can see differences in infrared wavelengths reflected from objects.

Spectrum: A band of colors, as seen in a rainbow, produced by separation of the components of light by their different degrees of refraction according to wavelength. https://www.merriam-webster.com/dictionary/spectrum

Spectrum of radiation: Generally, electromagnetic radiation is classified by wavelength into radio wave, microwave, terahertz (or sub-millimeter) radiation, infrared, the visible region that is perceived as light, ultraviolet, x-rays and gamma rays. The behavior of EM radiation depends on its wavelength. https://en.wikipedia.org/wiki/Electromagnetic_spectrum

Standard: An idea or thing used as a measure, norm, or model in comparative evaluations. https://www.standard.com/

Standard operating procedure (SOP): Identifies not only how digital images are to be captured but when they are to be captured and probably how they will be stored and protected.

Static: Not changeable. The opposite of dynamic. www.machinima.com/article.php

Stationery reference point: See Reference point.

Stealth technology: Radar-absorbent RAM is used in stealth technology to disguise a vehicle or structure from radar detection. https://en.wikipedia.org/wiki/Radiation-absorbent_material#Use_in_stealth_technology

Steradian: The SI unit of solid angle, having its vertex in the center of a sphere, cuts off an area of the surface of the sphere equal to that of a square with sides of length equal to the radius of the sphere.

Stereoscope: An optical device for creating stereoscopic (or three-dimensional) effects from flat (two-dimensional) images. It is provided with lenses, under which two equal images are placed, so that one is viewed with the right eye and the other with the left. Observed at the same time, the two images merge into a single virtual image which, as a consequence of our binocular vision, appears to be three-dimensional. www.minicizotti.it/html/english/glossary.html

Stereoscopic/3-D photography: Stereoscopy, stereoscopic imaging, or 3-D imaging is a technique to create the illusion of depth in a flat photograph, movie, or other two-dimensional image by presenting a slightly different image to each eye. en.wikipedia.org/wiki/Stereo-photography

Sterilized: Made free from bacteria, DNA, or any other living microorganisms.

Stinker juice: Composed of fluid purging from the natural body openings and additional fluids created by the maggots as they break down the soft tissues of the remains.

Stitch together: It is possible to stitch hundreds or even thousands of photos together into stunning images with billions of pixels. Stitching can be done vertically, horizontally, and/or laterally. The only issue with stitching software is for the images to be taken with the proper overlap initially. https://www.photojoiner.net/merge-photos

Stopped-down mode exposure metering: The lens aperture is reduced to the size of its setting before the time of the exposure

Stratification: A system or formation of layers, classes, or categories. Where layers of material or objects offer the opportunity to unpick a chronology of deposition, it is important to an investigation. https://www.vocabulary.com/dictionary/stratification

Stratigraphy: The branch of geology concerned with the order and relative position of strata and their relationship to the geological time scale. The analysis of the order and position of layers of archaeological remains. https://www.dictionary.com/browse/stratigraphy

Striated toolmarks (impression and pattern evidence): Impression toolmarks occur when the tool comes into perpendicular contact with an object. Striated toolmarks occur when the tool is moved across or through an item with enough force to produce scratch-type markings.

Striations: A series of ridges, furrows, or linear marks.

Structure from motion: An automated process mimicking the human ability to see depth through stereo vision by using multiple photographs taken from multiple locations around or across an object of interest.

Subcutaneous: Beneath the skin but above the fascia and muscle.

Subject brightness range: The difference in luminance between the darkest and lightest areas of the subject, in both negative and print.

Subjective evidence: Personally observable and demonstrable but not necessarily independently measurable.

Superimposition: To impose, place, or set over, above, or on something else. The technique is most useful for the matching of facial marks such as scars, moles, or ear structure on two photos of the same person. https://www.dictionary.com/browse/superimpose

Supporting evidence: When photographs are captured of primary evidence and if the photographs are used at trial, the photographs are secondary or supporting evidence. (See Primary evidence.)

Taphonomy: The branch of paleontology dealing with the processes of fossilization. https://www.merriam-webster.com/dictionary/taphonomy

Technical: Of or relating to a practical subject organized according to scientific principles. wordnet.princeton.edu/perl/webwn

Technical investigations: Technical investigations are forensic engineering solutions to insurance, legal, and manufacturing problems. www.ptiforensic.com/

Tent lighting: A light tent or light box is a contraption with translucent sides that diffuses light coming from multiple sources. This allows for even, nearly shadow-less lighting against a simple, solid background. https://digital-photography-school.com/how-to-use-a-light-tent-for-small-product-photo

TerraServer.com: Provides aerial photography and USGS topographic maps for a fee.

Testify: Give testimony in a court of law. wordnet.princeton.edu/perl/webwn

Testimony: A solemn statement made under oath; an assertion offering firsthand authentication of a fact; something serving as evidence. wordnet.princeton.edu/perl/webwn

Texture: For the best-quality 3-D model, it is necessary to create "textures" from the original images. Taking a step back to the dense point cloud creation stage, it is important to understand the RGB colors for each generated point are obtained from the respective pixel. In the mesh creation stage, the RGB values from the points are initially transferred to the mesh.

Thermal imaging/thermography: Infrared thermography (IRT), thermal imaging, and thermal video are examples of infrared imaging science. Thermographic cameras usually detect radiation in the long-infrared range of the electromagnetic spectrum (roughly 9,000 to 14,000 nanometers or 9 to 14 μm) and produce images of that radiation, called thermograms. https://en.wikipedia.org/wiki/Thermography

3-D models: In 3-D computer graphics, 3-D modeling is the process of developing a mathematical representation of any surface of an object (either inanimate or living) in three dimensions via specialized software. The product is called a 3-D model. https://en.wikipedia.org/wiki/3-D_modeling

Through the lens exposure systems (TTL): A flash mode acronym for through the lens metering where the

amount of light is controlled by a sensor in the camera reading the light coming through the lens and controlling the total amount of light allowed to reach the sensor.

Time-date stamp (TDS): Used on some older video cameras for marking the film to show when it was being exposed. Similar in purpose to a data back for a 35 mm SLR. The TDS is no longer needed, however, because the video itself is marked by the camera in the image metadata to show when it was made.

Time of flight: Measures the time taken for a light pulse to travel to a target and back.

Title card: A title card should include the unique number/descriptor of the incident/project, date/time of incident, location of incident, photographer name and affiliation, and date of photographs.

Tonality: The color scheme or range of tones used in a picture. https://www.dictionary.com/browse/tonality

Tonal rendition: Light size and quality, harsh or soft; also you can control the tonal range of an image in order to end up with a satisfying rendition of an actual scene.

Toolmarks: Unique imperfections, such as distinctive scratches, scrapes, and other minute nicks and flaws. Toolmarks are produced when two items, one not necessarily a tool, come into forcible contact with each other. They are made by two distinct motions: impression and striation.

Total darkness: Total absence of light.

Total luminous flux: The SI unit of luminous flux is the lumen (lm). One lumen is defined as the luminous flux of light produced by a light source that emits 1 candela of luminous intensity over a solid angle of 1 steradian. In other systems of units, luminous flux may have units of power. https://en.wikipedia.org/wiki/Luminous_flux

Total station: An optical surveyor's instrument that combines a transit and an electronic distance measuring device. A total station calculates angles and distances for surveyed objects. This information can be used to create topographic maps. www.archaeological.org/webinfo.php

Trace evidence: Fibers, hairs, vegetation, debris, paint residue, makeup, etc., can establish contact between or among the crime scene, victim, and assailant (associative evidence).

Trajectory analysis: A trajectory or flight path is the path that an object with mass in motion follows through space as a function of time. In classical mechanics, a trajectory is defined by Hamiltonian mechanics via canonical coordinates; hence, a complete trajectory is defined by position and momentum, simultaneously. https://en.wikipedia.org/wiki/Trajectory

Trajectory rods: Brightly colored fiberglass rods that provide a durable and convenient means to illustrate trajectories through solid objects for photographic purposes. The rods are 24 or 48 inches long and ¼ inch in diameter. https://www.shopevident.com/category/.

Transparency: In photography, a transparency is a still, positive image created on a transparent base using photochemical means. The terms slide and reversal film are also used. Contrast with negative and print. en.wikipedia.org/wiki/Transparency_(photography)

Triangulation measurement: Optical triangulation methods based on a laser light sheet and a camera are frequently used as a surface measurement technique in a wide range of applications. In surveying, the tracing and measurement of a series or network of triangles in order to determine the distances and relative positions of points spread over a territory or region, especially by measuring the length of one side of each triangle and deducing its angles and the length of the other two sides by observation from this baseline. https://en.wikipedia.org/wiki/Triangulation

Tripping mechanism: Hazards to pedestrians often easily remedied, but also easily overlooked until a severe incident occurs.

