Impression, Pattern and Trace Evidence Symposium

Forensic Technology
CENTER OF EXCELLENCE

A program of the National Institute of Justice

NIJ | National Institute of Justice

STRENGTHEN SCIENCE. ADVANCE JUSTICE.

January 22–25, 2018

Renaissance Arlington Capital View Hotel

Arlington, Virginia

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Hello 2018 IPTES Attendees!

Welcome to the second annual Impression, Pattern, and Trace Evidence Symposium (IPTES) hosted by the National Institute of Justice and coordinated by its Forensic Technology Center of Excellence at RTI International. On January 22–25, 2018, hundreds of attendees will join us in Arlington, Virginia, to discuss advances and recent discoveries in the forensic sciences and how the forensic sciences aid in criminal investigations.

The IPTES was designed to bring together practitioners and researchers to enhance information sharing and promote collaboration among impression, pattern, and trace evidence analysts, law enforcement, and legal communities. The planning and steering committees have worked with great effort to bring you 13 compelling workshops over Monday and Tuesday, followed by two full days of scientific sessions: two keynote addresses, three plenary sessions, two open panel discussions, 30 posters, and 48 oral presentations—totaling over 100 presenters.

This year our special keynotes include Wednesday's address by Supervisory Special Agent Richard Marx of the FBI Evidence Response Team, sharing his expertise on "Forensic Science in a Mass Casualty Event (How Forensic Science Help Solved the Case)." Our Thursday keynote will be given by Adam Benforado, Professor of Law at Drexel University and book author, speaking on the subject of his best seller "Unfair: The New Science of Criminal Injustice."

Stakeholders of the criminal justice system continuously need venues such as this to share scientific developments that result from research, advances in forensic practice and operational management, and policy improvements. We are elated that this week has come as the information sharing, networking, dialogue, and opportunities that will ensue are sure to make this a memorable event for all attendees. In the name of impression, pattern, and trace evidence—Let's begin!

Respectfully,

Jeri D. Ropero-Miller, PhD, F-ABFT
Director
Forensic Technology Center of Excellence
Center for Forensic Sciences, RTI International

Gerry LaPorte, MSFS
Director
Office of Investigative and Forensic Sciences
National Institute of Justice

Directors

Jeri D. Ropero-Miller

Dr. Jeri Ropero-Miller is a Principal Investigator (PI) and Director for RTI International's Center for Forensic Sciences. She is a Board-certified Forensic Toxicologist with Fellow status in the American Board of Forensic Toxicology (F-ABFT). Dr. Ropero-Miller has more than 20 years of experience conducting research in forensic toxicology, drug surveillance, and hair drug-testing studies. She has led projects that focus on professional development and training, laboratory efficiency, technology transition, technology evaluation, databases, and program monitoring and evaluation. Prior to her tenure with RTI, she served as the Deputy Chief Toxicologist at North Carolina's Office of the Chief Medical Examiner. She is currently on the Board of Directors for the ABFT and the American Academy of Forensic Sciences (Secretary). She is a member of the Society of Forensic Toxicologists, the International Association of Forensic Toxicologists, the American Society of Crime Laboratory Directors, the International Association of Chiefs of Police, and the Toxicology Subcommittee of the National Institute of Standards and Technology (NIST) Organization of Scientific Area Committees (OSAC). She served leadership roles for the Scientific Working Group for Forensic Toxicology, the NIST OSAC, the Chemistry/Instrumental Analysis Scientific Area Committee, and as a Laboratory Inspector for ABFT and for the National Laboratory Certification Program.

Gerry LaPorte

Mr. Gerald (Gerry) LaPorte serves as the Director in the Office of Investigative and Forensic Sciences at the National Institute of Justice (NIJ), whose mission is to improve the quality and practice of forensic science through innovative solutions that support research, development, technology, evaluation, and information exchange for the criminal justice community. His primary duties are to oversee the management of over $400 million in grants and provide expert analysis and advice on agency-wide programs and issues of national impact relating to forensic science. Mr. LaPorte has been employed in various capacities in the forensic sciences since 1993, and prior to joining NIJ, he was the Chief Forensic Chemist at the United States Secret Service. Mr. LaPorte received his Bachelor of Science and Bachelor of Commerce in Business Administration from the University of Windsor in Canada and his Master of Science in Forensic Science from the University of Alabama at Birmingham. He is a member of the American Academy of Forensic Sciences, Mid-Atlantic Association of Forensic Scientists, American Society of Questioned Document Examiners, and the American Bar Association – Criminal Justice Section. Mr. LaPorte has conducted over 100 lectures, seminars, and training events in 13 different countries for law enforcement agencies, professional organizations, and technical experts. He has more than 20 publications, including chapters in three text books, and his lectures and workshops have related to the analysis of questioned documents and forensic science policy. He is a member of various organizations and served as the co-chair for the Standards Practices and Protocols Interagency Working Group under the Executive Office of the President of the United States and on the National Commission on Forensic Science until its close in 2017.

IPTES Coordinators

Nicole Jones

Ms. Nicole Jones is the Associate Director of the Center for Forensic Sciences (CFS) at RTI International. She has more than 20 years of experience in chemical analysis, quality systems management, and quality assurance, including 10 years of experience working with the National Laboratory Certification Program (NLCP) and as a laboratory inspector. She has also served as the Program Coordinator for CFS and as the Project Manager of the Forensic Science Technology Center of Excellence, which is a cooperative agreement with the National Institute of Justice (NIJ).

Ms. Jones is responsible for evaluating CFS-supported U.S. Department of Justice (DOJ) grant activities, including technology evaluation, technology assistance, and technology transfer. In this role, she serves as a liaison between state, local, and federal law enforcement; NIJ; and the research community. In support of these efforts, she has convened expert panels in the areas of crime scene and medicolegal death investigation, impression and pattern evidence, instrumental analysis, non-standard DNA, standard DNA, optical topography, and the laboratory directors working group for strengthening forensic science services. These working groups reviewed current technologies, identified research gaps, and developed strategic plans to strengthen NIJ's forensic programs and the criminal justice community; Ms. Jones has developed guidelines and published reports and proceedings in support of these efforts. She received a Bachelor's degree in Forensic Chemistry from Ohio University and a Master's degree in Criminal Justice Administration with an emphasis in Forensic Science Administration from Loyola University.

Erica Fornaro

Ms. Erica Fornaro is a Senior Project Management Specialist in the Center for Forensic Sciences (CFS) at RTI International. In this capacity, she assists with managing contractual compliance issues; developing resolutions to meet productivity, quality, and client-satisfaction goals; coordinating outreach; and developing marketing for multiple projects within CFS. She works daily with clients, RTI employees, project teams, and contractors to develop and manage project timelines, schedules, and deliverables.

Ms. Fornaro manages commercial and government projects, which include the Forensic Technology Center of Excellence, funded by the National Institute of Justice (NIJ), and the Bureau of Justice Assistance Sexual Assault Kit Initiative – Training and Technical Assistance Cooperative Agreement funded by the Bureau of Justice Assistance (BJA), RTI Forensics Training Program, and RTI Breath Alcohol Certification Program. As a Senior Project Management Specialist for these and other projects at RTI, Ms. Fornaro serves as the knowledge transfer coordinator, which includes managing the organization, development, practice, administration, and maintenance of new and existing educational development, practices, dissemination methods, media, community events, outreach, and the progression of the project. She collaborates with technical and design teams to fulfill contractual requirements and serves as key staff in negotiations and implementation of new software used in RTI collaborative webcasting resources.

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FTCoE Leadership Series

Every forensic science professional is a leader. Our society relies on the credibility and fairness of the criminal justice system. Forensic scientists play an important and fundamental role in the criminal justice community and are key to keeping our communities safe.

Therefore, the FTCoE developed an online forensic leadership series that discusses innovation, standards, ethics, and organizational excellence.

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Funding for this series provided by NIJ award number 2016-MU-DX-K110

Instructors

- Terry Anderson
- Dean Gialamas
- Timothy Scanlan
- Jeremy Triplett
- Jody Wolf

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- Generations
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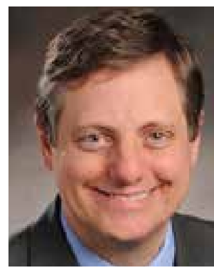
Learn More at the FTCoE website:
www.ForensicCOE.org/leadership-series

Recording Live in Salon 4 and at Wednesday's Panel Discussions



Hosted by Dr. John Morgan and Produced by Lauren Mangum

RTI International's Center for Forensic Science presents Just Science, a podcast for forensic science professionals and anyone with an interest in learning more about how real crime laboratories are working to do their job better, produce more accurate results, become more efficient, and solve more crimes. This podcast deals with a range of issues, including leadership in the crime lab, new technologies, sexual assault response, and broader challenges for science and public security. We cover every type of forensic discipline, including DNA, fingerprints, trace evidence, toxicology, controlled substances, crime scene investigation, and much more! **#JustScience**

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NIJ is the federal government's lead agency for forensic science research and development as well as the administration of programs that facilitates training, improves laboratory efficiency and reduces backlogs. The mission of NIJ's Office of Investigative and Forensic Sciences is to improve the quality and practice of forensic science through innovative solutions that support research and development, testing and evaluation, technology, information exchange, and the development of training resources for the criminal justice community.

Through the research, development, testing, and evaluation process, we provide direct support to crime laboratories and law enforcement agencies to increase their capacity to process high-volume cases and provide needed training in new technologies. With highly qualified personnel and strong ties to the community, NIJ's Office of Investigative and Forensic Sciences plays a leadership role in directing efforts to address the needs of our nation's forensic science community.

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RTI International and its academic- and community-based consortium of partnerships work to meet all tasks and objectives for the Forensic Technology Center of Excellence (FTCoE), put forward under the National Institute of Justice (NIJ) Cooperative Agreement No. 2016-MU-BX-K110.

RTI INTERNATIONAL

The FTCoE is led by RTI International, a global research institute dedicated to improving the human condition by turning knowledge into practice. With a staff of more than 5,000 providing research and technical services to governments and businesses in more than 75 countries, RTI brings a global perspective. The FTCoE builds on RTI's expertise in forensic science, innovation, technology application, economics, DNA analytics, statistics, program evaluation, public health, and information science.

This forum is funded through a cooperative agreement from the National Institute of Justice (2016-MU-BX-K110), Office of Justice Programs, U.S. Department of Justice. Neither the U.S. Department of Justice nor any of its components operate, control, are responsible for, or necessarily endorse, this forum. The opinions, findings, and conclusions or recommendations expressed in this forum are those of the presenter(s) and do not necessarily reflect those of the Department of Justice. Any products and manufacturers discussed are presented for informational purposes only and do not constitute product approval or endorsement by the U.S. Department of Justice.

Agenda

Short Agenda

Monday, January 22

8:00–12:00	Workshop Sessions
12:00–1:00	Lunch (on your own)
1:00–5:00	Workshop Sessions

Tuesday, January 23

8:00–12:00	Workshop Sessions
12:00–1:00	Lunch (on your own)
1:00–5:00	Workshop Sessions

Wednesday, January 24

8:00–8:05	Welcome — Jeri Ropero-Miller
8:05–8:15	Opening Remarks — Gerald LaPorte
8:15–8:30	DOJ's Support of Forensic Science — Ted Hunt
8:30–9:30	Keynote Address — Richard Marx
9:30–9:45	Break
9:45–12:00	Statistics Panel
12:00–1:20	Lunch (on your own)
1:20–3:20	Statistics and Testimony from the Practitioner and Juror Point of View Panel
3:20–3:50	Break
3:50–5:10	Breakout Sessions (Impression and Pattern/Trace Evidence)
5:10–6:30	Poster Session and hot cocoa bar provided (compliments of the hotel)

Thursday, January 25

8:00–9:40	Breakout Sessions (Impression and Pattern/Trace Evidence)
9:40–10:00	Break
10:00–12:00	Breakout Sessions (Impression and Pattern/Trace Evidence)
12:00–1:30	Lunch (on your own)
1:30–3:30	Breakout Sessions (Impression and Pattern/Trace Evidence)
3:30–3:50	Break
3:50–4:50	Closing Keynote Address — Adam Benforado
4:50–5:10	Closing Remarks— Department of Justice

The posters will be available for viewing in the Pre-function Area from 1:30pm on Wednesday, January 24, 2018 until 3:30pm on Thursday, January 25, 2018.

Registration Hours

Monday, January 22

7:00am–5:00pm

Tuesday, January 23

7:00am–5:00pm

Wednesday, January 24

7:00am–12:00pm

#IPTES2018

Full Agenda

| Monday, January 22 | (Workshops)

1/22/2018	Salon 2	Studio E	Salon 1	Studio B	Studio D	Studio A
8:00–12:00	**Statistical Interpretation Software for Friction Ridge Skin Impressions (FRStat) Workshop** Henry Swofford, MS, and T.M. Wortman, BS, U.S. Army Criminal Investigation Command	**Implementation of 3D Technology, Analysis, and Statistics for Firearm and Toolmark Examinations** Xiaoyu Alan Zheng, MS, Thomas Brian Renegar, PhD, Michael Stocker, BS, Johannes Soons, PhD, National Institute of Standards and Technology; Ryan Lilien, PhD, Cadre Research; Erich Smith, MS, FBI	**Intra- and Inter-Variability of Footwear Test Impressions: An Inter-Active Workshop** Chris Hamburg, BS, Oregon State Police Forensic Services Division, Portland Metro Laboratory; Jeff Jagmin, BS, Supervising Forensic Scientist, WSP Crime Laboratory Division, Seattle Laboratory	**Probabilities and Likelihood Ratios in Pattern Evidence Evaluation** Steven Lund, PhD (Statistics), and Hari Iyer, PhD (Mathematics), National Institute of Standards and Technology	**Forensic Wood Identification** Larry Peterson, BS, Georgia Bureau of Investigation (Retired) and U.S. Army Criminal Investigation Laboratory (Retired)	**Applied Polarized Light Microscopy for Trace Evidence Examiners - Day 1** Andrew Bowen, MS, U.S. Postal Inspection Service Sebastian Sparenga, MS, McCrone Research Institute
12:00–1:00	**LUNCH (on your own)**					
1:00–5:00	Session continues	Session continues	Session continues	Session continues	Session continues	Session continues

| Tuesday, January 23 | (Workshops)

1/23/2018	Salon 1	Salon 5	Salon 2	Salon 6	Studio C	Studio A
8:00–12:00	**3D Footwear and Tire Tread Impression Capture** Song Zhang, PhD, Purdue University; James Wolfe, MS, Consulting Forensic Scientist; David P. Baldwin, PhD, Special Technologies Laboratory, U.S. Department of Energy/ National Nuclear Security Administration	**No More Either Or: Working Together to Solve Compatibility Issues Between Impression Enhancement and DNA Analysis** Jessica Zarate, MS, and Jodi Lynn Barta, PhD, Madonna University	**Fracture Examinations Workshop** John R. Vanderkolk, BA, Indiana State Police Laboratory	**Foundations of the Interpretation of Pattern and Trace Evidence (Source and Activity Levels)** Patrick Buzzini, PhD, Sam Houston University; Norah Rudin, PhD, Forensic DNA Consultant; Keith Inman, PhD, California State University East Bay; Glenn Langenburg, PhD, Elite Forensic Services, Inc.; Cedric Neumann, PhD, Two Ns Forensics, Inc.	**Chemometrics Without Equations for Forensic Scientists** Donald Dahlberg, PhD, Lebanon Valley College Brooke W. Kammrath, PhD, D-ABC, The University of New Haven	**Applied Polarized Light Microscopy for Trace Evidence Examiners - Day 2** Andrew Bowen, MS, U.S. Postal Inspection Service Sebastian Sparenga, MS, McCrone Research Institute
12:00–1:00	LUNCH (on your own)					
1:00–5:00		**Analyzing Interactions of Latent Prints with Blood** Nicole Praska, MLS(ASCP), University of Minnesota Twin Cities; Carey Hall, MLS, CLPE; Sandra Day O'Connor College of Law at Arizona State University	**Expert Assisting Computerized System for Evaluating the Degree of Certainty in 2D Shoeprints** Sarena Wiesner, MS, Head of Questioned Documents Lab, Department of Identification Forensic Science, Israel Police; Yaron Shor, MS, Toolmark	Session continues	Session continues	Session continues

| Wednesday, January 24 | (Sessions)

Wednesday, January 24 — Salon 1–7	
	Keynote and Plenary Sessions—Moderated by Nicole Jones, MS, RTI International
8:00–8:05	**Welcome** Jeri Ropero-Miller, PhD, F-ABFT, Director, FTCoE, Center for Forensic Sciences, RTI International
8:05–8:15	**Opening Remarks** Gerald LaPorte, MSFS, Director, Office of Investigative and Forensic Sciences, NIJ
8:15–8:30	**DOJ's Support of Forensic Science** Ted Hunt, JD, Senior Advisor to the Attorney General on Forensic Science, DOJ
8:30–9:30	**Keynote Address** **Forensic Science in a Mass Casualty Event (How Forensic Science Help Solved the Case)** Supervisory Special Agent Richard Marx, MS, FBI Evidence Response Team
9:30– 9:45 — BREAK	
	Statistical Approaches to Forensic Interpretation—Panel moderated by Jose Almirall, PhD, Florida International University, and John Morgan, PhD, RTI International
9:45–10:00	**Reality Check — What Is Expected from Expert Witnesses** Steven Lund, PhD, National Institute of Standards and Technology
10:00–10:15	**Challenges Faced by Experts When Communicating Forensic Evidence to Triers of Fact: A Statistician's View** Hari Iyer, PhD, National Insitute of Standards and Technology
10:15–10:30	**The Use of Similarity Measures (Scores) to Quantify the Weight of Forensic Evidence** Cedric Neumann, PhD, South Dakota State University
10:30–10:45	**Statistical Analysis in Forensic Science Evidential Value of Multivariate Data** Daniel Ramos, PhD, Universidad Autonoma de Madrid, Spain
10:45–11:00	**The Anatomy of Forensic Identification Decisions: Rethinking Current Reporting Practice in a Decision-Theoretic Perspective** Alex Biedermann, PhD, University of Lausanne
11:00–12:00	**DISCUSSION**

Wednesday, January 24 — Salon 1–7

12:00–1:20 — LUNCH (on your own)

Statistics and Testimony from the Practitioner and Juror Point of View—Panel moderated by Xiaoyu Alan Zheng, MS, National Institute of Standards and Technology, and John Morgan, PhD, RTI International

1:20–1:35	**Statistical Interpretation and Reporting of Fingerprint Evidence at the U.S. Army Criminal Investigation Laboratory** Henry Swofford, MS, U.S. Army Criminal Investigation Laboratory
1:35–2:05	**LR Testimony Cross-Examined** Hari Iyer, PhD, and Steven Lund, PhD, National Institute of Standards and Technology, and Chris Fabricant, JD, Innocence Project
2:05–2:20	**Factors Which Influence Juror's Interpretation of the Value of Forensic Science Testimony** Alicia Wilcox, PhD, Husson University
2:20–3:20	**DISCUSSION**

3:20–3:50 — BREAK

	Impression and Pattern—Salon 1–4	Trace Evidence—Salon 5–7
	Moderated by Derrick McClarin, MSFS, FBI	Moderated by Vincent Desiderio, MSFS, U.S. Postal Inspection Service
3:50–4:30	**Status Update on the Development of a 3D Scanning and Analysis System for Cartridge Cases** Ryan Lilien, PhD, Cadre Research	**Developments in Particle Combination Analysis and Particle Combination Analysis in Footwear Investigations** David Stoney, PhD, Stoney Forensic, Inc.
4:30–5:10	**Fracture Mechanics-Based Quantitative Matching of Forensic Evidence Fragments: A) Methodology and Implementations and B) Statistical Framework** Ashraf Bastawros, PhD, and Ranjan Maitra, PhD, Iowa State University	**Location Detection and Characterization in Mixtures of Dust Particles** Madeline Ausdemore, PhD, South Dakota State University **Elemental Analysis of Adhesive Tapes as Forensic Evidence by LA-ICP-MS and LIBS** Claudia Martinez-Lopez, MS, Florida International University

5:10–6:30	**Poster Session** Hot cocoa bar provided (compliments of the hotel)

The posters will be available for viewing in the Pre-function Area from 1:30pm on Wednesday, January 24, 2018 until 3:30pm on Thursday, January 25, 2018.

| Thursday, January 25 | (Sessions)

Thursday, January 25		
	Impression and Pattern—Salon 1–4	**Trace Evidence—Salon 5–7**
	Moderated by Cedric Neumann, PhD, South Dakota State University	Moderatedy by Chris Taylor, BS, U.S. Army Criminal Investigation Laboratory
8:00–8:20	**The Evaluation of the Joint Value of Paint and Toolmark Evidence Using Bayesian Networks** Patrick Buzzini, PhD, Sam Houston State University	**Untangling the Relationship between Hair Microstructure and Ancestry** Sandra Koch, MS, Pennsylvania State University
8:20–8:40	**Implementing 3D Virtual Comparison Microscopy into Forensic Firearm/ Toolmark Comparison** Erich D. Smith, MS, FBI Laboratory, Firearms/Toolmarks Unit	**An Assessment of Head Hair Comparison via Protein Profiling** Joseph Donfack, PhD, Federal Bureau of Investigation
8:40–9:00	**"Congruent Matching" — Theory and Application in Forensic Image Identification** John Song, PhD, National Institute of Standards and Technology	**Instrumental Validation of a Scanning Electron Microscope with Energy Dispersive X-Ray Spectroscopy** Amy Reynolds, MA, Boston Police Department Crime Laboratory
9:00–9:20	**Estimating Error Rates of Firearm Identifications Using the CMC Method** Theodore Vorburger, PhD, National Institute of Standards and Technology	**Attenuated Total Reflection Infrared Microscopy and Charpy Impact Tester for Analysis of Automotive Paint Smears** Barry Lavine, PhD, Oklahoma State University
9:20–9:40	**Objective Comparison of Striated Toolmarks Produced from Ten Consecutively Manufactured Cold Chisels Measured by Contact and Optical Surface Profilometry and Comparison Microscopy** Robert Thompson, MSFS, National Institute of Standards and Technology	**Development of Infrared Library Search Prefilters for Automotive Clear Coats from Simulated ATR Spectra** Barry Lavine, PhD, Oklahoma State University
9:40–10:00 — BREAK		
	Impression and Pattern—Salon 1–4	**Trace Evidence—Salon 5–7**
	Moderated by Michael Gorn, MSFS, FBI	Moderated by Jeffrey Dake, MSFS, U.S. Army Criminal Investigation Laboratory
10:00–10:20	**Quantitative Methods for Forensic Footwear Analysis** Martin Herman, PhD, National Institute of Standards and Technology	**Further Persistence Studies of PDMS Condom Lubricants** Mickayla Dustin, BS, Institute of Environmental Science and Research

Thursday, January 25

10:20–10:40	**A Comprehensive Research on Shoeprints RACs** Yaron Shor, MS, Israel Police Department of Investigative Forensic Sciences	**Subpopulation of Fibres and Their Importance to Forensic Science** Cátia Pontedeira, MS, London South Bank University
10:40–11:00	**The Effects of a Prior Examiner's Status and Findings on Lay Examiners' Shoeprint Match Decisions** Nadja Schreiber Compo, PhD, Florida International University	**Comparison of Intra-Roll Subclass Characteristics in Polymer Films** Daniel Mabel, MS, Cuyahoga County Medical Examiner's Office
11:00–11:20	**Generalizing Across Forensic Comparative Science Disciplines** John Vanderkolk, BA, Indiana State Police Laboratory	**The Effect of Fingerprint Chemicals on the Chemical Analysis and Comparison of Duct and Cloth Tapes** Joanna Bunford, PhD, New South Wales Forensic and Analytical Science Service
11:20–11:40	**Sufficiency and Complexity Factors in Handwriting Examination** Cami Fuglsby, MS, South Dakota State University, and Linton Mohammed, PhD	**Integration of Pulp and Paper Fiber Microscopy into a Course on Forensic Paper Examination and Authentication of Historical Documents for Forensic Chemistry and Art Conservation** Douglas Ridolfi, MS, Buffalo State College
11:40–12:00	**Deep Learning in Handwriting Comparison** Sargur Srihari, PhD, University at Buffalo, The State University of New York (SUNY)	**Transfer and Persistence of Glass Fragments: Experimental Sudies Involving Vehicle and Container Glass** Tatiana Trejos, PhD, West Virginia University

12:00–1:30 — LUNCH (on your own)

	Impression and Pattern—Salon 1–4	Trace Evidence—Salon 5–7
	Moderated by Cary Oien, MS, FBI	Moderatedy by Sandra Koch, MS, Pennsylvania State University
1:30–1:50	**Using Eye Tracking to Understand Decisions by Forensic Latent Print Examiners** R. Austin Hicklin, PhD, Noblis, and JoAnn Buscaglia, PhD, FBI	**Swab Touch Spray Mass Spectrometry for Rapid Analysis of Organic Gunshot Residue from Human Hand and Various Surfaces Using Commercial and Fieldable Mass Spectrometry Systems** Patrick Fedick, BS, Purdue University
1:50–2:10	**Thematic Trends of Latent Print Examination Criticisms and Reports** Thomas Wortman, BS, U.S. Army Criminal Investigation Laboratory	**Evaluation of Field-Portable GC-MS with SPME Sample Collection for Investigator Use at Fire Scenes** John DeHaan, PhD, Fire-Ex Forensics, and Zachary Lawton, MS, PerkinElmer, Inc.

Thursday, January 25

2:10–2:30	**Statistical Error Estimation for an Objective Measure of Similarity to a Latent Image** Donald Gantz, PhD, George Mason University	**Forensic Sampling and Analysis from a Single Substrate: Surface-Enhanced Raman Spectroscopy Followed by Paper Spray Mass Spectrometry** Patrick Fedick, BS, Purdue University
2:30–2:50	**Occurrence and Utility of Latent Print Correspondences That Are Insufficient for Identification** David Stoney, PhD, Stoney Forensic, Inc.	**Identification of Organic and Inorganic Gunshot Residues by Electrochemical and Spectrochemical Methods** Tatiana Trejos, PhD, West Virginia University
2:50–3:10	**A Bayes Factor for Fingerprints, Using a Modified Approximate Bayesian Computation Approach** Jessie Hendricks, MS, South Dakota State University	**Instrumental Analysis of Gunshot Residue (GSR) – Reconstruction of Crime Scenes** Zachariah Oommen, PhD, Albany State University
3:10–3:30	**Assessing and Reducing Variability in Friction Ridge Suitability Determinations** Heidi Eldridge, MS, RTI International	**Evaluation of Error Rates in the Determination of Duct Tape Fracture Matches** Tatiana Trejos, PhD, West Virginia University

3:30–3:50 — BREAK

Closing Keynote and Remarks—Moderated by Nicole Jones, MS, RTI International

3:50–4:50	**Closing Keynote:** **Unfair: The New Science of Criminal Injustice** by Adam Benforado, JD
4:50–5:10	**Closing Remarks** Department of Justice

Workshops

| Monday, January 22 |

Salon 2 — Full Day

Statistical Interpretation Software for Friction Ridge Skin Impressions (FRStat) Workshop

H.J. Swofford, MS, Chief, Latent Print Branch; T.M. Wortman, BS, Latent Print Branch, United States Army Criminal Investigation Laboratory

Description: Over the last few years, USACIL has been taking incremental steps toward the development, validation, and implementation of FRStat, a software that facilitates the evaluation and reporting of the statistical strength of fingerprint evidence. Through a combination of lectures, group discussions, and practical exercises, this workshop will provide participants with the appropriate knowledge, skills, and abilities to establish a statistical foundation for latent print examinations using FRStat software to ensure that examinations are conducted and conclusions articulated in a more scientifically defensible manner.

Abstract: Over the years, the forensic science community has faced increasing criticism by scientific and legal commentators, challenging the validity and reliability of many forensic examination methods that rely on subjective interpretations by forensic practitioners. Of particular concern, as noted in 2009 by the National Research Council (NRC) of the National Academies of Science (NAS) and the President's Council of Advisors on Science and Technology (PCAST) as recently as September 2016, is the lack of an empirically demonstrable basis to substantiate conclusions from pattern evidence. As a result, the ability for the judiciary to reasonably understand the reliability of the expert's testimony for the given case is limited. Consistent with several academic commentators, both the NRC and PCAST strongly encouraged the forensic science community to develop tools to evaluate and report the strength of forensic evidence using validated statistical methods. While these concerns apply to nearly every pattern evidence discipline, the forensic fingerprint discipline has received most of the attention because fingerprint analysis is one of the most widely used techniques in the criminal justice system. As a result, over the last several years, numerous methods and models have been proposed to provide a statistical estimate of the weight of fingerprint evidence; however, none have been widely accessible to the forensic community, thus prohibiting their ability to be further evaluated or implemented in routine casework. Consequently, forensic science laboratories throughout the United States have been unable to adequately address the concerns raised by the NRC and PCAST by demonstrating the reliability of fingerprint evidence for the case at hand.

Over the last few years, USACIL has been taking incremental steps toward the development, validation, and implementation of FRStat, a software that facilitates the evaluation and reporting of the statistical strength of fingerprint evidence. In March 2017, USACIL implemented FRStat in routine casework and began reporting the statistical strength of fingerprint evidence within the military criminal justice system. Currently, FRStat is the only method known to be in operational use within the United States that provides

the capability to ensure that the strength of fingerprint evidence is evaluated against an empirically grounded basis.

Through a combination of lectures, group discussions, and practical exercises, this workshop will provide participants with the appropriate knowledge, skills, and abilities to establish a statistical foundation to latent print examinations using FRStat software to ensure that examinations are conducted and conclusions articulated in a more scientifically defensible manner.

Disclaimer: The opinions or assertions contained herein are the private views of the authors and are not to be construed as official or as reflecting the views of the United States Department of the Army or United States Department of Defense.

Studio E — Full Day

Implementation of 3D Technology, Analysis, and Statistics for Firearm and Toolmark Examinations

Xiaoyu Alan Zheng, MS, Thomas Brian Renegar, PhD, Michael Stocker, BS, Johannes Soons, PhD, National Institute of Standards and Technology; Ryan Lilien, PhD, Cadre Research; Erich Smith, MS, FBI

Description: This full-day workshop provides foundational knowledge and real-world applications of emerging research, tools, and automated technologies for firearm and toolmark (FA/TM) analysis. An overview of the direction and methodologies currently being employed in FA/TM research will be provided, as will future roles in which these technologies can be utilized. A case study will be presented on how the FBI Laboratory Firearms/Toolmarks Unit (FTU) has been evaluating, validating, and incorporating 3D technologies into casework and mapping out that challenges that laboratories could face with implementation. Attendees will also have an opportunity to participate in several Collaborative Testing Services (CTS) tests using virtual comparison microscopy to learn about its utility in everyday casework.

The goal of this workshop is to provide participants with foundational knowledge of emerging tools and technologies related to FA/TM comparisons. Training will include the theory underlying different styles of 3D microscopes, the acquisition of quality traceable data, processing methods for raw data, quantitative comparison algorithms, statistical frameworks for FA/TM, and virtual microscopy (VM). Participants should walk away from this training armed with operational knowledge for any future implementation of advanced 3D technologies in their laboratories.

This workshop will impact the forensic science community by presenting a potential framework for the future use of automated technologies to supplement an FA/TM examiner's comparisons. The technologies and algorithms presented comprise a pathway to directly quantify an objective identification metric with associated statistical error rates.

Salon 1 — Full Day

Intra- and Inter-variability of Footwear Test Impressions: An Interactive Workshop

Chris Hamburg, BS, Oregon State Police Forensic Services Division, Portland Metro Laboratory; Jeff Jagmin, BS, Supervising Forensic Scientist, WSP Crime Laboratory Division, Seattle Laboratory

Description: This workshop, which is limited to six participants, will be a collaborative effort between the participants and the presenters to actively conduct baseline research that will generate data to be formally published at a later date by all the participants.

This workshop is designed to answer basic questions, such as the following: How much size variation is there when one person makes a test impression? How much size variation is there between individuals making test impressions with the same shoe? Are different examiners able to repetitively capture randomly acquired characteristics (RACs) in their test impressions?

Abstract: This workshop is based on the NWAFS's Special Research Topics. However, instead of a workshop with one presenter and many students, this workshop will be a collaborative effort involving all the participants, with "mentors" guiding the research. This workshop is intended to conduct baseline research that will generate data to be formally published at a later date.

There is currently no known published research that addresses the differences in examiners' physical attributes (e.g., foot size, weight, and gait) and how they might affect test impressions.

This workshop is designed to answer basic questions, such as the following: How much size variation is there when one person makes a test impression? How much size variation is there between individuals making test impressions with the same shoe? Are different examiners able to repetitively capture/replicate RACs in their known test impressions?

This workshop will involve using three different sets of shoes. Two of the sets will contain a total of three of the same make/model shoes in sizes 9, 11, and 13. One of these two sets will have a continuous outsole design, and the other will have a design with a separate heel and toe. The third set will consist of one size 15 shoe. Marks (RACs) will be made in similar locations on the outsole of each shoe. Additionally, each participant will have their feet measured using a Brannock Device.

The participants will each make three test impressions with each shoe using an Identicator® Inkless Shoe Print Kit (The Safariland Group). The test impressions will then be scanned at 600 ppi. Each student will evaluate the test impressions they made and annotate how many known RACs were captured on their test impressions. A predetermined and consistent set of marks on each outsole will be measured using Photoshop (or a similar program). The students will then record their measurements of predetermined RAC locations.

Once all the workshop participants have completed their assessments and measurements, the class will be open to all other symposium attendees. These attendees can contribute to the data pool by making exemplars with the aid of the workshop participants. Attendees may also join the class to observe and discuss.

Each person will have a range, mean, and standard deviation calculated for each shoe. The resulting values will be compared to the group's ranges, means, and standard deviations for each shoe size using analysis of variance (ANOVA). Spreadsheets with formulae will be developed prior to the workshop. Fully analyzed data should be available to the workshop attendees at the conclusion of the workshop. Further work will be required from all participants prior to publishing the data.

The significance of these findings as they relate to casework will not be critically evaluated. The data collected from this workshop may offer information on what is, or is not, being recorded when one takes a test impression. However, the data collected and statistical analysis conducted will facilitate further study.

This workshop will be limited to six participants plus the two mentors.

Probabilities and Likelihood Ratios in Pattern Evidence Evaluation

Steven Lund, PhD (Statistics), and Hari Iyer, PhD (Mathematics), National Institute of Standards and Technology

Description: Probabilities and likelihood ratios (LRs) provide an important framework for evaluating evidence. Many practitioners are interested in better understanding the relevance of the LR framework to their professional practice. This workshop will introduce the LR framework in the context of assessing pattern evidence using examples from latent prints, footwear impressions, and toolmark impressions. We will discuss how the LR framework relates to common current practices and how computer-aided, quantitative comparisons can benefit evidence evaluation. This course does not require any previous familiarity with statistics, as it will avoid unnecessarily technical language or complicated mathematics. At the end of the workshop, participants will have a sound conceptual understanding of probabilities, LRs, and their potential strengths and limitations.

Abstract:

Scope.

(a) Starting from first principles, explain to practitioners what probability is, what LRs are, and why these are useful ideas when thinking about communicating the evidence to triers of fact.

(b) Use examples from pattern evidence disciplines to illustrate these concepts.

(c) Use simple interactive exercises to enable participants to experience the process involved in arriving at probabilities and LRs.

(d) Explain the need for extensive exploration of the basis upon which judgments of probabilities and LRs are made.

Objectives. Our objective is to address the points mentioned above without the use of technical terminology or complicated mathematical equations and without sacrificing the key underlying concepts. We believe that a high level of mathematical sophistication is not necessary for understanding the fundamental ideas.

We plan to use many examples based on pattern evidence disciplines to communicate the essential ideas. We also plan to incorporate hands-on exercises in which the participants will go through the steps involved in assessing probabilities and LRs. This will enable them to identify areas where personal judgements are made based on their training and experience and/or available empirical data.

Upon completion, the participants should have a good grasp of the fundamental concepts of probability and LRs.

Brief narrative introduction. The workshop will comprise two modules. The first module will be presented in the morning session and the second module in the afternoon session. The first module will be a logically complete unit by itself so that participants who are able to attend only the half-day session can still benefit from the information presented. The afternoon session will provide an opportunity to include extended discussions, Q&A, and additional hands-on activities that provide further insights.

Morning Session:

- We will begin by presenting an assortment of case-like pattern comparisons to introduce the fundamental questions of the LR framework (similarity and typicality): Could the questioned pattern have originated from the same source as the control pattern? Could it have originated from a different source? What information influences our responses to these questions?
- A brief illustration using coin flipping and sampling jelly beans from a jar will introduce concepts of probability and LRs.
- We will then conduct a hands-on exercise to examine and categorize pairs of paper samples and make a conclusion (i.e., same source/identification, different source/ exclusion, or inconclusive).
- Using ground truth and the reported conclusions, we will assess error rates and LRs for each conclusion level.
- We will revisit the collection of comparisons to further refine the ordering in terms of perceived similarity and construct a corresponding receiver operating characteristic (ROC) chart.
- We will use the ROC chart to translate the perceived similarity in "case" assessments to corresponding score-based LRs.
- We will discuss the importance of identifying a case-specific collection of reference comparisons when evaluating method performance.
- We will also discuss the influence of within- and between-examiner variability and the size of the reference collection used on assessments of comparison method performance.

Afternoon Session:

- Hands-on activity: Participants will work with fingerprint pairs (simulated and realistic) and make a conclusion (i.e., identification, exclusion, or inconclusive). Using the results, they will construct an ROC chart. They will also be shown the results from a computer fingerprint-matching algorithm and the associated ROC chart. The group will discuss the information relayed by these charts. The activity will also lead to 'error-rate' discussions and associated issues.
- Hands-on activity: Participants will work with footwear impression pairs (simulated and realistic) and follow steps similar to those used in the case of fingerprints.
- Computer-assisted quantification of similarities between latent and exemplar pairs will be discussed, and the use of ROC charts for discriminating between better algorithms and poor algorithms will be illustrated.
- Score-based LRs will be introduced. Mated and Non-mated score distributions will be described. The strengths and limitations of statistical modeling of these distributions will be discussed and illustrated.
- Participants will be given ample time to ask questions on any of the concepts discussed in the workshop, and the Q&A session will be followed by a group discussion and instructors' opinions.
- Key concepts from the workshop will be revisited in summary form.

Methods/Approach. We plan to illustrate the underlying concepts using pattern evidence discipline examples and hands-on exercises, as outlined above.

Results & Findings. Our own past experience with teaching workshops has demonstrated that practitioners can appreciate and understand probability and LRs without needing any particular prerequisite other than logical thinking. This workshop is built on this premise.

Conclusions. The more familiar a practitioner is with the concepts of probability and LRs, the more comfortable they can be when communicating forensic evidence to triers of fact during courtroom testimony or when writing forensic examination reports.

Studio D — Full Day

Forensic Wood Identification

Larry Peterson, BS, Georgia Bureau of Investigation (Retired) and U.S. Army Criminal Investigation Laboratory (Retired)

Description: This workshop is intended for scientists with no or some experience in forensic wood identification. It will include lectures on the macroscopic and microscopic features that are useful for discrimination/classification, sample preparation, and laboratory exercises for hands-on examinations. Students with experience can concentrate on laboratory exercises during the introductory instruction. Microscopes will be available for the laboratory exercises. Discussions will include case examples and considerations for courtroom testimony.

Abstract: Wood examination is one of the ever-shrinking specialty areas of trace evidence that needs to be supported. Training in such areas is difficult for individual laboratories to provide. The object of this workshop is to combine an introductory-type workshop for inexperienced examiners with a platform for examiners who infrequently perform examinations and would like to expand their experience. The hands-on approach is crucial to ensure that the participants understand both the sample preparation techniques and morphological characteristics needed for success in wood characterization. Examining whole wood blocks and forensic-sized samples will be included in the laboratory exercises. Examiners with no experience can begin with lectures on wood structure and sample preparation techniques. Examiners with experience can begin the laboratory exercises immediately, working in pairs.

Studio A — Two Full Days (Monday–Tuesday)

Applied Polarized Light Microscopy for Trace Evidence Examiners

Andrew Bowen, MS, U.S. Postal Inspection Service
Sebastian Sparenga, MS, McCrone Research Institute

Description: This workshop will introduce participants to the theory and application of polarized light microscopy (PLM). This technique is extremely versatile and can provide valuable data for the identification, characterization, and comparison of a wide variety of trace evidence materials. Lecture presentations will be supplemented with hands-on microscopy exercises designed to reinforce the material. Topics covered will include lectures and/or exercises related to image formation, proper microscope set-up, refractive index measurement, basic optical crystallography, retardation and birefringence, extinction characteristics, and compensators. The afternoon of the second day will provide participants with an opportunity to practice the covered techniques.

Abstract:

Scope. This 2-day workshop is designed for trace evidence examiners who either lack formal training in PLM or whose training in this area was not recent. This is a hands-on workshop that will include lecture presentations, instructor demonstrations projected from a microscope, and participant exercises using polarized light microscopes and prepared samples. The workshop will introduce participants to fundamental PLM concepts, including the basic optics involved in image formation in a compound light microscope, refractive index, isotropy, anisotropy, retardation, birefringence, extinction characteristics, compensators, and basic optical crystallography. The theory behind these concepts will be paired with practical exercises designed to teach participants to make appropriate measurements/observations of their samples and understand the significance of their observations. Participants will have opportunities to apply what they have learned to real-world samples that are relevant to multiple trace evidence disciplines.

Narrative. This workshop will introduce participants to the theory and application of PLM. This technique is extremely versatile and can provide valuable data for the identification, characterization, and comparison of a wide variety of trace evidence materials. It is essential equipment for virtually all hair and fiber analysts but has broad applications beyond this discipline in areas where it is much less widely used. For example, PLM can be used to identify and characterize pigments and fillers in paint, polymers, tape, and adhesives. It is a critical tool for the examination of soil and other geological evidence and is valuable for the identification of explosive materials and residues. PLM can also assist in the identification of glass fragments and is an essential piece of equipment for the identification of general unknowns.

Despite its utility in analytical chemistry, PLM instruction is rarely included in university chemistry curricula. This workshop provides an introduction to this topic for trace evidence examiners who did not obtain PLM training during their formal education or for trained practitioners who do not use this instrument on a regular basis and need a refresher on the subject.

The two presenters have over 30 years of combined experience in microscopy instruction, and they both routinely apply PLM in their casework and research activities. Based on this experience, the presenters believe that hands-on activities are essential to learning this technique. During this workshop, the lecture presentations will be supplemented with live demonstrations through an instructor microscope and hands-on microscopy exercises designed to reinforce the material. These lectures, demonstrations, and exercises are designed to teach participants about image formation in a compound light microscope, proper microscope set-up (Kohler Illumination), refractive index measurement, basic optical crystallography, isotropy and anisotropy, retardation and birefringence, extinction characteristics, and the use of compensators. On the afternoon of the second day, participants will be able to practice the covered techniques. Participants are encouraged to bring in materials similar to those encountered in casework so that they can apply the workshop training to real-world samples relevant to their work.

The goal of the workshop is to provide a foundation of basic PLM theory and application that participants can use as a starting point in their professional microscopy training. This experience will enable participants to attend future workshops or professional training courses that have basic PLM training as a pre-requisite.

Salon 1 — Half Day, Morning Session

3D Footwear and Tire Tread Impression Capture

Song Zhang, PhD, Purdue University; James Wolfe, MS, Consulting Forensic Scientist; David P. Baldwin, PhD, Special Technologies Laboratory, U.S. Department of Energy/ National Nuclear Security Administration

Description: The workshop consists of a brief presentation of the operation and capabilities of a prototype structured light 3D imaging system being developed with National Institute of Justice (NIJ)-funding. The system is intended to provide rapid capture of 3D images of footwear and tire tread impressions. The attendees will spend most of the workshop in hands-on operation of the device and software, challenging the system, and providing feedback to the developers to inform improvements and revisions to the concept.

Abstract: This workshop will provide an overview of state-of-the-art non-destructive optical 3D scanning technologies and allow participants to interact with and evaluate a prototype portable structured light 3D imaging system for capturing shoe and tire impressions. The goal of this NIJ-funded project is to develop a fully automated portable system with an easy-to-use-graphical user interface (GUI) that can capture shoe or tire impressions in substrates such as snow or soil, which are typically challenging to analyze using optical 3D scanning technologies. Ultimately, we hope that this more affordable and easy-to-use 3D scanning system will be commercially available to the forensic community to improve both the collection and analysis of 3D impression evidence. After the hands-on portion, practitioners will also have an opportunity to discuss how 3D images can be incorporated into laboratory comparisons and case workflow.

The entire hardware system includes a digital complementary metal–oxide–semiconductor (CMOS) camera, a digital-light-processing projector, and a laptop computer. The camera and projector are precisely synchronized to allow a sequence of defocused binary structured patterns to be precisely captured by the camera. The captured images are processed to create a 3D surface map at camera pixel spatial resolution and, simultaneously, a color photograph (or texture) that is 100% aligned with the 3D point. The image acquisition takes a fraction of a second, and the automatic 3D reconstruction takes a few seconds. 3D data can be immediately visualized on the screen for quality examination or saved to a media in standard 3D mesh formats (e.g., OBJ, STL, or PLY).

The GUI includes the camera control module, visualization module, and data-handling module. The entire GUI was developed with Qt, C++, OpengGL, and OpengCV, with special emphasis on making the GUI intuitive and easy to use. The camera control module allows a user to manually/automatically adjust exposure of the camera and then click a button for 3D image acquisition. The visualization module enables the user to examine the quality of the data in both 2D and 3D. This module allows 3D data manipulation, such as zoom-in and zoom-out, rotation, and translation, and the selection of different visualization modes, such as shaded, textured, or mesh rendering. The data-handling module offers data reading/ writing and filtering, if the user chooses it.

Salon 2 — Half Day, Morning Session

Fracture Examinations Workshop

John R. Vanderkolk, BA, Indiana State Police Laboratory

Description: After an introductory lecture about patterns and the examination process, the participants and instructor will break, tear, or cut a variety of objects that could be found at crime scenes and then reassemble pieces of those objects. Then, the participants will examine pieces of objects that the instructor had previously broken, torn, or cut. The comparative scientist participants will study the features of the separated pieces to ascertain whether they had once been connected to and part of each other. Thus, participants will develop a better understanding of making judgments regarding whether items had ever formed a continuous object.

Abstract:

Scope. Many objects can be broken, torn, or cut apart at crime scenes and associated with objects found at other investigative locations. The workshop will cover a range of topics from how things or objects are generated in nature or manufactured to how objects are naturally or unnaturally broken, torn, cut, or separated. The processes of human judgment and decision-making will be discussed. Then, the process of examining things will be addressed, followed by many practical exercises using known ground truth objects and pieces of objects to determine whether the separated pieces had ever been connected to each other.

Narrative. After an introductory lecture and discussions during the workshop, the participants and instructor will break, tear, separate, or cut a variety of objects and then reassemble the pieces of those objects. Then, the participants will examine pieces of objects that the other participants had previously broken, torn, separated, or cut. Subsequently, they will examine pieces of objects that the instructor had previously broken, torn, separated, or cut. The comparative scientist participants will study the repeatable and unique features of broken, torn, separated, or cut objects often found at crime scenes to ascertain whether they had once been connected to and part of each other. After analyses, comparisons, and evaluations, the participants will develop a better understanding of how to make a judgment regarding whether items had ever formed a continuous object based on the quality and quantity, levels of clarity and levels of measurements of the repeatable and unique features of the pieces.

Salon 2 — Half Day, Afternoon Session

Expert Assisting Computerized System for Evaluating the Degree of Certainty in 2D Shoeprints

Sarena Wiesner, MS, Head of Questioned Documents Lab, Department of Identification Forensic Science, Israel Police; Yaron Shor, MSc, Toolmark and Materials Lab, Department of Identification Forensic Science, Israel Police

Description: In this hands-on workshop, participants will learn how to use a program for the computerized detection of the borders of randomly acquired characteristic (RAC) contours and the beta version of a RAC match-evaluating software, including demonstrations. The rarity of accidental characteristics on an example sole (as seen on the test impression) will also be evaluated. All of the participants will receive a DVD containing the dataset and the applications. The meaning of each step will be discussed, as will current limitations and future improvements.

Abstract: Both the 2009 National Research Council (NRC) report, *Strengthening Forensic Science in the United States: A Path Forward*, and the recent President's Council of Advisors on Science and Technology (PCAST) report to the President, *Forensic Science in Criminal Courts: Ensuring Scientific Validity of Feature-Comparison Methods*, urged the forensic science community to put "more science into the Forensic science". This is a very challenging task, and despite the significant effort consistently directed toward fulfilling this objective, this goal has not been fully accomplished.

