The author(s) shown below used Federal funds provided by the U.S. Department of Justice and prepared the following final report:

Document Title: Smartphone Technology for Capturing Untreated Latent Fingerprints Feasibility Research

Author(s): Tony Warren

Document No.: 242954

Date Received: July 2013

Award Number: 2011-DN-BX-K536

This report has not been published by the U.S. Department of Justice. To provide better customer service, NCJRS has made this Federally-funded grant report available electronically.

Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

National Institute of Justice
Award No. 2011-DN-BX-K536

Project Title: **Smartphone Technology for Capturing Untreated Latent Fingerprints Feasibility Research**

PI: Tony Warren
EOIR Technologies Inc.
4312 Carr Drive
Fredericksburg, VA 22408
Telephone: (540) 834-0764
Email: twarren@eoir.com

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

ABSTRACT

In support of the FY11 Applied Research and Development in Forensic Science for Criminal Justice Purposes, the objective of the research is to determine the feasibility of using digital images of untreated latent fingerprints for identification purposes to support the original proposal of creating a portable handheld imaging device for latent fingerprints. Our methodology is to collect latent fingerprints images using common, commercially available hardware and then have those images independently evaluated to determine the validity of our approach.

Our collection methodology used photographic techniques, spectral filters, imaging devices, and various illumination sources. The research focused on two key factors:

1. The best method and tools to reliably capture useful images.
2. Whether the captured latent prints were identifiable by a latent print examiner (LPE) or Cogent's Automatic Fingerprint Identification System (AFIS).

We developed a methodology to capture untreated latent fingerprints from specific substrates at a quality-level similar to dusted latent fingerprints and established confidence that these images can be used by an AFIS or a latent print examiner for identification purposes.

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

Table of Contents

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

EXECUTIVE SUMMARY

Description of the problem

Recovering latent fingerprints is a process that typically involves the use of chemicals or powders, lifting tape, and potential transport of materials to a lab. Once recovered, the fingerprints may be examined and compared to known fingerprints to identify the individual that left them behind. This practice is mostly used to identify a person of interest that may have been involved in a crime or present at a crime scene. This method is useful when time can be allocated and powders and chemicals are readily available to use. But what happens when time is not available? What is the method to collect latent fingerprints when materials cannot be analyzed at a lab or when the collector does not want to leave traces of powders or chemicals? Is there a quick and easy method that can be implemented to collect reliable latent fingerprints?

Previous research has concluded that dusting powders and chemicals are required to capture latent fingerprints from a multitude of surfaces. These powders and chemicals provide a contrast enhancement so the user can see and capture the latent fingerprint for identification purposes. Although it is standard practice to use dusting powders or chemicals to reveal latent fingerprints, several tools do exist that allow the user to collect untreated latent fingerprint images. One of these tools require the use of a specialized viewing lens and the use of a 254nm UV light source[1]. Users of this tool have described the viewing system as cumbersome with long setup times and as being potentially harmful due to hazardous shortwave UV light emissions. Therefore, further research is needed to find a more efficient method to reduce the time and equipment required to capture untreated latent prints.

This report provides a detailed description of the feasibility research that was performed in the effort to digitally extract untreated latent fingerprints with a Canon SLR and a Smartphone camera. We examine the different uses of spectral filters and lighting techniques to further improve the image quality. Additionally, we apply our methods to different substrates, such as ceramic, glass, acrylic, duct tape, metal, and vinyl tape, to achieve proper contrast levels to produce images with discernible fingerprint ridge details.

[1] http://www.spexforensics.com/applications/category/reflective-ultra-violet-imaging-systems-ruvis

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

Purpose, Goals, and Objectives

This research was designed to address the aforementioned problems by performing a feasibility study of capturing untreated latent fingerprints quickly and reliably for identification purposes. The primary goal is to support our idea of creating a device that can image untreated latent fingerprint images and then use those images for identification purposes. To achieve this goal, several factors will have to be investigated. The factors can be summarized as:

1. Can a photograph provide enough contrast to distinguish the latent fingerprint from the substrate?
2. What is the method to use to increase the contrast between the latent fingerprint and substrate?
3. Can the images be used for identification purposes?

Research Design and Methods

The feasibility research investigates the use of different lighting sources, spectral filters, substrates, and methods to discover which tools and approach best suits the goal of obtaining a reliable latent fingerprint image without the use of powders or chemicals. Each experiment is separated into different phases of research to properly interpret how different variables affect the images of latent fingerprints.

Throughout the experiments, the latent fingerprint samples' composition and donors were kept relatively the same. All of the prints were from the same two adult male donors. The fingerprints were made using sebaceous oil from either rubbing the head area or from a reference pad. Since there is no scientific means of determining the fingerprint's age outside of a controlled setting, the age of the fingerprints were not factored into the experiment.

Over thirteen thousand photographs were taken with different combinations of light sources, spectral filters, camera settings, and camera lens to capture as a much ridge detail as possible from the latent fingerprints. Once we determined the best combination to image a latent fingerprint, we applied the method to 8 different substrates to determine how different surface textures affected the camera's ability to capture fingerprint ridge details. The substrates contained a combination of smooth, course, glossy, dull, porous, and non-porous textures. To evaluate how effective our methods were, the images were examined by a LPE as well as processed through Cogent's AFIS.

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

We began our research by attempting to photograph fluorescence from a latent fingerprint. We wanted to determine if fingerprint fluorescence would be emitted using common illuminating sources and whether it could be used to provide enough contrast between the fingerprint's ridges and substrate's background. Prior research indicated that fingerprint residue contains chemicals that produce fluorescence peaks at 330nm and 440nm when excited with a 280nm laser. We decisively selected a range of common illumination sources, ranging from ultraviolet (UV) light to Infrared (IR) light that could potentially excite the latent fingerprints to produce enough fluorescence to be photographed. We also selected a range of camera filters that would be used to filter out the incident light and transmit any fluorescence emissions that may be present.

The first two experiments began with using a standard Canon EOS 7D camera along with different combinations of camera settings, spectral filters, UV flashlights, and a variable light source. We began taking photos of latent fingerprints placed on a ceramic substrate while attempting to excite the fingerprint residue with UV flashlights and the variable light source. We used different camera settings in conjunction with different spectral filters to try to isolate and photograph as much fingerprint fluorescence as possible.

Next we experimented with other light sources and camera configurations. Photographs were taken using a ring light attachment and a light guide (also known as coaxial lighting). Both light sources provided incident light for all angles around the latent fingerprint. We also utilized a macro lens to improve the fingerprint ridge detail and to conform to the Biometric Identity Management Agency (BIMA) standard of 1000 pixels per inch (PPI) for photographing fingerprints. The images taken of the latent fingerprints improved drastically. With the improvement of the image details, we applied this method to other substrates.

Once all the images were taken with the Canon 7D camera, several images from each experiment were sent to Cogent and NFSTC to be evaluated. Each image was evaluated by a NFSTC LPE and processed through Cogent's AFIS. All the results were returned and compared to determine what method of photographing latent fingerprints produced the most effective results.

The last phase of our experiments consisted of replacing the Canon 7D camera with a Smartphone camera. The Smartphone camera lacked many of the settings and controls when compared to the Canon 7D camera. Images were taken using only the light guide and white LED ring light since

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

these light sources were shown, in the previous experiments, to provide a high amount of fingerprint ridge detail. These images were sent to NFSTC for evaluation.

Two additional experiments were performed to further test the proof of concept for imaging untreated latent fingerprints. For the first additional experiment, NFSTC provided random objects with latent fingerprints. The objective was to locate and photograph any latent prints that may have been left by an unknown person or persons. NFSTC then evaluated the images and returned the results. For the second additional experiment, several images of dusted latent fingerprints taken using the light guide and macro lens were processed through AFIS to compare the quality scores to the scores of untreated latent fingerprints.

Results

Fingerprint Fluorescence Excitation

Attempting to excite the latent fingerprint with different wavelengths of illumination did not yield enough ridge detail to be used for identification purposes. The illumination sources had a problem illuminating the whole latent fingerprint due to the angle of the incident light. The greater the angle of the incident light, the less reflected light the camera was able to capture. This problem could be corrected by tilting the camera in the opposite angle of the incident light, but this correction introduces a displacement in the apparent position of the object (parallax distortion) into the image. It also could not be determined, from the naked eye, whether any fingerprint fluorescence was produced by the illumination sources although partial fingerprint ridges could be seen in the images. Even though the fluorescence could not be determined through observation, it was observed that some of the reflected from the light sources produced some visible fingerprint ridges. We also observed that the incident light angle determined how detailed the fingerprint ridges appeared in the images.

Ring Light with Macro Lens

Changing the light source to a ring light and utilizing a macro lens dramatically increased the level of detail of the imaged latent fingerprints from non-porous substrates. On smooth textured surfaces, not only were the ridges visible but the fingerprint pores could be observed in the images.

Several images were processed and matched to known fingerprints within Cogent's AFIS. Cogent commented that the quality of our digitally extracted images on most substrates was so good that they thought they had been dusted. Most of the images achieved a high quality AFIS score of 2 or 3,

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

which indicates AFIS could correctly identify ridges, valleys, ridge details, and the image contained low background noise. NFSTC LPEs commented that the images contained discernible ridge detail.

It was also found that the ring light did not always produce a clean image. Most notably, the rough aluminum texture of the aluminum sheets used as one of the test substrates would scatter the light across the surface, which would produce an image with uneven lighting.

Light Guide with Macro Lens

To correct the uneven lighting caused by the ring light, a light guide was used in conjunction with the macro lens. The light guide was by far the best lighting for all of the non-porous surfaces. The latent fingerprints could clearly be seen and analyzed.

The images that were sent to Cogent and NFSTC for analysis returned with very high AFIS scores and the LPEs were very satisfied with the quality of the photographs.

Smartphone Images

It was quickly discovered that it was more challenging to replicate the same image quality as the Canon 7D using the smartphone. The smartphone did not contain nearly the same amount of features and controls as the Canon 7D camera. The smartphone camera sensor was not as sensitive as the Canon camera and it was difficult to get proper light exposure. Also, the smartphone does not contain the same magnification as the Canon macro lens. Artifacts and noise were found in the images and this became more apparent when the images were cropped and enhanced.

Dusted Latent Fingerprint vs. Untreated Latent Fingerprint Score Comparison

When the dusted latent fingerprints were processed through AFIS, the quality scores were on par with the quality scores of the untreated latent fingerprints using the same methodology. With an AFIS quality scale of 1-14 (1 being the highest quality), both sets of images had similar scores between 3 and 5. Both sets of images also had similar amounts of minutiae that were matched to the inked fingerprints.

NFSTC Sample Items

The images of latent fingerprints taken from the sample items provided by NFSTC were evaluated by an LPE to determine if the images contained discernible fingerprint ridges. It was determined that most of the images contained discernible fingerprint ridges. Most images were of

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

partial ridges, similar to those most likely to be collected from a crime scene. Since the origins of the fingerprints were unknown, we did not attempt to match the fingerprints through AFIS.

Conclusions

Our research has concluded that photographing untreated latent fingerprints can be a viable and non-destructive approach that could be followed up with powder or chemical treatment if required. Using the camera, light guide, and macro lens combination proved to be the best option to capture reliable and consistent latent fingerprints. Attempting to photograph fingerprint fluorescence did not prove to be very useful since, in most cases, fluorescence could not be observed in the images.

The research also concluded that the incident light angle and proper light exposure were the most important aspects of photographing latent fingerprints. The light source provided the best exposure when it was placed “in line” with the viewing angle, hence, the use of the light guide. Proper light exposure was a major factor when the image was submitted for analysis. Other than the condition of the latent fingerprint, light exposure usually determined how much fingerprint detail could be seen in the photograph. It also determined how well the image could be enhanced by software to increase the contrast between the fingerprint ridges and background. While the Canon 7D camera had various settings to control the light exposure, the smartphone used in the experiment was not able to effectively compensate for the different levels of lighting. Two disadvantages for the smartphone were lack of camera configuration settings and a small sensor size which results in poor light exposure and increased pixel noise.

We were able to show that the untreated latent fingerprint images from non-porous surfaces very similar to images of dusted fingerprints. When the images of dusted fingerprints and images of untreated fingerprints were processed through AFIS, both sets of images scored very similar to each other and resulted in matching the latent prints to a known inked print.

Latent fingerprints captured from the NFSTC sample items suggested that the camera system and methodology used during the experiments could be implemented for field use. Although most of the latent fingerprints were partial prints or smudged, fingerprint ridges were visible in the photographs and could possibly be used for investigative or identification purposes.

Overall, while not all the images taken from all the substrates produced detailed fingerprint ridges, we were able to capture latent prints from smooth, flat, non-porous substrates with third level

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

detail, the highest level achievable. Other images from textured, flat, non-porous substrates produced latent fingerprints with second level detail. Our research determined that even though imaging untreated latent fingerprints has limitations, it can be used as a viable substitute to dusting when dusting is not a necessity and the ridge details can be captured and examined using the techniques and procedures developed within this research.

Further research into smartphone technology would prove to be useful in determining the best available options to improve the image quality of untreated latent fingerprints. Larger camera sensors, improved camera settings, and improved lighting options would result in the same image quality as those captured with the Canon 7D camera. It would also result in a further improvement on the portability and compactness of the overall imaging system.

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

1 INTRODUCTION

The most common methods for retrieving latent fingerprints from non-porous materials are with the use of a dusting powder, chemical compounds, or cyanoacrylate fuming. All these methods require some type of contact with the fingerprint residue such as dusting with powder or chemically enhancing the latent fingerprint. These methods can be time consuming and can lead to problems if not performed correctly. Fingerprint dusting can be messy and over dusting or smudging can take place, rendering the latent print useless. Chemical compounds and cyanoacrylate fuming takes time and usually cannot be implemented at the crime scene.

Our goal is to test the feasibility of retrieving latent fingerprints without the use of powders or chemicals. This method must be able to capture the latent fingerprint with a high degree of reliability and quality so that it can be used for identification purposes.

The main problem with imaging a latent fingerprint is the lack of contrast between the fingerprint ridges and its background. This problem leads to the use of chemicals or powders to increase the visibility of the latent fingerprint. This concept is what stimulates this research to develop a product or to implement a technique that solves the problem of imaging untreated latent fingerprints.

This research encompasses an array of variables and methods that will be tested to determine optimal settings for taking images of untreated latent fingerprints. Those variables and methods will include:

1. The use of different light sources
2. The use of different imaging devices
3. The use of different camera lenses
4. The use of camera filters
5. Various camera settings
6. The use of various substrates
7. The ability to capture fingerprint fluorescence

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

2 MATERIALS AND METHODS

Our approach to be successful with imaging untreated latent fingerprints would require finding a set of tools and techniques that would enhance the ridges of the latent fingerprint as much as possible and have the ability to photograph the enhancement at an acceptable quality. The following tools and methods were utilized to discover how a user would be able to retrieve a latent fingerprint without having to use powder or chemicals.

Illumination Devices

Past research suggests that specific light wavelengths are able to excite the chemical compounds found in fingerprint residue. These excited chemical compounds release specific wavelengths of light, known as fluorescence, which then can be used to assist in the identification of significant fingerprint details. We collected a number of illumination devices to use on latent fingerprints for the purpose of observing and photographing the fingerprint fluorescence. We also utilized several white light sources that provided different methods of incident lighting. The following list details our illumination devices.

1. LED Flashlights (Each flashlight's center wavelength is listed below)
   - 9 LED UV flashlights (365nm, 375nm, 385nm, 400nm)
   - Inova 5 LED Blue flashlight (470nm)
   - 12 LED UV flashlight (395nm)

365nm 375nm 385nm 395nm 400nm 470nm

2. Omnichrome Variable Light Source
   - Weight: 28 pounds (12.7 Kg);
   - Dimensions: 8" x 14 1/2" x 17" (20.3 cm x 36.9 cm x 43.2 cm);
   - 300-Watt Xenon lamp
   - 6-foot (1.8 m) liquid light guide
   - 6-foot (1.8 m) fiber optic cable
   - Internal Filter Wheel with:

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

  - 300 to 400 UV filter
  - 485 nm filter
  - 450 nm filter
  - 570 nm filter
  - 700 to 1100 nm IR filter
  - 400 to 530 nm Broad band filter
- Continuous Wavelength Selection: 300 to 750 nm (selectable in increments of one nanometer)
- Continuous Bandwidth Adjustment: 20 to 100 nm (selectable in increments of one nanometer)

3. Digi-Slave Ultra II Camera Ring Light (White LED Light)
   - 24 oversized, super-bright LEDs (up to 12W)
   - Full- or half-light capability
   - Variable-power dial

4. Light Guide (Episcopic Coaxial Illuminator)
   - 5 high power white LEDs (1A each)

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

Imaging Devices

Several imaging devices with different specifications were chosen so the images from each device could be compared to determine the level of quality needed for photographing latent fingerprints.

1. Canon EOS 7D (Standard)

   (See Appendix H for camera specifications)

2. Modified Canon EOS 7D (Internal UV/IR filter removed)

   (See Appendix H for camera specifications)

3. Droid X Smartphone

   (See Appendix I for smartphone specifications)

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

Camera Lenses

Certain camera lens were chosen to vary the distances of the imaging device from the latent fingerprint to determine if there is an optimal distance that is required to capture the latent fingerprint ridge detail. The following lenses were used to photograph latent fingerprints:

1. Canon EF-S 18-55mm Lens
   (See Appendix J for camera lens specifications)

2. Canon 60mm Macro Lens
   (See Appendix J for camera lens specifications)

Spectral Filters

An important aspect of photography is the imaging device's ability to capture the reflected light from the object being photographed. There are many techniques and devices used to enhance the reflected lighting. We chose to focus on specific spectral filters in an attempt to capture certain wavelengths of light being projected from the untreated latent fingerprint. The spectral filters shown below will capture the characteristics of light being emitted from the fingerprint.

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

1. Spectral Blocking and Passing Filters

   (See Appendix K for spectral filters specifications)

IR Passing Filter

UV Passing Filter

IR Blocking Filter

UV/IR Blocking Filter

2. Colored Filters

   (See Appendix K for spectral filters specifications)

Green Filter

Orange Filter

Blue Filter

Red Filter

Yellow Filter

Background Substrates

Much like how the type of substrate the latent fingerprint is imprinted on determines how the crime scene investigator will collect the fingerprint, the type of substrate will determine whether the latent fingerprint can or cannot be collected through photography. Our research includes photographing latent fingerprints from eight substrates (Figure 1) to determine how porosity and reflectivity of the substrate influence the quality of the latent fingerprint images.

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

Shown below are the substrates that were used to deposit and subsequently photograph latent fingerprints (Figure 1). Four types of the same fingerprints were used for each substrate. Each quadrant on the substrates contained one of the specific types of fingerprint. (Figure 2) illustrates which quadrant was used for each of the fingerprints.

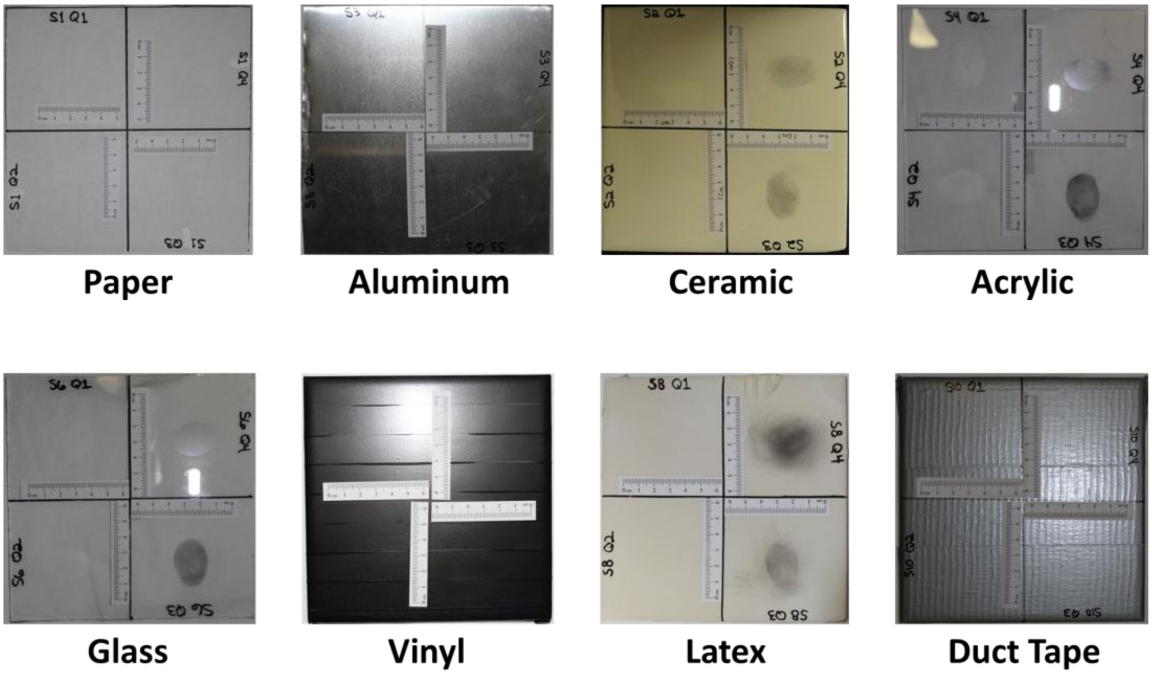


Figure 1: Substrates

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

Quadrant 1 (Q1): Latent fingerprint.

Quadrant 2 (Q2): Oily latent fingerprint.

Quadrant 3 (Q3): Latent fingerprint dusted with black fluorescent powder.

Quadrant 4 (Q4): Latent fingerprint dusted with normal black powder.

