# Using 3D Laser Scanners in Crime Scenes:

# Understanding Advantages and Disadvantages

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# Contents

## Abstract

The regular use of 3D laser scanners at crime scenes and traffic accidents has been around for more than five years now. Not all law enforcement agencies use this technology, primarily because of costs associated with scanners, hardware and software. These agencies instead continue to use manual measuring and diagramming techniques. The intent of this paper is to determine if scanner use is worth the cost. Primary and secondary research involving eight criteria helped discover the outcome. The findings revealed that though manual measuring and diagramming still have an important part in crime scene processing, scanners are worth the value in visual renderings, perspective observations, time management (including manpower costs), and most importantly, unmatched precise measurement and calculation capabilities.

## Introduction

### *3D Laser Scanner Defined*

According to Absolute Geometrics, 3D laser scanning is defined as "the process of capturing digital information about the shape of an object with equipment that uses a laser or light to measure the distance between the scanner and the object."[i] The use of 3D laser scanners in numerous applications is ever-expanding in an effort to make work easier, more accurate, and more efficient. This technology provides improved quality of life and perspective never before imagined.

Consider the use of scanners in the following applications: The auto-body industry uses scanners to review and assure proper body contour lines. Scanners are used in archeology. An example is the reconstruction of a 1,700 year old mummy, a Peruvian ruler dubbed Lady of Cao (Figure 1).[ii] Manufacturing Engineering Technology Professor Rick Orr explained that geometric shapes in dental crowns and orthodontics are meticulously formed with scanners, and prosthetics, including a bird's beak, are engineered to tight tolerances for comfort and reliability.[iii]


**Figure 1: Reconstructing Lady of Cao. Photo capture (2018) from http://www.blog-uk.faro.com/3d-documentation-2/heritage/**

Other scanner uses include engineering and monitoring the structural integrity of bridges, dams, buildings, and roadway management. Police and the military use scanners for reconnaissance, evacuation planning, traffic accident reconstruction, aviation accident reconstruction, and crime scene documentation.

*Old School CSI*

Photographing and hand-sketching diagrams at crime scenes have been successful techniques used by investigators, long before the introduction of scanners. If photographs tell the story, diagrams provide the canvas backdrop. Forensic Scientist George Schiro said, “Crime scene photographs and sketches are both required to form symbiotic relationships, because two-dimensional photographs can potentially distort spatial relationships, and sketches help put photographs into perspective.”[iv]

The Department of Justice (DOJ) published a crime scene training manual that explains necessary tools to assist in manual sketching, including graph paper, pencil, measuring tape, and clip board. Examples in the manual provide instruction on how to diagram birds-eye-view floor plans and elevation plans on one sheet of paper (Figure 2).[v]

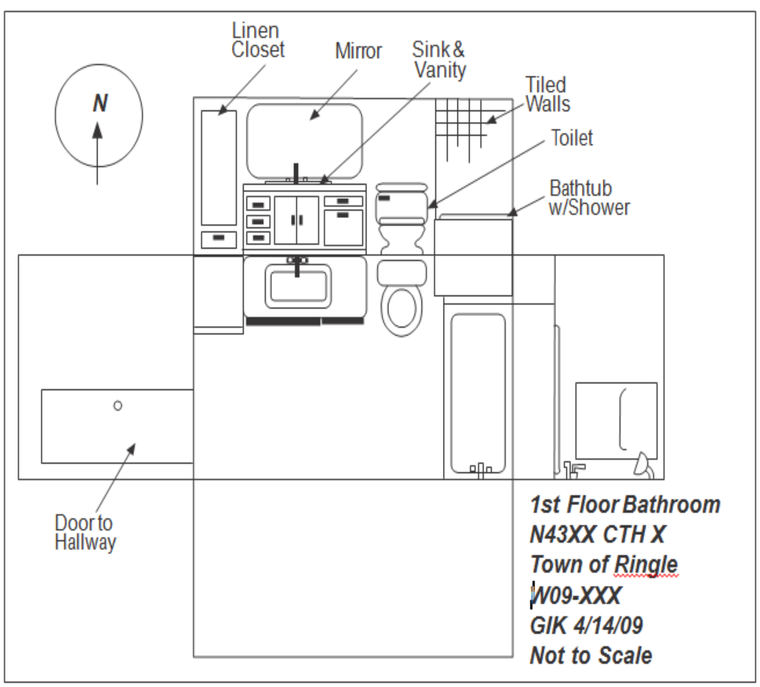


**Figure 2: Diagramming techniques from USDOJ Crime Scene Training Manual (2013), Page 21**

*Bloodstain Spatter:*

Bloodstain spatter is commonplace in crime scenes and therefore important to mention in this paper. Bloodstain spatter is the end result of blood particles flying through the air, caused by gravity or other force, and impacting surfaces such as walls, ceilings, and floors. It can originate from swinging fists or weapons as cast off blood, from bullets entering or exiting the body, or from objects striking a pool of blood. It is examined in order to determine the area of convergence anywhere in 3D space.

Traditional tangent and string methods of bloodstain analyses involve meticulous equations of spatter elongation. A more pronounced elongation indicates a steeper angle of trajectory. Strings are stretched parallel to the long axis of spatter, and angled from the surface according to the pronouncement of the elongation. Perfectly round spatter with no elongation would indicate trajectory of 90 degrees to the surface, such as a nose bleed droplet falling under gravity and striking the floor. Figure 3 provides a visual of how manual bloodstain pattern analysis is conducted.[vi]

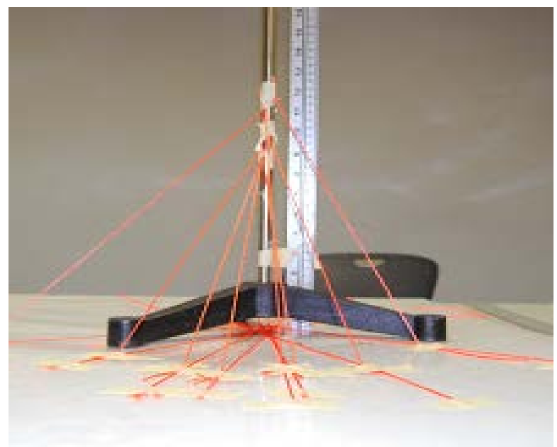

**Figure 3: Tangent and string bloodstain analysis; http://drnik46.blogspot.com/2008/09/bloodstain-pattern-analysis.html (2018)**

The use of a computer aided design (CAD) software program, such as FAROZone, eliminates the need to manually stretch strings to visualize trajectory. It also allows an investigator to virtually return to the crime scene at any given time and obtain measurements of anything desired. This would be impossible with manual measurements after the crime scene or the reconstruction of the crime scene has been released.[vii]

*Comparison*

Manually measuring crime scenes with grid paper, clip boards, and measuring tapes take a lot of time and may be susceptible to errors. Along with minimal margin of error, scanner manufacturers tout claims of quick and easy setup, data collection, learning curve, and professional CAD presentations.

This paper will use a combination of primary and secondary research to investigate the thesis that laser scanner-based methods are better for diagramming crime scenes than traditional pencil and paper methods. Primary research will involve interviews with forensic science practitioners and practical exercises using both methods. Secondary research will look at publications, presentations and vendor materials. Research criteria will include the following:

1. Measurement Accuracy
2. Time Efficiency
3. Officer Safety
4. Cost Analysis
5. Data Collection and Evidence Preservation
6. Courtroom Acceptance
7. Future of Manual Measuring and Diagramming
8. Indoor/Outdoor Use

## UPD and FARO Practical Exercise

Crime Scene Investigators Brent Benner and Alan Kalinowski provided a scanner demonstration at the Unified Police Department (UPD).[viii] This demonstration provided information on scanner capabilities and limitations.

UPD owns three FARO Focus tripod-mounted scanners and one FARO Freestyle handheld scanner (Figure 4). One of the three Focus scanners and the Freestyle scanner are assigned to the Crime Scene Investigations Unit (CSI). The other two Focus scanners are assigned to the Collision Analysis Reconstruction Unit (CAR). The CSI scanners are deployed about twice a month on all homicides, possible homicides, suicides, and officer-involved shootings. The CAR scanners are deployed almost daily to investigate car accidents where fatalities or possible fatalities occur. UPD maintains Memorandums of Understanding (MOU's) with neighboring law enforcement jurisdictions to assist with investigating serious car accidents and major crimes anywhere in the Salt Lake Valley. It is not uncommon to have multiple scanners from various agencies working the same scene.[ix]


**Figure 4: FARO Freestyle and iPad, and FARO Focus (2018) www.faro.com/products/construction-bim-cim/faro-focus/**

The Freestyle handheld scanner is used in tight locations, such as a bathroom or the passenger compartment of a vehicle. The Freestyle can also be used on incidents such as suicides, where only the immediate area of a crime scene is scanned and not an entire room.

Kalinowski favors the Freestyle, because an attached iPad allows the operator to view what is being scanned instantaneously. Although the Freestyle serves a purpose, Benner is not a fan. The Freestyle seems finicky and jittery. The operator must use caution to methodically scan in patterns similar to taking panoramic photos or mowing a lawn.[x]


**Figure 5: The author of this paper holding the Handyscan 300 handheld laser scanner (2017)**

Manufacturing Engineering Technology Professor Taylor Foss, and the author of this paper, Darwin Little, conducted a practical exercise using the Creaform Handyscan 300 handheld laser scanner (Figure 5).[xi] Similar to Benner's assessment of the Freestyle, the Handyscan did not perform as expected and provided for a frustrating experience. The handyscan did not scan smoothly. It did not interact well with software. The manufacturing company demonstrated poor product customer service. The instruction manual was ridiculously cumbersome and caused much confusion.

The Freestyle operated much better than the Handyscan, and the Focus greatly exceeded the expectations of author of this paper in regards to scanning and photographing, as well as providing virtual representations through easy to use CAD software.

The tripod-mounted FARO Focus has a digital display and controls located at one end of the scanner head (Figure 6). Based on preset scanning parameters, it takes about six minutes for the Focus scanner head to rotate and capture all the data and photos for one scan. Parameters such as black and white or color, quality, and resolution determine the amount of time it takes per scan.