A practical method of conducting pattern comparison is clearly demonstrated by the shoeprint examination process. Today, shoeprints found at crime scenes are compared manually against suspect shoes. The first step is to determine whether the class characteristics, such as the sole pattern, size, and wear, match. Matching these features narrows down the potential population of shoes that could have left the shoeprint, but their discriminative value is limited. Once a match is achieved in all class characteristics, the shoeprint comparison examiner searches for accidental characteristics that appear both on the sole of the shoe and on the shoeprint from the crime scene. Randomly acquired characteristics (RACs) are features on a shoe outsole resulting from random events of the removal or addition of material to the outsole. These include, but not limited to, cuts, scratches, tears, holes, stone holds, abrasions, and the acquisition of debris. The location, orientation, and shape of these characteristics must match to support the connection between the shoe and the shoeprint. If such RACs are identified, the examiner evaluates their rarity based on his knowledge and experience and the level of confidence derived from the combination of all the accidentals found on the shoeprint. This process depends heavily on the expertise and subjective decisions of the examiner. An automated method for calculating the rarity of RACs would be more objective and, thus, increase the reliability of the results.

An extensive research project conducted during the last decade (sponsored partially by the National Institute of Justice [NIJ]) made a major step in this direction: a computer algorithm that will enable the shoeprint expert to quantitatively estimate the evidential value of RACs is being developed.

Test impressions, which are controlled prints made with the examined shoe, were collected for this research. The test impressions were created according to international standards. The outcome is a good representation of the shoe. A database of over 13,000 RACs from nearly 400 shoe soles was collected semi-automatically. The location, orientation, and contour of each RAC on each impression were determined. An algorithm for evaluating the rarity of RACs was developed and can be used to assist in reaching an expert opinion rather than relying on the examiner's memory and presenting the reasoning in court.

This software focused on RACs only and not on the patterns of soles or other class characteristics. The rationale behind this decision was that the shoe industry changes its shoe sole patterns frequently, and therefore, a database of shoe sole patterns would have a short lifespan. In contrast, the materials used to manufacture shoe soles are not altered frequently, and the tearing behavior of all shoe soles is similar. Thus, such a database will be useful for an extended period of time.

The methodological concept presented during the workshop represents a large step toward transforming the entire area of pattern comparison to an agreed-upon, scientifically based field. It may also lead to the establishment of large databases and algorithms to calculate the chance to find other features, similar (under restrictions) to those examined for the various comparison fields.

In this hands-on workshop, participants will learn how to use a program for the computerized detection of the borders of RAC contours and a beta version of a RAC match-evaluating software, including demonstrations. The rarity of accidental characteristics on an example sole (as seen on the test impression) will also be evaluated. The meaning of each step will be discussed, as will current limitations and future improvements.

All of the participants will receive a DVD with the dataset and applications.

Salon 5 — Half Day, Morning Session

No More Either Or: Working Together to Solve Compatibility Issues Between Impression Enhancement and DNA Analysis

Jessica Zarate, MS, and Jodi Lynn Barta, PhD

Abstract: Impression evidence, both blood and non-blood, is a common component at many crime scenes. Current fluorogenic enhancement methods for impression evidence are problematic for DNA preservation and are often impractical for crime scene use. This may lead to an either/or decision made during evidence collection based on whether to enhance the impression and potentially damage the DNA evidence or gather the DNA evidence, which may destroy impression evidence. Zar-Pro™ Fluorescent Blood Lifting Strips have been successful in lifting, enhancing, and preserving bloody impression evidence, providing a highly sensitive method for processing and fluorogenically enhancing bloody impression evidence that can be preserved and utilized over long time intervals. However, the viability of subsequent DNA analyses has not been established. This project proposed an integrated two-phase approach, in a collaboration between impression specialists and DNA analysts, to test the viability of DNA in evidence processed with Zar-Pro™ lifters and to develop and optimize a DNA extraction protocol suitable for use with this technology. During the initial phase of the project, over 1,200 impressions were laid in five biological fluids on a series of seven substrates that range from non-porous to semi-porous to porous. To determine the viability of the DNA over time when fixed to the Zar-Pro™ lifters, trials were established to test 3-month, 6-month, and 12-month intervals. The preliminary results are encouraging and show that DNA is preserved and can be retrieved from impression evidence lifted and enhanced using Zar-Pro™ lifters. The findings support the ideal situation: collaborators working together to overcome challenges in evidence collection and analysis. The goals of this project include the development of simple, time- and cost-effective, non-toxic methods that are safe for use at crimes scenes and provide opportunities for subsequent DNA recovery in the laboratory. Simplifying collection and preservation while expanding the utility of impression enhancement methods to include DNA analysis has the potential to transform how technicians approach crime scene evidence.

We would be willing to provide a presentation of this research and then a workshop demonstrating the Zar-Pro™ Fluorescent Blood Lifting Strips and allowing participants to use the technology themselves.

Materials for this workshop were donated by Tri-Tech forensics.

Salon 5 — Half Day, Afternoon Session

Analyzing Interactions of Latent Prints with Blood

Nicole Praska, MLS(ASCP), University of Minnesota Twin Cities; Carey Hall, MLS, CLPE; Sandra Day O'Connor College of Law at Arizona State University

Description: Recent research has demonstrated that latent prints and blood can interact in manners beyond the deposition of an impression in a blood matrix. For example, blood may come into contact with a latent print already on the surface, or a finger may make contact with a bloodstain already present. Understanding the characteristics of these interactions can be useful if the probative value of this type of evidence is called into question. This workshop will examine relevant research, introduce characteristics to consider when analyzing apparent bloody fingerprints, and provide practical exercises for attendees to practice and review.

Abstract: Generally, bloody fingerprints are understood to occur when blood is present on the finger at the time of deposition. In the past several years, questions have been asked in courtrooms regarding whether an apparent bloody fingerprint may actually have been caused by other mechanisms, such as blood interacting with a latent print already on the surface or a clean finger making contact with a surface already contaminated with blood. Research into these propositions has shown that they could indeed be possibilities. As a result, the probative value of an apparent bloody fingerprint may be called into question. Because of the correlation between this type of evidence and violent crimes, better understanding of this topic is needed to alleviate doubt in relevant cases. Research has also shown that the various mechanisms may be distinguishable based on the characteristics and details visible within an impression, particularly if images of the questioned impression both before and after processing with any chemical reagents are available. Therefore, careful analysis of apparent bloody fingerprints is essential to provide clarity in each case. Although there is no method to prove which mechanism actually produced an apparent bloody fingerprint, a thorough analysis with attention to the specific details that have been shown to be useful in distinguishing one theory from another is vital if the evidence is disputed.

The goal of the workshop is to provide the participant with the knowledge and skills to appropriately analyze apparent bloody impressions, focusing on details that may not necessarily aid in the identification or exclusion of a source but that are important to document because of the challenges that could arise given recent defense inquiries. Upon completion, participants will be able to provide a complete record of their observations for the court to consider in the event that such a record is needed.

The proposed workshop will introduce participants to this topic and the research that has been conducted in recent years. The primary focus will be on a paper published in 2013 (see below) by the co-authors, but relevant research by others will also be included. Then, participants will be instructed on what characteristics/details to analyze in apparent bloody impressions and how to document them accurately. A demonstration exercise will be completed as a group prior to independent work. Ten practical exercises will be distributed to each participant to complete within an hour (working with images only). The exercises will present a variety of images, representing each of the three discussed mechanisms and including both processed and unprocessed impressions. Next, the group will review each exercise together to discuss what details were present and documented in each image. The mechanism that produced each image will be revealed, and the group will have the opportunity to compare and contrast these results with the characteristics observed. Finally, real case studies will be presented to demonstrate bringing practice into application, and then, the workshop will conclude.

Praska, N., & Langenburg, G. (2013). Reactions of latent prints exposed to blood. *Forensic Science International, 224*(1–3), 51–58.

Salon 6 — Full Day

Foundations of the Interpretation of Pattern and Trace Evidence (Source and Activity Levels)

Patrick Buzzini, PhD, Sam Houston University; Norah Rudin, PhD, Forensic DNA Consultant; Keith Inman, PhD, California State University East Bay; Glenn Langenburg, PhD, Elite Forensic Services, Inc.; Cedric Neumann, PhD, Two Ns Forensics, Inc.

Description: This workshop focuses on the foundations of the interpretation of different types of forensic evidence. Through examples and exercises, the participants will be familiarized with the basic concepts underlying the inference of the source of samples of forensic interest and the variables (e.g., transfer, persistence, and detection) that must be accounted for when making inferences about the activities that generated these samples. During the workshop, the participants will explore the benefits and limitations of different frameworks for the evaluation and reporting of the probative value of forensic evidence.

Abstract: Forensic scientists involved in trace, pattern, and impression evidence are typically mandated to (1) determine the nature of unknown substances, (2) conduct comparative examinations to offer conclusions on the source of recovered material or impressions (defined as 'source' level inference), or (3) provide information on the relevance and usefulness of the recovered material or impressions in the context of a case (defined as 'activity' level inference).

Addressing these questions requires the analyst to 'interpret' the (analytical or observational) results obtained from the examination of the evidence. In other words, it requires the use of a framework to transform the data resulting from the examination of the trace and reference material into information that can be reported to any party in the legal system.

This inferential framework must be logical, coherent, and scientifically supported. Furthermore, forensic scientists need to be able to explain, justify, and present their thought process to their audience. When interpreting evidence, the expert needs to consider the questions relevant to the case, avoid major interpretive fallacies, and, overall, consider uncertainties related to the generation, recognition, collection, examination, and evaluation of the evidence. Only then will the analyst combine all these pieces of information to form a conclusion.

The scope of this workshop is to introduce a decision-theoretic model that formalizes human decision-making and use it to explore the interplay among the different types of questions, data, and sources of bias commonly encountered by forensic scientists and the different conclusion schemes that are used in the different sub-fields.

In this workshop, both trace and pattern/impression evidence will be regarded beyond the traditional view of source determination. We will consider that a piece of forensic evidence is the result of an activity or a set of plausible activities. A decision-theoretic model will be used throughout the workshop to highlight some key aspects of inference in forensic science to answer questions at the 'source' and 'activity' levels using case contextual information. The proper sequence of revealing the case information—commonly known as sequential unmasking—will also be explored.

By applying the model during case studies and exercises, the participants will explore how to formulate relevant questions that may be of interest to the legal system. For example: at what point of the examination process should these questions be formulated? What type of information (e.g., location, transfer, persistence, recovery, detection, quantity, or

match probability) is necessary to address these questions? These exercises will also enable the participants to appreciate how the different conclusion schemes commonly used by forensic scientists are related to one another, identify their capabilities and their pitfalls and limitations, and realize that the lack of availability of a certain type of information may limit their choice when deciding which type of conclusion to report. Finally, the model will be used to identify the different steps in the decision-making process where errors may occur or where an examiner's thought process may be subject to bias. Recognizing these sources of error and potential bias will enable the participants to devise strategies, such as sequential unmasking, and, importantly, when to implement these strategies. The overarching goal is to institute an approach, codified in a program, to limit the occurrence of erroneous conclusions.

Studio C — Full Day

Chemometrics Without Equations for Forensic Scientists

Donald Dahlberg, PhD, Lebanon Valley College; Brooke W. Kammrath, PhD, D-ABC, The University of New Haven

Description: This introductory workshop concentrates on two areas of chemometrics: (1) exploratory data analysis and pattern recognition and (2) regression. Participants learn to apply techniques such as principal component analysis (PCA), soft independent modeling by class analogy (SIMCA), principal component regression (PCR), and partial least squares regression (PLS) safely. The most commonly used methods of outlier detection and data pretreatment will also be illustrated. Understanding the chemometric process without having to learn matrix algebra will be emphasized.

Abstract: Chemometrics is the use of mathematics, chemistry, and logic to obtain information from chemical systems. Recently, it has become increasingly important for criminalists to learn the principles of chemometrics so that that they can understand current forensic science literature and potentially utilize these statistical methods in casework. This workshop was created so that those not fluent in matrix algebra can take advantage of the powerful tool of chemometrics.

There are three potential uses of chemometric analysis: exploratory analysis, regression analysis, and classification. Exploratory analyses, such as principle component analysis (PCA), seek to discover possible outliers and reveal whether there are patterns or trends in the data. Regression analysis is used to predict related properties with the goal of developing a model that correlates the information in the set of known measurements to the desired property. Partial least squares (PLS) and principle component regression (PCR) are examples of chemometric algorithms for performing regression. Chemometric classification is the assignment of samples to predefined categories and predicting that an unknown sample belongs to one of several distinct groups. Canonical variate analysis (CVA) and PLS discriminant analysis (PLS-DA) are examples of chemometric classification techniques.

This introductory workshop concentrates on two areas of chemometrics: (1) exploratory data analysis and pattern recognition and (2) regression. Participants learn to apply techniques such as PCA, soft independent modeling by class analogy (SIMCA), PCR, and PLS safely. The most commonly used methods of outlier detection and data pretreatment will also be illustrated. Understanding the chemometric process without having to learn matrix algebra will be emphasized.

General Sessions

| Wednesday, January 24 |

8:00–9:30 — Keynote and Plenary Session

Moderated by Nicole Jones, MS, RTI International

8:00–8:05 — Welcome

Jeri Ropero-Miller, PhD, F-ABFT, Director, Forensic Technology Center of Excellence, RTI International, Center for Forensic Sciences

8:05–8:15 — Opening Remarks

Gerald LaPorte, MSFS, Director, Office of Investigative and Forensic Sciences, NIJ

8:15–8:30 — DOJ's Support of Forensic Science

Ted Hunt, JD, Senior Advisor to the Attorney General on Forensic Science, DOJ

8:30–9:30 — Keynote Address

Forensic Science in a Mass Casualty Event (How Forensic Science Help Solved the Case)
Richard Marx, MS, Supervisory Special Agent, FBI Evidence Response Team

9:45–11:45 — Statistician Panel

Moderated by Jose Almirall, PhD, Florida International University, and John Morgan, PhD, RTI International

Statistical Approaches to Forensic Interpretation
Steven Lund, PhD, Hari Iyer, PhD, Cedric Neumann, PhD, Daniel Ramos, PhD, Alex Biedermann, PhD

9:45–10:00

Reality Check — What Is Expected from Expert Witnesses
Steven Lund, PhD, National Institute of Standards and Technology

Abstract: Forensic practitioners often cite training and experience as the basis of expertise when offering an opinion or conclusion in report writing or testimony. Indeed, for any discipline, the observations made by a field of experts inform many aspects of evidence evaluation, such as what results a given evaluation method has produced under different scenarios, what evaluation methods have been effective in discriminating between possible scenarios, and what factors have affected the performance of a given evaluation process. Experts are frequently expected to reach beyond what could be supported by data alone (even with a large database) to provide the meaning of their findings for a particular case. Such inferences require assumptions that may fall outside the realm of anyone's expertise and raise the need for non-trivial uncertainty assessments.

10:00–10:15

Challenges Faced by Experts When Communicating Forensic Evidence to Triers of Fact: A Statistician's View

Hari Iyer, PhD, National Insitute of Standards and Technology

Abstract: During a criminal trial, triers of fact receive evidential information from experts. They are expected to process this information and arrive at a conclusion regarding the "guilt" or "innocence" of the defendant being tried. In an ideal system, there would be no wrongful convictions and no erroneous acquittals. In practice, errors do occur, and we seek a system that minimizes such errors. The challenge is that, in actual cases, the system rarely receives feedback as to whether the decision arrived at in any particular case was correct or incorrect.

The information presented by experts to the triers of fact, and the manner in which this information is presented, are important components of the judicial system that could have a significant effect on the correctness of court decisions. In this presentation, we outline some common modes of information transfer from experts to triers of fact and identify advantages and disadvantages of some of these modes.

10:15–10:30

The Use of Similarity Measures (Scores) to Quantify the Weight of Forensic Evidence

Cedric Neumann, PhD, South Dakota State University

Description: Scholars are promoting the use of Bayes factors (also called Likelihood Ratio) to quantify and report the weight of forensic evidence. However, apart from trivial situations, such as glass refractive index or allelic designations of single forensic DNA profiles, forensic evidence can only be represented using high-dimension heterogeneous random vectors, whose probability distributions cannot be modelled. Some have proposed to summarize forensic evidence using similarity measures between pairs of objects and to quantify the weight of the evidence represented by these similarity measures. This presentation reviews the benefits and exposes some of the limitations of "score-based Bayes factors."

Abstract: Legal and scientific scholars are promoting the use of the Bayesian framework to describe the interaction of the information provided by a piece of forensic evidence with other pieces of information (e.g., background information, other case information, other forensic evidence). By extension, these scholars propose to quantify and report the weight of a given piece of evidence using a Bayes factor (also called Likelihood Ratio). Assigning Bayes factors requires one to define and measure features from objects of forensic interest (e.g., minutiae location, type and direction on a friction ridge impression), represent these features in some mathematically compatible manner (e.g., transmittance as a function of time for the spectrophotometric analysis of a fiber), and model their probability distributions.

Apart from trivial situations, such as the refractive index of glass shards or the designation of the alleles in a single forensic DNA profile, forensic evidence can only be represented using high-dimension heterogeneous vectors of random variables, whose probability distributions cannot be modelled. To address this issue, some have proposed to summarize forensic evidence using similarity measures (such as the Automated Fingerprint Identification System (AFIS) or Integrated Ballistic Identification System (IBIS) scores) between pairs of objects, and to quantify the weight of the evidence represented by these

similarity measures. Unfortunately, the use of similarity measures to represent forensic evidence introduces significant biases in the resulting weight of a piece of evidence.

The purpose of this presentation is to review the benefits and expose some of the limitations of "score-based Bayes factors." During this presentation, we describe several possible ways to construct "score-based Bayes factors" and study their convergence to the "true value" of the Bayes factor using examples where that value exists. Our results show that "score-based Bayes factors" may over- or undervalue the weight of the evidence in unpredictable ways. Furthermore, our results show that the advocated use of so-called "calibration methods" does not improve the lack of reliability of "score-based" methods. Finally, our results show that, except in one situation, "score-based Bayes factors" are not coherent with respect to the fundamental axioms of probability. Our results led us to conclude that efforts to quantify the weight of evidence in a more transparent manner, when based on similarity scores, may result in the same types of unreliability issues with respect to forensic conclusions, than the ones that are of great concern today. At the end of this presentation, we will discuss research avenues that address the issues of dimensionality and heterogeneity, while being statistically rigorous and coherent.

This project was supported in part by Award No. 2014-IJ-CX-K088, awarded by the National Institute of Justice, Office of Justice Programs, U.S. Department of Justice. The opinions, findings, and conclusions or recommendations expressed in this presentation are those of the authors and do not necessarily reflect those of the Department of Justice.

10:30–10:45

Statistical Analysis in Forensic Science Evidential Value of Multivariate Data

Daniel Ramos, PhD, Universidad Autonoma de Madrid, Spain

Abstract: In this presentation, recent advances in likelihood ratio (LR) computation for multivariate trace evidence are discussed. Several different techniques are identified as important to explain the latest improvements in the performance of LR models for forensically realistic datasets. Some examples are given, mainly for laser ablation inductively coupled plasma mass spectrometric glass analysis. Rigorous and appropriate empirical validation before their use in casework is highlighted as critical for any LR model. Finally, different avenues to be explored in future research are proposed.

10:45–11:00

The Anatomy of Forensic Identification Decisions: Rethinking Current Reporting Practice in a Decision-Theoretic Perspective

Alex Biedermann, PhD, University of Lausanne

Description: In this talk, I present and defend the view that logical and balanced expert reporting focusing on the value of forensic findings only—now widely understood in terms of likelihood ratios—is not a dogmatic choice but an inevitable conclusion given the lack of foundation of traditional reporting formats that express direct opinions as to hypotheses (e.g., "identification" or "exclusion"). My argument relies on the interpretation of expert conclusions as decisions, a perspective that favors full transparency in what is fundamentally at stake with any decision based on forensic findings.

Abstract: Over the past few years, forensic identification practice has seen a semantic shift in the labeling of expert conclusions. Increasingly, the notions of identification and individualization are referred to as decisions. At the same time, substantial progress has been made in developing balanced and transparent approaches for quantifying the

probative value of the results of comparative forensic examinations (e.g., using likelihood ratios). This field of practice and research is now more generally known as "forensic interpretation." Further, it has become clear that the proper role of scientists in forensic interpretation is to focus only on the findings and their value and to avoid expressing direct opinions as to the (probable) truth of propositions. However, researchers and practitioners who adhere to traditional reporting formats such as "identification" and "exclusion" are still critical of such approaches. In my talk, I will critically examine this traditional position from a decision-theoretic viewpoint. First, I will present the standard ways in which the notion of decision is understood and used in a variety of fields, including statistics and the law. This review will also include the empirical perspective emphasized by the President's Council of Advisors on Science and Technology (PCAST) in its recent review of selected branches of forensic science. Second, I will introduce elements of decision theory and illustrate them in the context of forensic inference of source. This formal analysis aims to unravel the logical structure—that is, the anatomy—of what is at stake for any decision-maker attempting to reach forensic inference of source conclusions. In particular, I will argue that the understanding and justification of forensic identification as a decision requires assumptions to be made about key issues that lie beyond the forensic examiner's area of competence: A typical example for such an assumption is the assessment of the relative undesirability of erroneous decisions. This decision-theoretic perspective calls traditional reporting policies and formats into question, especially categorical conclusions of common source. I shall further argue that the understanding of the broader process of forensic inference of source as a decision problem is not in conflict with reporting practices restricted to the value of the findings only but can accommodate it neatly as a defensible reporting format.

11:00–12:00

DISCUSSION

1:20–3:20 — Statistics and Testimony from the Practitioner and Juror Point of View Panel

Moderated by Xiaoyu Alan Zheng, MS, National Institute of Standards and Technology, and John Morgan, PhD, RTI International

1:20–1:35

Statistical Interpretation and Reporting of Fingerprint Evidence at the U.S. Army Criminal Investigation Laboratory

Henry Swofford, MS, U.S. Army Criminal Investigation Laboratory

Description: In March 2017, the United States Army Criminal Investigation Laboratory (USACIL) began reporting the statistical strength of fingerprint evidence within the military criminal justice system and is currently navigating a way forward for the broader forensic fingerprint discipline toward stronger scientific foundations and improved practices. This presentation will provide a general explanation of the statistical methods employed, discuss policies and procedures governing their use in casework, and discuss how other federal, state, and local forensic service providers can work toward implementing similar reforms within their laboratories.

Abstract: The results of forensic fingerprint examinations are traditionally based on the visual comparison and subjective opinions of forensic examiners and reported as categorical statements of inclusion or exclusion of a particular individual as the source of a

latent print. In 2009, the National Research Council (NRC) encouraged the forensic science community to develop tools to evaluate and report the strength of forensic evidence using validated statistical methods rather than rely solely on the subjective opinion of forensic examiners. The recommendations of the NRC are consistent with those of the President's Council of Advisors on Science and Technology (PCAST) in 2016 and the American Academy for the Advancement of Science (AAAS) in 2017. The primary concern of the NRC, PCAST, and AAAS is the legal field's inability to assess the reliability of fingerprint comparison results for a given case at hand without validated statistical data concerning the strength of the findings, thus bringing into question the scientific validity of fingerprint evidence and its admissibility in criminal courts.

Over the last few years, the United States Army Criminal Investigation Laboratory (USACIL) has been taking incremental steps forward to facilitate the transition from solely subjective, experience-based practices to integrating more robust, scientifically demonstrable, and data-driven practices for latent print examination. As part of this effort, the USACIL has developed, validated and implemented a method that facilitates the evaluation and reporting of the statistical strength of fingerprint evidence. In March 2017, the USACIL began reporting the statistical strength of fingerprint evidence within the military criminal justice system and is currently navigating a way forward for the broader forensic fingerprint discipline toward stronger scientific foundations and improved practices. This presentation will provide a general explanation of the statistical methods employed, discuss policies and procedures governing their use in casework, and discuss how other federal, state, and local forensic service providers can work toward implementing similar reforms within their laboratories.

Disclaimer: The opinions or assertions contained herein are the private views of the authors and are not to be construed as official or as reflecting the views of the United States Department of the Army or United States Department of Defense.

1:35–2:05

LR Testimony Cross-Examined

Hari Iyer, PhD, and Steven Lund, PhD, National Institute of Standards and Technology, and Chris Fabricant, JD, Innocence Project

Description: Likelihood Ratios (LRs) provide an important framework for evaluating evidence, but there are potential issues with their envisioned casework implementation. A primary concern is the adequate portrayal of the extent to which reported LR values depend on personal modeling choices. We present hypothetical cross-examinations of an expert offering LR testimony based on (1) a single model and corresponding validation effort and (2) an extensive collection of plausible models designed to inform uncertainty. This effort will emphasize the importance of candidly illuminating relationships among interpretation, data, and assumptions.

Abstract:

Scope.

(a) Explain to practitioners what the strengths are of the Likelihood Ratio (LR) Paradigm when thinking about communicating evidence to triers of fact.

(b) Explain what role data, assumptions, and models play when attempting to summarize the evidence in terms of a single number LR to be used as weight of evidence.

(c) Explain the personal choices that are often made when developing models for LR.

(d) Explain the need for extensive exploration of alternative assumptions and models and their impact on LR calculations for the testimony to be considered science-based and to withstand cross-examination.

Objectives. Our objective is to address the points mentioned above using an easily understandable example series of questions an attorney might ask an expert witness regarding the process involved in the witness's assessment of LR. The ideas can be presented without appeal to technical details and to be accessible to a general audience. We will use two scenarios—(1) a scenario where the expert has relied on a single model with the claim that it has been validated and (2) a scenario where the expert has conducted an extensive analysis of many plausible models to provide information regarding uncertainties associated with the offered LR—to demonstrate the effectiveness (or lack thereof) of each method to give a fair portrayal of uncertainties and to be able to withstand informed cross-examination.

Brief narrative introduction. In response to calls from the broader scientific community and concerns of the general public, experts in many disciplines of forensic science have increasingly sought to develop and use quantitative methods to convey the meaning of evidence to others, such as an attorney or members of a jury. Support is growing, especially in Europe, for a recommendation that forensic experts communicate their findings using an LR. If an LR is reported, however, experts should also provide information to enable triers of fact to assess its fitness for the intended purpose. A primary concern should be the extent to which a reported LR value depends on personal choices made during its assessment. Even career statisticians cannot objectively identify one model as authoritatively appropriate for translating data into probabilities, nor can they state what modeling assumptions one should accept. Rather, they may suggest criteria for assessing whether a given model is reasonable. We describe a framework that explores the range of LR values attainable by models that satisfy stated criteria for reasonableness. The exploration of several such ranges, each corresponding to different criteria, provides the opportunity to better understand the relationships among interpretation, data, and assumptions.

Methods/Approach. We plan to illustrate the underlying concepts using two hypothetical cross-examination scenarios involving an expert offering LR testimony in court. Scenario 1 will assume that the expert bases his or her interpretation on a single model with associated validation efforts. Scenario 2 will be based on an expert who has conducted a thorough investigation of many plausible models and is better able to convey the range of LR results that may all be considered plausible. The presentation should be accessible to a general audience.

Results & Findings. Our own theoretical investigations have demonstrated that, de- pending on the amount of empirical information available, the range of LR values one might consider reasonable may be so wide that the validity of a single number offered to triers of fact may be unjustified or it may be unfit for purpose.

Conclusions. Unless the expert offering LR testimony has conducted extensive uncertainty analysis and provides this information during testimony (or in reports), triers of fact will be unable to assess the weight of the provided evidence in an informed manner.

2:05–2:20

Factors Which Influence Juror's Interpretation of the Value of Forensic Science Testimony

Alicia Wilcox, PhD, Husson University

Description: This presentation will review the author's recent doctoral work on how jurors in homicide trials comprehend and place weight on forensic science testimony. The data were collected over 24 months in Maine by interviewing jurors about the forensic science experts who testified at trials. The results of this research show that, from the juror's perspective, expert witness credibility influences a juror's determination of the reliability of the evidence presented. The research also highlights that the way the pattern evidence expert testified—e.g., in a narrative form, using demonstrative aids—influenced how well the juror understood the evidence and, in turn, how reliable they determined the evidence to be.

Abstract:

Scope. Forensic Scientists and, in particular, pattern examiners who testify in jury trials

Objective. To inform practicing forensic scientists about how jurors determine credibility in an expert witness and the reliability of forensic science evidence. Credibility and reliability are two key factors that influence how much weight jurors place on testimony. The presentation aims to empower pattern experts to take time to teach the jury how they came to their conclusions and to use demonstrative aids where possible.

Brief Narrative. The judicial system calls upon expert witnesses to testify in court when complex or specialized knowledge, beyond that of the lay person, is needed to interpret the evidence. Expert witnesses explain the meaning of the evidence and can express their opinion of its significance within the context of the circumstances of a given case. In a jury trial, it is the responsibility of the jury to listen to, assimilate, comprehend, and place the appropriate weight on the expert testimony in their final decision-making.

Knowledge of how juries comprehend forensic science evidence and how this type of testimony influences decision-making is sparse. The United States National Academy of Science report, Strengthening Forensic Science in the United States: A Path Forward (National Research Council, 2009), called upon the greater forensic science community to address weaknesses in the forensic science disciplines. One of the weaknesses highlighted was a lack of research into how juries use and comprehend forensic evidence.

This study aimed to investigate the perceptions jurors have of expert witness testimony, delivered as oral evidence, by prosecution forensic scientists in homicide cases in the United States. Using a mixed-methods approach and both questionnaires (n=29) and direct one-on-one interviews (n-22), data were gathered from juries after they had completed jury duty in one of nine homicide cases. How jurors determined the credibility of an expert witness and their views of the reliability of evidence presented to them by the witnesses they were exposed to were explored. The importance of forensic evidence in the jury decision-making process and the tensions between the expertise and experience of the witness were also explored, together with jurors' views of technology and understanding of the science presented.

The role of the use of narrative in evidence was explored in particular through the use of demonstrative aids to explain the scientific evidence. Jurors described that deeper understanding resulted from such testimony. Jurors also suggested that the expert witness's education and years of experience were favored over certification and laboratory accreditation and that the credibility of the witness was reported to be a key factor in the juror's acceptance that the evidence presented was reliable. This work has also exposed the degree to which jurors evaluate the reliability of forensic science evidence based on the credibility of the expert witness.

2:20–3:20

DISCUSSION

| Wednesday, January 24 |

3:50–4:30

Status Update on the Development of a 3D Scanning and Analysis System for Cartridge Cases

Ryan Lilien, PhD, Cadre Research

Description: The ability to measure and compare 3D surface topographies is emerging as a powerful new tool within firearm and toolmark analysis. Over the past few years, and supported in part by grants from the National Institute of Justice (NIJ), we developed a hardware system for acquiring micron-scale surface topographies and software tools for the visualization and analysis of these surfaces. Our system is now in use by several forensic laboratories. In this presentation, we will report on our group's recent progress developing our scan acquisition system, tools for virtual comparison microscopy, and a statistically grounded scoring function.

Abstract: The ability to measure and compare 3D surface topographies is emerging as a powerful new tool within firearm and toolmark analysis. When accurately measured, these topographies represent a one-to-one geometric mapping between the scanned digital surface and the actual physical surface. Over the past few years, and supported in part by grants from the National Institute of Justice (NIJ), we have developed a hardware system for acquiring micron-scale surface topographies and software tools for the visualization and analysis of these surfaces. Our system is now in use by several forensic laboratories, and many of the ideas we initially introduced are being adopted by other scanning systems. In this presentation, we will report on our groups' recent progress in three main areas.

First, we will describe our core imaging technology, which is based on an improved version of photometric stereo. Our method uses a gel-based sensor pad to remove the influence of surface reflectivity on the imaging process. The setup allows micron-scale scans to be acquired within minutes. Acquired scans are brought into our analysis software for visualization and comparison.

Second, we will describe our work in virtual microscopy, which is the examination of digital representations of objects rather than the physical objects themselves. Virtual microscopy offers many novel uses to the forensic examiner, including remote data sharing/collaboration, visualization, access to historic casings, annotation of cartridge case surfaces, verification, and proficiency testing. We will describe our work to validate virtual microscopy, which involved 56 examiners at 15 laboratories and two proficiency-style test sets.

Finally, we will discuss our work developing a statistically grounded comparison function. This function identifies geometric similarity between two surface topographies and quantifies the identified agreement to compute a statistical match probability. Such a function will allow an examiner to supplement their identification or elimination conclusions with a statement regarding false-match probabilities.

In summary, over the past several years, we have developed a fast, accurate, and economical system for the 3D imaging of cartridge cases. The 3D surface scans produced by systems like ours are quickly becoming a valuable resource for the toolmark examiner. The presented work demonstrates the feasibility of our method and represents an important step toward validating this new technology for use in firearm and toolmark examination.

4:30–5:10

Fracture Mechanics-Based Quantitative Matching of Forensic Evidence Fragments: A) Methodology and Implementations

Ashraf Bastawros, PhD, T.A. Wilson Professor of Engineering, Aerospace Engineering, Iowa State University, and United States Department of Energy Ames Laboratory Associate

Description: The matching process can be subjective and reliant on operator judgment, and numerically quantifying the confidence in the match decision is not possible. Here, we show that the principles of fracture mechanics can be combined with statistical learning tools to provide an automated, data-driven approach for obtaining the match probability. Our developed methodology uses the quantitative description of the microscopic features on the fracture surfaces, which we establish as unique and informative regarding the fracture mechanism, to not only classify candidate fracture pairs with very high accuracy but also quantify the probabilities of these matches.

Abstract:

Scope: This presentation will summarize a framework for objectively matching the fracture surfaces of brittle materials. The proposed framework investigates the fundamental scientific basis for forensic analysis of fractured and torn surfaces, derived from the quantitative details of the material microstructure and the established concepts of deformation mechanisms, fracture process zones, and their scaling, in the field of fracture mechanics. The framework has the potential for forensic application across a broad range of fractured materials and/or toolmarks with diverse textures and mechanical properties.

Objective: To developed a methodology utilizing the quantitative description of the microscopic features on the fracture surfaces, which we establish as unique and informative regarding the fracture mechanism, to not only classify candidate fracture pairs with very high accuracy but also quantify the probabilities of these matches. Spectral analysis of 3D fracture surface topography measurements is employed to associate or differentiate fracture surfaces for physical comparisons. We incorporated an understanding of material failure mechanisms (developed in the field of fracture mechanics) with digital image analysis to construct protocols for the association (or exclusion) of pairs of surfaces.

Narrative:

Introduction: The basis for physical matching is the assumption that an indefinite number of matches exist along the fracture surface. The irregularities of the fractured surfaces are considered to be unique and may be exploited to individualize or distinguish correlated pairs of fractured surfaces. For example, the complex jagged trajectory of a macro-crack in the forensic evidence specimen can sometimes be used to recognize a “match” by an examiner or even by a layperson on a jury. However, fracture experts need experience, understanding, and judgment to make reliable examination decisions using comparative microscopy and tactile pattern match. However, the microscopic details imprinted on the fracture surface carry considerable information that could provide quantitative forensic comparisons with higher evidentiary value. The focus of this work is on developing a fracture mechanics-based analysis with quantified match probabilities for forensic physical matches for a variety of materials.

Methodology: The rough and irregular metallic fracture surfaces carry many details of the metal microstructure and its loading history. Mandelbrot, Passoja, & Paullay (1984) first showed the self-affine scaling properties of fractured surfaces to quantitatively correlate the material resistance to fracture with the resulting surface roughness. The self-affine nature of the fracture surface roughness has been experimentally verified for a wide range of materials and loading conditions. A key finding is the variation of such surface descriptors when measured parallel to the crack front and along the direction of propagation. Additionally, it was observed that while self-affine characterization of the crack roughness exists at a scale length smaller than the fracture process, the surface character becomes more complex and non-self-affine at larger length scales.

Motivated by these observations, it can be speculated that a randomly propagating crack will exhibit unique fracture surface topological details when observed from a global coordinate that does not recognize the crack propagation direction. This work explores the existence of such uniqueness of a randomly generated fracture surface at some relevant length scales. The uniqueness of these topological features implies that they can be used to individualize and distinguish the association of paired fracture surfaces. Our hypothesis is that the microscopic features of the fracture surface possess unique attributes at some relevant length scale that arise from the interaction of the propagating crack-tip process-zone and microstructure details. The corresponding surface roughness analysis of this surface using a height-height correlation function shows promise of individuality. These microscopic feature signatures should exist on the entire fracture surface as it is influenced by three primary factors: the material microstructure, the intrinsic material resistance to fracture, and the direction of applied load. This work explores the existence of such a length scale and the corresponding unique attributes of the fracture surface. A statistical framework is developed to provide a basis for the quantification of error probabilities for the process.

Approach: Two sets, each consisting of nine knives from the same manufacturer and having an average grain size of dg = 25–35 µm were fractured at random. For clarity, we refer to the surface attached to the knife handle as the *base* and the surface from the tip portion of the knife as the *tip*. Each pair of fractured surfaces was imaged using a standard non-contact 3D optical interferometer (Zygo-NewView 6300). An extended set of nine topological images with a 550-µm field of view were collected on each fracture surface. The mathematical operator of two dimensional fast Fourier transform was applied to each image to calculate its spectral frequency distribution. For comparison, the spectra of a pair of images were correlated with each other within a banded radial frequency domain with ranges of 5–300 mm^{-1} using 2D statistical correlation. That is, we calculated the correlation between the spectra from corresponding images on the tip and base surfaces in different frequency bands. Image pairs for when the tip and base surfaces were from the same knife are *true matches*, while those pairs from when the tip and base surfaces were from different knives are true *non-matches*. Correlation analysis showed clear separation (with generally lower values for the true non-matches and higher values for the true matches) for the 5–10-mm^{-1} and 10–20-mm^{-1} frequency band ranges, respectively, as shown in Figure 1 (side and top distributions in each figure). Beyond these frequency ranges, the correlation histograms of the true match and true non-match begin to be less distinctive from each other. For the first set, Figure 1(a) shows complete true non-match separation in all paired correlations when both the 5–10-mm^{-1} and 10–20-mm^{-1} frequency ranges are considered together. In the second set, there is one image pair among the true matches that cannot be distinguished from the true non-matches. However, when all nine image pairs (connected with a solid line) for this true match are considered, collectively, the values are distinctive enough to separate the true matches from the true non-matches. This complete set of nine images is exploited to provide a decision rule to predict a true match and non-match with high accuracy.

Funding Source: National Institute of Justice award No. 2015-DN-BX-K056

Reference:

Mandelbrot, B. B., Passoja, D. E., & Paullay, A. J. (1984). Fractal character of fracture surfaces of metals. *Nature, 308*, 721–722.

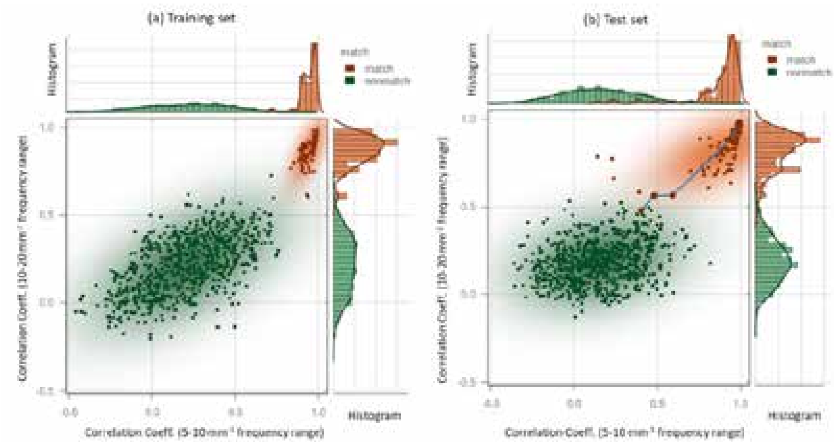

Fig. 1. Plot of correlations between the each of nine base-tip image pairs of the nine knives in the (A) first set and (B) second set of knives. The plot is for correlations in the 10–20-mm^{-1} frequency range against those obtained in the 5–10-mm^{-1} frequency range. Colors indicate true matches and true non-matches. In (A), all correlations from true matches are distinct from those of the true non-matches when both frequency ranges are considered together. In (B), one correlation from a true match image pair cannot be individually separated from the correlations of the true matches but can be individually separated in conjunction with the other correlations from the eight other image pairs (to which it is connected by a line). The margins indicate the distribution of correlations at each frequency range and show that using only one frequency range leads to poorer discrimination between the true match and true non-match signatures.

Fracture Mechanics-Based Quantitative Matching of Forensic Evidence Fragments: B) Statistical Framework

Ranjan Maitra, PhD, Professor, Department of Statistics, Iowa State University

Description: The matching process can be subjective and reliant on operator judgment, and numerically quantifying the confidence in the match decision is not possible. Here, we show that the principles of fracture mechanics can be combined with statistical learning tools to provide an automated data-driven approach for obtaining the match probability. Our developed methodology uses the quantitative description of the microscopic features on the fracture surfaces, which we establish as unique and informative regarding the fracture mechanism, to not only classify candidate fracture pairs with very high accuracy but also quantify the probabilities of these matches.

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Objective: To developed a methodology utilizing the quantitative description of the microscopic features on the fracture surfaces, which we establish as unique and informative regarding the fracture mechanism, to not only classify candidate fracture pairs with very high accuracy but also quantify the probabilities of these matches. Spectral analysis of 3D fracture surface topography measurements is employed to associate or differentiate fracture surfaces for physical comparisons. We incorporated an understanding of material failure mechanisms (developed in the field of fracture mechanics) with digital image analysis to construct protocols for the association (or exclusion) of pairs of surfaces.

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Introduction: The basis for physical matching is the assumption that an indefinite number of matches exist along the fracture surface. The irregularities of the fractured surfaces are considered to be unique and may be exploited to individualize or distinguish correlated pairs of fractured surfaces. For example, the complex jagged trajectory of a macro-crack in the forensic evidence specimen can sometimes be used to recognize a "match" by an examiner or even by a layperson on a jury. However, fracture experts need experience, understanding, and judgment to make reliable examination decisions using comparative microscopy and tactile pattern match. However, the microscopic details imprinted on the fracture surface carry considerable information that could provide quantitative forensic comparisons with higher evidentiary value. The focus of this work is on developing a fracture mechanics-based analysis with quantified match probabilities for forensic physical matches for a variety of materials.

Methodology: The rough and irregular metallic fracture surfaces carry many details of the metal microstructure and its loading history. Mandelbrot, Passoja, & Paullay (1984) first showed the self-affine scaling properties of fractured surfaces to quantitatively correlate the material resistance to fracture with the resulting surface roughness. The self-affine nature of the fracture surface roughness has been experimentally verified for a wide range of materials and loading conditions. A key finding is the variation of such surface descriptors when measured parallel to the crack front and along the direction of propagation. Additionally, it was observed that while self-affine characterization of the crack roughness exists at a scale length smaller than the fracture process, the surface character becomes more complex and non-self-affine at larger length scales.

Motivated by these observations, it can be speculated that a randomly propagating crack will exhibit unique fracture surface topological details when observed from a global coordinate that does not recognize the crack propagation direction. This work explores the existence of such uniqueness of a randomly generated fracture surface at some relevant length scales. The uniqueness of these topological features implies that they can be used to individualize and distinguish the association of paired fracture surfaces. Our hypothesis is that the microscopic features of the fracture surface possess unique attributes at some relevant length scale that arise from the interaction of the propagating crack-tip process-zone and microstructure details. The corresponding surface roughness analysis of this surface using a height-height correlation function shows promise of individuality. These microscopic feature signatures should exist on the entire fracture surface as it is influenced by three primary factors: the material microstructure, the intrinsic material resistance to fracture, and the direction of applied load. This work explores the existence of such a length scale and the corresponding unique attributes of the fracture surface. A statistical framework is developed to provide a basis for the quantification of error probabilities for the process.

Approach: We used machine learning methods to obtain a decision rule using the fracture surface images from one set of knives and used that to predict whether every base-tip sequence of image pairs indicated a match or a non-match. Our decision rule consisted of two stages: computing the probability that two specific aligned images match each other and then computing the probability that the base and tip match each other based on the results from the set of aligned images from that base and tip. Within each set of knives, the correlations within and frequency bands between aligned image pairs were computed to generate a set of correlations between all base and tip pairs in the set. For example, the frequency bands of the first image of the base of a knife were compared to the frequency bands of the first image of the tips of the rest of the knives in the set, and a similar process is followed for the other eight images for that base. Using the training set, a quadratic discriminant analysis classifier was trained to identify matching base and tip pairs on the set of correlations for the frequency range and a logistic regression classifier with a weakly informative prior was trained for the frequency range. These classifiers then produced a vector of 18 match probabilities for each base and tip pair. This was reduced to one dimension by projecting it onto the first principal component of the 18 probabilities for the set of base and tip pairs. A linear discriminant analysis classifier was then trained on this 1D projection to produce a final probability that the given base and tip pair is a match. The resulting classifier had perfect discrimination between matching and non-matching base and tip pairs when applied on both the training and test set.

Funding Source: National Institute of Justice award No. 2015-DN-BX-K056

Reference:

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| Thursday, January 25 |

8:00–8:20

The Evaluation of the Joint Value of Paint and Toolmark Evidence Using Bayesian Networks

Patrick Buzzini, PhD, Sam Houston State University

Description: The joint value of paint and toolmark evidence will be discussed in the context of different scenarios. The typical question addressed following comparative examinations involving both paint debris and toolmarks is whether questioned specimens originated from a given painted object. Should both types of evidence be examined and reported, their joint evaluation may be overlooked or insensibly left to the trier of fact. Bayesian networks are used to evaluate uncertainties related to the two considered types of evidence not only at the so-called source level but also at an activity level.

Abstract: Tools are objects often used to access properties, break or open objects (e.g., cabinets or drawers), or hit an individual, as a weapon. Tools can impart indentations and/or dragged marks on the surfaces with which they come into contact. If painted, tools can shed paint debris, often in the form of chips or powders. Tools can also retain material debris from the surface exposed to the contact, such as paint, wood, or plastic. The clarity of marks, the size of the imprinted area, or the quantity of materials having transferred and persisted may be limited. The occurrence of these traces in low quality and quantity may considerably affect the evaluation of their evidential value. The joint value of toolmarks as well as architectural and tool paint will be discussed in the context of different scenarios. Typically, the outcomes of the examinations of the two sets of material clues are offered separately. Paint debris may not even be considered for examination if high-quality toolmarks are recovered. The typical question addressed following comparative examinations involving both paint debris and toolmarks is whether questioned specimens originated from a given painted object. Toolmark examiners offer conclusions that range from identification, inconclusive, elimination, or unsuitable for examination. Trace evidence examiners tend to offer conclusions that follow an "association" scale (which correspond to a posterior probability from a Bayesian perspective) or to use limited conclusions such as "cannot be excluded" or "could come from." Should both types of evidence be examined and reported, their joint evaluation may be overlooked or insensibly left to the trier of fact without appropriate guidance.

This presentation will consider typical cases in which the contribution of each piece of evidence is moderate (e.g., resulting in an inconclusive decision), one offers a strong evidential value and the other a weak one and vice versa, or the outcome of a piece of evidence does not agree with the other (i.e., dissonant evidence). When pertinent, the combination of these two types of evidence is addressed at the activity level as opposed to the source level. This means that the uncertainties related to the presence of such marks in a given location is addressed and not merely the uncertainties concerned with their origin. For example, in a scenario in which a toolmark is recovered on a window frame and microscopic paint flakes are recovered on a screwdriver, the following propositions may be considered: "The screwdriver was used to force the window frame" and "another tool was used to force the window frame." This pair of propositions screens and encapsulates the two sets of source-level propositions such as a) "The toolmark was left by the screwdriver" and "the toolmark was left by another tool" and b) "The paint flakes come from the window frame" and "the paint flakes come from another painted object."

The uncertainties related to the observations of paint and toolmark evidence types are treated by means of Bayesian networks. Bayesian networks are graphical models that allow the dissecting of a complex problem into simpler, though related, pieces. Bayesian networks can address uncertainties between dependent variables in an intuitive and natural way. Depending on the scenarios, toolmarks and paint debris may be assumed to be dependent in various ways. For example, in the absence of acquired characteristics, it cannot be guaranteed that the specifications of the paint attributes (e.g., color and detected chemical profile) are not related to the physical class characteristics of a tool (e.g., shape of blade and size, metal alloy composition). Also, it cannot be guaranteed that the acquired characteristics on a tool may not depend on the physical manufacturing characteristics of a tool or on the property of the paint to adhere to the surface of the blade of a tool and as a consequence to affect the creation of striae or other defects. In this presentation we will show how Bayesian networks can provide insight to address questions involving these features and how they may be used to assess activity-level propositions in specific cases.

