OSAC PROPOSED STANDARD
2025-N-0022
Standard for Terrestrial LiDAR Scanner Data Capture

Crime Scene Investigation and Reconstruction Subcommittee
Scene Examination Scientific Area Committee
Organization of Scientific Area Committees (OSAC) for Forensic Science

Draft OSAC Proposed Standard

OSAC 2025-N-0022
Standard for Terrestrial LiDAR Scanner Data Capture

Prepared by
Crime Scene Investigation and Reconstruction Subcommittee
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This OSAC Proposed Standard has completed an open comment period and a rigorous technical and quality review by the originating OSAC unit (e.g., subcommittee), their parent body (e.g., scientific area committee), and the OSAC Standards Review Panel.

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Foreword

This document delineates standards and recommendations for the capture of data using a terrestrial LiDAR scanner (TLS) during scene documentation. The approach outlined is recommended as good professional practice even though the facts and issues of each situation require specific considerations and may involve matters not expressly dealt with herein. Not every portion of this document may be applicable to every incident or investigation. It is up to the individual documenting the scene to apply the appropriate recommended procedures in this guide to a particular incident or investigation. In addition, it is recognized that time and resource limitations may limit the degree to which the recommendations in this document will be applied in a given investigation. The responsibility of the individual capturing the data for evidence preservation, and the scope of that responsibility varies based on such factors as the jurisdiction, the status of the individual as a public official or private sector investigator, indication of criminal conduct, and applicable laws and regulations. This document should be utilized in conjunction with local regulations and any requirements set forth by entities capturing TLS data to inform or augment policies relating to the collection and preservation of physical evidence.

This standard draws heavily from and takes language verbatim from the Forensic Technology Center of Excellence. (2022). Guidelines for the use of terrestrial LiDAR scanners in criminal justice applications. U.S. Department of Justice, National Institute of Justice, Office of Investigative and Forensic Sciences supported by Award No. 2016-MU-BX-K110, awarded by the National Institute of Justice, Office of Justice Programs, U.S. Department of Justice.

This standard also provides guidance on some safety issues but is not exhaustive. It is the responsibility of the appropriate agency to develop a full health and safety plan for scene responders.

All hyperlinks and web addresses shown in this document are current as of the publication date of this standard.

Keywords: *capture; data; terrestrial LiDAR scanner; TLS; 3D scanning; terrestrial laser scanner; scene documentation; scene diagramming*

Table of Contents

Standard for Terrestrial LiDAR Scanner Data Capture

1 Scope

This document establishes guidelines for the capture of data using terrestrial LiDAR scanners (TLS), including procedures for documenting scenes and associated evidence with the TLS. If compliance with this standard is claimed, justification for any deviation from this standard shall be documented.

2 Normative References

The following references are indispensable for the application of the Standard. For dated references, only the edition cited applies. The latest edition of the referenced document (including any amendments) applies for undated references.

2.1 OSAC 2023-N-0002, *Standard for Scene Documentation Procedures*

2.2 OSAC 2023-N-0003, *Standard for Diagramming Scenes*

2.3 See Annex C, (informative) Bibliography, for other references.

3 Terms and Definitions

For the purposes of this document, the following definitions and acronyms apply:

3.1
accuracy (of measurement)
the closeness of the agreement between the result of a measurement and a true value of the measurement. (ASTM E2544-11a)

3.2
artificial common reference object
strategically placed objects (e.g., spherical, checkerboard, retroreflective, or coded markers), in the scan area to serve as reference points between scan positions to enable registration or for measurements; also referred to as “target(s).” (FTCoE, 2022; modified)

3.3
cloud-to-cloud registration (C2C)
see “targetless registration.”

3.4
demonstrative evidence
evidence in the form of a representation of an object; it is not the object itself but a representation (e.g., photograph, map, diagram, video, animation) used to illustrate or explain other evidence or testimony. (Black’s Law Dictionary, 2019)

3.5

known-length artifact

an item with a known size that is introduced into the scan area to allow for an accuracy check of the individual scan data. (FTCoE, 2022)

3.6

light detection and ranging (LiDAR)

a remote sensing technology that measures distance by illuminating a target, typically with a laser and analyzing the reflected light. (RTI International, 2016; modified)

3.7

metrological traceability

property of a measurement result whereby the result can be related to a reference through a documented unbroken chain of comparisons, each contributing to the measurement uncertainty. (OSAC Lexicon)

3.9

point

an abstract concept describing a location in space that is specified by its coordinates or other attributes. (ASTM E2544-11a)

3.10

registration

the process of determining and applying to two or more data sets, the transformations that locate each dataset in a common coordinate system so that the data sets are aligned relative to each other. (ASTM E2544-11a)

3.11

resolution

a configurable parameter on a terrestrial LiDAR scanner (TLS) that defines the angular increment between successive measurements in the horizontal and vertical directions, which in turn determines the point spacing on a surface at a specified distance from the scanner. Higher resolution settings produce smaller angular increments, resulting in smaller point spacing, denser point clouds, and increased detail in the captured data.

3.12

substantive evidence

evidence offered to establish the truth of a matter to be determined by the trier of fact. (Black's Law Dictionary, 2019)

3.13

target(s) (n)

see "artificial common reference object."

3.14

target-based registration

a method of aligning multiple three-dimensional (3D) scans using artificial common reference objects (e.g., spheres, checkerboards, or coded markers) that are placed within the scene and captured by the scanner from multiple positions. The known geometric properties or spatial relationships of these targets are used to compute the relative position and orientation of each scan. Also referred to as “targeted registration.”

3.15

targetless registration

a method of aligning multiple 3D scans by identifying and matching overlapping geometry or features common to each scan, without the use of artificial common reference objects. This technique relies on the inherent structure of the scanned environment to compute the relative position and orientation of each scan. Also referred to as “cloud-to-cloud registration.”

