Data Fusion - Merging Aerial, Mobile, & Static Lidar for Road and Bridge Design
Data Fusion:

• Using multiple data sets, acquired through multiple acquisition tools, and ‘fusing’ into one cohesive DTM surface for design.
# Methods of Collection

<table>
<thead>
<tr>
<th>Method of Collection</th>
<th>Resolution/Point Density</th>
<th>Range/Altitude</th>
<th>Ideal For</th>
</tr>
</thead>
<tbody>
<tr>
<td>MMS LiDAR</td>
<td>6000 pts/m²</td>
<td>&lt;200 meter</td>
<td>Roads assets mapping, pavement condition</td>
</tr>
<tr>
<td>Aerial LiDAR</td>
<td>2 to 25 pts/m²</td>
<td>1,000 to 5,000 meter</td>
<td>Wide area collect and corridors</td>
</tr>
<tr>
<td>High Altitude Imagery</td>
<td>7.5 to 30 cm (0.25 to 1.0 ft.)</td>
<td>5,000 to 24,000 ft. AGL</td>
<td>Wide area collect, corridors, oblique</td>
</tr>
<tr>
<td>Normal Altitude Imagery</td>
<td>5.0 to 100 cm (0.16 to 3.2 ft.)</td>
<td>2,500 to 20,000 ft. AGL</td>
<td>Wide area collect and corridors</td>
</tr>
<tr>
<td>Low Altitude Imagery (Renaissance)</td>
<td>1.5 to 7.5 cm (0.05 to 0.25 ft.)</td>
<td>900 to 3,000 ft. AGL</td>
<td>Corridor and medium size projects</td>
</tr>
<tr>
<td>Unmanned Aerial System (UAS)</td>
<td>0.5 to 7.5 cm (0.02 to 0.25 ft.)</td>
<td>50 to 700 ft. AGL</td>
<td>Small projects within few hundreds acres</td>
</tr>
<tr>
<td>Thermal Imaging</td>
<td>15 cm to 60 cm (0.5 to 2.0 ft.)</td>
<td>1,000 to 5,000 meter</td>
<td>Small to medium size projects</td>
</tr>
<tr>
<td>Traditional Survey</td>
<td>Varies</td>
<td>Line of Sight (usually up to 1000' EDM for vertical)</td>
<td>Small to medium size projects</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Method of Collection</th>
<th>Project Size</th>
<th>Horizontal Accuracy</th>
<th>Vertical Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>MMS LiDAR</td>
<td>1000's linear miles</td>
<td>5 to 30 cm (0.16 to 1.0 ft.)</td>
<td>1.8 to 15 cm (0.06 to 0.50 ft.)</td>
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<tr>
<td>Aerial LiDAR</td>
<td>1000's of square miles</td>
<td>30 to 45 cm (1.0 to 1.5 ft.)</td>
<td>5 to 15 cm (0.16 to 0.5 ft.)</td>
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<td>High Altitude Imagery</td>
<td>1000's of square miles</td>
<td>7.5 to 30 cm (0.25 to 1.0 ft.)</td>
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<tr>
<td>Low Altitude Imagery (Renaissance)</td>
<td>&lt;100 sq. miles</td>
<td>5 to 30 cm (0.16 to 1.0 ft.)</td>
<td>5 to 30 cm (0.16 to 1.0 ft.)</td>
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<tr>
<td>Unmanned Aerial System (UAS)</td>
<td>&lt;1000 acres</td>
<td>5 to 30 cm (0.16 to 1.0 ft.)</td>
<td>5 to 30 cm (0.16 to 1.0 ft.)</td>
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<tr>
<td>Thermal Imaging</td>
<td>&lt;50 sq. miles</td>
<td>50 to 100 cm (1.7 to 3.2 ft.)</td>
<td>N/A</td>
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<tr>
<td>Traditional Survey</td>
<td>Varies (terrain, SUL requirement)</td>
<td>Varies (2.5 to 15 cm [0.08 to 0.50 ft.)</td>
<td>Varies (0.9 to 7.5 cm [0.03 to .25 ft])</td>
</tr>
</tbody>
</table>
Advantages of Digitally Acquired Data for Design

• Ever wish your surveyor had not skipped over something or taken another shot to help define a driveway or curb ramp?
• How often do you wonder if they really shot the exact point you intended them to?
• Ever wish you had just turned around and taken another picture looking the other direction?
• How long after your survey was completed did you ask these questions?
Advantages of Digitally Acquired Data for Design

• LiDAR and Imagery produced basemaps and TINs give the designer the ability to validate the information from which they are designing.