8:20–8:40

Implementing 3D Virtual Comparison Microscopy into Forensic Firearm/Toolmark Comparison

Erich D. Smith, MS, FBI Laboratory, Firearms/Toolmarks Unit

Description: In 2012, the Firearms/Toolmarks Unit (FTU) of the FBI Laboratory began acquiring 3D instrumentation to determine whether this technology could be used to enhance the forensic pattern-based discipline of firearm/toolmark identification by providing objective information to establish the statistical significance and associated uncertainty of a conclusion. If successful, these technologies would not only provide an objective conclusion but possibly create efficiency in forensic casework with a high number of submitted components and provide a larger-scaled view of captured information for analysis and evaluation. Since that time, the FTU has acquired the following systems for evaluation: Sensofar-Confocal Interferometry and Focus Variation, Cadre Forensics-Topmatch GS 3D, Alicona-Infinite Focus, EvoFinder, and a GigaMacro. To assess these platforms, the FTU developed a validation plan encompassing a two-phase approach. Phase one included developing a method to assess the instruments' measuring capabilities and what type of standard could be used to collect that information, determining the collection parameters to acquire the image, and identifying the appropriate sample data sets for collection and evaluation. The initial data samples selected for evaluation included a previously distributed proficiency test that the FTU had used from 2003 to 2012 and three test sets assembled from the FBI Laboratory's consecutively manufactured slides and barrels collection. To ensure that bias was not introduced into the evaluation by the examiner performing in the virtual comparison, all of the samples acquired for scanning were renumbered and entered into the system by a proctor, and the instrument's algorithm was not displayed; thus, the participant would not have any additional influence. The outcome of these data sets demonstrated that 3D technology would be a viable operation for performing virtual comparisons on ammunition components, and the FTU began its final step of the validation process, which included previously analyzed casework samples. The first system to have this last step finalized was the Cadre Forensics-Topmatch GS 3D system. To ensure ground truth in the casework sample sets, known test fires were intermixed within the casework samples and were included in the examiner's evaluation. The examiners contributing to the casework assessment varied in their years of experience. To ensure sample anonymity, all samples were renumbered entered by a proctor, and comparison results were recorded on individual answer sheets, which were collected and retained. This presentation will discuss the implementation process, challenges encountered, proposed work flows, the preparation of Standard Operating Procedures, and the use of the technology in operational casework.

8:40–9:00

"Congruent Matching" — Theory and Application in Forensic Image Identification

John Song, PhD, National Institute of Standards and Technology

Abstract: For more than 100 years, firearm and toolmark identification has been based on the visual comparison of toolmark images by a trained firearm and toolmark examiner. However, the scientific foundation of firearm and toolmark identification has been challenged recently by National Research Council (NRC) and President's Council of Advisors on Science and Technology (PCAST) reports (NRC, 2009; PCAST, 2016). In response, we developed a congruent matching cells (CMC) method for the objective comparison of impression toolmarks and evaluation of the weight of the evidence or the

error rate (Song, 2013, 2015). The CMC method is based on the principle of discretization—it divides the compared topography image pairs into correlation cells and uses four identification parameters to quantify both the topography similarity of the correlated cell pairs and the pattern congruency of the registered cell pairs in x-, y-, and angular positions. The comparison metric is the number of CMC (i.e., the number of cell pairs that meet both the similarity and congruency requirements).

An initial test on breech face impressions of a set of 40 cartridge cases fired with consecutively manufactured pistol slides showed wide separation between the distributions of CMC numbers observed for known matching (KM) and known non-matching (KNM) image pairs (Chu, Tong, & Song, 2013). Another test on 95 cartridge cases from a different set of slides manufactured by the same process also yielded widely separated CMC distributions, consistent with the first test.

In addition to the CMC method for breech face impressions, we have developed alternative methods based on congruent matching for other regions of interest on bullets and cartridge cases. The congruent matching cross-sections (CMX) method is proposed for firing pin image correlations (Zhang, Tong, Song, & Chu, 2016): the firing pin image is sliced into horizontal layers, yielding a cross-section profile for each layer. Three parameters are proposed for determining the similarity of the topography pairs: similarity of the paired profiles and their registration in the horizontal (angular) and vertical (or layer) positions. Validation tests using 40 cartridge cases of three different brands of ammunition fired from 10 firearms produced by three different manufacturers yielded clear separation between KM and KNM image pairs (Zhang et al., 2016).

The congruent matching profile segments (CMPS) method is proposed for striated toolmarks, such as those found on bullets (Chu, Song, Soons, & Chen, 2017): the captured 3D topographies on the land engraved areas (LEAs) are processed by striation edge detection. The resulting 3D striation signatures are compressed into 2D profiles for representing the individual characteristics of bullet LEAs. Each compressed LEA profile is divided into profile segments for accurate correlation using four identification parameters: the 2D profile similarity is quantified by cross-correlation function, and the congruency of profile segment patterns is determined by the twist angle, index number of the correlated LEAs, and series number of correlated profile segments at each LEA. A set of test bullets were fired from 10 consecutively manufactured gun barrels: 10 pairs of KM bullets for training and 15 unknown bullets for tests. In total, 595 image pairs were correlated with the CMPS method: 46 KM and 549 KNM pairwise image correlations, each consisting of 6×6 land comparisons. The results of this initial test of the CMPS method show no false identifications or false exclusions (Chu et al., 2017).

We are also working on the congruent matching features (CMF) method for the correlation of complex features of firearm evidence, such as ballistics images with strong sub-class characteristics. The 3D topography images are divided into specific features of peaks and valleys by a central-line truncation method (Ott, Soons, Thompson, & Song, in press), and those peak and valley features are correlated using the CMF method. A similarity map has been developed by the CMF method to identify and illustrate the similar and dis-similar regions on the correlated image pairs (Ott et al., in press).

The large number of cell (or section, profile, and feature) correlations associated with the CMC (or CMX, CMPS, and CMF) method using multiple identification parameters facilitates a statistical approach to modeling error rates. We have developed an error rate estimation procedure based on the CMC method for breech face evidence identifications (Song et al., n.a.).

References:

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9:00–9:20

Estimating Error Rates of Firearm Identifications Using the CMC Method

Theodore Vorburger, PhD, National Institute of Standards and Technology

Description: We applied the congruent matching cells (CMC) method to identify same-source (matching) pairs of topography images of breech face impressions on cartridge cases and estimate their false-positive error rates. First, we analyzed test fires from two different sets of consecutively manufactured 9-mm pistol slides finished using a sand and bead blasting process. The topography images were acquired using confocal microscopy. For both sets, we observed a significant separation of the similarity score (i.e., the number of identified CMC cells) between known matching (KM) and known non-matching (KNM) image pairs. To estimate the false-positive error rate, the KNM CMC histograms were modelled by a binomial distribution with only one fitted parameter: the probability of a pair of KNM cells to be classified as a (false positive) CMC cell pair. For KNM comparisons, the underlying assumption of Bernouilli cell trials seems a reasonable approximation, but this is not the case for KM comparisons. The extrapolation of the model to the region where the bulk of KM CMC values are observed yields extremely small predicted error rates for producing false positives. We have also obtained data for breech face impressions on test fires from four other pistol brands manufactured using different methods. For all brands, the histograms for KNM pairs are consistently confined to small CMC values and are well described by the binomial distribution.

Abstract: Marks left on cartridge cases and bullets by firearms may be used to identify those firearms. For many years, the determination of whether two cartridge cases or two bullets were fired by the same firearm has been conducted by experts through visual comparison of the toolmarks using 2D reflectance comparison microscopy. Recently, however, the application of areal (3D) surface topography measurement and analysis to firearm and toolmark identification has provoked much interest among forensic examiners, surface metrologists, and vendors of topographic microscopes. A key advantage of 3D topography measurement is that the respective images are less affected by experimental conditions, such as lighting, making them more amenable to objective numerical analysis. The key property to quantify here is toolmark similarity. Are the firearm toolmarks on two surfaces similar enough for attribution to the same source, and can we estimate the respective uncertainty?

The growth in research in this field has been helped by improvements in the measurement, analysis, and visualization of surface topography. We used confocal microscopy to acquire topography images of the breech face impression on 9-mm cartridge cases. We then used the congruent matching cells (CMC) method (Song, 2013) to identify same-source (matching) image pairs. The CMC method divides the reference image into correlation cells. Each cell is then registered to the cell-sized area of the compared image that has maximum topography similarity, as defined by the respective correlation coefficient. Four parameters are used to quantify both the topography similarity of the correlated cell pairs and the pattern congruency of the registered cell locations. An identification (declared match between images) requires a significant number of CMCs (i.e., cell pairs that meet all similarity and congruency requirements).

We initially applied the method to the breech face impression on cartridge cases fired from two different sets of consecutively manufactured pistol slides of the same brand finished using sand and bead blasting. The first set, which was assembled by Fadul, Hernandez, Stoiloff, & Gulati (2012), consists of 40 impressions from 10 slides yielding 780 image pairs: 717 known non-matches (KNM) and 63 known matches (KM). The second set, which was assembled by Weller, Zheng, Thompson, & Tulleners (2012), consists of 90 impressions from 10 slides and five impressions from one additional slide that was not consecutively manufactured. The latter set yields 4,465 image pairs: 4,095 KNM and 370 KM pairs. For both sets, there is a significant separation of the CMC values between KM and KNM image pairs.

Estimating error rates for firearm evidence identification is a fundamental challenge in forensic science. To estimate the false-positive error rate for the samples described above, the KNM histograms are modeled by a binomial distribution with only one fitted parameter: the probability of a pair of KNM cells to be classified as a (false positive) CMC cell pair. For KNM comparisons, the underlying assumption of Bernouilli cell trials seems a reasonable approximation. Extrapolating the model to the region where the bulk of CMC values are observed for KM pairs yields extremely small predicted error rates for producing false positives. The underlying Bernouilli assumptions of independent cell trials and a constant cell trial success probability do not apply to KM comparisons and require modifications to the respective distribution models.

We are working to scale up the CMC analysis method and statistical models to realistic populations of firearms. We measured the breech face impression on test fires obtained from 9-mm semiautomatic pistol slides from four other brands manufactured using

different methods. For all brands, the histograms for KNM image comparisons are consistently confined to small CMC values and are well described by the binomial distribution model, thus supporting the prospect for applying the models to larger populations and realistic case work. Our goal is to create a system for automated objective firearm identification, including a quantitative assessment of the strength of the evidence, to support the visual comparison of topography images by a trained expert.

References:

Fadul Jr., T. G., Hernandez, G. A., Stoiloff, S., & Gulati, S. (2012). *An empirical study to improve the scientific foundation of forensic firearm and tool mark identification utilizing 10 consecutively manufactured slides*, NIJ Report No. 237960, National Institute of Justice.

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9:20–9:40

Objective Comparison of Striated Toolmarks Produced from Ten Consecutively Manufactured Cold Chisels Measured by Contact and Optical Surface Profilometry and Comparison Microscopy

Robert Thompson, MSFS, National Institute of Standards and Technology

Description: This scientific investigation employs consecutively manufactured tools (chisels) to produce striated toolmarks whose contour profiles were measured by 1) contact stylus profilometry, 2) non-contact 3D optical profilometry, and 3) the quantitative consecutive matching stria (QCMS) method. The striated toolmark profiles were measured using contact stylus 2D profilometry and non-contact optical 3D profilometry. Profile similarity and differences were compared using two mathematical methods: cross-correlation function (CCF) and the recently developed congruent matching profile segments (CMPS) method. The chisel toolmarks were also compared using comparison microscopy and measured by the QCMS method.

Abstract: This is the first scientific investigation to employ consecutively manufactured tools (chisels) to produce striated toolmarks whose contour profiles were measured by 1) contact stylus profilometry, 2) non-contact 3D optical profilometry employing infinite focus microscopic surface measurement, and 3) the quantitative consecutive matching stria (QCMS) method. Striated toolmarks were made pairwise in a controlled manner from 10 consecutively manufactured cold chisel blades. Comparison tests between toolmarks made in this manner have the best potential for producing microscopic agreement between two or more different tool sources, resulting in false-positive identification. The striated toolmark profiles were measured using contact stylus 2D profilometry (Form Talysurf) and non-contact optical 3D profilometry (Alicona). Profile similarity and differences of known matching (KM) and known non-matching (KNM) toolmarks were compared using two mathematical methods: cross-correlation function (CCF) and the recently developed congruent matching profile segments (CMPS) method. Both 2D profile and 3D topography comparisons show a wide separation between KM and KNM CCF score distributions when the full-length profile comparisons were made. Similarly, large separations of

KM and KNM score distributions were also the result of profile segment comparisons performed by CMPS. Replicas of the KM and KNM chisel toolmarks were also compared using comparison microscopy, and the similarity and differences were measured by the QCMS method. The results of these comparisons also demonstrate a wide separation of distributions between the QCMS "runs" in KM and KNM toolmark comparisons, and no KNM comparisons exceeded three consecutive matching stria. The score distributions were also examined in a subjective statistical manner for their theoretical estimations of matching probability and demonstrate an exceedingly rare probability of sufficient agreement that would result in false-positive identifications.

10:00–10:20

Quantitative Methods for Forensic Footwear Analysis

Martin Herman, PhD, National Institute of Standards and Technology

Description: An end-to-end proof of concept is presented for a system that performs quantitative footwear impression comparisons. The system uses quantitative methods for identifying features present in questioned and known footwear impressions and metrics for summarizing the degree of correspondences and discrepancies among these features in the form of comparison scores. The end-to-end system includes image feature extraction, feature-based matching, comparison score generation, and creation and analysis of score distribution charts and receiver operating characteristic (ROC) charts, including error rate estimation. The goal is for these methods to be used by footwear examiners to provide more scientifically valid information for court cases.

Abstract: Given a questioned impression (crime scene) and a test impression (obtained from a shoe of interest), an important question to triers of fact is "did the shoe corresponding to the test impression also make the crime scene impression?" The 2009 National Academy of Sciences report and 2016 President's Council of Advisors on Science and Technology report state that forensic footwear identifications are largely subjective. This has raised questions about the reliability and scientific validity of footwear examinations. Both reports have expressed the need for quantitative assessments of footwear evidence using scientifically valid methods.

In this talk, we present an end-to-end proof of concept for a system that performs quantitative footwear impression comparisons. The system uses quantitative methods for identifying features present in questioned and known footwear impressions and metrics for summarizing the degree of correspondences and discrepancies among these features in the form of comparison scores. The system is meant to be used by footwear examiners during evidence evaluations by providing them with the comparison scores and other quantitative information to help place the scores in context. The goal is to provide more scientifically valid information for court cases and higher degrees of accuracy, repeatability, and reproducibility than today's methods.

The end-to-end system includes image feature extraction, feature-based matching, comparison score generation, and creation and analysis of score distribution charts and receiver operating characteristic (ROC) charts, which facilitate error rate assessment. We use simulated crime scene data, synthetic crime scene data, and test impressions to perform our experiments.

For feature extraction, we use a hybrid human/computer feature extraction step, followed by an automated quantification of the degree of correspondences and discrepancies between the impressions being compared. The hybrid feature extraction leverages the

training and expertise of footwear examiners for the identification and extraction of potentially discriminating features from crime scene impressions. We demonstrate a graphical user interface (GUI) for extracting features and their local positions; the algorithm then refines the features using mathematical and optimization methods. We have implemented three methods for marking features on images: (1) manual-only mark up of geometric features, such as points lines, circles, and polygons; (2) automatic adjustment of these features to better fit the grey-scale gradient; and (3) automatic extraction of features based on manually extracted ones.

We have implemented preliminary feature-based matching algorithms using graph theoretic approaches, including the maximum clique algorithm. These are used to generate comparison scores, which summarize the degree of correspondences and discrepancies between compared impressions. This step is fully automated; all results are repeatable and reproducible.

We then create score distribution charts and ROC charts. Suppose we have a representative collection of known mated and non-mated pairs of impressions. The best scoring system will produce the greatest separation between the distribution of scores for mated pairs (say F_{mated}) and the distribution of scores for non-mated pairs (say, $F_{non\text{-}mated}$). Ideally, the distributions F_{mated} and $F_{non\text{-}mated}$ would be completely disjoint. That is, scores for mated pairs would never occur as scores for non-mated pairs and vice versa. We use the ROC metric to describe how successful a given scoring system is in ranking mated pairs ahead of non-mated pairs of impressions. Our goal is to develop comparison scores that have superior performance with respect to their ROC. Scoring procedures that result in a large true-positive rate at any given false-positive rate are of interest and are the better-performing procedures.

For applications to casework, the casework score obtained from matching the crime-scene image with the test impression is plotted on the score distribution charts to obtain reference percentiles. Suppose we have a collection of ground truth-known mated and non-mated impression pairs that are considered to be representative of impression pairs obtained under conditions similar to the current crime scene conditions. We will refer to such a collection as a case-relevant reference dataset. The meaning of the comparison score obtained for the casework pair of impressions is to be understood in the context of the mated and non-mated score distributions computed from this case-relevant reference dataset. Specifically, for a particular pair consisting of a crime scene impression and a reference impression, one can compute the comparison score and use the case-relevant reference dataset to determine what proportion of the distribution of mated scores equal or exceed this score and also what proportion of the distribution of non-mated scores equal or exceed this score. We can also choose other methods of evidence interpretation, such as score-based likelihood ratios. Such information, along with a careful description of the case-relevant reference dataset, can be used to help make weight of evidence assessments.

10:20–10:40

A Comprehensive Research on Shoeprints RACs

Yaron Shor, MS, Israel Police Department of Investigative Forensic Sciences

Description: A comprehensive research project is being conducted by the Center for Statistics and Applications in Forensic Evidence (CSAFE) and the Toolmarks and Materials Laboratory of the Israeli Police. In this research, 120 pairs of similar shoe will be worn by students from Iowa State University for a period of 1 year. The initial results of the research will be presented. Accidental characteristics on the same model and size of shoes will be examined, and a statistical evaluation will be performed to show how strong the evidence can be. The statistical method used to analyze the results could result in greater understanding and acceptance among the scientific world and the judicial system.

Abstract:

Introduction: Both the National Research Council (NRC) in 2009 and the President's Council of Advisors on Science and Technology (PCAST) in 2015 urged the forensic science community to put "more science into the Forensic science". This is a very challenging task, and despite the significant effort constantly directed toward fulfilling this objective, this goal has not been fully accomplished. In the last decade, the forensic scientists have been urged to use more scientific methods and change their methodologies to make forensic science more scientific.

Scope: The authors, together with CSAFE, are conducting the most comprehensive research done on shoeprint soles, focusing on collecting data in a meticulous way to create a database and algorithms that will result in great progress in shoeprint comparison.

Methods: This research will begin with the distribution of 120 pair of two models of shoes in two sizes to volunteers (students at Iowa State University). Thus, samples of 30 similar shoes will be worn during a period of 1 year. Every month, a test impression will be made from each shoe, and the degree of wear and the development of randomly acquired characteristics (RACs) will be tracked.

The shoe sole images will be captured using at least three methods:

1. Using the traditional method of fingerprint powder and sticky film
2. Using a shoe sole 2D scanner produced by EverOS (also available to National Institute of Standards and Technology [NIST] collaborators)
3. Using high-resolution 2D photography

We are also exploring the possibility of obtaining 3D images from the shoe soles at each measurement. At each measurement, we will scan both the right and left shoes and perform the measurement in triplicate.

Conclusions: The outcome of this research, which remains in its first stage, will be presented and could substantially influence how we analyze the results of shoeprint comparisons. This research could provide experts with new scientific and statistical tools to support the new standard demanded by the NRC and PCAST reports

10:40–11:00

The Effects of a Prior Examiner's Status and Findings on Lay Examiners' Shoeprint Match Decisions

Nadja Schreiber Compo, PhD, Florida International University

Description: Research has found inconsistent results regarding the extent to which cognitive bias influences fingerprint analysis (see (Dror & Cole, 2010) and often focuses on the comparison stage of the process, largely ignoring the mandatory technical review step by a second examiner. In collaboration with the Miami-Dade Police Department's Forensic Services Bureau, the present study examines the effects of contextual information on forensic decision-making analogous to the verification/technical review stage of pattern identification analysis using forensically relevant shoeprint comparisons appropriate for novice evaluators.

Abstract:

Introduction: Recent analyses of DNA exonerations reveal that errors related to forensic science can contribute to wrongful convictions (Dror & Bucht, 2012). Often these errors result from misrepresentation or misinterpretation of forensic evidence at trial, but in some cases, human errors known as "cognitive biases" can produce errors in forensic judgments (NAS, 2009). In addition to shedding important light on the potential effect of human bias on forensic examinations, the National Academy of Science report highlights the importance of collaborative research involving forensic scientists and academics in understanding and minimizing the role of interpretive bias and "sources of human error" across a broad range of forensic disciplines.

Studies suggest that a person's prior beliefs, motives, and situational context can influence how a piece of forensic evidence is perceived and interpreted during analysis (Kassin et al., 2013). One of the more widely researched forensic science disciplines with a well-documented vulnerability to cognitive bias is fingerprint analysis (Dror & Cole, 2010). However, previous research on bias in fingerprint analysis has focused on a single examiner's decision, largely ignoring the mandatory technical review step by a second examiner in the fingerprint examination protocol (SWGFAST, 2013).

Very few studies have systematically examined the effects of prior information on reviewers' decision-making during the verification stage of fingerprint analysis. The limited data available suggest that knowledge of a prior examiner's decision can influence an examiner's analysis of a fingerprint (e.g., Pacheco, Cerchiai, & Stoiloff, 2014). Langenburg et al. (2009) examined the importance of the source of prior information to explore whether a status difference could influence decision-making during the verification stage. Results suggested that when prints were from a different source, "inconclusive" responses increased when participants were aware of a prior examiner's decision relative to a control condition that received no information about a prior decision. This effect was "stronger" when participants were novices at fingerprint analysis compared with experts. However, participants were also provided with additional information about the prior examiner's justification for each decision, complicating the interpretation of the findings and underlying theoretical mechanisms.

In addition, laboratory studies have drawn criticism from practitioners for using novice evaluators (e.g., student participants) and stimuli arguably beyond their level of experience and training (e.g., fingerprint, handwriting, voice comparison; Kukucka & Kassin, 2016; Smalarz et al., 2016), limiting the generalizability of findings to real-world contexts.

Scope and Objectives: To address this limitation of prior research and to expand on the understudied effect of the technical review step, the present study examines the potential bias associated with the technical review step using shoeprint comparisons, stimuli that were used to screen potential applicants for firearm and tool mark positions at the Miami-Dade Police Department Forensic Services Bureau (MDPD FSB). Thus, using stimuli appropriate for novice evaluators in a controlled laboratory setting, the present study examines how knowledge of a prior examiner's conclusion (in the absence of the prior examiner's reasoning) and knowledge of the prior examiner's level of experience affect lay reviewers' evaluation of shoeprint comparisons. This allowed the researchers to test for cognitive bias in the technical review process using a controlled analog lab-based paradigm.

Method: *Design*. The study employed a 4 (previous decision type: match vs. non-match vs. inconclusive vs. none) by 3 (prior information: forensic expert vs. student vs. anonymous) by 2 (stimuli type: match vs. non-match) mixed between-within participants design, with repeated measures on the last factor.

Materials and Procedure. The shoeprint comparison test was developed by the MDPD FSB and consists of 20 footwear impressions. Upon entering the lab, student volunteers were told that the purpose of the study was to assess students' performance on a stimuli comparison task that is commonly used as an entrance exam for forensic examiners. Participants were seated in front of a computer and were instructed that they were about to view a series of shoeprint pairs that had been previously assessed. For each pair, they were asked whether the two stimuli were a match, non-match, or not sure/inconclusive. After each comparison, they were asked for the confidence in their decision on a scale from 1 to 7 and to rate the difficulty of the task on a scale from 1 to 7, with lower numbers indicating less confidence/difficulty. Participants were randomly assigned to one of three prior information/source conditions: receive information about a prior decision made by a forensic expert, receive information about a prior decision made by another student, or receive information about a prior decision made by another person (status of person was not given). For participants in the prior information conditions, the prior decision was either identified as a match by the prior examiner (correctly and incorrectly so), a non-match (correctly and incorrectly so), or inconclusive (all incorrectly so as ground truth is known), or participants were not given any information regarding previous decisions. Finally, participants answered demographic questions and were debriefed.

Results: Preliminary data on 60 participants suggest that the type of decision made by the prior examiner (i.e., match, non-match, inconclusive, or none) influences the accuracy of the second examiner's decision, $F(3,51) = 3.03$, $p = .038$. Accuracy was defined as the number of correct decisions (i.e., deciding it was a match when it was, in fact, a match) divided by all possible decisions. When a prior examiner deemed the pair inconclusive, the second examiner was significantly less accurate (40% accurate) compared with when the prior decision was a non-match (73% accurate) or no information was given (77% accurate).

Discussion: This study design enables testing for cognitive bias in a controlled lab setting without losing applied relevance. Preliminary data suggest that knowledge of a prior examiner's conclusion may bias stimulus analysis, especially if the prior examiner's decision was inconclusive. It is important to point out that data patterns are subject to change between now and December, given the ongoing data collection and corresponding increase in experimental power.

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11:00–11:20

Generalizing Across Forensic Comparative Science Disciplines

John Vanderkolk, BA, Indiana State Police Laboratory

Description: Science provides generalizations about aspects of natural and unnatural objects. The variety of pattern and impression disciplines share many common aspects. Currently, these pattern disciplines are somewhat independent. However, these disciplines could use generalized terminology, explanations, examination processes, and ranges of conclusions. As explanations of forensic comparative science evolve, making more generalizations across pattern and impression disciplines should be considered. This presentation will provide a strategy for how the many pattern and impression disciplines can be generalized across disciplines.

Abstract:

Scope: To discuss how natural patterns cannot be repeated, how unnatural patterns can be repeated, and how forensic comparative science needs persistency of both types of patterns to conduct meaningful examinations. By considering objects with generalized descriptions of repeated or unique features, comparative science disciplines can more easily come together under one umbrella of examination processes and results.

Objectives: To demonstrate how firearm/toolmark, shoe/tireprint, friction skin, documents, biometrics, and other comparisons-of-things disciplines can use the same attitude about and approach to their examination process.

Brief Narrative: Natural patterns cannot be repeated. Unnatural patterns can be repeated. This discussion will present how using a common approach to the examination of things will work across disciplines in forensic comparative science.

Introduction: The presentation will discuss the commonalities across disciplines and how the disciplines can be considered as being subsets of the examination of shapes.

Methods: The presenter will discuss the commonalities and then depict branching off for specific aspects of a discipline.

Approach: The presenter will describe commonalities across disciplines and demonstrate a flowchart depicting how commonalities can be shared. Then, idiosyncrasies within a specific discipline will branch off that flowchart.

11:20–11:40

Sufficiency and Complexity Factors in Handwriting Examination

Cami Fuglsby, MS, South Dakota State University, and Linton Mohammed, PhD

Description: In this presentation, we will explore and discuss the issues associated with the use of an automated handwriting verification system to characterize the relationship between handwriting complexity and the so-called likelihood of a chance match. This work will focus on integrating an automated system with the recently developed Modular Approach for Handwriting Examination. The preliminary statistical results will be illustrated with a convenience sample of handwritten documents collected by the Counterterrorism and Forensic Research Unit of the FBI Laboratory Division. The statistical suggestions will be evaluated and discussed using a separate collection of writing samples from Dr. Mohammed's practice.

Abstract: Forensic Document Examiners (FDEs) are often tasked with comparing handwriting to contribute to determining whether there is common writership between two sets of handwritings, normally designated as questioned and known. The examination is conducted by a comparison process in which features of both sets of writing are extracted, examined, and evaluated for differences and similarities. Similarities are, in general, indicative of one writer. However, to judge the strength of the similarities in support of one writer, the FDE must also make a judgement on whether, and how often, such similarities are expected if the handwriting samples are the product of two writers.

In the first part of the examination, the FDE has to make a determination as to whether or not one or both sets of handwriting contain sufficient information in terms of amount and complexity for a meaningful comparison to be made. However, in the handwriting examination literature, sufficiency and complexity data are lacking. Different examiners may express a range of opinions concerning whether or not the quantity of known and questioned writing is insufficient for a comparison. This decision is usually expressed in terms of the perceived complexity in the documents submitted for comparison. To date, there are no empirical data showing how comparing varying amounts of handwriting affects the reliability of FDEs or, indeed, if there is a threshold where the FDE's decision becomes unreliable.

According to the modular approach to handwriting comparison, the amount of skilled writing and relative frequency of similarities between writing from different writers (also known as the likelihood of a chance match) have a hypothesized inverse linear relationship. One of the complicating factors is the sufficiency determination in the modular approach, which is inherently subjective. Consequently, decisions may vary widely between examiners. In this study, we use an automated system to examine and compare varying amounts of handwriting, where the relative frequency of similarities between writing from different writers is studied as a function of the number of words in a document. The handwriting samples provided are compared in pairs. The results will suggest when a sufficient comparable amount material is available and determine when the material is complex enough to provide the relative frequency of similarities for a chosen threshold.

This research will result in a potential uniform baseline of sufficiency and complexity for FDEs when comparing the same evidence, which may result in more reliable conclusions between and within FDEs. The comparison methods used include a Poisson Process, (Corrected) Chi-Square Classifier, Kullback-Leibler Distance, and Dirichlet Multinomial Likelihood Ratio, which are applied to the set of features extracted by the FLASH ID system on a set of handwritten documents collected as a convenience sample. The likelihood

of a chance match is estimated for each comparison method using a newly developed, statistically rigorous methodology. In this talk, we will explore the potential constraints for this study, including the automated system by itself, the chosen threshold, and the comparison methods used by the automated system, which may use different criteria than those used by FDEs. Although the methodologies may not be directly transferable to FDEs, they do provide data currently lacking in the FDE literature.

11:40–12:00

Deep Learning in Handwriting Comparison

Sargur Srihari, PhD, University at Buffalo, The State University of New York (SUNY)

Abstract: Deep learning is an approach to artificial intelligence in which feature representations of the world are learned automatically rather than determined by humans. Deep learning methods are in contrast to traditional machine learning algorithms, which require human-crafted feature engineering. Because deep learning algorithms work on high-dimensional raw inputs, more information is kept, the chance of finding better features is enhanced, and better generalization to unseen data is possible. In impression evidence analysis, such as handwriting examination, human experts use years of training to extract features from raw data. Visually extracted subtle features, from known and questioned documents, are used to determine whether they have the same writer as the source. Although deep learning methods have outperformed other algorithms on the task of recognizing handwritten characters, their use with the handwriting comparison task remains to be explored. The goal of this research is to apply deep learning methods to extract representations from handwriting images. Because both spatial and temporal features must be extracted, the task is challenging. The deep learning architectures we are exploring include convolutional neural networks (CNNs), stacked auto-encoders, and recurrent neural networks (RNNs). The end-goal is to incorporate these architectures into an end-to-end system for handwriting comparison. In this paper, we will present preliminary results with CNNs and auto-encoders.

1:30–1:50

Using Eye Tracking to Understand Decisions by Forensic Latent Print Examiners

R. Austin Hicklin, PhD, Noblis, and JoAnn Buscaglia, PhD, FBI

Description: Fingerprint comparisons may involve a complex mixture of perceptual "subroutines." Relatively little is known about how examiners move their eyes to accomplish these tasks or what information guides the search process. Eye gaze information was collected while 121 latent print examiners conducted specific tasks: counting ridges, following ridges, and searching for particular features in a comparison print. Spatial and temporal metrics were used to characterize examiner eye behavior during these tasks. The results of this research may be useful in future eye-tracking research deconstructing the fingerprint comparison task to understand the relations between examiner behavior and conclusions.

Abstract: A variety of studies have evaluated the latent print examination process (e.g., Hicklin et al., 2011; Hicklin, Buscaglia, & Roberts, 2013; Ulery, Hicklin, Buscaglia, & Roberts, 2011, 2012; Ulery, Hicklin, Roberts, & Buscaglia, 2014a, 2014b, 2016, 2017), but relatively little research has addressed the fundamental basis of this visual task: how examiners use their eyes to accomplish these tasks and what visual information guides the examination process (Busey et al., 2011; Busey, Swofford, Vanderkolk, & Emerick, 2015; Busey, Yu, Wyatte, & Vanderkolk, 2013; Parada et al., 2015). This presentation

will discuss the results of a study conducted to gain a greater understanding of how latent print examiners perform analysis and comparison tasks and of why examiners make different determinations. By asking examiners to annotate or mark up their work, some understanding of the information those examiners relied upon in making their determinations has been gained, but this is limited to the information they felt was worthy of annotating. Eye gaze information can facilitate better understanding the factors that lead to differences in examiners' interpretations and, ultimately, their conclusions.

Eye-tracking technology was used to monitor examiners as they performed their tasks to learn what visual information they used and how they worked with that information. Eye tracking allows us to determine not only how examiners differ in the features they look at in the images, but also how they aggregate information from those images, that is, using both spatial and temporal aspects of eye tracking. Analyses of why some examiners make inconclusive conclusions when others exclude or individualize will provide information that can be used to improve the reliability of the latent print comparison process, particularly for more challenging comparisons.

In this study, over 130 hours of eye gaze information were collected from 121 practicing latent print examiners as they performed over 2,000 fingerprint comparisons and over 1,200 other tasks designed to isolate specific behaviors that arise during comparison. The latter tasks included ridge counting, ridge following, and searching for a designated feature group ("find the target") in a comparison print. Eye gaze was sampled at a rate of 1 KHz using a camera and infrared illumination. The raw data were calibrated, partitioned into saccades (rapid eye movements) and fixations (eye movements with median duration = 0.27 s), and mapped onto image coordinates for subsequent analysis. Examiner annotations from previous research studies were available for the majority of the comparisons.

The presentation will discuss how eye behavior is associated with examiners' determinations, including the extent to which eye behavior can explain erroneous determinations (false positive and false negative conclusions) and nonconsensus determinations (conclusions that differ from the majority of examiners). The presentation will also discuss how eye behavior is affected by the difficulty of comparisons and how the presence or absence of visual context affects eye behavior. The results of this study reveal explanations for how some errors occur. The presentation will describe how examiners use information in the latent print and how that relates to comparison efficiency and risks of misinterpretations. Variability in the eye-tracking data and issues in the interpretation of these data that will be important to future research will be discussed.

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1:50–2:10

Thematic Trends of Latent Print Examination Criticisms and Reports

Thomas Wortman, BS, U.S. Army Criminal Investigation Laboratory

Description: This presentation will provide a broad summary of the thematic trends of several recent critical reports as they currently pertain to latent print examinations and how the community at large has responded to these criticisms. The intention of the presentation is to initiate a dialogue and encourage the practitioner community to undertake a candid evaluation of these criticisms and identify the true gaps in current practices. With this perspective, we can take a more proactive approach to address these gaps moving forward.

Abstract: In 2009, the National Academy of Sciences (NAS) released a report entitled, *Strengthening Forensic Science in the United States: A Path Forward*. Largely the first of its kind in the United States, this report brought to light many gaps within the forensic sciences that were not previously realized within the forensic science practitioner community. Since that time, similar reports—such as the 2012 *Latent Print Examination and Human Factors: Improving the Practice through a Systems Approach* published by the National Institute of Standards and Technology (NIST) in conjunction with the National Institute of Justice (NIJ), and the report released in 2016 by the President's Council of Advisors on Science and Technology (PCAST) entitled *Forensic Science in Criminal Courts: Ensuring Scientific Validity of Feature-Comparison Methods*, and the American Academy for the Advancement of Science's (AAAS's) 2017 report entitled *Forensic Science Assessments: A Quality and Gap Analysis – Latent Fingerprint Examination*–cover similar elements relating

to assessing gaps within the forensic disciplines and, specifically, throughout forensic latent print examinations.

Over the last decade, the forensic science community (researchers, policy makers, practitioners, and other stakeholders) has taken strides to address the criticisms brought forth by these broad reviews of the discipline. Despite these efforts, and as more reports are released, some commonalities amongst the criticisms persist. This presentation will provide a broad summary of the thematic trends of these reports as they currently pertain to latent print examinations and how the community at large has responded to these criticisms. The intention of the presentation is to initiate a dialogue and encourage the practitioner community to undertake a candid evaluation of these criticisms and identify the true gaps in current practices. With this perspective, we can take a more proactive approach to address these gaps moving forward.

Disclaimer: The opinions or assertions contained herein are the private views of the authors and are not to be construed as official or as reflecting the views of the United States Department of the Army or United States Department of Defense.

2:10–2:30

Statistical Error Estimation for an Objective Measure of Similarity to a Latent Image

Donald Gantz, PhD, George Mason University

Abstract: The research project is a 1-year effort funded by the National Institute of Justice (NIJ) and started on January 1, 2018. The research project is addressing two key issues raised in *Strengthening Forensic Science in the United States: A Path Forward*. This presentation will introduce and demonstrate the computation of an objective measure of similarity between a latent image and an exemplar image that is largely automated and requires no minutiae markup. The objective measure addresses the Report statements that, “the assessment of latent prints from crime scenes is based largely on human interpretation.” Furthermore, the objective measure addresses the Report statement, “Clearly, the reliability of the ACE-V process could be improved if specific measurement criteria were defined.” The research goal of the project is to provide a statistical assessment of the rarity of the objectively measured similarity to a latent image for any case exemplar. The rarity statement is expressed in the context of an atypicality index relative to measured similarity to the latent image for known non-mate exemplar images. Atypicality is a statistical concept that addresses many questions pertaining to forensic science; for instance, “does a case exemplar image belong to a specified population of non-mates to the latent image?” This research will provide valuable products for forensic science researchers who study the interpretation of evidence and inference concerning the source of a trace of unknown origin. For a latent image, the research project is computing the objective similarity measure for all exemplars in a very large set of known non-mate images as a basis for complex statistical analyses that will define an atypicality index. The research is validating the utility of the atypicality index for supporting forensic science decision-making by assessing risks associated with alternative decisions. This project’s quantification of decision error risk addresses the *Path Forward* Report, which states in its Summary, “Although there is limited information about the accuracy and reliability of friction ridge analyses, claims that these analyses have zero error rates are not scientifically plausible.”

The research project uses the technology of a novel Latent Image examination tool to create a non-minutiae based objective measure of the similarity between an Exemplar Image and a Latent Image. This tool was described in detail in a 2014 *Forensic Science International*

article[1], and it was demonstrated at forensic science meetings in 2015.[2,3] The proposal for this project provided evidence that the objective measure being used in this research is very accurate when applied to the Latent and True-Mate Images from the National Institute of Standards and Technology (NIST) Special Database 27 (SD27) Latent Data Set.

1. Gantz, D. T., Gantz, D. T., Walch, M. A., Roberts, M. A., & Buscaglia, J. (2014). A novel approach for latent print identification using accurate overlays to prioritize reference prints. *Forensic Science International, 245*, 162–170.
2. A novel software-based toolset for latent print examination. (2015). Presented at *The American Academy of Forensic Sciences 67th Annual Scientific Meeting*, Orlando, Florida.
3. Innovative toolsets for latent print examination using accurate overlays. (2015). Presented at *The EAFS 2015 European Academy of Forensic Science Conference, Prague*, Czech Republic.

The project is also using the SD27 Set to demonstrate that current technology can compute a non-minutiae based measurement of similarity together with an associated error statement concerning that measurement. The project is producing and evaluating statistical models based on each of the Good, Bad, and Ugly Latent Images from the SD27 Set. The presentation will include preliminary computational results that support the promise of the research.

The research utilizes the LatentSleuth workstation, which requires minimal manual processing of the latent image by a latent fingerprint examiner and then automatically provides distortion-adjusted overlays (Warps) to arbitrarily large sets of exemplar images. The LatentSleuth Workstation includes a very sophisticated toolbox that supports latent fingerprint examiners during Comparison. LatentSleuth is currently being evaluated by crime laboratories as a tool for increasing the efficiency of latent fingerprint examiners in the Analysis and Comparison phases of latent examination. The LatentSleuth technology is utilized to build a Latent Enrollment Process that is used to define an Objective Measure of Similarity to a Latent Image for an arbitrary exemplar image.

The research project focuses on in-depth statistical analysis on a very large body of Objective Similarity Measurement data, which are generated by applying the Latent Enrollment Process to the images in the SD27 Latent Data Set. The statistical assessments of the rarity of true-mate Similarity Measurements are the responses to the Path Forward Report introduced above. This presentation will demonstrate the method of modeling the spurious similarity that non-mate exemplar images can exhibit to a particular latent image. Historical development stages of the modeling of spurious similarity have been presented by the researchers at both forensic science and statistics conferences (A similarity score, 2013; Automated statistically ranked, 2012; Evaluating forensic science evidence, 2015; Ridge specific markers, 2012).

Automated statistically ranked latent-to-reference print overlays (Poster). (2012). *Presented at the NIJ Impression and Pattern Evidence Symposium (IPES 2012)*, Clearwater, Florida.

Ridge specific markers for latent fingerprint identification. (2012). Presented at *EAFS 2012 European Academy of Forensic Science Conference*, The Hague, The Netherlands.

A similarity score for fingerprint images. (2013). Presented at *The Statistics in Forensic Science Topic Contributed Paper Session at the Joint Statistical Meetings*, Montreal, Canada.

Evaluating forensic science evidence using a computational pairwise comparison algorithm to establish a range of spurious similarity and to discriminate true similarity. (2015). Presented at *DTRA/NSF ADT Program*, Arlington, Virginia.

2:30–2:50

Occurrence and Utility of Latent Print Correspondences That Are Insufficient for Identification

David Stoney, PhD, Stoney Forensic, Inc.

Description: Latent prints that have insufficient characteristics for identification (no value for identification [NVID]) often have discernable characteristics that could form the basis for lesser degrees of correspondence or probability of occurrence within a population. Currently, those latent prints that experts judge to be insufficient for identification are not used as associative evidence. How often do such prints occur? What is their potential value for association? Would they actually impact case investigations or prosecutions in a useful way? The goal of the present project is to make a reasonable measurement of the occurrence and usefulness of latent print correspondences that are insufficient for identification.

Abstract: Latent prints that have insufficient characteristics for identification (no value for identification [NVID]) often have discernable characteristics that could form the basis for lesser degrees of correspondence or probability of occurrence within a population. Currently, those latent prints that experts judge to be insufficient for identification are not used as associative evidence. How often do such prints occur? What is their potential value for association? Would they actually impact case investigations or prosecutions in a useful way? The goal of the present project is to make a reasonable measurement of the occurrence and usefulness of latent print correspondences that are insufficient for identification.

Current program objectives (Phase I) are to

- Collect 1000+ latent prints from casework, representative of current practices, with clear Level 2 ridge detail but that fall below the threshold "of value for identification."
- Under reasonable, well-defined assumptions and well-defined currently available methods, measure an expected maximum associative value (selectivity) for each of these latent prints.
- Categorize the rates of occurrence and associative value by the type of case (violent crimes vs. property crimes) and by currently available, objective measures of latent print quality.
- Use the findings, along with input from key constituencies, to design the scope and specific details for Phase II: determining, under reasonable assumptions and specific case contexts, the potential contribution of these prints to actual criminal prosecutions.

This presentation will give results from Phase I and discuss the scope and details of Phase II.

Using six donor forensic science laboratories, 1,717 NVID latents from 1,024 cases have been collected. Each latent print was screened by the principal investigator and re-assessed by a highly qualified, certified latent fingerprint examiner with respect to the NVID decision and probable number of Level 2 minutiae. Approximately 54% of the latent prints collected have met program requirements.

Measurements of associative value were made using an expected score-based likelihood ratio (ESLR). Auto-encoding of minutiae was performed using a SAGEM-Morpho Light-Out system in version 10. Quality maps for latent prints were obtained using the Universal

Latent Workstation (ULW v6.4.1 with LQMetrics). Auto-encoded minutiae were accepted only for contiguous regions of the latent print showing higher quality (Quality 2 and above). Similarity scores were computed using a Morpho DMA equipped with a matcher in version 9.

Measurements are underway. To date, most prints (69%) show an ESLR with weight of evidence between 10^3 and 10^6. None of the NVID latents meeting program criteria showed an ESLR lower than 10^3.

This work provides, for the first time, a measurement of the occurrence and associative value of NVID latents in casework. The actual usefulness of these prints depends on the case context. In Phase II, we will be working with investigators, prosecutors, and crime laboratories to study prints found in well-defined case contexts. Phase II will answer whether, how often, and to what degree associations from these latent prints could answer questions of relevance within specific case contexts.

This project was supported in part by Award No. 2016-R2-CX-0060 awarded by the National Institute of Justice, Office of Justice Programs, U.S. Department of Justice. The opinions, findings, and conclusions or recommendations expressed in this presentation are those of the authors and do not necessarily reflect those of the Department of Justice.

2:50–3:10

A Bayes Factor for Fingerprints, Using a Modified Approximate Bayesian Computation Approach

Jessie Hendricks, MS, South Dakota State University

Description: The Bayes factor has been advocated to quantify the weight of forensic evidence. However, it cannot be directly evaluated in many situations because of the complexity of the mathematical characterization of the evidence.

Approximate Bayesian Computation (ABC) is an algorithmic method that allows the assignment of a Bayes factor in these settings. We propose a novel approach to assigning ABC Bayes factors that addresses one of the algorithm's main issues, based on a property of the receiver operating characteristic (ROC) curve. We used our methods to revisit a fingerprint model previously published in the *Journal of the Royal Statistical Society*.

Abstract: Many scholars have advocated the use of the Bayes factor to quantify the weight of forensic evidence. However, issues arise in evaluating the Bayes factor for fingerprint evidence (and many other forensic evidence types) because of the complexity of the mathematical characterization necessary to capture the information contained in the evidence. For example, a friction ridge pattern is commonly characterized by heterogeneous high-dimensional random vectors containing information on minutia locations and spatial relationships, minutia types, and minutia orientations.

The difficulty in evaluating the Bayes factor lies in the necessity to assign probability distributions to these complex random vectors. Many methods that avoid directly modeling the distribution of fingerprint characteristics have been proposed, although none have been accepted in practice.

This research revisits the methods proposed by Neumann, Evett, and Skarrett (2012) to assign a Bayes factor for fingerprint evidence by using an Approximate Bayesian Computation (ABC) algorithm previously developed for use in population genetics.

The ABC algorithm results in an approximate Bayes factor for model selection. Here, we have adapted the ABC algorithm for the fingerprint setting where each model describes a

different proposition for how a latent print was generated. For example, the first proposition might be that a given individual left the trace, while the second proposition might be that a random person from a relevant population left it. The ABC Bayes factor can be assigned without defining a probability distribution for the random vectors characterizing fingerprint evidence. Instead, many pseudo-fingerprints are generated with respect to each of the proposed models. Using a specially-designed measure of distance between the mathematical characterizations of two fingerprints, distances are calculated between the latent print and each of the generated pseudo-fingerprints. Intuitively, small distances correspond to pseudo-fingerprints that are "similar" to the latent print.

In a similar fashion to Neumann et al., the original ABC algorithm proposes defining a similarity threshold such that distances less than that threshold correspond to pseudo-fingerprints that are "similar" to the trace, and distances greater than the threshold correspond to dissimilar pseudo-fingerprints. The ratio of the number of pseudo-fingerprints generated under each model that are considered "similar" to the unknown latent print is used as a proxy for the Bayes factor.

Issues with the choice of the similarity threshold have been recognized and documented in the literature on ABC. We propose a novel approach to address this issue, based on a property of the receiver operating characteristic (ROC) curve that allows us to remove the need to choose a similarity threshold in the algorithm. The first derivative of the curve can be evaluated near zero and used to assign the Bayes factor for the two considered propositions.

To test the performance of the modified ABC algorithm for assigning a Bayes factor for fingerprints, we have conducted a large-scale experiment that considers separately each of the following as the latent print donor from the first proposition: the true source of the latent print, the closest non-matching finger from a large database (4 million fingerprints), and a finger from a random individual in the database. In each of these cases, a relevant subset of individuals in the database was used as the population considered in the second proposition. By testing in each of these settings, we could confirm that the model produced an ABC Bayes factor that consistently provided support for the correct proposition.

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3:10–3:30

Assessing and Reducing Variability in Friction Ridge Suitability Determinations

Heidi Eldridge, MS, RTI International

Description: Variability within and between examiners on value decisions has been well-documented, but what factors most influence decision-making? Can variability be reduced? And is the suitability decision more nuanced than a binary value/no value response?

Research is underway to understand how examiners reach suitability decisions, explore the use of multiple value scales, and develop a software tool to reduce variability in suitability decisions.

A white box study involving over 100 latent print examiners has collected data on the information examiners believe is most diagnostic in reaching their decisions and recorded their suitability decisions along four scales: value, complexity, Automated Fingerprint Identification System (AFIS) quality, and difficulty. Preliminary results will be shared.

Abstract: Variability within and between examiners on value decisions has been well-documented, but what factors most influence decision-making? Can variability be reduced? And is the suitability decision more nuanced than a binary value/no value response?

This talk describes ongoing research to understand how examiners reach suitability decisions, explore the use of multiple scales of value for different applications, and develop a software tool to reduce variability in suitability decisions.

A white box study involving over 100 latent print examiners has collected data on the information examiners believe is most diagnostic in reaching their decisions and has asked them to render suitability decisions along four suitability scales: value, complexity, Automated Fingerprint Identification System (AFIS) quality, and difficulty. Preliminary results that characterize the relationship between diagnostic factors and suitability decisions will be shared. These data will be combined with objective clarity and rarity data in the second phase of the project to develop a software tool to reduce variability in suitability decisions.

One hundred latent fingermark images were selected in a pseudo-random draw from a database containing over 1,600 casework impressions of varying quality. From these 100 images, each participant was presented with 30 images such that individual participants viewed different marks, and each mark was viewed by between 26 and 41 participants. Over 100 participants completed the study.

