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Defining AFIS Latent Print "Lights-Out"

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EXECUTIVE SUMMARY

The criminal justice communities use the science of fingerprints to perform two major operations. The first is 10-print fingerprint operations with the primary purpose of establishing an individual's fingerprint biometric identity and their respective criminal history record. The second is forensic latent print examinations with the primary purpose of supporting criminal investigations in an effort to solve crimes. Both operations are crucial in supporting subsequent legal proceedings. This paper introduces and explores an incremental approach to automating more of the forensic latent print examination process.

Since the 1960's National Institute of Standards and Technology (NIST), Information Technology Laboratory (ITL) has been instrumental in Automated Fingerprint Identification Systems (AFIS) 10-print fingerprint research and development. These efforts culminated with the establishment of the first fingerprint interchange standard in 1986 and the continuous updating of the standard. The latest draft revision to the standard is the ANSI/NIST-ITL 1-2011, "Data Format for the Interchange of Fingerprint, Facial, and Other Biometric Information." In 2006 NIST ITL initiated the Evaluation of Latent Fingerprint Technology (ELFT) program; a prime objective of ELFT is to test AFIS technology accuracy when searching and matching crime scene latent prints against large 10-print fingerprint repositories.

The ELFT program focuses on testing the current AFIS latent print operational scenario as commonly implemented by law enforcement agencies world-wide. Specifically, the process begins with a latent print expert's analysis of crime scene latent prints followed by a determination of which latent prints, if any, are to be submitted to AFIS search and match processes. The AFIS results are then manually compared by the expert to establish an identification or exclusion with the listed candidates. The AFIS segment of this scenario has several variations which can be explored and tested. One key variation is to extract the standard AFIS fingerprint minutiae of the latent print automatically, thus saving the expert significant time from the time-consuming encoding process. This variation is referred to as Automatic Feature Extraction and Matching (AFEM). Another variation, generally an extension of AFEM, is to utilize the newly defined fingerprint features, referred to as the Extended Features Set (EFS), which go beyond the standard AFIS minutiae. The ELFT program included several studies which incorporated both AFEM and EFS scenarios. These tests results have been published and are available on the NIST website. The ELFT program has limited its AFIS testing to stay within the current practices of the forensic latent print examination.

The term "lights-out" has been used within the AFIS 10-print fingerprint operations to suggest that no human intervention is involved. Before this term can be applied in the forensic latent print operation a more in-depth understanding is required. The end-to-end latent print examination process is presented and seven tiers are described for potential "lights-out"

scenarios. A major objective of this paper is to define these seven tiers and establish a common understanding for each. Doing so will enable future testing of latent print "lights-out" scenarios to be clearly defined and operational implementations and consequences associated with each tier to be fully understood.

The paper describes seven tiers of possible latent print "lights-out" scenarios. Starting with Tier 1, each tier progressively invokes more automated processes. Tier 1 has undergone ELFT testing at NIST and results indicate potential for operational benefits for increased effectiveness in solving more crimes. While tiers one through seven provide a range of potential "lights-out" operations for AFIS latent print examinations, for technical reasons, only Tiers 1 and 2 are implementable now or in the near term. Tiers 3 through 7 reflect our concept of an incremental approach to full lights-out capability. They were chosen so that each step represents a meaningful increase in capability. The meaningfulness of each increased capability for all tiers should be assessed with regards to the effect on the end-to-end process, workload throughput, and accuracy.

To truly understand the impact of each tier on latent print operations a cost/benefits analysis is desirable. As suggested by these seven tiers, for AFIS Latent Print "Lights-Out" operation there is a need for common understanding and consensus on definitions. It is noted that there are even other possible scenarios which can be designated, with yet more tiers, but it is the intent of this paper to provide a framework for further discussion with the objective of establishing standard terminology for AFIS Latent Print "Lights-Out" operations.

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ABSTRACT

The term "lights-out" for AFIS ten-print fingerprint operations has been around for many years and is generally understood to mean "no human intervention is involved." But is this term appropriate for AFIS latent print operations? Is it truly possible to conduct AFIS latent print searches without human intervention?

The short answer is: not entirely, but the amount of human expert assistance can be greatly reduced. To determine where the effort can be reduced requires a careful examination of: a) the various stages of a latent print examination and AFIS processes; b) the traditional role of the human expert in each stage, c) the difficulty of automating the task done by the expert, and d) the gain/loss in performance that might result from eliminating human involvement. The logical result of such an examination is that various AFIS latent print "lights-out" scenarios emerge in a tiered manner, but the tiers are not necessarily sequential. Part of the benefit of this discussion is to create a common understanding and standard terminology for these scenarios or modes.

This paper examines seven scenarios, defined herein as Tiers 1 through 7, entailing ever increasing amounts of automation. Some of the salient pros and cons of each tier are briefly discussed. It is suggested that more complete analysis of the seven tiers requires a good cost/benefit model.

Defining AFIS Latent Print "Lights-Out"

1. Introduction

Over the past 30 years forensic science, and latent print examinations in particular, has seen tremendous advances through the use of computer technology. One of the most important advances is the introduction of Automated Fingerprint Identification System (AFIS). The history and development of AFIS's is discussed in references [1] and [2].

AFIS technology began in the 1970s (Rockwell-Autonetics/Printrak) and has continuously and dramatically improved. Initially, AFIS technology was developed to facilitate the ten-print fingerprint operations. The advances in accuracy of AFIS ten-print fingerprint operations were so dramatic that during the 1980s and 1990s many agencies began implementing what has been commonly described as "lights-out" operations, suggesting that there is no human ten-print fingerprint expert involved in this operation. Agencies learned, primarily through operational experience, the appropriate ten-print match score thresholds that must be set for their system to reliably predict identifications. This resulted in little need for the human expert to be involved in the mate/impostor decision. (Although certain borderline cases might still require human adjudication.)

In addition to the upper threshold, a second lower threshold can be established that would reliably predict an exclusion decision (i.e., definitely not a mate). Match score results residing between these two thresholds would still require human expert involvement.

Each agency needed to establish these thresholds based on their particular AFIS system; performance metrics (accuracy), data base size, and other factors. Once the appropriate thresholds were established, tested, and validated, the agency could make the decision to bypass the human expert, and automatically update an individual's criminal history record if an identification was effected. If, on the other hand, an exclusion decision resulted -- implying that there was no prior arrest record for that individual in the repository -- the new record might automatically be added to the repository. This process became known as AFIS ten-print "lights-out" operations, and is summarized in Figure 1. This figure depicts the conceptual end-to-end ten-print operation, beginning at the left side by the arrest booking process, and ending on the far right with a legal setting, such as a court room.

