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U.S. NATIONAL FOOTWEAR DATABASE SYSTEM
FEASIBILITY STUDY

from *shoes* to *clues*

December **2021**

U.S.
National Footwear Database System
Feasibility Study

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1 INTRODUCTION

The National Institute of Justice (NIJ), Office of Investigative and Forensic Sciences (OIFS) and the Federal Bureau of Investigation (FBI), Laboratory Division (FBI Laboratory) entered into an inter-agency agreement (IAA) on August 25, 2016. On November 7, 2016, FBI and NIJ personnel convened at the FBI Laboratory to kick off the *National Footwear Database (NFD) Evaluation* (hereinafter referred to as the "project"). The significant work on the project was conducted by the authors from August 2017 to March 2020.

As the research, development, and evaluation agency of the U.S. Department of Justice (DOJ), the NIJ invested in the project because they believe that the future implementation of a U.S. NFD system has the potential to positively impact research efforts in the forensic footwear discipline. This impact could be realized through the generation of footwear class characteristic datasets; these datasets could enable researchers to develop statistical evaluation methods to improve the interpretation of footwear class characteristics by forensic footwear examiners (FFEs). The NIJ also believes that the NFD system would fill a void in the current U.S. law enforcement capabilities, providing a repository for storing footwear data and serve as an efficient tool to exploit it to generate criminal intelligence.

The project path was loosely defined by the IAA, but significant latitude was provided to the FBI Laboratory when it came to addressing the objectives and items in the statement of work (SOW); footwear intelligence, and the use of an operational database, is a novel concept here in the U.S. so much of the project's investigations embarked on uncharted territory. For this reason, the project took many paths as its track and objectives were refined based on progressive findings; some of the objectives were overcome by project learnings. Efforts were made to obtain relevant U.S. metrics that would provide objective means to inform the conclusions and recommendations; unfortunately, for the most part, that data was elusive; the U.S. does not maintain a good source of operational footwear data from which to understand its value as a crime solving tool. It would be helpful to know how the volume of footwear evidence collected and the number of leads generated using footwear impact investigations and adjudications downstream. A contributor to the lack of footwear data is the absence of an NFD in which to maintain and from which to output such data. This hypothesis was supported by successes acquiring relevant metrics from international partners in the United Kingdom (U.K.) and Switzerland, each of whom actively practice footwear intelligence using information technology (IT) solutions for sharing information. International data was helpful in demonstrating the value of footwear for intelligence.

The culmination of the project is this report, which provides the project team's findings, conclusions, and recommendations. This report lays the foundation for a roadmap to develop footwear intelligence practices in the U.S. and implement regional pilot studies across the country. It is our hope that this report ignites a renewed interest in footwear evidence and highlights its value for criminal intelligence across the U.S. law enforcement community. This is a valuable opportunity for the community to *transition the project's research and evaluation into practice*—a core mission of the NIJ.

1.1 BACKGROUND

Footwear impressions left behind at crime scenes (questioned impressions or Qs) are routinely collected along with suspects' footwear (known footwear or Ks). These evidence items are routinely analyzed by qualified FFEs in crime laboratories and forensic units for the purpose of source attribution. The results of these analyses are provided to investigators and prosecutors who are considering how to proceed with charges or prosecution, with the goal of case adjudication. This routine practice is referred to as ***evidential analysis*** herein. However, in the U.S., there is a gap in law enforcement capabilities—footwear evidence and information are not being routinely used in any uniform way to generate intelligence. Using Pasquier's definition of *criminal intelligence* as a foundation [1], ***footwear intelligence*** is *the product of organizing, analyzing, and evaluating footwear data to assist law enforcement in decision making for the purpose of solving crime and preventing future crime*. Today, for the most part, questioned impressions and arrestees' footwear are not being cataloged in a database to enable connecting the dots using footwear. Law enforcement must rely on other evidence, methods, and systems to generate leads. Currently, FFEs in crime laboratories conduct footwear make (brand) and model determinations (aka "database searches") to associate product information with the source of Qs. Generally, the output of those examinations is a laboratory report containing the make, model, and an image of the bottom of the footwear item (the outsole); unfortunately, these reports have limited investigative lead value.

To address this gap, the NIJ called on the FBI Laboratory to conduct research to assess whether a national system that serves as a comprehensive tool to generate leads using footwear could be developed and shared across the U.S. law enforcement community. This tool should be able to store, share, and search footwear class characteristics and case information.

NIJ believes that the development of an NFD system could positively impact law enforcement operations *directly* by providing the U.S. with a new intelligence tool and *indirectly* through the development of footwear datasets that could provide the data needed to quantify the significance of footwear class characteristics, thus advancing the state of the forensic footwear discipline. These impacts would address recommendations or needs reported by four noteworthy organizations: the National Research Council (NRC), the NIJ Forensic Science Technology Working Group (TWG), the Organization of Scientific Area Committees (OSAC), and the President's Council of Advisors on Science and Technology (PCAST).

- In 2009, the NRC reported, "The development of scientific research, training, technology, and databases associated with DNA analysis have resulted from substantial and steady federal support for both academic research and programs employing techniques for DNA analysis. Similar support must be given to all credible forensic science disciplines if they are to achieve the degrees of reliability needed to serve the goals of justice." [2]

- Over the past several years (at least as far back as 2013), the NIJ Forensic Science TWG published operational technology requirements (needs) relevant to this evaluation, including the need for a national footwear database of known and crime scene impressions; algorithms to aid in automated search and association of crime scene impressions with makes and models from known footwear reference collections; and determination of relevant populations for the interpretation of class associations in footwear evidence. [3–9]

- The OSAC Footwear & Tire Subcommittee published the development of an NFD as a research need in 2016 and again in 2021. [10–11] In 2021, this need was assessed as a major gap in the current knowledge with research currently being conducted to address that gap. "A national footwear database would help make footwear evidence much more useful in criminal intelligence. This database would allow multiple agencies to share footwear information, including determining the make/model of a shoe from shoe impressions, linking crime scenes by comparing crime-scene impressions, and linking suspects to crimes by comparing arrestee footwear with crime-scene impressions." [11]

- The PCAST, in 2016, reported, "The [White House] Office of Science and Technology (OSTP) should coordinate the creation of a national forensic science research and development strategy." Within the strategy, the PCAST called on the OSTP to address plans and funding needs for the "development of forensic feature databases, with adequate privacy protections, that can be used in research." [12]

The project's SOW directed the FBI Laboratory to use the following approach when conducting this feasibility study.

- Identify similar database efforts within the DOJ and conduct internal assessments of those databases to understand their scope, history, and the pros and cons associated with them.

- Establish a working group (WG) to assist in the evaluation of this effort.

- Identify other individuals and agencies that can provide further information regarding database development, including the FBI Criminal Justice Information Services (CJIS), the Defense Forensic Science Center (DFSC), and the National Institute of Standards and Technology (NIST).

- Engage with CJIS to evaluate their ability to host and deliver a shared IT solution to state and local law enforcement agencies.

- Evaluate existing commercial off-the-shelf (COTS) products for their ability to meet existing needs and to identify new requirements.

As stated above, *the project should assess whether a national database that serves as a comprehensive tool to generate leads using footwear could be developed and shared across the U.S. law enforcement community*. On the surface, this objective is reasonable since it addresses the gap NIJ identified. However, upon further examination, this objective speaks only to the tool

required to address this gap. An early project learning was that this objective must be expanded to address the people and processes surrounding the tools and technology that will make up a future NFD system. People tend to focus on the tool when looking for a solution to an identified problem. Whether it be software, hardware, or other technology, the tool will not likely achieve the desired outcome without considering the other two essential components of any 'system'—*people* and *processes*. For that reason, all three components were considered when conducting this feasibility study.

While the primary focus of the project relates to the footwear discipline, other forensic disciplines might benefit from the development of relevant datasets. To capitalize on lessons learned from the project, the NIJ requested that an assessment of the footwear findings be performed to determine if they could be applied to other forensic disciplines. This report did not specifically address how the outcomes could be applied to other disciplines, but the authors hope that stakeholders in other disciplines to find the information herein useful to their area of expertise.

1.2 MATERIALS AND METHODS

The authors served as the project team and were responsible for the leadership and execution of the project. However, they relied on support from and engagement with many other individuals from many different agencies and organizations, both domestic and international. The team utilized various materials and methods to accumulate the project knowledge reported herein.

Early in the project, the following eight areas of interest were identified and supporting objectives were developed for each. These areas and objectives served to focus and direct the project and to organize acquired project knowledge.

- U.S. Footwear Intelligence Gap
- Current State of Footwear Forensics in the U.S.
- International Footwear Intelligence Programs
- Existing U.S. National Forensic Databases
- Legal, Policy, and Privacy Analysis
- Law Enforcement and the Footwear Industry
- Standards and Technology
- Law Enforcement Research

1.2.1 Literature Review

A literature review provided the foundation on which to build the team's project knowledge, informed the project's scope, and enabled the team to develop an execution plan. The literature review included articles, reports (from law enforcement and other government organizations), policies and procedures, presentations, press releases, and case studies. Some of these sources were published in peer-reviewed journals or presented at professional

conferences, others were obtained online, and others are unpublished and were obtained through the team's engagement with specific individuals and agencies.

1.2.2 Engagement with U.K. NFD Stakeholders

At the onset of this project in September 2017, FBI Laboratory personnel traveled to London for a week where they met with several U.K. NFD stakeholders to learn about the U.K.'s national footwear database system and footwear intelligence practices. The Metropolitan Police Service (London) (hereinafter referred to as the "Met Police") hosted this multi-agency conference during which meetings, presentations, and demonstrations took place. That week was very beneficial to set the stage for this multi-year assessment: it enabled the team to realize the benefits of their NFD system, identify additional points of contact, and identify additional areas of investigation. This engagement was an asset to the team during their research.

