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University of Massachusetts Lowell 3D Contactless Fingerprint Scanner: Technology Evaluation

(Version 2)

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NLECTC
Sensor, Surveillance, and
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Center of Excellence

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1.0 EXECUTIVE SUMMARY

The Sensors, Surveillance, and Biometrics Center of Excellence (SSBT CoE) has performed testing and evaluation (T&E) of a contactless fingerprint scanning device developed for the National Institute of Justice (NIJ) by the University of Massachusetts Lowell (UML). Initially, this task was to include a full round of testing and evaluation of the device, its capabilities, and the suitability of produced images for matching. Ultimately, due to UML prototype delivery delays and shifts in SSBT CoE priorities, the scope and nature of the T&E activities has been reduced to focus on a baseline technology evaluation of the prototype fingerprint scanners.

As of Q4 2012, UML has delivered three prototypes to the CoE. The first prototype required local power (an AC outlet) to function; however, the second two prototypes include battery packs which were intended to allow the system to be more mobile. Unfortunately, neither battery pack provided power to the units during our evaluation. According to UML, the devices require 7 Amps (7A) of power to operate; however, the batteries included by UML are marked 5A. CoE staff notified UML of the discrepancy, but no explanation or corrective measure was provided. One of the final two prototypes has an issue with scanning single fingers, causing the image to be badly distorted. CoE staff and UML representatives witnessed this behavior prior to transferring the devices to the CoE, and UML tagged that device prior to delivery.

The prototypes provide an interesting insight into the potential utility of contactless scanners. They are most likely of use to researchers examining the effects of deformation due to pressure, matching capabilities, and contactless sensors in general. At least two of the prototypes delivered will require some adjustments to the mirror alignments prior to further research use. The systems are not suitable for field deployment or operational evaluation by criminal justice organizations due to their various technology and functional shortcomings.

The prototypes delivered are primarily stand-alone scanners without any underlying biometric database or matching capability. The single-finger scanner (when properly calibrated) provides full nail-to-nail rolled-equivalent fingerprints. Image scans from the three systems all include some level of image quality issues, with the first scanner producing acceptable images with minor alignment/quality issues to the third scanner with significant warping and distortion. The single-finger images appear to be 430 pixels per inch (ppi) rather than the 700 ppi stated by UML. The 4-slap capability of the scanner is somewhat less than ideal, but with proper alignment of the camera and mirror, 4-finger capture should be possible. The quality of 4-slap images is acceptable with occasional issues from external illumination sources. The 4-slap images appear to be 340 ppi rather than the 72 ppi stated by UML. The PC software does not segment the image into individual fingerprints. Additional software development would be required to build a full collection system and enable features such as sequence checking. Neither collection areas meet current FBI Appendix F capture area requirements.

2.0 INTRODUCTION

The SSBT CoE has performed T&E of a contactless fingerprint scanning device developed for NIJ by UML. Initially, this task was to include a full round of testing and evaluation of the device, its capabilities, and the suitability of produced images for matching. Ultimately, due to UML prototype delivery delays and shifts in SSBT CoE priorities, the scope and nature of the T&E activities has been reduced to focus on a baseline technology evaluation of the prototype fingerprint scanners.

Figure 2.0-1 UML Prototype Contactless Fingerprint Scanner

2.1 Background

In 2009, UML was awarded NIJ grant funds to develop a mobile contactless fingerprint collection device (Award# 2009-IJ-CX-K021). The project was to develop a fast-capture fingerprint scanner that utilizes contactless optical sensors to collect nail-to-nail fingerprints.

Dr. Samson Mil'shtein of UML (principal investigator) demonstrated a version of the prototype during the NIJ Biometric Technology Working Group (TWG) in May 2011. This iteration of the prototype included liveness detection of single fingers by vein scanning with an infra-red light process. The prototype was very lightweight but was apparently somewhat fragile, with a high chance of needing recalibration after shipping or rough motions.

It was expected that UML would deliver three (3) prototypes to the CoE to begin T&E activities early in the first half of 2011. Unfortunately, delivery of the prototypes was delayed. The first of the prototypes was made available to the CoE in Q1 2012. Center staff travelled to UML in March 2012 to be trained on the prototype, accept delivery, and return with it to the Center's testing labs. As a result of the delay in delivery, CoE resources were reallocated to other tasking and T&E efforts for the UML devices was re-scoped to an Overview Evaluation.

As of Q4 2012, UML has delivered three prototypes to the CoE. The first prototype required local power (an AC outlet) to function; however, the second two prototypes include battery packs which were intended to allow the system to be more mobile. Unfortunately, neither battery pack provided power to the units during the evaluation. According to UML, the devices require 7 Amps (7A) of power to operate; however, the batteries included by UML are marked 5A. CoE staff notified UML of the discrepancy, but no explanation or corrective measure was provided. One of the final two prototypes has an issue with scanning single fingers, causing the image to be badly distorted. CoE staff and UML representatives witnessed this behavior prior to transferring the devices to the CoE, and UML tagged that device prior to delivery.

2.2 Contactless Fingerprint Technologies Assessment

In addition to an evaluation of the UML prototype scanner, the NIJ SSBT 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 vs. contactless fingerprint technologies. This report, *Contactless Fingerprint Technologies Assessment*, examines the initiatives in government, industry, and academia aimed at pursuing contactless fingerprint collection technologies.

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, correct placement of the finger(s) by the subject, necessary precautions must be taken to ensure movement of the subject's fingers do not impact scan quality, and the scanner must be able to accommodate the myriad of different sizes and shapes and condition 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 will become silos of data whose usage is limited.

It is the finding of the CoE that commercial off-the-shelf 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, for instance), additional investment and development would be required. The report identified NIJ, Department of Homeland Security Science & Technology Directorate, and Department of Defense Biometrics Identity Management Agency 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.

3.0 SYSTEM EVALUATION

The UML research objective was to create a single-finger, nail-to-nail, rolled-equivalent contactless fingerprint scanner. The scope of this effort was eventually extended to include 4-slap capabilities. The prototype, as delivered, scans a single finger in approximately 1 second (4-slap in approximately the same time) and wirelessly transmits the image to software running on a remote computer. The full initialization, scan, and transmit cycle requires approximately 15-20 seconds. Future iterations of the device could include non-wireless (USB/Ethernet) transmission of images.

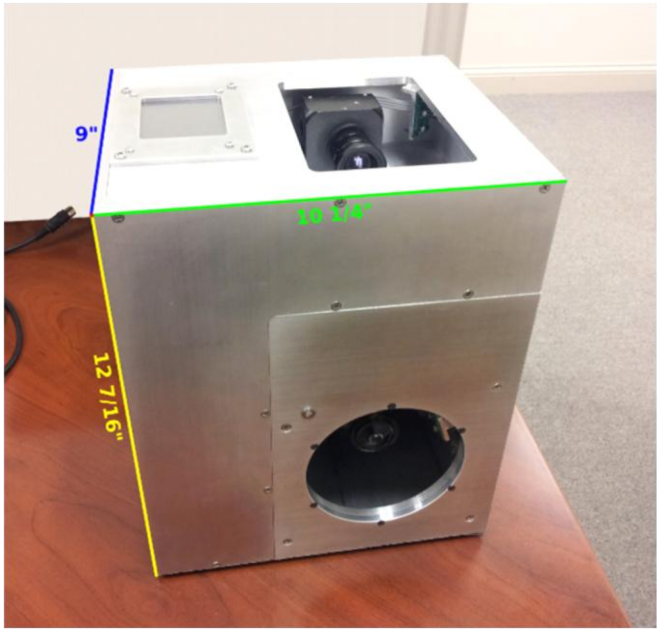

Figure 3.0-1 Dimensions of UML Prototype

3.1 System Hardware/Software

The systems delivered by UML are 40% larger and much heavier than the version shown at the 2011 NIJ Biometric TWG. The new version measures 12 $^{7/16}$" x 10 $^{1/4}$" x 9" and is constructed out of ¼" thick aluminum for all internal and external support structures. The system is comprised of two cameras (one line-scan, one full-frame), a touch-based control panel, various mirrors and light-emitting diodes (LEDs), and is powered by either a power adapter or rechargeable batteries.