3.16

terrestrial LiDAR scanner (TLS)

an instrument that is used for 3D mapping tasks that acquire complex geometric data from a static position, typically mounted on a tripod, where each point is determined by the position (X, Y, Z) and the intensity (i) of the returning signal. Also referred to as “terrestrial laser scanner.” (RTI International, 2016; modified)

NOTE: terrestrial refers to or relating to land as distinct from air or water. (Miriam Webster, 2022)

4 Overview of Terrestrial LiDAR Scanner (TLS) Data

Terrestrial LiDAR scanning provides a robust method for capturing accurate 3D representations of scenes. By preserving the spatial relationships between objects and documenting the in situ environment. The use of a TLS supports detailed analysis, scene reconstruction, and visual presentation for both investigative and legal applications. This section outlines the primary uses of the TLS in forensic science, the types of data typically collected, and the different levels of accuracy required based on the intended purpose of the scan data.

OSAC 2023-N-0002, Standard for Scene Documentation and OSAC 2023-N-0003, Standard for Diagramming Scenes shall be used in conjunction with this document. OSAC 2023-N-0002 provides general standards for the documentation of scenes, upon which additional specific requirements, such as this document, will be based. OSAC 2023-N-0003 provides more specific standards for the diagramming of scenes, and applies directly to this document, as terrestrial laser scanning is a specific form of scene diagramming.

4.1 Purpose and Use in Forensic Documentation

4.1.1 A TLS is employed to capture high-resolution 3D spatial data and, when applicable, color imagery at scenes. When appropriately implemented, TLS technology enables the accurate documentation of evidence in its original context by preserving spatial relationships between objects and features within the environment. The data collected can be used for scene reconstruction, analysis, visualization, and presentation in legal proceedings.

4.1.2 TLS documentation may include, but is not limited to, the following scene elements:

- Physical evidence
- Bloodstain patterns
- Bullet defects or trajectories
- Evidence markers and identification labels
- Footwear, tire track, or other impression evidence
- Location and position of human remains
- Damage to vehicles or property
- Firearms and weapons
- Non-evidentiary site features (e.g., topography, structural elements, furniture)
- Surveillance camera locations
- Potential viewpoints and available sightlines of witnesses or involved parties

4.2 Types of Forensic TLS Applications

4.2.1 TLS can be utilized in two primary forensic contexts, each with distinct accuracy, resolution and evidentiary requirements:

4.2.2 General Scene Documentation

- This application involves capturing broad, contextual 3D data of the overall scene environment. The purpose is to create visual representations that allow for clear understanding of the scene layout. While precision is important, this type of data does not typically support analytical conclusions. It is commonly used to produce demonstrative evidence for courtroom presentations, enabling juries, attorneys, and other stakeholders to visualize the scene. Because the data is not relied upon for scientific analysis, strict metrological accuracy is not required.

4.2.3 Critical Evidence Documentation

- This application requires higher accuracy and resolution to capture specific evidence features in detail. TLS data used in this context supports forensic analysis and scientifically valid conclusions, such as:
    - Trajectory reconstruction
    - Bloodstain pattern analysis
    - Spatial analysis of evidence placement and relationships
- TLS data collected for these purposes may be offered as substantive evidence in court. As such, the reliability of the measurements is paramount. Operators must follow

stringent protocols for equipment calibration, measurement validation, and procedural documentation to ensure the integrity and admissibility of the data.

4.3 Field Considerations

4.3.1 When deploying TLS equipment in the field, operators shall consider:

- The intended use of the scan data (demonstrative vs. substantive)
- The resolution and accuracy required based on the evidentiary needs
- Environmental conditions that may affect data quality
- The proper scanner settings, calibration status, and scene configuration, and the documentation of same.

5 Preparation for TLS Scanning

Prior to initiating TLS data collection at a scene, it is critical to ensure that environmental, procedural, and technical factors are properly addressed. Adequate preparation helps ensure the integrity of evidence, supports the reliability of scan data, and ensures that the documentation is suitable for both investigative analysis and potential courtroom presentation. This section outlines the standards and recommended preparatory steps and operational considerations for successful deployment of TLS technology in the field.

5.1 Scene Security

5.1.1 Scene security should be established in accordance with recognized best practices. Refer to ANSI/ASB Best Practice Recommendation 160, Best Practice Recommendation for Initial Response at Scenes by Law Enforcement Officers. 2024. 1st. Ed. (added April 2, 2024) for detailed guidance.

5.1.2 The scene should be secured prior to scanning to prevent alteration, contamination, or disturbance of evidence.

5.1.3 The area designated for scanning should remain free of personnel and moving objects (e.g., vehicles) for the duration of scanning operations to preserve the as-found environmental context and ensure complete and unobstructed data capture.

5.2 Order of Operations

5.2.1 Due to its non-invasive nature and its ability to capture as-found conditions, TLS scanning should be prioritized immediately after initial photographic documentation and the marking of all known evidence by scene investigators, with priority given to areas containing transient evidence or evidence of significant investigative interest (e.g., human remains), to ensure that all spatial relationships are recorded accurately.

5.2.2 The stability of the scanner setup shall be verified prior to initiating each scan to maintain measurement accuracy. Recommendations for equipment to enhance scanner stability as well as additional scanning resources are provided in Annex A.

5.2.3 Scanner settings and data capture methods shall be evaluated for each scan based on prevailing environmental factors (e.g., lighting, temperature, surface conditions) to optimize data quality.

5.2.4 In scenes with rapidly changing conditions (e.g., wildfires, precipitation, wind) or transient evidence, operators may modify capture settings to record as much detail as possible without compromising personal safety.

