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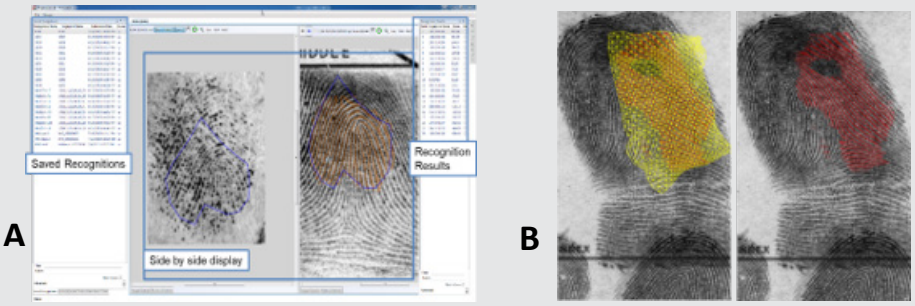
SUCCESS STORY
LatentSleuth™: A Case Study on the Impact of Federal R&D Funding



The LatentSleuth interface (A) offers a "comparator" view that enables latent-to-reference analysis.[1] The workstation's algorithm enables matching despite skin elasticity (B).

"Effective funding programs have enabled 18 years of innovation that has improved practice in the forensic sciences."

—Donald Gantz
George Mason University

Context

The development of technologies to improve the objective collection, analysis, and interpretation of evidence is driven by the multiple stakeholders that make up the forensic science enterprise. Funders of research and development efforts play a key role in enabling testing, validation, and continuous improvement of forensic tools and techniques. Department of Justice (DOJ) funding mechanisms, through agencies such as the National Institute of Justice (NIJ) and the Federal Bureau of Investigation (FBI), support a rich portfolio of innovations that help sustain this forensic innovation ecosystem.

This case study illustrates the impact of DOJ funding that enabled a company. university, and federal government collaborative research team to create FLASH ID, a quantitative handwriting analysis software, which ultimately spawned a quantitative latent fingerprint-to-reference product, LatentSleuth. Beyond providing resources for technology development, this funding enabled:

- the support of an ongoing "family tree" of collaborators across multiple universities;
- evaluation and use of LatentSleuth in a crime laboratory; and
- extensive research into the development and application of statistics-based methods for interpretation and presentation of impression and pattern evidence.

NIJ and the FBI Laboratory, both within the DOJ, ultimately help drive the development of a collaborative research community that helps enable just forensic outcomes.

Objectives

- Highlight the value of Department of Justice (DOJ's) funding support to the forensic innovation ecosystem
- Demonstrate how federal funding enabled public-private R&D collaboration leading to the development of FLASH ID™, LatentSleuth, and statistical methods that are advancing the impression and pattern evidence disciplines
- Describe the LatentSleuth product and its value to the impression and pattern community

[1]Gantz, D.T., Gantz, D.T., Welch, M.A., Roberts, M.A, and Buscaglia, J. (2014) A novel approach for latent print identification using accurate overlays to prioritize reference prints. Forensic Science International. Volume 245, December 2014, Pages 162-170.
https://doi.org/10.1016/j.forsciint.2014.10.026

Federal R&D Funding and Its Role in the Development of LatentSleuth

Latent print analysis, or comparison of friction ridge patterns from fingerprints, has played a significant role in criminal investigations for over a century. Today, courts widely accept latent fingerprints as critical pieces of evidence that can link a suspect to a crime. Latent fingerprints are collected from a crime scene by forensic specialists who use chemical or physical methods to reveal and recover prints from objects and surfaces and are typically recorded photographically. Latent print examiners (LPEs) compare these collected latent print images to "exemplars," or known references, to determine identification or conclude whether these prints may share the same source.[2]

