MOBILE LIDAR TECHNOLOGIES:

A user's perspective and applications

MOBILE LIDAR APPLICATIONS TO INFRASTRUCTURE PROJECTS

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Bayamón, PR & Florida, USA

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COLEGIO DE INGENIEROS Y AGRIMESORES DE PUERTO RICO

Randy Ortega, PSM
Project Manager

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

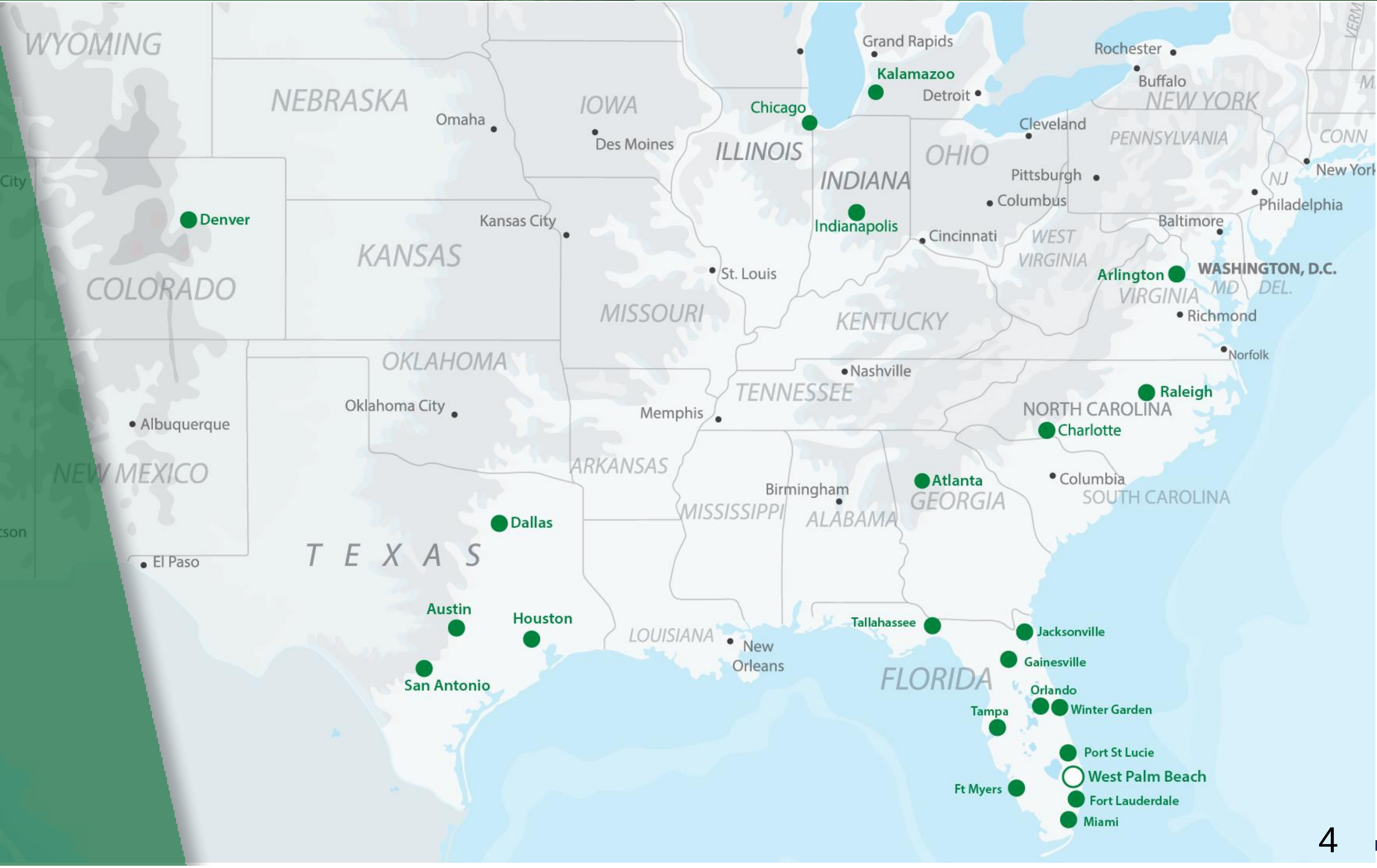
EXPERIENCE

- 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

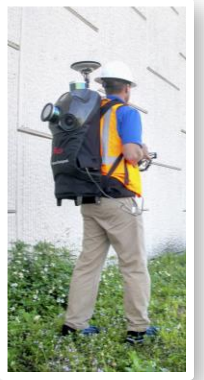
NATIONAL FIRM – LOCAL PRESENCE

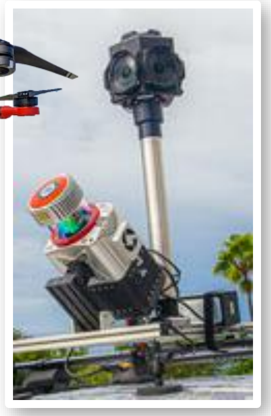
CORPORATE
ARLINGTON
ATLANTA
AUSTIN
CHARLOTTE
CHICAGO
DALLAS
DENVER
FT. LAUDERDALE
FT. MYERS
GAINESVILLE