5.3 Management of Reflective and Transparent Surfaces

5.3.1 Reflective and transparent surfaces may introduce artifacts (e.g., due to reflection, diffraction, or refraction) during scanning. Preparation of such surfaces is optional but recommended to mitigate artifacts. However, any forensic evidence present on these surfaces shall be documented and collected prior to preparation.

5.3.2 Surface preparation methods may include:

- Covering surfaces with materials such as clean sheets, paper, sterilized surgical drapes, or opaque plastic wrap.
- Applying coatings, some of which dissipate over time while others remain opaque and require removal (e.g., sublimation spray, dry shampoo, fingerprint powder).

5.4 Field Instrument Settings

5.4.1 Point spacing and accuracy shall be selected to meet or exceed the resolution required by the software for the intended forensic application, based on the capabilities and settings of the TLS. If necessary, refer to Annex B for point spacing calculation methods.

5.4.2 When color data capture is needed, based on the capabilities and settings of the TLS, exposure settings shall be adjusted to ensure appropriate visual representation of the scene.

5.4.3 File naming conventions shall conform to the established protocols of the Forensic Science Service Provider (FSSP).

5.5 Reference measurements

5.5.1 Each TLS instrument on a scan project shall include at least one reference measurement, preferably toward the beginning of the scan project. Each TLS instrument on a scan project should include an additional reference measurement toward the end of the scan project. This process provides the ability to independently verify that the TLS instrument functioned properly throughout the entire project.

- Consider additional reference measurements for larger and/or multi-day scan projects.

5.5.2 Reference measurements can be performed in several ways. One method involves placing a known-length artifact, such as a yardstick or similar device, within the scene; its length can then be compared to the corresponding measurement in the scan data; that comparison process is outside the scope of this document.

- The known-length artifact should be calibrated by an accredited third party, such as the National Institutes of Technology (NIST), ensuring metrological traceability.
- The known-length artifact should be positioned at an angle and slope relative to the scanner to assess accuracy across all three spatial axes.

5.5.3 Alternatively, if a suitable artifact is unavailable, a metrologically traceable device, such as a NIST-certified tape measure or electronic distance measurement (EDM) instrument, should be used to measure the distance between two easily identifiable, fixed points in the scene for comparison.

6 Operating the TLS at the Scene

For more complete reconstruction of a scene using a TLS, multiple scans must be aligned—or registered—into a single coordinate system. Proper scan overlap, target placement, scanner positioning, lighting control, and documentation practices are essential for preserving spatial relationships, minimizing occlusions, and ensuring the completeness and reliability of the final dataset. This section outlines the key considerations and best practices for scan planning and execution, including overlap, line-of-sight management, registration method selection, external lighting, and field note documentation.

6.1 Line-of-sight

6.1.1 Scanner placement shall be selected to minimize data occlusions created by objects between the scanner and areas of evidentiary interest. Operators shall evaluate the scene from the scanner's perspective to anticipate and address blind spots. In some situations, this may mean placing the scanner positions closer together, raising or lowering the scanner position, or capturing additional scan positions to fill in any voids or occlusions.

6.1.2 The incidence angle of the laser beam relative to a surface affects the accuracy of surface measurements. Measurement precision decreases as the incidence angle becomes more oblique; greater accuracy is achieved when the laser beam is more perpendicular to the surface being scanned.

6.1.3 In certain scenarios, a localized area of distortion—referred to as a "hot spot"—may occur when a scanner is positioned relatively close to the surface and oriented approximately perpendicular (90°) to the surface. Measurements within or near this area may be unreliable or inaccurate. To mitigate this effect on forensically important surfaces, the TLS shall be repositioned at a slight angle relative to the affected area to improve data accuracy.

6.2 Targetless Environment

6.2.1 When targetless or cloud-to-cloud registration is used, sufficient overlap shall be maintained, based on the scene geometry, distance between scan positions, as well as the settings and capabilities of the TLS and/or software, between adjacent scan positions, to allow the software to accurately align the datasets. Overlap is typically achieved by ensuring that consecutive scans share rigid and recognizable geometry.

6.3 Targeted Environment

6.3.1 In open or minimally structured environments (e.g., fields, parking lots, or areas with few distinct features), targets shall be used to achieve accurate registration when the area lacks the surface complexity necessary for reliable cloud-to-cloud alignment.

6.3.2 When target-based registration is employed, a combination of the scanner's inclinometer plus two targets or three targets without inclinometer data shall be visible in common between each scan pair to allow for accurate alignment. Note that some TLS systems may require more than three targets; operators shall verify equipment-specific requirements.

6.3.3 Targets shall not be placed in a co-linear or co-planar configuration, as this limits the ability to resolve spatial relationships in three dimensions. Target elevations shall be varied by placing targets at different heights.

6.3.4 Multiple target types may be used in combination (e.g., spherical and checkerboard targets) to facilitate registration. Depending on the target type used for targeted registration, the position and orientation of the target(s) shall be considered; see Section 6.1.3 and 6.1.4 of this document.

6.3.5 In scenes with repetitive or homogenous geometry—such as multi-level stairwells, hotel corridors, or office buildings, artificial common reference objects—or targets— may be required to assist with alignment, as targetless registration may be unreliable in these environments.

6.3.6 Target placement shall be planned to optimize visibility across scans. Figures 1 and 2 illustrate recommended indoor target placement strategies in environments with repetitive features. Figure 3 demonstrates suggested scan positions and spherical target placement around the exterior of a vehicle when using targeted registration.