Latent print examinations have traditionally relied heavily on the trained expertise of forensic examiners to conduct manual comparisons between the latent print and the reference prints, although innovations such as automated fingerprint identification systems (AFIS) have facilitated the use of digital imaging technology to obtain, store, share, and analyze fingerprint data.[3] Since the 2009 publication of the National Academy of Sciences' (NAS's) **Strengthening Forensic Science in the United States: A Path Forward** report, forensic disciplines, including the impression and pattern evidence discipline, have been challenged on issues of accuracy, reliability, and validity. The report deemed the standard method employed by LPEs for fingerprint identification, the Analysis-Comparison-Evaluation-Verification (ACE-V) method, a subjective process without a quantifiable error rate. As a result, the research community has worked to apply statistical methods to pattern analysis to strengthen the ACE-V process and improve the quality of latent print evidence for court proceedings.

LatentSleuth has emerged as an innovative, commercially available workstation that provides objective and quantitative analysis in latent-to-reference (and latent-to-latent) fingerprint matching.[4, 5] This latent print analysis product was developed by Sciometrics (formerly Gannon Technologies Group) in partnership with George Mason University (GMU), with funding support from the NIJ and the FBI. Beyond funding, the FBI Laboratory provided project oversight and technical guidance that helped transition LatentSleuth from a concept to a prototype and eventually a commercialized product. LatentSleuth quantifies the Level 2 ridge structure of a fingerprint, including the friction ridge paths and events (e.g., bifurcations, ending ridges, dots, and continuous ridges)

The National Institute of Justice has funded research efforts to improve automated latent fingerprint comparisons. In addition to LatentSleuth awards, a selection of these awards include the following:

2019-R2-CX-0041: Latent Fingerprint Image Enhancement & Matching Using Deep Generative Adversarial Networks.

2018-DU-BX-4228: Statistical Infrastructure for the Use of Error Rate Studies in the Interpretation of Forensic Evidence

2016-R2-CX-0060: Occurrence and Utility of Latent Print Correspondences that are Insufficient for Identification

2014-IJ-CX-K088: Foundational Research into the Quantification of the Value of Forensic Evidence for Complex Evidential Forms arising from Impression and Pattern Evidence

2010-DN-BX-K267: Improving the Understanding and the Reliability of the Concept of "Sufficiency" in Friction ridge Examination

2009-DN-BX-K229: Establishing the Quantitative Basis for Sufficiency: Thresholds and Metrics for Friction Ridge Pattern Detail Quality and the Foundation for a Standard

2009-DN-BX-K228: Application of spatial statistics to latent print identifications: Towards improved forensic science methodologies

2009-DN-BX-K208: Quantitative Measures in Support of Latent Print Comparison

[2] Ulery, B.T., Hicklin, R.A., Roberts, M.A., and Buscaglia, J. (2014). Measuring What Latent Fingerprint Examiners Consider Sufficient Information for Individualization Determinations. *PLoS ONE 9*(11): e110179. https://doi.org/10.1371/journal.pone.0110179
[3] National Institute of Justice, "Fingerprints: An Overview," March 27, 2013, nij.ojp.gov: https://nij.ojp.gov/topics/articles/fingerprints-overview
[4] Sciometrics, LLC (2019). LatentSleuth: Empowering Latent Print Examiners. https://www.sciometrics.com/assets/files/Sciometrics%20LatentSleuth%20Info%20Sheet%20May2018.pdf
[5] Gantz, D.T., Gantz, D.T., Welch, M.A., Roberts, M.A, and Buscaglia, J. (2014) A novel approach for latent print identification using accurate overlays to prioritize reference prints. Forensic Science International. Volume 245, December 2014, Pages 162-170. https://doi.org/10.1016/j.forsciint.2014.10.026

that help determine identification.[6] LatentSleuth enables advanced comparisons between latent and reference prints returned from AFIS searches based on a quantitative evaluation of their similarity. Key features of the technology include:

