MOBILE LIDAR TECHNOLOGIES:
A user’s perspective and applications

MOBILE LIDAR APPLICATIONS TO INFRASTRUCTURE PROJECTS

Randy Ortega, PSM
Bayamón, PR & Florida, USA
EDUCATION
• BS in Land Surveying from University of Puerto Rico at Mayaguez
• BS in Civil Engineering from University of Puerto Rico at Mayaguez

PROFESSIONAL LICENSES
• Professional Surveying License in Puerto Rico
• Professional Surveyor & Mapper in Florida

EXPERIENCE
• 1 year as Field Survey crew chief in Arecibo Observatory
• 3 years Survey Crew Chief/Survey Technician in Texas
  • Construction Layout
  • Topographic & Boundary Surveys
• 4 years as Survey Technician/Field Crew Supervisor in Florida
• 3 years as Professional Surveyor in Florida with WGI
AGENDA

- TYPES OF MOBILE LIDAR, SENSORS, AND USES
- INDUSTRY STANDARDS – TRANSPORTATION PROJECTS
- CONTROL POINTS & TARGETS LAYOUTS
- DATA PROCESSING & EXTRACTION WITH TOPODOT
- APPLICATIONS
LIDAR is a surveying technology that measures distance by illuminating a target with a laser and analyzing the reflected light.

LiDAR is not photography or photogrammetry.

Collection of hundreds of thousands or millions of points per second.

Accuracy and precision from several meters to less than one centimeter. “You’re only as good as your control”

Coverage areas that can include hundreds of square miles, dozens or hundreds or roadway miles, or one specific site.
Mobile LiDAR Sensors in Motion
TYPICAL SYSTEM AND COMPONENTS

• **Laser** - Measures relative distances by emitting a pulse of light and measuring the speed of its return. Common types of lasers are Time of Flight (ToF) and Phase-shift. Phase difference technique has a medium range, high accuracy, and is ultra-fast, whereas the time-of-flight technique has a longer range but is slightly slower and has slightly less accuracy.

• **GNSS Receiver** - Global Navigation Satellite System. Common GNSS are GPS, GLONASS, Galileo & Beidou (Chinese for big dipper “buy-do”) Uses satellite constellations to provide positioning.

• **IMU** – **Inertial Measurement Units**. Captures data about movement such as attitude (pitch, roll, yaw) and velocity with gyroscopes and accelerometers.

• **DMI – Distance Measuring Instrument** – Wheel pulse transducer. For detecting wheel rotation to calculate wheel speed, distance traveled, and vehicle speed.

• **Cameras** – Planar and Spherical. Used to colorize point cloud as well as provide photographic site inventory and SLAM positioning.

• **SLAM - Simultaneous localization and mapping**. Algorithms utilizing sensor data (LiDAR & cameras) to compute positioning.
LEICA PEGASUS

- SCANNER THAT PRODUCES 1.0M POINTS PER SECOND AT HIGHWAY SPEEDS
- HOUSES UP TO 4 BUILT IN CAMERAS, WITH 1-2 OPTIONAL
- TYPICAL RAW ACCURACY: 0.022 M – HZ, & 0.015 M – VT.
PEGASUS – MIXED APPLICATION
• DUAL SCANNER THAT PRODUCES 3.6M POINTS PER SECOND AT HIGHWAY SPEEDS
• HIGH PERFORMANCE INS/GNSS UNIT
• HOUSES UP TO 9 OPTIONAL CAMERAS
• IMPROVED FILTERS FOR NOISE REDUCTION.
• ACCURACY/PRECISION: ~3MM-5MM

RIEGL VMX-2HA
RIEGL VMY-2

- Dual scanner that produces 400k points per second at highway speeds.
- 560 PTS/M²
- System lightweight 24-28 lbs.
- Foldable
- Accuracy/precision: ~5MM-10MM
Leica Pegasus Backpack

Portable Mobile Lidar system for smaller areas
Supplements obscured areas
Lightweight (approximately 40lbs)

Uses

- Pedestrian walkways, bridges
- Side slopes
- Building interiors (stairwells, multilevel)
- Water Treatment plants
- Electric substations
- Industrial settings
AERIAL LIDAR (UAVs)

- Fixed wing aircraft or helicopter mounted; downward facing configuration
- Collection of millions of points per second
- Utilizes GPS positioning systems, inertial measurement, and targeting if precise collection is required
- Ideal for large coverage areas and remote areas
- Riegl Sensor with Sound pulse to penetrate layers of vegetation
- Raw Accuracy of 0.10’ – 0.25’ (+/- 3cm – 6cm)
Teledyne Geospatial, Galaxy T2000

- 3x Units Project-Ready for Rapid Turnaround on Large Projects
- Most Efficient and Versatile Topographic Lidar Sensor
- Superior Lidar Resolution and Precision
- Each Integrated with a 100MP RGB Metric Camera
Teledyne Geospatial, G2 Sensor System