The scanner has two methods of gathering subjects' fingerprints: a rotational nail-to-nail scan and a four-slap scanner. The single-finger scanner is comprised of a set of mirrors and a rotational scan-arm. The scan-arm is mounted to the front of the unit and rotates around the user's fingertip. The fingerprint image is reflected back into the housing where a line-scan camera gates the image. The scan process requires the user to place their finger into the device approximately 1". The finger is in full view during the process. The 4-slap area is situated on the top of the device and images the user's fingers in sequence to perform a full 10-print collection in three scans: 4-fingers left hand, 4-fingers right hand, 2 thumbs.

3.1.1 Control and Debug Interface

The system's configuration and scanning capabilities are controlled through a touch-based interface mounted on the top of the scanner enclosure. This control panel enables a trained operator to perform limited configuration of the system, initiate scans, and view status messages. The touch-based interface consists of three components from Gumstix: a resistive LCD touch-screen (DSP00035), Palo 35 LCD control board (PKG30035), and a Gumstix Overo Fire COM (GUM3503) control module. This control module runs an embedded Linux operating system backend which interfaces with the resistive touch screen interface. The module uses an 802.11b wireless interface to transmit the scanned fingerprints to the server software. A side panel under the control interface opens, giving access to a USB-based COM port mounted on the board to enable a direct command-line interface useful for monitoring and debugging the back-end operating system during the initial setup of the system. Scanning capture cannot be controlled or initiated through the USB port. The interface features the needed communications, debugging, and user interface hardware to enable fingerprint capture on the device.

The software interface displays the current IP address, firmware version, and wireless link strength in the status bar across the top. The system interface is laid out in a 4x2 grid with buttons sized for easy finger access. Using these buttons, an operator can initiate scans, connect the scanner to an 802.11b network, and perform some limited configuration.

Figure 3.1.1-1 Scanner Control Interface

3.1.2 Power

The UML scanners have been engineered to operate in two modes of power: main-line (AC) and battery pack. In AC mode, the device requires a circuit with 7 amps of output current capacity available. UML has installed rechargeable battery packs in two of the three units with the goal of making the unit more mobile. However, evaluation findings determined that the battery power mode was nonfunctioning (see Section 3.1.4.1).

Figure 3.1.2-1 Internal System View (left) Without Battery and (right) With Battery

3.1.3 PC Server Software

The system requires server-side software running on a Windows PC on the same local network as the scanner. The software provided by UML is laboratory-quality software used to demonstrate how the scanner works. Its feature-set is limited, capable of connecting to the scanner and receiving images.

3.1.4 Evaluation Findings

3.1.4.1 Hardware

The scanner is built out of ¼” thick aluminum throughout its casing and internal support structure for sturdiness and durability. The device was intended to be a mobile scanner, but given the size and heft of the device, it fails to meet this objective and would be suited for use in an installed or semi-permanent fashion. On the other hand, the solidness of the build may help counter some disruptions from vibration or jostling during operation.

The installation of the unit requires that there be 7 amps (7A) of service left on the circuit to which the scanner is attached. While this may not pose everyday issues, it does require some planning and assistance from an electrician to determine where it may be installed. UML integrated rechargeable batteries into the design to facilitate usage in temporary locations or where the available power capacity is not known. Of note is the fact that UML has stated the unit requires 7A on an electrical circuit, but the batteries installed in the two units are labeled 5A. CoE staff requested clarification on this point. UML acknowledged the request and is looking into the answer. Unfortunately, during the course of the evaluation, we found that the batteries did not provide power to the system. Either the charging mechanism is not working properly, or the batteries are not supplying enough power to the device. Due to these issues and the brevity of this evaluation, we were unable to verify UML's assertions as to the batteries' expected longevity or to identify the source of the non-functional batteries.

3.1.4.2 Software

The PC software delivered by UML is laboratory-level software. It provides adequate means for demonstrating that the scanner collects images, but little else. Some features are shown, but not implemented for this hardware, such as the 'Secure Mode' checkbox (highlighted in yellow in Figure 3.1.4.2-1) and the combo-box (highlighted in red in Figure 3.1.4.2-1) with options for "Normal", "Infrared", "Binarized", and "Enhanced" images.

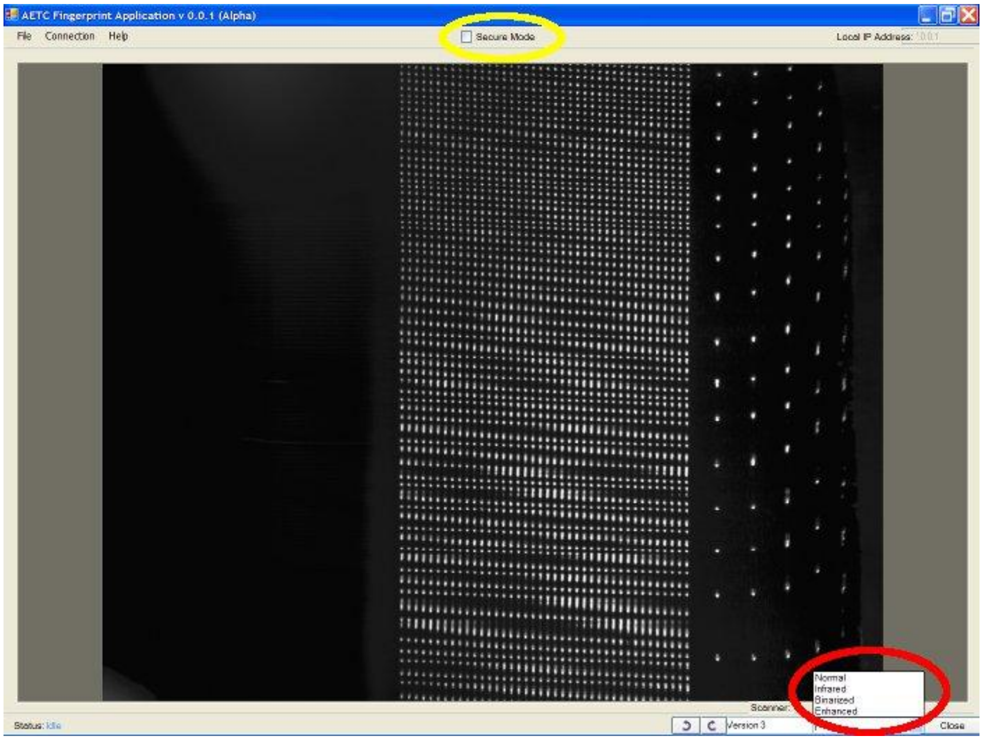

Figure 3.1.4.2-1 Server Software Interface

According to UML, the version of software that was delivered shows these options but they have no function with these scanners. These features of the software package are used for other systems developed by UML. Similarly, the "Secure Mode" checkbox is not used with these prototypes.

3.1.4.3 System Setup

Setting up the system is generally straight-forward. Although the hardware supports 802.11g, UML states the system requires an 802.11b network connection. For our evaluation, we used a Linksys WRT54G wireless router set to "B only", and connected the PC directly to the router via cat-5 cable. The scanner was plugged into an AC outlet and connected wirelessly to the WRT54G. For our testing runs, the scanner communicated with the PC software as indicated in the operating manual. Although the 802.11b connection allowed the system to communicate with a PC wirelessly, most modern networks use the faster 802.11g or 802.11n. Additionally, the system transmits data “in the clear” without encryption. Considering the nature of the data being transmitted, encryption should be mandatory.

Setting up the scanner to connect to the wireless network and then to the PC software required additional initial setup. With each scanner, we found it helpful to connect the system to the PC via the USB COM port on the interface board during the initial setup. This provided us the capability to check logs, monitor processes, and troubleshoot the configuration and wireless connection.

Prior to connecting the system to the network, it must be configured via the resistive touchpad (or Linux command-line via the debug port). Specifically, the SSID must be specified, the IP address of the computer running the server software must be entered, and the wireless connection must be initiated by pressing the ‘Connect’ button (or executing the wl.sh script on the command-line). On several occasions, we were forced to reboot the system before the configuration changes took effect.

The systems will occasionally drop off the network and lose communications. Sometimes pressing ‘Connect’ repeatedly would fix this issue, others would require a reboot of the system.

