DPRG

Geomatics Engineering and Autonomous Vehicles

JOINT TRANSPORTATION RESEARCH PROGRAM
Discovery with Delivery
Since 1937
JTRP

INDIANA DEPARTMENT OF TRANSPORTATION
INDOT

Indiana Department of Transportation

Joint Transportation Research Program

Lyles School of Civil Engineering

Purdue University

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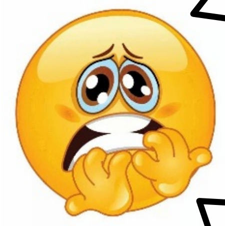
Advanced Driver Assistance Systems: Motivation

Driving



- Collision avoidance

- Traffic congestion avoidance

- Air pollution avoidance

Advanced Driver Assistance Systems: Levels

DPRG

- **Level 0:** Full human control
- **Level 1:** Some functions (steering/acce[illegible]n/deceleration) are controlled by the car.
- **Level 2:** Driver is disengaged from phy[illegible] operating the vehicle by having his/her hands off the steering wheel AND foot [illegible]al at the same time.
  - However, the driver must still always b[illegible] to take control of the vehicle.
- **Level 3:** The driver is still present and [illegible]ervene if necessary, but is not required to monitor the situation in the same wa[illegible]es for the previous levels.
- **Level 4:** Fully autonomous – vehicles a[illegible]gned to perform all safety-critical driving functions and monitor roadw[illegible]ns for an entire trip.
  - limited to the Operational Design Domai[illegible]eaning it does not cover all driving scenarios
- **Level 5:** Fully-autonomous – expects the vehicle's performance to equal that of a human driver, in every d[illegible]

The car becomes safer.

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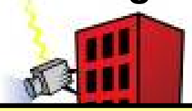
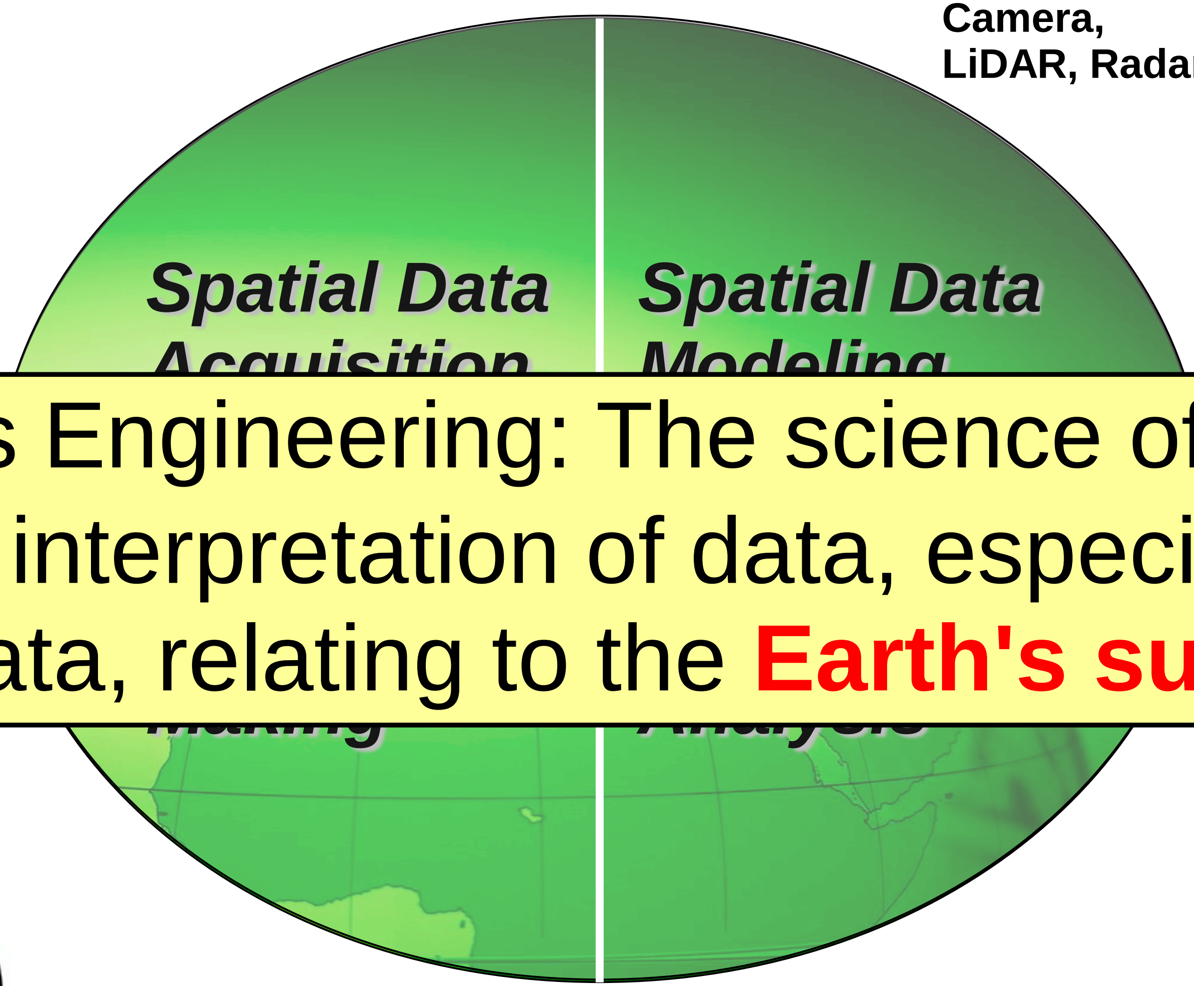
Connected/Autonomous Vehicles

- **Implementation of connected and autonomous vehicle technology will produce a shift in the decision making paradigm as it relates to existing and planned transportation infrastructure.**
- **Automation of road vehicles is accelerating:**
  - Substantial private investment,
  - Successful demonstrations, and
  - Significant public discussion
- **Self-driving cars would not go far without Geomatics Engineering technologies.**

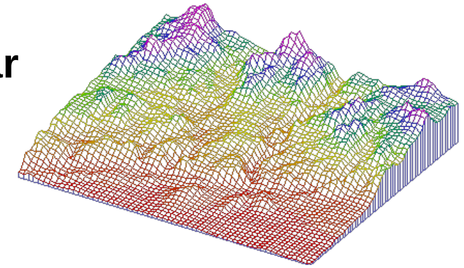
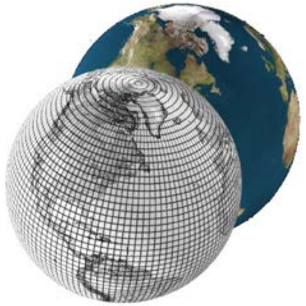
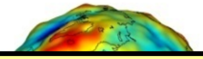
Geomatics Engineering


GPS, Remote Sensing

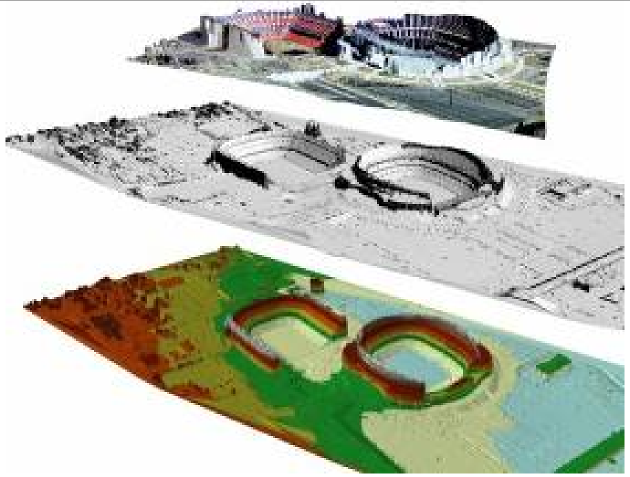




Camera, LiDAR, Radar

Geomatics Engineering: The science of the collection, analysis, and interpretation of data, especially instrumental data, relating to the **Earth's surface**.

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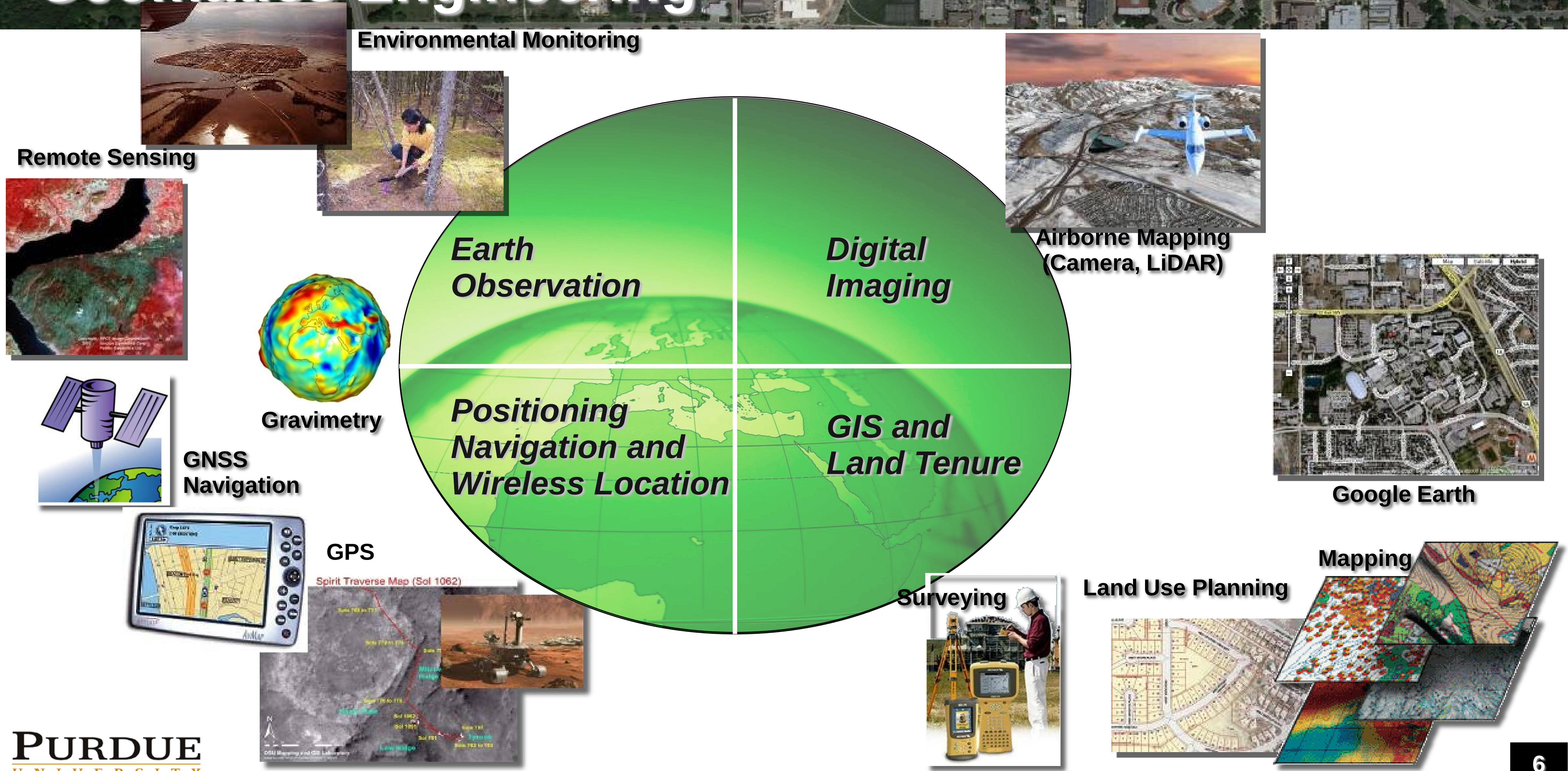
Geomatics Engineering