- Computer algorithms describing nonlinear transformations (referred to as the "warp" technology) that enable the analysis and detection of complex features (such as ridge skeletons) while remaining independent of rotation and distortions because of skin elasticity.
- Matching capabilities that uniquely extend beyond standard features including the tips of the fingers and palm prints. This enables the matching and examination of difficult latent prints with small, distorted, or few characteristics.
- Overlays of the latent print are generated onto each reference print with precise placement information.
- Side-by-side analysis and annotation tools for the examiner to evaluate the prints, record observations, and build case documentation.
- A distortion grid that examiners may superimpose on the print to see the amount and location of distortion that is needed for the latent to be warped onto reference prints. With this visualization and knowledge of the substrate and development processes, the examiner can assess whether distortion is reasonable for that impression

Links to final reports and a recent FTCoE webinar providing an overview of the development and validation of LatentSleuth are provided below:

FTCOE webinar June 2021 - A Comprehensive Look at LatentSleuth (by Sciometrics, GMU, & VA DFS)

2016-DN-BX-K004: VA DFS NIJ Final report—March 2021 - Evaluation of an Emerging Automated Searching Technology to Improve the Efficiency and Reliability of Latent Print Comparisons

2017-IJ-CX-0029: GMU NIJ Final report—Dec 2020 - Statistical Error Estimation for an Objective Measure of Similarity to a Latent Image

The LatentSleuth workstation for latent fingerprint examination evolved from a technology developed for the Forensic Language Independent Analysis System for Handwriting Identification (FLASH ID) workstation as a result of a research partnership with the FBI Laboratory, GMU, and Sciometrics. FLASH ID compares handwriting in a "like-to-like" manner at the level of involuntary handwriting strokes that characterize a mature writer.[7] Available from Sciometrics, the LatentSleuth workstation is currently being used by a variety of laboratories around the country and has been evaluated by the Virginia Department of Forensic Sciences (VDFS) through an NIJ grant.[8] The LatentSleuth platform, which leverages the same competitive similarity algorithms developed for FLASH ID, streamlines the workflow and optimizes decision-making time for LPEs. Key benefits include:

- Reduction in fatigue because examiners can make decisions about matches in a more time-efficient manner.
- Potential reduction in case backlogs and increase in match rates for complex latent prints, facilitated by the tool's automated workflows.
- Improved utilization of latent prints gathered at the crime scene. The tool enhances identification of lower quality or more difficult latent prints, especially when the orientation of the print is unknown.

[6] Scientific Working Group on Friction Ridge Analysis, Study, and Technology. Document 10: Standards for Examining Friction Ridge Impressions and Resulting Conclusions (Latent/Tenprint). https://www.nist.gov/system/files/documents/2016/10/26/swgfast_examinations-conclusions_2.0_130427.pdf

[7] Gantz, D.T. and Walch, M.A. (2013). FLASH ID: *Handwriting Derived Biometric Analysis Software*. NIST Measurement Science and Standards in Forensic Handwriting Analysis Conference. https://www.nist.gov/system/files/documents/oles/FLASH-ID-Presentation-NIST-Walch-Gantz.pdf

[8] NIJ grant 2016-DN-BX-K004: Evaluation of an Emerging Automated Searching Technology to Improve the Efficiency and Reliability of Latent Print Comparisons.

- Efficiency improvements by offloading the search process to a computer algorithm. LPEs can maximize the time they spend making decisions from matched overlays rather than searching latent prints. This enables LPEs to compare the latent print across more exemplars with potentially little increase in their workload.

- Potential to expose serial criminal activity based on matching of latent prints across cases.

In addition to continuous improvement of the scoring algorithms and statistical models of random similarity for the FLASH ID and LatentSleuth workstations, this research community is ultimately working towards establishing statistics-based, objective measures of similarity in the impression and pattern evidence disciplines.

