Contactless Fingerprint Technologies Assessment

(Version 2)

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National Institute of Justice
Sensor, Surveillance, and Biometric Technologies (SSBT)
Center of Excellence (CoE)

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1.0 EXECUTIVE SUMMARY

The National Institute of Justice (NIJ) Sensor, Surveillance, and Biometric Technologies (SSBT) Center of Excellence (CoE) has undertaken an assessment of current activities in government, industry, and academia regarding research and development (R&D), products, and comparative investigations of contact versus contactless fingerprint technologies. Existing wet-ink and live scan are the primary fingerprint collection methods currently in use. While these are mature technologies that are used in myriad applications – civil, law enforcement, and military – they do have certain drawbacks. Wet-ink fingerprinting requires an operator with special training who collects the fingerprints. In addition, collections of the same individual may be inconsistent between operators. Additionally, wet-ink collections require materials that must be replaced by operators and involves clean-up for both operators and subjects alike. Live scan devices address the material and cleanup aspects of wet-ink collections, but can introduce issues of their own. Such devices can suffer from interference from latent fingerprints left on the scanner platen, high failure to acquire rates due to variations in skin condition (dry, moist, oily, or worn), and variation in prints due to varying amounts of pressure during the scan. Both of these technologies continue to have drawbacks inherent to contact-based methods of fingerprint collection.

This report examines the initiatives in government, industry, and academia aimed at pursuing contactless fingerprint collection technologies. Contactless fingerprint scanning technologies offer several potential advantages over the current collection methods: higher quality fingerprint images, faster capture times, unattended fingerprint collection, and a drastically reduced likelihood of the spreading of contaminants among subjects. Information for this report was gathered by the SSBT CoE from vendors, researchers, and available literature from Spring 2011 to Spring 2012.

It is the finding of the CoE that commercial off-the-shelf (COTS) devices are available that are targeted primarily at access-control scenarios with a local database of enrollees. While it is possible that these devices could be modified for use in an enhanced capacity (with remote Automated Fingerprint Identification Systems (AFISs), for instance), additional investment and development would be required. This report has identified NIJ, Department of Homeland Security (DHS) Science & Technology Directorate (S&T), and Department of Defense (DoD) Biometrics Identity Management Agency (BIMA) as the government agencies most active in funding contactless sensor technologies, with several manufacturers performing internally funded R&D, and on-going activities at academic institutions.

Table 1: Devices, Companies, and Funding Sources Identified in This Report

Company	Device(s)	Funding Source(s)
FlashScan3D	Single-finger, tenprint, single-finger rolled-equivalent, and full-hand scanners	DHS, National Institute for Hometown Security, DoD BIMA, Army Research Laboratory (ARL)
General Electric	Tenprint scanner	DHS
TST Biometrics	BiRD 3/BiRD 4	*Not Specified*
Touchless Biometric Systems	TBS Guard 3D	*Not Specified*
Touchless Biometric Systems	Touchless Ten Printer	NIJ
University of Massachusetts Lowell	Rotational single-finger scanner	NIJ
Carnegie Mellon University, HandShot, LLC	HandShot ID	NIJ
NEC	HS100-10	*Not Specified*
IDair (division of Advanced Optical Systems)	AIRprint, ONEprint	Internal Funding
MorphoTrak	Finger-on-the-Fly	Internal Funding
Lumidigm	Stereoscopic fingerprint sensor	*Not specified*
AFIS and Biometrics Consulting, Inc	Fingerprint-on-the-Move	DHS

2.0 INTRODUCTION

Fingerprint biometrics is used for identification efforts of all kinds, from civil and law enforcement to military uses. Vast databases of millions of enrollees exist to protect our borders, identify criminals, and validate the identities of friends and foes alike. Fingerprinting technologies used to populate these databases have evolved since the early days of fingerprint collection. Current fingerprinting techniques are focused on improved quality and usability. Two methods are currently in wide use: wet-ink and live scan. In the wet-ink technique, the subject's fingerprints are covered in ink and then pressed and rolled onto a fingerprint card. Live scan technology scans a subject's fingerprint without the need for ink, requiring the user to press their fingers against a platen to acquire the fingerprint information.

Current fingerprinting technologies either use or mimic the wet-ink method of gathering fingerprints. Such methods produce flat images of a three dimensional object (the finger). In the process of gathering the flat image, the fingers are pressed against paper or a platen and distortions of the three-dimensional (3D) fingerprints are created. Such distortions may not be uniform throughout a single fingerprint or between administering operators due to changes in pressure and other factors. Additionally, issues from too much or too little ink, smearing, worn fingerprints, and contaminants that interfere with new scans or transmit between users make traditional or live scan fingerprinting less than ideal.

Fingerprint biometrics is particularly important to law enforcement, as they form the basis of criminal identification and investigation activities. NIJ supports law enforcement through exploration and stimulation of research into new technology areas. In accordance with this role, NIJ SSBT CoE has conducted an assessment of contactless fingerprint technology and products to capture the landscape and options available to practitioners and biometrics researchers.

Contactless fingerprinting (CFP) technology aims to address issues experienced with wet-ink and live scan technologies, while providing more fingerprint detail (useful for latent examiners), improving hygiene, requiring less operator training, and increasing time-savings. In addition, CFP technology is expected to speed up access control and identity processing in high traffic areas, such as facility access and customs and border applications. This technology, however, is not without its challenges. For instance, necessary precautions must be taken to ensure movement of the subject's fingers does not impact scan quality, and the scanner must be able to accommodate the myriad of different sizes, shapes, and conditions of fingers. Perhaps most important for the widespread adoption of the technologies, wet-ink and live scan databases are in wide use by the government, military, and law enforcement. Therefore, a primary challenge to the adoption of CFP technology is in providing and proving the capability be fully backwards compatible with these technologies. Without such capabilities, CFP databases could become silos of data whose usage is limited.

2.1 CFP Efforts Identified

R&D of CFP technologies is ongoing and is being funded by multiple agencies and companies. The primary efforts identified in this report correlate to actual devices in various stages of prototypes or full commercial products. Many of these devices were funded by government agencies, the most active among these are DHS S&T, NIJ, and DoD BIMA. Those systems not

funded by government agencies, but through internal vendor funding, are largely intended for access control scenarios using local databases and are not intended to function in a wider federated biometric enterprise. Most of the CFP efforts focus on access control using locally-accessible databases. The remaining devices tend to focus on interoperability with existing AFIS-style databases (e.g., IAFIS, NGI, IDENT, or ABIS). A large hurdle for such interoperability seems to be a lack of confidence among stakeholders on unrolling techniques, pressure deformation issues, and established device certification requirements (e.g., Federal Bureau of Investigation (FBI) Appendix F requirements).

In general, organizations have funded CFP R&D with the following objectives and/or applications.

- Investigate the potential for baseline match performance improvements using fingerprints captured with greater detail, larger captured surface area, and lack of deformation by interactions with physical sensors
- Understand the fundamental performance of CFP technologies to advance the biometric science and engineering community
- Explore the interoperability of fingerprint images generated from CFP and 3D scanners with existing legacy fingerprint databases
- Establish operational guidance and best practices ahead of adoption by state and local criminal justice agencies
- Improve the throughput of physical identification at facility access and customs and border entry points
- Reduce cross-contamination hygiene at high throughput identification points
- Reduce operator assistance and involvement in physical access applications

2.2 Contactless versus Touchless Biometrics

In performing the research for this report, it became apparent to the CoE that the term "Contactless Fingerprinting" had a range of definitions depending on the audience. "Contactless" may refer to the sensor itself. The user may be required to place their hands directly on the machine, but the fingertips do not make contact with the sensor (a clarification of the term "fingertip" with respect to biometrics is available[1]). On the other end of the spectrum, the entire process may be completely contactless. The user stands at a distance from the sensor and holds their hand in the air to have their fingerprint scanned. This end of the "contactless" scale is true touchless biometrics. The application of touchless biometrics realizes the potential of contactless technologies, providing the benefits of faster subject processing and higher quality data gathering while addressing the issues of current generation techniques. The devices in this report span the range of this continuum, requiring varying levels of contact by the user.

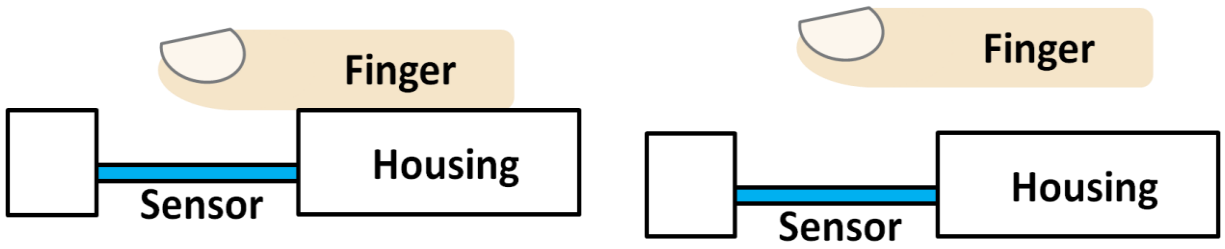

Figure 1: Contactless Fingerprint Scanning Examples
Depending on the vendor/researcher, "contactless fingerprint" technologies can mean devices where (left) the finger touches the devices but is separated from the sensor or (right) devices where the finger is completely isolated from all components.

2.3 Survey and Assessment of Contactless Fingerprint Technology Efforts

In order to compile this report, the Center gathered data by polling government agencies, attending conferences, contacting vendors, and performing general literature research. The devices and efforts identified in this report span a range from early technology R&D, through advanced prototypes, to commercial offerings. Using the available data of each system, we provide assessment notes on the capability, applicability, and readiness of each. Information on certain devices may be sparse due to various factors, such as lack of response from vendors or stakeholders or the sensitive nature of commercial R&D projects. For ease of reference, a summary of key characteristics are included in each device section (see Table 2).

NOTE: The SSBT CoE has not conducted any laboratory or field testing to verify the performance or features of specific devices or scanning technologies. Assessments are based on subject matter expertise, available literature, and vendor materials and responses to inquiry.

This document is intended to provide a canvassing of the current landscape of contactless fingerprint initiatives taking place from Spring 2011 to Spring 2012.

2.4 About NIJ SSBT CoE

The NIJ SSBT CoE is a center within the National Law Enforcement and Corrections Technology Center (NLECTC) System. The Center provides scientific and technical support to NIJ's R&D efforts. The Center also provides technology assistance, information, and support to criminal justice agencies. The Center supports the sensor and surveillance portfolio and biometrics portfolio. The Centers of Excellence are the authoritative resource within the NLECTC System for both practitioners and developers in their technology area(s) of focus. The primary role of the Centers of Excellence is to assist in the transition of law enforcement technology from the laboratory into practice by first adopters.

Table 2: Contactless Technology Summary

Attribute	Value
Scanning Technique	Describes the foundational technical approach used by the device to capture fingerprints.
Scanning Target	Describes what part of the finger and/or hand is scanned by the device.
Touchless	Describes whether the device is truly "touchless." Systems that require a person to touch any component of the scanner are recorded as "No," while those that may involve unintentional contact from subject movements are classified as "Yes."
Primary Uses	Uses intended by the manufacturer, or likely uses by law enforcement: • Standoff • Enrollment • Time & Attendance • Access Control (Physical) • Access Control (Gateway) – High throughput processing of subjects (e.g., facility access, customs) • Access Control (Logical) • Mobile Identification • Other (Undetermined)
AFIS Enrollment	Whether the device is capable of producing images suitable for enrollment in a criminal justice interoperable AFIS.
Remote AFIS Compatibility	Whether the device provides the capability to submit to remote AFIS systems and conforms to biometrics transmission standards (e.g., EFTS, EBTS, and ANSI/NIST ITL).
Scanning Resolution	Effective scanning resolution of the device. 500 pixels per inch (ppi) is the current standard; however, 1000 ppi is expected to become important with next-generation AFIS systems in the near-term.
Operator Assistance	The level to which a trained operator is required to assist the user of the system: 1. None 2. Enrollment Only 3. Yes – Software Operation 4. Yes – Instructor Guidance Required
Maturity Level	The readiness of each device for deployment in the field. 1. R&D 2. Prototype (i.e., Testable device is available) 3. Pre-Commercialization 4. Commercial

3.0 CONTACTLESS FINGERPRINT R&D ACTIVITIES

3.1 AIRprint

AIRprint is a concept developed and funded by Advanced Optical Systems, Inc. (AOS) for the rapid acquisition of fingerprints at a standoff distance of 2 meters (http://www.idairco.com/products/).[2] An individual briefly stops in front of the scanner and holds up a hand with the palm facing the device. The sensor locates the hand and collects the finger imagery. While current revisions of the sensor operate on individual fingers, AOS reports that future updates may include full-hand, multi-finger, and/or rolled equivalent capture. The collected imagery is processed for storage or matching to existing databases. Total collection and processing time for AIRprint is under one second, however, the time required to match a fingerprint to a database may be longer. Based on the match results, access is granted or denied.