**Figure 6: Readout controls located on one side of the FARO Focus scanner head. Retrieved 2018 from http://matrixti.com/matrix-on-manufacturing/3d-laser-scanning-industrial-plant-design/**

A scanner head operates by rotating about a vertical axis atop the tripod, capturing data in 360 degrees (green arrow in Figure 7). The scanner mirror, angled at 45 degrees to the laser light source, spins about a horizontal axis, capturing data in 300 degrees (red arrow in Figure 7). The spinning mirror refracts the laser light. The light reaches out and measures all objects (millions of points) at the speed of light (red line in Figure 7). The only space not scanned is a cone-shaped area on the floor, directly underneath the tripod. Since the scanner actually emits laser light out the front 180 degrees and out the back 180 degrees (as the mirror spins from the front, up and over to the back) the scanner head really only needs to rotate 180 degrees to capture everything in 360 degrees. This cuts the scanning duration by half.[xii]

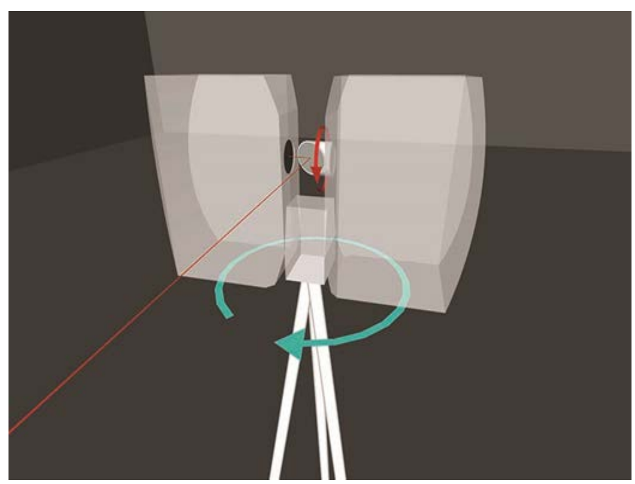

**Figure 7: Scanner head rotates atop the tripod about a vertical axis, while the spinning mirror rotates about a horizontal axis.**

*Registering*

Registering (or stitching) is the term used when two or more scans are merged together. Registering provides an overall view from different scanner head locations. Once all scans are registered, the viewer can select different scanner head locations to walk around a car or other object in order to view all sides, as each scanner location can only capture line of sight.

Registering has historically been done back at the office, after all scans are completed; however, newer technology allows registering on-the-go, such as with FARO's newest scanner, called the S-40. The S-40 scan range is about 20 feet, which is a shorter distance than the Focus. This provides a better outcome, as investigators tend to scan within this shorter distance between moves. The S-40 obtains natural targets to aid in registering. Natural targets include well-defined objects such as door hinges, street signs, and corners of buildings.

Older scanners rely more on sphere and checkerboard targets (Figure 8). Sphere and checkerboard targets require more setup and takedown time. At least three targets placed in an asymmetric pattern in each scan are required. It is best when targets from previous scans are visible to subsequent scans. Targets help identify or pinpoint references in space, where adjacent scans can relate and occupy the same sphere or checkerboard space during registering. Spheres are mounted on tripods or on magnetized bases. One of the common sphere sizes is a 200 mm diameter. Checkerboards (or other designs) are flat sheets of paper with varying defining patterns that attach to wall surfaces.[xiii]

**Figure 8: Sphere and checkerboard targets (2018). https://shop.laserscanning-europe.com/Large-laser-scanner-checkerboard-targets-as-a-set**

## WVCPD and Leica

**Figure 9: Leica ScanStation P16; leica-geosystems.com/en-us/products/laser-scanners/scanners/-**

Crime Scene Investigator Angela Petersen operates a Leica ScanStation C10 scanner. A similar model, the P16, is displayed as Figure 9. The C10 is an older, heavy-duty and cumbersome scanner. It requires multiple heavy cases to carry its equipment. Its tripod is also heavy-duty. Its robustness works well on outdoor scenes, as it will not tip over in the wind, will not overheat, and will not freeze. Moving the C10 tripod to multiple locations within an indoor crime scene is cumbersome and time-consuming compared to other scanners; however, the end result is impressive. The C10 provides hundreds of thousands of measured points per second, but it takes about 45 minutes per scan.[xiv]

Leica has developed a scanner that work well and quickly indoors, called the Leica BLK360 (Figure 10). The BLK360 can produce a scan in three minutes and scans for an entire house in about an hour. It scans millions of points per second. Its head is much lighter and smaller, similar in size to a 20 ounce drink cup. It fits into a single backpack along with all the gear. Its tripod is small and light. It is capable of scanning the area under the tripod by inverting the head. It eliminates the need for costly and time-consuming targets. There is still a question in Petersen's mind as to how it will withstand the outdoor elements, including wind. Weights may be required to prevent wind from blowing over the camera-style tripod.[xv]

**Figure 10: Leica BLK 360 is the "world's most portable and easy to use imaging laser scanner." http://psg.leica-geosystems.us/page/scanstation-3d-laser-scanners/**

## WSU and FARO Practical Exercise

*Scene Set Up*

Criminal Justice Professor Dr. Brent Horn, and the author of this paper, Darwin Little, conducted a practical exercise using a FARO Focus and sphere and checkerboard targets at an indoor mock crime scene. The crime scene was set up at a WSU college dorm. The scene included an entryway, vanity area, toilet room, shower room, and a large bedroom. The bedroom contained bunk beds, two desks, two chairs, two chest of drawers, and two closets. Props for the scene included bullet casings, handgun, laptop, backpack, fake blood, blanket, throw rug, and a mannequin. Figure 11 depicts the bedroom and the mannequin on the bottom bunk.[xvi]

The scene was ultimately scanned three different times, identified as Group 1, Group 2, and Group 3. Each group had 10, 9, and 10 individual scans respectively. Each group will be explained in greater detail.

**Figure 11: Looking west from the threshold of the bedroom doorway; pristine photo of the mock crime scene by Darwin Little on 07 May 2018**

*Scan Plans*

The order of forensically processing a crime scene includes taking pristine photographs and video; identifying blood, DNA, latent and patent fingerprints, and other evidence; setting numbered markers at key evidence locations; taking a second set of photographs with the numbered markers; preparing a scan plan and use the scanner; making a hand-sketch diagram, and collecting evidence. [xvii]

Scan plans are an important part of the process. Scan plans help document the strategic placement of the scanner tripod and targets in relationship to evidence and objects blocking line of sight. This type of record provides understanding during the investigative process.[xviii]

The FARO Focus training manual (2015) indicates that during project planning, scan plans help the operator “select proper target arrangements and scanner positions… (Scan plans) can also be used during registration to clarify how scans relate”[xix] to one another and to other objects.

Figure 12 is the scan plan for WSU scan groups 1 and 2. Figure 13 is the scan plan for WSU scan group 3. The color red on the scan plans indicates the locations of the scanner tripod. Blue indicates the sphere and checkerboard target placements. Typically, minimal measuring is done on scan plans, as they are usually just used as a pictorial reference.

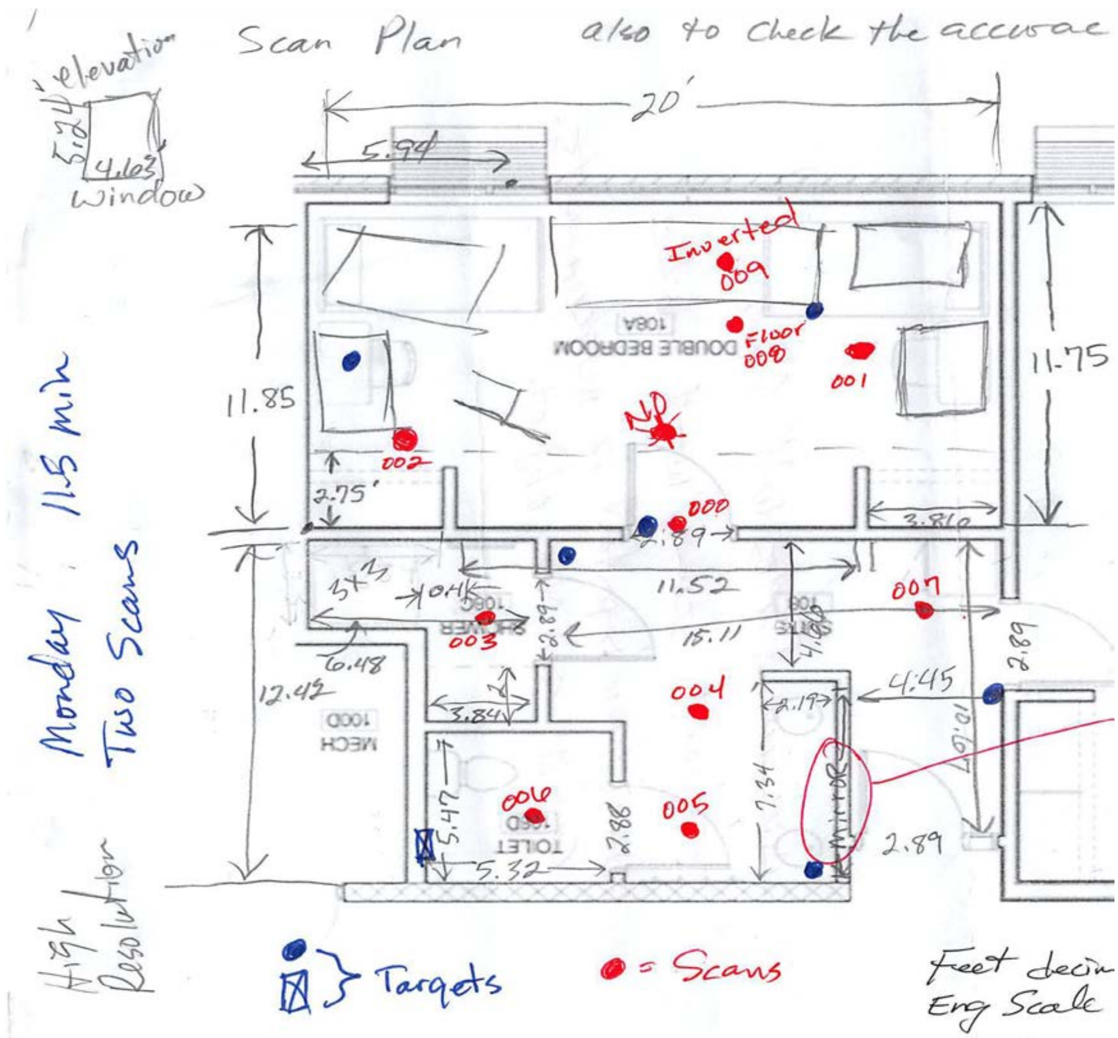


**Figure 12: Scan Plan for Scans 1 and 2 at WSU, combined with rectangular coordinate measurements in feet tenths by Brent Horn and Darwin Little**

