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

Document Title:	Assessing the Quality of 3-Dimensional Imaging on the BrassTrax HD3D System and Evaluating an In-Silico Solution to Confirm NIBIN Hits
Author(s):	City and County of Denver, Denver Police Department Crime Laboratory
Document Number:	254585
Date Received:	March 2020
Award Number:	2015-DN-BX-K034

FINAL SUMMARY OVERVIEW

Assessing the Quality of 3-Dimensional Imaging on the BrassTrax HD3D System and Evaluating an In-Silico Solution to Confirm NIBIN Hits

Award - 2015-DN-BX-K034

INTRODUCTION AND STATEMENT OF PURPOSE

Firearms examination involves the analysis and comparison of microscopic marks that are transferred to ammunition components as they are discharged through a firearm. The individual nature of these marks allows examiners to determine if recovered cartridge cases or bullets were fired by a specific firearm. Traditionally, these examinations support or refute theories of how a crime may have occurred during the course of an investigation, and are often conducted weeks or months after the occurrence of the crime. However, with the advent of database systems, forensic science has emerged as a powerful tool for providing early intelligence during the course of investigations to assist with solving, or preventing, crime. Through the use of databases such as the Automated Fingerprint Identification System (AFIS) and the Combined DNA Index System (CODIS), investigators are provided with intelligence derived from evidence collected at crime scenes that can refine investigations. Firearms examiners use a similar database known as the National Integrated Ballistic Information Network (NIBIN). Established in 1999, NIBIN provides the means by which examiners can discover links between previously unrelated gun crimes, providing intelligence through which local law enforcement can identify and target active shooters [1].

All ballistic data entry occurs at the local component of NIBIN – the Integrated Ballistic Identification System (IBIS). IBIS uses state of the art photography to digitally capture the unique marks on each cartridge case. Information about a captured specimen is also collected, including caliber, and class characteristics. Once captured, images of a particular cartridge case are uploaded to a server where they are correlated by algorithms that score patterns imprinted by the firing pin and breech face. The purpose of correlation is to select potential matches from among all previously submitted cartridge cases. This occurs in two stages; first, candidates are narrowed to those that match class characteristics (e.g. circular firing pin impression vs. rectangular). Second the IBIS algorithm scores and ranks potential matching candidate cartridge cases. Once the correlation is complete, IBIS provides a ranked list of potential cartridge case matching pairs for examiners to review. Any pair from the correlation list that looks similar enough is then examined under a microscope by firearms examiners to confirm the association.

The workflow of evidence through IBIS/NIBIN occurs in six stages:

1. Submission of evidence to the NIBIN site;
2. Fired cartridge cases (either test-fired from a firearm or collected at a crime scene) are imaged on IBIS and uploaded to the image database;
3. Images are correlated with all previously submitted samples with similar class characteristics;
4. The resulting list of possible matches is compiled and made available for review through the IBIS imaging system;
5. The respondent list is reviewed by a trained technician or firearm examiner;
6. Cartridge cases for potential matches are retrieved for microscopic comparison to either confirm or refute the match;
7. If confirmed, assigned investigators are notified of the match.

A 2013 study by William King, et al. identified several deficiencies in the day-to-day operation of the NIBIN program [2]. One of the more striking deficiencies is the timeliness with which NIBIN sites identified and reported hits. Among their study of nineteen NIBIN sites, the average time that passed between a crime and the identification of a NIBIN hit was 101 days. This finding is significant because, unlike the AFIS and CODIS databases, where evidence is associated directly with individuals, NIBIN matches associate items of evidence to each other. Each of these associations require an assessment of the details of each crime and necessitate further investigation before a potential suspect is identified. The need for post-match investigations for NIBIN associations requires that this work be completed in a timely way. Delays in entering evidence to the database, or in reviewing correlation results can lead to significant delays in identifying and reporting matches. These delays can reduce the impact of NIBIN to investigators and ultimately diminish its usefulness as an investigative tool.

While the potential for delays exist at all stages of the workflow, only two are outside the control of the NIBIN site: 1) the initial submission of the evidence, and 2) resubmission of the evidence to confirm a potential match. Of particular interest to this study are the delays associated with match confirmation. Many laboratories that house and operate IBIS equipment are county, state or federal agencies. These laboratories typically do not maintain custody evidence once examinations are complete. Consequently, these sites must rely on submitting agencies to return evidence for a match confirmation. In a recent poll of AFTE members, more than 70% of NIBIN sites experience waits of two weeks or more before that evidence is resubmitted to their site for confirmation. Of those, more than half wait one month or more before evidence is resubmitted [3]. This leads to large delays before any forensic intelligence is reported, further delaying any follow-up investigation.