AIRprint was designed with both the military and law enforcement communities in mind. However, because the development has been funded entirely by Advanced Optical Systems, Inc., several modifications and upgrades have been studied but have not been implemented. The device is not currently ruggedized and lacks autofocus, but AOS claims both features could be completed within a few months at a customer's request. AOS reports that integration with Cross Match Technologies' SEEK II is currently being studied to augment that system's dual iris scan and facial capture with touchless fingerprint acquisition. According to a news article, the U.S. Marine Corps expressed interest in the technology after observing a demonstration.[3] AOS also claimed that the Madison AL Police Department was interested in the system.[2]

In January 2011, AOS founded IDair to provide a commercial outlet of the biometric technologies resulting from AOS's R&D activities. AOS continues to serve Federal Government customers.[4]

3.1.1 Select Patents

- Richard Leon Hartman, et al. (Advanced Optical Systems, Inc.); *Remote measurement of object orientation and position;* Patent# US7505609 (March 17, 2009)
- Richard L. Hartman and Keith B. Farr (Advanced Optical Systems, Inc.), *System for processing and recognizing objects in images*, Patent# US7526100 (April 28, 2009)
- Hartman Richard L (Advanced Optical Systems, Inc.), *System and method for measuring the dimensions of moving packages*, Patent Application# WO2003025498 (September 20, 2002)
- Joel Dean Burcham, et al. (Advanced Optical Systems, Inc.); *Contactless fingerprint acquisition and processing;* Patent Application# WO2012048177, US20120086794 (October 7, 2011)

3.1.2 Technical Specifications and Description

The AIRprint device demonstrated to the CoE measured six inches in length and four inches in depth and height making it a true mobile device. Inside the unit's housing are a Light Emitting Diode (LED) bulb and two 1.3 megapixel cameras. With the LED bulb providing the light source, one camera captures horizontally polarized light while the other receives vertically polarized light. When the light hits a finger, the ridges of the fingerprint reflect one polarization

of light and the valleys reflect another. By separating the horizontal and the vertical polarization, the device can send the separate images to a computer via USB interface. Software on the PC is used to overlap the two images and produce a fingerprint.

Figure 2: AIRprint Standoff Fingerprint Scanner
Courtesy of IDair

3.1.3 Assessment Notes

During the demonstration attended by CoE staff, AIRprint performed as expected at its fixed distance of 2 meters. AOS indicated that polarity filters would allow the system to function in daylight at the same distance. The scanner examined during the demonstration was too bulky to be used as a hand-held device, but would be easily utilized at stationary or man-portable checkpoints. AOS reports that newer hardware revisions with a more compact case (as shown in Figure 2) may be suitable for hand-held/weapon mounted scenarios. AIRprint currently has a resolution of 500 ppi, but 1000 ppi is under development by AOS. Although AOS is confident in their products' ability to pass AFIS quality tests, AIRprint does not have Appendix F certification and cannot do AFIS enrollment. According to AOS, this is largely due to the fact that Appendix F constraints do not apply to standoff distance sensors.

Table 3: AIRprint Summary

Attribute	Value
Scanning Technique	Polarized reflected light
Scanning Target	Individual fingers (all)
Touchless	Yes
Primary Uses	Standoff, Access Control, Mobile Identification
AFIS Enrollment	No
Remote AFIS Compatibility	No
Scanning Resolution	500 ppi
Operator Assistance	Yes – Instructor Guidance Required
Maturity Level	Pre-commercialization

3.2 HandShot ID

HandShot ID is a direct high-contrast, high-resolution imaging system to simultaneously obtain 1000 ppi images of all 10 rolled-equivalent fingerprints and both palm friction ridge patterns and minutiae within less than 5 seconds. Carnegie Mellon University (CMU) received a $1.5 million investment from NIJ from 2005 – 2007 to develop the technology.[5,6] A spin-off company, HandShot LLC, was formed in 2009 to further commercialize the technology.[7] Attempts to reach the company (or principal investigator, Dr. Latanya Sweeney) for further details were unsuccessful.

According to a news article,[8] HandShot has evolved through 12 prototypes since 2004, from an enclosure where the hand enters without touching anything to waving your hand in front of a camera. The enclosed version of HandShot uses up to 36 cameras mounted on an arc to digitally photograph the fronts and sides of the hand. In addition to providing more detailed information, the high resolution 3D prints are captured without the need to touch a platen in the device. Versions of the software can work with standard cameras and laptops.

The high resolution cameras that are used to capture the biometric region of the hand are configured to produce 1000 ppi images. Although the present iteration could operate at a resolution lower than 1000 ppi, more minutiae of the friction ridges in the biometric region of the hand can be captured at resolutions around 1000 ppi, resulting in a more detailed image.

The precise number of high resolution cameras required to capture the biometric region of the hand is not fixed. The greater the pixel resolution of a camera, the larger the area that can be captured in focus at 1000 ppi. Thus, fewer cameras may be used if they are of higher resolution as long as they can still collectively capture all surfaces of the biometric region. The capabilities and physical characteristics of the cameras and lenses used will also help determine how far the cameras should be from each other, as well as how far they should be from the respective sections of the biometric region. The types of cameras and lenses will then in turn dictate the necessary dimensions of the enclosure to accommodate the cameras. For instance, HandShot determined that with a 5 megapixel Kodak RTM DX7590 camera with a 1:1 macro lens, 18 cameras (including the one that captured images at low resolution) would be adequate.

3.2.1 Select Patents

- Latanya Arvette Sweeney, et al. (Handshot, LLC); *Method and system for capturing fingerprints, palm prints and hand geometry;* Patent# US7660442 (February 9, 2010)
- Latanya Arvette Sweeney, et al. (Handshot, LLC); *Frontal hand capture of fingerprints, palm prints and hand geometry using contactless photography;* Patent# US8358336 (January 22, 2013)

3.2.2 Technical Specifications and Description

Researchers at Carnegie Mellon University published a detailed whitepaper report on the HandShot system.[9] HandShot ID's multiple cameras capture high-resolution, high-contrast, surface-topography-discriminate images through the use of oblique blue light and special spotlights from various angles operating sequentially. In operation, the system first receives a

hand in a fist orientation through the opening of the enclosure. This is followed by an opening of the fist with the palm facing down. The position, orientation and hand geometry of the hand are determined from the images captured by a low resolution camera. Once the hand is recognized to be in the optimal orientation and to have stopped moving, the high resolution capture sequence is initiated.

The high resolution capture sequence starts with a flash of one of the lights. During the flash, the high resolution cameras each photograph their respective sections of the biometric region to capture image data. Once the first light has been extinguished, another light will flash and each high resolution camera will again capture second image data. This process continues until all of the lights have flashed in sequence.

After all of the second image data has been captured, a gross map of the hand is created based on the first image data. The gross map is a two-dimensional representation of the user's hand. The images of each section of the biometric region are roughly tiled onto the corresponding area of the gross map by matching up certain points in the second image data to the corresponding points in the gross map. The high resolution images are rotated and scaled as appropriate to properly align all of the second image data on the gross map. After the rough tiling, the positions of adjacent images are corrected to reflect the best fit of the friction ridges between the adjacent images. The second image data may then be adjusted to account for the curvature of the biometric region.

At the conclusion of the tiling procedure, an overall image of the biometric region will have been compiled from the second image data. The overall image can then be optimized with regard to contrast. Once adjusted for contrast, the overall image can then be converted to conform to standard formats for the purposes of matching biometric data with other samples. The overall image can be converted to grayscale and then into black and white. The equivalent of rolled fingerprints can be produced by performing a pressure deformation algorithm, which simulates the deformities caused by pressing a finger against a surface.

HandShot claims compliance with standards in the field including:[9]

- Image specifications meet or exceed the FBI's Criminal Justice Information Services (CJIS) Electronic Fingerprint Transmission Specification (EFTS) as well as the National Institute of Standards and Technology (NIST) M1 committee standards for fingerprints and palm prints
- Output complies with ANSI/NIST-ITL 1-2000 data format interchange standards.

3.2.3 Assessment Notes

Table 4: HandShot ID Summary

Characteristic	Status
Scanning Technique	Composite digital camera images
Scanning Target	Full Hand
Touchless	Yes
Primary Uses	Other (Undetermined)
AFIS Enrollment	No
Remote AFIS Compatibility	No
Scanning Resolution	1000 ppi
Operator Assistance	Yes – Software Operation
Maturity Level	R&D

3.3 HandID

HandID is a follow technology to HandShot ID (see Section 3.2 HandShot ID) developed by CMU under the same NIJ grant award.[5,6] The goal of the system is to extend the contactless capture in HandShot ID to one capable of digital photography of a freely posed hand, capturing all five fingerprints, finger flats, palm prints, and hand geometry at high resolution (i.e., 1000 ppi) in 5 seconds. The system would then produce ink-like prints of those biometrics, matchable by a legacy AFIS database.

As of the writing of the NIJ final report in 2009, HandID was in the early R&D stages. CMU demonstrated that, given a frontal view of a freely posed hand, the system automatically locates and tracks a hand, computes hand geometry measurements, captures high-resolution prints of palms and individual presented fingers, and produces ink-like prints from photographic images. Research has involved imaging in structured (enclosures with controlled light), semi-structured (open with semi-controlled lighting/background), and unstructured environments (naturally occurring with uncontrolled lighting/background). Photographic capture and the production of qualitatively-similar ink-like prints under these conditions appears to have been successful, but foundational experiments and testing related to reliability, reproducibility, and match performance compared to a livescan and/or rolled-equivalent fingerprint control dataset have not been reported.

A spin-off company, HandShot LLC, was formed in 2009 to further commercialize the technology.[10] Attempts to reach the company (or principal investigator, Dr. Latanya Sweeney) for further details were unsuccessful.

3.3.1 Select Patents

- See Section 3.2.1 Select Patents

3.3.2 Technical Specifications and Description

As of 2009, HandID consisted of a commercially available 6 MP camera with a 60mm macro lens with a capture area sufficient to photograph a palm or single finger. Images are captured and then converted stepwise through custom developed image processing algorithms to produce a grayscale ink-like print from a digital photograph. The resulting print is 1000 ppi. The system does not appear to simultaneously capture the palm, five fingerprints, and hand geometry; those biometrics must be captured sequentially. Note that this information may be dated, depending on the level of R&D activity performed by HandShot LLC in the interim.

3.3.3 Assessment Notes

HandID is in an early R&D stage, with features and components that have not been integrated with respect to hardware or software. The goal of the system is encouraging and would make an asset to criminal justice, homeland security, and defense applications. However, as of the 2009 NIJ report, only basic functionality has been demonstrated and many steps remain before a functional prototype is completed and biometric collection (capture and probe submission/interoperability) is demonstrated.

Table 5: HandID Summary

Characteristic	Status
Scanning Technique	Digital camera images
Scanning Target	Full hand – palm, five fingers, hand geometry
Touchless	Yes
Primary Uses	Other (Undetermined)
AFIS Enrollment	No
Remote AFIS Compatibility	No
Scanning Resolution	1000 ppi
Operator Assistance	Yes – Instructor Guidance Required
Maturity Level	R&D

3.4 University of Massachusetts Lowell Single-finger Rolled-Equivalent Scanner

Funded by NIJ, the University of Massachusetts Lowell (UML, http://www.uml.edu/Research/AETC/) has developed a prototype rolled-equivalent scanner with liveness detection.[11,12] This prototype scanner performs a 180 degree nail-to-nail scan by using an optical sensor mounted on a rotational arm. The scan is designed to perform in two phases: fingerprint acquisition and liveness detection. The first phase rotates a scanner arm around the finger, scanning the fingerprint. The second phase rotates the scanner arm back to the 'home' position while performing a liveness detection procedure. More recent iterations of the prototype do not support liveness detection (see Section 3.4.2 Technical Specifications and Description). The entire process takes approximately 2 seconds.

