BACKGROUND:

The DotProduct DPI-8 handheld scanner is a 3D measurement device that employs a near structured infrared light and RGB depth imaging system to create point cloud data. The instrument is composed of a PrimeSense Carmine 1.082 RGB and depth sensor and an NVIDIA SHIELD Android Tablet. The tablet contains all the processing hardware and software required to interpret data captured by the PrimeSense unit. The software specific to the operation of the sensor and measurement processing is DotProduct PHI.3D version 2.1.

In simple terms, the DPI-8 emits a calibrated pattern of infrared light points and determines distances to measured objects based upon observed distortions in the calibrated pattern. These distortions are created by geometric and textural variations in the measured environment. Last, the RGB camera applies true color values to the measured point cloud data to create a more photo-realistic representation of the measured area.

Prior to the acquisition of the DPI-8, OPD FIS has primarily used a Leica ScanStation C10, tripod mounted laser scanner for the documentation of measurements at major case crime scenes. OPD FIS has also used Leica Cyclone software for processing point cloud data and extracting measurements. The DotProduct DPI-8 handheld scanner is intended to supplement the measurement data collected by the Leica C10. The DPI-8, by virtue of its size and handheld operation, is able to capture measurements in small spaces or difficult to reach environments commonly encountered at crime scenes. The fact that the native, losslessly compressed .DP point cloud data sets are easily imported into Cyclone software is an added benefit.

The manufacturer's stated specifications for the DPI-8 are as follows:

- Working Range: 2 feet – 12 feet
- Recommended Range: 3 feet – 8 feet
- Working Temperature Range: 41F – 104F
- Recommended Temperature Range: 60F – 85F
- Point Density: ≤ 1.7 mm @ 3.3 feet / ≤ 3.4 mm @ 6.6 feet

RANGE	Typical Accuracy	Minimum Accuracy
< 3.3 feet	99.8%	99.6%
3.3 feet – 6.6 feet	99.5%	99.2%
6.6 feet – 11 feet	99.2%	98.8%

DotProduct specifies several conditions that can impact the quality of data produced by the DPI-8 scanner. Range, temperature, ambient lighting conditions, reflectivity, operator skill, scene fitness (geometry) and the

total time of data collection can all impact the accuracy of DPI-8 produced point cloud data. In general, the closer the sensor is to the measured surface, the more accurate it will be. Temperatures at the extremes, or outside, of the operating range will adversely impact measurement data quality. Being an infrared oriented device, the sensor will not operate properly in direct sunlight. Surfaces without inherent variations in the surface geometry will create tracking difficulties for the sensor. Extended collection times (> 10 minutes) will degrade the quality of the point cloud data through the accumulation of frame-to-frame tracking drift.

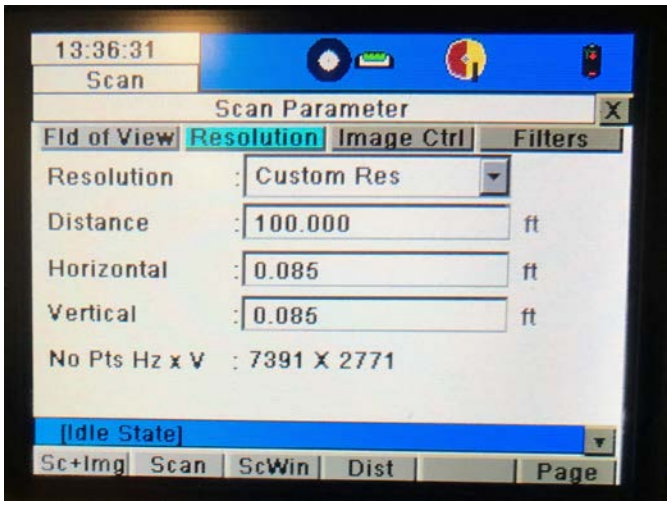
DotProduct also specifies numerous quality control procedures to mitigate the impact of adverse conditions and to maximize the accuracy of point cloud data collection. Operating within the recommended temperature ranges, allowing the system / sensor to reach full 'warm-up' as indicated by PHI.3D, using surveyed targets or scale bars with known distances, and keeping capture times as short as possible are all methods that will contribute to the accuracy of DPI-8 scanner data.

