TxDOT Terrestrial Lidar Specifications and Workflow for Design-Grade Mapping Applications

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Terrestrial Lidar Project Requirements

- RPLS overseeing the Terrestrial Lidar project must be TxDOT precertified in work category 15.3.3 Terrestrial Lidar
- Terrestrial Lidar accuracy must be +/- ≥0.04-ft vertical RMSE relative to control targets.
- Terrestrial Lidar Scan Plan must be developed for each scanning project. Scan and target locations must be planned prior to field mobilization. Scan locations are critical in determining the required overlap between adjacent scans.
  - Scans with a minimum 5-20% overlap for adjacent scans. A greater percentage overlap may be required and determined by the Terrestrial Lidar RPLS Project Manager.
- Terrestrial scanning data collection must be monitored during acquisition on the scanner or a linked remote tablet.
- Scans must be repeated if data quality is compromised by weather, pedestrians/vehicles, vibrations, or incorrect tripod setup.
- A Lidar ground-truthing report must be provided as part of the final deliverables.

Terrestrial Scanner Technology Requirements

- A minimum scan range accuracy of 1.9mm @ 10-meter, 2.9mm @ 20-meter, and 5.3mm @ 40-meter resolution.
- 360° horizontal field of view and 300° vertical field of view.
- Range up to 100-meters for outdoor scanning.
- A minimum of two million points per second.
- The scanner must include 360° HDR imagery.
- The scanner must have integrated altimeter, compass, and GNSS.

Terrestrial Lidar Data Requirements

- Point cloud data should be provided in LAS format accompanied by metadata.
- Spherical Images supplied in JPEG format.
- All Lidar data must be classified to ASPRS 1.2 (or above) specifications.
- The point cloud must be appropriately tiled to facilitate end-user computing efficiency.
- For optimal data quality, the point cloud must contain a minimum of 6,000 points per square meter.

Terrestrial Lidar Accuracy Requirements

Terrestrial Lidar accuracies are as follows:

- Hard Surfaces:
  - Bridge and Highway corridor scanning: ≥0.04-ft. accuracy.

- Extraction distances:
    - Lidar accuracy is diminished with distance from the sensor (Lidar points spread with distance similar to a shotgun shot pattern). The Terrestrial Lidar Project Manager must understand and follow the scanner manufacturer's laser range limitations in regards feature extraction beyond the scanner range.

Terrestrial Lidar Workflow

1. PROJECT PLANNING

Site Plan

Site plans are developed in a KMZ, to determine the estimated number of scans to complete full coverage of the bridge object or corridor length. Typically, field crews will have a better perspective once in the field in determining the exact amount of scanning required to capture the complete area. Terrestrial scanning is a line-of-sight technology (any obstructions between the laser and the object will create voids within the pointcloud data), therefore, scan locations and proper distance between overlapping scans is critical in acquiring a complete dataset for feature extraction or 3D modeling. The scanner is positioned around the bridge site (or along a corridor) taking individual scans from varying viewpoints to capture complete site data.

Control Network Layout

An appropriate number of Lidar ground control points will be strategically placed around the object. A KMZ with project limits and control layout for the terrestrial scanning project will be provided to field crews for efficient scanning.

Environmental Factors

Environmental considerations play a pivotal role in the planning phase of Terrestrial Lidar projects. The following is a list of common environmental factors that can significantly impact Lidar quality:

- <u>Precipitation:</u> All scanning activities must occur in dry conditions. Standing water on the ground or morning dew can create void areas within the Lidar point cloud. Water or frozen precipitation has limited reflectivity, making it crucial to ensure dry ground at the time of data collection through thorough planning and forecasting.

- Dust: Airborne dust or debris, whether caused by wind or traffic, can introduce noise within the Lidar point cloud.
- Electromagnetic Interference: Railroad crossings, toll booths, and powerlines are potential sources of signal interference with ground-based Lidar collection. Careful consideration and planning are required to mitigate these interferences and ensure data accuracy.