The prototype demonstrated during the NIJ 2011 Biometrics Technology Working Group Meeting was a compact device that was constructed similarly to the computer-aided design

(CAD) model provided below (see Figure 3).[13] Due to staff changes and funding restrictions, the prototype has gone through variations in size and capability (see Section 3.4.2 Technical Specifications and Description).[14]

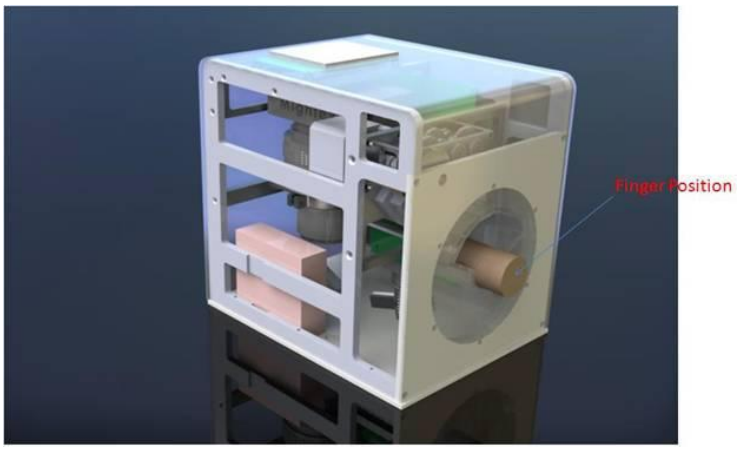

Figure 3: CAD Rendering of UML Rolled-Equivalent Fingerprint Scanner Courtesy of UML

3.4.1 Select Patents

- *No relevant patents identified*

3.4.2 Technical Specifications and Description

For fingerprint acquisition, the UML prototype uses a line scanning camera that is fed data from a rotational scanning arm mounted approximately 3" from the subject's finger. The scanning is performed using high-intensity blue LEDs to illuminate the finger. The previous versions of the prototype used a 400 mW near infrared LED to illuminate the finger and extract vein patterns to perform liveness detection in approximately 0.75 seconds. UML reports that current iterations of the prototype sacrificed this capability in order to be more user-friendly. The vein pattern technology requires users to insert their fingers further into the machine. According to UML, subjects have been uncomfortable placing their finger inside a machine.[13] The line-scanned image is assembled by an on-board computer and transmitted wirelessly to a host machine running a special software package that displays the scanned image. The resulting image is a nail-to-nail rolled-equivalent fingerprint that is 2048x700 pixels at 1000 ppi (up-sampled from 700 ppi). UML states that the minutiae on this image adhere to NIST standards. Note that FBI Appendix F and Electronic Biometric Transmission Specification (EBTS) do not permit 1000 ppi images produced from extrapolating (i.e., up-sampling) from lower resolution images. Therefore, the UML prototype images would only be usable at 500 ppi resolution in criminal justice, homeland security, or military applications.

UML reports the unit may be operated on battery power, which is reported to last 72 hours or approximately 1000 scans. However, a prototype unit delivered to the SSBT CoE did not possess that feature.[15]

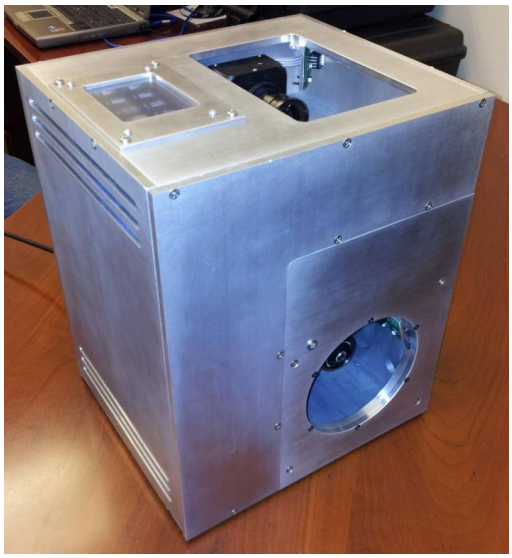

Figure 4: UML Fingerprint Scanner Prototype
As delivered to the NIJ SSBT CoE in March 2012

The unit acquires images using a grayscale scan. At NIST guidance, UML added the feature of binary (black-and-white) output for better Level 1 feature matching. This binary mode results in loss of some Level 2-3 detail. UML reports a recognition rate of 100% in internal laboratory testing when performing 1:1 matching using the same device for collection and recognition. The gallery used in this testing contained 150 fingerprints from 15 subjects, resulting in over 11,000 match comparisons.

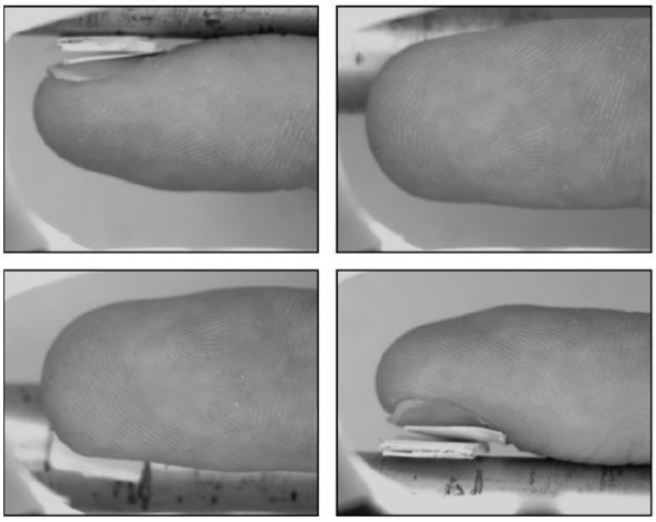

Figure 5: Sample Finger Images of a Rotational Scan
Courtesy of UML

The device's capabilities were expanded to include a 4-slap fingerprint/palmprint collection option on the top surface of the device. This 4-slap capability is based on a stationary camera

and does not provide rolled-equivalent capture data. This mode of collection is contactless to the fingertips, but results in the user placing their hands directly on the top surface of the device.[13]

3.4.3 Assessment Notes

The UML contactless fingerprint prototype performs a fast scan (~2 seconds) of the subject finger and provides a high resolution unrolled image of the finger. It requires a small area of contact for the single-finger scanning module that would require cleaning between uses to prevent the spread of contaminants between subjects. The same is true for the 4-slap/palm scanning area; however, much more contact with the system is likely, thus increasing the opportunity for contamination between subjects. These contact areas do not interfere with the scanning sensors, so such cleanings would be for hygiene rather than quality of the scanned image.

The included software is in line with what would be expected of a prototype. Additional hardware and software refinement would be required before it would be practical in a field environment.

A baseline performance assessment was completed by the NIJ SSBT CoE, and will be publically available from the National Criminal Justice Reference Service (http://www.ncjrs.gov) in early 2014.[15]

Table 6: UML Prototype Summary

Characteristic	Status
Scanning Technique	Line scanning optical camera
Scanning Target	Single Finger; 4-slap/Palm
Touchless	No
Primary Uses	Enrollment
AFIS Enrollment	No
Remote AFIS Compatibility	No
Scanning Resolution	Single Finger: 700 ppi (up-sampled to 1000dpi) 4-slap/Palm: 72 ppi
Operator Assistance	Yes – Instructor Guidance Required
Maturity Level	Prototype

3.5 General Electric 10-finger Scanner

In 2012, DHS was funding General Electric (GE, http://ge.geglobalresearch.com/) to design and build a tenprint contactless fingerprint scanner.[16] The scanner is currently in the R&D phase and future revisions may have different aspects than those reported here. The device is a portable unit with an open-sided slot for fingerprint scanning with a viewport which displays the user's hand (when inserted) and provides an overlay which guides the user in placing their fingers appropriately for scanning. The device is expected to be capable of performing a full tenprint rolled-equivalent scan by scanning a user's fingers in groups: four-slap first hand, four-slap second hand, and two thumbs together.[17]

While the GE device is addressing challenges of 3D contactless fingerprint capture through advanced technology, GE engineers recognize that its Human Machine Interface is a primary concern to widespread adoption of the technology. The GE device aims to be intuitive for users and provide simple guidance throughout the capture process. By putting most of the burden of capture on the system rather than the user, GE increases the likelihood that this technology can be used in many locations with little to no operator intervention.

3.5.1 Select Patents

- Mohammad Mehdi DaneshPanah, et al. (General Electric Company); *System and method for depth from defocus imaging;* Patent# US8340456 (December 25, 2012)
- Gil Abramovich, et al. (General Electric Company); *Method and system for contactless fingerprint detection and verification;* Patent# US8406487 (March 26, 2013)
- Gil Abramovich, et al. (General Electric Company); *Apparatus and method for contactless high resolution handprint capture;* Patent Application# EP2506189 (March 28, 2012)
- Gil Abramovich, et al. (General Electric Company); *Method and apparatus for forming multiple images;* Patent Application# US20120250159 (October 4, 2012)

3.5.2 Technical Specifications and Description

Due to the commercially sensitive nature of this effort, thorough details on the GE 10-finger scanner were not made available for this report. According to GE, the device itself is expected to be portable enough for a single person to carry and deploy. The GE 10-finger scanner performs multi-finger capture and is designed for use with the general adult population. The scanner performs a tenprint capture at 1000 ppi by capturing two 4-slap acquisitions, followed by a scan of both of the user's thumbs. During each scan, each finger is imaged at four separate focal distances. The device analyzes the areas of the images that are in focus and reconstructs the 3D shape of the finger based on a "global finger shape assumption." The device then unrolls each 3D fingerprint into rolled-equivalent prints. These unrolled rolled-equivalent prints are expected to be used for matching or possibly enrollment activities.[18]

3.5.3 Assessment Notes

This project is being funded by DHS S&T. Additional information and detailed/current specifications of this system were not available as of this writing.

Table 7: General Electric Tenprint Prototype Summary

Characteristic	Status
Scanning Technique	Multi-focus digital images combined into a 3D global finger shape
Scanning Target	Individual Fingers (all)
Touchless	Yes
Primary Uses	Enrollment, Access Control (Gateway)
AFIS Enrollment	Undetermined
Remote AFIS Compatibility	Undetermined
Scanning Resolution	1000 ppi
Operator Assistance	Yes – Software Operation
Maturity Level	Pre-commercialization

3.6 AFIS and Biometrics Consulting, Inc. Fingerprint-on-the-Move

AFIS and Biometrics Consulting, Inc. (ABC, http://www.afisandbiometrics.com/) was funded by DHS S&T to develop a framework for identification on the move using standoff biometrics.[19] ABC's Fingerprint-on-the-Move is a component of their Biometrics Identification on the Move System (BIMS) for capturing multiple biometrics from a user in a contactless fashion as the user moves through the system. BIMS utilizes COTS hardware to perform all data gathering activities and relies on backend software to perform fusion and identification tasks. The Fingerprint-on-the-Move (FoM) component of BIMS works conceptually like a barcode scanner at a supermarket. The user places their hand in the scanning area, and the system photographs the hand and identifies the subject.

Figure 6: ABC, Inc. Fingerprint-on-the-Move Scanner
Courtesy of ABC, Inc.

Figure 7: Scanning a Hand Through ABC Inc.'s FoM
Courtesy of ABC, Inc.

3.6.1 Select Patents

- *No relevant patents identified*

3.6.2 Technical Specifications and Description

ABC's FoM system uses COTS hardware to perform contactless fingerprint collection. The device is approximately 4ft tall x 2ft wide x 1.5ft deep. The device uses a 21 Megapixel Canon 5D Mark II camera with EX-580 flash for fingerprint acquisition.[20]

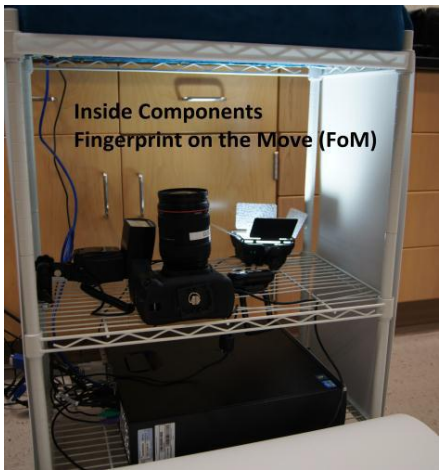

Figure 8: Internal Components of the ABC, Inc FoM
Courtesy of ABC, Inc.