VALIDATION PROCESS:

All scans for this validation were completed on 24 February 2017 at the Omaha Police Department's Central Headquarters (505 S. 15th St., Omaha, NE). An area was chosen in the building that would present obvious challenges to the measurement capabilities of the DPI-8 scanner. An area with light gray, pattern free walls and pattern free floors was chosen. A corner with adjacent doorways was included to provide sufficient geometric texture for the DPI-8 to function. In addition, two (2) DotProduct april tag sheets were affixed to the walls to assist with image tracking during data capture.

DotProduct has provided the Omaha Police Department with a Brunson AccuScale-DP kit with the aim of providing ISO certified, known reference measurement artifacts for this validation study. This kit contains a set of three (3) 2.2 meter bars that are manufactured in an ISO 9001 compliant process and referenced to NIST traceable artifacts during construction. The AccuScale-DP kit has the additional advantage of being indexed for length throughout a wide array of ambient temperature conditions. The AccuScale-DP kit also facilitates computer aided, center of target locating within the DotProduct PHI.3D software. This removes any user induced error when picking measurement points to verify the 2.2 meter lengths. The AccuScale-DP bars were placed in a configuration with one 2.2 meter pole dedicated to the X and Z axes, respectively. In addition, this validation study will include scan data from a Leica Twin Target pole that is a NIST traceable reference artifact (serial # 131) with a given length of 1.700 meters. The inclusion of this reference artifact increases the robustness of the validation results in that it does not benefit from automated target center acquisition in PHI.3D and it stands outside of the "scale bar targeting" process recommended by DotProduct to maximize the accuracy of their point cloud data.

Two (2) scans were performed by two separate operators with the DPI-8 scanner (serial # 201511334 / calibration file 1411261316_201511334.cal) at distances of approximately 3' to 9' from the Z axis of the Brunson AccuScale bar array. This same space, and the reference artifacts in it, were scanned a single time with a Leica ScanStation C10 laser scanner (serial # 1261398) to provide baseline measurement values on the reference artifacts in the test array. The C10 scanner was placed at a distance of 12' from the center of the test array. The C10 scanner used in this exercise is current on manufacturer maintenance / firmware and is regularly tested against a NIST traceable Leica Twin Target pole. The scan density of the C10 was placed at a mid-level within this instrument's capabilities and at the same specifications commonly used at active crime scenes by OPD FIS personnel. Point spacing on the C10 was set at .085' x .085' at 100'. Scanning boundaries and distances were established with a Leica DISTO Classic 5a laser measurement device.



Measurements of the AccuScale-DP bars were conducted within PHI.3D on the DPI-8 instrument to validate the correct operation of the internal software and point cloud optimization routine. In both of the two (2) data sets from the DPI scanner, each AccuScale bar was properly measured at 2.2 meters within PHI.3D. All of the measurement data was then imported into Leica Cyclone software (version 9.1.5) to conduct measurements of the NIST traceable Twin Target pole. Cyclone measurements in both the DPI-8 point clouds and the C10 point cloud were made from user specified point picks determined by two (2) separate operators. Automated center of target picking was deliberately avoided to maintain method consistency between the two instruments and simulate actual casework conditions. The Cyclone measurement results and relative accuracies are recorded in the table below.

Point Cloud Source	Todd Petrick Measurement of TTP	William Henningsen Measurement of TTP	Manuel Garcia Measurement of TTP	Percent Accuracy
ScanStation C10		1.702 meters	1.705 meters	99.88% / 99.71%
Todd DPI-8	1.705 meters	1.704 meters		99.71% / 99.76%
William DPI-8	1.706 meters	1.705 meters		99.64% / 99.71%

As of this writing, we have encountered no significant variance in the precision or accuracy of data from the DPI-8 and the Leica ScanStation C10 laser scanner. Any differences noted here are likely attributable to two sources. The first source of variance lies within the minute differences in sampled points / areas between the instruments. The second source of variance is attributable to the acuity of a particular user's point selection within the Leica Cyclone software used to extract the comparative measurements from each instrument's individual point cloud.

CONCLUSION:

All of the calculated accuracies for the DPI-8 scanner are within the manufacturer specifications as tested in conditions that are challenging for the instrument to document. The DotProduct DPI-8 scanner meets our expectations for precision and accuracy as it is pertains to measuring spatial relationships at crime scenes. Approval is recommended for the instrument, when applicable, as the sole source of spatial measurement data at crime scenes or as a supplement to measurement data from the Leica ScanStation C10 laser scanner.