• It allows for the extraction of additional information without a return visit to the field.

• Provides more complete representation of the existing conditions.

• Collect it all now, and extract those elements you may not even know you need for design today, later.
Utility Line and Vertical Obstruction

Bridge Vertical Clearance  Utility Vertical Clearance  Other Obstructions
Railroad (Other Applications)
DOT Design Grade Project
5-mile Corridor
KYTC KY-194 Pikeville

- Existing Road Design - Reduce curves, Widen road
- Safety – Keep personnel off roadway
- Provide a comprehensive cost effective solution
- Obtain 3D horizontal and vertical information for infrastructure to be used as needed during design process
- Accurate road surface data – 0.20’ horizontal 0.06’ vertical
- Accurate (60’) infrastructure data – 0.20’ horizontal 0.20’ vertical
- Accurate data for remainder of the project – 1.0’ horizontal, 0.5’ vertical
- 1” = 40’ scale planimetric and topographic mapping with 1’ contours - 0.5’ contours on roadway
- Orthoimagery at 0.25’ pixel resolution
- 3D Point Cloud (60’) corridor
- Mobile mapping Imagery
KYTC KY-194 Pikeville

- Develop an approach considering the unique complexity of the project site - blind curves, little or no shoulder, high walls and drop offs, heavy industry, manufacturing facility, sub-station, heavy traffic (semi-trucks), school bus route, bridges, overhead structures, power lines, etc.
- Obtain new 1” = 350’ scale aerial imagery of the entire site
- Obtain new Mobile mapping data for the 5-mile, 60’ roadway corridor 0.20’ horizontal 0.06’ vertical
- Use existing Statewide 1.5-meter LiDAR adjusted to the project control to be used for DTM
Planimetric and Topographic Mapping Using Statewide LiDAR
Mobile LiDAR
Comprehensive Cost Effective Solution

Mobile Mapping System for a 5-mile, 60' Corridor
- 2 Day targeting and Acquisition
- One collection, multiple uses
- Cross sections and profiles anywhere
- Includes feature extraction of edge of pavement
- 3-D point cloud provides infrastructure data
- Fee = $9,000 per line mile

Existing Aerial LiDAR and New Digital Terrain Model
- Adjusted Existing 1.5 meter LiDAR from Statewide Program, DTM, Contours, Contour Labels spot Elevations
- Fee = $38,000

Traditional Survey for Roadway Surface Data
- Two weeks with daily lane closures and safety risk
- Cross sections located at 50' intervals
- Fee = $10,000 per line mile

New Aerial LiDAR and DTM
- 1.5 meter LiDAR from Statewide Program, DTM, Contours, Contour Labels spot Elevations
- Fee = $68,000
Petersburg Road and Overman Road

• Highland County Engineer’s Office
• Safety improvement project correcting distance issues
Accuracy Validation

- Field checked using traditional survey
- Collected data at 50’ interval along the centerline of the road

<table>
<thead>
<tr>
<th>Number</th>
<th>Field Survey</th>
<th>Mobile Mapping</th>
<th>Delta</th>
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</tbody>
</table>
Cassady Avenue

- City of Columbus
- General road and pedestrian improvements
- Mobile mapping and traditional survey
Project Control

Petersburg and Overman Road
• Woolpert set eight control targets

Cassady Avenue
• Woolpert set forty control targets
Limitations

- Impediments, line of sight
  - Vegetation. The LiDAR will penetrate it, but some areas will require additional processing or QA/QC. Where error cannot be reduced, traditional field survey can be used.
Limitations

• Impediments
  − Heavy vegetation and tall grass
  − Wet pavement
  − Standing water on the pavement or in ditches
  − Stationary obstacles

• Mitigation for Impediments
  − Mowing or supplement with traditional survey
  − Waiting for favorable weather
  − Supplement with Static LiDAR
Limitations

• Understand the technology and its strengths and weaknesses.
• Know your desired accuracy. This has a big impact on the amount of control needed.
  – Be systematic with your targeting. Every site is different.
  – Woolpert R&D efforts are reducing the number of targets needed.
  – Targets don’t always need to be set at a particular interval.
• LiDAR is based on line of sight. What you see is what you get.
Bridge Replacement

- Project is to widen the existing structure and increase the vertical clearance on the interstate while salvaging the existing substructure.
- ODOT provided aerial mapping including Planimetrics and TIN.
- Woolpert performed traditional survey on existing utility features and a static LiDAR scan of the bridge.
- Data was merged to create the basemaps used in design.
Bridge Scan

• Bridge Deck Thickness
  – We knew the original bridge deck had been overlaid, but records were unclear as to the exact thickness of the overlay. No coring required, since using top and bottom scans to calculate the thickness.