The system captures the full hand as it is presented to the scanner. The full-color image is converted to gray scale and then segmented into fingerprints and palm-areas. According to ABC, this results in good friction ridge definition and a large number of reliable minutiae and ridge structures. The segmented images are processed through standard AFIS fingerprint processing, enhancement, and feature extraction. The FoM then packages the segmented images into a "search packet" (ABC term) that is formatted in accordance with ANSI/NIST and EBTS standards (versions were not specified). The number of minutiae captured is dependent on the condition of the skin. Scans of average skin types produce 30-40 reliable minutiae per fingerprint and over 200 on the interdigital palm area. The search packet is processed against an AFIS database. Using a database populated with full records that contain average to good quality tenprint rolled and tenprint flat images (total of 20 fingerprint images per individual), ABC reports that positive identification is close to 100%.[21]

3.6.3 Assessment Notes

ABC representatives indicated that while this technology would not identify users 100% of the time, in practice it would be useful in situations where a checkpoint with a FoM device could be used for "pre-screening."[19] According to ABC, the FoM could identify general population subjects 80% of the time and the remaining 20% of un-identified subjects could be routed to secondary screening. Using this type of technology could reduce the resources and time required to manually screen every individual that passes through the checkpoint.

In addition to FoM, ABC Inc. has developed a Mobile BIMS (M-BIMS) capability for use with smart phones. M-BIMS is a software-based solution that takes advantage of the capabilities of current generation consumer-grade smartphone hardware to perform contactless fingerprint and facial data collection using the smartphone's onboard camera. The data collected is then transmitted to a backend server for matching activities.

Table 8: ABC, Inc. FoM Summary

Characteristic	Status
Scanning Technique	High resolution digital camera
Scanning Target	Full Hand
Touchless	Yes
Primary Uses	Access Control (Gateway)
AFIS Enrollment	No
Remote AFIS Compatibility	Yes
Scanning Resolution	500 ppi
Operator Assistance	No
Maturity Level	Pre-Commercialization

3.7 FlashScan3D Single-finger Scanner

FlashScan3D (FS3D) is developing 3D scanning devices for biometric and forensic applications (http://www.flashscan3d.com/). The company is partnered with University of Kentucky to leverage their research in this area.[22] The FS3D single-finger scanner is a compact structured-light illumination (SLI) single point-of-view (POV) scanner. This device is currently being readied for commercialization by FS3D. Both DHS S&T and BIMA have contributed funds to the device's development.[16] FS3D performs the scanning of a fingerprint using SLI, which projects a structured pattern of light onto the finger's surface to generate a 3D representation of the surface of the finger. Such a scan produces high resolution images and retains Level 2 and 3 extended feature set[23] details that can be lost during wet-ink or live scan methods.[24] SLI is the basis of all four FlashScan3D devices covered in this report (see Sections 3.8 – 3.10).

Figure 9: FlashScan3D Single-Finger Scanner
Courtesy of FlashScan3D

3.7.1 Select Patents

- Laurence G. Hassebrook, et al. (University of Kentucky Research Foundation); *System and technique for retrieving depth information about a surface by projecting a composite image of modulated light patterns;* Patent# US7440590 (October 21, 2008)
- Laurence G. Hassebrook, et al. (University of Kentucky Research Foundation); *Lock and hold structured light illumination;* Patent# US8224068 (July 17, 2012)
- Laurence G. Hassebrook, et al. (University of Kentucky Research Foundation); *System and method for 3D imaging using structured light illumination;* Patent# US8509501 (August 13, 2013)
- Laurence G. Hassebrook, et al. (University of Kentucky Research Foundation); *Rotate and Hold and Scan (RAHAS) Structured Light Illumination Pattern Encoding and Decoding;* Patent Application# US20120113229 (June 24, 2011)

3.7.2 Technical Specifications and Description

FS3D developed multiple versions of the 3D contactless fingerprint scanners using the SLI single POV technique. In the SLI single POV approach, the scanner consists of a commercial off-the-shelf projector used to project SLI patterns and a high resolution camera to capture the shape of the deformed SLI patterns reflected from the target being scanned. The light pattern is translated across the finger, resulting in fine-level distortions of the light pattern, which are captured optically. In the single-finger scanner, the light pattern is shifted by mechanically moving a light projector. The projector and camera have optical triangulation and are hardware

synced to work at a high frame rate. The highest possible frame rate is usually the highest common factor of the projector refresh rate and the camera frame rate. The scanner connects to a standard PC via USB and HDMI. The FS3D software runs on the PC and transmits the SLI pattern via the HDMI connection and data collection is performed over USB.

In April 2012, an FS3D engineer claimed that the single-finger scanner can meet FBI Appendix F technical requirements.[25]

3.7.3 Assessment Notes

According to FS3D, this device is the flagship of the line. It performs a full 3D contactless scan of a single subject finger. The scan is performed in approximately 2 seconds after the subject's finger is positioned and the scan is initiated. The scan results in a full 3D representation of the finger with the topography intact. The 3D representation is not a full nail-to-nail scan, but it contains more information than a flat (slap) fingerprint. This "more than a flat, less than a rolled" representation is a consequence of gathering image data from only one angle (the bottom of the finger). Figure 10 shows an example of the 3D fingerprint at different angles. The 3D fingerprint is then processed in software algorithms to flatten and prepare the print for backwards compatibility with existing databases.

FS3D reports that updates are in the pipeline to enhance the capabilities of this unit and that commercialization efforts are proceeding.

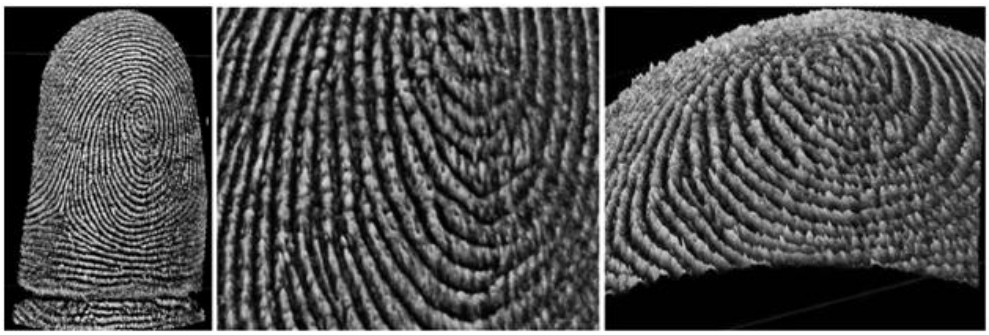

Figure 10: 3D Fingerprint Ridge and Pore Detail
Courtesy of FlashScan3D

Table 9: FlashScan3D Single Finger Scanner Summary

Characteristic	Status
Scanning Technique	Moving structured light illumination
Scanning Target	Single Finger
Touchless	No
Primary Uses	Enrollment, Other (Undetermined)
AFIS Enrollment	No
Remote AFIS Compatibility	No
Scanning Resolution	500 ppi
Operator Assistance	Yes – Software Operation
Maturity Level	Commercialization

3.8 FlashScan3D Tenprint Scanner

The FS3D contactless tenprint scanner (http://www.flashscan3d.com/) is another in the line of contactless fingerprinting devices being developed based on the technologies used in their single-finger scanner (see Section 3.7 FlashScan3D Single-finger Scanner). This device captures a full tenprint sequence of fingerprints of a subject. The device captures a tenprint set by performing a scan of two 4-finger slaps followed by a scan of the two thumbs together. The software then processes these 3D scans, performs flattening routines, and generates a wet-ink equivalent virtual "fingerprint card". The device currently requires an attendant to activate the scans.

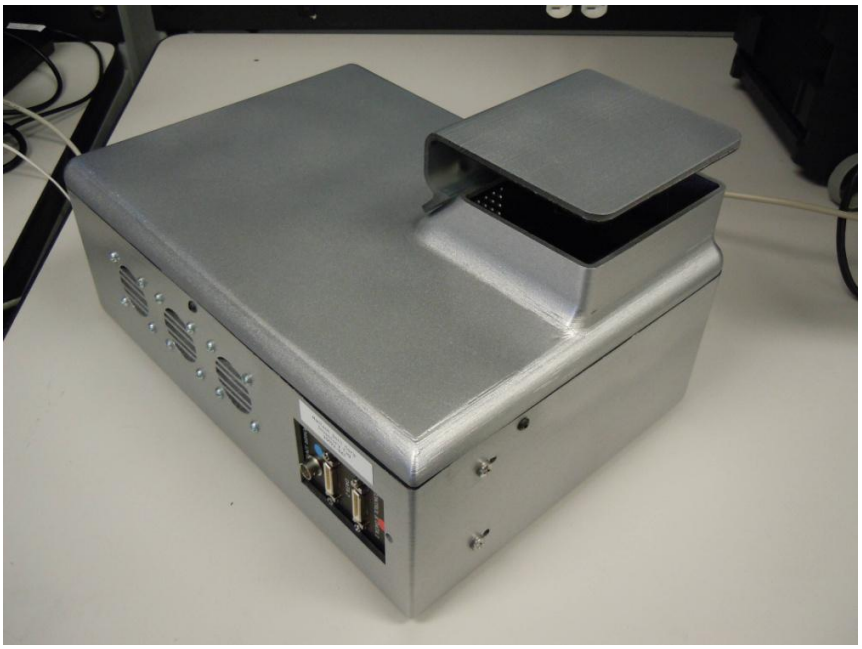

Figure 11: FlashScan3D Tenprint Scanner
Image taken during data collection by CoE

3.8.1 Select Patents

- See Section 3.7.1 Select Patents

3.8.2 Technical Specifications and Description

The FS3D tenprint scanner performs the same type of SLI scanning described in Section 3.7 FlashScan3D Single-finger Scanner) for the single-finger scanner. However, this scanner expands on the technique by adding the capability to differentiate multiple fingers in a single scan. According to FS3D, the current version of the prototype (see Figure 11) has not undergone miniaturization efforts. The size of the enclosure affords plenty of room for the needed internal components, cooling, and a contactless scanning area with a guide to assist the user in correctly positioning his fingers. The scanner results in the same "more than a flat, less than a rolled" type of scan as the FS3D single-finger scanner.

In April 2012, an FS3D engineer claimed that the tenprint scanner can meet FBI Appendix F technical requirements.[25]

3.8.3 Assessment Notes

FS3D's touchless tenprint scanner exhibits several issues typical to prototypes: long scan times, specific setup instructions, and unintuitive user interface. The system is touchless; however, incidental contact is likely to occur given the narrowness of the distance between the guide and the fingers. Maintenance of the prototype is currently difficult, as it requires removing the finger-guide shield (or complete removal of the top of the device) and cleaning of mirrors and lenses of dust contamination. These maintenance issues are typical of early prototypes and are not (usually) indicative of the maintenance needs of the final version of the commercialized product. FS3D states that this device is in a prototype state and is not ready for formal test and evaluation.

Table 10: FlashScan3D Tenprint Scanner Summary

Characteristic	Status
Scanning Technique	Moving structured light illumination
Scanning Target	4-slap
Touchless	Yes
Primary Uses	Enrollment, Other (Undetermined)
AFIS Enrollment	No
Remote AFIS Compatibility	No
Scanning Resolution	500 ppi
Operator Assistance	Yes - Software Operation
Maturity Level	Prototype

3.9 FlashScan3D Single-finger Rolled-Equivalent Scanner

The FS3D contactless rolled-equivalent fingerprint scanner (http://www.flashscan3d.com/) is a compact, easy-to-use SLI scanner. The device builds on the technologies that FS3D honed on their single-finger scanner (see Section 3.7 FlashScan3D Single-finger Scanner), but adds the capability to scan the full surface of the fingerprint area (i.e., nail-to-nail). Funding of the development of this scanner was provided by DHS S&T and BIMA. The user places their finger in a plastic guide which steadies and directs the finger during the scan. An attendant initiates the scan and instructs the user to slide the guide across the scanning area while multiple cameras capture images of the SLI fingerprint data from different angles. This data is translated into 3D data and processed to produce a full 3D point-cloud of the nail-to-nail fingerprint. This 3D fingerprint is then unrolled to produce a nail-to-nail rolled-equivalent fingerprint.

