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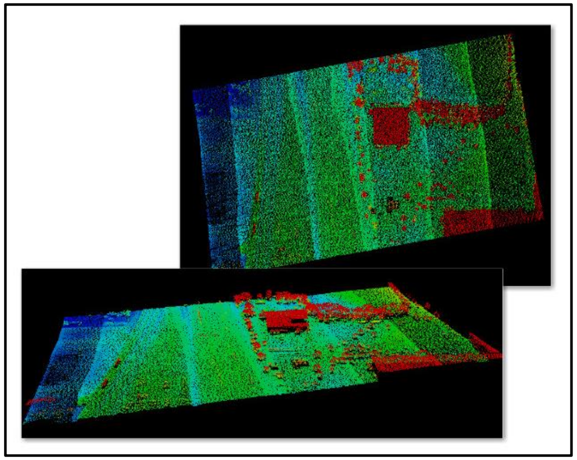

Implementation of Aerial LiDAR Technology to Update Highway Feature Inventory (MPC-462)

Presented by:

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Department of Civil and Environmental Engineering

Utah State University

Our partners:

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Acknowledgments

Outline

1. Introduction
2. Road Inventory Methodologies
3. LiDAR Technology
4. Field Experiment and Data Collection
5. Airborne LiDAR Data Processing
6. Conclusions and Future Work

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Introduction

- Background
  - MAP-21 requires each state to establish a risk-based **asset management plan** for the National Highway System (NHS) to improve or preserve the condition of the assets and the performance of the system.
- Research Objective
  - The main focus of this research project is to evaluate the application of airborne data collection methods in updating highway inventory.

ASSET TYPE	QUANTITY
Pavement & Bridge Assets	
Pavement NHS	115,694,396 SY
Pavement Non-NHS	57,850,911 SY
Bridges NHS	14,451,169 SF
Bridges Non-NHS	6,258,935 SF
Other Assets	
ATMS Devices	Lump
Signal System	1255 Each
Walls	71,820,494 SF
Pipe Culverts	16,553 Each
Barrier	7,347,574 FT
Signs	96,160 Each
Pavement Markings	26,000 Miles
Rumble Strips	26,287,969 FT
Fences	1,890 Miles
Cattle Guards	895 Each

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Road Inventory Methodologies

- Road Inventory
  - Road inventory is a compilation of components and conditions of road system.
- Methodologies
  - Field inventory
  - Photo/video log
  - Integrated GPS/GIS mapping
  - Aerial/satellite photography
  - Terrestrial LiDAR, mobile LiDAR, and airborne LiDAR.

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Methodology Classification

	GPS	GPS and Image	GPS, Image and LiDAR
Land-based	Field Inventory Integrated GPS/GIS mapping systems	Photo/Video log	Terrestrial LiDAR Mobile LiDAR
Air- or Space-based		Aerial photography Satellite photography	Airborne LiDAR

Field Inventory

- *Advantages*
  - Low equipment cost
  - Minimal training requirements for personal
  - Low data reduction efforts
  - Capable of collecting rich road inventory data

- *Disadvantages*
  - Personal exposed to dangerous traffic environment
  - Block the traffic to some extent
  - Long collecting time
  - Labor intensive
  - Low accuracy

Photo/Video Log

- *Advantages*
  - Safer
  - More accurate
  - More efficient

- *Disadvantages*
  - More data reduction efforts
  - Subject to weather condition

Integrated GPS/GIS Mapping

- *Advantages*
  - Low initial cost
  - Low data reduction efforts
  - High precision

- *Disadvantages*
  - Exposure to traffic and field

Aerial/Satellite Photography

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LiDAR Technology

❖ LiDAR

- ❑ Light Detection and Ranging (LiDAR) is a remote sensing technology that collects geometric and geographic information of targets on the Earth's surface in the form of point clouds.

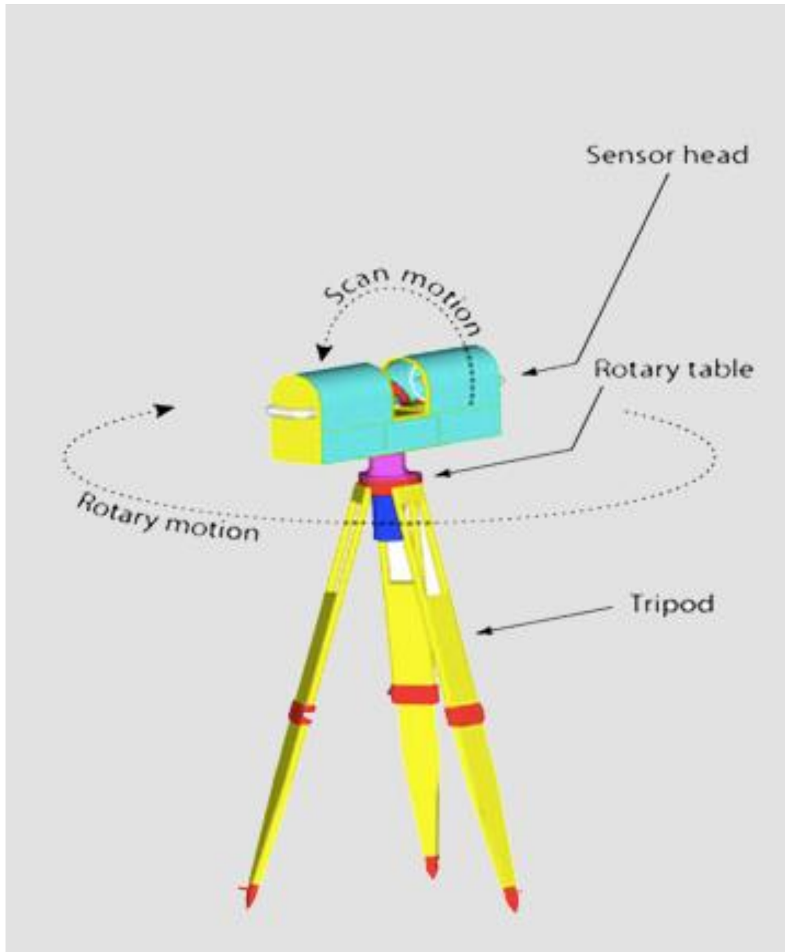
❖ Classification

- ❑ Terrestrial Laser Scanning (TLS)
- ❑ Mobile Laser Scanning (MLS)
- ❑ Airborne Laser Scanning (ALS)