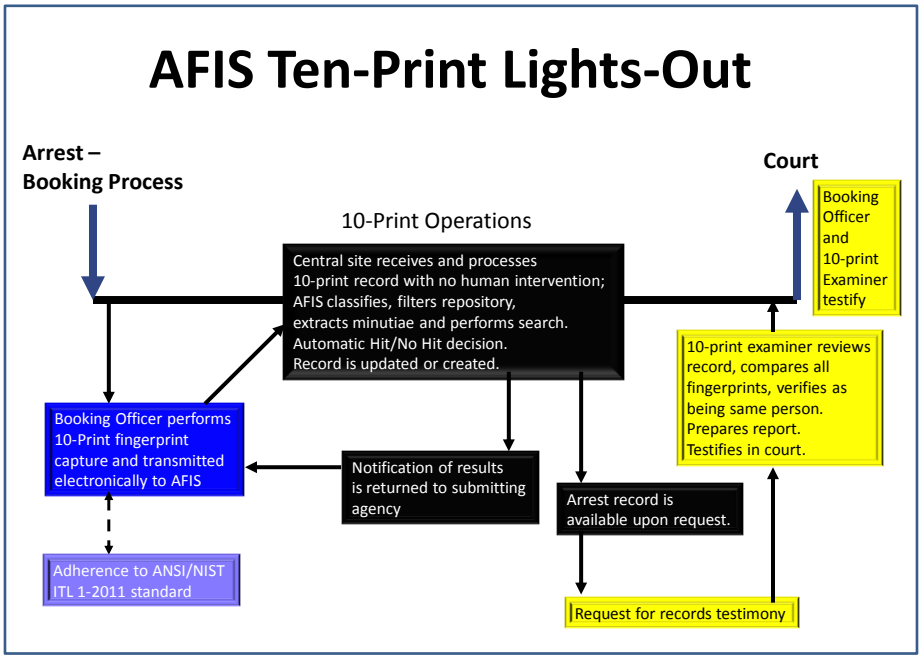

Figure 1: AFIS Ten-Print Lights-Out

The 10-print fingerprint operations are supported by the NIST Special Report 500-271 [3]; this report is key to achieving the "lights-out" concept. Further, NIST Special Report 500-280 [4] is key to the front end process of describing the best practices for the mobile acquisition of an individual's biometric features. As progress is made toward more latent print "lights-out" processes, existing standards will need to be revised and best practice documents created.

2. AFIS Technology for Latent Prints

Latent print identifications can potentially provide the identity of the perpetrator of a criminal act. In parallel with the AFIS ten-print fingerprint technology, efforts were made to significantly automate latent print operations. As a result, AFIS technology has proven to be extremely beneficial in supporting forensic latent print examinations by providing effective means for searching latent prints from crime scenes against large fingerprint and palm print repositories.

However, AFIS technology has been much more challenged by latent print processing than ten-print processing, and the accuracy of AFIS systems for latent prints remains significantly lower. The factors contributing to this lower accuracy include: a) the average size of a latent print is less than a fully rolled fingerprint; b) impression qualitative factors –such as clarity -- are generally lower; c) the finger position of a latent print is generally unknown; d) the orientation is generally less certain; and finally d) the "fingerprint" might actually come from another friction ridge area, such as the palm. (From an information theoretic view, the above factors

can be summarized by saying that the amount of information is less, while the search space is greater.)

Historically, these difficulties have required a latent print expert to be directly involved in the process. Much to their credit, the AFIS manufacturers over the years have made steady improvements in addressing these factors. So much so, that several law enforcement agencies have recognized the potential for some form of AFIS latent print "lights-out" processing.

But is “lights-out” appropriate for AFIS latent print operations? Is it possible no human expert intervention could be achieved, and, yet, maintain acceptable accuracy? To answer these, there is a need for the various AFIS Latent Print “lights-out” scenarios to be defined and analyzed. Doing so creates common understanding and the establishment of standard terminology.

3. AFIS Latent Print Operations

Figure 2 depicts the typical AFIS latent print operation used by most agencies today. In contrast to the AFIS ten-print fingerprint operations, which start with the arrest booking process, the AFIS latent print operations begin at the crime scene.

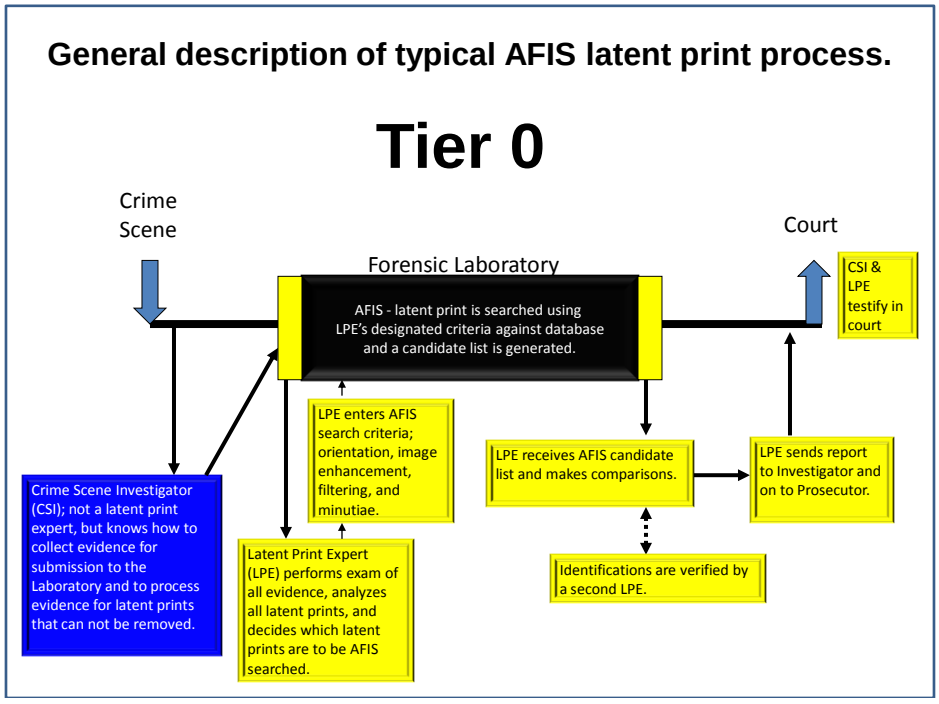

Figure 2: Tier 0, a typical description of AFIS latent print process.