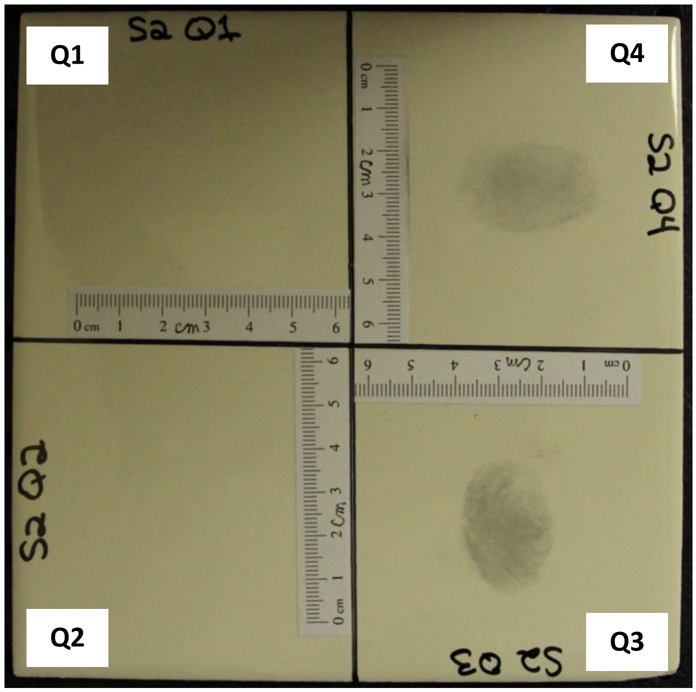


Figure 2: Four quadrants of each substrate

The fingerprints in quadrants 1 and 2 are used to determine how the amount of fingerprint residue affects the latent print's image. Quadrant 1 latent prints were placed by first wiping the fingertip with a cloth to reduce any excess sebum. Quadrant 2 latent print was placed by first wiping the fingertip across the forehead or neck area to create excess sebum. Quadrants 3 and 4 serve as a gauge to compare the level of detail between the images of the untreated latent fingerprints and images of the dusted fingerprints. All the fingerprints were gathered from the same middle-aged male donor. The fingerprints were not aged prior to examination.

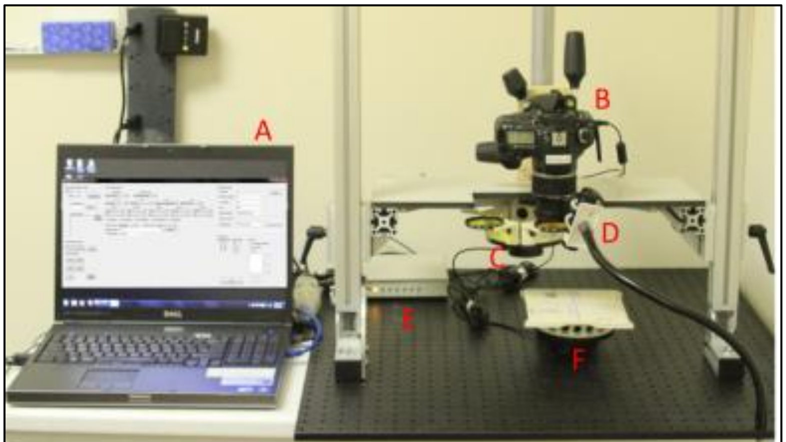
Test Bench Development

Since a large number of images would be collected during the research, a test bench was developed to facilitate this process. The test bench allows for a more efficient and consistent

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

photography process. The variables can be easily controlled and the images remain more precise than attempting to manually change and configure all the variables while trying to capture a large number of photographs.

The test bench in Figure 3 was developed in two stages. First stage included all the physical aspects of the test bench such as length, width and height of the platform, mounts for the light source, substrate, spectral filters and imaging devices, and an automated rotary controller to interchange which spectral filters and substrate quadrants will be used for the photograph.



A. Laptop w/ controller software
B. Imaging Device (Canon 7D modified)
C. Rotary Positioner w/ colored filter attachment
D. Light Source
E. Rotary Positioner Switchbox
F. Rotary Positioner w/ sample plate

Figure 3: Test bench setup

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

The second stage was used to develop the software (Figure 4) to control the imaging device and automated controller. The software controls the settings on the imaging device as well as which spectral filter and substrate quadrant to use for the photograph. A series of photographs can easily be taken by predefining which variables the user wants to include in the images.

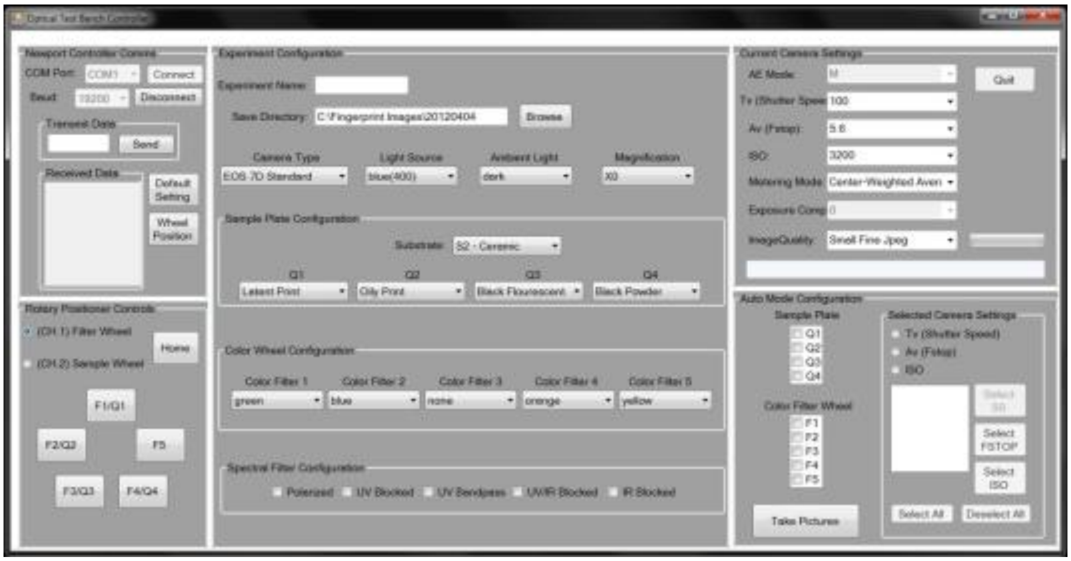


Figure 4: Software user interface

Phases of Research and Trials

During the research, there were a number of experiments conducted to determine the best approach to imaging latent fingerprints. These experiments were divided into phases and each phase served as a building block for the next phase. Once we confirmed our approach was successful and the image results were repeatable, we carried out a trial with items sent from NFTSC to determine how our techniques would favor in the field. Described below are the research phases and trials that were performed.

Phase 1 (UV Light Excitation)

The first phase consisted of trying to excite the latent fingerprint with the UV flashlights in an attempt to determine if residues in the fingerprint will emit any fluorescence. Over five thousand photographs were taken with a multitude of camera settings, spectral filters, and UV light sources to determine if any fingerprint fluorescence could be captured in the image and if so, to what extent does the fluorescence enhance the fingerprint's ridges. The results are detailed in section 3.

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

Phase 2 (Visible Light Excitation)

The second phase was an extension of phase 1. Instead of using the UV flashlights, we used a variable light source which allowed us to vary the light wavelength within the visible light range. We attempted to excite the latent fingerprint with the variable light source to determine if the fingerprint would fluoresce within a specific visible light wavelength. The light wavelength was increased from 425nm to 700nm with 25nm steps in between. Within each step, multiple images were taken using various spectral filters and camera settings in an attempt to capture any fluorescence that may have been emitting from the fingerprint. The results are detailed in section 3.

Phase 3 (LED Ring Light with Macro Lens)

The third phase consisted of capturing as much reflected light from the latent fingerprint as possible. To do so, we incorporated a LED ring light onto the camera. The ring light projected white light around the entire fingerprint. We changed the camera lens to a macro lens, allowing us to get closer to the latent print and photograph more detail. This combination dramatically increased the visibility and contrast of the fingerprint ridges. More detail could be seen in the fingerprint ridges and this made enhancing the image with software much easier. With the increase in image quality, we requested NFSTC's LPEs to examine these images to get a professional evaluation. The results are detailed in section 3.

Phase 4 (Coaxial Light Guide with Macro Lens)

Phase 4 was an improvement on phase 3. Through visible inspection of the images from phase 3, there were some lighting inconsistencies such as intense spots caused by reflections off of the highly reflective substrates and a dark void in the middle of the latent fingerprint photographs due to the circular light pattern from the ring light. To solve these issues, we implemented a coaxial light guide which projects a diffused light onto the fingerprint. This light source removes the bright reflective spots and produces even lighting across the entire image. More photos were taken using the various substrates and these were submitted to NFSTC as well as Cogent for their expert evaluations. The results are detailed in section 3.

Phase 5 (Untreated and Dusted Fingerprint Image Comparison)

We compared our latest advancement of untreated latent fingerprint images to those images of dusted latent fingerprints. Rather than visually comparing the images, we wanted to quantify how our

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

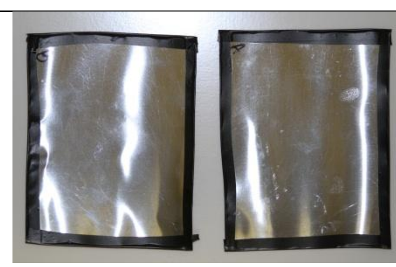
untreated latent fingerprint images compared to the dusted latent fingerprint images. Images of dusted fingerprints were processed by Cogent's AFIS to acquire their image quality score and matching confidence score. These scores were compared to the untreated fingerprint scores to determine their similarities and differences. The results are detailed in section 3.

Phase 6 (Smartphone Images)

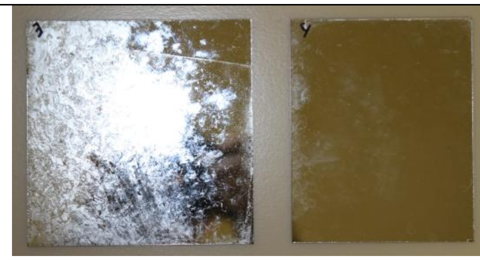
We used the same methodology from phase 4 and phase 5 except the Canon camera was replaced with a Droid X smartphone. Since the smartphone did not allow for a lens attachment, no additional lens or spectral filter were used. Two sets of images were taken from four different substrates. One set was taken using the ring light and the other set was taken using the light guide. Since the smartphone camera had very limited controls, the camera was set to its automatic shooting condition. As expected, the lack of smartphone controls limits the quality of images that would be comparable to those collected with the Canon 7D camera.

Phase 7 (NFSTC Sample items)

To test how our methodology might be applied in the field, NFSTC sent us random objects with latent fingerprints that would be commonly found at a crime scene or area of interest. Our goal was to locate and photograph the latent prints using our equipment and techniques and then have those images critiqued by a LPE. Listed below are the items that were used in this trial. The images and evaluations are detailed in section 3.

Substrate	Overall Image
Aluminum Sheets	
Plastic Cases	

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

Substrate	Overall Image
Simulated Improvised Explosive Device	
Mirrors	
Plastic Sheets	
Bullet Casings	
Wooden Block	

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

Substrate	Overall Image
Plastic Zip Ties	

Table 1: Images of sample substrates

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

3 RESULTS

Our research has undergone several phases. Each phase included the adjustment of several variables in order to improve the quality of the latent fingerprint images as well as coordinating with NFSTC and Cogent for their expert evaluations. The result from each phase is detailed below.

Phase 1 - UV Light Excitation

This phase of research was to determine whether fingerprint fluorescence could be excited from within the 365nm - 470nm UV light range using standard UV light flashlights. While over five thousand images were taken using multiple variables, the best results are shown in Appendix A. The photographs were taken from a ceramic substrate using the standard Canon 7D camera. The images include the use of different spectral filters, camera settings, and light sources.

After reviewing the images taken with the LED UV flashlights, we concluded the camera did not capture enough fluorescence from the latent fingerprints. The latent fingerprint ridges are only made visible by the reflection from the flashlights. This may be due to either one or a combination of the filters not inability to isolate the suggested optimal fluorescence spectrum peaks of 330 nm and 440 nm or the difference between the excitation emissions and fluorescence emissions was not large enough to distinguish between them (Stokes shift).

We also observed that there wasn't enough contrast between the fingerprint ridges and background. As seen in Table 2, the ridges do not contain enough detail and most of the ridges are missing from the image.

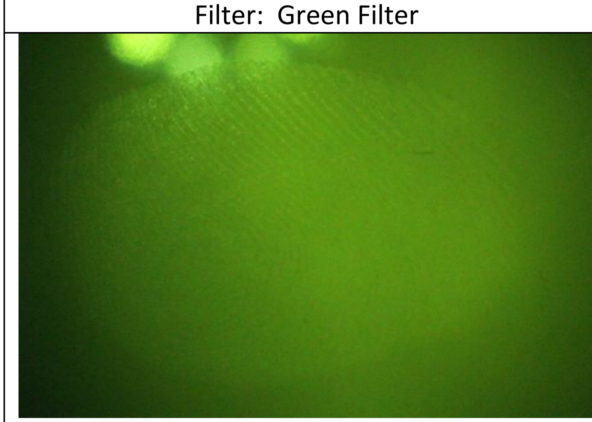
Original Image Excitation Wavelength: 395 nm Filter: Green Filter	Enhanced Image
	

Table 2: LED UV light source image enhancement

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

Phase 2 - Visible Light Excitation

In a further effort to capture fingerprint fluorescence, a tunable light was utilized to excite the fingerprint residue. Multiple spectral filters and various camera settings combined with a wider range of light sources were tested to find if any fluorescence existed in any of the visible light wavelengths. All the images were also compared to each other to determine whether the latent fingerprint's contrast appeared more defined under a specific light wavelength due to any fluorescence that may have appeared. Appendix B displays the best images captured using various camera settings, colored filters, and visible light wavelengths. Since we did not know the exact composition of the latent fingerprint or whether the fingerprints would be contaminated during the experiments, we used various light wavelengths to try to observe other elements that may possibly fluoresce at longer wavelengths.

After reviewing the images taken using the tunable light source, latent fingerprint fluorescence could not be seen in the captured images Table 3. The level of detail in the images remained the same as the previous phase of research and did not improve. It is very possible that the excitation wavelengths were longer than the fluorescence emission wavelengths, in which case they would have interfered with any emissions from the fingerprint.

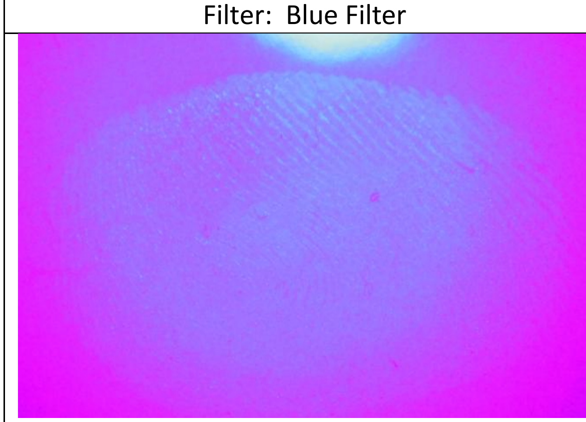
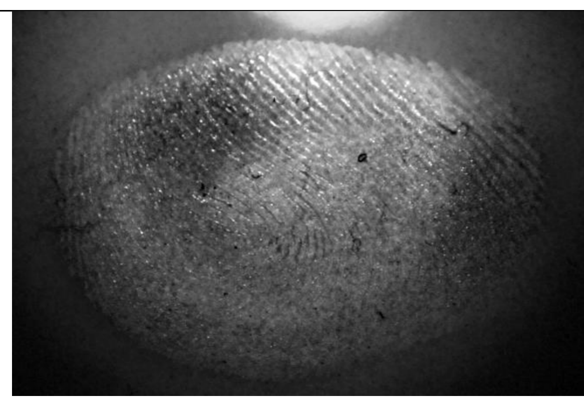
Original Image Excitation Wavelength: 425 nm Filter: Blue Filter	Enhanced Image
	

Table 3: Tunable light source image enhancement

Phase 3 - LED Ring Light with Macro Lens

This phase of research involved improving the contrast between the substrate and latent fingerprint ridges by capturing as much of the reflected light from the fingerprint residue as possible This led us to incorporate a ring light, which provided lighting from all angles of the latent fingerprint, and a macro lens to increase the reproduction ratio. This combination greatly improved the detail of the

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

latent fingerprint without the use of any spectral filters or the attempt to capture fingerprint fluorescence. We also tested this method using both the standard Canon 7D camera and the modified Canon 7D camera. The camera settings (ISO, shutter speed, aperture) were adjusted based on the intensity of the light to provide the best amount of exposure. For this phase, we focused on imaging only the normal latent fingerprints since there wasn't a simple way to quantify the distribution of oil on a fingerprint. Eight images captured using the standard camera and eight images captured using the modified camera were sent to NFSTC for evaluation. A comparison of the captured images to the enhanced images are shown in Appendix C. Included in the comparison are the LPE's description about the quality of the images.

The evaluation from NFSTC yielded favorable results from most of the substrates. Ridge details were discernible and the images contained low ISO noise. Because the ring light is very bright, the camera sensor sensitivity (ISO) could be reduced to its minimum thus reducing pixel noise. Some common faults with the ring light were intense specular reflections and uneven lighting over the latent fingerprint.

Phase 4 - Light Guide with Macro Lens

This phase of research improved the lighting condition by replacing the LED ring light with a light guide. The light guide projects diffused lighting directly on top of the latent fingerprint via a beam splitter (Figure 5). This further improves the contrast of the fingerprint by evenly highlighting the ridges of the entire fingerprint and, in some instances, providing a backlighting effect when used with highly reflective substrates. This backlighting affect causes the fingerprint ridges to appear darker than the background. Using the same substrates from the phase 3 ring light research, eight images were once again captured with the standard camera and eight images were captured with the modified camera. All sixteen images were sent to NFSTC for evaluation. Six of the NFSTC enhanced images were sent to Cogent to be processed through their AFIS.

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

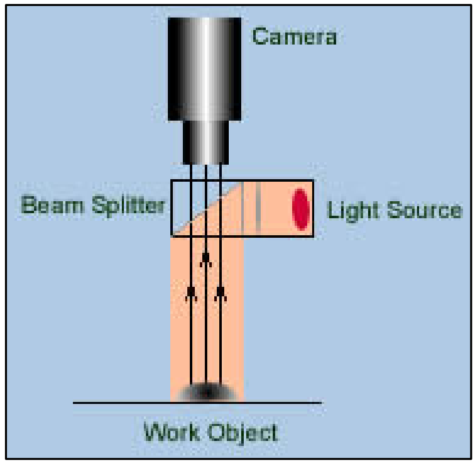


Figure 5: Coaxial Light Guide

NFSTC evaluated the images by first enhancing the original images to a black and white photo and then using filters to increase the contrast of the fingerprint ridges. Appendix D shows the comparison between the captured images and enhanced images from NFSTC as well as any quality differences between the standard camera and modified camera. The LPE's comments are also included to reflect the quality of the images.

The use of the light guide provided a greater amount of detail than did the ring light. With the light source diffused over the entire latent print, more reflected light from the latent fingerprint ridges could be captured and seen in the photographs. A visual inspection also suggests that the fingerprint ridges appeared more pronounced when capturing photographs using the modified camera instead of the standard camera. The light guide's light intensity was lower than that of the LED ring light. To maintain the proper image exposure, we had to slightly increase the camera's ISO which increased the pixel noise in the photographs.

Cogent processed our images through AFIS which provided us with two different evaluations. The first evaluation illustrated that our images could be reliably processed through AFIS and matched to a known fingerprint. The second evaluation determined the modified camera performed better than the standard camera, as indicated by the higher confidence scores and higher quality scores. The AFIS results between the Canon cameras from the ceramic, duct tape, and metal substrates are shown in Appendix D.

The AFIS assessments illustrate the minutiae that were found on the latent fingerprint image and details which minutiae were matched to the known fingerprint. Most of the images were able to achieve a high quality score of 2 or 3 which indicates AFIS could correctly identify ridges, valleys, and

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

ridge details, and the image contained a minimal amount of background noise. All but one of the matched images had a high confidence score which indicates AFIS, with a high degree of accuracy, was able to match the likely known fingerprint to the latent fingerprint.

Figure 17 in Appendix D illustrates that AFIS can still extract minutiae from a poorly photographed latent fingerprint. Unfortunately, due to the lack of minutiae points found in this latent fingerprint, AFIS could not match the latent fingerprint to a known fingerprint.

Phase 5 - Dusted Fingerprint Comparison

Images of dusted latent fingerprints were collected and compared to the images collected in phase 4. The goal was to determine if there was a significant quality difference between the images. From the results shown in Appendix E, the quality scores and minutiae found were very similar to one another. Most of the quality scores from both sets of the images ranged from 3 to 5. AFIS also discovered a significant amount of minutiae from most of the images.

As seen before, the smooth substrates contained better detail than the textured substrates. While the images of the latent prints from textured substrates fared better when dusted with black powder, the untreated prints still contained enough minutiae to make a favorable match to a known inked fingerprint.

Phase 6 - Smartphone Images

NFSTC evaluated the images of untreated latent fingerprints captured using a Droid X smartphone. Since the smartphone does not contain the same camera settings found on a Canon 7D, we were not able to control the ISO noise in the photographs. Also the smartphone does not contain a mount for a macro lens so no special lenses were used.

After NFSTC enhanced the photos, most of them contained high ISO noise and improper light exposure, which was due to a smaller camera sensor and not being able to adjust for the brightness of the light source. Although the images were not as precise as the images from the Canon 7D camera, visible ridges could be seen within most of the photographs. The light guide light source still produced the best images even though the images were underexposed. The images using the ring light were overexposed and contained the same uneven lighting pattern as seen earlier using the Canon 7D camera. Overall, the images, shown in Appendix F, did contain visible fingerprint ridges that could be used for identification purposes.

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

Phase 7: NFSTC Sample Items

The results shown in Appendix G demonstrate that commercial equipment combined with our techniques have the ability to capture acceptable images of untreated latent fingerprints. The images were captured using the coaxial light guide and modified Canon 7D camera. Most of the images are of partial latent fingerprints, which would typically be seen at a crime scene or place of interest. Based on the comments provided by the LPE, we were successful in capturing latent fingerprints from objects that could be potentially analyzed for latent prints.