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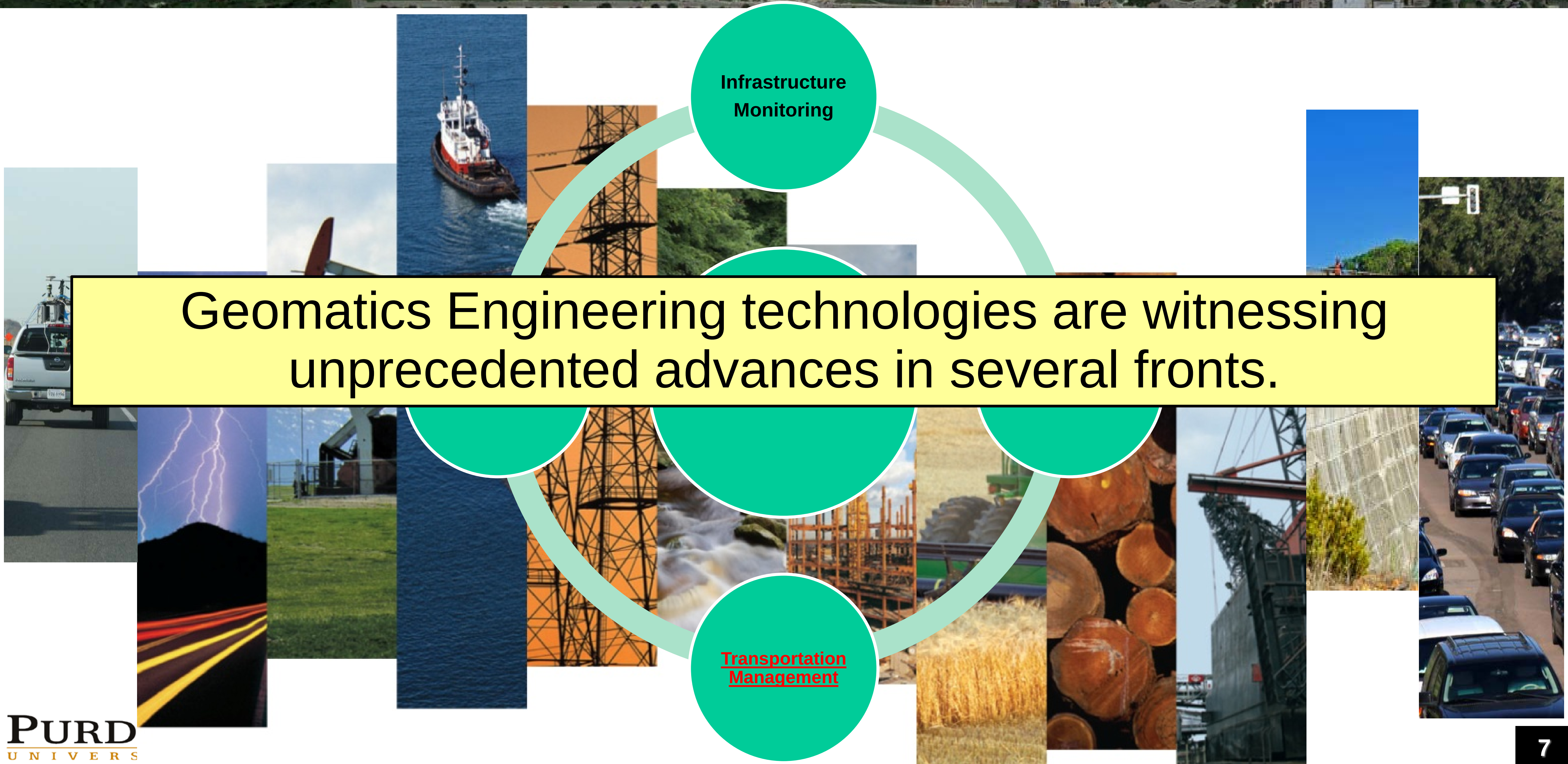
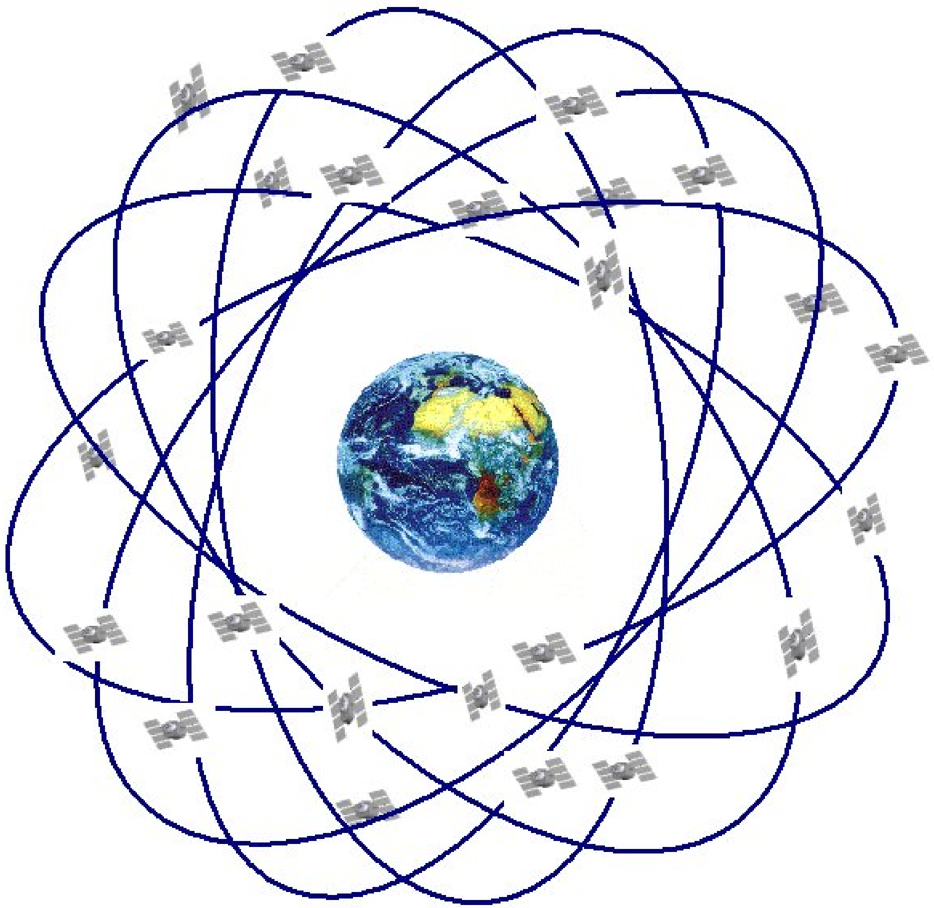
Geomatics Engineering: Emerging Applications

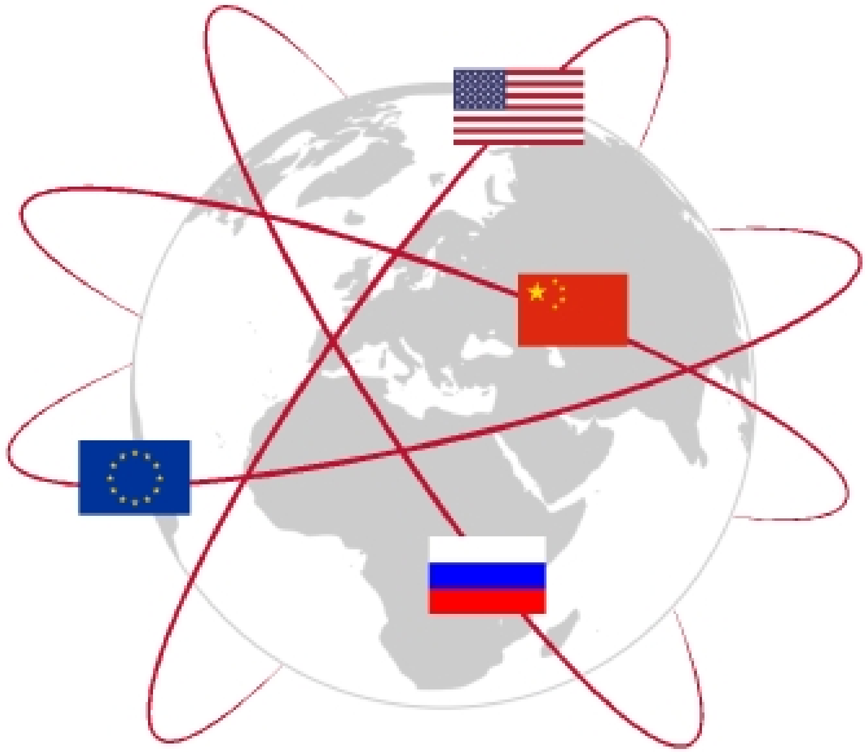


Geomatics Engineering technologies are witnessing unprecedented advances in several fronts.

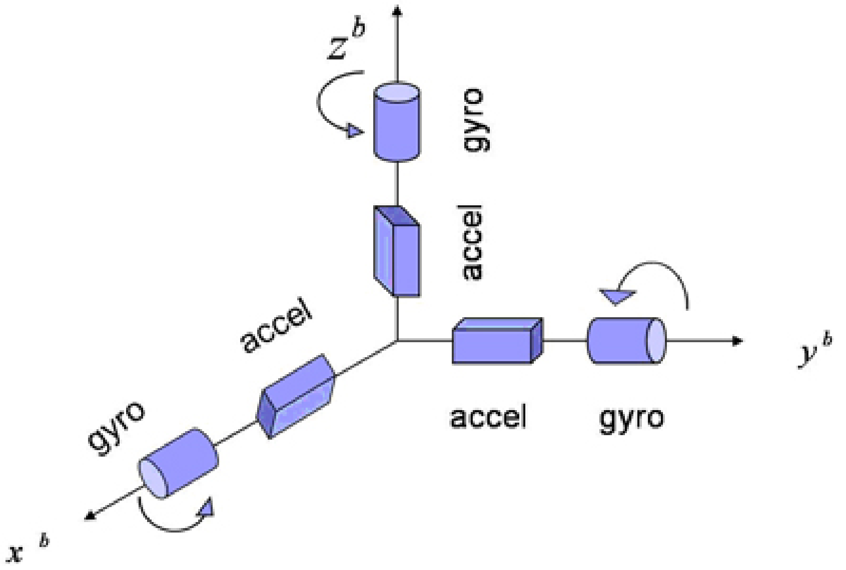
GNSS Positioning



GPS (USA)
Galileo (EU)
GLONASS (Russia)
COMPASS (China)



