



**IAI Workshop W196**  
**National Harbor, MD**  
**August 25, 2023**



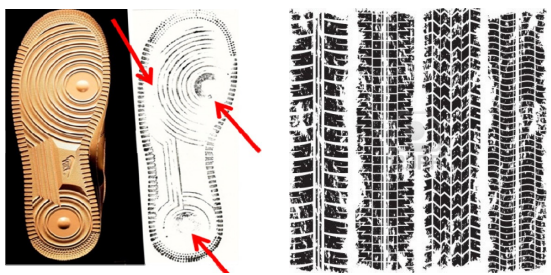
# **Footwear Impression Evidence: A NIST Scientific Foundation Review**

**Kelly Sauerwein, Ph.D.**

**John M. Butler, Ph.D.**

**Melissa K. Taylor**

*NIST Special Programs Office*



# Acknowledgments and Disclaimer

**Points of view are the presenters** and do not necessarily represent the official position or policies of the National Institute of Standards and Technology.

Certain commercial entities are identified in order to specify experimental procedures as completely as possible. In no case does such identification imply a recommendation or endorsement by the National Institute of Standards and Technology, nor does it imply that any of the entities identified are necessarily the best available for the purpose.

# W196 Planned Schedule

Time (approx.)	Time estimates	Topic	Presenter
10:00am – 10:15am	15 min	Welcome to Workshop and Introductions	Kelly & Everyone
10:15am – 10:30am	15 min		
10:30am – 11:15am	45 min		Kelly & Melissa
11:15am – 12:00pm	45 min		Kelly & Melissa
12:00pm – 1:00pm	60 min	LUNCH	
1:00pm – 1:45pm	45 min	Input on Claims and Issues: Topic 2	John & Melissa
1:45pm – 2:30pm	45 min	Input on Claims and Issues: Topic 3	Kelly & Melissa
2:30pm – 3:00pm	30 min	Wrap-up, Q & A, and Next Steps	John & Kelly

# Introductions

Kelly & Everyone

# About Me: Kelly Sauerwein

Ph.D. (2018) University of Tennessee, Knoxville (Biological Anthropology)

Specialize in taphonomy and human decomposition processes for time since death estimation, method validation, and human factors applications.

3 years with NIST:

- Physical Scientist with SPO Scientific Foundation Review Program (2020-present)

Foundation Reviews:

- Bitemark Analysis
- Digital Investigation Techniques

Authored papers in digital evidence quality management techniques, postmortem biometrics, ethical treatment of human remains for curation & research.

Executive Secretary, Scientific Working Group in Digital Evidence (SWGDE)



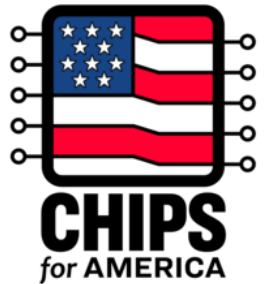
Sunset over the Bosphorus, Istanbul

# NIST History and Overview

- Started in 1901 as the **National Bureau of Standards (NBS)** with roots back to the Constitution
- Name changed in 1988 to the **National Institute of Standards and Technology (NIST)**
- Part of the U.S. Department of Commerce
- **Mission:** To promote U.S. innovation and industrial competitiveness by advancing measurement science, standards, and technology in ways that enhance economic security and improve our quality of life.
- **Core Values:** Perseverance, Integrity, Inclusivity, Excellence
- Primary campuses in Gaithersburg, Maryland and Boulder, Colorado
- >6,000 employees and associates - *<100 total work on forensic science topics*
- Supply >1300 reference materials (<https://www.nist.gov/srm>)
- **Defines the official time for the U.S.** (<https://time.gov/>)



**NIST Director**  
Dr. Laurie Locascio



<https://www.nist.gov/about-nist>


# NIST Forensic Science Program

<https://www.nist.gov/spo/forensic-science-program>

**Special Programs Office**

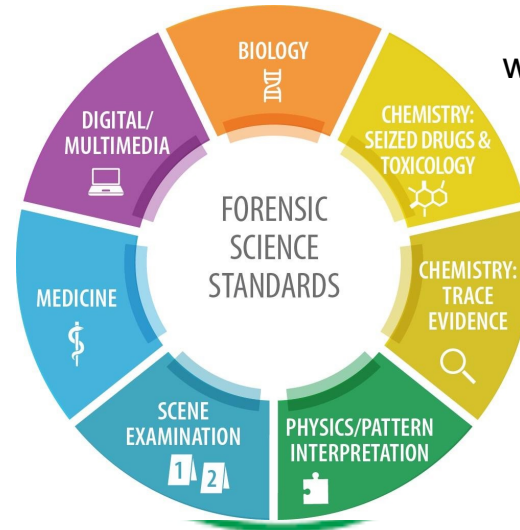
Shyam Sunder

## Research at NIST in 8 focus areas:

 Biometrics	 Digital Evidence
 Drugs and Toxicology	 Evidential Statistics
 Firearms and Toolmarks	 Forensic Genetics
 Forensic Science Quality Assurance	 Trace Evidence

Robert Ramotowski

## Standards efforts involve administering OSAC



22 forensic disciplines  
with >800 participants from  
across the community



>4,000 terms  
organized by forensic discipline



>130 implementers  
forensic science service providers

John Paul Jones

## Foundation Studies



DNA Mixture Interpretation

Digital Investigation Techniques

Bitemark Analysis

Firearm Examination

John Butler

# Introductions & Expectations

- **Your Name**
- **Your Laboratory/Employer**
  - **Or are you a student?**
- **What you hope to learn in this workshop?**



# Notes on What You Hope to Learn Today

(summary of participant responses)

- See what NIST is doing
- Everything!
- Thoughts and feelings on footwear
- General issues with foot impressions
- What is this all about?
- Where are things going to go from here
- Daubert review
- What NIST is up to with foundation studies
- Admissibility of identification science
- Figure out the gaps and how to mitigate them
- Training and learning on footwear
- What is going on with standards
- General background on NIST
- Evaluation of scientific principles on underpinning physics of footwear
- Strengthen footwear evidence in US (a lot of potential in this study)
- Learning from collective knowledge
- How we standardize the work to help it be reliable
- Disseminating research so practitioners can use it more – and sharing where more research is needed

# Goals for Today's Workshop

- Introductions to what NIST has done so far in this area
- Emphasis on Discussion
  - Goal is to generate discussion on key topics in footwear impression examination
  - **Questions and comments are encouraged!**
- All points of view are sought, but please remember to be respectful of fellow attendees

# W196 Planned Schedule

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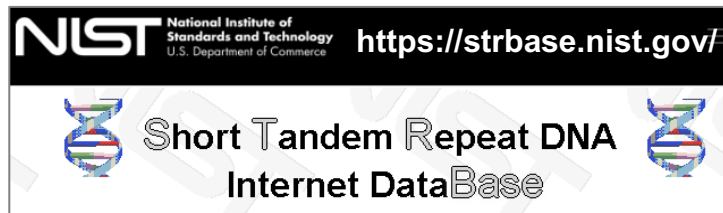
# Overview of NIST Scientific Foundation Studies

John

# My Background and Interests

- B.S. Chemistry (BYU: 1992), Ph.D. Analytical Chemistry (UVA: 1995)
- Researcher with the **FBI** (1993-1995), **AFDIL** (1995-1996), a **start-up company** (1997-1999), **NIST** (1995-1997, 1999-2013, 2013-present)
- 25+ years at NIST
  - CSTL NRC Postdoc (1995-1997)
  - CSTL/MML Applied Genetics Project & Group Leader (1999-2008, 2008-2013)
  - **NIST Fellow (2008-present); in Special Programs Office since April 2013**
  - Awards (partial list): PECASE (2002), DOC Silver (2002), DOC Gold (2008), Flemming (2008), Condon (2010), Presidential Rank (2015)
- Vice-Chair, National Commission on Forensic Science (2013-2017)
- President, International Society for Forensic Genetics (currently)

*I enjoy compiling helpful information and sharing with the community*



I perform research in forensic science, write articles (>180 so far; #7 most cited in forensic science, #1 U.S.) and teach others about what I have learned (>600 talks and workshops given in 27 countries **with six textbooks** so far) – *my focus now is on scientific foundation reviews*

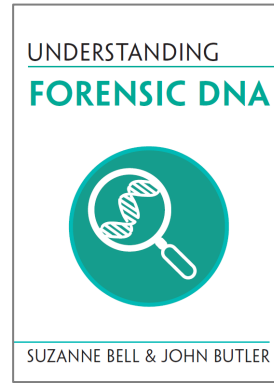
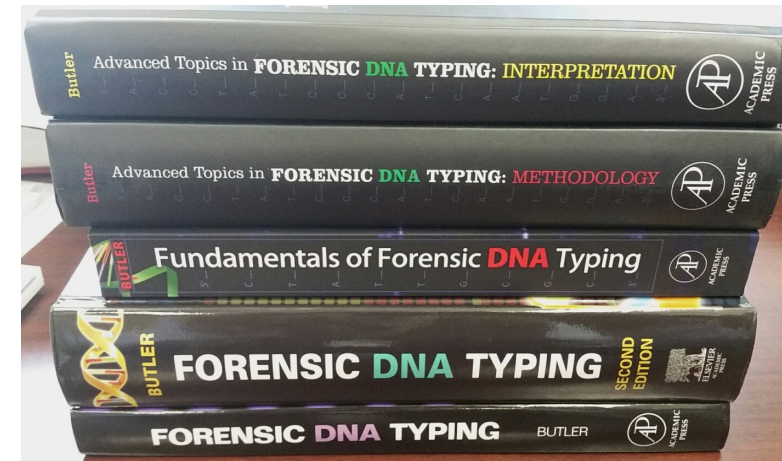


221B Baker Street, London (2015)



Lyon, France (2019)

- 2015
- 2012
- 2010
- 2005
- 2001



Cambridge U. Press  
2022

Writing the Books on Forensic DNA: Interview with John Butler  
<https://www.youtube.com/watch?v=e6yDJuV1TIs>

# Why This Workshop and Why Now?

1. To **share** with interested members of the footwear/tire impression community our plan for a foundation study in this area
2. To **seek** feedback and input at an early stage in our review
3. To **find** potential participants to assist our project team that will help write the NIST report (there will also be opportunity during a public comment period to provide feedback)
4. To **support** the community by creating comprehensive literature and data information recourses that can benefit future training efforts

NIST Interagency Report  
NIST IR 8352sup1

**CSAFE Bitemark Thinkshop Report**

Center for Statistics and Applications in Forensic Evidence (CSAFE)

## October 2019 Thinkshop

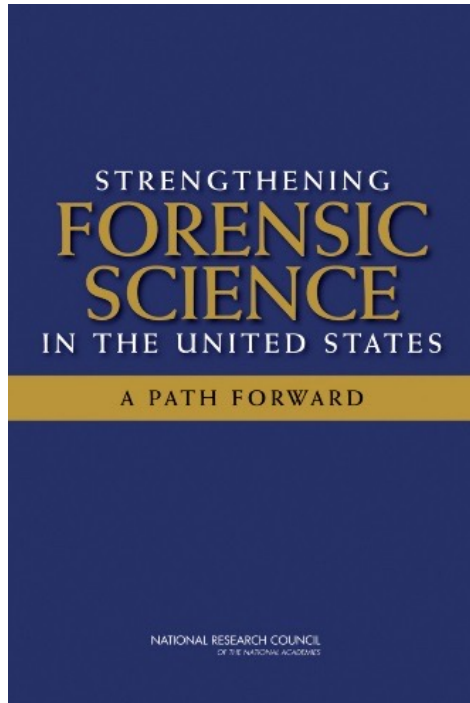
Topic 1: Understanding Dentition (Teeth)

Topic 2: Understanding Bitemarks (Transfer Measurable Characteristics)


Topic 3: Data Interpretation Strategies

# Requests for Understanding What Data Exists Supporting Forensic Science Methods and Practices

NRC Report (2009)



NCFS Recommendation (2016)

**NATIONAL COMMISSION ON FORENSIC SCIENCE** 

**Recommendation to the Attorney General  
Technical Merit Evaluation of  
Forensic Science Methods and Practices**


<b>Subcommittee</b>	<b>Date of Current Version</b>	07/06/16
Scientific Inquiry and Research	<b>Approved by Subcommittee</b>	26/08/16
<b>Status</b>	<b>Approved by Commission</b>	12/09/16
Adopted by the Commission	<b>Action by Attorney General</b>	[dd/mm/yy]

**Commission Action**  
On September 12, 2016, the Commission voted to adopt this Recommendation by a more than two-thirds majority affirmative vote (77% yes, 19% no, 3% abstain)

*Note: This document includes recommendations developed and adopted by the National Commission on Forensic Science and proposes specific acts that the Attorney General could take to further the goals of the Commission. The portion of the document directly labeled "Recommendations" represents the formal recommendations of the Commission. Information beyond that section is provided for context. This document does not necessarily represent the views of the Department of Justice or the National Institute of Standards and Technology. The National Commission on Forensic Science is a Federal Advisory Committee established by the Department of Justice. For more information, please visit: <https://www.justice.gov/ncfs>.*

**Overview**  
The National Commission on Forensic Science (NCFS) has already approved a Views Document on the importance of establishing the technical merit of all forensic science methodologies. The required studies should be independently<sup>1</sup> evaluated and accepted prior to the creation of documentary standards<sup>2</sup> involving test methods and practices based on these disciplines.


PCAST Report (2016)



**REPORT TO THE PRESIDENT  
Forensic Science in Criminal Courts:  
Ensuring Scientific Validity  
of Feature-Comparison Methods**

Executive Office of the President  
President's Council of Advisors on  
Science and Technology

September 2016



NISTIR 8225 (2020)

**NISTIR 8225**

**NIST Scientific Foundation Reviews**

John M. Butler  
Melissa K. Taylor  
Sheila Willis\*  
*Special Programs Office  
Associate Director of Laboratory Programs*

Hari Iyer  
*Statistical Engineering Division  
Information Technology Laboratory*

Peter M. Vallone  
*Biomolecular Measurement Division  
Material Measurement Laboratory*

Rich Press  
*Public Affairs  
Director's Office*

\*International Associate under contract; retired director of Forensic Science Ireland

This publication is available free of charge from:  
<https://doi.org/10.6028/NIST.IR.8225>

December 2020



U.S. Department of Commerce  
Wilbur L. Ross, Jr., Secretary

National Institute of Standards and Technology  
Walter Copan, NIST Director and Undersecretary of Commerce for Standards and Technology

“demonstrating the validity of forensic methods”

(Recommendation #3)

“technical merit evaluation”

**Congressional funding uses NCFS language**

“establishing foundational validity”

**NIST: a “Scientific Foundation Review”**

# Trustworthy Results: A Shared Common Interest

NISTIR 8225 (2020)



**NIST: a “Scientific Foundation Review”**

Obtaining reliable (trustworthy, consistently accurate) results is an important goal for forensic science, which NIST, as part of the forensic science ecosystem, shares in all our activities

With NIST scientific foundation reviews, we are

1. Documenting the **key scientific principles** that underpin current methods and practices
2. Cataloging **available literature and information** that describe the state of the field
3. Recommending strategies so that the community and its stakeholders **can have confidence in the results obtained** from a particular method or practice



# Clarification on What NIST Is and Is Not



- NIST is a Federal government **science agency** and does not comment on legal admissibility
- NIST is **not a regulatory agency**
- NIST **focuses on research and assisting with developing standards** (e.g., OSAC or SRMs)
- NIST **does not conduct forensic science casework**

# Scientific Foundation Studies

<https://www.nist.gov/forensic-science/interdisciplinary-topics/scientific-foundation-reviews>

Goal: Identify the scientific foundations that support and underpin forensic methods and document and assess empirical evidence for the reliability of these methods using publicly available data and peer-reviewed literature.

NIST Internal Report  
NIST IR 8354

## Digital Investigation Techniques: A NIST Scientific Foundation Review

James R. Lyle  
Barbara Guttman  
*Software and Systems Division*

John M. Butler  
Kelly Sauerwein  
Christina Reed  
Corrine E. Lloyd  
*Special Programs Office*

This publication is available free of charge from:  
<https://doi.org/10.6028/NIST.IR.8354>

November 2022

November 2022  
84-pages



U.S. Department of Commerce  
Gina M. Raimondo, Secretary

National Institute of Standards and Technology

Laurie E. Locascio, NIST Director and Under Secretary of Commerce for Standards and Technology

Digital evidence examination **rests on a firm foundation based in computer science**. Extensive testing of over 250 widely used digital forensic tools showed that **most tools perform their intended functions with only minor anomalies**.

NIST Interagency Report  
NIST IR 8352

## Bitemark Analysis: *A NIST Scientific Foundation Review*

Kelly Sauerwein  
John M. Butler  
Christina Reed  
*Division 602 - Special Programs Office  
Laboratory Programs  
National Institute of Standards and Technology*

Karen K. Reczek  
*Division 601 - Standards Coordination Office  
Laboratory Programs  
National Institute of Standards and Technology*

This publication is available free of charge from:  
<https://doi.org/10.6028/NIST.IR.8352>

March 2023

March 2023  
42-pages



U.S. Department of Commerce  
Gina M. Raimondo, Secretary

National Institute of Standards and Technology

Laurie E. Locascio, NIST Director and Under Secretary of Commerce for Standards and Technology

Forensic bitemark analysis **lacks a sufficient scientific foundation** because the three key premises of the field are not supported by the data.

## Supplemental Documents

114 pages NIST Interagency Report  
NIST IR 8352sup1

### CSAFE Bitemark Thinkshop Report

Center for Statistics and Applications in Forensic Evidence (CSAFE)

10 pages NIST Interagency Report  
NIST IR 8352sup2

### Standards and Guidelines in Forensic Odontology

Karen K. Reczek

13 pages NIST Interagency Report  
NIST IR 8352sup3

### Summary of Published Criticisms of Bitemark Foundations and Responses by Forensic Odontologists

John M. Butler

30 pages NIST Interagency Report  
NIST IR 8352sup4

### Bitemark Analysis Reference List

Kelly Sauerwein

30 NISTIR 8351-DRAFT

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## DNA Mixture Interpretation: *A NIST Scientific Foundation Review*

John M. Butler  
Melissa K. Taylor  
Sheila Willis\*  
*Special Programs Office  
Associate Director of Laboratory Programs*

Hari Iyer  
*Statistical Engineering Division  
Information Technology Laboratory*

Peter M. Vallone  
*Biomolecular Measurement Division  
Material Measurement Laboratory*

Rich Press  
*Public Affairs  
Director's Office*

\*International Associate under contract; retired director of Forensic Science Ireland

This publication is available free of charge from:  
<https://doi.org/10.6028/NIST.IR.8351-draft>

June 2021

DRAFT  
June 2021  
250-pages



U.S. Department of Commerce  
Gina M. Raimondo, Secretary

National Institute of Standards and Technology

James K. Olthoff, Performing the Non-Exclusive Functions and Duties of the Under Secretary of Commerce for Standards and Technology & Director, National Institute of Standards and Technology

Received [extensive public comments \(~500 pages\)](#) that are being considered along with additional information since June 2021. We will release a final report when completed.

# NIST Scientific Foundation Reviews (so far)

## 1. DNA Mixture Interpretation (initial pilot study)

- Began in September 2017
- AAFS 2019, ISHI 2019, ISHI 2020, AAFS 2021, AAFS 2022 workshops conducted
- **250-page report released for public comment on June 9, 2021, with a 3-hour webinar held on July 21, 2021**

## 2. Bitemark Analysis – **final report released March 14, 2023**

- Began in October 2018
- Workshop held in October 2019
- **Report released for public comment on October 11, 2022, with a 2-hour webinar held on October 27, 2022**

## 3. Digital Investigation Techniques – **final report released November 21, 2022**

- Began in February 2019
- Interlaboratory “black box” study conducted from June to November 2020
- **Report released for public comment on May 10, 2022, with a 2-hour webinar held on June 1, 2022.**

## 4. Firearm Examination

- Began in October 2019
- Gathering literature and focusing on error rate studies

## 5. Footwear Impressions (IAI meeting in August 2023)

**Reports will be provided with each foundation study and made available for a public comment period**

<https://www.nist.gov/topics/forensic-science/interdisciplinary-topics/scientific-foundation-reviews>

# Downloads of NIST Foundation Reports

NIST Foundation Study Report	Number of Downloads (through 30 June 2023)
Digital Investigation Techniques (draft)	11620
Digital Investigation Techniques (final)	3635
DNA Mixture Interpretation (draft)	8839
Bitemark Analysis (draft)	1165
Bitemark Analysis (final)	6300
Bitemark Analysis (supplemental documents)	346 + 282 + 287 + 373 1288

# NIST Webinars and Community Outreach Efforts

**DNA: ASCLD 2023**

## NIST Webinars (free) During the Public Comment Period

### DNA draft report – *3-hours on July 21, 2021*

- Registered: >1,000
- Actual: 1,199 (main presentation), 234 (Q&A)

### Digital draft report - *2-hours on June 1, 2022*

- Registered: 862
- Actual: 210
- Recording views: 185

### Bitemark draft report - *2-hours on Oct 27, 2022*

- Registered: 393
- Actual: 198
- Recording views: 24

**Forensics@NIST**  
2018, 2020, 2022

## Conference Presentations/Workshops

### • AAFS

- DNA: 2018, 2019, 2020, 2021
- Digital: 2020, 2022, 2023
- Bitemark: 2022
- Firearm: 2020, 2021, 2023

Bitemark (2019)  
CSAFE Thinkshop

### • ISHI

- DNA: 2018, 2019, 2020, 2021 (ISFG: 2019)

### • AFTE

- Firearm: 2021, 2023

Additional Firearm  
BKA, NFI: 2020  
ASCLD Lightning: 2021  
FIU: 2021  
NIJ Forum: 2022

### • IAI

- Firearm: 2022, 2023
- **Footwear: 2023**

### • SWGDE

- Digital: 2020, 2021, 2022

Additional Digital (2022)  
NCC, IACP, F3 (UK), IEEE


# Updates for CFFLD

*Regular updates are provided upon request to CFFLD during their quarterly meetings*

CFFLD  
5 May 2022

## NIST Scientific Foundation Reviews

<https://www.nist.gov/topics/forensic-science>



RESEARCH. STANDARDS. FOUNDATIONS.