4 CONCLUSIONS

Based on our research, photographing untreated latent fingerprints can be reliably used in conjunction with treatments such as powdering but may also have applications outside of crime scene investigations. Using the camera, coaxial light guide, and macro lens combination proved to be the best option to capture reliable and consistent latent fingerprints on smooth, shiny non-porous substrates. Attempting to photograph fingerprint fluorescence did not prove to be useful and, in most cases, fluorescence could not be observed in the images.

The research also concluded that the incident light angle and proper light exposure were the most important aspects of photographing latent fingerprints. The light source provided the best exposure when it was placed "in line" with the viewing angle, hence, the use of the coaxial light guide. Proper light exposure was a major factor when the image was submitted for analysis. Other than the condition of the latent fingerprint, light exposure usually determined how much fingerprint detail could be seen in the photograph. It also determined how well the image could be enhanced by software to increase the contrast between the fingerprint ridges and background. While the Canon 7D camera had various settings to control the light exposure, the smartphone used in the experiment was not able to effectively compensate for the different levels of lighting. Two disadvantages for the smartphone were lack of camera configuration settings and a small sensor size, which results in poor light exposure and increased pixel noise.

We were able to show that the untreated latent fingerprint images were of similar quality to images of dusted fingerprints taken from the same non-porous substrates. When the images of dusted fingerprints and images of untreated fingerprints were processed through AFIS, both sets of images scored very similar to each other and could be matched to a known inked print.

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

Latent fingerprints captured from the NFSTC sample items proved that the camera system and methodology used during the experiments could be implemented for field use. Although most of the latent fingerprints were partial prints or smudged, some of the images were suitable for analysis and identification purposes.

Overall, while not all the images taken from all the substrates produced detailed fingerprint ridges, we were able to capture latent prints from smooth, flat, non-porous substrates with third level detail, the highest level achievable. Other images from textured, flat, non-porous substrates produced latent fingerprints with second level detail. We believe that we were able to show how further development for our originally proposed project could lead to a portable product for photographing untreated latent fingerprints.

Further research into smartphone technology would prove to be useful in determining the best available options to improve the image quality of untreated latent fingerprints. Larger camera sensors, improved camera settings, and improved lighting options might result in similar image quality as those captured with the Canon 7D camera. It would also result in a further improvement in the portability and compactness of the overall imaging system.

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

5 REFERENCES

Yamashita, Brian, and Mike French

2011 Latent Print Development. The Fingerprint Sourcebook: 7-28, 7-29. Rockville, MD.

Vanderkolk, John R.

2011 Examination Process. The Fingerprint Sourcebook: 9-8, 9-9. Rockville, MD.

"CSI: X-Ray Fingerprints", *Sciencedaily.com*, Science Daily, 1 Dec. 2006. Web. Mar. 2012.

"How does fingerprint powder work?", *scientificamerican.com*, Scientific American, 2 Sept. 2002. Web. Mar. 2012.

Worley, Christopher G., Sara S. Wiltshire, Thomasin C. Miller, George J. Havrilla, and Vahid Majidi. "Detection of Visible and Latent Fingerprints By Micro-X-Ray Fluorescence". International Centre for Diffraction Data (2006): 363-368. Print.

May, Robert F. "Photography of Latent Prints Utilizing Transmitted Light". Forensic Science Training Unit FBI Academy.

Berg, Erik. "Digital Enhancement and Transmission of Latent Prints Who Will Set The Standards?". *Scafo.org*. Southern California Association of Fingerprint Officers, July 1996. Web. Mar. 2012.

Branwyn, Gareth. "Forensics Lab 8.0: Revealing Latent Fingerprints – Introduction". *blog.makezine.com*. Make:. 16 Aug. 2009. Web. Mar. 2012.

McManigal, Paul. "Crime Scene Investigation: Latent Print Photography". *helium.com*. Helium. 12 Mar. 2007. Web. Mar. 2012.

Richards, Austin Dr. "Reflected Ultraviolet Imaging for Forensics Applications". *company7.com*. Company Seven. 28 Mar. 2010. Web. Mar. 2012.

"SceneScope Advance RUVIS UV Imager". *crimescope.com*. SPEX Forensics. Web. Mar. 2012.

Allman, Robert Jr. "Imaging of Fingerprints". *wavesignal.com*. Web. Mar. 2012.

Akiba, Norimitsu Ph.D, Naoki Saitoh, Kenro Kuroki Ph.D. Fluorescence Spectra and Images of Latent Fingerprints Excited with a Tunable Laser in the Ultraviolet Region. Journal of Forensic Sciences, September 2007, Vol. 52, No. 5. 1103-1106.

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

Bullock, K.M., J.S. Harris, P.L. Laturnus. Use Of A Simple Coaxial Lighting System To Enhance Fingerprint And Handwriting Evidence. Canadian Society of Forensic Science Journal 1994, Vol. 27, No. 2. 69-80.

Pfister, R. The Optical Revelation of Latent Fingerprints. Fingerprint World 1985: 10(39): 64-70.

S.S. Lin, K.M. Yemlyanov, E.N. Pugh, Jr., and N. Engheta. Polarization-based and specular –reflection-based noncontact latent fingerprint imaging and lifting. Canadian Society of Forensic Science Journal 2006, Vol. 23, No. 9. 2137-2153.

6 DISSEMINATION OF RESEARCH FINDINGS

Warren, Tony, and Mark Pesses, PhD

Untreated Latent Fingerprint Imaging Feasibility Research. Presented at the 2012 NIJ Conference General Science Poster and Networking Session, Arlington, VA, June 19.

Richard Robison, Director, EOIR Intelligence Analysis Division

Results presented during the Stockton Police Department "Latent Print Project Using Mobile Identification" Conference, Stockton, CA October 24, 2012.

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

Appendix A. **Images Collected from Phase 1 (UV Light Excitation)**

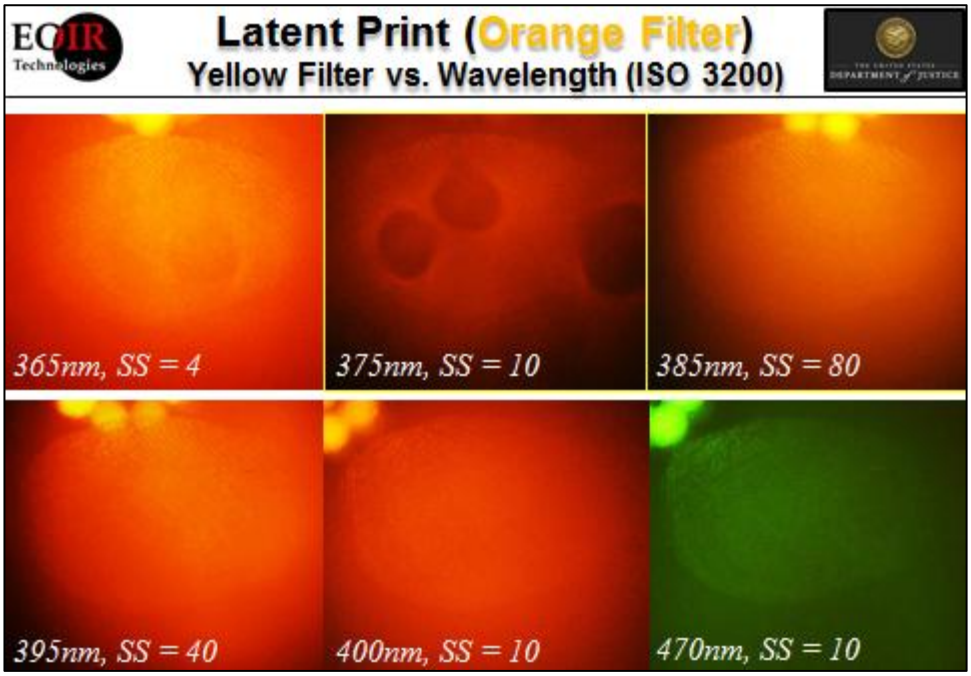


Figure 6: Images of a latent print using the orange camera filter and various camera settings

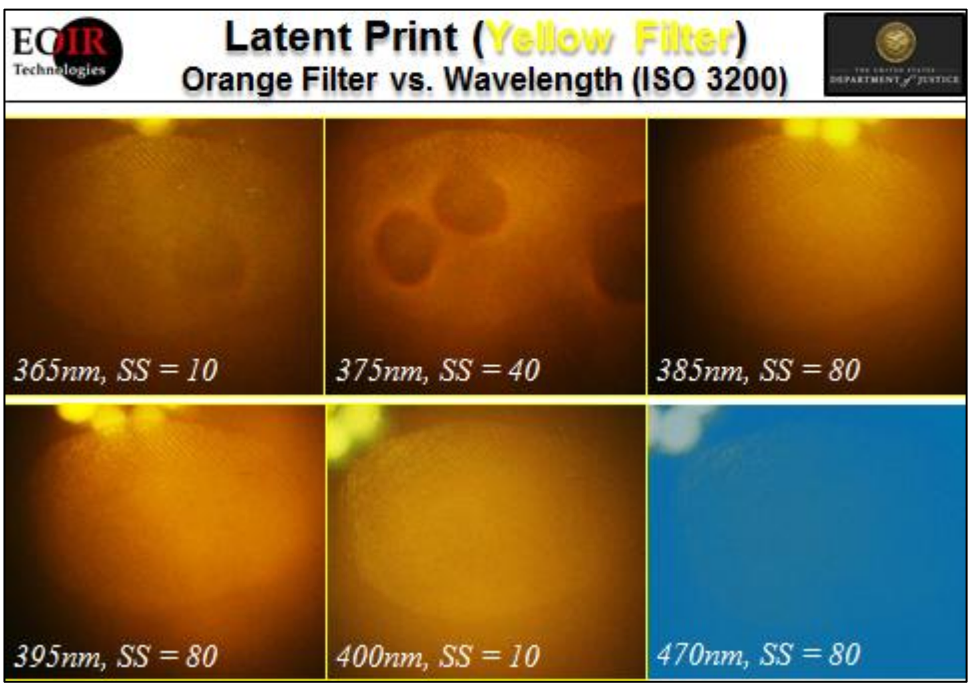


Figure 7: Images of a latent print using the yellow camera filter and various camera settings

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

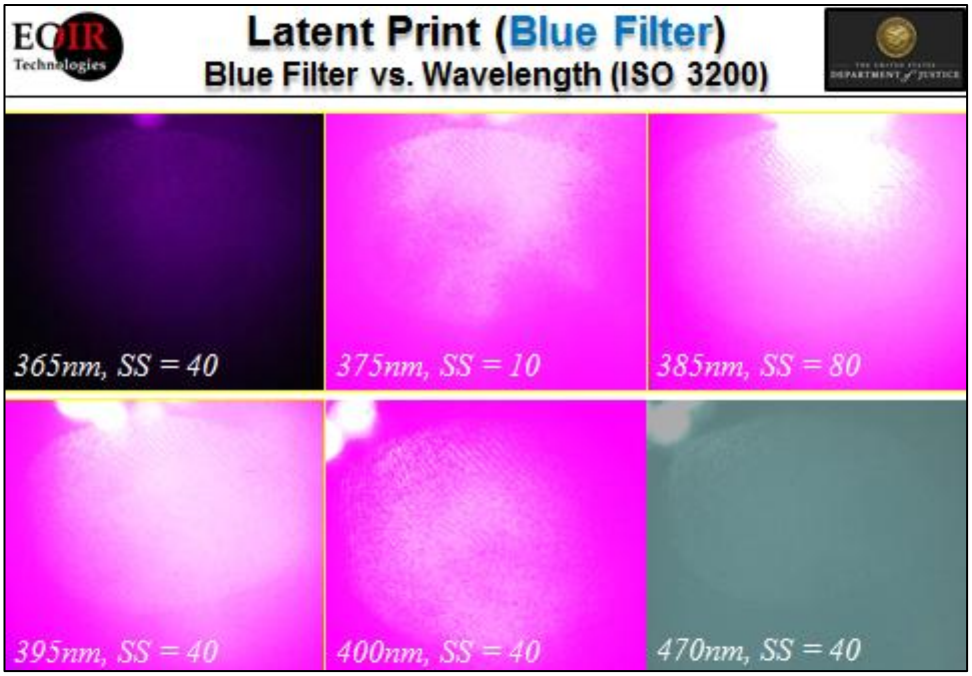


Figure 8: Images of a latent print using the blue camera filter and various camera settings

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

Appendix B. Images Collected from Phase 2 (Visible Light Excitation)

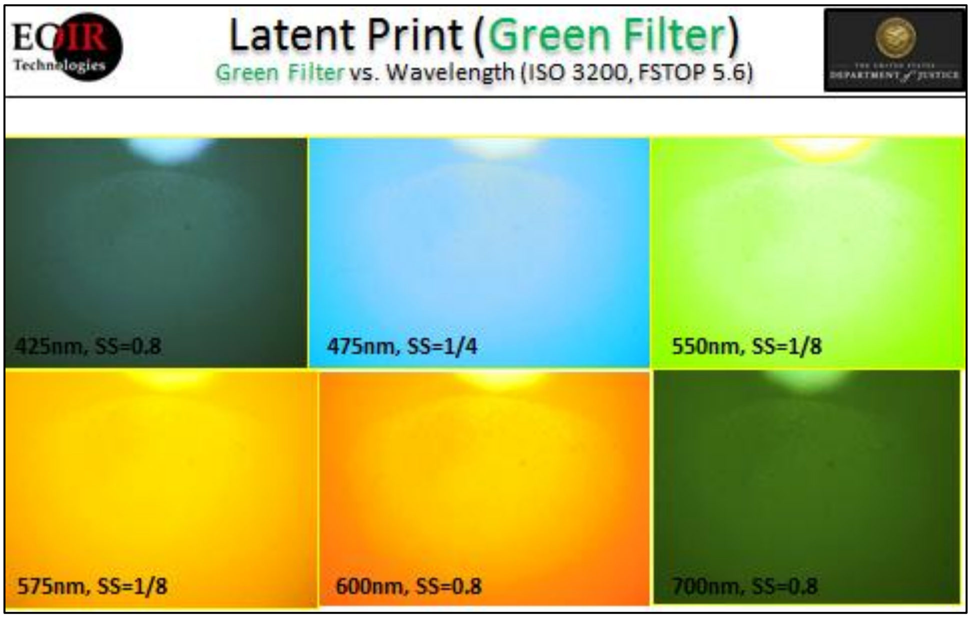


Figure 9: Images of a latent print using a green filter at specific wavelengths

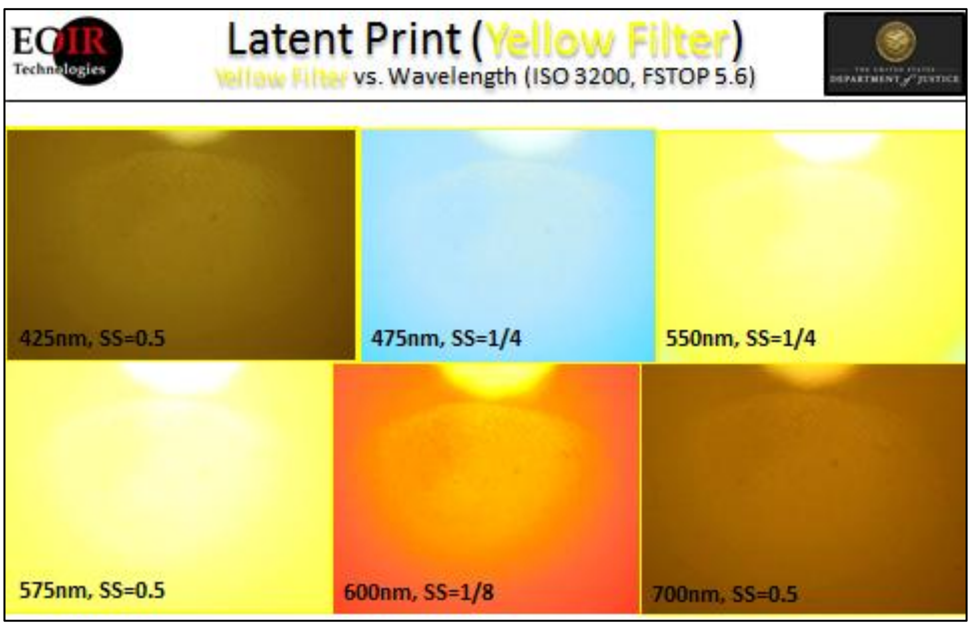


Figure 10: Images of a latent print using a yellow filter at specific wavelengths

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

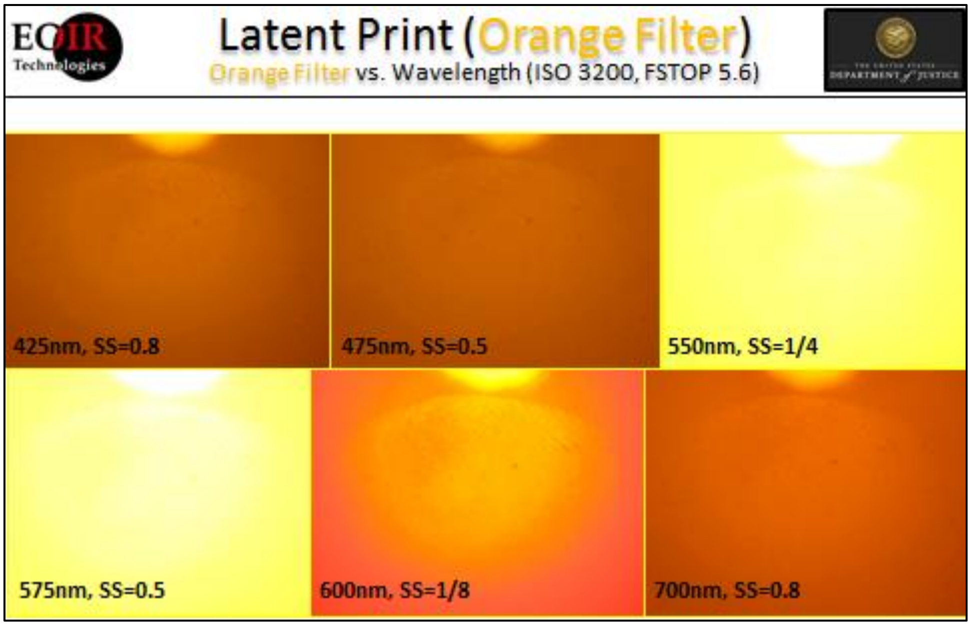


Figure 11: Images of a latent print using an orange filter at specific wavelengths

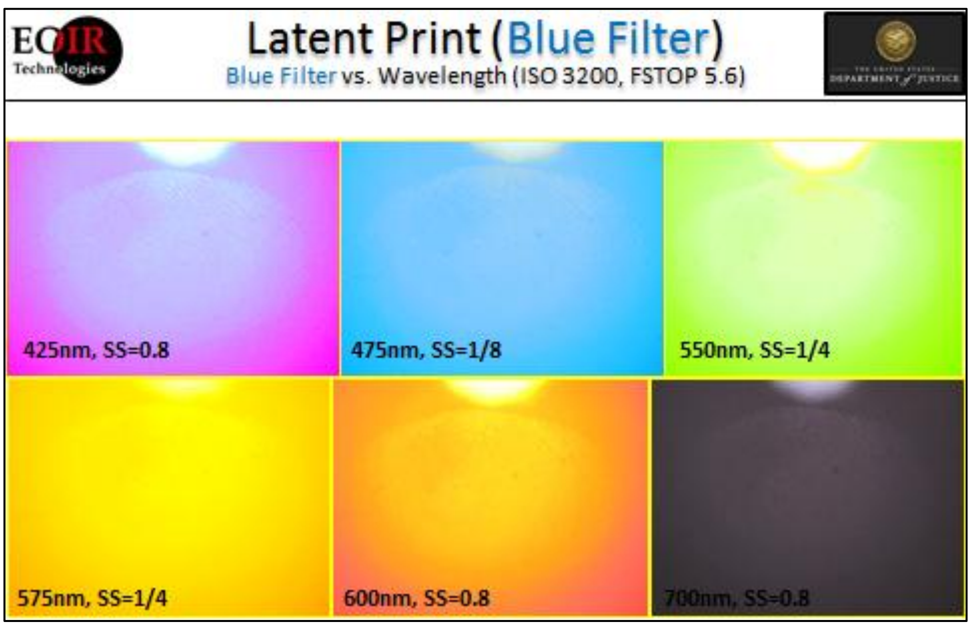


Figure 12: Images of a latent print using a blue filter at specific wavelengths

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

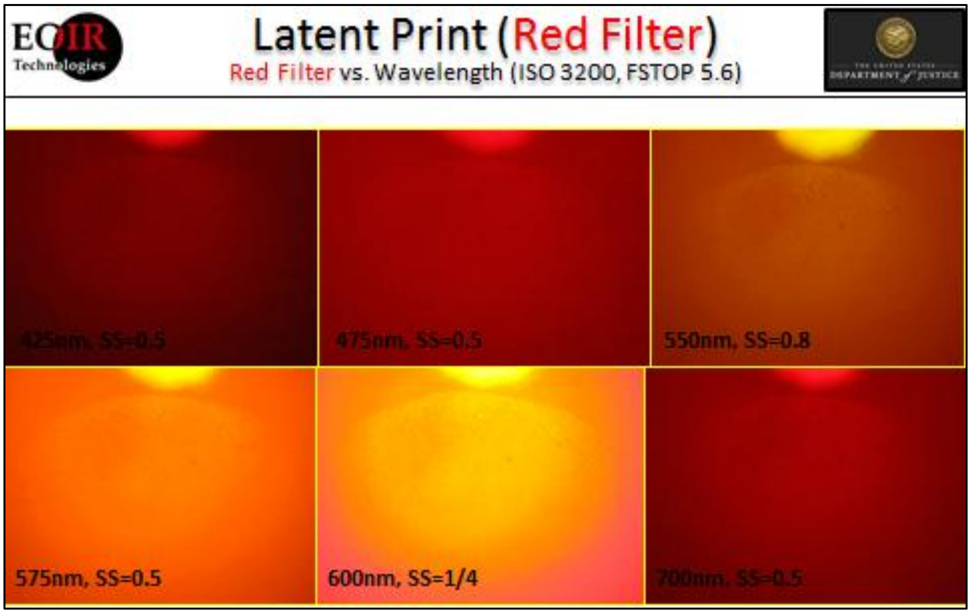


Figure 13: Images of a latent print using a red filter at specific wavelengths

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

Appendix C. Images Collected from Phase 3 (LED Ring Light with Macro Lens)

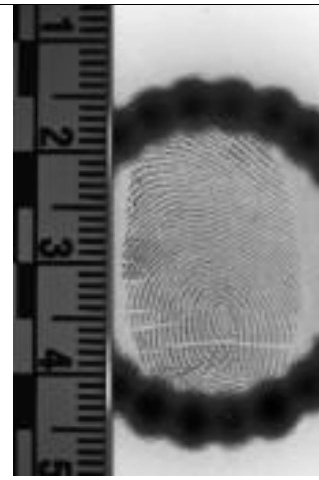
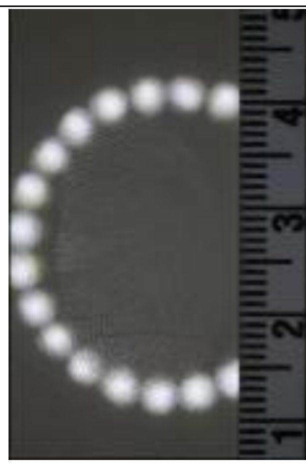
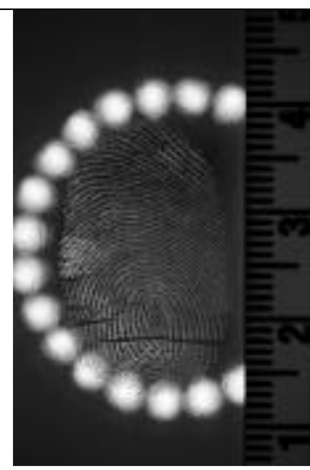
Substrate: Ceramic		
Camera Type	**Original Image**	**NFSTC Enhanced Image**
Canon 7D (IR/UV filter removed)		
NFSTC Comments	Excellent detail. Low ISO noise. Excellent focus.	
Camera Type	**Original Image**	**NFSTC Enhanced Image**
Canon 7D (Standard)		
NFSTC Comments	Excellent ridge detail.	