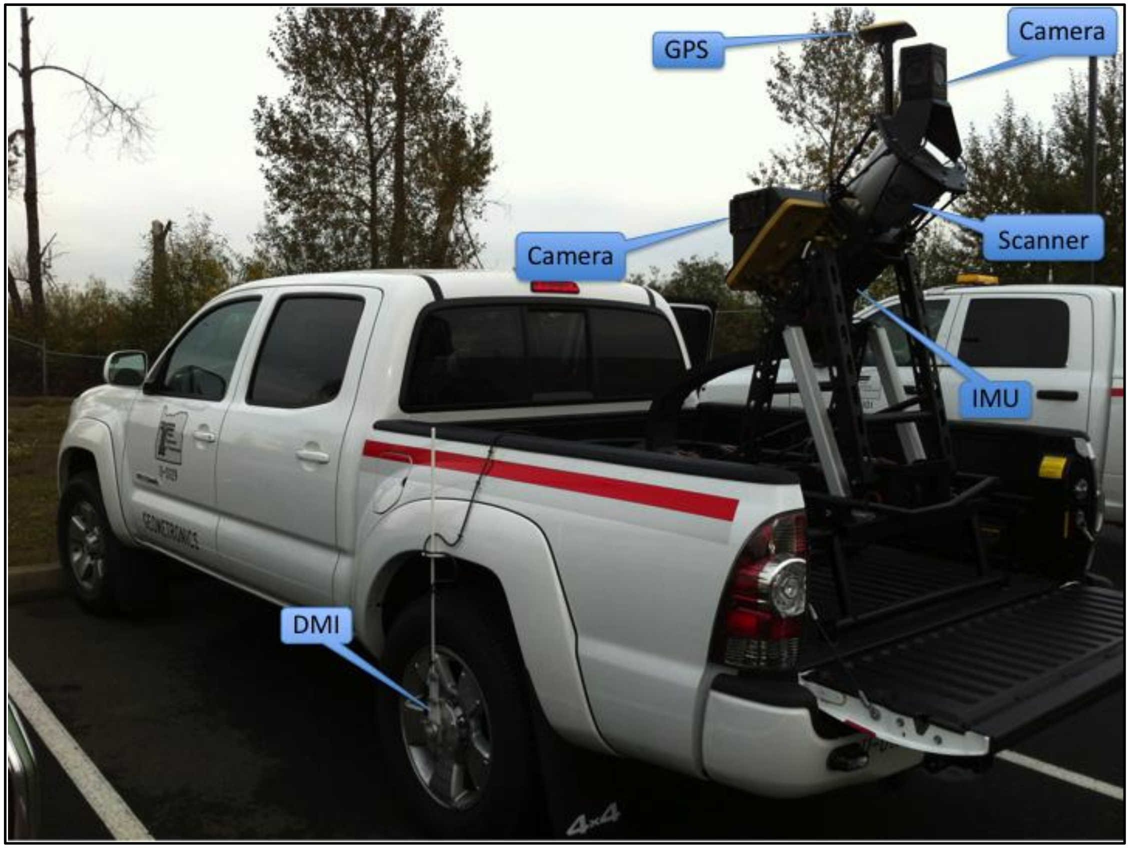
How LiDAR works?

- LiDAR sensor measures time from when laser pulse sent to when received.
- The time is converted to distance between LiDAR sensor and objects.
- The measured distance is then combined with the position and orientation information obtained from the Global Positioning System (GPS) and the Inertial Measurement Unit (IMU) system to generate three-dimensional information of the target objects.