**NIST** NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY  
U.S. DEPARTMENT OF COMMERCE

CFFLD Virtual Meeting  
8 September 2022

## Digital Investigation Techniques: A NIST Scientific Foundation Review

John M. Butler, PhD  
NIST Special Programs Office

[john.butler@nist.gov](mailto:john.butler@nist.gov)



**NIST** NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY  
U.S. DEPARTMENT OF COMMERCE

CFFLD Virtual Meeting  
3 February 2023

## Bitemark Analysis: A NIST Scientific Foundation Review

John M. Butler, PhD  
NIST Special Programs Office

[john.butler@nist.gov](mailto:john.butler@nist.gov)

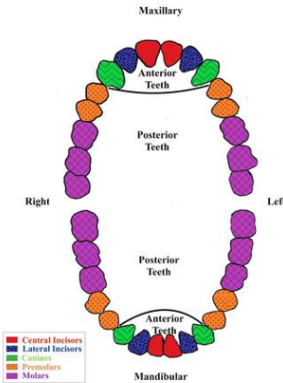


Illustration of a typical human dentition viewed in standard anatomical position.  
Credit: K. Sauerwein/NIST

**NIST** NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY  
U.S. DEPARTMENT OF COMMERCE

CFFLD Meeting  
Austin, TX  
30 April 2023

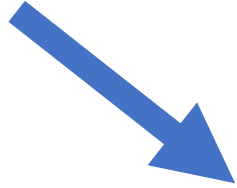
## DNA Mixture Interpretation: A NIST Scientific Foundation Review

John M. Butler, PhD  
NIST Special Programs Office

[john.butler@nist.gov](mailto:john.butler@nist.gov)

# NIST Process

**Initial Input**  
(Resource Group,  
Workshop, Interlab  
Study, etc.)



**DRAFT  
Report**

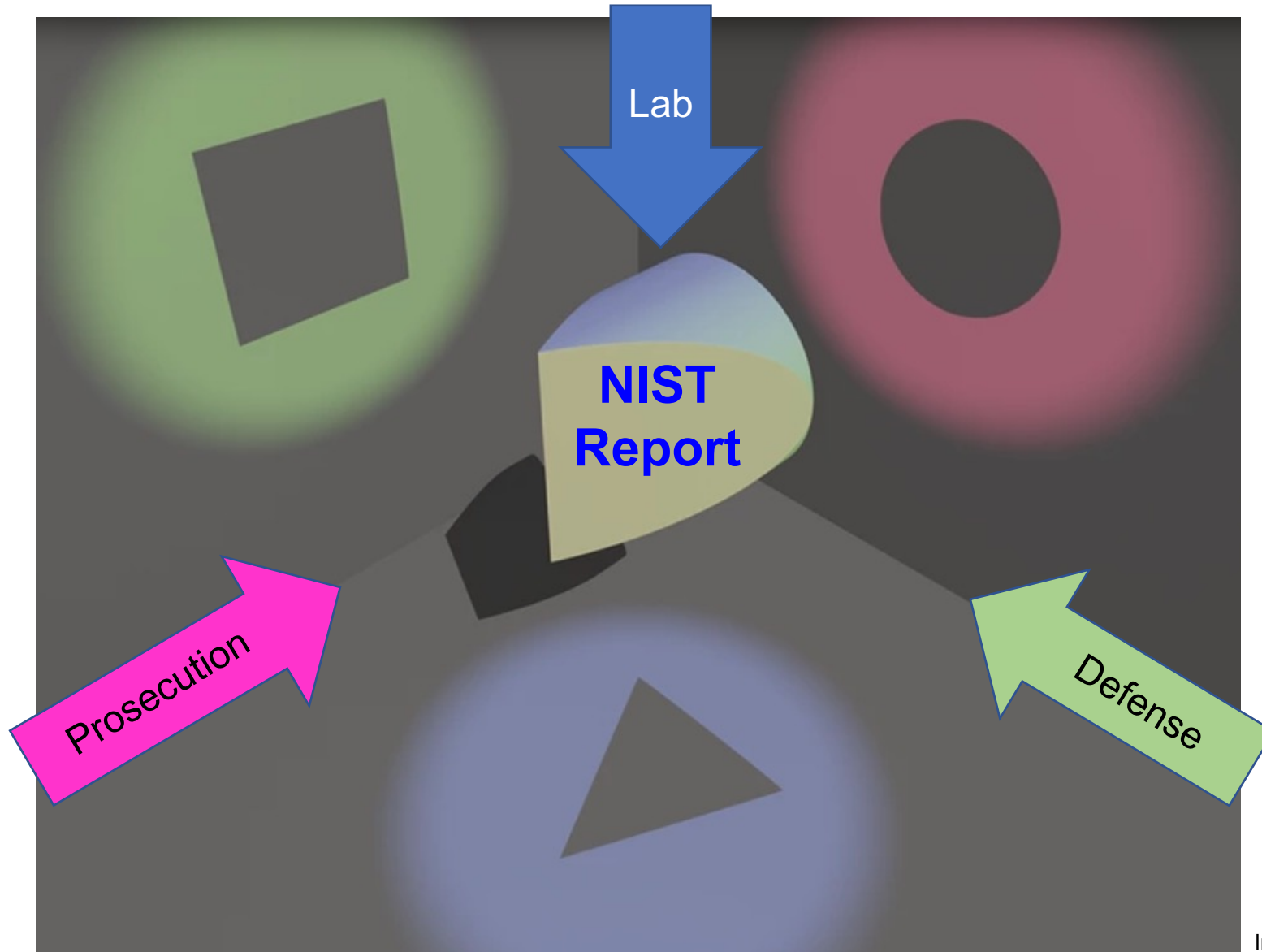


**Public Comments  
on Draft Report**



**FINAL  
Report**

# We Recognize That There Are and Will Be Many Different Perspectives and Lenses on Our Foundation Reports...



**This is Why  
Public Comment  
is so Important!**

Why Issue a Draft?  
Scientific dialogue is  
vital to a scientific  
foundation review!



# What Question(s) Are We Attempting to Answer?

Background information on NIST scientific foundation reviews is available in NISTIR 8225 at <https://doi.org/10.6028/NIST.IR.8225>.

- A scientific foundation review, also referred to as a technical merit evaluation, is a study that documents and assesses the foundations of a scientific discipline, that is, the trusted and established knowledge that supports and underpins the discipline's methods.
    - Our preface states: “What established scientific laws and principles as well as empirical data exist to support the methods that forensic science practitioners use to analyze evidence?”
1. What established **scientific laws and principles** underpin this forensic science method?
  2. What publicly available **empirical data** exist to support the methods that forensic science practitioners use to analyze evidence?

# What Question(s) Are We Not Attempting to Answer?

- a) General **global reliability statements** based on aggregate performance across many types of samples and many different examiners
  
- b) We are not making any statements about **the degree of reliability for any individual cases** because we did not review the necessary information (as this was out-of-scope of our study)

Our findings are intended to inform future improvements to practice

# Past and Present Foundation Studies

John Butler, Program Lead

[john.butler@nist.gov](mailto:john.butler@nist.gov)

301-326-8692 (cell)

Kelly Sauerwein (SPO)

Christina Reed (SPO)

Heather Waltke (Associate)

Melissa Taylor (SPO)

**NISTIR 8351-DRAFT**  
(June 2021)

## DNA Team

- ➔ John Butler (SPO)
- Hari Iyer (ITL)
- Rich Press (SPO/PAO)
- Melissa Taylor (SPO)
- Pete Vallone (MML)
- Sheila Willis (International Associate)

*DNA Mixture Resource Group*  
(13 practitioners and researchers)

**NISTIR 8352-DRAFT**  
(October 2022)

## Bitemark Team

- ➔ Kelly Sauerwein (SPO)
- John Butler (SPO)
- Karen Reczek (SCO)
- Christina Reed (SPO)

**NISTIR 8354-DRAFT**  
(May 2022)

## Digital Team

- ➔ Barbara Guttman (ITL)
- Jim Lyle (ITL)
- Mary Laamanen (ITL)
- ➔ John Butler (SPO)
- Corrine Lloyd (SPO)
- Christina Reed (SPO)
- Craig Russell (ITL)
- Kelly Sauerwein (SPO)

**NISTIR 8412 Black Box Study**  
(Feb 2022)

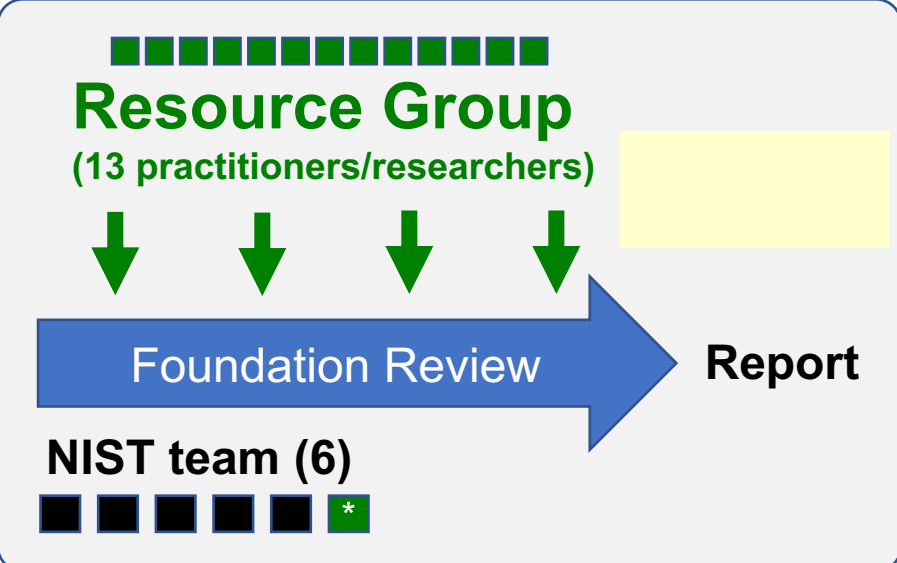
**NISTIR 8353-DRAFT**  
(Summer 2023)

## Firearm Team

- ➔ Ted Vorburger (PML→Associate)
- Wayne Arendse (DFS→Omega)
- ➔ John Butler (SPO)
- Greg Klees (DOJ/ATF)
- Steve Lund (ITL)
- Robert Thompson (SPO)
- Heather Waltke (Associate)
- James Yen (ITL)
- Jason Weixelbaum (Contractor)
- Shannan Williams (SPO)

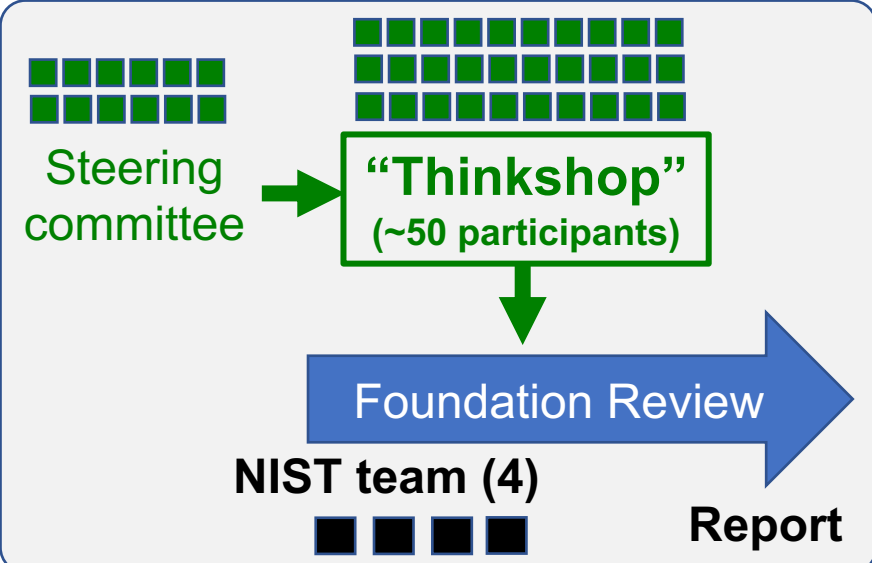
# Community Involvement and Input

### Model 1



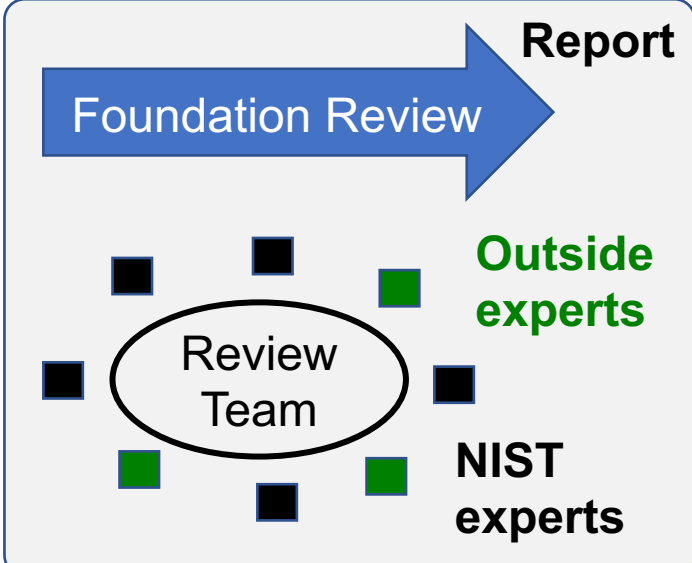
DNA Mixture Interpretation

### Model 2



Bitemark Analysis

### Model 3



Firearm Examination

**Model 4 Digital Evidence**  
Incorporated an interlaboratory study

Public Comment is sought on each report  
(they are initially released as “DRAFT”)

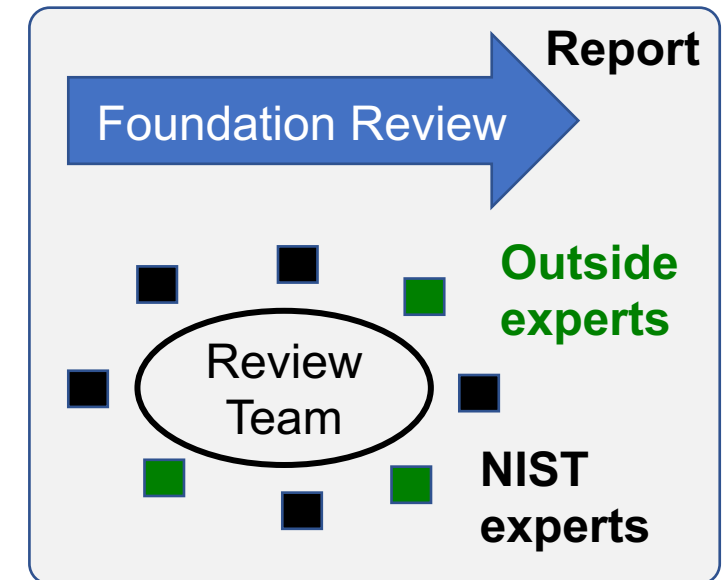
# Approach and Types of Data to Examine with Footwear Impression Evidence Foundation Study

Process Map  
created

Literature  
gathered

Workshop  
for input

- Published scientific literature
  - With a focus on peer-reviewed journals
- Publicly accessible proficiency test data
  - e.g., <https://cts-forensics.com/program-4.php>
- Publicly accessible validation data
  - e.g., <https://forensicstats.org/footwear-data-sets/>



**Footwear  
Impression  
Combining elements  
of Models 1, 2, & 3**

# 16 Publicly Available CTS Proficiency Tests

## Footwear Imprint Evidence

Year	CTS Test <small>533/5331 photos, 534/5332 DVD, 5335=digital download</small>	# Participants	# Samples
2014	14-533, 14-534	243, 38	7 Q, 2 K
2015	15-533, 15-534	222, 39	7 Q, 2 K
2016	16-533, 16-534	176, 38	8 Q, 2 K
2017	17-5331, 17-5332, 17-5335	154, 40, 21	7 Q, 2 K
2018	18-5331, 18-5332, 18-5335	129, 37, 20	9 Q, 2 K
2019	19-5331, 19-5332, 19-5335	122, 21, 36	6 Q, 2 K
2020	20-5331, 20-5335	113, 82	7 Q, 2 K
2021	21-5331, 21-5335	92, 63	7 Q, 2 K
2022	22-5331, 22-5335	94, 75	10 Q, 2 K
2023	23-5331, 23-5335	82, 63	6 Q, 2 K*
2024			

\* Provided 3D scans of recovered shoes

## Tire Track Imprint Evidence

Year	CTS Test <small>5351 photos, 5355 digital download</small>	# Participants	# Samples
2017	17-5351, 17-5355	30, 10	4 Q
2018	18-5351, 18-5355	31, 16	4 Q
2019	19-5351, 19-5355	38, 14	4 Q
2020	20-5351, 20-5355	30, 27	4 Q
2021	21-5351, 21-5355	35, 32	4 Q
2022	22-5351, 22-5355	28, 50	5 Q
2023			
2024			

**Total Number of Decisions: 231,759**  
(2,341 participants x 99 Q items decisions)

[cts-forensics.com/program-4.php](https://cts-forensics.com/program-4.php)

# CSAFE Footwear Data Sets

<https://forensicstats.org/footwear-data-sets/>

## FOOTWEAR DATA SETS



### Shoe Outsole Impression Data Set, 2018

Images of 160 pairs of athletic shoes in two styles and four sizes. Participants wore the shoes for at least 10,000 steps per week, and images of the shoes were taken at five-week intervals, producing five observation points for each pair of shoes.



### 2D Footwear Outsole Impression Data Set, 2020

A database of two-dimensional images of footwear outsole scans. There are 1,500 impressions from 150 pairs of used shoes. The information about the database contains the ID of the users, genders (for size), brands, models and sizes.



### Crime Scene Shoe Impression Data Set, 2021

A database of impressions from 330 shoes: 165 made in blood and 165 made in dust. A different subset of shoes was used for each impression type, and there is an unenhanced and an enhanced version of each impression. All impressions are oriented with the toe at the top



### ShoeRinsics Data Set, 2023

ShoeRinsics learns to predict shoe-tread depth from fully supervised synthetic data and unsupervised retail image data. This database includes two training data sets and two validation data sets consisting of shoe-tread images and print pairs.