In Tier 0, the blue box indicates that the person processing the crime scene is the crime scene investigator (CSI). While the CSI is trained to process crime scene evidence for the presence of latent prints, they are not latent print experts (for the purpose of this paper). The CSI's objective is either to: a) collect the evidence and send it to the forensic laboratory; or b) to process evidence for the presence of latent prints which cannot be removed from the crime scene. Regardless of the option selected, the CSI does not perform the analysis or comparison of these latent prints with any known exemplars. At this point, the CSI can personally transport the evidence, including any developed latent prints, directly to the forensic laboratory; and/or the CSI can electronically transmit any (all) developed latent prints to the forensic laboratory.

An excellent resource exists in the Scientific Working Group on Friction Ridge Analysis, Study and Technology (SWGFAST) document, "Standards for Examining Friction Ridge Impressions and Resulting Conclusions" Appendix A, Reference [5], which depicts the entire latent print examination process. Appendix A is a work product of the NIST/National Institute of Justice (NIJ) sponsored Human Factors Expert Working Group on Friction Ridge Analysis. The presentation by B.S. Swann, Reference [6], also provides a good introduction to latent print processing and needs at the Federal Bureau of Investigation (FBI). While the FBI's requirements are unique in certain respects, this presentation is indicative of the needs of larger law-enforcement agencies.

To truly appreciate the term "lights-out," the end-to-end process must be understood, along with knowing where the human expert plays a role. It is possible that creating a "lights-out" environment in one part of the end-to-end process creates more work in another.

This paper describes seven variations of AFIS latent print "lights-out" operations. For each variant we describe the "lights-out" part, with its benefits and disadvantages. The nomenclature used for these seven variations is "Tiers," specifically Tier One through Tier Seven. Tier 0 was used to refer to the typical AFIS latent print operations used by most agencies today, which does not involve any "lights out" concept.

These seven tiers are limited to the most common latent print process, specifically, that of searching a latent print against a repository of known prints. The other types of latent print searches, such as a new ten-print fingerprint record added to the repository used in searching against the unsolved latent fingerprint file (reverse searches), or a latent print search against the unsolved latent fingerprint file, are not included. (The number of tiers can be extended to accommodate these other scenarios.)

A second limitation of this discussion pertains to the risk associated with extrapolating technology out too far. We recognize that as we move to more automated process requiring less human involvement that the development of new automated tools may actually cause

changes for the next logical scenario. Regardless, we can only address the common practices known today but remain cognizant of this risk in our discussion. Therefore, we recommend that periodic reviews of these tiers would be prudent for assessing their relevance as technology advances. Our goal is simply to identify and define the various “lights-out” concepts without dwelling too deeply into the details.

This leads us into the third limitation of our discussion. The scenario for each tier is at a conceptual high level and there are several aspects within each box that may have many issues. Of primary concern is the perception that the flow (use of arrows) throughout each figure indicates a binary decision point to move onto the next box. While our primary objective is to identify where the human expert performs tasks which could become automated, i.e., become “lights-out” processes, we recognize that some of these tasks are very complex. For example in Tier 0 a box indicates that the “LPE receives AFIS candidate list and makes comparisons” followed by a box which indicates “identifications are verified by a second LPE.” (LPE = Latent Print Expert.) The first box certainly has several possible outcomes; identification, exclusion, inconclusive, and resubmit with modification(s). In this paper we do not explore these many options. Once again, we reference the SWGFAST document "Standards for Examining Friction Ridge Impressions and Resulting Conclusions" Appendix A, Reference [5], which depicts the flow of activity for a given decision at any point within the entire end-to-end process.

The figures are color-coded so as to indicate the specific type of individual or system performing a task. The blue boxes indicate that a human, but not a fingerprint expert, is performing the task described. The yellow boxes indicate tasks performed by a latent print expert. The black boxes indicate operations performed in an automated "lights out" environment, i.e., with no human intervention. To easier discern the changes from tier to tier a shadow has been added to the box which has changed from the previous tier. The color of the shadow indicates the color of the box in the previous tier.

Upon receipt of the evidence and/or electronically transmitted latent prints the latent print expert performs the analysis. If physical evidence is received then the latent print expert processes this evidence for the detection of latent prints. All latent prints, whether derived from the physical evidence or transmitted electronically, are analyzed by the latent print expert for a determination of their value for comparison purposes. Some of the latent prints may turn out to be of no value for either identification or exclusion, and these may be summarily dismissed. Latent prints which are determined to be of value (for either identification or exclusion) are then compared with available exemplars of individuals known to have been at the crime scene. This includes persons possibly involved in the criminal act, victims, or any other individuals having legitimate access to the evidence. If there are no known exemplars, or

the comparison process results in no identifications, then the latent print expert makes a determination as to which latent prints, if any, are suitable for searches using AFIS technology.

The latent prints suitable for being searched in an AFIS are digitally scanned, image enhanced as necessary, and optional search criteria (classification, finger position, an individual's physical descriptive information) are entered into the AFIS. The latent print expert then performs the technical process of encoding the minutia of the latent print. Generally, this minutiae encoding process is common across all AFIS technologies, but each vendor has specific methods for how this task is to be performed to optimize performance for that particular AFIS matcher. After completing these tasks, the latent print expert will launch the search of the latent print against the fingerprint repository. The output of the AFIS search is a match report consisting of a ranked list of candidates. The latent print expert then compares the latent print with each of these candidates. If an identification results from the AFIS search it needs to be verified by a second latent print expert.

Once all of the appropriate documentation has been completed for the entire latent print examination a report is generated and submitted to the appropriate entity. If the investigation results in the arrest of an individual then the latent print expert may be needed to testify during the legal proceedings.

Recall that in Tier 0 the latent print expert is performing all of the AFIS latent print tasks stated above, and there is no "lights-out" process being performed.

3.1 AFIS Latent Print "Lights-Out" – Tier 1

Figure 3 depicts an AFIS latent print process invoking automatic feature extraction and matching, the least amount of "lights-out" possible.