INS for Position & Attitude Estimation

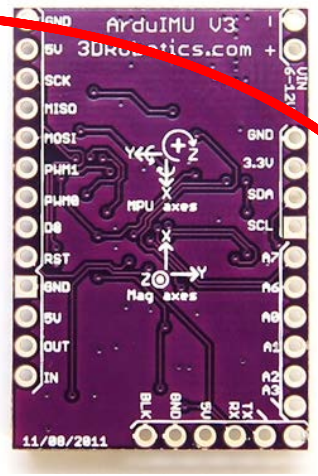


Inertial Measurement Unit
3 accelerometers, 3 gyroscopes

Navigation Grade
>$50K
>5lb

Tactical Grade
$10K-20K
~1lb

Commercial
$0.5K-3k
<5oz



MEMS
<$500

Imaging Systems



Traditional Mapping Cameras

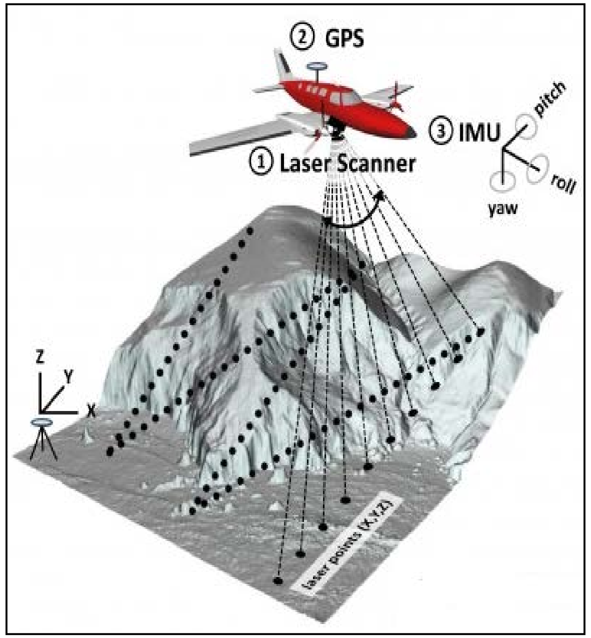
Large-Format Imaging Systems

Low-Cost Digital Cameras

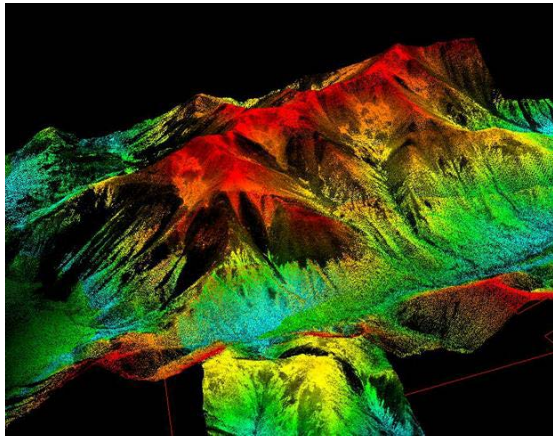
Medium and Small-Format Digital Imaging Systems

Laser Scanning

Airborne Laser Scanning

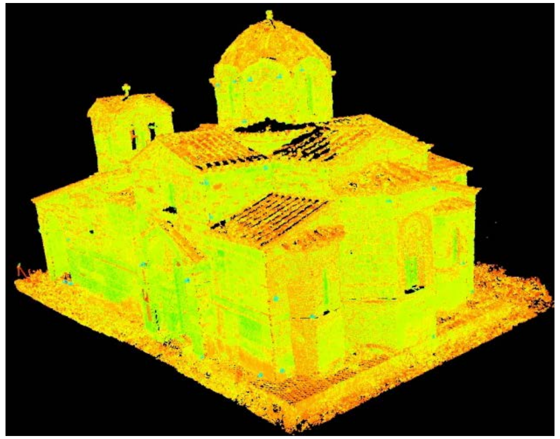


Source: seaice.acecrc.au



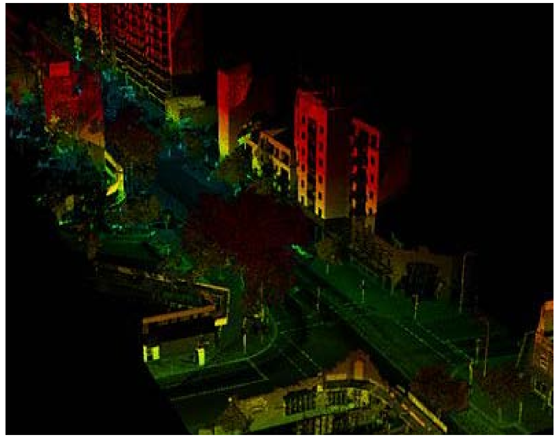
Static Terrestrial Laser Scanning

Source:www.cage.curtain.edy.au



Kinematic Terrestrial Laser Scanning

Source:www.optech.ca/lynx.htm



Laser Scanning

Optech Pegasus System

In addition to sensor technologies, Mobile Mapping Systems (MMS) have changed the way we derive geospatial products.

RIGEL VUX-1
Survey-grade sensor

Velodyne HDL-32

Velodyne VLP-16

Mobile Mapping Systems (MMS)

Airborne

<u>Mobile Mapping Systems (MMS)</u> are moving platforms upon which multiple sensors/measurement systems have been integrated to provide three-dimensional near-continuous positioning of both the platform's path in space and simultaneously collected geo-spatial data.

UAV

Mobile Mapping Systems: Wheel-Based

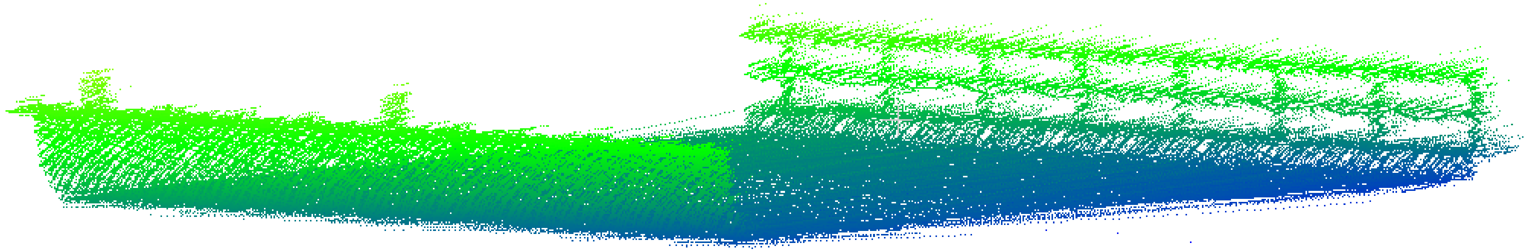
The Ohio State University

Mobile Mapping Systems: Wheel-Based

University of Calgary

DPRG

Mobile Mapping Systems: Wheel-Based



Purdue University

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Wheel-Based Mobile Mapping Platforms: Sensors

- **HDL32E**
  - 32 Channels
  - 700,000 Points per Second
  - +10° to -30° Vertical FOV

- **VLP16**
  - 16 Channels
  - 300,000 Points per Second
  - -15˚ to +15˚ vertical FOV

- **SPAN-CPT**
  - 20 Hz GNSS position collection rate
  - 100 Hz IMU measurement rate
  - Accuracy in position < 2cm
  - Accuracy in attitude

    ~ 0.008˚ in the roll/pitch

    ~ 0.035˚ in heading directions

Wheel-Based Mobile Mapping Platforms: Sensors

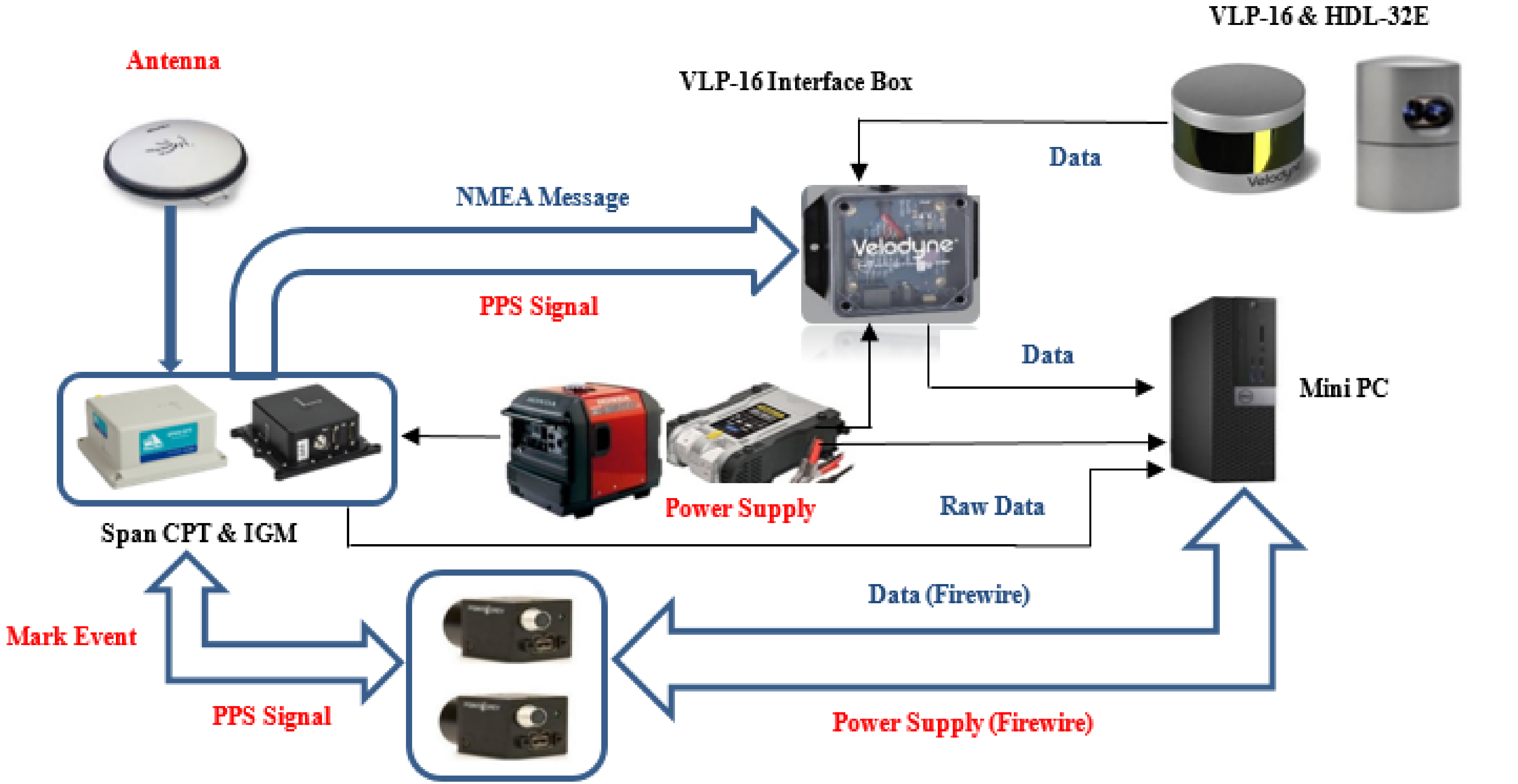
- *Imaging Unit*

Flea2G 5.0 MP Color

Resolution	2448 x 2048
Frame Rate	7.5 FPS
Megapixels	Up to 5.0 MP
Chroma	Color
Sensor Type	CCD
Readout Method	Global shutter
Sensor Format	2/3"
Pixel Size	3.45 µm
Lens Mount	C-mount
ADC	12-bit

