Recent NIST Activities in Forensic Science:
Examining Scientific Foundations and Innovation-to-Implementation Issues

John M. Butler & Robert M. Thompson
National Institute of Standards and Technology
Special Programs Office, Forensic Science Program
Disclaimer & Acknowledgments

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 equipment, instruments and materials 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 materials, instruments or equipment identified are necessarily the best available for the purpose.

Acknowledgments: NIST foundation review teams (DNA and firearms) and the DNA Mixture Resource Group for their insights.
• NIST Activities in Forensic Science and Background Information

• NIST Scientific Foundation Reviews
  1. DNA Mixture Interpretation (Sept 2017 – present)
  2. Bitemark Analysis (Oct 2018 – present)
  3. Digital Evidence (Feb 2019 – present)
  4. Firearms Examination (Oct 2019 – present)

• Research Innovation to Implementation (RI2I) Symposium
  • Held June 19-20, 2019

• Future Activities: Forensics@NIST: November 5, 2020
  • Workshops (November 6)
Forensic Science is 1 of 8 Featured Topics on NIST Website
https://www.nist.gov/
NIST Forensic Science Activities

Conduct Research and Collaborate

**Intramural Research**
- DNA
- Digital
- Fingerprints
- Firearms
- Footmarks
- Statistics
- Drugs/Toxins
- Trace

**Extramural Research**
- funding a NIST Center of Excellence in Forensic Science (CSAFE: since 2014)

1920s - present

Partner with Community to Strengthen Policies and Practices

National Commission on Forensic Science (NCFS) with DOJ

2013 - 2017

Convene Meetings to Examine Issues

Human Factors Working Groups
- with NIJ

2009 - present

Explore Scientific Foundations

Initial efforts with DNA mixture interpretation and bitemark analysis

2017 - present

https://www.nist.gov/topics/forensic-science
NIST Research Focus Areas

FORENSIC SCIENCE TOPICS

- DNA & BIOLOGICAL EVIDENCE
- DIGITAL EVIDENCE
- FINGERPRINTS & PATTERN EVIDENCE
- BALLISTICS
- TRACE EVIDENCE
- Drugs/Toxins

https://www.nist.gov/topics/forensic-science
“In an effort to make hair comparison a more useful technique for investigating crimes, scientists at the National Institute of Standards and Technology (NIST) have developed a new way to dissolve hair proteins without destroying them. Once in solution, the protein molecules from two hairs can be analyzed and compared, yielding objective, quantitative results. …”
DNA & Biological Evidence

DNA Mixtures: A Forensic Science Explainer

NIST Builds Statistical Foundation for Next-Generation Forensic DNA Profiling

Human DNA Standard: A Q&A With NIST’s Becky Steffen (blog post)

https://www.nist.gov/topics/dna-biological-evidence
Ballistics
(Firearms Examination)

- Kennedy Assassination Bullets Preserved in Digital Form
- NIST Updates Forensic Standard Reference Materials
- How Good a Match is It? Putting Statistics into Forensic Firearms Identification

https://www.nist.gov/topics/ballistics
Videos on Forensic Science Research

https://www.nist.gov/video-gallery
Detective X Film awarded an Emmy® in 2018!

Awarded June 23, 2018 by the National Academy of Television Arts & Sciences: National Capital Chesapeake Bay Chapter

10 minute video: https://www.youtube.com/watch?v=a97A44ORnrE

Detective X: (Re) Discovering Wilmer Souder

NIST staff members Leon Gerskovic, Robin Materese and Jose Garcia show off their Emmy® Award for “Detective X: (Re) Discovering Wilmer Souder.”