- Dual Laser Configuration
- Unprecedented Pulse Density and Spacing
- Helicopter & UAV Density at Fixed-Wing Cost & Scale
- Semi-Oblique Pitch Angle for Vertical Feature Capture
# High-Resolution Interstate Test: I565 – Aerial Lidar Results Numeric

## Lidar Pulse Stats

<table>
<thead>
<tr>
<th>Nominal Pulse Density</th>
<th>Aggregate Point Density (90% of 1M Samples)</th>
<th>Point Density - Mode</th>
<th>Beam Footprint Diameter, (Mean Elev - Nadir)</th>
<th>Nominal Pulse Spacing</th>
<th>Aggregate Nominal Pulse Spacing</th>
</tr>
</thead>
<tbody>
<tr>
<td>70.4 pls/m²</td>
<td>244.4 pts/m²</td>
<td>244.1 pls/m²</td>
<td>6.1” (1/e²), 4.3” (1/e)</td>
<td>11.9 cm - 4.7”</td>
<td>6.4cm - 2.5”</td>
</tr>
</tbody>
</table>

## Lidar Accuracy and Precision Stats

<table>
<thead>
<tr>
<th>Control Panel Sample Size</th>
<th>DZ to Control (Min, Max)</th>
<th>Mean DZ to Control</th>
<th>Relative Interswath DZ</th>
<th>Standard Deviation to Control (1σ)</th>
<th>Intraswath Precision - Smooth Surface Repeatability</th>
<th>Absolute RMSEZ - 95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>110 - Hard Surface</td>
<td>-0.102’ +0.098’</td>
<td>+0.015’</td>
<td>90% &lt;0.131’</td>
<td>0.040’</td>
<td>0.14’</td>
<td>0.042’ - 0.082’</td>
</tr>
</tbody>
</table>

## Efficiency and Image Stats

<table>
<thead>
<tr>
<th>AOI Size (Area, Length)</th>
<th>Lidar Buffer Width Off AOI</th>
<th>Flight Lines</th>
<th>Time of Acquisition (Includes Turns, No Transit)</th>
<th>Corridor Line Efficiency</th>
<th>Image GSD (Min, Max)</th>
<th>Mean Image GSD</th>
</tr>
</thead>
</table>
LAS OLAS BOULEVARD DESIGN SURVEY - Broward County, Florida

Design Survey w/TML, R/W Control Survey, Drainage, and SUE
ACCURACY STANDARDS & GUIDELINES

- FDOT Surveying and Mapping Handbook – Version March 29, 2019
- California Department of Transportation (CALTRANS) Survey Manual 2011
- National Cooperative Highway Research Program (NCHRP) Report 748
- Federal Geographic Data Committee (FGDC) – Part 3: National Standard for Spatial Data Accuracy
38.1. MINIMUM TML SYSTEM SENSOR COMPONENTS

- LiDAR sensor
  - Follow OSHA Regulation 1926.54 and manufacturers’ recommendations when using any laser equipment. Never stare into the laser beam or view laser beams through magnifying optics, such as telescopes or binoculars. Additionally, the eye safety of the traveling public and other people should be considered at all times and the equipment operated in a way to ensure the eye safety of all.

- GNSS receivers
  - One or more onboard (roving) GNSS dual frequency receiver(s) capable of RTK data and kinematic data that can be post processed.
  - One or more static GNSS dual frequency receiver(s) at base station(s) capable of simultaneous collection and storage of RTK data and kinematic data that can be post processed.
  - An IMU which typically consists of an electronic gyro within a sealed unit mounted securely on or near the primary sensor.
  - A DMI typically mounted near vehicle wheel housing. It is used primarily as a supporting measurement that allows for sensor collection at relative distance intervals and can suspend measurements while the vehicle is motionless due to vehicle traffic stops during collection.