The purpose of this project was to examine the possibility of utilizing three-dimensional (3D) imagery for the limited purposes of confirming NIBIN matches. 3D imagery and its possible application to Firearm and Toolmark Identification has been previously studied. Bolton-King et al. reviewed several 3D imaging technologies with the aim of determining the optimum applicable technique [4]. Other studies exist detailing the proposed development of automated systems using 3D measurements as the basis of comparison [5-6]. While these studies demonstrate the potential of 3D imagery, none discuss the use of captured 3D images to affect an in-silico (e.g. on screen) comparison of microscopic characteristics between two imaged specimens (Step 6 of the NIBIN workflow).

BrassTrax HD3D, the current input component of IBIS, was deployed in 2015 and provided an upgrade in 3D imaging technology. The ability of firearms examiners to conduct comparisons with this new technology was compared to the traditional method of a microscope comparison. Data from these were used to address the following research goals:

1. Study the ability of examiners to accurately identify matching cartridge cases using 3D imaging technology.
2. Derive descriptive statistics for the difference in performance between when the BrassTrax HD3D is used by an examiner versus microscopic comparison.

The following research objectives guided the experimental design:

Objective 1: Establish a potential error rate for utilizing 3D images to confirm NIBIN hits.

Objective 2: Compare the effectiveness of confirming NIBIN hits between the comparison microscope and 3-dimensional images from BrassTrax HD3D.

Objective 3: Examine any workflow and time differences between microscopic and in-silico methods that could impact the timeliness of reporting matches to investigators.

Objective 4: Propose the most time efficient and accurate way to confirm NIBIN matches in terms of standard operating procedures and interpretation guidelines.

Objective 5: Assess the accuracy of the algorithms utilized during the correlation of images on the NIBIN database.

PROJECT DESIGN AND METHODS

The study relied on the BrassTrax HD3D cartridge case acquisition station. The HD3D system uses topographic scanning to render a three-dimensional image of a cartridge case surface. Ultra Electronics-Forensic Technology, Inc., the manufacturer of the system, claims that their 3D imaging will provide comparison capabilities that are "well beyond the conventional comparison microscope" [6-7]. To conduct the proposed research, it was necessary to build a database that is separate from that used for casework on a daily basis by NIBIN sites across the United States. DPDCL examiners built this database utilizing the "demonstration" category for image entry. Entries under this category are not placed within the real-world database, thereby allowing for the capturing of images without affecting actual case correlations.

To populate the database, the research relied on test-fired cartridge cases collected and stored during thirteen years of NIBIN use. The advantages of using these cartridge cases were: 1) each set of cartridge cases in the collection was fired by the same firearm, so they provided a known matched set; and 2) using these cartridge cases minimized the time and expense necessary to generate samples for entry into the study database. Five hundred pairs of 9mm Luger caliber cartridge cases with similar class characteristics were selected and used. Cartridge cases from each pair will be permanently marked with the same identifier (e.g.1 through 500) to make sure that they can be paired again. After marking, each pair will be split and separated into two groups, A and B (see Figure 1). Each of these groups will be treated as follows:

- Group A – Test Sets

    1. This group was used to create test sets of twenty-five unknown specimens. Included in each test set were a number of cartridge cases that *did not* have a true match in the database. The number of non-matches were unknown to the examiner performing the comparisons.

- Group B

    1. Each cartridge case in this group had its permanent identifier masked with a label containing a new, randomly generated unique identifier. This set was used to populate the research database.

    2. In addition to populating the database, this set of cartridge cases also served as the known cartridge cases against which unknown specimens were compared.

Data collection was designed to occur in two phases. The first phase required participating examiners to use on-screen comparison of 3D images as well as comparison microscopy. This phase was designed to establish an error rate and provide the basis for statistical evaluation of the two comparison methods. The second phase was designed to assess how well the algorithms used during correlation perform by examining where in the result list a true match is returned