• Accurate Location of Beams
  – As-built representation of the existing structure, allows for measurement of existing deflection and camber along the existing beams at any location.

• Accurate Representation of the Piers
  – The rounded ends of the existing piers were added onto for the widening.
  – The LiDAR data assists in determining the as-built skew at each pier for proper span analysis, design and beam fabrication.
Data Fusion – ODOTD5
GUE-513-8.65

Bridge Scan

• Accurate Deck Overhang
  - LiDAR provided an accurate representation of the existing deck overhangs, which varies due to the curved deck and dog-legged beams.
Data Fusion – ODOT D5 GUE-513-8.65

Basemap

• Scanned data was merged into the ODOT provided data to create the project basemaps.
Data Fusion – ODOT D5 GUE-513-8.65

Combined Data Isometric View
Data Fusion – ODOT D5 GUE-513-8.65

Combined Data with Stationary Lidar Point Cloud Overlaid
Data Fusion – ODOTD5 GUE-513-8.65

- Bridge Deck, Beams, and Piers in Point Cloud
- Comparable Photo Image
Bridge Rehabilitation

• Widen existing bridge from 2-lanes to 3-lanes and increase vertical clearance over Interstate 70.

• Mobile Mapping LiDAR was used to collect the existing pavement, keeping our surveyors out of the traveled way and reducing impacts to traffic flow.

• Static LiDAR was used on the underside of the bridge and behind piers to supplement the Mobile LiDAR.
Bridge Rehabilitation

• Traditional survey was used to pick up areas beyond the pavement, utilities, and project control.

• Statewide LiDAR and aerial mapping were used to provide a background and help in determining drainage areas and watersheds.
Westbound I-70 Approaching Arlington Road Bridge
Data Fusion – ODOTD7 MOT-70-3.34

MMS Collect at Arlington Rd Bridge from I-70
Data Fusion – ODOTD7 MOT-70-3.34
Data Fusion – ODOTD7 MOT-70-3.34
• Point Cloud NB Approach to Bridge Along Arlington Road

• Photo Image NB Approach to Bridge Along Arlington Road
The Colorado Department of Transportation-Interstate 70, Floyd Hill to Empire
CDOT “TMOSS” Mapping

- 18.5 mile long corridor – 1000’ width
- Existing Road Design - Reduce curves, Widen road, add toll lanes
- **Safety – Keep personnel off roadway**
- Provide a **comprehensive cost effective solution**
- Obtain 3D horizontal and vertical information for infrastructure to be used as needed during design process
- Accurate road surface data – 0.06’ horizontal 0.06’ vertical – **Mobile Mapping Lidar**
- Accurate (ROW) infrastructure data – 0.10’ horizontal 0.06’ vertical – **field survey**
- Accurate data for remainder of the project – 1.0’ horizontal, 0.5’ vertical – **aerial photography**
- 1” = 50’ scale planimetric and topographic mapping with 1’ contours
- Orthoimagery at 0.5’ pixel resolution
- 3D Point Cloud of corridor (ROW)
- Mobile Mapping Imagery
- Seamless 3D Microstation/InRoads dataset to CDOT standards

The “Twin Tunnels”
Veteran’s Memorial Tunnels

- Prior project-as-built is a portion of this project
- Design surveys, tunnel monitoring during blasting and construction of new bores
- **2016 ENR Mountain States Best Project Award Winner-Best Highway/Bridge Project**

The “Twin Tunnels”
Project Control

Primary Control
• Corridor previously set by CDOT forces

Mobile Mapping Targets
• Woolpert set 256 painted targets
• Horizontal – GPS RTK
• Vertical – Differential Levelling
Mobile Mapping Target Layout

- Project Target Layout
- Target Layout Through the Tunnels
2 - 700 Foot Long Tunnels
Comprehensive - Lighting and other infrastructure within the bore

Dimensioning – accurate, true curvature
Bridge Clearances

Sub-structure Mapping
Girders, piers, columns

Clearance dimensions
Underground Utilities

- SUE – Level “B”
- Gas
- Water
- Electric
- Fiber Optics
- Telephone
- Cable TV
Accuracy

• Field checked using traditional survey
• Collected data at 40’ intervals along the outside (shoulder side) edges of pavement
• Average difference was 0.055 feet
Questions/Comments

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