# CSAFE Footwear Efforts

<https://forensicstats.org/footwear/>

- Partially funded as a NIST Center of Excellence
- Iowa State University, Carnegie Mellon University, University of California – Irvine, University of Virginia, Duke University, West Virginia University

## FOCUS Areas

Project FW.I - Occurrence and Persistence of Accidental Mark Locations on a Shoe Sole



Project FW.II - Statistical Models for the Generation and Interpretation of Footwear Impression Evidence



Project F.W.III – Characterization of Footwear in Local Populations



Project F.W.IV – Statistical and Algorithmic Approaches to Shoeprint Analysis







## Some Recent Presentations on CSAFE Footwear Research (see <https://forensicstats.org/footwear/>)

- AAFS 2023 [presentation](#): Hana Lee & Alicia Carriquiry, Source identification of shoeprints in mock crime scene using an algorithm based on automatic alignment (25 slides)
- AAFS 2023 [presentation](#): Valerie Han & Alicia Carriquiry, A comparison of various score-based likelihood ratio (SLR) methods for the quantitative assessment of footwear evidence (15 slides)
- IAI 2022 [presentation](#): Valerie Han & Alicia Carriquiry, A New Algorithm for Source Identification of Look-alike Footwear Impressions Based on Automatic Alignment (22 slides)
- AAFS 2022 [presentation](#): Jayden Stack, Rick Stone, Colton Fales, and Susan VanderPlas, Automatic Class Characteristic Recognition in Shoe Tread Images (18 slides)
- IAI 2021 [presentation](#): Alicia Carriquiry, Footwear research in CSAFE (45 slides)

# Recent NIST Research Projects on Footwear

## Funded by NIJ and Led by Marty Herman and Steve Lund

### 1. Quantitative Measures for Footwear Impression Comparisons (Started in Fiscal Year 2017, \$598,315)

The three major tasks in the project are (1) develop algorithms for hybrid feature extraction based on a human examiner guiding a computer algorithm that automatically extracts features, (2) collect a modest library of footwear data of known 'mated' and 'non-mated' pairs of impressions for development and testing, and (3) develop algorithms for computing comparison scores that summarize the degree of correspondences and discrepancies of features in two impression images. These tasks will be implemented over a two-year time frame.

NIST is partnering with footwear examiners from the FBI, Charlotte County (Florida) Sheriff's Office, and the Defense Forensic Science Center.

See [Forensics@NIST 2020 Presentation](#) (slides 25-43)

### 2. Quantitative Evaluation of Footwear Evidence: Advancing the Footwear Impression Comparison System (FICS) towards Casework Application (Started in Fiscal Year 2020, \$609,700)

The major project tasks are (1) collect and analyze impressions from at least 200 staged crime scenes (and corresponding test impressions) for algorithm testing, (2) automate clarity markups of crime scene impressions and refine other workflow components to address limitations identified during testing, (3) use FICS to participate in the FBI black box study. These tasks will be implemented over a two-year time frame.

NIST is partnering with footwear examiners from the FBI and will be working closely with CSAFE. Expected products include conference presentations, scientific papers, seminars, training workshops, tutorial videos, and implementations of all our algorithms that could be used by others.

See [Forensics@NIST 2022 Presentation](#) (Day2.4.mov; 21-30 minutes)

# NIST Research Publications on Footwear Evidence

Received: 4 August 2020 | Revised: 24 November 2020 | Accepted: 3 December 2020

DOI: 10.1111/1556-4029.14658

**PAPER**

*J Forensic Sci.* 2021;66:890–909

JOURNAL OF  
FORENSIC SCIENCES 

Criminalistics

## Comparing footwear impressions that are close non-matches using correlation-based approaches

Gautham Venkatasubramanian MSc | Vighnesh Hegde MSc | Sarala Padi PhD |  
Hari Iyer PhD | Martin Herman PhD

Received: 26 February 2021 | Revised: 5 June 2021 | Accepted: 30 June 2021

DOI: 10.1111/1556-4029.14802

**PAPER**

*J Forensic Sci.* 2021;66:2232–2251

JOURNAL OF  
FORENSIC SCIENCES  

Criminalistics

## Quantitative evaluation of footwear evidence: Initial workflow for an end-to-end system

Gautham Venkatasubramanian MSc | Vighnesh Hegde MSc | Steven P. Lund PhD |  
Hari Iyer PhD | Martin Herman PhD

 NATIONAL CRIMINAL JUSTICE REFERENCE SERVICE

OFFICE OF JUSTICE PROGRAMS  
BJA BJS NIJ OJP OVC SMART 

The author(s) shown below used Federal funding provided by the U.S. Department of Justice to prepare the following resource:

Document Title: Quantitative Measures for Footwear Impression Comparisons  
Author(s): Martin Herman, Ph.D., Steven Lund, Ph.D., Hari Iyer, Ph.D., Gunay Dogan, Ph.D., Adam Pintar, Ph.D., Yooyoung Lee, Ph.D.  
Document Number: 303985  
Date Received: December 2021  
Award Number: DJO-NIJ-17-RO-0202

This resource has not been published by the U.S. Department of Justice. This resource is being made publicly available through the Office of Justice Programs' National Criminal Justice Reference Service.

Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

<https://www.ojp.gov/pdffiles1/nij/grants/303985.pdf>

# An Excellent Collection of Resources Already Available

<https://treadforensics.com/>



HOME

ABOUT

STANDARDS

RESEARCH

ADMISSIBILITY

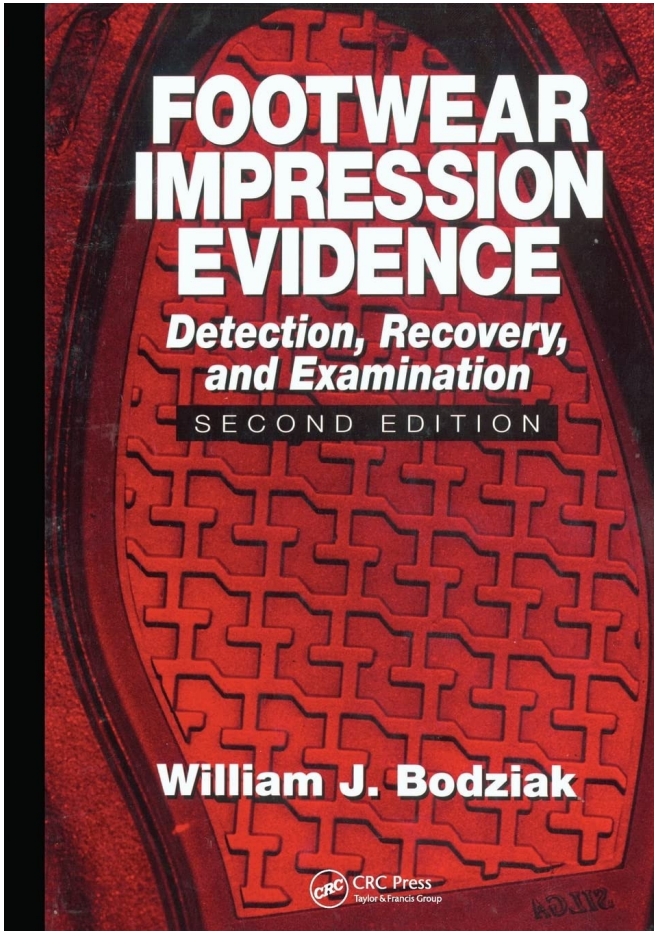
PUBLICATIONS

SWGTTREAD FORUM

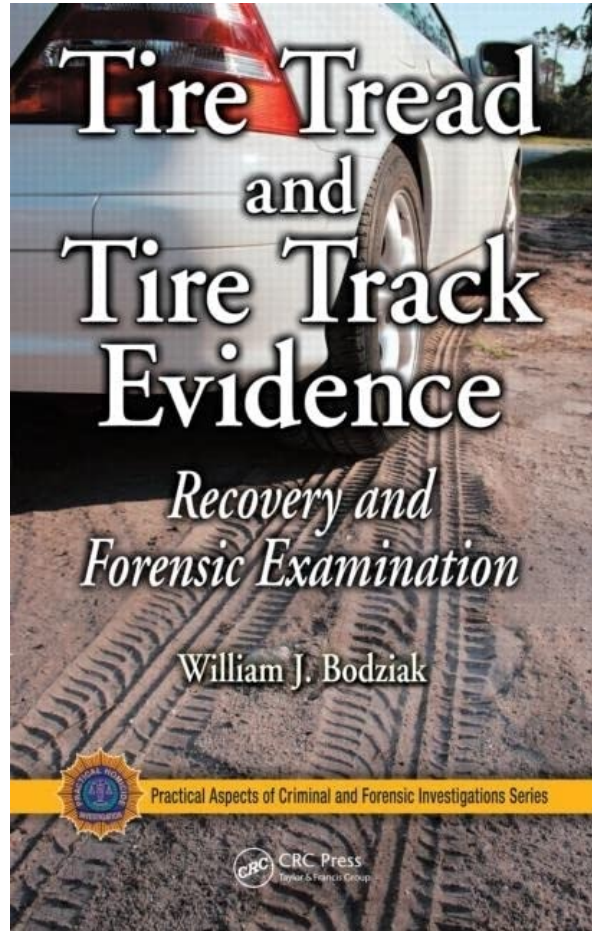
Tread Forensics is a website dedicated to providing footwear and tire resources to the forensic community. The site went live in April 2017 and was created to perpetuate the online resources available at SWGTREAD.org.

The Scientific Working Group for Shoeprint and Tire Tread Evidence (SWGTTREAD) was created in 2004 by the FBI Laboratory to standardize and advance the forensic analysis of footwear and tire impression evidence. The first meeting took place in September 2004 and the last in March 2013. From 2004 to 2013, the working group was co-funded by the FBI and the National Institute of Justice (NIJ). However, In October 2014, the [Footwear and Tire Subcommittee](#) of the [National Institute for Standards and Technology](#) (NIST) [Organization of Scientific Area Committees](#) (OSAC) was created. At that point, SWGTREAD decided to discontinue its operations and focus its efforts on supporting the subcommittee; however, the OSAC subcommittee identified the latest versions of the SWGTREAD standards as the baseline documents that best reflect the current state of the practice of forensic footwear and tire analysis and thus re-published them on the [subcommittee's website](#).

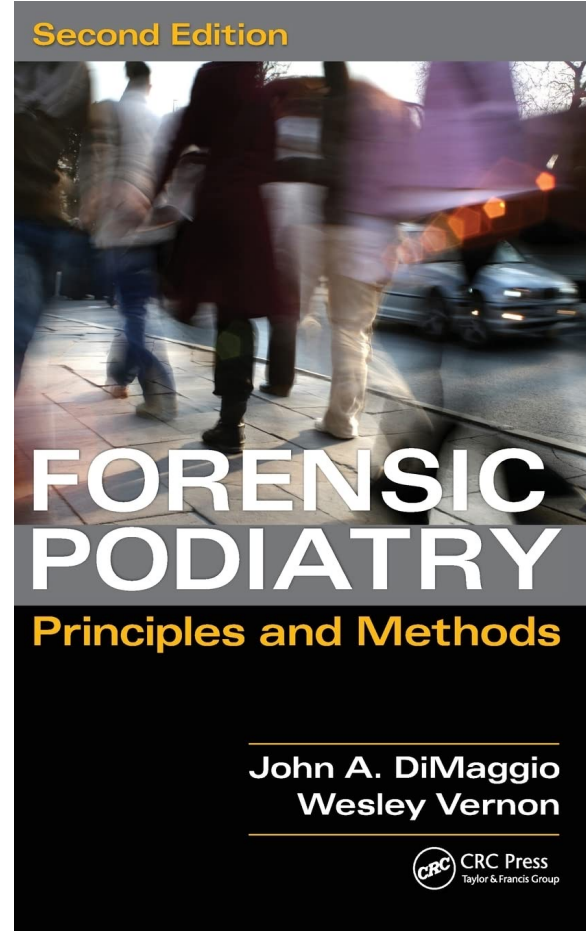
# Books on Footwear and Tire Tread Analysis



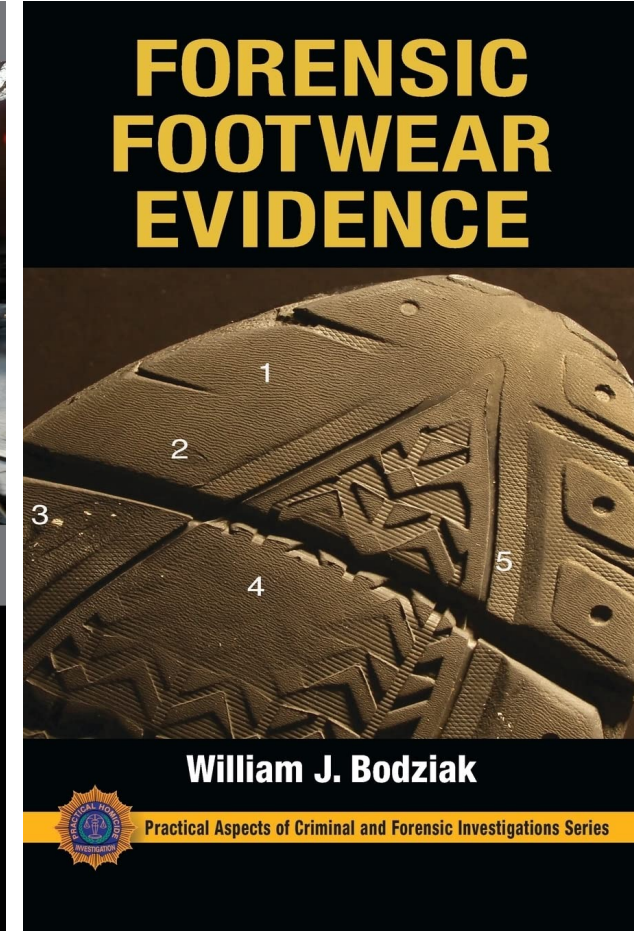
(CRC Press, 2000)



(CRC Press, 2008)



(CRC Press, 2017)



(CRC Press, 2017)

# Recent Interpol Reviews on Shoe Marks

<https://www.interpol.int/How-we-work/Forensics/Forensic-Symposium>

<https://www.interpol.int/content/download/13472/file/INTERPOL%2018th%20IFSMS%20Review%20Papers-2016.pdf>

## Criminalistics Marks, 2013-2016

Martin Baiker, PhD  
Section of Weapons and  
Division of Chemical  
Netherlands Forensic  
Laan van Ypenburg 6  
[m.baiker@nfi.minvenj](mailto:m.baiker@nfi.minvenj)

Forensic Science International: Synergy 2 (2020) 521–539

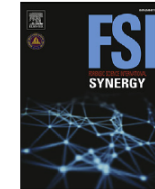
Contents lists available at [ScienceDirect](#)



ELSEVIER

Forensic Science International: Synergy

journal homepage: <https://www.journals.elsevier.com/forensic-science-international-synergy/>



## Interpol review of shoe and tool marks 2016-2019

Martin Baiker-Sørensen\*, Koen Herlaar, Isaac Keereweer, Petra Pauw-Vugts, Richard Visser

Section of Firearms and Tools  
Netherlands

Forensic Science International: Synergy 6 (2023) 100308

Contents lists available at [ScienceDirect](#)



ELSEVIER

Forensic Science International: Synergy

journal homepage: [www.sciencedirect.com/journal/forensic-science-international-synergy](http://www.sciencedirect.com/journal/forensic-science-international-synergy)



## Interpol Review Paper of Marks and Impression Evidence 2019-2022

Jonathan Charron, Catherine Currier, Philip Hess\*, Patrick Jacobs, Jeremy Zerbe

Comparative Evidence Unit, Sacramento County District Attorney's Laboratory of Forensic Services, 4800 Broadway, Suite 200, Sacramento, CA, 95678, United States

**104 references  
(2013-2016)**

**154 references  
(2016-2019)**

**49 references  
(2019-2022)**

# Additional Resources for the Footwear Community

- **Comprehensive literature list** (in progress)
  - Printed articles (*see binders brought today*)
  - Google Drive with all articles
  - Articles are initially for project team members and can hopefully be made more widely available to aid future training
- **Process Map**
  - Created with input from the OSAC Footwear & Tire Subcommittee
  - Completed in June 2022 (*11" x 17" copies available today*)

# Literature Summary (so far)

Kelly



# Sources of Information Gathered So Far

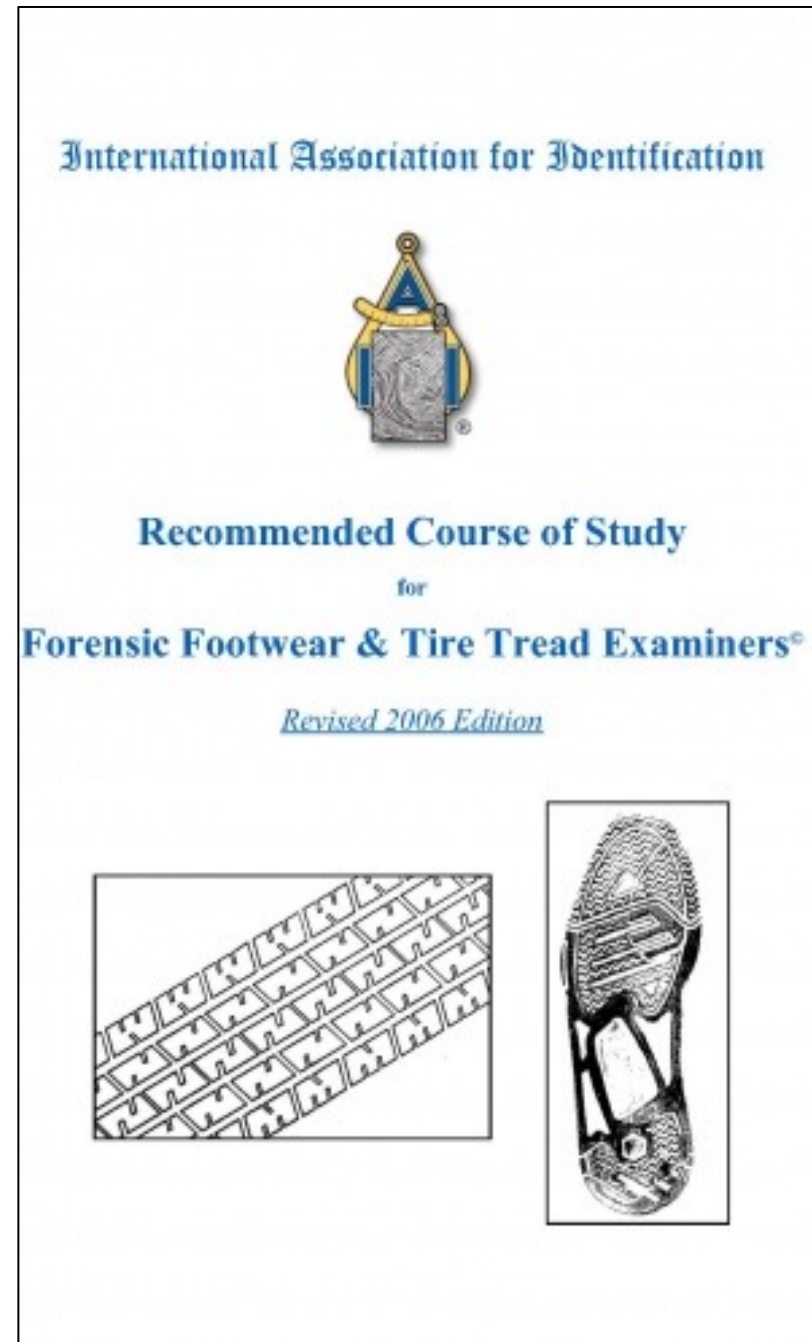
**875+ references span from 1930-2022**

Publicly available sources including:

- Peer-reviewed scientific publications
  - Documentary standards (SWGTTREAD, OSAC, ASB)
  - Footwear and Tire Examination Process Map
  - Professional association training material
- 
- Bibliographies:
    - IAI Training Manual (2006)
    - SWGTREAD Response to White House SoFS (Subcommittee on Forensic Science) RDT&E(2011)
    - OSAC Footwear/Tire SC Response to PCAST's request for information (2015)
    - OSAC FWTT: Foundational Studies Related to Footwear Impression Evidence (2017)
    - Shoe, Foot, & Tire Impression Evidence, and Casting Bibliography (2019)

# Resources: IAI Training Manual

- 383 resources
  - Includes 76 unpublished papers and presentations
  - 13 non-English articles (e.g. Swedish, German, Japanese)
- 1932 – 2006
- Only 2 articles in last 25 years & both in 2006; next recent: 1994
  - 137 articles b/t 1980-1998
- Incorrect references including misspellings, typos, volume/date/issue not listed
- Available from IAI webstore
- How is this being used?



## Product Page - Recommended Course of Study for Footwear and Tire Track Examiners

[Return to Store](#)

### Recommended Course of Study for Footwear and Tire Track Examiners

\$56.00 USD

- Frequency: Updated as required
- Editor: IAI Footwear and Tiretrack Subcommittee

#### ABSTRACT

The IAI Footwear and Tire track Subcommittee has developed this valuable resource which outlines a model for essential training requirements concerning footwear and tire track examinations.

A detailed lesson plan for basic study organizes the type and extent of minimum instruction needed in the various aspects of footwear and tire track identification. Topics include manufacturing processes, impression photography, enhancement methods, recovery by lifting and casting and decision making. There is also an extensive list of recommended reference material in the form of books, articles and ancillary programs.

The reference section will be updated regularly by the IAI Footwear and Tire Track Subcommittee.