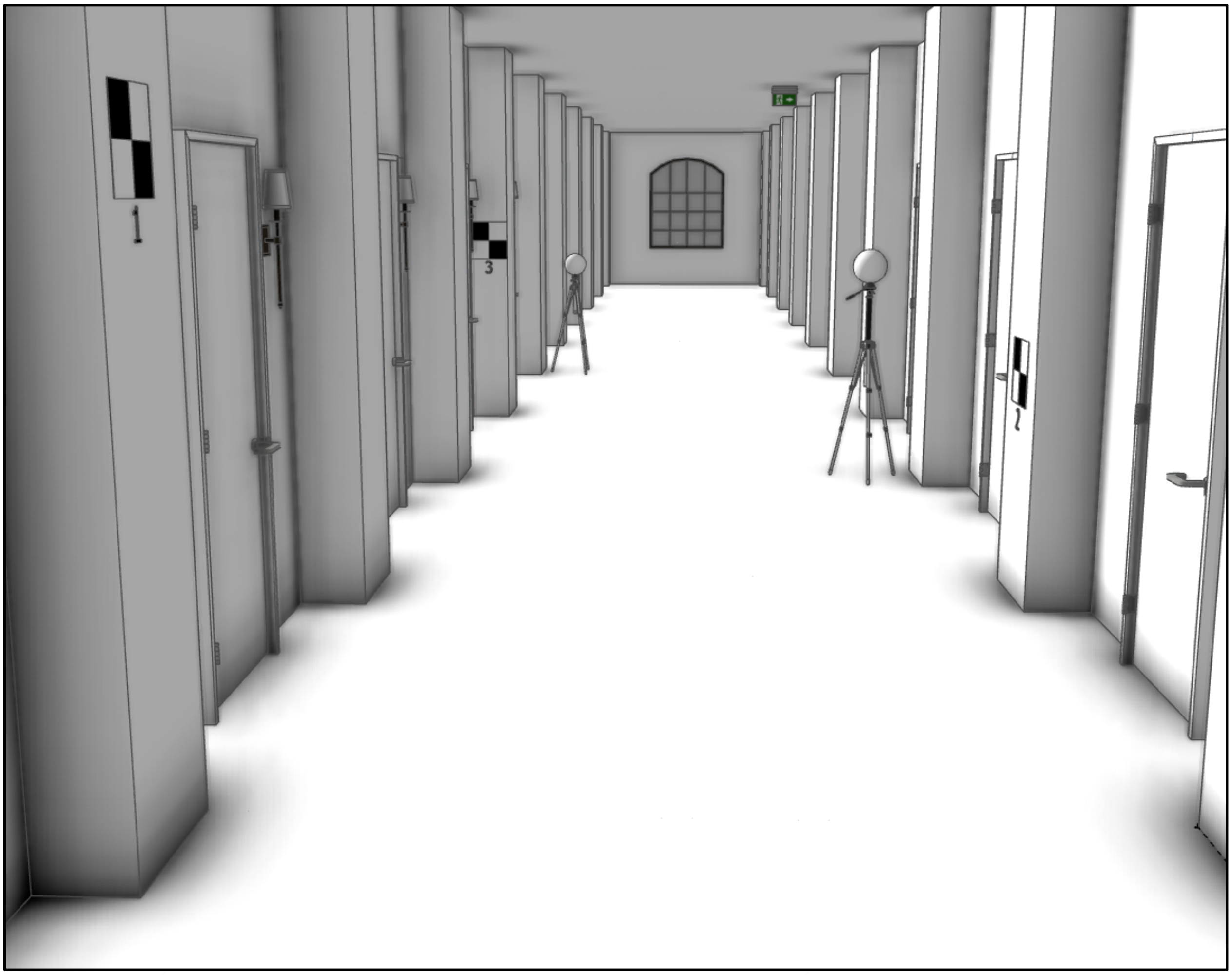
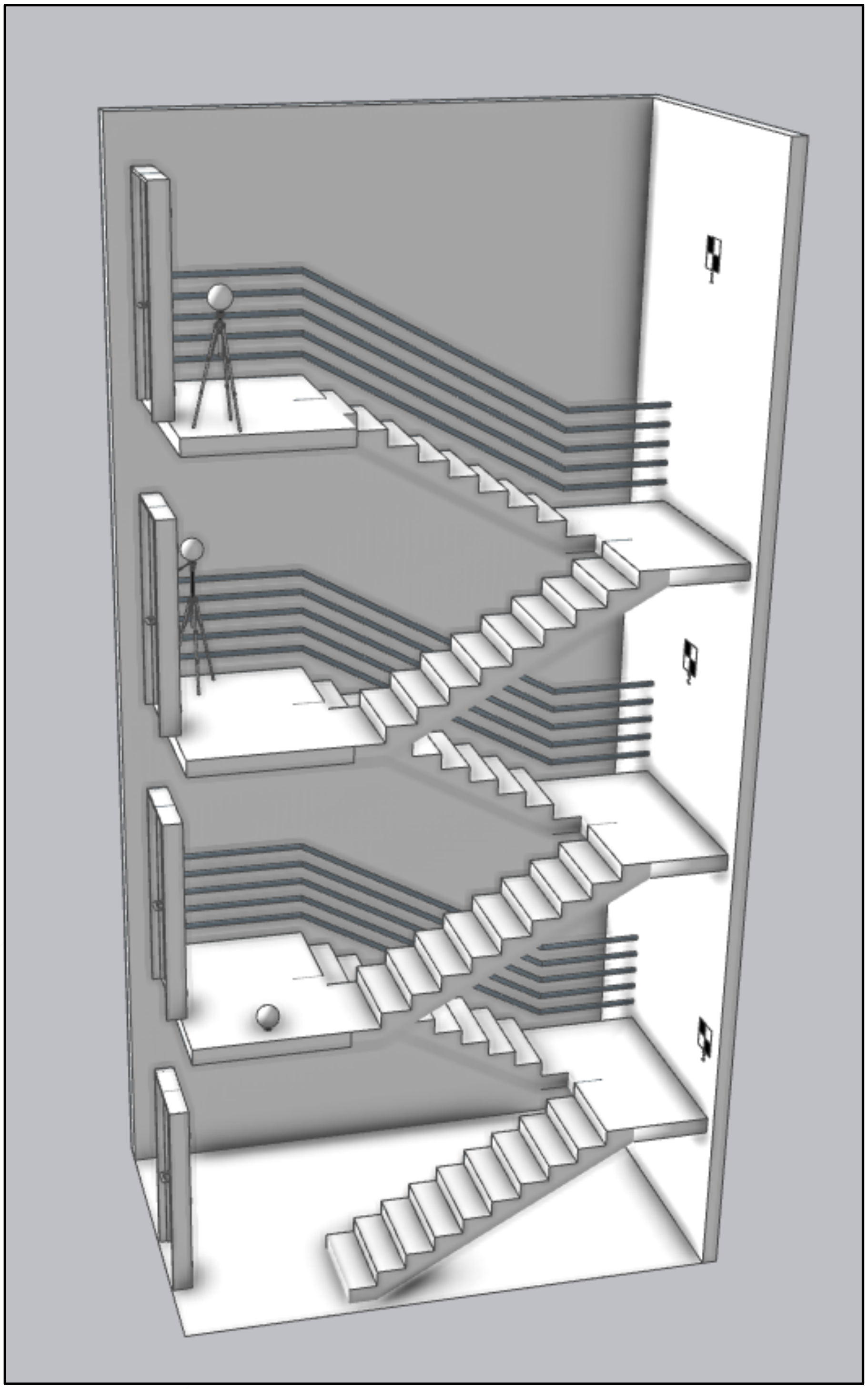