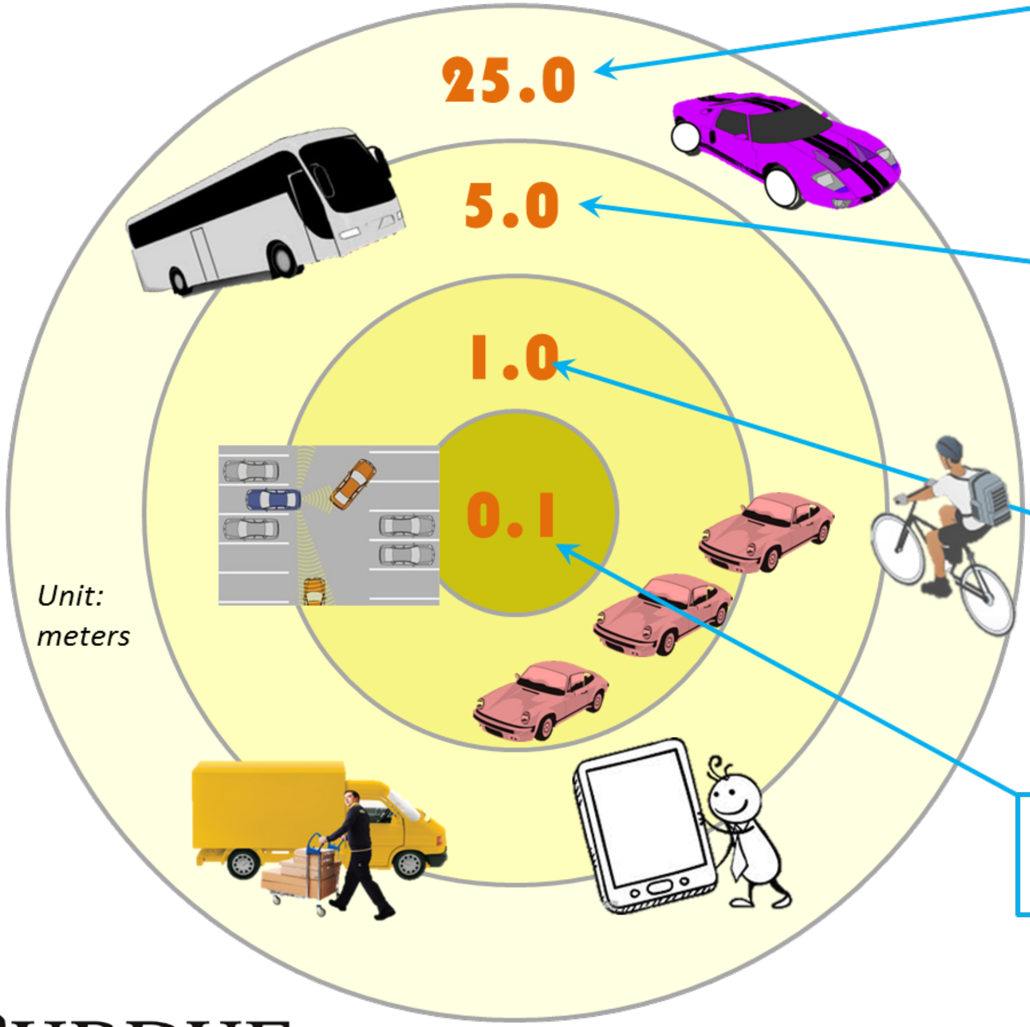
Wheel-Based Mobile Mapping Platforms

Sensor Integration



Connected/Autonomous Vehicles: Challenges

Level of Required Accuracy in Transportation Management



- Trip travel information
- fleet management
- stolen vehicle recovery
- dynamic route guidance

- in-car navigation
- urban traffic control
- emergency call
- road user charging

- collision avoidance
- restraint deployment
- intelligent speed adaptation

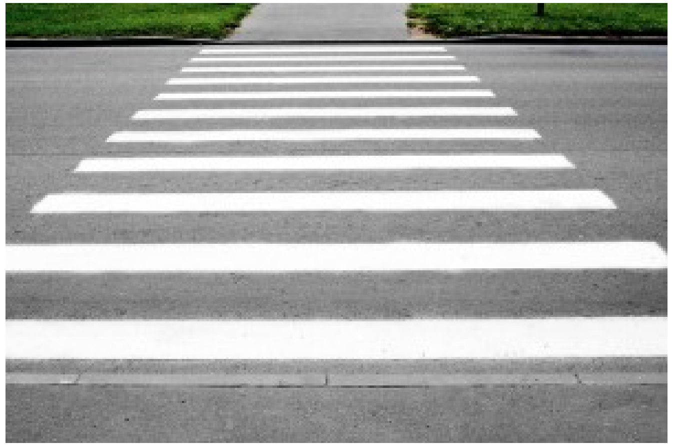
- Automated highway
- lane control

- Real world problems:
  - *Weather*
  - *Construction*
  - *Obsolete information*
- Sensors:
  - *Cost*
  - *Calibration*
  - *Wear and tear*
- Interactions:
  - *Communication*
  - *V2V Coordination*
- Reliability:
  - *Driver education*
  - *Driver testing*
  - *Uniformity among states*
  - *Accuracy requirements*

Connected/Autonomous Vehicles: Current Status

- Data processing for extraction and transmission of useful information, such as:

  - o Accurate 3D point cloud reconstruction
  - o Feature identification
    - ✓ Lane markers,
    - ✓ Stop/yield signs,
    - ✓ Pole-like features
    - ✓ Zebra-crossings



Ubiquitous Mobile Mapping Systems

Ubiquitous Mobile Mapping Systems

- The regulation sets a 2018 deadline for rearview monitoring technology to be standard on passenger vehicles sold or leased in the United States.
- In most vehicles, the technology will consist of a back-up camera.
- In conjunction with onboard GNSS units, we have the basic elements of a low-cost MMS.

Ubiquitous Mobile Mapping Systems

- Velodyne Solid-State Hybrid Ultra Puck Auto
- Cost $500; Range 200m
- Intended for ADAS level 4 & 5
- Ford will be using the Velodyne Solid-State Hybrid for its ADAS.

MMS & Work Zone Data Collection (I65 – 178/158)

August 12nd, 2016

MMS & Work Zone Data Collection (I70 – Vigo)

November 5th, 2016

MMS & Work Zone Data Collection (I65 – 193/203)

December 1st, 2016

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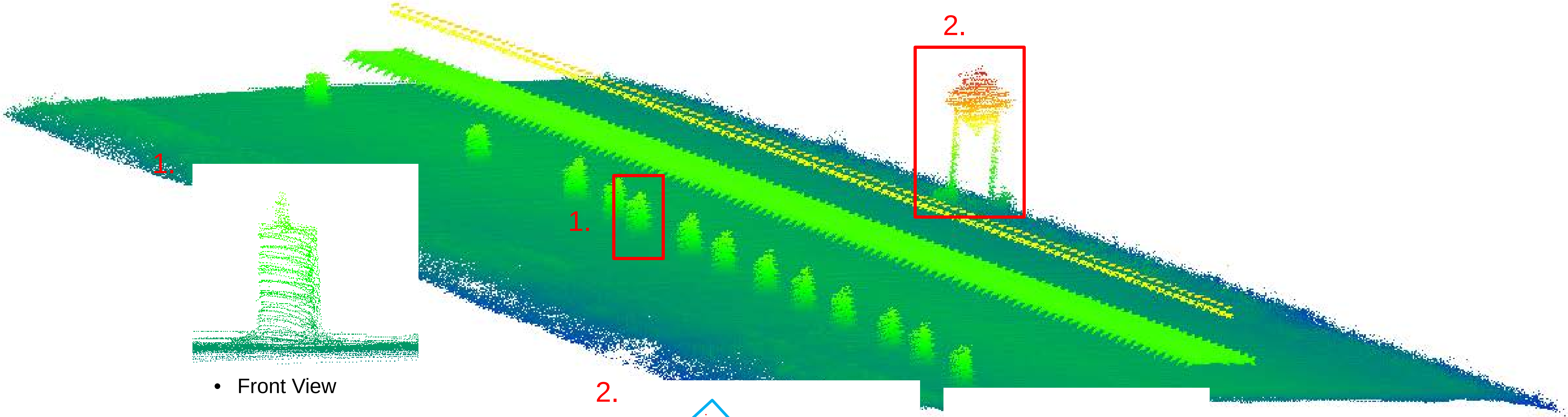
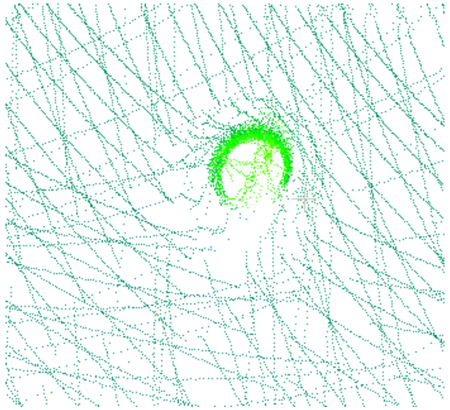
Identifiable Features in Mobile LiDAR Data

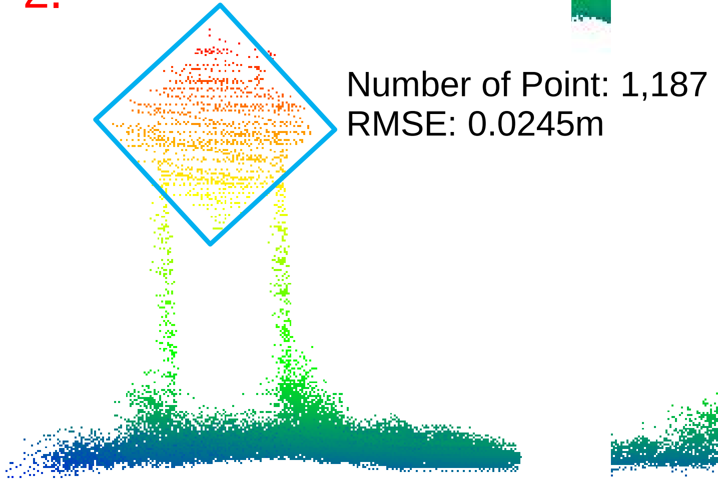


- Front View

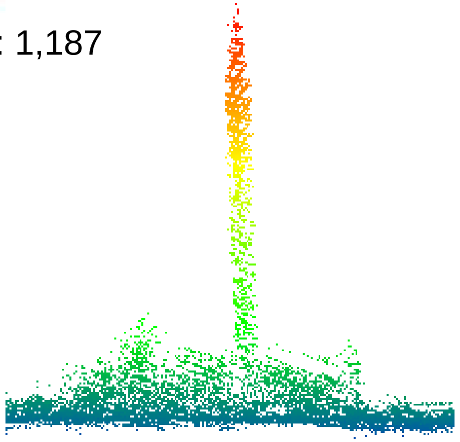


- Top View

2.