2. SURVEY CONTROL

Terrestrial Lidar targets are established prior to data acquisition. Targets on a tripod (shown at right) are placed on a known control point (etched mark on concrete or iron rod, as shown in Figure 1 & 2) and are used to georeference the registered pointcloud. The following techniques are used to set the control targets (set on tripods) on during data acquisition:

Figure 1: Etch mark on concrete, hard surface to set up a target on tripod over known point

Figure 2: Iron Rod to set up a target on tripod over known point

3. DATA ACQUISITION

The scanner is positioned around a bridge or along a highway corridor, taking individual scans from varying viewpoints to capture complete site data. Scanner distance from target locations and the distance between scan locations (for proper overlap %) are required for effective terrestrial scanning field practice. The scanning technician must monitor data acquisition on the scanner or on a linked remote tablet to ensure that all required scan angles and data coverage reaches the full buffer area beyond the project limits.

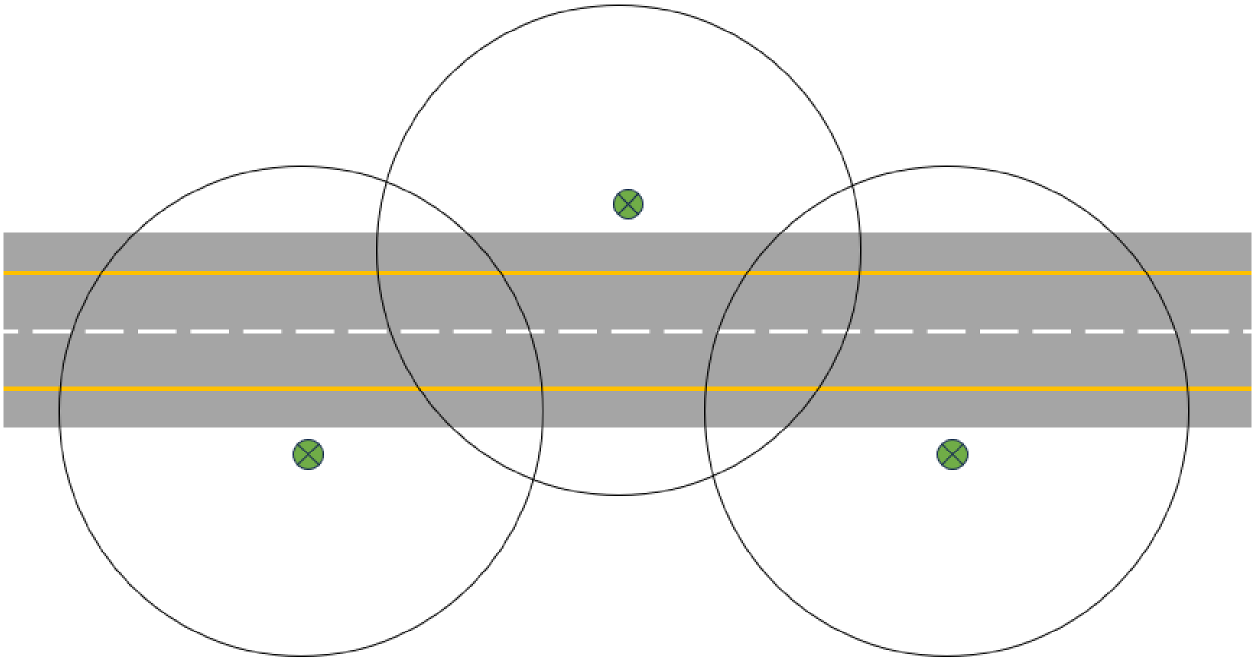

Figure 3: 5-20% scan overlap

4. DATA PROCESSING

Individual scans are processed to LAS or LAZ formats and images are georeferenced to Lidar.