HOUSTON
INDIANAPOLIS
JACKSONVILLE
KALAMAZOO
MIAMI
MILWAUKEE
ORLANDO
PORT ST. LUCIE
RALEIGH
SAN ANTONIO
TALLAHASSEE
TAMPA
WINTER GARDEN



WGI'S GEOSPATIAL DIVISION - THE PACE OF INNOVATION





TERRESTRIAL STATIC LiDAR
2005

TERRESTRIAL MOBILE LiDAR w/TopoDOT
2015
4,600 Corridor Miles

TERRESTRIAL MOBILE LiDAR
(BACKPACK)
2017

AUTONOMOUS SURFACE VESSEL
2018

AERIAL UAV LiDAR
2018

MULTI-PLATFORM LiDAR
2019

AERIAL LiDAR
2022

WGI GEOSPATIAL

AGENDA

- TYPES OF MOBILE LIDAR, SENSORS, AND USES
- INDUSTRY STANDARDS – TRANSPORTATION PROJECTS
- CONTROL POINTS & TARGETS LAYOUTS
- DATA PROCESSING & EXTRACTION WITH TOPODOT
- APPLICATIONS

DEFINITION

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 MOBILE MAPPING SYSTEM

Camera System
Sky / road camera

IMU
Leica P20 (removable)
Z+F 9012 Profiler

Laser Scanner
Leica P20 (removable)
Z+F 9012 Profiler

Power Supply
One cable connection
10 hours operation time

Roof Mounting
Standard roof rack
System fits in one case

Global GNSS/GPS
Triple band / all constellations
Novatel Propak 6

Light Sensor
Automatic light sensor / exposure control

Camera System
8 CCD Cameras
4 Mega Pixels, 360° Cov.

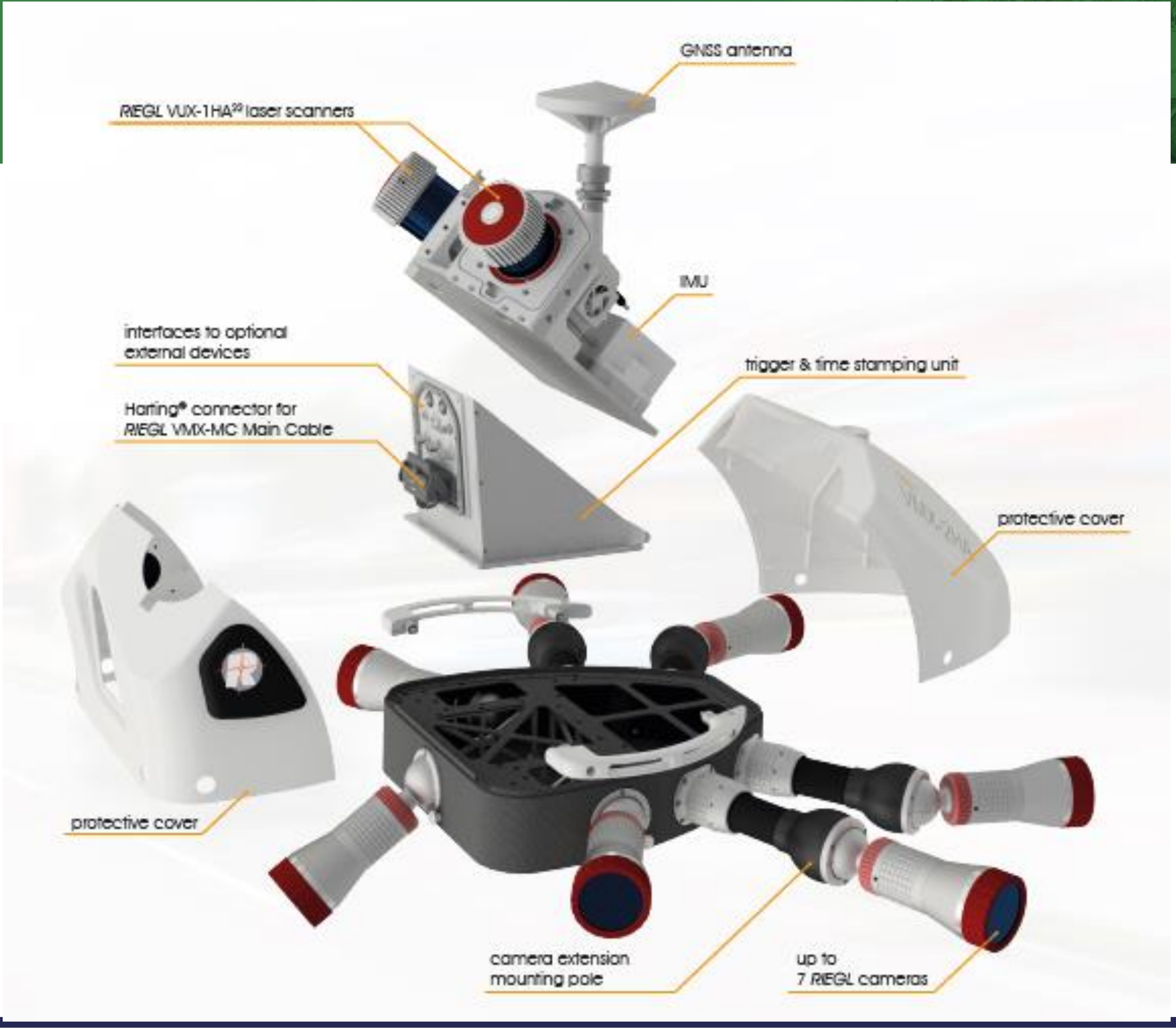
Handles
Access around unit for easier mounting