1.2.3 Project Working Group Meetings

An international, inter-disciplinary, and inter-agency WG comprised of 22 members with various backgrounds and expertise was formed to provide guidance and subject matter expertise to the team throughout the project. The WG convened twice for three days of in-person meetings held on January 9–11, 2018 and June 4–6, 2019 in Fredericksburg, VA. This WG was an invaluable resource that filled the gap in knowledge and expertise in many relevant areas, which resulted in obtaining valuable reference material and directing the project path. The WG meetings provided an interactive forum to exchange project information with experts from various domains (e.g., academia, law enforcement, private industry, and research) representing the U.S., U.K., and Switzerland. This forum enabled the team to define (and refine) the project scope; identify additional sources of information; gain a better understanding of law enforcement operations within the U.S. and internationally; and define the U.S. footwear intelligence gap. The WG membership, excluding the authors, is listed (in alphabetical order) below. Additional ad hoc experts were invited to and participated in these meetings.

Justin Cook	**John Grassel**	**Amanda Hunter**
FBI CJIS	Rhode Island State Police	FBI Laboratory
Charless Fowlkes	**Taylor Grazulewicz**	**Jeremy John**
University of California, Irvine	FBI Training Division	DFSC
Michael Gorn	**Julie Henderson**	**Danyela Kellett**
FBI Laboratory	Bedfordshire Police (U.K.)	Lancashire Constabulary (U.K.)
Eric Gilkerson	**Martin Herman**	
FBI Laboratory (Retired)	NIST (Retired)	**Gerry LaPorte**
		NIJ (Formerly)

Cary Oien
FBI Laboratory

Julien Pasquier
Neuchâteloise Police
(Switzerland)

Eric Pokorak
FBI Laboratory

Andy Polk
Footwear Distributors and
Retailers of America

Matt Priest
Footwear Distributors and
Retailers of America

Luther Schaeffer
NIJ (Formerly)

Jacqueline Speir
West Virginia University

Charlie Thorpe
Sarasota County Sheriff's
Office (Retired)

Richard Vorder Bruegge
FBI Operational
Technology Division

Mike Wallace
FBI Office of General
Counsel

Alan Zheng
NIST

1.2.4 Engagement with Other FBI Divisions

The breadth of the FBI was used throughout the project and was a proven asset. There is an enormous diversity of expertise in the FBI that is held by many extraordinary individuals. Individuals and teams within the following divisions (in alphabetical order) provided input and or responses to the team's inquiries: the CJIS Division, the Finance and Facilities Division, the Office of General Counsel (OGC), the Office of Partner Engagement, the Office of Private Sector (OPS), the Office of Public Affairs, and the Operational Technology Division. Input was solicited during in-person and virtual listening sessions and inter-office communications.

1.2.5 Engagement with the FBI National Academy

Listening sessions were executed with law enforcement leaders enrolled in the FBI National Academy (NA). The NA is a 10-week professional course of study, provided at the FBI Training Division, for both U.S. and international law enforcement managers nominated by their agency heads because of their demonstrated leadership qualities. These engagements enabled the team to communicate directly in an open forum with law enforcement representatives at all levels. During those sessions, the project team briefed the students on the project and footwear intelligence. Most importantly, the students provided valuable feedback that helped define the current state of footwear forensics in the U.S. and identify potential roadblocks to near-term footwear database implementation.

1.2.6 Engagement with Existing U.S. National Forensic Database Stakeholders

The team identified three existing U.S. national forensic databases that are relevant to the project—the *Combined DNA Index System (CODIS)* for DNA, the *Next Generation Identification (NGI) System* for fingerprints, and the *National Integrated Ballistic Information Network (NIBIN)* for firearm cartridge casings. Later in the project, the team discovered the

FBI Laboratory's *Rapid DNA* initiative, which is not a database but rather a new practice with surrounding people, processes, and tools that is also relevant to the project. This initiative will result in the implementation of a national solution to enable field personnel (in both booking and scene environments) to collect DNA, analyze it, and search it on CODIS to generate actionable intelligence.

Several specific areas of interest associated with these systems and initiatives were identified based on their relevance to informing a future NFD system, including their: history; system architecture; legal, policy, and privacy impacts; support structure; and operations. Much of the team's knowledge of these well-established databases was obtained through engagement with their stakeholders. Engagement included listening sessions with and system demonstrations by subject matter experts (SMEs). These engagements, over the course of the project, provided practical insights regarding their operational workflows, their support structures, and the components of these systems that were applicable to an NFD system. An unexpected benefit of these interactions was the identification of additional topics for investigation, such as legal and policy concerns.

1.2.7 Engagement with the Footwear Industry

The team engaged the Footwear Distributors and Retailers of America (FDRA), specifically the President and CEO Matt Priest and the Senior Vice President Andy Polk, to obtain a behind-the-scenes look at the footwear industry. The FDRA was a source of valuable industry information and a conduit to other industry professionals. Interactions with these industry experts helped identify how this industry's resources (e.g., footwear images, information, and experts) may be leveraged in the future. Additionally, the FBI OPS provided details regarding how the FBI engages the private industry, including footwear manufacturers and retailers, for the mutual benefit of the FBI and private corporations.

1.2.8 Briefings to External Partners

The project team had several opportunities to brief aspects of the project to various audiences. These briefings were used to increase awareness about footwear intelligence and obtain feedback from stakeholder groups that had not already been reached. These outreach efforts resulted in furthering the team's understanding of the U.S. footwear intelligence gap. The following is a list of briefings that were provided during the project.

- FDRA Board Meeting (Washington, DC, May 2017)
- U.K. NFD Stakeholders Meetings (London, England, September 2017)
- International Association for Identification (IAI) Educational Conference (San Antonio, TX, July 2018)
- IAI Educational Conference (Reno, NV, August 2019)
- NIJ Forensic Laboratory Needs Technology Working Group (FLN-TWG) Meeting (Houston, TX, November 2019)

1.2.9 COTS Products Evaluations

Five COTS footwear databases and one outsole scanner were identified and investigated to understand the currently available solutions. Two of the COTS products were in use in the FBI Laboratory prior the project (*Foster+Freeman SoleMate FPX* and *Everspry EverOS*), two were acquired by the FBI Laboratory as part of the project (*Bluestar NFD* and *Everspry EverASM*), and vendors for the remaining two (*Forensity FAST* and *Hobbit Imaging Solutions PRIDE and TRIS*) provided demonstrations. These products were evaluated based on the current limited use of FDs in the FBI Laboratory (i.e., performing make and model determinations using vendor-provided reference collections), which is the standard practice for most crime laboratories and forensic units in the U.S. They were also evaluated by considering how these products might be used in the future when footwear information would be cataloged, searched, and accessed by law enforcement agencies to exploit it for intelligence. These evaluations sought to determine if any of the current products could meet the needs of the future state (and to what extent) and identify gaps in technology. For additional product perspectives that were incorporated into the evaluations, the team engaged with representatives from three local law enforcement agencies who either deployed a COTS solution or in the process of implementing a COTS solution, which provided empirical evidence of the impacts of implementation. The details of these evaluations will not be disclosed since the FBI, part of the U.S. federal government, is prohibited from providing an opinion regarding products and services. However, learnings from the evaluations were incorporated into **Section 2.4**.

1.3 ACKNOWLEDGEMENTS

2 CONCLUSIONS

The findings and conclusions reported here were identified through the analysis of the knowledge acquired during the three-year study timeframe. The body of knowledge for this project was organized in the eight categorical focus areas listed in **Section 1.2**. These conclusions bridge the gap between these focus areas by providing big-picture determinations and foreshadowing the actionable recommendations provided in **Section 3**.

2.1 CONCLUSION 1

> Footwear information is a valuable source of intelligence that is underutilized in the U.S.

Criminals must walk through the scene during the commission of their crimes. Therefore, footwear impressions are present at most crime scenes. They are often latent, requiring expertise and specific equipment and supplies to detect and recover, which leads to them often being overlooked. Even when collected today, they are not being cataloged in databases to generate leads because such databases do not exist. The lack of a footwear database systems, in part, discourages its collection since footwear evidence only becomes useful when a suspect is developed, and their footwear is collected. Without footwear databases, it is difficult for agencies to share footwear information, much less sharing that information among agencies. The absence of footwear evidence repositories is a major reason why this evidence type is underutilized for intelligence. This belief is supported when considering the evidence types that are prioritized at crime scenes—*DNA* and *fingerprints*. DNA and fingerprints both have well-established local, state, and national databases in which to deposit the evidence and exploit it for intelligence. Besides having databases, these biometrics "have the power to directly identify suspects." These two factors contribute to investigators' perceived value of these evidence types. However, the focus on identification leads law enforcement to undervalue other forms of evidence, including footwear, "which can be used to generate leads, eliminate suspects, reconstruct sequences of events, and identify links in serial crimes." [13] Despite their prioritization and intelligence value, it should be noted that "[fingerprints] are found in a best performing police service at 25% and DNA at 7% of burglaries, which means [fingerprints] are not found at 75% and DNA at 93% of burglaries. … There are many offenders escaping detection because they take basic precautions not to leave the biometric forms of evidence, but with respect to footwear, for example, they cannot fly" [14]