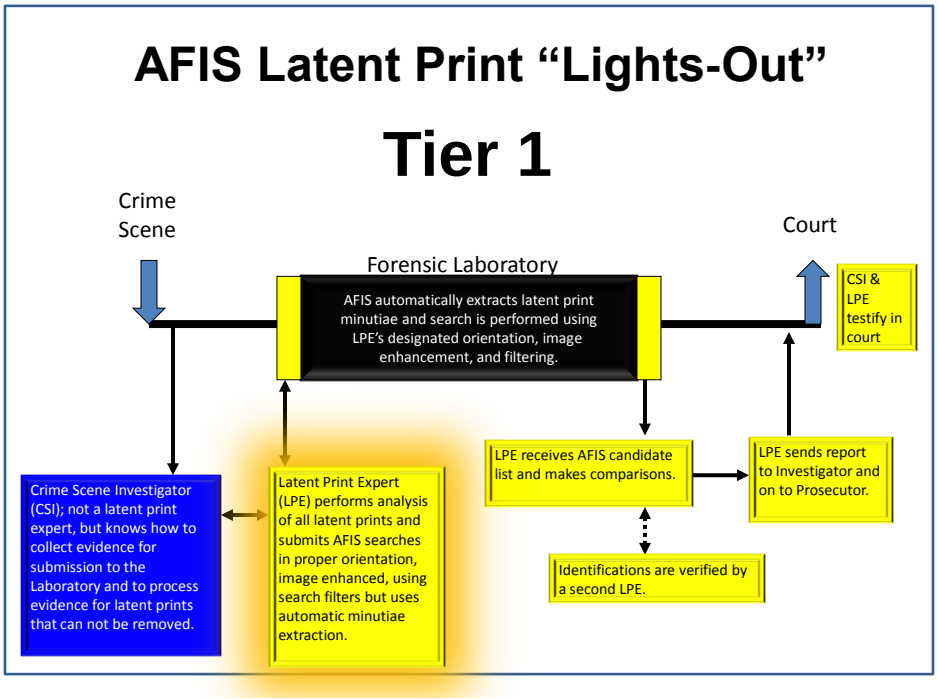

Figure 3: AFIS Latent Print "Lights-Out" – Tier 1

All of the processes described in Tier 0 are still applicable, except that in Tier 1 the latent print expert does not perform the minutia encoding. After the latent print expert has digitally scanned the image and performed any necessary image enhancement, the expert enters any search criteria (for example finger position, pattern class, or orientation). The search is launched and the latent print minutiae extraction process is performed automatically. In Tier 1 the latent print expert does not review or edit the automatically extracted minutia.

The Tier 1 concept is currently utilized by some agencies and has demonstrated many successes. In 2008 and 2009, the National Institute of Science and Technology (NIST), in concert with AFIS technology providers (typically vendors of AFIS systems), performed a series of tests referred to as the Evaluation of Latent Fingerprint Technology (ELFT). The purpose and methodology for these tests is covered in the Concept of Operations (CONOPS), Ref. [7]. Phase I and II testing was specifically designed to test the feasibility of automated feature extraction. The results of the ELFT Phase II tests have been published and are available in Ref. [8]. We interpret the ELFT results as favorable, and supporting the concept of submitting appropriately selected latent prints for search using automated feature extraction. Additional information on the ELFT Project can be found on the NIST Website, and in particular the links provided in ref. [9-11].

A benefit associated to the Tier 1 concept is that a latent print expert would benefit significantly by not having to perform the time-consuming minutiae encoding process. It is generally acknowledged that the minutiae encoding process performed by a latent print expert requires anywhere from 5 to 20 minutes. The accuracy of the automatic minutia extraction process is directly linked to the qualitative aspects of the latent print; the higher the image quality the more accurate the minutia extraction, and the more accurate the minutia extraction the more accurate the AFIS search and match.

A challenge for the latent print expert is to recognize when the latent print image quality is below the threshold that will cause AFIS search accuracy to suffer, resulting in a probable miss. Also, if the search resulted in a miss does the latent print examiner then resubmit the search using manually encoded minutia? (This type of decision may require extensive operational experience, a cost/benefit model, or both.)

The benefit of the Tier 1 process is that a significant number of latent prints could be quickly processed without the cumbersome process of manual minutiae encoding. A possible consequence is a shift of resources. The latent print expert saves time at the front-end (by having the minutia automatically extracted), allowing more time for the backend process of examining candidates. But these benefits exist only if more identifications result from the same amount of resources. But suppose after the first search no identification(s) is made. Should the print now be manually encoded by the latent print expert and a second search submitted to the AFIS? This, of course results in an increase in the workload. Obviously, the Tier 1 concept requires further study by an agency to determine the optimal operational points for their specific AFIS. But the potential for improved efficiency and effectiveness exists.

3.2 AFIS Latent Print "Lights-Out" – Tier 2

Figure 4 depicts operations similar to Tier 1, but eliminates the need to perform any AFIS pre-search functions. Such functions include: image enhancement processes, orienting the print to an upright position, and/or entering any search criteria (classification, finger position, and/or physical descriptors) used to filter the repository to reduce the penetration rate.