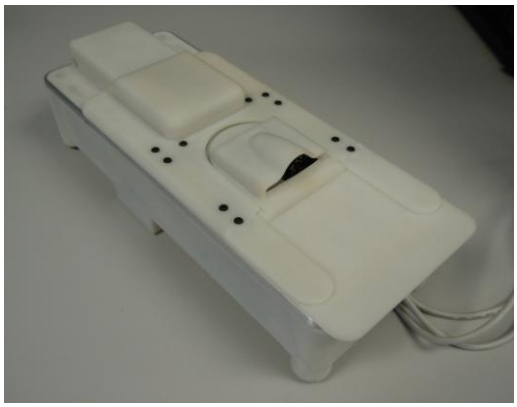

Figure 12: FlashScan3D Rolled-Equivalent Scanner
Image taken during data collection by CoE

3.9.1 Select Patents

- See Section 3.7.1 Select Patents

3.9.2 Technical Specifications and Description

During the scan, the FS3D device guides a user's finger through a projected SLI pattern that is captured in narrow image slices using multiple cameras to gather information from different areas of the finger as it passes over the imaging sensors. The device uses multiple USB cameras housed within the unit along with an advanced optics system to perform the image capture. The data gathered from the imaging sensors is packaged into a 3D format and stitched together to build a full 3D nail-to-nail representation of the user's finger. This representation can then be flattened to create a rolled-equivalent fingerprint that is similar to a wet-ink rolled fingerprint. The primary difference between this device and the others FS3D has developed is that instead of the projected light moving across the finger, the light pattern is fixed and the finger is moved by the subject. According to FS3D, this improves the data collection and simplifies the engineering.[26] FS3D states that this device is in a prototype state and is not ready for formal T&E at present.

3.9.3 Assessment Notes

FS3D's rolled-equivalent scanner is in an early prototype stage. It exhibits several issues typical to prototypes: long scan times, specific setup instructions, and unintuitive user interface. The system is not touchless, as the user is required to insert their finger into a guide. Maintenance of the system requires the removal of this guide for cleaning.

Table 11: FlashScan3D Rolled-Equivalent Scanner Summary

Characteristic	Status
Scanning Technique	Fixed structured light illumination on moving finger
Scanning Target	Single-finger rolled equivalent
Touchless	No
Primary Uses	Enrollment, Other (Undetermined)
AFIS Enrollment	No
Remote AFIS Compatibility	No
Scanning Resolution	1000 ppi
Operator Assistance	Yes – Instructor Guidance Required
Maturity Level	R&D

3.10 FlashScan3D Full-hand Contactless 3D Scanner

The National Institute for Hometown Security (NIHS) funded the development of a variant of FS3D's fingerprint scanner that is capable of scanning the full hand of a subject (http://www.flashscan3d.com). This scanner is in a prototype phase and uses a SLI sub-windowing technique to scan and reconstruct a 3D image of the surface of a user's full hand. This scanner would have the advantages of providing full fingerprint definition as well as palm information that is expected to become more important to criminal justice in the future. While the sensor itself is contactless, the overall system is not touchless. Figure 13 shows an early prototype version of the full-hand scanner in use.[27] A later prototype version was also presented at a technical conference, wherein FS3D reported that this device is in a later stage commercialization effort with delivery to DHS planned for 2013.[25]

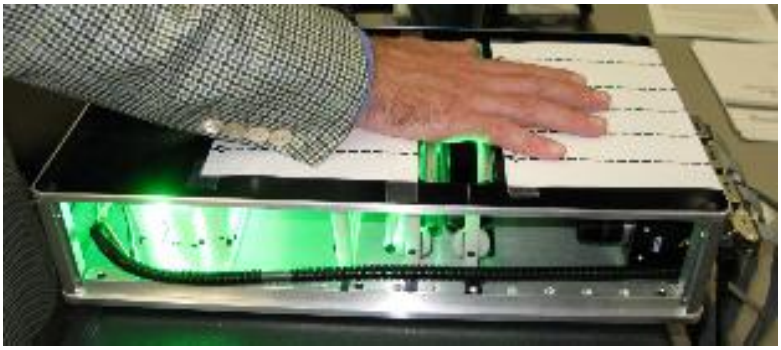

Figure 13: SLI Sub-window based Full Hand 3D Scanner (early prototype) Courtesy of FlashScan3D

Figure 14 below shows a full hand-print captured by the Full-hand Contactless 3D Scanner, as well as the fingerprints extracted from the scan.

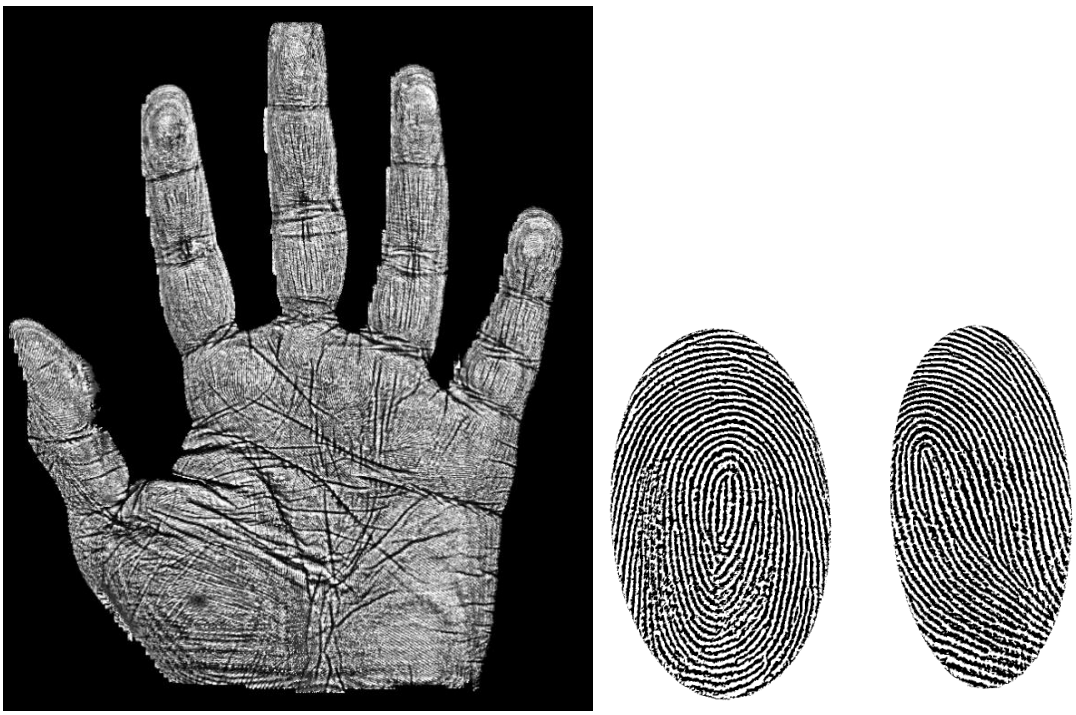

Figure 14: Sample of Palm and Fingerprint Images
Courtesy of FlashScan3D

3.10.1 Select Patents

- See Section 3.7.1 Select Patents

3.10.2 Technical Specifications and Description

The latest version device is a black box scanner where the subject slides their hand over a large window.[25] The FS3D full-hand scanner captures the subject's five fingers and palm print at 500 ppi resolution in a single scan. During this scan, multiple samples are taken of the hand as it passes over the scanning region. These images are then processed to reconstruct a full 3D scan of the hand topography. The projection system is an LED line source with projection optics, and the imaging system consists of four high speed Camera Link cameras that capture the image slices at 450 frames per second.[27]

FS3D reports that for matching test performance, Neurotech Verifinger and NIST Bozorth3 software is used on sixteen fingerprints bulked out with NIST fingerprint data to create a dataset. Post processing has improved from 2 minutes to 30 seconds. The company is working with a 3rd party for device ergonomics and then plan to field test. This device is in a later stage commercialization effort; delivery to DHS was reported to be planned for 2013.[25]

3.10.3 Assessment Notes

The FS3D contactless full-hand scanner is a relatively large SLI sub-windowing scanner. The scanner is not touchless, as the user is required to slide their hand across a surface and over the scanning window. Maintenance of the system, as it is designed for the prototype, requires cleaning the surface. The configuration of this scanner would expose users to contaminants left by previous users unless maintenance is performed between users. These contaminants may not affect the quality of acquisition, but it could be spread among users of the system, similar to a traditional full hand contact scanner. This system appears to be one of the more robust and closest to commercial viable of FS3D's various offerings; this is likely due to interest from DHS in utilize contactless hand scanners for high-throughput gateway access control at immigration and border control.

Table 12: FlashScan3D Full-Hand 3D Scanner Summary

Characteristic	Status
Scanning Technique	Fixed structured light illumination on moving hand
Scanning Target	Full hand
Touchless	No
Primary Uses	Access Control (Gateway)
AFIS Enrollment	No
Remote AFIS Compatibility	No
Scanning Resolution	500 ppi
Operator Assistance	No
Maturity Level	Pre-commercialization

3.11 TBS Touchless Ten Printer (TTP)

In 2005, NIJ awarded funding to Touchless Biometric Systems (TBS) North America (http://www.tbs-biometrics.com) for the development of a 10-finger contactless fingerprint scanner.[28,29] The Touchless Ten Printer (TTP) has undergone three iterations under NIJ funding and is currently still in the R&D phase; future revisions may have different aspects than those reported here. The device is a table-top sized unit with an open-sided slot for fingerprint scanning with an LCD screen that directs the user in placing their fingers appropriately for scanning. The device is expected to be capable of performing a full tenprint scan by scanning a user's fingers in groups: four-slap first hand, four-slap second hand, and two thumbs together. Images produced by TTP include 3D models of the fingers with fingerprint details mapped over the surface as well as corresponding gray-scale rolled-equivalent fingerprint images.[29]

Figure 15: TBS Touchless Ten Printer
Courtesy of TBS

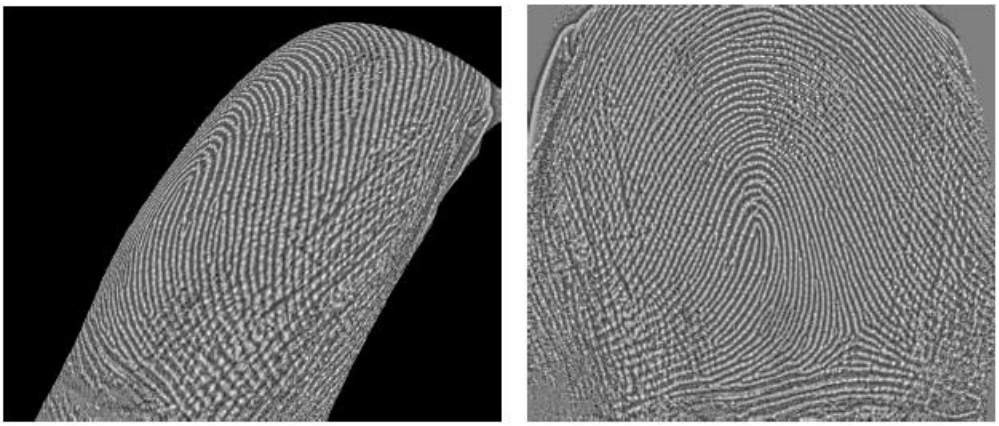

Figure 16: 3D Model and Unrolled Image of a Finger from TTP
Courtesy of TBS

3.11.1 Select Patents

- Roger Van Diepen, et al. (TBS North America Inc.); *Apparatus for recording biometric data*; Patent Application# DE102008046490A1 (September 9, 2008)
- Chris Maurer, et al.; *Device for recording biometric data;* Patent Application# US20110135164A1 (June 12, 2009)

3.11.2 Technical Specifications and Description

The TTP performs a tenprint capture at 1000 ppi by capturing two 4-slap acquisitions and a scan of both of the user's thumbs.[29] The device unrolls the fingerprint scans into rolled-equivalent prints, which are then used for matching or possibly enrollment activities. Subjects place the

four fingers of a hand within a side opening of the TTP, segmented by guide posts to improve proper positioning. A display screen on the top of the scanner provides instructions and graphics to aid the user. Once the fingers are inside the device, a camera view of the fingers can be seen in the user interface along with superimposed boxes. The user shifts the position of their fingers to align with the boxes and to place them in the correct plane of capture.