Footwear intelligence in the U.S. is limited primarily to local agencies sharing footwear information through less efficient means such as emails, task force meetings, and other intra- and inter-agency communication methods. These agencies often rely on FFEs in crime laboratories to associate the makes and models of the sources of scene impressions and provide images of and information about footwear items responsible for making Qs. But

these outputs don't possess much lead potential on their own. Investigators are responsible for taking the laboratory results, identifying similar patterns at other scenes, or locating that pattern on an arrestee's footwear item. This is not efficient. Due to these challenges, footwear evidence is primarily reserved for prosecution through the evidential analysis of the Qs to the Ks.
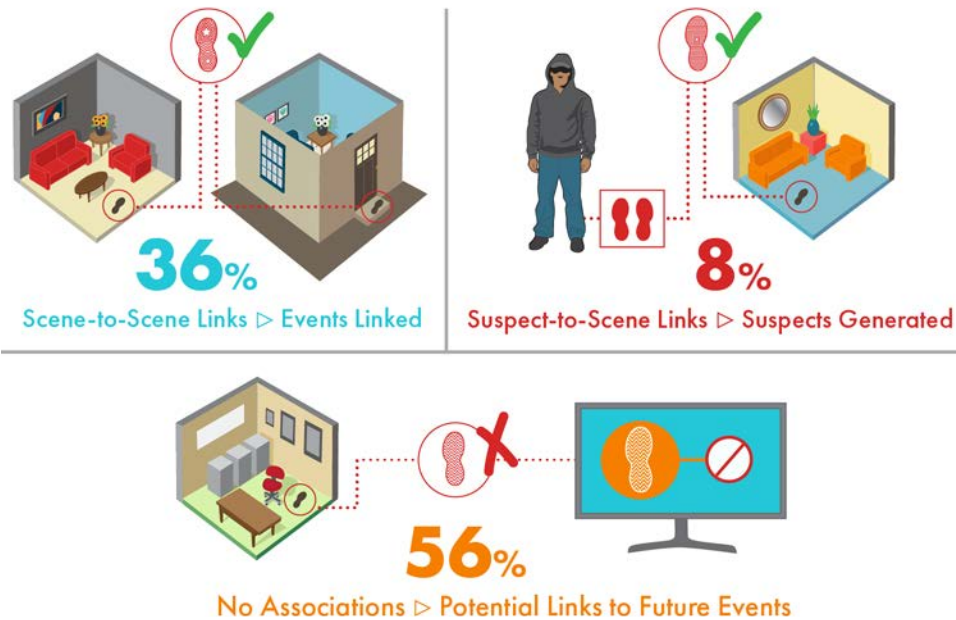
Footwear information is a valuable source of intelligence when looking at the successes realized, and resources invested abroad, notably in the U.K. and Switzerland. The U.K. is the best-known example of a country that has implemented a truly national footwear database system. It has refined its forensic intelligence practices over the last 50 years, dating back to the 1970s, which included the use of footwear evidence. [15] Initially, some law enforcement forces across the U.K. each maintained their own systems and had limited sharing of footwear information. But, as time went by, they determined that there is value in connecting these systems to share information among forces across the country. Sharing also allowed the footwear reference collection to grow significantly faster by multiple forces contributing to a single repository of footwear records.

A contributing factor to the U.K.'s prolific collection and use of footwear for intelligence is the passing of legislation in 2006 documented in the *Serious and Organised* (sic) *Crime and Police Act*, giving booking officers the power to take impressions from footwear worn by individuals arrested for a recordable offense. This legislation gave booking officers the same rights for footwear as the collection of DNA, fingerprints, and photographs. [16] The U.K. continues to retain the legal authority to record arrestees' footwear. [17]

From 2015 to 2017 the Neuchâteloise Police in Switzerland recovered 4,762 footwear impressions with the following intelligence successes: 36% of them generated scene-to-scene links and 8% of them generated suspect-to-scene links. So, 44% of the footwear data added to this Swiss system during that period had intelligence value and the remaining 56% holds the potential to provide leads as new events are entered into the system (see **Figure 1**). [18] In a series of 44 residential burglaries in Switzerland: 14 events (31%) yielded probative footwear impressions only (i.e., neither probative DNA nor fingerprints were collected from any of these events), six events (14%) yielded both a probative footwear impression and a probative DNA profile, and no probative fingerprints were obtained from any of the 44 events. [1]

International partners in the U.K. and Switzerland report that, not only does footwear provide the power to generate actionable intelligence, but it does so quickly (almost in real time). "With the use of an efficient [footwear] database, information can be obtained 'instantly'." [19] In September 2016, the Met Police collaborated with Bluestar Software (the software contractor who supports the U.K. NFD) and went live with Tread Finder, an innovative and cutting-edge system designed to rapidly generate intelligence using footwear. This system integrates the Everspry EverOS outsole scanner to rapidly record arrestees' footwear and automatically searches the arrestees' patterns against the records contained in the U.K. NFD. [20] The system generates an intelligence report that is automatically emailed to the investigator within ten minutes. [21]

Results of Footwear Evidence Exploitation in Neuchâtel (Switzerland)
4,762 Impressions Collected and Catalogued 2015–2017

36% Scene-to-Scene Links ▷ Events Linked

8% Suspect-to-Scene Links ▷ Suspects Generated

56% No Associations ▷ Potential Links to Future Events

FIGURE 1. *Intelligence value associated with 4,762 crime scene footwear impressions collected and cataloged in the Neuchâteloise Police's footwear database during 2015–2017.*

According to Pasquier, "The primary purpose of a [footwear] database should be the detection and the establishment of links between [impressions] taken from scenes for intelligence purpose[s]." It is an efficient source of link detection. On the contrary, footwear generates suspects less often than biometric forms of evidence (see the blue bar in **Figure 2**). This is likely a result of the permanence of biometrics versus footwear's limited lifetime; footwear items wear out and are taken out of 'circulation.' [19] Despite this limitation, multiple scenes linked through footwear could provide the gateway to the suspect when biometric evidence is collected at one of those linked scenes.

Comparison of Results of Footwear Database, AFIS, and CODIS
2012 Data from Six States in Switzerland
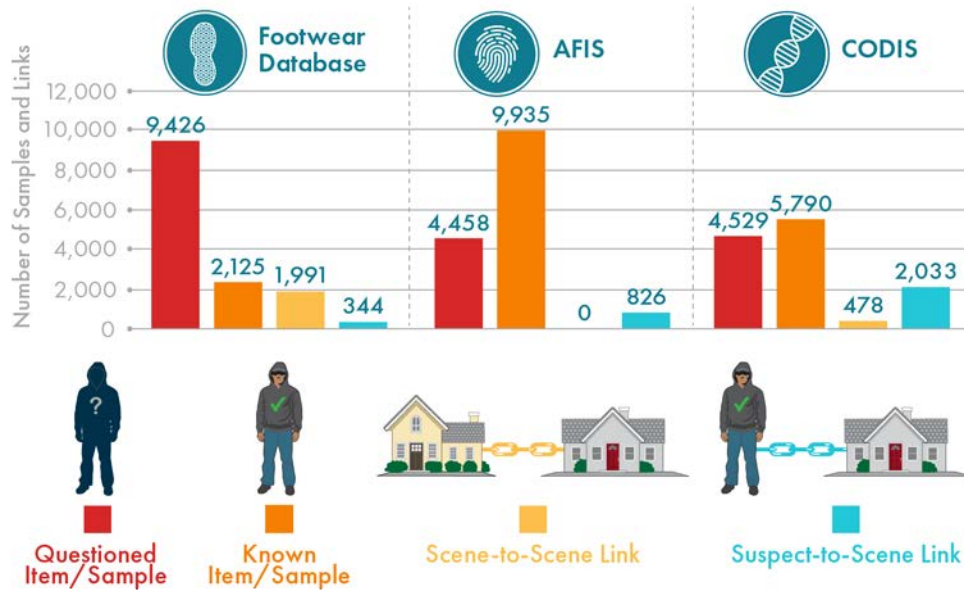
FIGURE 2. The results reported by six Swiss states—Fribourg, Geneva, Jura, Neuchâtel, Valais, and Vaud—during 2012, which compares the volume of evidence collected and the intelligence value across footwear, fingerprint, and DNA evidence.

In this report, footwear has been compared to DNA and fingerprints to demonstrate how these evidence types contribute differently to intelligence. However, having a holistic view of all the evidence in combination with contextual case information allows law enforcement to draw a more precise and reliable hypothesis for investigation. [1] Rossy, et al. illustrated how links made by a single data type (i.e., footwear, DNA, or contextual information) can be coupled together to maximize the intelligence potential of any one by detecting links between more than one data type and thus detecting a series. His illustration (re-imagined as **Figure 3** below) depicts a single crime series linking seven events; this series contains three groups (i.e., links made using a single data type) and three multi-data-type links (e.g., Event 4 linked by both footwear and DNA). [22] Therefore, the ideal footwear system would have the ability to incorporate other evidence information to harness the power of multiple data types.

FIGURE 3. *A hypothetical reconstruction of a crime series of seven events which was generated using contextual information, DNA, and footwear.*

It is through the detection of more links and more series among non-violent crimes that law enforcement can mitigate future violent crime. Data and case studies suggest that criminal activity escalates; burglars become violent criminals. "According to a Florida State study, 52 percent of [DNA] database hits against murder and sexual assault cases matched individuals who had prior convictions for burglary." Three agencies who received DNA funds from the NIJ—Miami-Dade Police Department, Palm Beach County Sheriff's Office, and New York City Police Department—discovered, "Analyzing DNA from property crimes can have major public safety benefits." [23] Chaplinsky noted, "The deployment of forensic evidence resources proves valuable not only in solving 'minor' crimes; it also serves as a proactive approach of collecting forensic data on past and future offenders of serious or violent crimes." [24] In 1985, Los Angeles County investigators arrived at a double-homicide scene and found an interesting shoeprint in a planter bed outside the victims' home. Within short order, the same footwear pattern was found at five residential murder scenes. The shoeprints and the killer's modus operandi were law enforcement's first clues that a serial killer was roaming the county. The serial killer was later identified as Richard Ramirez, who is infamously known as the Night Stalker. Ramirez had a prior criminal record, which included non-violent offenses such as drugs and vehicle violations. [25] Anthony Castillo Sanchez, the man convicted of the 1996 rape and murder of Jewell "Juli" Busken in Norman, Oklahoma, was previously convicted of several other crimes, but none of them involved violence. [26–27] Interestingly enough, the forensic evidence where Busken's body was recovered was limited to footwear impressions associated with a Nike shoe, DNA from her leotard, and the bullet that killed her. [28] So, if U.S. law enforcement can implement and utilize footwear database systems to link burglaries, link individuals to burglaries, and link

burglaries to violent crimes, it is possible that lives could be saved, and law enforcement efficiencies could be created.