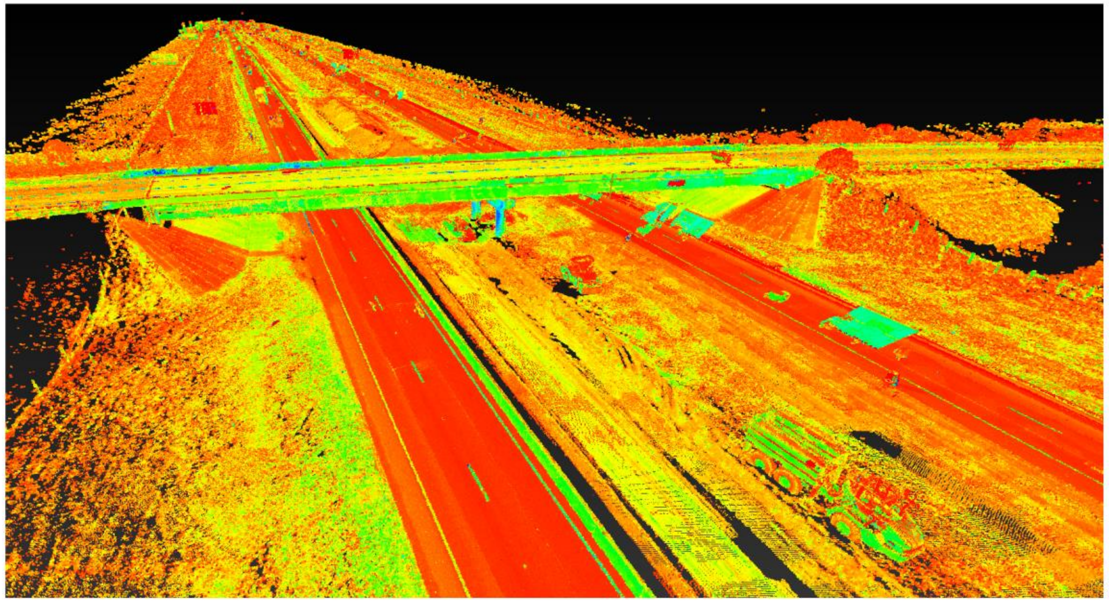
PEGASUS – MIXED APPLICATION

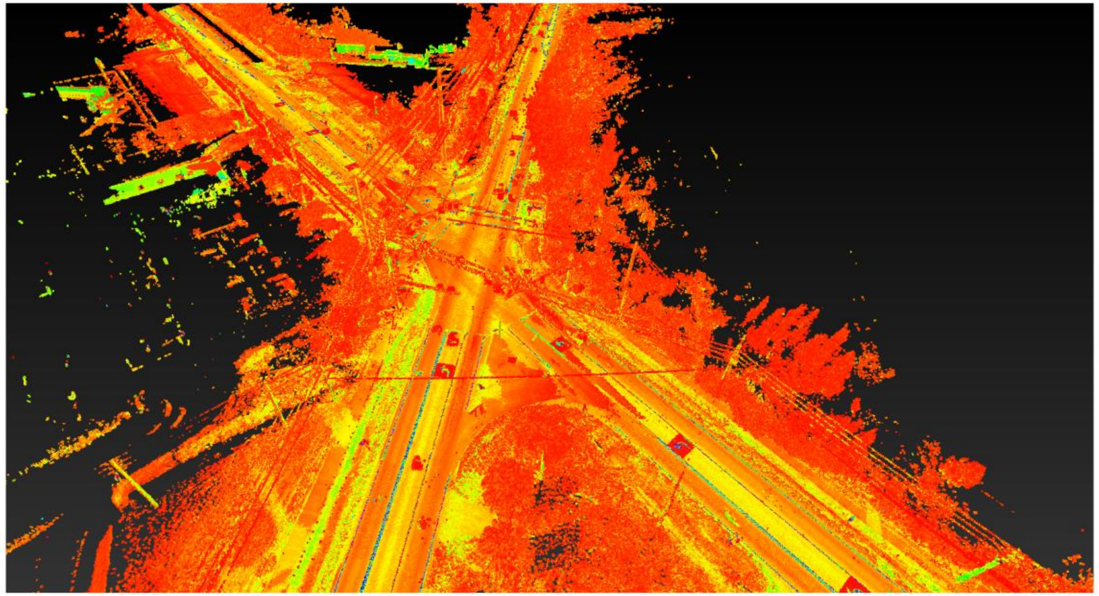
RIEGL VMX-2HA

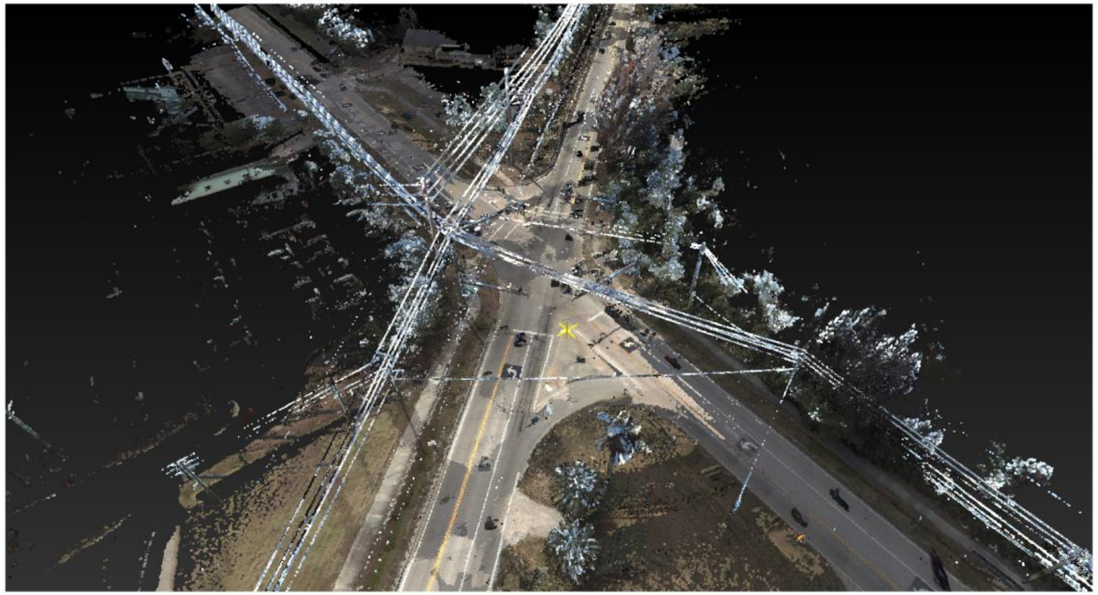
- DUAL SCANNER THAT PRODUCES 3.6M POINTS PER SECOND AT HIGHWAY SPEEDS
- HIGH PERFORMANCE INS/GNSS UNIT
- HOUSES UP TO 9 OPTIONAL CAMERAS
- IMPROVED FILTERS FOR NOISE REDUCTION.
- ACCURACY/PRECISION:~3MM-5MM