# SWGTHREAD 2011 Response to White House SoFS (Subcommittee on Forensic Science) RDT&E

- **107 references**; 7 references in common with IAI Training Guide
- 14 sets of questions:
  1. What literature exist that addresses the number of characteristics/identifying marks required to render a conclusion?
  2. What is the literature that discusses the use of statistics to support an examiner's conclusion?
  3. What literature exists that measures the consistency of examiner conclusions, incorporating multiple examiners, with various training and experience, given the same sample set of known "matches" and known "non-matches" of varying quality?
  4. What is the literature that addresses the effects of examiner experience/training/caseload in shoeprint/tire tread examinations?
  5. What is the literature on the potential and actual cognitive bias in shoeprint and tire tread examinations?
  6. What literature exists that investigates the effects of environmental conditions on shoeprint/tire treads? What is the literature that documents the formation of individual characteristics amongst a group of people wearing the same shoe for the same period of time?
  7. What is the literature that investigates the transfer of identifying features from sole or tread to impression medium across differing substrates?
  8. What is the literature hat investigates the development of defects/individualizing characteristics on different sole or tread materials?
  9. What literature exists that describes the automated systems in shoeprint/tire tread examinations? What literature exists that addresses the accuracy and validity of automated systems in shoeprint/tire tread examinations? What literature exists that addresses the effectiveness of human examiners and automated systems used in conjunction to render a conclusion in shoeprint/tire tread examinations?
  10. What is the literature on error rates in shoeprint/tire tread examinations?
  11. What is the literature that addresses the feasibility and reliability of partial print comparisons (i.e., situations where some of the sole pattern may be present with individual detail, but there is insufficient detail to compare class characteristics)?
  12. What is the literature that describes the rarity of class characteristics and uniqueness of individual characteristics in shoeprints/tire treads? What published databases exist that describe the frequency statistics of various shoeprint tire tread patterns?
  13. What is the literature on quantification; measurement precision and uncertainty in shoeprint/tire tread examinations? For example are there studies that would help describe "small" and "large" scratches in terms of measurement uncertainty? For example is  $>1.0\text{cm} \pm 0.1\text{cm}$  big and how jagged does a scratch need to be before it is unique?
  14. What is the literature on population-based studies that describe variation (e.g., due to gender, pathologies, heigh/weight, running vs walking, stride, etc.)?

# OSAC FW/TT SC Response to PCAST's Request for Information (2015)

- **41 references**; 2 references in common with IAI Training Manual
- 6 sets of questions:
  1. What studies have been published in the past 5 years RE: FW/TT? What studies have been published in the past 5 years that support the foundational aspects of each of the pattern-based forensic science methods, including (but not limited to) FW/TT? What studies are needed to demonstrate the reliability and validity of these methods?
  2. Have studies been conducted to establish baseline frequencies of characteristics or features used in these pattern-based matching techniques? If not, how might such studies be conducted? What publicly accessible databases exist that could support such studies? What closed databases exist? Where such databases exist, how are they controlled and curated? If studies have not been conducted, what conclusions can and cannot be stated about the relationship between the crime scene evidence and a known suspect or tool (e.g., firearm)?
  3. How is performance testing (testing designed to determine the frequency with which individual examiners obtain correct answers) currently used in forensic laboratories? Are performance tests conducted in a blind manner? How could well-designed performance testing be used more systematically for the above pattern-based techniques to establish baseline error rates for individual examiners? What are the opportunities and challenges for developing and employing blind performance testing? What studies have been published in this area?
  4. What are the most promising new scientific techniques that are currently under development or could be developed in the next decade that would be most useful for forensic applications?
  5. What standards of validity and reliability should new forensic methods be required to meet before they are introduced in court?
  6. Are there scientific and technology disciplines other than the traditional forensic science disciplines that could usefully contribute to and/or enhance the scientific, technical, and/or societal aspects of forensic science? What mechanisms could be employed to encourage further collaboration between these disciplines and the forensic science community?

# OSAC FWTT: Foundational Studies Related to Footwear Impression Evidence (2017)

- **90 references:** articles, books, presentations
- 11 references in common with IAI Training Guide
- Studies related to:
  - Reliability and examination of class (manufactured) characteristics
  - Reliability and examination of wear and randomly acquired characteristics
  - Examiner conclusions
  - Automated classification of footwear, database creation, and intelligence
  - Terminology

[https://www.nist.gov/system/files/documents/2018/10/26/foundational\\_publications\\_footwear\\_20170224.pdf](https://www.nist.gov/system/files/documents/2018/10/26/foundational_publications_footwear_20170224.pdf)

# Shoe, Foot, & Tire Impression Evidence and Casting Bibliography (2019)

- **1042 resources:** articles, books, presentations
  - Wide range of topics included:
    - Podiatry, Anthropology, Fingerprint Analysis, Bloodstain Pattern Analysis, Pathology
    - Some not related to our applications for footwear or tire impression examination
  - 1930 – 2016
- 173 references in common with IAI Training Guide
- Many references unavailable or misspellings/errors/duplications

Hochrein, Michael from *A Bibliography Related to Crime Scene Interpretation with Emphasis in Geotaphonomic & Forensic Archaeological Field Techniques*. 19<sup>th</sup> Edition

[https://www.researchgate.net/publication/332472283\\_Section\\_Shoe\\_Foot\\_and\\_Tire\\_Impression\\_Evidence\\_Bibliography](https://www.researchgate.net/publication/332472283_Section_Shoe_Foot_and_Tire_Impression_Evidence_Bibliography)

# Sources of Information

- References in common between all 5 bibliographies:
  - Bodziak WJ (1986) Manufacturing process for athletic shoe outsoles and their significance in the examination of footwear impression evidence. *Journal of Forensic Sciences*, 31(1):153-176.
  - Hamm ED (1989) The individuality of class characteristics in Converse All-Star footwear. *Journal of Forensic Identification*, 39(5):277-292.
  - Keijzer J (1990) Identification of value imperfections in shoes with polyurethane soles in comparative shoeprint examination. *Journal of Forensic Identification*, 40(4):217-223
  - Music DK, Bodziak WJ (1988) Evaluation of the air bubbles present in polyurethane shoe outsoles as applicable in footwear impression comparisons. *Journal of Forensic Sciences*, 33(5):1185-1197.
  - Zmuda CW (1953) Identification of crepe-sole shoes. *Journal of Criminology, Criminal Law, and Police Science*, 44(3):374-378.



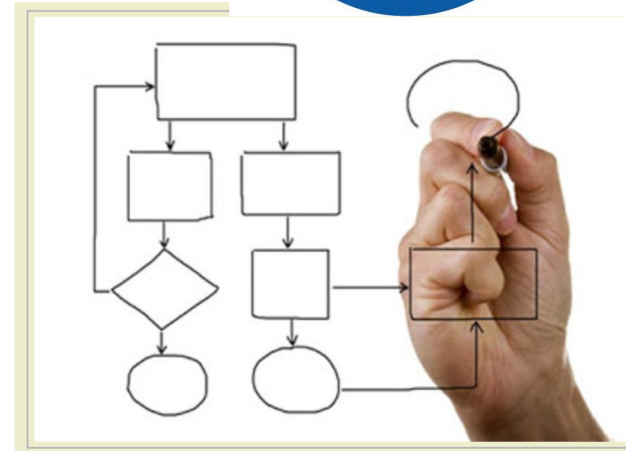
Author	Sample	Topic/Conclusion
Zmuda 1953	N=200 crepe soled shoes, 100 consecutively cut soles, ~50 sole assemblies.	Details the manufacturing process and materials used to make a particular crepe soled shoe. Found that overall no two crepe soles examined were found to be exactly alike due to variations that occur during the manufacturing process.
Bodziak 1986	N/A	Details the most common manufacturing processes of the outsoles of athletic footwear and significant individualizing characteristics
Music & Bodziak 1988	N/A	Describes the chemical, mechanical, and physical variables that influence the position and contour of air bubbles in outsoles
Hamm 1989	N/A	Describes assembling process of Converse All-Stars and characteristics such as mold design, foxing strip, bumper guard, heel label which can be highly individual.
Keijzer 1990	N= 22 soles (14L, 8R)	Air bubbles tended to occur in the same places on the sole surface with some being similar in size and shape. Occasional imperfections due to dirt or damage to a mold can be identifiable as such and be of great identification significance.



# Additional Work Products from OSAC

<https://www.nist.gov/osac/osac-work-products>

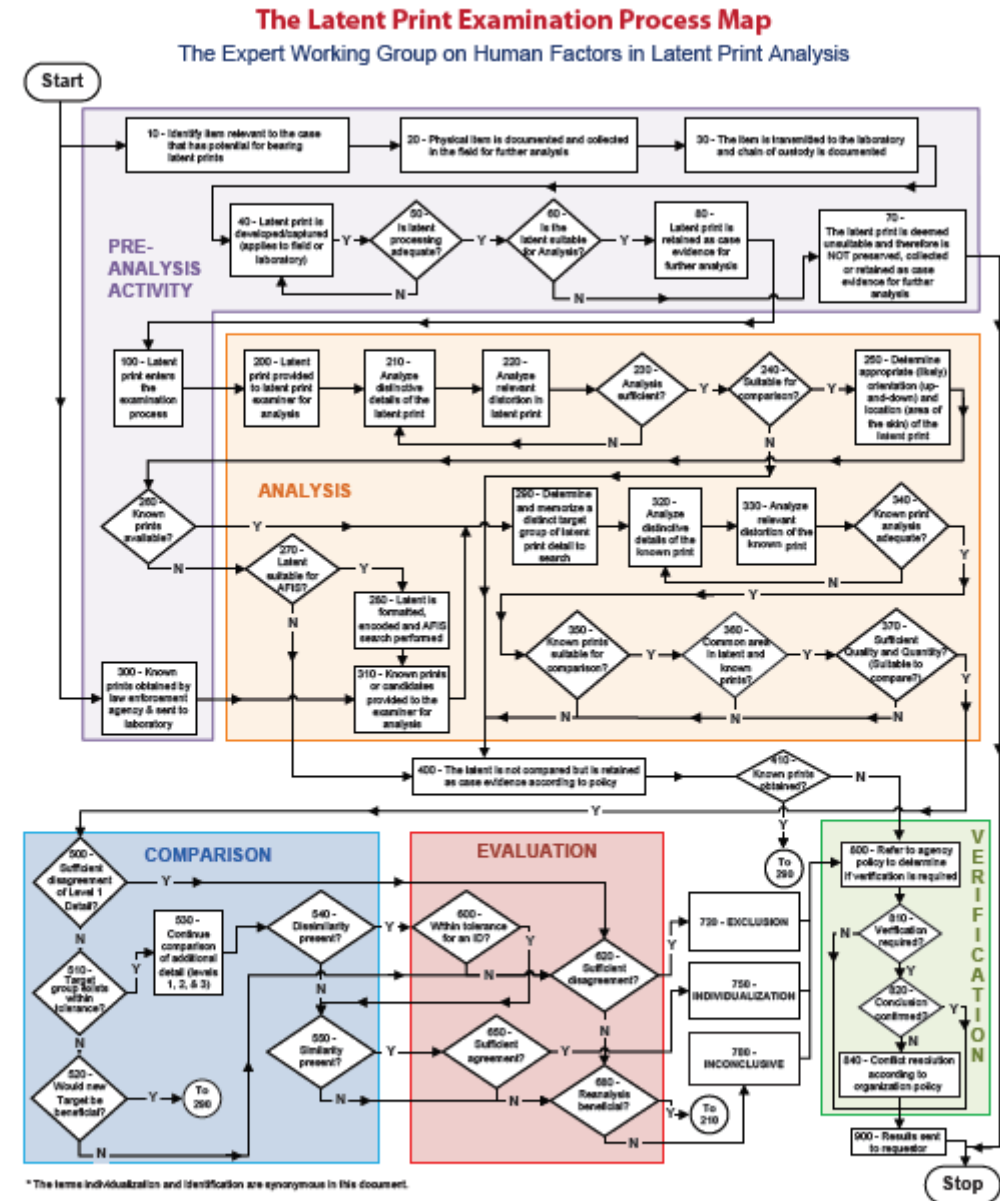
- Bibliographies
- Interlaboratory comparisons
- OSAC Lexicon
- ➔ • Process maps
- R&D needs
- Reference documents
- Standards development maps
- Technical guidance documents
- Webinars/presentations



# Process Maps Create a Shared Understanding

- Shows others how a process is done
- Helps users to analyze how the process could be improved
- Improves communication between individuals engaged in the same process

*Beneficial in understanding terminology and standard practices. Helpful in training and scenario analysis.*



# Process Maps Created to Reflect Current Practices

<https://www.nist.gov/organization-scientific-area-committees-forensic-science/osac-work-products>

***Created in partnership with practitioners from OSAC and other groups***

**Goal:** To create discipline-specific process maps that offer a visual description of current forensic evidence examination practices.

1. [Friction Ridge Process Map](#) (February 2012; 1 page; December 2019; 13 pages)
2. [Speaker Recognition Process Map](#) (September 2019; 32 pages)
3. [Firearms Process Map](#) (January 2021; 25 pages)
4. [Handwriting Analysis](#) (May 2021; 1 large page)
5. [Human Forensic DNA Analysis Process Map](#) (May 2022; 42 pages)
6. [Footwear & Tire Examination Process Map](#) (June 2022; 37 pages)
7. [Seized Drugs Process Map](#) (November 2022; 19 pages)
8. [Fire Investigation Process Map](#) (March 2023; 18 pages)

**Interactive Process Map  
for Latent Print Examination**  
<https://ipm.nist.gov/lpe>



- *In development...* (crime scene investigation, wildlife, more firearms examination)

<https://www.nist.gov/spo/forensic-science-program/process-mapping>

# **Introduction to Process Maps and Footwear & Tire Examination Process Map**

Melissa

# About Me: Melissa K. Taylor

- B.A. Public Policy (UMD)
- 20 years working with the Forensic Sciences
  - Consultant for NIJ General Forensics Program
  - Senior Forensic Science Research Manager, NIST Special Programs Office
  - Focus on impression and pattern evidence-related research, process mapping, and human factors
- Publications related to human factors, human subjects research, evidence management, building state-of-the-art crime labs, and AFIS interoperability
- Leads NIST human factors, process mapping efforts, and AFIS interoperability projects
- Recent interests: everything AI

# Big Questions in Forensic Science

- Do we understand the task/processes/system?
- Do we have the right analytical methods/technologies?
- Do we have the right people,
  - in the right roles ...
  - with the right information ...
  - and the right skills?
- How best can we communicate the work that has been done?

# Process Defined

A process is a series of **definable**, **repeatable** and **measurable**, **verifiable** steps which transforms inputs into outputs of value to a customer (internal or external).

It has a specific starting point and ending point with an ordered, sequenced set of activities that must be performed.







**Standard Shoelace Knot  
(aka Bunny Rabbit)**



**Two Loop  
Shoelace Knot  
(aka Bunny Ears)**



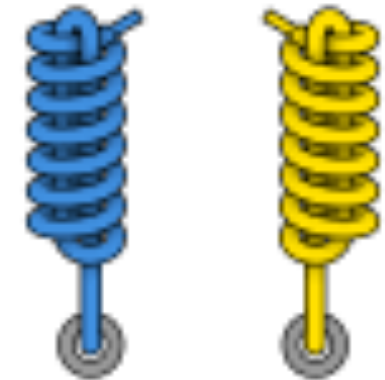
**Ian's Fast Shoelace Knot  
(aka World's Fastest  
Shoelace)**



**Surgeon's Shoelace  
Knot  
(aka Sherpa Knot)**



**Better Bow Shoelace  
Knot**



**Boat Shoe Knot  
(aka Heaving Line Knot)**





## Balanced Shoelace Knot

If both stages are tied in **opposite** directions, those twists cancel out each other, resulting in a “balanced” knot that sits straight (bows lying across the shoe from left to right) and that stays securely tied.



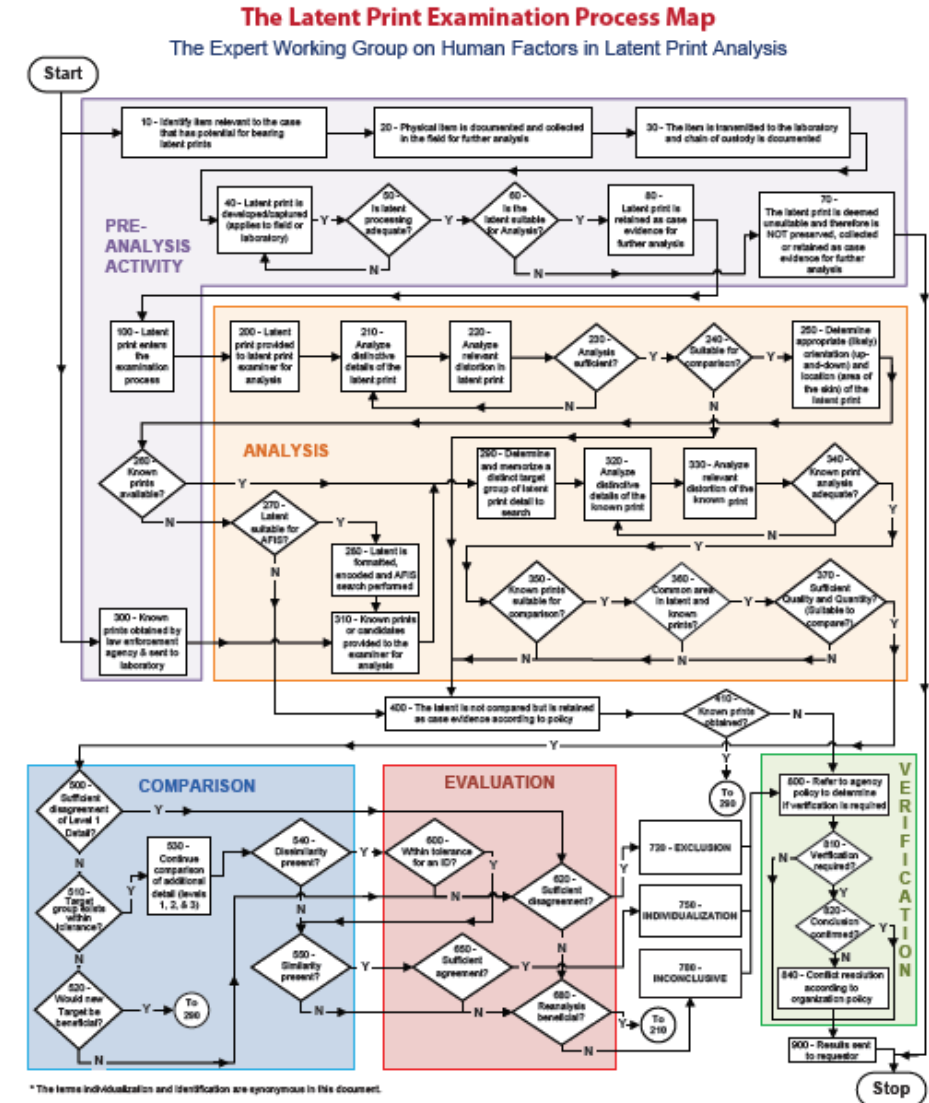
## Un-balanced “Granny Knot”

If both stages are tied in the **same** direction, those twists compound each other, resulting in an “un-balanced” knot that sits crooked (bows lying along the shoe from heel to toe) and that comes loose more easily.

# What is a Process Map?

It's a tool that:

- Visually depicts the
  - flow of work
  - steps
  - people involved in a process
- Helps users to analyze how the process could be improved
- Improves communication between individuals engaged in the same process



# Types of Process Maps

## Level 1 –The Macro Process Maps

- Visualizes only major process steps and their relationship to each other
- Can be used with only a general understanding of the purpose of the process and its steps

## Level 2 – Worker Bee Process Maps

- Visualizes **ALL** the major steps a worker takes to complete a process
- Contains the exact steps, the exact inputs, outputs, metrics and the exact people that are needed to execute the process

## Level 3 – Micro Process Maps

- Focuses on a specific area, a group of steps, or a single step in the process that may be causing a challenge
- Breaks down steps further into actions

# How we do it: Constructing a Process Map

- There are **NO** right or wrong steps in the map.
- Everyone should see their process in the map.
- If someone does it, it gets mapped.