2.2 CONCLUSION 2

> The current state of U.S. law enforcement prevents the successful implementation of a national footwear intelligence solution, including the use of a database, to exploit footwear evidence.

The current capability of U.S. law enforcement, at all levels, to generate actionable intelligence using footwear is low. There are many contributing factors that are responsible for this assessment. To improve the current state, the U.S. law enforcement community must work together to mitigate the limitations identified below.

As stated previously, footwear evidence is under-collected from crime scenes when compared to DNA and fingerprints and not proportionate to the number of scenes that are attended, most of which contain footwear impressions. The training and experience of field personnel, agency resources (both human and fiscal), and field personnel's perceived value of this evidence type are likely contributors to this deficit. The detection and collection of this evidence requires specialized training and somewhat specific equipment, and the capabilities and limitations of this evidence are not well understood across the law enforcement community. Anecdotal data indicating low collection rates of footwear evidence align with empirical evidence reported by the U.S. Bureau of Justice Statistics (BJS) through their 2009 and 2014 *Census of Publicly Funded Crime Laboratories*. The BJS reported that laboratory analysis request rates for impression evidence (including footwear and tires) was between 0.27% and 0.19%, significantly less than DNA with rates between 6.00% and 9.00% and fingerprints with a rate of 7.00%. [29] The rates of evidence collection can be inferred from these rates of request. These values contrast with those obtained from Switzerland and the U.K. Based on 2012 law enforcement data from six states in Switzerland, Pasquier reported that footwear impressions were recovered 27% more than fingerprints and DNA (see **Figure 2**). [19] In 2014, the Met Police reported even greater disparity between DNA recovery and footwear at burglaries; Met Police personnel were 44% more likely to recover footwear impressions than DNA. [21]

Despite the relatively low number of footwear requests across the country, there are only a limited number FFEs in crime laboratories and forensic units qualified to analyze this evidence. Many agencies don't have examiners dedicated to footwear, they are cross trained in other disciplines (e.g., fingerprints, firearms, or trace) with only part of their time on the bench dedicated to footwear analysis. This lack of human resources dedicated to footwear examinations has led to increased turnaround times, which is problematic for investigators who benefit from timely results to direct their investigations.

In U.S. crime laboratories, there is a lack of established and standardized forensic intelligence practices. "Forensic laboratories typically report results only after they have been

fully processed and reviewed for use in court proceedings in accordance with stringent quality management protocols." [30] Evidence follows a singular evidential analysis path that is intended 'sole'ly for use in courts of law. These laboratory practices exceed that required to provide timely investigative leads to the field. Footwear make and model determinations are included in the laboratory analyses that result in undesirable response times through this singular approach. Lopez, et al. reported, "The forensic intelligence approach, however, provides an opportunity to use existing forensic data (both preliminary and confirmed results) together with existing situational and other pertinent crime data to produce case leads, link cases, or inform investigative and proactive tactical, operational, and strategic policing. The forensic data produced for intelligence may not necessarily be the complete forensic report needed for presentation in court, but it can potentially inform investigations if integrated in a timely manner." [30] Laboratories must change their business practices to acknowledge that the laboratory results have *more than one purpose*, *more than one audience*, and *more than one deadline*. The results may be provided for lead purposes to the investigator who needed them yesterday, or they may be intended for the prosecutor at trial that takes places months in the future. So, laboratory practices and the associated results must reflect that notion. *It is about providing the right answer at the right time*. [31] In other words, the laboratory analyst's *answer* may vary over time depending on the question being asked and how the results will be used. [18] Laboratories must balance "quality and efficiency to get the right answer to stakeholders in a timely manner." [31] Laboratories can still provide quality and reliable results without adhering to the same practices across the board. This belief was reported by the authors of a recent Bureau of Justice Assistance (BJA) report. "Another way to reduce lab backlogs is to establish policies, standards, and procedures for the prioritization of submissions and develop guidance for officers in the field submitting evidence and case work." [32] The positive impacts associated with developing intelligence-led laboratory practices were further described in a recent NIJ report. "Investigators can use the information to determine if the results are relevant to the investigation and, if appropriate, may follow with full, confirmatory testing. Often, preliminary testing can demonstrate that no further testing is needed. This can have a tremendous impact on the laboratory, freeing up resources and personnel, reducing turnaround times, and ultimately reducing the backlog." [33]. The U.S. must recognize that the "detection of [footwear] links is not intended to systematically lead to judicial follow-up, but first of all to be integrated and analyzed together with other sources of information in order to support decision-making as part of a process of criminal intelligence." [19] Empirical evidence of these beliefs were realized at the Houston Forensic Science Center. That agency addressed an identified issue with the timeliness of its Automated Fingerprint Identification System (AFIS) searches and confirmations. In 2015, they used the principles described above—the right results for the intended recipient when they're needed—and developed a new approach to managing latent print throughput. The changes they implemented resulted in reducing the number of confirmations they performed by 84%. After the contributor received the laboratory-issued investigative lead report, only 16% of those submissions were re-submitted for confirmation. [31]

The lack of existing local and regional footwear intelligence programs, including the use of a database, is a major contributor to the conclusion that the U.S. is not ready for a national footwear system. Agencies are not routinely recording arrestees' footwear. They are not routinely collecting and cataloging scene impressions. As with the lack of distinct forensic intelligence practices in crime laboratories, there are no specific footwear intelligence practices established within the U.S. law enforcement community which both laboratory and field personnel can follow to implement such programs. Some negative impacts associated with the lack of established footwear intelligence practices (including appropriate people, processes, and tools) were realized through the team's investigations into two local agencies that implemented small-scale footwear intelligence programs. These agencies were not completely aware of the requirements associated with implementation, maintenance, and the supporting technologies. These agencies focused primarily on recording arrestees' footwear and uploading them to a local footwear database using a COTS solution and, unfortunately, were unable to achieve the desired results. It makes sense to follow the same path as those who came before us—CODIS and NGI. These national systems were created only after local and regional DNA and fingerprint databases were well established, the surrounding practices had been developed, and they had business cases to justify that their value would only increase if they connected the disparate systems to work across state lines.

With the help of attorneys in the FBI OGC, preliminary legal, policy, and privacy analyses were conducted to understand how system implementation would be impacted from those perspectives. According to their research, there are no laws in the U.S. that explicitly permit or prohibit the recording of arrestees' footwear during booking and cataloging those records in a database for intelligence purposes. Caselaw has established that people do not have a privacy interest in what they display to the public. See, e.g., United States v. Mara, 410 U.S. 19, 21 (1973). So, privacy is less of a concern regarding the recording of footwear at arrest since it is an item of clothing and publicly displayed; it is similarly non-intrusive to taking photos of the arrestee during booking to record their appearance. It is equally well established that when a person is under arrest and being booked into a jail, their privacy interests in their clothing are further frustrated: "[C]lothing or other belongings may be seized upon arrival of the accused at the place of detention and later subjected to laboratory analysis … [and] the results are admissible at trial." See, e.g., United States v. Edwards, 415 U.S. 800, 804 (1974) (footwear seized from inmate's belongings and analyzed at laboratory held admissible). See also Hancock v. Nelson, 363 F.2d 249 (1st Cir. 1966); United States v. Caruso, 358 F.2d 184 (2nd Cir. 1966); United States v. Williams, 416 F.2d 4 (5th Cir., 1969); Golliher v. United States, 362 F.2d 594 (8th Cir., 1966); Evalt v. United States, 382 F.2d 424 (9th Cir., 1967). Although the *Fourth Amendment* states that seizures and searches may not be made without a search warrant, there are exceptions; warrantless search and seizure of an arrestee's clothing may be made at a place of lawful detention, incident to arrest. See Edwards 415 U.S. at 802-03. Despite these findings, additional analyses are needed to satisfy that required to implement a national program, specific to footwear recording, collection, and laboratory analyses. More in-depth analyses will be performed prior to implementation; privacy matters will be addressed through the completion of the privacy impact assessment (PIA).

Before an NFD system can be implemented, decisions must be made regarding who will administer the system, where the data will reside, and the specific IT infrastructure that will be used to connect the thousands of agencies across the country. The team collaborated with CJIS to explore potential IT solutions for a future footwear system, but no decisions were made since they would be premature given that there is no plan to implement a system in the near term.

Based on the deficiencies and shortcomings reported above, implementing an NFD system today will not allow the full benefits of such a tool to be realized, given that the surrounding people and processes are not established. Additionally, the U.S. has not proven footwear's intelligence value in terms of cost effectiveness and level of outcomes expected (i.e., a "business case" has not been established) to justify NFD system implementation *now*, which requires the establishment of a new national program—a serious undertaking from the standpoints of both time and money. Standing up this new program requires, at a minimum, a multi-million-dollar investment (both at implementation and annually throughout the system's lifetime), conducting a privacy impact assessment (PIA), and defining system requirements. Unfortunately, the cost benefits of exploiting footwear are not well understood in the U.S. due to the lack of footwear intelligence programs from which to extract the metrics required to quantify footwear's return on investment (ROI). This gap prevents police chiefs, sheriffs, and politicians from being able to look objectively at footwear. Those decision makers need to know how it contributes to solving crime when compared to other evidence and information. When faced with decreases in funding, agencies must make sound judgments, based on data, when allocating their resources. This concern for resources is real across the law enforcement community, including those agencies at the federal level.

2.3   CONCLUSION 3

> The future vision of U.S. footwear intelligence programs, including their use of a footwear database, requires a partnership between laboratory and field operations; only through this collaboration can footwear information be fully exploited for intelligence.