Tunable laser: A laser whose wavelength of operation can be altered in a controlled manner. https://en.wikipedia.org/wiki/Tunable_laser

Two-point perspective: Linear perspective in which parallel lines along the width and depth of an object are represented as meeting at two separate points on the horizon, 90 degrees apart as measured from the common intersection of the lines of projection.

Ultraviolet lighting: Sometimes referred to as black light.

Unethical behavior: Unethical behavior is an action that falls outside of what is considered morally right or proper for a person, a profession, or an industry. Individuals can behave unethically, as can businesses, professionals, and politicians. https://examples.yourdictionary.com/examples-of-unethical-behavior.html

Unmanned aerial vehicles (UAVs): Recognized as ideal platforms for acquiring an overlapping grid of photographs above a fixed area of ground, from which accurate 3-D data can be constructed using photogrammetric software.

Variable ND filter: Round, and as its name implies, is adjustable for light transmission, usually between two and eight stops of light reduction

Vector: A vector is a mathematical object with a size, called the magnitude, and a direction. For example, a vector would be used to show the distance, velocity, and direction something moved in. https://simple.m.wikipedia.org/wiki/Vector

Vertical: Perpendicular to the horizon. Up and down. www.asu.edu/cfa/wwwcourses/art/SOACore/glossary.htm

Vertical shift: Vertical shift is how far the function is shifted vertically from the usual position. The easiest way to determine vertical shift is to determine by how many units the "starting point" (0,0) of a standard sine curve, y = sin(x), has moved to the right or left, and horizontal shift is computed the same way.

Viewing distance: The distance between an observer and the object being viewed. http://www.idigitalphoto.com/dictionary/viewing_distance

Viewpoint: The position of the camera in relation to the subject. www.startphoto.com/learn/glossary/glossary_v.htm

Virtual cloud: A virtual private cloud (VPC) is an on-demand configurable pool of shared computing resources allocated within a public cloud environment, providing a certain level of isolation between the different organizations using the resources. https://en.wikipedia.org/wiki/Virtual_private_cloud

Virtual reality (VR): A computer simulation of a real three-dimensional world, often supplemented by sound effects. People often associate virtual reality with a body suit and head gear that includes an internal screen. These computerized images can be simulated in any environment, making you feel like you're really there. A more common use for VR is seen in many 3-D computer games. www.cem.uvm.edu/util/html/definitions.php

Virtual tour: A computer-generated tour in which the viewer gets the sense of actually walking through the space. www.artsconnected.org/artsnetmn/spaces/vocabulary.html

Visible spectrum: The visible spectrum is the portion of the electromagnetic spectrum that is visible to the human eye. Electromagnetic radiation in this range of wavelengths is called visible light or simply light. A typical human eye will respond to wavelengths from about 380 to 740 nanometers. https://en.wikipedia.org/wiki/Visible_spectrum

Vision: Visual perception is one of the senses, consisting of the ability to detect light and interpret (see) it; known as sight or naked eye vision. Vision has a specific sensory system. en.wikipedia.org/wiki/Vision_(sense)

Vision study: Photographs representative of the way the scene looked to the person making the photographs and representative of how the scene may have looked to someone else in the past.

Visual acuity: Clarity of vision. Acuity is measured as a fraction of normal vision; 20/20 vision indicates an eye that sees at 20 feet what a normal eye should see at 20 feet; 20/400 vision indicates an eye that sees at 20 feet what a normal eye sees at 400 feet.

Visual cue: A signal and reminder of something; aiming to be self–explanatory and preattentive, it brings to mind knowledge from previous experiences providing a framework for its own interpretation. https://infovis-wiki.net/wiki/Visual_Cue

Visualization: The production of two- and three-dimensional pictures; or graphs of the numerical results of computations. www.nacse.org/demos/coping-with-unix/coping-with-unix/node188.html

Visualizing targets: The search phase of an archaeological examination generally seeks to identify anomalous characteristics indicative of a hidden burial. These characteristics might be topographical (a subtle slump or rise in ground level) or environmental (alterations in vegetation colonization) in nature.

Visual perception: Visual perception refers to the brain's ability to make sense of what the eyes see. This is not the same as visual acuity, which refers to how clearly a person sees (for example, 20/20 vision). A person can have 20/20 vision and still have problems with visual perceptual processing. https://childdevelopment.com.au/areas-of-concern/fine-motor…/visual-perception/

Visual task: Conventionally designates those details and objects that must be seen for the performance of a given activity and includes the immediate background of the details or objects.

Voir dire: A vetting process where the witness's qualifications and expertise are established.

Wavelength: The distance between two successive points of an electromagnetic waveform, usually measured in nanometers (nm). One nanometer equals one billionth (10^9) of a meter. www.cetpak.com/Technical/glossary.htm

White balance: White balance (WB) is the process of removing unrealistic color casts, so that objects that appear white in person are rendered white in your photo. Proper camera white balance has to take into account the "color temperature" of a light source, which refers to the relative warmth or coolness of white light. https://www.cambridgeincolour.com/tutorials/white-balance.htm

White point: A white point is a set of tristimulus values or chromaticity coordinates that serve to define the color white in image capture, encoding, or reproduction. https://en.wikipedia.org/wiki/White_point

Wide-aperture exposure metering: The lens aperture is not reduced to the size of its setting until the instant of the exposure.

Wi-Fi cameras: Send alerts to a smartphone.

Wireless network interface controller (WNIC): A network interface controller that connects to a wireless radio-based computer network. A high-speed wireless network card that is used to access a network through a USB port on a

computer or laptop. https://en.wikipedia.org/wiki/Wireless_network_interface_controller

Witness mark: A punch mark or scratch used to position or locate a part in its proper spot; the mark is made on each half of the assembly so that upon reassembly the marks can be lined up. A scoring or scribing of a line on a machined surface. Something that serves as evidence; a sign.

Working distance: Distance from the front of the lens surface to the subject. The more frequently used term *shooting distance* refers to the distance between the subject and the image plane.

Wound: A wound is a physical trauma where the skin is torn, cut, or punctured. Exposed to air, there is not only a significant chance of death due to loss of blood but increased chance of bacteria entering the wound or an infection.

Zone system: Methodology introduced by photographer Ansel Adams for determining optimal exposure and appropriate development for an individual photograph. Based on analysis of subject luminosities in terms of 11 gray tones, labeled zones 0 through X, and previsualization of them as print densities.

Z plane: The vertical counterpart of the three-dimensional world. Many people forget the Earth and everything in the galaxy has at least three dimensions. So, look up and down as well as straight ahead when investigating and/or searching for evidence.



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Index

Note: *Italicized* page numbers refer to figures, **bold** page numbers refer to tables.