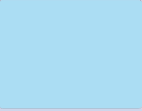











## How we do it: Constructing a Process Map

Since this is a descriptive process mapping exercise, no **SHOULD** statements are considered during the creation

# How we do it: Standard Process Map Shapes

Symbol	Name	Description
	Process	The most frequently used flowchart shape shows an action, task or operation that needs to be done
	Subroutine	Shows a multistep action that may be predefined in a standard, by lab policy, and/or by examiners; it could also mean that there is already a flowchart that can be used as a reference
	Document	Indicates a process step that generates documentation
	Decision	The point at which a decision needs to be made; the arrows flowing from the decision shape will be labeled with yes or no
	Arrow	The arrows indicate the direction in which the flowchart should be read
	Connector	In order to connect to different page or section of the chart, and you can't draw a line
	Input/Output	Summarizes the material or information entering or leaving the process
	Terminator	Represents the entry and exit points of your flowchart

# How we do it: Selecting the Mapping Team

- 7-10 people who **DO** the work
- Diverse Group
  - Different schools of thought/learning/training/practice
  - Lab Type - State/Local/Fed/Private, Large, Small
  - Geographic
  - Years of Experience
  - Age, Sex, Race, etc.
  - International Representation
- Trainers, Auditors

# **The Footwear and Tire Process Mapping Team**



**Melissa Taylor - Facilitator**

**Heather Waltke – Facilitator/Lucid Chart**

**Cory Bartoe**

**Leslie Hammer**

**Amanda Hunter**

**Alan Kainuma**

**Tony Koertner**

**Vanessa Styx**

**Alicia Wilcox**

# How we do it: Mapping Team

**Come willing to share.**

They may find it helpful to have access to the following materials during the meetings:

1. A copy of their agencies' **SOPs** or other reference documents (e.g., **checklists, standards**). Documents such as these may provide useful terms and definitions and may also serve as a reminder of forgotten steps.
2. **Case examples.** They may find it useful to come to the meeting with a few case examples/scenarios in mind that can be used to test the completeness of the process map.
3. **Other process maps** that cover the discipline. Some labs may have undergone process mapping exercises in the past or individuals may be aware of an existing process map in the published literature. It may be helpful to refer to previous process maps for language suggestions or recommendations on the ordering of steps.

# How we do it: Constructing a Process Map

**Step 1: Determine the Boundaries** - Determine the start and stop points to your flow of process steps

**Step 2: List and Sequence the Steps** - Write down the process steps as they exist now.

- If there are feedback arrows, make sure feedback loop is closed

**Step 3: Check for Completeness (internal)**

- “Walk the process”, repeatedly
- Analyze/review from finish to start

**Step 4: Finalize the Map (external)**

- Did we miss anything?

# Process Map Key Elements



- Intro and scope
- 30K process “overview”
- Disclaimers
- Map directionality
- Agency driven tasks and decisions (PAP)
- Loops, process linkages, and general “flow”
- Task “stops” and dealbreakers
- Points of variation
- Critical steps during examination

# Intro and Scope

The National Institute of Standards and Technology (NIST) facilitated the development of this Footwear and Tire Examination Process Map through a collaboration between the NIST Forensic Science Research Program and the NIST administered Organization of Scientific Area Committees (OSAC) for Forensic Sciences (specifically OSAC's Footwear and Tire Subcommittee).

This Footwear and Tire Examination Process Map (Current Practice) captures details about the various procedures, methods and decision points most frequently encountered in the discipline of footwear and tire examination from a national perspective and discipline requires examiners to make many decisions that can impact the quality and accuracy of results. The discipline by providing a behind-the-scenes perspective into the various components and de

reflect current practices

Process mapping is the visual representation of the critical steps and decision points of a process. Components of the process are deconstructed, placed into specific shapes within a flowchart and connected by one-way arrows to indicate directionality regarding decisions as well as progression throughout the overall process. The shape of each box assists the reader by representing a specific type of activity.

This process map captures the **diverse** practices of multiple laboratories, with the goal of allowing a footwear and tire examiner to find their process represented in the map. To ensure this, the mapping team avoided creating a map of what **should** be done (i.e. best practices) and instead attempted to represent all reasonable variations of casework **currently performed** by footwear and tire examiners. For this reason, it is important to state that the OSAC Footwear and Tire Subcommittee does not necessarily support or endorse (as best practices) all of the different steps and paths depicted in this process map.

This map is not intended to be a step-by-step instruction manual outlining minutia, nor is it intended to be so broad that it lacks utility. Rather, judgments were made by the process mapping group as to which steps should be combined and which steps should be divided further. Certain processes represented in the map vary by examiner or agency. Processes and decisions may also be dictated by agency policy or law.

## Process Map Applications:

The Footwear and Tire Examination Process Map is intended to be used to help improve efficiencies while reducing errors, highlight gaps where further research or standardization would be beneficial, and assist with training new examiners. It may also be used to develop specific laboratory policies and identify best

## Scope of the Footwear and Tire Examination Process Map:

examination such as the examination of questioned footwear and tire impressions and the comparison of these impressions to known footwear or tires. Several topics are omitted from this map including crime scene collection and intercomparison of questioned impressions. These topics may subsequently be addressed by the process mapping team, an individual laboratory or a standardization committee.



# The 30,000 foot view

1000 - Administrative Assessment

2000 - Technical Assessment

3000 - 5000 Questioned Impression Processing and Analysis

6000 - Known Footwear/Tire Analysis

7000 - Reference Search

8000 - Comparison/Evaluation

9000 - Verification

Other - not included in this map\*



Underlined Word  
Word that will be defined in the glossary

**Technology Assist**  
Technology that aids in the steps on this page

**Input Box**  
Outlines the inputs at the beginning of each section

**Output Box**  
Describes an output of the steps on the page

**Discontinuation of Assessment or Examination**

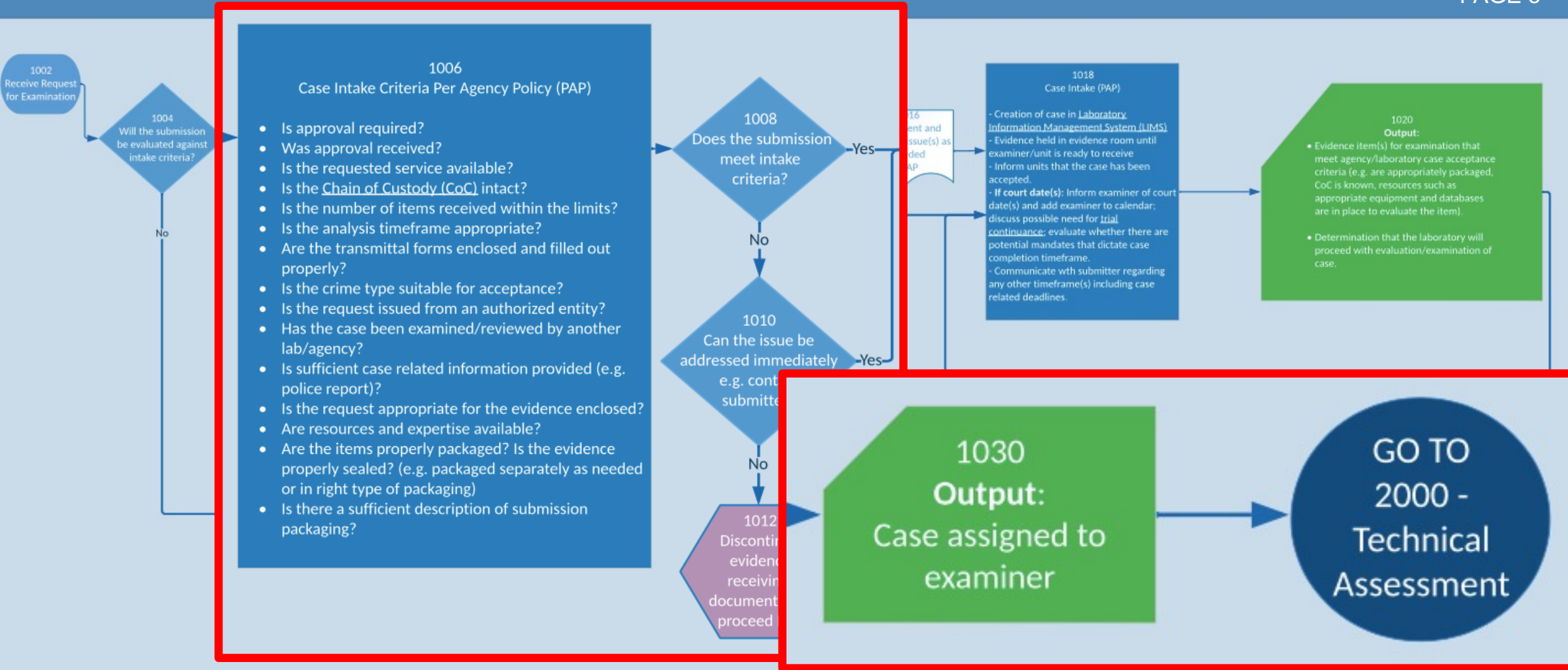
Legend	
	Process start/end
	Process
	Decision
	Subprocess
	Document

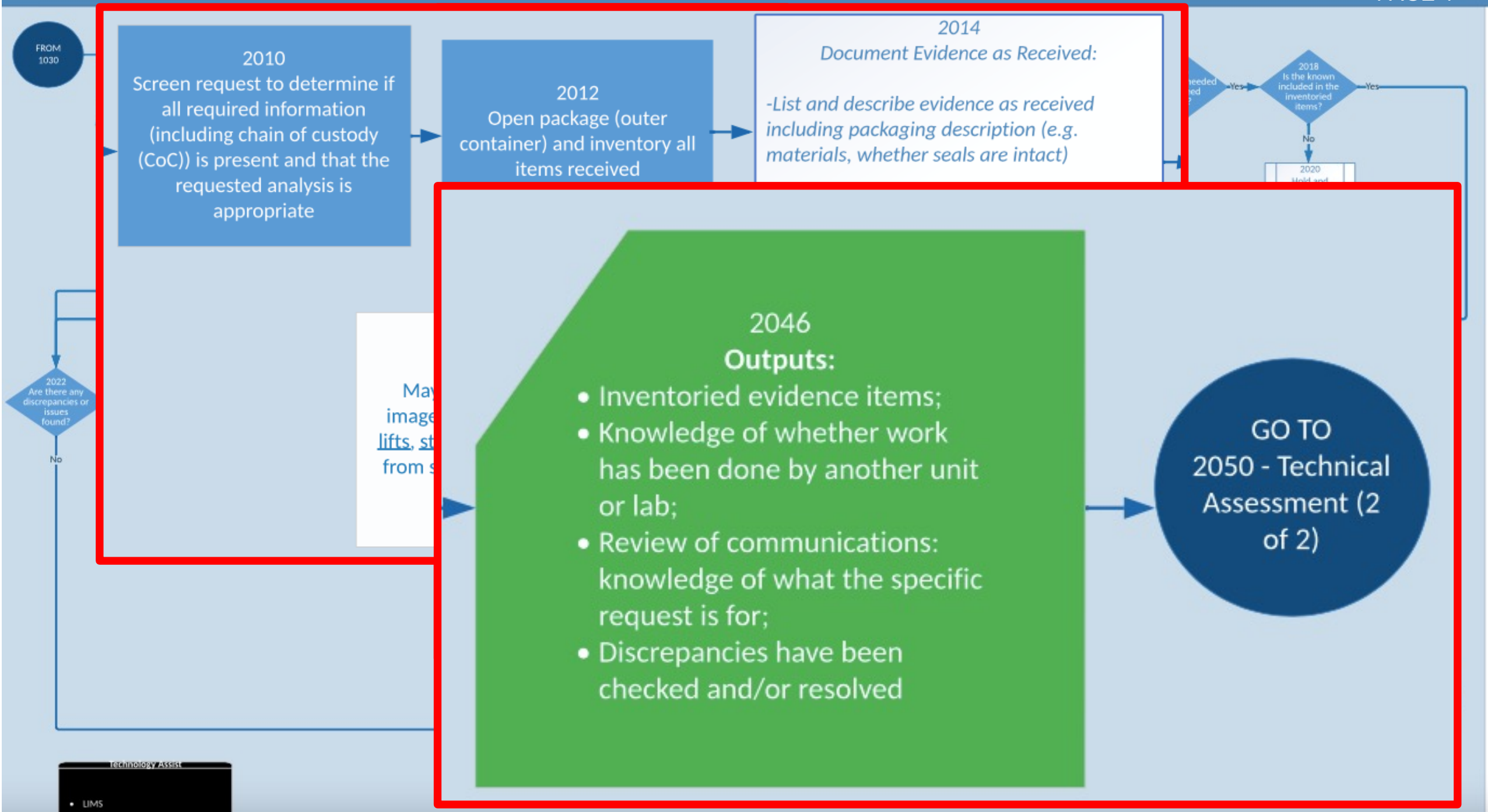
# Administrative

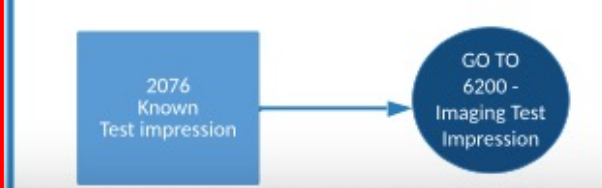
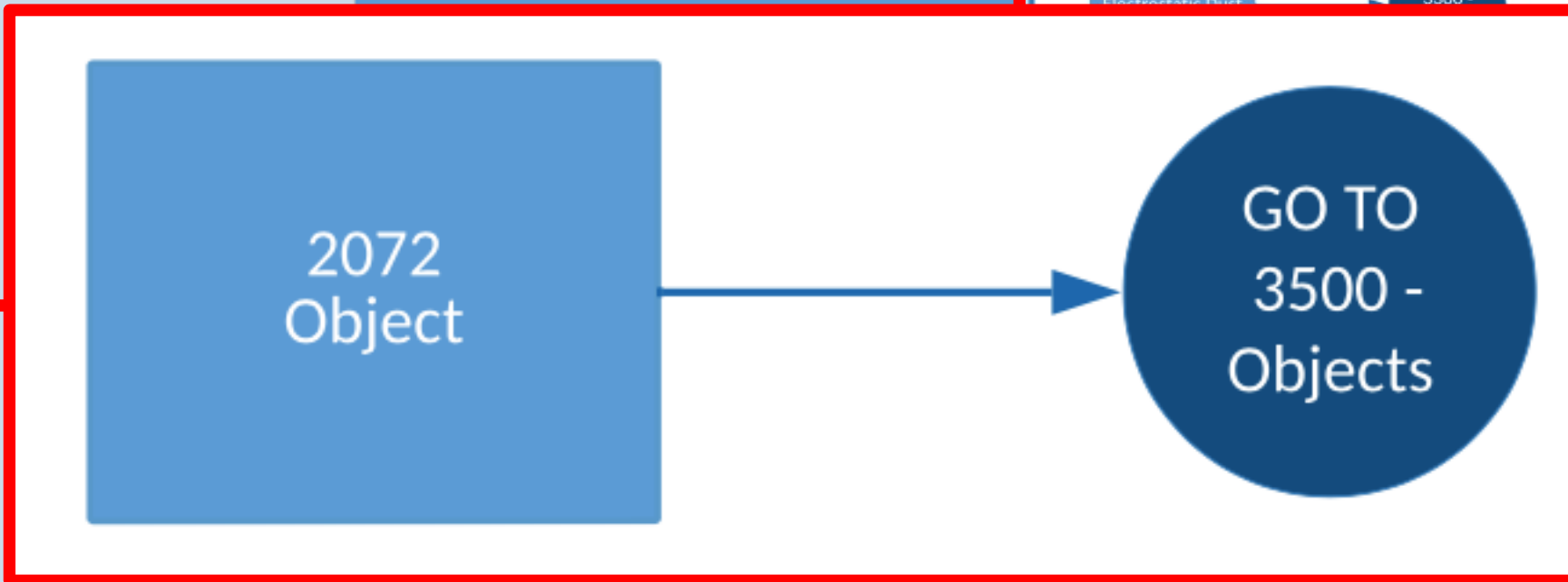
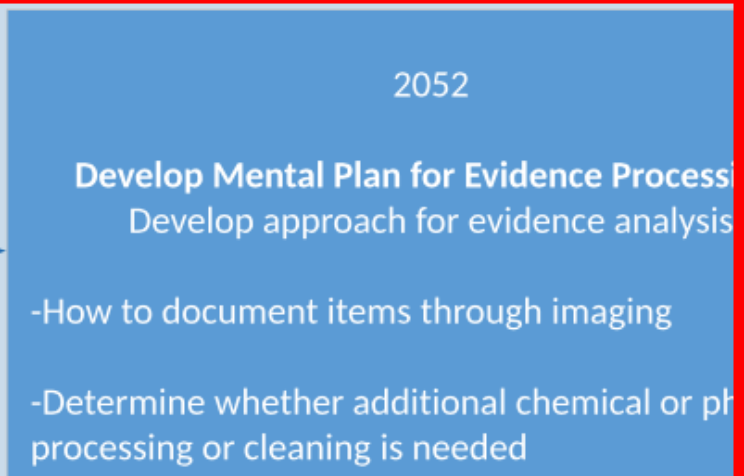
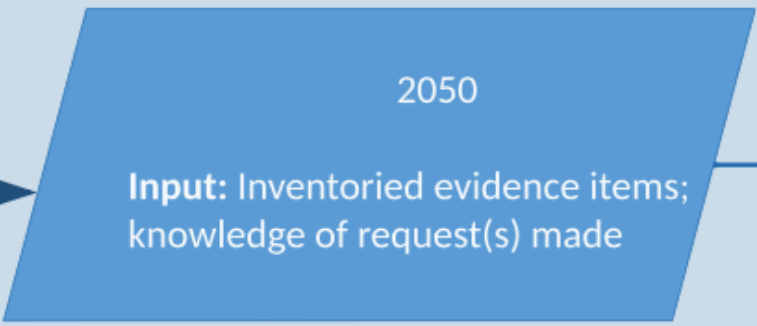
1000 - Administrative Assessment

PAGE 3

[Return to Overview](#)



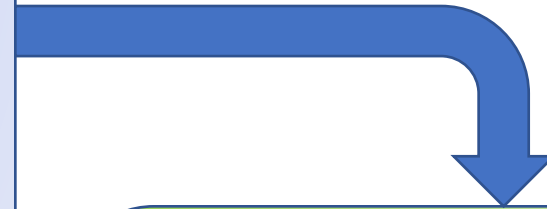




# Objects

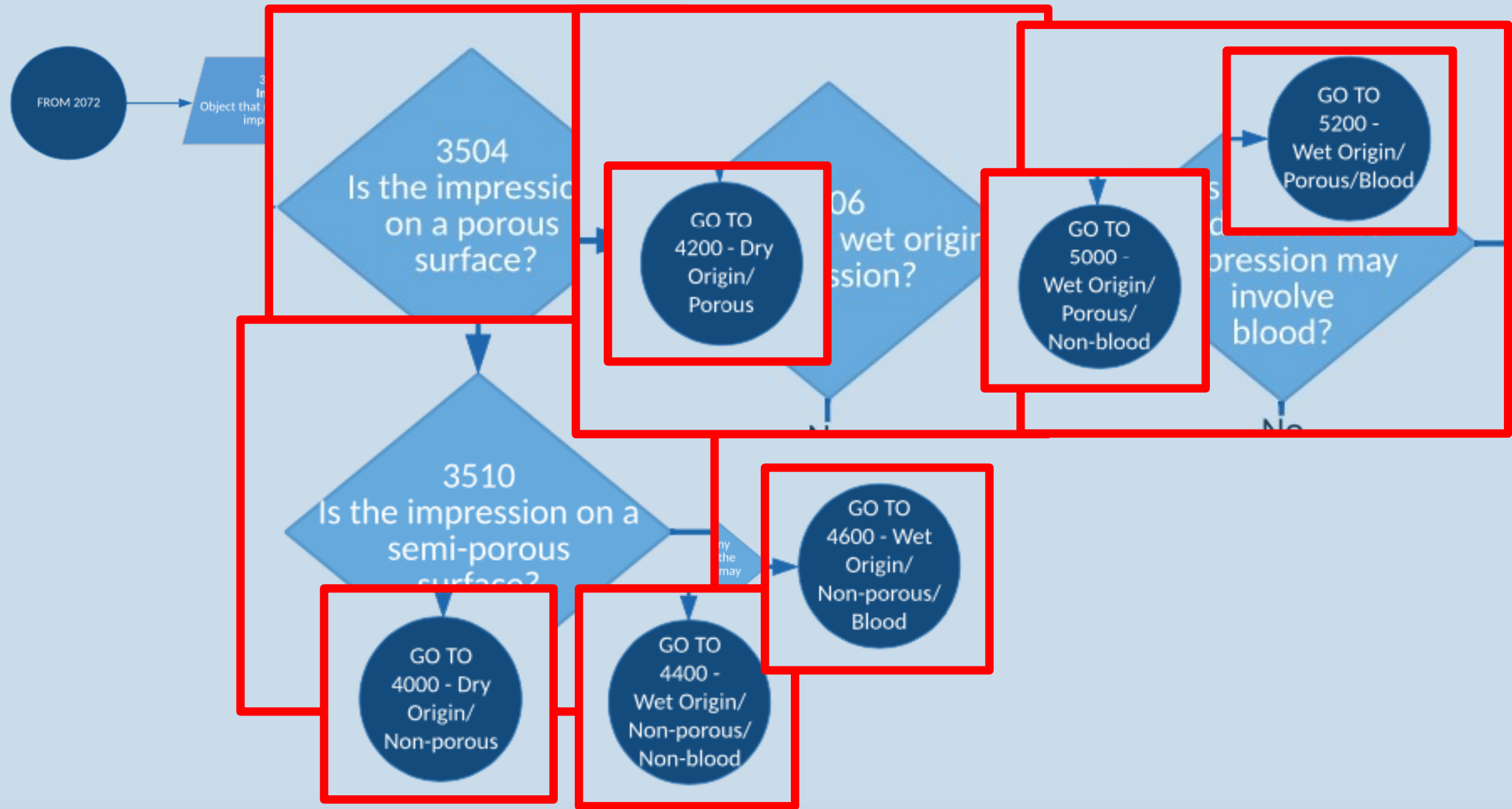
- Origin

- Dry (e.g., dust, dirt)
- Wet (e.g., dew, snow, other liquid)
  - Blood
  - Non-blood



- Substrate

- Non-porous (e.g., tile, glass)
- Porous (e.g., textile, carpet)
- Semi-porous (e.g., glossy paper, cement)



# Object: Dry Origin/Non-Porous Substrate

4004  
 Conduct visual examination to locate impressions (e.g. techniques involving white/visible light such as side/oblique lighting or alternate light source (ALS)); document condition as received.