Table 4: Image evaluation of latent fingerprints from a ceramic substrate

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

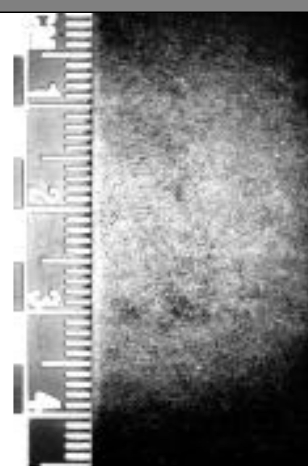
Substrate: Paper		
Camera Type	**Original Image**	**NFSTC Enhanced Image**
Canon 7D (IR/UV filter removed)		
NFSTC Comments	Very faint ridge detail can be extracted from edges of print area. Insufficient contrast from background prevents clarity.	
Canon 7D (Standard)		
NFSTC Comments	Very faint ridge pattern can be extracted from edges of print area in the blue channel. Insufficient contrast from background prevents clarity.	

Table 5: Image evaluation of latent fingerprints from a paper substrate

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

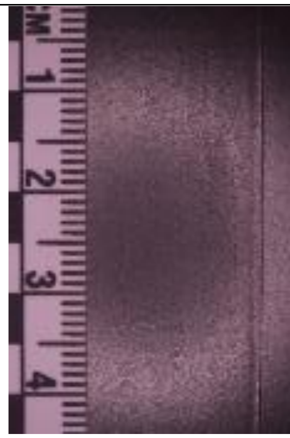
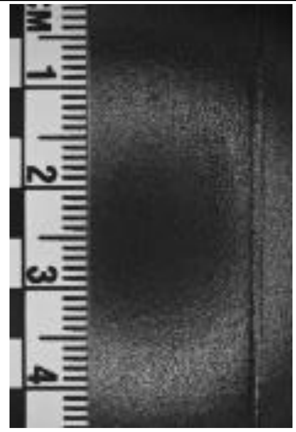
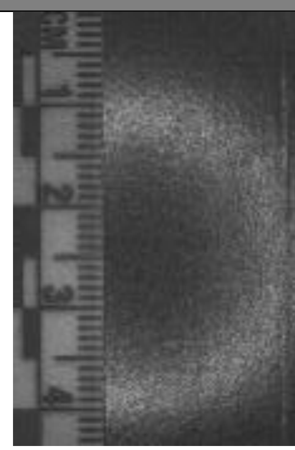
Substrate: Vinyl Tape		
Camera Type	**Original Image**	**NFSTC Enhanced Image**
Canon 7D (IR/UV filter removed)		
NFSTC Comments	Some fluorescing was observed along the edges of the print area in the blue channel but was of too-low contrast to extract ridge detail. I suspect the low angle of the light caused the background texture to be enhanced.	
Canon 7D (Standard)		
NFSTC Comments	Some fluorescing was observed along the edges of the print area in the blue channel but was of too-low contrast to extract ridge detail. Extensive post processing required.	

Table 6: Image evaluation of latent fingerprints from a vinyl tape (non-adhesive side) substrate

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

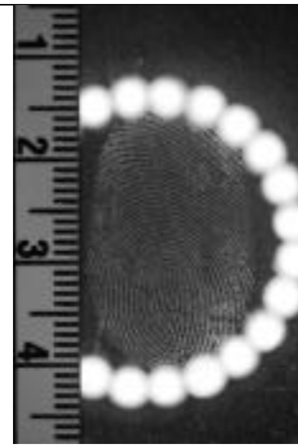
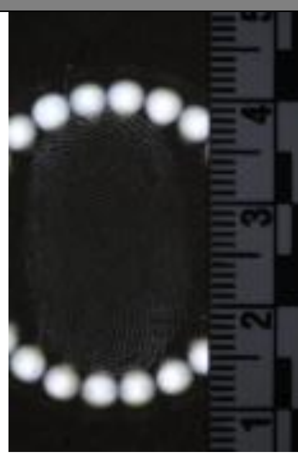
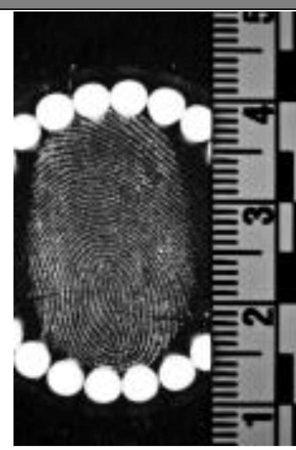
Substrate: Glass		
Camera	**Original Image**	**NFSTC Enhanced Image**
Canon 7D (IR/UV filter removed)		
NFSTC Comments	Excellent image detail. Excellent contrast. Very low ISO noise. Edges of print partially obscured by "doubled" image from reflective or transparent surface.	
Canon 7D (Standard)		
NFSTC Comments	Excellent clarity and detail. Visible reflections of ridge detail create "doubling" effect.	

Table 7: Image evaluation of latent fingerprints from a glass substrate

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

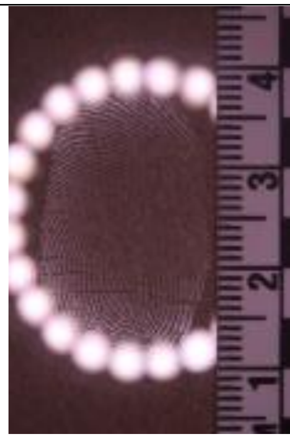
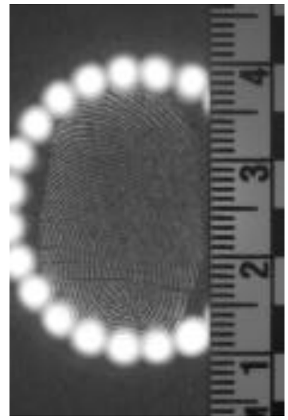
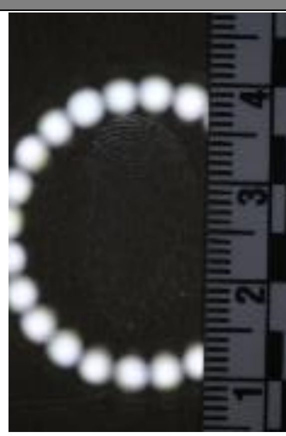
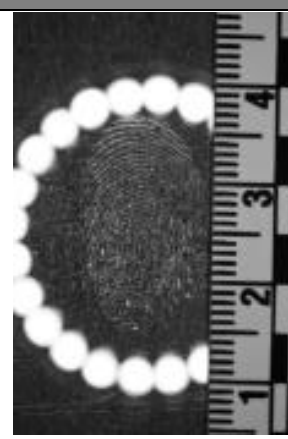
Substrate: Plastic		
Camera	**Original Image**	**NFSTC Enhanced Image**
Canon 7D (IR/UV filter removed)		
NFSTC Comments	Excellent image detail. Sufficient contrast around edge of image due to glare from ring light. Low ISO noise. Center of print area required minimal enhancing for contrast.	
Canon 7D (Standard)		
NFSTC Comments	Excellent detail around edges of print - likely due to difference in refraction or reflection of light angle between substrate & print oils. Center of print shows much less contrast and more background texture. Some post-processing required.	

Table 8: Image evaluation of latent fingerprints from a plastic substrate

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

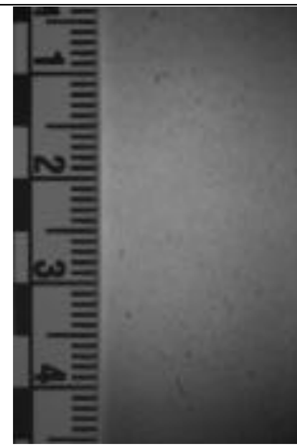
Substrate: Latex		
Camera Type	**Original Image**	**NFSTC Enhanced Image**
Canon 7D (IR/UV filter removed)		
NFSTC Comments	No ridge detail discernible - only surface texture of background.	
Canon 7D (Standard)		
NFSTC Comments	No visible detail.	

Table 9: Image evaluation of latent fingerprints from a latex substrate

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

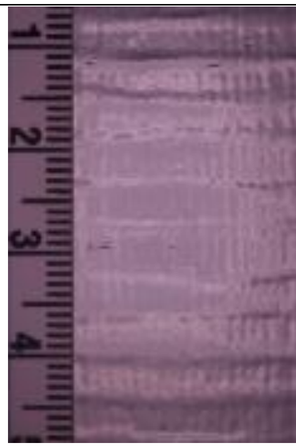
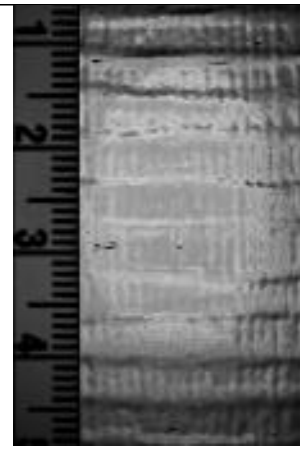
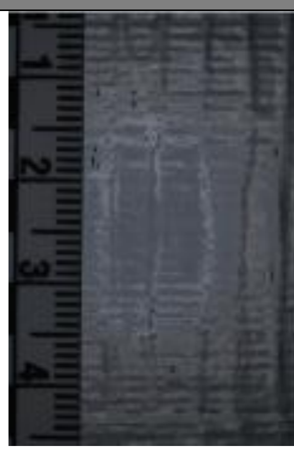
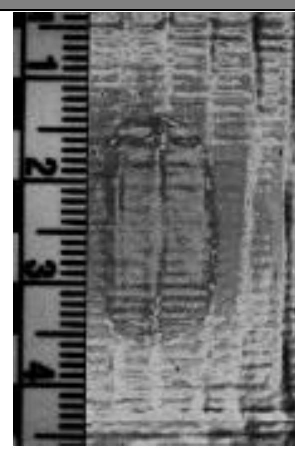
Substrate: Duct Tape		
Camera Type	**Original Image**	**NFSTC Enhanced Image**
Canon 7D (IR/UV filter removed)		
NFSTC Comments	Very small area of ridge detail visible around edge of print area in blue channel only appear as diagonal lines overlaying glare areas of background texture.	
Canon 7D (Standard)		
NFSTC Comments	Some ridge pattern can be discerned. Very low contrast with background. Extensive post-processing required.	

Table 10: Image evaluation of latent fingerprints from a duct tape (non-adhesive side) substrate

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

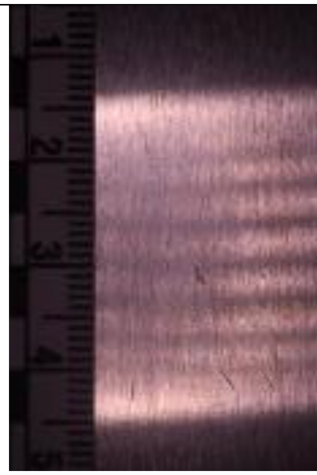
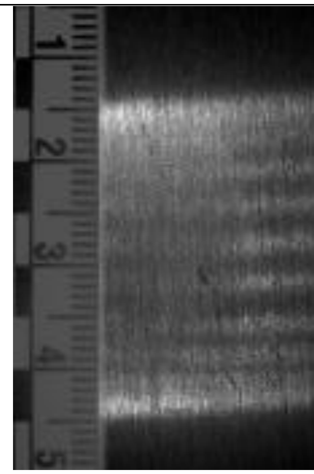
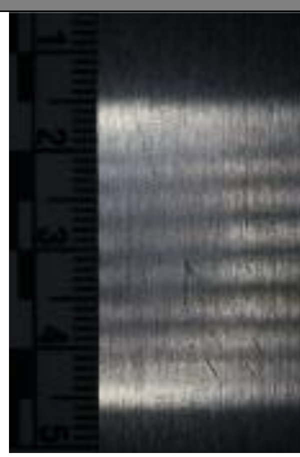
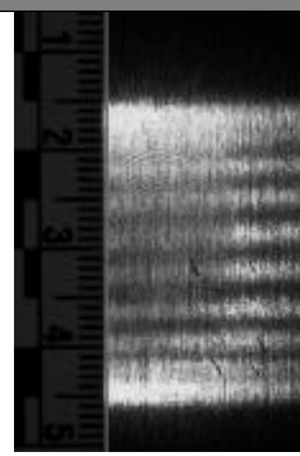
Substrate: Metal		
Camera Type	**Original Image**	**NFSTC Enhanced Image**
Canon 7D (IR/UV filter removed)		
NFSTC Comments	Very faint ridge detail discernible in the red & green channels. Extensive post processing required.	
Canon 7D (Standard)		
NFSTC Comments	Some ridge pattern visible in between areas of glare off substrate.	

Table 11: Image evaluation of latent fingerprints from a metal substrate

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

Appendix D. Images Collected from Phase 4 (Light Guide with Macro Lens)

Substrate: Ceramic		
Camera Type	**Original Image**	**NFSTC Enhanced Image**
Canon 7D (IR/UV filter removed)		
NFSTC Comments	Clarity good; ISO noise level too high	
Canon 7D (Standard)		
NFSTC Comments	Image appears to be out of focus. ISO noise interfering with image quality. Sufficient detail captured.	

Table 12: Image evaluation of latent fingerprints from a ceramic substrate

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

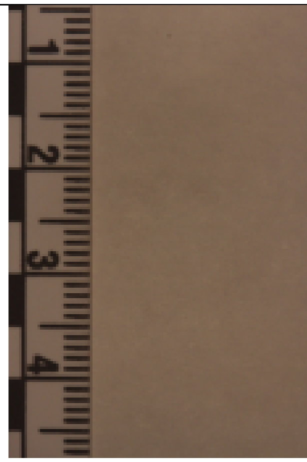
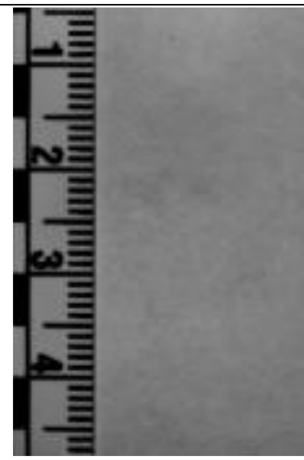
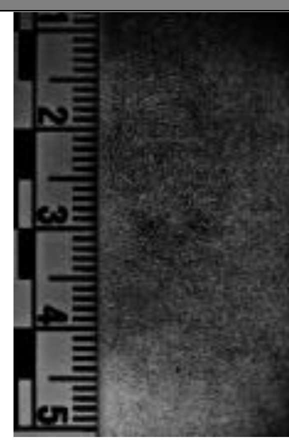
Substrate: Paper		
Camera Type	**Original Image**	**NFSTC Enhanced Image**
Canon 7D (IR/UV filter removed)		
NFSTC Comments	Image too faint to discern ridge detail; ISO noise too high - obscuring image detail.	
Canon 7D (Standard)		
NFSTC Comments	Image appears out of focus at surface, in-focus at scale. Shallow depth of field from open aperture would explain this. ISO noise interfering with image quality. Very faint ridge detail can be observed. Contrast is very low.	

Table 13: Image evaluation of latent fingerprints from a paper substrate

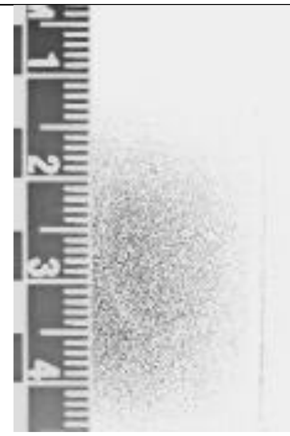
Substrate: Vinyl Tape (Non-adhesive side)		
Camera Type	**Original Image**	**NFSTC Enhanced Image**
Canon 7D (IR/UV filter removed)		
NFSTC Comments	Some fluorescence can be observed against the background texture in the upper right quadrant of the expected print area, but ISO noise is far too high to extract ridge detail.	
Canon 7D (Standard)		
NFSTC Comments	ISO noise interfering with image quality. Very faint ridge detail can be observed in the red & green channels. Contrast is very low.	

Table 14: Image evaluation of latent fingerprints from a vinyl tape (non-adhesive side) substrate

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

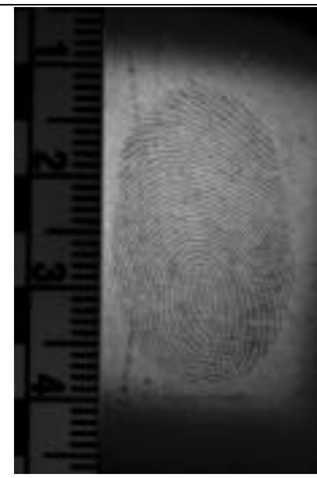
Substrate: Glass		
Camera	**Original Image**	**NFSTC Enhanced Image**
Canon 7D (IR/UV filter removed)		
NFSTC Comments	Image appears to be slightly out of focus. Ridge pattern can be observed. Some detail is obscured by ISO noise.	
Canon 7D (Standard)		
NFSTC Comments	Image appears to be out of focus, or with motion blur. ISO noise interfering with image quality. Some ridge detail captured.	

Table 15: Image evaluation of latent fingerprints from a glass substrate

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

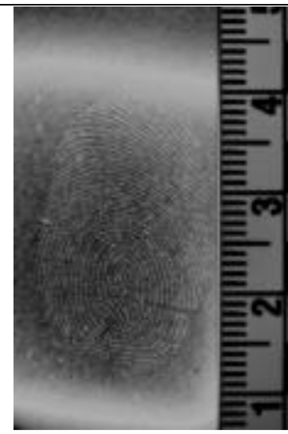
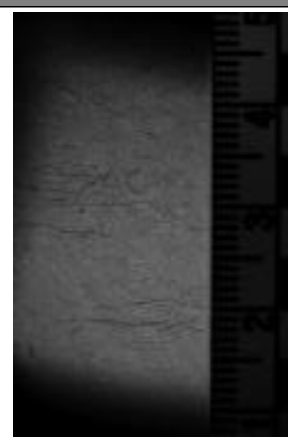
Substrate: Plastic		
Camera Type	**Original Image**	**NFSTC Enhanced Image**
Canon 7D (IR/UV filter removed)		
NFSTC Comments	Ridge pattern can be observed. Some detail is obscured by ISO noise.	
Canon 7D (Standard)		
NFSTC Comments	Image appears to be out of focus, or with motion blur. ISO noise interfering with image quality. Some ridge pattern captured.	

Table 16: Image evaluation of latent fingerprints from a plastic substrate

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

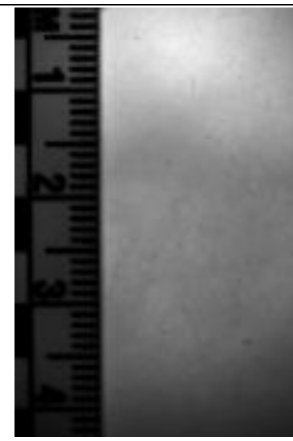
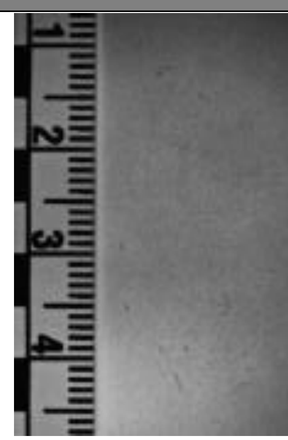
Substrate: Latex		
Camera Type	**Original Image**	**NFSTC Enhanced Image**
Canon 7D (IR/UV filter removed)		
NFSTC Comments	No discernible ridge detail present.	
Canon 7D (Standard)		
NFSTC Comments	No ridge detail discernible.	