Impacts of Federal Funding on the Forensic Innovation Ecosystem

The successful development and commercialization of the FLASH ID and LatentSleuth is a testament to the impact and value of federal investments in research and development in the forensic sciences. This journey serves as an illustration of the value that federal funding can bring to the forensic innovation ecosystem. Federal funding support can:

Enable practitioners to pilot emerging technologies: Beyond funding for initial technology development, NIJ provides funding mechanisms that effectively lower the barrier for testing, evaluating, and implementing emerging technologies in practicing forensic labs. This benefits both the technology developer and the laboratory: researchers or companies get the opportunity to work with practitioners to pilot the technology, and laboratories are provided the means to adopt new value-adding technologies. Interaction between these parties leads to robust feedback cycles that drive continuous improvement of forensic technology. In the 2016 grant mentioned above, VDFS incorporated the technology into its comparison workflow to understand how the tool might impact efficiency and reproducibility. The study found that LatentSleuth produced accurate results but did not necessarily lead to a significant reduction in examiner time spent looking for ridge detail correspondence. Rather, the tool was most helpful in situations with larger numbers of latent prints, even if those prints were of lower quality. VDFS has gone on to use LatentSleuth regularly in its casework. The NIJ grant gave it the opportunity to thoughtfully evaluate and incorporate the technology in the way that best fit its needs. This feedback has influenced development of a newer and improved generations of the LatentSleuth workstation.

Examples of relevant recent NIJ solicitations include the **Research and Evaluation for the Testing and Interpretation of Physical Evidence in Publicly Funded Forensic Laboratories** and the **Research and Development in Forensic Science for Criminal Justice Purposes** funding opportunities.

Support graduate and postdoctoral research to sustain a collaborative ecosystem: Grant funding supports graduate and postdoctoral researchers, building a legacy that can help expand on the existing research, train future talent, and continue the cycle of collaborative development. The "family tree" of researchers supported through multiple projects, shown in Figure 1, illustrates how funding can develop a community of researchers who ultimately help drive the science forward. Although this tree is not exhaustive, it is meant to illustrate the impacts of the partnership between Sciometrics, GMU, South Dakota State University (SDSU), the University of Central Florida (UCF), and the FBI Laboratory Research and Support Unit, and the funding efforts driving the research. This network has expanded not only through training of graduate students, but also through collaboration across institutions. This network has resulted in more than 30 related publications, numerous presentations, and the adoption of FLASH ID and LatentSleuth workstations by laboratories.

The **Intelligence Community Postdoctoral Research Fellowship Program** provided funding for three postdoctoral fellows to support research that ultimately led to the development of FLASH ID and the statistical foundational research for pattern evidence. Chris Saunders, who joined the team as a postdoc in 2006, played a key role in building this community through his career. While at GMU, he served as mentor and principal investigator to projects that were supported by postdocs and graduate students. After roles as an Oak Ridge Institute for Science and Education (ORISE)/FBI Laboratory Visiting Scientist and signal processing engineer at MITRE, Dr. Saunders took a faculty position at SDSU, where he continued his research through an NIJ grant,[9] in collaboration with Dr. Gantz and Sciometrics. This research has led to partnerships and collaboration with a number of graduate students and postdocs; some have continued on with research through NIJ grants of their own to investigate and address challenges in forensic statistics. Former students have continued on to roles in federal agencies, the private sector, and academia. Two are currently involved in the development of standards as NIST Organization of Scientific Area Committee Advisory Council Subcommittee members. Now an Emeritus Professor at GMU, Dr. Gantz has engaged Dr. Saunders and his research team at SDSU to continue the development and validation of LatentSleuth for statistical modeling of random similarity to a latent image.

Collectively address key gaps in forensic science: DOJ funding is informed by key forensic needs outlined by stakeholders and professional organizations in the community. These strategic investments enable innovations and research developments that help lead to more just outcomes. Beyond the development of individual value-adding products, processes, and techniques that improve the experience of end users, these funding mechanisms can target key challenges that can ultimately revolutionize the discipline. The LatentSleuth funding journey illustrates the evolution of quantitative, statistics-based methods to measure accuracy and reliability in two disciplines that have historically relied on manual comparison methods, addressing key concerns outlined in the 2009 NAS report. Informed by these consensus-based needs, these DOJ funding sources can help support a research community that truly addresses the needs of the forensic community.