A

ABFO No. 2 Bite Mark Standard Reference Scale, 260, *261*, 275, *601*, 601
Abrasion, 132, 288
Acceptable focus, 30
Accessory lenses, 30
Accident scenes, 367–385
  case studies, 376–385
    documentation of inspection, 383–385
    trip and fall incident, 376–380
    victim recovery, examination, and identification, 380–382
  close-up views, 372
  environmental documentation at traffic crash, 370–371
  incident site photography, 369
  macro views, 372
  mass casualty incident/multicasualty incident photography, 374–375
  mid-range views, 372
  overall views, 371–372
  photographic documentation, 367–368
  scene photographic documentation, 371–372
  slip, trip, and fall incidents, 368–369, 376–380
  traffic crash photography, 369–370
  traffic crash reconstruction photography, 373
  vehicle photographic documentation, 372–373
Accidental death, 570; *see also* Autopsy photography
Accreditation standards, 17
Accuracy, 80
Adams, Ansel, 157
Adaptation, 4
Adjustment layers, 12
Admissibility, 118–120, 162
Adobe Bridge, 503
Adobe Photoshop, 57, 79–80, 503
  Calculations function, 101, 108–110
  Color Dodge function, 109–110
  Dodge and Burn tool, 118–120
  Dust and Scratches settings, 110
  Graphics Processor Settings, 81
  Lab Color mode, 101–102, 106
  Line tool, 111
  Linear Dodge function, 110
  resampling methods, 95
  settings, 80–81
  Shadows/Highlights command, 110
  system requirements, 81
  Transform function, 111
  Unsharp Mask, 110
Adobe Premier, 503
Adobe System, 57
Aerial photography, 453–458; *see also* Drone photography
  angles to work, 455–457
  batteries, 457
  camera equipment, 457
  camera settings, 457
  clothing in, 453–455
  commercial aerial image providers, 475
  history, 474
  Internet resources, 474–475
  memory cards, 457
  orienting the photographs, 458
  photos for court, 458
  and rotor blades, 457
  3D displays, 457–458
  time of day, 455
  using helicopters for surveillance photos, 458
  videos, 457
  and weather conditions, 455
Aerial surveillance, 338
Aeronautical decision-making (ADM), 462
Age progression
  age-related facial changes, 624–627
  extrinsic aging, 623–624
  facial aging, 524–526, 623–627, 626–627
    later adulthood, 626
    middle age, 626
    old age, 627
    young adulthood, 626
  facial changes in adulthood, 626–627
  facial changes in juveniles, 524–526
  and forensic art, 627–628
  hard and soft tissue age-related changes, 627
  intrinsic aging, 623–624
Aircraft crash, *267–268*, 267–268
Aircraft engine documentation project, *270–271*, 270–271
Aircraft oil pump, *269*, 269–270
Airport security, 33–34
Allin, Boyd, 218
Ambient light, 230–231
American Board of Forensic Engineers, 3
American College of Forensic Examiners, 3
Anaglyph imaging, 189–191
Angle of separation, 443
Angle of view, 30
Angular correction, 280–283
Animation, 654–656
Antishake system, 140–141
Aperture, 30–31, 152, 518
Aperture Priority mode, 519
APS-C imaging sensor, 91
Arca-Swiss camera plate, *39–40*
Arson, 418–421
Artifacts
  mitigation of, 111–112
  reduction of, 112–113
Assignment identification card, 19
ASTM International, 58
Audio surveillance, 339
Auditing conditions, 481–494
  bridge photography, 486–489
  building collapse, 483–486
  crane failure, 481–483
  roadway accident, 490–494
Authentication, 14
Autoexposure
  built-in flash, 254–255
  oblique flash, 251–253
  proper exposure of small subjects, 255–256
Autoexposure Bracket (AEB) function, 163
Autofocus
  computerized active, 145
  computerized passive, 145–148
  contrast detection, 148
  phase detection, 148
Automated Fingerprint Identification System (AFIS), 56, 94, 105
Automatic mode, 519
Automatic resampling, 95
Autopsy photography, 569–579
  accidental death, 570
  burn injuries, 572
  cause of death, 570
  external examination of the body, 573–575
  fatalities and injuries at fire scenes, 569–570
  and forensic autopsy objectives, 569–570
  homicide, 570
  internal examination, 575–579
    body with chest plate removed, 575–576
    individual organs, 579
    neck organs and tongue, 579
    skull and brain examination, 576–579
  manner of death, 570
  mechanism of death, 572
  natural death, 570
  normal autopsy, 573
  process, 573
  suicide, 570
  undetermined manner of death, 570
Avulsion, 132
Axial lighting, 256–258
Ayres, T.J., 217

B

Background colors, 105–110
Backing up data, 602
Backscatter, 504, 505
Bailey, George G., 114
Baker, J. Stannard, 215
Barnard, George, 3
Batteries, 27, 457
  and cold weather, 27
  Li-ion, 27
  NiMH, 27
  tips, 27
Battery grip, 27
Bayer pattern, 171
Bayer sensor, 171
Beam splitter, 185
Bell Labs, 391
Berg, Erik, 115, 120

Best evidence rule, 15
Bias, 57–58
Bicubic resampling, 95
Bicubic Sharper resampling, 95
Bicubic Smoother resampling, 95
Bilinear resampling, 95
BING map/aerial database, 474
Binocular vision, 180
Bit, 82–83
Bit depth, 82–83
Bite Mark Case Review, 120
Bite mark impressions, 132–133
  cast preparation, 133
  cast preservation, 133
  casting, 133
  correcting distortions, 260
  definition of, 132
  photographic documentation of, 133
  scales, 260
  types of, 132
Blair v. Pelham (1875), 114
Blood
  collection of blood evidence, 418
  dried bloodstains, 418
  evidence, 416–418
  photography, 417–418
  visualization, 417
  wet bloodstains, 418
Blow flies, 587–591
Blurring, 442
Body fluids, 414
Bolton standards, *623*, 623
Bomback, E.S., 215
Booth Derringer handgun, 303–308, *308*
Booth, John Wilkes, 303, 304, 306
Brain examination, 576–579
Brewster, David, 181
Bridge photography, 486–489
Brightness
  digital projector, 653
  scene, 224–226
Brittle fractures, 53
Broken chair, 268, *268*
Brooklyn Museum of Art, 3
Building collapse, 483–486
Bullet trajectory laser photography, 310–312
Bullets, 133–135
  ballistic comparison, 298–300
    editing photographs, 299–300
    photos from negative results, 299
  photographic documentation, 134, *135*
Burn injuries, 572
Burr, Raymond, 47
Byte, 82

C

C.S.I. effect, 47
Calculations function, 108–110
Calibration of digital images, 69–79
  accident/crime scenes, 69
  distortion identification, 70–72
  medium objects, 73–76
  small objects, 76–79
Calipers, *262*, 262
Camera(s)
  batteries, 27
  choosing, 24–25
  default settings, 26
  focusing, 142–148
  in forensic odontology, 599–600
  getting started, 25–26
  hand-holding, 140–142
  handling, 26
  versus the human eye, 220–221, *221*
  lenses, 28–30
  maintenance, 31–33
  memory, 27–28
  menus, 26
  new, 25
  versus scanners, 99–100
  size, 25
  in water and underwater photography, 500, 501, 502
Campbell, Nathan Louis, 359–364
Canned air, 33
Canon Rebel XT, 142
Carlton, Chester, 57
Category 1 images (documentation images), 11–12
Category 2 images (evidentiary images), 11–12
Cellphones, 352–353
  cameras, 523–524
  forensic photography, 272–274
Central flight controller (CFC), 464–465; *see also* Drone photography
Cephalometrics, 623
Certification, 3, 6
Certified Forensic Photography & Imaging, 6
Chain of custody, 15
Challenger shuttle accident, 46
Charge coupled device (CCD), 30
Checker shadow illusion, *106*
Checklist
  interpersonal violence documentation, **561**
  making better photographs, 34–36
Cheek retractors, 601
Chromatic adaptation, 526
Chrominance values, 110
Circle of confusion, 30
Circular polarizing lens filter, 543, 544
Clandestine photography, 337–344
  aerial, 338
  audio surveillance, 339
  fixed location, 337, 339–340
  mobile, 337, 340–342
  remote, 338–339
  vehicular, 337, 340–342
  video surveillance, 339
  walking, 338
  ways and means, 342–343
Close-up lenses, 244, *244*
CloudWorx, 393
CMOS imaging sensors, 171
CMYK (cyan, magenta, yellow, black), 12
Cognitive image analysis, 84
Color Dodge function, 109–110
Color filter arrays, 99–101
Color(s)
  accuracy, 526
  balance, 550–551
  checker, 537
  controlling, 537–538
  in documentation of interpersonal violence findings, 559, *560*
  in injury photography, 536–538
  management, 537–538
  rendition, 170–174
  unwanted, 538–539
  and white balance, 538
Commercial off-the-shelf (COTS) software, 80
Commonwealth of Virginia v. Robert Douglas Knight (1990), 115
Commonwealth v. John C. Best (1902), 114
Compact cameras, 25; *see also* Camera(s)
CompactFlash (CF) memory cards, 27–28
Complementary metal-oxide semiconductor (CMOS), 30
Composition, 35
Computational photography, 176–177
Computer-aided design (CAD), 654–656, 655
Computerized active autofocus, 145
Computerized passive autofocus, 145–148
Conspicuity, 209–210, 222
Contour maps, 477
Contrast, 35–36, 209–210, 442
Contrast detection autofocus, 148
Contusion, 132
Copy stand, 315
Corpse, 413; *see also* Autopsy photography; Crime scene photography
Courtroom displays, 648
  digital projectors, 653
  evidence camera systems, 652–653
  laser scanning technology, 657–658
  physical prints, 651–652
  3D animation, 654–656
  trial boards, 651–652
  video monitors, 653–654
Covert cameras, 25
Covert filming, 356
Crane failure, 481–483
Craniofacial growth and development, 620–623
  basic growth concepts, 620–622
  Bolton standards, 623, *623*
Creelman, D. Douglas, 106
Crew resource management (CRM), 462
Crime scene photography, 405–422
  blood evidence, 416–418
  case study, 418–421
  crash scenes, 423–434
  crime scene processing, 408–409
  evidence markers, *411*
  evidence types, 410–412
    shoe prints, *410*, 410–412, *411*
    tire tracks, *412*, 412
  Federal Evidence Rules 901 and 1001, 407
  fire scenes, 423–434
  homicide scene, 412–415
    body fluids, 414
    evidence collection, 414
    fingerprints, 414–415
    photography of the corpse, 413
    trace evidence, 414
  imaging sequence, 407–408
  metadata, 406–407
  original files, 407
  photo log sheet, 407–408
  photogrammetry, 435–443
  photographs as evidence, 406
  scene types, 410
  scientific method, 408
Crop factors, **169**, 169–170
Crop tool, 73–74, 76
Cross v. U.S. (1998), 120
Cross-examination, 645
Cross-polarization, 543–544, *545*, *546*
Cube-tent box, 316
Cutting marks, 131