Figure 1. Example of placement of checkerboard and spherical registration targets at varying heights along a hallway containing repeating structural elements.

327 

328 *Figure 2. Example of placement of checkerboard and spherical registration targets across multiple levels*
329 *of a stairwell.*

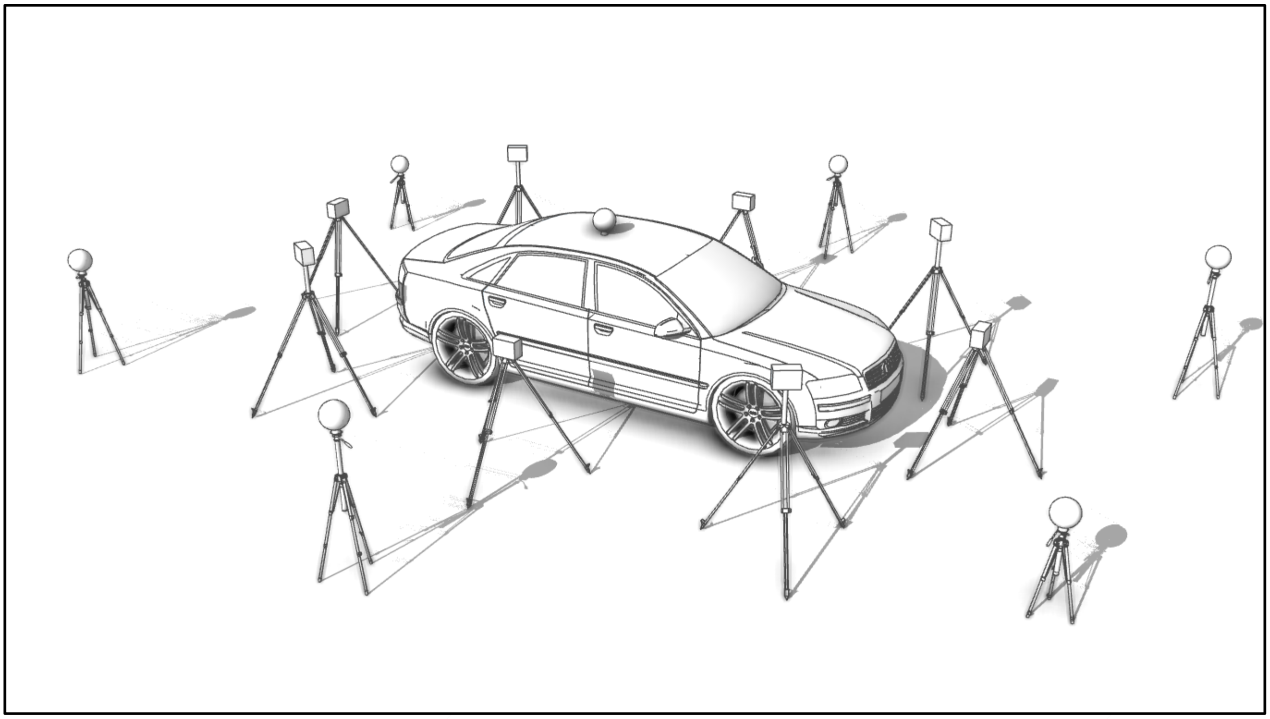


Figure 3. Example placement of spherical registration targets and recommended scan positions around the exterior of a vehicle.

6.4 External lighting

6.4.1 When external lighting is used to support color capture, direct illumination into the laser scanner should be avoided, as it may result in color washout or overexposure.

6.4.2 External lighting should be positioned below the scanner when feasible, to minimize the introduction of additional objects into the scan and to provide illumination without compromising color accuracy.