3.2 Single-Finger Scanner

The primary contactless scanner on the unit performs a nail-to-nail rolled equivalent fingerprint capture utilizing a scan-head that rotates through a 180° arc. The scanner uses a line-scan camera that captures a single line of 700 pixels at a time. The scanner utilizes blue LEDs to illuminate the surface of the finger during the scan-head’s rotation and provide uniform usable lighting throughout the scan. A set of mirrors mounted both inside the unit and on an arm that rotates around the user’s finger provides the line-scan camera with the full view of the user’s nail-to-nail fingerprint. As the scan-arm rotates around the finger, the line-scan camera takes 2048 1x700 pixel samples. The onboard computer assembles these samples into the fingerprint image by stacking the single bands side-by-side. The result is a “rolled-equivalent” image that is 2048x700 pixels at 700ppi (which is up-sampled to 1000ppi).

The scan process requires the user to place his fingertip on a stationary guide while an operator initiates the scan. The user must wait for the scan-head to rotate around their finger to the ‘start’ position and hold the finger in place during the actual scan.

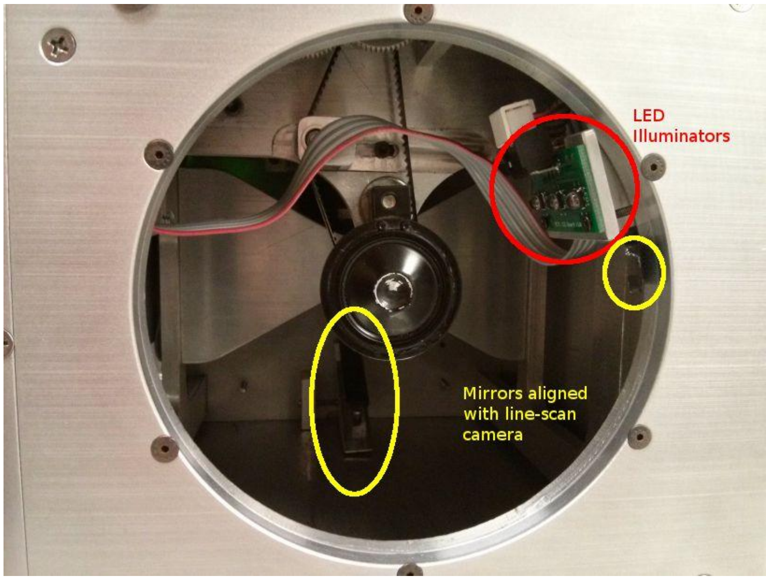

Figure 3.2-1 Single-finger Scanner View

3.2.1 Images Acquired

Due to procedural restrictions, CoE was unable to report on actual fingerprint capture for this evaluation due to privacy concerns attached to fingerprint images. Instead, NIST calibration cylinders were used to demonstrate the images obtained from the scanners. The reference cylinders are anodized aluminum cylinders roughly the size of a finger with ordered arrays of marks machined into the surface with microtools; one cylinder has an array of dots while the other is the optical inverse with a grid array.

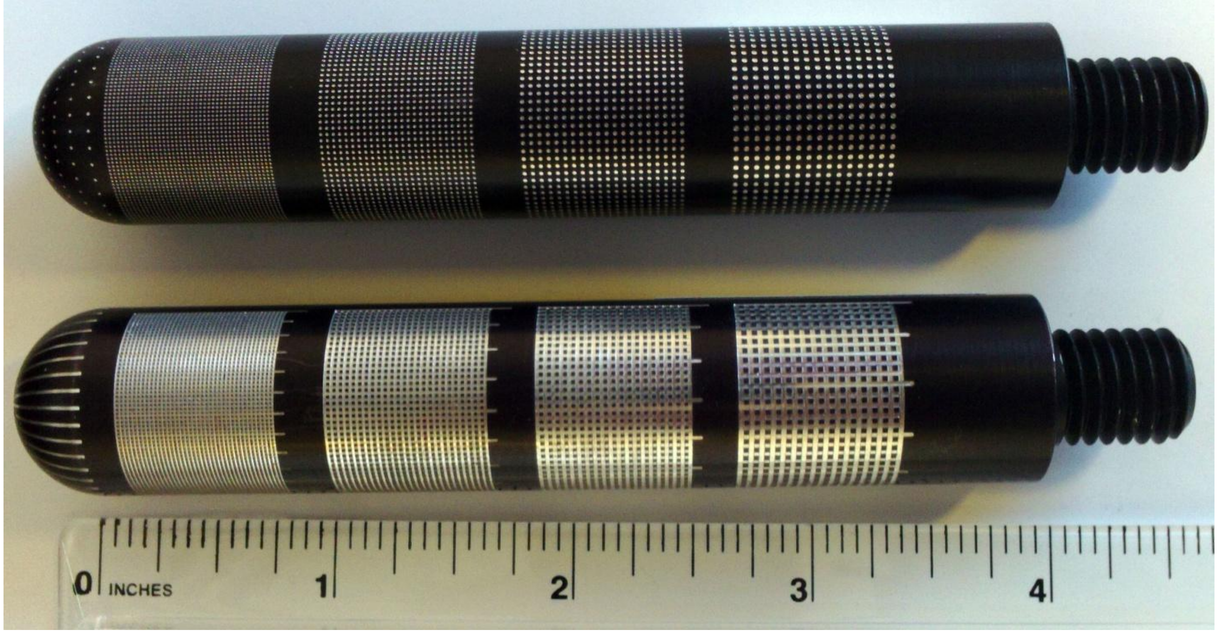

Figure 3.2.1-1 NIST Calibration Target Cylinders

Each of the two types of cylinder were mounted to a jig and aligned with the scanner to ensure the best positioning for the scan. Each scanner performed differently with respect to image quality. Images from each of the scanners are presented below. The Scanner 2 images include results of shaking the jig, simulating possible tremors in the user’s hand.