D

Da Vinci, Leonardo, 181
Daguerre, Louis Jacque Mande, 3
Damp objects, 609
Data backups, 602
Data integration, 14
Data integrity, 14
Daubert standard, 643–644
DaVinci Resolve, 503
De Toth, Andre, 182
Decompression chamber, 505
Decompression illness (DCI), 505
Deep field photomacrography, 187–189
DeFrance, Charles, 305
Dental mirror, *42*, 601–602, *602*
Depth-of-field (DOF), 30–31, 35, 142
  in crime scene photogrammetry, 442
  elements of, 152–153
  footwear photographs, 125
  in injury photography, 518–520, 524, 541–542, 551–553
  in macrophotography, 244
Derringer handgun, 303–308
Detection Theory, A User's Guide (Macmillan and Douglas), 106
Dew point, 33
Diffused flash, 294–297
Digital evidence, storage, 20–21
Digital images
  calibration, 69–79
  categories of, 11
  digital quality versus film quality, 159
  formats, 11–12, 59–60
Digital imaging, 1
  history of, 56–57
  legal ramifications, 113–118
  standards, 58
Digital light processing (DLP), 653
Digital night photography, 214
Digital projectors, 653
  DLP, 653
  LCD, 653
  LED, 653
  screen versus wall, 653
  throw ratio, 653
  wired versus wireless, 653
Digital zoom, 30
Direct examination, 645
Disaster mortuary operational response team (DMORT), 402
Dispersed flash, 294–297
Distance to object, 440–441
Distortion
  correction, 31, 70–72, 260
  identification, 70–72
Dive profile, 505
Dive team, 495–497; *see also* Underwater photography
  entanglements, 497
  injuries, 497
  safety, 497
  team roles and duties, 495–497
  training, 497
Diving conditions, 497–499; *see also* Underwater photography
  cold water, 498
  contaminated water, 498
  currents, 497–498
  low visibility, 499
  tides, 497–498
  weather, 497–498
  working at depth, 498
DJI Mavic 2 Pro, 472
Documentation images, 11
Documents, 313–336
  digital examination of, 328–336
  forensic document examination, 313–314
  handwriting photography, 314–316
  original versus nonoriginal documents, 313–314
  and PDF, 325–336
Dodge and Burn tool, 118
Downsampling, 95–96
Doyle, Arthur Conan, 2, 4
Drone photography, 459–479; *see also* Aerial photography
  benefits of, 475–479
  FAA requirements, 460–464
  for forensics, 468–473
  learning to fly drone safely, 464–468
  ortho-image, *470*
  practical considerations, 459
  rules of engagement in, 459–460
  single aerial establishing image., *470*
DSLR cameras, 25, 510; *see also* Camera(s)
  hand-holding, 140, *141*
  housing, 376
  image sensors, 91–92, 142–143
  in injury photography, 535
Duckworth, John, 4, 215
Ducos du Hauron, Louis Arthur, 189–191
Ductile fractures, 53
Duplicate
  admissibility, 422
  definition of, 422
Dust footprints, 127–128
  electrostatic dust lifter, 127
  gel lifters, 127–128
  lift preservation, 128
  photographic documentation, 127
  Stat-Lift, 128
Dycam Model 1, 57
Dynamic marks, 131
Dynamic range, 158–159

E

Edison, Thomas, 2
Electromagnetic radiation, 388
Electromagnetic spectrum, 388
Electromagnetic wave, 388
Electromagnetic wavelengths, 316–317
Electronic flash units (EFUs), 208–209, 258–259
Electronic speed controllers (ESCs), 465; *see also* Drone photography
Electronic viewfinders, 351
Electrostatic dust lifter, 127
ELMO, 652
Emergency response team (ERT), 402–403
Entomological photography, 581–597
  blow flies, 587–591
  current status, 597
  distinguishing insects from noninsects, 591
  documenting temperature in indoor cases, 595
  and forensic entomologists, 583–587
  general procedures, 584–587
  macrophotography, 592–595
  presenting photographic and tabular evidence in court, 595–597
  scales in, 592
Evidence
  authentication, 421–422
  collection, 414
  documenting, 13–14
  Federal Rules of Evidence, 421–422
  identification, 421
  painting with light, 235–237
  spoliation, 42
Evidence camera systems, 652–653
Evidence photography
  scales for, 262–265
  scientific method, 49
Evidentiary images, 11
  categories, 92–93
  digital processing, 85–89
Excavation, 607
EXchangeable Image File format (EXIF) data, 106
Exhumation, 609–610
Existing-light photography, 210–211, 230–231
Expert witness, 643–648
  "illusory" expert testimony, 121
  and attorney, 646–647
  Daubert standard, 643–644
  definition of, 643
  ethical considerations, 646
  forensic photographer as, 648
  legal framework, 643–644
  testimonies, 644–646
Exploded shotgun, 265–266, *266*
Explosions, 515–516; *see also* Fire and explosion photography
Exposure
  basics, 524
  compensation, 154
  determining, 158
  in documentation of interpersonal violence findings, 559
  overexposed images, 156
  triangle, 524–525
  underexposed images, 156
  values, 524
Exposure compensation, 154
Exposure values (EVs), 153
Extension bellows, 246–248
Extension tubes, 245, *245*
External flash cameras, 531–532
Extrinsic aging, 623–624
Eye
  versus the camera, 220–221, *221*
  spectral sensitivity, 221

F

Face; *see also* Facial analysis
  components of, **614**
  landmarks, **614**
  postmortem depiction, 632–633
Facial aging, 623–627, 624–627
  in adulthood, 626–627
    later adulthood, 626
    middle age, 626
    old age, 627
    young adulthood, 626
  basic concepts, 623
  full maturation of nasal measurements, **625**

full maturation of orbital measurements, **625**
hard and soft tissue age-related changes, 627
in juveniles, 524–526
Facial analysis, 612–618
anthropometrical analysis, 613–618, *615*
categories of images, 612
comparison scale, **613**
facial components, **614**
facial indices, **617**
facial landmarks, **616**
morphological analysis, 612–613
superimposition, 617–618
Failure mechanism, 53
Fair and accurate representation, 11–15
Falls, 368–369
Farber, Eugene, 218
Far-infrared, 389, 390
Fast Fourier transform (FFT) filter, 80
Fast Fourier transform (FFT), 120
Federal Rules of Evidence
Rule 1001-04, 15
Rule 702, 15
Rule 901, 15
Fehring, Dawn, 115
Field of view, 169
Field photography, 510–514
architectural, structural, and/or design features, 512
contents, 513–514
doors, windows, and vents, 512
electrical components, wiring, and arc mapping, 513
exterior, 510–511
fire detection and protection system, 512–513
interiors, 512
key identifiers, utilities, and access, 512
title, 510–514
Field training officer (FTO), 18
Field training program, 18
Field/accident scenes, 367–385
case studies, 376–385
documentation of inspection, 383–385
trip and fall incident, 376–380
victim recovery, examination, and identification, 380–382
close-up views, 372
environmental documentation at traffic crash, 370–371
incident site photography, 369
macro views, 372
mass casualty incident/multicasualty incident photography, 374–375
mid-range views, 372
overall views, 371–372
overall views, 372
photographic documentation, 367–368
scene photographic documentation, 371–372
slip, trip, and fall incidents, 368–369, 376–380
traffic crash photography, 369–370
traffic crash reconstruction photography, 373
vehicle photographic documentation, 372–373
Files
electronic transfer, 110–111
hard copies, 110–111
sharing, 110–111
Film quality versus digital quality, 159
Final Cut Pro, 503
Fingerprints
collection, 416
at crime scene, 414–415
development, 415
documentation, 416
fuming, 416
identification, 416
latent, 415
mobile fingerprint scanner, 416
molded, 415
patent, 415
plastic, 415
searching for, 415
types of, 415
Fire and explosion photography, 507–516
basics of fire, 507–508
black-and-white images, 514
documentation during fire events, 509
equipment, 509–510
cameras, 510
lenses, 509
macro lens, 509–510
zoom lens, *509*, 509
explosions, 515–516
fatalities and injuries at fire scenes, 569–570
field photography, 510–514
architectural, structural, and/or design features, 512
contents, 513–514
doors, windows, and vents, 512
electrical components, wiring, and arc mapping, 513
exterior, 510–511
fire detection and protection system, 512–513
interiors, 512
key identifiers, utilities, and access, 512
title, 510–514
National Fire Protection Association (NFPA) Standard 921, 509
panoramic and 360-degree images, 514
role in documentation, 507–508
temperature-adjusted photographs, 514
tinted images, 514
vehicles, 514
Fire triangle, *508*
Firearms photography, 133–135, 285–288, 294–297
ballistic comparison, 298–300
editing photographs, 299–300
photos from negative results, 299
Booth Derringer handgun, 303–308
camera stability, 293
digital editing, 297–298
distance, 293–294
documentation, 134, *135*, 290–303
flashes, 294–297
focusing, 293–294
framing, 293–294
using scales in, 290–292
Fixed focal-length lenses, 29
Fixed lens cameras, in handwriting photography, 315
Fixed location surveillance, 337, 339–340; *see also* Surveillance photography
Flash burn, 609
Flashes; *see also* Lighting
on-camera, 539
diffused, 294–297
dispersed, 294–297
in firearm and toolmark photography, 294–297
in forensic odontology, 600
modes, 539
multiple, 540
off-camera, 539
Flat lighting, 530–531
Flight Standards District Office (FSDO), 462
F-number/f-stop, 152
Focal length, 28
in crime scene photogrammetry, 442
fixed, 29
in injury photography, 527–528
normal, 28–29, *29*
Focus distance, 550
Focusing, 142–148
computerized active autofocus, 145
computerized passive autofocus, 145–148
contrast detection autofocus, 148
depth of field, 142
in documentation of interpersonal violence findings, 559
hyperfocal, 144–145
in injury photography, 527–528
manual focus, 142
phase detection autofocus, 148
sensor size, 142–143
visual acuity, 142
Foldable masonry ruler, *292*
Footwear impression
dust footprints, 127–128
electrostatic dust lifter, 127
gel lifters, 127–128
lift preservation, 128
photographic documentation, 127
Stat-Lift, 128
footprints in other medium
blood, 128
oil or grease, 128
snow, 128
water, 128
footprints, definition, 124
overview, 122–123
photographic documentation of, 124–127
required equipment, 125
three-dimensional casting, 126–127
three-dimensional photography, 125–126
two-dimensional photography, 126
Forensic anthropology and photography, 612–637
age progression analysis, 619–628
age-related facial changes, 624–627
craniofacial growth and development, 620–623
extrinsic aging, 623–624
facial aging, 623–627
facial changes in adulthood, 626–627
facial changes in juveniles, 524–526
facial head forms, 620, *621*
facial structure, 619–620
human face, 619
intrinsic aging, 623–624