The capture region within TTP consists of three cameras positioned in an arc below each of four designated finger positions. Large arrays of LEDs are positioned above and below the hand to provide full illumination during image capture. The cameras and LEDs are used to capture high resolution photographic images of each individual finger (and their associated fingerprint details). Structured light is also projected onto the fingers from two symmetrically positioned projectors positioned in between the cameras. The intersection of the structure light patterns is extracted from the resulting high resolution images to produce a point cloud used to generate a 3D model of each individual finger. The capture images are used to produce a 3D model of the finger and a rolled-equivalent unwrapped fingerprint image for use in biometric applications.

3.11.3 Assessment Notes

From the available reference, the TTP device appears to be a fairly robust 3D contactless fingerprint scanner capable of capturing all ten prints and producing 3D and nail-to-nail rolled-equivalent images. Although it is a prototype still in the R&D stage, the form factor, user interface, and capture engineering appears well developed and suitable for laboratory and/or field evaluations by a third party.

The TTP Phase I and II were evaluated by NIST in 2007 as part of the Fast Capture Evaluation project.[30] Phase II TTP evaluations identified two primary issues with the device – finger images were mirrored along the vertical from biometric standards and the grayscale distribution of pixels was unimodal, as opposed to the expected bimodal distribution from ridges and valleys. The grayscale issue was improved over Phase I TTP performance. Results from the TTP Phase I and II evaluations were shared with TBS and NIJ. It is possible that TBS addressed those issues in Phase III, but the final report to NIJ does not discuss the topics. Note that the TBS commercial scanner was found by the CoE to still produce mirrored fingerprint images (see Section 4.1.5 Assessment Notes).

Table 13: TBS TTP Summary

Characteristic	Status
Scanning Technique	Composite digital camera images with structured light for 3D modeling
Scanning Target	1-4 Fingers captured nail-to-nail
Touchless	No
Primary Uses	Enrollment, Other (Undetermined)
AFIS Enrollment	No
Remote AFIS Compatibility	No
Scanning Resolution	1000 ppi
Operator Assistance	None

Characteristic	Status
Maturity Level	Prototype

3.12 MorphoTrak Finger-on-the-Fly

MorphoTrak (http://www.morphotrak.com) internally funded and developed a fast-capture contactless fingerprint capture device designed to collect a user's single-hand four fingerprints as the user passes the sensor without the need for the user to stop for processing. The scanner has been integrated into Morpho's Gatekeeper-on-the-Move (GOTM) biometric identification environment. In such a "biometric corridor," a user walks past one of these scanners, swipes their hand, and continues on to the next biometric detector without stopping. The Finger-on-the-Fly component scans and processes the user's fingerprints and generates a "hit-list" of candidates (or often, the exact match) that is then passed from the Finger-on-the-Fly system to the next biometric system in the corridor. Morpho hosted a GOTM Joint Capability Technology Demonstration (JCTD) effort that was sponsored by U.S. Central Command (USCENTCOM).[31] This device is intended for scanning and verification only, and does not have the capability to capturing enrollment images.

3.12.1 Select Patents

- De Virel Francois Defresne (SAGEM Securite), *Biodetector functioning without contact*, EP1987472 (June 24, 2009)
- Francoise Dufresne De Virel (Morpho), *Contactless biodetector*, Patent# US8340371 (December 25, 2012)

3.12.2 Technical Specifications and Description

MorphoTrak claims that the Finger-on-the-Fly device uses optical technology that is able to capture more fingerprint data than from a traditional slap print, but less than a full rolled print. The module is roughly the size of a computer tower and is capable of contactless four-finger acquisition. The device is designed for continuous movement acquisition, capturing multiple fingerprint images at a high frame-rate at a resolution of 500 ppi. The system requires the subject to perform a full tenprint enrollment on a live scan device prior to using the Finger-on-the-Fly system for identification. MorphoTrak claims a 98% accuracy of identification in lab/testing environments and is examining the in-theater capabilities of the unit.

3.12.3 Assessment Notes

Center staff attended demonstrations of the MorphoTrak contactless scanner.[32] During these demonstrations, MorphoTrak representatives indicated that they plan to increase the scanner's capabilities to capture 1000 ppi fingerprints and may pursue enrollment capabilities with this device. In the demonstrations attended, the scanner worked reliably, with 4-fingerprint capture occurring in < 1 second and identification of the user within a few (2-5) seconds. This scanner is designed for high traffic areas and is completely touchless. The system uses fingerprints collected from a live scan device as the source to match against. This demonstrates the scanner's potential interoperability with existing AFIS systems. The device itself is portable, but is not currently small enough to be easily used in mobile applications (e.g., police cruisers). Based on

demonstrations observed, the device is promising for scenarios where having a trained operator assisting the user is undesirable, or for high throughput areas. The use of this device requires no specific subject understanding.

According to Morpho's technology roadmap, they expect to integrate a touchless tenprint rolled-equivalent capture device for enrollment purposes into their GOTM system in the 2012-2013 timeframe. This additional feature was requested by DoD to provide a reduction in time required for each enrollment. This new enrollment device is planned to build on MorphoTrak's existing contactless fingerprint technology; however, no additional information was made available.[33]

Table 14: MorphoTrak Finger-on-the-Fly Summary

Characteristic	Status
Scanning Technique	Digital camera image
Scanning Target	1-4 Fingers
Touchless	Yes
Primary Uses	Access Control (Gateway)
AFIS Enrollment	No
Remote AFIS Compatibility	Yes
Scanning Resolution	500 ppi
Operator Assistance	No
Maturity Level	Pre-Commercialization

3.13 Lumidigm

Lumidigm has developed a prototype sensor for contactless fingerprint acquisition based on a poly-imaging technique. According to the company's website (http://www.lumidigm.com), the Lumidigm sensor captures images of a target finger from two synchronized perspectives using multiple color LEDs.[34] The sensor performs continuous capture to gather data for subsequent processing. Lumidigm reports that this combination of photometric stereo, stereo imaging technologies and continuous capture allows the sensor to gather enough data about the finger to build a "quasi-3D" representation of the finger for biometric extraction.

3.13.1 Select Patents

- Robert K. Rowe, et al. (Lumidigm, Inc.); *Contactless multispectral biometric capture;* Patent# US7995808 (August 9, 2011)
- Stephen P. Corcoran, et al. (Lumidigm, Inc.); *Biometric detection using spatial, temporal, and/or spectral techniques;* Patent# US8355545 (January 15, 2013)

3.13.2 Technical Specifications and Description

According to the Lumidigm website, the device uses two CMOS imaging sensors that are aligned to view fingerprints at approximately 10 cm distance.[34] The sensor provides lighting

via three color LEDs (red, green, and blue) from three different angles. Each sensor records images of the finger from its set angle while the finger is illuminated by different colored light from known angles. When a finger is presented to the sensor, the device captures synchronized video streams at approximately 10 frames per second. A ring-buffer setup is used that allows the current scan image plus the preceding 29 images to be archived for subsequent processing, including temporal analysis of the data. The current user interface displays the images being actively scanned to assist the user in proper placement of the finger. Once the finger is appropriately placed, the system captures a series of images from each CMOS sensor, from which a focus profile is computed. The system compares the focus of each image and uses the pair of images that are the most in focus. Lumidigm uses algorithms based on stereo imaging and shape from color to build a "quasi-3D" representation of the finger from which to extract biometric information.

3.13.3 Assessment Notes

From the available information, it is unclear whether the Lumidigm sensor technology is compatible with existing wet-ink repositories. The developer has performed small-scale testing that appears to show a good separation between genuine and imposter scores. The software interface appears to be in the early prototype phase. A more robust software package and hardware implementation would be required before this system would serve a practical purpose.

Table 15: Lumidigm Contactless Fingerprint Sensor

Characteristic	Status
Scanning Technique	Stereoscopic digital images using multiple color illumination to capture 3D representation
Scanning Target	Single Finger
Touchless	Yes
Primary Uses	Other (Undetermined)
AFIS Enrollment	No
Remote AFIS Compatibility	No
Scanning Resolution	Undetermined
Operator Assistance	Yes – Instructor Guidance Required
Maturity Level	Prototype

3.14 Additional R&D Efforts

DHS and DoD funded Authenti-Corp to perform development in this technology area with a contract awarded in April of 2008.[16] However, efforts to contact Authenti-Corp were unsuccessful. No patents were identified for Authenti-Corp.

3.15 Additional Patents

Additional patent applications and issuances were identified during the course of investigating contactless fingerprint technologies that are worth noting.

- Asher Perez (Classifeye Ltd.), *Non-contact optical means and methods for 3d fingerprint recognition,* Patent Application# WO2006016359 (August 9, 2005)
    - The company, Classifeye Ltd., closed on September 3, 2011.[35]

- Waleed S. Haddad, *Non-contact optical imaging system for biometric identification,* Patent# US6853444 (February 8, 2005)

- Haddad Waleed S, et al.; *Lid and housing apparatus and method for non-contact fingerprint imager;* Patent Application# WO2004102351 (May 11, 2004)
    - Haddad was previously affiliated with Pay by Touch, a company that attempted to deploy biometric payment options in retail stores.[36] The company closed in 2008.[37]

- Shahram Orandi, et al.; *Standard calibration target for contactless fingerprint scanners;* Patent Application# US20130070977 (September 21, 2012)
    - This patent is for a physical calibration standard developed at NIST. The SSBT CoE utilized the standard in a technology evaluation of the UML Single-finger Rolled-Equivalent Scanner (see Section 3.4 University of Massachusetts Lowell Single-finger Rolled-Equivalent Scanner).

- Michitaro Manabe, et al. (Fujitsu Limited, Fujitsu Frontech Limited); *Body part guidance control method for non-contact biometrics authentication device and non-contact biometrics authentication device*; Patent# US8270680 (September 18, 2012).

- Soichi Hama, et al. (Fujitsu Limited); *Noncontact biometric identification device;* Patent Application# US20130259328 (March 22, 2013)
    - Fujitsu has conducted R&D and product development on a contactless hand vein biometric scanner.[38]

- Heeseung Choi, et al. (Industry-Academic Cooperation Foundation, et al.); *Contactless type of fingerprint image obtaining apparatus using mirror;* Patent# US8243131 (August 14, 2012)

- Ruell Hartwig Dr (Siemens AG), *Arrangement for detecting finger dermal ridges,* Patent Application# DE3424955 (July 6, 1984)

- Anatoli Stobbe, *Device for contactless optical acquisition of biometric characteristics of at least one body part,* Patent Application# US20040120553 (October 3, 2003)

- Daniel H. Marcus, Michael Schiller (Fingermatrix, Inc.); *Direct finger reading* Patent# US4787742 (November 29, 1988)

4.0 CONTACTLESS FINGERPRINT EXISTING PRODUCTS

4.1 TBSGuard 3D-Line

The TBSGuard 3D-Line is a pair of touchless fingerprint scanners manufactured by TBS (http://www.tbs-biometrics.com/). It is a system solution designed for access and time and attendance applications, as well as civilian and criminal identification. The product line is comprised of three main components: 3D-Enroll, 3D-Terminal, and the BioAdmin software package. While TBS also offers several different touch-based sensors, the TBSGuard 3D-Line of sensors are all touchless. In addition to the 2008 Frost and Sullivan European Biometric Access Control Product Innovation of the Year Award, TBS claims as a list of references for its products a varied mixture of international police departments, banks, datacenters, and business operations units.[39,40] Unlike the R&D work conducted for NIJ (see Section 3.11 TBS Touchless Ten Printer (TTP)), the commercial products are sold through the parent company, based in Switzerland.