Federal funding support has driven the development of an innovation ecosystem to address key challenges in the impression and pattern evidence discipline.

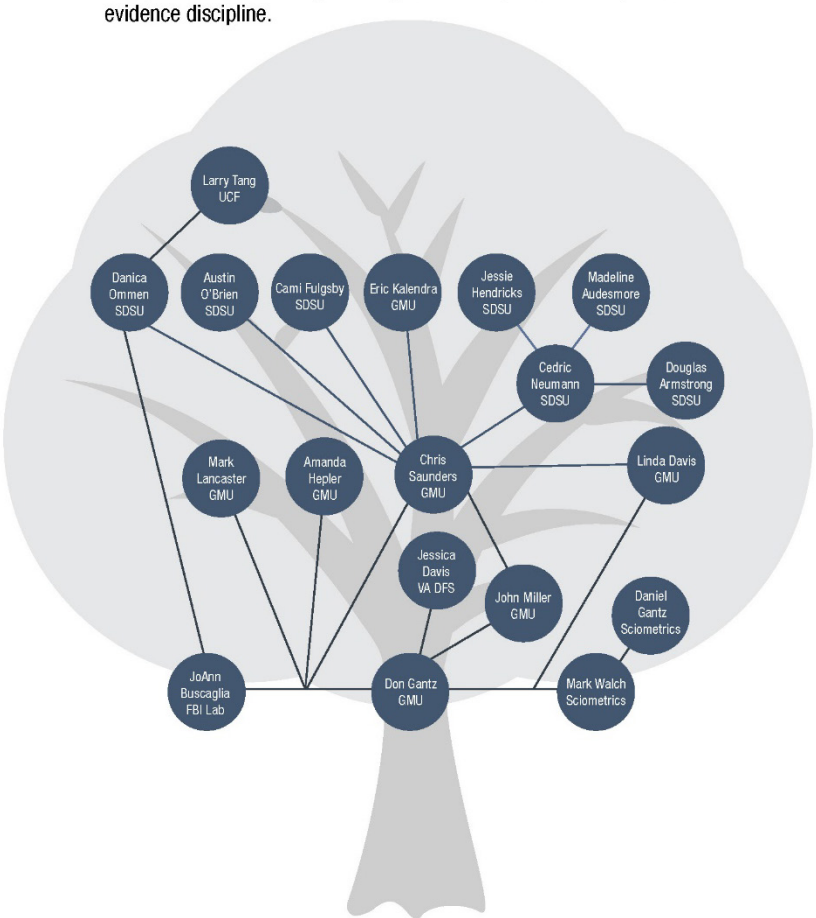


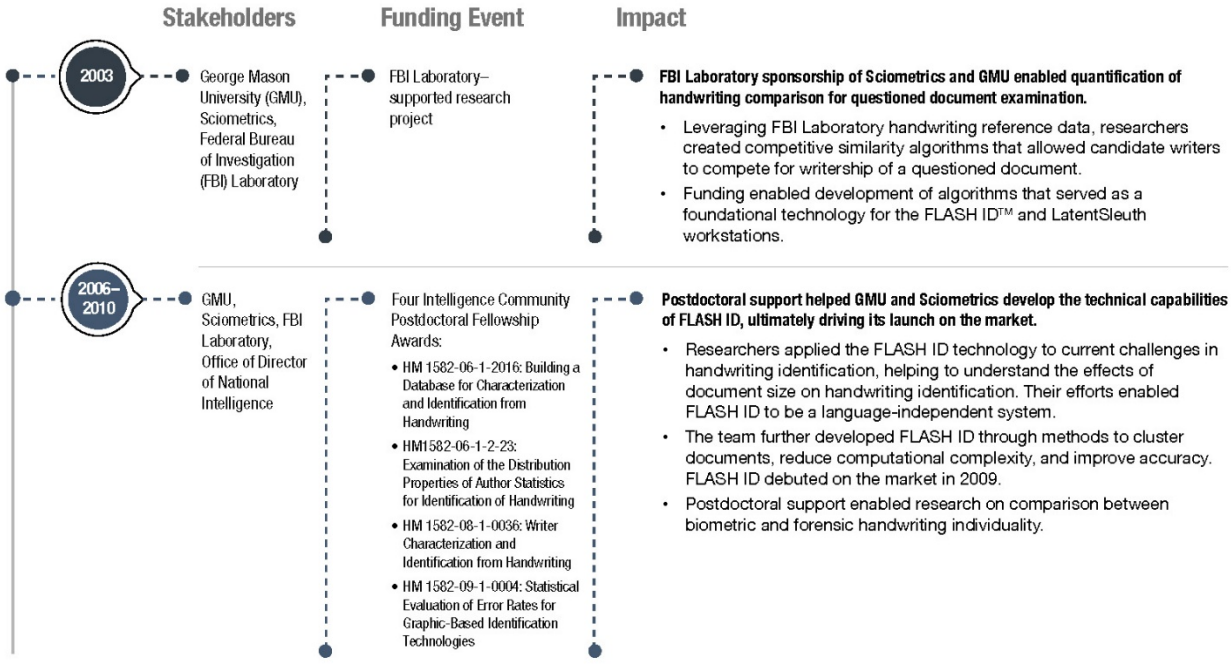
Figure 1: Funding opportunities have enabled the cultivation of a "family tree" of federal researchers, private