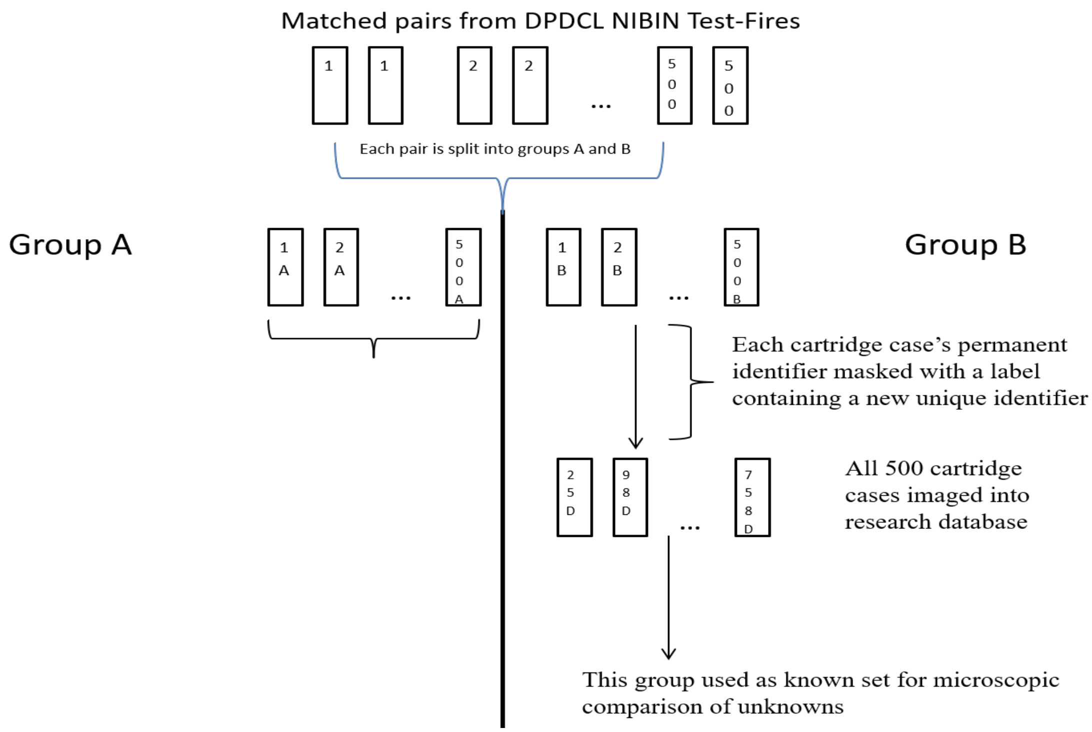

Figure 1: Sample Schematic

Phase I

This phase of the project was designed to test the hypothesis that an examiner will correctly locate matched cartridge cases within the 500-specimen database regardless of the comparison method used. To accomplish this, each participating examiner was assigned three different sets of twenty-five unknown specimens (Sets 1, 2 and 3):

Set 1 - 3D images of each specimen were captured. Examiners compared these images to the 3D images in the research database in an attempt to identify the correct matching pair.

Set 2 - Cartridge cases were microscopically compared to the Group A cartridge cases used to populate the research database.

Set 3 – 2D images of each specimen were captured. Examiners compared these images to the 2D images in the research database in an attempt to identify the correct matching pair.

During this part of the experiment, the correlation and ranking capabilities of IBIS *were not* used with regard to the 3D and 2D image comparisons.

Phase II

This phase of the study seeks to provide insight into how well the proprietary algorithms of the IBIS technology perform when comparing and ranking images. To accomplish this, all 500 images from the research database were placed into the real-world database. The 500 matching cartridge cases from Group B were then imaged into the system and correlated with the same parameters as an actual entry. The results of these 500 correlations were then examined to see where in the correlation result list the true match was returned.

Results from each phase of the study will be analyzed to determine what, if any, error rate exists. For the purposes of this study, an error is defined as 1) an examiner fails to identify the matching pair for an unknown (false negative), or 2) if an incorrect match was made (false positive). The underlying causes of any errors will be assessed and reported. This data will allow the research team to address the benefits and limitations of in-silico confirmation of NIBIN matches by documenting:

1. The quality of 3D images captured by BrassTrax HD3D, and;
2. The accuracy of comparisons utilizing 3D images versus comparison microscopy of actual cartridge cases.

DATA ANALYSIS AND FINDINGS

The research team experienced a number of set-backs during the project period and not all data gathering and analysis was complete at the time of this report. To date, a total of 24,729 comparisons have been made utilizing 3D imagery, 13,606 microscopic comparisons have been conducted and 9,303 comparisons have been made through 2D images as part of Phase I.

The collection of data for Phase II is also ongoing. An ancillary analysis of casework data tracked by the DPDCL Firearms unit for NIBIN entries in 2018 show that 95.3% of confirmed hits were ranked within the top 10 candidates. 98.1% of confirmed hits were ranked within the top 30.

The research team will continue to gather and analyze data through the remainder of the project period. It is anticipated that result of the research project will be published in the Association of Firearm and Toolmark Examiners (AFTE) Journal. If possible, the research team also plans to present this research at the annual AFTE Training Seminar.