4.1.1 Select Patents

- Rudolf Hauke, Giuseppe Parziale (TBS Holding AG); *Method and device for collecting biometric data;* Patent# US7392939 (July 1, 2008)
- Rudolf Hauke, et al. (TBS Holding AG); *Method and arrangement for optical recording of biometric finger data;* Patent# US7599531 (October 6, 2009)
- Rudolf Hauke, et al. (TBS Holding AG); *Method and arrangement for optical recording of data*; Patent# US7606395 (October 20, 2009)
- Peter-Michael Merbach, Hans-Peter Nothaft (TBS Holding AG); *System for high contrast contactless representation of strips of the skin;* Patent Application# US20050117784 (April 10, 2003)
- Rudolf Hauke, et al. (TBS Holding AG); *Contactless biometric recognition;* Patent Application# WO2005045746 (October 8, 2003)
- Hauke Rudolf, et al. (TBS Holding AG); *Non-contact identification method for recognizing biometric features of body parts like finger lines, uses optical image capture from different perspectives*; Patent Application# DE2003147316 (October 8, 2003)
- Peter-Michael Merbach, et al. (TBS Holding AG); *Touchless biometric recognition*; Patent Application# US20050226474 (October 8, 2003)

4.1.2 3D-Enroll

The 3D-Enroll unit is primarily a sensor used in detecting and capturing an enrollee's fingerprints.[41] It comes in two variants, one designed for access control and time reporting and one designed for civil and criminal identification. In both instances, acquisition and management of the fingerprints occurs via a standard PC running the BioAdmin software connected to the 3D-Enroll unit. The captured prints are converted to templates and encrypted via a commercially available algorithm from Innovatrics. In addition to feature extraction and template creation, TBS uses the Innovatrics solution for template matching. TBS reports that for access control applications, the entire database is encrypted along with the templates. In the case of the civil and criminal identification variant, output is both nail-to-nail rolled equivalent

fingerprint images as well as encrypted templates. In addition to the 2D rolled equivalent images, optional 3D images of the finger can be shown in which the captured finger image is wrapped onto a truncated cone approximation. TBS claims that the 2D-Rolled Equivalents are fully compatible with the images generated by conventional sensors while meeting or exceeding NIST Fingerprint Image Quality (NFIQ) criteria. In both variants fingerprint capture requires less than one second with a claim of no "failures to enroll" by the manufacturer.

4.1.3 3D-Terminal

The 3D-Terminal combines the company's 3D-Enroll unit with a 4.3" LCD screen and optional RFID reader to provide touchless identification for time keeping and access control applications.[42] The terminal is engineered to be integrated into a network although it does possess standalone capability for identification (1:N) and verification (1:1) when used with the TBS BioAdmin software. According to TBS, although enrollees can be registered directly at the terminal, the system is designed around the idea that enrollment is performed using the 3D-Enroll unit with the goal of achieving the highest quality image. Those using the terminal for access would then have the terminal's image checked against the image collected via the 3D-Enroll unit. TBS claims a capture time at the terminal of less than one second and an identification time of less than two seconds with a database capacity of 20,000 users, which is extensible. TBS places no upper limit on the recommended database size for identification and thus, the impact to matching speeds beyond the capacity of 20,000 is unclear.

The terminal unit itself, 5.7" x 8.1" x 3.7" (W x H x D), incorporates several security measures to ensure system integrity. Registered fingerprints are stored as encrypted templates to protect user data. The 3D Terminal box contains a manipulation contact and silent alarm trigger that can be incorporated into an existing security system to prevent tampering. Customers can specify from available options to supplement the standard security measures, including the addition of a PIN code, card interface, liveness detection, camera, and/or microphone.

4.1.4 Technical Specifications and Description

4.1.4.1 3D-Enroll

The 3D Enroll device utilizes three cameras to produce a geometrical 3D model. The 3D image is "virtually unrolled" using a truncated cone construct to create a flat 2D image. The 3D Enroll device, which measures 5.7" x 5.6" x 3.5" (W x H x D), contains an opening in the center for finger placement. The user places their finger in the opening without the need to touch any part of the device and the fingerprint is captured in less than two seconds. A master fingerprint for system enrollment is recorded and then converted to a template, which will be used for matching purposes. The Civil/Criminal variant of 3D Enroll additionally produces 2D rolled equivalent images at a resolution of 500 ppi that are compatible with 2D touch sensors (although minor issues were identified during SSBT CoE use, see Section 4.1.5 Assessment Notes). The device is designed for indoor use only and is connected to a standard PC via a USB 2.0 connection.[41] The 3D-Enroll scanner was priced at $1,300 in a quote to the SSBT CoE in October 2013.[43]

Figure 17: TBS 3D-Enroll Device
Courtesy of TBS Inc.

4.1.4.2 3D-Terminal

The 3D Terminal device makes use of the same 3-camera multiview, touchless approach as the 3D Enroll but without the ability to produce rolled equivalent images. TBS reports that it performs identification (1:N) and verification (1:1) and will recognize a user in less than two seconds based on a database volume of up to 5,000 templates. The Terminal is designed as an access control unit and has a self-contained LCD screen for user interaction. Measuring 5.7" x 8.1" x 3.7" (W x H x D), it is meant for indoor use only. In order to communicate with a security network the 3D Terminal has standard LAN (10/100 Mbit) and USB 2.0 connections while offering the option of a WLAN capability. Because the unit is self-contained, it features a manipulation contact and silent alarm trigger to alert security in the event of tampering. User-facing security options, such as liveness detection and/or requiring a PIN code, are available at additional cost. Template matching capabilities and data encryption of all templates as well as the database where the templates are stored is accomplished through the use of Innovatrics algorithms.[42] The 3D-Terminal was priced at $2,100 for the scanner and BioAdmin Management Software in a quote to the SSBT CoE in October 2013.[43]

Figure 18: TBS 3D-Terminal Device
Courtesy of TBS Inc.

4.1.5 Assessment Notes

TBS's offerings are intended for access control scenarios that draw off of a local database for verification activities. The system is touchless, and employs a "red light/green light" method to assist users in properly positioning their finger. Once the finger is in the proper positioning, the scan is fast. While the system is touchless, users are required to put their finger into a recessed cavity for scanning, and it is relatively easy to come in contact with the device.

During research conducted by the SSBT CoE, it was discovered that collected images did not follow ANSI/NIST standards with respect to orientation; they were mirror reflections of the accepted standard and initially produce poor matching performance when fed into conventional algorithms.[44] While easily addressed in data processing, it is an example that illustrates potential complications when working with a device developed primarily for civilian applications or that relies on its own local database.

In the process of acquiring a TBS 3D Enroll device for other Center activities, delays were encountered due to the fact that the devices are sourced in Europe. Shipping and Customs delays may be experienced when ordering these devices.

Table 16: TBSGuard 3D Summary

Characteristic	Status
Scanning Technique	Composite digital camera images
Scanning Target	Single finger, nail-to-nail rolled equivalent
Touchless	Yes
Primary Uses	Enrollment, Time & Attendance, Access Control (Physical)
AFIS Enrollment	No
Remote AFIS Compatibility	No
Scanning Resolution	500 ppi
Operator Assistance	None
Maturity Level	Commercial

4.2 TST BiRD 3/4

Based in Germany, TST Biometrics provides technology and sensors for contactless identification of fingerprints. The BiRD series of contactless fingerprint devices are used for time/attendance and access control for mission-critical applications, such as national border controls and high security areas. TST Biometrics reports that the devices are full-service, offering both enrollment and matching capabilities depending on configuration.

Note: As of September 2013, TST Biometrics appears to have closed business and the BiRD 3 and 4 are no longer manufactured.[45,46] However, scanners may still be available from third party distributors.

Both the BiRD 3 and BiRD 4 devices were available in multiple configurations, including a desktop scanner, wall mounted scanner and as OEM components to enable integration in customized solutions. The four main components that make up both devices are the sensor head, housing, communication board, embedded board. The modular construction technique used by TST Biometrics results in two primary versions of the BiRD 3 and three primary versions of the BiRD 4. Outward differences between the BiRD 3 and BiRD 4 are an ergonomically improved housing on the BiRD 4 and its use of Innovatrics for an enrollment and identification algorithm, as opposed to VeriFinger for the BiRD 3. In regards to the BiRD 4, TST Biometrics states it contains improved electronics and new lighting geometry when compared to the BiRD 3. However, attempts to clarify that difference with TST Biometrics went unanswered. It should also be noted that TST Biometrics does not have a distributor or reseller located in the US.

The BiRD 3 sensor was available as desktop scanner, on-wall mounted scanner or OEM components. It has a modular design that allows connection with different communication hardware for using USB or Ethernet communication. Also a custom hardware board can be connected directly to the sensor. The CMOS camera optical sensor comes standard with an IR-filter, which TST Biometrics claims makes it insensitive towards the influence of ambient light, making for a higher-contrast image.

To scan, the finger is placed over the integrated guide in order for it to recognize the fingerprint. During recognition, a camera captures the controlled illuminated finger and produces a high-quality image of the fingerprint. Biometric features are extracted from this photo image. This custom template is compared to templates stored in an existing database to identify the user. TST Biometrics reports fingerprint acquisition time is less than one second.

Multispectral imaging is used for liveness detection on the BiRD 3. During this process, the finger is illuminated with light of different wavelengths. The reflected spectrum is then analyzed. The biological elements in live fingers (e.g., water, blood, etc.) absorb certain wavelengths and return a characteristic reflected spectrum of light.[47] Additionally, TST Biometrics uses cross-polar imaging to capture information from the subcutaneous skin layers of the finger. When combined using an algorithm, the results of these two independent measurements are computed into an LFD value of between 0 (false finger) and 5 (live finger). A threshold can then be set on the device depending on the protection requirements of the application.

4.2.1 Select Patents

- Hans Einighammer, Mark Gilenko (TST Biometrics Holding AG); *Method and device for recognition of natural skin;* Patent# EP1395959 (June 23, 2010)
- Markus Dilger, et al. (TST Biometrics Holding AG), *Recording of fingerprints using a digital camera;* Patent Application# WO2011072671 (December 1, 2010)
- Markus Dilger, et al. (TST Biometrics Holding AG); *Method for detecting biometric features;* Patent Application# WO2011116761 (January 21, 2011)
- Hans Einighammer, at al. (TST Biometrics Holding AG); *Method and device for recognition of natural skin during contact-free biometric identification of a person*, Patent Application# US20120033063 (October 14, 2011)

4.2.2 Technical Specifications and Description

The BiRD 3 device uses an optical sensor in the form of a CMOS camera that electronically records the sensor light reflected off of the finger. The result is a high-contrast surface image of the finger. The modular construction of the BiRD 3 series enables integration in customized solutions. According to TST Biometrics, there are several possible ways of installing the sensor, which can be sold separately:

- Parallel camera interface of the sensor head
- TST communication-board for USB 2-0 or Ethernet 10/100 Base-T
- TST embedded board interface; SPI, UART, CAN, RS232/485 or 12C

The TST BiRD 3 uses the VeriFinger Standard Software Development Kit (SDK) to incorporate the VeriFinger 4.2 algorithm into the BiRD's biometric manager software.

According to TST Biometrics, conformance testing was performed by the Fraunhofer Institute and International Biometric Group against established biometric standards and industry protocols.[48,49] The BiRD 3 Sensor is reported to comply with the following protocols, although it is important to note that these test procedures have not been revised or approved to address any potential incompatibilities with CFP technologies:[50]

- FBI Document IAFIS-DOC-01078-7.1: "Electronic Fingerprint Transmission Specification" (EFTS), US Department of Justice, Federal Bureau of Investigation, May 2005
- MITRE Technical Report: "Test procedures for verifying IAFIS image quality requirements for fingerprint scanners and printers", MITRE Center for Integrated Intelligence Systems, April 2005
- FBI IQS-CD Software for data evaluation EFTS/F, US Department of Justice, Federal Bureau of Investigation
- ANSI/INCITS 409.1-2005
    - Information technology – Biometric Performance Testing and Reporting
      Part 1: Principles and Framework
      International Committee for Information Technology Standards 25-Oct-2005
- ANSI/INCITS 409.2-2005

- Information technology – Biometric Performance Testing and Reporting
  Part 2: Technology Testing and Reporting
  International Committee for Information Technology Standards 25-Oct-2005
- ANSI/INCITS 409.3-2005
  - Information technology – Biometric Performance Testing and Reporting
    Part 3: Scenario Testing and Reporting
    International Committee for Information Technology Standards 25-Oct-2005

4.2.3 Assessment Notes

The TST Biometrics devices reportedly perform fingerprint acquisition in less than 1 second. Multiple configurations are available for tailored solutions. The scanners are resistant to bad scans due to ambient light. Liveness and spoof detection is performed through multi-spectral imaging and cross-polar imaging.