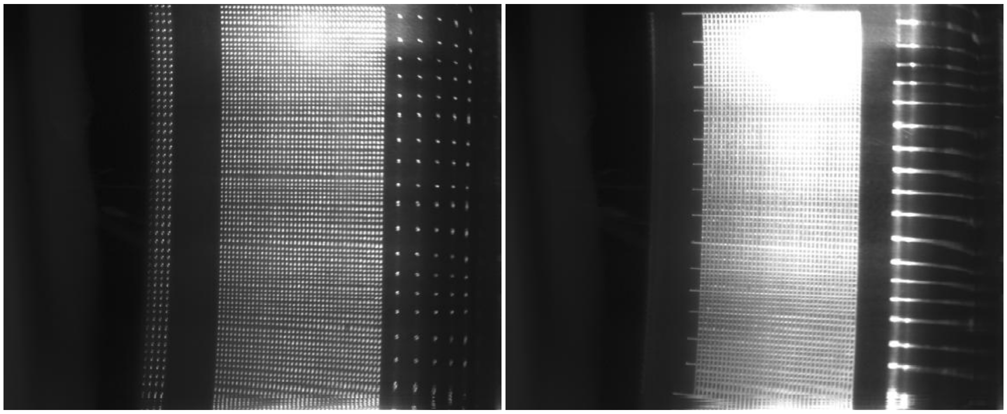

Figure 3.2.1-2 Scanner 1 Single-Finger Images

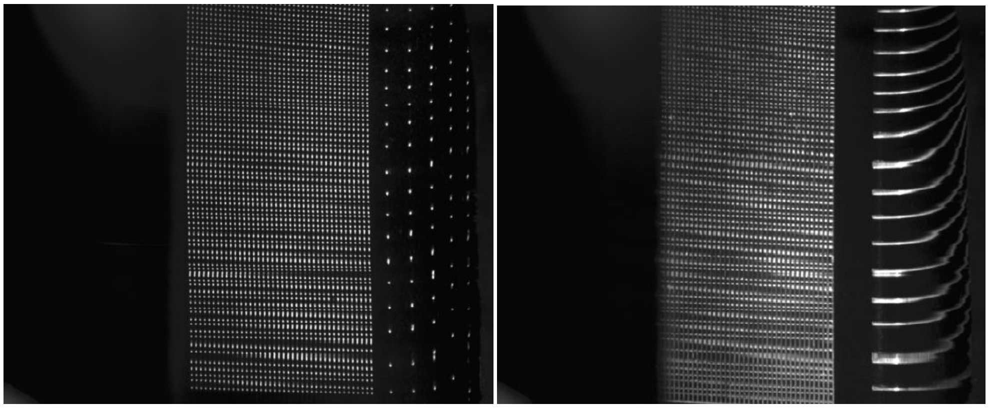

Figure 3.2.1-3 Scanner 2 Single-Finger Images

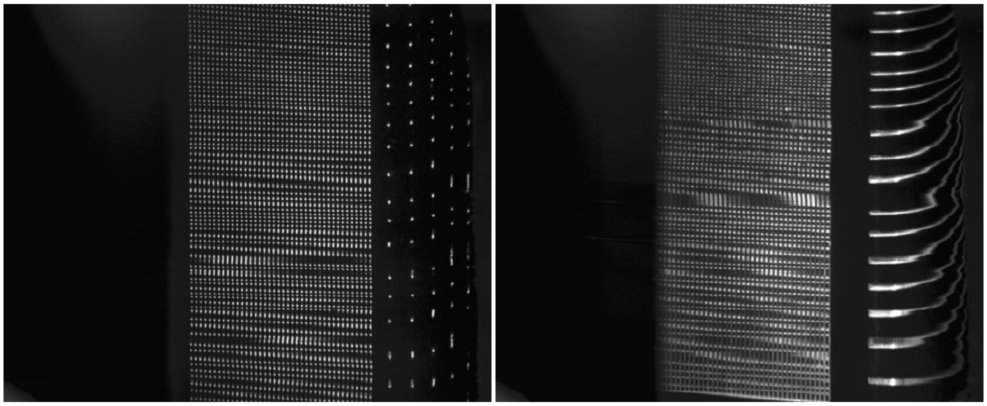

Figure 3.2.1-4 Scanner 2 Single-Finger Images (shaken)
The jig holding the reference cylinders was shaken during imaging to evaluate the effect on captured images

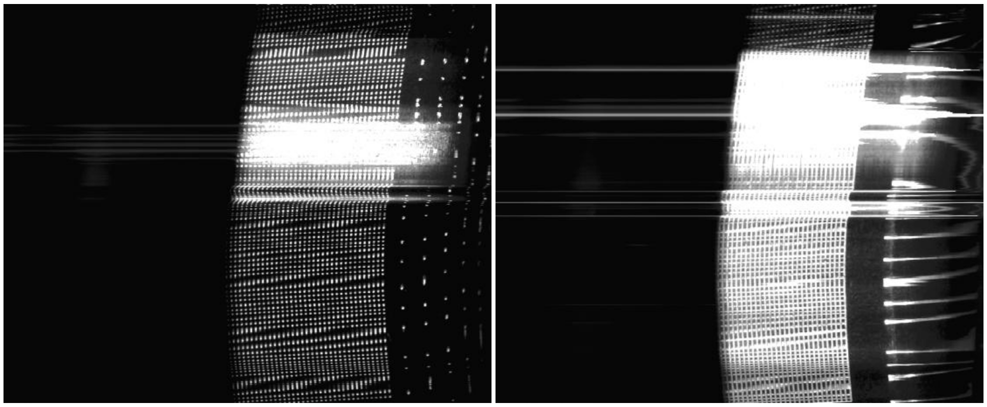

Figure 3.2.1-5 Scanner 3 Single-Finger Images
The scanner was known to have some imaging alignment/calibration issues prior to scan capture.

3.2.2 Evaluation Findings

The single-finger scanner provides a relatively user-friendly method of acquiring a fingerprint. The user is provided a guide to indicate where the finger should be placed, and the actual scan-time is approximately one second. The full scan process requires approximately 10.5 seconds with an additional 4-8 seconds required to transmit the scan to the PC software for display. The scan process is performed in 3 phases with a requiring a total of 10.45s to complete on average.

Table 3.2.2-1 Single Finger Scan Capture Times

Scan Phases	Seconds
Initializing	8.15s
Move to Start Position	1.2s
Perform Scan	1.1s
Total Scan Time	**10.45s**
Transmit to PC	4-8s
Total Acquisition Time	**15-19s**

Although previous iterations of the prototype included liveness/spoof detection via near-infra-red vein recognition, that feature was removed in this version because that technology required the scanner to be mounted further inside the system. This configuration was determined to be infeasible by UML due to the reluctance of subjects to place their finger into a device without being able to see what was being done. Therefore, the scanner was moved closer to the outside of the unit where ambient light caused the liveness detection to fail.

Our scan tests show these scanners to be sensitive to any type of vibration, with anomalies noted when shaking the jig, jostling the table, or introducing other forms of outside vibration. Although the heavy frame was intended to mitigate and/or eliminate these issues, it has not been sufficient in doing so. Even with the heavy frame, the current UML scanner engineering was sensitive to minor vibrations.

A primary concern when testing this scanner was the brightness of the LEDs. The position of the LEDs below the finger causes them to shine directly up into the user’s field of view. Most users will watch as their finger is scanned, and the LEDs are bright enough to cause discomfort and possibly injury. Each of the three blue illumination LEDs are operating at 2-3 watts. CoE staff members are examining the requirements for protective eyewear based on the LED data sheets and power consumption. UML recommends that eye guards used for welding should suffice to protect the user. This operational requirement further complicates deployment in non-research applications.

The NIST calibration cylinders are an important first step in establishing quantitative and repeatable measurements of contactless fingerprint scanner performance and image quality. However, there are limitations to what can be applied to the UML devices with the calibration cylinders in their current state. As of this report, the cylinders are available to a small group of biometric research organizations, but the companion software, algorithms, and metrics for interpreting and analyzing the resulting cylinder images does not yet exist. Ideally, a researcher would scan a calibration cylinder and feed the resulting image into a software suite, which would provide quality scores regarding various attributes. Example attributes would include horizontal and vertical linear consistency, existence of optical aberrations, blurriness/sharpness, etc… These metric scores would establish an absolute metric that could be compared across contactless devices and prototypes and would aid in correcting engineering issues or calibration/alignment. As it stands, images of the calibration cylinders can be examined for aberrations, inconsistencies and described in a qualitative manner only.

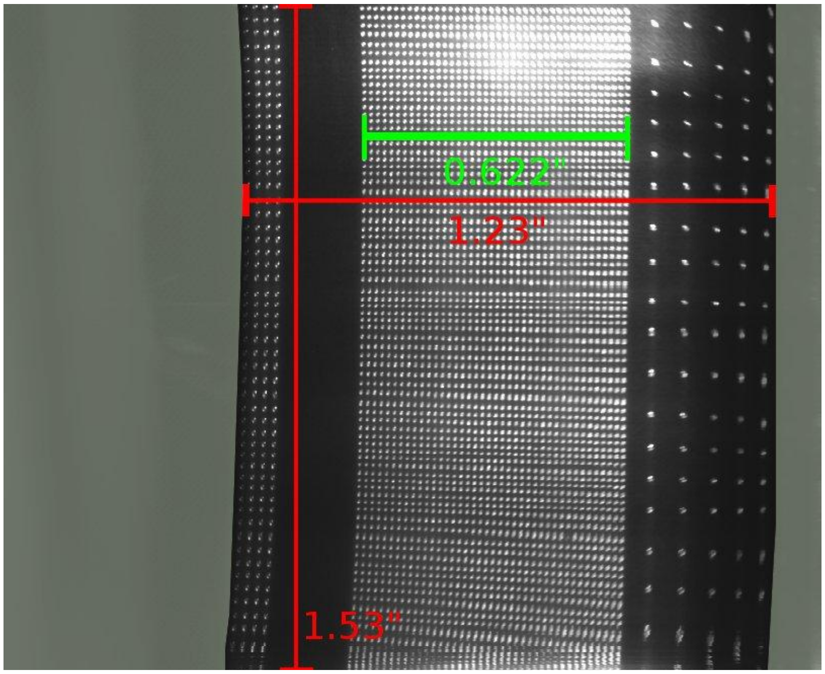

Figure 3.2.2-1 Measurement Scale and Scan Area of NIST Cylinders On UML Single-finger Scanner

Using the precisely measured markings on the NIST test targets, we can accurately determine the effective size of the scan region. In Figure 3.2.2-1, the scan region is highlighted and its dimensions are marked in red. The scan captures detail in good order out to the fingertip in the upper portion of the scan, but much of the image area (shaded in gray in Figure 3.2.2-1) provides no fingerprint information. When calibrated properly, the capture area is approximately 1.5”x1.2”. As shown in Table 3.2.2-2, this falls short of Appendix F requirements.