DELAYS IMPACTING THE PROJECT

As mentioned in the previous section, the project team experienced a number of obstacles. Chief among these were two significant delays in overtime authorization. City policies require that exempt (salaried) employees receive authorization for overtime work from the director of Human Resources. During the first year of the grant project (2016), this authorization was not received until April. This was compounded by delays associated with personnel changes and extended personnel absences, as well as complications with building the research database necessary for Phase I. Due to these delays, the team requested and received an extension of one year for the project. With the extension, a new request for overtime authorization was submitted and the authorization was not received until August 2017. It should be noted that the overtime delay in 2017 was due in part to a city-wide migration to a new human resource software platform. In total, the team was unable to work on the project for ten months during the first two years of the project.

Late in 2017, a change of scope was submitted to add the additional research objective discussed in Phase II above. To help accomplish this objective, a budget modification, submitted jointly with the change of scope, sought to reallocate extra funds for the contracting of a research assistant. (These extra funds stemmed from an upgrade to the NIBIN equipment that was provided free of charge. The original grant award allocated funds to purchase this upgrade.) The change of scope was approved in February 2018, and the budget modification was approved in May. The process of contracting with the research assistant began right away, but proved to be a far more complicated endeavor than anticipated. After working on hiring the contract position for nearly two months, it became clear that various requirements set forth by the City, including insurance and business registration provisions, would not be met within a timeline that would allow for a contract position to complete the necessary work.

Owing to the difficulties experienced by the research team, a series of meetings were held between department heads, grant administrators and participants, and financial personnel. The goal of these meetings was to improve the timeline for overtime approvals and to identify efficiencies within other processes that affect the administration of grants. As a result, those participating in on-going and future grants are better prepared to handle obstacles as they occur.

IMPLICATIONS FOR CRIMINAL JUSTICE POLICY

The use of NIBIN and the implementation Crime Gun Intelligence Centers (CGIC) has changed since the proposal for this project was submitted. Multiple CGIC sites now exist and all operate under the understanding that timeliness is a critical component to the successful use of NIBIN intelligence. Current accepted standards dictate that NIBIN associations be disseminated as unconfirmed leads, ensuring that vital information is provided to investigators as quickly as possible. Confirming NIBIN hits can then occur as part of the follow-up investigation or a full laboratory analysis of the evidence. Because unconfirmed leads are issued based upon in-silico review of cartridge case images, the data provided by this project demonstrate that unconfirmed leads do provide accurate information upon which investigators can act. As such, the validation of the use of 3D images could have a broad impact for CGIC initiatives that do not have immediate access to evidence.

Over the course of this research project, the algorithms utilized by NIBIN/IBIS have also improved. The question of how deep into a correlation list an analyst must look before concluding that there is no match, or hit, continues to be a point of debate. Some sites review all results in a correlation list (which can number in the hundreds), while others only review the top ten or twenty. Justifications for any particular site's policy varies, from citing FTI's claims to assessment of real world results. Once completed, the assessment of the correlation algorithms undertaken by this project will provide data useful to agencies as they examine and implement best practices with regard to correlation reviews.

REFERENCES

[1] "ATF Fact Sheet: National Integrated Ballistic Information Network (NIBIN)". May 2014. ATF publications page. <https://www.atf.gov/publications/factsheets/factsheet-nibin.html>. Accessed 201 Apr 3.

[2] King, Wm., Wells, Wm., Katz, C., Maguire, E., and Frank, J., "Opening the Black Box of NIBIN: A Descriptive Process and Outcome Evaluation of the Use of NIBIN and Its Effects on Criminal Investigations, Final Report" Report 243875, Department of Justice, Washington, DC, 2013.

[3] "NIBIN Evidence Return Time". AFTE Forums <http://www.afte.org/forum/smf1/index.php?topic=10466.msg56901;topicseen#new>. Accessed 2015 Apr 3.

[4] Bolton-King, R., Evans, J., Smith, C., Painter, J., Allsop, D., and Cranton, W., "What are the Prospects of 3D Profiling Applied to Firearms and Toolmark Identification?" AFTE Journal, Vol. 42, No. 1, Winter 2010, pp. 23-33.

[5] Bachrach, B., "Development of a 3D-based automated firearms evidence comparison system", Journal of Forensic Science, Vol. 47, Number 6, November 2002, pp. 1253-1264.

[6] Song, J., "Proposed 'NIST Ballistics Identification System (NBIS)' Based on 3D Topography Measurements on Correlation Cells," AFTE Journal, Vol. 45, No. 2, Spring 2013, pp. 184-194.