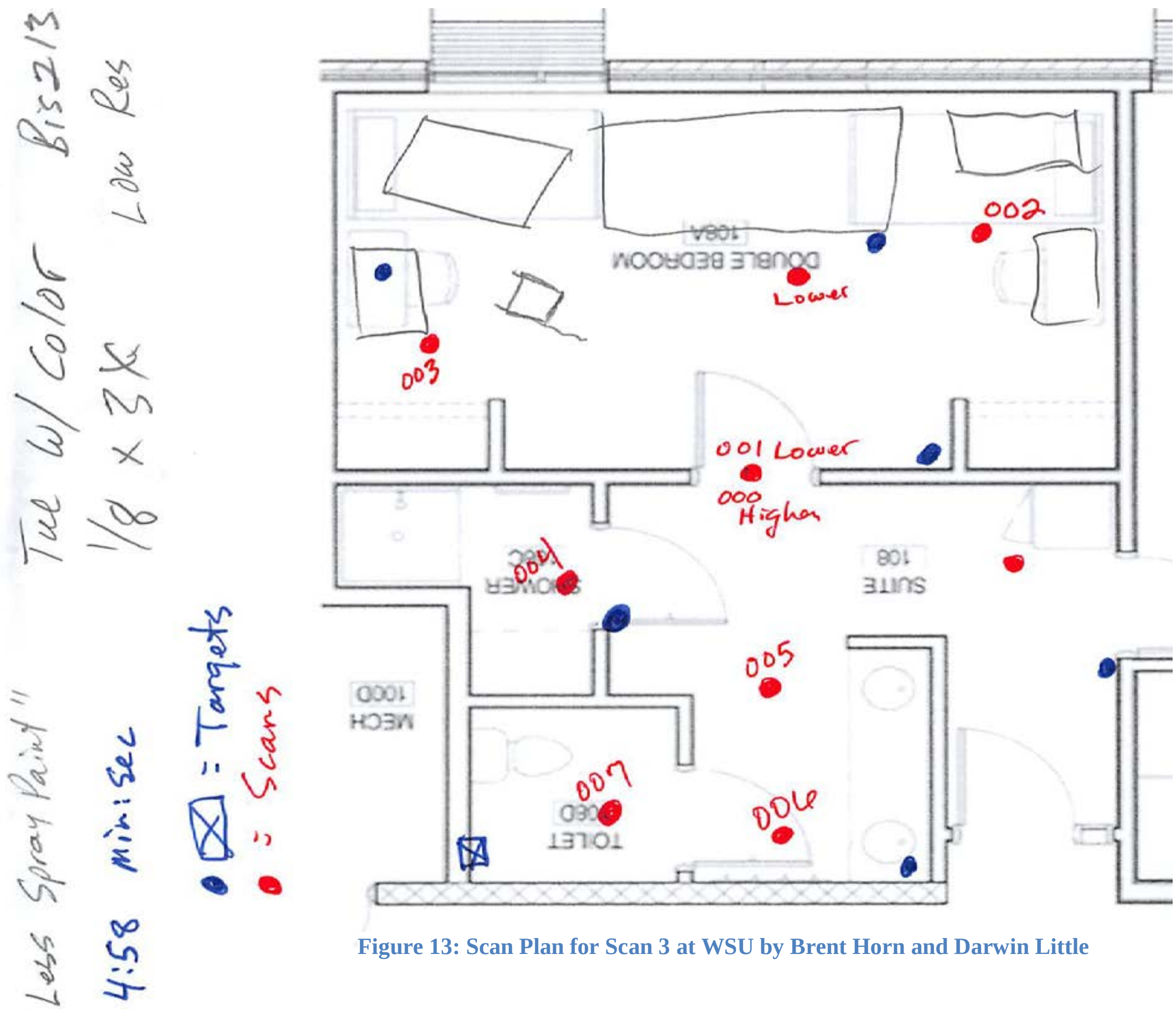


Figure 13: Scan Plan for Scan 3 at WSU by Brent Horn and Darwin Little

*Parameters*

As briefly mentioned previously, some of the scanner parameters include color, resolution and quality. Choosing the parameters on these features may depend on time constraints, lighting, scene size, environmental conditions, and indoors or outdoor use.

If color is selected, then the scanner takes a series of 82 photographs after each scan. Scanner photographs are in addition to the still photographs taken before the laser is set up. Scanner photographs will be used as an overlay to the laser diagrams on the webs-share end-product. When color is used, lighting of the crime scene becomes critical. Too much light will wash out the view (over-exposure). Too little light will provide insufficient detail. Natural light is best. Color representations are best used in courtroom presentations.

Black and white works best in any light, but also in low light or bright light. Black and white scans interpret object detail as infrared reflectivity representations. The more reflective the object, the whiter it will look in the view. High reflective objects, such as a mirror, are difficult to scan. Black and white representations are best used for investigative purposes and when time on scene is short.

Resolution determines the density of scan points (spacing from one point to another). A higher resolution setting provides sharper images.

Quality determines how much time is used for the scanner to sample and confirm the accuracy of measured points. Increasing quality increases the time required to confirm accurate measurements. Higher quality settings provide less noise or less extraneous points. Quality selection will affect the range of the scan or the distance in which the scanner can accurately scan.[xx]

According to FARO's training manual, "resolution and quality are the most important scan parameters because they affect the level of detail captured, scan duration, and the ability to register scans properly."[xxi]

Scanners use inclinometers, compasses, and global positioning systems (GPS). There is no need to identify reference points for the scanner or its tripod. It really does not care about the location of the (XYZ) origin. The origin is established later in CAD programs. The scanner knows when it is on the floor (Figure 14), five feet off the floor, or on the second floor.[xxii]


**Figure 14: Photo taken by Darwin Little at the WSU practical, showing the FARO scanner head removed from the tripod and placed on the floor, ready to scan items at a lower point of view, such as under the bed. One possible problem is that the carpet may allow the scanner head to vibrate. Additionally, shadows and exposure to light are different from one scan to another on different elevations when stitched together.**

*Scanning*

The three scan groups were taken in order to review differences in the parameters (color, resolution and quality). Figure 15 provides the data in spreadsheet format from all three groups. To help understand how to decipher the data, one quarter resolution is considered higher resolution than one eighth. 4X quality means that the scanner confirmed its measurements more times than 3X, taking more time to do so. The Mean Scan Error represents the ability of the program software to register the scans together. Of note is the comparison of millions of points. Group 3 had 655.4 million scanned points, which seems excessive at first glance, considering its resolution and quality were lower; however, it had one more scan than group 2. Additionally, Group 3 maintained more duplicate points in the final product than groups 1 or 2 (the duplicate points statistic is not included in the chart). [xxiii]

| **Group Number** | **1** | **2** | **3** |
|---|---|---|---|
| Resolution (1/4=high; 1/8=low) | 1/4 | 1/4 | 1/8 |
| Quality (4x=longer time) | 4x | 4x | 3x |
| Color/BW | BW | Color | Color |
| Photos | No | Yes | Yes |
| Max Scan Point Error (mm) | 1.3 | 0.9 | 1.3 |
| Mean Scan Point Error (mm) | 9.9 | 0.8 | 0.9 |
| Minimum Overlap (%) | 46.1 | 38.8 | 44.1 |
| Scans per Group | 10 | 9 | 10 |
| Minutes per Scan | 8:30 | 11:30 | 4:58 |
| Millions of Points | 341 .4 | 727.1 | 655.4 |

**Figure 15: Scan group comparison chart**

The results of each scan group revealed interesting qualities and problems. In each scan group, line of sight and lighting discrepancies were challenging. Techniques to address line of sight included setting the scanner head directly on the floor to capture evidence under the bed and against the wall. Suspending the scanner inverted in the spokes of the upper bunk bed was attempted to capture evidence near the body and against the wall. Black and white or color were used to address reflectivity contrast and shade discrepancies.

*Web-Share*

After each scan group was completed, the data, which fits on an SD Card, was removed from the scanner and placed in a computer with a quality video card and sufficient memory. An SD Card is capable of fitting all the raw scanner data because it only contains an inconsequential number of photographs and measurements for each point.

The FARO computer software took the ten scans in scan group 1, the nine scans in scan group 2, and the ten scans in scan group 3, and registered them into three separate visual files. The three files, now much larger point clouds, were obviously unable to fit back onto the SD Card. They were now ready to be placed into a web-share, ready-to-go product, allowing anybody a watered-down view from any computer. Web-share files do not maintain all the fine visual quality expected for courtroom presentations. FAROZone or other CAD software is required for professional presentations.

In the web-share overview (birds-eye-view), the operator can select any of the inverted teardrops as a view point (Figure 16). These teardrops are specific locations in space where the scanner head was positioned. By selecting a teardrop, the operator can observe the scene from that viewpoint. The limitation of viewing 3D on a 2D computer screen is like viewing a map of the globe unfolded on a flat table. 3D and panoramic views, available on each teardrop, have their advantages and disadvantages while working with visual distortion and measurements.[xxiv]


**Figure 16: Web-Share overview (birds-eye-view) of scanner positions in group 1. The red is what the scanner by the front entry can see (BIS2131_a007).**

*Scan Group 1*

Intuitively, if an operator had sufficient time, the higher quality and the higher resolution would seem to provide the best results; however, similar to spraypainting a car too slow or too close, the paint will run. The inverted scan just under the top bunkup may have been too close to the body, and the resolution was set too high. The images turned out ok, but the mean scan point error was greater than expected after all ten scans were registered.