developers, university research professors and graduate students who work to apply statistical methods to the impression and pattern evidence discipline.

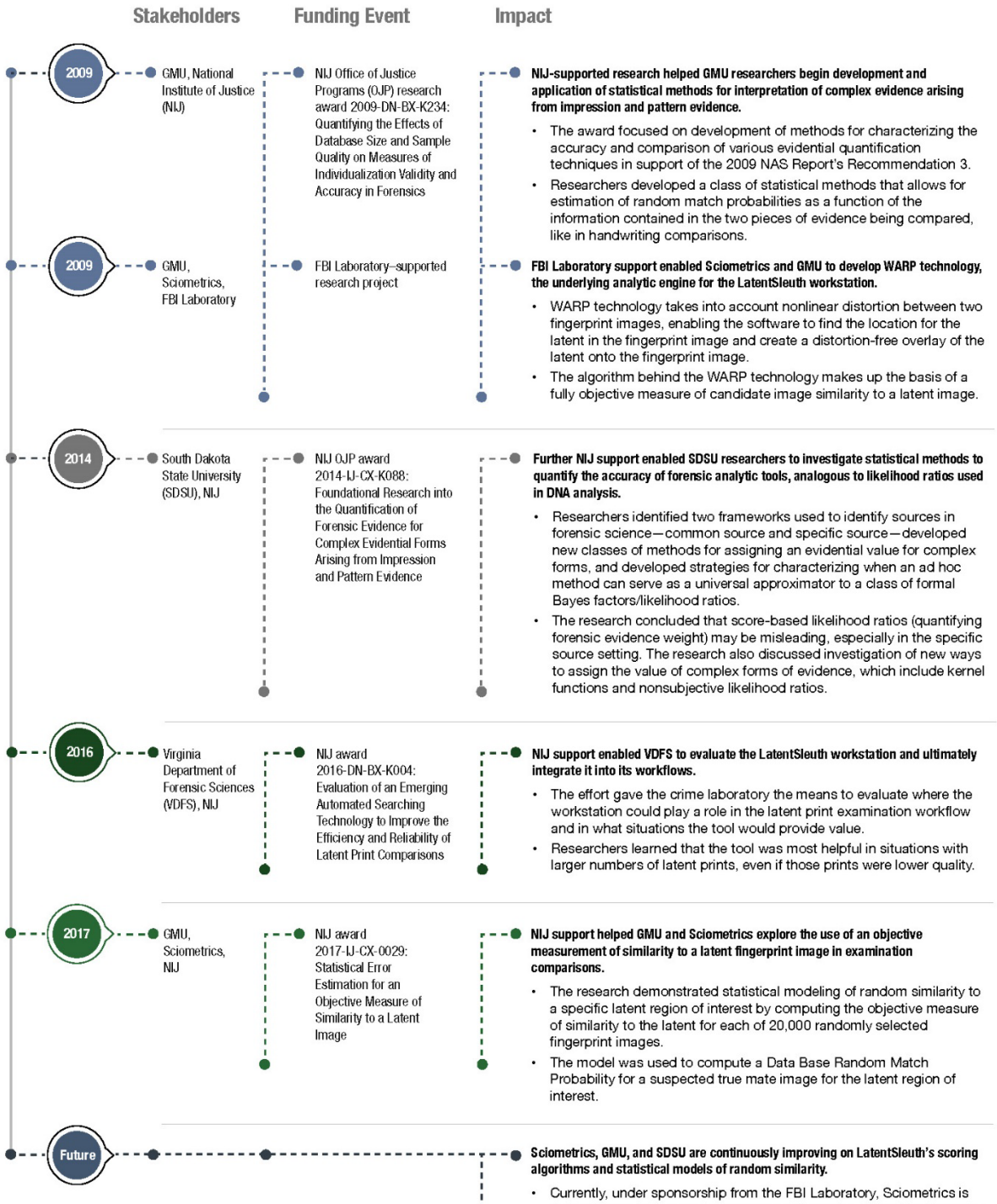
[9] NIJ Grant **2014-IJ-CX-K088**: Foundational Research into the Quantification of Forensic Evidence for Complex Evidential Forms Arising from Impression and Pattern Evidence.