"For … intelligence to be useful, both intelligence units and forensic labs must proactively collaborate to establish protocols and processes for sharing intelligence." [32] "Forensic [practitioners] can't contribute to [the] intelligence process if isolated." [18] "Developing investigative leads requires investigators, laboratory personnel, and prosecutors to engage in a systems-based approach, collaborating closely and transparently on forensic cases. This level of collaboration can yield considerable benefits on workloads for all of the forensic service providers involved, and ultimately help them process cases in a more efficient and timely manner to better serve justice." [33]

Currently, the outcomes of forensic analyses (including footwear evidence) are transactional. The field submits evidence and a request to the crime laboratory. Crime laboratory

personnel conduct the requested analyses, issue a report, and provide the report and the evidence back to the contributor. Field personnel have access to contextual case information housed in systems that are not integrated with those operated in crime laboratories. With respect to footwear, the footwear expert would benefit from access to contextual case information to assist the investigator with generating intelligence to direct their investigation. Similarly, the investigator could have a more holistic view of the crimes they are investigating through easy access to forensic data using a shared laboratory-field IT solution. [30] Finding methods to efficiently share the required case information and establishing new intelligence practices in laboratories will surely benefit investigations.

For laboratory analysts to institute intelligence practices and streamline their practices, they would benefit from access to additional case information (i.e., contextual information). This type of information can increase efficiencies by targeting specific exams and avoid unnecessary ones. Despite the benefits that contextual information provides, studies have shown that examiners are impacted (biased) by contextual information that they are presented with during forensic analyses. [34–35] This finding resulted in human factors and legal experts advocating for the introduction of 'masking' practices in crime laboratories; they believe that this information is irrelevant to scientists. These recommended procedures reduce the case information that practitioners are exposed to. The authors and others acknowledge that this concern should be considered when developing laboratory practices [32, 36]; however, the human factors experts overlook the fact that evidence is variable (produced through dynamic and uncontrolled means), its analyses require adapting forensic expertise and established practices to deal with this variability, and, more importantly, masking contextual information can prevent practitioners from producing actionable intelligence. Forensic science is an applied science that seeks to reveal as much information about the evidence as accurately as possible and to the degree required to answer the questions when they are being asked. Additionally, forensic results must be timely and relevant. To accomplish these goals, given the limited human resources in crime laboratories today, the scientist and the investigator must work together to make logical and strategic decisions to avoid unnecessary exams or identify additional probative exams. This necessary partnership will require a paradigm shift by rethinking laboratory practices, specifically defining two paths for analysis—*intelligence* and *prosecution*.

2.4 CONCLUSION 4

> A future NFD system requires trained, competent, and active users; standardized practices, including classification of records; and technology that enables efficient acquisition, search, and output.

A future NFD *system* will only be as good as the people, processes and tools which make up the system. This system will be comprised of the databases (i.e., the repositories of footwear data); other technology for the acquisition, query, and output of the data; the roles and

responsibilities of its users; the protocols and workflows associated with performing activities within it; and its administration.

2.4.1 People

There are specific roles and responsibilities that must be included in an NFD system to enable the accurate and efficient sharing of information. It is important that the participants be trained and are competent to fulfill their specific role(s). They also must actively perform their responsibilities to ensure that the system operates as intended, and that no specific category of participant is limited by another. The roles within the system include the following categories of personnel.

- **Crime Scene Investigators (CSIs)** will record the footwear evidence, and acquire it (with associated event information) into the scene database.

- **Booking Officers** will record arrestees' footwear and acquire it (with associated offense information) into the arrestee database.

- **Footwear Experts** will perform SME functions that require footwear expertise (e.g., classification of new footwear records and inter-record assessment of other class characteristics). They will work behind the scenes to curate the footwear data so that it can be used by investigators and crime analysts to generate intelligence.

- **Investigators and Crime Analysts** will record additional case information in the database and conduct queries using footwear data (including the frequency of patterns) in concert with results of other evidence analyses, contextual data, and trends in crime. They will generate internal NFD intelligence reports or incorporate NFD data into other systems, all for the purpose of producing tactical, operational, and strategic intelligence.

- **IT Experts** will maintain the IT infrastructure, develop and validate technology, manage user access, and inform system requirements to ensure that the system's components comply with relevant technology standards (e.g., the current state of the art, existing COTS products, and interfaces with other systems).

- **Administrators** will provide the management functions of the system. They will manage human and fiscal resources, including contracts, and align those resources with the mission and strategy of the system's funding and oversight organization(s). They will establish and maintain a system administration structure to include interfaces with agency administrators, service level agreements, and a change-management board to define and document standards for system use and change-management practices. They will generate system-level reports to comply with federal policy requirements (and other applicable laws) and determine system performance. These reports will also inform future system modifications and improvements. Administrators will also implement and maintain a training program for the system's user base.

Within the roles described above, it is imperative that the operational participants—CSIs, booking officers, footwear experts, investigators, and crime analysts—are trained and competent specific to their use of the system (to the extent required) to maintain the quality of the data and an acceptable level of system performance. A suitable training program and performance evaluations will address this need. An NFD system training program would be much like that implemented by NIBIN through its NIBIN National Correlation and Training Center (NNCTC). The NNCTC in Huntsville, AL provides four structured courses—*Triage*, *Acquisition*, *Correlation*, and *Train the Trainer*. There may also be relevant overlap with the training provided by CODIS to its user base that should be considered, but the scope of that system's training program is narrower with respect to the categories of participants and the processes they perform.

2.4.2 Processes

It is important that future NFD system stakeholders operate using standardized practices from *acquisition* to *classification* to *query* to *output*. To achieve this requirement, the participants must be using a common 'language' (i.e., the terminology they use across the system and their use of the data fields). These critical components, when implemented successfully, will encourage consistent use of the database for the greater good of the system. Consistency is critical because of the many individuals and agencies working within a single database. Some are small; some are large; and some agencies have one individual filling a singular role while others will use one individual to fill several roles. A one-size-fits-all approach to system development and implementation will not work in this case. There are some notable processes that are worth mentioning here—*acquisition and data entry*, *pattern classification*, and *query and output practices*. Some practices will be impacted by external groups, agencies, and organizations (e.g., legislative and accrediting bodies) so the future system developers should take measures to mitigate any identified impacts, leading to wider user and agency adoption.

2.4.2.1   Acquisition and Data Entry

An NFD system requires that the images and information associated with both questioned impressions and arrestees' footwear be recorded and uploaded to the system. These are considered acquisition activities. Much of the data entered during acquisition will be manual so quality measures must be incorporated, when possible, to increase accuracy and standardization; data integrity will surely impact its potential use downstream.

Cataloging arrestees' footwear serves two functions. Firstly, it provides the primary source of reference material against which all records will be classified. The arrestees' footwear will first be added to the arrestee database. Then the associated imagery will be sanitized (i.e., stripped of personally identifiable information (PII)) leaving only the footwear pattern, which will be uploaded to the National Footwear Reference Collection (NFRC). Secondly, it can generate suspect-to-scene links when cross checking the arrestees' footwear data with the scene data. Acquiring scene footwear records and maintaining that data in an NFD

enables the development of suspects, the linking of scenes, and the detection of trends in crime. The system is dysfunctional without either input—*arrestees' footwear* or *scene impressions*. This impact was realized through the team's engagement with two local agencies who deployed footwear databases. Those instances focused primarily on recording arrestees' footwear while not giving the same attention to collecting and acquiring crime scene data. This disparity prevented these agencies from reaping the fruits of their labors; their efforts increased the size of their local footwear reference collections, but the absence of scene records prevented them from generating the valuable intelligence that they were seeking.

2.4.2.2   Pattern Classification

The operational footwear records (both scene and arrestee) in an NFD system should be organized based on their pattern. A pattern-centric system will provide maximum link potential through its one-to-many database structure. Both the U.K. and Switzerland came to this conclusion and implemented one-to-many systems. This structure is achieved through the population of a centralized footwear reference collection; all system participants contribute their new patterns to this singular reference collection. Footwear experts classify any new operational entries by querying the reference collection, whose records are linked to scene and arrestee records (from past crime and booking events) (see **Figures 4 and 5**). This classification method is an effective way to organize the data to maximize the system's intelligence output. It enables the investigator or crime analyst to query the system and generate a list of both scene and arrestee records that have the same pattern as their pattern of interest. After which, they will filter their 'hit' list of potential links using both pattern frequency and contextual information (e.g., geography, date and time, modus operandi, and offense type). Filtering the data generates footwear leads. These leads can be integrated with other evidence results (e.g., a DNA profile at one of the events) to establish links and detect crime series.
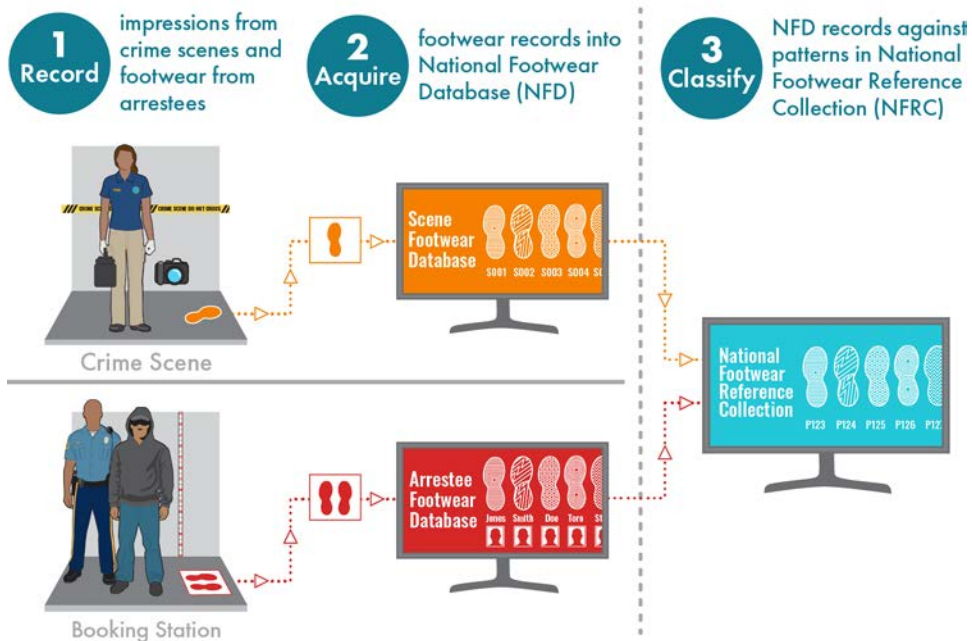
The easiest way for system developers to achieve the desired one-to-many, pattern centric system is to define a pattern naming convention that provides an easy way to organize the patterns within the reference collection. The U.K. uses the brand name followed by a serial number (e.g., "Nike 123", "Adidas 456", and "Fila 789"). This nomenclature diverges from the current make and model name (or number) that is currently being used by U.S. law enforcement. Currently, U.S. footwear experts refer to a popular Nike shoe as the "Nike Air Force 1" whereas U.K. experts (using their NFRC) refer to it as the "Nike 356." This change (which some may consider a paradigm shift) will likely feel uncomfortable for U.S. footwear experts and investigators as they're accustomed to referencing footwear by the make and the model. But the model name is only useful to law enforcement when they search the Internet for more information about a specific footwear item, the Nike Air Force 1 in this case. The model name is rarely printed on or molded into footwear, so it is generally not possible for investigators to locate the model of interest in a suspect's closet using the model name. When confronted with a closet full of footwear during the execution of a search warrant, the investigator's biggest clue for finding the item of interest (as they turn over all the suspect's footwear) is the outsole image that was provided in the FFE's laboratory report.