6.5 Scene Documentation

6.5.1 Scanner operators shall document their activities in notes and/or diagrams to support transparency, repeatability, and the integrity of the scan data. If applicable, notes and/or diagrams should include information relevant to the scene and scanning operation, including but not limited to the following, unless captured in the individual scan metadata:

- Date and time of documentation
- Case number or identifier
- Name of the scanner operator
- Weather and lighting conditions at the time of scanning
- Scanner make, model and serial number
- Date of last calibration

- Scanner settings and resolution used
- Types and locations of targets used
- Reference measurements utilized
- Locations of any reference, GPS, or other control points
- Scene diagram or photographs illustrating scanner and/or target positions
    - See Figure 4 for an example of a residential scene diagram.
    - See Figure 5 for an example scene diagram for a roadway scan setup with target placement.
- Locations of known critical measurements
- Observations of any factors that may have impacted data collection
- References of scan positions to fixed landmarks
- Position and location of any reference ties (e.g., survey stakes, nails) to support repeatability

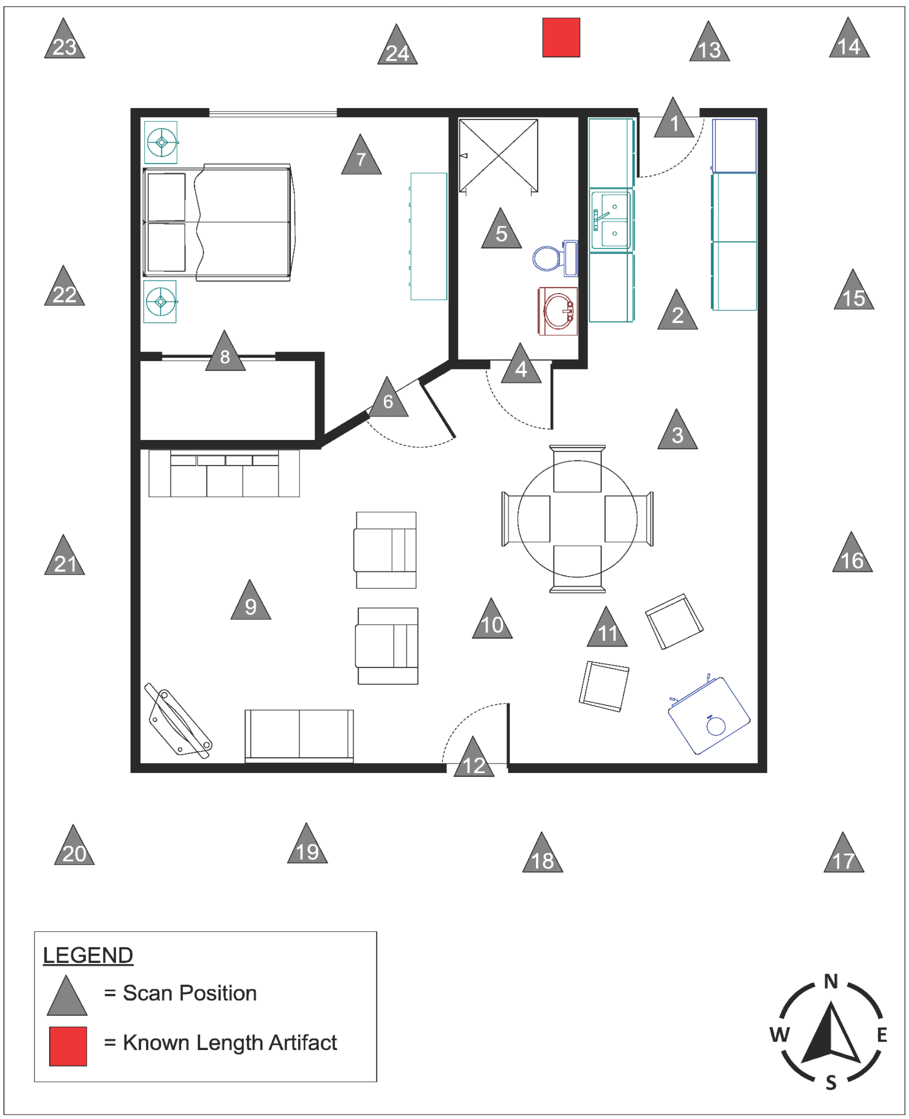


Figure 4 - Example scene diagram illustrating scanner positions for a residential scan project.