In the white box phase of this study, participants were asked to use a Picture Annotation System (PiAnoS) web interface to view and analyze each of the 30 images. For each image, participants were asked to annotate only the information that they noted and considered in making their suitability decisions. As this was not a test of visual acuity but of decision-making, participants were specifically instructed *not* to annotate everything they could see but only those things that factored into their decisions. Tools were provided for annotating minutiae type and confidence, incipient ridges, pores, target groups, and diagnostic minutiae clusters. Participants were also invited, but not required, to use quality mapping tools.

After completing their annotations, participants were asked a series of questions about their observations of pattern type, clarity, distortion, and level 3 detail and how they impacted their decisions. They were further asked to render a suitability decision along each of four scales: value, complexity, AFIS quality, and difficulty.

Descriptive analyses were performed on the data to describe the relationships between annotated variables and the suitability decisions that were reported. Future phases of this research will use machine learning to identify the most diagnostic variables and create a model to predict suitability decisions along the four scales based upon an optimized combination of the annotations entered by examiners for key variables and objective clarity and rarity data as measured by existing models. This model will ultimately be offered for use in reducing variability in suitability decisions within working laboratories. Preliminary results of the white box study phase of the project are presented here.

| Wednesday, January 24 |

3:50–4:30

Developments in Particle Combination Analysis Particle Combination Analysis in Footwear Investigations

David Stoney, PhD, Stoney Forensic, Inc.

Description: Particle combination analysis (using very small particles [VSPs]) is a new approach, highly significant for its potential to expand the number of cases to which trace evidence can meaningfully contribute and for its ability to include a quantitative statistical approach to data interpretation. Research has demonstrated that this approach has exceptional promise to expand the number of cases where trace evidence can be used and to provide quantitative measures of evidential value. The laboratory analyses are highly efficient, utilizing existing crime laboratory personnel and equipment.

Abstract: Particle combination analysis (using very small particles [VSPs]) is a new approach, highly significant for its potential to expand the number of cases to which trace evidence can meaningfully contribute and for its ability to include a quantitative statistical approach to data interpretation (Stoney & Stoney, 2014; Stoney, Bowen, & Stoney, 2015). Research has demonstrated that this approach has exceptional promise to expand the number of cases where trace evidence can be used and to provide quantitative measures of evidential value. The laboratory analyses are highly efficient, utilizing existing crime laboratory personnel and equipment.

The current state of development of Particle Combination Analysis will be briefly reviewed: what has been demonstrated, what has been suggested, and what remains to be done. Prior research, employing *reasonable choices* of analytical and statistical parameters, has (1) demonstrated the presence of highly discriminating VSP profiles on the surfaces of common items of physical evidence, (2) characterized VSP combinations using analytical instrumentation and expertise commonly available in forensic laboratories, (3) developed statistically rigorous measurements of correspondence between VSP profiles, and (4) produced objective measures for the resulting probative value (Stoney, Bowen, & Stoney, 2015; Stoney, Neumann, Mooney, Wyatt, & Stoney, 2015; Stoney & Stoney, 2017).

The reasonable choices of analytical and statistical parameters employed in prior research were sufficient to demonstrate feasibility and potential. Systematic development and validation of these methods requires that the analytical and statistical parameters be more critically examined and that the key factors influencing the performance of the methods be identified.

The optimization of a VSP analysis protocol requires that factors influencing the reliability, costs, and selectivity be identified. Separating factors (a quantity or quality that does have an influence upon the system) from variables (a quantity or quality that might have an influence upon the system), requires a screening stage of experimental design. The result will be identification of a few important, controlling factors that must be addressed

in order to meaningfully optimize the protocol. It will also provide information, such as the variability and magnitude of effects that will be needed for the next stage of process improvement.

Determination of the key factors and the magnitude of their effects will result in a significantly improved capability. Analytical and computational parameters, previously selected as *reasonable choices*, can be revised and replaced, with a combined effect that will have a material impact. Secondly, these results will provide necessary input to experimental designs that will permit systematic improvement and optimization. Identification of key factors will enable these critical steps and further the transition of particle combination analysis to practice. Thirdly, and most importantly, the results will contribute directly to the fundamental advancement of a new quantitative and broadly applicable approach to trace evidence. Well-documented factors and effects for one VSP analysis protocol will allow parallel, collaborative assessments of alternative options for high-efficiency analysis of VSP (such as micro Raman methods, micro X-ray fluorescence [XRF], genetic analysis, or alternative scanning electron microscopy/energy dispersive spectroscopy [SEM/EDS] protocols).

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Particle Combination Analysis in Footwear Investigations

David Stoney, PhD, Stoney Forensic, Inc.

Description: Although it is well recognized that criminals track dust to and from every crime scene, dust particles on a suspect's shoes are very seldom used as evidence linking the accused to the crime. The major obstacle preventing the use of this type of evidence is that the shoes have mixtures of particles arising from activity before, during, and after the crime itself. Particle combination analysis allows the separation of particle signals arising from different sources and can be applied to the interpretation of mixtures of particles found on the soles of footwear.

Abstract: The separation of particle signals arising from different sources is one of the enabling operations for particle combination analysis (PCA) (Stoney & Stoney, 2014). Although it is well recognized that criminals track dust to and from every crime scene, dust

particles on a suspect's shoes are very seldom used as evidence linking the accused to the crime. The major obstacle preventing the use of this type of evidence is that the shoes have mixtures of particles arising from activity before, during, and after the crime itself (Morgan et al., 2009). Methods separating the evidentiary particle "signal" from background noise would enable a powerful new and widely applicable forensic capability. This capability would augment traditional footwear pattern evidence with objective quantitative associations, addressing one of the specific issues raised in the 2009 National Academy of Science (NAS) report. To help pursue this possibility, methods are being developed and tested that will lead to better understanding of the loss and replacement of very small particles (VSPs) on the contact surfaces of footwear.

Prior work established that a 250 m walk (approximately 175 steps per shoe) removes and replaces particles on the outermost contact surfaces of footwear (Stoney, Bowen, & Stoney, 2016). It is important to achieve a better understanding about how quickly this replacement occurs. This understanding will (1) help interpret the significance of the traces found on the contact surfaces (representing the most recent environment(s) to which the footwear was exposed—How recent?) and (2) provide a foundation for the differential analysis of these traces and those found on other areas of the footwear.

Two distinctly different and commonly encountered types of shoe soles were used in this study: athletic shoes (with flexible rubber soles) and work boots (with hard rubber soles). Three well-characterized environmental sites with characteristic VSP profiles (distinguishable by defined qualitative and quantitative particle characteristics) were used for footwear exposures under dry, dusty conditions.

Thirty-six pairs of shoes (18 pairs of each type) were exposed to a "loading site" by walking distances of 175 steps/shoe: six pairs (12 shoes) of each type in each of the test site environments. For each set of 12, two shoes (one pair) were set aside as a control (zero steps in the second environment). Each of the remaining five pairs of shoes were exposed for a different number of steps to second of the three environmental sites: 5, 10, 25, 50, and 100 steps/shoe.

VSPs were recovered from the contact surfaces of all shoes by swabbing, analyzed by polarized light microscopy and interpreted using a (1) chi-square measure of distance and (2) Latent Dirichlet Allocation model developed by two of the authors at South Dakota State University (M.A. and C.N.).

Substantial loss and replacement of VSP occurs on contact surfaces of footwear in as little as five steps/shoe. By 25 steps/shoe the replacement is substantially complete. Knowledge of the rapid loss and replacement on contact surfaces provides a basis to explore differential analysis of (1) VSP signals from the contact areas of footwear and (2) those from more recessed areas of the footwear sole.

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4:30–4:50

Location Detection and Characterization in Mixtures of Dust Particles

Madeline Ausdemore, PhD, South Dakota State University

Description: Dust particles from shoes may reveal the presence of an individual at some location, for example, a crime scene. We have developed a model to resolve mixtures of dust profiles and answer two foundational questions:

1) Given a mixture from N locations, with samples from each, what is the proportion of each location in the mixture?

2) Given a mixture from N+M locations, with samples from N locations, what are the dust profiles and respective contributions of the M unknown locations?

This presentation gives an overview of the model, discussing the concepts behind it, its performance, and some results when applied to real-life data.

Abstract: Dust particles recovered from the soles of shoes may allude to the locations recently visited by an individual. In particular, they may indicate the presence of an individual at a particular location of interest, for example, the scene of a crime.

A dust profile at any given location can be described by the respective proportions of the different particle types that are present at that location. The dust mixture recovered from a shoe, then, corresponds to a mixture of the dust profiles of the different locations that have been visited by the individual wearing the shoes. During this project, we have developed a statistical model that resolves mixtures of dust profiles and answers two foundational questions:

1) Given samples of dust from N known locations, and a mixture of dust (consisting exclusively of some or all of the N known locations) recovered from under a pair of shoes, what proportion of the dust mixture originates from each of the N locations?

2) Given a mixture of dust from N+M locations recovered from under a pair of shoes, but samples of dust from only N known locations, what are the dust profiles of the M unknown locations, and in what proportions are these M unknown locations present in the dust mixture?

Our model is based on Latent Dirichlet Allocation, which is a generative probabilistic model developed for natural language processing. For this project, we modify the original model to account for multiple sources where dust can be generated and multiple locations where dust sampled might be recovered. We also introduce constraints to facilitate the training of the model. Parameters are estimated using Variational Bayesian Inference.

The scope of our presentation is to familiarize the audience with an objective, interpretative approach that may considerably change the way small particles are used for forensic purposes. The first objective of our presentation is to convey the gist of our model by means of a simple acyclic graph, which will aid in portraying the generative process of dust mixtures. The use of this acyclic graph will allow the audience to gain insight into the generative process of dust samples as well as the underlying relationships that exist between

sources that generate dust, dust profiles at given locations, and the respective proportions of these profiles in dust mixtures, without having to delve into complex mathematics.

Following this brief overview of the concepts behind the model, the second objective of our presentation is to discuss the performance and robustness of the model under different scenarios using simulated data. The first round of simulations investigates the ability of the model to accurately determine the true mixing proportions of N known dust locations in a dust mixture (a) when the dust profiles at these locations are (dis)similar from each other and (b) for different levels of dilution (e.g., for N=2, our dilution levels were 1:1, 1:2, 1:3, 1:4, and 1:9). The second round of simulations is similar in execution but this time focuses on mixtures composed of dust from a known element (i.e., dust profiles from a varying number of known locations) and an unknown element (i.e., dust profiles from a varying number of unknown locations). This set of simulations serves to describe the extent to which the model is able to extract the profile(s) and relative contribution(s) of the unknown location(s) to a mixture of dust under the same conditions studied during the first round of simulations (i.e., mixtures of multiple similar profiles in varying proportions, mixtures of multiple distinct profiles in varying proportions). Overall, our results show that it is possible to resolve mixtures of dust profiles, hence removing one of the main limitations of the use of particles in forensic science. Furthermore, our model can be used to statistically associate mixture elements with given locations of interest. The implication of our results is that the examination of dust particles has great potential as a forensic tool in the near future.

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4:50–5:10

Elemental Analysis of Adhesive Tapes as Forensic Evidence by LA-ICP-MS and LIBS

Claudia Martinez-Lopez, MS, Florida International University

Abstract: Pressure-sensitive adhesive tapes are often submitted as evidence, as they may be used for packaging drugs, in the manufacture of improvised explosive devices to immobilize victims in assault and rape cases, among other criminal activities. The use of Laser Ablation-Inductively Coupled Plasma-Mass Spectrometry (LA-ICP-MS) and Laser Induced Breakdown Spectroscopy (LIBS) has been shown to improve the discrimination and characterization capabilities for tape analysis over other, more conventional methods by detecting over 15 elements in the analysis of electrical tapes. The method for the analysis and comparison of tapes by LIBS was developed and reported here for the first time. A comparison of the analytical figures of merit for the analysis of electrical and packaging tapes using both LA-ICP-MS and LIBS is also reported.

Two inter-laboratory trials were completed including several active forensic laboratories and academic researchers. The first inter-laboratory test consisted of the analysis of three known electrical tapes (Ks) and three questioned electrical tapes (Qs) by conventional methods: physical characterization and microscopy, Scanning Electron Microscopy/Energy Dispersive Spectroscopy (SEM/EDS), Fourier Transform Infrared Spectroscopy (FTIR) and Pyrolysis-Gas Chromatography-Mass Spectrometry (Py-GC-MS), and LIBS and LA-ICP-MS. The participants were asked to compare each K to all the Qs. The samples selected consisted of two 3M Scotch and a General Electrical tape.

A second inter-laboratory test was designed comprising only the elemental analysis methods: SEM/EDS, LIBS, X-ray Flourescense (XRF), and LA-ICP-MS. The samples sent for the second inter-laboratory test consisted of one K and three Qs. The three electrical tape samples were Scotch 3M, not differentiated by organic/molecular spectroscopy or physical analysis. The main conclusions from both inter-laboratory trials were as follows:

- The Scotch 3M tapes were not always differentiated when using microscopy, FTIR, and SEM/EDS. These techniques were not always suitable to detect slight differences in the chemical composition of these 3M tapes.
- LA-ICP-MS and LIBS correctly associated each K to its respective duplicate sample within the Qs as well as found major differences between the different 3M tapes and increased the element menu by more than 10 elements for LIBS and 15 elements for LA-ICP-MS.
- The reporting language varies greatly between laboratories for the physical description(s) of the samples and for the final reporting and interpretation of the findings.
- Similarly, the methods of analysis for LA-ICP-MS and LIBS were developed and optimized for packaging tapes. A sample set consisting of eight packaging tapes originating from Asia were analyzed by both methods, and the performance of LIBS was assessed by comparing the results to the well-established LA-ICP-MS. The use of these laser-based methods allowed for the detection of up to 7 elements by LIBS, and 11 elements by LA-ICP-MS. In addition, LIBS proved especially useful in detecting elements that were problematic by LA-ICP-MS such as lithium and potassium. Multivariate analysis of the data was used to visualize chemical similarities and/or differences obtained by each technique.

A "Total Light Area" normalization was used, as this strategy provided very good analytical figures of merit for the comparison of packaging tapes for the selected elements. The best-performing comparison criteria for the packaging tapes by LIBS were found to be spectral overlay and comparing the means +/-5s. These results show that LIBS is a viable alternative to the already established LA-ICP-MS for forensic analyses and comparisons of tape evidence.

| Thursday, January 25 |

8:00–8:20

Untangling the Relationship between Hair Microstructure and Ancestry

Sandra Koch, MS, Pennsylvania State University

Description: Patterns of variation in morphology and microstructure are frequently applied in forensic contexts to resolve or support questions of ancestry and personal identification. Human hair varies considerably in form and color within an individual and among groups. We tested the reliability and limitations of traits frequently applied in forensic hair examinations by measuring the diversity in human hair form, its size and shape, and the density and distribution of pigment granules (melanosomes) within hair. Differences in hair form and cuticle thickness are apparent between broadly defined geographic ancestry groups, but these categories do not necessarily reflect our modern admixed world.

Abstract: This presentation will cover a portion of my dissertation research as it relates to hair traits and their association to ancestry. I will focus on research resulting from two collections of human hair. The first is the historic Trotter hair collection, used in some of

the foundational research on human variation. The second is a recent study at Pennsylvania State University, where we sampled human hairs along with DNA for genotyping to estimate genetic ancestry. The hair samples from these collections have been used to study the relationship between hair form and microstructure with ancestry.

Part 1: Human scalp hair is highly visible and can exhibit pronounced variability in color, degree of curl, cross-sectional shape, diameter, and length. Variation exists within and between populations. In recent years, the lack of quantitative studies focused on hair morphology has been cited as a contributing factor for the imprecision, and lack of reliability, noted in forensic reports (President's Council of Advisors on Science and Technology (PCAST) and National Academy of Science (NAS) reports). These critiques failed to account, however, for studies of morphological variation in hair by race undertaken by early 20th-century anthropologists.

Method: Using oil immersion microscopy and ImageJ, we measured hair shape, size, and pigmentation patterns within and among populations using hair samples from the Trotter Collection at the Smithsonian National Museum of Natural History. Mildred Trotter was an anatomist and physical anthropologist whose studies of hair form variation, growth, somatic distribution, racial characteristics, and sex differences during the early part of the 20th century make up some of the foundational research that led to microscopical hair analysis as conducted in forensic laboratories today.

Result: Analyses of hair dimensions and the number and distribution of pigment particles within a hair cross section revealed variability within groups and demonstrated that hair traits are not easily separable into distinct categories by ancestry.

Discussion: These findings offer support for eliminating the use of the outdated three-category racial typologies. We observed general trait patterns that may be useful for future research and point to the need for additional research on the effects of admixture to better assess ancestry traits in human hair.

Part 2: The three-layer structure of hair and differences in individuals, groups, and between groups has been the focus of much research.

Method: Using transmission electron microscopy (TEM) we investigated the degree of cuticle variability within individual hairs, within an ancestry group, and between groups. Forensic hair analysis incorporates assessments of thin or thick cuticle dimensions generally associated with ancestry, but these broad trends have not been rigorously investigated. We tested these assumptions using hair samples from participants of known European, East Asian, and African genetic ancestry.

Result: Measurable differences were found in cuticle thickness and in the number of cuticle layers among all three groups.

Discussion: Hairs associated with African ancestry tend to have thinner cuticles with fewer layers making up the cuticle, while hairs from people of European and East Asian ancestry tend to have thicker cuticles made up of more layers. Variation between European and East Asian samples showed some dissimilarity in cuticle thickness and in the number of layers, but these distinctions were not statistically significant. Testing European and East Asian hairs against African hairs showed statistically significant differences in the cuticle thickness and number of layers.

Part 3: The racial terminology used by forensic scientists to classify hairs is outdated and no longer scientifically supported. We conducted a blind interlaboratory study and reviewed proficiency test report language to examine how forensic analysts are currently analyzing and describing hair. Combining trait descriptions with ancestry terminology will be presented as a way forward for hair analyses. Ancestry assessments from the hairs analyzed in the interlaboratory study and their known levels of genetic ancestry will be used to demonstrate the extent that hair examiners can indicate admixed ancestry.

Conclusion: Using both light microscopy and TEM, we tested hair traits used by forensic analysts when classifying ancestry based on hair form and patterning of microscopic characteristics. From these tests, we found that there are differences in hair shape and cuticle dimensions between broadly defined ancestral populations. We also found significant within-person variability and within-group variation, so some traits should be used with caution when attempting to rely on measurements to classify unknown hairs to a particular ancestry group. How to appropriately qualify conclusions and report language will be discussed.

This research has been funded by a combined grant from National Science Foundation (NSF)-National Institute of Justice (NIJ) (award 1453571), "Variation in Human Hair Morphology within and among Human Populations."

8:20–8:40

An Assessment of Head Hair Comparison via Protein Profiling

Joseph Donfack, PhD, Federal Bureau of Investigation

Abstract: Recently, scientists from Lawrence Livermore National Laboratory's Forensic Science Center and other collaborators developed a hair shaft protein-based method for human identification. This method exploits genetic information preserved in hair proteins in the form of single amino acid polymorphisms (SAPs). As such, the SAP profiling technique has the potential to play a critical role in our ability to complement forensic microscopic hair comparison.

The goal of our research was to conduct a preliminary assessment of the efficacy and reliability of SAP profiling for its potential use in forensic casework. We conducted two preliminary studies: 1) determining the adequate hair shaft length required for analysis via SAP profiling using a protein extraction method developed in our laboratory and 2) evaluating the accuracy of current methods for identifying SAPs.

On the first objective, a single hair from a single donor was serially sectioned into five hair lengths, from 2cm to 0.12cm. Our study identified 299 proteins and 130 proteins in 2cm and 0.12cm of hair shaft, respectively. Of these proteins, about 85% were non-keratins and 3% were hair keratins. Hair keratins were mostly resistant to a decrease in hair length. Thus, we determined hair segments of 2cm to 0.12cm can provide enough information for proteomic analysis.

The second objective of this study was to determine the best method to accurately identify SAPs from mass spectral data. Typical mass spectral analysis software does not have the ability to identify peptides that may vary from public protein reference sequence databases (i.e., genetically variant peptides or GVPs). Two alternative options to identify GVPs and SAPs are to 1) use an open software program called Global Proteome Machine (GPM) or 2) build a custom database of human protein sequences that mass spectral analysis software can search against.

For this pilot study, we compiled SAP profiles of two keratin proteins (KRT86 and KRT35) derived from three human subjects using both methods. The GPM method created profiles that contained on average about twice as many SAPs than our custom database. Sequencing of nuclear DNA obtained from the three donors, which helps determine false positive and

false negative rates, will also be presented. Based on our preliminary data, it is clear the main concern for the SAP profiling technique is no longer whether we can extract proteins from small hair lengths (e.g., 0.12cm) but is now identifying a set of core SAPs that could be used for human hair shaft comparison.

8:40–9:00

Instrumental Validation of a Scanning Electron Microscope with Energy Dispersive X-Ray Spectroscopy

Amy Reynolds, MA, Boston Police Department Crime Laboratory

Description: This presentation will discuss the complex process of validating scanning electron microscooe with energy dispersive X-ray spectroscopy (SEM/EDS). The information gained from this presentation can be used in any laboratory setting to validate an SEM/EDS for use with trace evidence samples, including glass, tape, paint, general unknowns, and gunshot primer residues.

Abstract: The push for ISO 17025 accreditation of all forensic science laboratories has been ongoing, and one of the requirements of the accreditation process is the validation of methods, specifically section 5.4.5 in the ISO 17025 document. After purchasing and installing our JEOL IT300LV SEM with Oxford X-Max^N EDS using the AZtec software, the task of validating the instrument for use with trace evidence samples was the next step. In the attempts to cover ISO 17025 validation requirements, our accrediting body's supplemental requirements, and our own laboratory's validation requirements, a plan was drafted, edited, and eventually carried out. The Boston Police Crime Laboratory validated the SEM/EDS to determine the reliability, reproducibility, and sensitivity of the instrument. The validation included verifying the magnification and measurement tools using a copper grid, testing the resolution of the EDS with a known Manganese (Mn) standard, determining the X-ray range using a known Molybdenum (Mo) standard, determining the lower eV limit using a known Boron (B) standard, testing the beam energy range by examining the Bremsstrahlung curve, monitoring the consistency of the probe current with a pinhole aperture and a current meter, and analyzing the reproducibility of the spectra using different trace evidence samples. After performing several repetitions on all these steps, a validation report was drafted and the SEM/EDS procedure for trace evidence casework samples was finalized. Gunshot primer residue is a new category of testing for the Boston Police Crime Laboratory, therefore, the validation of the SEM/EDS for analyzing gunshot primer residues has started, and this validation plan has been revisited and edited as new information is obtained from the forensic science community. Discussing the complex validation process of the SEM/EDS for trace evidence sample analysis, including gunshot primer residues, may assist other laboratories with their validation and avoid duplicating efforts.

Special Thanks are to be given to Matney Wyatt (US Army Criminal Investigation Laboratory), David Edwards et al. (JEOL), and Richard McLaughlin et al. (Oxford), and other forensic scientists.

9:00–9:20

Attenuated Total Reflection Infrared Microscopy and Charpy Impact Tester for Analysis of Automotive Paint Smears

Barry Lavine, PhD, Oklahoma State University

Description: A procedure to simulate paint smears generated in vehicle-vehicle or vehicle-pedestrian hit-and-run collisions using a Charpy impact tester has been developed.

Currently, paint smears encountered in a collision cannot be created in a laboratory. Using a Charpy impact tester, paint smears acquired on metal and plastic surfaces have been analyzed by IR microscopy. A Charpy impact tester can simulate an automobile collision with controllable collision speed and direction. Multivariate curve resolution applied to line maps of these smears show regions where the layers of paint are separated. The long-term goal is the development of forensic standards for paint transfer and paint smear analysis.

Abstract: Paint smears, which represent a type of automotive paint sample found at a crime scene, have proven problematic to forensic automotive paint examiners as there are no reference materials available in paint databases to generate hit-lists of potential suspect vehicles. A procedure based on a Charpy impact tester has been developed to generate smears (e.g., abraded or deformed clear coats, clear coat and color coat layers mixed together, or clear coat, color coat, primer, and e-coat layers mixed together) due to paint transfer from an automotive substrate to any surface of interest under conditions simulating those of a real collision. As revealed by an attenuated total reflection (ATR)-infrared (IR) microscope and multivariate curve resolution, there is separation of the automotive paint layers in some regions of the line map but not in other regions. In contrast, a paint smear appears intact in all regions of a line map using transmission IR microscopy. The unmixing of the layers is evident only with ATR-IR microscopy because of its superior spatial (x, y, and z) resolution. Because smeared paint in all likelihood undergoes melting due to the heat generated by the impact, a separation phenomenon may occur during fluid flow due to differences in viscosities and/or affinities for the substrate. This result indicates that paint smear standards can be developed for proficiency testing using the approach described here. The Charpy technique can also simulate an automobile collision with controllable collision speed and direction as well as momentum/energy transfer. This suggests that investigative lead information about the speed and momentum of a vehicle involved in a collision as well as the make, line, and model of the vehicle can potentially be obtained from a paint smear using ATR-IR microscopy to analyze the smear and a Charpy impact tester to simulate the smear.

9:20–9:40

Development of Infrared Library Search Prefilters for Automotive Clear Coats from Simulated ATR Spectra

Barry Lavine, PhD, Oklahoma State University

Description: A simulation algorithm has been developed to correct ATR spectra for distortions such as the relative intensities and broadening of the bands, the introduction of a wavelength shift at lower frequencies, and frequency shifts for some vibrational modes due to high pressure applied by the DAC used to generate the IR spectra in the PDQ database. Currently, forensic laboratories in the United States are using ATR with increasing frequency to collect FTIR spectra of automotive paints. The simulation algorithm is crucial for scientists who rely on chemical information contained in the clear coat and primer layers when attempting to identify a motor vehicle from a sample of paint.

Abstract: A previously published study featuring an attenuated total reflection (ATR) simulation algorithm (Lavine, Fasasi, Mirjankar, Nishikida, & Campbell, 2014) that mitigated distortions in ATR spectra was further investigated using pattern recognition techniques to evaluate its efficacy in enhancing searching of infrared (IR) transmission libraries. In the present study, search prefilters were developed from simulated ATR spectra to identify the assembly plant of a vehicle from ATR spectra of the clear coat layer.

Four-hundred-fifty-six IR transmission spectra from the Paint Data Query (PDQ) database that spanned 22 General Motors assembly plants serving as a training set cohort were transformed into ATR spectra by the simulation algorithm. These search prefilters were formulated using the fingerprint region (1500 cm^{-1} to 500 cm^{-1}). Both the simulated ATR spectra (training set) and the experimental ATR spectra (validation set) were preprocessed for pattern recognition analysis using the discrete wavelet transform, which increased the signal to noise of the ATR spectra by concentrating the signal in specific wavelet coefficients. ATR spectra of 14 clear coat samples (validation set) measured with a Nicolet iS50 Fourier Transform Infrared Spectroscopy (FTIR) spectrometer were correctly classified in the assembly plant(s) of the automotive vehicle from which the paint sample originated using search prefilters developed from 456 simulated ATR spectra. The ATR simulation algorithm successfully facilitated spectral library matching of ATR spectra against IR transmission spectra of automotive clear coats in the PDQ database.

Emmons (2007) and coworkers previously reported that frequency shifts for some vibrational modes are observed in IR spectra of polymers measured in a high-pressure transmission diamond anvil cell (DAC). Emmons attributed these observed frequency shifts to the removal of void spaces in the polymer which occurred during the compression of the sample by the DAC. Although the advanced ATR correction module of OMNIC™ cannot correct for this type of spectral shift when converting ATR spectra to IR transmission spectra, the ATR simulation algorithm can correct for these shifts because the simulation algorithm utilizes both the IR transmission spectra of automotive clear coats from the PDQ library and the corresponding ATR spectra of the same paint samples to develop estimates of the incident angle relative to normal for the internal reflection element, the refractive index of the clear coat layer, and the thickness of the paint sample after compression by the DAC. As there are currently no commercial vendors that distribute high-pressure DAC with sufficient energy throughput for automotive paint analysis, the ATR simulation algorithm described here will allow forensic laboratories to continue to utilize the spectral database of PDQ for IR library matching.

Emmons, E. D. (2007). *Vibrational spectroscopy of polymers at high pressure* (Doctoral dissertation). University of Nevada, Reno.

Lavine, B. K., Fasasi, A., Mirjankar, N., Nishikida, K., & Campbell, J., (2014). Simulation of attenuated total reflection infrared absorbance spectra – Applications to forensic analysis of automotive clear coats. *Applied Spectroscopy, 68*(5), 608–615.

10:00–10:20

Further Persistence Studies of PDMS Condom Lubricants

Mickayla Dustin, BS, Institute of Environmental Science and Research

Description: Analysis of intimate swabs from alleged sexual assaults for the presence of condom lubricants is becoming a routine request for trace forensic laboratories. Persistence studies of such lubricants are vital to supporting the interpretation of forensic samples analyzed for the presence of condom lubricants. Previous research has focused on the persistence of polydimethylsiloxane (PDMS) in the vagina. This research has investigated the persistence of PDMS on the penis, in the mouth, and on skin. This research also investigated whether PDMS is present on tampon products available on the New Zealand market and whether PDMS can be detected on swabs that have previously undergone DNA extraction.

Abstract: Analysis of intimate swabs from alleged sexual assaults for the presence of condom lubricants is becoming a routine request for many trace forensic laboratories. The increasing public awareness of the high evidential value of DNA has seen an increase in the use of condoms by sexual offenders.

Persistence studies of such lubricants are vital to supporting the interpretation of forensic samples analyzed for the presence of condom lubricants.

Most condoms in New Zealand are lubricated with polydimethylsiloxane (PDMS), with fewer containing water-soluble lubricants such as polyethylene glycol (PEG). Intimate swabs are routinely analyzed for the presence of PDMS by extracting the swabs with hexane and analyzing these extracts using pyrolysis-gas chromatography-mass spectrometry (Py-GC-MS).

Previous research has focused on the persistence of PDMS in the vagina. This presentation will include the results of research focused on investigating the persistence of PDMS on the penis, in the mouth, and on skin. This research also investigated whether PDMS is present on tampon products available on the New Zealand market and whether PDMS can be detected on intimate swabs that have previously undergone DNA extraction.

Methods:

Penis. Volunteers applied a condom to their penises for a few minutes. After removal of the condom they self-swabbed their penises at specified time intervals and recorded their activities during this time.

Mouth. A blank swab was taken from the mouth of each volunteer by asking the volunteer to rub a cotton swab against the inside of the cheeks and gums. A condom was then placed on a carrot, and the volunteer moved this around in his or her mouth for a minute to simulate oral sex. The volunteer then self-swabbed the inside of the cheeks and gums after specified time intervals. Some volunteers were asked to abstain from eating and drinking during these time intervals.

Skin. Volunteers' forearms were marked using a marker into areas of approximately the same size. Prior to the transfer of PDMS, a control sample was taken by swabbing the inner forearm with a wet swab (preliminary trials determined that wet swabbing recovered more PDMS from skin than dry swabbing). A condom was then placed on a carrot or cucumber and firmly swiped against volunteers' inner forearms. One area of the forearm was swabbed immediately for the initial trials. Volunteers then self-swabbed each marked area of their inner forearms after specified time intervals. The volunteers were asked not to use any personal care products that contained PDMS or other silicone-containing compounds during the time intervals.

Tampons. A range of tampon products available on the New Zealand market was donated by colleagues. One tampon per product was analyzed by extracting four strips of the outer layer and cotton from below the surface. Any applicators present in these products were also analyzed by swabbing the applicator and extracting these swabs.

Swabs for DNA extraction. Two sets of cotton tip swabs were loaded with a known volume of a PDMS solution. One set of swabs was retained as the control swabs, and the second set was extracted for DNA, using standard DNA methods. The swab heads remaining after DNA extractions were extracted and analyzed. The supernatant from the DNA extraction process was also analyzed.

10:20–10:40

Subpopulation of Fibres and Their Importance to Forensic Science

Cátia Pontedeira, MS, London South Bank University

Description: This presentation investigates a subpopulation of fibres (red-pink cottons) found in a fibre population study developed in London. From a total fibre population of 2,387, some 188 were classified as red-pink cotton fibres, and the presence of subpopulations was considered. This presentation displays the main results from this subpopulation study and explores the importance of identifying subpopulations in fibres for criminal investigations.

Abstract: A fibre population study with 2,387 fibres was conducted at London South Bank University to gauge the frequency with which they appeared (to be used in criminal investigations). London South Bank University classroom seats were collected using tape and analyzed with different techniques. This university was chosen because it has a representative sample of seats with several different fibres, given the mixed origin of students.

Each fibre from the population study was analyzed individually and classified accordingly (e.g., color, characteristics, natural or synthetic, presence of medulla, presence of delustrant). Fibres were analyzed using Low-Power Microscope, High-Power Microscope, Comparison Microscope (using different light sources), Fourier Transform Infrared Spectroscopy (FTIR) and Microspectrophotometry (MSP). From the population study, it was concluded that the majority of fibres were natural (82%), most of them blue-colored cotton. Other characteristics such as presence of delustrant on synthetic fibres were also observed in some fibres. The most common combination of fibres was blue-black cotton (497 fibres), and the least common were acetate fibres other than blue-black. Cottons were found in all the colors apart from black-black. Comparing the front of the seats with the back of the seats, it was found that cotton fibres were much more prevalent in the front of the seats and that synthetic fibres were less discrepant (a similar number of synthetic fibres was found in front of the seats and in the back of the seats). After classification of all fibres, a fibre population was found and respective statistics were outlined. Some types of fibres, namely cottons, were very common in this population study. Subpopulation studies are important because they can increase the certainty of two fibres being from a similar garment. In comparing a pink cotton fibre with criminal evidence, it would be known that pink fibres are not very common and therefore, in the presence of a match, the probability of the two fibres being from the same garment would be much higher. But in some cases, the fibre could be very common (e.g., blue cotton fibres), and consequently subpopulations might help to increase or decrease the strength of a piece of evidence. Using this fibre population, I analyzed subpopulations of red-pink fibres. Despite being more infrequent than blue cotton fibres, red-pink fibres were interestingly found often in this study. So there is clear interest in studying this type of fibre further. This study analyzed 188 red-pink cotton fibres. Using MSP, spectra to all these fibres were obtained and compared. Twenty-one subpopulations of red-pink cotton fibres were found with a range of 2 to 11 fibres in each. About 100 could not be included in any subpopulation study due to their specific spectrum, a point to be further discussed. The presentation includes a discussion of the findings of subpopulation studies, a perspective from Europe, particularly their importance in criminal investigations.

10:40–11:00

Comparison of Intra-Roll Subclass Characteristics in Polymer Films

Daniel Mabel, MS, Cuyahoga County Medical Examiner's Office

Description: This presentation will assess the weight of comparing intra-roll subclass characteristics in polymer films. Extrusion patterns, heat seals, perforation patterns, and other incidental manufacturing features will be compared within individual rolls of plastic garbage bags. Multiple rolls of plastic bags of the same manufacturer and type will be purchased from multiple vendors. The subclass features on each bag within a roll will be compared to determine pattern variation from the beginning to the end of the roll. It is hypothesized that intra-roll variation will be low but may show evidence of features and/or patterns shifting during manufacture.

Abstract: Polymer films are commonly encountered as forensic evidence in a wide variety of criminal cases. Plastic bags can be utilized as weapons for the purpose of asphyxiation or suffocation, as wrappings to conceal victims' bodies or body parts, as a means of disposal of incriminating evidence, and as drug packaging.

Latent prints, DNA, foreign hairs, and fibers can all be present on or in plastic bags and can be valuable in connecting a suspect to a victim or a crime scene. Comparisons of polymer films can also be made to establish an association between a known and a questioned bag or to eliminate a known bag as being the source of a questioned bag.

The examination of polymer films includes chemical analysis of the components as well as comparison of multiple physical class characteristics such as length, width, color, film thickness, film layer structure, orientation of fold lines, seal marks, hem width, and perforation pattern. Levels of association between plastic bags range from the association of general class characteristics to the unique identification of individualizing characteristics, that is, a physical/fracture match formed between consecutively manufactured bags from the same roll. However, there are levels of association in between, which rely on the comparison of subclass characteristics. Subclass characteristics are unintentionally produced surface features like die lines that result from the manufacturing process. Per the AFTE Glossary (version 6.101613, 2013), subclass characteristics are "features that may be produced during manufacture that are consistent among items fabricated by the same tool in the same approximate state of wear. These features are not determined prior to manufacture and are more restrictive than class characteristics."

The current study aims to assess intra-roll variation of subclass characteristics on polymer films. Multiple rolls of plastic bags of the same manufacturer and type will be purchased, if possible from multiple separate vendors. The extrusion patterns, heat seals, perforation patterns, and other manufactured features from each bag within a single roll will be examined to determine if the pattern shifts, repeats, and/or changes from the first bag to the last. It is hypothesized that intra-roll variation will be minimal since the striations in the extrusion patterns are largely formed by semi-permanent tool marks in the manufacturing die. These tool marks may change over time as new wear and damage accumulate on the die but should feasibly remain consistent within a single roll of bags. It is possible that the extrusion pattern will shift left or right within a roll depending on the specific manufacturing process. This research does not aim to be comprehensive in scope. Rather, the current study aims to demonstrate that subclass characteristics are consistent within a single roll of plastic bags. If the same subclass characteristic features are encountered in known and questioned polymer films during a casework comparison, there is potential for a stronger associative conclusion between the two items than would exist between two items sharing class characteristics alone. Further study of this topic will expand the sample

size and will include additional manufacturers and types of polymer film. Future study also aims to address the inter-roll variation of subclass characteristics on polymer films.

11:00–11:20

The Effect of Fingerprint Chemicals on the Chemical Analysis and Comparison of Duct and Cloth Tapes

Joanna Bunford, PhD, New South Wales Forensic and Analytical Science Service

Description: Adhesive tapes are often submitted to crime laboratories as evidence associated with violent criminal activities. Adhesive tapes are usually searched for additional evidence such as DNA, fingermarks, fibers, and other trace elements. These collections generally take precedence over analysis of the actual tape and consequently, preliminary evidence collection techniques might influence the original tape composition. This project examined the effect of fingerprint chemicals on eight different tapes, and their chemical analysis and comparison against the original untreated tape. Three fingerprint treatments were used on fresh as well as one-month old prints. Various analytical techniques were utilized including visual examination and non-destructive instrumental analyses.

Abstract: Pressure-sensitive adhesive (PSA) tapes are often submitted to crime laboratories as evidence associated with violent criminal activities. Adhesive tapes are not only collected for their exploitation as an evidence type in themselves but are also searched for other evidence such as DNA, fingermarks, fibers, and hairs. These collections often take precedence over analysis of the actual tape, and consequently these preliminary evidence collection techniques might influence the original tape composition, particularly with respect to the use of fingerprint chemicals.

Through casework, it has been observed that on some occasions where a tape sample from a scene or person has been treated with fingerprinting chemicals prior to submission for comparison to a known roll, minor but reproducible differences have been observed between the samples. While this could show that the tape pieces are from a different source, whether the presence of the chemical treatment may have been an influence must also be considered.

This research project examined the effect of different fingerprint chemicals and treatments on eight different PSA tapes, including those with and without scrim, their chemical analysis, and the comparison with the original untreated tape. The fingerprint chemicals used were cyanoacrylate fuming, Rhodamine 6G staining, and black and white powder suspensions (Wet Wop™). The chemicals were applied on fresh prints as well as on one-month old prints. The analytical techniques utilized for the tape examination included visual examination by the unaided eye, the Macroscope, and a Video Spectral Comparator (VSC6000). In addition, non-destructive instrumental analyses were adopted. These involved Attenuated Total Reflectance (ATR) Spectroscopy, RAMAN Spectroscopy, and X-Ray fluorescence (XRF) technology. The influence of the tested chemicals with the instrumental analyses on the tape samples showed that the powder suspensions had no observable impact on the tape. Cyanoacrylate and Rhodamine 6G staining on the other hand showed significant changes in the overall appearance of the Fourier transform infrared spectroscopy (FTIR) spectra compared with the original untreated tape. No impact was observed for the XRF analyses, and limited information was obtained using RAMAN. This initial work demonstrates that care should be taken when it is known that tape pieces have been chemically treated prior to submission for comparison against a known sample. The findings have provided useful data for forensic chemists at New South Wales Forensic

and Analytical Science Service (NSW FASS), which may aid them in interpreting their casework findings.

Due to limited time and the limited scope of this initial study, further research has been proposed. This includes:

- Additional analyses by the chosen techniques such that a statistical evaluation of the data could be performed to visualize minor details and enhance the differences and similarities not observed by visual comparison of the spectra alone
- Any chemical reaction between the tape itself and the fingerprint treatment
- Aging studies
- Environmental degradation studies
- Effect of untangling methods, particularly with respect to using chemicals, on the tape structure and composition

Dr. Bunford would like to thank Fabienne Brack for her hard work undertaking this study and writing her report, NSW FASS and University of Technology, Sydney.

11:20–11:40

Integration of Pulp and Paper Fiber Microscopy into a Course on Forensic Paper Examination and Authentication of Historical Documents for Forensic Chemistry and Art Conservation

Douglas Ridolfi, MS, Buffalo State College

Description: This is a class that is an off-shoot of a general class in questioned documents. It was designed to be relevant to both forensic chemistry and art conservation students. Case studies involve the study of historical documents from medieval manuscripts to the Hoffman Forgeries and the Bush Air Force Reserve memos. In each case, students will be introduced to relevant techniques in the analysis of typography and paper and merger of ink and paper. Authentication of documents through watermarks, chemical analysis and identification of incipient components, and paper fiber identification and pulping processes as revealed by chemical staining rounds out students' experience in analysis of papers and how they form a part of art work, manuscripts, and the production of identity and security documents.

Abstract: This course will concentrate on the examination of paper using special lighting methods, photography, and measurements using forensic instrumentation. The class will look at laboratory techniques for the recovery of writing from faded, burned, water-soaked, shredded, and obliterated documents using forensic and art conservation methods. Also covered will be the dating of documents via fiber composition, pulping chemistry (as determined by micro-chemical tests and stains), manufacturing methods, and watermarks. The analysis of book binding and general typography as a means to establish provenance and authentication of historical manuscripts will be conducted through the examination of historical cases. As time permits and depending on student interest, simple calligraphy and illuminated manuscript techniques will be practiced.

This class will be offered as a supplement to material introduced in FOR312, FOR 612, and FOR 497/598: Examination of Questioned Documents. An important, but specialized area of questioned documents involves detection of fraudulent alteration to documents and authentication of historical documents. The successful application of these skills requires knowledge of paper chemistry, paper manufacture, paper composition, and how these

materials are organized, whether as a medical record or historical illuminated manuscript. This class will demonstrate the special skills needed to maximize recovery of information from documents under a variety of conditions. Students will have the opportunity, through class exercises, to develop skills in the application of logical thinking and appropriate testing to accurately age a document and evaluate the significance of this information.

Sample research projects include:

- Research an historical case involving documents of questioned authenticity and develop an approach to authenticate the document(s), developing an outline and flowchart of procedures and key diagnostic methods.
- Research a method related to paper conservation and prepare a step by step guide, listing necessary materials and sufficient detail to carry out the procedure; discuss any limitations.
- Research a method in conservation that might be applicable to forensic paper examination such as:
    - Conservation methods to flatten folded paper facilitating the application of Electrostatic Detection Apparatus (ESDA) and oblique lighting techniques for the visualization of indented writings in crumbled documents
    - Research poly film encapsulation methods or other applicable methods for preservation of burned documents
    - Research recovery methods for water-soluble paper
- Research the differences between art and business paper in terms of manufacture, use, grading, and forensic characterization.
- Research the identification and characterization of recycled paper—its manufacture, uses, and extent of production in the USA and overseas.
- Research the identification and characterization of paper used in specific applications:
    - Tissue paper
    - Toilet paper
    - Parchment paper
    - Art paper
    - Water-soluble (dissolving) paper
    - Security paper
    - Other paper of your choice
- Research an instrumental or chemical method for advanced characterization of paper such as elemental analysis; discuss the procedure, instrumentations, sample preparation, limitations, and general applications.
- You are setting up your own private papermaking and stationery business. Describe the type of materials and equipment you would need, prices, suppliers, type of paper products you intend to produce, and your proposed market, and create a brochure describing your product(s), equipment, and prices for prospective customers.
- You are setting up your own private calligraphy business for the production of illuminated letters as a central feature. Describe the type of materials and equipment you would need, prices, suppliers, type of products you intend to produce, and your proposed

market, and create a brochure describing your product(s), equipment, and prices for prospective customers.

- You intend to forge an historical document of your choice. Describe the procurement of materials, aging steps, alterations, contents needed to establish provenance, and other incidentals needed to produce the document and avoid detection. The document and time period must be different from the student project piece.
- Other suitable projects related to forensic document examination, preservation, authentication, or review of historical case studies involving document authentication, with instructor approval.

11:40–12:00

Transfer and Persistence of Glass Fragments: Experimental Sudies Involving Vehicle and Container Glass

Tatiana Trejos, PhD, West Virginia University

Description: Studies of transfer and persistence of glass, as well as the frequency of occurrence of background glass in the general population of glass material, are key for the forensic comparison and interpretation of glass evidence. This presentation describes the lessons learned from mock cases involving the breaking of vehicle glass and container glass. Different mock kidnappings, vehicle crashes, and murder scenarios were set up at West Virginia University's crime scene complex, while a systematic study was conducted to evaluate 1) distribution and transfer of backward and forward fragmentation, 2) persistence of glass after several activities, and 3) secondary transfer of glass.

Abstract: Experimental studies that estimate the distribution, transfer, and persistence of glass fragments are relevant for the interpretation of glass evidence. This study aims to add to that body of knowledge by evaluating transfer and persistence of vehicle glass and container glass under common scenarios.

Experiments were designed to simulate transfer of vehicle glass during kidnapping, vehicle crash, and murder scenarios. The transfer of glass to the person involved in the breaking event, to individuals nearby, between the person who broke the glass and another object, and to crime scene investigators attending the scene has been investigated.

A kidnapping scenario was devised involving the breaking of a driver's side car window with the victim in the driver's seat and three suspects positioned around the breaking window. Prior to the event, background glass was collected from those participating to provide a baseline control. Following the smashing of the window, the victim was bound and thrown into the trunk of the suspects' vehicle, and then the suspects drove away. After the scenario concluded, evidence was collected from the victim, the suspects, the exterior of the victim's car, and the interior of both the suspects' and victim's vehicles.

A vehicle crash scenario was conducted in collaboration with the Insurance Institute of Highway Safety for lateral and frontal crashes. The inside of the vehicle was sampled before and after the crash. Recovery of glass from the dummy passenger's and driver's clothing was completed after first responders attended the scene.

A murder event, with container glass as the murder weapon, was conducted inside one of West Virginia University's crime scene houses. Containers (wine and beer bottles) were broken against the victim with constant applied force. The clothing of the person who broke the bottles was collected afterwards, after the person performed some controlled activities such as walking, running, and/or driving. Secondary transfer to the vehicle driven by the suspect was also investigated.

Each experiment was repeated three times to evaluate the variability of fragment distribution. The glass pieces gathered were then sorted by size and documented. The immediate area around the impact sites were divided into quadrants, and heat maps representing the fragment quantities distribution, by fragment size, were created to evaluate the backward fragmentation patterns. Hand picking, vacuuming, and taping was used for the collection of glass at the scene, while at the laboratory, visual examination with microscope and light sources, taping, picking, scraping, and/or vacuuming were used for the recovery of glass. Examination and comparison of glass was conducted at the laboratory using refractive index and elemental analysis.

The transfer and persistence study provided important information that can be used for interpretation of glass fragments involving breaking of car side windows, windshields, and containers: a) secondary transfer was observed on the suits worn by the crime scene recovery team and from the suspects to the vehicle's seats, b) the majority of glass greater than 1 mm was lost from activity and secondary transfer, c) the majority of the backward fragmentation produced fragments smaller than 1 mm, d) the distance the fragments were ejected varied with the applied force, thickness of the glass, and shape/size of the glass, e) the majority of the vehicle's forward fragmentation was distributed between the front seats, with similar amounts of glass recovered from the driver and front-passenger seats in cases of lateral breaking impacts.

1:30–1:50

Swab Touch Spray Mass Spectrometry for Rapid Analysis of Organic Gunshot Residue from Human Hand and Various Surfaces Using Commercial and Fieldable Mass Spectrometry Systems

Patrick Fedick, BS, Purdue University

Description: Organic gunshot residues, specifically methyl centralite and ethyl centralite, are characteristic compounds that forensic analysts look for when determining potential shooters. These compounds have long been analyzed by a number of instrumental techniques, many of which involve extensive sample preparation or have lengthy analysis times. Touch swab spray ionization, an ambient ionization technique, allows for the direct swabbing of the hands of suspected shooters for trace residues and detects the presence of these organic gunshot residues. This ambient ionization method requires no sample preparation, offers real-time analysis, and can be paired with a portable ion trap mass spectrometer for *in situ* analysis.