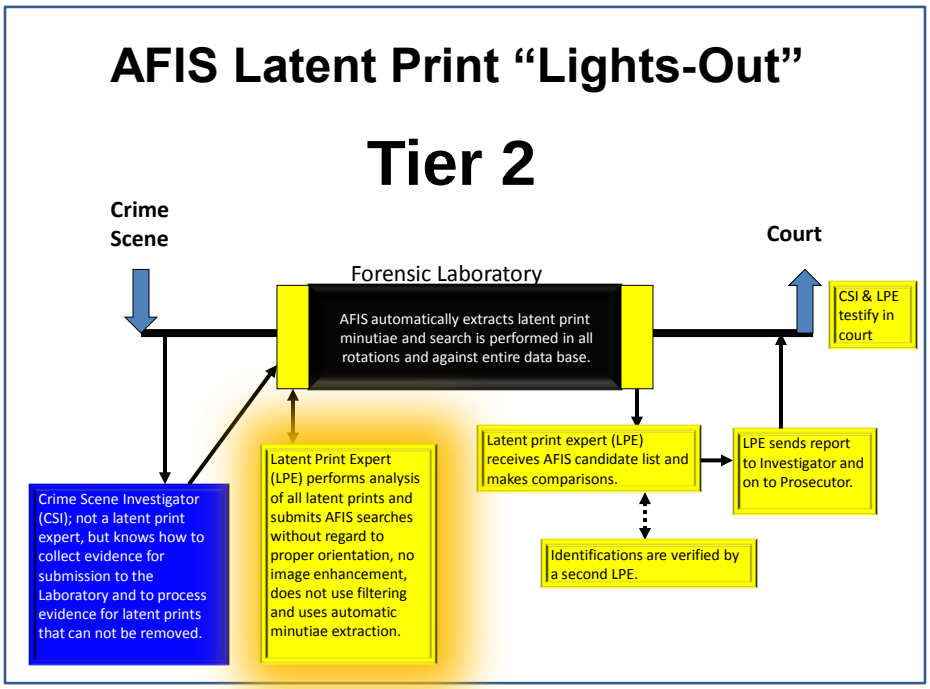

Figure 4: AFIS Latent Print "Lights-Out" – Tier 2

The benefits of Tier 2 are obvious, as significant time savings are achieved by the latent print expert not having to perform the degree of analysis necessary to provide all the search criteria used for initiating the AFIS latent print search. A possible undesirable consequence of the Tier 2 concept may be a significant AFIS accuracy loss. Requiring the AFIS to access the entire fingerprint repository ("cold search") and to search all possible rotations increases the computing resources unnecessarily, and may actually diminish the search accuracy. All other consequences of Tier 1 are also applicable in Tier 2; and the Tier 2 concept requires further study and research by an agency in determining the operational points for their specific AFIS operation.

3.3 AFIS Latent Print "Lights-Out" – Tier 3

Figure 5 depicts the same latent print operation as defined in Tier 1 but adds the aspect of the identification decision being made by the AFIS, and not a latent print expert. Tier 3 follows the same logic as depicted in the AFIS ten-print fingerprint operations (Figure 1) in that the AFIS matcher scores needs to be high enough to pass a threshold. This ensures reliability (accuracy); in other words, the AFIS matcher score is indicative of an identification.

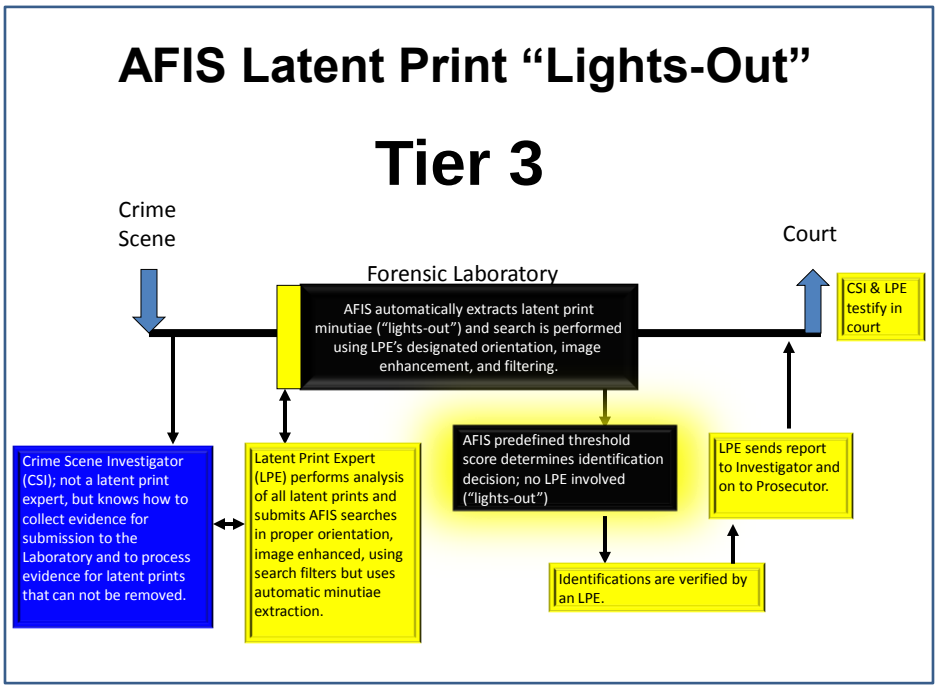

Figure 5: AFIS Latent Print "Lights-Out" – Tier 3

The final step is to have the tentative identification verified by a latent print expert. This is an interesting variant of the traditional scenario involving two latent print experts: the first expert performs the identification, and a second expert performs the verification. In Tier 3 concept first latent print expert is being replaced by the AFIS matcher decision process.

The benefit associated with Tier 3 is that the latent print expert can rapidly filter through large numbers of AFIS latent print searches involving numerous separate criminal investigations. The expert then can quickly turnaround cases, saving significant time, and allowing the handling of a larger volume of casework. One potentially negative consequence is that greater amount of bias can enter into the verification process due to the influence of the AFIS matcher score. Another (negative) consequence is that there will be a continual need to reevaluate the AFIS matcher thresholds as the fingerprint repository grows in size, the composition (image quality, crime type, etc.) changes, or improvements are made to the matcher.

A separate, and even more interesting, consequence of the Tier 3 concept is the potential complexities before the courts. It is possible that the AFIS search could indicate an identification, but the latent print expert would not verify the identification. An even more problematic scenario is where the AFIS search does not meet the upper identification threshold ("sure hit"), but exceeds the lower threshold ("maybe"), and the latent print expert is willing to

identify/verify the latent print. Would courts be "troubled" by such a decision process? Would this require a second verification by a human expert?

Yet another scenario is where the top two ranked AFIS candidates are both above the threshold for identification (upper threshold), but the highest ranked candidate is not a correct candidate, while the second-ranked candidate is the true mate. The latent print expert verifies the second ranked candidate and excludes the higher ranked candidate. The court's (jury's) perception of such a scenario may be a degraded confidence – or worse.

3.4 AFIS Latent Print "Lights-Out" - Tier 4

Figure 6 depicts AFIS latent print operations similar to Tier 3, but in Tier 4 the AFIS performs the final verification process, and not the initial identification. Tier 4 AFIS latent print searches result in the candidate list being presented to the latent print expert, who then makes any identifications. This decision is then passed back to the AFIS for an automated verification process. This verification step will almost certainly use more information than was used for placement on the candidate list. This may require going back to the images (latent print and the selected known exemplar), and, in fact, a completely different system (or matcher) may be required than for the original search and match process.