Credit: J. Stoughton/NIST

https://www.nist.gov/video/detective-x-re-discovering-wilmer-souder

Article: https://www.nist.gov/featured-stories/who-was-detective-x

For more information on Wilmer Souder, see June 2016 colloquium:
CSAFE: NIST Center of Excellence in Forensic Statistics

NIST has invested $20M over 5 years (2015-2019) renewal is under consideration

Webinars: https://forensicstats.org/forensic-scientist-education-center/

Newsletters: https://forensicstats.org/news-events/monthly-csafe-newsletters/
OSAC: Organization of Scientific Area Committees for Forensic Science

OSAC Adds 25th Standard to the Registry

OSAC's Standards Bulletin - January 2020

OSAC's October Newsletter & Annual Report

https://lexicon.forensicosac.org/
>4,000 terms organized by forensic discipline

https://www.nist.gov/topics/organization-scientific-area-committees-forensic-science
NIST Has Organized Multiple Meetings to Assist the Forensic Science Community and Stakeholders

Held every two years to update everyone on NIST research efforts (2012, 2014, 2016, 2018)

June 19-20, 2019

https://www.nist.gov/topics/forensic-science/conferences-and-events
Human Factors Working Groups

Collaborative work with the National Institute of Justice

Errors in pattern-based forensic science disciplines can be mitigated through management of potentially biasing information

- Latent Print Examination (February 2012)
- Handwriting Analysis (February 2020)
- DNA Interpretation (started in February 2020)
- Firearms Examination (starting in late 2020)


Process maps (being) developed for each of these forensic disciplines
Inputs and Relative Relationships of Efforts

Gather Literature and Available Data

Scientific Foundation Review

DNA Mixture Interpretation
Scientific Foundation Review

Create Process Map

Human Factors Working Group
Requests for **Understanding What Data Exists**

Supporting Forensic Science Methods

NRC Report (2009)

NCFS Recommendation (2016)

PCAST Report (2016)

“demonstrating the validity of forensic methods”

(Recommendation #3)

“technical merit evaluation”

“establishing foundational validity”

**NIST: a “Scientific Foundation Review”**
Plans for our NIST Scientific Foundation Reviews

- Outlines our plans to conduct studies and report findings along with historical overview of previous efforts (NAS, SoFS, PCAST, AAAS) and similar international activities

- **Feedback sought on our draft**

- Public Comment Period held
  - September 24 to November 19, 2018
  - 13 responses received (27 pages)

https://www.nist.gov/system/files/documents/2019/02/12/draft_nistir_8225_comments_received.pdf

Published September 24, 2018

https://doi.org/10.6028/NIST.IR.8225-draft
NIST Pilot Plans for Technical Merit Evaluation

• Initial NIST efforts would look at three examples selected from different areas, as we learn if the approach can be effective:
  • DNA
  • Firearms
  • Bitemarks

• Seek input from a variety of experts
• Conduct a literature review
  • Reference list will be publicly available as part of the study findings
• Evaluation of literature claims
• Conduct interlaboratory studies
  • Where possible, assess quality of work in operation – with de-identified participants
• Publish findings and recommendations
• Provide training for judges, lawyers, jurors, practitioners, …
  • Develop training aids to convey the capabilities and limitations of studied forensic disciplines
Recommendation #1: NIST should establish an in-house entity with the capacity to conduct independent scientific evaluations of the technical merit of test methods and practices used in forensic science disciplines.

Recommendation #2: The results of the evaluations will be issued by NIST as publicly available resource documents. NIST’s evaluation may include but is not limited to: a) research performed by other agencies and laboratories, b) its own intramural research program, or c) research studies documented in already published scientific literature. NIST should initially begin its work by piloting three resource documents to establish their design and requirements. The release of these documents should be broadly disseminated in the scientific and criminal justice communities and accompanied by judicial trainings.
Similar Efforts by Other Groups

• **AAAS**
  With funding from the Arnold Foundation, AAAS conducted two gap analysis studies:
  • **Fire Investigation** (published in July 2017)
  • **Latent Prints** (published in Sept 2017)
  https://www.aaas.org/page/forensic-science-assessments-quality-and-gap-analysis

• **NIFS** (Australia/New Zealand)
  • In 2016, started a forensic fundamentals gap analysis (beginning with anthropology, document examination, shoemark comparison, and bloodstain pattern analysis)
  • In 2019, shared empirical study design ideas
NIST Scientific Foundation Reviews Underway

1. DNA Mixture Interpretation (initial pilot study)
   • Began in September 2017
   • AAFS 2019 and ISHI 2019 workshops conducted
   • Report being drafted…