Table 17: Image evaluation of latent fingerprints from a latex substrate

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

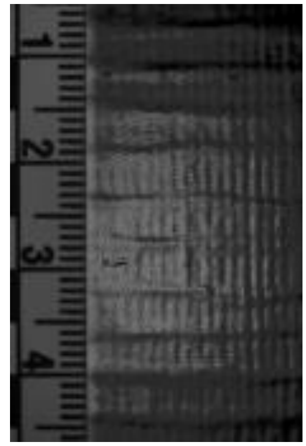
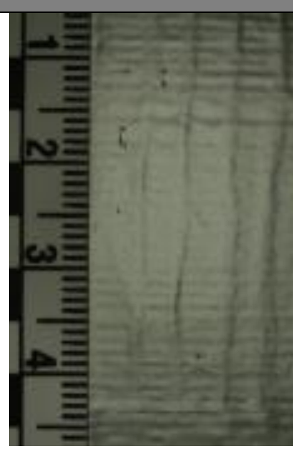
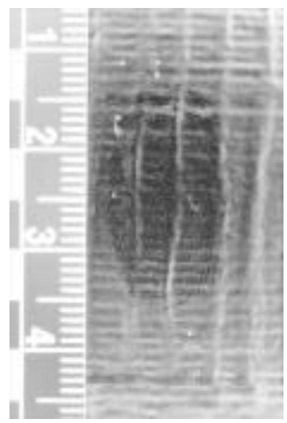
Substrate: Duct Tape (Non-adhesive side)		
Camera Type	**Original Image**	**NFSTC Enhanced Image**
Canon 7D (IR/UV filter removed)		
NFSTC Comments	Ridge pattern can be observed. Some detail is obscured by ISO noise.	
Canon 7D (Standard)		
NFSTC Comments	Image appears out of focus at surface, in-focus at scale. Shallow depth of field from open aperture would explain this. Some ridge pattern discernible. ISO noise obscuring ridge detail.	

Table 18: Image evaluation of latent fingerprints from a duct tape (non-adhesive side) substrate

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

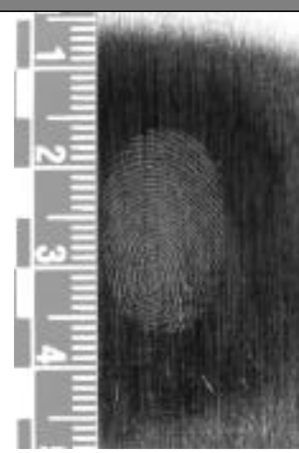
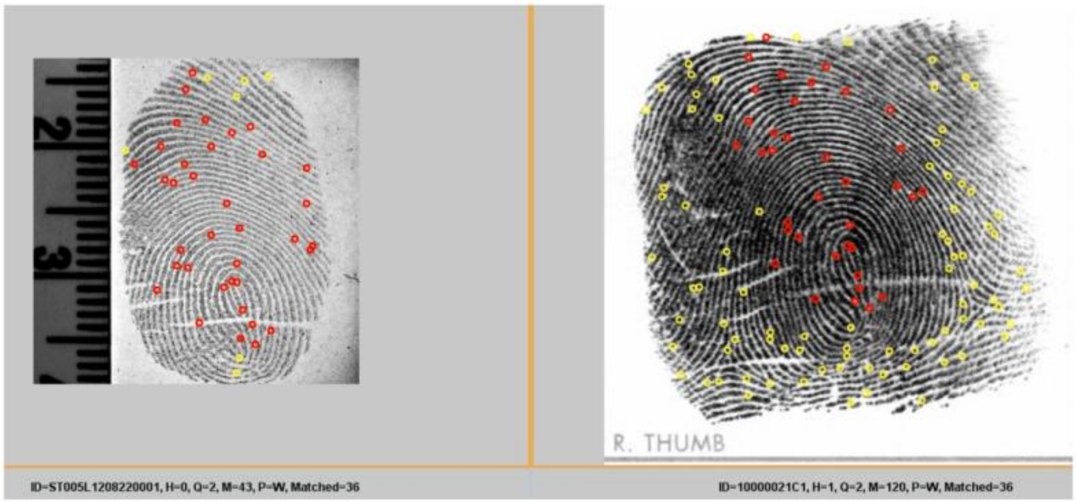
Substrate: Metal		
Camera Type	**Original Image**	**NFSTC Enhanced Image**
Canon 7D (IR/UV filter removed)		
NFSTC Comments	Ridge pattern can be observed. Extensive post-processing required to compensate for background texture. Some detail is obscured by ISO noise.	
Canon 7D (Standard)		
NFSTC Comments	Image appears out of focus at surface, in-focus at scale. Shallow depth of field from open aperture would explain this. Ridge pattern can be discerned. Some ISO noise interference visible in ridge detail.	

Table 19: Image evaluation of latent fingerprints from a metal substrate

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

IMG1382_Ceramic_LightGuide_FSCamera.jpg

Image		Status	
Dimensions:	1102 x 1654 Pixels 1.102 x 1.654 Inches	Has been modified:	No
		Has a selection:	No
Pixels Per Inch:	1000.000	Number of layers:	1
Pixel depth/colors:	Grey - 8 bits/channel	Number of alpha channels:	0



With a score of 2639, this shows a very high degree of matching confidence. Each image has a quality score of 2, which is very good. The latent has 43 minutiae, and the tenprint has 120 minutiae. 36 minutiae matched.

Comment: The import was smooth and seamless.

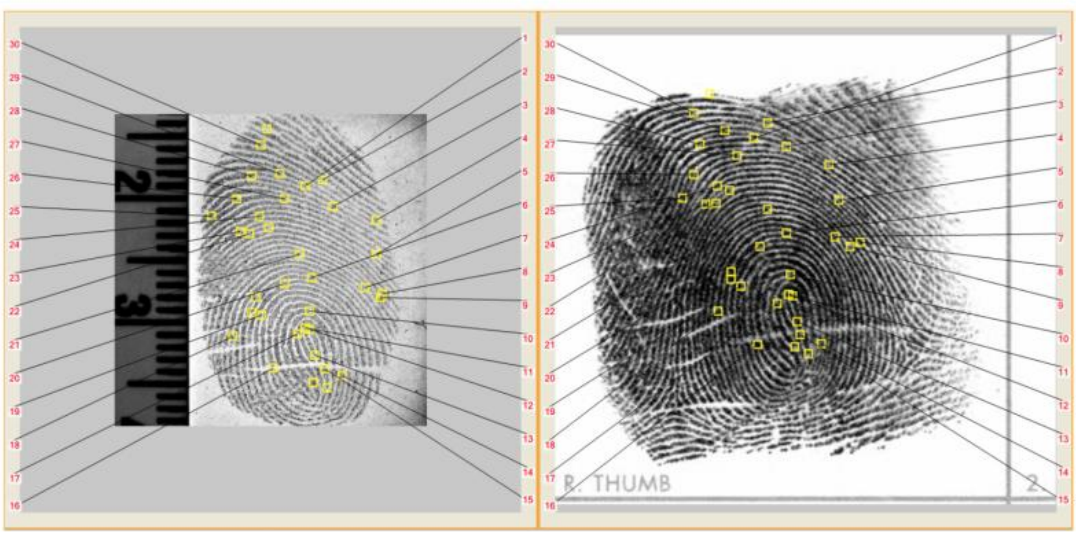
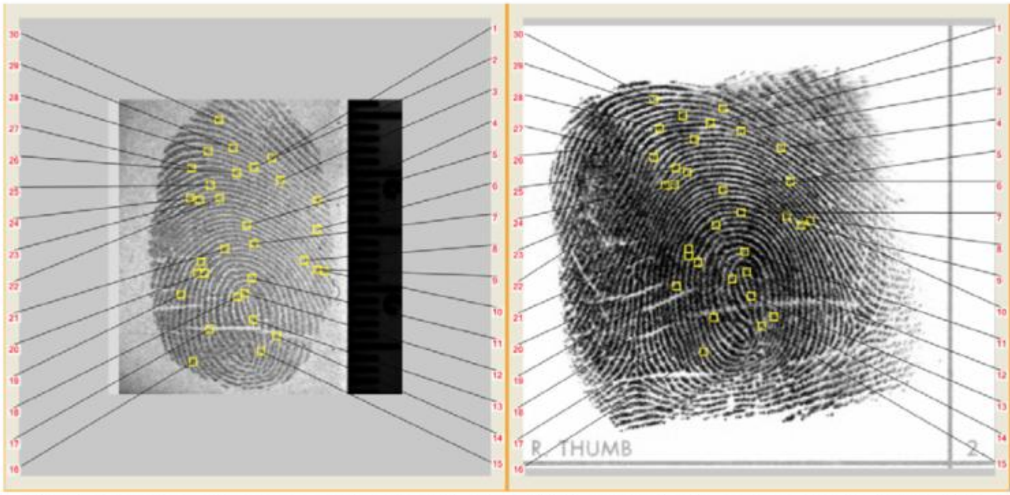


Figure 14: AFIS evaluation of a latent fingerprint on a ceramic substrate using the modified camera



This latent to tenprint search was a match to a R. THUMB, score 2121, with a quality of 3, 43 minutiae extracted, and 32 minutiae matched to the record.

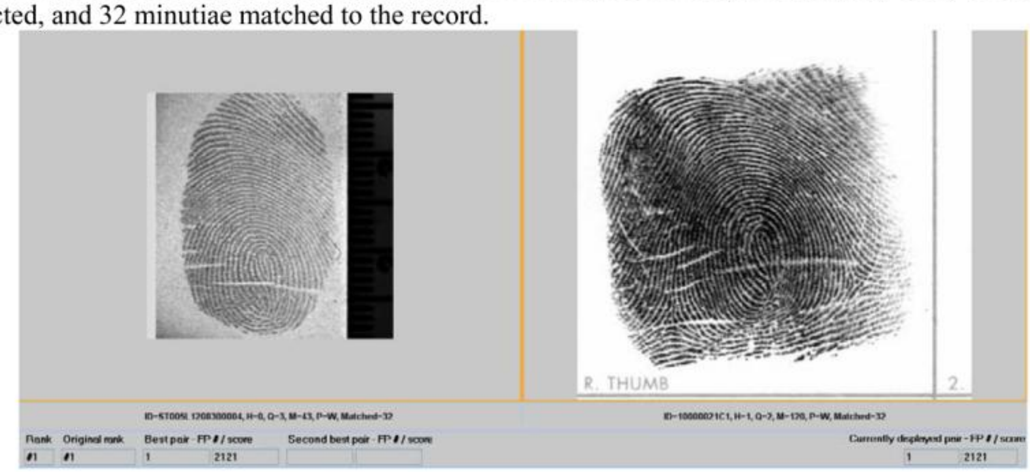
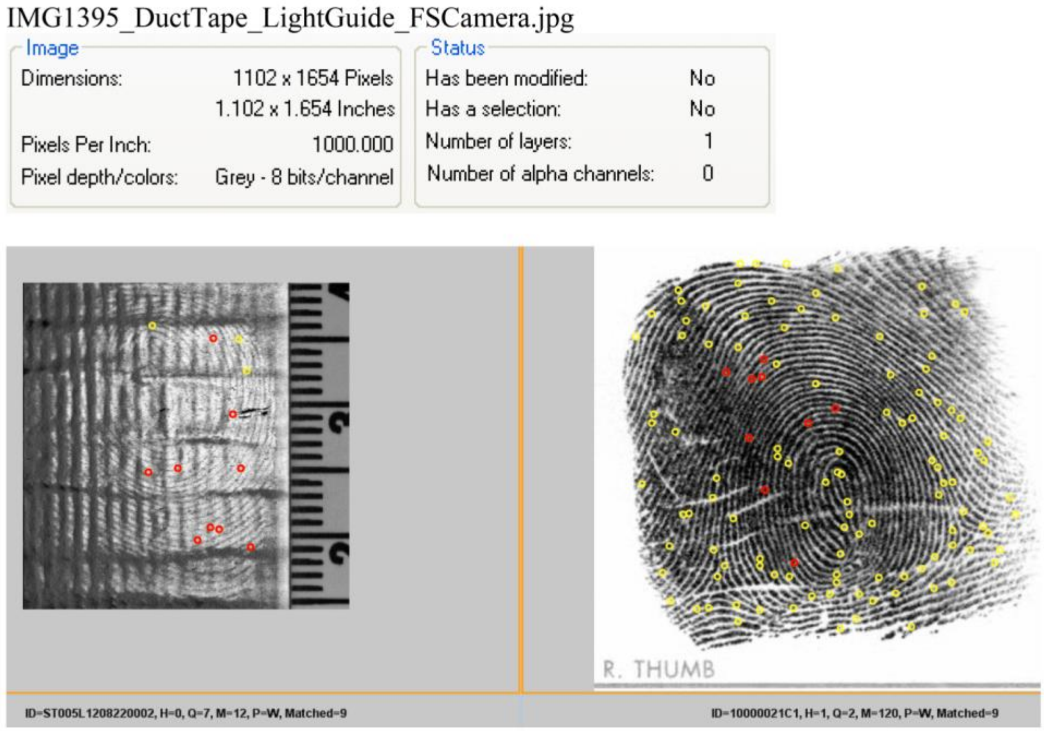


Figure 15: AFIS evaluation of a latent fingerprint on a ceramic substrate using the standard camera

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.



With a score of 913, this shows slightly over the 800 threshold matching confidence. The tenprint image has a quality score of 2, which is very good. The latent image has a quality score of 7, which is fair. The latent has 12 minutiae, and the tenprint has 120 minutiae. 9 minutiae matched.

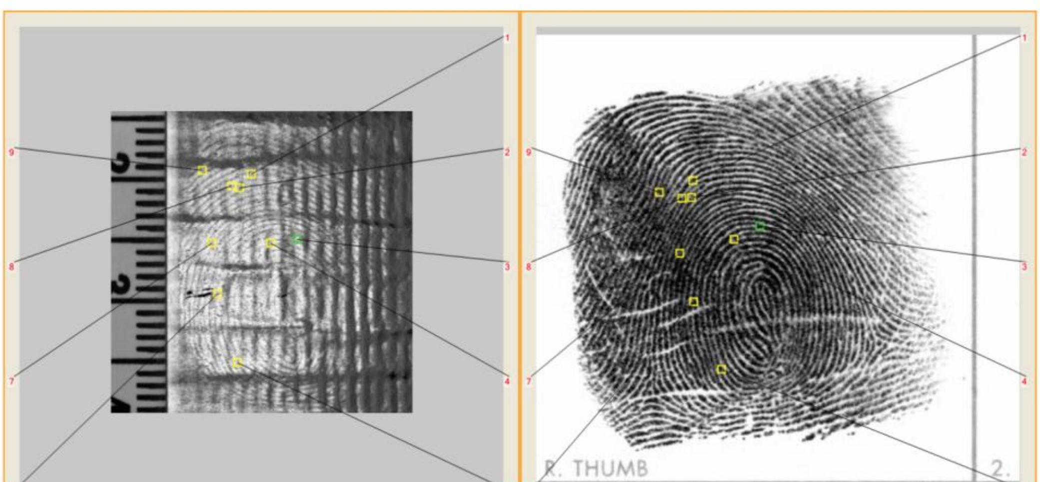


Figure 16: AFIS evaluation of a latent fingerprint on a duct tape substrate using the modified camera

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

The latent (below) to tenprint search did not locate a match, with a quality of 14, 5 minutiae extracted, and not matched to a record.

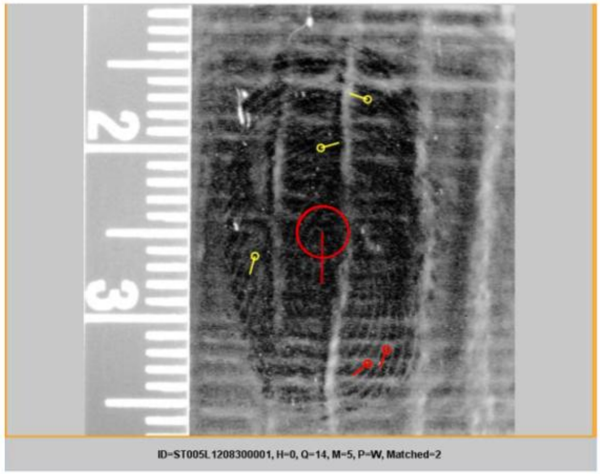
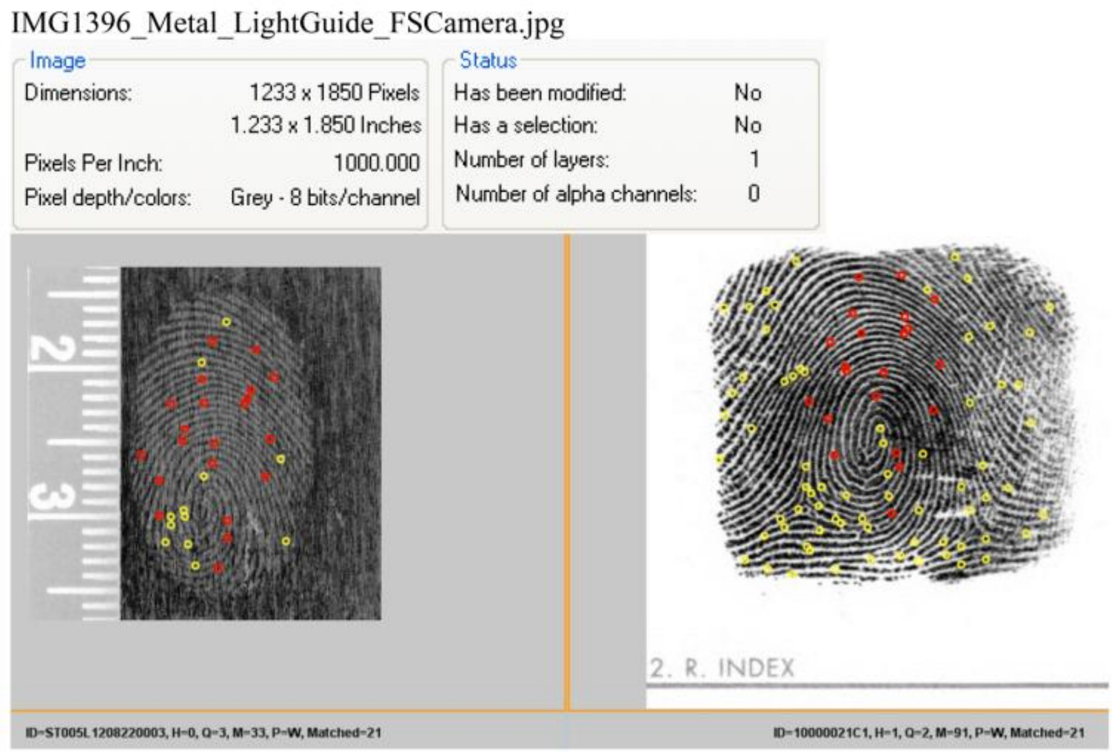


Figure 17: AFIS evaluation of a latent fingerprint on a duct tape substrate using the standard camera

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.



A score of 1607, this shows fair matching confidence. The tenprint image has a quality score of 2, which is very good. The latent image has a quality score of 3, which is good. The latent has 33 minutiae, and the tenprint has 91 minutiae. 21 minutiae matched.