The option of black and white was used in scan group 1 (Figure 17). This allowed for great reflective detail. One problem with black and white is the blanket and the pants on the body maintained similar reflectivity properties, making it difficult to visually distingush between the two. Another concern that may have caused the high mean scan point error was that a sphere target was placed directly above the first scanner head, located in the bedroom doorway.[xxv]

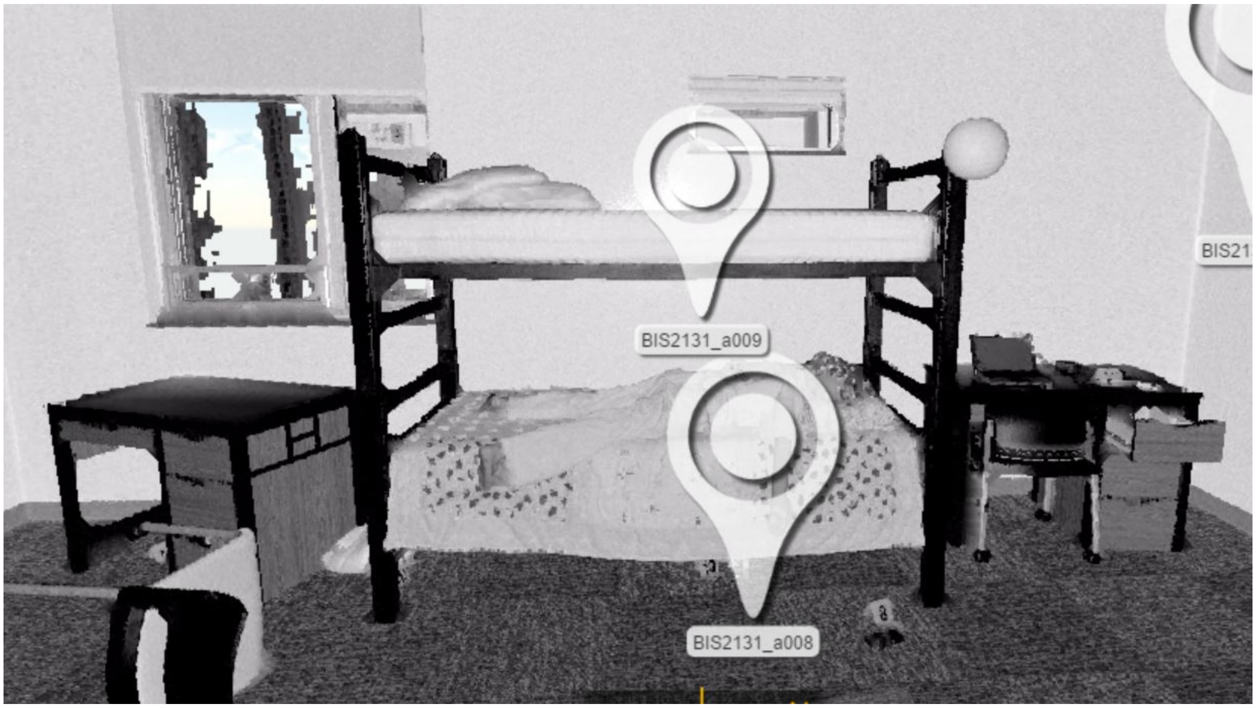


**Figure 17: Looking west from the viewpoint of the scanner in the bedroom doorway; black and white scan from group 1. Note: this and all subsequent scan captures were collected from a web share program at low quality.**

*Scan Group 2*

Scan Group 2 maintained similar resolution and quality properties. Color was the only change. The inverted scan just under the top bunk bed was eliminated. Minutes per scan understandably increased to 11.5, because photographs were taken after each scan. The mean scan point error improved and the photograph overlay onto the reflectivity allowed for better visualization contrast, except for areas of overexposure, such as above the door in Figure 18.

Scanners have a difficult time with objects that are too reflective, such as mirrors. To the scanner, the toilet door reflected in the vanity mirror in Figure 18 appears instead as a door situated further beyond the back of the sinks, with the mirror acting as a simple hole in the wall. This shadowing effect is easily cleaned in CAD. Some operators cast baby powder or fingerprint power on mirrors in an effort to minimize this reflectivity phenomenon.[xxvi]

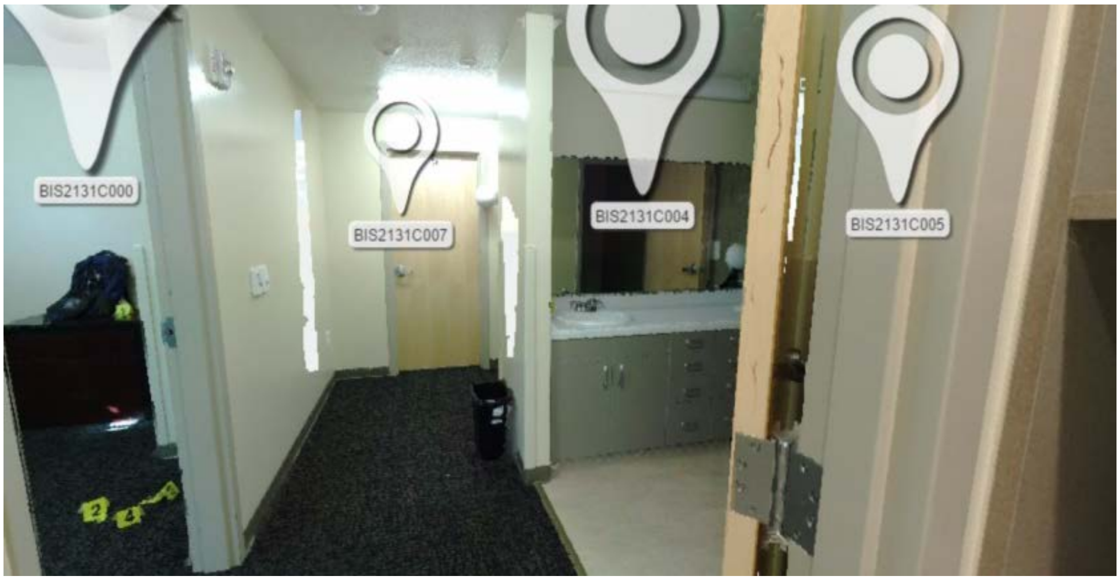


**Figure 18: Looking north from the viewpoint of the scanner located in the shower room; color scan from group 2. Note the detail in the wood grain of the door. The inverted teardrops are actual scan head locations.**

*Scan Group 3*

Some of the target locations were changed before starting scan group 3 in an attempt to improve target acquisition when registering. Specifically, the target sphere directly above the scanner in the bedroom doorway was moved to a different location. The number of scans in scan group 3 increased back to 10. Instead of the inverted scan just below the top bunk bed, two scans were taken from the bedroom doorway at different heights.

Observe the shadow line on the wall between the upper and lower bunk beds in Figure 19. The shadow was made by the contour of the body from the viewpoint of the scanner on the floor. In reality, the shadow should have been made by the top bunk bed blocking the ceiling light, from the viewpoint of a scanner five feet above the floor. The shadow contour line of the bunk bed on the wall would have then been a straight line.

**Figure 19: Looking southwest from the viewpoint of the scanner located at the north side of the bedroom; target-based color scans from group 3.**

Notice the distortion on the bunk bed frame and the misaligned targets in Figures 19 and 20 respectively. When attempting to register the ten scans in group 3, the program did not like the targets. This obviously resulted in a less-than-desirable mean scan point error (not displayed). Remember that according to FARO's training manual, resolution and quality settings are the most important scan parameters because they affect among other things, the ability to register scans properly.[xxvii] Having more knowledge and training, the author of this paper may have been able to better adjust the scanner parameters in order to properly register the scans.

Theories into why this problem occurred include the use of color, lower resolution, and lower quality settings. Dr. Horn believes the distortion was caused by the wall paint, spheres, and bedframe reflecting similarly. The lighting in the room, including the contrasts of too much or too little, did not help with the color photo overlay. Ultimately, the problem was the result of color and exposure, not reflectivity.[xxviii]

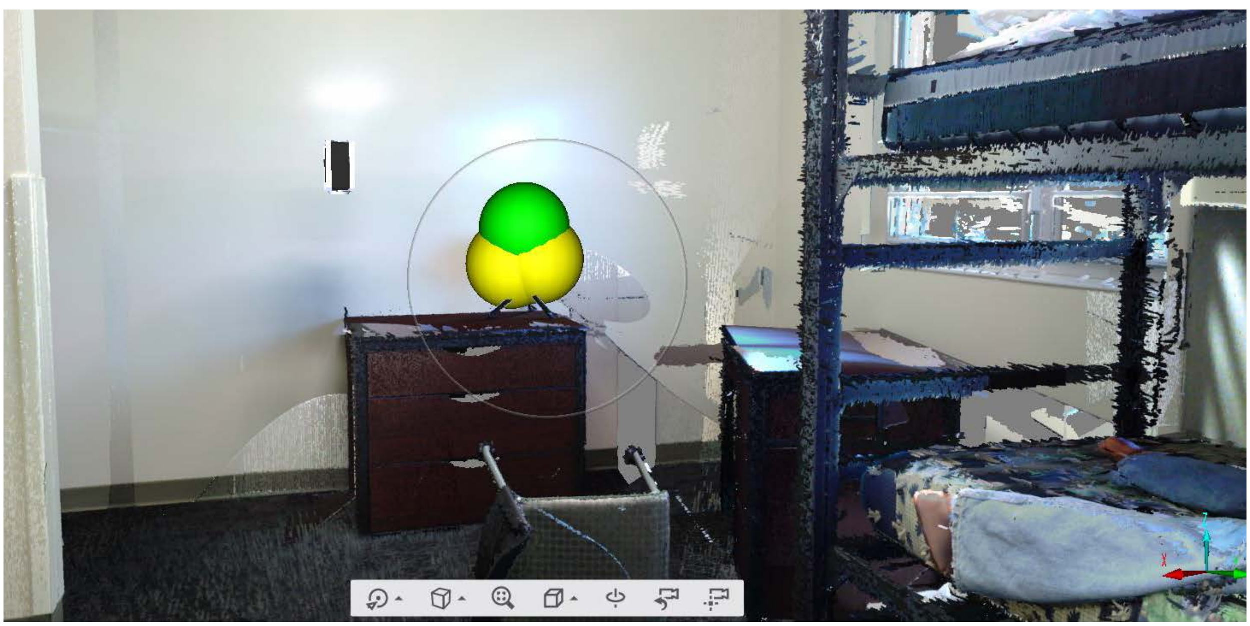

**Figure 20: Looking south from the viewpoint of the scanner located at the north side of the bedroom; target-based color scans from group 3.**