Therefore, moving to a pattern-classified reference collection and a new record naming convention is a positive change that will keep the database organized for efficient query so the desired footwear intelligence capability can be realized. A generic naming convention like "P123," "P124," and "P125" which excludes the brand name is also an option, but, when known, the make and model should be included as metadata for each of the reference records. The Neuchâteloise Police in Switzerland implemented a similar nomenclature, replacing "P" for "pattern" with "M" for "motif".

Missing from the above classification description is the required 'coding' step. Outsoles are generally comprised of geometric shapes (or descriptors), logos, and text. These outsole design components can be deconstructed to describe the footwear item. The descriptors, logos (from a database), and text can be used as inputs to query the system. This is possible because each new record added to the database is coded during acquisition which attributes a set of descriptors and other outsole features to each record. Some of the COTS products, those produced by Bluestar, Everspry, and Hobbit Imaging Systems, have semi-automated coding utilities whereby they extract pattern information from the images (using algorithms). They are referred to as semi-automated since some level of user input is required, yet the degree of human intervention varies between these products. Some of them enable users to combine the semi-automated output with descriptors, logos, and text for more flexibility. This flexibility is very useful when the footwear expert is presented with a low-quality scene impression that contains distortion, overlapping impressions, or interference from the background (substrate), which is common, because it is more efficient to manually code the record, bypassing semi-automated feature extraction. Pasquier concluded that the automation of outsole coding should not be the goal of a footwear database. The impression variability and the current state of pattern recognition limits the capability of automation and, on average, takes more time to code new records. Based on his research, he determined (using two algorithms) that the automated coding process (including manual correction), on average, took between two and twenty minutes; these average times do not include querying the database. This contrasts with manual descriptor coding which took approximately six minutes for the user to perform both the coding and search functions. [19] Future developments in automated pattern recognition may result in performance improvements that can be incorporated into future footwear systems.
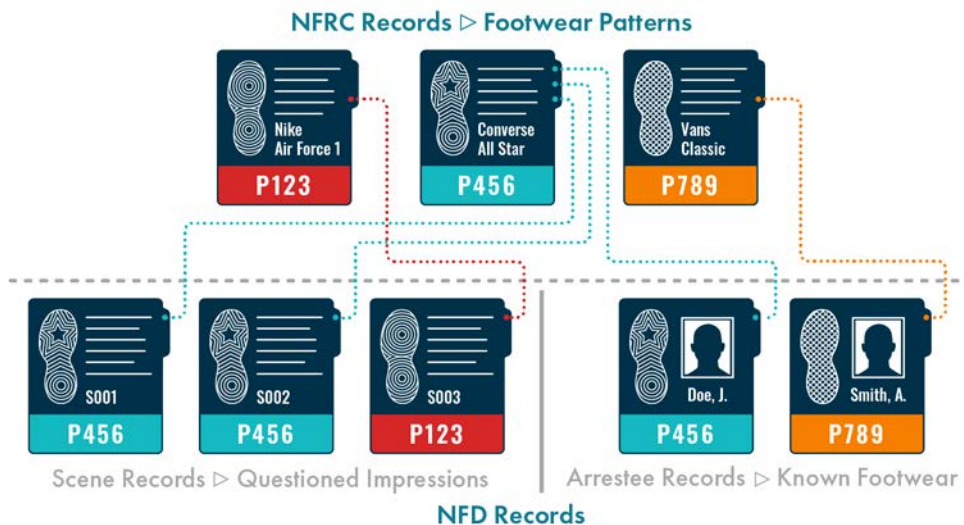
Future State of Footwear Intelligence
Major Front End Processes

1 Record impressions from crime scenes and footwear from arrestees

2 Acquire footwear records into National Footwear Database (NFD)

3 Classify NFD records against patterns in National Footwear Reference Collection (NFRC)

FIGURE 4. *The major processes associated with populating an NFD system with scene and arrestees records and readying them for query to detect links.*

Future State of Footwear Intelligence
Record Classification (Performed by Footwear Expert)

NFRC Records ▷ Footwear Patterns

Nike Air Force 1 — P123
Converse All Star — P456
Vans Classic — P789

S001 — P456
S002 — P456
S003 — P123

Doe, J. — P456
Smith, A. — P789

Scene Records ▷ Questioned Impressions   Arrestee Records ▷ Known Footwear

NFD Records

FIGURE 5. *A hypothetical example showing the relationship between three scene records, two arrestee records, and three NFRC records in an NFD, after the scene and arrestee records have been classified.*

2.4.2.3   Query and Output Practices

Critical to the utility of an NFD system is the need to integrate contextual data with the footwear data. It is only through filtering records with matching patterns that the system can generate reliable footwear intelligence (see **Figure 6**). This requirement differs from that of DNA and fingerprints; it is possible for those biometrics to link an individual directly to the evidence without considering context. Several filtering criteria relevant to footwear were identified, including *geography*, *offense type*, *modus operandi*, *date and time*, and *pattern frequency*. So, these criteria, at a minimum, should be requirements for a future system.
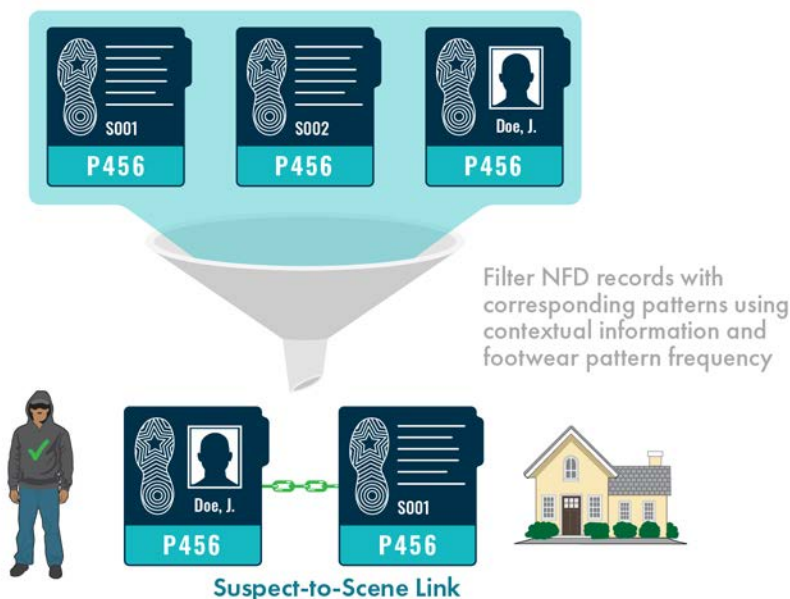
When conducting searches and detecting links, outputting the results may be accomplished using static preformatted reports, customizable reports, or dynamic graphical user interfaces (GUIs) that can be manipulated by users. The investigators and crime analysts are the target operational users for the outputs so representatives from those groups should inform the output requirements. One feature that should be a requirement for an NFD system is the visualization of crime events and other points of interest (e.g., suspects' residences) on a dynamic and interactive map. This feature is synonymous to searching for restaurants or gas stations nearby on your smartphone. It is much easier to pinpoint a destination when presented with your options on a map versus in a list. This is also true for records in an NFD. A map allows users to see points of interest and how they interact with other locations in the surrounding area (e.g., highway exits, neighborhoods, and commercial properties). This visualization also makes clusters of crime events more apparent when users are presented with long lists of possible leads; clusters may indicate a serial offender or trends in crime. For these reasons, the U.K. implemented this feature into their system. [37] The frequency of the pattern within the database, including instances in both scene and arrestee records, when considered with other information, specifically geography, provides the end user with additional information to consider when generating links using footwear evidence. A common pattern found in a large geographic region may not be as significant as a rare pattern found in the same size region. For example, the detection of a common Nike Air Force 1 sneaker at 150 crime scenes in a 100-mile radius is less significant than a handful of detections of an uncommon Bruno Magli dress shoe within the same 100-mile radius.

Management reports will also be required to generate the system metrics required to determine the system's effectiveness (e.g., ROI), identify pinch points, detect deficiencies in processes, identify underperforming agencies, and generate successes. These management reports will aid the system administrators when preparing the required program-level reports and identifying areas for improvement.

Future State of Footwear Intelligence
Query and Link Detection (Performed by Investigator or Crime Analyst)

NFD Records Classified to NFRC Record #P456

Filter NFD records with corresponding patterns using contextual information and footwear pattern frequency

Suspect-to-Scene Link

FIGURE 6. *Using the hypothetical example from* **Figure 5***, the process of filtering scene and arrestee records associated with the same pattern using criteria (i.e., context and pattern frequency), which generates footwear links.*

2.4.3 Tools

There are many tools associated with a footwear database system that are integral to its operation. This project's SOW focused on the tools for an NFD system and developing requirements associated with them. However, it is premature to develop detailed requirements for a U.S. NFD system (as required for acquisition) since there is no immediate plan to implement a system. Despite that determination, applicable tools and basic requirements are documented below to inform efforts by other groups who will be responsible for developing acquisition-suitable requirements and standards for a future system.