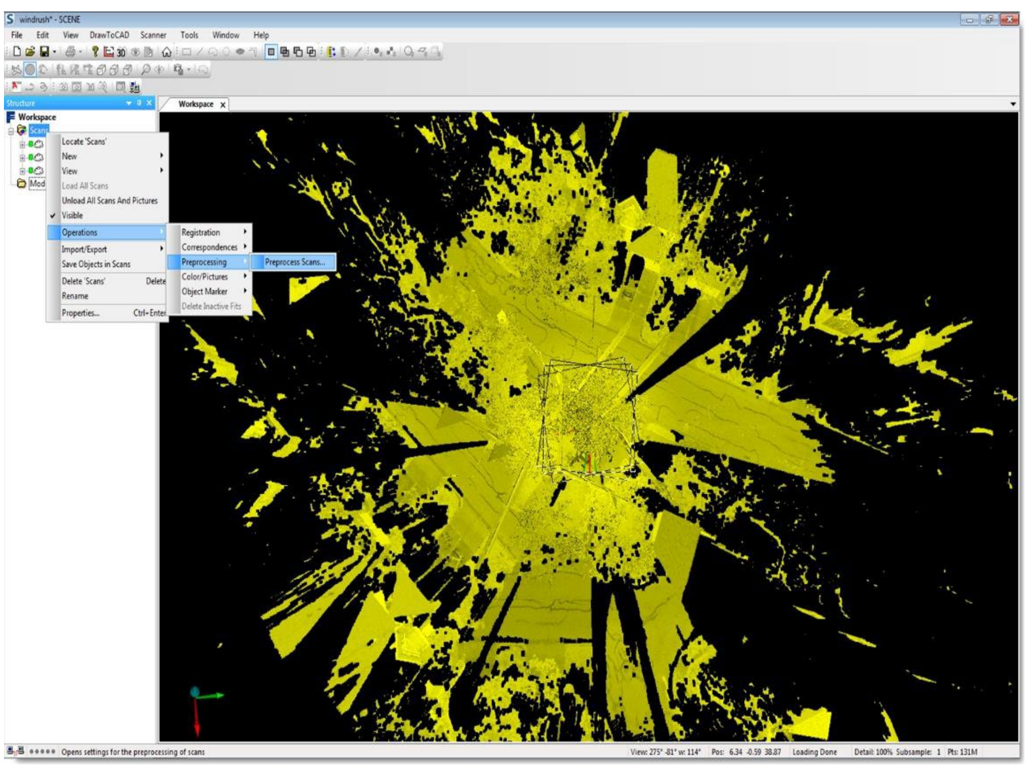

Figure 4: Raw individual and unregistered scans

5. REGISTRATION

Individual processed scans of an object will be registered together in a parent coordinate system. This ensures each scan is correctly aligned to overlapping scans. Once registration is complete, individual scans are combined as a single pointcloud and ready for 2D planimetric and 3D DTM feature extraction.