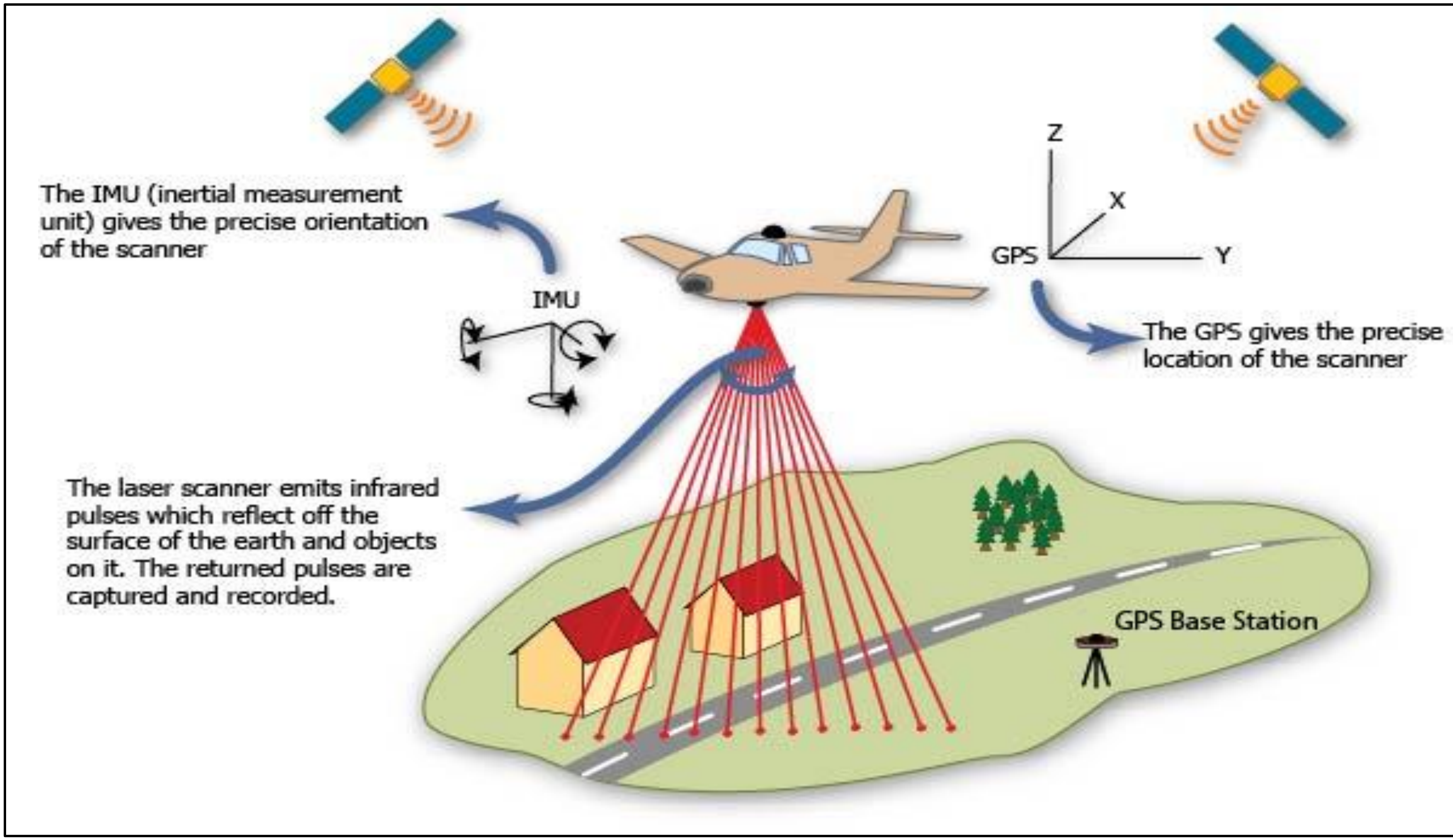
Terrestrial LiDAR



Mobile LiDAR



Airborne LiDAR



Airborne LiDAR

Components

- Flight management system
- The airborne platform
- Laser scanner
- Position and orientation system
- Control and data recording unit (computer)

Applications

- Collecting and recording highway inventory data
- Traffic flow estimation
- Highway corridors mapping

Comparison of LiDAR Systems

	Airborne LiDAR	Mobile LiDAR	Terrestrial LiDAR
Advantages	High degree of automation Safe operation Less affected by atmospheric conditions Efficient Direct view of pavement and building tops Faster coverage Larger footprint Point density is more uniform High post-processing efficiency	Safe Good view of pavement Direct view of vertical features Higher density Cost effective	Higher flexibility Higher resolution Higher accuracy Easy to use Highest level of detail
Disadvantages	Poor view of vertical features Lower point density More horizontal positioning uncertainty	Cannot capture building tops Slower coverage Small footprint	Inefficient Lowest cost efficiency Limited to project size

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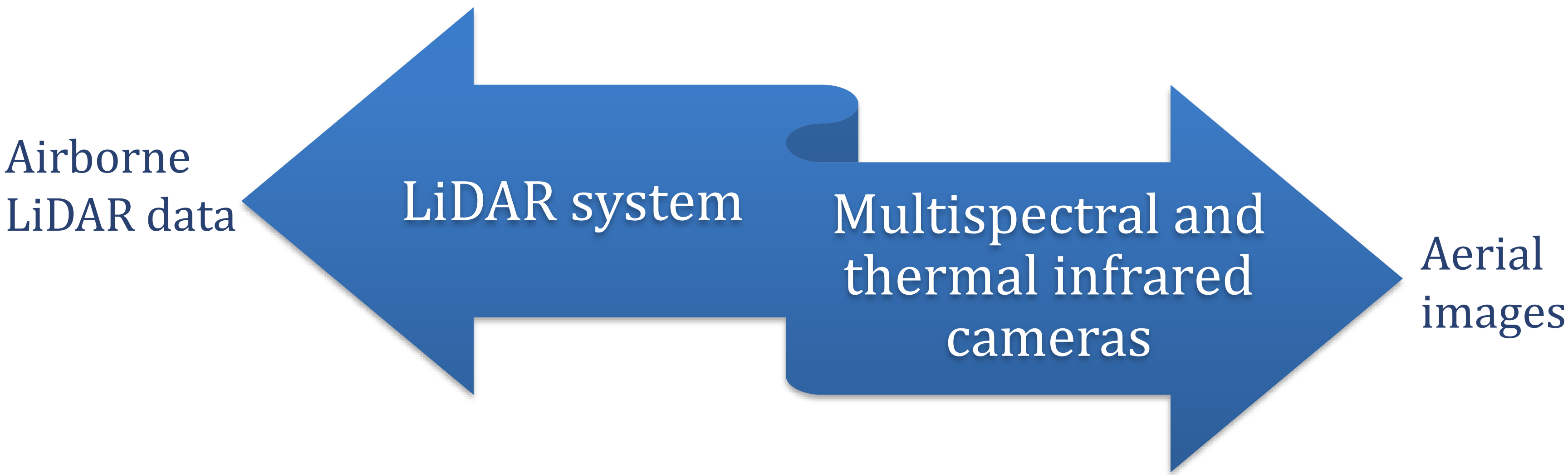
Field Experiment and Data Collection

- Methodology

Remote Sensing Service Laboratory (RSSL)