RIEGL VMX-2HA



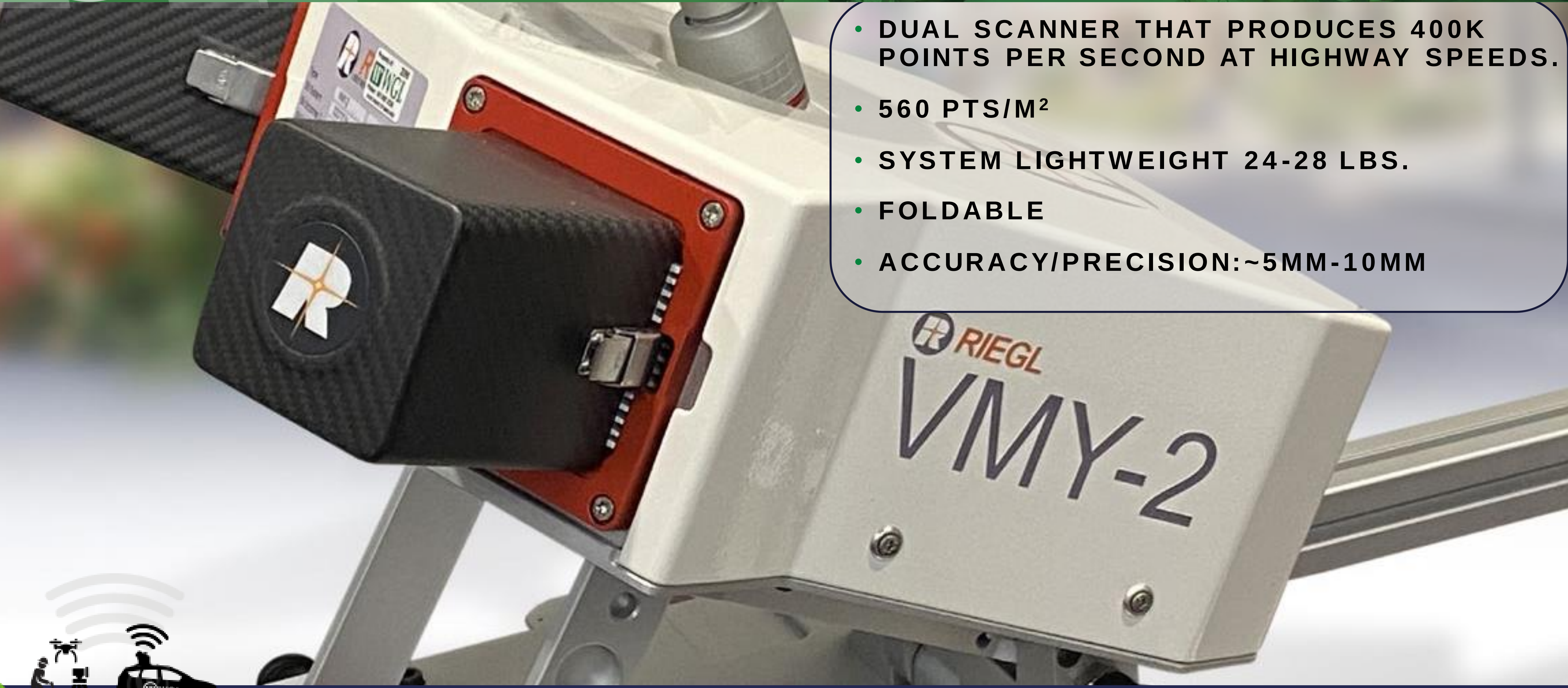


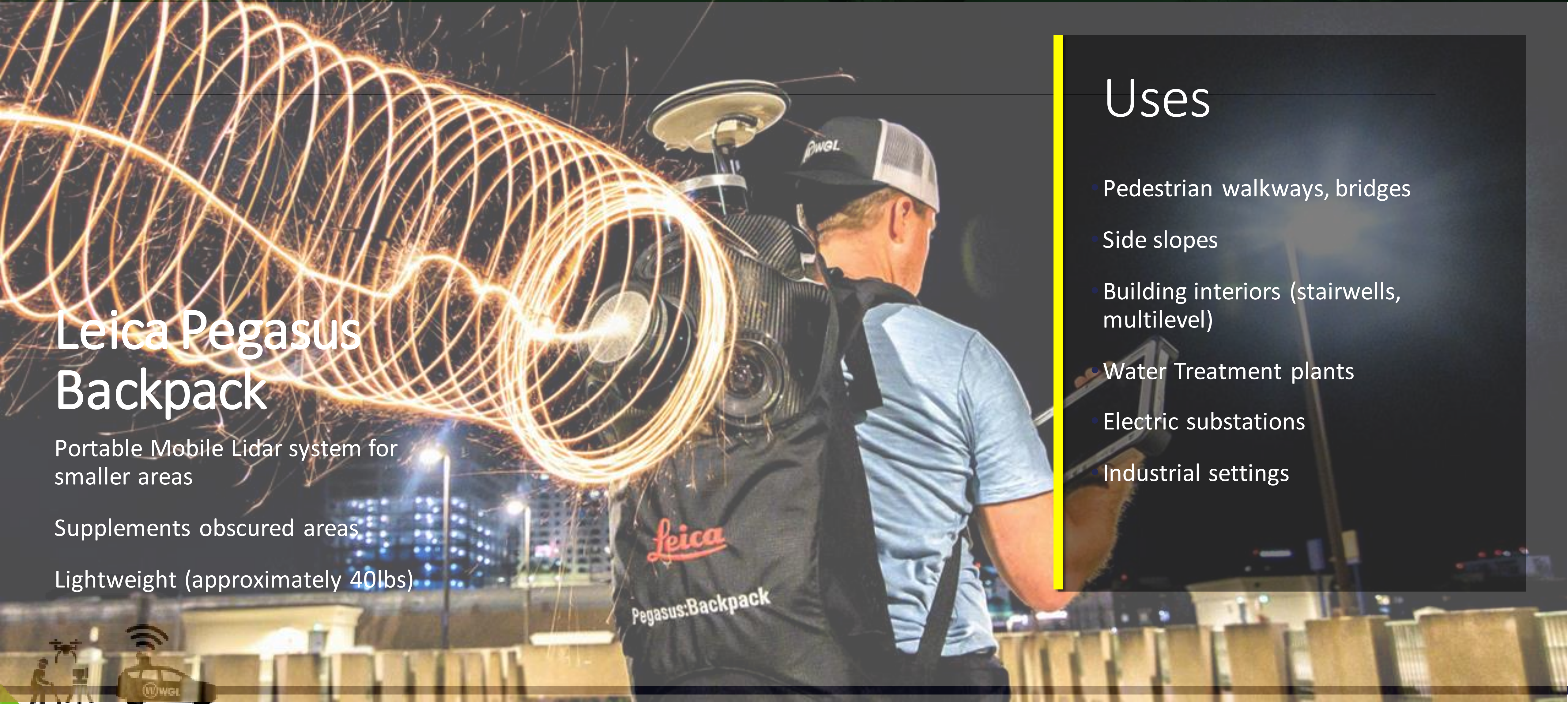




RIEGL VMY-2

- DUAL SCANNER THAT PRODUCES 400K POINTS PER SECOND AT HIGHWAY SPEEDS.
- 560 PTS/M^2
- SYSTEM LIGHTWEIGHT 24-28 LBS.
- FOLDABLE
- ACCURACY/PRECISION:~5MM-10MM