Abstract: Forensic investigation into the possibility of a suspect discharging a firearm in recent years has expanded from elemental inorganic gunshot residue analyses to molecular organic gunshot residue (OGSR) analyses. Protocols have been developed for the collection and analysis of OGSR which focus heavily on the stabilizers present in many ammunition types such as methyl centralite (MC) (1,3-dimethyl-1,3-diphenylurea) and ethyl centralite (EC) (1,3-diethyl-1,3-diphenylurea). These two compounds were selected from the expansive list of OGSRs because they are not commonly used in any other application and would therefore be among the most discriminatory compounds for determining if a person has potentially discharged a firearm. The complementary nature of OGSR analysis adds a level of confirmation to the typical inorganic analysis that is traditionally performed. OGSR has been shown to be detectable on skin hours after discharging a firearm; however, there is degradation over time and improved *in situ* analysis would greatly benefit the forensic community.

Currently OGSR analysis has been accomplished by a number of analytical techniques, many of which require lengthy chromatography or extraction techniques. Forensic staples like gas chromatography and ultra-high-performance liquid chromatography have demonstrated their capabilities of identifying and determining the presence of OGSR. While these methods are reliable analytical techniques, they suffer from lengthy analysis times and are not amenable to *in situ* analysis. Similarly, the standard sampling methods for OGSR are various forms of swabs and stubs. In order for these chromatographic methods to be utilized, an extraction technique, such as a solid phase microextraction, must be performed. Where swabs and stubs are convenient methodologies for sampling, when combined with extraction techniques, the number of experimental and sample preparation steps increases, amplifying analysis time and extending the room for operator error and sources of contamination.

Presented here is an ambient ionization method that requires no sample preparation, offers real-time analysis, and can be paired with a portable ion trap mass spectrometer for *in situ* analysis. Swab touch spray utilizes a rayon-tipped swab to collect the analytes of interest by swabbing the dry swab over the area of interest (i.e., the hands of a suspected shooter, or an article of clothing of the suspected shooter). The swab is constructed with an aluminum handle which allows a high voltage lead to be connected directly to the swab to promote ionization when a solvent is applied. The aluminum handle is pertinent to swab touch spray because this is how the high voltage is applied; other handles like wood or plastic are nonconductive. This talk will demonstrate the ease of swab touch spray ionization, its forensic feasibility for OGSR, and its ability to be coupled to a portable mass spectrometer for *in situ* analysis.

All spectra were recorded in positive ion mode using a Thermo LTQ Orbitrap XL Hybrid Ion Trap-Orbitrap mass spectrometer (San Jose, CA) or a home-built Mini 12 rectilinear ion trap (Purdue University, West Lafayette, IN). All Mass Spectrometry/ Mass Spectrometry (MS/MS) product ion scan mass spectra were generated through collision-induced dissociation (CID). Each swab was individually packaged with a tamper-proof label, removed from packing only to swab, and then returned to the casing. Each surface (bare hands, gloved surfaces, clothing, and spent casings) were swabbed in a circular motion after discharging the firearm. Approximately 20 circular motion passes were performed over the area of interest, for example, the top side of the right hand between the thumb and the pointer finger. The swabs were positioned vertically (approximately 8 mm) above the inlet of the mass spectrometer. High-Performance Liquid Chromatography (HPLC)-grade methanol was applied to the swab via pipette to ensure that the swab was completely wet and a continual flow of methanol spraying solvent was delivered to the swab at a varied flow rate to maintain a steady spray. A high voltage of 5.5 kV was applied to the aluminum handle, and the generation of a spray could be visually observed.

Four different 9 mm handguns, with four different ammunitions, were used in this study. Different firearms and ammunitions were selected to determine if this could be a universal method. To minimize the confounded variables of shooter, ammunition, and firearm, the casing of each expended ammunition was swabbed and analyzed for the presence of MC and EC.

Three ammunitions were found to contain MC and EC, and a single discharge of the firearm provided enough of both compounds to be detected by swab touch spray mass spectrometry. The lower limit of detection for both MC and EC was lower than 50 ng on the LTQ XL. The researchers checked the inside of the other ammunitions' spent rounds and detected both MC and EC in all three. MC and EC were not detected in the fourth ammunition. As the composition of the bullets are not public knowledge, the researchers also swabbed the inside of the spent casing to determine if the lack of detection of MC and EC was a result of the swab or the lack of the two compounds found in the ammunitions. There was no signal of MC or EC for the casing either, to which the researchers propose that there may not be any MC or EC in this ammunition, or the MC and EC is more limited in quantity, and the quantity transferred to the surface is below the limit of detection of the technique. The Mini 12 was also able to detect both MC and EC after the discharge of a single round of ammunition. Determining if a potential suspect discharged a firearm is a time-sensitive matter. The Mini 12, which has been shown to be capable of *in situ* analysis, has demonstrably provided law enforcement with an answer in a more rapid, simple sampling method. Swab touch spray has been shown to be an effective method for identifying OGSR from a variety of surfaces: hands, gloves, clothing, and spent shell casings. This ambient technique requires no sample preparation, no lengthy analysis times, and is capable of in-field analysis.

1:50–2:10

Evaluation of Field-Portable GC-MS with SPME Sample Collection for Investigator Use at Fire Scenes

John DeHaan, PhD, Fire-Ex Forensics, and Zachary Lawton, PerkinElmer, Inc

Description: Laboratory-grade identification, by gas chromatography-mass spectrometry (GC-MS), of ignitable liquid residues from suspected arson scenes is essential for the investigation to advance but entails time delays of shipping evidence and awaiting laboratory results. This study examines the use of field-portable GC-MS that can give forensic laboratory–grade analytical results at the scene in minutes. This can aid the interpretation of fire patterns, canine search alerts, and elimination of endogenous volatiles of no evidentiary significance. Sampling is via Solid Phase Microextraction (SPME) fiber to minimize chances of contamination and permit rapid analysis by trained hazardous material fire personnel. Debris samples can then be taken for laboratory analysis.

Abstract:

Objective: There has been no significant advancement in on-scene forensic fire debris analysis in over a decade. The ability to identify an ignitable liquid accelerant at the fire scene would provide fire investigators useful data, increasing their efficiency and effectiveness. This research project was intended to establish if the identification of ignitable liquids could be achieved at the fire scene.

Introduction: This approach is of particular value today when many law enforcement forensic laboratories, due to staffing shortages, are dropping fire debris analysis as a provided service or are assigning such cases such low priority that they are not analyzed in a reasonable time. With no laboratory analysis, canine alerts (or human suspicions) cannot be presented as evidence of an incendiary fire in judicial proceedings. With laboratory-grade analysis performed at the scene, the fire investigator would be able to proceed with the investigation with the results already in hand while still at the scene.

Method: Initial testing demonstrated that the field-portable gas chromatography-mass spectrometry (GC-MS) with Solid Phase Microextraction (SPME) fiber sampling technique can confirm the identity of ignitable liquid vapors at the fire scene consistent with ASTM fire debris analysis techniques.

Approach: A second series of tests conducted in room fire tests that were allowed to burn to full-room involvement demonstrated that accurate ignitable liquid vapor identification

could be achieved even when the vapors were measured (using a state-of-the-art "sniffer" at part-per-billion concentrations) after real-world fires. These debris samples were sent to a certified laboratory to confirm the results from the field data. A limiting factor in the field application of GC-MS was determined when the data produced had to be analyzed by a qualified GC-MS specialist to confirm the identification of the ignitable liquid. The current test series is being conducted with the services of a certified fire investigator (CFI) who is also a trained hazardous material responder, with the assistance of a certified arson accelerant canine. This will evaluate the accuracy of the canine detector in concert with the field-portable GC-MS against certified forensic laboratory analysis of the fire debris recovered from full-room fires.

2:10–2:30

Forensic Sampling and Analysis from a Single Substrate: Surface-Enhanced Raman Spectroscopy Followed by Paper Spray Mass Spectrometry

Patrick Fedick, BS, Purdue University

Description: Sample preparation is a bottleneck in the analysis and processing of forensic evidence. Time-consuming steps in many forensic tests involve separations, such as chromatography or extraction techniques, typically coupled with mass spectrometry. Ambient ionization ameliorates these slow steps by reducing or eliminating sample preparation. Here, we describe the use of a paper substrate, the surface of which has been inkjet printed with silver nanoparticles, for surface-enhanced Raman spectroscopy (SERS). The same substrate can also act as the paper substrate for paper spray mass spectrometry. The coupling of SERS and paper spray ionization creates a rapid, forensically feasible analysis combination.

Abstract: Forensic science relies heavily on so-called "hyphenated techniques," such as gas chromatography-mass spectrometry (GC-MS) or liquid chromatography-mass spectrometry (LC- MS), because of their long history of providing reliable, reproducible, and validated information. While reliable, these hyphenated analytical techniques suffer from relatively long analysis times, and they are typically not amenable to *in situ* analysis. The standards set by ASTM International and Scientific Working Group for the Analysis of Seized Drugs (SWGDRUG) recommendations follow these practices, which makes nonchromatographic approaches a challenge unless a more attractive capability is newly available. These standards state that mass spectrometry is a validated "Category A" technique, the highest category based on discriminating power, but that a secondary technique must be utilized, for example nuclear magnetic resonance (NMR) spectroscopy, Raman spectroscopy, any of a number of separation techniques, or even colorimetric tests.

Paper spray (PS) ionization is an ambient ionization method which makes use of a paper substrate cut to a sharp tip from which ions are generated with the application of a high voltage and solvent. This simple technique can be used for direct sampling of complex mixtures. PS ionization has proven useful in the analysis of a wide variety of samples including dried blood spots, drugs of abuse, chemical warfare agents, and bacteria. Recent advances in PS ionization include surface modifications for improved ionization or reactive applications. Although PS excels as a rapid, cost-effective, and easy-to-use method, forensic applications require a secondary technique for analyte confirmation. Another paper-based method that has been developed, not for mass spectrometry but rather for Raman spectroscopy, involves the use of paper surface Raman substrates. Raman spectroscopy has gained popularity in forensics because of the increased sensitivity achieved in surface-enhanced Raman spectroscopy (SERS). A particular advantage of paper SERS (pSERS) substrates is the ease with which they can be created using inkjet printers. Fabrication of

pSERS substrates is straightforward compared with the typical microfabrication of SERS substrates, and it minimizes the cost of fabrication. pSERS substrates have been used to detect drugs, fungicide, pesticides, and polymerase chain reaction (PCR) products. While pSERS substrates are commercially available and attractive for forensics, this method too requires a second instrumental technique for confirmation.

Recognizing the complementary nature of these two methods, we demonstrate here the utilization of a commercial pSERS substrate for Raman spectroscopy analysis followed by mass spectrometry. The amalgamation of the two techniques provides a simple and fast forensic methodology requiring minimal sample preparation. To test this, standard solutions were pipetted onto the pSERS substrate, or the paper substrate was used to swab a surface, and a Raman spectrum was recorded after drying. The pSERS substrate then was used as the paper substrate for PS mass spectrometry, and a spectrum was recorded for the same sample. The entire analysis time was a few minutes.

With the SWGDRUG guidelines being explicit on the requirement of two different methods, five drugs of abuse were tested by the combined pSERS Raman/paper spray-mass spectrometry (PS-MS) method. The selection of drugs encompassed several relevant samples. The increased use of synthetic designer drugs worldwide was the reason why 4-methylethcathinone was selected. Hydromorphone and morphine were selected because they are isobars and the Raman spectra aid in distinguishing them. Finally, heroin and fentanyl were selected because they have caused an increase in substance abuse and overdoses, especially in young adults. Production of fentanyl is a low-cost operation, and it is typically used to cut heroin, which has caused numerous overdoses. Spectra for heroin and fentanyl in their pure form as well as a simulated street sample in which the heroin is cut with fentanyl in a 10 to 1 ratio were collected. All the drug samples had distinguishable characteristic Raman shifts, and even the mixture street sample could be identified. This method was also tested for explosive residues of 2,4,6-trinitrotoluene (TNT), cyclotrimethylenetrinitramine (RDX), cyclotetramethylene-tetranitramine (HMX), and chemical warfare agent simulants, such as diisopropyl methylphosphonate (DIMP), dimethyl methylphosphonate (DMMP), and dichlorvos.

The use of a pSERS substrate for both Raman and PS-MS allows rapid analyte identification and confirmation without sample preparation steps as well as the use of a single substrate for complementary spectroscopic measurements. Both Raman and PS-MS can be performed in the ambient environment, which makes the coupling of the two instrumental techniques so appealing. The decrease in analysis time as compared with the hyphenated chromatography techniques could help decrease forensic sample backlogs. The substrates are low cost and readily integrated into a forensic laboratory workflow. These substrates work for both SERS and PS-MS, and as a cost-saving method, a biopsy punch could be employed to create five pSERS substrates from one test strip. Additionally, because the substrates are inkjet printed, highly customizable patterning could be employed to fit the needs of the study. This study has shown the range of compound types to which this dual instrumental method is applicable. The ability to help distinguish isobaric compounds, confirm compounds that do not readily provide informative tandem mass spectra, and finally the ability to swab a surface and analyze the compounds all add to the strength of this technique. The study has not been extended to quantitation, but quantitation using added internal standards in PS-MS is detailed in the review cited while modest quantitative performance in SERS without standards is reported. While not shown in this presentation, PS has been performed in situ on a portable mass spectrometer, and commercial portable Raman spectrometers are available. The ability to potentially perform this technique in situ would add value to the combined methodology.

2:30–2:50

Identification of Organic and Inorganic Gunshot Residues by Electrochemical and Spectrochemical Methods

Tatiana Trejos, PhD, West Virginia University

Description: This presentation describes the development of an approach to expanding current capabilities for gunshot residue (GSR) detection. Electrochemical and laser-induced breakdown spectroscopy (LIBS) techniques are proposed as screening methods that are quicker, more selective, and more powerful than any current field-testing technique. These methods offer superior information by simultaneous detection of trace organic and inorganic components and identification of a larger number of elements used in modern ammunitions. In addition, LIBS can generate 3D-chemical images for more objective estimations of shooting distance. These screening methods are anticipated to reduce error rates associated with contamination and sample loss during collection and analysis steps.

Abstract: In 2016, the US faced over 100,000 gun-related deaths and injuries, including 385 mass shooting events. Forensic laboratories provide valuable support in these investigations, through the chemical identification of firearm discharge residues (FDR) to identify a potential shooter, determine firing distances, or differentiate between a potential homicide, suicide, or accidental shooting. The scientific validity of this field relies on extensive research and standardization of the existing methods. Nonetheless, there are still some remaining challenges in this arena in terms of speed of analysis, preservation of evidence, accuracy, and interpretation of results. For instance, the detection of FDRs is influenced by many uncontrollable factors such as time and activities after the shooting as well as environmental contamination and interferences that could lead to errors. Thus, there is a critical need to improve the speed and reliability of these determinations. The combination of the detection of organic gunshot residue (OGSR) and inorganic gunshot residue (IGSR) is an attractive novel approach, particularly when sound chemometric data treatment is used for interpretation purposes.

The motivation of this study is to develop a more practical, simpler, faster, and superior approach to the identification of FDR, capable of simultaneous detection of IGSR and OGSR using laser-induced breakdown spectroscopy (LIBS) and electrochemical sensors. LIBS is a rapid chemical analysis technique that uses a pulsed laser for direct qualitative and quantitative analysis of materials with no sample preparation and minimal destruction. LIBS allows extremely fast measurements (usually 30–50 seconds for multiple-shot analysis) and simultaneous multi-element detection in the low parts per million (ppm) range. On the other hand, electrochemical sensors use electrical stimulation to induce redox reactions of the analyte at the surface of the electrode. Inorganic species (e.g., Pb, Cu, Zn, Sb) and organic species (e.g., nitroaromatics, nitroamines) are electroactive, allowing the detection of FDRs at low ppb levels. Electrochemical methods offer several advantages including rapid response, low cost, good sensitivity, good selectivity, and potential for miniaturization. Electrochemical and LIBS techniques are proposed as screening methods that are quicker, more selective, and more powerful than any current field-testing technique. These methods offer superior information by simultaneous detection of organic and inorganic components and identification of a larger number of elements used in modern ammunitions. Sampling methods were selected to remain compatible for subsequent confirmatory methods (scanning electron microscopy/energy dispersive spectroscopy [SEM/EDS]) in the same sample.

Optimization of the LIBS and electrochemical sensors was conducted using response surface Box Behnken experimental designs. Standards were prepared by spiking 50ng to 25 ug of Pb, Ba, Sb, Cu, Ti and Zn over a surface of approximately 1cm^2 of SEM carbon

adhesives. The rapid scanning of the laser beam across a single line of 100um by 7mm allowed the qualitative identification of 2 to 10 different emission lines per target element in less than 1 minute. Linearity better than 0.985 was obtained for Pb, Ba, and Sb with reproducibility between replicate measurements better than 11% Relative Standard Deviation (RSD). Limits of detection for Ba (2 ± 0.2 ng), Pb (20 ± 3ng), and Sb (100 ± 12ng) demonstrate the method fit for purpose. Optimization of the electrochemical sensors demonstrated the feasibility of cyclic voltammetry (CV) and Square Wave Anodic Stripping Voltammetry (SWASV) for the rapid detection of inorganic and organic target compounds. Current research is focused on the use of disposable electrodes that permit laboratory and field- based testing. The detection of a mixture of 0.5ug (Pb, Sb) and 1.0ug (2,4-Dinitrotoluene (DNT), 2-Nitrodiphenylamine (DPA) was possible in 120 seconds. A 0.1 M acetate buffer (pH 4.5) was used as electrolyte to dissolve the mixture of metals and DNT. Seventy samples, 40 from shooters' hands and 30 from non-shooters' were collected as part of the validation study. Pistol (9mm and .22) and revolver (.357 Magnum) were fired at the ballistics laboratory under controlled environmental conditions, and at an open shooting range, using different types of leaded and lead-free ammunition. LIBS and electrochemical screening tests allowed the simultaneous detection of trace levels of OGSR and IGSR in just a few minutes (e.g., Pb, Ba, Sb, Cu, Al, Si, Ca, Sr, Ti, Zn, Sn, DPA, NG, and DNT). Less than 1% false positives and false negatives were observed after screening with both methods. The almost non-destructive nature of the approach would serve as a fast screening test prior to confirmation of IGSR by SEM/EDS. The application of such screening methods could reduce backlogs in forensic laboratories, reduce overall costs of analysis, and represent a promising alternative for onsite applications that require fast response and efficient decision-making.

2:50–3:10

Instrumental Analysis of Gunshot Residue (GSR) – Reconstruction of Crime Scenes

Zachariah Oommen, PhD, Albany State University

Abstract: GSR particles from the surroundings of bullet holes have been characterized as a function of primer type and particle distribution. Scanning electron microscopy (SEM) images were used to verify size and shape of the GSR particles, and energy dispersive spectroscopy (EDS) to verify the elemental composition in a single particle. The same specimens are further subjected to time-of-flight secondary ion mass spectrometry (ToF-SIMS) and X-ray photon spectroscopy (XPS) analysis to identify the respective surface chemistry, molecular nature, and molecular mass of the GSR particles. Both inorganic and organic components of GSR in the elemental and combined form can be identified using SIMS. The study was helpful in distinguishing between real GSR particles derived from a particular firearm and those derived from environmental contamination for forensic investigations. Shooting distance, type of firearm, and nature of the incidents have been studied from characterization results.

3:10–3:30

Evaluation of Error Rates in the Determination of Duct Tape Fracture Matches

Tatiana Trejos, PhD, West Virginia University

Description: In this study, the occurrence of false positives and false negatives was investigated for 2000 blind comparison end tapes (hand-torn and scissor-cut duct tape samples), analyzed by independent examiners. The combination of physical features, microscopic features, and match scores was used to classify the physical end matching results into five qualitative categories. Match scores were calculated as a relative ratio of observed matching sections per scrim area. Frequency graphs were created to visualize the distribution of true positives and true negatives as well as to define thresholds for match/non-match decisions.

Abstract: A piece of tape utilized in gaging a victim or assembling an improvised explosive device could become important evidence in forensic and intelligence investigations. In addition to potential DNA, fingerprint, or trace evidence left on the tape backing or adhesive, the tape itself could provide critical information in the reconstruction of an event. For instance, the identification of a fracture match between a piece recovered from a victim and a piece recovered from a suspect could demonstrate that the two pieces were once part of the same roll. Unlike some marks left on pattern evidence, tape fracture features are not "imprinted" into a surface, nor can they be reproduced or predicted. As a result, a random match of tape ends is considered very unlikely.

Regardless of its probative value, the identification of a tape fracture match relies on the examiner's opinion in identifying distinctive features across the tape ends. This could become problematic due to the lack of standardized criteria to make match/non-match judgements. Thus, there is a critical need to develop such criteria and to assess the validity and accuracy of tape fracture match determinations. In the absence of standard thresholds and associated error rates, the identification of tape fracture matches will remain subjective, and their scientific validity will likely be challenged in court.

Our long-term goal is to develop an effective strategy to qualify and quantify distinctive features in tape end examinations and to develop standard automated algorithms that complement and substantiate the examiner's observations. As a first step, the aim of this study was to establish mechanisms to qualify and quantify tape end match features, develop an approach to estimate threshold values, and evaluate if the assumption that random tape fracture matches are unlikely is supported by experimental data.

In this study, the occurrence of false positives and false negatives was investigated for 2000 blind comparison end tapes (hand-torn and scissor-cut duct tape samples), analyzed by three independent examiners. The combination of physical features, microscopic features, and match scores was used to classify the physical end matching results into five qualitative categories. Match scores were calculated as a relative ratio of observed matching sections per scrim area, with values ranging from 0 to 1, where the closer the number to 1 the more distinctive features observed along the tape ends. Frequency graphs were created to visualize the distribution of true positives and true negatives as well as to define thresholds for match/non-match decisions.

Three main tear patterns were observed in the hand-torn tape samples. The most common pattern observed among torn tapes was angled (42%), followed by wavy (35%), and puzzle-like (22%). The microscopic features of the puzzle pattern showed higher match scores (77% at 1.0 score and 23% at 0.9), while the other two patterns were skewed to 0.9 scores with ~25% of the fractures at match scores between 0.5 and 0.8, and a higher incidence of false negatives observed in wavy patterns. The overall accuracy of the test, calculated from the area under the curve of receiver operating characteristics (ROC) graphs, was 99.6% for hand-torn tapes, and 99.8% for scissor-cut tapes, with 0% false positives and 1–2% false negatives. The results show that false positive fracture matches of duct tapes are uncommon and that variability between individuals and between method of separation were minimal. A sample set of 500 tape ends was further manipulated to simulate normal stretching of the tape ends during crime scenarios, and the error rates and frequency distribution rates were investigated. Relative match scores were found to be a good classifier/predictor for fracture match determinations and are expected to help as a step toward the harmonization of conclusions among forensic examiners.

| Impression and Pattern |

Fingerprints on Clothing: Evidence about Fingerprint Visualization on Distinct Types of Fabrics

Ruben Sousa, MS, London South Bank University

Description: This presentation aims to explore some work done in the fingerprint field, specifically, the development of fingerprints on clothing and the types of clothing that reveal more fingerprint details. This presentation will explore two different techniques (lumicyano fumes and ninhydrin) and several different types of fabrics of two different colors (black and white) to establish the conditions under which high-quality fingerprints on fabrics can be developed.

Abstract: Fingerprints are a very important type of evidence in forensic science. In crimes where there is direct contact, fingerprints can be used as conclusive proof. Currently, investigations and research into the visualization of fingerprints on clothing are lacking, although such studies could be very important for specific crime investigations, such as rape, where contact between the offender and the victim's clothes is inevitable.

With the starting hypothesis on the possibility of developing fingerprints on clothing, I began my investigation at London South Bank University. Two different techniques were tested to develop fingerprint visualization (lumicyano fumes and ninhydrin), and 13 different types of fabrics (mainly used in clothing) were used. These fabrics were carefully chosen to be the most commonly used in clothing worldwide. The color of the fabric was found to be a factor that could affect the performance of techniques, and therefore, both dark and light samples of all types of fabrics were tested. Five samples of each fabric type in black and white (totaling 10 samples of each type of fabric) were analyzed. The fabrics tested were cotton, wool, silk, satin silk, polyester, acetate, linen, cotton (40%)-polyester (60%), cotton (60%)-polyester (40%), viscose, nylon, lycra-elastane, and cotton-elastane (3%). All fabrics were tested for authenticity using Fourier-transform infrared spectroscopy (FTIR) and a pre-arranged fabrics database. To prevent the occurrence of risks during this research, specific training on fingerprint development with a Superglue cabinet and ninhydrin was undertaken. After all suitable conditions were guaranteed, research using both methods was initiated. The researcher's fingerprints were deposited on clean samples of fabrics under normal, dirty conditions (that is, the researcher did not wash his hands prior depositing the fingerprints).

After a couple of days, the fingerprints became naked-eye visible on some of the fabrics. Different light methods were tested to visualize the fingerprints, and a few fingerprints that were not visible to the naked eye were made visible under UV light. Fabric and chemical control samples were also tested to guarantee their suitability. Fingerprints deposited on white samples were more easily developed with ninhydrin, whereas those on dark samples were more easily developed with lumicyano fumes. Using the ninhydrin technique, the white acetate fabrics retained the best fingerprint quality. In contrast, polyesters and cotton (40%)-polyester (60%) samples were the most suitable for the development of fingerprint visualization using Lumicyano. Almost all fingerprints deposited on man-made fabrics

were visible using the lumicyano fumes technique. The development of fingerprints on these different fabrics will be explored in this presentation, with reference to the fabrics that are suitable for the development of decent-quality fingerprints and those that are the most problematic for forensic analysis.

During all the experiments, pictures that clearly confirm that fingerprints can be visualized from fabrics were taken. In a small number of samples, it was possible to observe some distinctive features of the fingerprint, including their patterns and distinctive characteristics (e.g., bifurcations and ridge endings).

Potential Impact and Application of 3D Scanning, 3D Modeling, and 3D Printing in Toolmark Examination

Sun Yi Li, BS, Sam Houston University

Description: 3D scanning, 3D modeling, and 3D printing have gained increasing popularity in designing and manufacturing functional products in many industries. In this presentation, toolmarks on bullets produced by 3D-printed gun barrels will be compared to those produced by conventional ones. Bullet striations produced by gun barrels manufactured from the same digital model were also examined and compared. Preliminary data of the individual characteristics observed throughout the test-firing of the 3D-printed gun barrels were found to be consistent. Striations on bullets test-fired from the two identically 3D-printed barrels led to elimination as the bullets would have been fired from the same barrel. Future forensic application of 3D scanning, modeling, and printing will be discussed in this presentation.

Abstract:

Scope. Although functional 3D-printed products are increasingly available on the market, the implications of their impacts on toolmark and pattern examination remain unknown. The new technology of 3D scanning, modeling, and printing might complicate forensic toolmark examination. However, this technology might also offer new opportunities for the standardization of forensic examinations of toolmark and pattern evidence.

Objectives. To understand the impact of 3D manufacturing technology in toolmark examination, two functional 3D-printed gun barrels were manufactured by 3D scanning, modeling, and printing. The toolmarks and patterns generated during the test-firing were examined.

Introduction. 3D printing is a manufacturing process that can potentially transform a virtual digital model into a real-world 3D solid object. This process is popular for producing prototypes of many designs. The affordability and availability of 3D printing have increased in recent years, and it has emerged as a method of choice for manufacturing functional products in many industries, including firearms. Therefore, proactive studies and research on the implications of this new technology in forensic toolmark examination is needed.

Methods/approach. Currently, no published data for toolmark examinations of bullets discharged from a 3D-printed metal firearm are available. Our approach was to manufacture 3D-printed metal gun barrels to study the impact of 3D scanning, 3D modeling, and 3D printing on forensic toolmark examination. In this presentation, the toolmark examination of bullets discharged from 3D-printed metal gun barrels will be discussed. The 3D modeling was built based on the physical dimensions of the 1911 using computer software with and without the use of 3D scanners.

Results & findings. Because of the rough surfaces of the untreated 3D-printed products, the gun barrels required some hand-fitting to fit into the 1911 frame. The interior of the

gun barrel was left untreated. In total, 100 cartridges were discharged from each barrel to examine and compare the striations left on the bullets. During test-firing, the first 50 rounds from both barrels were discharged without incident; however, substantial improper extractions were observed throughout the test-firing, resulting in stove-piped cartridge cases. At approximately the 65th round, the slide started to lock up and did not cycle back to extract the cartridge case. A ball-peen hammer was used to move the slide backwards and expose the fired cartridge case. Multiple attempts were made to clean, dremel, and lubricate the chambers to facilitate extraction; none of these efforts proved successful, and the malfunction continued until the end of the 100th test-fire cycle.

The striations on the bullets were successfully collected and preserved for examination and comparison.

Conclusion. Post-printing surface treatment of such barrels might be needed to eliminate mechanical malfunction of the firearm. Examining the bullets fired from both barrels revealed that all 100 bullets could easily be differentiated from each other. The individual characteristics of the striations were consistent throughout the test-firing. When comparing the striations on the bullets fired from two identically printed barrels, they could be easily eliminated as having been fired from the same barrel. When the 3D scanning, modeling, and printing process is well controlled, we envision that it may offer a new way to design and produce standard tools for toolmark or pattern evidence examination.

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Progress in Developing a Footwear Randomly Acquired Characteristics (RACs) Reference Collection for Frequency and Spatial Distribution Analysis

Brian Eckenrode, PhD, Department of Justice

Abstract: Footwear impressions are often deposited on a surface when an individual wearing a shoe moves, such as when entering and exiting a crime scene. Once detected and recovered, this evidentiary item can provide valuable investigative linkages to a suspect. A forensic footwear examiner may conclude an identification when there are sufficient similarities between the questioned impression and the known footwear, specifically with regard to attributing the class, wear, and randomly acquired characteristics (RACs). Recently, there have been courtroom challenges regarding the discrimination potential of footwear evidence, particularly when there are mass productions of similarly modeled and sized shoes. To address these challenges, the FBI is currently compiling data on the frequency and spatial distribution of RACs detected on the outsoles and marked using Photoshop™ of more than 1,500 boots with a similar outsole pattern. A visualization of the individualizing differentiation and results to date between marked boots in the database will be represented in a heat map.

Laterally Reversed Latent Prints Detected with Amino Acid Reagents

Vici Inlow, Fingerprint Specialist, CLPE, and Mary Lou Leitner, CLPE; United States Secret Service

Description: The occurrence of laterally reversed latent print images of friction ridge skin impressions detected with amino acid reagents on porous substrates has been observed. As the ability of the reagents utilized to detect trace amounts of amino acid deposits of friction ridge skin impressions on a substrate becomes more sensitive, more latent print images are being developed. Such is the case with the reagent1,2-indanedione and its ability to develop laterally reversed latent prints. The increased use of 1,2-indanedione in the field demonstrates the need to address issues regarding the recognition of a latent print potentially being laterally reversed.

Abstract: A laterally reversed latent print is a mirror image of the orientation of the friction skin ridge detail from a finger, palm, or foot that has been left on an item. A number of articles have been written about the transfer of friction ridge detail from one surface to an adjoining or abutting surface (Czarnecki, 2005; Kershaw, 2000; Lane, Hilborn, Guidry, & Richard, 1988). This presentation discusses the laterally reversed print that is on the opposite side of the surface, where the amino acid matrix is absorbed through the porous substrate from the front or top to the back or bottom.

The three demonstrated cases are different types and weights of paper that were processed with the reagent 1,2-indandione using standard protocol and then visualized with either an alternative light source or laser with the proper filtration. Latent prints were developed, and upon further examination, the prints were found to be laterally reversed images that had soaked through the back of the papers. Although 1,2-indandione was used in these cited cases, it should be noted that laterally reversed latent prints have also been developed with the 1,8-diazafluoren-9-one (DFO) and ninhydrin reagents.

Recognition of laterally reversed prints should be included in training modules and procedural protocols for examiners, photographers, technicians, and others involved in the examination or documentation of latent print impressions.

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A Picture is Worth 1000 Minutiae – A Case Review of Fingerprint Identifications Made in the Photographs of Child Pornography

Valerie Fulton, MA, Hillsborough County Sheriff's Office

Description: This is a case review of the 2015 Dannie Ray Horner child pornography case. After a unique discovery was made by the digital forensic expert while reviewing the files on the suspect's computer, the fingerprint analyst was called in. Digital imagery taken in clear focus by the abuser with his Samsung mobile phone allowed for his fingers to be identified in the photographs of child pornography themselves. This left no doubt as to who was behind the camera and the abuser of a child too young to speak for himself.

Abstract: What began in late 2014 as an investigation by Homeland Security into the distribution of child pornography ultimately led to a history-making case for the agencies involved. A collaboration between the Sarasota Police Department and the Sarasota County Sheriff's Office brought forth the arrest and conviction of Dannie Ray Horner on 26 charges, including capital sexual battery, molestation, possession, and distribution and transmission of child pornography.

While working on a tip from the Internet Crimes Against Children (ICAC), the Sarasota Police Department developed suspect Dannie Ray Horner. After a thorough investigation of the digital media by the Sarasota County Sheriff's Office Intelligence Digital Forensics Expert John McHenry, a unique discovery was made. Friction ridge detail was apparently

visible in several photos of child pornography, and after editing the photographs, they were submitted to the Automated Fingerprint Identification System (AFIS) unit for fingerprint examination.

For this case, the fingerprint identification was key to bringing the case together. This identification prevented the defense from being able to say someone else was in the photos creating the child pornography and abusing the child. The email address that was associated with many of the transactions for distribution was a common email shared by the suspect's business partner at Two Dans Painting. It would have been easy to use the "not me" card as both subjects were named Dan. The fingerprint identification allowed for the State Attorneys to move forward with the sexual battery and molestation charges as there was no doubt as to which "Dan" was responsible.

This case was rather uncharted territory for all parties involved. Several questions and challenges arose from the state and the defense while preparing for this case. Although the suspect's face was never in the photos, having a positive identification to the hands that were causing harm to this child was the ultimate proof needed. Challenges to be discussed include the following:

- Reversing the fingerprint image to mirror that of the traditional latent print
- Visual color distinction when you are used to looking at "black and white"
- Taking major case prints and expressing why they are necessary
- Questioning the true motive behind taking on "a case like this"

Ultimately, this case demonstrates how still images of an offender's hand can be used to secure a conviction but also highlights how fingerprint detail in any form of digital media can be used in a wide variety of investigations. Furthermore, investigators should always be on the lookout for these opportunities of fingerprint detail in media and work in conjunction with the fingerprint examiners to determine if they are suitable for comparison.

Is Latent Print Viability Affected by Heat (Accumulated Degree Hours) from 60-Watt Incandescent Light Bulbs?

Olivia Colella, BS, Virginia Commonwealth University

Description: There is currently a lack of research in the patterns and impressions field, including how prolonged heat exposure impacts fingerprints. In this study, fingerprints were deposited on 60-watt incandescent light bulbs, and the bulbs were left on for varying amounts of time (up to 1 month). Following exposure, fingerprints were recovered using conventional methods and assessed for quality. Time and temperature were combined into a linear regression model, which described the relationship between time of exposure and print viability. Ultimately, this research demonstrates the persistence of latent prints and contributes to the growing body of work supporting latent print analysis.

Abstract: This presentation will increase the audience's understanding of how time and temperature as a combined variable impact the viability of latent fingerprints deposited on 60-watt incandescent glass light bulbs. The lack of research regarding the potential effect of varying environmental factors on pattern and impression evidence, as discussed in the 2009 National Academy of Sciences (NAS) report (National Research Council, 2009), will be directly addressed. A statistical regression model (using accumulated degree hours as the independent variable) will be used to describe the relationship between heat and latent print viability.

In the fall of 2016, the Henrico County Police Department in Richmond, VA recovered a print from a lightbulb encountered in a burglary case and speculated that it had been removed to prevent suspect identification from CCTV; the defendant, however, asserted that he had touched this light bulb months prior to the crime (Detective/Fingerprint Examiner, n.d.), and there was no published research from which to assess the validity of this claim. Current research has addressed the detection limits of certain components of fingerprint residue, such as serine, which has been detected by gas chromatography-mass spectrometry after exposure to temperatures of up to 150 °C (Birnbaum, 2011). Although this information is valuable, it does not address the practicality of crime scene investigators visualizing and preserving prints or use time and temperature to estimate the time since a fingerprint was deposited.

This project addresses issues not covered by this study by (1) recovering latent prints with conventional methods, (2) evaluating fingerprint quality based on a previously established 11-point scale (Dhall, Sodhi, & Kapoor, 2013), and (3) relating the combined variables of time and temperature in a reliable regression model that can be used to describe the relationship between heat and latent print viability. Through the use of the regression model and popular fingerprint recovery methods, this study will provide sound evidence for the persistence of latent fingerprints and provide law enforcement with additional information that can be useful during the course of investigations.

In performing this study, 10 light sockets were mounted on five strips of shipping wood and wired in parallel to provide equal amounts of electricity to each bulb. Each 60-watt incandescent lightbulb was secured into each light socket with gloves. Once secured, nine fingerprints were deposited on each bulb with medium pressure. A 12-hour baseline test was performed to determine the best length of time to leave the bulbs on for subsequent testing. After the baseline test, the units were turned on for 18 hours, 48 hours, 72 hours, 120 hours, 168 hours, 240 hours, 336 hours, 504 hours, and 672 hours. A thermal imaging camera monitored the units to record the generation of heat from different parts of the bulbs. After each allotted time period, the prints were enhanced with black powder and lifted with tape on to a lifting card to be examined for quality using an 11-point scale.

Latent prints were recovered through the baseline test (1488 ADH); thus, the units were left on longer. Latent prints were still recovered after 18-hour heat exposure (2813.4 ADH). Of the 81 prints recovered, 54 ranked within the top half of the 11-point scale and were identifiable. Similar results were obtained after 48 hours (7502.4 ADH) and 72 hours (11253.6 ADH). During these tests, 89 and 83 latent prints were recovered, and 58 and 61 were deemed identifiable, respectively. Additionally, latent prints were persistent and proven recoverable after 5 days (18756 ADH), 7 days (26258.4 ADH), 10 days (37512 ADH), 2 weeks (52516.8 ADH), 3 weeks (78775.2 ADH), and 1 month (105033.6 ADH). Prints insufficient for identification were often adversely affected by moisture in the print and movement when the print was deposited, which occurred independently of heat.

In conclusion, the persistence of latent prints exposed to heat over long periods of time supports the persistence of latent prints, could provide valuable information to law enforcement, and is an important addition to the body of work in the field of pattern and impression analysis.

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Time Lapse Case Study of Atypical Hyperlinearity and Effect on Friction Ridge Skin Visibility

Meredith Coon, MSFS, Baltimore Police Forensic Science and Evidence Management Division

Description: Mrs. Meredith Coon has conducted a time-lapse study of atypical hyperlinearity (heavy creasing) in her fingerprints since she was 19 years old. Over the course of the 10 years that followed, she has recorded her fingerprints at regular intervals. Mrs. Coon's fingerprints demonstrate that although heavy creasing is often attributed to advanced age, young adults can also display such traits. The creases in her fingerprints are so prevalent and pronounced that some of her fingerprint recordings are unusable for identification. This presentation will incorporate images of Mrs. Coon's fingerprints recorded at various intervals over a 10-year period.

Abstract: In the fingerprint community, the common rule of "thumb" is that the amount and severity of creases within an impression is directly correlated to the age of the subject. This information is spread as common and reliable knowledge, but this mantra should be checked when analyzing particular individuals. This presentation is a case study on the author, who even in her teenage years experienced extreme creasing with no disease status. This creasing is very dramatic and completely obliterates the friction ridge details, especially when the skin is dry. This condition also appears to affect other members of the author's family and does not appear to worsen exclusively with age but is adversely affected by environmental factors. Repeated recordings of the author's skin and that of family members are used in a time lapse fashion to demonstrate the severity of creasing and the unpredictability of the friction ridge recordings.

Enhanced Reflected Light Microscope Imaging with Reflection Transformation Imaging Methods and Open Source Software

John Ossi, MS, Ossi Imaging

Description: Users of reflected light microscopes and macroscopes may be able to extract additional textural information from images by employing reflection transformation imaging (RTI). This method works with open-source software and nearly any microscope with sufficient objective working distance; however, it requires specific image collection methods. Post processing the images allows interactive re-lighting of the specimen from any direction, revealing image textures not visible using other methods. The history, methodology, application to trace microscopy, and image results are presented in comparison to images collected using conventional methods.

Abstract: Most reflected light microscopes use some form of oblique illumination when viewing most specimens, except for polished metallurgical preparations. The directionality of the light provides textural information to the examiner. Many microscope manufacturers now offer light-emitting diode (LED) ring light illuminators for stereo microscopes and darkfield illuminators for compound microscopes outfitted with user-assignable

segmentations, suggesting the importance of controlled directional oblique illumination. Although progress is being made, these advancements alone are currently insufficient to employ the method outlined below because many illumination trajectories are required. This method requires oriented directional light sources that are sequenced during image collection. Processing with open-source software reveals specimen topography and textures that might not otherwise be visible. Image collection methods can be used with any light microscope with sufficient objective working distance and any light source that can be repositioned around the specimen.

Reflection transformation imaging (RTI) is a photographic image collection and computational display method that captures surface images of opaque specimens. Post processing the images allows interactive re-lighting of the subject from any direction. Polynomial Texture Mapping open-source software developed at Hewlett Packard permits the mathematical enhancement of the subject's surface shape and color attributes. The enhancement functions of RTI reveal surface information that may not be apparent to the unaided eye or other observational methods. Oblique reflected light illumination is the most common way to view specimens. Light strikes the specimen at an angle off the optic axis. Single images taken with unidirectional light accentuate topographic features, making the illuminated side of a feature bright, contrasted against the shadow side. RTI methods suggest collecting up to 64 images using a unique lighting azimuth/compass direction for each image. The specimen, optics, and camera remain fixed with only a single, near point source of light changing to a new location for each image. This method is outlined and the associated open-source software demonstrated in comparison to traditional microscope collection methods.

Shoeprint Lab Survey

Sarena Wiesner, MS, Israel Police Department of Investigative Forensic Sciences

Description: One of the major criticisms of the 2009 National Academy of Sciences (NAS) report was that there are no common working standards set for all laboratories performing forensic examinations. The survey presented here addresses these issues to map the current situation of shoeprint laboratories worldwide.

Nearly 70 shoeprint laboratories from around the world participated in this survey. The following issues were compared: the quality standards of the laboratories, the requirement for expert certification, the work load, and comparison and reporting procedures. The relationship between these parameters was also investigated.

Abstract: In 2009, the National Academy of Sciences (NAS) published a report named, *Strengthening Forensic Science in the United States, A Path Forward*. Among the common issues noted in this report was the lack of common quality assurance demands and working procedures of all forensic laboratories. Substantial effort has been invested in promoting these issues since this report, and the survey presented here was performed to gain a sense of the current situation of shoeprint laboratories and help focus on aspects that need reinforcement.

The subjects approached in this survey concern the quality standards of the laboratories, the requirement for expert certification, the work load, and comparison and reporting procedures. The survey was distributed to laboratories worldwide. The participating laboratories were contacted using several methods. A personal request was sent to experts who were personally acquainted with the authors. They were requested to forward the survey to other laboratories they were familiar with. In addition, a link to the survey was posted on a professional-oriented social networking site. Anonymity was promised.

The distributions of responses to the various questions were analyzed, and the relationships among them were examined using Pearson correlation. Sixty-nine responses were received from various laboratories. Approximately 50% of the answers were received from Europe, ~30% from North America, ~15% from Oceania (Australia and New Zealand), and the rest from other continents. Of the laboratories that answered, 43% are national, 17% regional, 30% local, 3% academic, and 4% private. Most laboratories employ no more than three practitioners, and ~70% handle no more than 100 cases annually. Nearly 80% of the laboratories have fully written working procedures, and only 9% have no written procedures at all. Most of the laboratories are accredited (77%), and the vast majority of them have International Organization for Standardization (ISO) 17025. Most of the laboratories perform proficiency tests (87%), and of them, 65% perform them once a week and 23% twice a year. The proficiency tests come from various sources. The most popular commercial test is distributed by Collaborative Testing Services (CTS), but there are several other companies as well. Most European laboratories perform the European Network of Forensic Science Institutes (ENFSI) test. Several laboratories perform their own proficiency tests.

The effects of the geographical region and whether it is central or local on accreditation, standard operating procedures (SOPs), cases per year (per person), comparison method, required education, number and type of proficiency tests, international certification, training (time and requirements), verification, and exposure to background information were studied.

The presence of correlations between the different internal requirements (education, SOPs, accreditation, bios, verification, and training requirements and period) were examined, and whether a correlation existed between the personal work load and quality control (accreditation, written SOPs, verification, proficiency tests, and training period) was also investigated.

Most of the answers were received from laboratories in Europe and the United States. It is also probable that because of the data collection method, the results presented may represent the situation in well-established laboratories as opposed to small, isolated ones.

This presentation will address the subjects mentioned above, suggest possible explanations for the differences among laboratories, and recommend actions to further promote standards for shoeprint laboratories.

Dependence Among Randomly Acquired Characteristics on Shoeprints and Their Features

Sarena Wiesner, MS, Israel Police Department of Investigative Forensic Sciences

Description: Randomly acquired characteristics (RACs), such as scratches or holes on shoe soles, have great value in shoeprint comparison. The relationships among three RAC features—location, shape type, and orientation—are investigated. If these features and the RACs are independent of each other, a simple probabilistic calculation could be used to evaluate the evidential value of RACs. Using a data set of approximately 380 shoes, RACs and their features were determined to not be independent of each other or the shoe sole pattern. Some of the dependencies found are probably caused by pattern elements.

Abstract: The 2009 National Research Council (NRC) report, Strengthening Forensic Science in the United States: A Path Forward, and the recent President's Council of Advisors on Science and Technology (PCAST) report to the President, Forensic Science in Criminal Courts: Ensuring Scientific Validity of Feature-Comparison Methods, call for improving the scientific basis of forensic procedures. This presentation examines basic assumptions in

the field of shoe comparison currently used to define the degree of rarity (DOR) for a given shoe sole.

Footwear examination starts with comparing the size, pattern, and wear of the shoe in question to the print found in the crime scene. Then, the sole's DOR is calculated based on the randomly acquired characteristics (RACs) that scar its contact surface. These marks are caused by abrasions on the outsole. Unlike manufacturing flaws, the creation of RACs depends on the owner's walking patterns, the material of the shoe sole, the surface with which it comes into contact, the pattern of the shoe, and its wear and tear. RACs are characterized by several features, such as their location, orientation (angle), and shape, which are used to compare shoes.

Previous studies assume that the features of a given RAC are independent of each other, as are the RACs themselves. Therefore, the DOR of a single RAC is calculated by multiplying the probabilities of its features, and the DOR of the entire shoe is calculated by multiplying the DORs of all its RACs. However, if the independence assumption does not hold, the calculations would be incorrect, and the rarity of a certain shoe may be overestimated. The goal of this presentation is to statistically test the independence assumption.

The focus is on the relationship among the features of a given RAC using data collected by the Division of Identification and Forensic Science (DIFS). Three propositions are tested; each contends that the RACs are created randomly and independently on the shoe sole, but each also includes the following:

- The shape type of the RAC is independent of its location.
- The orientation of the RAC is independent of its shape type.
- The orientation of the RAC is independent of its location.

The null hypothesis of independence includes two parts. First, it assumes that RACs are independent; thus, the occurrence of a particularly configured RAC does not predict the occurrence of another with a certain configuration. Second, the hypothesis assumes that RAC features are also independent (i.e., the shape type distribution does not depend on the RAC's location or orientation). Under the null proposition, this statistic has an approximately $\chi 2$ distribution. The larger the value of $\chi 2$, the more evidence exists against independence.

The propositions above were tested and rejected, showing that an association does exist among the features. Two analyses were conducted to control for the effect of the sole pattern. Association was found between the shape type and location and between the shape type and orientation, even within a specific shoe pattern. The calculation of the DOR as a product of probabilities is, therefore, invalid, and the dependence should be modeled for a well-founded evaluation of the DOR.

The elements that make up the shoe sole comprise an important feature that affects the creation of RAC. The analysis accounts for the shoe sole patterns, but because they consist of a large number of different elements, a more detailed analysis is required. Using three sample patterns, this study demonstrated how the dependence between RACs' features and shoe sole patterns can be tested. These questions and similar issues regarding the possible reasons for these dependencies were investigated and will be analyzed and discussed in the presentation.

JUST WHEN YOU THINK IT'S A FINGER...

Michael Frost, BS, Maricopa County Sheriffs Office

Description: This poster presentation will include a brief overview of a case and enlargements of a latent print, a known print, and photographs depicting the area where the latent print was, which led to the false assumption that the impression was made by a finger, specifically a thumb. The item was re-examined in the laboratory by the latent examiner, and additional laboratory photographs were taken of the impression, resulting in additional portions of previously unseen friction ridge detail being photographed. This led the latent examiner to re-evaluate the latent impression and change his opinion on the origin of the impression from being made by a finger to having been made by the interdigital area of a palm, which ultimately led to the identification of a suspect.