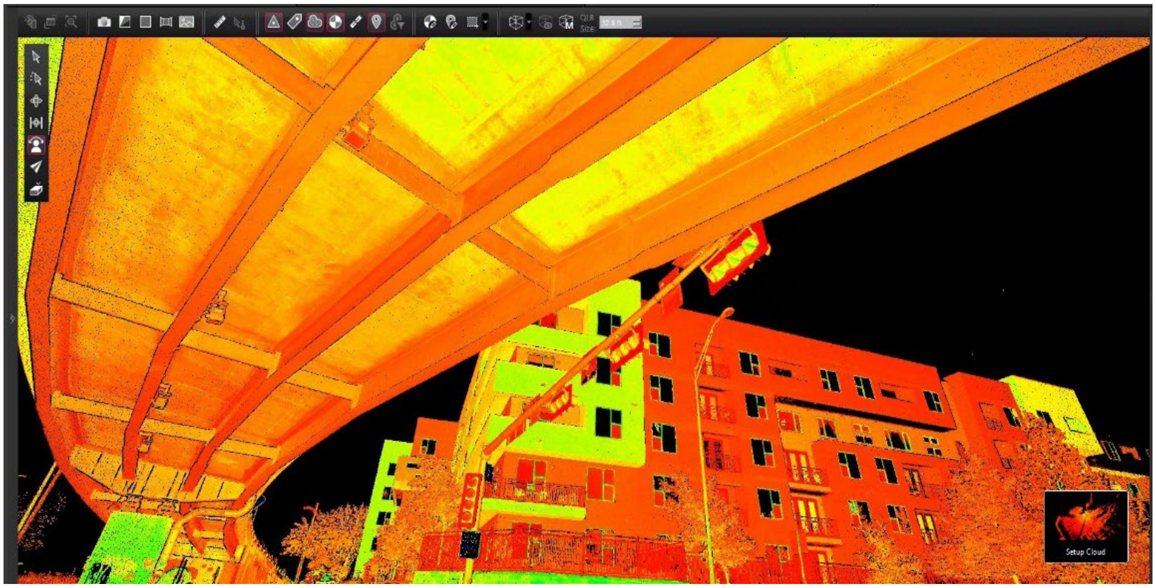

Figure 5: Registered scan data of bridge substructure, displayed in intensity

Point Cloud Noise

Terrestrial Lidar captures points on all surfaces within the distance, surface reflectivity, and/or angle of incidence limits for the Lidar system. Points on surfaces such as vehicles or false points caused by the distortion of the laser signal return are considered noise and must be removed.

6. FEATURE EXTRACTION

2D/3D planimetric/3D DTM feature extraction is performed using a point cloud data management, data quality assessment, and extraction software (similar to TopoDOT and Terrasolid). Feature extraction is carried out by utilizing both the Lidar and calibrated, georeferenced images. All terrestrial scanning feature extraction will adhere to the TxDOT Photogrammetry Feature Collection Standards, outlined in the TxDOT Surveyors' Toolkit.

• Lidar technicians will collect all 2D/3D planimetric and 3D DTM features typically shown at a 1” = 50’ map scale, as standard in MicroStation Open Roads Designer (ORD) and will comply with TxDOT CADD Standards.