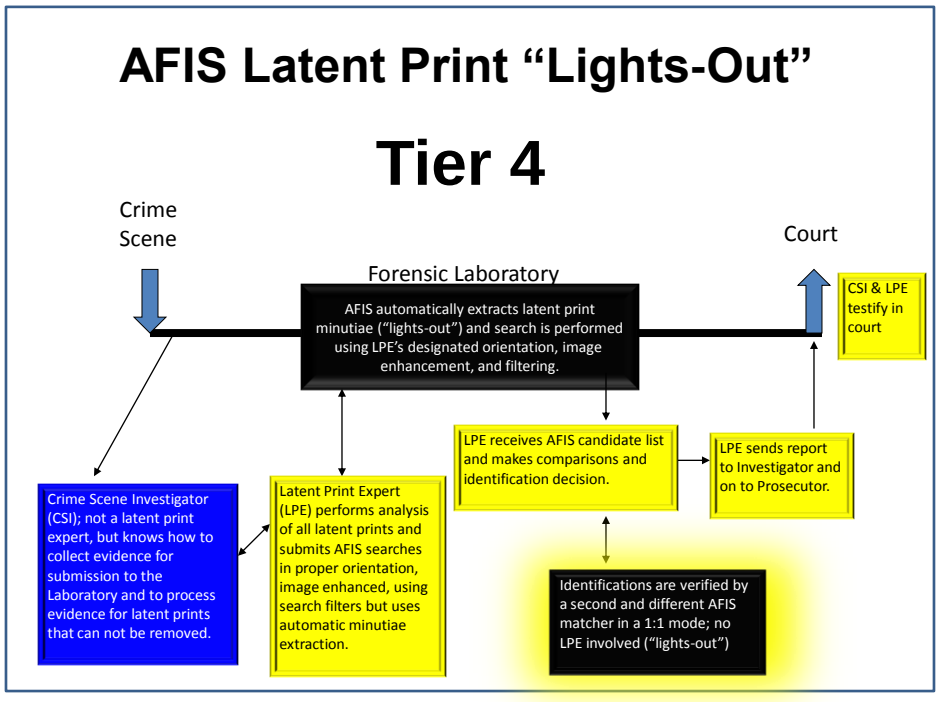

Figure 6: AFIS Latent Print "Lights-Out" – Tier 4

It is conceivable that both the latent print expert and the automated verification matcher could render the same conclusion but based on different criteria. As stated previously under Tier 3, it would be interesting to see how the experts and courts handle such a situation.

Tier 4 opens the door for the discussion regarding the use of statistically-based probability models in support of conclusions made by the latent print expert. Statistically-based probability models and automated AFIS verification matchers (1:1) are two fundamentally distinct processes. While Figure 6 does not depict the use of a probability model the diagram could easily be revised to a) either replace the AFIS verification matcher with the probability model, or b) insert it as an additional process. This matter is a point of discussion in and of itself and will not be explored herein.

3.5 AFIS Latent Print "Lights-Out" - Tier 5

Figure 7, Tier 5, depicts the latent print operations as an aggregate of Tiers 2, 3, and 4. Tier 5 includes the automated feature extraction function, the automated identification decision process, and the automated verification process. The latent print expert's role is limited to the front end process of initiating the AFIS search criteria and at the backend of writing the final report. All of the major decision-making is performed by the automated process without input by the latent print expert. To some degree this may be considered as a use of completely objective metrics, eliminating the subjectivity and biases often attributed to latent print experts.

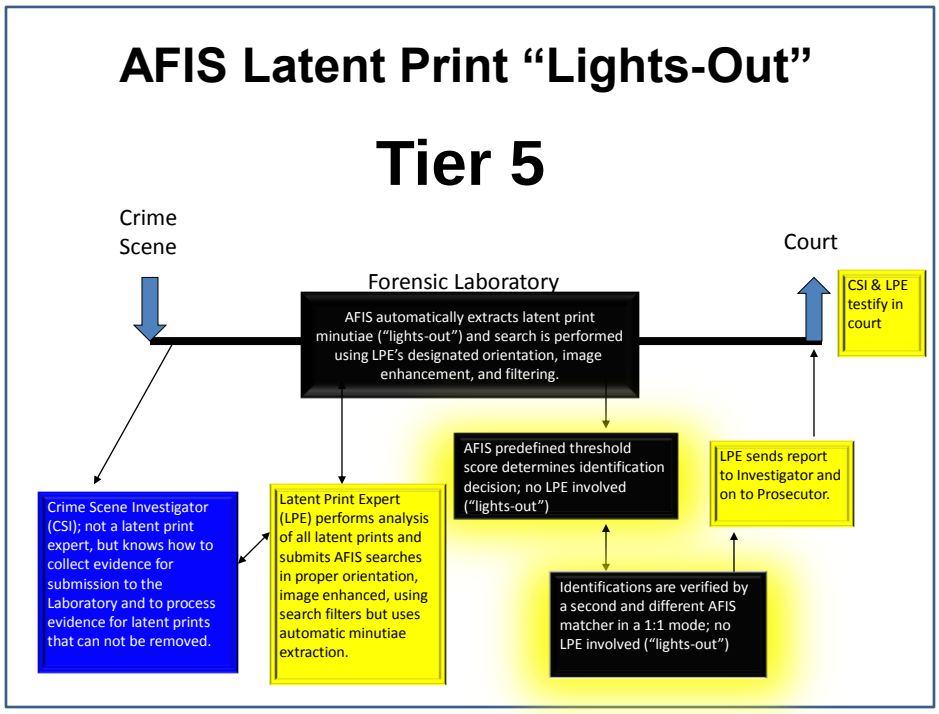

Figure 7: AFIS Latent Print “Lights-Out” – Tier 5

All of the benefits and consequences previously mentioned for Tiers 2, 3, and 4 are applicable to Tier 5. The aggregate of these benefits and consequences pose both interesting opportunities and challenging scenarios for operational acceptance and legal considerations.

3.6 AFIS Latent Print "Lights-Out" - Tier 6

Tier 5 already encompasses such a high degree of automation it is difficult to see opportunity for further automation. Figure 8, Tier 6, depicts a change from the prior tiers in that the focus is at the front end of the process. In Tier 6 the CSI, not the latent print expert, directly inputs the latent prints into the AFIS. This concept is similar to Tier 2 in that there is now no pre-search filtering of the repository using classification, finger number, orientation, etc. But an important difference is that the CSI would not determine whether the latent prints are even suitable for any comparison, let alone an AFIS search. Thereby, all latent prints developed at the crime scene or on the evidence would be submitted for AFIS search.