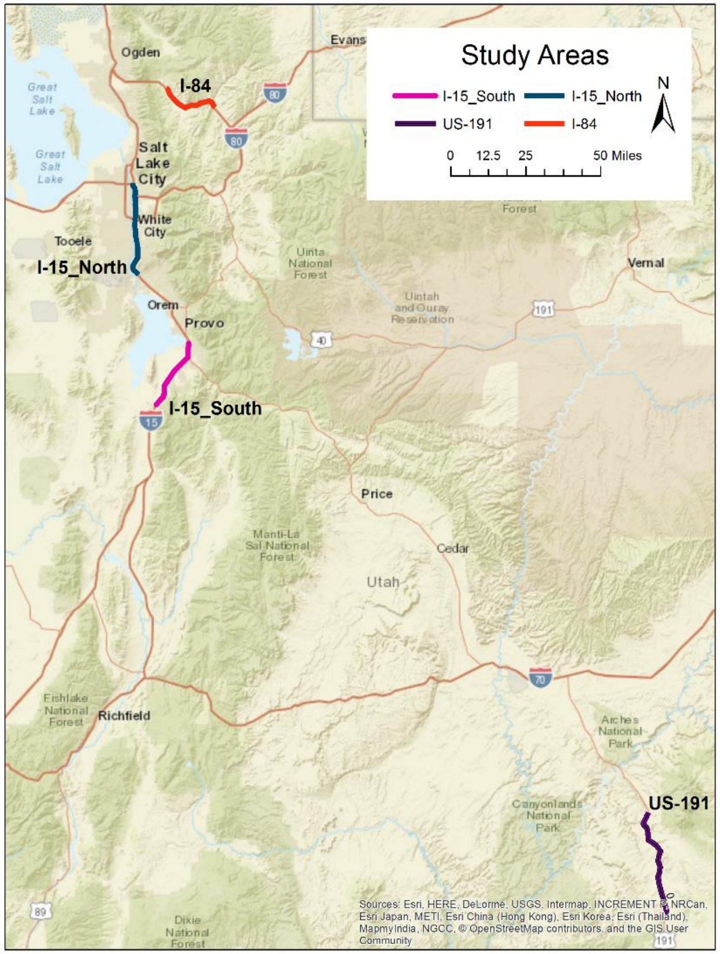
Utah State University (USU)



Data Collection Equipment

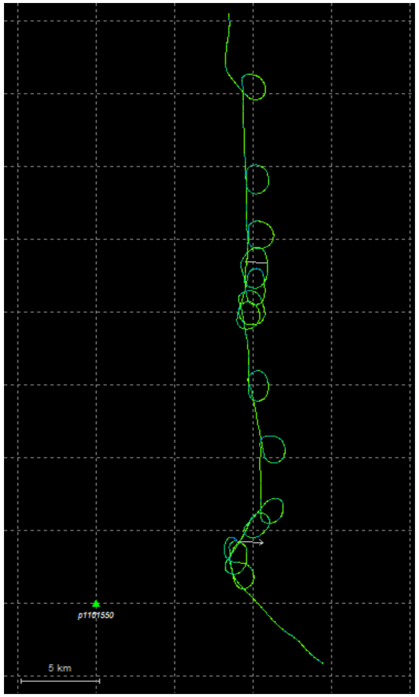
Study Areas

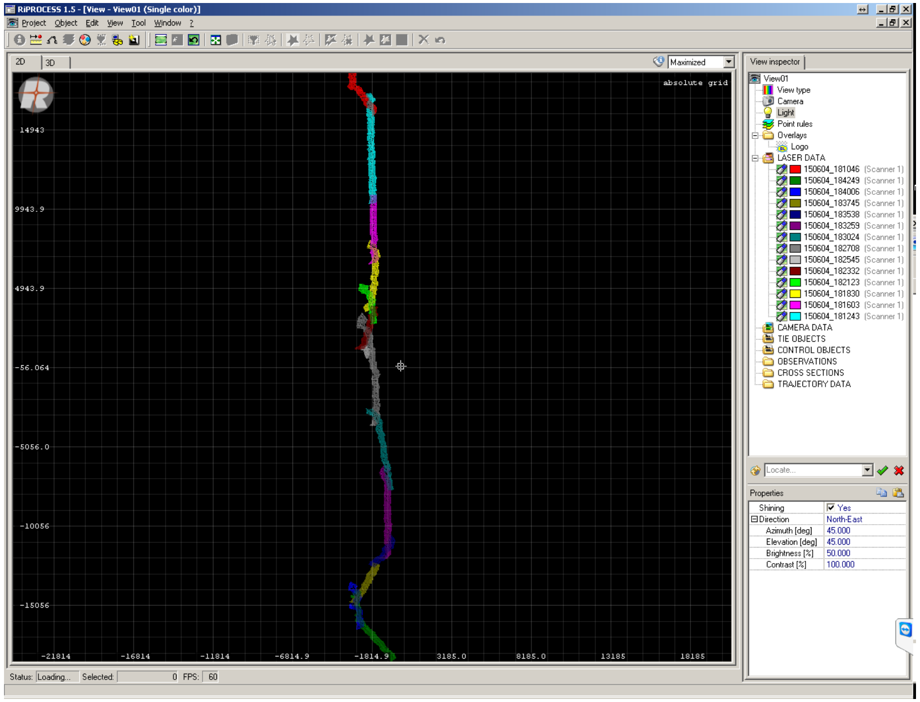
- I-84: Mountain Green to Morgan County/Summit County (MP 97-113)
- I-15 North: MP 284-307
- I-15 South: From Santaquin to Springville (MP 241-260)
- US-191: MP 84-112



Data Preprocessing

- Waypoint Inertial Explorer software - raw GPS/IMU data
- RiAnalyze software - LiDAR data
- RiProcess software - coordinates





Accuracy of Airborne LiDAR Data

Summary of USGS NGP guidelines v.13 for LiDAR data quality

RMSE	Condition	Source
12.5 cm	Fundamental vertical accuracy (in the clear)	USGS
10.0 cm	Within swath overlap regions	USGS
7.0 cm	Relative accuracy within individual swaths	USGS