2. Bitemark Analysis
   • Began in October 2018
   • Workshop held in October 2019

3. Digital Evidence
   • Began in February 2019
   • Interlaboratory study announced in February 2020

4. Firearms Examination
   • Began in October 2019
   • Gathering literature and information on error rate studies

Reports will be provided with each foundation review
Initial Concerns Raised by Some Regarding Our Initial DNA Project

• Everything is fine with DNA – leave it be

• There are standards for DNA interpretation already
  • **FBI QAS 2011 9.6.4** Laboratories analyzing forensic samples shall have and follow a documented procedure for mixture interpretation that addresses major and minor contributors, inclusions and exclusions, and policies for the reporting of results and statistics.

• You need additional experts working on this study

• Available information is being ignored, such as unpublished validation studies
Purpose of our DNA Mixture Interpretation Review

Primary Goals:

1. **Develop a bibliography of relevant literature**
2. Define underlying principles, characterize capabilities and limitations of methods for mixture analysis
3. Identify knowledge gaps for future research
4. Inform the forensic community and non-specialists of findings (judges, attorneys, & general public)
5. **Create a framework for potential future NIST foundational reviews in forensic science** (others have already started)

Workshop conducted: Feb 2019 (AAFS) and Sept 2019 (ISHI)  
**Working to complete a draft report for release…**
AAFS Workshop (February 2019)

DNA Mixture Interpretation Principles: Observations from a NIST Scientific Foundation Review

Chair: John M. Butler (NIST),
Co-Chair: Sheila Willis (NIST Guest Researcher)

8 hours, 17 presenters, 19 talks, 406 slides

Speakers (left-to-right):
NIST team & Resource Group

Joel Sutton (DFSC)
Jack Ballantyne (UCF)
Keith Inman (Cal State East Bay)
John Butler (NIST)
Lisa Schiermeier-Wood (VA DFS)
Peter Vallone (NIST)
Melissa Taylor (NIST)
Ray Wickenheiser (NYSP)
Robin Cotton (BU)
Bruce Heidebrecht (MSP)
Hari Iyer (NIST)
Eugene Lien (NYC OCME)
Sheila Willis (NIST associate)
Jennifer Breaux (MoCo, MD)
Charlotte Word (consultant)
Roger Frappier (CFS-Toronto)
Rich Press (NIST)

Resource Group members not pictured:
Todd Bille (ATF Laboratory)
Tamyra Moretti (FBI Laboratory)
ISHI Workshop (September 2019)

DNA Mixture Interpretation Principles and Best Practices

John M. Butler, PhD
Hari K. Iyer, PhD
Sheila Willis, PhD

3 hours, 3 presenters, 167 slides

Topics Covered

• Why have DNA mixtures and trace DNA become so prevalent?
• Are all DNA mixtures difficult to interpret?
• Why are complex DNA mixtures difficult to interpret?
• UNCERTAINTY #1: When is a peak a peak?
• UNCERTAINTY #2: Whose peak is it anyway?
• What is probabilistic genotyping software, and how does it help?
• How confident can one be that the DNA is related to the crime?
• Should labs just stop analyzing complex DNA mixtures altogether?

Making Sense of Forensic Genetics (2017)

- Developed by European Forensic Genetics Network of Excellence (EuroForGen-NoE) and published with Sense about Science

- **Free PDF file** available for download

- **Final point made**: “As DNA profiling continues to grow more sensitive, and it is used in more investigations, the need for accurate communication between scientists and nonscientists only grows - both to ensure that their expectations of the technology are realistic, and its limits are properly understood…”
Lots of Change in the Past Few Years for DNA Mixture Interpretation…

- Growth of **probabilistic genotyping software (PGS)** use throughout the U.S. forensic DNA community
  >50 U.S. laboratories now using STRmix, TrueAllele, or Lab Retriever

- Many new publications on theory and data behind probabilistic genotyping models (primarily those used in STRmix)

- Widespread adoption of new STR megaplex kits and in some cases new CE instrumentation that has required additional validation studies

- New guidelines and standards released and in development (e.g., SWGDAM 2017, FBI QAS 2020)
Data Resources Sought for Examination in Our Review

Interlaboratory data reveal the degree of reproducibility with a method across multiple laboratories.