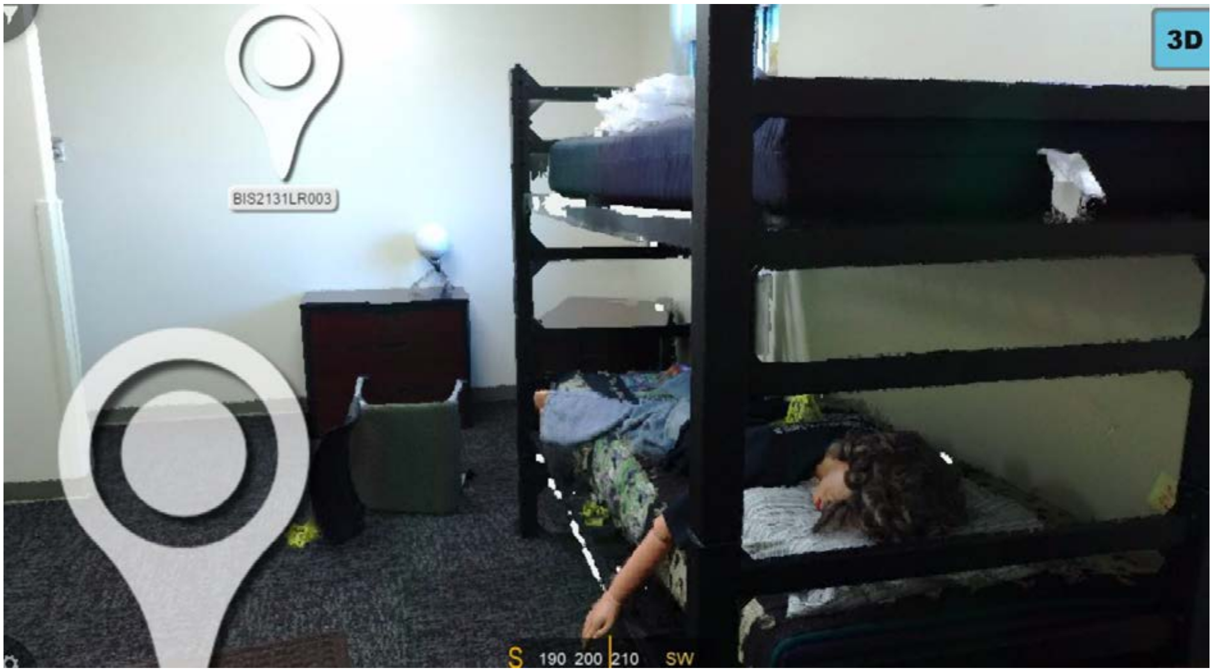


**Figure 21: Looking south from the viewpoint of the scanner located at the north side of the bedroom; top-down and cloud-to-cloud registering color scans from group 3.**

Figure 21 is the result of re-registering, using the top-down and cloud-to cloud process. This takes more time, but notice how the spheres now occupy the same geometric space, how the bedframe distortion is minimized, and how the shadow on the wall is appropriately represented. This provided better alignment and a more acceptable mean point error (Figure 15).

Dr. Horn explained the different types of registration process: 1. Target-based registration uses both natural, sphere, and checkerboard targets. Target-based registration was a quicker process, but it did not provide the appropriate visual results as demonstrated in Figures 19 and 20; 2. Instead of targets, top-down registration uses inclinometer, compass, and GPS sensor data to position the scans relative to the scanner position; 3. Cloud-to-cloud registration takes all the individual dimensional points and tries to overlap the duplicate data between scans. Cloud-to-cloud is more precise, but registration takes substantially more time to process.[xxix]

*Virtual Measuring*

While viewing any object in web-share virtual 3D format, the operator has the capability to measure anywhere from point A to Point B. It does not matter if it is a top-down view, an elevated view, or even a perspective or foreshortened view. However, the operator must use caution when selecting points to measure. For example, if measuring across the front of the chest of drawers, it must be confirmed that the starting point and ending point are actually selected on the front. Anywhere beyond, even slightly, and the program will think the point to measure is instead on the wall behind. Panning the view assures proper point selection.[xxx]

Design Engineering Technology Professor Jeremy Farner teaches that certain CAD software using XYZ coordinates, such as Solidworks, does not measure objects in foreshortened views (parallax). This is because such measurements appear distorted and are without a universal scale.[xxxi] Scanners collect measurements using the Polar technique (azimuth) and not (XYZ) coordinates with a (000) origin; therefore, any object in any view in the scanner's point cloud can be accurately measured.

Dr. Horn explained the reason the scanner and accompanying point cloud data are so important is because the prosecutor, defense attorney, jury and judge are more interested in how far, for example, bullet casings are from certain locations in space (such as five feet off the floor if a person were standing in the bedroom doorway firing a handgun). The interest is not at the (00) origin at some remote corner of a room, which is the location where most investigators start their manual measurements.[xxxii]

*Hand-Sketch Diagrams*

Petersen uses both techniques of manual measuring and laser scanning on many crime scenes. Using both techniques assures that her work is accurate. Instead of using a measuring tape for hand-sketching, Petersen uses the handheld Leica laser disto-meter.[xxxiii] Figure 22 displays two brands of disto-meters, Bosch and Leica. Using a disto-meter eliminates the need for another person to hold the zero end of the measuring tape, maintains accurate measurements within industry tolerances, and eliminates potential human errors such as slack and twists in the measuring tape. The disto-meter also provides much smaller incremental measurements, unlike the longer measuring tapes or the rolo-meters that display one quarter inch as the smallest increment.[xxxiv]


**Figure 22: Bosch and Leica Laser Disto-Meters**

Figures 23 and 24 depict hand-sketch diagrams from the WSU scene. Both Bosch and Leica disto-meters were used to obtain the measurements. Letters identifying evidence locations were used in Figure 24 in an effort to maintain an uncluttered view, as opposed to the lines drawn in Figure 23. Using letters in this manner is a common practice. North should usually be at the top of the diagrams, but for ease of drawing and locating the (XY) origin reference point, based on the shape and size of the bedroom, west became the top of each diagram displayed in this paper. The letter locations in Figure 24 correlate with the spreadsheet letters in Figures 25 and 26. Figure 27 is a spreadsheet with elevation measurements. Each spreadsheet provides meters and feet conversions.

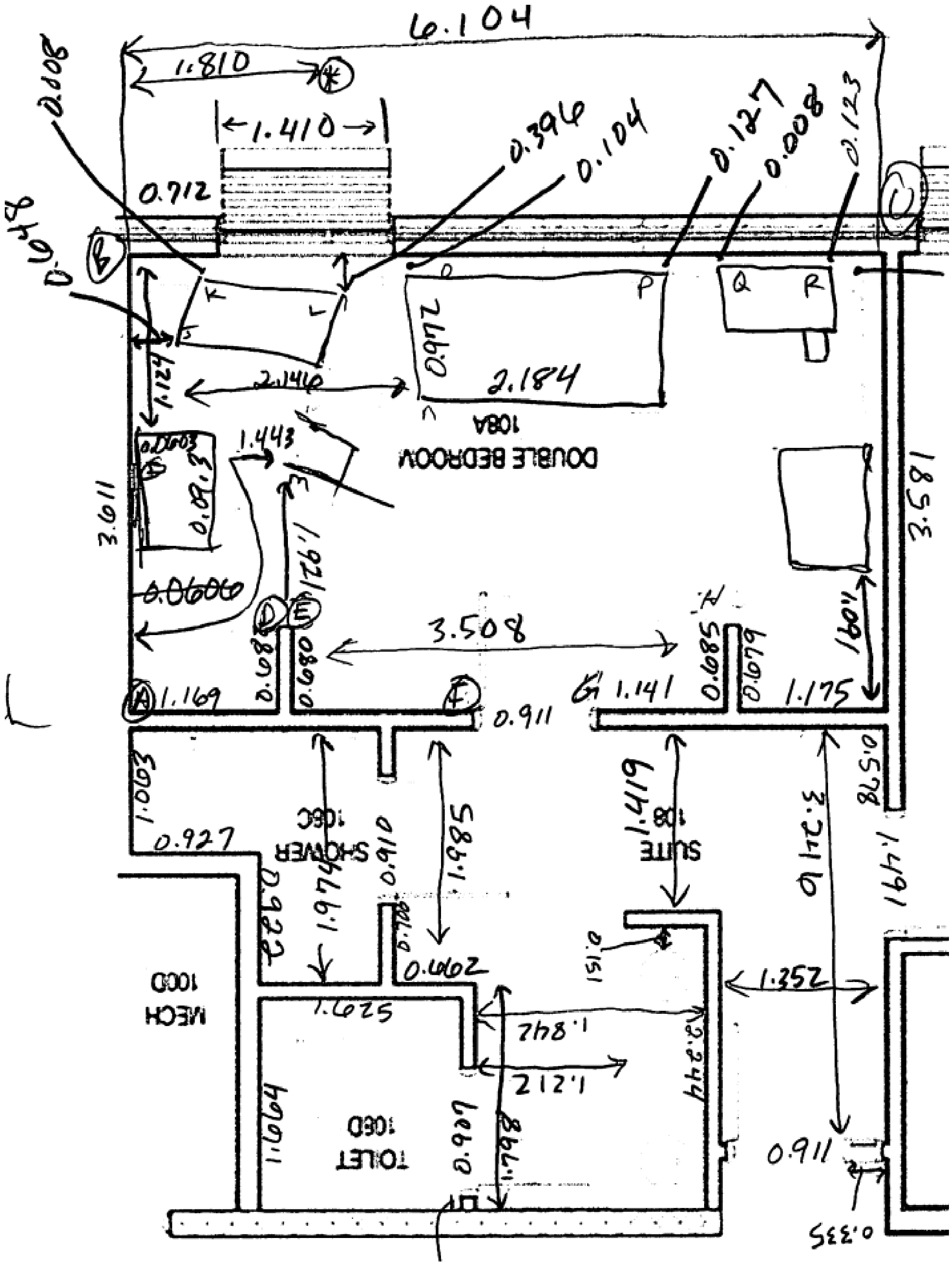


**Figure 23: Hand-sketch diagram by Brent Horn and Darwin Little at WSU (Rectangular coordinate measurements in meters)**