Summary of LiDAD data accuracy assessment

RMSE Requirement	Condition	Estimated RMSE Achieved
7.0 cm	Relative accuracy within individual swaths	Less than 7.6 cm estimated
10.0 cm	Within swath overlap regions	7.6 cm average measured
12.5 cm	Fundamental Vertical Accuracy (in the clear)	Not Assessed but was likely achieved

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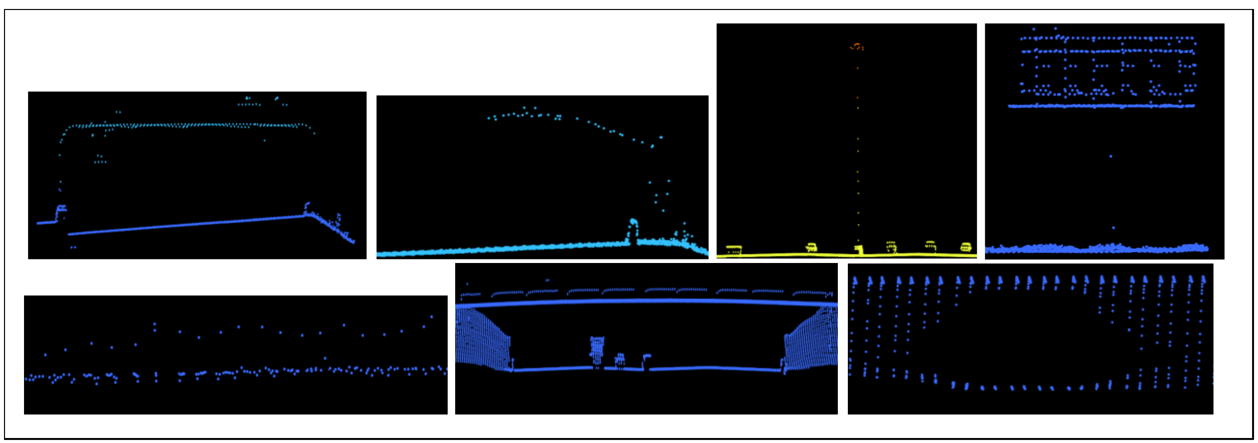
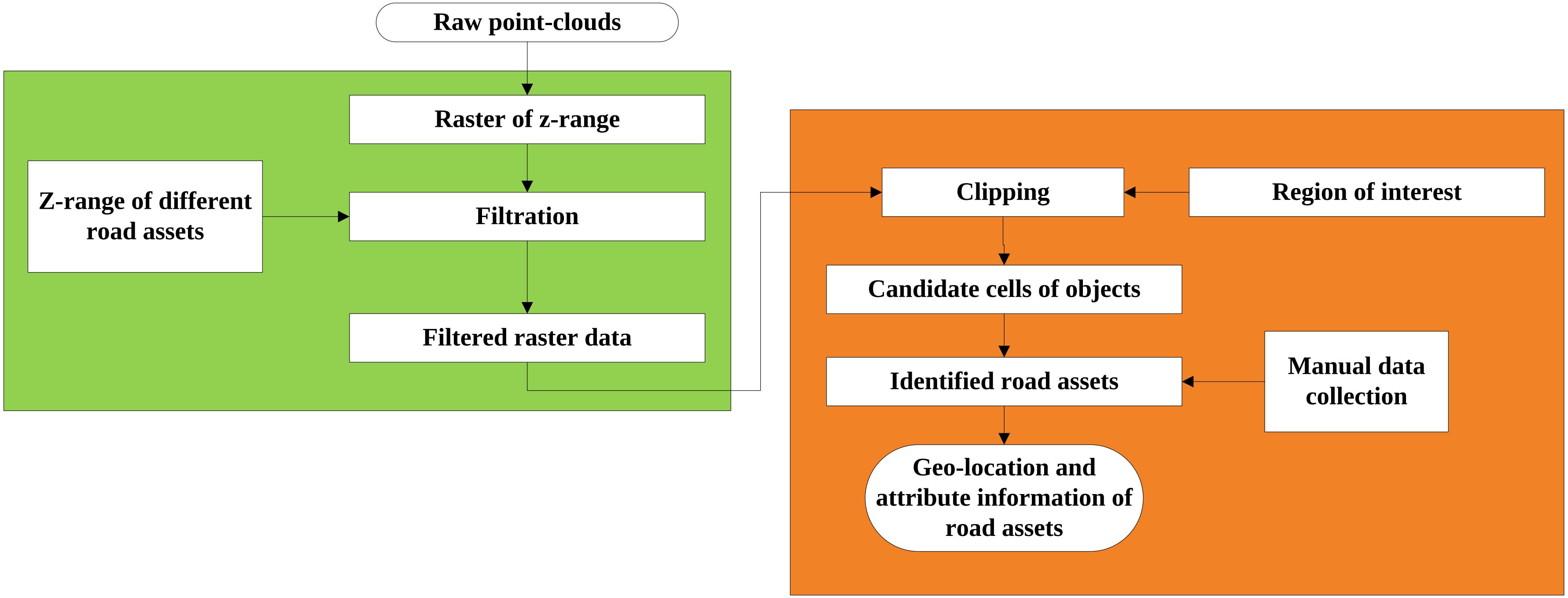
Airborne LiDAR Data Processing

(a) Large traffic sign, (b) traffic signal, (c) light pole, (d) billboard, (e) barrier, (f) bridge and (g) culvert.