Some of the applicable technologies are tangible system components that the participants will interact with to execute the processes described above while others are not. Tangible components include acquisition and output devices and interactive GUIs. The repositories of footwear data and the supporting infrastructure are intangible but are equally important to the system's operation. The major technology components of a footwear database system are the software application, the database, user workstations, peripherals (e.g., outsole scanners and printers), and the IT infrastructure. Ideally, the software application will be web based making it accessible via any mainstream and secure browser on any Internet-

connected device (e.g., a PC, a Mac, a tablet, or a smartphone). Online accessibility provides easy, on-demand access to both field and laboratory personnel. The technology solution developed to support a footwear database system must be able to perform the following operations.

- Acquire footwear data (e.g., scene impressions and arrestees' footwear) and associated case information.
- Organize the data in a logical manner using standardized methods.
- Provide appropriate accesses to the data by all users, in both the field and the laboratory.
- Query the data using footwear-specific search criteria.
- Filter search results using contextual information (including geography) and footwear pattern frequency.
- Report search results in forms that meet the needs of its users to detect links and generate intelligence.

Not only must the system perform these operations, but it must do so efficiently when operated by the various categories of users that will interact with the system. Rossy, et al. reported this finding eloquently. "Of importance is to consider that the database must be simple, input of data rapid, and it must conform to specific organisations (sic) that separate forensic[s] from intelligence unit[s]. The fluidity of the process is critical to its usability and performance. Many choices about the [use] of the database are derived from these constraints." [22]

2.5 CONCLUSION 5

An NFD could provide a source of needed footwear data for researchers to improve the state of footwear forensics; however, privacy laws, law enforcement sensitivities, and the absence of ground truth may impair their use of the database.

A future NFD will contain PII and law enforcement-sensitive information. There are laws surrounding the protection of that data that must be considered and addressed when a decision to implement is made. If the forensic footwear discipline is ever going to develop methods for the statistical interpretation of the evidence, researchers must get access to the required data. An NFD could fill that gap, to some extent. Researchers need operational data to generate relevant populations to apply the appropriate significance to corresponding class characteristics observed by practitioners in casework. Researchers would like to obtain sanitized law enforcement data associated with both questioned impressions and arrestees' footwear. They would require access to images of the evidence and a variety of evidence metadata like the location of the crime; the date and time when the crime occurred; the offense type; the gender of the offender; and the make, model, and size of the footwear. However, it will be difficult to transfer such data to researchers based on privacy and law

enforcement sensitivities; further legal analysis is required to make any definite determinations. The U.K. Home Office implemented a policy in 2017 to address the transfer of operational data from its national forensic databases to researchers—*Forensic Information Databases Service (FINDS): Process for Release from the Forensic Information Databases for Research Purposes*. FINDS includes the National DNA Database, IDENT1, and the National Footwear Database. This policy ensures that research requests for samples, profiles, and data from any of the FINDS databases are authorized and processed according to the Forensic Information Databases Strategy Board's policy. [38] The developers of a future U.S. NFD could use this U.K. policy as an input to future legal analysis assessing the ability to provide NFD data to researchers who are working to further forensic science.

The ground truth associated with the footwear data contained in a future operational NFD will be unknown. It will house records associated with Qs and Ks, and these two data types can be associated using their class characteristics. But it is impossible to determine that a specific footwear item is the source of a questioned impression with absolute certainty. This is problematic for researchers who rely on ground truth data to train their algorithms and evaluate their performance (e.g., the accuracy with which the system can locate the true mate, and the time it takes to do so). The lack of ground truth in the operational system poses yet another challenge to leveraging an NFD for research.

Let's assume that future legal analysis determines that some of the data from an NFD can be transferred from operations to research. Initially, it made sense to develop a mirrored NFD system for researchers with a similar look and feel to the operational instance and a conduit for sharing data. After further consideration, the authors believe that the creation of two disparate systems with customized user interfaces and data import/export functionality might provide a more eloquent solution to provide each user group with the data they need and presented in a way that makes sense to each. Operational users will be concerned about acquiring operational records, searching them, and generating pattern frequencies and intelligence reports; the researchers will also be interested in pattern frequencies, but they will also be interested in developing automated footwear pattern recognition algorithms, developing relevant populations, and using the footwear data outside of an NFD system. It is these disparities and the limited amount of data that will likely be shared that contribute to this belief. When, and if, these two footwear systems are developed, researchers and operational stakeholders will have to collaborate on the most efficient methods for exchanging information for the benefit of both communities.

This project was initiated to address the research needs required to improve the state of the forensic footwear discipline. However, the priority when developing an NFD system should focus on creating a new tool to solve crime. After the system has been fielded and sufficiently established, decisions should be made regarding how the system can be used by researchers. The research benefits of the system are secondary, and the resources expended to address research during system development should reflect that notion; however, stakeholders would be remiss if they did not keep research in mind during development.

3 RECOMMENDATIONS

The team determined that it would be neither feasible nor fiscally responsible to implement a U.S. NFD system *now* because the U.S. law enforcement community would not generate intelligence using footwear information that was commensurate with the level of effort expended to recover, catalog, and analyze the information associated with this evidence type. It was disappointing to come to this conclusion; however, recommendations were developed to provide a practical pathway to *transition the project's research and evaluation into practice*. The recommendations reported here provide progressive and short-term solutions to the current limitations associated with exploiting footwear information in the U.S. for the benefit of all law enforcement. It is through acting on these recommendations that the U.S. can take footwear from its current low-profile status and limited utility to a revered source of actionable criminal intelligence.

3.1 RECOMMENDATION 1

> Establish a national footwear intelligence board comprised of experts from agencies and organizations who represent relevant stakeholder communities (including forensic footwear analysis, crime scene investigation, criminal investigation and intelligence, legal, technology, and law enforcement administration) that are capable of addressing the needs of local, state, federal, and tribal law enforcement.

To elevate footwear evidence and information in the U.S. and exploit it for criminal intelligence, it is imperative that the stakeholders in a future NFD system develop standardized practices, standards relevant to footwear intelligence, and detailed system requirements. A federal agency should stand up a national expert board to address these identified needs and work towards advancing footwear intelligence in the U.S. This recommendation aligns with how the U.K. progressed from local footwear intelligence programs to a national solution. "On [August 30–31, 2005], members of the [Police Support Unit (PSU)] and [Association of Chief Police Officers (ACPO)] National Footwear Development Group (NFDG) attended a workshop to shape the future for the exploitation of footwear evidence and intelligence by the police service in England and Wales. Delegates first assessed the current capability of police forces to exploit footwear in the context of stakeholder requirements, and then sought to identify the changes necessary in order to meet these more fully." The U.K. Home Office reported the findings from that joint workshop, which focused on defining the U.K.'s vision for the exploitation of footwear evidence for intelligence. [39] That workshop led to the U.K. establishing the National Footwear Board in October 2006. [16] Based on the work by the National Footwear Development Group and the National Footwear Board, the ACPO tasked the National Policing Improvement

Agency (NPIA) in November 2007 "to develop an integrated solution across policing that would allow forces to research and share footwear intelligence." [37]

The U.S. board should consider the following areas when developing requirements and standards—*system architecture*; *legal, policy, and privacy issues*; *training*; and *public relations*.

There are several system-architecture details that must be addressed prior to developing detailed system requirements. The IT infrastructure, or 'landing spot,' must be determined (e.g., the National Data Exchange (N-DEx) system, the NGI system, or the Justice Unified Telecommunications Network (JUTNet)) as this decision will impose integration requirements. It is necessary to define a pattern classification scheme and the associated pattern nomenclature. Pattern classification is important from the perspective of NFD system requirements since changing the classification scheme after deployment would have significant impacts that should be avoided. For this reason and prior to deployment of its NFRC, the U.K. convened a change group of experienced footwear experts who created a standard coding language, including the NFRC record naming convention and 14 descriptors. [40]

In the U.S., per DOJ policy, a privacy impact assessment (PIA) must be completed "before initiating a new collection of information that will be collected, maintained, or disseminated using information technology and that includes any information in identifiable form in certain circumstances involving the public." This requirement ensures the appropriate protections and civil liberties of U.S. citizens. [41] Therefore, a PIA must be completed prior to system implementation. Preliminary legal analysis was conducted in areas relevant to the NFD system, but additional analysis is required prior to deployment, including U.S. law enforcement agencies' authority to record arrestees' footwear during booking at all levels; their ability to use the database contents for evidential analysis; and their ability to share database contents with law enforcement researchers. Efforts by the board to address these identified legal, policy, and privacy issues will shortcut the official execution of these analyses at the time of system implementation.

The board should develop a public relations strategy to increase awareness of footwear evidence, communicate its value for intelligence, and enhance the capabilities of law enforcement professionals to recover this evidence. The board could collect and broadcast footwear success stories using deliverables that reach the appropriate law enforcement audiences. It could develop training resources on the best practices for recovering footwear evidence from scenes and using that evidence in investigations and prosecutions. The U.K. published three relevant resources that could serve as templates for and inform this board's public relations strategy—the 2007 *Footwear Intelligence Guidance for Scientific Support* [42], the 2007 *Footwear Marks Recovery Manual* [43] and the 2011 *Investigating Burglary: A Guide to Investigative Options and Good Practice* [44].

A concern for state and locals might be their lack of expertise in footwear evidence and how to use it to enhance their investigative posture. This worry provides a practical opportunity for the national footwear intelligence board to impact operations. The board could provide training and resources (like those developed in the U.K. mentioned above) to regional

program participants to enhance their capabilities. The board could develop a regional footwear expert network that share the responsibility of performing the SME functions in the system, specifically the pattern classification services. This regional network would mimic the group of NIBIN experts at the NIBIN NNCTC who perform SME functions remotely for agencies who lack expertise and or equipment to perform those required functions.