Leica Pegasus Backpack

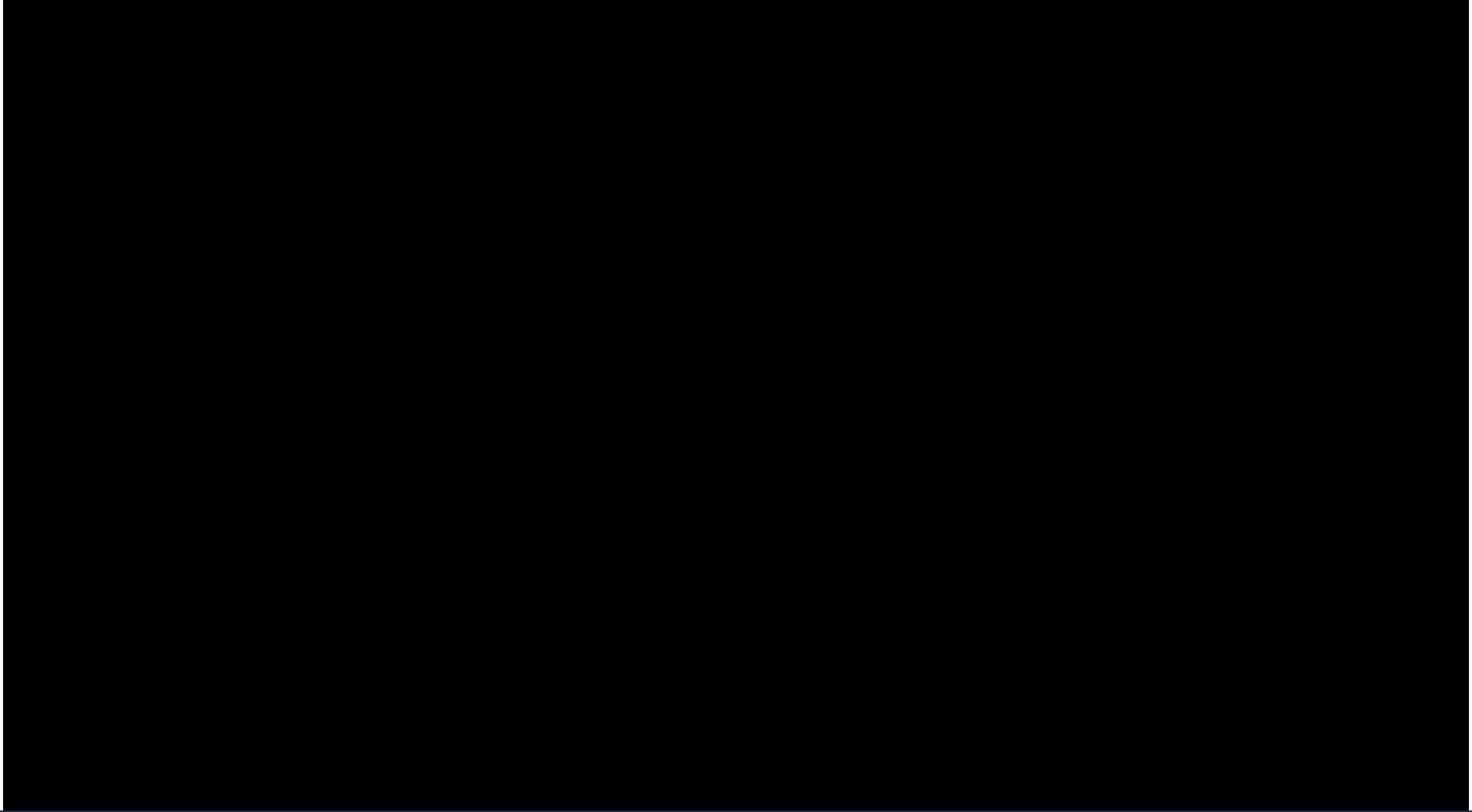
Portable Mobile Lidar system for smaller areas