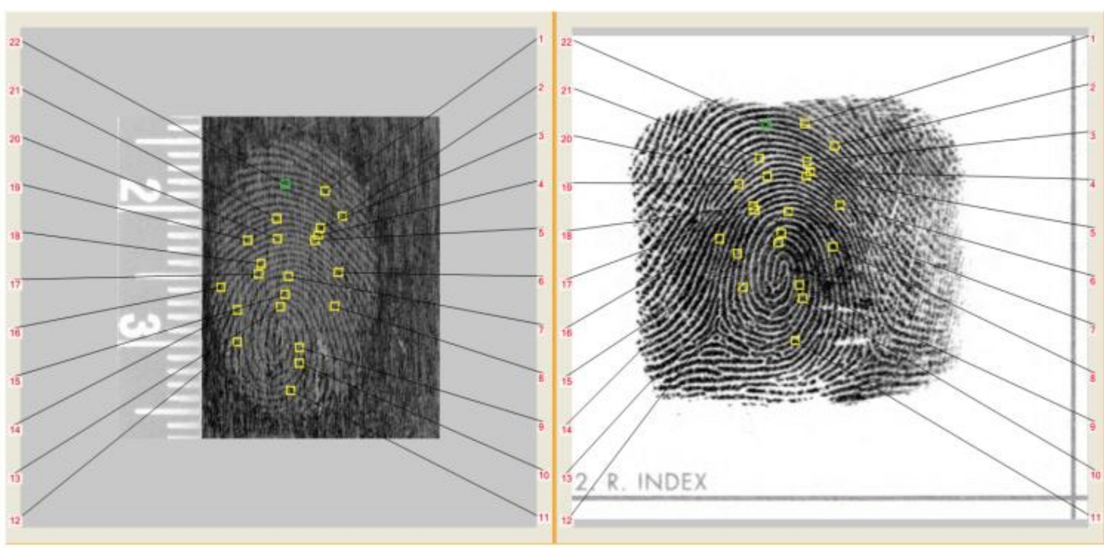


Figure 18: AFIS evaluation of a latent fingerprint on a metal substrate using the modified camera

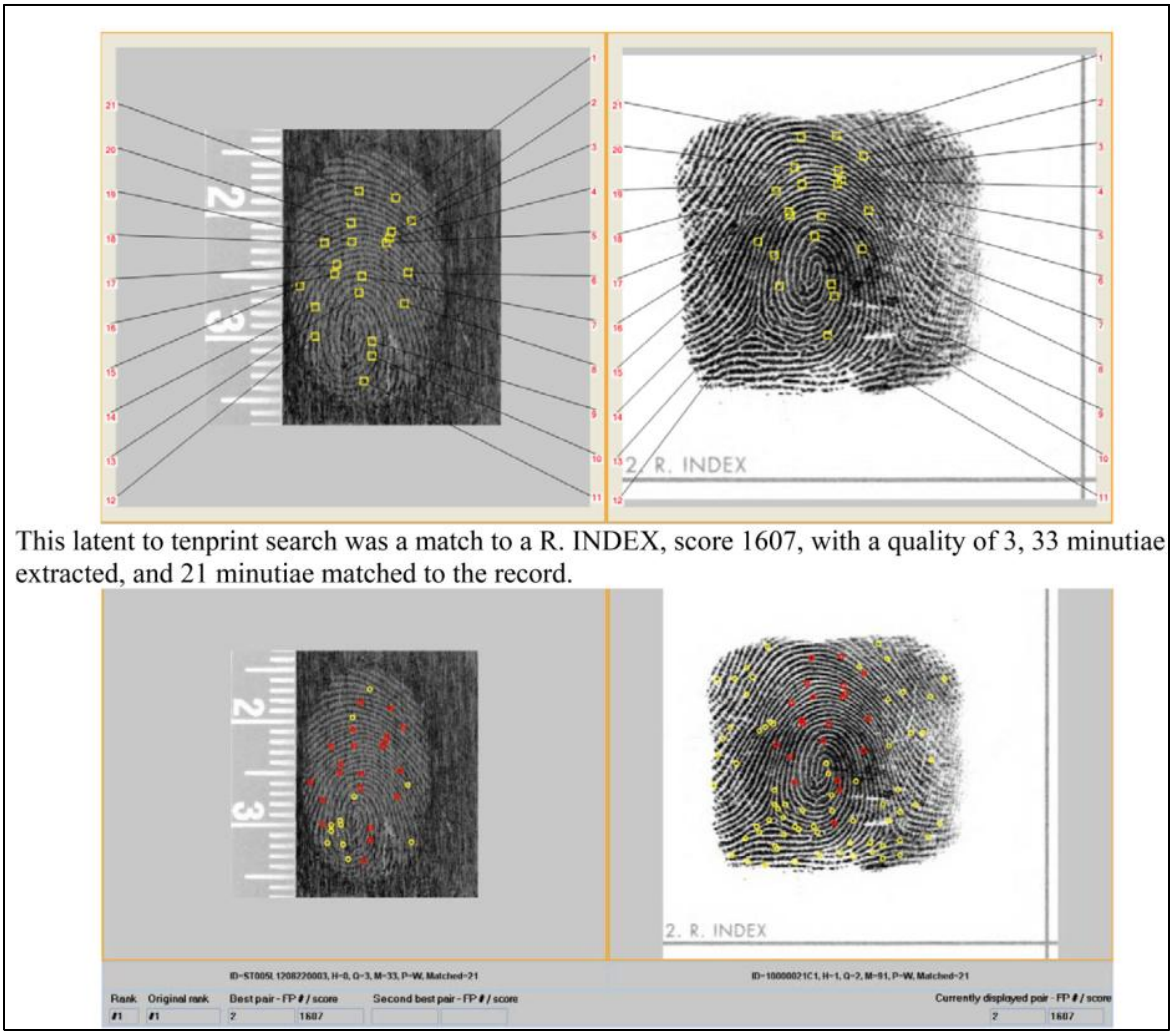
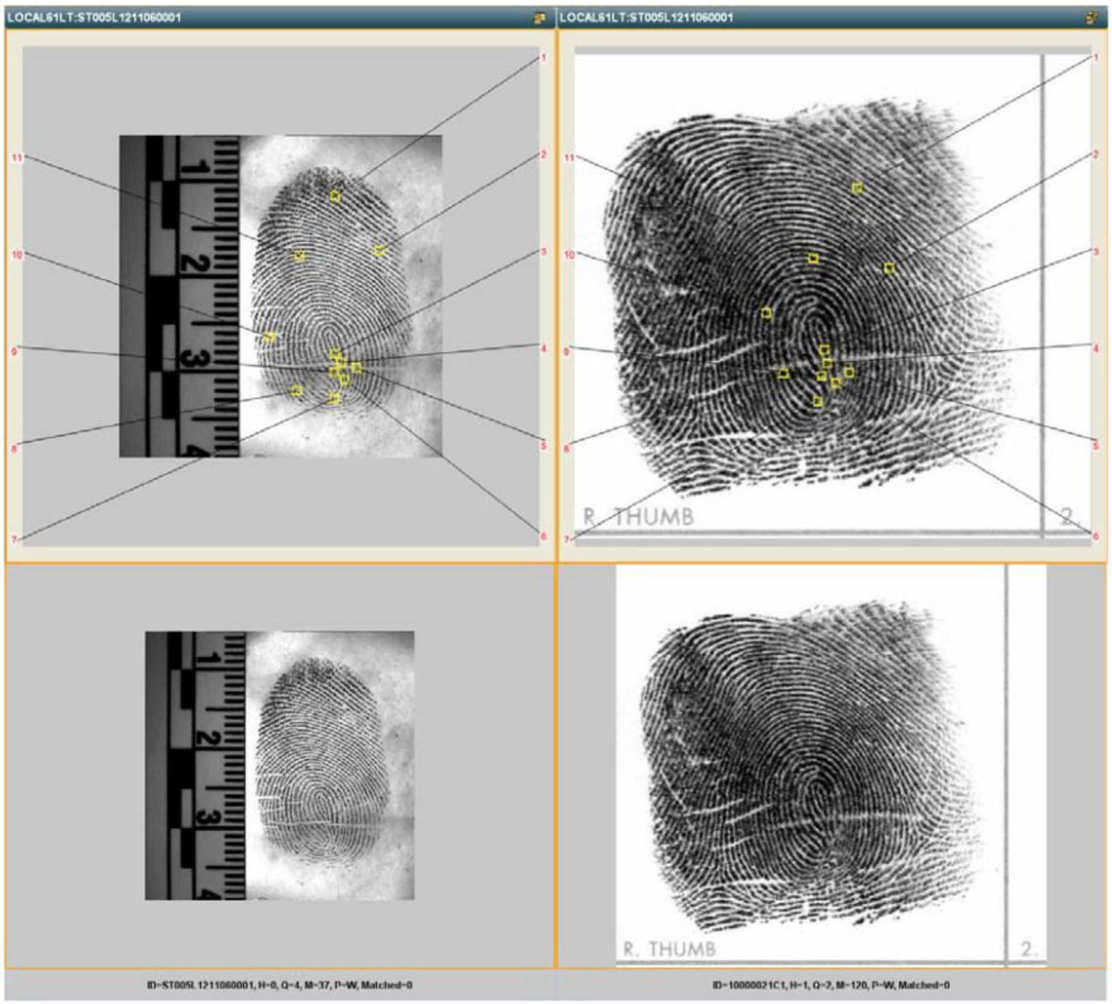


Figure 19: AFIS evaluation of a latent fingerprint on a metal substrate using the standard camera

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

Appendix E. Images Collected from Phase 5 (Dusted Fingerprint Comparison)

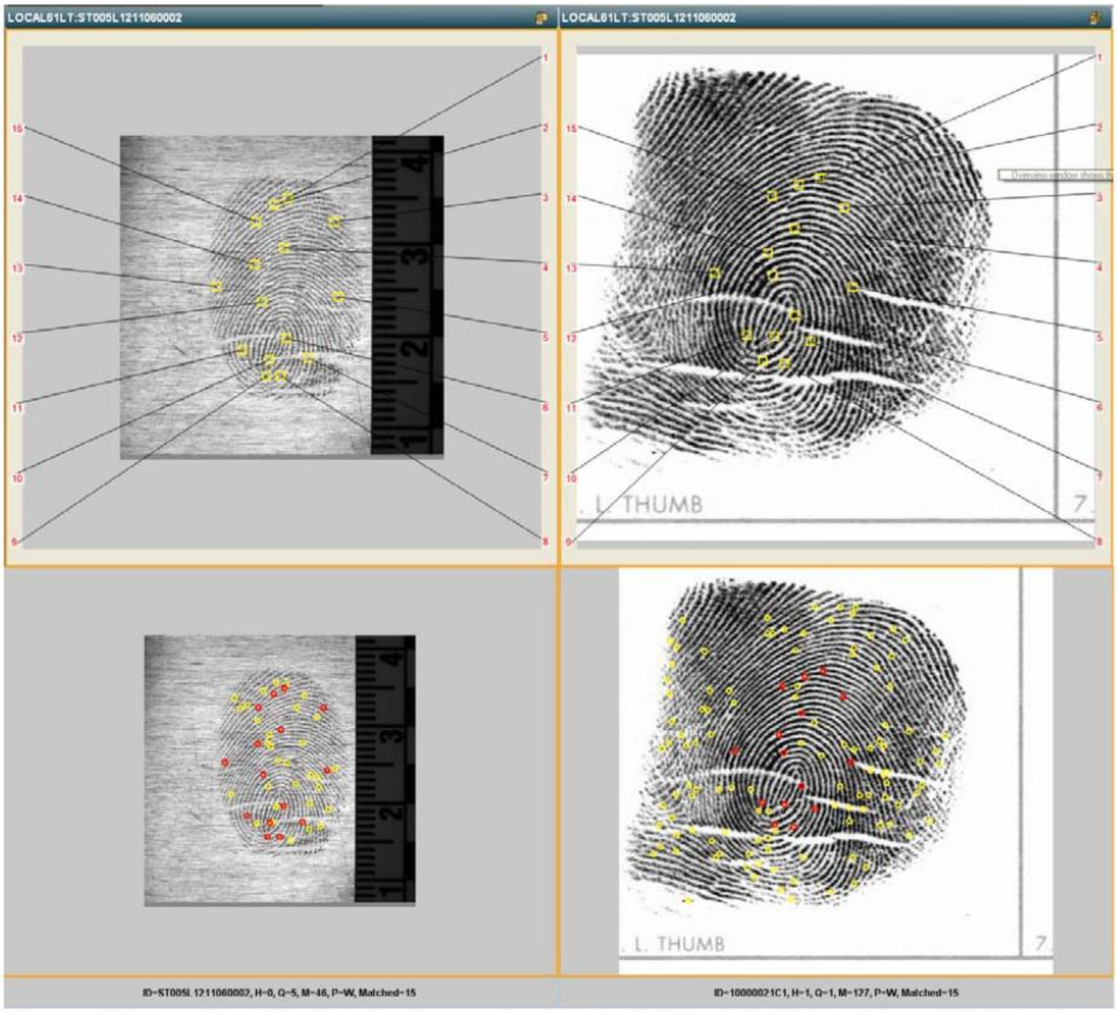
IMG_0037_Ceramic (1).tif



As you can see, the quality was 4, with 37 minutiae, matching the right thumb. My opinion: this latent was likely processed via black powder and brush. Excellent quality image.

Figure 20: Image evaluation of a dusted fingerprint from a ceramic substrate

IMG_0041_Metal (1).tif

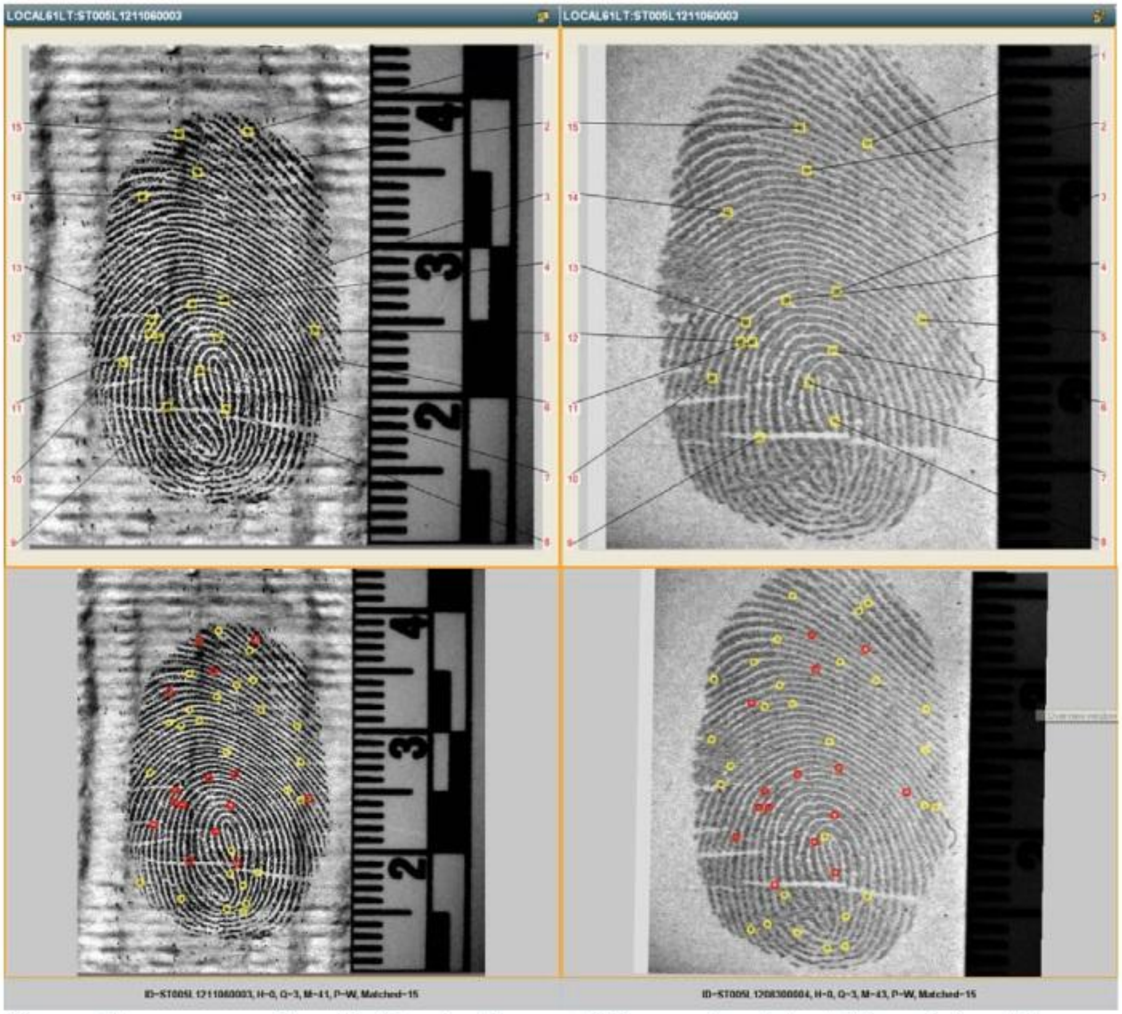


The quality was 5, with 46 minutiae, matching the left thumb. My opinion: this latent was likely processed via black powder and brush. Very good quality image.

Figure 21: Image evaluation of a dusted fingerprint from a metal substrate

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

IMG_0042_DuctTape (1).tif



The quality score was 3, with 41 minutiae, matching another latent. My opinion: this latent was likely processed via black powder and brush. Excellent quality image. I am confused why the system did not bring back a tenprint hit.

Figure 22: Image evaluation of a dusted fingerprint from duct tape

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

Appendix F. Images Collected from Phase 6 (Smartphone Images)

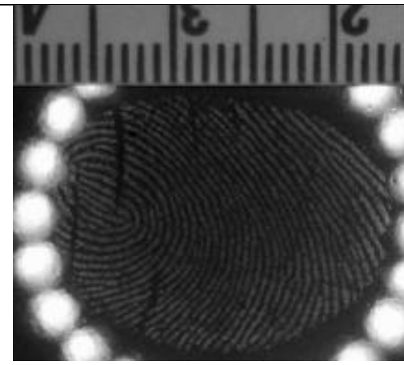
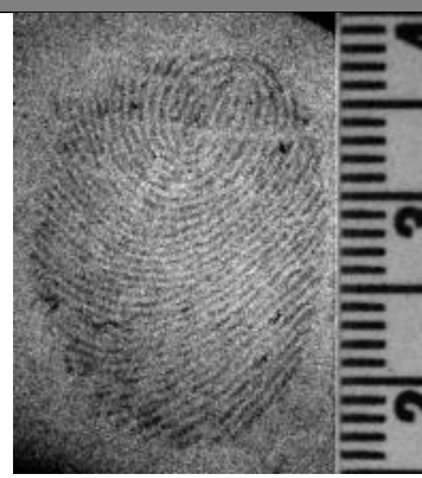
Substrate: Ceramic		
Light Source	**Original Image**	**Enhanced Image**
Ring Light		
NFSTC Comments	Image slightly over-exposed. Ridges visible, with small area obscured by glare from ring light.	
Light Guide		
NFSTC Comments	Image under-exposed. Ridges visible.	

Table 20: Latent fingerprint images from ceramic substrate captured with a smartphone

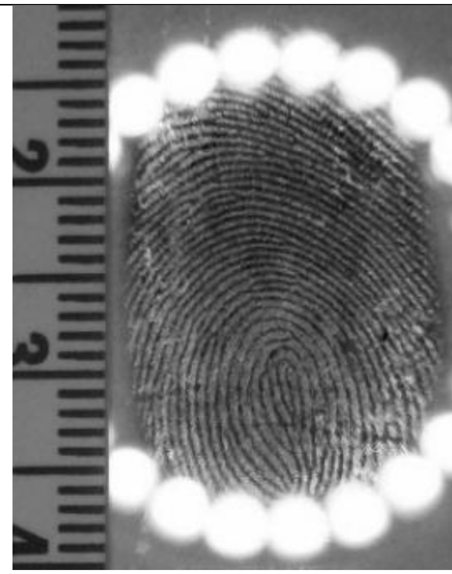
Substrate: Glass		
Light Source	**Original Image**	**Enhanced Image**
Ring Light		
NFSTC Comments	Ridges visible, with small area obscured by glare from ring light. Image appears doubled due to transparency and reflection off rear surface.	
Light Guide		
NFSTC Comments	Ridges visible.	

Table 21: Latent fingerprint images from glass substrate captured with a smartphone

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

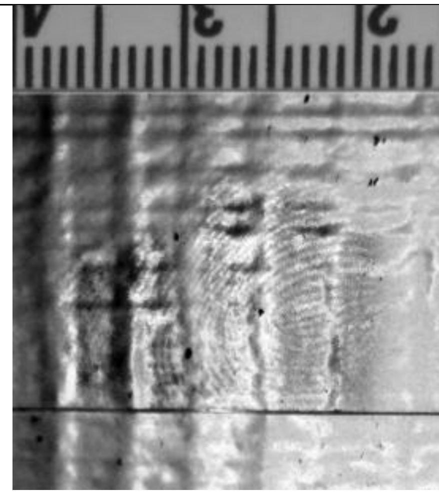
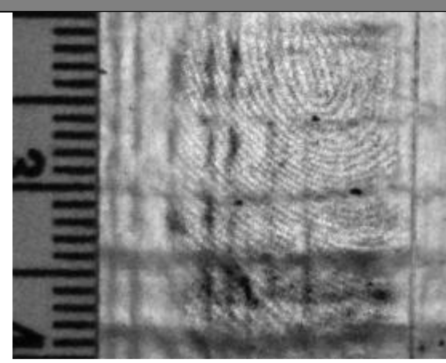
Substrate: Duct Tape		
Light Source	**Original Image**	**Enhanced Image**
Ring Light		
NFSTC Comments	Camera sensor not parallel to surface. Area of interest highly over-exposed. Some ridges visible. Background texture obscuring pattern.	
Light Guide		
NFSTC Comments	Image under-exposed. Some ridges visible.	

Table 22: Latent fingerprint images from duct tape substrate captured with a smartphone

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

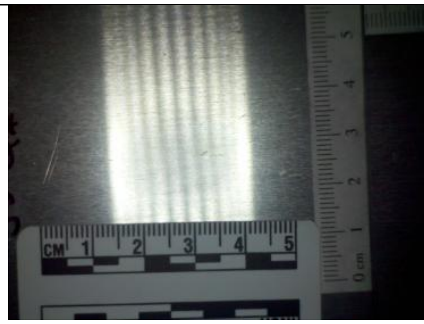
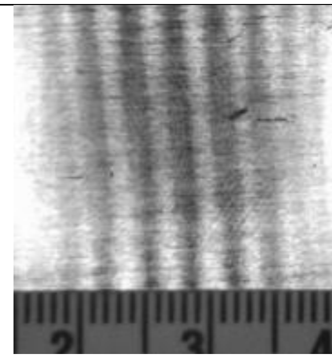
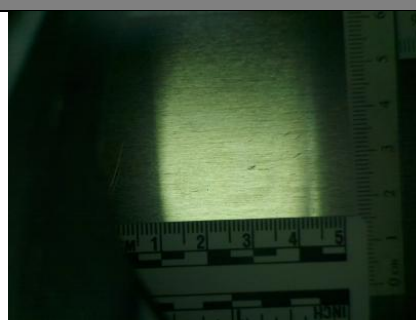
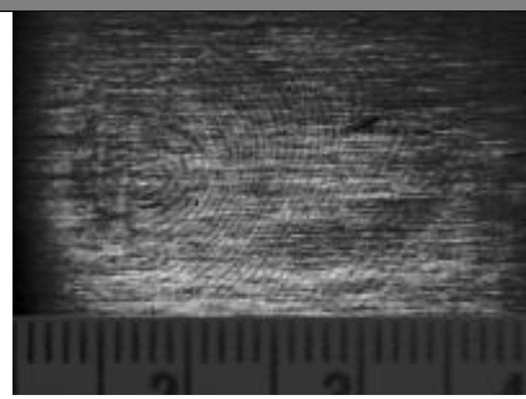
Substrate: Metal		
Light Source	**Original Image**	**Enhanced Image**
Ring Light		
NFSTC Comments	Surface is out of focus.	
Light Guide		
NFSTC Comments	Few ridges visible. Surface texture & (what I assume is oblique) lighting significantly interfering with detail.	