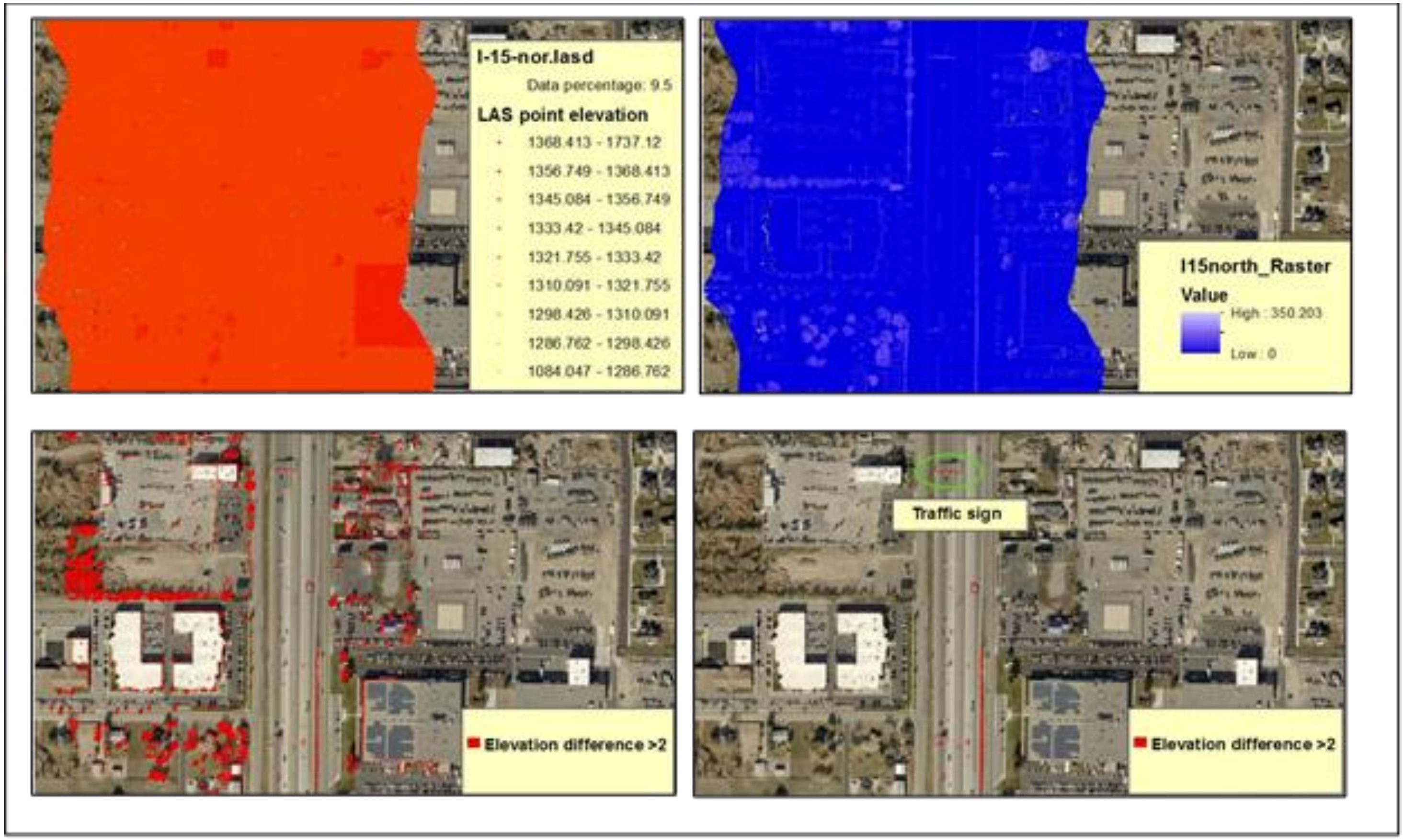


(a) Large traffic sign, (b) traffic signal, (c) light pole, (d) billboard, (e) barrier, (f) bridge and (g) culvert in LiDAR data.