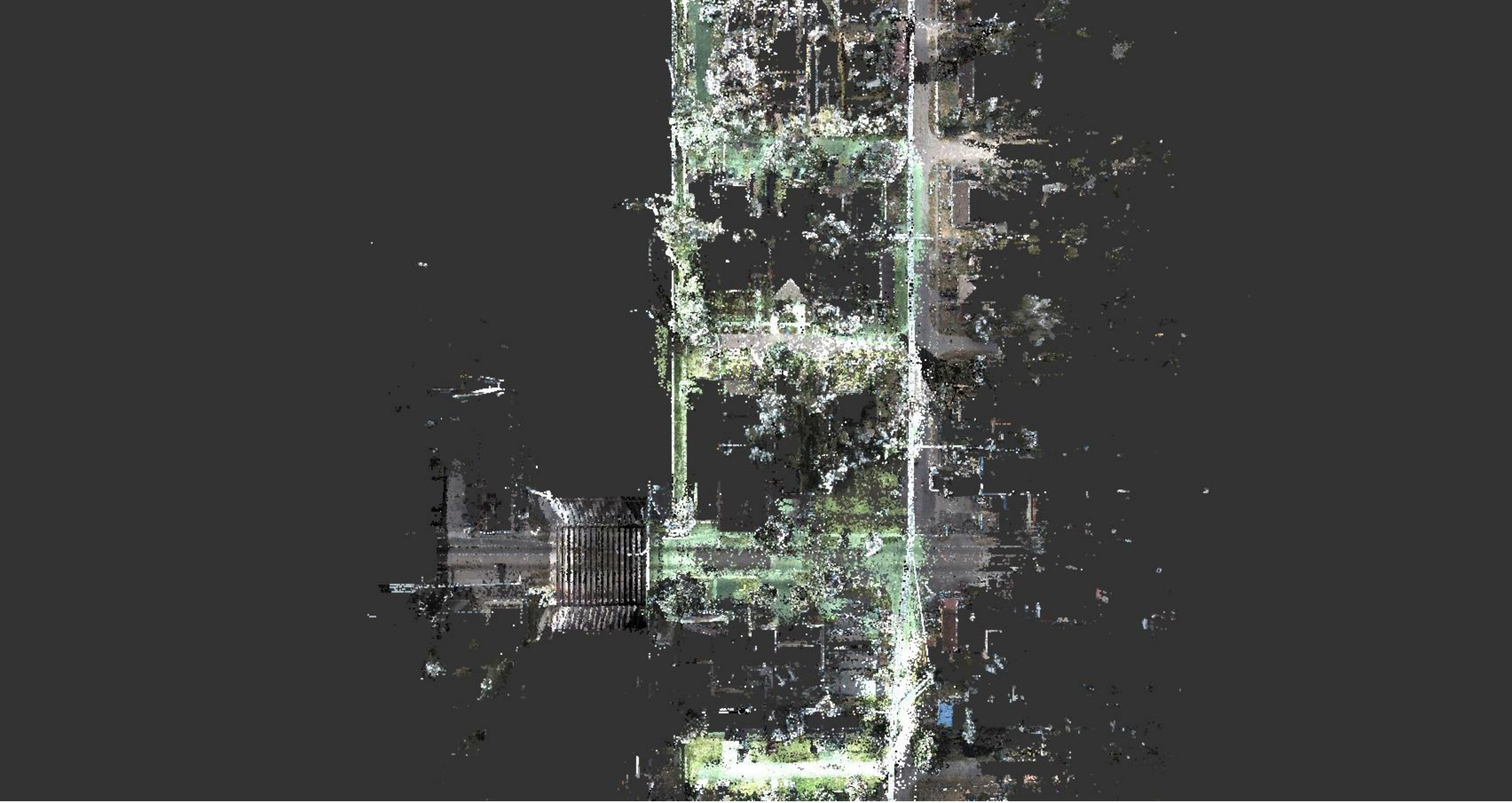
Supplements obscured areas

Lightweight (approximately 40lbs)