Proficiency test (PT) and internal validation data demonstrate the ability to obtain reliable results under specific laboratory conditions in a single laboratory.

Published articles in peer-reviewed scientific journals typically establish the broad base of what is possible.
Initial Draft Report *(too long → being revised)*

- Executive Summary, Acknowledgments and Disclaimer
- Introduction to the Review
- DNA Mixture Principles and Practice
- Data Sources
- **Reliability** (validation and LR discrimination & calibration)
- **Relevance** (DNA transfer & activity)
- New Technologies (potential & limitations)
- **Appendix 1**: Relevant Literature Listing *(currently 631 references)*
- **Appendix 2**: DNA Basics & Glossary *(currently 122 terms defined)*

*Other potential appendices or ancillary documents are being considered as well*
Foundation Study on DNA Mixtures

• Increased sensitivity had two immediate consequences
  1) Need to deconvolute mixtures which were more prevalent because more DNA was detected
  2) Information needed on transfer to help assess the relevance of the recovered DNA

• Most of the literature is concentrated on the first point

• The second point is particularly important for mixtures when at least some of the contributing genotypes are likely to be irrelevant

TOPICS DISCUSSED IN THINKSHOP

Science Question 1 (Understanding Dentition): Are there measurable characteristics or features in human dentition that vary among individuals and are persistent within an individual?

Science Question 2 (Understanding Bitemarks): Do bitemarks transfer measurable characteristics of the dentition to the substrate?

Science Question 3 (Data Interpretation Strategies): What interpretation strategies (techniques and practices) produce the most accurate and reliable results?
A digital evidence interlaboratory study was announced this morning in the Digital & Multimedia Sciences section.

**DIGITAL & MULTIMEDIA SCIENCES**

Presentation C7 (Thursday, February 20, 9:35-9:50am)

The National Institute of Standards and Technology (NIST) Scientific Foundation Study for Digital Examiners

*Barbara Guttman, BA*; *Mary T. Laamanen, MS*; *Craig Russell, MS*
Models for Community Involvement & Input

Model 1

**Resource Group**
(13 practitioners/researchers)

AAFS & ISHI workshops

Foundation Review

NIST team (6)

DNA Mixture Interpretation

Model 2

**Steering committee**

External literature review

“Thinkshop”
(~50 participants)

Foundation Review

NIST team (3)

Bitemark Analysis

Model 3

Foundation Review

Review Team

Outside experts

NIST experts

External literature review

Report

Firearms Examination
# Firearms Examination Core Team Members

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<thead>
<tr>
<th>#</th>
<th>Team Member</th>
<th>Association</th>
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<tbody>
<tr>
<td>1</td>
<td>Ted Vorburger</td>
<td>NIST contractor (retired NIST researcher)</td>
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<tr>
<td>2</td>
<td>Robert Thompson</td>
<td>NIST researcher (formerly ATF firearms examiner)</td>
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<tr>
<td>3</td>
<td>James Yen</td>
<td>NIST statistician</td>
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<td>4</td>
<td>Steve Lund</td>
<td>NIST statistician</td>
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<tr>
<td>5</td>
<td>John Butler</td>
<td>NIST researcher (\text{connection to DNA review})</td>
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<td>6</td>
<td>Shannan Williams</td>
<td>NIST researcher</td>
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<td>7</td>
<td>Wayne Arendse</td>
<td>DC Dept of Forensic Sciences (firearms examiner)</td>
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<tr>
<td>8</td>
<td>Greg Klees</td>
<td>ATF Laboratory (firearms examiner)</td>
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<tr>
<td>9</td>
<td>Heather Waltke</td>
<td>NIST contractor (\text{connection to future NIST/NIJ Firearms Human Factors Working Group})</td>
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Firearms Examination Foundation Review

SCOPE:
Review of the scientific foundations for the forensic analysis and identification of firearms evidence

Marks on cartridge cases and bullets

403 references collected for consideration as of February 6, 2020
Firearms Examination Scope Discussions

What is in:

1. Comparison methods
2. Comparison microscopy as applied to both bullets and cartridge cases
3. Regions of interest
   • tool working surface to include breech face, firing pin, barrel rifling, chamber, extractor/ejector, magazine lip
   • ammunition manufacturing marks, surface features
4. Statistical approaches
5. Algorithmic comparison methods
 Firearms Examination Scope Discussions

What is not in:

1. Non-firearms tool mark evidence (e.g., chisel marks)
2. Firearm classification (e.g., barrel length, caliber)
3. Shooting scene reconstruction
4. Gun shot residue (GSR)
5. Trace metal profiling
6. Automated investigation methods (e.g., NIBIN)
Bullet Black Box Study

Conducted by NIST and Noblis to measure the accuracy and reproducibility of conclusions by firearms examiners in comparing bullets.

Each participant will conduct 100 comparisons, using physical samples (fired bullets, mailed to participants), with responses entered on the study website.

Interested?
firearms@noblis.org
Research Innovation to Implementation (RI2I)

Forensic Science Research Innovation to Implementation Symposium

NIST / Gaithersburg, MD / June 19-20, 2019/ NIST.GOV/RI2I

https://www.nist.gov/news-events/events/2019/06/forensic-science-research-innovation-implementation-symposium-ri2i
Notes from the NIST Research Innovation to Implementation in Forensic Science Symposium (RI2I)
June 19-20, 2019

Meeting held June 19-20, 2019 at NIST with ~100 attendees
  • Breakouts facilitated and discussions captured by SNA International

59 page document

Published in November 2019 as a NIST Special Publication
  • https://doi.org/10.6028/NIST.SP.2100-02
For crime laboratories, transferring forensic science research into practice is a challenging problem. Thousands of research papers are published in forensic science journals every year, yet many innovations never make it to the crime lab.

What can the forensic science community do differently so that new technologies come online faster? How can we reduce the obstacles to successful innovation?

Two breakout sessions conducted with participants
Court Perspective on Barriers in Implementing New Technology

Risk aversion is an important factor

https://doi.org/10.6028/NIST.SP.2100-02 (Figure 1, p. 33)
A common theme discussed in each group was **communication** and the gap that can exist between stakeholders.
Some Ideas Discussed

• Explore the creation of a national organization (e.g., National Laboratory) that could potentially serve as a resource for all forensic laboratories preparing to implement a new technology

This organization could provide support by:

1. Reviewing and evaluating new innovations so that every laboratory manager does not have to perform the same tasks individually

2. Serving as a repository for information including:
   a) Cost-benefit analyses
   b) Validation studies
   c) Return on investment (ROI) studies
   d) Standard operating procedures
   e) Other pertinent documents that may streamline the implementation process for a busy and often overworked laboratory
Possible Next Steps (1)

1. Investigate ways to enhance communication between forensic stakeholders

2. Investigate ways to incentivize researchers and businesses to implement technology that is helpful and tailored to forensic laboratories
   
   This may include incentives for work with forensic practitioners to address and overcome operational challenges faced by forensic laboratories
Possible Next Steps (2)

• Assessing laboratories periodically to help determine where they have gaps and recommend what new technology might be helpful
• Developing solutions to terminology differences among researchers, operational personnel, and courts
• Supporting validation studies by providing:
  • Guidance for validation studies
  • Validation samples
  • External review services
• Making equipment available for laboratories to evaluate
• Providing centralized training to educate stakeholders (e.g., courts on new technology, researchers and scientists on court admissibility and general acceptance, researchers on operational challenges and the need for new technology)

Considering a Validation Workshop for June 2021
Forensics@NIST 2020

November 5, 2020

Morning plenary sessions (will be webcast)

Afternoon breakout sessions by disciplines (not webcast)

DNA research activities
Firearms (3D imaging)
Drug analysis
Digital evidence
Trace analysis
Statistical analysis

Workshops (on the following day)
1) DART-MS in Forensic Science
2) Forensic Cannabis Quality Assurance

Thank you for your attention!

301-975-4049
john.butler@nist.gov

301-975-2118
robert.m.thompson@nist.gov

www.nist.gov/forensics