Note: As of September 2013, TST Biometrics appears to have closed business and the BiRD 3 and 4 are no longer manufactured.[45,46] However, scanners may still be available from third party distributors.

Table 17: TST BiRD 3/4 Summary

Characteristic	Status
Scanning Technique	Digital camera image with multispectral imaging for liveness detection
Scanning Target	Single finger
Touchless	Yes
Primary Uses	Time & Attendance, Access Control (Physical), Access Control (Gateway)
AFIS Enrollment	Undetermined
Remote AFIS Compatibility	Undetermined
Scanning Resolution	500 ppi
Operator Assistance	None
Maturity Level	Commercial

4.3 ONEprint

IDair's ONEprint is a rapid, touchless fingerprinting system (http://www.idairco.com/products/). Developed and funded by AOS and commercialized by IDair, ONEprint is designed to facilitate access via a touchless scan of a fingerprint for verification. The primary goal of ONEprint is to speed access through restricted, high traffic areas. IDair reports that the system captures and verifies a print in approximately two seconds. ONEprint is designed to replace touch devices with a contactless solution. During enrollment, the user's finger is scanned and encoded onto a key fob, which is given to the user. When access is desired, the user presents the key fob to the scanner and provides a finger scan. By comparing the scanned fingerprint against the data on the associated key fob, ONEprint is able to verify whether the key fob holder is the key fob owner

without accessing a gallery database of users. For areas with a high volume of traffic and no need for two-factor security identification, IDair claims that implementation of ONEprint would reduce both the access time and the error rate over use of conventional touch-based biometric access solutions.[2]

According to IDair, ONEprint is a full-service device offering both local enrollment and matching capabilities. Cleaning of the device after each use is not necessary due to the contactless nature of the optical sensor. Of additional value is the elimination of residual latent prints interfering with collection due to the device being touchless.

Enrollment to the ONEprint system must be assisted. A technician flashes a card containing a printed QR code up to the optical sensor and the system is placed into enrollment mode. The enrollee's finger(s) are then scanned and associated with a key fob. Once enrolled, the user waves the key fob in front of the ONEprint unit. After the key fob registers, the user presents their finger to be scanned. The scanned fingerprint is compared to the record associated with the key fob. If the two are matched, access is granted.

NOTE: As of November 2013, the product data sheet indicates that ONEprint does not require an RFID key fob and can match against an existing database to facilitate access control.[51]

4.3.1 Select Patents

- See Section 3.1 AIRprint

4.3.2 Technical Specifications and Description

ONEprint utilizes an optical sensor for enrollment and matching activities. The optical sensor used is similar to the cameras used in advanced smart phones currently on the market. There are no autofocus or zoom capabilities in ONEprint. However, the physical design of the unit mitigates this by requiring placement of the user's finger at the optimum focal length of approximately three inches from the camera.

Figure 19: ONEprint Scanner
Courtesy of IDair

4.3.3 Assessment Notes

The ONEprint device is designed for use in physical access control scenarios only. In its current configuration, the device implements a two-factor authentication scheme (key fob + fingerprint), and tracks only a single fingerprint per individual. The device is contactless, with incidental contact possible if the user rests their fingertip on the plastic housing. As no contact is required with the sensor or other system components, maintenance needs are reduced.

Table 18: AOS ONEprint Summary

Characteristic	Status
Scanning Technique	Digital camera image
Scanning Target	Single finger
Touchless	Yes
Primary Uses	Enrollment, Access Control (Physical)
AFIS Enrollment	No
Remote AFIS Compatibility	No
Scanning Resolution	500 ppi
Operator Assistance	Enrollment Only
Maturity Level	Commercial

4.4 NEC HS100-10

In early 2011, NEC announced the development of a single-finger contactless fingerprint scanning device with liveness/spoof detection: the HS100-10 (http://www.nec.com/en/global/solutions/security/products/hybrid_finger.html). The HS100-10 is a USB device that connects to a Microsoft Windows computer and enables biometric authentication for scenarios from personal and business security through medical records management applications. The user places their finger over the optical scanning area, resting their fingertip and base on the plastic housing of the scanner. The scanner samples the fingerprint as well as vein pattern and, through NEC's software, identifies the user and unlocks the system. Commercial availability of this device was reported as May 2011.[52]

4.4.1 Select Patents

- Teruyuki Higuchi (NEC Corporation); *Biometrical feature inputting system, image synthesizing apparatus, and image synthesizing method;* Patent# US8184871(May 22, 2012)
- Toshio Kamei (NEC Corporation); *Biometric Authentication device, biometric authentication method, and storage medium;* Patent# US8542095 (September 24, 2013)

4.4.2 Technical Specifications and Description

The HS100-10 is a multi-modal scanner that captures fingerprint data as well as finger vein patterns of the subject. The commercial version of the device has a USB 2.0 interface for connection to a Microsoft Windows (32-bit XP/Vista/7) PC. NEC reports that by using the included software, the scanner can be used to protect access to the PC via fingerprint-based logon and screensaver unlocking. These features can also be exploited in enterprise management software packages from major vendors, such as IBM and Novell. NEC also offers the HS100-10 in an embedded component configuration for applications such as fingerprint-based ATMs.

The HS100-10 claims a 600+ ppi scanning resolution and a compact size (52mm X 89mm X 48mm) for the USB 2.0 version. The embedded version dimensions would be dependent on the specific implementation.[53]

4.4.3 Assessment Notes

The NEC HS100-10 scanner was announced early in 2011 with commercial availability reported to be May 2011; however, as of January 2012 no direct method of ordering was available.

The HS100-10 was designed as an access-control mechanism, and integrates with stand-alone PCs as well as Active Directory and other major access management environments. These capabilities place it in a favorable light for the specific area of access control. However, in the broader technology arena, the system does not appear to fulfill the needs of multiple sectors of the law enforcement community. While the device is small and mobile, it does not appear to have the capability of interfacing with AFIS or booking systems. With additional software and funding, these options may be made viable. In every available example of its use, it does not show itself to be touchless. While the sensor itself is contactless, and the fingerprint is non-deformed, users are shown placing their fingers in contact with the plastic casing and holding the unit with the other fingers of their hand.

Table 19: NEC HS100-10 Summary

Characteristic	Status
Scanning Technique	Digital camera image
Scanning Target	Single finger with vein pattern
Touchless	No
Primary Uses	Access Control (Logical)
AFIS Enrollment	No
Remote AFIS Compatibility	Undetermined
Scanning Resolution	600 ppi
Operator Assistance	None
Maturity Level	Commercial

5.0 TECHNOLOGY ADOPTION ASSESSMENT

One of the objectives of this report was to examine what efforts were being made in comparative investigations of contact versus contactless fingerprint technologies. While some of the vendors and developers interviewed had performed small-scale internal examinations, the CoE has identified no concerted efforts to compare contact versus contactless fingerprinting. The assumption is made that contactless technologies will provide better fingerprinting of hard-to-fingerprint subjects (excessively dry hands, worn fingerprints, etc.) and that the increase in Level 2 and Level 3 extended feature set detail of contactless images will lead to more utility in matching efforts. Questions of compatibility with existing databases and reliability of unrolling techniques are still raised by stakeholders.

Developers of most of the systems examined by the CoE focused on access control scenarios, which only require the devices to validate a scanned fingerprint against a print that was enrolled by that same scanner (or a known scanner using the same technology). In order for these systems to be used with existing fingerprint databases, scans from these devices must be made conformant to the standards in use by wet-ink and live scan fingerprint devices. Additionally, the scans must undergo unrolling and distortion correction in order to maintain match accuracy with fingerprints in existing databases.

At present, each developer uses different scanning techniques (e.g., full 3D scanning, line-scan imaging, image-wrapping) and different unwrapping techniques (e.g., overlaying the image on a cylinder and unwrapping, using finger geometry to determine how to unroll the fingerprint, full 3D point-cloud unrolling). These differences in technologies and techniques raise the specter of doubt in stakeholders and need to be addressed in order to encourage the widespread adoption of these scanners.

At this time it is premature to discuss operational deployment and transitions from live scan to CFP technology for all of the reasons discussed here and in the introduction section of the report. Before the technology is an option for criminal justice agencies, the match performance, interoperability with legacy datasets, and certification under FBI and NIST requirements will have to be addressed. These are challenges actively being researched and worked in the biometric and criminal justice scientific and policy communities. However, the potential benefits remain significant enough to continue to drive research, development, test, and evaluation.

6.0 SUMMARY

The efforts identified in this report serve to provide an overview of the state of Contactless Fingerprinting Technology. Advances in sensors are bringing us closer to fulfilling the vision of contactless fingerprint biometrics. Realizing this vision may provide a cleaner, faster method of gathering fingerprint data. Additionally, it may increase the quality of the fingerprint records though higher scanning resolution and reduce the costs associated with training and operating the devices. Most of the devices surveyed are prototypes; those that are actual products are tuned primarily for access control. While some of these systems could be useful in the law enforcement and corrections arena as they currently exist, the core technologies show promise for more wide-spread use. Additional development and integration efforts would be required before they would be of benefit for the wider law enforcement community.

Much of the R&D identified in this report was funded by government entities, mainly DHS, NIJ, and DoD BIMA. The commercial devices were developed with purely internal funding, and tend to be designed for access control only. Of the devices discussed in this report, only the FS3D devices appeared to perform a full 3D scan of the fingerprint topography. Others used various methods from approximating the curvature of the actual finger to determine how best to unroll the scan, to unrolling the scan using cylinder-unrolling techniques. Because of the varying scanning technology and unrolling and distortion techniques used between vendors, it will be important to reassure stakeholders of the validity, repeatability, and matchability of the fingerprints produced by these systems. Adoption of this technology will require stakeholders and end users to be confident of the compatibility of the new systems with existing databases.

APPENDIX A: ACRONYMS, ABBREVIATIONS, & REFERENCES

A.1 Acronyms & Abbreviations

ACRONYM	DESCRIPTION
3D	Three Dimensional
ABC	AFIS and Biometrics Consulting, Inc.
AFIS	Automated Fingerprint Identification System
AOS	Advanced Optical Systems, Inc.
ARL	Army Research Laboratory
BIMA	Biometric Identity Management Agency
BIMS	Biometrics Identification on the Move System
CAD	Computer-Aided Design
CFP	Contactless Fingerprint
CJIS	Criminal Justice Information Services
CMU	Carnegie Mellon University
CoE	Center of Excellence
COTS	Commercial Off-The-Shelf
DHS	Department of Homeland Security
DoD	Department of Defense
EBTS	Electronic Biometric Transmission Specification
EFTS	Electronic Fingerprint Transmission Specification
e-IC	Enterprise Integration Center
FBI	Federal Bureau of Investigation
FoM	Fingerprint-on-the-Move
FS3D	FlashScan3D
GE	General Electric
GOTM	Gatekeeper-on-the-Move
JCTD	Joint Capability Technology Demonstration
LED	Light Emitting Diode
NFIQ	NIST Fingerprint Image Quality
NGI	Next Generation Identification
NIHS	National Institute for Hometown Security
NIJ	National Institute of Justice
NIST	National Institute of Standards and Technology
NLECTC	National Law Enforcement and Corrections Technology Center

ACRONYM	DESCRIPTION
POV	Point-of-View
Ppi	Pixels per inch
R&D	Research and Development
S&T	Science and Technology
SLI	Structured-Light Illumination
SSBT	Sensor, Surveillance, and Biometric Technologies
TBS	Touchless Biometric Systems
UML	University of Massachusetts Lowell
USCENTCOM	U.S. Central Command

A.2 References

[1] FBI, *Guidelines for Capturing Palmprints and Supplementals,* http://www.fbi.gov/about-us/cjis/fingerprints_biometrics/guidelines-for-capturing-palmprints-and-supplementals (revised September 2010).
[2] Joel Burcham, IDair; Prototype demonstration and technology discussion with Phillip Wiggin (Arlington, VA; October 13, 2011).
[3] Sandra Swanson; "Fingerprints Go the Distance," *MIT Technology Review;* http://m.technologyreview.com/biomedicine/27052/ (January 14, 2011).
[4] IDair, "About Us," http://idairco.com/company-view (Accessed June 4, 2012).
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