The collection rate (epoch) of the TML system sensors must be sufficient to meet project accuracy and point density requirements.
<table>
<thead>
<tr>
<th>Operation/Specification</th>
<th>TML Survey</th>
</tr>
</thead>
<tbody>
<tr>
<td>TML positional accuracy requirements relative to Project Control Points and Validation Points</td>
<td>Type A: $V \leq 0.06 \text{ ft}$, Type B: $V \leq 0.10 \text{ ft}$, Type C: See Note 5</td>
</tr>
<tr>
<td>Maximum post-processed baseline length</td>
<td>5 miles, 10 miles</td>
</tr>
<tr>
<td>Minimum number of common healthy satellites in view for GNSS base stations and mobile scanner</td>
<td>See Notes 1 thru 4</td>
</tr>
<tr>
<td>Maximum PDOP during TML data acquisition</td>
<td>5</td>
</tr>
<tr>
<td>Allow sufficient time between overlapping collection passes to ensure change in satellite constellation. Recommend at least 3 different satellites in view.</td>
<td>Each Overlapping Pass</td>
</tr>
<tr>
<td>Minimum overlapping coverage between adjacent runs</td>
<td>20%</td>
</tr>
<tr>
<td>Minimum number of project transformation points required</td>
<td>4</td>
</tr>
<tr>
<td>LiDAR point density requirements (see note 8)</td>
<td>($\geq 20 \text{ pts/ft}^2$), ($\geq 10 \text{ pts/ft}^2$), See note 9</td>
</tr>
<tr>
<td>Recommended maximum spacing for Project Control Point pairs along the project corridor, Project Control Points should be located on each side of scanned roadway</td>
<td>1000 ft intervals, 1500 ft intervals, See Note 5</td>
</tr>
<tr>
<td>Recommended maximum Validation Point spacing along the project corridor for QA purposes as safety conditions permit (see Note 3)</td>
<td>1000 ft intervals, 1000-2500 ft intervals, See Note 5</td>
</tr>
<tr>
<td>Minimum NSSDA Horizontal and Vertical Check Points</td>
<td>20 points - see note 7</td>
</tr>
</tbody>
</table>
Validation Points may also serve as NSSDA check points to meet the requirements of this section. However, if critical areas of the point cloud are to be used outside of the locations of the Validation Points, then additional check points will be needed in those areas to meet this requirement.
TYPES OF TARGETS
TARGET LAYOUTS

EXPO CONVENCION CIAPR 2022
• Absolute – Location
  - Point cloud in relation to established coordinate system

• Relative – Distance
  - Point to point distance within cloud
## QC – MOBILE LIDAR TARGETS REPORT EXAMPLE

### Table

<table>
<thead>
<tr>
<th>Index</th>
<th>Point</th>
<th>Easting</th>
<th>Northing</th>
<th>Elevation</th>
<th>Abs(Deviation X)</th>
<th>Deviation X</th>
<th>Abs(Deviation Y)</th>
<th>Deviation Y</th>
<th>Abs(Deviation Z)</th>
<th>Deviation Z</th>
<th>Dist XY</th>
<th>Template Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>150</td>
<td>MSP602</td>
<td>1307096.96</td>
<td>40.136</td>
<td>0.022</td>
<td>0.022</td>
<td>0.007</td>
<td>0.007</td>
<td>0.001</td>
<td>0.024</td>
<td>60°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>151</td>
<td>MSP602</td>
<td>1506922.31</td>
<td>54.397</td>
<td>0.059</td>
<td>0.059</td>
<td>0.021</td>
<td>0.006</td>
<td>0.006</td>
<td>0.082</td>
<td>60°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>152</td>
<td>MSP603</td>
<td>1305181.5</td>
<td>33.958</td>
<td>0.047</td>
<td>0.047</td>
<td>0.033</td>
<td>0.033</td>
<td>0.035</td>
<td>0.057</td>
<td>60°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>153</td>
<td>MSP603</td>
<td>1306165.8</td>
<td>37.142</td>
<td>0.049</td>
<td>0.049</td>
<td>0.038</td>
<td>0.035</td>
<td>0.032</td>
<td>0.052</td>
<td>60°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>154</td>
<td>MSP620</td>
<td>1314479.67</td>
<td>25.7776</td>
<td>0.007</td>
<td>0.007</td>
<td>0.011</td>
<td>0.011</td>
<td>0.01</td>
<td>0.013</td>
<td>60°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>155</td>
<td>MSP620</td>
<td>1316082.31</td>
<td>16.64</td>
<td>0.023</td>
<td>0.023</td>
<td>0.029</td>
<td>0.029</td>
<td>0.04</td>
<td>60°</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Graphs

- **Deviation X**
- **Deviation Y**
- **Deviation Z**

### Additional Information

- **AVG**: 0.0109
- **RMSE**: 0.0371
- **Within Tolerance (%)**: 100

**EXPO CONVENCION CIAPR 2022**
Open your phone camera app and scan the QR Code to access Orbit Demo data

https://publication.wgigeo.tech/publication/BPEexample
• Asset Management GIS
• Breakline Extraction tool for 3D Topographic surveys
• Detailed Roadway Conditions Report tool
• Cross Slope Analysis tool
• Electric Transmission Locations
• Among Other Applications
PROS & CONS

DISADVANTAGES

• Buy-in Prices
• File Sizes & Hardware To Process/Host Files
• Software Trained Personnel

ADVANTAGES

• Safety! Safety! Safety!
• Improved Time Field Collections For Time Constrained Projects
• More Data For Less Cost
• Able To Collect Data In Hard-to-reach Places Without An Instrument Setup
• Easier Transitions To GIS Platforms And Asset Management