The footwear board could also be a stakeholder in future U.S. efforts to develop inter-disciplinary forensic intelligence practices as recommended by the authors of the recent Global Advisory Committee's report. "It is incumbent upon both criminal intelligence units and crime labs to proactively collaborate to establish protocols and processes for the sharing of intelligence." [32]

Prior to initiating the national footwear intelligence board, the NIJ should establish a new short-term WG (a "Footwear Intelligence Development Group") to draft a short-term action plan to address the findings, conclusions, and recommendations reported herein. It should also define the mission of the board; identify an appropriate sponsoring organization; and identify stakeholders (agencies, organizations, and individuals) to populate the board's membership. The Criminal Intelligence Coordinating Council (CICC) may be an appropriate organization to administer this board. This council is sponsored by the BJA. "The [CICC] supports state, local, and tribal law enforcement and homeland security agencies in their ability to develop and share criminal intelligence and information nationwide." [45]

3.2   RECOMMENDATION 2

> Establish a federal grant initiative to foster the implementation of regional footwear intelligence programs.

In partnership with the ATF, the BJA administers the *Local Law Enforcement Crime Gun Intelligence Center (CGIC) Integration Initiative*. This initiative "is a competitive grant program that provides funding to state, local, and tribal government entities that are experiencing precipitous increases in gun-related violent crime" which encourages their collaboration with their local ATF partners to identify and prosecute violent criminals. Under this initiative, in FY 2020, the BJA issued ten awards for a total of $6,444,045. [46] Through this initiative and overall system improvements, NIBIN has been able to increase its percentage of acquisitions (i.e., the process of acquiring new cartridge cases into the database and entering the associated case information which enables them to be searched in the system) performed within 10 days of seizure by 9.2% from July 2018 (31.4%) to August 2019 (40.6%). [47] An initiative like this developed specifically to address the gap in footwear intelligence would encourage U.S. state and local agencies to implement regional footwear intelligence programs.

Initiating a footwear intelligence program supported by an IT solution will require a significant investment by the participating agencies. It will also impact the current overall

productivity of those agencies as they will be required to allocate some of their resources to this new venture. They will need to increase their footwear evidence collection rates, record arrestees' footwear, acquire the evidence into the footwear database, classify the new footwear records, and conduct queries to generate intelligence. Some agencies may be hesitant to step up and implement a footwear program due to the lack of case studies and existing footwear intelligence practices in the U.S. despite the successes realized abroad. A federal grant initiative, with a substantial funding stream, would serve two purposes which could quell their concerns. Firstly, it would demonstrate that decision makers at the federal level believe that footwear has untapped potential, making it easier for agencies to convince their management that a footwear intelligence program is a worthwhile venture. Secondly, it would eliminate some of their fiscal concerns.

Another advantage of the proposed grant initiative is that the administering agency would provide national-level oversight of the regional programs. The overseeing agency should develop relevant metrics and performance measures to determine program success, recognize weaknesses, and identify areas for improvement. They should then require that awardees agree to provide required system-use and performance metrics with some pre-determined frequency. The administrators could also serve as a clearinghouse for case studies and program successes that they could broadcast across the national law enforcement community.

3.3   RECOMMENDATION 3

| Implement regional footwear intelligence programs.

The establishment of regional footwear intelligence programs (pilots) in the U.S. provides opportunities to develop people; establish standardized practices; define technology requirements; increase the law enforcement community's awareness of footwear evidence and its value for intelligence; and build a business case for a future national solution. There needs to be a significant number of high-profile cases that get the attention of law enforcement executives and innovative politicians. These case studies will generate the required interest to put footwear evidence on the national stage, resulting in garnering support from those decision makers who are in positions to effect change across the law enforcement community.

Regional programs will be an inter-agency consortium of field and laboratory personnel. The personnel will have broad representation to fill the roles detailed in **Section 3.4.1**. The state bureaus would fill the role of program administrator as they already facilitate state-level, inter-agency law enforcement services, including IT, investigative, and oversight. Leveraging the state bureaus' services will be critical to the success of regional footwear intelligence programs. Their IT backbone will enable the efficient sharing of information and a centralized footwear database.

Executing regional programs instead of local programs addresses the known fact that criminals cross jurisdictions when committing their crimes. The likelihood of detecting links

using footwear (or any other evidence for that matter) increases when using a regional, multi-agency approach. This determination is supported by data provided by Rossy et al. Rossy reported the contributions of footwear relative to situational (contextual) information, DNA, and images in the detection of links generated using a regional Swiss crime intelligence database during the 2009–2011 period. His data illustrates the intelligence benefits of sharing data within a region (six states) versus using only the data generated by a single state. Contextual information contributed most to links at the state level (71%) with forensic evidence only providing 29% of the total links. When the data is expanded to the regional level (by looking across state lines), the results flip-flop; forensic evidence became very valuable contributing 75% of the links and context fell to 25%. Additionally, and of importance here, links generated using footwear increased from 19% to 49% when going from a state to a region (see **Figure** 7). [22]
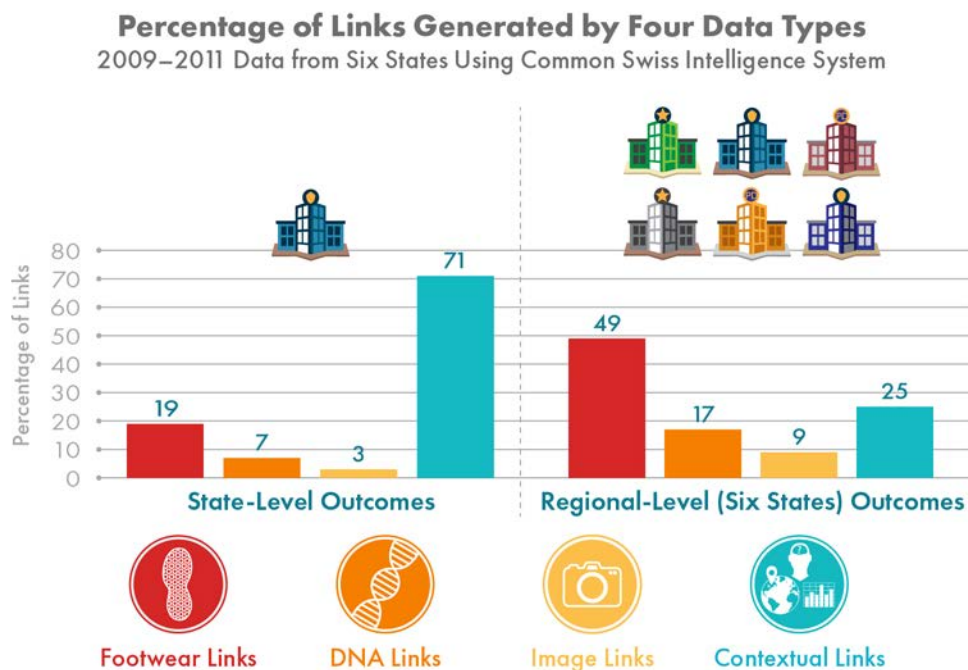
FIGURE 7. *State- and regional-level data from a Swiss intelligence database that was collected from six states during 2009–2011, which compares the percentage of links generated by four data types—footwear, DNA, images, and contextual information.*

CODIS and NGI were born out of local and state implementations (pilots) during which tools were refined, practices were standardized, people were trained, and case studies were generated. These pilots laid the foundation and provided the required justification for national implementation years later. It makes sense that the footwear discipline would follow suit by starting with regional footwear intelligence implementations that could eventually lead to national integration. The ability of U.S. law enforcement to exploit footwear information will likely remain stagnant until regional pilots are implemented.

The requirements and practices developed by the national board could be used as a framework for the implementation of regional footwear intelligence programs. Before implementing these programs, pilot study participants should be identified based on their progressive practices and their experience with footwear evidence; the national footwear board could identify potential participating agencies. The board could provide leadership and SME support to the stakeholders in regional programs when they are confronted with issues that would benefit from expertise beyond that possessed by the stakeholders. The federal grant initiative would provide the funding source and oversight for these programs.

4 DISCUSSION

The *current state of U.S. law enforcement* will not permit the successful implementation of an NFD system even though the team determined that footwear is underutilized for criminal intelligence domestically. This gap in U.S. law enforcement capabilities will not be solved by introducing this new tool, as the people and processes are not in place. The U.S. recognizes that footwear evidence is a means of source attribution, inclusion, and exclusion through its evidential analysis; however, there is a lack of recognition of footwear as an evidence type that can detect links and direct investigations. It very difficult to produce actionable intelligence using this evidence type given the absence of footwear databases. This deficiency has led to a lack of standardized footwear intelligence practices, an insufficient number of case studies and successes in the U.S. highlighting footwear's value for intelligence, and an overall lack of progress in the footwear intelligence area.

Stakeholders in the forensic footwear discipline recognize the need for research to move the discipline forward through the introduction of new tools and methods. It is this innovation that could introduce statistical evaluation methods to improve footwear experts' interpretation of their findings and increase the standardization of their results. A footwear database could partially solve the problem, but it will not be a repository of ground truth data, a key input to the development of robust methods and a means to measure system performance.

Despite these determinations, the U.S. has a critical opportunity to change course and work strategically to overcome today's stumbling blocks. A short-term strategy is outlined in **Section 3** where three actionable recommendations are detailed. In addition to this report, other research efforts and assessments were recently completed or are in progress that call for standardization of forensic intelligence practices in the U.S. [30, 32] The authors are hopeful that the outcomes of this project and other related projects will serve as a catalyst to grow the utility of footwear evidence in the U.S. from an input at trial to a valuable source of data to *generate leads*, *increase crime solvability*, and *prevent future crime*.

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