Table 3.2.2-2 Single-finger Roll Capture Area vs. FBI Appendix F Preferred Capture Size

Capture Area	Inches
UML Scanner	1.53x1.23
Appendix F: Single-finger Roll	**1.6x1.5**

3.2.2.1 Evaluation Findings: Scanner 1

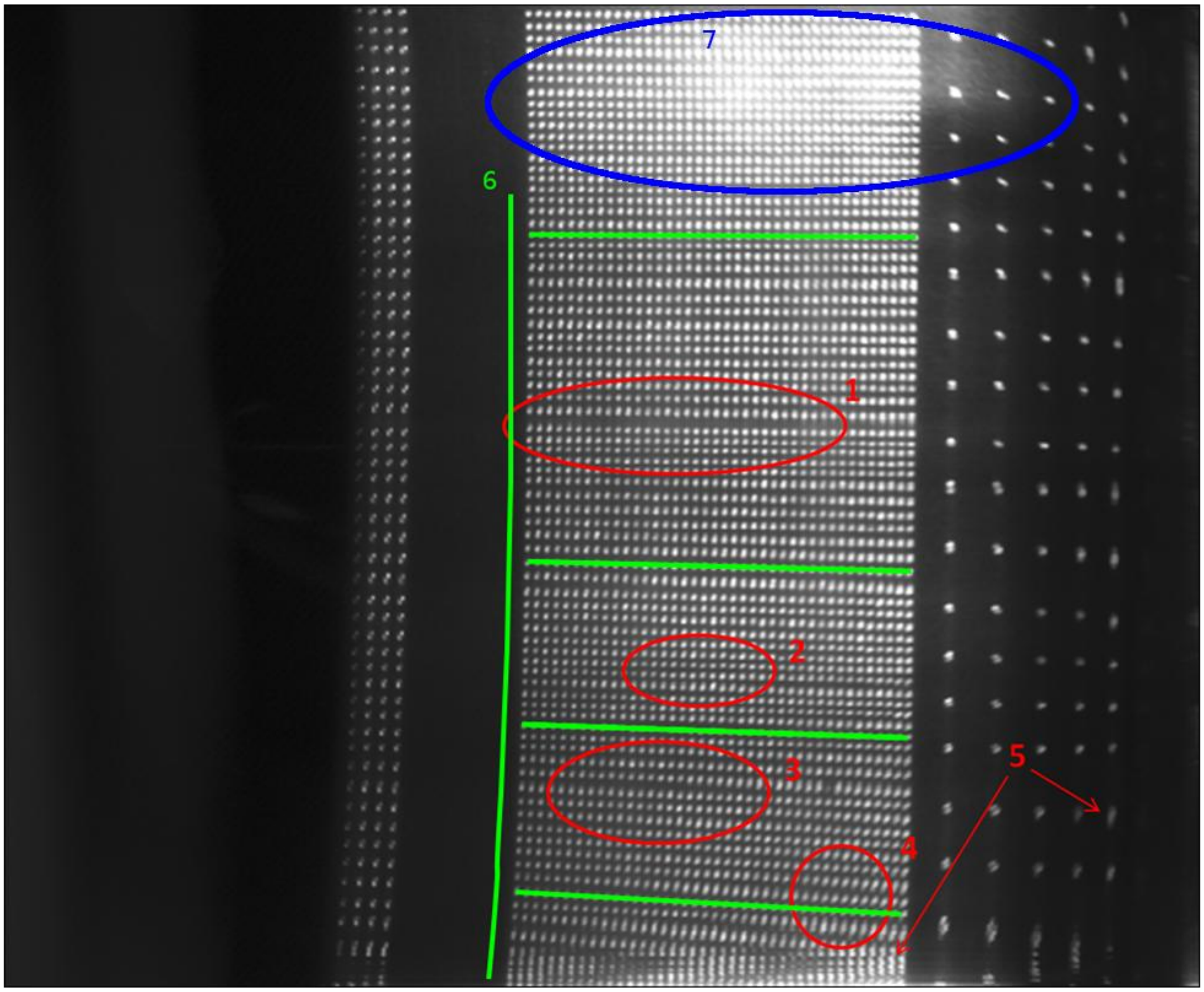

Figure 3.2.2.1-1 Scanner 1 Single-Finger Image (close-up)

Scanner 1 provided the most consistent images for the single-finger scan, producing relatively good quality scan of the NIST calibration cylinder. The calibration surface marks appeared consistent and in good order over much of the scan that would cover a subject's fingerprint. However, there were a number of anomalies and artifacts in the resulting image:

1. Errors in expanded vertical line spacing
2. Errors in compressed vertical line spacing
3. Inconsistent (warped) horizontal line scanning
4. Blurred calibration marks
5. Distortions at the edges of the scan
6. Alignment errors that get progressively worse near the bottom of the image
7. In many scans of the NIST targets, we see moderate-to-severe reflective light issues. (These did not appear in scans UML performed of actual fingers to demonstrate the working devices.)

While Scanner 1's images are the most uniform, it does not appear that they would meet Appendix F levels of accuracy. In examining the bitmap files produced by the scanners and aligning them with the known measurements from the NIST calibration cylinders, the images appear to be 430 ppi rather than the 700 (or 1000) ppi stated by UML. Appendix F requires tight tolerances in pixel accuracy, measured against standardized scan targets. At present, the NIST cylinder targets do not have a mapping to these requirements. However, given the accuracy required by Appendix F, it is unlikely that any of these scans would be acceptable with the anomalies clearly visible to the untrained eye.

As discussed previously, the NIST calibration cylinders are a "prototype" reference without accompanying algorithms or metrics for quantifying image issues. As a result, this evaluation can only use the qualitative appearance of the scanned image to gauge the relative quality and consistency between the scanners and highlight areas that may require further consideration.