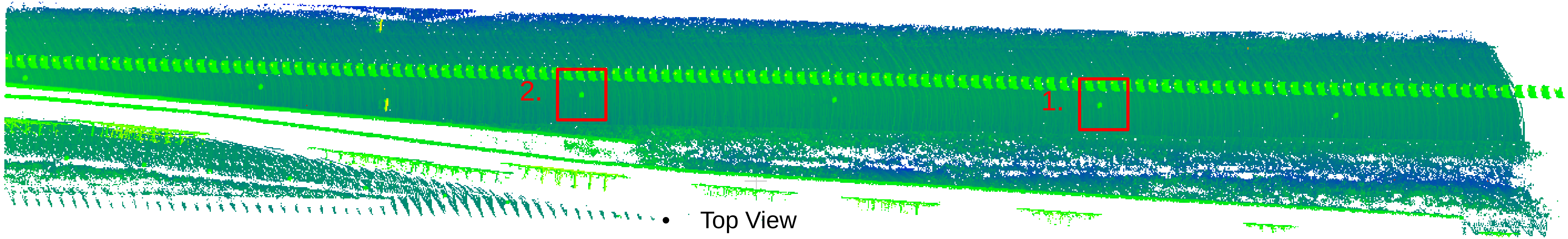
- Front View



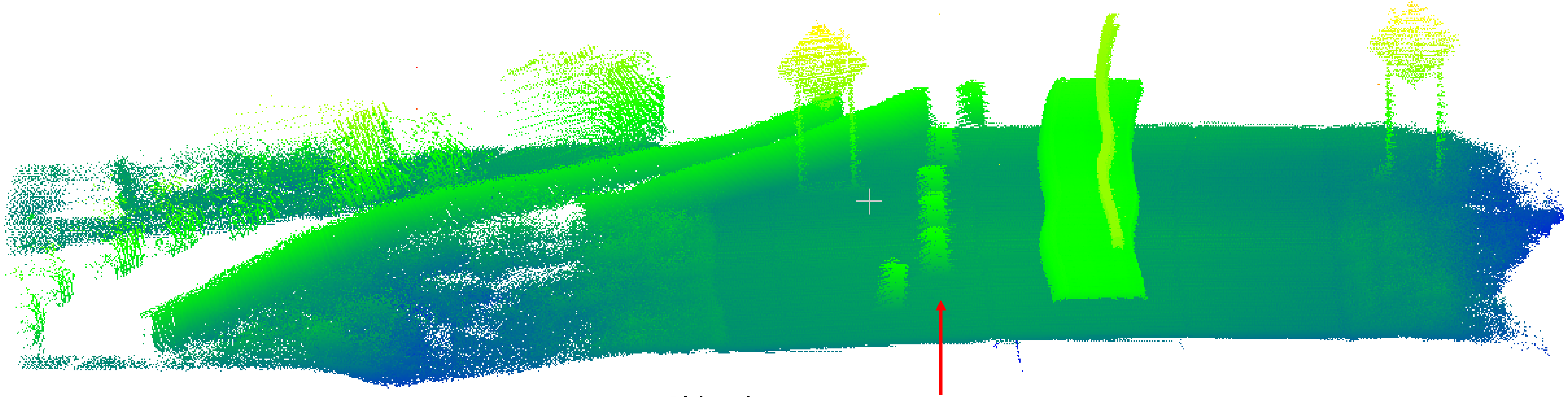
- Side View

- Colored by height

Identifiable Features in Mobile LiDAR Data



- Top View



- Side View

Alignment of barrels

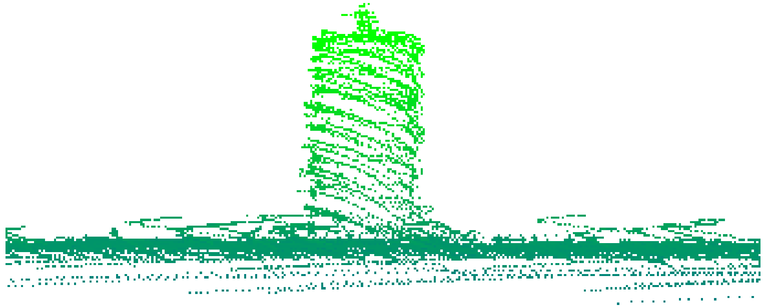
- Colored by height

Identifiable Features in Mobile LiDAR Data

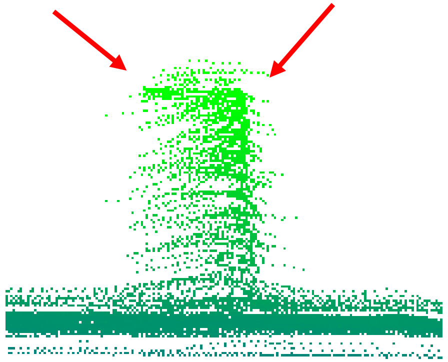
1.

Less points on this side

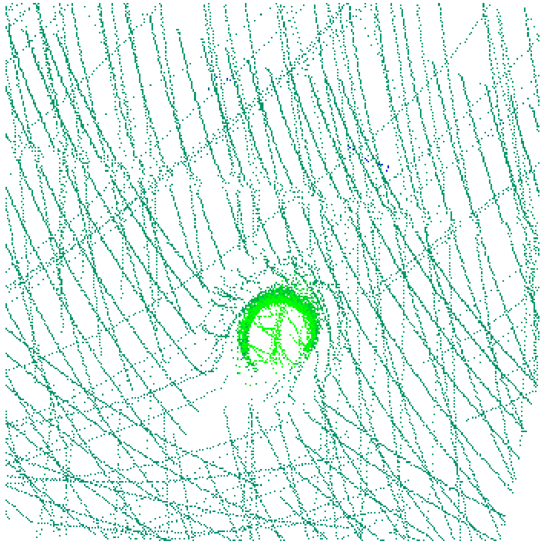
More points on this side



- Front View

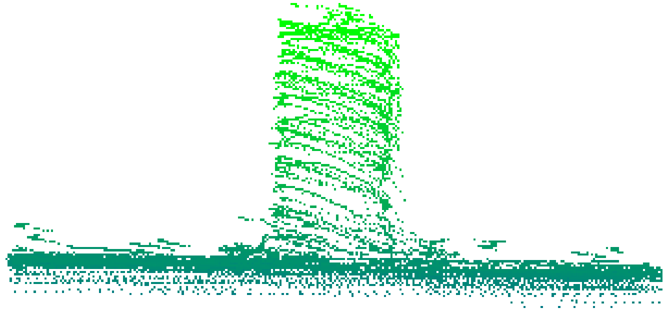


- Side View

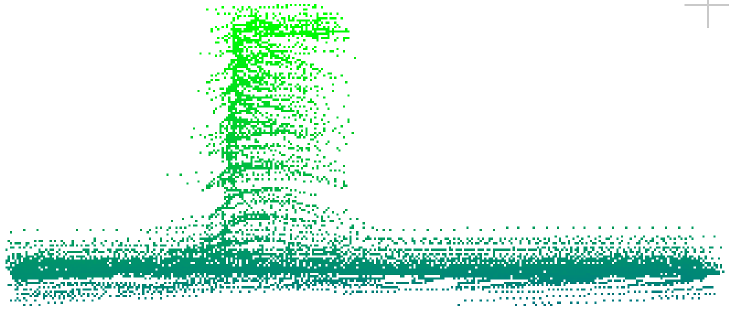


- Top View

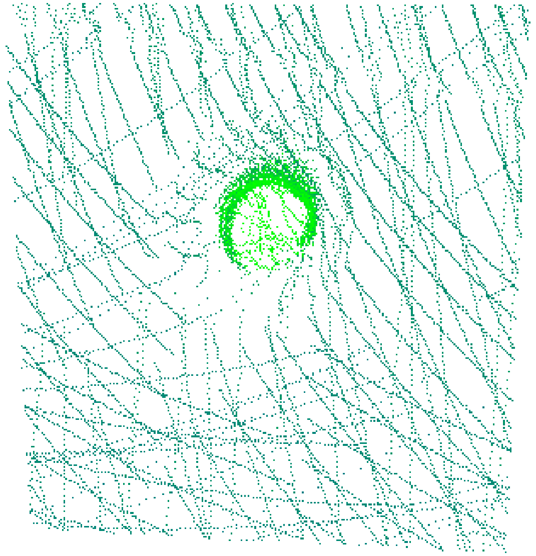
2.