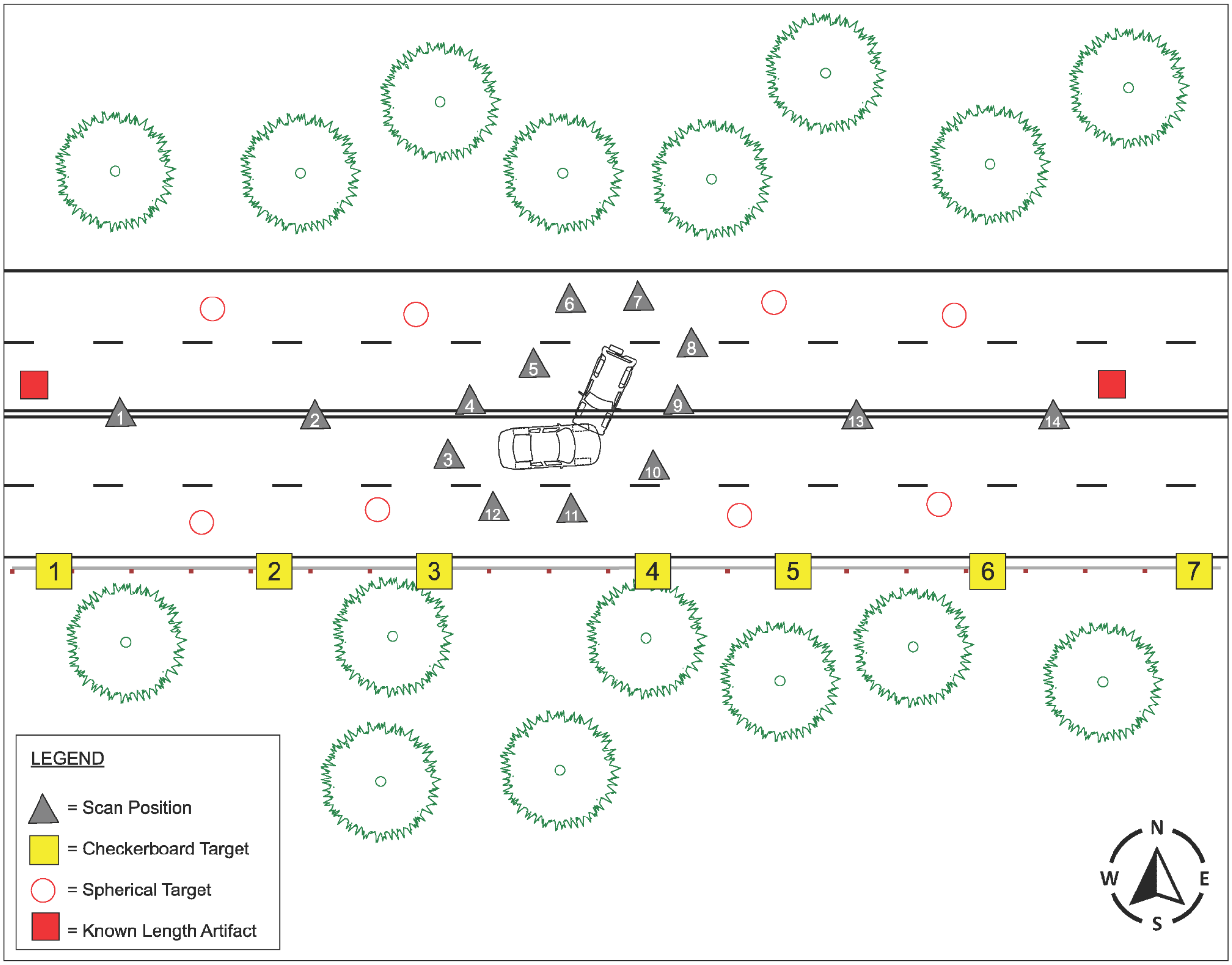


Figure 5. Example scene diagram illustrating scanner positions and target placements for a roadway scan project. Checkerboard targets (shown in yellow) are positioned along a fence or guardrail adjacent to the roadway.

Annex A
(Informative)

Suggested Equipment List

This table provides a list of general equipment that may assist operators in efficiently conducting terrestrial LiDAR scanning (TLS) in field environments, as well as in the subsequent transfer and processing of scan data.

Description	Purpose
On-Scene Accessories	
Sphere Set	Spherical targets for use during scanning operations
Checkerboard Target Stickers (50)	Contrast targets for use during scanning operations
Reflective String or Chalk	For marking evidence with time-of-flight scanners
D-100 Nonaqueous Developer	For reducing the reflectivity of reflective or transparent surfaces such as mirrors or glass
Door Stops	To wedge doors open between rooms/areas to provide for connector scans
Dump Pouch	For carrying and easily accessing multiple items while scanning on scene
External Lighting	To aid in the capture of color data in dark environments
Laser Scanner Backpack	Customized rolling backpack to carry all scanning equipment and accessories
Tripod Leg Accessories: Snowshoes / Spikes / Rubber Feet / Stabilizer	For increased tripod stability in variable ground conditions
Platform Tripod	Stable platform for scanner when used on soft surfaces or on ground

Platform Tripod Adapter	Threaded adapter for using with different scanner types
LED Headlamps	For working in low light scenes
Mini Flashlight	For working in low light scenes
Pocket Rod	Known-length artifact
Stylus Pens	To write with and us as stylus on scanner graphical user interface / touch screen
Travel Chair	Small chair to sit in during long scan projects
Reflective Tape	To affix to tripod legs for visibility
Data Management / Processing	
Blu-ray Burner/Reader	For transference of data from laptop to elsewhere and official copies of data (if not integrated into computer)
High Capacity (Gaming) Laptop with GPU	Laptop for portable processing of scans
Large Capacity Thumb Drive or SSD	For transference/storage of data
SD Card Reader	For transference of data to laptop
Memory Card Safe	For maintaining SD cards during transit and non-use
150W Power Inverter	For charging batteries and accessories if vehicle is only power source on scene

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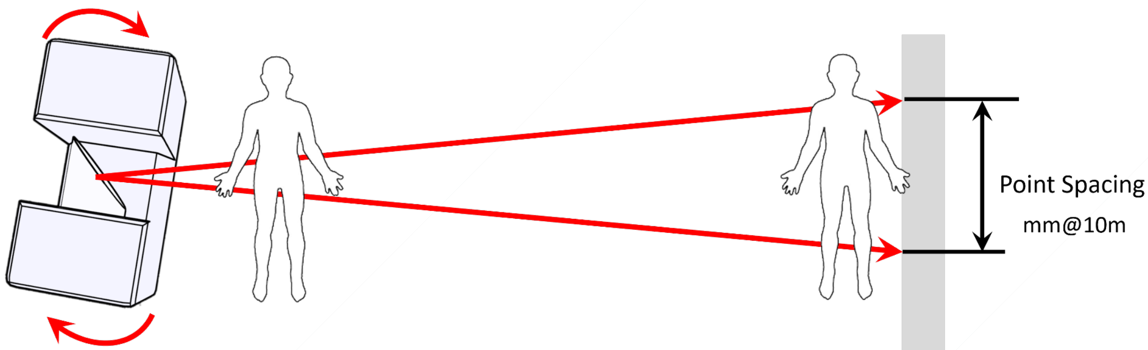
Annex B

(Informative)

Point Spacing Calculation

This annex provides guidance for calculating point spacing on a target surface based on the distance from the scan position and the selected resolution setting of the terrestrial laser scanner (TLS).

The calculation is derived from a trigonometric relationship that models the spacing between adjacent points as a function of the scanner's resolution and the distance to the target surface.