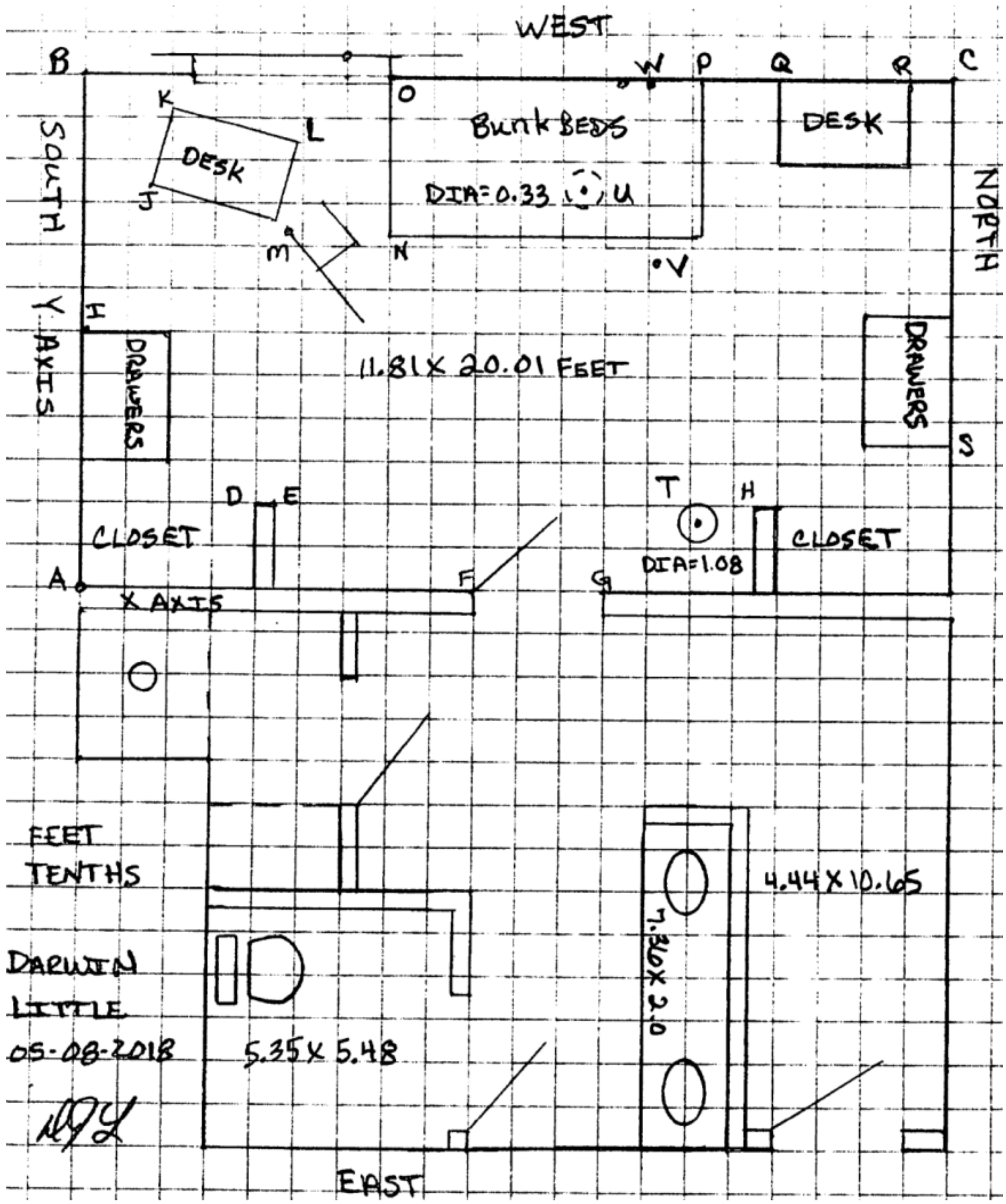


**Figure 24: Hand-sketch of the WSU scene by Darwin Little. Letter Locations were used to maintain a clean document. Measurements were in feet.**

| Letter | Bedroom (XY) Measurements | X=Distance from Y Axis | | | | Y=Distance from X Axis | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Description | Meter | Ft. Dec. | Feet | Inches | Meter | Ft. Dec. | Feet | Inches |
| A | Reference Point SE Bed Rm Corner | 0.00 | 0.00 | 0 | 0 | 0.00 | 0.00 | 0 | 0 |
| B | South/West Intersecting Walls | 0.00 | 0.00 | 0 | 0 | 3.60 | 11.81 | 11 | 9 6/8 |
| C | North/West Intersecting Walls | 6.10 | 20.01 | 20 | 1/8 | 3.58 | 11.75 | 11 | 9 |
| D | South Closet Interior Wall | 1.17 | 3.84 | 3 | 10 1/8 | 0.68 | 2.23 | 2 | 2 6/8 |
| E | South Closet Exterior Wall | 1.27 | 4.17 | 4 | 2 | 0.68 | 2.23 | 2 | 2 6/8 |
| F | Bedroom Entry Hinge Side | 2.73 | 8.96 | 8 | 11 4/8 | 0.00 | 0.00 | 0 | 0 |
| G | Bedroom Entry Latch Side | 3.64 | 11.94 | 11 | 11 2/8 | 0.00 | 0.00 | 0 | 0 |
| H | North Closet Exterior Wall | 4.78 | 15.68 | 15 | 8 2/8 | 0.69 | 2.26 | 2 | 3 1/8 |
| I | South Chest Back Right Corner | 0.00 | 0.00 | 0 | 0 | 2.49 | 8.17 | 8 | 2 |
| J | South Desk Left Front Corner | 0.65 | 2.13 | 2 | 1 5/8 | | 0.00 | 0 | 0 |
| K | South Desk Left Rear Corner | | 0.00 | 0 | 0 | 3.60 | 11.81 | 11 | 9 6/8 |
| L | South Desk Right Rear Corner | | 0.00 | 0 | 0 | 3.21 | 10.53 | 10 | 6 3/8 |
| M | Chair West Back Leg | 1.44 | 4.72 | 4 | 8 6/8 | 2.60 | 8.53 | 8 | 6 3/8 |
| N | Bed Southeast Corner | 2.15 | 7.05 | 7 | 5/8 | 2.53 | 8.30 | 8 | 3 5/8 |
| O | Bed Southwest Corner | 2.15 | 7.05 | 7 | 5/8 | 3.50 | 11.48 | 11 | 5 6/8 |
| P | Bed Northwest Corner | 4.33 | 14.21 | 14 | 2 4/8 | 3.47 | 11.38 | 11 | 4 5/8 |
| Q | North Desk Back Left Corner | | 0.00 | 0 | 0 | 3.60 | 11.81 | 11 | 9 6/8 |
| R | North Desk Back Right Corner | 5.70 | 18.70 | 18 | 8 3/8 | 3.49 | 11.45 | 11 | 5 3/8 |
| S | North Chest Right Rear Corner | 6.10 | 20.01 | 20 | 1/8 | 1.09 | 3.58 | 3 | 6 7/8 |
| T | Bullet Casings By Bedroom Entry | 4.87 | 15.98 | 15 | 11 6/8 | 0.52 | 1.71 | 1 | 8 4/8 |
| U | Bullet Casings By Bed | 2.60 | 8.53 | 8 | 6 3/8 | 2.82 | 9.25 | 9 | 3 |
| V | Cell Phone | 4.01 | 13.16 | 13 | 1 7/8 | 2.31 | 7.58 | 7 | 7 |
| W | Gun | 3.97 | 13.02 | 13 | 2/8 | 3.59 | 11.78 | 11 | 9 3/8 |

**Figure 25: Distance conversion chart corresponding with measurements in the bedroom**

| Letter | Rectangular Measurement Description | Meter | Ft. Dec. | Feet | Inches |
|---|---|---|---|---|---|
| T | Diameter of Casings by Bedroom Door | 0.33 | 1.08 | 1 | 1 |
| T | Diameter Center From Closet Wall | 0.44 | 1.44 | 1 | 5 3/8 |
| T | Diameter Center from South Wall | 0.52 | 1.71 | 1 | 8 4/8 |
| U | Diameter of Casings By Bed | 0.10 | 0.33 | 0 | 3 7/8 |
| U | Diameter Center from West Wall | 0.79 | 2.59 | 2 | 7 1/8 |
| U | Diameter Center from North Wall | 2.60 | 8.53 | 8 | 6 3/8 |
| V | Phone From West Wall | 1.29 | 4.23 | 4 | 2 6/8 |
| V | Phone From NorthWall | 2.09 | 6.86 | 6 | 10 2/8 |
| W | Gun from West Wall | 0.02 | 0.07 | 0 | 6/8 |
| W | Gun From North Wall | 2.13 | 6.99 | 6 | 11 7/8 |
|  | Blood On Wall Under Bed from North Wall | 2.28 | 7.48 | 7 | 5 6/8 |
|  | Desktop Width |  | 0.00 | 0 | 0 |
|  | Desktop Depth |  | 0.00 | 0 | 0 |
|  | Chest Top Width | 0.93 | 3.05 | 3 | 5/8 |
|  | chest Top Depth | 0.60 | 1.97 | 1 | 11 5/8 |
|  | Bed Width | 2.18 | 7.15 | 7 | 1 7/8 |
|  | Bed Depth | 0.97 | 3.18 | 3 | 2 2/8 |
|  | Vanity Full Hallway Y Length | 3.78 | 12.40 | 12 | 4 7/8 |
|  | Vanity Hallway to Cubpords X Length | 1.21 | 3.97 | 3 | 11 5/8 |
|  | Vanity hallway to Mirror X Length | 1.84 | 6.04 | 6 | 4/8 |
|  | Bathroom X Length | 1.63 | 5.35 | 5 | 4 1/8 |
|  | Bathroom Y Length | 1.67 | 5.48 | 5 | 5 6/8 |
|  | Shower Stall X Length | 0.93 | 3.05 | 3 | 5/8 |
|  | Shower Stall Y Length | 1.06 | 3.48 | 3 | 5 6/8 |
|  | Shower Shelves X Length | 0.97 | 3.18 | 3 | 2 2/8 |
|  | Shower Shelves Y Length | 0.92 | 3.02 | 3 | 2/8 |
|  | Entry Hallway X Length | 1.35 | 4.44 | 4 | 5 2/8 |
|  | Entry Hallway Y Length | 3.25 | 10.65 | 10 | 7 6/8 |

**Figure 26: Distance Conversion Birds-Eye View**

| Elevation Rectangular Description | Meter | Ft. Dec. | Feet | Inches |
|---|---|---|---|---|
| Floor to Ceiling | 2.44 | 8.01 | 8 | 1/8 |
| Window Top Opening to Ceiling | 0.00 | 0.00 | 0 | 0 |
| Windsill top to Floor | 1.01 | 3.31 | 3 | 3 6/8 |
| Window Height | 1.60 | 5.25 | 5 | 3 |
| Window Width | 1.41 | 4.63 | 4 | 7 4/8 |
| Window South Edge to South Wall | 0.71 | 2.33 | 2 | 4 |
| Window North Edge to South Wall | 2.12 | 6.96 | 6 | 11 4/8 |
| Top Mattress Top to Floor | 1.53 | 5.02 | 5 | 2/8 |
| Bottom Mattress Top to Floor | 0.66 | 2.17 | 2 | 2 |
| Blood Above Bottom Mattress to Floor | 0.79 | 2.59 | 2 | 7 1/8 |
| Blood Below Bottom Mattress to Floor | 0.39 | 1.28 | 1 | 3 3/8 |
| Blood Below Bottom Mattress to North Wall | 2.28 | 7.48 | 7 | 5 6/8 |
| Gun From North Wall | 2.13 | 6.99 | 6 | 11 7/8 |
| Blood On Wall Under Bed from North Wall | 2.28 | 7.48 | 7 | 5 6/8 |
| Bathroom Countertop Height | 2.80 | 9.19 | 9 | 2 2/8 |
| Bullet Hole to Ceiling | 2.17 | 7.12 | 7 | 1 3/8 |
| Bullet Hole to South Wall | 1.81 | 5.94 | 5 | 11 2/8 |
| Small Window | | | | |

**Figure 27: Distance conversion birds-eye-view and elevation charts**

## Research Criteria Findings

### *Measurement Accuracy*

Any manual measuring device used to investigate crime scenes, such as measuring tapes and disto-meters, should be compared to each other as well as to a known standard using International Organization for Standardization (ISO) criteria.[xxxv]

Similar, industry standards require 3D laser scanners undergo annual re-calibration and accuracy confirmation checks by their manufacturers. Periodic checks should also be conducted in the field by the operator. A known measurement device should be included in each scan to confirm accuracy.