- Front View

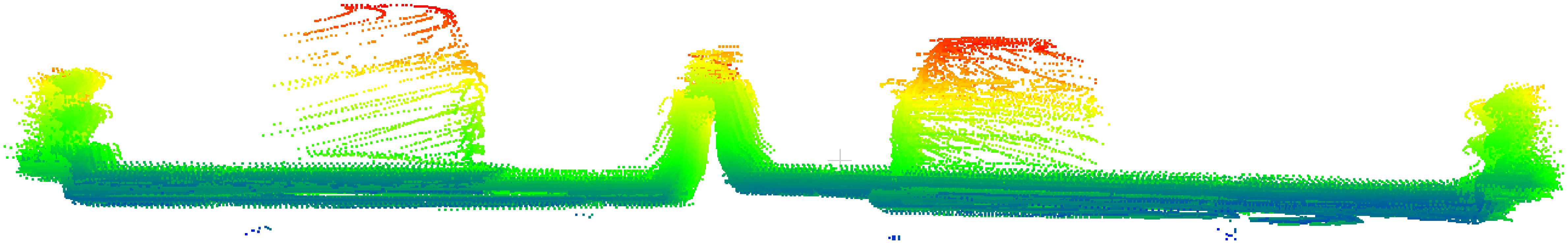


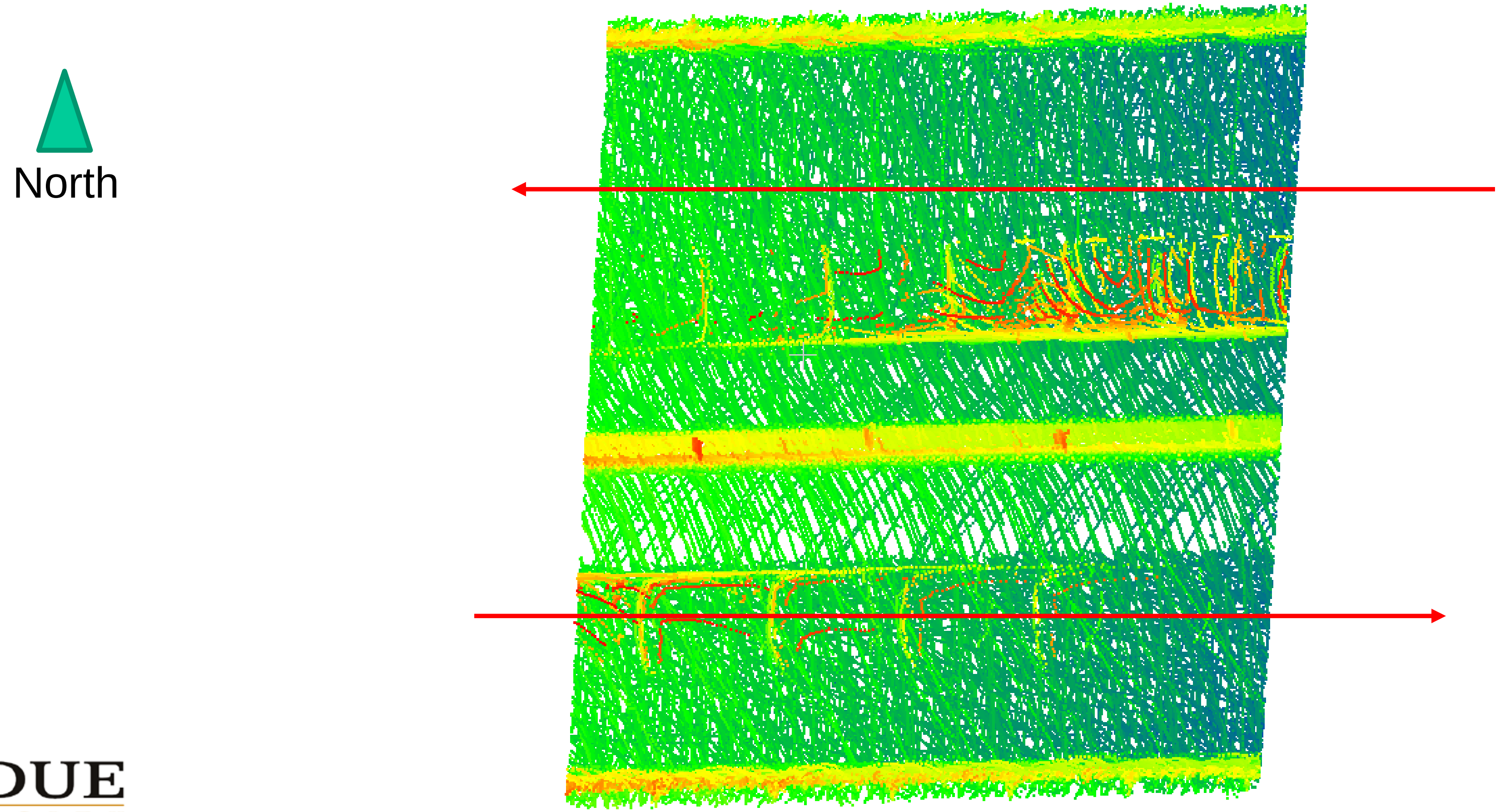
- Side View



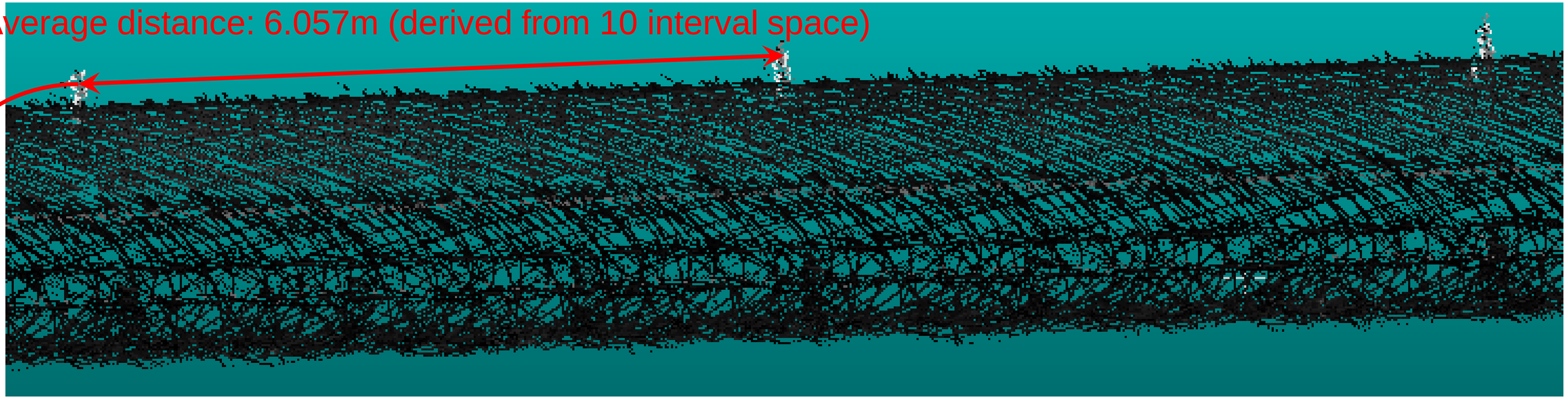
- Top View
- Colored by height

Identifiable Features in Mobile LiDAR Data



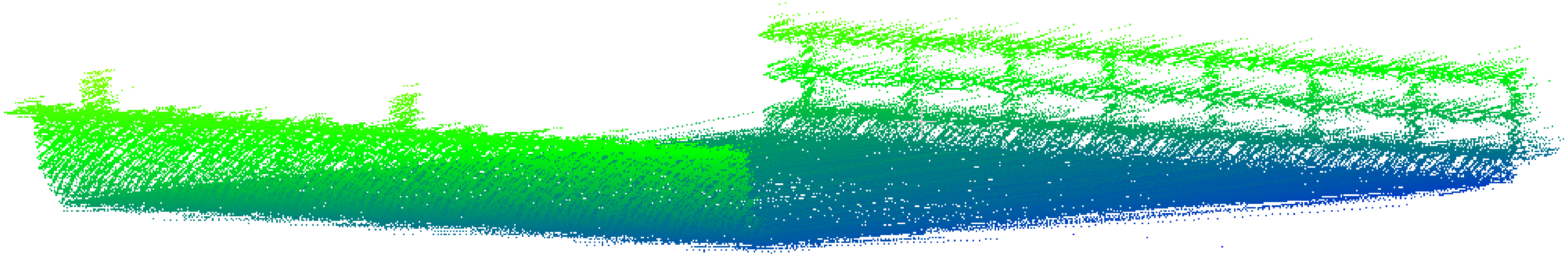


Identifiable Features in Mobile LiDAR Data



We can see the reflective boards

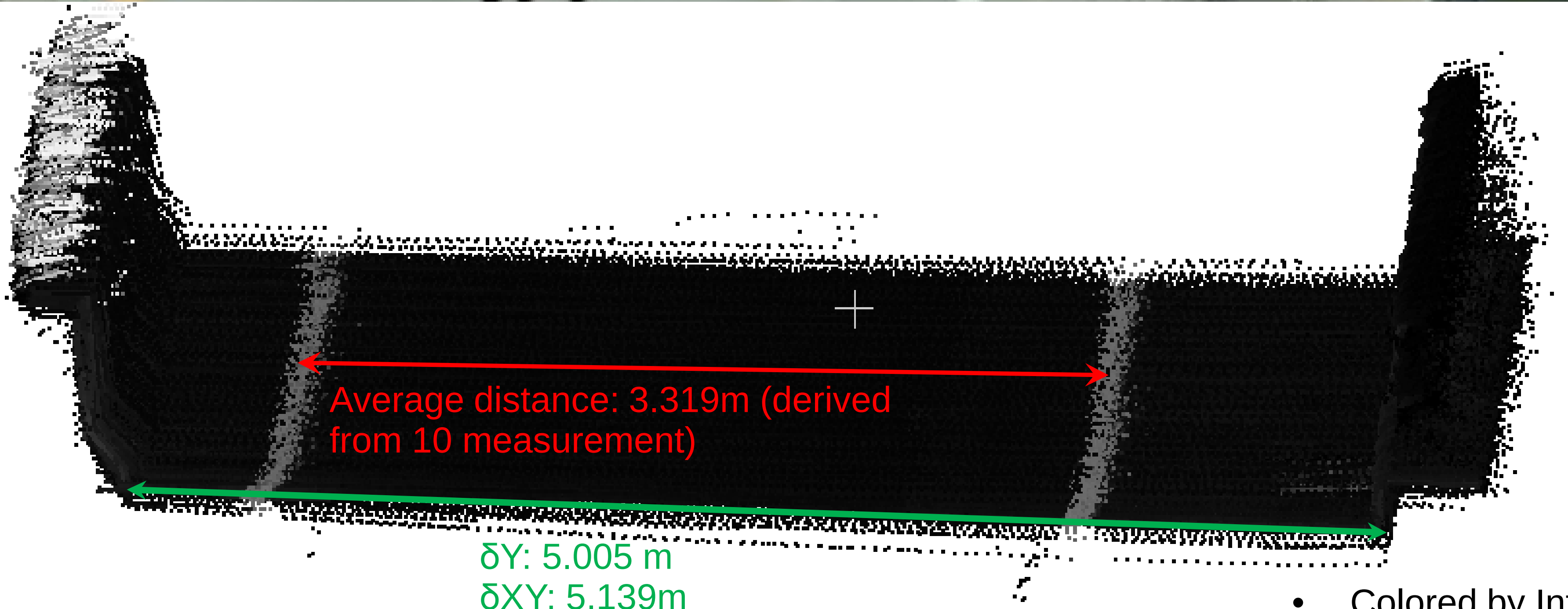
- Colored by Intensity



- Side View

- Colored by height

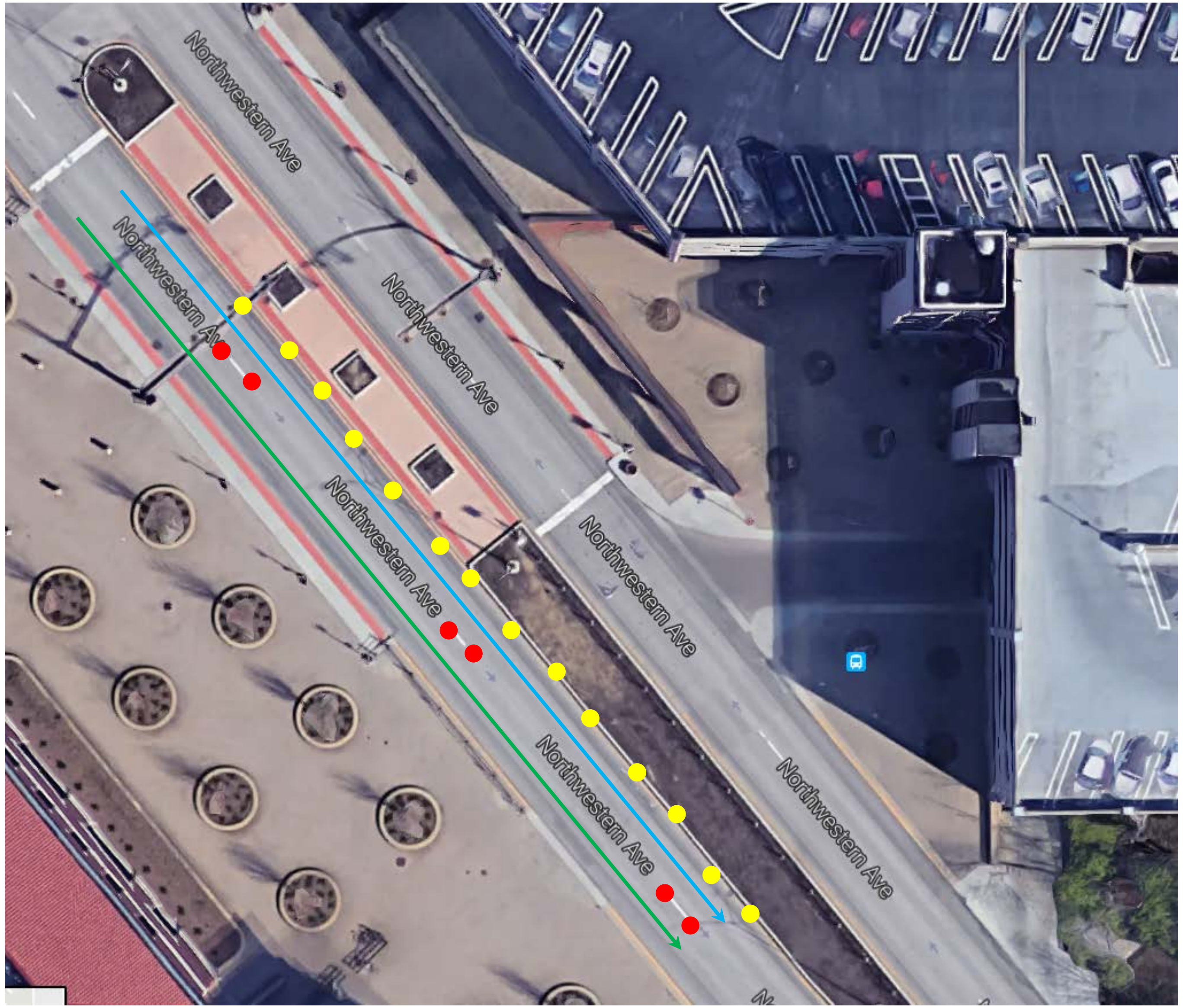