The development of a robust research community working toward quantitative measures of error, accuracy, and reliability has helped incorporate statistics into the analysis of impression and pattern evidence. Better yet, it has helped to seed strong links between forensic scientists and statisticians, helping to further build connections in the forensic innovation ecosystem.

Federal funding has consistently played a key role in the evolution of the FLASH ID and LatentSleuth workstations. The following timeline provides a summary of the DOJ funding mechanisms that supported the development and continuous improvement of the technology.

Federal Funding Timeline of LatentSleuth™




Stakeholders
Funding Event
Impact
2009
GMU, National Institute of Justice (NIJ)
NIJ Office of Justice Programs (OJP) research award 2009-DN-BX-K234: Quantifying the Effects of Database Size and Sample Quality on Measures of Individualization Validity and Accuracy in Forensics
NIJ-supported research helped GMU researchers begin development and application of statistical methods for interpretation of complex evidence arising from impression and pattern evidence.
The award focused on development of methods for characterizing the accuracy and comparison of various evidential quantification techniques in support of the 2009 NAS Report's Recommendation 3.
Researchers developed a class of statistical methods that allows for estimation of random match probabilities as a function of the information contained in the two pieces of evidence being compared, like in handwriting comparisons.
2009
GMU, Sciometrics, FBI Laboratory
FBI Laboratory–supported research project
FBI Laboratory support enabled Sciometrics and GMU to develop WARP technology, the underlying analytic engine for the LatentSleuth workstation.
WARP technology takes into account nonlinear distortion between two fingerprint images, enabling the software to find the location for the latent in the fingerprint image and create a distortion-free overlay of the latent onto the fingerprint image.
The algorithm behind the WARP technology makes up the basis of a fully objective measure of candidate image similarity to a latent image.
2014
South Dakota State University (SDSU), NIJ
NIJ OJP award 2014-IJ-CX-K088: Foundational Research into the Quantification of Forensic Evidence for Complex Evidential Forms Arising from Impression and Pattern Evidence
Further NIJ support enabled SDSU researchers to investigate statistical methods to quantify the accuracy of forensic analytic tools, analogous to likelihood ratios used in DNA analysis.
Researchers identified two frameworks used to identify sources in forensic science—common source and specific source—developed new classes of methods for assigning an evidential value for complex forms, and developed strategies for characterizing when an ad hoc method can serve as a universal approximator to a class of formal Bayes factors/likelihood ratios.
The research concluded that score-based likelihood ratios (quantifying forensic evidence weight) may be misleading, especially in the specific source setting. The research also discussed investigation of new ways to assign the value of complex forms of evidence, which include kernel functions and nonsubjective likelihood ratios.
2016
Virginia Department of Forensic Sciences (VDFS), NIJ
NIJ award 2016-DN-BX-K004: Evaluation of an Emerging Automated Searching Technology to Improve the Efficiency and Reliability of Latent Print Comparisons
NIJ support enabled VDFS to evaluate the LatentSleuth workstation and ultimately integrate it into its workflows.