As an example, consider a scanner specification sheet indicating a point spacing of 6 mm at a distance of 10 meters. The "half-angle" must first be calculated and the problem treated as a pair of right triangles.

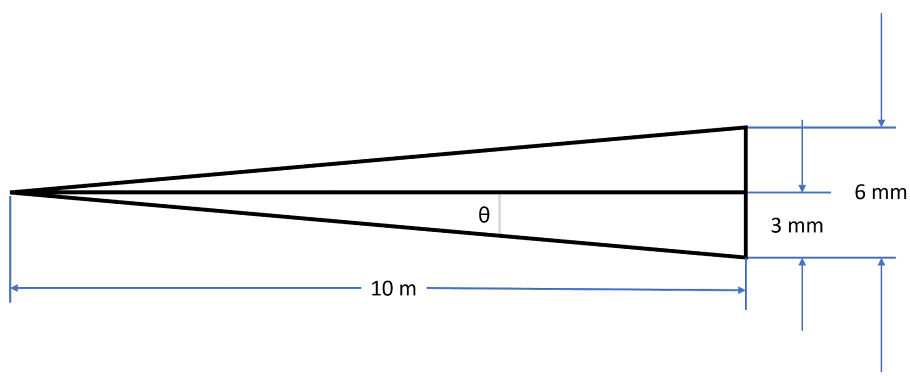
$$tan\theta = \frac{opposite}{adjacent}$$

$$tan\theta = \frac{0.003}{10}$$

$$tan\theta = 0.0003$$

$$\theta = arctan(0.0003)$$

$$\theta = 0.0172°$$



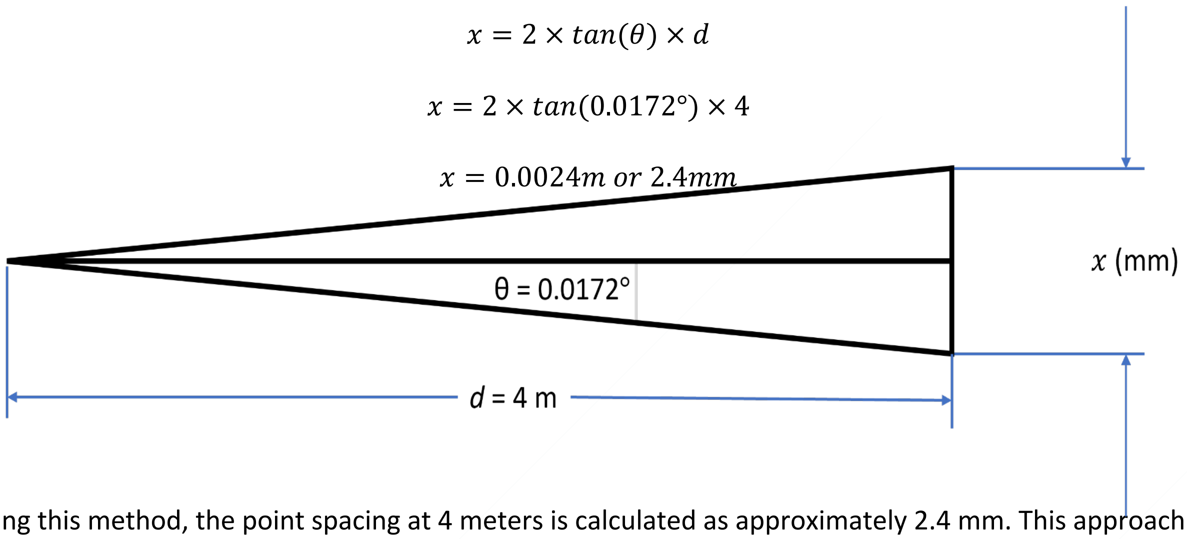
This spacing corresponds to a total angular separation of 0.0344°, or a half-angle of 0.0172°, which represents the angle between the centerline of the scan beam and one adjacent point.

To calculate the point spacing (x) at a different distance (d), the same angular resolution (θ) can be applied. For instance, at a distance of 4 meters and using a half-angle of 0.0172°, the point spacing can be computed using the following formula:

$$x = 2 \times tan(\theta) \times d$$

$$x = 2 \times tan(0.0172°) \times 4$$

$$x = 0.0024m \ or \ 2.4mm$$



Using this method, the point spacing at 4 meters is calculated as approximately 2.4 mm. This approach ensures consistency in estimating point density at varying distances and resolutions, supporting the selection of appropriate scanning parameters for different forensic applications.

Alternative Point Spacing Calculation:

To determine the point spacing on an intended surface a certain distance away from the scanner and using a scanner's specified resolution setting—typically listed as a point spacing at a specified distance (e.g., a resolution of 6 mm at 10 m)—use the following calculation:

1) Divide the intended scanner-to-target distance by the resolution setting's reported scanner-to-target distance.

$$\frac{intended\ distance}{resolution\ distance} = x$$

2) Multiply the resulting ratio by the resolution setting's reported point spacing.

$$x \times resolution\ point\ spacing = intended\ point\ spacing$$

As an example, to calculate the point spacing on an intended surface at a distance of 4 meters away from the scanner, using a resolution setting of 6 mm at 10 meters:

$$\frac{4\ m}{10\ m} = 0.4$$

$$0.4\ \times 6\ mm = 2.4\ mm$$

Intended point spacing at 4 meters = 2.4 mm

Annex C
(informative)

Bibliography

This is not meant to be an all-inclusive list, as the group recognizes other publications on this subject may exist. When this document was drafted, these were some of the publications available for reference. Also, any mention of a particular hardware or software tool or vendor as part of this bibliography is purely incidental, and any inclusion does not mean that the authors of this document are endorsing it.

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