facial analysis, 612–618
anthropometrical analysis, 613–618, *615*
categories of images, 612
comparison scale, **613**
facial components, **614**
facial indices, **617**
facial landmarks, **616**
morphological analysis, 612–613
superimposition, 617–618
postmortem depiction, 632–633
basic enhancements, 632
correcting facial injury in, 632–633
finishing touches, 633
photographing the dead, 632
3D facial reconstruction, 633–634
Forensic archaeology and photography, 605–610
body recovery, 609
darkness, 610
distinctions between colors of soil, 608–609
excavation, 607
formal exhumation, 609–610
glare and flash burn on damp objects, 609
large-scale searches, 607
neighboring graves, 610
outdoor crime scenes, 605–607
disorientation, 605–606
target visualization, 606–607
photographing into the grave, **607**, *607–608*, 607–608
Forensic art, 627
Forensic document examination (FDE), 313–314
Forensic engineers, 3
Forensic entomologists, 583–587
Forensic imaging
hardware, 79–80
software, 79–80
Forensic odontology, 599–604
antemortem records, 599
backing up data, 602
case study, 603–604
equipment, 599–604
ABFO No. 2 Scale, *601*, 601
cheek retractors, 601
dental mirror, 601–602, *602*
digital camera, 599–600
flashes, 600
photographs that should be made, 602
Forensic photographers, hiring, 6
Forensic photography
definition of, 659
described, 660–661
importance of, 659
online courses, 663
scene recording, 663
subjects, 662–663
teaching, 660–661
Foster and Freeman Video Spectral Comparator (VSC) series, 318, *319*
Fourier, Jean Baptiste, 120
Fractography, 53
Fractures, 52, 288
brittle, 53
ductile, 53
witness marks, 53
Fragmentary evidence, 47
Fredericks, Grant, 120
Fricke, Lynn, 215
Friction marks, 288
Front-surface mirrors, 42
Frye hearing, 117
Fuji-Film, 57
Fundamentals of Trial Techniques (Mauet), 652

G

Galton Francis, 57
Gamma rays, 389
Gel lifters, 127–128
Ghost photography, 3–4
Ghosting, 163–164
GIF, 640
Gilford, James J., 306–307
Gimbals, 436
Glare, 609
Glare box, 227–229, *228*
Global positioning system (GPS), 17, 393
Glossary, 665–695
Go-kits, 42–43
for traffic accidents, 43
what to pack in, 43
Google Earth Pro, 474
Google Inc., 475
Google Maps, 474
GoPro, 376, 503
Gorillapod, *37*
Gossen Luna-Pro exposure meter, *150*
Graphics processors, 81
Gray card, 151
Gripping, 288
Ground control points, 477
Gruppioni, Alice, 359

H

Half-pixel shifts, 171
Haloid Corporation, 56–57
Handgun casing markings, *266–267*, 266–267
Hand-holding the camera, 140–142
Handwriting photography, 314–316; *see also* Questioned documents
alternative light source equipment, 317–320
case studies, 321–322
copy stand, 315
cube-tent box, 316
fixed lens cameras, 315
image stabilizer, 315
light box, 316
lighting, 316
macro lens, 314–315
photomicrography, 323–325
point-and-shoot cameras, 315
scales, 315–316
scanning, 324–325
taking pictures in, 316
Hard drives, 502
Hardware, 79–80
Harris, James, II, 216
Harris, James, Sr., 216
Harris, Richard, 13
Hartman, Brett X., 117–118
Hash value, 14
Hayden, Eric, 117, 120
Health Insurance Portability and Accountability Act (HIPAA), 556
Heat release rate (HRR), 508
Hemorrhage, 132
Henry, Edward, 57
Hertz, 388
Heyer, Barbara, 119, 120
High dynamic range (HDR), 161–166
and admissibility, 162
ghosting, 163–164
histogram, 161–162
imaging, 162–164, *164–165*
RAW versus JPEG, 162
software, 163
High image quality, 92
Highlight details, retaining, 159
Histogram, 154–155, 161–162
RGB, 156–157, *157*
Hobley, Madison, 418–421
Holmes, Oliver Wendell, 181
Holmes, Sherlock (fictional detective), 2
Holohan, Robert, 216
Holshue, Dan, 115–116
Home-Cad scale, 263
Homicide scene, 412–415; *see also* Autopsy photography; Crime scene photography
body fluids, 414
evidence collection, 414
fingerprints, 414–415
photography of the corpse, 413
trace evidence, 414
Homicide, defined, 570
Horizontal field of view, 30
Houdini, Harry, 4
House of Wax (movie), 192
Hughes Aircraft Co. Laboratories, 391
Human capacity, 13
Human face, 619
craniofacial growth and development, 620–623
facial head forms, 620, *621*
facial muscles, *621*
facial structure, 619–620
Human vision, 4, 213–214, 316
Hunter Graphic Information Systems, 115
Hydrostatic inspection, 505
Hyperfocal focusing, 144–145
Hypothesis, 49
Hyzer, J.B., 217
Hyzer, William, 215, 216–217

I

IBM, 390
Identification card, 19
Ignition source, 508
Illuminance, 212–213, 219, 233
Image analysis, 81
cognitive, 84
quantitative, 84–85
Image capture, best practices for, 89–94
Image capture formats, 11–12, 59–60
best practices for, using digital camera, 91–92
Image enhancement, 87
Image file formats, 639–641
GIF, 640
JPEG, 639–640
PDF, 640–641
PNG, 640
RAW, 640
TIFF, 640
Image manipulation, 67–68, 76
Image processing
guidelines, 102