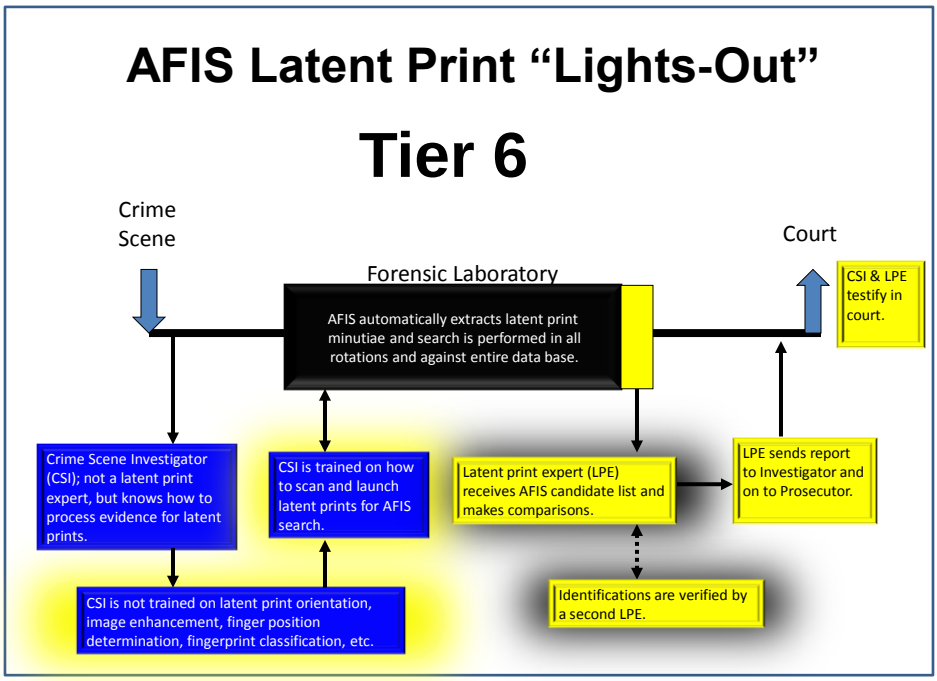

Figure 8: AFIS Latent Print "Lights-Out" – Tier 6

A benefit associated with Tier 5 is the immediate search of latent prints directly from the crime scene, with results available as quickly as the AFIS can perform the search and match. This process eliminates delay associated with a backlog of latent print examinations at the forensic laboratory. However, the decision-making process (whether an identification) still resides with the latent print expert at the forensic laboratory. The consequence of this process is the potential of an overwhelming volume of AFIS searches confronting the latent print expert having to make the comparisons of all candidates resulting from each search. The number of the AFIS latent print searches that should not even be initiated could be potentially quite high and thereby wasting a significant amount of the latent print expert's time. What appears to be a significant time savings at the front end could possibly result in an excessive amount of wasted human expert time at the backend. Additionally, significant additional AFIS computing resources would be required, also with potential associated waste.

3.7 AFIS Latent Print "Lights-Out" - Tier 7

Figure 9 depicts the aggregate of Tiers 1 through 6. Tier 7 has removed the latent print expert from the entire process except for the final report and the need for testimony in court. The AFIS latent print searches are initiated by the CSI, the AFIS searches rely on automatically extracted

information, and the decision of an identification and the verification are performed using automated processes.

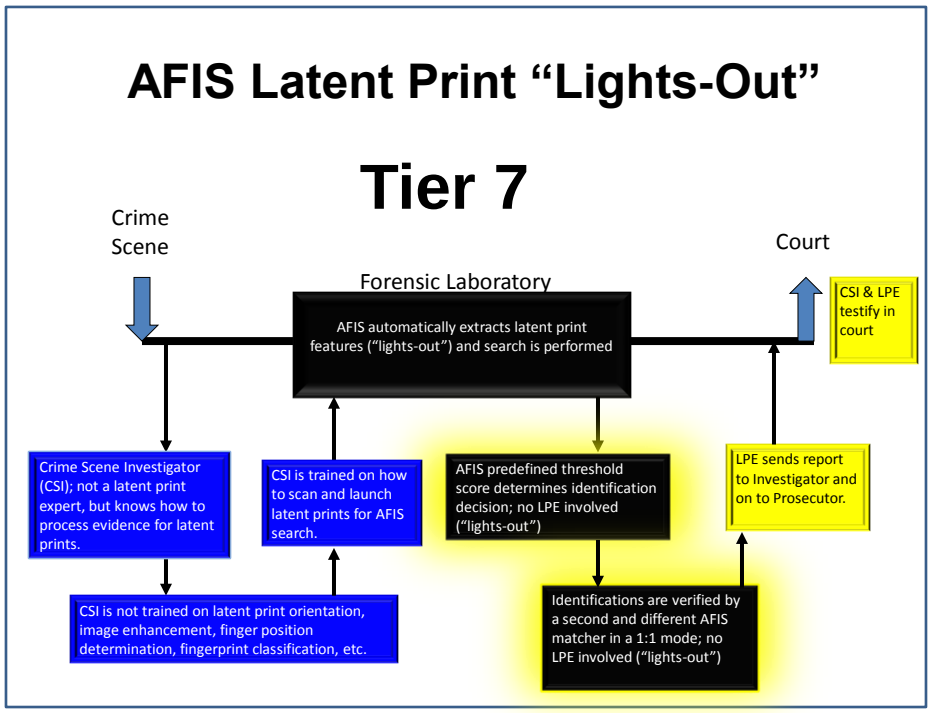

Figure 9: AFIS Latent Print "Lights-Out" – Tier 7

The benefits associated with Tier 7 have significant resource savings in time and manpower, but an increase in computing resources. One could argue, theoretically, that more crimes would be solved, with dramatically reduced turnaround times, through the use of objective metrics that eliminate the subjectivity and bias associated with latent print expert examinations. On the other hand, depending on the AFIS performance metric (accuracy) many crimes could remain unsolved that otherwise would be solved if a lower tier scenario were implemented.

4. Cost/Benefit Modeling

We have identified seven different scenarios that may be considered as types of "lights-out" operations. How would we evaluate these? A very promising approach is by means of a cost/benefit model. It is beyond the scope of this paper to develop such a model in detail, and we will restrict ourselves to the general concept. (In the model we ignore the cost of processing when the match score resides between the identification and exclusion thresholds.)