Flowchart of an ArcGIS-based Algorithm

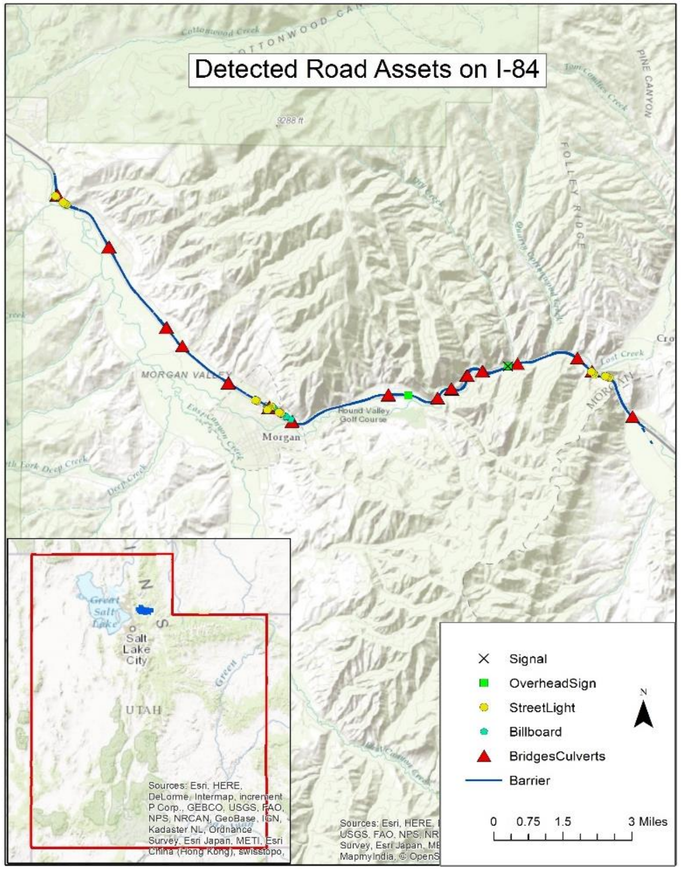


Data Processing Example

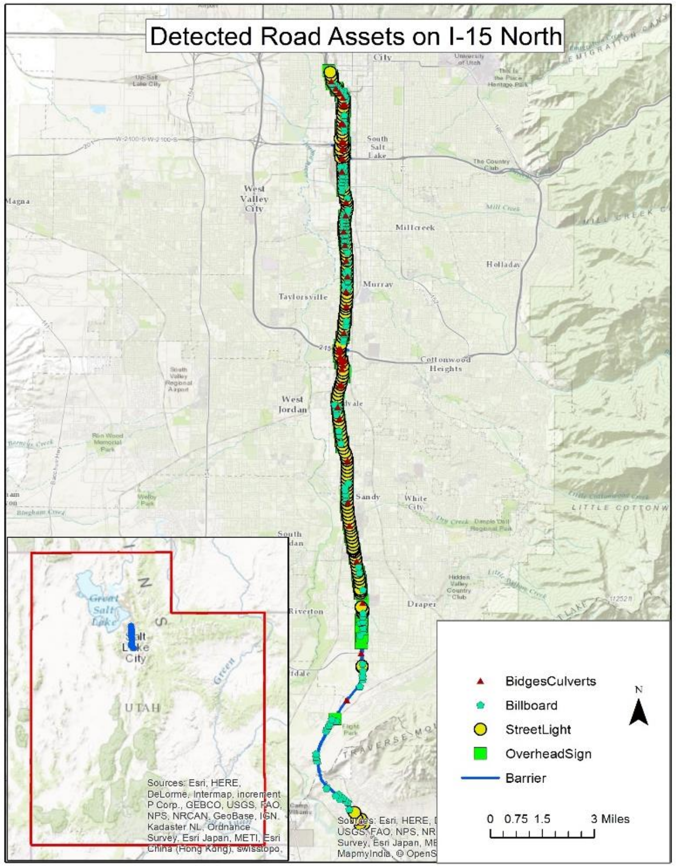


(a) Original LAS data, (b) raster data, (c) filtered raster data, and (d) clipped data