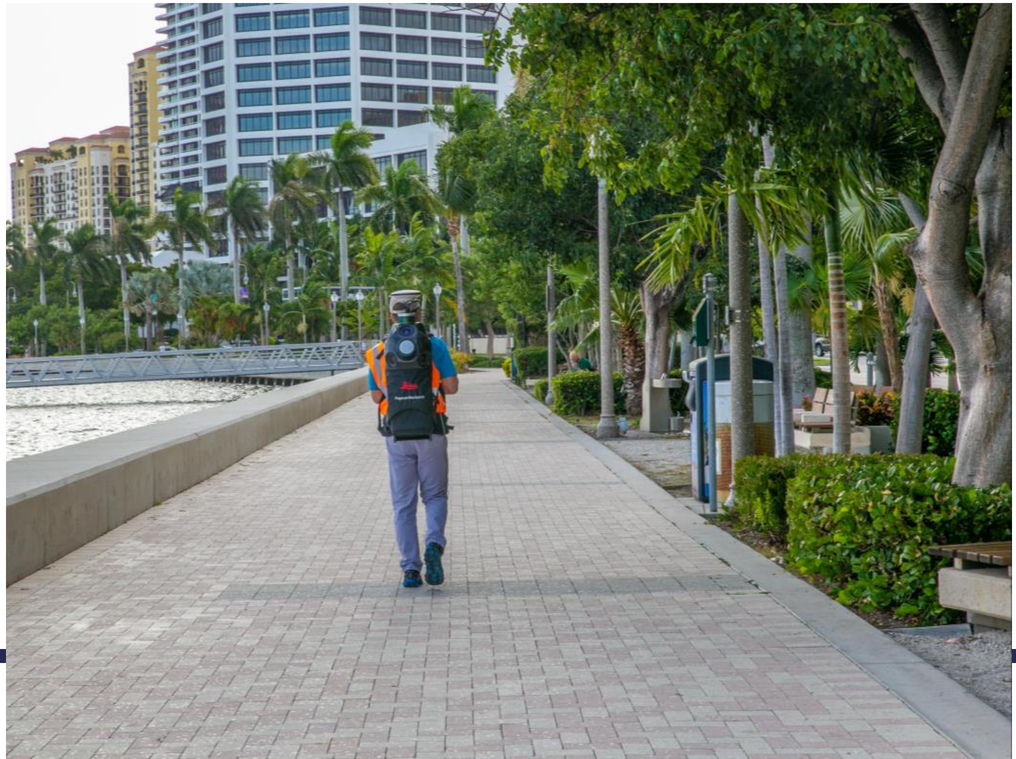
Uses

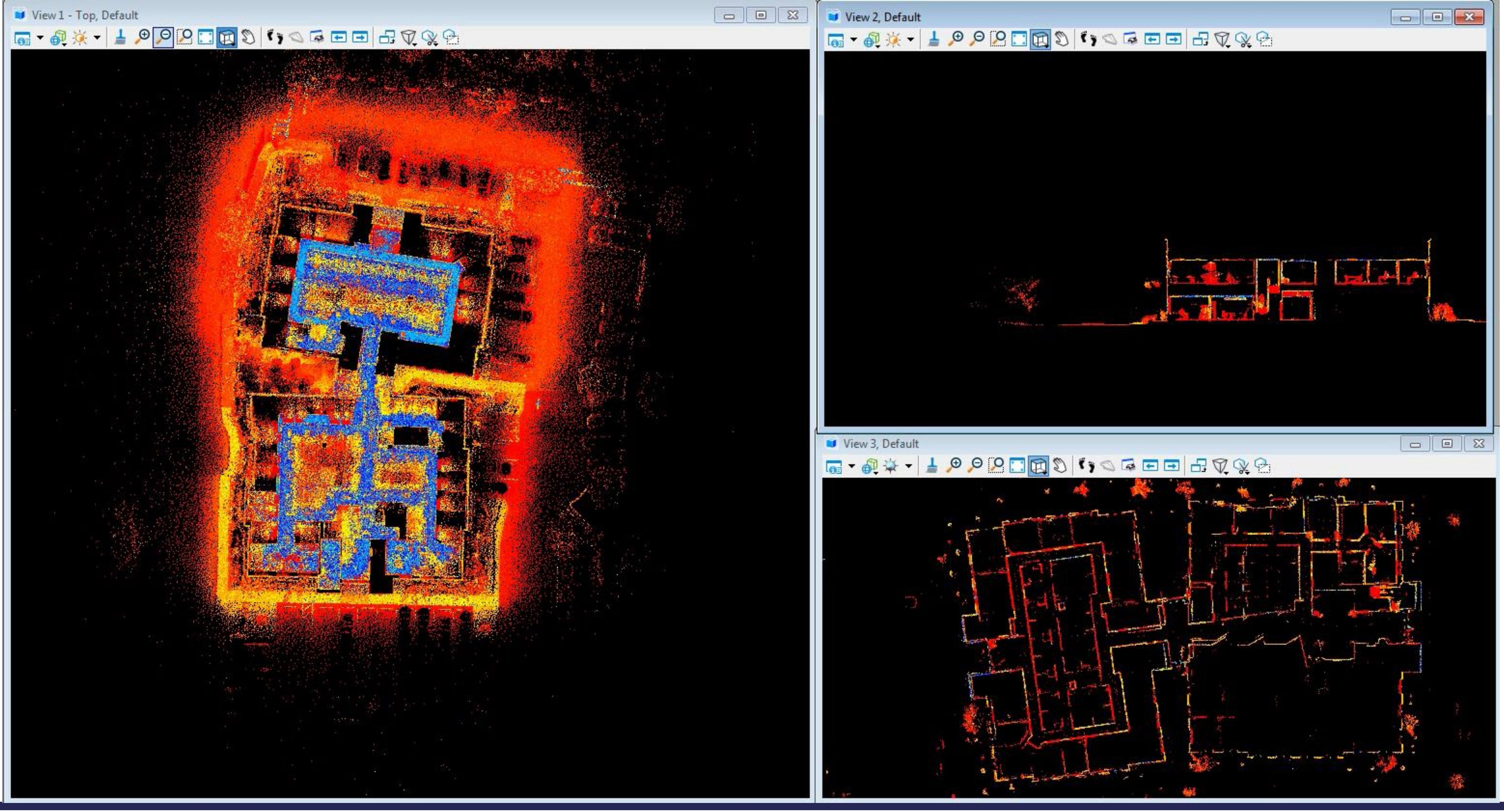
- Pedestrian walkways, bridges
- Side slopes
- Building interiors (stairwells, multilevel)