4022  
 Are there impression(s) visible?

4034  
 Determine appropriate imaging settings to capture available detail in the impression. (See Imaging Considerations - Taking Images)

4038  
 Does the image capture the available detail?

Yes → GO TO 4050

4050  
 Conduct Lift?

Yes → GO TO 4060 - Dry Origin/ Non-porous (2 of 2)

- Perspective
- Scale (make sure this is present)
  - Appropriate scale type (e.g. L scale)
  - Focus
  - Resolution
  - Camera settings
  - Filter(s) used (if any)
  - Lighting
    - Use a stabilizer (PAP)? (e.g. Use a copy stand)
    - Direct, oblique, transmitted, axial, or reflected
  - Formatting:
    - Usable format needed
    - TIFF, JPEG, RAW
  - Identifiers present (e.g. L, R, a, b, c, 1, 2, 3, and any agency specific labels PAP)
  - No distortion
  - Identify and account for presence of multiple impressions
  - Note if there has been any processing prior to imaging
  - Depth of field (e.g. account for curved surface, proximity of camera to impression)
  - Contrast
  - Noise reduction
  - Camera position (e.g. Is plane parallel to substrate?)

4014  
 Are there issues with lighting to consider?

4016  
 Is backlighting needed?

4018  
 Is the surface clear (e.g. glass)?

4020  
 Is there any background interference to consider?

- Technology Assist
- Alternate light source (ALS)

# Foundational Assertions/Claims

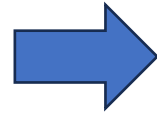
1. **Outsole features can be used to greatly reduce a suspect pool of shoes**
  2. **Accidental characteristics (RACs) can be used for identification of footwear**
- From Dec 2015 response to PCAST request for information:
    - *Provided a list of 25 articles published between NRC 2009 report and PCAST 2015 request*
    - **Hancock et al. (2012)** – 500 impressions (124,750 pairwise comparisons) from University of Auckland, New Zealand; 97% of the outsole patterns were only encountered once; for partial prints, ~94% of the dataset was distinguishable
    - **Gross et al. (2013)** – 402 impressions (80,601 pairwise comparisons) from MN BCA casework examined with a four-tiered hierarchy of analysis; 99% of all impressions were distinguishable without considering wear on the outsole
    - **Wilson (2012)** – 39 pairs of same shoe worn by the same person
    - **Petraco et al. (2010)** – five pairs of the same shoe worn by the same person; studied wear over time; correct identification of the five pairs of shoes was ~92%
    - **Sheets et al. (2013)** – cut a set of “accidentals” into each shoe in 11 pairs; each shoe better matched itself than any other shoe to which it was compared



# Sections to Explore with Footwear Impression Evidence

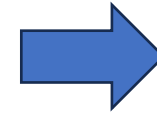
## Footwear

(Class Patterns,  
RACs)



## Impression/Imprint

(Transfer, Detection,  
& Recovery)



## Examination

(Comparison, Interpretation,  
& Reporting)

## Topic 1

Discriminability

## Topic 2

Transferability

## Topic 3

Interpretability

# **Topic 1:**

# **Discriminability**

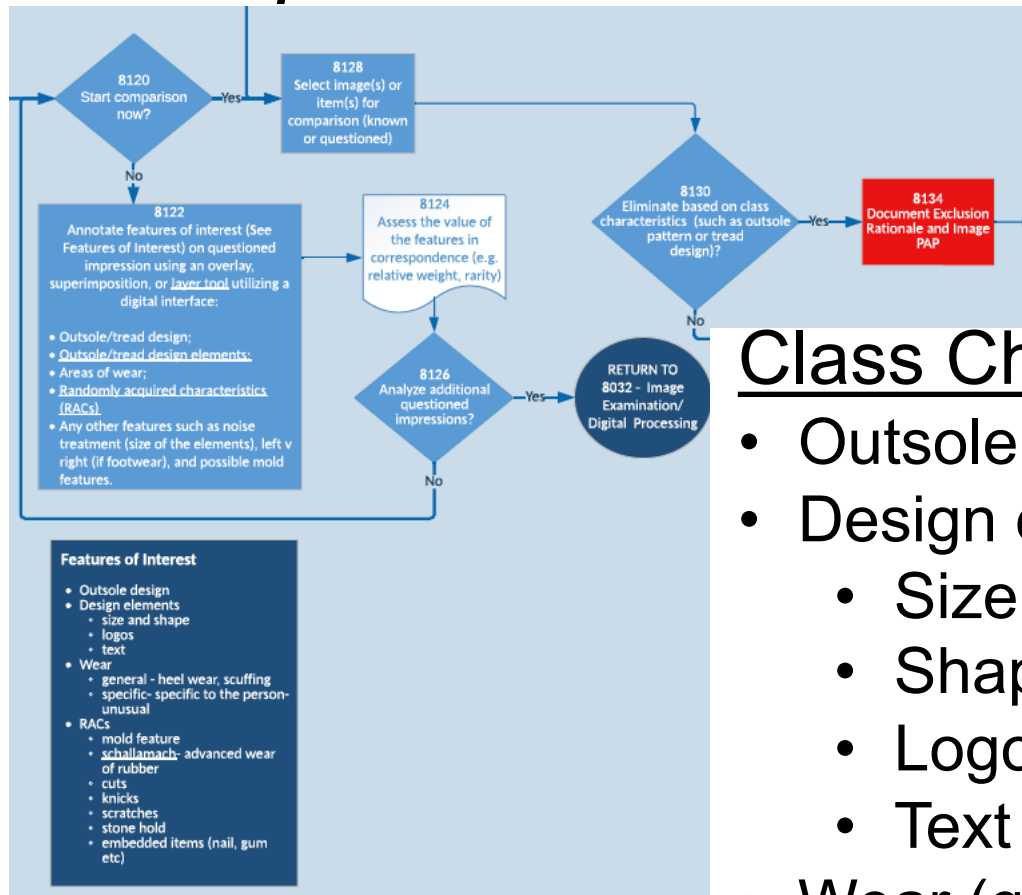
# Discriminability

**Claim: Outsole features can be used to greatly reduce a suspect pool of shoes and accidental characteristics (RACs) can be used for identification of footwear**

- *Question 1: What features are the most informative for comparisons in footwear impression examinations?*
- *Question 2: How is a randomly acquired characteristic (RAC) accurately differentiated from a class characteristic?*

# Discriminability

- *Question 1: What features are the most informative for comparisons in footwear impression examinations?*



## Class Characteristics

- Outsole design
- Design elements:
  - Size
  - Shape
  - Logo
  - Text
- Wear (general)
  - Heel wear, scuffing

## RACs

- Mold features
- Advanced wear of rubber
- Cuts, nicks
- Scratches
- Stones
- Holes
- Embedded items
- Gouges

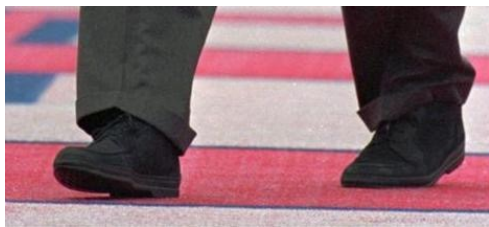
**Topic 2:**

**Transferability**

**Detection, & Recovery of  
Imprint/Impression**

# Footwear Impression Evidence in the O.J. Simpson Case

<https://footwearnews.com/shop/shoes-guide/oj-simpson-shoes-bruno-magli-1202691446/>



Portion of a photograph taken September 26, 1993 by Harry Scull, Jr. of O.J. Simpson wearing Bruno Magli Lorenzo shoes

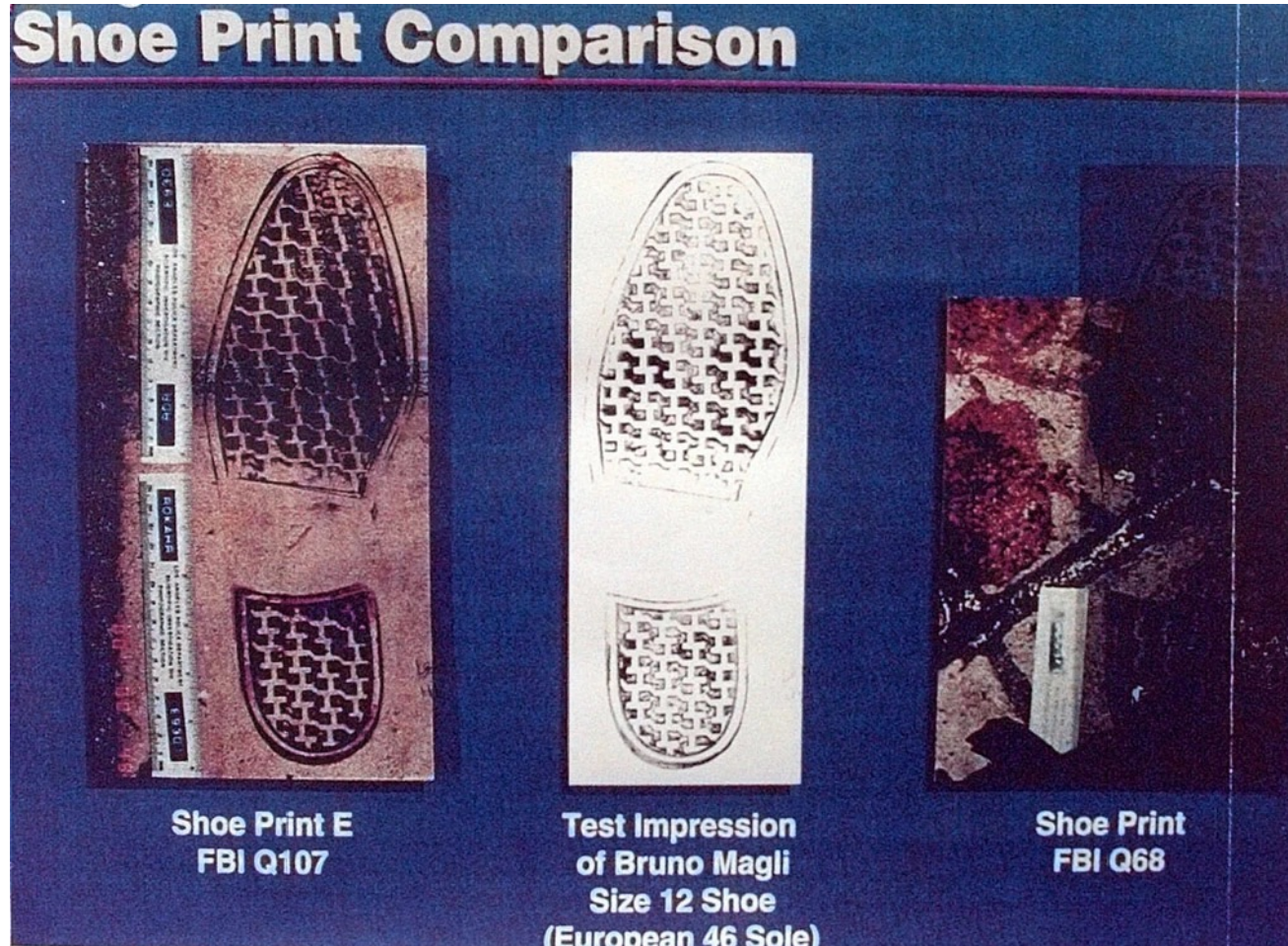


Exhibit 403 from the court room was released following testimony by FBI shoe print expert William Bodziak in 1996. *AP IMAGES*.

Bodziak, W. (2000) Footwear Impression Evidence, 2<sup>nd</sup> Edition. CRC Press

Chapter 15

(pp. 431-458)

“The Footwear Evidence in the O.J. Simpson Trial”

# Transfer Example

*Nature* (1974) 250: 762-764

## Murder involving discovery and first application of fluorescence of tyre prints

J. H. Loughran,

Warwickshire Constabulary Headquarters, Leek Wotton, Warwickshire, UK

J. B. F. Lloyd and T. R. Watson

Home Office Forensic Science Laboratory, Gooch Street North, Birmingham 5, UK.

- In July 1973 a Mini Estate vehicle, which had been set on fire, was discovered near a crime scene
- It has been parked in a clean garage that was relevant to the crime in question
- The concrete garage floor was examined under UV light and **fluorescing tyre marks** were observed
- The tread patterns were from Goodyear G800 in the front and Kelly Springfield KR1 tires on the rear

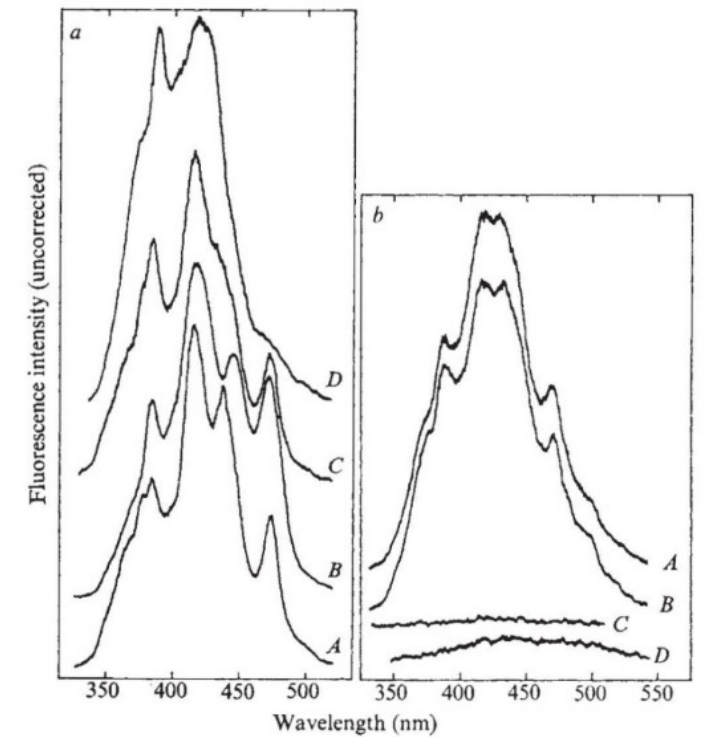


Fig. 2 a, Synchronously excited (30 nm interval) fluorescence emission spectra of chloroform extracts from prints, on silica gel, of various tyre samples: A, Michelin X; B, Goodyear G8 remould; C, Goodyear G8; D, Pleak remould.

b, Synchronously excited (30 nm interval) fluorescence emission spectra of chloroform extracts of: A, nonfluorescent concrete from scene after contact overnight with tyre from Mini Traveller; B, concrete from fluorescent tyre print found at scene; C, concrete underlying that used in B; D, nonfluorescent concrete from Albion Street garage.

Date	SWGTHREAD Document Title
03/2005	Guide for the Collection of Footwear and Tire Impressions in the Field
03/2005	Guide for the Collection of Footwear and Tire Impressions in the Laboratory
03/2005	Guide for the Detection of Footwear and Tire Impressions in the Field
03/2005	Guide for the Detection of Footwear and Tire Impressions in the Laboratory
03/2005	Guide for the Preparation of Test Impressions from Footwear and Tires
03/2005	Scope of Work Relating to Forensic Footwear and/or Tire Tread Examiners
03/2006	Guide for Minimum Qualifications and Training for a Forensic Footwear and/or Tire Tread Examiner
03/2006	Guide for the Examination of Footwear and Tire Impression Evidence
03/2006	Guide for the Forensic Documentation and Photography of Footwear and Tire Impressions at the Crime Scene
03/2006 rev. 03/2013	Range of Conclusions Standard for Footwear and Tire Impression Examinations
03/2007	Guide for Casting Footwear and Tire Impression Evidence
03/2007	Guide for Lifting Footwear and Tire Impression Evidence
03/2008	Guide for Casework Documentation
09/2008	Guide for the Chemical Enhancement of Bloody Footwear and Tire Impression Evidence
03/2013	Standard for Terminology Used for Forensic Footwear and Tire Impression Evidence



# Guidance Documents (OSAC/ASB)

Date	ASB Document Title (in yellow if on OSAC Registry)
2019	(ASB 021) Best Practices for the Preparation of Test Impressions from Footwear and Tires
2020	(ASB 049) Best Practice Recommendation for Lifting of Footwear and Tire Impressions
2022	(ASB 052) Best Practice Recommendation for the Detection and Collection of Footwear and Tire Impression Evidence
2020/ 2022	(ASB 126) Best Practice Recommendation for Casting Footwear and Tire Impression Evidence at the Crime Scene
2021/ 2022	(ASB 050) Best Practice Recommendation for Photographic Documentation of Footwear and Tire Impression Evidence
2020/ 2022	(ASB 051) Scope of Work for a Footwear/Tire Examiner
2020/ 2022	(ASB 095) Standard for Minimum Qualifications and Training for a Footwear/Tire Forensic Science Service Provider
2019	(ASB 097) Terminology Used for Forensic Footwear and Tire Evidence
2020/ 2022	(ASB 099) Standard for Footwear/Tire Examination Proficiency Testing Program
2023	(ASB 137) Standard for Examination and Documentation of Footwear and Tire Impression Evidence

# Transferability of Footwear/Tire Impressions

***Claim:*** Footwear/tire impressions reliably reflect the features present on the source shoe/tire.

*Question 1: What contributes to variability in imprints/impressions from the shoe producing the mark and how is that variability measured?*

*Question 2: What methods (imaging, measurement) reliably and reproducibly capture the information present in the imprint/impression?*

# Transferability of Footwear/Tire Impressions

*Question 1: What contributes to variability in impressions from original shoe and how is that variability measured?*

- List types of variables that cause deformation/distortion
- How does variability affect accuracy of impression formation/data collection?
- Does variation caused by variables such as gait, demographics (sex, height, weight), stride, etc., have a measurable affect on transfer accuracy or impression quality?

# Transferability of Footwear/Tire Impressions

*Question 2: What methods (imaging, measurement) reliably and reproducibly capture the information present in the imprint/impression?*

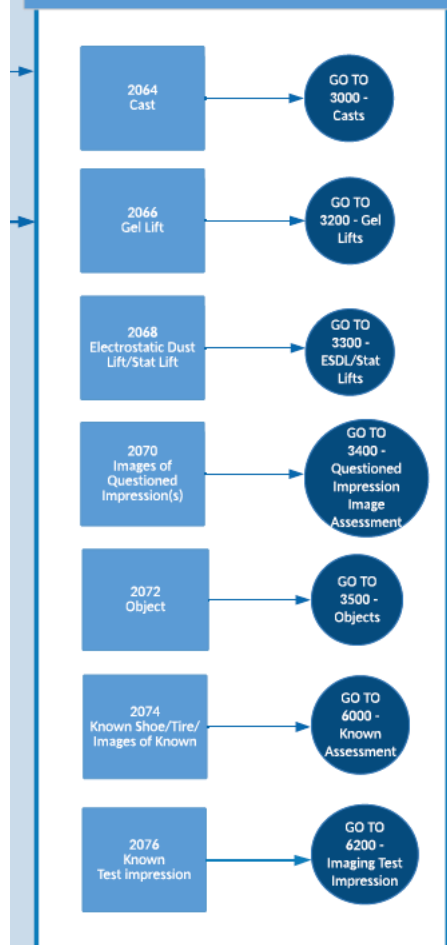
- Types of methods cited in literature and training guide
  - Photographic techniques, lighting, casting the impression (different challenges for different surfaces)
- Different roles of crime scene investigators and forensic examiners
- Should there be a focus on specific substrates?
  - Currently, soil, snow, sand, cement, rain, paint mentioned in literature
  - What is the least ideal substrate in terms of collecting accurate/reliable impression data?  
What is the ideal substrate?
- How do you approach the adoption of new techniques?