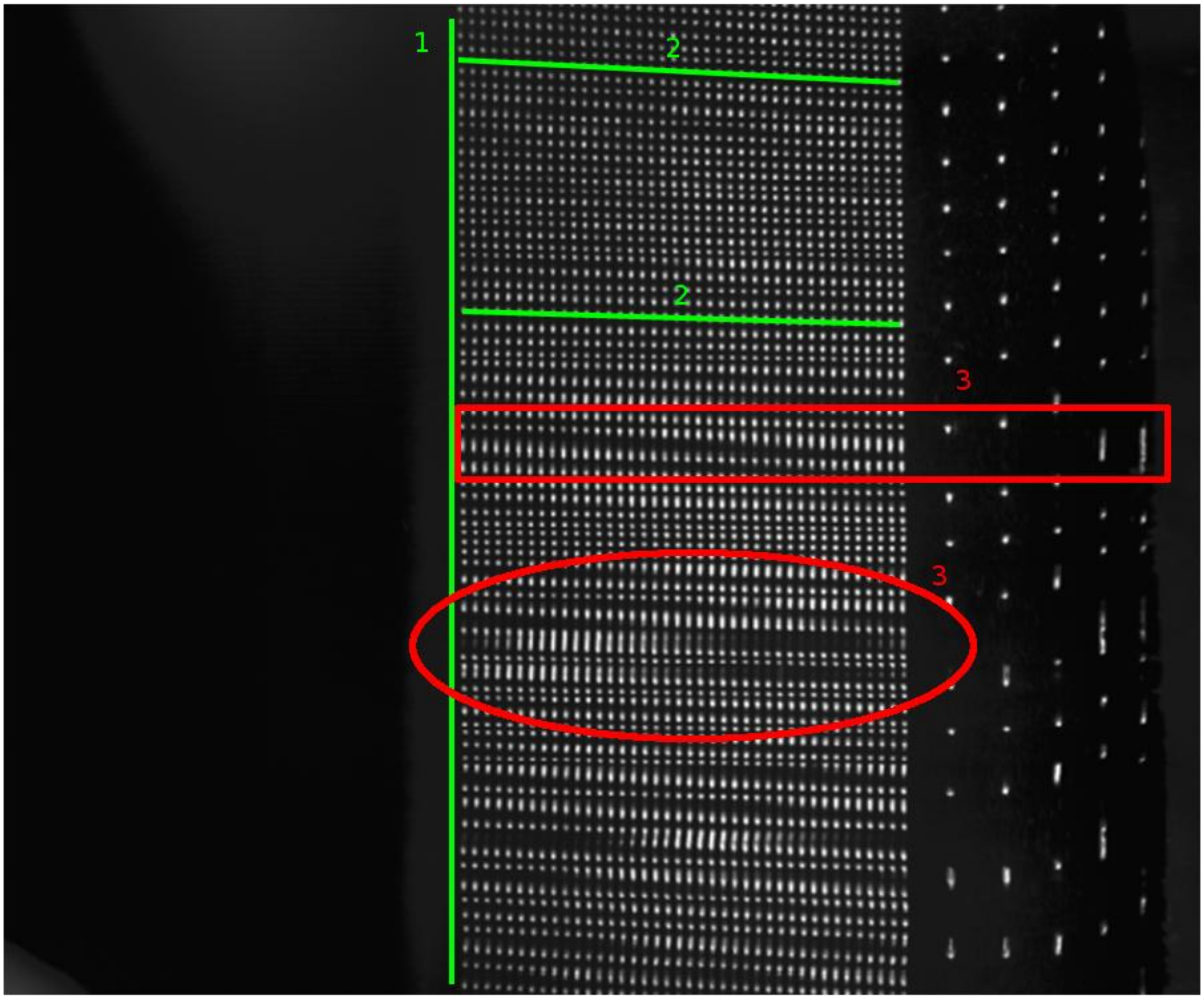

Figure 3.2.2.1-2 Scanner 2 Single-Finger Image (close-up)

The images acquired from Scanner 2 were significantly more distorted with some smearing effects particularly in the lower third of the image. In comparison to the images from Scanner 1, Scanner 2 images contain the following features:

1. Vertical alignment of the target area is much more uniform
2. Generally static amount of horizontal misalignment
3. Serious smearing issues (both of target points as well as black spaces)

The smearing issues appear to be induced by vibration. As shown in Figure 3.2.1-3 vs. Figure 3.2.1-4, these anomalies worsen when the scan target is shaken during the scan.

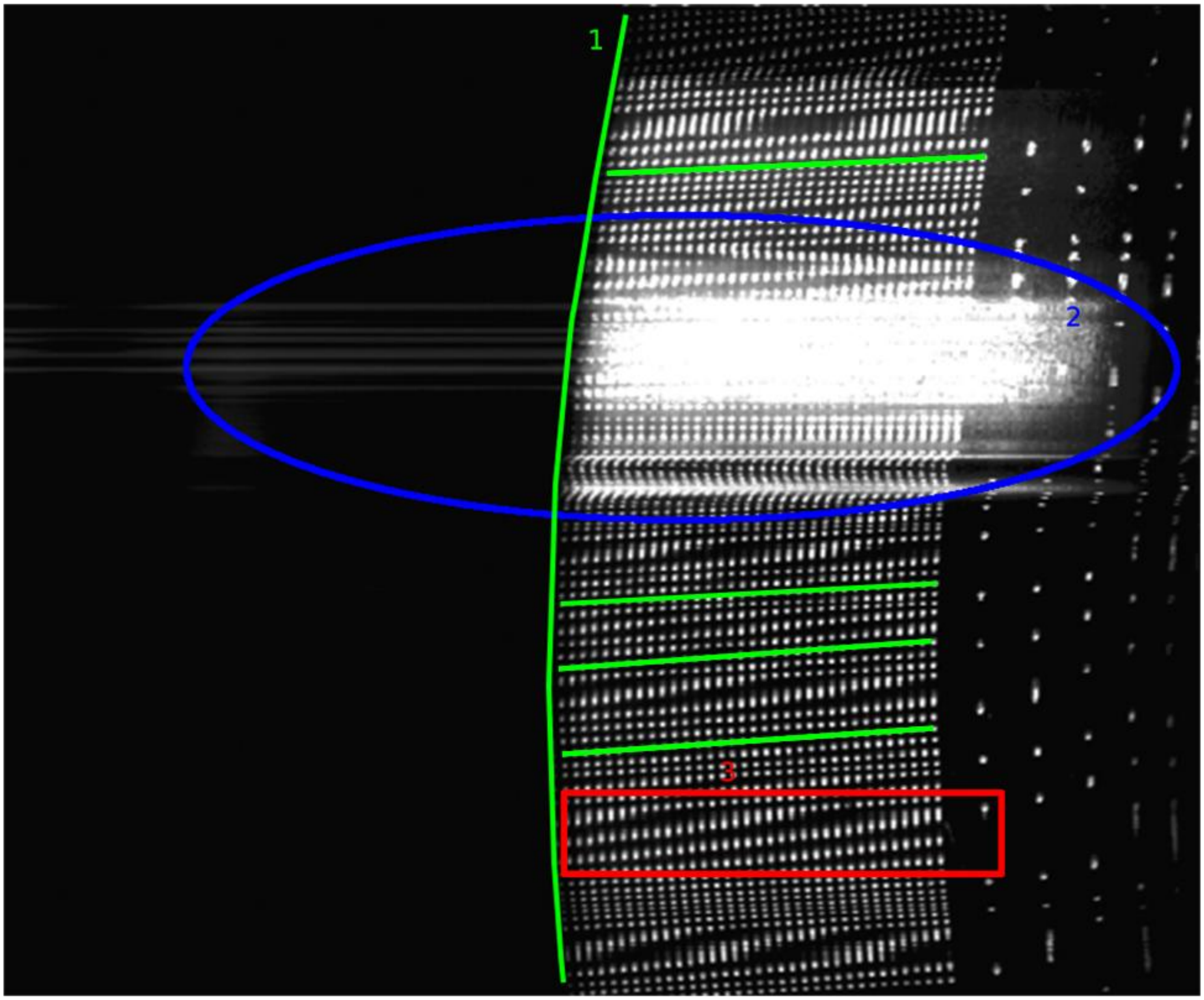

Figure 3.2.2.1-3 Scanner 3 Single-Finger Image (close-up)

The images acquired from Scanner 3 were distorted beyond those of the other two scanners with severely distorted vertical alignment highlighted in green (Figure 3.2.2.1-3) in addition to the anomalies seen in the other scanners. The issues with Scanner 3's poor image quality were noted by UML prior to the CoE accepting delivery and prevented deeper analysis. Although quite distorted, the images from Scanner 3 still show the same issues as Scanners 1 and 2:

1. Horizontal and vertical misalignment
2. Glare effects from the metallic NIST target
3. Serious smearing issues (both of target points as well as black spaces)

As exemplified in the images from Scanner 2 (Section 3.2.2.1) and Scanner 3 (Section 3.2.3.1), the devices can become optically misaligned and/or the gearing may require recalibration or maintenance causing moderate to severe image degradation. After discussions with UML, it was determined that the anomalies seen in the scan images are primarily caused by issues with gear calibration. CoE staff inquired into the feasibility of performing calibration on the devices to correct the issue with the intent of capturing further non-damaged images. It was determined that the necessary gear assembly calibration is a time-consuming, sensitive process that may make the scans worse if done by CoE staff rather than trained UML team members.

3.3 4-slap Scanner

A 4-slap scanner was added to the prototype after UML obtained feedback from local law enforcement on possible use-cases. Sequence errors are a problem when dealing with single-finger collection devices. The addition of a 4-slap scanner would provide the system with a capability to perform sequence checks, or possibly allow the submission of identification flats. The 4-slap scanner is built into the top of the unit, with a large open area cut out to enable the user’s fingers to be scanned.

Figure 3.3-1 4-slap Collection Area (Prototype View)

The 4-slap scanner has three components: LED lighting, a mirror, and a camera. This arrangement of hardware is controlled by the ‘4-slap’ and ‘Palm’ buttons on the touch-screen interface. The system could not be used for palm prints, as the active scan area is not of sufficient size for certification (See Table 3.3.2-1). Both selections seem to perform the same activity of capturing the image from the camera.

3.3.1 Images Acquired

Due to procedural restrictions, the CoE was unable to capture actual fingerprints for this evaluation. Instead, NIST calibration cylinders were used to demonstrate the quality of images obtained from the scanners. Each of the two types of cylinder was placed on the scanner and positioned as fingers would be. In addition, the backs of a set of fingers were captured to demonstrate the capture area as it pertains to capturing a subject’s hand. Each scanner performed differently with respect to image quality, lighting, and usable scan-area. Images from each of the scanners are presented below.