Abstract: This was a homicide investigation involving a female victim found buried in a rural area of Arizona. Identification of the victim and further investigation led detectives to an apartment where a male subject lived. He was the last person to have seen the victim alive. A search warrant of the residence was conducted and included searching it for visible and latent bloodstains, both of which were found. Among the visible bloodstains was a patent impression in blood on the back of a kitchen chair. The patent impression was photographed on scene, and photographs of this impression were later used in a latent comparison. The impression contained a large loop, believed to be a right slant loop, specifically a thumb print. A comparison of the impression was made to the victim and male subject and initially, the impression was excluded to the fingerprints of both subjects. An Automated Fingerprint Identification System (AFIS)/Next Generation Identification (NGI) search was conducted using the search criteria of a finger with a right slant loop with negative results.

The item of evidence was then re-examined in a laboratory setting, and additional friction ridge detail, found around the edge of the chair, was noted and photographed. This detail helped in the identification process because of its presence and location and aided the latent examiner in determining that the loop pattern was made by a palm, specifically the interdigital area of a right palm. The impression was compared to the known prints of the victim and suspect and was identified as having been produced by the male suspect.

This is a case of a latent examiner having tunnel vision and focusing on one aspect of an impression. It is also a case that brings to light the importance of physically seeing an item of evidence and examining it wholly, rather than relying on photographs of the evidence to do a latent comparison. If the examiner had been able to more thoroughly examine the actual item the impression was found on prior to doing his first comparison, the suspect would have been identified during the initial comparison.

*This case is still active and awaiting trial.

Policy Decisions In Latent Print Examination Affect Specificity

Carey Hall, MLS, Minnesota Bureau of Criminal Apprehension

Description: The assessment of the value of latent print impressions is often defined in an agency's Standard Operating Procedure. Policy decisions regarding the approach to determining value can change the number of impressions that will be retained and compared by examiners. Although none of these approaches is wrong, each has a different false-negative rate and affects specificity. However, policy changes are made with little consideration of the impact to the criminal justice system. Within the latent print community, the value of exclusion decisions has been minimized because of their perceived limited importance to our traditional partners.

Abstract: Latent print examination uses two main approaches to determine the utility of an impression, as defined by the Scientific Working Group for Friction Ridge Analysis, Study and Technology (SWGFAST). In one approach, impressions that cannot be identified will not be preserved, documented, or retained. In the second approach, impressions that cannot be identified but can be excluded are preserved and compared. More recently, a third approach to define which marks cannot be excluded but can be identified has emerged: value for identification only. While none of these approaches is wrong, each has a different false-negative rate and affects specificity. This lecture will explain how changes in policy can impact specificity. The intent is to introduce examiners and policy-makers to the concepts of sensitivity and specificity and how changes might impact the criminal justice system by providing real examples from erroneous conviction cases.

An Investigation of the Factors Necessary to Produce Three-Dimensional Fabric Impressions in Automotive Finishes

Jessica Hovingh, Pennsylvania State University

Description: In some vehicle-pedestrian collisions, 3D patterns from clothing fabric may be impressed into vehicle surface coatings. Generally, the focus in these cases is the association of physical evidence collected from the scene, victim, and suspect vehicle; the force required to produce 3D impressions has received little attention. The aim of this study is to elucidate the factors involved in the production of 3D patterns. Two impact devices—a pendulum (6-foot arm) and a drop-hammer impact testing device (10-foot drop height)—were used to examine the effect of varying the impact force on the production of 3D impressions in automotive finishes.

Abstract: In some vehicle-pedestrian collisions, patterns from clothing fabric may be impressed into the surface coatings of the hood, front fascia, bumper, and fenders. Occasionally, patterns are found in headlamp assemblies and other polymeric vehicle components. Generally, the focus in these cases is the association of physical evidence, such as biological material, paint, and glass, collected from the scene, victim, and suspect vehicle. 3D fabric patterns impressed onto vehicles often contain embedded fibers, and these fibers and patterns may assist in providing important associative evidence. The force required to produce these patterns, which could yield important information regarding vehicle velocity at impact, has received little attention. The aim of this study is to elucidate the various factors involved in the production of 3D impressions. Variables studied include the type of fabric (structure and composition), surface coating, angle of impact, and impact force. This study utilizes two impact devices located within the Pennsylvania State University College of Engineering's Civil Infrastructure Testing and Evaluation Laboratory (CITEL): a pendulum impact tester (6- foot arm) and a drop-weight impact testing device (10-foot drop height).

The pendulum impact tester utilizes a dome-shaped weld cap mounted to the front of the arm at its end. It is covered with a layer of foam and the test fabric to simulate a clothed human kneecap. The impact site of the pendulum arm is permitted to collide with vehicle components that are cut to an approximate 23 cm by 23 cm square, which is clamped to a rigid metal backer plate. To vary the impact force, the pendulum arm is raised or lowered; weights can be added to further increase the impact force. The precise impact force is calculated by analyzing high-speed video recorded with a Phantom V711 digital camera.

The drop-weight impact testing device consists of a cylindrical 14.8-kg steel weight suspended by a pulley in a clear polyvinyl chloride (PVC) pipe guide. A layer of fabric is placed over a 10 cm by 10 cm section of vehicle component. A stainless-steel disk is

positioned at the base of the guide tube over the fabric and vehicle component. To vary the impact force, the drop height is raised or lowered; additionally, the diameter of the stainless-steel disk can be altered to disperse the impact force over a smaller or larger area. The precise impact force is calculated based on the drop weight, height, and impact area.

With fabric type, surface coating, and impact angle held constant, preliminary results show repeatable fabric imprint pattern formation, provided a minimum pendulum height is reached. This permits the determination of the impact force and assessment of pattern production as other factors are varied. Initial evaluations of the patterns on each vehicle component, both pre- and post-impact, have been conducted using stereo microscopy and micro-level terrain mapping of the fabric using a Leica DVM6 digital microscope. Other variables, including the angle of impact, surface coating, surface treatment, and fabric type, will be examined in future studies.

Applying Reflection Transformation Imaging Methods and Open Source Software to Tire Tread and Shoe Print Image Collection

John Ossi, MS, Ossi Imaging

Description: Tiretread and shoeprint images contain textural information. The accepted image capture methods suggest collecting three images with the light source at a low azimuth angle, changing the light source compass direction by 120° for each of the three images. Collecting images at additional light source directions, as outlined in the reflection transformation imaging (RTI) methods, and utilizing open-source post-processing and display software may allow examiners to extract additional information in the future that might not otherwise be available.

Abstract: Tiretread and shoeprint images contain textural information. The accepted image capture methods suggest collecting three images with the light source at a low azimuth angle. Only the light source compass direction is moved 120° after collecting each of the three images. Although molds may exist, the original impression evidence is not retained. Collecting images at additional light source directions, as outlined in the methods below, will allow examiners to extract additional information in the future that might not otherwise be available. The downside is the additional time might be required to collect the additional images. The outlined methods offer a pathway to accelerate the image collection process and eliminate the need for a lighting assistant.

Reflection transformation imaging (RTI) is a photographic image collection and computational display method that captures images of the surface of opaque specimens. Post processing the images allows interactive virtual re-lighting of the subject from any direction. Polynomial Texture Mapping, an open-source software developed at Hewlett Packard, permits the mathematical enhancement of the subject's surface shape and color attributes. The enhancement functions of RTI reveals surface information that may not be apparent to the unaided eye or by using other observational methods. Oblique reflected light illumination is the most common way of viewing specimens. Light incidents the specimen at an angle off the optic axis. Single images taken with a unidirectional light accentuate topographic features by making the illuminated side of a feature bright, contrasted against the shadow side. RTI methods suggest collecting up to 64 images and using a unique lighting azimuth/compass direction for each image. The specimen, optics, and camera remain fixed, and only the single quasi-point source of light changes to a new location for each image. This method is outlined, and the associated open-source software is used to illustrate the resulting enhanced images. This method can be used with almost any camera and appropriate light source.

The collection of 64 images is time prohibitive and may require the employment of an assistant to move the light source following the collection of each image. Because tiretread and shoe impression features are often linear, reducing the total number of images collected along the specimen's axis and using an electronic flash movable array should make image collection times reasonable while offering the additional images that examiners might need.

Incorporating a Statistical Model into Forensic Shoeprint Analysis

Andrew Kimble III, Albany State University

Abstract: To date, there is little statistical backing that can be applied to forensic shoe print analysis. Current methods of data collection include shoe sole powdering and scanning. We begin data analysis by scanning a sample of shoes and compiling them into a database. The samples collected include five different shoe sole patterns with two pairs of each type. We collected five images of each individual shoe. The objective of this image collection is to compute the Hu moments present in each individual shoe. Hu moments are eight points invariant to scale, rotation, and translation. The sensitivity to change of these moments makes them potentially useful in identifying the unique characteristics of any given print. The Hu moments corresponding to the images are then used in the training of a statistical model. This model can provide a score indicating whether an individual shoe would be a match with each element of the established database.

Shoeprints: The Path from Practice to Science

Sarena Wiesner, MS, Israel Police Department of Investigative Forensic Sciences

Description: The 2009 NAS report and the 2016 PCAST report, made it clear that many traditional forensic disciplines have not evolved with the broader scientific community, particularly with respect to the lack of modern statistical approaches and quality control measures.

This presentation proposes a set of initial steps to improve the practice of shoeprint comparison. These include quality control, creating a large representative data base, developing a model that explains the creation of RACs on shoe soles, reducing bias in the comparison process, studying various types of noise that exist on crime scene prints and preforming black box experiments.

Abstract: The 2009 NAS report which evaluated and set required standards for the various forensic fields caused an earthquake in the forensic community. Some of these aspects standards were addressed in the 2016 PCAST report and identified as future thresholds for courts in the USA.

For most fields of forensic evidence, current methods fall short of a scientifically objective and quantitative analysis that can be presented in court when trying to determine a match between samples.

This presentation will focus on footwear analysis. The identification of footwear impressions is based on the comparison of a print found at the crime scene with a test impression made from a suspect's shoe. Weight is given to the RACs (Randomly Acquired Characteristics) that result from random processes of wear and tear, such as holes, scratches etc. One of the common methods currently used to present the level of confidence in the connection between the test impression and the crime scene print is an ordinal scale, such as the SWGTREAD scale, which is a subjective approach to the estimation of confidence or significance, rather than one based on an explicit statistical model. The current method of evaluating RACs clearly reduces the potential suspects' shoe population but it lacks formal statistical analyses based on large databases, and fails to provide a scientific and quantitative scale for assessing the match between a crime scene print and a suspect's shoe.

Current challenges of evaluating shoeprint evidence from the collection stage to the submission of testimony in court from will be surveyed. Practical recommendations and initial scientific steps will be proposed to carry the shoeprint comparison field along the path from practice to science.

The complexity of the shoeprint comparison process requires high practice standards both for the lab and for the practitioners. A detailed Standard Operating Procedure (SOP) is needed to ensure that the work is preformed professionally and based on a standard working procedure. This minimizes error, makes the procedure more objective, less operator dependent and increases the transparency of the process. Laboratory accreditation by an exterior institute is another safety net to prevent careless work. Working by SOP in an accredited Laboratory assures working standards. Proficiency tests ensure professional working quality. Successfully preforming proficiency test at least once a year by each practitioner in the lab is necessary to safeguard a basic level of professional competence. Blind proficiency tests can ensure an even higher level of competency.

Forensic laboratories should establish routine quality assurance and quality control procedures including blind testing and performance testing to guarantee the accuracy of forensic analyses and the work of forensic practitioners as well. Blind proficiency tests can be created internally or collaboratively among several cooperating laboratories. In such tests, the examiner is not aware that the test cases are not real ones. For performance testing, sample cases are re-examined by other experts or the same experts after a period of time and the results are compared.

Verification is a key step for preventing error during routine case work. After an examiner reaches a conclusion and writes the report, a second expert reviews the case. The optimal form of verification is to perform a blind comparison independently and then to compare the results with the original report (double blind) to prevent confirmation bias. Contextual bias may influence decision making during the working process, hence should be minimized as much as possible. Maintaining high lab standards cannot be complete without investing in the professional training of the examiners. A scientific background is recommended for all examiners. Academic scientific studies educate in logical and systematic thinking, and the limitations of human knowledge, which is a basic need of the forensic practitioners' work. Specific training in the profession of shoeprint comparison should be a major step before the examiner is permitted to write expert opinions. This should be limited to certified examiners.

A crucial issue is that the current procedure involves almost no statistics that are based on large scale datasets related to either class characteristics or RACs, since these are not available. The distribution of shoe-sole patterns in a specific geographic area constantly changes. The shoe industry changes the patterns sold periodically, and people regularly replace their old shoes with new ones. For this reason, keeping an up-to-date database of shoe-soles to assist in statistic calculations challenging.

The aforementioned studies use very simple statistical tools. The work that has been done triggered the need for ongoing statistical research which includes developing a model that explains the creation of RACs, adjusting statistical calculations according to the relevant population in each casefile, estimating the covariance structure of RACs and analyzing the crime scene noise by the use of experiments. An example of the latter would be the collection of noisy shoeprints by conducting a controlled experiment and comparing the prints from the experiment to the test impressions made from the shoes under controlled conditions.

Automated systems, if developed, can assist the examiners in reaching objective conclusions. For example, an automatic system that finds the shoe pattern on crime scene print prior to observing the suspect shoes or an automatic system that will find the RACs and an examiner will approve them, would both reduce confirmation bias.

Medical diagnostics is a field facing similar challenges as forensic science in assessing the performance of human expert examiners working with complex data. both rely on expert human capabilities which cannot be readily reduced to a set of objectively defined rules and both face the need to continuously upgrade professional skills. The capability and knowledge base of practitioners may be difficult to measure effectively in each area. The approaches developed by the medical society to handle these challenges, could be adapted by the forensic community as well. The overall performance of the expert, a physician or a forensic expert, should be addressed as a "Black Box", which gives a non-transparent result to the effectiveness of the expert, based on empirical tests of performance. In contrast, "White Box" tests attempt to understand aspects of how expert examiners make decisions.

Case Study of a Robbery Which Turned into a Homicide

Sabrina Walker, BS, Maricopa County Sheriffs Office

Abstract: This is an interesting case that occurred in August 2009 in an affluent area of Cave Creek, Arizona. I was called to the crime scene, which contained a large beautiful house with an older deceased man just inside a partially open front door. He was tied with electrical cords behind his back and was face down on the floor.

My duty was to try to collect all the evidence within this crime scene and obtain evidence of a suspect. This case study will take you through the crime scene methodology. This presentation will also include the human element of the crime scene processing. I aim to cover what went right with the crime scene processing and impression evidence and what lessons I learned about what not to do. This presentation will also address the importance of teamwork and being part of a good crime laboratory when working a large case with an enormous amount of impression evidence. I will take you through the search for the shoes with the impressions that matched those found within the home. Additionally, I will review the importance of a latent examination for a suspect found with a crucial area within the crime scene.

My goal is to conduct a review of the two trials that were held in Maricopa County Superior Court. I will review the verdicts and go over the evidence and the importance of the evidence in the convictions of the suspects.

Finally, I will review the importance of the complete processing of a crime scene and how the most insignificant pieces of evidence can make a substantial impact on the jury. DNA is not always the guiding factor in jury judgement. Finally, I will emphasize how missed details can ruin cases.

Barrier Penetration Characteristics of PolyCase Inceptor ARX Ammunition

Peter Diaczuk, PhD, Pennsylvania State University, Eberly College of Science, Forensic Science Program, and Andrew Winter, Centenary University

Description: PolyCase ammunition has some novel design features, specifically the construction and unique shape of its ARX bullet. Several studies have shown that traditional bullets have predictable interactions with many yielding and non-yielding intermediate substrates. The newly marketed ARX bullet behaves quite differently. The manufacturing process and the materials used do not lend themselves to a traditional hollow point design, however, the PolyCase engineers have devised an alternative to a cavity in the form of three large "flutes" in the bullet's ogive. These flutes create characteristic triangular perforations in automobile sheet metal.

Abstract:

Introduction. Recently, a new entry into environmentally friendly ammunition has appeared on the commercial market. The PolyCase ammunition company, out of Savannah, Georgia, has created a new bullet design and construction. PolyCase ammunition has some novel design features in all its marketed products, specifically the construction and unique shape of its ARX bullet. Prior studies by the authors and other researchers have shown that traditional jacketed and hollow point bullets have predictable interactions with many yielding and non-yielding intermediate substrates. The newly marketed ARX bullet behaves quite differently. Not only is the bullet lead-free but it also comprises copper spheres in a polymer matrix, manufactured using an injection molding process. This manufacturing process does not lend itself to a traditional hollow point design, however, the bulletsmiths at PolyCase have devised a unique alternative to a cavity in the form of three large flutes in the ogive of the bullet. These flutes create characteristic triangular perforations in automobile sheet metal.

Methods / approach. Several calibers and styles of PolyCase-brand ammunition were test-fired at various barriers, including drywall, paneling, plywood, architectural glass, windshield glass, and sheet metal of different thickness gauges. Automobile sheet metal provided the most characteristic bullet holes when perforated by the fluted ARX bullets as compared with traditional hollow point or full metal jacket bullets. The results were replicated using firearm barrels, with both left-hand and right-hand twists, and different barrel lengths, which offered slightly different velocities as measured with a chronograph near the muzzle. In addition to assessing the bullet hole itself, high-speed photography revealed that a piece of metal was being dislodged from the substrate by the bullet's impact. To capture these "punchouts," ballistic gelatin was placed near the exit holes of the bullets and allowed recovery of the small metal pieces that were dislodged.

Results and findings. Sheet metal pieces that simulated automobile body parts were positioned a few feet from the muzzle of several different firearms and were fired upon using the PolyCase Inceptor ARX ammunition. The fluted ARX bullets consistently created triangular holes in the sheet metal. The larger the caliber, the larger the size of the triangle, however, alternating firearms with different barrel rifling twist directions did not have a visible effect on the shape of the holes created.

The ARX bullet was "deconstructed" by dissolving the polymer matrix and evaluating its IR spectrum to determine that it was nylon. The metal spheres were examined using scanning electron microscopy/energy dispersive spectroscopy (SEM/EDS) to assess their relative size, shape, and metallurgy. The bulk of the mass was obtained from copper spheres, but being less dense than the lead core of a traditional bullet, the ARX bullet traveled at a greater velocity than its traditional counterpart.

Conclusion. Reproducible triangular holes were made in sheet metal by the PolyCase Inceptor ARX bullets. Traditional bullet designs from other manufacturers do not produce triangular holes. Triangular "punchouts" were recovered from the recovery medium (ballistic gelatin blocks) positioned directly downrange of the sheet metal, along with witness panels to keep track of secondary missiles and post-impact bullet fragments.

The fluted ogive of the PolyCase ARX bullets produces characteristic holes in sheet metal. The style of bullet hole morphology can be readily distinguished from traditional hollow point and full metal jacket bullet types. Recognition of this unique style of perforation may provide useful information for shooting scene reconstructions.

Duct Tape Physical Matching by Various Separation Methods Using Quantitative Analysis

Michelle Marx, MS, Stevenson University

Abstract: Duct tape is often associated with criminal activity and can be used as an evidentiary link between the suspect, victim, and crime scene. Physical matching is the strongest association in forensic science comparative examinations and has a significantly high evidentiary value. This study was designed to further the results obtained by McCabe et al. (2013) by statistically evaluating the error and accuracy rates associated with duct tape physical matching. A blind study analyzing four methods of separation of five brands of duct tape was conducted by an untrained analyst. The lowest accuracy observed was 91.50%, the highest false-positive rate was 10.00%, the highest false-negative rate was 6.74%, and the highest inconclusive rate was 2.25%. Overall, the results showed that an untrained analyst can obtain high accuracy (96.61%) and low misidentification rates (3.33%). This study further confirms the high degree of certainty associated with using the physical matching technique in identifying duct tape samples as matching or non-matching. The study also shows that different brands, grades, and separation methods have varying contributions to misidentifications and inconclusive rates.

Keywords: duct tape, physical matching, fracture matching, error rates, statistical analysis, forensic science.

| Trace |

Statistical Characterization of Commercial and Homemade Aluminum Powders in Explosives Using Automated Particle Micromorphometry

JenaMarie Baldaino, MS, and JoAnn Buscaglia, PhD, Federal Bureau of Investigation; Danica Ommen, PhD, Department of Statistics at Iowa State University

Description: Aluminum (Al) powders are commonly used in pyrotechnics and explosives to increase the heat of explosion. Al powders can be produced industrially or at home using amateur methods. The primary goal of this project is to investigate the potential of particle micromorphometry to differentiate Al powder sources and to provide insight into the method of Al powder manufacturing. This presentation addresses fundamental factors of Al particle metrology including sample preparation, imaging parameters, and methods to minimize sampling biases as well as issues with these large multidimensional datasets and the initial statistical methods under investigation.

Abstract: Starting materials for an improvised explosive device (IED) are readily obtainable from local commercial sources. Aluminum (Al) powder, a common metallic fuel, has a wide variety of legitimate uses and is widely available without significant regulatory constraints (Kosanke & Kosanke, 2007). Al powders can be obtained from industrial manufacturers or can be produced inexpensively using basic instructional manuals and videos. Due to the online sharing of instructional manuals and published books on how to construct IEDs, bomb-makers are now informed on the easily accessible household materials that can be used to make explosive chemical mixtures (Larabee, 2015).

Previous results using scanning electron microscopy/energy dispersive spectroscopy (SEM/-EDS) showed morphology and surface characteristics can differentiate some methods of Al powder production (i.e., industrial vs. home-made) (Baldaino, Hietpas, & Buscaglia, 2017). Particle micromorphometry may be used as a complementary method to gain additional information to differentiate Al powder sources. This presentation addresses fundamental factors of Al particle metrology including sample slide preparation, imaging parameters,

and potential methods to minimize sampling biases; the statistical methods used to analyze these large multidimensional datasets will be discussed.

Al powder samples were obtained from legitimate industrial manufacturers, various "in-house" production methods, and seized IEDs. The amateur methods were replicated to produce Al powder from easily available sources including: Al foil,; metallic spray paints,; Al ingots produced by melting from Al cans which were then filed or lathed,; pPyrotechnics,; and catalyst packets from binary exploding targets. To prepare microscope slides for imaging, a subsample containing ~1000µg from the bulk Al powder was placed into a microtube containing Permount® mounting medium. The solution was mixed until evenly dispersed and then an aliquot of the subsample was placed dropwise onto a microscope slide and a cover slip added. To determine the appropriate number of subsamples required to adequately represent the bulk Al powder, a subset of 17 Al powder samples were prepared using 10 subsamples and three3 aliquots for each subsample (i.e., 30 aliquots in total per sample). Leave-One-Out Cross-Validation (LOOCV) was performed on this subset of samples; and it was determined that seven subsamples of the bulk Al powder and three aliquots for each subsample (i.e., 21 aliquots per sample) were sufficient to obtain a representative sample of the bulk Al powder.

Transmitted light microscope images (n≈4,200 fields of view/sample) of the Al samples were acquired using an automated stage and automated Z-focus. Dimensional analysis was calibrated using a National Institute of Standards and Technology (NIST)-traceable stage micrometer; polystyrene spheres of 100µm, 50µm, and 10µm were used as secondary standards to assess linear calibration. Images were batch processed using commercial image analysis software and customized code. Each image was converted to a binary image to enhance edge detection, and the particles were counted and measured. Seventeen parameters were measured for each particle within the image field of view including: area, aspect ratio, perimeter, roundness, mean diameter, mean feret, radii (maximum and minimum distance from particle centroid to edge), radius ratio, box height, box width, and fractal dimension. The large multidimensional datasets (n≈90,000–500,000 particles/sample) were analyzed using an open-source statistical package.

The datasets are too large and complex to analyze at this point without some dimensionality reduction. Our preliminary work focused on the use of a weighted summary of 17 morphometric measurements on the subsamples.: Tthis was achieved by first taking weighted averages of the particles per fields of view (FOV), yielding a 17-dimensional vector for each FOV (i.e., average particle for each FOV). Then, the average of the average vectors for each FOV per aliquot was calculated, giving a 17-dimensional vector per aliquot. Likewise, the average vector across the aliquots corresponding to a given subsample was calculated, resulting in one 17-dimensional vector for the entire subsample for each sample. The classification accuracy between sources of Al powders using this weighted approach and results from the various multivariate statistical methods tested will be presented.

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The Evidentiary Significance of Automotive Paints from the Northeast: A Study of Red Paint

Kaitlin Kruglak, BS, The University of New Haven

Description: This presentation will provide physical and chemical population data on automotive paints in the Northeast, thus informing criminalists on the significance of automotive paint characteristics. This research was conducted to help demonstrate the significance of population studies pertaining to automotive paints.

Abstract: This research was completed to provide data relating to the significance of automotive paint chips found in a specific population. Research has previously been conducted regarding Midwestern automotive paint populations (Palenick, Palenick, Groves, & Herb, 2016) as well as populations regarding the layer chemistry of the paints (Zięba-Palus & Borusiewicz, 2006). But to date, no research has been conducted on automotive paints from the Northeast. This research looks at paint samples from the Northeastern portion of the United States and uses both common and emerging techniques for automotive paint analysis.

The populations of automotive paints are constantly changing, and thus need to be thoroughly monitored. By investigating these populations, forensic scientists can begin to understand the significance each individual automotive paint may hold. In order to do this, the physical appearance, layer structure, and layer chemistry can be analyzed to provide a forensic examiner with more detail that can be used to give strength to a conclusion made during an automotive paint examination.

This population study involved the discrimination of red automotive paints using a comparative analysis approach and data analysis. The red samples were chosen as a target group from a larger automotive paint population based on popularity among consumers and manufacturers. The first portion of the analysis used stereomicroscopy, brightfield, and polarized light microscopy to analyze all samples collected in the population. This study has analyzed the paint samples from approximately 200 automobiles ranging from the years 1989 to 2017. The macroscopic and microscopic characteristics of each sample analyzed included relative surface color, presence of effect pigments, relative size of effect pigments, number of different pigments, number of layers, layer color, layer texture, and relative thickness of the layers. The population data obtained varied from previously released reports from Midwestern (Palenik et al., 2016) and North American (Axalta Coating Systems, 2016) automotive paint populations. The Midwestern study analyzed 300 samples, and the North American study was conducted on a much larger scale, but each one demonstrates the importance of this type of study. For example, the present research had a 20% gray-colored frequency which differed from the less than 10% obtained in the Midwestern study and 16% in the North American study. The target color of red had a 13% frequency in the current study, compared with 15% in the Midwest study and 10% in the North America study.

Next, only the red automotive paints were further analyzed using a comprehensive sequence. This helped to determine the differentiating power of the analytical sequence as well as to analyze the chemical properties of similarly colored paints. Current laboratory methods were used to analyze the red automotive paints, including ultraviolet-visible microspectrophotometry (UV-Vis MSP), scanning electron microscopy/electron dispersive x-ray spectroscopy (SEM/EDX), and Fourier transform infrared spectroscopy (FTIR). In addition, this research used Raman microspectroscopy, an emerging technique for automotive paint analysis that has been demonstrated to provide valuable pigment information (Palenik et al., 2016).

This study was conducted to highlight the significance of automotive paint comparisons and the characteristics each sample possesses. The frequency data and the degree of differentiation is important information as it can provide a foundation for determining the significance of indistinguishable samples.

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An Investigation of Chemometric Spectral Transfer Methods for the Forensic Analysis of Traditional Nail and Gel Polishes

Alyssa Smale, Lebanon Valley College

Description: Replicate attenuated total reflection (ATR)-Fourier transform infrared spectroscopy (FTIR) spectra of 98 different shades of red and pink fingernail polishes and gels were recorded using three different infrared spectrometers. Chemometric methods were used to classify the samples. No two instruments of the same type produce exactly the same spectra, necessitating the construction of a chemometric model on each instrument used to identify samples. Spectral transfer methods require a small number of spectra in order to apply the "parent" model to spectra taken on "daughter" instruments. Blind tests, spectra of new bottles of polish, and samples exposed to various environmental conditions were used to evaluate the model.

Abstract: Fragments of fingernails are a type of trace and transfer evidence found at crime scenes or on suspects, especially in cases in which the victim utilized self-defense. In today's society, wearing nail polish is very common, and billions of dollars are spent on nail polish each year. Attenuated total reflection (ATR)-Fourier transform infrared (FTIR) spectroscopy can be used to quickly and reliably differentiate between traditional nail and gel polishes, allowing for the identification of a polish found as evidence by comparing it with a known polish in a database. This research aimed to create a spectral database of several different red and pink traditional nail and gel polishes of various brands as well as calibration models that allow for the proper identification of samples analyzed on different FTIR spectrometers.

ATR-FTIR spectroscopy can detect the chemical components in traditional nail and gel polish samples. Additionally, through chemometric analysis, it is possible to analyze differences in the spectra of each polish or gel and to distinguish between the samples. It has previously been demonstrated that by using chemometrics, one can differentiate between polishes and gels and identify a sample as a specific brand and a specific color within that brand. This research focused on testing the ability of different instruments to perform these classifications, which would then enable the creation of a polish database.

The nail polish collection used in this study contained 49 different traditional polishes from seven different brands and 49 different gel polishes from seven different brands, totaling

98 bottles. All gel samples were cured under a UV light for 3 minutes. On three different ATR-FTIR spectrometers, five spectra were collected for each polish, totaling 490 spectra for each instrument, and a grand total of 1470 spectra.

The spectra for one instrument were analyzed by the chemometric software Solo (Eigenvector Research, Inc.). The spectra were preprocessed using Multiplicative Signal Correction (MSC), which corrects for multiplicative effects and baseline offset. A chemometric technique called "K" Nearest Neighbors (KNN) was used to classify the spectra. Each of the 98 bottles was assigned a class corresponding to brand and color. Each class contained the five replicate spectra of each polish. KNN works by plotting all the spectra based on the absorbance value at each frequency and measuring the distance between an unknown sample and all the other samples in the database. KNN will assign the class of the unknown sample according to the three closest samples in the database. Using MSC and KNN, the software was able to perform an 84% correct sample bottle classification and a 100% correct brand classification.

To improve these results, Generalized Least Squares Weighting (GLSW) was used. GLSW works by determining which variables in a spectrum are important in describing "clutter," defined as noise and other real phenomena that are unrelated to the object of interest. These variables are then de-weighted, allowing the variables that are important to distinguishing between the traditional nail and gel polishes to be identified more easily. Using MSC and GLSW data pretreatment, KNN generated a 98.6% correct sample bottle classification and a 100% brand classification. In no case was more than one replicate misclassified.

Creating a model that can correctly classify the polish samples by brand and bottle was the first step. The second task arose from the fact that no two instruments of the same type produce exactly the same spectra, making it unlikely for a spectral database to work properly on instruments other than the one on which the database was created. There are two options for the success of a spectral database. The first would be the construction of a chemometric model on each instrument used to identify samples, which is not ideal, cost effective, or practical. The second is the use of spectral transfer methods, which require a small number of spectra to be collected on a "daughter" instrument in order to apply the "parent" model to spectra taken on "daughter" instruments. For this research, direct standardization algorithms were used to create spectral transfer matrices that corrected each spectrum taken on the daughter spectrometers. This allowed the use of the parent model on spectra taken on daughter instruments with 99% correct classification.

Lastly, robust testing of the model and calibration transfer methods were performed using blind tests and simulated real world samples. The blind testing used bottles of colors that exist in the data set as well as new bottles not in the original set. It was expected that the model would correctly classify colors that were already in the learning set, classify the new colors correctly by brand, and not classify any bottles that were from a brand not in the original learning set. Additionally, five colors from the collection were painted on acrylic nails for simulated real world experiments. A nail of each color was exposed to different environmental conditions and ATR-FTIR spectra were collected from the samples over time to see if degradation occurred and if the model could still correctly classify the samples.

This research proved that ATR-FTIR spectroscopy can detect very subtle differences between several nail polishes and gel samples that appear similar to the human eye. Chemometric models can be used to correctly classify replicates of various samples as a specific polish or gel, and calibration transfer methods can be used to apply models to new instruments and obtain the same results. The methodology behind this research has applications beyond nail polish, and calibration transfer methods can be very useful within the field of forensic science.

Trace Isotope Analysis of Dental Enamel for Micro-Regional Geographic Attribution of Human Remains in Virginia

Nicole Palmer, BS, Virginia Commonwealth University

Description: Trace element isotope ratios in surface and bulk dental enamel can successfully be used to geographically attribute unidentified human remains through the use of inductively coupled plasma mass spectrometry (ICP-MS) analysis. The analysis of the bulk and surface enamel can indicate the birthplace and recent residence, respectively, of individuals. This study examined ca. 90 teeth from 65 donors obtained from different regions within Virginia. Ultimately, this methodology could contribute to the compilation of a database of chemical isotope ratios by locality within Virginia, which could be applied to unidentified remains in long-term storage in the many Offices of the Chief Medical Examiner (OCME) in Virginia.

Abstract: This presentation highlights the utility of trace element isotope ratios in dental enamel as a means of enhancing biological profiles, providing a method for the geographic attribution of birthplace and recent residence of unidentified human remains. Ultimately, this methodology could contribute to the compilation of a database of chemical isotope ratios by locality within Virginia, where there are currently ca. 165 cases of unidentified human remains in long-term storage in the four Virginia Offices of the Chief Medical Examiner (OCME) regions. In many of these cases, the remains are severely decomposed or skeletal and do not match any reports of missing persons, and fingerprints, DNA profiles, dental conditions, and facial approximations of these individuals have generated no leads in identification.

Dental enamel preserves well despite decomposition and holds promise for the expansion of new forensic identification methods. The bulk enamel composition ceases to change appreciably after a certain age and is thus indicative of an individual's birthplace (or early childhood residence), while the surface enamel composition continues to change, due to surface ion exchange and diffusion, and is indicative of an individual's recent residence (Molleson, 1988).

This study examined the bulk and surface enamel samples of ca. 90 teeth from 65 donors obtained from the Mission of Mercy and the Remote Area Medical Projects in Wise County, Grundy, Warsaw, and Emporia, Virginia, with approval from the Virginia Commonwealth University Institutional Review Board. Patients scheduled for an extraction were approached by a researcher and asked for written informed consent; if consent was provided, the patient was asked questions concerning age, sex, city and state of birth, and city and state of residence. Individuals in this study, who were born and currently reside in Virginia, had a donor age range of 21 to 70 years. The average donor age was 46.9 years: an average donor age of 48 years for 36 females, and an average donor age of 45.4 years for 29 males. These locations were selected to expand on a pool of 74 samples from 52 donors' previously compiled samples, predominately from central and northern Virginia, collected from the Virginia Commonwealth University emergency dental clinic in Richmond (Stein, Ehrhardt, Hankle, & Simmons, 2017).

After extraction, samples were disinfected in 10% neutral buffered formalin for two weeks. Surface enamel was etched directly using a trace metal-free nitric acid and glycerin solution, while bulk enamel was dissolved in trace metal-free nitric acid after the enamel was ground into a fine powder using a mortar and pestle. Samples were analyzed for the following trace elements via inductively coupled plasma mass spectrometry (ICP-MS): ^{7}Li, ^{11}B, ^{25,26}Mg, ^{27}Al, ^{52}Cr 3^{+}, ^{55}Mn, ^{57}Fe, ^{59}Co, ^{58,60}Ni, ^{63,65}Cu, ^{64,66,68}Zn, ^{69,71}Ga, ^{78}Se, ^{86,87,88}Sr, ^{204,206,207,208}Pb, ^{209}Bi. Principal Component Analysis and Discriminant Function Analysis were performed to examine multivariate relationships among samples and determine which trace elements drove compositional differences among the samples and the locality groups.

The results from a one-way analysis of similarities (ANOSIM) yielded significant differences ($p \leq 0.00420$) between bulk and surface enamel ratios of individuals by geographic locality. Tooth characteristics (e.g., restorations, caries, debris, discoloration, chipping, cracking, and occlusal wear) did not significantly affect the isotope ratios of either the surface or the bulk enamel. This suggests that geographic determinations based on the isotope ratios of bulk and surface enamel are most likely neither influenced nor obscured by the tooth type and/or tooth characteristics. Significant correlations were found for bulk enamel ratios with the geographic location of an individual's birthplace and for surface enamel ratios with recent residence.

In conclusion, trace isotope ratios are useful in determining where individuals were born and currently reside, adding information to the biological profiles of unidentified remains and generating additional leads in the identification of these individuals.

Keywords: human identification, trace isotope ratios, dental enamel

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Identifying Human-Touched Objects Suitable for Microbiome-Based Forensic Applications: Reverse Fingerprint Lifting

Zachariah Oommen, PhD, Tiffany Johnson, and Uzoma Okafor, PhD, Albany State University

Abstract: Latent fingerprint lifting has been carried out on objects to identify and classify human-touched objects within a workplace. This can be readily applied to both traditional (fingerprint analysis) and microbiome-based forensic identification. Several workplace objects such as a keyboard, mouse, phone, doorknob, stapler, and cabinet handle have been used for the study. Dusting the print in an office set-up is not advisable, due to the possibility of fine microscopic dust particles moving around the whole area. Secondly, dusting may disturb microbiome-based forensic analysis. Attempts have been made at reverse lifting—lifting the print and then developing it through dust lifting and chemical methods. Alternate light source (ALS) has been used to enhance the observation and to locate the latent print. Visible fingerprints are photographed and traditional methods of dusting with suitable powders have been used to lift the print. The method seems to work well with glazed/smooth surfaces.

| Interdisciplinary |

Methods to Identify Gunshot Residue (GSR) Pattern Evidence on Decomposed Skin

Meaghan Dougher, BA, Pennsylvannia State University

Description: The effect of decomposition on the persistence and detection of gunshot residue (GSR) powder patterns will be explored along with an investigation into methods for identifying GSR on decomposed skin. GSR powder patterns, particularly powder stippling patterns, were assessed using two animal models: pig skin and live anesthetized bull calves.

Methods investigated included digital photography, stereo light microscopy, infrared photography, histology, scanning electron microscopy, and chromophoric tests including modified Griess, sodium rhodizonate, and dithiooxamide tests. Preliminary results indicate that certain methods may be more appropriate depending on the state of decomposition, the firearm and ammunition used, and other factors.

Abstract: Gunshot residue (GSR) powder patterns can be useful in forensic cases because they can be used in shooting reconstruction in firearm-related incidents. When a firearm is discharged at an intermediate range-of-fire, a GSR powder pattern is typically observed on the target substrate. When the substrate is live skin, a specific type of powder pattern, powder stippling, can result when partially consumed and unconsumed gunpowder kernels impact live skin and result in small, punctate abrasions that cannot be wiped off the surface of the skin. In some instances, the gunpowder kernels can become embedded in the tissue, which may be referred to as "powder tattooing." In this discussion, the collective phenomena of punctate abrasions and kernel embedding following intermediate range-of-fire will both be referred to as simply "powder stippling." If the GSR powder patterns are of sufficient quality, these patterns can be visualized with various methods to indicate the use of a firearm on the substrate. The preservation, condition, and persistence of these patterns, though, are dependent on a variety of factors. In particular, decomposition is a dynamic, complex process that can potentially alter any physical evidence, such as GSR, present on the body; however, there is little information available on how decomposition could impact the condition of such powder patterns over time.

In this pilot study, the effect of decomposition on the persistence of GSR powder patterns was investigated on two animal models, and different methods were evaluated to identify GSR on the two target substrates. Two types of animal skin were shot with a firearm, subjected to decomposition under differing conditions, and assessed using different visual and chemical enhancement methods for the presence of GSR. In one experiment, fresh pig skin was shot using several combinations of handguns and ammunition to produce GSR powder patterns; skins were then subjected to decomposition fully exposed to the environment. In the second experiment, two groups of five anesthetized live bull calves were clipped to remove hair from the target site, shot with a handgun at a distance of approximately two inches in an attempt to produce powder stippling patterns, and chemically euthanized. The calves were then subjected to decomposition either fully exposed, partially buried in soil, covered in vegetation, or sprayed with insect repellant. An eleventh calf was used as a negative control to illustrate the stages of decomposition of the bull calf model. The methods attempted to identify GSR on the animal skins included digital photography, stereo light microscopy, infrared photography, modified Griess test for nitrates, sodium rhodizonate test for lead, dithiooxamide test for copper, histology, and scanning electron microscopy.

Preliminary results of this pilot study indicate that the most appropriate methods to identify GSR on decomposed skin will depend on the stage of decomposition, condition of exposure, the type of skin, and the particular combination of firearm and ammunition used. For most instances, the sodium rhodizonate test appears to be the most useful and sensitive chemical method to identify GSR on decomposed skin. In particular, GSR has been indicated using this chemical method on pig skin that is several weeks decomposed. These experiments also indicate that powder stippling may be hindered if the target exhibits skin with considerable fur. Furthermore, visual observation of the bull calf decomposition trials has indicated that the presence of GSR may limit the insect activity around the entry

wound. The experiments conducted are intended to serve as a pilot study. The trends that are indicated from the results can be used to direct more focused studies in GSR powder pattern and powder stippling investigations.

Ontologies for a Situation-Based Framework for Identity in Crime Scenes

William Nick, MS, North Carolina A&T State University

Abstract:

Scope: This work is part of an effort to formulate a computational framework for identity that can be used in forensic and other contexts. Current work focuses on physical crime scenes, but the focus is expanding to cyberspace.

Objectives: The work reported here seeks to develop ontologies that provide the concepts required to capture the information relevant to identity judgments regarding a crime scene. We consider the crime scene as embedded in a case (in the legal sense) viewed as a constellation of situations. Semantic-web standards are used to express ontologies and encode cases in a way that supports queries and inferences.

Narrative:

Introduction. Building a case to identify the culprit in a crime requires that one consider various sources of evidence and the situations out of which a case is constructed. The critical aspect is capturing the structure, which requires the appropriate trove of concepts. For this, we develop ontologies expressed in the Web Ontology Language (OWL).

Methods. This framework considers identity in terms of situations in the sense of Barwise's situation theory. A situation "supports" information. Situation types (abstract situations) can be tied to each other through "constraints," thus one situation may "carry" information about another as with, for example, the natural constraint by which smoke means fire. There are also conventional constraints governing speech by which an "utterance situation" "carries" information about a "described situation," and there may also be "resource situations" providing context. In the legal cases we consider, an identity judgment or id-situation is made as an utterance situation which carries information about the the described situation, which in this case is the crime scene.

The framework uses semantic-web standards to store and analyze information supported or carried by situations. The concepts instantiated in the information are organized in several ontologies (conceptualizations of domains) expressed in OWL. The situations making up a case are encoded in RDF (Resource Description Framework) using the terms defined in the ontologies. Typically, certain information-bearing objects cross situations, thus stitching them together to form a case. Information handled in this way becomes "smart data" and supports not only extended queries but also inference. A reasoner infers RDF statements ("triples") from other triples and relations in an OWL ontology. OWL ontologies can be supplemented with rules in the Semantic Web Rule Language (SWRL). We use SWRL rules for drawing conclusions about the culprit in a crime scene and for classifying situations and constellations of situations.

Approaches. A typical scenario might have fingerprints and mugshots of the culprit and (to keep things simple) fingerprints and mugshots of the small set of suspects. The situations making up the case include not just the id-situation and the crime scene but also resource situations, for example, where the fingerprints and mugshots on file were taken and the fingerprint from the scene was lifted. The ontologies allow one to capture these situations and how they are structured to form a case.

Our id-situation ontology focuses on situations and constellations of situations (i.e., id-cases) that involve id-judgments as well as any evidence supporting them. This ontology is built on the situation ontology and incorporates other ontologies that relate not only to the structure of a case but also to the specific kind of information, biometric artifacts, chains of custody, and procedures needed for evidence to support id-judgments. This includes the physical biometric ontology that addresses biometric artifacts (which has been our source of examples). These biometric artifacts are images of the suspects' physical features registered for use by forensic professionals. Consequently, for the information captured by physical biometrics, we have an extensive physical features ontology. This ontology relates specific surface features to specific persons, which allows the biometric images to serve as identifiers. Other ontologies used within the id-situation ontology include ontology stubs for personal records and for procedures for determining similarity of biometric images. Our law enforcement ontology recognizes various kinds of law enforcement agencies, law enforcement professionals, and suspects.

Future Work. We are relating our ontologies to so-called upper ontologies, which provide the most general concepts, so that we may more easily align our ontologies with appropriate ontologies that have already been published. We are also elaborating our ontologies and developing new ones as we tackle new example cases. With help from the Criminal Justice Program at North Carolina A&T State University, we are producing a web page where students may scrutinize legal cases.

Attribution. What is presented here is based in large part on work by Marguerite McDaniel of the Computer Science Department of the University of Maryland, College Park, performed as part of Dr. Albert Esterline's research group in the Computer Science Department in the College of Engineering at North Carolina A&T State University. She will be unavailable in January 2018, and this is submitted with her permission.

Handling Situation-Based Evidence in Identity Cases

Kofi Kyei, MS, North Carolina A&T State University

Abstract:

Scope: This work is part of an effort to formulate a computational framework for identity that can be used in forensic and other contexts. Current work focuses on physical crime scenes, but the focus is expanding to cyberspace.

Objectives: The work reported here seeks to capture how evidence in a case involving a crime scene conspires to support various identity judgments. Ontologies are being developed to capture a case as a constellation of situations where information is recorded or applied. Dempster-Shafer theory is being adapted to provide the framework for manipulating and combining information regarded as evidence.

Narrative:

Introduction. The criminal justice system relies heavily on evidence, and Dempster-Shafer theory provides powerful mechanisms for determining what confidence one may have in evidence combined from several sources and possibly modified. There is considerable structure in a legal case that makes available information in which we may have various levels of confidence. We capture this structure using a family of ontologies, and we adapt Dempster-Shafer theory to exploit this structure.

Methods. This framework considers identity in terms of situations in the sense of Barwise's situation theory. A situation "supports" information. Situation types (abstract situations) can be tied to each other through "constraints," thus one situation may "carry" information about another as with, for example, the natural constraint by which smoke means fire. There are also conventional constraints governing speech by which an "utterance situation" "carries" information about a "described situation," and there may also be "resource situations" providing context. In the legal cases we consider, an identity judgment or id-situation is made as an utterance situation which carries information about the the described situation, which in this case is the crime scene.

The framework uses semantic-web standards to store and analyze information supported or carried by situations. The concepts instantiated in the information are organized in several ontologies (conceptualizations of domains) expressed in OWL (Web Ontology Language). The situations making up a case are encoded in RDF (Resource Description Framework) using the terms defined in the ontologies. Typically, certain information-bearing objects cross situations, thus stitching them together to form a case. Information handled in this way becomes "smart data" and supports not only extended queries but also inference.

Dempster-Shafer theory distributes belief ("mass") to elements or sets of elements that are in a "frame of reference." Total mass sums to 1.0, with any unassigned mass going to the entire frame of reference. The "belief" that a given set A of elements covers what is the case is the sum of the masses of those sets that are included in A while the "plausibility" of A is the sum of the masses of the sets overlapping A. For any set A, belief and plausibility are between 0.0 and 1.0, and plausibility is never less than belief. Dempster-Shafer theory has various rules for combining mass functions when there are multiple sources of evidence, and there are various ways to manipulate mass functions and refine frames of discernment.

Approach. A typical scenario might have fingerprints and mugshots of the culprit and (to keep things simple) fingerprints and mugshots of the small set of suspects. The situations making up the case include not just the id-situation and the crime scene but also resource situations, for example, where the fingerprints and mugshots on file were taken and the fingerprint from the scene was lifted. The ontologies allow one to capture these situations and the evidence-relevant constraints among them. These constraints provide a structure for modifying and combining evidence as per Dempster-Shafer theory. The result is a framework that exposes the evidence-critical aspects of an entire case.

From a numerical point of view, there are three possible interpretations of constraints. One is that each situation or set of similar situations is a separate mass function and, therefore, when a constraint is in force, the mass function from the resource situation needs to be combined with the mass function from the id-situation. The second is to consider each resource situation as a refinement of the frame of discernment created in the id-situation. The third would be to consider the resource situation to be modifying the mass function.

Future Work. With help from the Criminal Justice Program at North Carolina A&T State University, we are producing a web page where students may scrutinize how evidence from multiple sources is amplified or diminished and combined in support of an identification.

Attribution. What is presented here is based on work by Emma Sloan of the Computer Science Department of Brown University, performed as part of Dr. Albert Esterline's research group in the Computer Science Department in the College of Engineering at North Carolina A&T State University. Ms. Sloan will be out of the country in January 2018, and this is submitted with her permission.