# Transferability of Footwear/Tire Impressions

**Question 2: What methods (imaging, measurement) reliably and reproducibly capture the information present in the imprint/impression?**

## Technical Assessment (2 of 2)

### 2062 - Item Characterization



### 4362 Select Chemical Processing Method(s)

Use case scenario, visual examination, knowledge, experience, training, preference, characteristics of substrate and matrix, and agency policy to:

- ▶ Select chemical or physical processing (and associated applicable lighting scheme) and
- ▶ Determine processing sequence (e.g. least destructive to most destructive):

Consider the following methods:

- Bromophenol Blue
- Potassium Thiocyanate
- Ammonium Thiocyanate
- Other

### 4688 Select Physical/Chemical Processing Method(s)

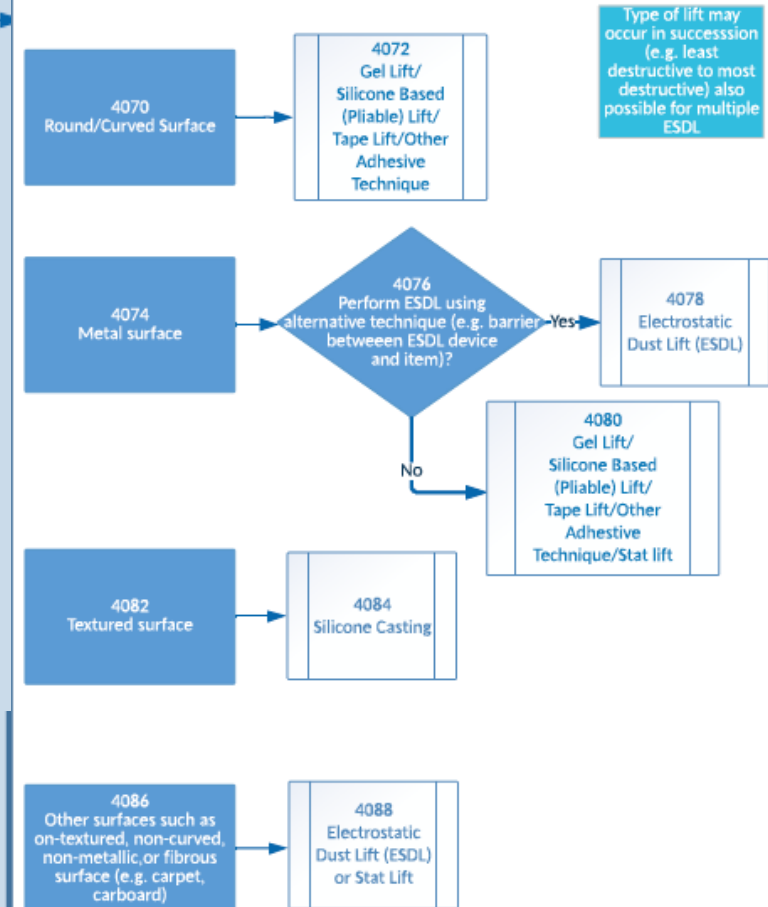
Use visual examination, knowledge, training, experience, preference, characteristics of substrate type (non-porous v semi-porous) and color, surface contaminants, and matrix, and/or agency policy to:

- ▶ Select chemical or physical processing technique (and associated applicable lighting scheme) and;
- ▶ Determine processing sequence (e.g. least destructive to most destructive) or if a fixative is needed.

Consider the following options:

- Light Surface: Leucocrystal violet (LCV), Amido black, Leucomalachite green, Hungarian red, Crowle's Double Stain, Coomassie Blue, 3,3'-Diaminobenzidine (D.A.B.)
- Dark Surface: Titanium dioxide
- Any surface color: Blue Star, Luminol, Acid Yellow 7 with forensic light source

4068 Use knowledge, experience, training, visual examination, surface characteristics, texture, and agency policy to select lift method(s) (if multiple lift methods will be used, also to determine succession plan):



# Topic 3:

## Interpretability

Examination of Footwear  
Impression Data

# Interpretability

**Claim: The current techniques and practices for the comparison, interpretation, and reporting of footwear impression evidence are accurate and reliable.**

*Question 1: What interpretation techniques produce the most accurate/reliable results?*

*Question 2: What sufficiency criteria are needed to establish reliability of impressions to a source outsole?*

*Question 3: How consistent and accurate are examiners' conclusions/interpretations of footwear impression evidence?*

# Interpretability

*Question 3a: How consistent and accurate are examiners' conclusions or interpretations?*

## Consistency:

- Majamaa & Ytti (1996)
- Shor & Weisner (1999)
- Hammer et al. (2013)
- Speir et al. (2020)

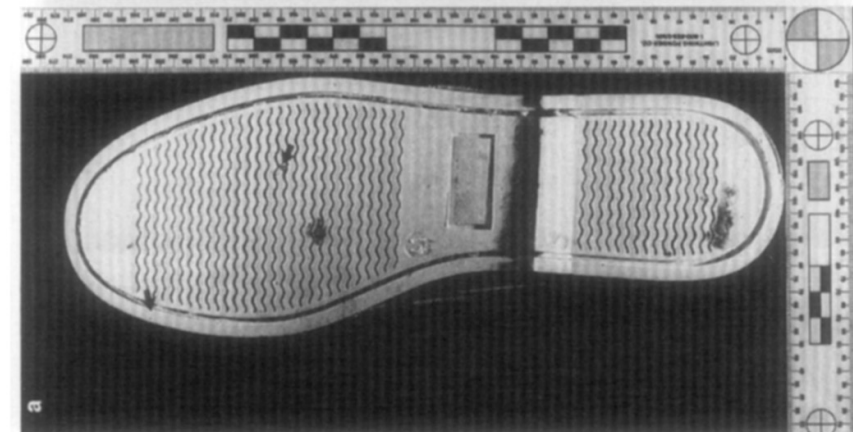
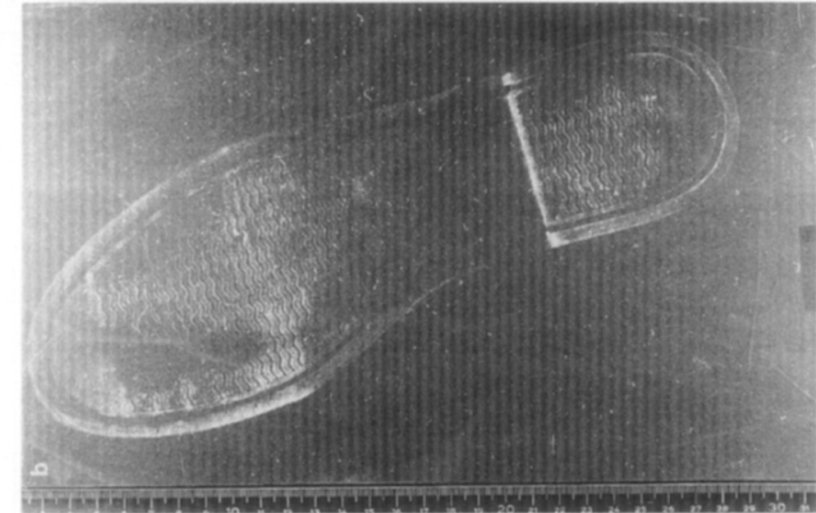
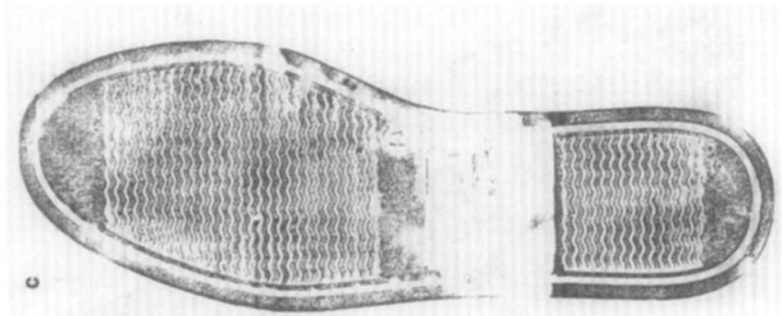
*Question 3b: What studies have assessed examiner agreement, accuracy, inter- and intra-rater reliability, repeatability, test-retest?*

- Richetelli et al. (2020)
- Hicklin et al. (2022)



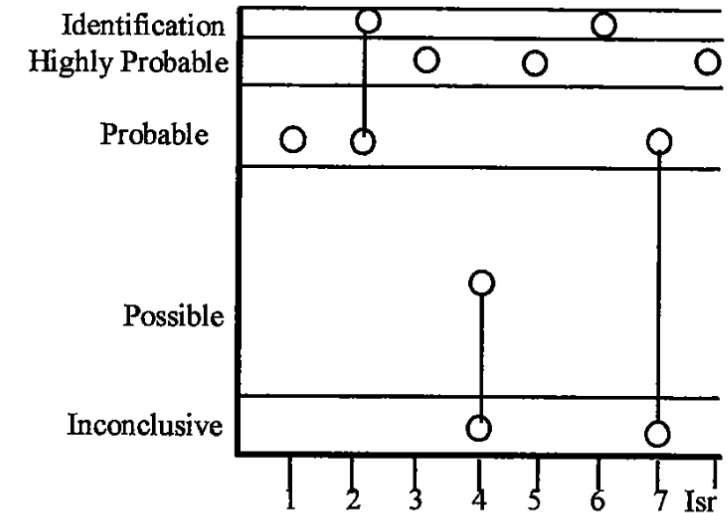
# Examiner Consistency

- Majamaa & Ytti (1996):
  - 6 simulated shoeprint cases: 33 forensic labs, 20 countries
    - 1 photo of shoe (K), 1 photo of shoeprint (Q) from scene (electrostatic dust lift), 1 test print of the shoe.
    - Accidental characteristics were marked on the photos of the shoes
  - Conclusions based on pattern, shape, size, and accidental characteristics.
    - List of available conclusions: *inconclusive, possible, probably, very probably, definite positive identification.*
    - Each examiner had to individually define the criteria used to reach their conclusions (e.g. type of features that must be present, degree of similarity/dissimilarity present)
  - Reported “remarkable variations” and “considerable differences” in conclusions formed by different examiners from identical cases.
    - Degree of variability was case specific



# Examiner Consistency

- Shor & Weisner (1999):
  - 2 actual case impressions: 23 experts from 7 different labs across 6 countries
    - Participants given photos of shoeprints from scene, photos of suspect shoes, actual test impressions of suspect shoes. Individual characteristics not indicated on photos.
  - Sample chosen for difficulty – questioned impressions deemed ambiguous by experts because of vague imprint at scene and difficulty in locating individual characteristics.
  - Participants allowed to use own conclusion scale for results
    - Conclusions transferred to the scale used in Israel where author's are based.
  - Ground truth not known
  - Conclusions varied between individual experts and between laboratories
    - 2 labs consistently gave highly conclusive results
    - 2 labs consistently reached lower levels of identification
  - Proposed need for international terminology for conclusions and guidelines for implementation.



4—Divergence of opinions graph for the “Converse All-Star”

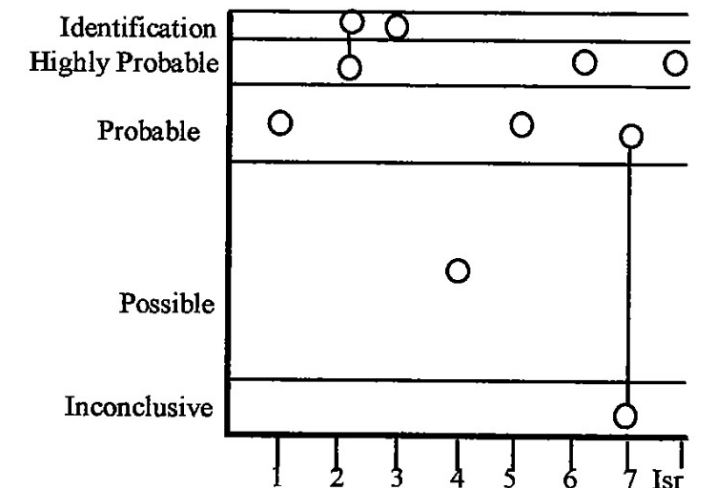


FIG. 6—Divergence of opinions graph for the “Adidas” shoe

# European Six-Level Conclusion Scale (2006)

- European Network of Forensic Science Institutes (ENFSI)
- ENFSI Expert Working Group Marks (EWG-Marks) Conclusion Scale Committee (CSC)
- Based on Bayesian framework (likelihood ratio approach) to describe the degree of support for one conclusion vs. others.

<i>Level</i>	<i>Likelihood Ratio</i> <i>(partial Bayes' rule)</i>	<i>Probability</i> <i>(full Bayes' rule, classical approach)</i>
1	Identification	Identification
2	Very strong support for proposition A Strong support for proposition A	Very probably proposition A
3	Moderately strong support for proposition A Moderate support for proposition A Limited support for proposition A	Probably proposition A
4	Inconclusive	Inconclusive
5	Limited support for proposition $\bar{A}$ Moderate support for proposition $\bar{A}$ Moderately strong support for proposition $\bar{A}$ Strong support for proposition $\bar{A}$ Very strong support for proposition $\bar{A}$	Likely not proposition A
6	Elimination	Elimination

A = hypothesis: the questioned tool produced the mark

$\bar{A}$  = (Not A) = alternative-hypothesis: the questioned tool didn't produce the mark (when using the full Bayes' rule, then even prior odds are assumed).

# SWGTTREAD Conclusions

Provides minimum criteria for different conclusions levels to allow for greater uniformity among examiners.

## SWGTTREAD 2006

- 7 categories of conclusion:
  - Identification
  - Probably Made
  - Could Have Made
  - Inconclusive
  - Probably Did Not Make
  - Elimination
  - Unsuitable

## SWGTTREAD 2013

- 7 categories of conclusion:
  - Identification
  - High Degree of Association
  - Association of Class Characteristics
  - Limited Association of Class Characteristics
  - Indications of Non-Association
  - Exclusion
  - Lacks Sufficient Detail

## Raymond & Sheldon (2015):

- Compared SWGTTREAD range of conclusions with in-house scales of conclusions from various labs of Australia and New Zealand.
- SWGTTREAD conclusion scale greatly improved clarity of the results and the comparability of conclusions among examiners.

# Uniform Language for Testimony & Reports (ULTR) for the Forensic Footwear Discipline

## I. Application

This document applies to Department of Justice examiners who are authorized to prepare reports and provide expert witness testimony regarding forensic footwear examination. Section III is limited to conclusions that result from the comparison of a known footwear item<sup>1</sup> to a questioned impression.<sup>2</sup> Section IV is applicable to all forensic footwear examinations unless otherwise limited by the express terms of an individual qualification or limitation.

## II. Purpose and Scope<sup>3</sup>

The Uniform Language for Testimony and Reports is a quality assurance measure designed to standardize the expression of appropriate consensus language for use by Department examiners in their reports and testimony. This document is intended to describe and explain terminology that may be provided by Department examiners. It shall be attached to, or incorporated by reference in, laboratory reports or included in the case file.

Department examiners are expected to prepare reports and provide testimony consistent with the directives of this document. However, examiners are not required to provide a complete or verbatim recitation of the definitions or bases set forth in this document. This is supplemental information that is intended to clarify the meaning of, and foundation for, the approved conclusions.

This document should not be construed to imply that terminology, definitions, or testimony provided by Department examiners prior to its publication that may differ from that set forth below was erroneous, incorrect, or indefensible. It should also not be construed to imply that the use of different terminology or definitions by non-Departmental forensic laboratories or individuals is erroneous, incorrect, or indefensible.

This document does not, and cannot, address every contingency that may occur. For example, an examiner may not have an opportunity to fully comply with its directives during a testimonial presentation due to circumstances beyond his or her control. In addition, this document does not prohibit the provision of conclusions in reports and testimony that fall outside of its stated scope. Finally, the substantive content of expert testimony may be subject to legal rules imposed by the court or jurisdiction in which it is provided.

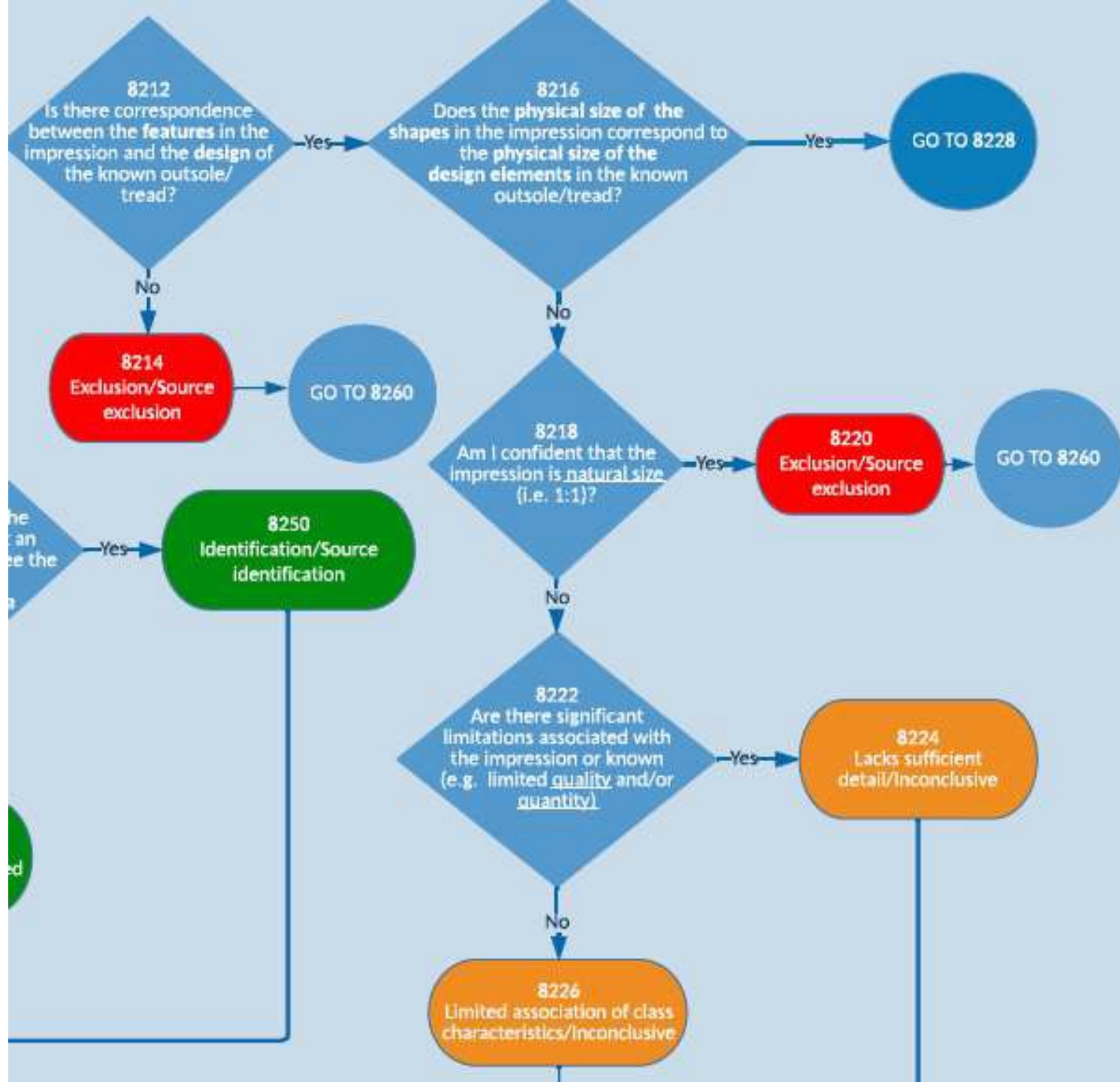
<sup>1</sup> A 'known footwear item' is a footwear item (e.g., a shoe, a boot or a sandal) whose origin was documented. A 'known footwear item' can be a physical item or a reproduction of that item (e.g., an image depicting that item or an impression made from that item).