Table 23: Latent fingerprint images from metal substrate captured with a smartphone

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

Appendix G. **Images Collected From Phase 7 (NFSTC Sample Items)**

- All images were taken using the coaxial light guide and modified Canon EOS 7D camera

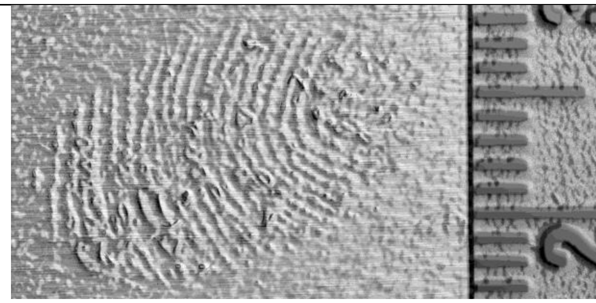
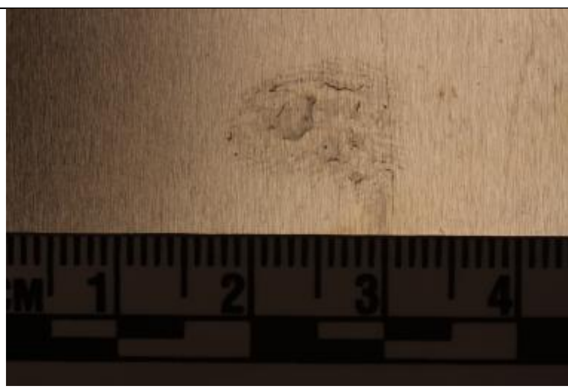
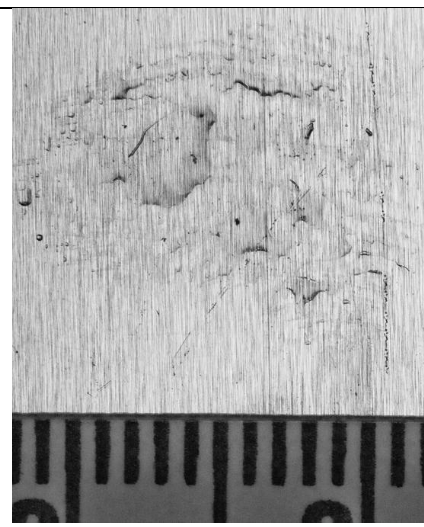
Substrate: Aluminum Sheet	
Original Image	**Enhanced Image**
	
NFSTC Comments	ridges visible
	
NFSTC Comments	ridges visible; liquid droplets obscuring detail

Table 24: Latent fingerprint images from aluminum sheet

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

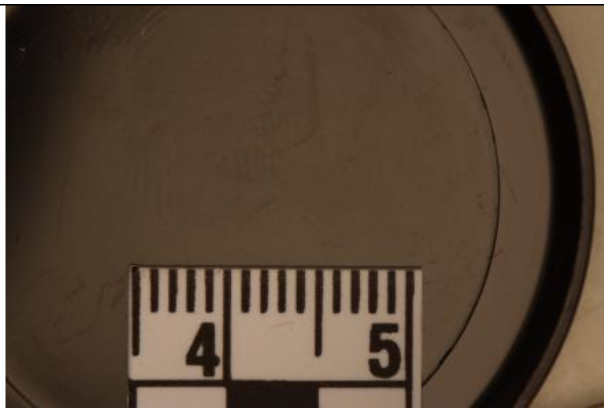
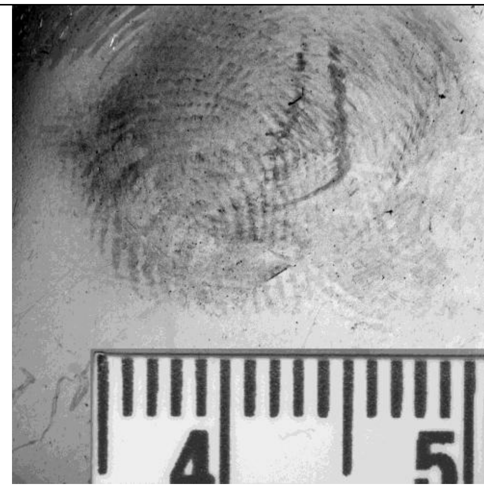
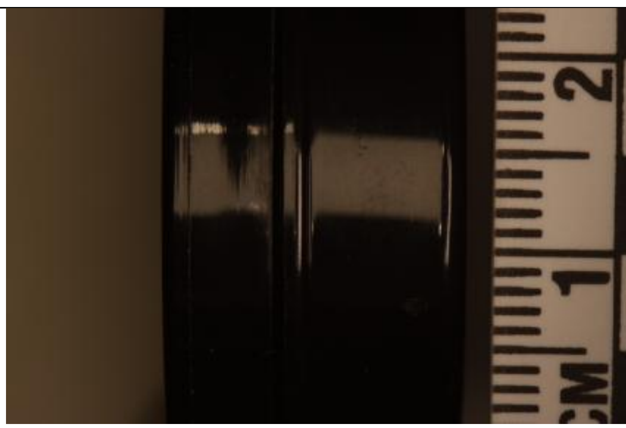
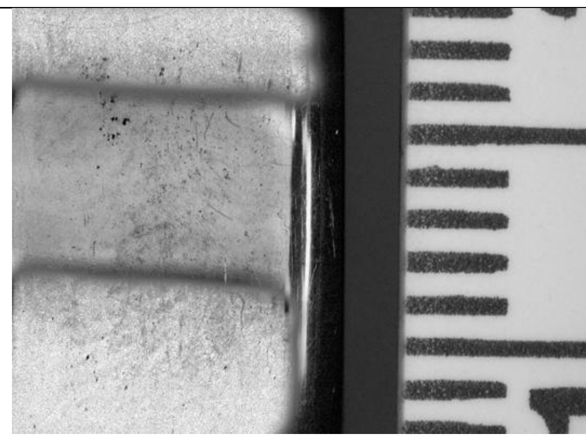
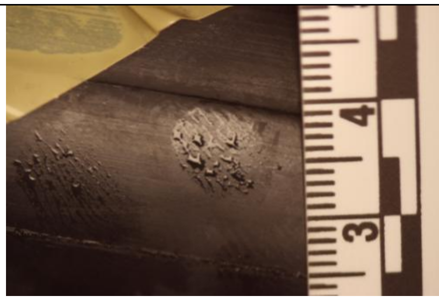
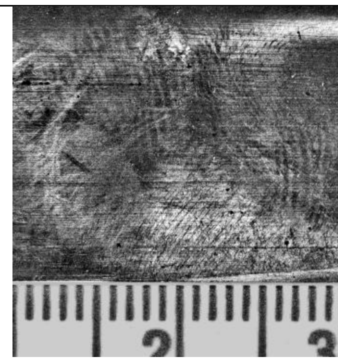
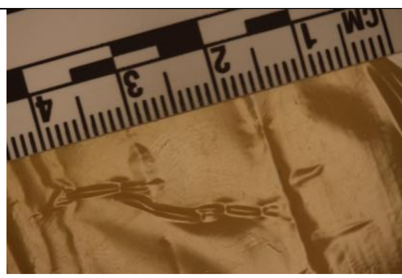
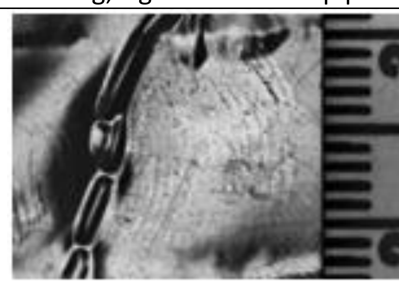
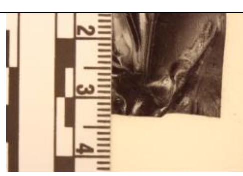
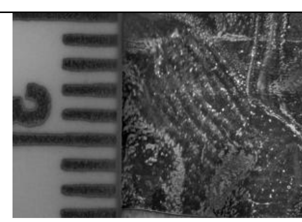
Substrate: Plastic Cases	
Original Image	**Enhanced Image**
	
NFSTC Comments	ridges visible; significant smudging and overlap; scale too small
	
NFSTC Comments	ISO320 introducing obscuring noise to image; few ridges visible; ridge area overlaps reflection into shadow area

Table 25: Latent fingerprint images from plastic cases

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

Substrate: IED Pressure Plate	
Original Image	**Enhanced Image**
	
NFSTC Comments	some ridge detail visible; liquid droplets obscuring small areas
	
NFSTC Comments	some ridges visible; ISO400 noise & background texture obscuring; significant overlap present
	
NFSTC Comments	few ridges visible; significant smudging
	
NFSTC Comments	some ridges visible

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

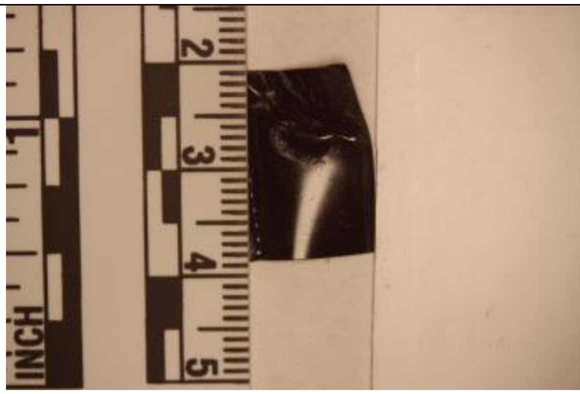
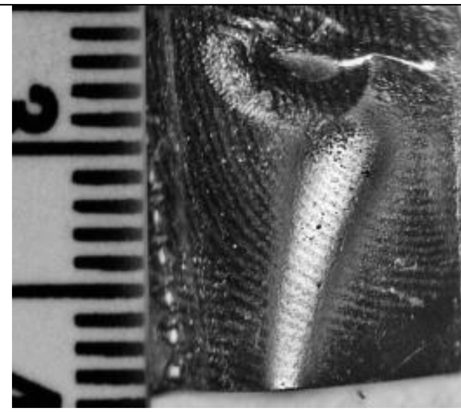
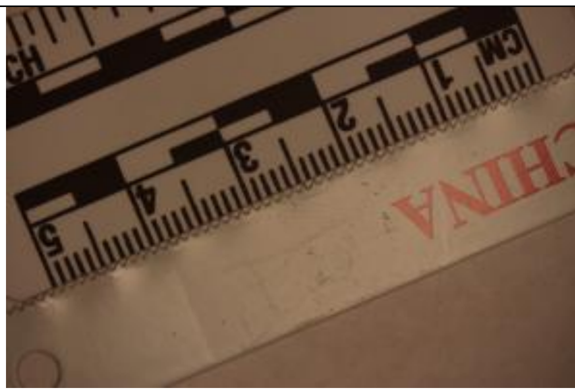
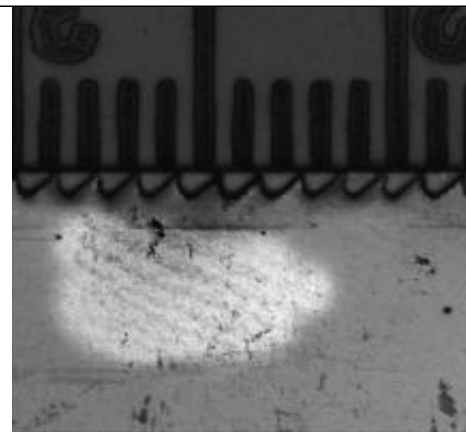
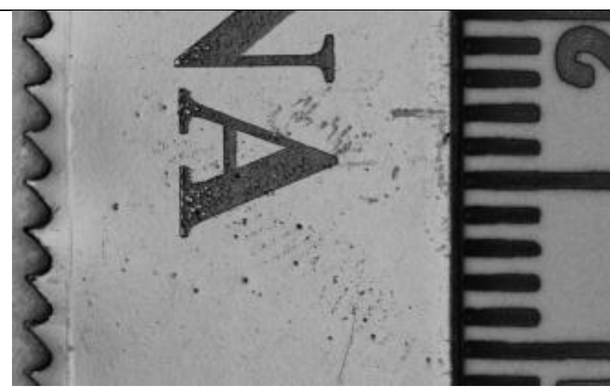
Substrate: IED Pressure Plate	
Original Image	**Enhanced Image**
	
NFSTC Comments	some ridges visible
	
NFSTC Comments	some ridges visible
	
NFSTC Comments	few ridges visible

Table 26: Latent fingerprint images from IED pressure plate

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

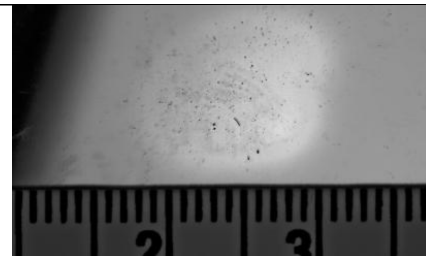
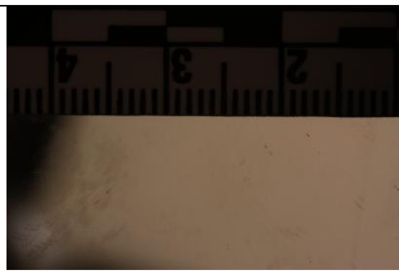
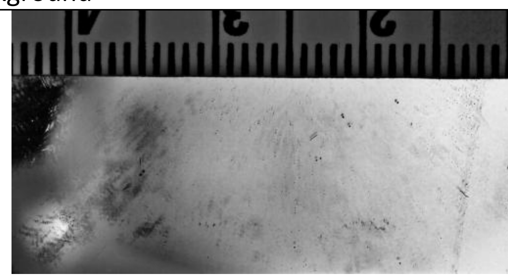
Substrate: Mirror	
Original Image	**Enhanced Image**
	
NFSTC Comments	few ridges visible; insufficient contrast with background
	
NFSTC Comments	no ridges visible

Table 27: Latent fingerprint images from mirror

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

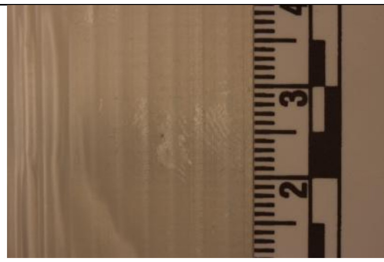
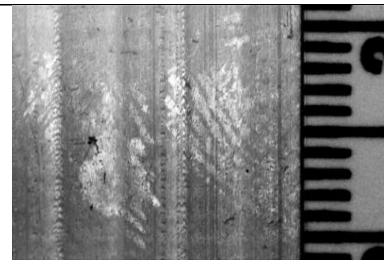
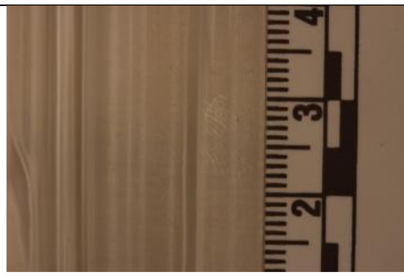
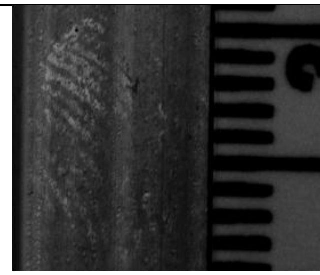
Substrate: Plastic Sheet	
Original Image	**Enhanced Image**
	
NFSTC Comments	some ridges visible
	
NFSTC Comments	some ridges visible

Table 28: Latent fingerprint images from plastic sheet

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

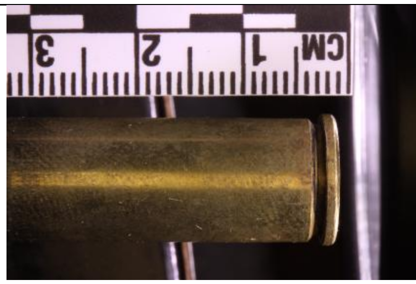
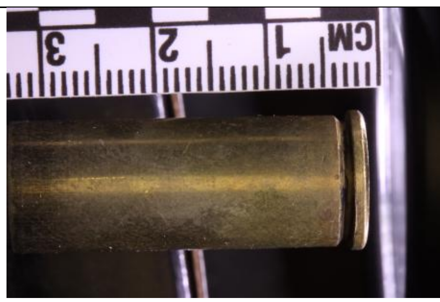
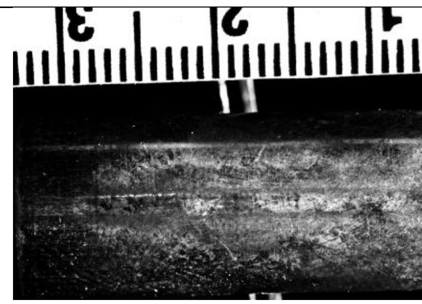
Substrate: Bullet Casings	
Original Image	**Enhanced Image**
	
NFSTC Comments	few ridges visible; heavily obscured by reflections, substrate texture & ISO400 noise
	
NFSTC Comments	few ridges visible; heavily obscured by reflections and substrate texture

Table 29: Latent fingerprint images from bullet casings

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

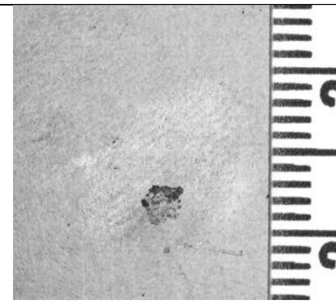
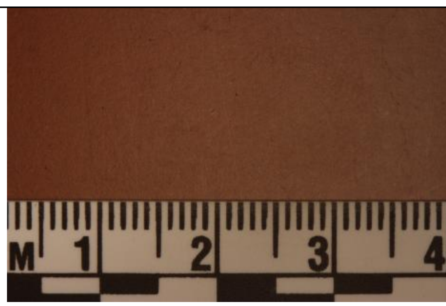
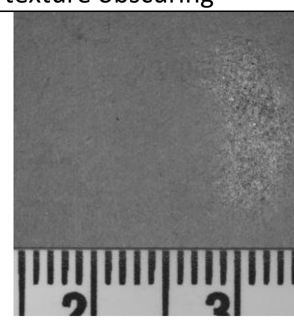
Substrate: Wooden Block	
Original Image	**Enhanced Image**
	
NFSTC Comments	few faint ridges visible; ISO200 noise & background texture obscuring
	
NFSTC Comments	few faint ridges visible; ISO400 noise & background texture obscuring

Table 30: Latent fingerprint images from wooden block

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

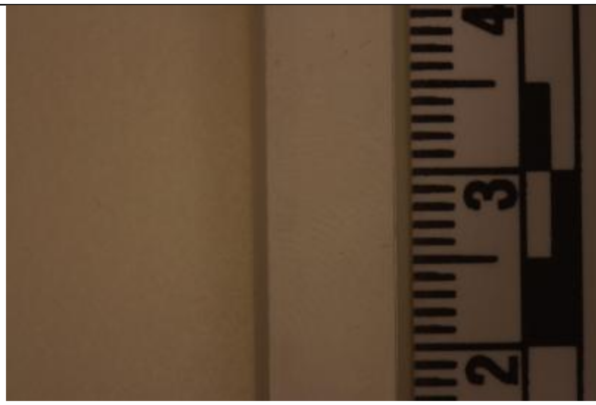
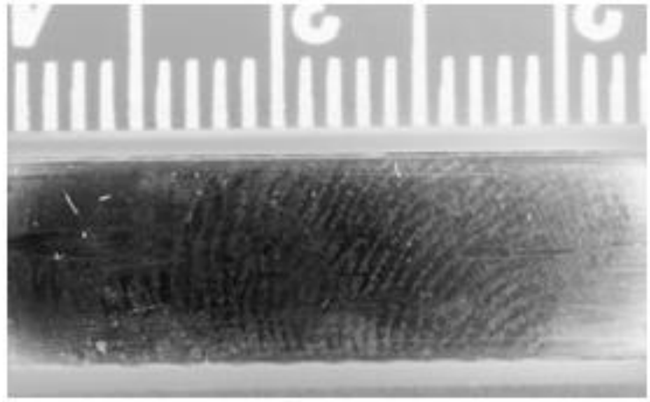
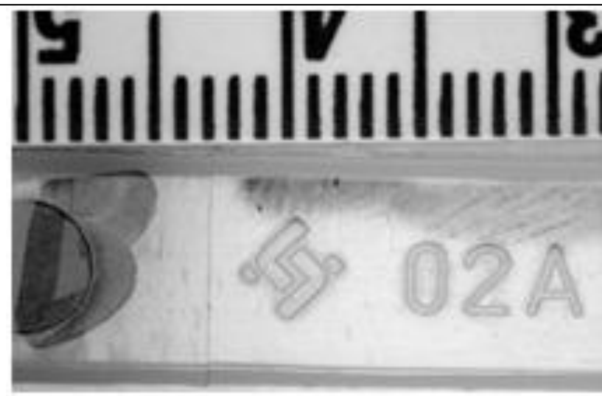
Substrate: Plastic Zip Ties	
Original Image	**Enhanced Image**
	
NFSTC Comments	ridges visible; some smudging
	
NFSTC Comments	few ridges visible

Table 31: Latent fingerprint images from plastic zip ties

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

Appendix H. Canon EOS 7D Specifications

Type
Digital, AF/AE single-lens reflex camera with built-in flash

Recording Media
CF Card Type I and II, UDMA-compliant CF cards, via external media (USB v.2.0 hard drive, via optional Wireless File Transmitter WFT-E5A)

Image Format
22.3 x 14.9 mm (APS-C size)

Compatible Lenses
Canon EF lenses including EF-S lenses (35mm-equivalent focal length is approx. 1.6x the lens focal length)

Lens Mount
Canon EF mount

Image Sensor

Type
High-sensitivity, high-resolution, large single-plate CMOS sensor

Pixels
Effective pixels: Approx. 18.0 megapixels

Pixel Unit
4.3 µm square

Total Pixels
Approx. 19.0 megapixels

Aspect Ratio
3:2 (Horizontal: Vertical)

Color Filter System
RGB primary color filters

Low Pass Filter
Fixed position in front of the CMOS sensor

Dust Deletion Feature
(1) Automatic Sensor Cleaning

- Removes dust adhering to the low-pass filter.

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

- Self-cleaning executed automatically (taking 2 sec.) when power is turned on or off. Manual execution also possible (taking 6 sec.).
- Low-pass filter has a fluorine coating.

(2) Dust Delete Data appended to the captured image

- The coordinates of the dust adhering to the low-pass filter are detected by a test shot and appended to subsequent images.
- The dust coordinate data appended to the image is used by the provided software to automatically erase the dust spots.

(3) Manual cleaning of sensor

Recording System

Recording Format
Design rule for Camera File System 2.0 and Exif 2.21

Image Format
Still: JPEG, RAW (14-bit, Canon original), sRAW, mRAW, RAW+JPEG
Video: MOV (Image data: H.264, Audio: Linear PCM)

File Size
(1) Large: Approx. 17.90 Megapixels (5,184 x 3,456)
(2) Medium: Approx. 8.00 Megapixels (3,456 x 2,304)
(3) Small: Approx. 4.50 Megapixels (2,592 x 1,728)
(4) RAW: Approx. 17.90 Megapixels (5,184 x 3,456)
(5) M-RAW: Approx. 10.10 Megapixels (3,888 x 2,592)
(6) S-RAW: Approx. 4.50 Megapixels (2,592 x 1,728)
Exact file sizes depend on the subject, ISO speed, Picture Style, etc.