Jose Almirall

Dr. José R. Almirall is a Professor in the Department of Chemistry and Biochemistry, Director Emeritus of the International Forensic Research Institute at Florida International University (FIU), and Director of the National Science Foundation (NSF)-funded Center for Advanced Research in Forensic Science. He was a practicing forensic scientist at the Miami-Dade Police Department Crime Laboratory for 12 years, where he testified in over 100 criminal cases in state and federal courts prior to his academic appointment at FIU in 1998. Professor Almirall has authored one book and ~135 peer-reviewed scientific publications in the field of analytical and forensic chemistry and presented ~700 papers and workshops in the United States, Europe, Central and South America, Australia, New Zealand, Japan and South Africa. The interests of Professor Almirall's research group include fundamental analytical chemistry and the development of analytical chemistry tools for use in forensic science including materials analyses using laser ablation inductively coupled plasma mass spectrometry. His research group has received three patents from technology developed at FIU and received ~$ 9 million in research funding from federal agencies such as the NSF, U.S. Department of Defense, National Institute of Justice, Technical Support Working Group, and industry sources. Professor Almirall has been a Fellow of the American Academy of Forensic Sciences (AAFS) since 1998. Additionally, he was the founding chairman of the Forensic Science Education Programs Accreditation Commission (FEPAC) of the AAFS, past Chair of the Scientific Working Group for Materials Analysis Glass subgroup, past member of the editorial board of the *Journal of Forensic Sciences*, and Editor-in-Chief of *Forensic Chemistry*, an Elsevier journal. He served on the Scientific Advisory Committee of the Commonwealth of Virginia in 2006–2016, and he has also served as a consultant to the United Nations Office on Drugs and Crime, the Government of Spain, and the U.S. Government. He currently serves as consultant to the International Atomic Energy Agency on the forensic analysis of materials. He was appointed to serve on the Forensic Science Standards Board of the National Institute of Standards and Technology-sponsored Organization of Scientific Area Committees (OSAC) as Chair of the Chemistry and Instrumental Analysis SAC of the OSAC and has served as chair of the Fire Scene Investigation working group of the AAAS. Dr. Almirall is also interested in commercializing technology developed in his laboratory and has started a company (Air Chemistry, Inc.) for this purpose.

Madeline Ausdemore

Ms. Madeline Ausdemore is a PhD student in statistics at South Dakota State University, specializing in interpretation of forensic evidence. Her current research focuses on the statistical interpretation and deconvolution of dust evidence to infer the presence of individuals at a location of interest.

Madeline has had the opportunity to work in various positions as a forensic statistician. She has worked as a visiting statistician at the U.S. Army Criminal Investigation Laboratory to analyze sexual assault data, advise in the development of a fingerprint model, and provide training to a portion of the laboratory's scientists. In addition, she has assisted in training over 100 forensic scientists in statistics through RTI International and has served in the Organization of Scientific Area Committees (OSAC) seized drugs subcommittee as a guest statistician. She currently works as a statistical consultant for Noblis, working on various projects with the FBI and Department of State.

JenaMarie Baldaino

Ms. JenaMarie Baldaino is a Chemist in the Explosives Unit of the FBI Laboratory. She received an MS in Forensic Chemistry Trace Evidence from Virginia Commonwealth University in 2016 where she also worked as a graduate teaching assistant. She began as an Oak Ridge Institute for Science and Education (ORISE) Visiting Scientist with the Counterterrorism Forensic Science Research Unit in the Laboratory in 2015 where she completed her master's thesis research, and she continued postgraduate research in explosives, trace evidence, microscopy, and statistics until 2017. In 2013, Ms. Baldaino graduated from James Madison University with a BS degree in Chemistry and Psychology. While an undergraduate, she completed an internship with Smiths Detection operating and analyzing data for a handheld Fourier transform infrared spectrometer for the military and first responders. She is a student member of the American Chemical Society (ACS) and the American Academy of Forensic Sciences (AAFS) as well as a member of the American Society for Trace Evidence Examiners (ASTEE).

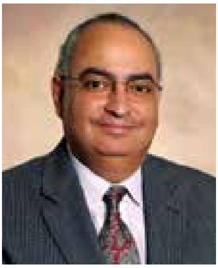
David Baldwin

Dr. David Baldwin is a research and development manager and physical chemist who has worked in forensic science research areas for the last 18 years. His projects have addressed trace chemical analysis, firearm and toolmark reliability studies, methods for footwear and tire tread analysis, and bloodstain pattern characterization and fluid dynamics. He is a member of Organization of Scientific Area Committees' (OSAC's) Physics and Pattern Scientific Area Committee (SAC) and former chair of the Scientific Working Group on Bloodstain Pattern Analysis (SWGSTAIN).

Jodi Lynn Barta

Dr. Jodi Lynn Barta, PhD, is professor and director of the Forensic Science Program (Forensic Science Education Programs Accreditation Commission accredited) at Madonna University. She is a forensic anthropologist with a degree in molecular genetics, specializing in the extraction of DNA from ancient and forensic biological materials. She has over 15 years of experience in extracting and amplifying DNA from low-copy-number and degraded human and animal remains. As an experienced forensic consultant, she has worked in conjunction with police agencies and the coroner's office on the analysis of forensic cases, including aging, sexing, and personal biology to assist in the identification of recovered human remains. She is a National Institute of Justice-funded researcher involved in research to optimize protocols to obtain DNA from biofluids lifted using Zar-Pro™ Fluorescent Blood Lifters (US Patent 8,025,852 B2). Her published research topics include methodological improvements for the extraction of ancient and forensic DNA; recovering bloody impressions from difficult substrates, including from human skin; defining methods to create consistent and reproducible fingerprint impressions deposited in biological fluids on a variety of substrates; ancient DNA analysis of Roman cemetery populations; and ancient DNA analysis of *Mycobacterium tuberculosis* from paleopathological skeletal remains.

Ashraf Bastawros



Dr. Ashraf Bastawros' research focuses on the micro-scale properties and behavior of engineered materials, including single-crystal and polycrystalline materials, thin films and multi-layers, porous solids, and biological materials. His strength is in linking microstructures and continuum theory through fundamental and applied experimental research. He has developed novel experimental techniques to (1) reveal the nature of deformation heterogeneity at the material microstructure length scale and (2) measure the thickness and properties of ultrathin films in the nanometer range. He has redeveloped almost the entire curriculum of mechanics of materials at Iowa State University (ISU). He has nurtured and mentored undergraduate and graduate students and junior faculty in the area of the micromechanics of materials: two assistant professors, one laboratory technicians, three post-doctoral scholars, eight PhD candidates (including two underrepresented racial and/or ethnic minority students [URMs]), 22 MS students, and 50 research experience for undergraduate participants (five URMs). Five undergraduate research assistants have attended graduate school, and one former PhD student has started a tenure-track faculty position at Georgia Tech. As the lead principal investigator (PI) or Co-PI, Dr. Bastawros has managed research grants in excess of $10 million. He has authored and coauthored more than 80 technical publications in journals and conference proceedings with 100 citations annually, on average, and nearly 1,600 total citations. He is also the recipient of a National Science Foundation (NSF) Faculty Early Career Development Program (CAREER) award, an ISU Young Engineering Faculty Research Award, and many other honors and best paper awards.

Adam Benforado

Mr. Adam Benforado is a professor of law at the Drexel University Kline School of Law and the best-selling author of *Unfair: The New Science of Criminal Injustice*. His research is focused on applying insights from psychology and neuroscience to legal issues. A graduate of Yale College and Harvard Law School, he served as a clerk for Judge Judith Rogers on the U.S. Court of Appeals for the District of Columbia Circuit and an attorney at Jenner & Block in Washington, DC. He has published numerous scholarly articles in law reviews and scientific journals, and his popular writing has appeared in *The New York Times, Washington Post, Scientific American, Slate*, and *The Atlantic*.

Alex Biedermann

Dr. Alex Biedermann is Associate Professor at University of Lausanne (UNIL) in Switzerland, Faculty of Law, Criminal Justice and Public Administration ¬– School of Criminal Justice. In 2002, he obtained an MSc in Forensic Science at UNIL and earned a PhD in 2007. From 2002 to 2010, Dr. Biedermann worked as a scientific advisor in the Federal Department of Justice and Police in Berne, Switzerland, in cases investigated by the Office of the Attorney General of Switzerland. He conducted several visiting (postdoctoral) research stays in Italy, the UK, Australia, and the US. Dr. Biedermann's current research concentrates on formal methods of evidential reasoning and decision-making at the intersection between forensic science and the law. His interests are multidisciplinary and involve forensic science, law, and various topics in probability and decision theory—in an international/comparative perspective.

Andrew Bowen

Mr. Andrew Bowen is currently a senior forensic chemist for the US Postal Inspection Service, where he has been employed for 6 years. Prior to this position, he spent 7 years as a forensic scientist for Stoney Forensic, Inc., a private forensic science consulting company. He started his career as a microscopist and instructor for the McCrone Research Institute, a not-for-profit teaching organization, where he was employed for 3 years. He is a member and past President of the American Society of Trace Evidence Examiners, a Member of the American Association of Forensic Sciences, and a Fellow of the American Board of Criminalistics in the area of Comprehensive Criminalistics. He currently serves as the Chair of the Organization of Scientific Area Committees (OSAC) Geological Materials Subcommittee.

Joanna Bunford

Dr. Joanna Bunford is a Senior Forensic Chemist and Head of the Trace Evidence Section in the Chemical Criminalistics Unit (CCU), New South Wales Forensic and Analytical Science Service (NSW FASS), Australia. She has over 16 years of experience, having previously worked as a forensic chemist at the Forensic Science Service UK and at New South Wales Police Force and as a consultant at the Centre for Forensic Science, University of Technology, Sydney. Dr. Bunford specializes in the examination, interpretation, and reporting of cases involving paint, glass, unknowns, and miscellaneous exhibits across a wide range of incident types including homicide, kidnapping, sexual assault, and gang-related crime. She has been involved in research related to the aforementioned evidence types, some of which has been published and presented at international conferences. She provides training and mentoring to staff in CCU and to both Police and Crime Scene officers.

Dr. Bunford is currently undertaking a Certificate of Advanced Studies in Statistics and the Evaluation of Forensic Evidence through the University of Lausanne, Switzerland (completion date January 2018). She is a co-author of "An Introductory Guide to Evaluative Reporting" published online by the National Institute of Forensic Science and The Australia and New Zealand Police Advisory Agency (NIFS/ANZPAA), a series of documents aimed at providing an overview of the subject area for forensic practitioners in Australia and New Zealand. Dr. Bunford is a supervisor to a PhD student looking at the micro-characterisation of household dust by scanning electron microscopy (SEM) and its utilisation in forensic examinations.

JoAnn Buscaglia

Dr. JoAnn Buscaglia is a Research Chemist with the FBI Laboratory in the Counterterrorism and Forensic Science Research Unit. Dr. Buscaglia received her PhD from the City University of New York in 1999 and a BS and MS in Forensic Science (Criminalistics) from John Jay College of Criminal Justice. Prior to joining the FBI Laboratory, she worked for 10 years in academia and as a consultant for both private- and public-sector forensic science, environmental, and industrial hygiene laboratories. Dr. Buscaglia's research is primarily focused in the areas of microscopy, microanalysis, and elemental analysis of trace materials; impression and pattern evidence; and the interpretation of data in a forensic context. She has delivered over 100 technical presentations at professional and scientific conferences and published book chapters and research articles in the peer-reviewed scientific literature. She also serves professionally: she is a member of the National Institute of Science and Technology (NIST) OSAC Forensic Science Standards Board and the Center for Statistics and Applications in Forensic Evidence (CSAFE) Technical Advisory Board. She is also a reviewer for journals and grants and a member of editorial and conference boards, advisory panels, and technical working groups, domestically and internationally. In 2013, she was honored with both the FBI Director's Award for Outstanding Scientific Advancement for her "Black Box" latent print examiner research and the Paul L. Kirk Award, the highest honor given by the American Academy of Forensic Sciences, Criminalistics Section, of which she is a Fellow.

Patrick Buzzini

Dr. Patrick Buzzini is an associate professor in forensic science with the Department of Forensic Science at Sam Houston State University. He graduated with both a BS and MS in forensic science from the oldest forensic science academic institution in the world, the *Institut de Police Scientifique* of the School of Criminal Sciences at the University of Lausanne, Switzerland. He obtained a PhD in forensic science from the same institution in 2007. Dr. Buzzini has more than 15 years of experience as a researcher, instructor, and caseworker in criminalistics, with emphasis in trace evidence. He has developed numerous courses in criminalistics, trace evidence, questioned documents, and physical evidence interpretation at both undergraduate and graduate levels. He has authored and co-authored numerous publications in peer-reviewed scientific journals, with emphasis in trace evidence. He has also delivered multiple oral and poster presentations at forensic conferences nationally and internationally. Dr. Buzzini has organized workshops and training sessions for practitioners in the field (i.e., forensic laboratory personnel), nationally and internationally, as well as continuing education courses for the legal community (defense counselors, prosecuting attorneys, and judges). His research interests include the forensic applications of microscopical and spectroscopic methods (i.e., Raman spectroscopy) to various types of trace evidence and questioned documents as well as addressing problems of physical evidence interpretation.

Olivia Colella

Ms. Olivia Colella is a graduate student at Virginia Commonwealth University (VCU) obtaining her Master's degree in Forensic Science with a concentration in Physical Evidence Analysis. At VCU, Ms. Colella is a graduate teaching assistant in serology and DNA analysis, molecular biology, pattern and impression analysis, and crime scene investigation. During the summer of 2017, she interned with the U.S. Postal Inspection Service, performing research focused on quality control/quality assurance and the new ANSI-ASQ National Accreditation Board requirements. She graduated from Longwood University in May 2016 with a degree in Biology. Ms. Colella is originally from Herndon, VA, and currently resides in Richmond, VA. Following graduation in May 2018, she plans to apply for jobs in the latent fingerprint and impressions field.

Meredith Coon

Mrs. Meredith Coon has conducted a time-lapse study of atypical hyperlinearity (heavy creasing) in her fingerprints since she was 19 years old. Over the course of the 10 years that followed, she has recorded her fingerprints at regular intervals. Mrs. Coon's fingerprints demonstrate that although heavy creasing is often attributed to advanced age, young adults can also display such traits. The creases in her fingerprints are so prevalent and pronounced that some of her fingerprint recordings are unusable for identification. This presentation will incorporate images of Mrs. Coon's fingerprints recorded at various intervals over a 10-year period.

Donald Dahlberg

Professor Donald Dahlberg is Professor Emeritus of Chemistry at Lebanon Valley College (LVC). Dr. Dahlberg earned a BS in Chemistry from the University of Washington and a PhD in Physical Chemistry from Cornell University. After decades of doing research in the area of Physical Organic Chemistry, he became involved in Chemometrics while on sabbatical in 1988 at the Center for Process Analytical Chemistry at the University of Washington. There, he learned chemometrics in the Bruce Kowalski group (co-founder of chemometrics). Upon returning to LVC, he taught chemometrics to undergraduate students for over a decade. Although retired from the classroom, he continues do consulting and supervises undergraduate research in industrial chemometrics. He wrote and teaches this workshop so that those not fluent in matrix algebra can take advantage of the powerful tool of chemometrics.

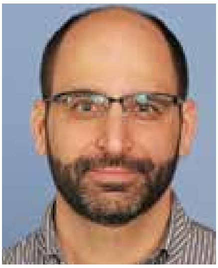
Jeffrey Dake

Mr. Jeffrey Dake is a Chemistry Technical Leader employed by the Defense Forensic Science Center, working in the Office of Quality, Initiatives, and Training. He is a former President of the American Society of Trace Evidence Examiners (ASTEE) and currently serves on the Education Committee for both ASTEE and the Midwestern Association of Forensic Scientists. He performs casework in the areas of lubricants, explosives, ethanol quant, and miscellaneous chemical identification.

John DeHaan

Dr. John DeHaan has over 45 years of experience in fire- and explosion-related forensic science and has been deeply involved with improving fire investigation. After earning his BS (Physics, 1969), he spent 29 years with public forensic laboratories. He has authored six editions of *Kirk's Fire Investigation* since 1982 and co-authored, with Dr. David Icove, *Forensic Fire Scene Reconstruction* since 2004. Since 1999, he has been president of Fire-Ex Forensics, Inc., a private consulting firm that provides services to police and fire agencies, public defenders, private attorneys, and insurers in fire and explosion cases across the US and internationally.

Vincent Desiderio



Mr. Vincent Desiderio possesses over 18 years of relevant forensic experience in both the public and private sectors in various forensic disciplines, including controlled substances analysis, firearms and toolmark examinations, forensic biology, fire debris, and trace evidence analysis. He is currently employed by the United States Postal Inspection Service as their Hazardous Materials Program Specialist. \He holds a Bachelor of Science degree in Human Biology from the State University of New York at Albany and a Master of Science degree in Forensic Science from John Jay College of Criminal Justice. Mr. Desiderio is a founding member and a Past President of the American Society of Trace Evidence Examiners, a Past President of the Northeastern Association of Forensic Scientists, a Past President of the New Jersey Association of Forensic Scientists, and a Fellow of the American Academy of Forensic Sciences. He is the immediate past Chair of the Fire Debris and Explosives Subcommittee within the Organization of Scientific Area Committees for Forensic Science; has served as a member of several working groups, including the Scientific Working Group for Materials Analysis, the Technical Working Group for Fire and Explosions, and ASTM International's E-30 Committee; and has been a Technical Advisor on the White House Subcommittee on Forensic Science Research, Development, Testing, and Evaluation Interagency Working Group.

Peter Diaczuk

Dr. Peter Diaczuk received his BS and MS in Forensic Science from John Jay College of Criminal Justice and his PhD in Criminal Justice, with a concentration in Forensic Science, from the City University of New York Graduate Center. Dr. Diaczuk served as President of the New York Microscopical Society and the Northeastern Association of Forensic Scientists. He is currently an Assistant Professor in the Forensic Science Program at Penn State University in University Park, PA. His research interests include firearms, toolmarks, energetic materials, and documenting these using high-speed photography.

Joseph Donfack

Dr. Joseph Donfack is a Research Biologist in the FBI Laboratory Counterterrorism and Forensic Science Research Unit. In his capacity, he is responsible for proposing, designing, executing, and delivering research in support of various casework units. Currently he is leading a research effort to evaluate protein sequencing as a potential tool to complement microscopic hair comparison.

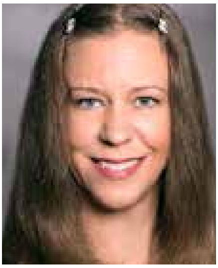
Meaghan Dougher

Ms. Meaghan C. Dougher is a graduate student pursuing her MPS in forensic science at Pennsylvania State University. She received a BS in biology and biological anthropology in 2016 from Boston University.

Mickayla Dustin

Ms. Mickayla Dustin recently graduated from the University of Auckland with a Postgraduate Diploma in Forensic Science in 2014. She obtained her undergraduate degree in Chemistry and Biochemistry from Massey University in 2013. She joined ESR (Institute of Environmental Science and Research) in Auckland, New Zealand, as a Senior Technician on the Physical Evidence team in July 2015. In this role, Ms. Dustin provides technical support to senior scientists, predominately on trace evidence analyses such as hydrocarbon fuel residues, condom lubricants, defense gas sprays, paint, and glass. She also examines and samples exhibits for blood, DNA, and gunshot residue. Additionally, Ms. Dustin helps the clandestine drug laboratory (clan lab) team at ESR by being on-call to attend clan labs with the senior scientist and the clan lab police team. She is also in training to assist with other types of crime scenes that the Service Centre teams at ESR attend.

Heidi Eldridge



Ms. Heidi Eldridge has been a forensic scientist for over 13 years, 12 of which have been as a latent print examiner. Ms. Eldridge is a Certified Latent Print Examiner with the International Association for Identification (IAI) and is a newly elected member of its Board of Directors. She also sits on the *Journal of Forensic Identification* (JFI) Editorial Board and was a member of the Scientific Working Group for Friction Ridge Analysis, Study and Technology (SWGFAST) until its dissolution. She is now a member of the Friction Ridge Subcommittee of the Organization of Scientific Area Committees (OSAC), the Academy Standards Board friction ridge consensus body, and numerous other working groups and advisory boards. Ms. Eldridge has been teaching latent print testimony for more than 5 years and is currently a PhD candidate in the Forensic Science program at the University of Lausanne. She recently left the bench and is now a Research Forensic Scientist with RTI International.

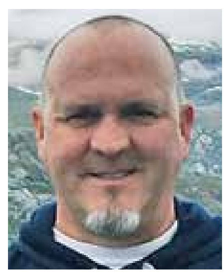
M. Chris Fabricant

As the Joseph Flom Special Counsel and Director of Strategic Ligation, Mr. Chris Fabricant leads the Innocence Project's Strategic Litigation Department, whose attorneys develop and execute national litigation and public policy strategies to address the leading causes of wrongful conviction, including eyewitness misidentification, the misapplication of forensic sciences, and false confessions. Over the course of his 20-year career in criminal justice, Mr. Fabricant has served as a clinical law professor, trial attorney, and appellate counsel. His writing, scholarship, and frequent public speaking focus on the intersection of science, law reform, and social justice.

Patrick Fedick

Mr. Patrick Fedick is a fourth-year doctoral student at Purdue University under the tutelage of Dr. R. Graham Cooks. Mr. Fedick is a PhD candidate in the analytical division of the chemistry department and is expected to graduate in May of 2019. His working thesis title is "Ambient Ionization and Portable Mass Spectrometry: Advances in Supporting the Warfighter, Monitoring of Clandestine Activities and Chemical Education." Mr. Fedick focuses primarily on ambient ionization (ionization in the open air of samples in their native state, without using sample preparation or separation) and portable mass spectrometry for *in situ* analysis. As a Department of Defense SMART Scholar, much of his interests are in in forensic and warfighter applications of portable mass spectrometry. Upon graduation in May of 2019, he is committed to work at the Naval Air Weapons Station at China Lake, California. There, he will work on support and development of portable mass spectrometers for pyrotechnics, explosives, and other ordnances in the laboratory setting and the field environment. Mr. Fedick has interned at the FBI through the Honors Internship Program, the Customs Border Protection through the Department of Homeland Security Science Technology Engineering and Mathematics internship program, and most recently the Department of Defense Naval Surface Warfare Center Crane through the Naval Research Enterprise Internship Program. Outside of research, Mr. Fedick is heavily involved in Purdue's Graduate Student Government and the chemistry departments' Graduate Student Advisory Board.

Michael Frost



Mr. Michael Frost works for the fourth most populated county in the United States of America and responds to crime scenes to provide technical assistance in the collection, preservation, and examination of evidence. He operates photographic equipment to obtain fingerprints, palm prints, and footprints, and document crime scenes, including from airplanes, helicopters, boats, and other types of motorized equipment. Mr. Frost processes evidence for fingerprints using powders, chemical techniques, and optical (alternate light source) techniques. He also conducts visual comparisons of inked and latent fingerprints and tire, shoe, and toolmark impressions and works under highly emotional conditions that are averse to sight, smell, and touch, dealing with dead bodies. He enters latent prints and 10 prints into the Arizona Automated Fingerprint Identification System (AZAFIS). He testifies in courtroom environments, trains Maricopa County Sheriff's Office (MCSO) personnel in forensic disciplines, facilitates presentations to the public about the Crime Lab, performs all duties of the Crime Lab Analyst position, conducts interviews and assesses the selection process for new hires, and trains and assesses new employees in the job duties of Crime Lab Analyst. Mr. Frost verifies latent print comparisons for the Crime Lab Analyst personnel, attends advanced meetings as a representative of the MCSO Crime Lab specific to the forensic disciplines of the job, and is certified as a RapidHIT operator able to enter evidence samples into an automated instrument, resulting in DNA in 2 hours.

Cami Fuglsby

Ms. Cami Fuglsby is in her first year of the Computational Science and Statistics PhD program in the Department of Mathematics and Statistics at South Dakota State University. Recently a graduate of the Master's program in the same department, her thesis focused on the sufficiency of an automated handwriting verification system using various comparison methodologies. Ms. Fuglsby had the opportunity to present on her research at the Joint Statistical Meetings and the International Conference on Forensic Inference and Statistics; at the latter, she was a recipient of a Stephen E. Fienberg Center for Statistics and Applications in Forensic Evidence (CSAFE) Young Investigator Travel Award. Ms. Fuglsby has supported researchers and developments within the questioned document community and is collaborating with researchers at the FBI over analysis of trace evidence.

Valerie Fulton

Ms. Valerie Fulton holds a BA in Studio Art from the University of Central Florida and an MA in Criminal Justice from Keiser University. She began her career in law enforcement in 2007 at the Sarasota County Sheriff's Office in the Quartermaster department. In 2010, when a position for a Ten Print Technician opened in the Automated Fingerprint Identification System (AFIS) Unit, she knew this was the career path for her. Without hesitation, she began to gather as much information about fingerprint identification as she could, even adapting a majority of her Masters degree papers to the topic of fingerprints in some fashion. In 2013, she accepted a promotion to Latent Print Examiner where her thirst for knowledge and growth only grew stronger. This ultimately lead to Ms. Fulton taking a position with the Hillsborough County Sheriff's Office as a Forensic Print Analyst in 2015. She is an active member with the International Association for Identification (IAI) and the Florida Division of the IAI. Throughout her career, she has had the pleasure of presenting her discipline to various groups, such as the Citizen Law Enforcement Academy, neighborhood watch groups, high school forensic clubs, Corrections Deputy Academy, deputy roll calls, and detective information sessions.

Donald Gantz

Dr. Donald Gantz is the Chair of the Department of Applied Information Technology in the Volgenau School of Information Technology and Engineering of George Mason University. In this position, he directs the Bachelor of Science in Information Technology Degree in which more than 1100 students are enrolled and the MS in Applied Information Technology with over 130 students. He was Interim Associate Dean for Undergraduate Studies in the School of Information Technology and Engineering during the Spring 2003 and Fall 2004 semesters. He is a Full Professor of Statistics. He has taught Applied Statistics, Probability Theory, Stochastic Systems, Computer Simulation and Control in graduate and undergraduate courses. He has done research in Forensics, Biometrics, Epidemiology, Mathematical Economics, Applied Statistics, Flight Test Analysis, Computer Performance Engineering and Capacity Planning, Computer Simulation, and Management Decision Systems.

Dr. Gantz directs the Document Forensics Laboratory of the Intelligence and Security Research Center (ISRC) which has partnered with Gannon Technologies Group to develop cutting edge methodologies for the quantification and analysis of handwriting and for automate finger print matching. They are applying these methodologies to multi-language document exploitation and biometric identification. The Lab has government funding and is staffed by statistics professors, research professors, postdoctoral research fellows and graduate research assistants.

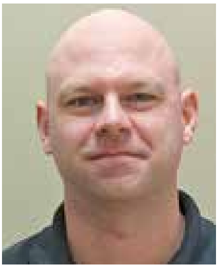
Michael Gorn

Mr. Michael Gorn is a footwear/tire examiner in the FBI Forensic Laboratory. Previously, he worked for the Sarasota (Florida) County Sheriff's Office, the Boston Police Department Crime Laboratory, and LGC Forensics in England. Mr. Gorn holds an MS in Forensic Science with a concentration in Criminalistics and a BS in Biology. He is certified in crime scene investigation through the International Association for Identification (IAI) and is a Fellow of the American Board of Criminalistics. He is also a past member of the Scientific Working Group for Shoeprint/Tire Tread Evidence, a current member of the Organization of Scientific Area Committees Subcommittee on Footwear/Tire Tread Evidence, and National Institute of Justice Technical Working Group on General Forensics. He is also a past chair of the IAI Footwear/Tire Track Examination Subcommittee. Outside of the United States, he has lectured on crime scene investigation and impression evidence in England, Finland, Estonia, Aruba, South Korea, and China.

Carey Hall

Ms. Carey Hall is a forensic scientist working for the Minnesota Bureau of Criminal Apprehension. She also does consulting work for Elite Forensic Services. She was previously employed by the Phoenix Police Department and now has a unique perspective on the variety of different office policies, workflow, and technology within various agencies. Ms. Hall has worked in latent prints for 9 years and is also an International Association for Identification (IAI) Certified Latent Print Examiner. She is a member of the Friction Ridge Organization for Scientific Area Committees (OSAC) Subcommittee and the co-chair of the city of Maplewood Police Advisory Commission. She obtained her Master's degree in Legal Studies from Sandra Day O'Connor College of Law at Arizona State University, where she worked to better understand the criticisms of forensic science and how it might be improved. Standard-setting and policy creation are Ms. Hall's primary interests, specifically, how scientific and empirical research can lead to adopting better policies.

Christopher Hamburg



Mr. Chris Hamburg is a Senior Forensic Scientist for the Oregon State Police Forensic Services Division. Mr. Hamburg graduated from the Willamette University in 1996 with a BS degree in Chemistry. His forensic career started with the Washington State Patrol (WSP) Tacoma Crime Laboratory in 2003 where he was assigned to the Microanalysis section. In this role, he performed examinations of evidence related to hairs, fibers, impressions, glass, and general criminalistics and responded to major crime scenes. In October 2008, Mr. Hamburg left WSP, moved to his home state of Oregon, and joined the Trace Evidence section of the Portland Metro laboratory.

Mr. Hamburg is a member of the American Academy of Forensic Sciences, International Association for Identification (IAI), Northwest Association of Forensic Scientists (NWAFS), and American Society of Trace Evidence Examiners. He is currently a member of the Organization of Scientific Area Committees (OSAC) Footwear and Tire Subcommittee and is certified in General Criminalistics by the American Board of Criminalistics.

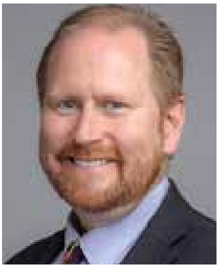
Jessie Hendricks

Ms. Jessie Hendricks is a second-year Master's student in the Department of Mathematics and Statistics at South Dakota State University. Currently, she is a Research Assistant working on the interpretation of forensic evidence under a grant from the National Institute of Justice. She plans to complete her degree in the Spring 2018 semester and continue her education in the PhD program at South Dakota State in the fall of 2018.

Martin Herman

Dr. Martin Herman is Senior Advisor for Forensics and IT in the Information Technology Laboratory of the National Institute of Standards and Technology (NIST). He leads NIST research in Footwear Forensics and is Co-Chair of the NIST Cloud Computing Forensic Science Public Working Group. Previously, he was Chief of the Information Access Division at NIST, where he was responsible for the Division's program in research, measurements, testing, and standards in information access technologies, including biometrics, speech processing and human language technologies, multimedia information access, information retrieval, image and video processing technologies, visualization and usability testing, human-computer interfaces, and smart spaces. Before that, he held the position of Group Leader of the Perception Systems Group at NIST, where he performed research in robotics, robot vision, and automated manufacturing. He has also held a faculty appointment at Carnegie Mellon University, where he performed research in computer vision. He received a PhD in Computer Science from the University of Maryland.

R. Austin Hicklin



Dr. R. Austin Hicklin is a Senior Fellow at Noblis, a non-profit research company. He has been involved in a broad range of biometric/forensic projects for various government agencies since 1995, including biometric and forensic standards, evaluations of latent print examiners, Automated Fingerprint Identification System (AFIS) engineering and interoperability, video analytics, fingerprint quality metrics, and evaluations of biometric identification systems. He designed and developed the Universal Latent Workstation for the FBI. He serves on the Organization of Scientific Area Committees (OSAC) Scientific Area Committee for Physics and Pattern Evidence. He has a BA from the University of Virginia, an MS from Virginia Tech, and a PhD from the University of Lausanne.

Jessica Hovingh

Ms. Jessica Hovingh is a 5th year student at The Pennsylvania State University pursuing a BS in Forensic Science. She enjoys assisting with two forensic science laboratory classes and works as a fingerprint technician for the campus police.

Ted Hunt

Mr. Ted R. Hunt is Senior Advisor to the Attorney General on Forensic Science at the Department of Justice. Prior to his appointment, he was Chief Trial Attorney at the Jackson County Prosecutor's Office in Kansas City, Missouri, where he served for 25 years as a state-level prosecutor and managed a large staff of trial attorneys. During that time, Mr. Hunt prosecuted more than 100 felony jury trials, the vast majority of which involved the presentation of forensic evidence.

Mr. Hunt is a former member of the National Commission on Forensic Science, the American Society of Crime Laboratory Directors/Laboratory Accreditation Board's Board of Directors, the Missouri Crime Lab Review Commission, the Organization of Scientific Area Committees Legal Resource Committee, and the National District Attorneys Association DNA Advisory Group. He also served as a member of the International Association of Chiefs of Police Forensic Science Committee and was an Invited Guest at the Scientific Working Group on DNA Analysis Methods.

Vici Inlow

Ms. Vici Inlow has been with the US Secret Service, Forensic Services Division, since June 1996. She began her law enforcement career in June 1975 and has worked with the Anaheim Police Department, San Mateo County Sheriff's Department, and Orange County Sheriff-Coroner Department in Santa Ana, CA. She attended Cypress College, California State University Fullerton, and the University of California at Irvine. Ms. Inlow is also a past president of the parent body of the International Association for Identification. She has taught processing methods for latent print detection nationally and internationally.

Keith Inman

Mr. Keith Inman holds a BS and MCrim, both from the University of California at Berkeley. He has been a Fellow of the American Board of Criminalistics. In his professional career, he has been employed as a criminalist by the Orange County Sheriff's Department, the Los Angeles County Sheriff's Department, the Los Angeles County Chief Medical Examiner-Coroner, the Oakland Police Department, and the California Department of Justice DNA Laboratory. He was also in private practice at Forensic Science Services of CA, Inc. and Forensic Analytical Sciences, Inc. Both of these companies were private crime laboratories that undertook prosecution and defense work. He is currently an Assistant Professor in the Criminal Justice Administration department at California State University, East Bay. He has also taught a variety of general forensic science and forensic DNA courses for the University of California at Berkeley extension and on-line. He co-authored *An Introduction to DNA Forensic Analysis and Principles and Practice of Criminalistics: The Profession of Forensic Science*. He is frequently invited to speak at legal symposia and forensic conferences and is active as an independent consultant and expert witness in forensic DNA.

Hari Iyer

Dr. Hari Iyer earned a PhD in mathematics from the University of Notre Dame and a PhD in statistics from Colorado State University. He was a professor of statistics at Colorado State University for about 30 years. He joined NIST's Statistical Engineering Division in 2014. His areas of interest include model uncertainty in measurements and statistical forensics. He is a fellow of the American Statistical Association.

Jeff Jagmin

Mr. Jeff Jagmin is a Supervising Forensic Scientist for the WSP Crime Laboratory in Seattle. Jeff graduated from the University of Washington in 1995 with a Bachelor of Science in Chemistry.

His forensic career started in 1996 with the WSP Tacoma Crime Laboratory where he was assigned to the chemistry section, performing examinations of controlled substances and suspected clandestine laboratory samples. He joined the WSP Statewide Incident Response Team in 1997. In this role, he responded to suspected clandestine laboratory scenes, and his duties included scene evaluation, safety, and collection. In 2002, Mr. Jagmin was assigned to the microanalysis section, where he was responsible for the examination of evidence in suspected explosives, fibers, impressions, hair screening, general criminalistics, and microscopy. In January 2008, he transferred to the WSP Seattle Laboratory when he was promoted to Supervisor of the Microanalysis Section.

Mr. Jagmin is a member of the American Academy of Forensic Sciences, IAI, NWAFS, and American Society of Trace Evidence Examiners. He is currently a member of the OSAC Footwear and Tire Subcommittee and was also a member of the Technical Working Group for Fire and Explosives (TWGFEX), where he was a co-chair of the explosives database committee. He has been involved with the NWAFS as a Special Research Mentor for three projects (two of which involve footwear) and two technical working group meetings (one for explosives and one for footwear).

Tiffany Johnson

Ms. Tiffany Johnson, from St. Ann, Jamaica, is a senior Forensic Science major at Albany State University. In the summer of 2017, Ms. Johnson completed an internship with the Atlanta Police Department-Special Victims Unit. She currently works as a Student Research Assistant for the National Institute of Justice-funded research "Surveying the Total Microbiome as Trace Evidence for Forensic Identification." This research focuses on identifying human-touched objects suitable for microbiome-based forensic application and reverse fingerprint lifting.

Brooke Kammrath

Professor Brooke W. Kammrath is an Assistant Professor of Forensic Science at the University of New Haven where she teaches undergraduate and graduate courses in Criminalistics, Forensic Microscopy, and Introduction to Forensic Science. In addition, she works as a forensic science consultant. She received her PhD in Criminal Justice with a specialization in Forensic Science from the Graduate Center of the City University of New York in 2013. She has a BA in Chemistry from Northwestern University (2000), an MA in Chemistry Education from New York University (2003), an MS in Forensic Science and MA in Criminal Justice from John Jay College (2007 & 2010), and an MPhil in Criminal Justice from the Graduate Center (2011). Dr. Kammrath's research interests include uniting microscopy with spectroscopy; the identification and characterization of microscopic samples of forensic interest; the statistical analysis of trace, pattern, and impression evidence; and investigations into the significance of physical evidence.

Andrew Kimble

Mr. Andrew Kimble III is a 20-year-old senior forensic science major from Long Island, New York. He currently attends Albany State University in Albany, Georgia, and his future endeavors will involve working with the FBI in their Crime Scene Department.

Sandra Koch

Ms. Sandra Koch is a PhD candidate in the Department of Anthropology with a specialization in microscopical analysis of hair at Pennsylvania State University. She is interested in the variation in hair microstructure and seeks to better understand differences in hair form among diverse human populations. In her research, she employs transmission electron microscopy and light microscopy to study variation within an individual, within a group, and between groups to determine the relationship between hair traits and ancestry. Having worked in the FBI Laboratory Trace Evidence Unit from 1997 until 2013, Ms. Koch combines her expertise in microscopy and trace evidence analyses with her passion for improving the microscopical analysis of hair to advance the understanding of this common but complex structure. She continues to be actively involved in the forensic community as a Fellow of the American Academy of Forensic Sciences and a founding member of the American Society of Trace Evidence Examiners; she maintains her certification by the American Board of Criminalistics in the hair and fiber discipline. As a past member of the Scientific Working Group for Materials Analysis and a current member of the Organization of Scientific Area Committees in the Materials (trace) subgroup, Ms. Koch strives to educate the scientific community about forensic hair analysis. She continues to be involved in the training of new hair examiners by teaching short courses and workshops on the forensic examination of hairs, fibers, feathers, and fabric damage. Today, Ms. Koch will be presenting portions of her ongoing research on the structural basis for visible patterns of variation in hair morphology and microstructure.

Kaitlin Kruglak

Ms. Kaitlin Kruglak is a second-year graduate student at the University of New Haven in West Haven, Connecticut. She received her BS in 2015 from The College of Saint Rose in Albany, New York, where she majored in forensic science. At both her undergraduate and graduate schools, Kaitlin has worked as a teaching assistant. At the University of New Haven, Ms. Kruglak is a teaching assistant within the forensics department. Her goal is to be a forensic scientist.

Mike Kusluski

Mr. Mike Kusluski is an Assistant Professor in the Forensic Science Program at Madonna University. He received his BS in Applied Physics from Wayne State University and his MFS degree from George Washington University. His career with the Michigan State Police, Detroit Police Department, and Ohio Bureau of Criminal Identification and Investigation forensic laboratories includes experience in Firearms & Tool Marks Examination, Bloodstain Pattern Analysis, Controlled Substances Analysis, and Crime Scene Investigation. He was also an adjunct faculty member at Wayne State University and taught forensic science courses for 16 years. He is a member of the American Academy of Forensic Sciences, the International Association for Identification, and the International Association of Bloodstain Pattern Analysts and is also a Fellow of the American Board of Criminalistics. Before transitioning into forensic science, Mr. Kusluski worked as a scientist, engineer, and laboratory supervisor in the private sector. He can be contacted at mkusluski@madonna.edu.

Kofi Kyei

Mr. Kofi Kyei was born and raised in Ghana. In February 2011, he moved to the United States for education and training; he has since become a citizen. He went to Sunyani Technical University for a Higher National Diploma in Electrical & Electronics Engineering (2005) and later obtained a Bachelor's degree in Information Technology Education from the University of Education Winneba (2010), both in Ghana. In 2015, he was awarded a Master's degree in Computer Science by Fitchburg State University in Fitchburg, Massachusetts. Mr. Kyei has worked in several fields including teaching, computer systems administration, and software engineering. Currently, he is pursuing a doctorate in computer science under the supervision of Dr. Albert C. Esterline at North Carolina A&T State University in Greensboro, North Carolina. His research focuses on reasoning about crime scene evidence.

Glenn Langenburg

Dr. Glenn Langenburg is a forensic consultant for Elite Forensic Services, LLC. At the Minnesota Bureau of Criminal Apprehension, he was a certified latent print examiner for 15 years. Glenn earned a BS in Forensic Science from Michigan State University in 1993 and an MS in Analytical Chemistry in 1999 from the University of Minnesota. He received his PhD in Forensic Science from the University of Lausanne, Switzerland. His thesis research focused on the decision-making aspects of fingerprint examiners utilizing the Analysis, Comparison, Evaluation, and Verification (ACE-V) process.

Barry Lavine

Dr. Barry K. Lavine is a Professor of Chemistry at Oklahoma State University in Stillwater, OK, where he both teaches and performs research in analytical and forensic chemistry. His research interests encompass many aspects of vibrational spectroscopy and chemometrics. He graduated with a PhD in Analytical Chemistry from Pennsylvania State University in 1986. Dr. Lavine has published more than 100 research papers, 20 book chapters, and 16 review articles and has edited 3 books. He is on the editorial board of several journals including the *Journal of Chemometrics* and the *Microchemical Journal*. He is also the Assistant Editor of Chemometrics for *Analytical Letters*. In 2015, Dr. Lavine was awarded the Kowalski Prize by the *Journal of Chemometrics* and in 2017 was the winner of the Chemometrics Award sponsored by the Eastern Analytical Symposium. He is a Fellow of the Society of Applied Spectroscopy (2016).

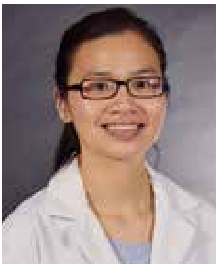
Zachary Lawton

Mr. Zachary Lawton is an Analytical Chemist and Application Scientist at PerkinElmer Inc. He earned his BS (Chemistry) from Illinois State University in 2014 and his MSc (Analytical Chemistry) from Illinois State University in 2016. As a graduate student at Illinois State University, he worked alongside law enforcement agencies, public universities, and RTI International on National Institute of Justice grants to develop portable mass spectrometers for screening forensic evidence. Mr. Lawton is the subject matter expert for PerkinElmer on portable gas chromatography/mass spectrometry (GC/MS) instrumentation and has collaborated with researchers across the globe to expand the capabilities of portable GC/MS and showcase its applications in the public safety, forensics, and environmental research areas.

Mary Lou Leitner

Ms. Mary Lou Leitner is a Fingerprint Specialist with the United States Secret Service, Forensic Services Division in Washington, DC. She began her forensics career in 1990 with the FBI Laboratory, Trace Evidence Unit, but had a calling to the latent print world. Ms. Leitner has been a fingerprint examiner for over 15 years and received her certification as a Latent Print Examiner in 2009. She holds a BS in Biology from California University of Pennsylvania. Her current duties include case work, assisting with National Center for Missing & Exploited Children (NCMEC) outreach programs, hazardous laboratory waste collection and management, and oversight of the hazardous waste contract.

Sun Yi Li



Ms. Sun Yi Li is a full-time PhD student in the Forensic Science Program at Sam Houston State University and has completed the first-year coursework with strong academic performance and a grade point average of 4.0. Specifically, Sun Yi has performed laboratory work associated with instrumental analysis and data interpretation using gas chromatography-mass spectrometry in forensic instrumental analysis and forensic toxicology classes. In addition to the knowledge obtained in the academic setting, Sun Yi interned at the Trace Evidence Division at the Harris County Institute of Forensic Sciences in Houston, TX. During this internship, Sun Yi assisted in the internal method validation of the new phase-mapping analysis for automobile paint systems using scanning electron microscopy/energy-dispersive X-ray spectroscopy. Classes specializing in advanced instrumental analysis and research methods will be taken during the fall semester of 2017. Sun Yi's research interest focuses on the application of advanced materials in chemical analyses of trace evidence in both the laboratory and the field.

Ryan Lilien

Dr. Ryan Lilien's research expertise focuses on the use of advanced scientific computing and statistical models to solve interdisciplinary research problems. Dr. Lilien earned an MD/PhD from Dartmouth Medical School and Dartmouth's Department of Computer Science. He was faculty at the University of Toronto cross-appointed between Computer Science and the Faculty of Medicine. He has received research funding from the Gates Foundation, National Institute of Justice (NIJ), National Institute of Standards and Technology (NIST), and Canada's National Sciences and Engineering Research Council. He is now located in Chicago and serves as Cadre Research's head of research and development while maintaining an adjunct appointment at the University of Toronto. Dr. Lilien leads the development of the TopMatch-GS 3D system (a 3D imaging and analysis system for firearm forensics and virtual microscopy). He has presented his group's steady progress on developing and validating the system at recent national and regional Association of Firearm and Toolmark Examiners (AFTE) meetings. He is also currently a member of NIST's Organization of Scientific Area Committees (OSAC) Subcommittee on Firearms & Toolmarks.

Steven Lund

Dr. Steven Lund majored in physics and mathematics at St. Olaf College and earned a PhD in statistics from Iowa State University. In 2012, he joined the Statistical Engineering Division of the National Institute of Standards and Technology (NIST), where much of his work has involved model uncertainty and statistical forensics.

Daniel Mabel

Dr. Daniel E. Mabel is a forensic scientist in the Trace Evidence Department at the Cuyahoga County Medical Examiner's Office in Cleveland, Ohio. He earned a Bachelor of Science in Chemistry from the University of Florida in 2008 and a Master of Science in Forensic Science from Virginia Commonwealth University in 2010. Mr. Mabel began working at the Cuyahoga County Medical Examiner's Office in 2011. He collects, processes, and examines items of trace evidence from the bodies of victims of violent death, from autopsies, and from outside law enforcement agencies. Mr. Mabel regularly performs analysis in the trace evidence subdisciplines of fiber, paint, tape, hair, gunshot primer residue, bloodstain pattern analysis, impressions, muzzle to target distance determination, physical/fracture matching, serology, and general chemical unknowns. He is a member of the American Society of Trace Evidence Examiners (ASTEE), the American Academy of Forensic Sciences, the Midwestern Association of Forensic Scientists, the International Association for Identification, the International Association of Bloodstain Pattern Analysts, and the American Chemical Society. He currently serves as Director of ASTEE as well as Chair of its Communications Committee.

Ranjan Maitra

Professor Ranjan Maitra has over 20 years of experience in developing and applying statistical methodology for the analysis of massive datasets with special reference to imaging and especially in the context of neuroimaging. He has collaborated extensively with radiologists and computer engineers in academia, government, and engineering. His main contributions to this proposed research activity will be in the development of statistical methods for the processing and analysis of images. He has nurtured and mentored graduate (six PhD candidates including three current students [two female and one Hispanic-American] and eight MS students including three current students (three female and one Hispanic-American) and undergraduate (three Freshman Honors students [two female] and two Alliance/Alliance for Graduate Education and the Professoriate fellowship students [two female and one African-American) students. Three of his students have tenured or tenure-track positions in United States academic institutions, one is a lecturer, a few have positions in government research laboratories and agencies, and others have positions in industry. He has been involved in research grants totaling at least $4 million to his home institutions He has authored and coauthored more than 30 technical publications in peer-reviewed conference proceedings. He is a recipient of the National Science Foundation's (NSF's) Faculty Early Career Development Program (CAREER) award.

Claudia Martinez Lopez

Ms. Claudia Martinez Lopez is a PhD candidate working in Dr. Jose Almirall's research group at Florida International University (FIU). She completed her Bachelor's and Master's degrees at FIU. Her work consists of analyzing adhesive tapes using laser-based methods for forensic purposes.

Michelle Marx

Ms. Michelle Marx is a recent graduate from Stevenson University with an MSc in Forensic Sciences (Chemistry and Crime Scene Investigation) and a BA in Chemistry from Goucher College. She previously worked for the US Army Research Laboratory doing research on lithium-ion batteries.

Richard Marx

Special Agent (SA) Richard Marx entered FBI New Agent training in March 1997.

SA Marx was a first office Special Agent in the Philadelphia Division where he was assigned to a drug squad and eventually was permanently assigned to the bank robbery and fugitive squad in 1998. He worked numerous cases involving violent crime and major offenders while assigned to the squad.

On August 9, 1998, SA Marx was part of a multi-division FBI Evidence Response Team that was deployed to Nairobi, Kenya to sift through the debris of Usama Bin Laden's bombing attack on the U.S. Embassy. In December 1999, SA Marx was deployed with the Philadelphia Division's Evidence Response Team to work morgue operations at the crash of Egypt Air Flight 990 off the coast of Rhode Island.

On September 12, 2001, SA Marx arrived at Fresh Kills Landfill with the Philadelphia Division's Evidence Response Team to assist in the recovery operations during the 9/11 attacks in New York City. SA Marx was designated as special agent in charge of the forensic recovery effort that sifted the 1.8 million tons of World Trade Center debris down to a quarter inch in size. He was in charge of the site from September 12, 2001 to August 9, 2002. The 11-month operation recovered over 4,500 human remains and over 75,000 personal effects and processed over 1,300 vehicles from Ground Zero. For his efforts, SA Marx was a finalist for the 2003 Director's Award and the Federal Employee of 2003.