A cost/benefit model attempts to capture all the benefits that accrue from a given course of action ("scenario"), as well as all the possible negative consequences. The latter include not only the direct cost of implementing a course of action, i.e., the actual cost of normal operations, but also the consequence of a mistake. In its most basic form the mathematical expression for the model appears as follows:

Net_Benefit = Benefit_of_correct_decision – cost_of_operation – penalty_for_wrong_decision … (1a)

In our case:

Benefit_of_correct_decision = benefit of a correct latent print identification × probability of making an identification … (1b)

cost_of_operation = includes both computer cost and human cost = computer cost + human expert cost

… (1c)

penalty_for_wrong_decision = cost incurred by a bad identification × probability of making a bad identification … (1d)

The last term is the most controversial. Some people argue that the probability of a false identification is negligible. But even if the probability is very small, the cost is very high (an agency being sued for wrongful arrest and conviction); so there may be a significant contribution from this term. An alternative interpretation – perhaps less controversial – is to consider this term as the cost of reducing false identifications down to some irreducible level.

In general, when equation (1) is fully developed it will contain one or more parameters, which represent controls over the process. (A picturesque way of looking at it is that these parameters represent control dial settings.) The objective is then to maximize equation (1) over all the parameters. Typically this requires that at least one parameter have a non-linear influence.

As stated earlier, we do not intend to fully develop these ideas in this paper, but we provide an example to illustrate the procedure.

Illustrative Example:

This illustrative example addresses an issue that would exist in Tiers 2, 4 and 6. Aside from the bigger end-to-end cost/benefit analysis needed for these tiers, a key sub-issue is to assess the expert time versus accuracy performance during the AFIS candidate comparison phase. The key question to be answered for this sub-issue is what is the optimum number of candidates to examine in order to make these tiers cost effective?

Candidates are assumed on a ranked list, with the candidate in first place having the highest score/value. The question is how many of these candidates should actually be examined so as to

optimize the net benefit. The probability of a candidate appearing on a list of length L is assumed given by

$$P(L) = (L/N)^{\alpha} \qquad \ldots (2)$$

In the above N is the size of the repository/background to be searched, and α is a constant characterizing the particular system, database, and average quality of the latent prints being searched. (For this example N = one million, and α = .04.) An important parameter influencing performance is the a priori probability that a mate is present in the repository, which we designate as P_{enroll}. The units for the benefit and cost are "arbitrary units" and were selected so that the benefit is twice the cost for a "representative" case. (This avoids having to actually assign dollar values.) The cost consists of two parts, the AFIS search cost, and a cost of examining a candidate by a human expert.

Figure 10 shows the resulting optimal number of candidates. The result depends upon P_{enroll}. For very small values of P_{enroll} the optimal number is zero – meaning that a search should not be performed. If P_{enroll} is large the optimal number increases to about 5.

The details will change depending upon parameter values selected; but it is true that it is difficult to come up with a scenario which requires examining more than ten candidates.

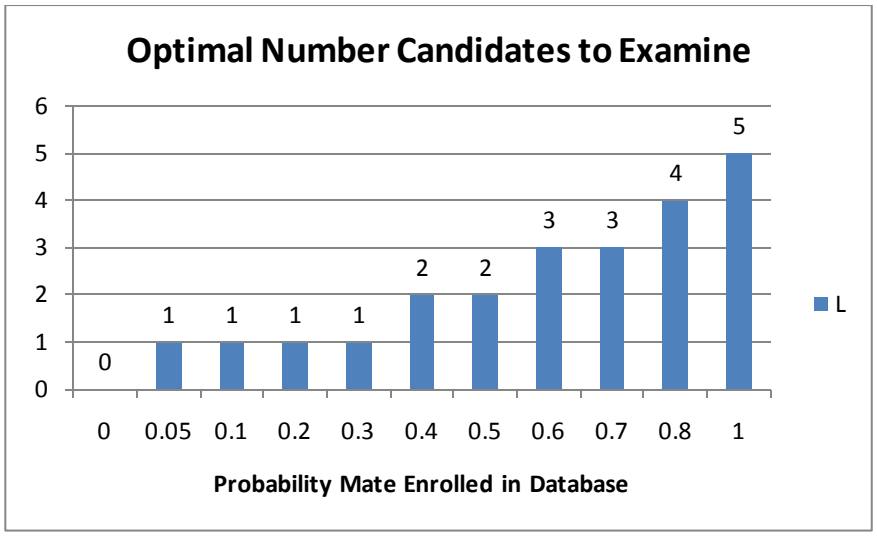

Figure 10: Example of Cost/Benefit Model for Optimizing AFIS Candidate Comparisons

5. Conclusions

While Tiers one through seven provide a range of potential "lights-out" operations for AFIS latent print examinations, the reality is only Tiers 1 and 2 are reasonable near term. The AFIS vendors have demonstrated significant improvements in matcher reliability and have also produced AFIS matchers which could support the verification (1:1) process. The ability to

migrate these capabilities into an operational environment requires significant independent and validation testing which has yet to be performed. Further, each agency utilizing AFIS technology would need to customize these advanced capabilities to their specific circumstance, as there are numerous factors influencing how best to implement these additional capabilities in a given AFIS and latent print operation.

Tier 1 has undergone ELFT testing at NIST and results indicate potential for operational benefits for increased effectiveness in solving more crimes. Exploring these operational opportunities would be an excellent topic for a future paper.

We would be remiss if we did not emphasize that there are significant other processes which take place in the forensic latent print examination beyond the focus of this paper (which is limited to the aspects associated with AFIS and the potential for "lights out" operations). To emphasize this point, the foremost component of the forensic latent print examination is the manual comparison of the latent prints with any known subjects or suspects believed to be involved in the criminal act. Another component is the importance associated to the initial analysis of the latent print, whether it is in support of manual comparisons or AFIS searching. Therefore, before any changes are made with regards to AFIS latent print operations the entire end-to-end forensic latent print examination process must be considered.

As noted by the seven tiers for AFIS Latent Print “Lights-Out” operation there is a need for common understanding and consensus on their definition. It is noted that there are even other possible scenarios which can be designated with yet more tiers but it is the intent of this paper to provide a framework for further discussion with the objective of establishing standard terminology for AFIS Latent Print “Lights-Out” operations.

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