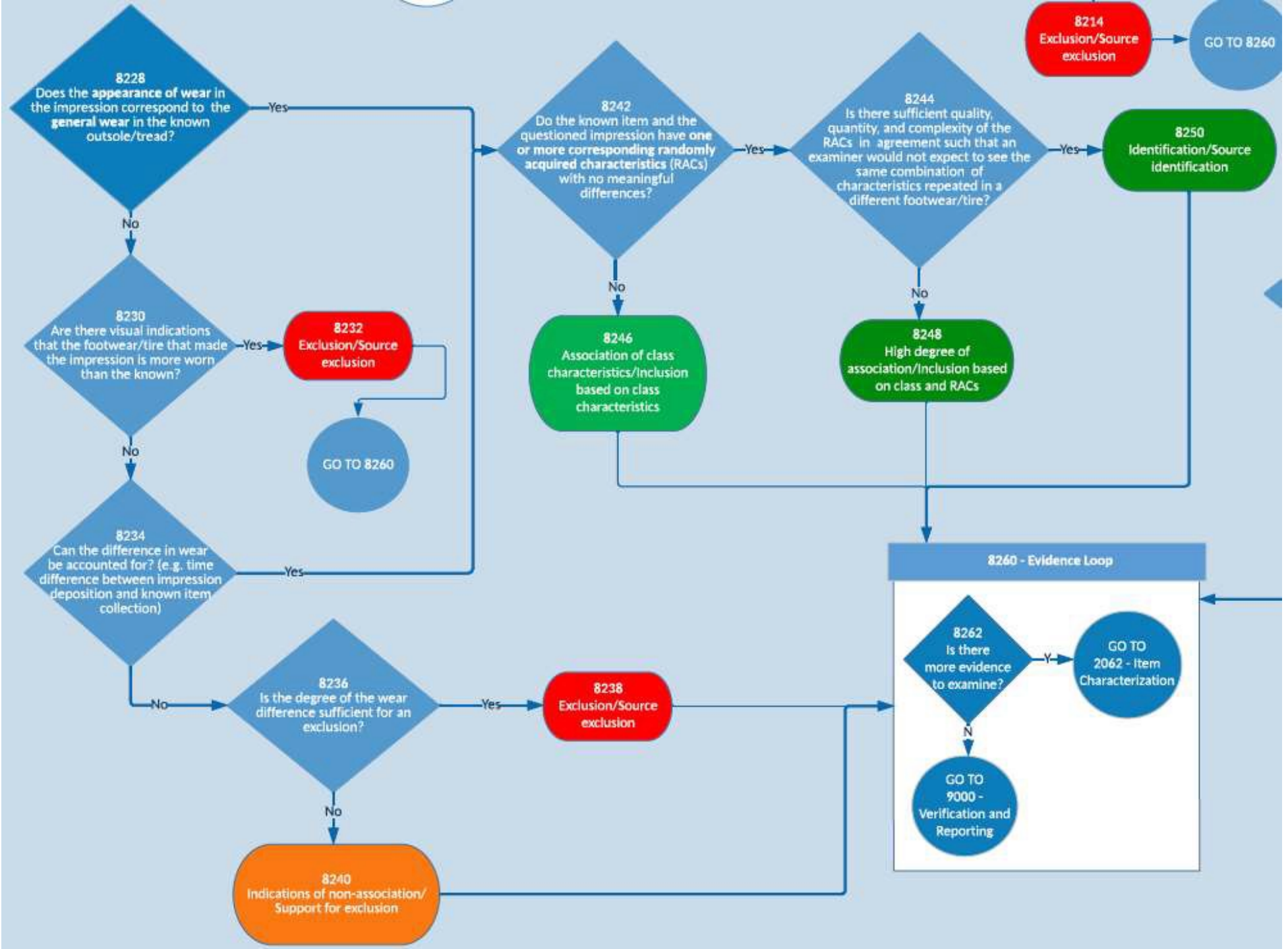
<sup>2</sup> A 'questioned impression' is an impression whose source is unknown.

<sup>3</sup> This document is not intended to, does not, and may not be relied upon to create any rights, substantive or procedural, enforceable by law by any party in any matter, civil or criminal; nor does it place any limitation on otherwise lawful investigative or legal prerogatives of the Department of Justice.

- Designed to standardize language used by DOJ examiners in reports and testimony.
- 6 categories of conclusion:
  - Source identification (i.e., identified)
  - Inclusion based on class & RACs (i.e., included)
  - Inclusion based on class characteristics (i.e., included)
  - Inconclusive
  - Support for exclusion
  - Source excluded (i.e., excluded)
- Also UTLR for Tire Tread analysis with same categories of conclusion.









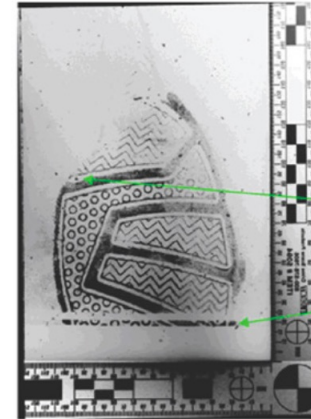
# Examiner Consistency

- Hammer et al (2013):
  - 6 sets of photos from simulated scenes evaluated by 40 IAI-certified footwear examiners from the U.S. and Canada
    - Examiners received 1 photo of the outsole of the known footwear, a test impression of that shoe, and a gelatin lift of an unknown impression.
    - All characteristics/features were clearly labeled for each impression.
    - In all cases the known was used to make the unknown impression.
  - 2006 SWGTREAD conclusion scale used:
    - Identification, Probably Made, Could Have Made, Inconclusive, Probably Did Not Make, Elimination, Unsuitable
  - Found “little variability” between examiners, majority of conclusions were consistent and between 2 consecutive options.
    - Case Study 3 generated largest range of responses
      - Identification (1), Probably (33), and Could Have Made (6)
      - Partial impression with one void in the unknown impression corresponding to a stone hold in the known shoe outsole.
      - Less variability in responses than Majamaa & Ytti (1996) study.

## Case 3

Assume that the outsole class characteristics of physical size and design (shape, orientation and relative position of design elements) are in correspondence.

Gel lift of a right forefoot impression



Observations

Overall general wear corresponds – fairly new outsole condition.

Void corresponds to location, shape and size of stone-hold in outsole.

Note: edge of table

WHAT WOULD YOUR CONCLUSION BE BASED ON THESE OBSERVATIONS ONLY?

Test impression of right shoe

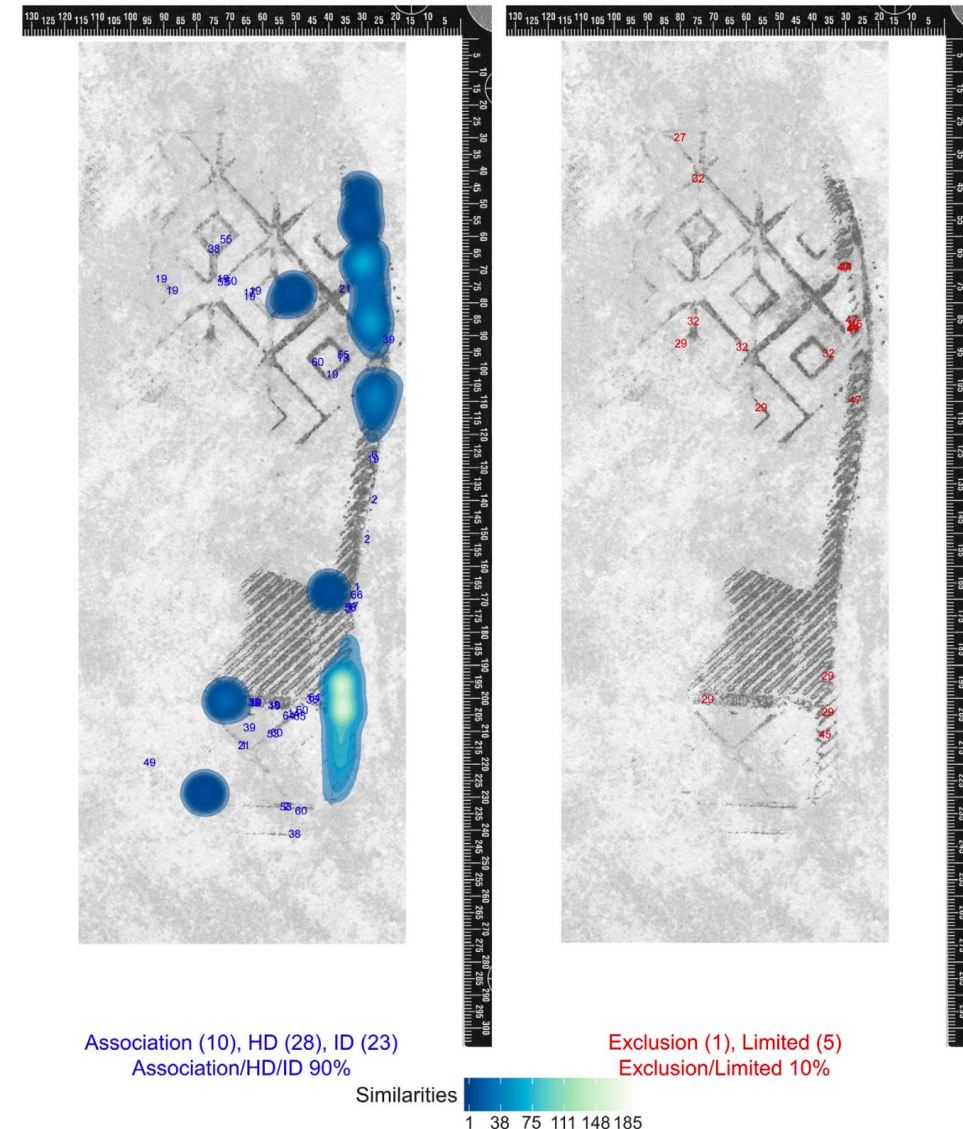


Right shoe



# Examiner Consistency

- Speir et al. (2020):
  - 70 footwear examiners each performed 12 comparisons across 7 simulated cases
    - 1 question impression, 1-2 outsole exemplars, 2 Handprint exemplar replicates per known shoe, blank acetates for overlay annotation, copy of SWGTREAD Conclusion Standard, CD of reporting software, and instructions.
    - Known: 3 different shoe manufacturers, 6 different shoe styles, 4 different sizes,
    - Unknown: 4 different substrates (ceramic, vinyl, linoleum tile, paper) in 3 mediums (blood, dust, wax) processed in 4 different methods (leucocrystal violet, digitally enhanced gel lift, magnetic powder & gel lift, digitally enhanced)
    - Participants annotated their own impressions
  - Considerable variation in feature identification/annotation (as low as 66.5% agreement)
  - Higher consistency in overall conclusions (average 85.6%)
    - Consistent with former studies when different in study design taken into account.



# Summary: Examiner Consistency

*How consistent and accurate are examiners' conclusions or interpretations?*

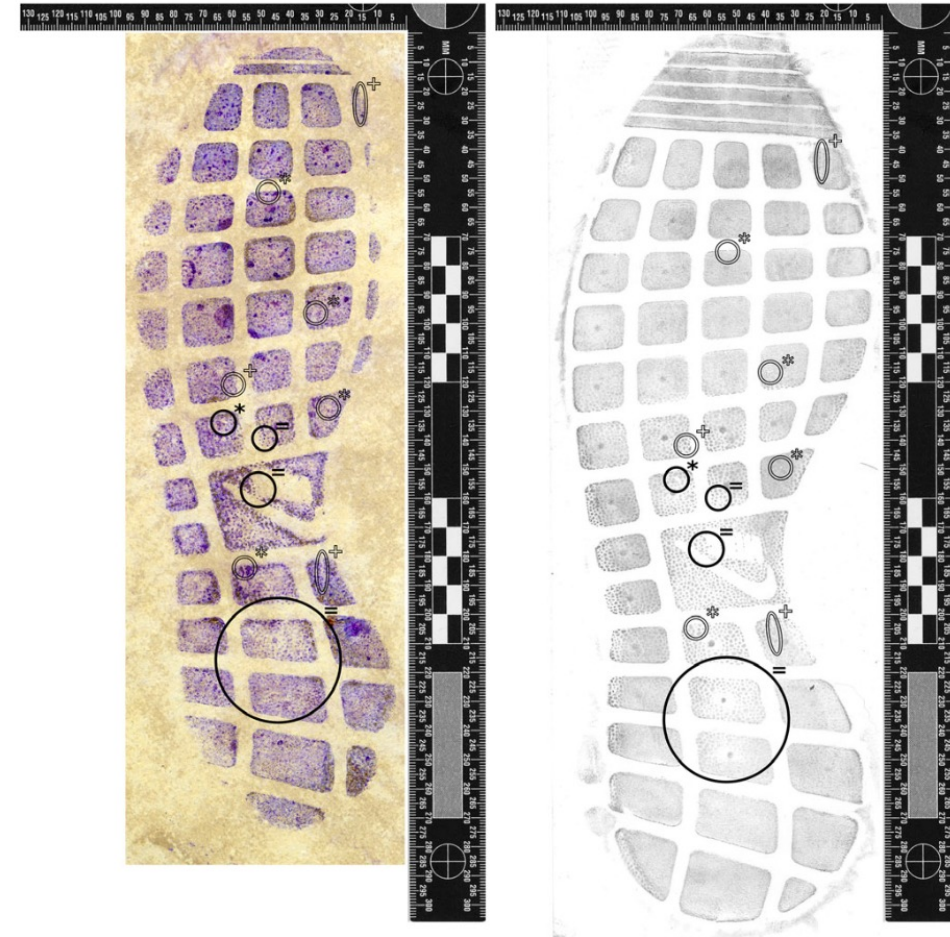
Source	Sample	Conclusion Scale	Consistency
Majamaa & Ytti (1996)	6 simulated cases, 33 labs, 20 countries, 198 comparisons	5-point scale	“remarkable variations” and “considerable differences”
Shor & Weisner (1999)	2 real cases, 23 experts, 7 labs, 6 countries, 40 comparisons	Examiners own, translated into Israeli scale	Variation between examiners and laboratories
Hammer et al. (2013)	6 simulated cases, 40 experts, 240 comparisons	SWGTHREAD 2006	“little variability,” majority consistent and between 2 consecutive options
Speir et al. (2020)	7 simulated cases, 70 examiners, 840 comparisons	SWGTHREAD 2013	85.6% (average)

# Examiner Accuracy

*How consistent and accurate are examiners' conclusions or interpretations?*

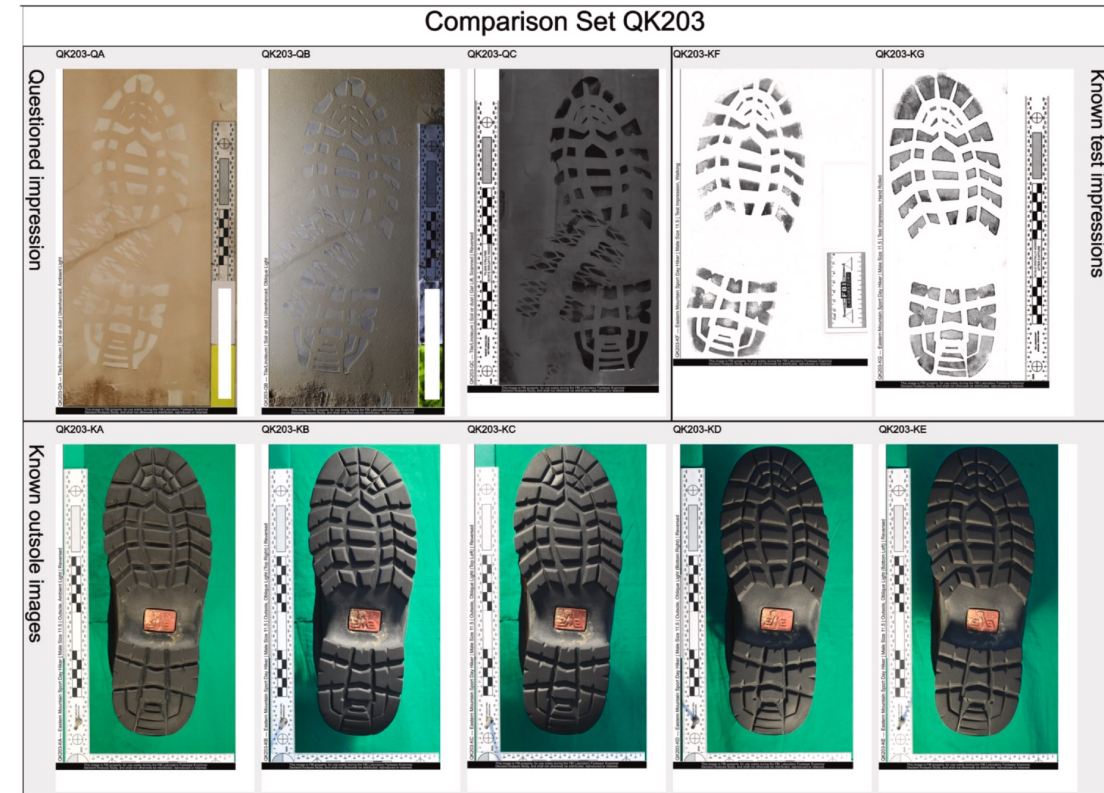
*What studies have assessed examiner agreement, accuracy, inter- and intra-rater reliability, repeatability, test-retest?*

- Richetelli et al. (2020): Range of conclusions, accuracy, consensus
  - Continuation of study reported in Speir et al. (2020).
    - 70 footwear examiners each performed 12 comparisons across 7 simulated cases
    - Ground truth known for each case
  - Evaluated both mated and non-mated pairs:
    - SWGTREAD 2013 conclusion standard with exclusion of Insufficient Detail category
  - Accuracy: 55.7% - 97.1% (average: 82.8% +/- 11.9%)
    - Mated pairs: 76.3% +/- 13% (median agreement 78.6%)
    - Non-mated pairs: 87.4% +/- 9.24% (median agreement 91.4%)



# Examiner Accuracy

- Hicklin et al. (2022):
  - 84 footwear examiners, up to 100 comparisons each, 40 mated, 60 nonmated sets
  - SWGTREAD 2013 conclusion scale + inconclusive option
  - Accuracy:
    - Consistent with Speir et al. (2020) & Richetelli et al. (2020)
    - Mated:
      - False Negative Rate (erroneous exclusion): 6%, Incorrect Association Rate: 1.8%
    - Non-mated:
      - False Positive Rate (erroneous inclusion): 0.2%, Incorrect Association Rate: 1.4%
  - Repeatability:
    - Participants assigned 10 sets twice
    - 60% repeated exactly (no change), only 0.7% were contradictions (e.g. ID to Exclude)
    - Of those changed, 79% were within one conclusion level.



# Summary Examiner Accuracy

*How consistent and accurate are examiners' conclusions or interpretations?*

*What have studies shown regarding examiner agreement, accuracy, inter- and intra-rater reliability, repeatability, test-retest?*

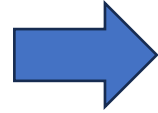
Source	Sample	Accuracy	Other info
Richetelli et al. (2020)	7 simulated cases, 70 examiners, 840 comparisons	55.7% - 97.1% (average: 82.8%)	Mated pairs: 76.3% (median: 78.6%) Non-mated pairs: 87.4% (median 91.4%)
Hicklin et al. (2022)	84 examiners, 6610 comparisons	Mated: False Negative Rate: 6% Incorrect Association Rate: 1.8%  Non-mated: False Positive Rate: 0.2% Incorrect Association Rate: 1.4%	Repeatability: 60% no change in response, 0.7% contradictions Of those changed, 79% were within one conclusion level

# Wrap Up & Conclusions

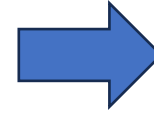
John & Kelly

# Sections to Explore with Footwear Impression Evidence

**Footwear**  
(Class Patterns,  
RACs)



**Impression/Imprint**  
(Transfer, Detection,  
& Recovery)



**Examination**  
(Comparison, Interpretation,  
& Reporting)

## Topic 1

Discriminability

## Topic 2

Transferability

## Topic 3

Interpretability

- Are these three areas an appropriate model?
- Are there topics in these three areas that should be addressed in the Foundation Review in addition to those brought up at this workshop?
- Can subclaims be identified?



# Footwear Impression Scientific Foundation Review: Next Steps

- Thank you for your participation today as it will be very helpful to us!
  - *And thanks to Christina for taking detailed notes*
- Establish footwear project team to conduct foundation review and write draft report
- When completed, provide draft report for public comment and conduct webinar during the public comment period

# What Would We Like from You?

1. If you have publications or presentations that we should consider, then please send them to us
2. Provide feedback on the process map
3. Contact us if you would like to be involved in the foundation project team
4. Sign up for updates on presentations, webinars, and release of the draft report

<https://www.nist.gov/forensic-science> (see bottom of the page)

## Stay in Touch

Sign up for our newsletter to stay up to date with the latest research, trends, and news for Forensic Science.

Sign Up

# Thank you for your attention!

**Acknowledgments:** Christina Reed for taking notes

- Congressional funding, NIST colleagues, David Kanaris, Jacqueline Speir

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contact us for  
further  
information**