Leica Geosystems General Manager Michael Cunningham explained that any technology admitted into court as exhibits or evidence must meet stringent National Forensic Science Technology Center (NFSTC) standards, including measurement accuracy to within 0.25 inch.[xxxvi] Scanners are more accurate than humanly possible, up to a thousandth of an inch, and may eliminate the need for stretching measuring tapes at crime scenes.[xxxvii]

Dr. Horn explained that even though scanner data itself is more accurate than humanly possible, registering multiple scans together may be subject to error propagation. For example, if six scans are registered lineally, the first scan may have an error rate of plus or minus two millimeters. The second scan would add two more millimeters, giving the second scan an error rate of four millimeters. This error rate would increase until the sixth scan, having an error rate of twelve millimeters. In an effort to eliminate this propagation, the operator should consider scanning in circles or in the pattern of a wagon wheel. Whenever possible, it is advised to register subsequent scans back to the first scan.[xxxviii]

*Time Efficiency*

The amount of time officers spend on crime scenes is lengthy and labor-intensive. Retired Deputy Sheriff Kent Boots said crime scene investigators tend to "focus on using a measuring method or tool that is faster. It does not matter how fast you measure and clear a scene if you measure the wrong item, measure incorrectly, or forget to measure at all."[xxxix] These errors in the field result in a waste of time, but are greatly diminished when using a scanner.

Benner and Kalinowski said that hand-sketching a crime scene usually requires three people: two to work the measuring tape and one to be the scribe. Using a total station requires at least two people: one to hold the reflector at each reference point and one to work the total station. A scanner requires only one person. Overall, a scanner takes about the same amount of time as hand-sketching. The benefit, however, include less people tromping around in the crime scene, minimizing scene contamination. Less people equal less total hours.[xl] Cunningham said, "Conventional forensic investigation methods are time-intensive and dependent on a subjective human decision-making process."[xli]

Target setup and take-down, can take some time, but newer scanners have eliminated the need for targets. Scanning an entire residence can now be done in about an hour or so. What took many hours back at the office to register is now done in minutes with on-the-go registering, simultaneously being done during the scanning process.

Advertisement claims of fast courtroom exhibit preparation are not accurate. Preparing exhibits from web-share to CAD diagram, or from manual measurements to CAD diagram, exhaust similar amounts of time.[xlii] The benefits of using a scanner include less time in the field, and multiple designs and fly-through graphics.

Leica just developed and marketed the new RTC360 scanner in June 2018. It is not so heavy, bulky, and cumbersome to move around indoors, nor is it so light that it tips over outdoors in the wind. With automated targetless field registration, Leica claims it is fast, agile, and precise.[xliii] Unlike the dinosaur C10 that takes between 30 to 45 minutes per scan with 50,000 scanned points per second, the RTC360 takes less than two minutes per scan with 2 million points per second, along with photos. Activated video on the RTC360 between scanner locations assists in scanner position orientation, requiring 40% less scans for registration than its predecessors.[xliv] Some of the topics expressed herein can be placed in multiple criteria sections. For example, a faster scanner, such as the RTC360, enhances officer safety and reduces overall staffing costs.

*Officer Safety*

Investigating major traffic accidents on busy roads and intersections is very dangerous. Officers tend to focus more on working the accident scene, especially when assuring the accuracy of manual measurements, than maintaining constant awareness of surrounding dangers. Scanners allow officers to stay out of travel lanes and intersections a substantially greater amount of time. Road closures become an inconvenience to an increasing impatient motoring public. Less stress on drivers equates to safer drivers. Manual measurements cannot compete with the speed and safety of scanners, day or night.

Though sometimes not considered as important as other criteria, personnel safety must take priority. Consider OSHA standards and the cost of preventable injuries, rehabilitation, and rising insurance premiums. Furthermore, cost analysis cannot be properly conducted on personnel killed on preventable job-site accidents.

*Cost Analysis*

Externally, closed roads or closed buildings mean commerce is not getting through. Internally, the cost of a 3D laser scanner, CAD software, sphere targets, annual maintenance and certifications, annual software licenses, data storage, computer hardware, and training can be highly expensive and cost prohibitive to small law enforcement agencies. The cost for such equipment ranges well over $100,000 over the span of a scanner's lifetime.[xlv] Larger agencies in the state of Utah, such as the Unified Police Department, West Valley City Police, Salt Lake City Police, Layton City Police, and the Utah Department of Public Safety (Utah Highway Patrol and State Bureau of Investigations) have the capability of possessing multiple scanners.

The price of a new Leica BLK360 is about $18,000. It is not yet completely determined, but annual maintenance and recertification costs may be just as expensive. The Leica C10 is about $100,000. Annual calibration costs for the C10 is about $17,000. The annual calibration maintenance costs as well as Leica not having the capability to take still photographs is some of the reasons many police departments purchase FARO, but FARO can be more expensive in other ways, such as required annual service and calibration contracts.[xlvi]

For smaller agencies, other techniques may need to be applied to be privy to such technical equipment. Some of these techniques include: purchasing refurbished equipment; renting newer equipment from manufacturers; forming a task force in order to share the cost and the use of the equipment; sharing the equipment with other departments within a municipality, such as police, water, building, and engineering; contracting with private companies for scanning and presentation services; or requesting mutual aid assistance from another agency.

The cost of a scanner and associated equipment can quickly be justified in saving valuable staffing time. In the construction industry for example, “manpower is approaching 75% of total costs of construction.”[xlvii] This figure is similar with most organizations, including municipal governments and police departments.[xlviii]

Employers in any corporation or industry are always searching for ways to reduce staffing costs while increasing productivity. One way to do this in the police realm is to use a scanner to quickly document a crime scene and move on to other projects. One investigator could scan all crime scenes, allowing other investigators to utilize their time with other aspects of the investigation. A scanner may allow municipalities to hold off on hiring additional investigative personnel due to increasing caseloads and reducing overtime expenses.

While considering the differences, one must also consider scanner depreciation. Scanner life can range several years, but newer technology is ever increasing speed and efficiency. Purchase programs help departments upgrade and cycle equipment about every five years.

*Data Collection and Evidence Preservation*

One of the reasons manual measurements and diagrams are prepared is to reconstruct and put everything back in its place off-site with mockups. This is what the National Transportation Safety Board (NTSB) has done for years with aviation accidents. Consider the labor-intensive work and time involved in manually documenting the debris field of an aviation accident, such as in Figure 28. Imagine how much easier an entire aviation accident can be, virtually reassembled with scans, point clouds, CAD software and computers. Though on a smaller scale, the same comparison can be employed with bullet or blood spatter trajectory analysis. Manually, "even the best investigators cannot measure everything or predict what might become significant after a crime scene has been released and new facts develop."[xlix]

**Figure 28: 16 September 2017, One Two Go Airlines Flight OG269 aviation accident after departing Phuket International Airport; photo retrieved June 2018.**

*Courtroom Acceptance*

There are always concerns about the validity of new and emerging technologies being introduced and accepted in court. For example, the change from 35 mm still photography to digital photography revealed court reluctance for grasping new technology. The paradigm shift was slow, but now, court acceptance to digital photography is commonplace. Another example is when DNA evidence was just emerging. Consider now the importance of modern DNA evidence in cold case investigations.

Anything that is introduced into a crime scene, such as sphere and checkerboard targets or measuring confirmation devices, can be problematic at trial. Benner and Kalinowski have had no problems at court by explaining the presence of such items immediately when the evidence is introduced and admitted as court exhibits.[l] A good way to explain the presence of spheres and checker board targets is to compare the presence and purpose of numbered placards identifying specific evidence in the crime scene.

It has been Petersen's experience that birds-eye-view 2D plans are still preferred for courtroom testimony and presentations. It does not matter if the plans are hand-sketched or CAD drawn. She has never had a problem explaining in court the presence of targets and measuring confirmation devices in her crime scene data and diagrams.[li]

In an effort to familiarize attorneys, juries, and judges to scanner technology, crime scene investigator Joe Swenson scans the courtrooms beforehand, where the trials will occur. This allows all courtroom parties to view and understand items of familiarity before diving into the actual crime scene. An explanation or comparison of other well-known technologies, such as the Lidar, a laser disto-meters, and digital photographs to the scanner is helpful. Another technique is to testify as to the reliability and accuracy of scanner use in other industries.[lii]

Leica expert witness Frank Hanhnel III provided the following courtroom-worthy suggestions: use a Leica NIST traceable validation tool (to confirm scan measurements); use point cloud processing software to improve appearance; ensure ahead of time that electronic hardware is compatible with the courtroom; have copies of training records and credentials; generate a 3D visualization and fly-through presentations of the courtroom.[liii]

FARO expert witness David Dustin also scans courtrooms prior to trial in order to present familiarity. Included in that wow factor is how Dustin can obtain courtroom measurements by opening his laptop and navigate a couple of mouse strokes. An object in court, such as a hanging picture on the wall, is both virtually and manually measured for the benefit of the jury.[liv]


**Figure 29: Eugene Liscio, 3D laser scanning expert witness**

Like other expert witnesses, Liscio scans courtrooms before testifying. Bringing the actual scanner and tripod into the courtroom and setting it up for demonstration purposes provides an exceptional benefit for observers to understand the technology, as is shown in Figure 29. Liscio has realized that bringing the technology into the courtroom actually helps judges and juries stay awake and pay attention. Prosecutors and defense attorneys utilize the technology equally. It is important when testifying to provide training and certification records, credentials, and professional organization memberships.[lv]

Retired attorney T.C. Kelly said, “Photographs of accidents and crime scenes have value, but they rarely have the same impact on juries as a three dimensional representation.”[lvi] Virtual scans allow jurors to visualize the scene in more detail than two-dimensional photographs. Unlike photographs, a scan’s perspective can be changed to give the jury a panoramic or bird’s-eye view of the scene. “A three dimensional representation even allows an expert to take a jury on an animated ‘fly-through’ of a crime or accident scene.”[lvii]

All the testimonials that have been expressed herein were provided with experts possessing exceptional credentials. One must, however, consider the intent behind the testimonials, seeing that most, if not all, benefit to some degree with one scanner company or another. There are non-biased considerations that extend far beyond the clout of testimonials. Such considerations include scholarly papers and court rulings, especially federal court rulings that have a sense of permanency about them.