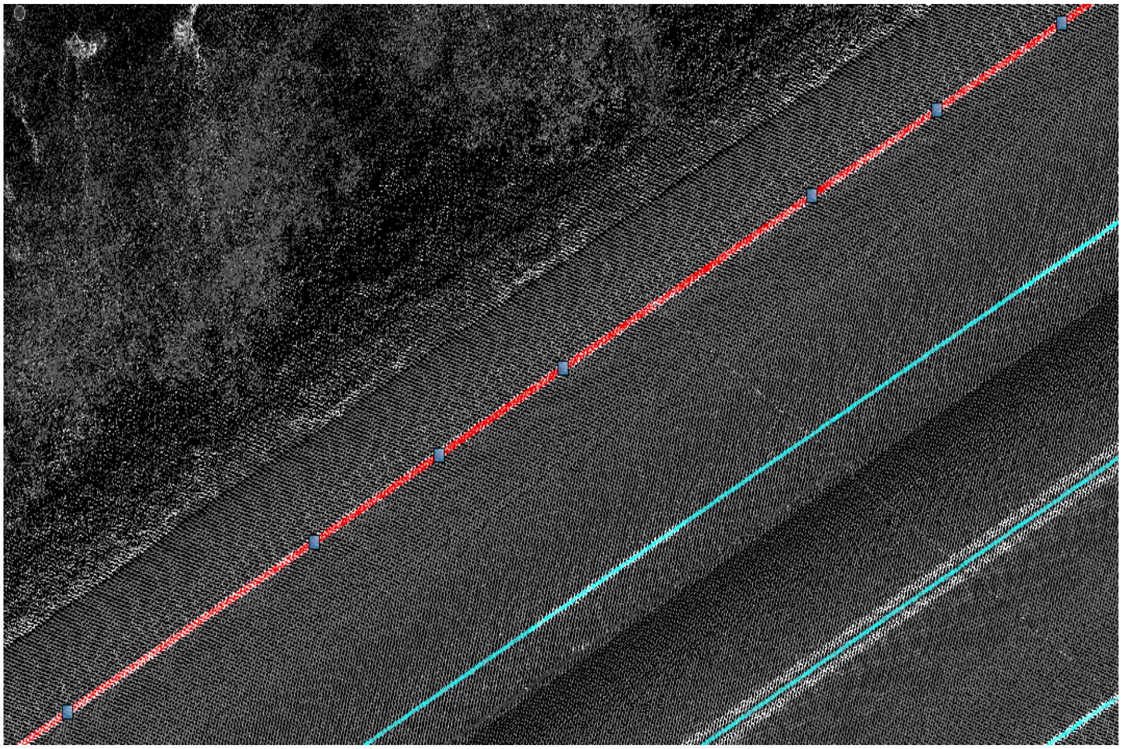

Figure 6: Terrestrial scanning data feature extraction of roadway corridor.

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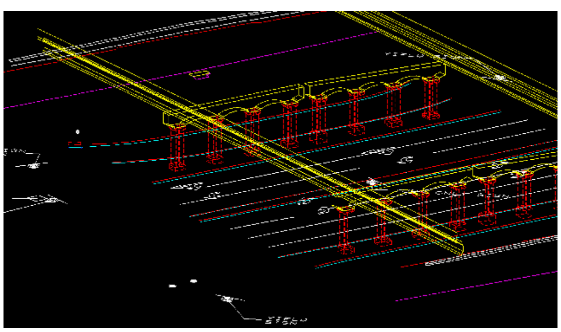

Figure 7: Bridge components extraction

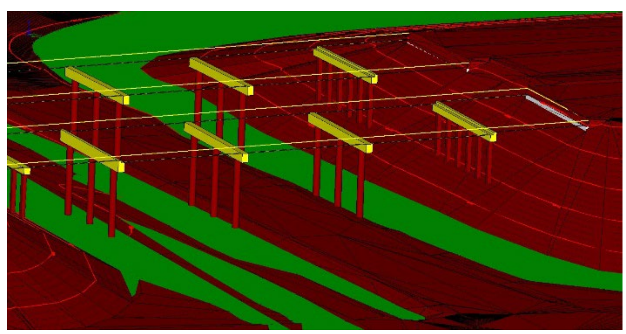

Figure 8: Bridge modeling

7. QA/QC OF TERRESTRIAL MAPPING:

All feature-extracted 2D planimetrics/3D DTM information will be initially edited by the RPLS Project Manager. Lidar ground-truthing checkshots will be compared with TIN. A preliminary TIN will be created and used as part of the initial review process before merging the final Lidar data with conventional survey data. Terrestrial Lidar projects are expected to include field ground-truthing checkshots for comparison with the Lidar.

- The determination of the ground-truthing check shot count for a project will be undertaken by an RPLS, considering factors such as terrain surface, urban and rural environments, tree cover/ground vegetation, GPS quality, pedestrian/vehicle/object obscuring, and other relevant considerations.

8. INTEGRATION WITH SUPPLEMENTAL SURVEY:

Integration of terrestrial Lidar mapping with conventional survey will be performed and reviewed by an RPLS. Any QC markups will be sent back to the Terrestrial Lidar Manager and the extraction team to perform any revisions and fixes. Any changes in the final data will require a TIN file to be re-generated and reviewed.

9. FINAL QA/QC:

Final QA/QC of merged Terrestrial Lidar and Conventional Survey data will be performed by an RPLS, and all mapping data will be prepared for final deliverables to the State.

10. TXDOT TERRESTRIAL LIDAR DELIVERABLES:

- KMZ containing site plan and control layout.
- Processed and classified pointcloud in LAS or LAZ (compressed Lidar file) format with metadata
- Georeferenced images in JPEG format
- 2D Planimetrics, 3D DTM, and TIN in MicroStation Open Roads Designer (ORD)
- ASCII point file containing Terrestrial Lidar ground control point locations