In July 2004, SA Marx was deployed as an Evidence Response Team member to Baghdad, Iraq to liaise with the Iraqi Survey Group and Joint Inter-Agency Terrorism Task Force. In March 2005, SA Marx was deployed to Phuket, Thailand by the FBI Laboratory Division as the Scientific Chairperson for the Thailand Tsunami Victim Identification Group tasked with retrieving DNA samples from the 3,700 victims of the deadly tsunami that destroyed Thailand's coast. SA Marx was promoted to Supervisory Special Agent (SSA) in the FBI Laboratory's Evidence Response Team Unit at the FBI Laboratory, Quantico, VA in April 2006. In August 2009–September 2009, SSA Marx developed and coordinated the deployment of FBI personnel, which culminated in the solving of 28 unsolved bombing cases against Iraqi civilians and coalition forces. He was nominated for the 2010 Director's Award for Special Achievement. SSA Marx has led FBI teams at the 2012 Aurora Century Cinema 16 mass shooting in Colorado, the 2013 Algerian US hostage killings, the 2013 Boston Marathon Bombing, the 2013 Asiana Flight 214 crash in San Francisco, and the 2013 Navy Yard shooting in Washington, DC.

He earned a Master of Science in Forensic Anthropology from the Boston University School of Medicine in 2013.

SSA Marx deployed from July to August 2014 to Ukraine and the Netherlands to assist in the recovery of human remains and Disaster Victim Identification efforts for the crash of Malaysian Airlines MH17. On June 12–21, 2016, SSA Marx led the FBI Laboratory Shooting Reconstruction Team (LSRT) that processed the Orlando Pulse Night Club Shooting Scene in Florida. SSA Marx was again deployed to co-lead the LSRT in July 2016 to process the large-scale shooting scene for the Dallas Police Shooting in Texas. SSA Marx was the Team Leader for the FBI LSRT that collected evidence and documented the scene at the Las Vegas Mandalay Bay/Route 91 Mass Shooting in October 2017.

Derrick McClarin

Mr. Derrick McClarin, MSFS, is a Physical Scientist / Forensic Examiner in the Firearms and Toolmarks Unit of the FBI Laboratory. Before being recruited by the FBI in 2014, he worked for the Alabama Department of Forensic Sciences (ADFS) as a case working examiner, an adjunct professor, and a researcher. After beginning his career in the field of toxicology, his aptitude for the development and application of new technologies led him to work in the firearms discipline.

Since joining the field of firearms and toolmark identification in 2009, Mr. McClarin's research has focused on the burgeoning field of 3D technology and its utilization in addressing the criticisms of the 2009 National Academy of Sciences report. Specifically, he has aimed to address the report's call for greater research and objectivity.

The results of Mr. McClarin's research have been published in the Association of Firearms and Toolmark (AFTE) Journal and has been presented at various conferences such as AFTE (Vegas 2010, Chicago 2011, and Buffalo 2012) and the Impression Pattern Impression Symposium (Clearwater 2012).

Linton Mohammed

Dr. Linton Mohammed has been in the field of forensic document examination for more than 30 years. His PhD thesis was entitled, "Elucidating spatial and dynamic features to discriminate between signature disguise and signature forgery behavior."

He has testified as an expert witness more than 100 times in the United States, England, and the Caribbean. He is the co-author of *The Neuroscience of Handwriting: Applications for Forensic Document Examination* and has published several papers in peer-reviewed journals.

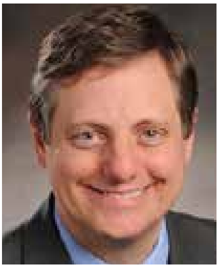
Dr. Mohammed has conducted or co-presented workshops on signature and document examination in Australia, Brazil, Canada, China, Latvia, Poland, Saudi Arabia, Turkey, and the United States. In 2012, he was given the New Horizon Award in Recognition of Exceptional Contributions in Scientific Research for the Advancement of Forensic Document Examination by the American Board of Forensic Document Examiners, Inc.

Dr. Mohammed is certified by the American Board of Forensic Document Examiners, Inc and holds a Diploma in Document Examination from the Chartered Society of Forensic Sciences.

He is a member and Past-President of the American Society of Questioned Document Examiners, Inc. and is currently serving as the Chair of the Questioned Documents Section of the American Academy of Forensic Sciences. He serves on the Editorial Review Boards of the *Journal of Forensic Sciences* and *Journal of the American Society of Questioned Documents* and is a guest reviewer for several other journals. He is an appointed member of the Expert Working Group in Human Factors in Forensic Document Examination sponsored by the National Institute of Standards and Technology (NIST). He also served for two years as an appointed member of the Physics/Pattern Evidence Scientific Area Committee of the Organization of Scientific Area Committees (OSAC) sponsored by NIST.

Dr. Mohammed is in private practice in Burlingame, CA (San Francisco Bay Area).

John Morgan



Dr. John Morgan is internationally recognized for his work in forensics, body armor, special operations technology, and predictive policing. He directs and develops forensic science research, training, and quality assurance programs, including the National Institute of Justice Forensic Technology Center of Excellence and the Substance Abuse and Mental Health Services Administration's National Laboratory Certification Program.

Currently, Dr. Morgan is responsible for management, business development, and strategic planning to maintain and grow programs in forensic science and related areas of education, policing, homeland security, defense, and international capacity building.

Previously, Dr. Morgan was a member of the Maryland House of Delegates and Congressional Science Fellow of the American Physical Society. He has served in the U.S. Department of Justice and the U.S. Department of Defense as a senior executive, managing programs that encompass scientific research, public safety, military technology, special operations, information systems, and standards. He received the 2007 Service to America Medal for his work to improve the nation's capacity to conduct DNA analysis.

Cedric Neumann

Dr. Cedric Neumann was awarded a PhD in Forensic Science from the University of Lausanne, Switzerland, for his work on the multivariate analysis and interpretation of ink evidence. This work was implemented by the Department of Homeland Security at the United States Secret Service and inaugurated in 2009. From 2004 to 2010, Dr. Neumann worked at the Forensic Science Service (FSS) in the United Kingdom. As head of the R&D Statistics and Interpretation Research Group, he contributed to the development of the first validated fingerprint statistical model.

He served Pennsylvania State University and its community as an Assistant Professor in Statistics, Forensic Science Program for 3 years and is now an Associate Professor of Statistics at South Dakota State University. Dr. Neumann's main area of research focuses on the statistical interpretation of forensic evidence—fingerprint, shoeprint, and traces. He served on the Scientific Working Group for Friction Ridge Analysis, Study and Technology (SWGFAST), was a member of the Board of Directors of the International Association for Identification (IAI), and is a member of the Organization of Scientific Area Committees (OSAC) Material (Traces) sub-committee.

William Nick

Mr. William Nick was born on May 23, 1990 in Morgantown, WV. He received his BS in Computer Science from North Carolina Agricultural and Technical State University in December 2012 and his MS in Computer Science from the same institution in May 2015. From the fall of 2015 until his graduation date, Mr. Nick has been funded under ARO contract no. W911NF-15-1-0524 and has conducted research related to this field of study. He is currently a PhD candidate in Computer Science.

Cary Oien

In March 2015, Mr. Cary Oien was named a Senior Level Scientist of the Scientific Analysis Section, Laboratory Division, FBI. The Scientific Analysis Section comprises five case working units (Chemistry, Cryptanalysis and Racketeering Records, Firearms/Toolmarks, Questioned Documents, and Trace Evidence), the Counterterrorism and Forensic Science Research Unit, and the Forensic Analysis Support Unit. Mr. Oien previously served as Chief of the Scientific Analysis Section, Chief of the Firearms/Toolmarks Unit, and Chief of the Trace Evidence Unit. Prior to those positions, he served as a forensic examiner in the Trace Evidence Unit for 11 years, conducting analyses in the disciplines of hair, fiber, fabric, fabric impressions, cordage, wood, and feathers. Earlier in his career, Mr. Oien was a Research Associate at the University of Minnesota, conducting biological control and field crop entomology research. He earned his MSc in entomology from the University of Minnesota.

Uzoma Okafor

Dr. Uzoma Okafor is an assistant professor of Chemistry and Forensic Science at the prestigious Albany State University and is a faculty member of the Forensic Science Unit. He has vast experience in curriculum development and course alignment and is actively involved in forensic science trace evidence research.

Over the years, Dr. Okafor has been the Coordinator of the Biomedical Forensic Science Online Certification program. He took charge of the program in its infancy and developed it into a more robust program with increased enrollment.

In 2012 and 2013, along with Dr. Henry Lee of the Henry C Lee Institute of Forensic Science at the University of New Heaven CT, he was invited to facilitate forensic science workshops at the University of Lagos, where he gave a talk on the need for the internationalization of forensic science curricula.

Dr. Okafor's research experience has involved various collaborations with researchers at universities and research institutes in the United States. As a result of his various research collaborations, he has more than 10 peer-reviewed journal publications and has delivered more than 15 research presentations at conferences. His keen interest in research collaboration resulted in his most recent National Institute of Justice grant award for a research project entitled, *Surveying the Total Microbiome as Trace Evidence for Forensic Identification*.

He has mentored many undergraduates in both research and academics. Dr. Okafor is a Minority Achievement Committee Fellow, Federation of American Societies for Experimental Biology Scholar, American Society of Microbiology Fellow, and American Society for Biochemistry and Molecular Biology Scholar.

Danica Ommen

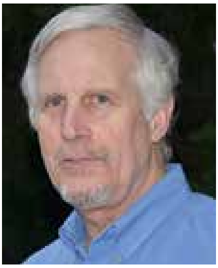
Dr. Danica Ommen is an Assistant Professor in the Department of Statistics at Iowa State University where she collaborates with the Center for Statistics and Applications in Forensic Evidence (CSAFE) Center of Excellence, funded by the National Institute of Standards and Technology (NIST). She received her PhD in Computational Science and Statistics from South Dakota State University in 2017. Her PhD research focused on deriving statistically rigorous approximations to the value of evidence for use in the forensic identification of source problems. Dr. Ommen received her BS in Mathematics in 2012 and her MS in Mathematics with an emphasis in Statistics in 2014, also from South Dakota State University. Prior to graduating, she participated in the ORISE Visiting Scientist Program with the Counterterrorism and Forensic Science Research Unit at the FBI Laboratory where she learned more about the science behind trace element analysis and analysis of impression and pattern evidence. This program furthered her interest in the statistical analysis of trace elements from materials such as copper wire and aluminum powder as well as the statistical analysis of handwriting. Dr. Ommen also served as a visiting researcher with the statistics group at the Netherlands Forensic Institute in 2016 where she worked to advance her knowledge of the relationship between the different statistical paradigms for forensic evidence interpretation. She has presented her research at many national and international conferences, and she is the first recipient of the CSAFE Stephen E. Fienberg Young Investigator Award.

Zachariah Oommen

Dr. Zachariah Oommen is the Director of the Forensic Science Program and a Professor of Forensic Science at Albany State University (ASU) in Albany, Georgia. His specialty is in forensic chemistry, forensic microscopy, fiber analysis, gunshot residue analysis, paint analysis, instrumental techniques and analysis, and forensic drug analysis. Dr. Oommen joined the ASU Department of Natural and Forensic Science in August 2002. He was promoted to Associate Professor in the Fall of 2007, received tenure in the Fall of 2008, and promoted to Full Professor in 2012. He is charged with program development, program improvement, student tracking, interfacing with the Forensic Science Education Programs Accreditation Commission (FEPAC), and course scheduling.

Dr. Oommen has published his research in 28 national and international journals. During his tenure at ASU, he was awarded three major external grants and 9 internal grants. One of the grants from US Department of Defense ($200,000) brought major state-of-the-art instruments to the Forensic Science Program. Another current grant from the National Institute of Justice is worth $633,000. Dr. Oommen is a fellow of the American Academy of Forensic Sciences. Twice, he served as Chair of the FEPAC on-site evaluation team.

John Ossi



Mr. John Ossi holds a BS in Geology from the University of Maryland and an MS in Geology from the University of Maryland. His thesis involved microscopy of Gulf Coast Lignites and how they reveal environments of deposition. Mr. Ossi has worked for over 30 years as an imaging scientist for microscope, analytical camera, and digital imaging companies. He has presented at forensic meetings on advanced photomicrography and Fourier transform enhancement of fingerprint images. Mr. Ossi has taught microscopy classes at the FBI, Smithsonian Institution, and Bureau of Alcohol, Tobacco, Firearms and Explosives (ATF) and is currently an independent imaging scientist.

Nicole Palmer

Ms. Nicole Palmer is a graduate student at Virginia Commonwealth University obtaining her MS in forensic science, with a concentration in trace evidence/chemistry. She graduated from the University of North Carolina at Wilmington in 2016 with a BS in chemistry. She will graduate in May of 2018, after which she aims to become a trace evidence examiner.

Larry Peterson

Mr. Larry Peterson retired from the Georgia Bureau of Investigation (GBI) with 30 years of experience in trace evidence examinations. After retiring from GBI, Mr. Peterson served over 8 years with the Defense Forensic Science Center/United States Army Criminal Investigation Laboratory (USACIL)/Trace Evidence Branch. He is a member of the American Academy of Forensic Sciences and Southern Association of Forensic Sciences. His areas of experience include hair, textiles, tape, glass, and wood, and he has provided courtroom testimony and training to other scientists in all these areas. Was an instructor for a one-day workshop in wood identification during the 1994 Southern Association of Forensic Scientists (SAFS) meeting.

Cátia Pontedeira

Ms. Cátia Pontedeira is a criminologist, researcher, and investigator in numerous areas. She received her master's in Forensic Science at London South Bank University and is currently pursuing her PhD in Criminology at the Faculty of Law of the University of Porto. Her master's dissertation explored a fibre population study in London. Ms. Pontedeira is currently working on violence prevention. She also lectures at ISMAI (University Institute of Maia, Portugal) on victimology, criminal profiling, and crime scene investigation techniques.

Nicole Praska

Ms. Nicole Praska is a forensic scientist in the Latent Fingerprint Section at the Minnesota Bureau of Criminal Apprehension (BCA). She earned her BS in Clinical Laboratory Science from the University of Minnesota. Ms. Praska is a certified Medical Laboratory Scientist, and prior to working for the BCA, she was employed as a Clinical Laboratory Scientist for HealthEast Medical Laboratory. Her experience in both medical and forensic laboratories has enhanced her perspective as a scientist, especially when facing the current challenges presented to forensic science. She particularly enjoys educating and training others. Ms. Praska has researched and presented on the interactions between latent prints and blood since 2011.

Daniel Ramos

Dr. Daniel Ramos is an Associate Professor at the Universidad Autónoma de Madrid (UAM). He is a member of the Audias Group (Audio, Data Intelligence, and Speech, http://audias.ii.uam.es). During his career, he has visited several research laboratories and institutions around the world, including the Institute of Scientific Police at the University of Lausanne in Switzerland, the School of Mathematics at the University of Edinburgh in Scotland, the Electrical Engineering school at the University of Stellenbosch in South Africa, and the Netherlands Forensic Institute (NFI). His research interests are focused on the forensic evaluation of findings using robust likelihood ratio (LR) models in a variety of disciplines, such as voice comparison or forensic chemistry, and on the validation of those LRs prior to their use in casework, for which he has recently co-proposed a Guideline with the NFI. Mr. Ramos is actively involved in several projects focused on different aspects of forensic science, pattern recognition, and signal processing. He has received several distinctions and awards and is the author of multiple publications in national and international journals and conferences. He is a regular member of scientific committees at international conferences and is often invited to give talks at conferences and institutions.

Thomas Brian Renegar

Mr. T. Brian Renegar is a Physical Science Technician in the Surface and Nanostructure Metrology Group of the Engineering Physics Division at NIST. He performs measurements and calibrations in the fields of surface metrology and ballistic identifications. He currently serves as Vice Chair of the American Society of Mechanical Engineers B46 Committee on the Classification and Designation of Surface Qualities.

Amy Reynolds

Mrs. Amy Reynolds is a Criminalist IV, in charge of the Trace Evidence Section at the Boston Police Department Crime Laboratory. She holds a BA in Biochemistry from the University of Colorado and an MS in Forensic Science from the University of Illinois at Chicago. Her background includes trace evidence, criminalistics, crime scene processing, and bloodstain pattern analysis. She is a certified Fellow in hairs and fibers and a certified Diplomate in criminalistics with the American Board of Criminalistics (ABC) as well as a Certified Crime Scene Investigator through the International Association for Identification (IAI).

Douglas Ridolfi

After graduating with a BS in Criminalistics from the University of California, Berkeley, Mr. Douglas Ridolfi entered the profession in 1977 and worked as a toxicologist with the Los Angeles County Medical Examiner's Office before joining the Los Angeles County Sheriff's Department Scientific Services Bureau where he worked in trace evidence, arson/explosives, footwear and tire tracks, serology, drug chemistry, clandestine drug labs, driver-impaired toxicology, and general crime scene work. He worked with the Santa Clara County District Attorney's Office performing trace, serology, firearm and tool mark, and questioned document work as well as crime scene services. Mr. Ridolfi joined the Illinois State Police working in questioned documents and footwear and tire tracks in the Carbondale laboratory as well as serology, DNA, and quality control and training facilitation in the Forensic Science Center, Chicago. He became DNA technical lead with Alameda County Sheriff's Office and continued processing crime scenes before joining the faculty of Buffalo State College in August 2012. Mr. Ridolfi teaches classes in introductory criminalistics and crime scene processing, optical microscopy, instrumentation, DNA analysis, and specialties including bloodstain pattern interpretation.

Norah Rudin

Dr. Norah Rudin holds a BA from Pomona College and a PhD from Brandeis University. She is a member of the California Association of Criminalists, a fellow of the American Academy of Forensic Sciences, and a Diplomate of the American Board of Criminalistics. After completing a post-doctoral fellowship at Lawrence Berkeley Laboratory, she served 3 years as a full-time consultant/technical leader for the California Department of Justice DNA Laboratory and has also served as consulting technical leader for the Idaho Department of Law Enforcement DNA Laboratory, the San Francisco Crime Laboratory DNA Section, and the San Diego County Sheriff's Department DNA Laboratory. Dr. Rudin co-authored *An Introduction to DNA Forensic Analysis and Principles and Practice of Criminalistics: The Profession of Forensic Science*. She is also the author of the *Dictionary of Modern Biology*. Dr. Rudin has taught a variety of general forensic and forensic DNA courses for the University of California at Berkeley extension and on-line. She is frequently invited to speak at various legal symposia and forensic conferences and recently served a gubernatorial appointment to the Virginia Department of Forensic Science Scientific Advisory Committee. She is currently co-chair of the Constitution Project Committee on DNA Collection. She remains active as an independent consultant and expert witness in forensic DNA.

Nadja Schreiber Compo

Dr. Nadja Schreiber Compo is an Associate Professor at Florida International University (FIU) in Miami and the Co-Director of the Legal Psychology PhD program. She earned her PhD at the University of Muenster, Germany, and was awarded a postdoctoral fellowship by the German Academic Exchange Service to continue her research at FIU. Her research focuses on investigative interviewing and witness memory, especially of vulnerable witnesses such as children or the intoxicated. Dr. Schreiber Compo focuses on potentially detrimental and beneficial interviewing techniques and their underlying cognitive and social mechanisms to improve the quality and quantity of witness and victim recall. She examines real-world interviewers' perceptions, experiences, behaviors, and confirmatory bias in a variety of settings including witness and victim interviewing and forensic expertise. Dr. Schreiber Compo has worked with several law enforcement agencies on research and investigative interviewing training and has consulted in various legal cases. She has been an invited speaker at the International Association of Forensic Toxicologists, the International Association of Chiefs of Police, the International Forensic Research Institute at FIU, the Miami-Dade Police Department Forensic Services Bureau, the Miami-Dade County and Allegheny County Public Defender's Office, the Texas Criminal Defense Attorneys Association, Research Unit for Criminal, Legal, and Investigative Psychology at the University of Gothenburg in Sweden, Wofford College, and Florida Atlantic University, among others. Dr. Schreiber Compo has published over 25 peer-reviewed articles and (co) authored over 70 presentations at national and international conferences. She is an Associate Editor for the journal *Applied Cognitive Psychology* and is on the editorial board of the APA journal *Psychology, Public Policy, and the Law*. Her research has been funded by the National Institute of Justice (NIJ), the National Science Foundation (NSF) and the Swedish Research Council.

Yaron Shor

Mr. Yaron Shor was enlisted by the Forensic Department of the Israeli Police force in 1987, after receiving an MSc degree in Physical Geography and an MBa in Business Administration from the Hebrew University in Jerusalem.

In 1991, he was nominated as the head of the soil, shoeprint and tiremark squad, in the Toolmarks and Materials Laboratory, Division of Identification and Forensic Science (DIFS), Israeli Police.

Mr. Shor has been a member of the European Network of Forensic Science Institutes (ENFSI) Expert Working Group Marks (EWG Marks) for shoeprint/tiremark examiners since 1995. He was also a member of the Special Committee of the Marks Working Group (an ENFSI WG) on "Harmonization of Conclusion Scales." In 2006, this WG published the European "Six-Level Conclusion Scale" for interpreting findings in the shoeprint area.

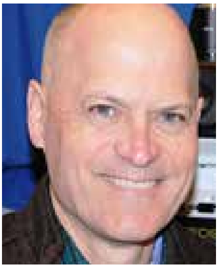
Since 2015, he has been a member of the Statistical and Applied Mathematical Sciences Institute (SAMSI) WG "Shoeprints as Evidence."

Mr. Shor has given many presentations at European and American meetings in the shoeprint and tiremark fields and has published numerous papers about topics in these areas. He has a long history of solving practical problems in shoeprint recovery and interpreting findings according to expert opinion. He leads research groups and develops projects. With his team, he received two research grants from the National Institute of Justice (NIJ). Several of his works contributed to the practice in these fields worldwide.

Alyssa Smale

Ms. Alyssa Smale is a senior chemistry major at Lebanon Valley College. She plans to attend graduate school for forensic science next fall. She has three years of research experience in inorganic chemistry and has switched to a forensic chemistry project as part of her honors senior research. The subject of this research is the result of a collaborative project between Dr. Donald Dahlberg of Lebanon Valley College and Dr. Brooke Kammrath of the University of New Haven.

Erich Smith



Mr. Erich D. Smith is a Physical Scientist Forensic Examiner and Technical Leader of the FBI Laboratory Firearms/Toolmarks Unit (FTU) and is a Regular member of the Association of Firearm and Tool Mark Examiners (AFTE). Mr. Smith has been working with and evaluating novel 3D technologies since 2013 to determine their capabilities in forensic firearms identification. In addition, Mr. Smith has served as the Quality Assurance and Training Program Manager for the FTU and is currently a member of the Subcommittee on Firearms & Toolmarks in the National Institute of Standards and Technology (NIST) Organization of Scientific Area Committees (OSAC).

John Song

Dr. Jun-Feng "John" Song is the Project Leader of the Forensic Topography and Surface Metrology Project of the National Institute of Standards and Technology (NIST). He is a mechanical engineer in the Surface & Nanostructure Metrology Group in the Engineering Physics Division of the Physical Measurement Laboratory at NIST. He was also a Postdoctoral Research Adviser for the National Research Council of the United States National Academies. In 1981, he received an MS in Mechanical Engineering from the Harbin Institute of Technology, Harbin, China. Before he came to NIST in 1987, he invented and patented the random profile roughness specimens. In 1995, these specimens were included in the American Society of Mechanical Engineers B46 standards. In 1994, he proposed a metrology approach to unifying the international Rockwell C hardness measurements. He has published two books and more than 150 papers. He received a NIST Bronze Medal Award in 1994, a NIST E. B. Rosa Award in 1997, and a NIST Judson C. French Award in 2002. In 2017, he was awarded a PhD by the University of Warwick—one of the top 10 universities in the United Kingdom—for his contributions in surface and forensic topography metrology.

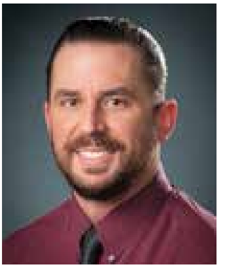
Johannes Soons

Dr. Johannes A. Soons is a mechanical engineer at the Surface and Nanostructure Metrology Group of the Physical Measurement Laboratory at NIST. He received his MSc and PhD degrees in Mechanical Engineering from the Eindhoven University of Technology in the Netherlands. Since 1994, he has worked at NIST as a researcher, group leader, and project leader, conducting research on surface texture and form metrology, precision machining, and the measurement and fabrication of precision optics. His current research focuses on the development and analysis of measurement methods, metrics, algorithms, and uncertainty analyses for objective forensic FA/TM identification. He is a member of the American Society of Mechanical Engineers and the American Society for Precision Engineering.

Ruben Sousa

Mr. Ruben Sousa has a Master's degree in Forensic Science from London South Bank University and a degree in Criminology that he finished in Portugal. Mr. Sousa's interests relate to forensic science as an important science to help criminal investigators discover and prove crimes. With specific training on the Professional Use of Projetiva Documentar Nirvis/PIA-7000 with Docustat DS-220, he is currently performing some forensic investigations at the Univesity of Maia (Portugal). His main areas of interest are fingerprints and other non-biological evidence, and his master's dissertation addressed fingerprints on clothing. Mr. Sousa also participates as an investigator in homicide and lethal violence research.

Sebastian Sparenga



Mr. Sebastian Sparenga is a senior research microscopist and instructor at McCrone Research Institute in Chicago, where he has been employed since 2004. He teaches a variety of microscopy-related courses, including Applied Polarized Light Microscopy, Microscopical Identification of Asbestos, Particle Manipulation and Sample Preparation for Microanalytical Techniques, Digital Imaging, Microscope Cleaning, and specialized training for the National Guard Bureau. Mr. Sparenga also performs microanalytical research on several topics, including microcrystal tests for illicit drugs and microspectrophotometry of fibers in UV-exposed environments.

Sargur Srihari

Dr. Sargur Srihari is a State University of New York (SUNY) Distinguished Professor in the Department of Computer Science and Engineering at the University at Buffalo, SUNY. He has been working in the fields of artificial intelligence (AI) and machine learning for over four decades. At present, he teaches a sequence of three courses: (i) introduction to machine learning, (ii) probabilistic graphical models, and (iii) deep learning.

A laboratory that Dr. Srihari founded, known as CEDAR, developed the world's first automated system for reading handwritten postal addresses. CEDAR was deployed by the United States Postal Service which eventually saved it millions of dollars and helped lower postal rates.

Dr. Srihari then spent a decade developing AI and machine learning methods for forensics—focusing on pattern evidence such as latent prints, handwriting, and footwear impressions. In particular, he developed a system for handwriting comparison which demonstrated the value of such evidence and allowed for the presentation of handwriting testimony in US federal court hearings. Dr. Srihari has served on the National Academy of Sciences Committee on Identifying the Needs of the Forensic Science Community. He has also served on the National Institute of Justice (NIJ) – National Institute of Standards and Technology (NIST) committees on Human Factors in Fingerprint Analysis and Handwriting Comparison. At present, he serves on the Houston Forensics Technical Advisory Board.

Dr. Srihari is a Fellow of the Institute of Electronics and Telecommunications Engineers (IETE) in India, Fellow of the Institute of Electrical and Electronics Engineers (IEEE), Fellow of the International Association for Pattern Recognition, and distinguished alumnus of the Ohio State University College of Engineering .

Dr. Srihari received a BSc in Physics and Mathematics from the Bangalore University, a BE in Electrical Communication Engineering from the Indian Institute of Science, and a PhD in Computer and Information Science from the Ohio State University.

Michael Stocker

Mr. Michael T. Stocker is a Physical Scientist with the Surface and Nanostructure Metrology Group at NIST. He has an AAS in Metrology from Butler County Community College and a BS in Computer Science from Hood College. He has been with the group since 2001 and has worked on various optics-related projects for the semiconductor industry, the fuel cell industry, and toolmark forensics. He has extensive experience in optical methodologies, including scatterfield and bright-field microscopy, scatterometry, ellipsometry, and areal surface topography measurements. He is currently a Technical Advisor for AFTE.

David Stoney

Dr. David Stoney has a PhD in Forensic Science from the University of California at Berkeley. He has served as Director of Forensic Sciences at the University of Illinois and Director of the McCrone Research Institute in Chicago. He is currently in private practice in Northern Virginia, conducting research and casework in small-particle analysis, trace evidence, and latent prints.

Henry Swofford

Mr. Henry Swofford received his BS in Biology with a minor in Chemistry from Georgia State University in 2008 and his MS in Forensic Science from the University of Florida in 2013. Between 2003 and 2008, Mr. Swofford worked as a laboratory technician for the Georgia Bureau of Investigation Division of Forensic Sciences. In 2008, he joined the United States Army Criminal Investigation Laboratory (USACIL) as a Physical Scientist/Latent Print Examiner and assumed additional responsibilities as the Research Coordinator for the Latent Print Branch from 2010 through 2014. After serving 9 months as a Quality Assurance Manager for the USACIL, Mr. Swofford was promoted to his current position as Chief of the Latent Print Branch in February 2015. Over his career, he has authored several articles and given over 100 professional presentations throughout the United States and international community related to forensic science methods and applications. He is certified by the International Association for Identification (IAI) as a Latent Print Examiner and Footwear Examiner. Mr. Swofford is a member of the Board of Directors of the IAI, is a member of the Editorial Board for the *Journal of Forensic Identification*, is the Chair for the Organization for Scientific Area Committees (OSAC) Friction Ridge Subcommittee, and is a member of the Academy Standards Board (ASB) Friction Ridge Consensus Body, in addition to other committees and professional affiliations.

Chris Taylor

Mr. Chris E. Taylor is a forensic chemist who has worked in forensic science for 25 years, spending almost 22 of those years working for the United States Army Criminal Investigation Laboratory (USACIL). His prior positions within the USACIL include Branch Chief of Forensic Case Management, Branch Chief, Trace Evidence and Firearms, Team Leader-Trace Evidence, Chemist-Trace Evidence, and Military Construction Army project officer liaison for the design and construction of the USACIL. Before joining the USACIL, he served as an assistant section supervisor and examiner in the Trace Evidence/Firearms Section for the Georgia Bureau of Investigation-Division of Forensic Sciences and interned in toxicology and serology with the Michigan State Police. He has been certified in Peace Officer Standards Training by the State of Georgia and currently holds certifications in hair and fiber analysis from the American Board of Criminalistics.

Mr. Taylor graduated from Michigan State University with a BS in Forensic Science. He is active in many forensic science organizations, including the National Commission on Forensic Science Accreditation and Proficiency Testing, forensic science standards development committees, and Interpol's Organizational Committee on Forensic Science and Organization of Scientific Area Committee's Chemistry and Instrumental Analysis Scientific Area Committee. He also served on the Department of Defense Forensic Executive Steering Group and was Co-chair of the Accreditation/Certification/Proficiency Tests Interagency Working Group, which fell under the National Science and Technology Council's Subcommittee on Forensic Science and served to inform the White House Office of Science and Technology. He also co-founded the American Society of Trace Evidence Examiners and the Scientific Working Group on Geological Materials. Honors include the American Academy of Forensic Sciences Regional Award, Criminalistics' Section Meritorious Service

Award, Department of the Army Superior Civilian Service Award, Department of the Army Commander's Award for Civilian Service, and United States Army Criminal Investigation Command Civilian Employee of the Year-Supervisor/Manager.

Robert Thompson

Mr. Robert M. Thompson has been a Senior Forensic Science Research Manager with the Special Programs Office-Forensic Sciences at the National Institute for Standards and Technology (NIST) for 9 years. He has over 38 years of experience as a Forensic Scientist and Criminalist. He is certified in Criminalistics by the American Board of Criminalistics (ABC) and is a past Chairman and current member of the Association of Firearm and Toolmark Examiners (AFTE) Certification Program Committee. He is a Fellow of the American Academy of Forensic Sciences and a Distinguished Member of AFTE.

Mr. Thompson was awarded a MFS from The George Washington University in Washington, DC and a BS in Forensic Science with a Chemistry minor from the California State University in Sacramento, California.

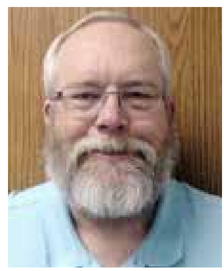
Prior to joining NIST, Mr. Thompson was a Senior Firearms and Toolmark Examiner for the Bureau of Alcohol, Tobacco, Firearms and Explosives (ATF) Forensic Science Laboratories and as a Forensic Scientist and Criminalist in crime laboratories with the Washoe County Sheriff's Department (Reno, Nevada), Oregon State Police, and the GeneLex Corporation (Seattle, Washington). His court-accepted expert testimony includes Firearms/Toolmark Identification, Proximity Testing, Serology and DNA analysis, Drug Analysis, Hair and Fiber Examination, Blood Spatter Reconstruction, Shoe Print Comparison, and Crime Scene/Shooting Reconstruction. Mr. Thompson has testified as an expert in numerous Federal and State courts and has active professional affiliations with several regional, national, and international forensic science societies.

He is published in the *Journal of Forensic Sciences, Forensic Science International, Journal for the Association of Firearm and Toolmark Examiners, Proceedings of SPIE – The International Society for Optical Engineering, NIST Journal of Research, Inside ATF, Measurement Science and Technology, FBI Crime Laboratory Digest*, and the *Proceedings of Saratov University (Russia)*

Tatiana Trejos

Dr. Tatiana Trejos is Assistant Professor of the Department of Forensic and Investigative Sciences at West Virginia University. Prior to her current role, she was Assistant Director of Academic Programs and Manager of the Trace Evidence Analysis Facility (TEAF) at the International Forensic Research Institute (IFRI), Department of Chemistry and Biochemistry, Florida International University. Dr. Trejos teaches forensic undergraduate and graduate courses and has extensive experience as instructor for forensic practitioners, prosecutors, and other law enforcement personnel. She has participated in different scientific working groups, including the NITECRIME group, funded by the European Union, and the Elemental Analysis Working Group (EAWG) and Glass Interpretation Working Group (GIWG), funded by the National Institute of Justice (NIJ). Dr. Trejos was appointed by the National Institute of Standards and Technology (NIST) to serve as a member of the Chemistry/Instrumental Analysis Scientific Area Committee's (SAC's) Materials (Trace) Subcommittee within the Organization of Scientific Area Committees (OSAC). She currently serves as the Chair of the Glass Task Group and Research Task Group. Dr. Trejos' research group focuses on the discovery, statistical analysis, and interpretation of chemical signatures by spectroscopic and spectrometric methods. She is interested in fast and effective analysis of materials that are relevant for criminal investigations (trace evidence, firearm investigations), public health (pharmaceuticals, food packaging) and counterterrorism (taggants, documents, Gun Shot Residues (GSRs), trace evidence). She is also interested in the study of transfer and persistence of materials to better understand how forensic evidence can help determine if a crime has been committed, the sequence of events that occurred at a crime scene, and the significance of such findings. Dr. Trejos has authored 30 peer-reviewed scientific publications and book chapters in the field of forensic chemistry and has presented over 90 oral presentations and posters at scientific meetings worldwide. She is a recipient of the prestigious science and technology award "Clodomiro Picado Twight" from the Costa Rican National Academy of Sciences (2015).

John Vanderkolk



Mr. John R. Vanderkolk received a Bachelor of Arts degree in forensic studies and psychology from Indiana University in 1979. He became an Indiana State Police trooper in 1979 and then a crime scene technician in 1983. In 1984, he was assigned as a criminalist in the laboratory, where he was trained in the disciplines of latent print, shoe/tireprint, firearm/toolmark, and fracture/physical comparative examinations. He was promoted to laboratory manager in 1996. He retired as a police officer in 2005, was rehired as a civilian, and is currently the manager of the Indiana State Police Laboratory in Fort Wayne.

Mr. Vanderkolk has delivered many lectures and workshops related to forensic comparative science at many international or regional seminars, criminal justice agencies, and universities. Some of his other professional activities include having been a member of the Scientific Working Group on Friction Ridge Analysis, Study and Technology and the National Institute of Standards and Technology (NIST)/National Institute of Justice (NIJ) Expert Working Group on Human Factors in Latent Print Analysis. He is currently a member of the editorial board for the *Journal of Forensic Identification* and the Physics/Pattern Scientific Area Committee for the NIST Organization of Scientific Area Committees.

Mr. Vanderkolk was awarded 'Distinguished Member' in the International Association for Identification (IAI), was a member of the IAI's Standardization II Committee, was the chair of the IAI's Forensic Identification Standards Committee, and is the chair of the IAI's Forensic Comparative Examination Committee.

Mr. Vanderkolk has authored or co-authored numerous journal articles on topics related to forensic comparative science. Additionally, he authored the 'Examination Process' chapter of *The Fingerprint Sourcebook* and the book, *Forensic Comparative Science – Qualitative Quantitative Source Determination of Unique Impressions, Images, and Objects*. He has been collaborating with Dr. Thomas Busey of the Indiana University Department of Psychological and Brain Sciences since 2002, studying expertise in latent print examiners. He has been collaborating with Drs. Ashraf Bastawros and Barbara Lograsso of Iowa State University on fractured metal examinations. Furthermore, he was a consultant for the US Department of Justice, Office of the Inspector General, and addressed the erroneous determination that Brandon Mayfield was the source of a fingerprint in the Madrid bombing case.

Theodore Vorburger

Dr. Theodore Vorburger is a Guest Researcher of the Surface and Nanostructure Metrology Group in the Engineering Physics at the National Institute of Standards and Technology and a former employee there. During that time, Dr. Vorburger was the leader of the group responsible for surface roughness and step height calibrations, which underpin the US measurement system for surface finish, and for traceable linewidth measurements using critical dimension atomic force microscopy.

Dr. Vorburger was co-leader of both a project to develop standard bullets and standard cartridge cases for forensics laboratories and a team assessing the feasibility of a National Ballistics Imaging Database of new guns under a National Academies Project. He is a member and former Chair of the American Society of Mechanical Engineers Standards Committee B46 on the Classification and Designation of Surface Qualities and a Subject Matter Expert for the equivalent Working Group under the International Organization for Standardization (ISO). He has a PhD in Physics from Yale University and is the author or co-author of more than 200 publications in the fields of surface metrology, nanometrology, surface physics, atomic physics, chemical physics, and automated measurements.

Sabrina Walker

Ms. Sabrina Walker has 20 years of experience with a large county agency. This experience includes processing approximately 100 crime scenes a year. The scopes of these crime scenes have included everything from Officer Involved Shootings to Homicides, Sexual Assaults, and all types of property crimes. While processing these crime scenes, Ms. Walkers' responsibilities include recognizing and preserving all evidence, including any impression evidence. This evidence is then used for any future analysis or prosecution of the crime. Testimony of the evidence findings is used when testifying in trial.

Ms. Walker received a BS in Career and Technical Education from Northern Arizona University and AAS degrees in Evidence Technology and Criminal Justice from Phoenix College. Her education included over 1,000 hours of specialty training within the following disciplines: Shoe/Tire Impressions, Latent Impression Evidences, Blood Spatter, Bullet Trajectory, Fatal Fire Investigation, and Trace Collection. She holds an Automated Fingerprint Identification System Certification and a Legis Certification. She is a Crime Scene processing instructor for the Maricopa County Sheriff's Office's Deputy Academy and a Crime Lab Duties instructor for East Valley Institute of Technology.

Sarena Wiesner

Mrs. Sarena Wiesner received her BSc in Chemical Engineering from The Technion, Israel in 1993 and her MSc in Applied Chemistry from the Casali Institute at the Hebrew University of Jerusalem in 2003. Her thesis topic was "Mass production of Indanedione and advancing the operational use of the reagent."

She was employed by the Fingerprint Development Laboratory in the Forensic Department of the Israeli Police force in 1994. She was certified as an expert in developing latent fingerprint in 1996 and has published many publications in this field.

Mrs. Wiesner was a member of the International Fingerprint Research Group. In 2002, she moved to the Toolmarks and Materials Laboratory and is now an expert in shoeprint comparison. Recently, she was nominated to be the head of the Questioned Documents Laboratory.

Mrs. Wiesner has been a member of the European Network of Forensic Science Institutes (ENFSI) Expert Working Group Marks (EWG Marks) for shoeprint/tiremark examiners since 2007. She is also a member of the Special Committee of the Marks Working Group (an ENFSI WG) on the "Collaborative Exercise Group."

Mrs. Wiesner has given numerous presentations at conferences in the United States and Europe and has published numerous papers about topics in these areas. She received, with her team, two research grants from the National Institute of Justice (NIJ). She was a member of the Statistical and Applied Mathematical Sciences Institute (SAMSI) WG "Shoeprints as Evidence." Presently, she is working with the Center for Statistics and Applications in Forensic Evidence (CSAFE) on a shoeprint research project. Several of her works contributed to the practice in these fields worldwide.

Alicia Wilcox

Dr. Alicia Wilcox earned her Bachelor's degree with double honors in Chemistry and Statistics from the National University of Ireland. She holds MS degrees in Forensic Science, Criminal Justice, and Business Administration from Strathclyde University in Glasgow, Scotland and Husson University, Bangor, Maine, respectively. She earned her PhD from the University of Dundee, Scotland, with a particular focus on how juries interpret forensic science evidence.

Dr. Wilcox has practiced forensic science for the past 17 years. She was responsible for researching and implementing procedures for analyzing anabolic steroids and the date rape drug γ-hydroxybutyric acid (GHB) at the Department of Justice, Equality and Law Reform in Dublin, Ireland. She was employed by the Maine State Police Crime Laboratory for almost a decade as a forensic scientist specializing in impression evidence. She has processed numerous crime scenes and has qualified as an expert witness in Maine, Massachusetts, Nevada, and Mississippi. Since 2012, Dr. Wilcox has worked as a forensic consultant on current and post-conviction cases.

She is currently an assistant professor of legal studies at Husson University in Maine. She holds four certifications from the International Association for Identification (IAI): Certified Senior Crime Scene Examiner, Certified Latent Print Examiner, Certified Footwear Examiner, and Certified Forensic Photographer. In addition to Dr. Wilcox's responsibilities at Husson, she is a past president and current board member of the New England Division of the IAI, is a member of the IAI footwear certification board, and sits on the footwear/tire subcommittee of the Organization of Scientific Area Committees (OSAC).

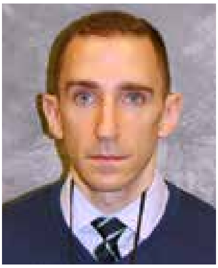
Andrew Winter

Mr. Andrew Winter received an MCJ in Criminal Justice from Boston University and an MS in Homeland Security with a concentration in Terrorism and Security Studies from Fairleigh Dickinson University. Mr. Winter is active law enforcement professional with over 17 years of experience. He is an Adjunct Instructor at Centenary University, which is located in Hackettstown, NJ. He teaches an undergraduate course in Forensic Science. Mr. Winter is the current Education Chair for the New York Microscopical Society. He is also a member of several forensic organizations, including the Association of Firearm and Toolmark Examiners, International Association for Identification, and Northeastern Association of Forensic Scientists.

James Wolfe

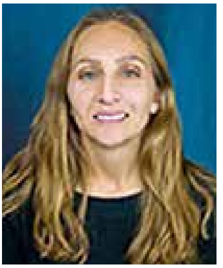
Mr. James Wolfe is a consulting forensic scientist whose career began in 1979 when he set up and managed the Alaska State Fish and Wildlife Protection Crime Laboratory. He transferred to the Alaska State Crime Laboratory in 1985 and expanded his expertise to include shoe and tire impression exams and crime scene investigations. Since retiring from the crime laboratory in 2004, he has continued his work in forensics as an independent consultant, teacher, and trainer. His research projects include developing techniques to help field officers more efficiently document and collect snow impression evidence.

Thomas Wortman



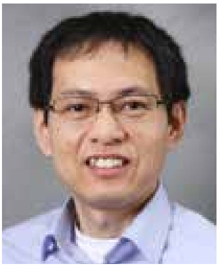
Mr. Tom Wortman is currently employed by the United States Army Criminal Investigation Laboratory (USACIL) as a Latent Print Examiner. Mr. Wortman has more than 10 years of forensic science experience, including 7 years in latent prints. Previously, he was employed at the Seattle Police Department's Latent Print Unit, where he served as their Quality Assurance Manager. Mr. Wortman started his forensic career at the Alaska Scientific Crime Detection Laboratory (ASCDL), where he worked for over 8 years as a Forensic Scientist. He is currently certified by the International Association for Identification (IAI) as a Certified Latent Print Examiner and a member of the Organization of Scientific Area Committees (OSAC) Subcommittee on Friction Ridge.

Jessica Zarate



Ms. Jessica Zarate, MS is currently an assistant professor in the Forensic Science Education Programs Accreditation Commission-accredited undergraduate Forensic Science Program at Madonna University and teaches forensic science coursework, including impression and trace evidence. She was a Michigan-certified police officer for eight years and is the inventor of Zar-Pro™ Fluorescent Blood Lifters (US Patent 8,025,852 B2). She has worked in impression analysis for over 9 years, including during her time as a police officer with the Northville City Police Department, when she collaborated and assisted with latent print enhancement in the Michigan State Police Northville Forensic Science Laboratory, Latent Print Unit. Her research work is focused within the impression evidence discipline, and she has published on a fluorogenic method for lifting, enhancing, and preserving bloody impression evidence; recovering bloody impressions from difficult substrates, including from human skin; and defining methods to create consistent and reproducible fingerprint impressions deposited in biological fluids on a variety of substrates.

Song Zhang



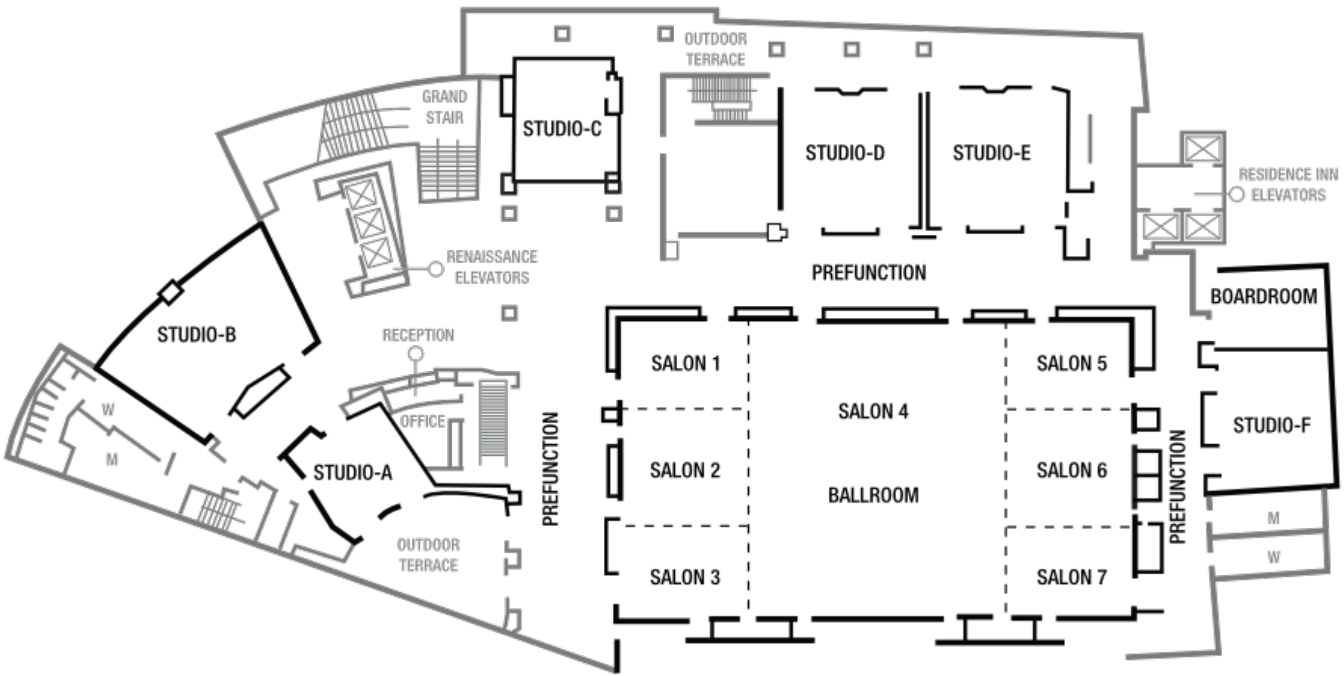
Dr. Song Zhang is an associate professor of mechanical engineering at Purdue University. His research mainly focuses on developing novel methods for 3D structured light imaging and 3D image data analysis. He has been credited with inventing the first-ever high-resolution, real-time 3D imaging system. Recently, he invented a binary defocusing method that has enabled both speed and resolution breakthroughs. He is a fellow member of SPIE, the international society for optics and photonics, and a senior member of the Optical Society of America (OSA).

Xiaoyu Alan Zheng

Mr. Xiaoyu Alan Zheng is a mechanical engineer with the Engineering Physics Division at NIST. He holds a BS in Mechanical Engineering from the University of Maryland Baltimore County and an MS in Mechanical Engineering from Johns Hopkins University. His primary research focuses on objective ballistics toolmark identifications. He is currently a technical adviser with the Association of Firearm and Toolmark Examiners (AFTE) and is serving on the Firearms and Toolmark subcommittee of the NIST OSACs.

Notes

MEETING ROOM

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