sequence, 102–105
capture, 102
duplicate, 103
process, 103–104
save, 104–105
storage, 102–103
Image rectification, 275–280
Image sensors, 30, 349–351
cleaning, 32
size, 68, 142–143, 169
Image size, 68–69
Image stabilization (IS), 140–141, 315, 442–443
Image-Pro, 57
Imaging software, 19–20
Immersive/virtual reality technologies, 191–192
iMovie, 503
Impression evidence, 121
bite mark impressions, 132–133
firearms and bullets, 133–135
footwear impression, 122–123, 124–128
indented writing, 135–136
tire impressions, 123, 128–130
toolmark impressions, 123–124, 130–132
Incident site photography, 369–370
Incident light metering, 151
Incision, 132
Increment weather photography, 33
Indanedione, 12
Indented writing, 135–136
Infrared, 389
Injury photography, 518–553
background, 536
best practices for, 520
camera settings and controls, 518–520
with cellphone cameras, 523–524
color accuracy, 526
color balance, 550–551
colors in, 536–538
composition and views, 535
depth of field, 541–542, 551–553
equipment, 526–527, 535
exposure in, 524–525
filling the frame in, 522
focal length in, 527–528
focus distance, 550
focusing in, 527–528
four levels or views, 520–522
close-up photographs, 521–522
mid-range photographs, 521
overall photographs, 520–551
initial documentation, 518–535
ISO noise, 548
lighting in, 525–526, 531–532, 538–541
perspective, 538
post processing, 535–536
proper composition, 522
specular highlights, 543–546
stability in, 523
techniques in, 532–534
having another person in the room, 532–533
putting it all together, 534–535
putting your subject at ease, 532
standard operating procedure, 533
workflow, 533–534
testing equipment, 546, 548–553
using what's in the bag, 546
viewer perspective in, 522–523, 528, 549–550
white balance, 550–551
INON strobe, 505
Insects, *see* Entomological photography
Inspection for auditing conditions, 481–494
bridge photography, 486–489
building collapse, 483–486
crane failure, 481–483
roadway accident, 490–494
Integrated Automated Fingerprint Identification System (IAFIS), 58
Integration Pilot Program (IPP), 460
Interferometry, 392
Internal flash cameras, 531
International Association of Identification (IAI), 6, 163
International Organization for Standardization (ISO), 17
Interpersonal violence documentation, 555–568
admissibility, 557
color in, 559, *560*
curved surfaces, *565*, 565
equipment, 558
evolving injuries, 567
exposure, 559
focusing in, 559
legal issues, 556
medical consent form, *568*
pre-project checklist, **561**
realism of images in, 559
redness, 566
scales in, 561–565, *562*
spot focus in, 566
spot metering in, 566
standard operating procedure, 558
utility of forensic images, 556
Intrinsic aging, 623–624
Inverse square law, 529–530
Isling, Kurt, 218
ISO, 152, 519
and aerial photography, 457
and injury photography, 518
in injury photography, 524
and low-light photography, 210
noise, 548–549
ISO/IEC 17025:2005, 80

J

Jennings, Thomas, 114
Jet Propulsion Laboratory (JPL), 102
Job/assignment identification card, 19
Jon line, 505
JPEG format, 11–12, 14–15, 60–62, 171–172, 639–640
artifacts, 111
and image quality, 92–93
versus RAW, 162

K

Kammerer, James, 118
Kelly-Frye hearing, 115
Kelvin color temperature, 170, 173
Kern, Thomas, 119
Kinect, 393
King, David, 218
Klein, Ernest, 216
Knight, Robert, 115
Kodak, 64

L

Lab Color mode, 101–102, 106
Laceration, 132
Large scene investigation, 399–404
aerial photography, 399
camera and kit, 399–400
personal safety equipment, 399
photographic protocol and/or guidelines for scene conduct, 400
safety considerations, 400
United Flight 93 crash site, 400–404
Laser
companies, 390–391
development, 390–391
history, 390
how it works, 391
military applications, 392
technologies, 391–392
uses of, 391
Laser rangefinders, 393
Laser scanning, 192, 388–397
black-and-white imagery, 396
color imagery, 396
Leica P-40 Scanstation, 397
and motion detectors, 393–395
point clouds, 395
professional uses of, 392–395
3-D modeling, 392–393
3-D reverse engineering, 397
X,Y,Z points, 395
Laser scanning technology, 657–658
LED/LED-lit monitors, 81
Legowik, John T., 305
Leica P-40 Scanstation, 397
Lens extension, 245
Lenses, 28–30, 509
accessory, 30
close-up, *244*, 244
equipment, rugged cameras, 510
fixed focal-length, 29
focal length, 28
macro, 250, 314–315, 509–510
prime, 443
screw-in, 244, *244*
telephoto, 168
zoom, 29–30, *509*, 509, *509*
Lenticular technologies, 189
LiDAR (light detection and ranging), 392–393
Light, 316–317, 389–390
Light box, 316
Light-emitting diode (LED), 526, 653
Light metering, 35
definition of, 149
equipment, 219
for exposure, 149–151
gray card, 151
incident light metering, 151
in low-light photography, 213, 219
matrix metering, 150
multizone metering, 151
at night, 211
reflected light averaging metering, 150–151
reflected light spot metering, 151
spot metering, 150
subject luminance, 149

through the lens, 149
types of, 213
Lighting, 35
alternative light source equipment, 317–320
alternative light sources, 316–325
on-camera flash, 539
covert filming, 356
diffused, 294–297
direction, 540–541
dispersed, 294–297
in firearm and toolmark photography, 294–297
flash modes, 539
in handwriting photography, 316
in injury photography, 525–526, 531–532, 538–541
intensity, 539
macrophotography, 250
multiple flashes, 540
off-camera flash, 540
in 3D forensic facial reconstruction, 634
in water and underwater photography, 500–501
Li-ion (lithium-ion) batteries, 27
Lincoln, Abraham, 303, 304, 306–307, 308
Lincoln, Robert Todd, 308
Line tool, 111
Linear Dodge function, 110
Linear polarizer filter, 543, 544
Liquid crystal display (LCD), 653
Litigation Animation, Inc., 359–364, 365
Locard exchange principle, 47
Locard, Edmond, 47
Locard's principle, 581
Loop, 86
Lossless compression, 111
Lost gas, 505
Low Altitude Authorization and Notification Capacity (LAANC), 464
Low image quality, 92
Low-light photography, 207–229
ambient light, 230–231
brightness, 224–226
capturing scenes in low light, 214–218
case studies, 219–220, 222, 227
conspicuity, 209–210
contrast, 209–210
digital night photography, 214
electronic flash units, 208–209
existing-light photography, 210–211, 230–231
and human vision, 213–214
illuminance, 212–213, 219, 233
and ISO, 210
light metering, 213, 219
luminance, 219
metering at night, 211
night photography, 210–212
night vision, 220
overview, 208
painting evidence with light, 235–237
perspective, 226
retroreflective light, 238–240
spectral sensitivity, 211–212
tips for, 211
Luco v. United States (1859), 113
Luke K. Blair v. Inhabitants of Pelham (1875), 114
Luminance, 219
Lung overexpansion injury, 505

M

Macmillan, Neil A., 106
Macro lenses, 250
in fire and explosion photography, 509–510
in handwriting photography, 314–315
Macrophotography, 168, 243–274
autoexposure, 251–256
axial lighting, 256–258
built-in flash, 254–255
case studies, 265–271
aircraft crash, *267–268*, 267–268
aircraft engine documentation project, *270–271*, 270–271
aircraft oil pump, *269*, 269–270
broken chair, *268*, 268
exploded shotgun, 265–266, *266*
handgun casing markings, *266–267*, 266–267
sealed beam, *269*, 269
close-up lenses, *244*, 244
depth of field, 244
extension bellows, 246–248
extension tubes, *245*, 245
lighting, 250
macro lenses, 250
magnification, 245–246
Nikon SB-29S Speedlight, 250
Nikon SB-R200 Remote Macro Flash, 250
oblique flash, 251–253
overview, 243–244
reversing rings, 248–250
scales, 259–265
Sigma macro flash, 250–251
for specific groups of insects or specific individual specimens, 592–595
tent lighting, 258–259
Maddox, Richard Leach, 4
Maggots, 588–590, 592–595
Magnification, 245–246
Maiman, Theodore, 391
Maintenance, 31–33
Manchester method, *635*, 635–636, *636*
Manfrotto locking camera plate, *39–40*
Manual focus, 142
Manual mode, 519–520
Mariner 4 spacecraft, 57
Marr, Bernard, 13
Maser, 390
Mason, Perry, 47
Mass casualty incident, 374–375
Mastro Almond v. the State of Georgia, 118
Mauet, Thomas, 652
Media Cybernetics Inc., 57
Media storage, 502
Medical consent form, *568*
Medium image quality, 92
Megapixels, 24
Memory cards, 351, 457
CompactFlash (CF), 27–28
erasing images from, 28
formatting, 28
Secure Digital, 28
in water and underwater photography, 502
Mesh creation, 443
Mesh files, 478–479
Message digest, 14
Metadata, 406–407
Microwaves, 389
Mirrorless cameras, 25, 535; *see also* Camera(s)
Mirrors, 42
Mobile fingerprint scanner, 416
Mobile surveillance, 337, 340–342; *see also* Surveillance photography
Modern vehicle graphics, 239
Monitors, 81
Monocular vision, *180*
Monopod, *40*, 559
Motion detectors, 393–395
Multicasualty incident photography, 374–375
Multiple flashes, 540
Multiple frequency phase shift, 392
Multiple jury monitors, 654
Multistroke marks, 131
Multizone metering, 151
Mumler, Richard, 3