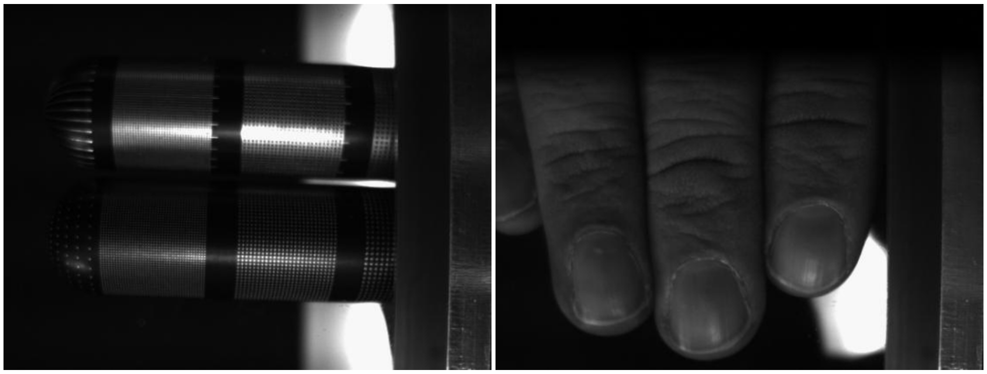

Figure 3.3.1-1 Scanner 1 Four-Slap Images
(Left) Two NIST calibration cylinder and (right) the back of a set of fingers.

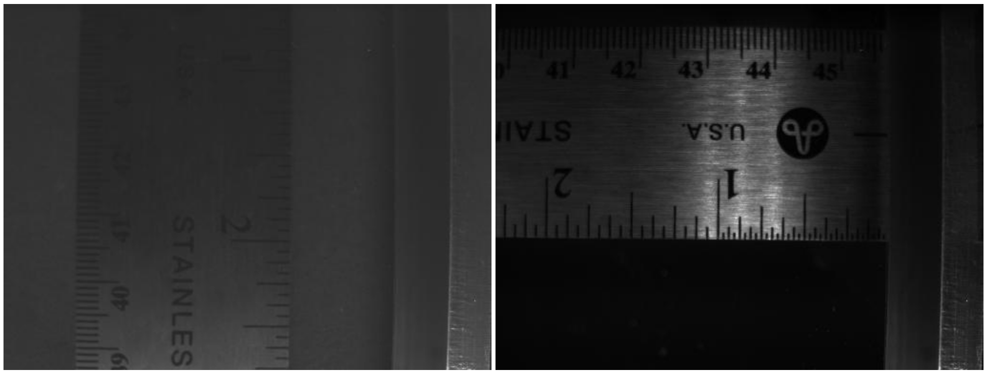

Figure 3.3.1-2 Scanner 1 Four-Slap Capture Dimensions

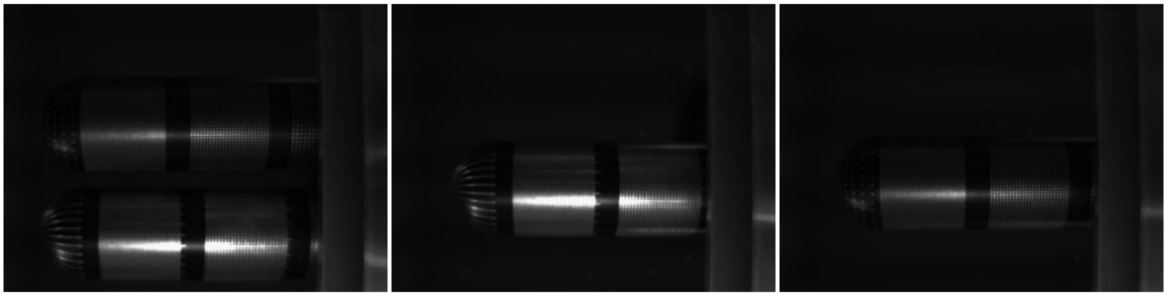

Figure 3.3.1-3 Scanner 2 Four-Slap Images

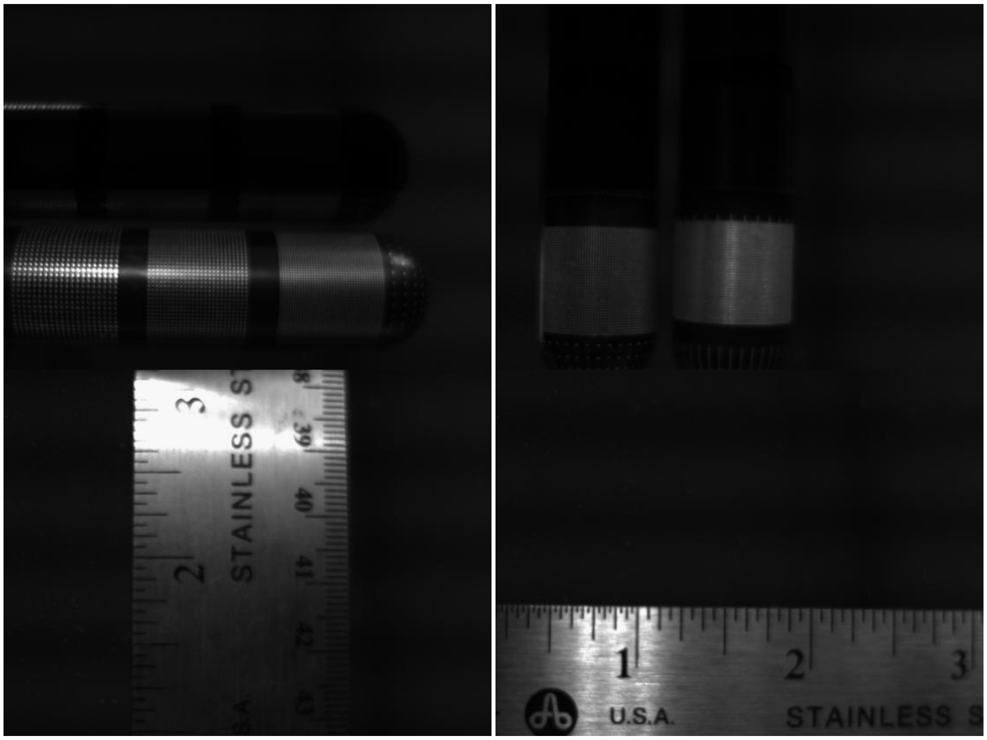

Figure 3.3.1-4 Scanner 3 Four-Slap Images

3.3.2 Evaluation Findings

The 4-slap scanner did not perform as well as the single-scanner during testing. The major issue encountered during the evaluation was lighting. The scans show a lack of uniformity in the lighting; however, the reflective qualities of the metal cylinders and ruler used caused this effect to be more pronounced. For an example of what a real scan may look like, the back-of-finger scan from Scanner 1 provides a better idea of how real fingers would be imaged (see Figure 3.3.1-1). Ambient light also causes issues with scan results. Since the 4-slap scan area is completely open and unshielded, overhead lights may cause poor scan results. In addition, the silvered mirror of the 4-slap scanner tends to require cleaning due to the scan area not being covered. It is worth noting that since the 4-slap scanner does not involve moving components or line scans, the captured images do not suffer from the same alignment, compress, or blurring issues seen in the single-finger calibration cylinder images (see Figure 3.3.2-1).