Recording Functions
Images record directly to the CF card. With the WFT-E5A attached, image recording to the CF card and to the USB external media connected to the WFT-E5A will be possible as follows:

(1) Standard

- No automatic switching of recording media.

(2) Automatic switching of recording media

- When the current recording media becomes full, it switches to another recording media automatically and continues recording.

(3) Separate recording

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

- Each recording media can be set to record a specific image-recording quality for each shot.

(4) Recording of identical images

- Images can also be recorded at the same size to both recording media. (RAW+JPEG, M RAW+JPEG or S RAW+JPEG is possible).

(5) Backup to external recording media

- Selected images, all images, and quick backup are possible.

Backup Recording
Enabled with Wireless File Transmitter WFT-E5A attached

File Numbering
Consecutive numbering, auto reset, manual reset.
Possible to create new folders and select folders in the CF card.
Firmware Version 2.0.X allows manually setting the file name, the first four alphanumeric characters, or the first three alphanumeric characters + image size.

Color Space
sRGB, Adobe RGB

Picture Style
Standard, Portrait, Landscape, Neutral, Faithful, Monochrome, User Defined 1-3

White Balance

Settings
Auto, Daylight, Shade, Cloudy, Tungsten Light, White Fluorescent Light, Flash, Custom, Color Temperature setting

Auto White Balance
Auto white balance with the image sensor

Color Temperature Compensation
White Balance Correction: ± up to 9 levels, in 1-step increments
White Balance Bracketing: ± up to 3 levels, in 1-step increments

Color Temperature Information Transmission
Provided

Viewfinder

Type
Eye-level pentaprism

Coverage
Approximately 100%

Magnification
Approx. 1.0x (-1m-1 with 50mm lens at infinity)/29.4° angle of view

Eye Point
Approx. 22mm (from eyepiece lens center)

Dioptric Adjustment Correction
-3.0 to +1.0m^{-1} (diopter)

Focusing Screen
Fixed

Mirror
Quick-return half mirror (transmission: reflection ratio of 40:60) with EF600mm f/4L IS USM or shorter lenses)

Viewfinder Information
AF information (AF points, focus confirmation light), Exposure information (Shutter speed, aperture, ISO speed, AE lock, exposure level, spot metering circle, exposure warning), Flash information (Flash-ready, flash exposure compensation, high-speed sync, FE lock, red-eye reduction light), Image information (Highlight tone priority, Monochrome shooting, maximum burst, white balance correction, CF card information), Composition information (Grid, electronic level), Battery check

Depth Of Field Preview
Enabled with depth-of-field preview button

Autofocus

Type
TTL-CT-SIR AF-dedicated CMOS sensor

AF Points
19-point all cross-type AF (f/2.8 at center: Dual Cross Sensor)

AF Working Range
EV -0.5-18 (at 73°F/23°C, ISO 100)

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

Focusing Modes
(1) Autofocus

- One-Shot AF
- Predictive AI Servo AF
* For automatic AF point selection, the AF point to start the AI Servo II AF operation can be selected.
* For automatic AF point selection, the active AF point can be displayed.
- AI Focus AF (Switches between One-Shot AF and AI Servo II AF automatically)

(2) Manual focus (MF)

AF Point Selection
(1) Manual selection: Single point AF
(2) Manual selection: Spot AF
(3) Manual selection: AF point expansion
(4) Manual selection: Zone AF
(5) Automatic selection: 19 point AF

AF Function Registration/Switching
With a Custom Function, four types of AF function settings can be registered in a group: 1. AF area selection mode, 2. AI Servo tracking sensitivity, 3. AI Servo AF tracking method, and 4. AI Servo 1st/2nd img priority.
*This function can be assigned to the depth-of-field preview button or lens A stop button by customizing camera controls/buttons (Custom Controls).

Selected AF Point Display
Indicated by transmissive LCD display in the viewfinder and on the LCD panel

AF Assist Beam
When an external EOS-dedicated Speedlite is attached to the camera, the AF-assist beam from the Speedlite will be emitted when necessary.

Exposure Control

Metering Modes
63-zone SPC TTL metering with selectable modes

- Evaluative metering (uses all 63 zones; linked to active AF point)
- Partial metering (approx. 9.4% of viewfinder at center)
- Spot metering (approx. 2.3% of viewfinder at center)
- Center-weighted average metering

Metering Range
EV 1-20 (at 73°F/23°C with EF50mm f/1.4 USM lens, ISO 100)

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

Exposure Control Systems
Program AE (Shiftable), Shutter-priority AE, Aperture-priority AE, Creative Auto, Full auto, Manual exposure, E-TTL II autoflash program AE

ISO Speed Range
Manually set by user, in P, Tv, Av, and M modes — ISO 100 thru 6400 (in 1/3 or full-stop increments)
Automatic ISO setting in P, Tv, Av, and M modes — ISO 100?6400; User-defined maximum ISO limit can be set from 400 thru 6400, in full-step increments (Firmware Version 2.0.X is required)
When Highlight Tone Priority is active: minimum possible ISO is 200
Automatic ISO setting in Basic Zone modes — ISO 100 thru 3200

Note: In Creative Zone modes (P, Tv, Av, M, and B modes) the maximum settable ISO speed (400?6400) will vary within the automatic automatic ISO speed range.*

*Firmware upgrade (Version 2.0.X) is required.

Exposure Compensation
Up to ±5 stops in 1/3- or 1/2-stop increments (AEB ±3 stops)
* Indicated up to ±3 stops on the LCD panel and in the viewfinder.

AE Lock
Auto: Applied in One-Shot AF mode with evaluative metering when focus is achieved

User-applied: By AE lock button

Shutter

Type
Vertical-travel, mechanical, Electronically-controlled, focal-plane shutter

Shutter Speeds
30 seconds to 1/8000th second; user-settable in 1/3 or full-step increments (available shutter speeds vary by shooting mode); plus Bulb

X-sync at 1/250th second with EOS Speedlites

Shutter Release
Soft-touch electromagnetic release

Self Timer
10-sec. or 2-sec. delay

Shutter Lag Time
Approx. 0.059 sec., according to Canon Inc. test methods and criteria

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

Built in Flash

Type
Retractable, auto pop-up flash

Flash Metering System
E-TTL II auto flash; Manual flash and Multi flash also possible.

Guide Number
12/39 (ISO 100, in meters/feet)

Recycling Time
Approx. 3 sec.

Flash Ready Indicator
Flash-ready icon lights in viewfinder

Flash Coverage
15mm lens angle of view (equivalent to approx. 24mm in 135 format)

FE Lock
Provided

Flash Exposure Compensation
±3 stops in 1/3- or 1/2-stop increments

External Speedlite

Zooming to Match Focal Length
Provided

Flash Metering
E-TTL II autoflash

Flash Exposure Compensation
±3 stops in 1/3- or 1/2-stop increments

FE Lock
Provided

External Flash Settings
Flash function settings, Flash C.Fn settings

PC Terminal
Provided

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

Drive System

Drive Modes
Single, High-speed continuous, Low-speed continuous, and Self-timer (10 sec. self-timer/remote control, or 2-sec. self-timer/remote control)

Continuous Shooting Speed
High-speed: Max. 8.0 shots/sec.
Low-speed: Max. 3.0 shots/sec.

Maximum Burst
JPEG (Large/Fine): approx. 110*/approx. 130**
RAW: approx. 23*/approx. 25**
RAW+JPEG (Large/Fine): approx. 17*/approx. 17**

*Figures based on Firmware upgrade (Version 2.0.X), ISO 100, Standard Picture Style and with 8GB CF memory card.

**Figures apply to 128GB UDMA 7 CF memory card.
Note: UDMA 7 CF memory card read/write speeds are not fully supported with the EOS 7D Digital SLR camera, if using UDMA 7 memory cards, the read/write speeds will be equivalent to UDMA 6

Live View Functions

Shooting Modes
Still photo shooting and video shooting

Focusing
Quick mode (Phase-difference detection)
Live mode/Face detection Live mode (Contrast detection)
Face detection Live mode
Manual focusing (5x/10x magnification possible)

Metering Modes
Evaluative metering with the image sensor (still photos)
Center-weighted average metering (video)

Metering Range
EV 1-20 (at 73°F/23°C with EF 50mm f/1.4 USM lens, ISO 100)

Grid Display
Provided (Two-type grid displays)

Exposure Simulation
Provided

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

Silent Shooting
Provided (Mode 1 and 2)

Video Shooting

File Format
MOV (image data: H.264; audio: Linear PCM (monaural))

File Size
Recording Size: 1920 x 1080 (Full HD), 1280 x 720 (SD), 640 x 480 (SD)

Frame Rates
1920 x 1080 (Full HD): 30p (29.97) / 24p (23.976) / 25p, 1280 x 720 (HD): 60p (59.94) / 50p, 640 x 480 (SD): 60p (59.94) / 50p

Continuous Shooting Time
Approx. 12 min. (Full HD); 12 min. (HD); 24 min. (SD)

Based on Canon's testing standards using a 4GB card.

Focusing
Autofocus: Quick mode, Live mode, Face Detection Live mode; manual

Exposure Control
Program AE, Manual exposure

Exposure Compensation
±3 stops in 1/3- or 1/2-stop increments

LCD Monitor

Type
TFT color, liquid-crystal monitor

Monitor Size
3.0 in.

Pixels
Approx. 920,000 dots (VGA)

Coverage
Approx. 100%
Viewing angle: 170°

Brightness Control
Auto: Brightness adjusted automatically by the light sensor, Manual: 7 levels provided

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

Coating
Anti-reflection, anti-dust coatings

Interface Languages
25 (English, German, French, Dutch, Danish, Portuguese, Finnish, Italian, Norwegian, Swedish, Spanish, Greek, Russian, Polish, Czech, Hungarian, Romanian, Ukraine, Turkish, Arabic, Thai, Simplified/Traditional Chinese, Korean, Japanese)

Tilt Display

On LCD Monitor
Electronic level indicates up to 360° roll and ±10° pitch in 1° increments.

In Viewfinder
The AF point display is used to indicate up to ±6° roll and ±4° pitch in 1° increments (during vertical shooting, up to ±4° roll and ±6° pitch).

Playback

Display Format
Single image, Single image + Image-recording quality/shooting information, histogram, 4- or 9-image index, magnified view (approx. 1.5x-10x), rotated image (auto/manual), image jump (by 10/100 images, index screen, by shooting date, by folder), slide show (all images/selected by date/folder)

Highlight Alert
Provided (Overexposed highlights blink)

Quick Control Function

Items
The following functions can be set (Press "Q" button to access Menu):

Shutter speed, aperture, ISO speed, exposure compensation, AEB, flash exposure compensation, AF point selection (including AF area selection modes), Picture Style, white balance, metering mode, Auto Lighting Optimizer, image-recording quality, AF mode, drive mode, and Custom Controls (camera controls/buttons customization).

Image Protection and Erase

Protection
Single images can be erase-protected or not

Erase
Single image, check-marked images or all images in the CF card can be erased (except protected images)

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

Direct Printing

Compatible Printers
PictBridge-compatible printers

Printable Images
JPEG images compliant to Design rule for Camera File System (DPOF printing possible) and RAW/sRAW images captured with the EOS 7D

Easy Print feature
Provided

DPOF: Digital Print Order Format

DPOF
Version 1.1 compatible

Direct Image Transfer

Compatible Images
JPEG and RAW images

*Only JPEG images can be transferred as wallpaper on the personal computer screen

Customization

Custom Functions
Total 27

Custom Controls
The following camera controls can be customized by assigning the desired function: Shutter button halfway pressing, AF-ON button, AE lock button, depth-of-preview button, lens AF Stop button, Multifunction button, SET button, Main Dial, Quick Control Dial, and Multicontroller.

Camera User Settings
Register under Mode Dial's C1, C2 and C3 positions

My Menu Registration
Provided

Interface

USB Terminal
For personal computer communication and direct printing (USB 2.0 Hi-Speed), used for connecting the Canon GP-E2 GPS Receiver*

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

*Firmware upgrade (Version 2.0.X) is required

Video Out Terminal
(1) Video OUT terminal: NTSC/PAL selectable
(2) mini-HDMI OUT terminal

Extension System Terminal
For connection to optional Wireless File Transmitter WFT-E5A

Power Source

Battery
One Battery Pack LP-E6
AC power can be supplied via AC Adapter Kit ACK-E6
With Battery Grip BG-E7 attached.

Number of Shots

Temperature	Shooting Conditions	
	AE 100%	50% use of built-in flash
At 73° F/23° C	approx. 1000	approx. 800
At 32° F/0° C	approx. 900	approx. 750
Live View shooting at 73°F/23°C	approx. 230	approx. 220
Live View shooting at 32°F/0°C	approx. 220	approx. 210

Battery Life
The above figures apply with a fully-charged Battery Pack LP-E6 without a Battery Grip
The figures above are based on CIPA (Camera & Imaging Products Association) testing standards

Battery Check
6-level display on top LCD panel.
"Battery Info" in Set-up Menu provides precise charge remaining indication, in 1% increments.

Power Saving
Provided. Power turns off after 1, 2, 4, 8, 15 or 30 min.

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

Date/Time Battery
One CR1616 lithium-ion battery

Start-up Time
Approx. 0.1 sec. (based on CIPA testing standards)

Dimensions and Weight

Dimensions (W x H x D)
Approx. 5.8 x 4.4 x 2.9 in./148.2 x 110.7 x 73.5mm

Weight
Approx. 28.9 oz./820g (body only)

Operating Environment

Working Temperature Range
32-104°F/0-40°C

Working Humidity Range
85% or less

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

Appendix I. Motorola DROID X Specifications

General

2G Network	CDMA 800 / 1900
3G Network	CDMA2000 1xEV-DO
SIM	Mini-SIM
Announced	2010, May
Status	Available. Released 2010, July

Body

Dimensions	127.5 x 65.5 x 9.9 mm (5.02 x 2.58 x 0.39 in)
Weight	155 g (5.47 oz)

Display

Type	TFT capacitive touchscreen, 16M colors
Size	480 x 854 pixels, 4.3 inches (~228 ppi pixel density)
Multitouch	Yes

Sound

Alert types	Vibration; MP3, WAV ringtones
Loudspeaker	Yes

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

3.5mm jack	Yes

Memory

Card slot	microSD, up to 32 GB, 16 GB included
Internal	6.5 GB storage, 512 MB RAM

Data

GPRS	No
EDGE	No
Speed	EV-DO Rev. A, up to 3.1 Mbps
WLAN	Wi-Fi 802.11 b/g/n, DLNA, Wi-Fi hotspot (Android 2.2)
Bluetooth	Yes, v2.1 with A2DP
USB	Yes, microUSB v2.0

Camera

Primary	8 MP, 3266x2450 pixels, autofocus, dual-LED flash
Features	Geo-tagging, face detection, image stabilization
Video	Yes, 720p@24fps
Secondary	No

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

Features

OS	Android OS, v2.1 (Eclair), upgradable to v2.3 (Gingerbread)
Chipset	TI OMAP3630 - 1000
CPU	1 GHz Cortex-A8
GPU	PowerVR SGX530
Sensors	Accelerometer, proximity, compass
Messaging	SMS (threaded view), MMS, Email, IM, Push Email
Browser	HTML, Adobe Flash
Radio	Stereo FM radio with RDS
GPS	Yes, with A-GPS support
Java	Yes, via Java MIDP emulator
Colors	Black
	- MP3/WAV/WMA/AAC+ player - MP4/WMV/H.263/H.264 player - TV-out (720p video) via HDMI 1.4 port - Active noise cancellation with dedicated mic - Google Search, Maps, Gmail, - YouTube, Google Talk - Document viewer - Photo viewer/editor - Organizer - Voice memo/dial/commands - Predictive text input

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

Battery

	Li-Po 1540 mAh battery
Stand-by	Up to 220 h
Talk time	Up to 8 h

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

Appendix J. **Camera Lens Specifications**

Canon EF-S 18-55mm Lens

Focal Length & Maximum Aperture	18-55mm f/3.5-5.6
Lens Construction	11 elements in 9 groups
Diagonal Angle of View	74° 20' - 27° 50'
Focus Adjustment	AF (DC motor), with manual focus option
Closest Focusing Distance	9.8 in./0.25m
Filter Size	58mm, P=0.75mm/1 filter
Max. Diameter x Length, Weight	2.7 in. x 3.33 in./68.5mm x 84.5mm (maximum lens length), 7.1 oz. (200g)

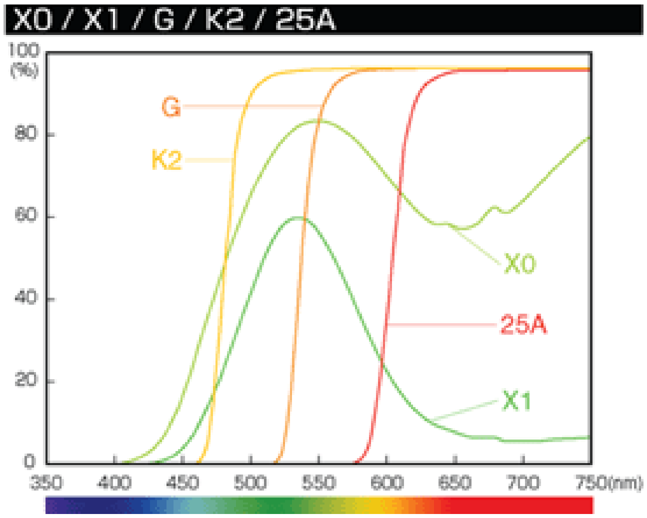
Canon 6 0mm Macro Lens

Focal Length & Maximum Aperture	60mm 1:2.8
Lens Construction	12 elements in 8 groups
Diagonal Angle of View	25°
Focus Adjustment	Manual
Closest Focusing Distance	0.2m /0.65 ft.
Filter Size	52mm
Max. Diameter x Length, Weight	2.9" x 2.8", 11.8 oz. / 73 x 69.8mm, 335g (lens only)

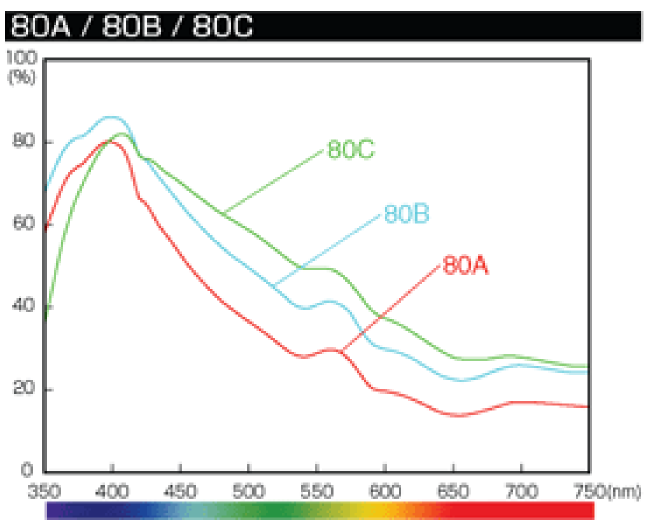
This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

Appendix K. Spectral Filters Specifications

Transmission curves for spectral filters:

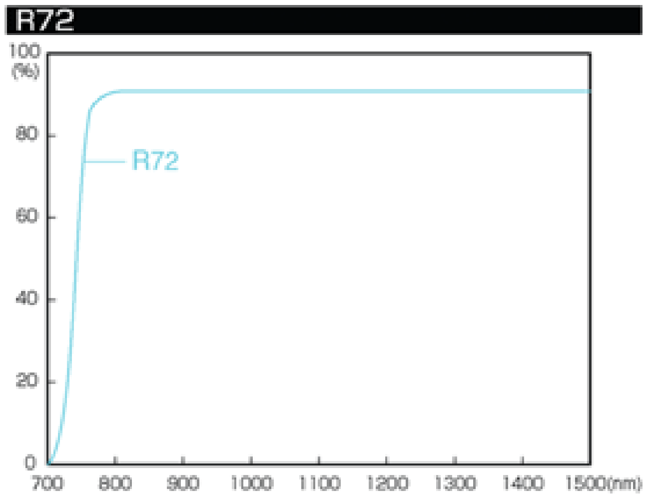


- Hoya Green Filter (X1)
- Hoya Yellow Filter (K2)
- Hoya Orange Filter (G)
- Hoya Red Filter (25A)

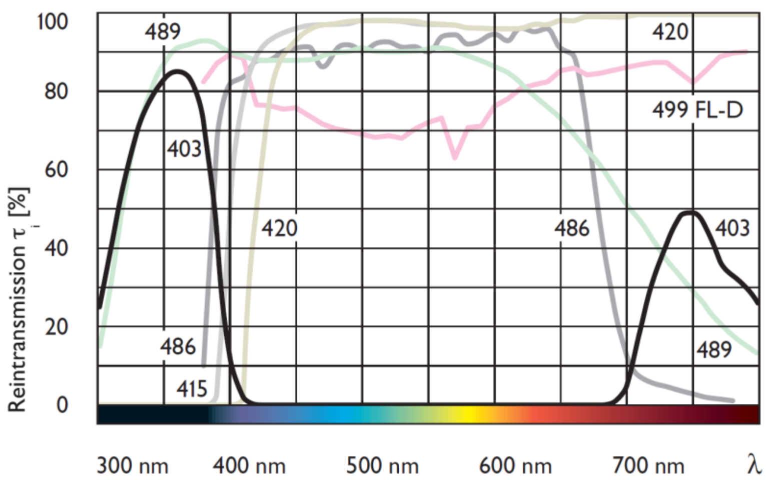


- Hoya Blue Filter (80A)

This document is a research report submitted to the U.S. Department of Justice. This report has not been published by the Department. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.



- Hoya IR Pass Filter (R72)



- B&W UV Pass Filter (403)
- B&W IR Blocking Filter (489)
- B&W UV/IR Blocking Filter (486)