N

Narcosis, 505
National Aeronautics and Space Administration (NASA), 102
National Fire Protection Association (NFPA) Standard 921, 509
National Institute of Standards and Technology (NIST), 20, 58
National Integrated Ballistic Information network (NIBIN), 289–290
Natural death, 570; *see also* Autopsy photography
Natural grid, 444
Nearest Neighbor resampling, 95
Neck organs, 579
Neural networks, 177
NGI (Next-Generation IAFIS) system, 105
Niepce, Joseph Nicephore, 3, 181
Night photography, 210–211
Night vision low-light photography, 220
Nikkor 18-70 zoom lens, *147*
Nikkor 60 mm macro lens, *147*
Nikkor 70-300G zoom, *147*
Nikon, 64
Nikon D70, image sensor, 142
Nikon D7500, 97
Nikon D810, 97
Nikon SB-29S Speedlight, 250
Nikon SB-R200 Remote Macro Flash, 250
NiMH (nickel metal hydride) batteries, 27
Ninhydrin print processing, 108–110
No-decompression limit, 505
Noise reduction filter, 80

O

Object Observation exercise, 3
Oblique flash, 251–253
Observation, 1–3
Off-camera flash, 539; *see also* Flashes; lighting
Olson, Paul, 217–218
On-camera flash, 539; *see also* Flashes; Lighting
Optical illusions, 105
Optical viewfinders, 351
Optical zoom, 39, 350
Organization capacity, 13
Original
definition of, 421–422
requirement of, 422
Orthographic imagery, 476–477
Overexposed images, 156

Overlap, 440, 443
Oxygen loading, 506
Oxygen toxicity, 506

P

Painting with light, 235–237
Paper cards, 264
Pattern evidence, 121
PDF documents, 325–327, 640–641
  definition of, 325
  degradation of digital images, 113
  and printing, 327–328
Pentax 1-degree spot meter, *150*
People of the State of New York, Respondent, v. Israel Rodriguez (1999), 118
People v. Perez, 118
Perry Mason effect, 47
Perspective
  correction, 226–227
  defined, 28
  disc, 444, *445*
  grid, 444, *444*
  optimizing, 36
  in technical investigations, 168–169
Peters, William, 305
Phase detection autofocus, 148
Photo Modeler, 475
Photogrammetry, 361–364
  10- to 15-degree incremental images, *437*
  blurring, 442
  capture at high resolution, 442
  contrast, 442
  crime scene, 435–443
  depth of field, 442
  distance to object, 440–441
  drone imaging, 475–476
  focal length, 442
  glossary, 442
  image stabilization, 442–443
  overlap and perspective, 440
  overlapping images, *437*
  panoramic style, *436*, *437*
  photo planning and capture, 436–440
  random textures, 442
  scaling and reference measurements, 440
  single-photo, 444–451
  3D model creation, 436
Photographic projects, 47–48
Photographs, 421
  checklist for making better, 34–36
  scientific storytelling with, 49
Photography
  brief history of, 3–5
  capacity for documenting evidence, 13–14
  definition of, 388
Photomicrography, 323–325
Photopills app, 223
Photoreceptors, 98–100
Physical prints, 651–652
Pick, 86
Pilot in command (PIC), 463
Pinching, 288
Pix4D Mapper, 436
Pixel shift, 171
Pixels, 25, 64–66, 106–107
Pixels per inch (PPI), 96–98
Platypod, *38*
PNG, 640
Point clouds, 395, 443
Point of critical focus (PCF), 552
Point of view, 35
Point-and-shoot cameras; *see also* Camera(s)
  hand-holding, 140–141, *141*
  in handwriting photography, 315
Polarizing film, 543, 544
Post-dive clean procedures, 506
Postmortem depiction, 632–633
  basic enhancements, 632
  correcting facial injury in, 632–633
  finishing touches, 633
  photographing the dead, 632
Postproduction, 357
Powell, George, III, 120
Preserve Details resampling, 95
Prime lens, 443
Print viewing distance, 144
Printed output, 66–67
Printers, 25
Print-ready files, 641
Procedure, 79
Program mode, 519
Projectors, 653

Q

Quantitative image analysis, 84–85
Questioned documents, 313–336
  digital examination of, 328–336
  forensic document examination, 313–314
  handwriting photography, 314–316
  original versus nonoriginal documents, 313–314
  and PDF, 325–336
Quincy M.E. effect, 47

R

Radiant energy, 388
Radio communication, 462
Radio waves, 389
Random textures, 442, 443
RAW file, 506
RAW format, 11, 14–15, 62–63, 162, 174–175, 640
Rear-surfaced reflectors, 42
Rechargeable batteries, 27
Recommendations, 32–33
Record keeping, 29
Recordings, 421
References
  ABFO No. 2 Bite Mark Standard Reference Scale, 260, *261*
  in crime scene photogrammetry, 440
  visual references, 36
Reflected light spot metering, 151
Reflectors, 238
Reliability, 118–120
Remote filming, 356–357
Remote surveillance, 338–339
Remotely operated vehicles (ROVs), 502
Repeatability, 80
Reproducibility, 80
Reproduction ratio, 245
Resampling, 94–96, 107
Rescue breath, 506
Resolution, 64–69, 83
  adjusting, 96–98
  downsampling, 95–96
  image manipulation, 67–68
  image size, 68–69
  monitor, 81, 107, 654
  pixels, 64–66
  printed output, 66–67
  and sampling, 94–95
  upsampling, 95–96
Retroreflective light, 238–240
Reverse engineering, 21, 397
Reversing rings, 248–250
Reyes, Victor, 119
RGB (red, green blue), 12
RGB histograms, 156–157, *157*
Ring method, 443
Roadway accident, 490–494
Rodd v. Raritan Radiologic Associates, 13, 117
Rokitansky method, 576
Rosati, Carlo, 305, *307*
Rotor blades, 457
Rugged cameras, 510
Ruler tool, 76–78

S

Savastano, George, 305
Scale invariant feature transform (SIFT), 443
Scales, 20
  in crime scene photogrammetry, 440
  in crime scene photographs, 592
  in documentation of interpersonal violence findings, 561, 561–565
  for evidence photography, 262–265
  in firearm and toolmark examinations, 290–292
  in forensic odontology, 601, *601*
  in handwriting photography, 315–316
  for macrophotography, 259–265
Scanners, 98–102
Scanning electron microscopy (SEM), 187
Scanning photomacrography, 187–189, *202–204*
Scars, *575*
Scene
  brightness, 224–226
  illumination, 223
Scientific documentation, 50–51
Scientific method, 46–47, 79
  in evidence photography, 49
  steps, 48–49
    collecting and analyzing the data, 48–49
    defining the problem, 48
    developing hypothesis, 49
    hypothesis testing, 49
    selecting final hypothesis, 49
  steps of, *2*
Scientific Working Group for Shoeprint and Tire Tread Evidence (SWGTREAD), 58
Scientific Working Group on Digital Evidence (SWGDE), 12, 58
Scientific Working Group on Friction Ridge Analysis, Study and Technology (SWGFAST), 58
Scientific Working Group on Imaging Technology (SWGIT), 11–12
  Category 1 and Category 2 images, 12
  guidelines, 58
  image authentication, 14
  image integrity, 14
Scratch marks, 288
Screw-in lenses, *244*, 244
Scuba, 499–500
Sealed beam, *269*, 269

Secure Digital (SD) memory cards, 28, 502
Secure hash algorithm (SHA), 14, 15
Sensor size, 142–143, 169
Serial number restoration, 301–303
SHA 256 hashing, 15
Shearing, 288
Shooting modes, 519–520
Shutter priority automation, 153–154
Shutter Priority mode, 519
Shutter speed, 153–154, 231, *232–234*, 518–519
Single blade/slicing, 288
Single-photo photogrammetry, 444–451
Size of camera, 25
Skaluba, George, 305
Sketches, 193–194
Skull, 619–620
  bones of, **620**
  front and side views, *620*
  photographic documentation of, 633–634
  positioning of, 634
  proportional comparison of fetal skull and adult, *623*
  reproducing, 634–635
Skull examination, 576–579
Slide rails, 185–186
Slips, 368–369
Small UAS Rule (14 CFR part 107), 459
Snipes, Wunda, 117–118
Snow photography, 33
Soft boxes, *535*
Software, 79–80
Software editing tools, 502–503
Spangler, Edrnan, 306–307
Special Authority for Certain Unmanned Systems (49 U.S.C. § 44807), 459
Spectral sensitivity, 211–212, 221
Specular highlights, 543–546
Spirit photography, 3–4
Spot focus, 566
Spot metering, 566
Standard development organization (SDO), 58
Standard operating procedures (SOPs), 17–21
  creating own, 58–59
  digital file storage, 20–21
  imaging software, 19–20
  job/assignment identification card, 19
  lack of unrelated images, 18–19
  mandatory things, 18–19
  record keeping, 29
  scales, 20
  standard set of required photos, 18–19
  training, 18
State of California v. Phillip Lee Jackson (1995), 5, 118
State of Connecticut v. Alfred Swinton, 87
State of Florida v. Victor Reyes (2001), 118–119
State of Ohio v. Brett X. Hartman (1997), 117–118
State of Washington v. Eric Hayden, 5
Static marks, 131
Stat-Lift, 128
Stephens, Gregory, 216
Stereo camera, 184
Stops, 153
Structure from motion, 443
Subject luminance, 149
Suicide, defined, 570
Surface interval, 506
Surveillance photography, 337–344
  aerial, 338, 453–458
  audio surveillance, 339
  fixed location, 337, 339–340
  mobile, 337, 340–342
  remote, 338–339
  vehicular, 337, 340–342
  video surveillance, 339
  walking, 338
  ways and means, 342–343
Surveillance videos, 339, 356
System requirements, 81