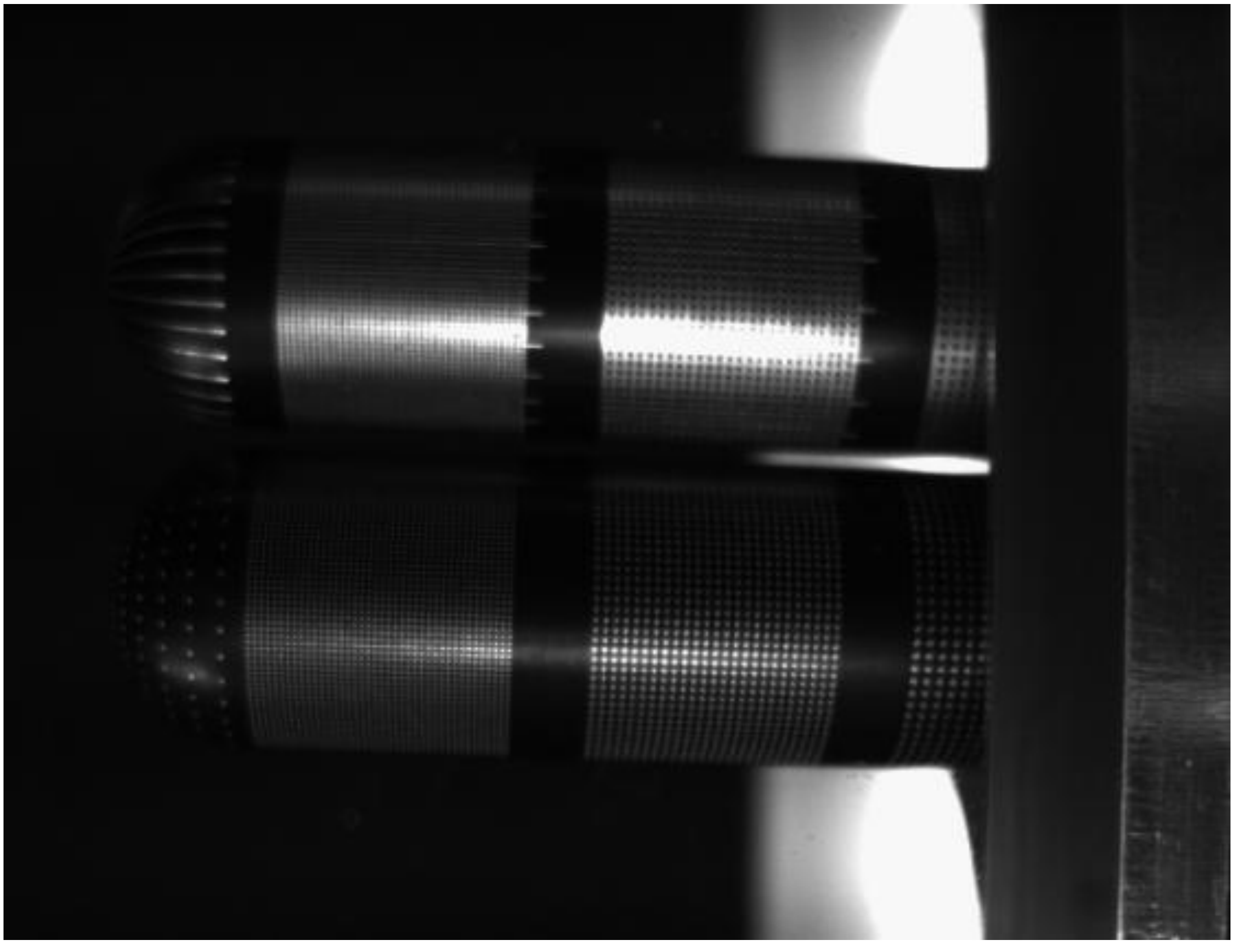

Figure 3.3.2.-1 Scanner 1 Four-Slap Image (close-up)

The first two scanners' 4-slap scan area is too small for most adults' hands to acquire a full 4-slap (Figure 3.3.1-1). Typical scans result in three fingers fully captured with a partial 4th finger. Scanner 3 fares better, but still falls short of the FBI EBTS Appendix F preferred capture sizes (Table 3.3.2-1). In examining the bitmap files produced by the scanners and aligning them with the known measurements taken of the scan area, the images appear to be 340 ppi rather than the 72 ppi stated by UML. On the topic of usability, it is unclear prior to the scan where the user's fingertips should be placed. This requires most scan attempts to be performed multiple times to get a proper scan.

Table 3.3.2-1 Four-Slap/Palm Scanner Capture Area vs. FBI Appendix F Preferred Capture Sizes

Capture Area	Inches
Scanner 1	2.31x2.12
Scanner 2	2.31x2.12
Scanner 3	3.0x2.25
Appendix F: Sequence Check	**3.2x2.0**
Appendix F: Identification Flat	**3.2x3.0**
Appendix F: Full Palm	**5.5x8.0**
Appendix F: Half Palm	**5.5x5.5**
Appendix F: Writer's Palm	**1.75x5.0**

4.0 CONCLUSION

The scanners delivered by UML provide an interesting insight into the potential utility of contactless scanners. They are most likely of use to researchers examining the effects of deformation due to pressure, matching capabilities, and contactless sensors in general. At least two of the prototypes delivered will require some adjustments to the gear assemblies and/or mirror alignments prior to further research use.

As the prototypes were delivered, the single-finger images acquired from Scanner 1 have the fewest distortions and have the best chance of being used for matching while the 4-slap scanner on Scanner 3 provides the capture area closest to those required by Appendix F. It should be noted that the NIST calibration cylinder images in this report do not currently have a direct correlation to expected match results. Some distortions in the images may be acceptable, but at present NIST has not provided methods of determining quality scores nor how minor distortions might affect those quality scores. Further examination using actual fingerprints may be warranted unless NIST calibration cylinder results can prove otherwise.

The power requirements of this scanner are important to note, as they may require additional planning prior to installation. The battery packs may provide some mobility, but currently the battery function is inoperable in both units. In addition, given the likelihood of misalignments caused by relocating the devices, the prototypes are best used in non-mobile scenarios.

The prototypes delivered are primarily stand-alone scanners. The single-finger scanner (when properly calibrated) provides full nail-to-nail rolled-equivalent fingerprints. The 4-slap capability of the scanner is somewhat less than ideal, but with proper alignment of the camera and mirror, 4-finger capture should be possible. However, as designed, the 4-slap capture window does not meet Appendix F requirements. The PC software does not appear to segment the image into individual fingerprints. Additional software development would be required to build a full collection system and enable features such as sequence checking.

Evaluation Summary: Positive Results

- Useful contactless scanner for biometric research
- Contains two methods of contactless capture – nail-to-nail single finger and fixed 4-slap
- Touch-screen controls are easy to use and intuitive
- Acceptable collection times from initializing to final image presentation

Evaluation Summary: Minor Issues

- Cable in Single-finger scan region sometimes interferes with scans
- Mirror and optics of 4-slap capture region requires regular cleaning due to open air design
- USB COM port is not engineered for standard collection (only troubleshooting)
- Some displayed software features are not for use with these devices
- Uses out-dated 802.11b wireless interface for communications
- Limited laboratory-quality software interface
- Software does not process 4-slap images (segmentation for identification or verification)

Evaluation Summary: Major Issues

Overall

- Complicated calibration procedures (gear assembly and optics)
- Sensitive to vibration and movement
- Lacks liveness detection of original prototype
- High current requirements when operated in AC mode, which complicates installation
- Too large and heavy for mobile deployments
- Cumbersome system setup (e.g., reboots, awkward wireless setup, dropped communications)
- Battery operation does not function, limiting portable operation

Single-Finger Capture

- Single-finger images contain spacing, compression, warping, and blurring artifacts due to mechanical rotation
- LEDs used in single-finger capture are too bright and represent a safety hazard to operators; no shielding or enclosure is included in the design to mitigate errant light

4-Slap Capture

- 4-slap scanner does not possess uniform lighting in scan
- Ambient light can negatively affect 4-slap image capture
- 4-slap capture area is too small to meet FBI Appendix F requirements

APPENDIX A: ACRONYMS AND ABBREVIATIONS

ACRONYM	DESCRIPTION
2D	Two Dimensional
3D	Three Dimensional
AC	Alternating Current
CFP	Contactless Fingerprint
CoE	Center of Excellence
COM	Serial Communication Port
DOJ	Department of Justice
IP	Internet Protocol
LE	Law Enforcement
LCD	Liquid Crystal Display
LED	Light Emitting Diode
NIJ	National Institute of Justice
NIST	National Institute of Standards and Technology
NLECTC	National Law Enforcement and Corrections Technology Center
PC	Personal Computer
ppi	Pixels per inch
R&D	Research and Development
SSBT	Sensor, Surveillance and Biometric Technologies
SSID	Service Set Identifier
T&E	Test and Evaluation
TTWS	Through-the-Wall Sensor
U.S.	United States
UML	University of Massachusetts Lowell
USB	Universal Serial Bus