In 2013, Leica Geosystems introduced a new NIST-traceable twin-target pole. This pole “definitively validates”[lviii] the accuracy of Leica laser scanners. This validation ensures that scan data evidence will hold up in court against rules of evidence, including the Daubert Standard. The Daubert Standard maintains strict requirements that “(govern) the admissibility of expert testimony regarding scientific evidence in US federal legal proceedings.”[lix]

One such Daubert Standard ruling took place on 30 September 2013 in the case of Stephen Cordova v. Albuquerque, in the United States District Court for the District of New Mexico. The United States Magistrate Judge Gregory B. Wormuth ruled in favor of the defendants’ (the city’s) Daubert motion. This motion will affect all subsequent similar cases.

In said case, Stephen Cordova filed a 42 U.S.C. § 1983 federal civil rights violation suit against the City of Albuquerque and a few of its officers, stemming from Cordova being shot during a police action. Judge Wormuth stated: "Cordova did not object to the scientific and technical validity of Leica Scanstation evidence or dispute that City Defendants have laid a proper scientific and technical foundation for the admissibility of this evidence during trial."[lx]

*Future of Manual Measuring and Diagramming*

Dr. Horn taught that there are four basic techniques in manually measuring a room for crime scene diagramming purposes:

1. Triangulation: measures a single object from two different reference points
2. XY coordinates: using (00) origin, sometimes called edge or baseline
3. Rectangular coordinates: 90 degree measurements from the nearest two XY walls
4. Polar (or azimuth) measurements: use a straight line measurement and an angle.

A debate exists in the criminal justice profession regarding the need to hand-sketch diagrams, now that 3D laser scanning is so prevalent. One side of the argument states that preparing two types of data (one from the scanner and the other from manual means) will potentially create discrepancies and problems for court prosecution. Dr. Horn explained this is a weak argument. It is very necessary to do a hand-sketch diagram with manual measurements because it validates the scanner, not the scanner to the sketch.[lxi]

The author of this paper agrees with Dr. Horn. It seems that over the past several years, manual diagramming is becoming a lost art. It is important to maintain and train this technique, as well as the technique of blood spatter analysis to all scanner operators. This is the best way practitioners and investigators can understand and best testify how scanners work.

*Indoor/Outdoor Use*

When purchasing a scanner for police investigations, manufacturers will ask for the main purpose of its use. Most scanners will generally work in all types of scenes, but there are specific scanners for specific jobs. Similar to how police are finding value in scanning accident and crime scenes, the United States Air Force has discovered its value at aviation crash sights.[lxii] The Leica C10 or a FARO Focus model will scan larger scenes and distances. The FARO S-40 or the Leica BLK360 is light, quick, and easy for any indoor scene. The FARO Freestyle can handle any scan in cramped areas where a tripod will not fit.

Motor vehicles traveling past a scanner in use do not seem to bother the end product, but things like leaves blowing in the wind or ocean waves may create registering issues. Benner and Kalinowski use their scanners in extreme temperatures. Sometimes they have to return the scanner to their vehicle to warm it up or cool it down before proceeding to the next scan. Fog may bother color, but less so with black and white scans. During rain storms, operators simply hold an umbrella over the scanner and dance around the rotation to avoid being captured in the scan.[lxiii] The laser beam will obviously capture the umbrella moving around above, but the view looking up is usually less important at outdoor scenes.

For small law enforcement agencies with limited budgets, the author of this paper suggests the purchase of a multi-function scanner for most indoor and outdoor scenes, such as the Leica BLK360 or the FARO S-40. Either selection eliminates the cost and setup time of the sphere and checkerboard targets. Even more intriguing for all types of scenes is Leica’s newest model, the RTC360 as previously explained.

## Conclusion

The use of 3D laser scanners at crime scenes improves measurement accuracy and data collection. Data evidence is virtually preserved indefinitely, as if the crime scene is never released. Manual diagramming continues to confirm the proper functionality of the scanner.

One of the great selling points for using a scanner is on-scene time efficiency. Having the capability to scan without costly sphere and checkerboard targets reduces cost and time even more. An experienced operator can scan a crime scene or traffic accident rather quickly by comparison, allowing the road to resume normal traffic quicker or the crime scene to resume normal daily activities sooner. Having officers in busy streets and intersections for less time is certainly a safer option. Having fewer officers at crime scenes reduce the possibility for scene contamination. Having fewer officers at crime scenes reduce staffing costs.

After the scans are complete in the field, more work, hours, days, and weeks are required in order to prepare diagrams, fly-through renderings, and courtroom-worthy presentations. Not a lot of research was conducted about presentation preparation, but time commitment to presentation preparation seems similar regardless of data collection method.

Courts, judges, and juries have accepted scanner technology and are eager to experience all that scanners have to offer. Case law, standards, training, recalibrations, and credentials provide critical support. Limitations are the result of antiquated courtroom electronic compatibility issues and prosecutors who do not fully utilize all features that scanners have to offer.

Confined spaces may prove difficult for a scanner on a tripod. Handheld scanners help in these situations, but these types of scanners have limitations. Handheld scanners work best with patient operators who scan in a logical grid pattern to obtain intelligible data.

Indoor and outdoor crime scenes alike benefit from the use of scanners. Outdoor elements can be challenging, including extreme hot and cold temperatures, precipitation, wind, bright light, or no light. Scanners, spheres and laptops are expensive and can be damaged by outdoor elements (not to mention someone tripping over a tripod leg). Sandbags may be used on lighter tripods to prevent wind from tipping over a scanner or a sphere.

Scanner costs have drastically reduced over the years. Eliminating spheres eliminates cost and time. Scanners and newer emerging software such as diagrams, fly-through renderings, and courtroom-worthy presentations are impressive and help eliminate doubt in court.

The author of this paper concludes that 3D laser scanning is the better option for reasons outlined in this paper. Aside from personnel safety, the most important feature of a 3D laser scanner is not the renderings or the presentations, but the ability to return and accurately measure any distance at any location, at any view, and at any time. This feature is simply unavailable through manual means.

End

Individuals Cited

1. Benner, Brent: Benner is a forensic investigator with Alan Kilanowski at the Unified Police Department (UPD) in Utah. He has been employed at UPD since 1992. He is a member of the International Association for Identification (IAI), and has operated the department's FARO scanner for the last five years. He has used various brands of total stations and scanners in the past, including Leica and FARO.
2. Boots, Kent: Boots is a retired deputy sheriff and owner of the California-based company called FactualDiagrams.com. He is a court-recognized expert witness in mapping, total station technology, CAD, and 3D scale diagraming.
3. Briggs, Jed: Briggs is the Finance Manager at Park City Municipal Corporation in Utah.
4. Cunningham, Michael: Cunningham is a manager at Leica Geosystems, in the Public Safety Group, Training and Service Operations Division.
5. Dustin, David: Dustin is the owner of Dustin Forensics in Adairsville, Georgia, which uses laser technology to create 3D models of crime scenes, traffic accidents, and other forensic services. He has been trained by FARO Industries, and in return, has helped FARO improve their training for law enforcement and forensic professionals.
6. Farner, Jeremy: Farner is an Assistant Professor in the Design Engineering Technology Department at Weber State University. He is the 2018 recipient of the John A. Lindquist Award for demonstrated outstanding commitment to mentoring WSU students.
7. Foss, Taylor: Foss in an instructor and runs the Concept Center in the Manufacturing Engineering Technology Department at Weber State University.

8. Hahnel III, Frank: Hahnel has worked for many years with local, state, and federal law enforcement agencies, prosecuting attorneys, and defense attorneys on significant cases in the use of laser scanners and courtroom presentations. He is an expert in the use of Leica 3D scanning systems.
9. Horn, Brent: Dr. Horn is the department chair, director of forensic science, and associate professor in the Criminal Justice Department at Weber State University.
10. Kalinowski, Alan: Kalinowski is a forensic investigator with Brent Benner at the Unified Police Department (UPD) in Utah. He received his Bachelor's Degree in Criminal Justice from Weber State University. He is a member of IAI, and is a certified crime scene investigator.
11. Kelly, T.C.: Kelly is a retired attorney who specialized in criminal defense, personal injury, and employment law in state and federal courts in the Midwest. He currently writes about legal issues for a variety of publications.
12. Liscio, Eugene: Liscio is an Adjunct Professor at the University of Toronto in 3D Forensic Reconstruction and Mapping, an expert witness on the subject, and a FARO 3D forensic trainer. He established his own company in 2005 in Toronto, Canada, called AI2-3D. His company specializes in forensic mapping, analysis, and 3D reconstruction of crime and accident scenes.

13. Petersen, Angela: Petersen has been a forensic investigator for West Valley City Police Department since 2013. Before that, she worked as a contractor for the Marines in Afghanistan, investigating crime scene latent prints and post-blast material examinations. Prior to Afghanistan, she worked for the Weber County Sheriff's Office Crime Scene Investigations (WCSO CSI). She has been a forensic investigator for a total of ten years. Petersen received her Bachelor's in Criminal Justice at Weber State University.
14. Schiro, George: Dr. Schiro is a forensic scientist and professor at the Louisiana State Crime Lab.
15. Swenson, Joe: Swenson is a detective with the Clark County Sheriff's Office Major Crimes Division in Vancouver, Washington. He has been using FARO scanners since January 2013.
16. Orr, Rick: Orr is a professor and department chair in the Manufacturing and Engineering Department at Weber State University.

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