T

Tabletop miniature tripod, *37*
Talbot, William Henry, 181
Tattoos, *575*, 575
Technical investigations, 167–178
  brain clues in, 168
  color rendition, 170–174
  and computational photography, 176–177
  overview, 167–168
  perspective, 168–169
  spatial relationship of objects in, 168
  texture, 175–176
  tonal rendition, 174–175
Technology capacity, 13
Telephoto lens, 168
Tent lighting, 258–259
TerraServer.com, 474
Texas Forensic Science Commission, 120–121
Texture, 175–176, 443
3D animation, 654–656
3D forensic facial reconstruction, 633–637
  assessment of remains, 633
  avoiding distortion in, 634–636
  backdrops, 634
  digital, 635
  finishing touches, 636
  lighting, 634
  Manchester method, *635*, 635–636, *636*
  photographic documentation of skull, 633–634
  photographing the final reconstruction, 636–637
  positioning of skull, 634
  reproducing the skull in, 634–635
  tissue depth markers, *635*, 635
  versus 2-D approach, 637
3D photography, 179–196
  anaglyph imaging, 189–191
  beam splitter, 185
  case study, 194–196
  for document and display, 183–184
  history, 180–183
  laser scanning, 192
  lenticular technologies, 189
  methods of, 183
  overview, 179–180
  scanning electron microscopy, 187
  scanning photomacrography, 187–189
  sketches, 193–194
  slide rails, 185–186
  stereo camera, 184
  3D information for analysis, 193
  and 3-D movies, 182–183
  two matched cameras, 186–187
  virtual reality, 191–192
3D point clouds, 478–479
3-D reverse engineering, 397
3D Studio Max, 362
Through the lens (TTL) metering, 149
Throw ratio, 653
TIF (tagged image file) format, 11, 63–64, 92–93
TIFF, 640
Time of flight, 391–392
Time-date stamp, 351
Tire impressions; *see also* Toolmarks
  cast preservation, 130
  casting, 130
  class characteristics, 129
  definition of, 128–129
  individual characteristics, 129
  photographic documentation of, 129
Tissue depth markers, 635, *635*
Titanic, 52
Tonal rendition, 174–175
Tongue, 579
Tool, 79
Toolmarks; *see also* Tire impressions
  class characteristics, 130
  cutting marks, 131
  definition of, 130
  dynamic marks, 131
  impressions, 123–124, 130–132, 288
  individual characteristics, 131
  multistroke marks, 131
  photographic documentation, 290–303
    camera stability, 293, 293–294
    digital editing, 297–298
    distance, 293–294
    flashes, 294–297
    focusing, 293–294
    using scales in, 290–292
  photographic documentation of, 131–132
    cast preparation, 132
    cast preservation, 132
    casting, 132
    guide, 131–132
  scraping, 288–289
  serial number restoration, 301–303
  static marks, 131
  striation, 288–289
Topographic maps, 477
Trace evidence, 414
Traffic crash photography, 369–370; *see also* Field/accident scenes
  camera equipment, 370
  close-up views, 372
  environmental documentation, 370–371
  location identification and measurement equipment, 370
  macro views, 372
  mid-range views, 372
  overall views, 372
  parallel photographs, 371
  perpendicular photographs, 371
  reconstruction photography, 373
  safety equipment, 370
  scene photographic documentation, 371–372
  vehicle photographic documentation, 372–373
Traffic signs, 239
Training, 18
Transform function, 111
Transportation Security Administration (TSA), 462
Travel tripod, *37*
Trial boards, 651–652
Tripod, 37–41, 523, 559
  "spider," 37, *38*

attachments, 39
design options, 37–39
reasons for, 41
strength, 38
Trips, 368–369
2-D forensic facial reconstruction, 637
2-D representation, 4

U

U search pattern, 506
Ultraviolet, 389
Uncertainty, 57–58
Underexposed images, 156
Underwater photography, 495–506
case study, 505
creating successful images in, 503–504
composing images, 504
identifying subjects, 503
shooting in low visibility, 504
shooting vide, 504
dive team, 495–497
entanglements, 497
injuries, 497
safety, 497
team roles and duties, 495–497
training, 497
diving conditions, 497–499
cold water, 498
contaminated water, 498
currents, 497–498
low visibility, 499
tides, 497–498
weather, 497–498
working at depth, 498
equipment, 499–503
lights, 500–501
maintenance, 503
media storage, 502
peripheral, 502
photo and video equipment, 500
professional imaging equipment, 501
scuba, 499–500
software editing tools, 502–503
underwater remotely operated vehicles, 502
Underwater remotely operated vehicles, 502
United Flight 93 crash site, 400–404
United States v. Balzano (1982), 120
Unmanned aerial vehicle (UAV), 461, 465–466, 471
Unmanned aircraft system (UAS), 461
Unsharp Mask, 110
Upsampling, 95–96

V

Van Arsdale, Michael, 305
Vehicular surveillance, 337, 340–342
Victim recovery, examination, and identification, 380–382
Video depositions, 355
Video display cards, 81
Video documentation, 355–356
Video monitors, 653–654
multiple jury monitors, 654
resolution, 654
size, 654
Video RAM, 81
Video surveillance, 339, 356, 359–364
Videography, 345–357, 356
camcorders, 352
cellphones, 352–353
cinema video cameras, 352
covert filming, 356
event re-creation, 356
for forensics, 468–473
hardware, 348–351
high-speed imaging, 356
image sensors, 349–351, *350*
manual camcorder controls, 349
postproduction, 357
protocol, 353–354
remote filming, 356–357
software, 354–355, 357
video admissibility, 347–348
video depositions, 355
video documentation, 355–356
video surveillance, 356
versus video-graphy, 345–346
water and underwater, 500
Virchow method, 576
Virtual cloud, 20
Virtual reality, 191–192
Virtual reality (VR) cameras, 362–363
Visibility, 506
Visible light, 389
Visual acuity, 142
Visual Law Group, 655
Visual perception, 49
Visual references, 36
Visual storytelling, 45–54
and Locard exchange principle, 47
photographic projects, 47–48
with photographs, 49
scientific documentation, 50–51
scientific method, 46–47
Visualization, 5–6, 57
Vivid Color-Pix, 503
Voir dire, 645

W

Walking surveillance, 338
Warnings, 32–33
Water photography, 495–506
case study, 505
creating successful images in, 503–504
composing images, 504
identifying subjects, 503
shooting in low visibility, 504
shooting vide, 504
dive team, 495–497
entanglements, 497
injuries, 497
safety, 497
team roles and duties, 495–497
training, 497
diving conditions, 497–499
cold water, 498
contaminated water, 498
currents, 497–498
low visibility, 499
tides, 497–498
weather, 497–498
working at depth, 498
equipment, 499–503
lights, 500–501
maintenance, 503
media storage, 502
peripheral, 502
photo and video equipment, 500
professional imaging equipment, 501
scuba, 499–500
software editing tools, 502–503
underwater remotely operated vehicles, 502
Water tow, 506
Westinghouse Research Laboratories, 390
Wheatstone, Charles, 181
White balance, 526, 537, 550–551
Wide-angle lens, 168
Winnek, Douglas F., 189
Wirt, William (jurist), 2
WolfVision, 652
Wooden tripod, *38*
Writings, 421

X

Xerox Corporation, 56–57
XQD cards, 502
X-rays, 389

Z

Zarbeco MiScope series, 318, *319*
Z-cutter, 506
Zero compensation, 154
Zero-perspective imaging, 187–189
Zimet, Deborah, 119
Zinc chloride, 12
Zone system, 157–158
Zoom lenses, 29–30, *509*, 509
Zworykin, Vladimir Kosma, 182