Lane-Width Evaluation



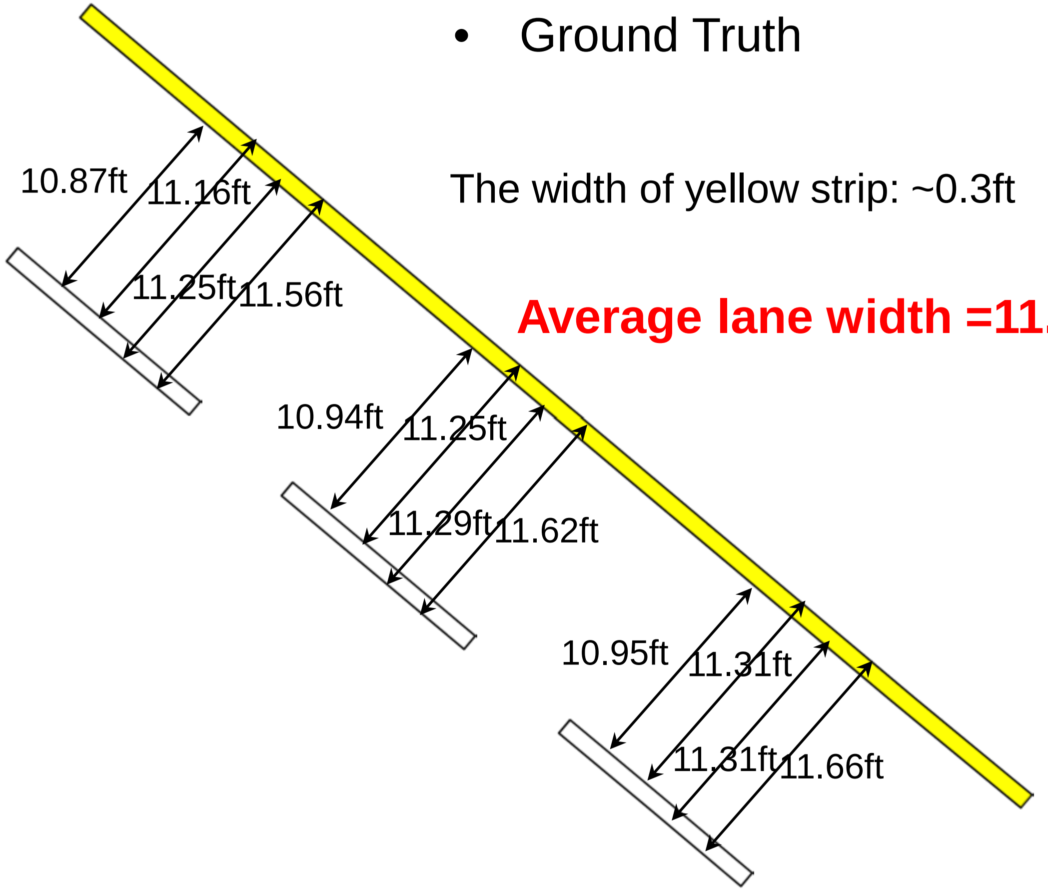
- Side View

- Colored by Intensity

Lane-Width Evaluation: Quality Control



- Ground Truth

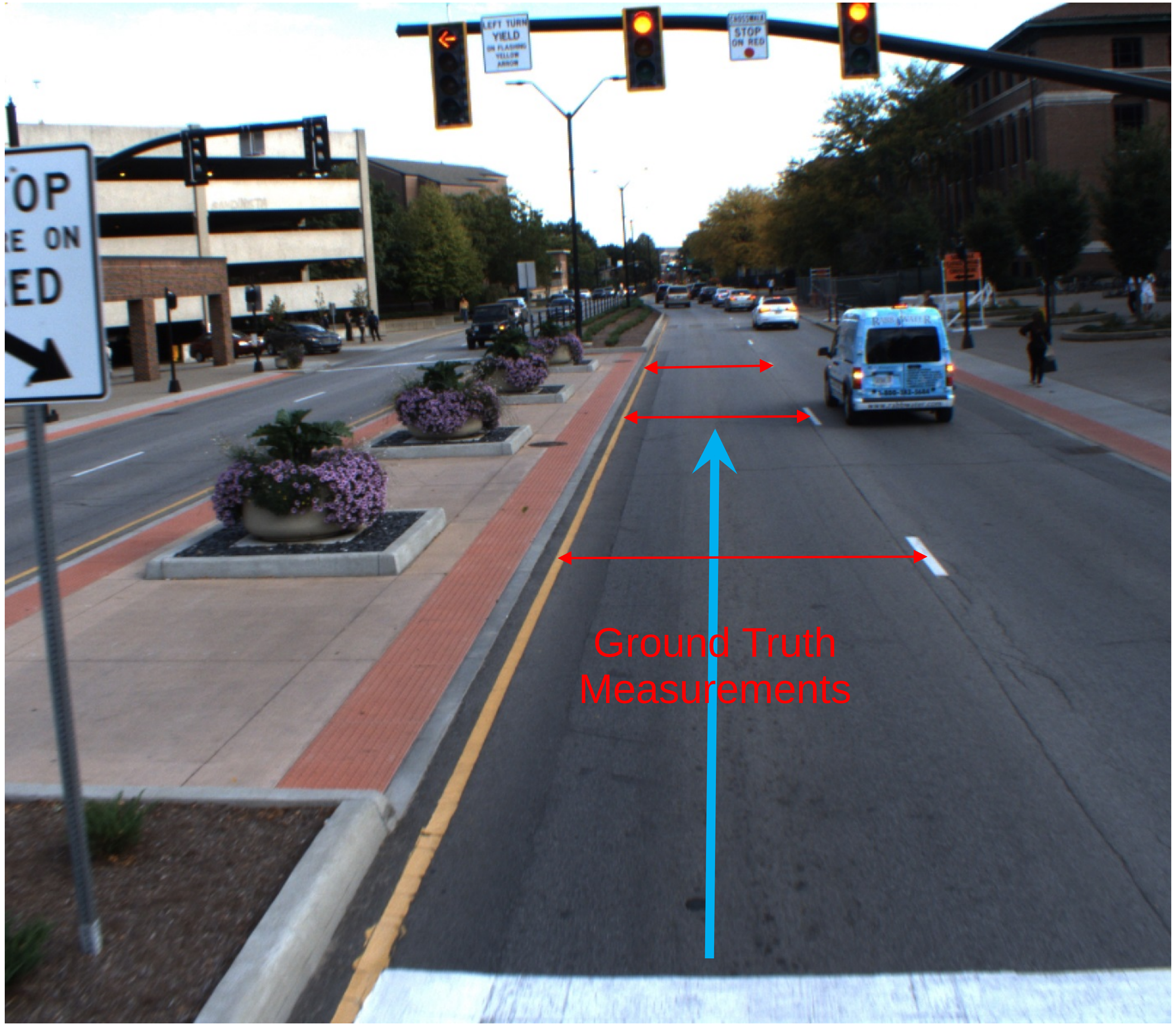


The width of yellow strip: ~0.3ft

Average lane width =11.26ft

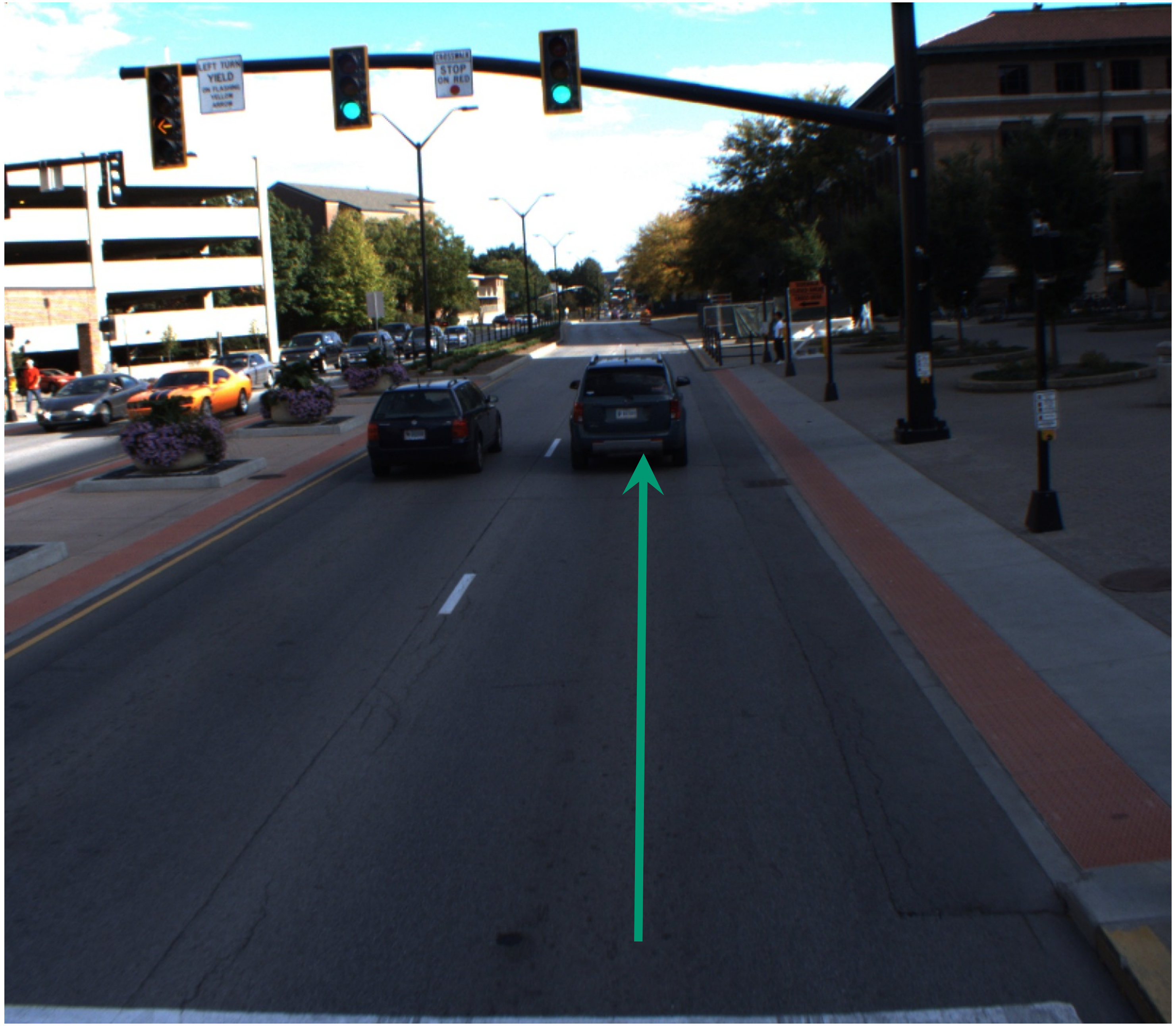
- **LiDAR dataset from two driving runs are tested (green & cyan).**
- **We have a central white line and yellow edge line.**
- **The illustrated red and yellow dots are the digitized points.**