Experiment results

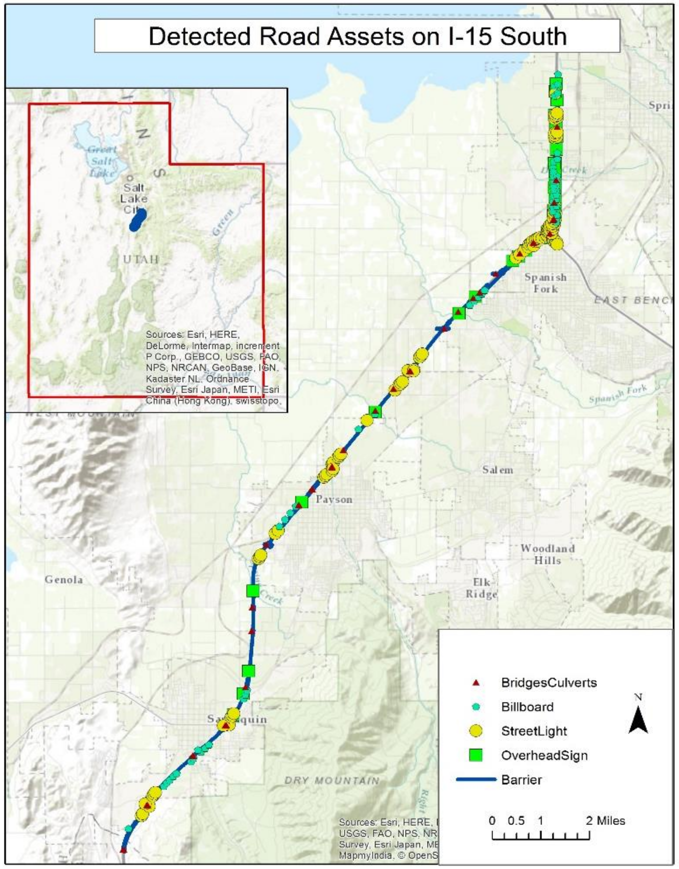


Detected assets along I-84

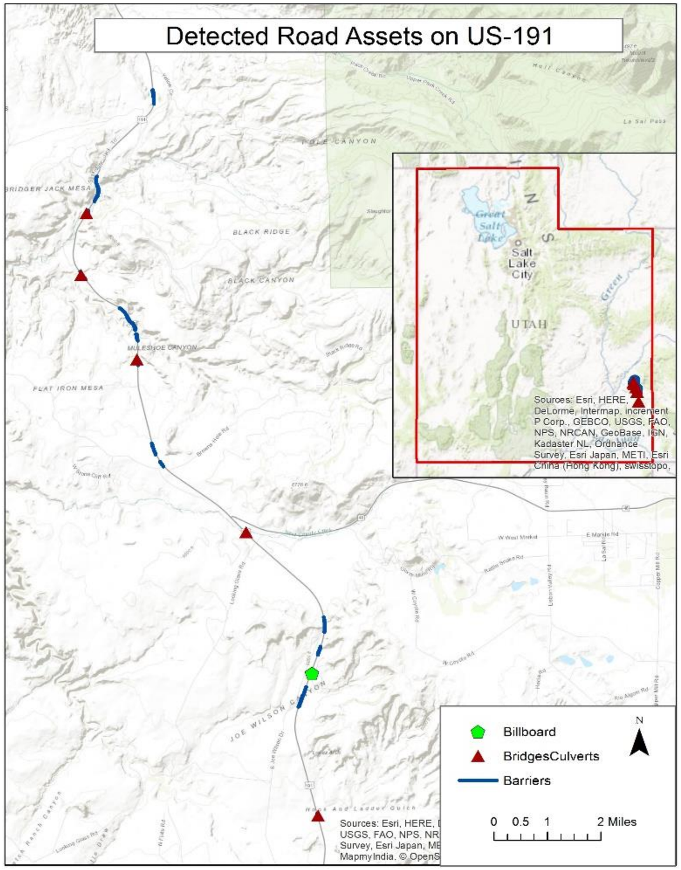


Detected assets along I-15 North

Experiment Results

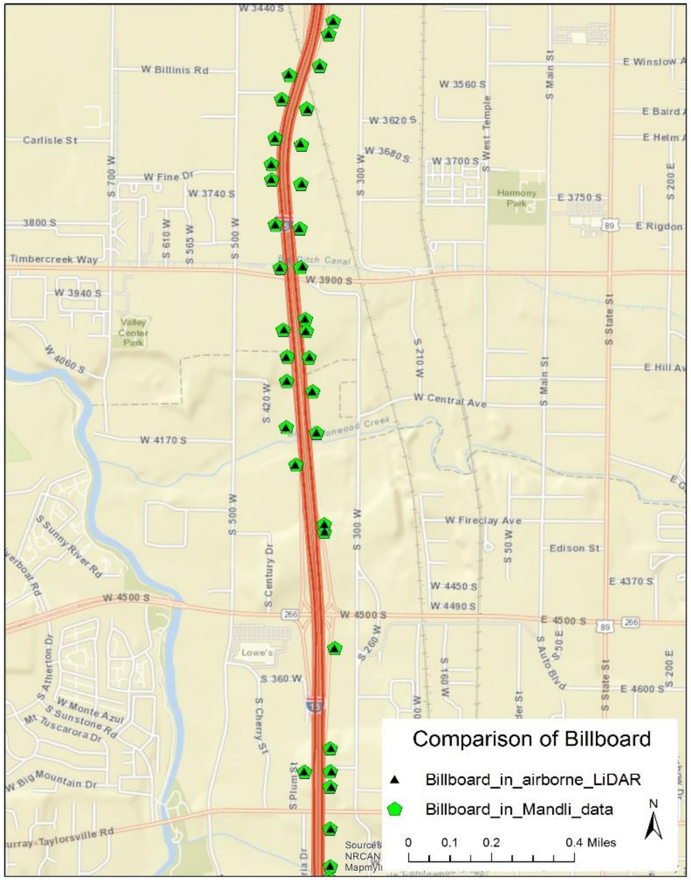


Detected assets along I-15 South



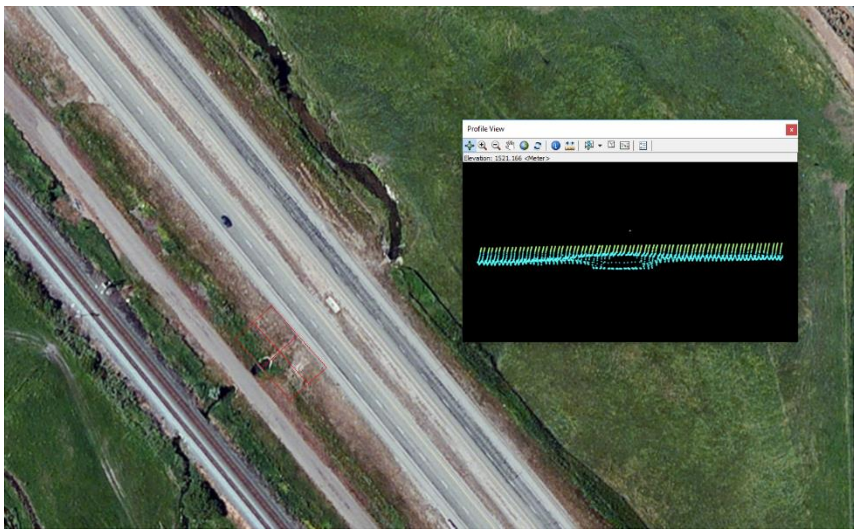
Detected assets along US-191

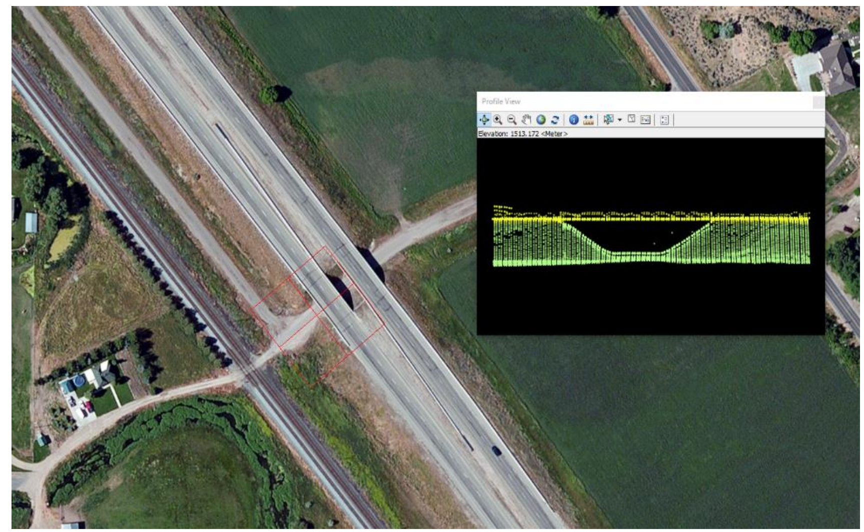
Comparison with Existing Dataset



Billboards in Mandli datasets versus billboards detected in our project

3D View of Culvert and Bridge





3D View of Culvert and Bridge in Airborne LiDAR Data (a) Culvert (b) Bridge

Study Limitations

Assets that cannot be properly identified

Reasons:

- Low point density
- Small surface area

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Conclusions

- Airborne data collection methods are promising in detecting some highway features, such as guardrails, medians, light poles, large road signs, as well as drainage grates.
- Airborne LiDAR data can provide a view of the roadway from a different perspective, so that some features that may have been hidden from the mobile platform can be effectively detected using aerial LiDAR data.
- Each data collection method has its advantages and limitations, the most effective approach to achieve the maximum level of accuracy and completeness is probably to combine data collected from multiple sources.

Further Reading

- Link to the report:
  - https://www.ugpti.org/resources/reports/downloads/mpc18-356.pdf
- Link to the journal article published in Measurement:
  - https://doi.org/10.1016/j.measurement.2017.03.026

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