The effort gave the crime laboratory the means to evaluate where the workstation could play a role in the latent print examination workflow and in what situations the tool would provide value.
Researchers learned that the tool was most helpful in situations with larger numbers of latent prints, even if those prints were lower quality.
2017
GMU, Sciometrics, NIJ
NIJ award 2017-IJ-CX-0029: Statistical Error Estimation for an Objective Measure of Similarity to a Latent Image
NIJ support helped GMU and Sciometrics explore the use of an objective measurement of similarity to a latent fingerprint image in examination comparisons.
The research demonstrated statistical modeling of random similarity to a specific latent region of interest by computing the objective measure of similarity to the latent for each of 20,000 randomly selected fingerprint images.
The model was used to compute a Data Base Random Match Probability for a suspected true mate image for the latent region of interest.
Future
Sciometrics, GMU, and SDSU are continuously improving on LatentSleuth's scoring algorithms and statistical models of random similarity.
Currently, under sponsorship from the FBI Laboratory, Sciometrics is determining whether random error modeling using LatentSleuth can be extended to error modeling using FLASH ID.
These collaborators are currently working with latent print examiners to demonstrate the value of the LatentSleuth workstation and better identify structures of latents that often lead toward an identification.
Sciometrics is working with a major cloud services provider to make LatentSleuth available as a service by police departments and crime labs.
Sciometrics has developed two mobile apps that capture fingerprints from individuals and latents that will be integrated with the cloud implementation of LatentSleuth.

Conclusion

Federal funding mechanisms play a key role in the forensic community, from supporting development of tools and techniques to enabling a strong and sustainable innovation ecosystem. The research partnership that led to commercialization of the LatentSleuth latent print analysis workstation provides a compelling case study of the impact of federal funding for research and development on the forensic community. Dr. Gantz, Sciometrics, and their collaborators are continuing to improve upon the FLASH ID and LatentSleuth products (while leveraging feedback from practitioners) and apply statistics-based methods towards the accurate and objective interpretation of impression and pattern evidence.

For more information on NIJ's funding opportunities, check out its **Current Funding Opportunities** page.

The Forensic Technology Center of Excellence provides **resources for forensic researchers** that help them understand the forensic innovation ecosystem and how they might transition their research into practice.

Contact Sciometrics for more information or to request a **FLASH ID** or **LatentSleuth** demonstration or free trial.

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More Information

FTCoE Contact

Jeri Ropero-Miller, PhD, F-ABFT
Senior Director, FTCoE, RTI International
jerimiller@rti.org

NIJ Contact

Gregory Dutton, PhD
Physical Scientist/Program Manager
Office of Investigative and Forensic Sciences
Gregory.Dutton@usdoj.gov

Technical Contacts

Rebecca Shute, MS
RTI International
rshute@rti.org

Michelle Verastegui-Sanchez, MS
RTI International
mverastegui@rti.org

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