Lane-Width Evaluation: Quality Control



- Captured by Flea Camera
- **Left Lane Run**

Lane-Width Evaluation: Quality Control



- Captured by Flea Camera
- **Right Lane Run**

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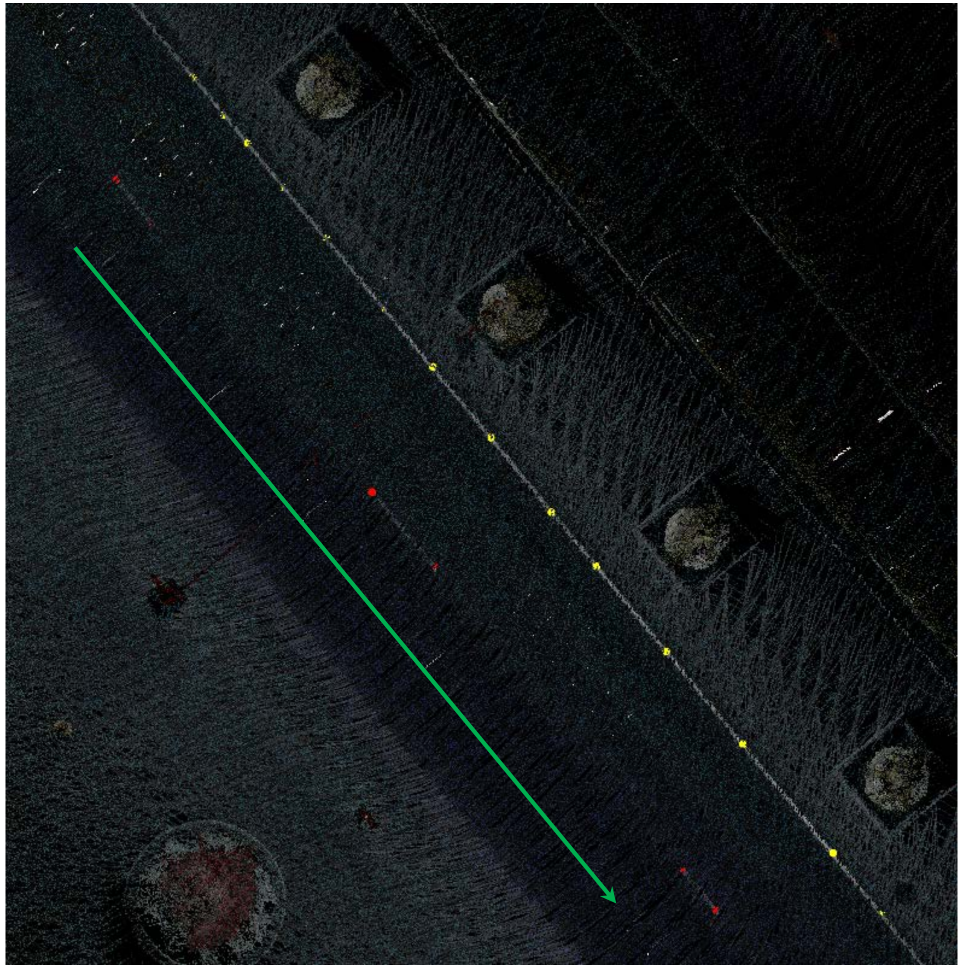
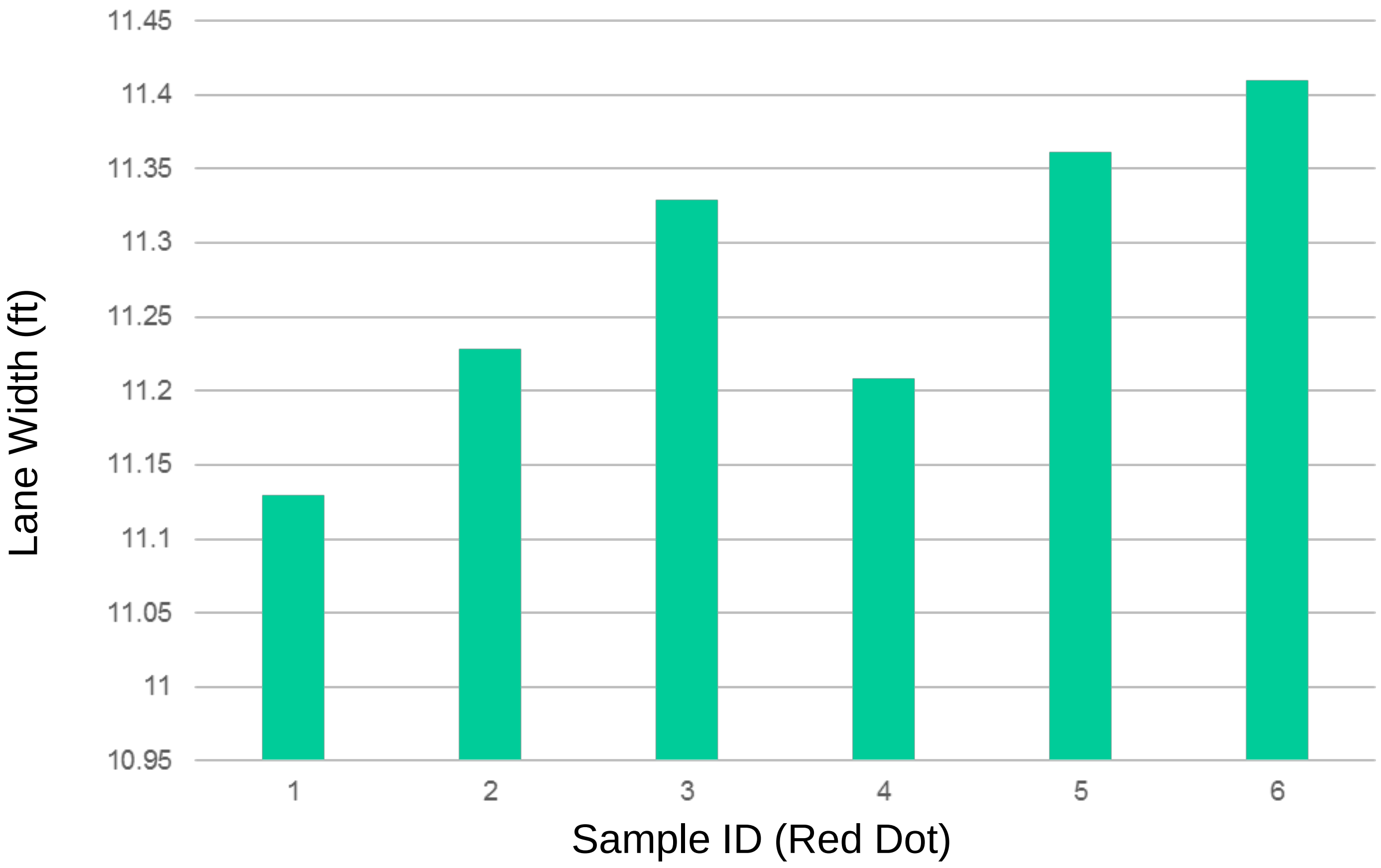
Lane-Width Evaluation: Quality Control (Right Run)



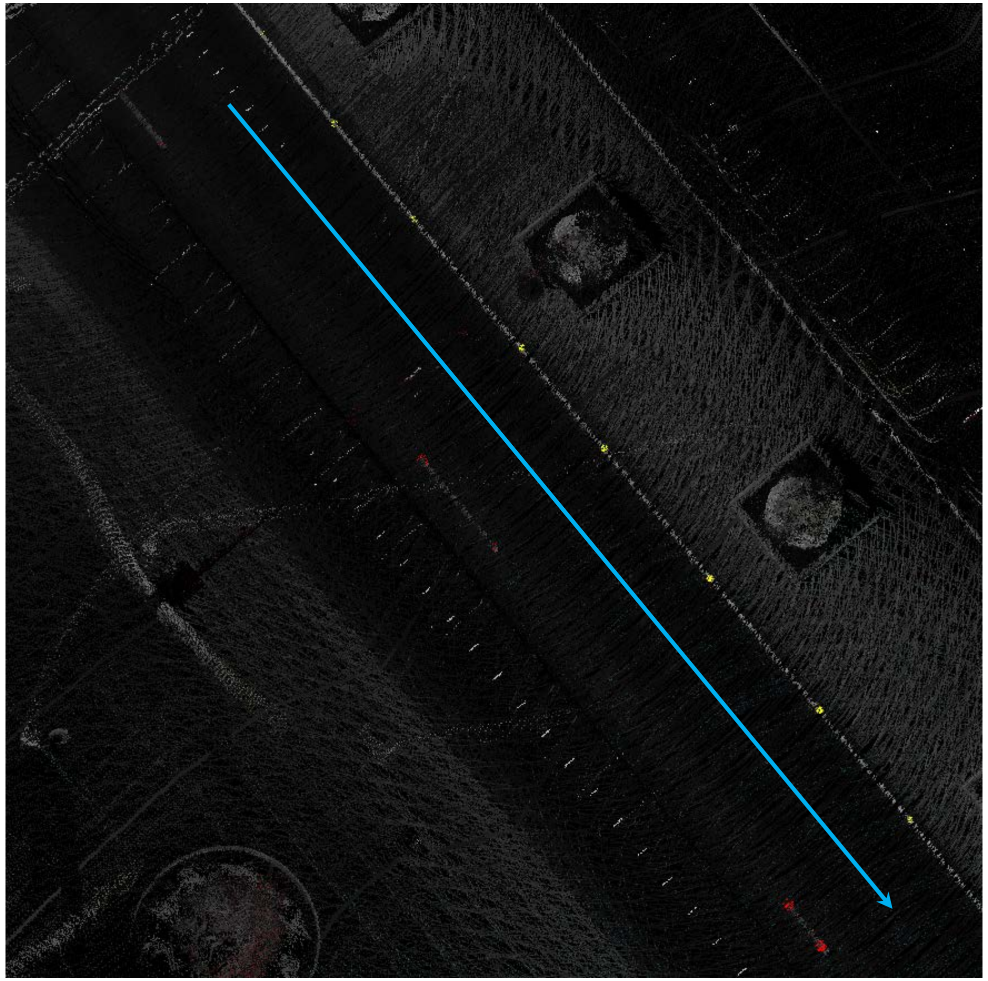


- Collected by HDL32E
- Red (6 pts) & yellow (14 pts)

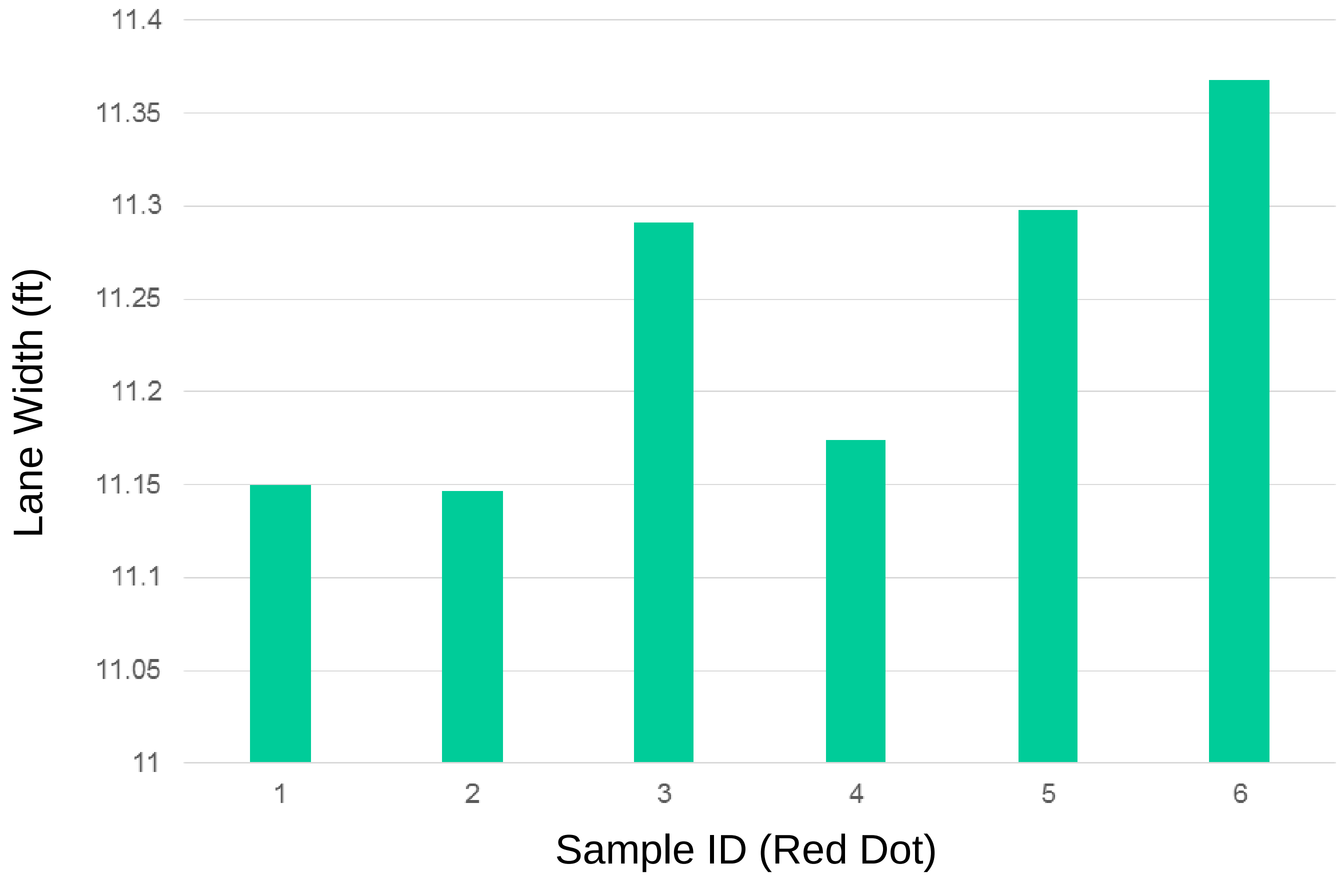
Average lane width = 11.28ft

Ground Truth: Average lane width =11.26ft

Lane-Width Evaluation: Quality Control (Left Run)



- Collected by HDL32E
- Red (6 pts) & yellow (10 pts)



Average lane width = 11.24ft

Ground Truth: Average lane width =11.26ft

Thank You