- Water Treatment plants
- Electric substations
- Industrial settings





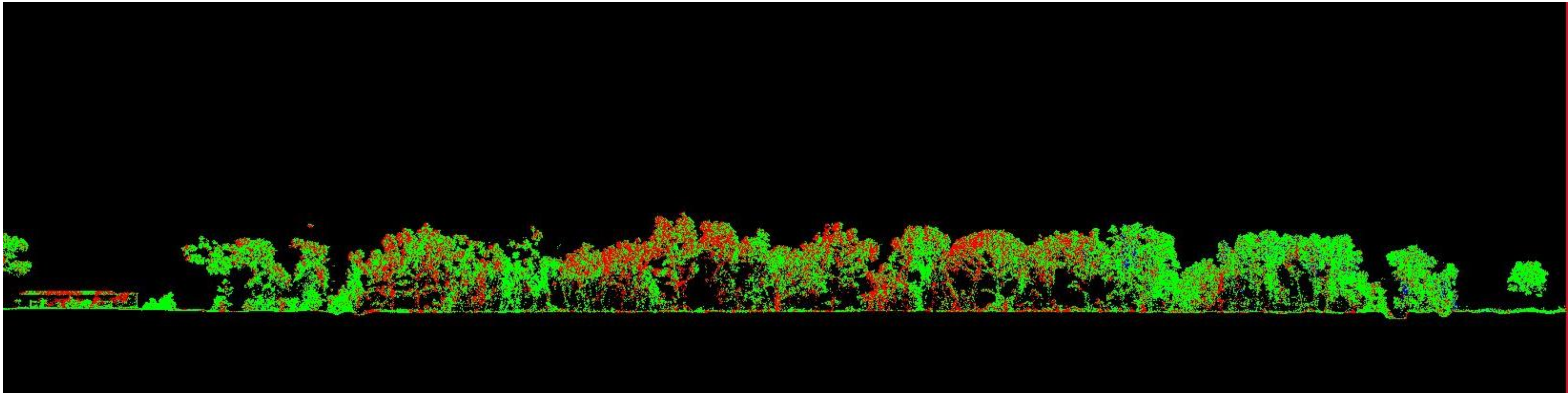

EST. 1925
Daytona
BEACH PIER
JOE'S
CRAB SHACK
EAT AT JOE'S

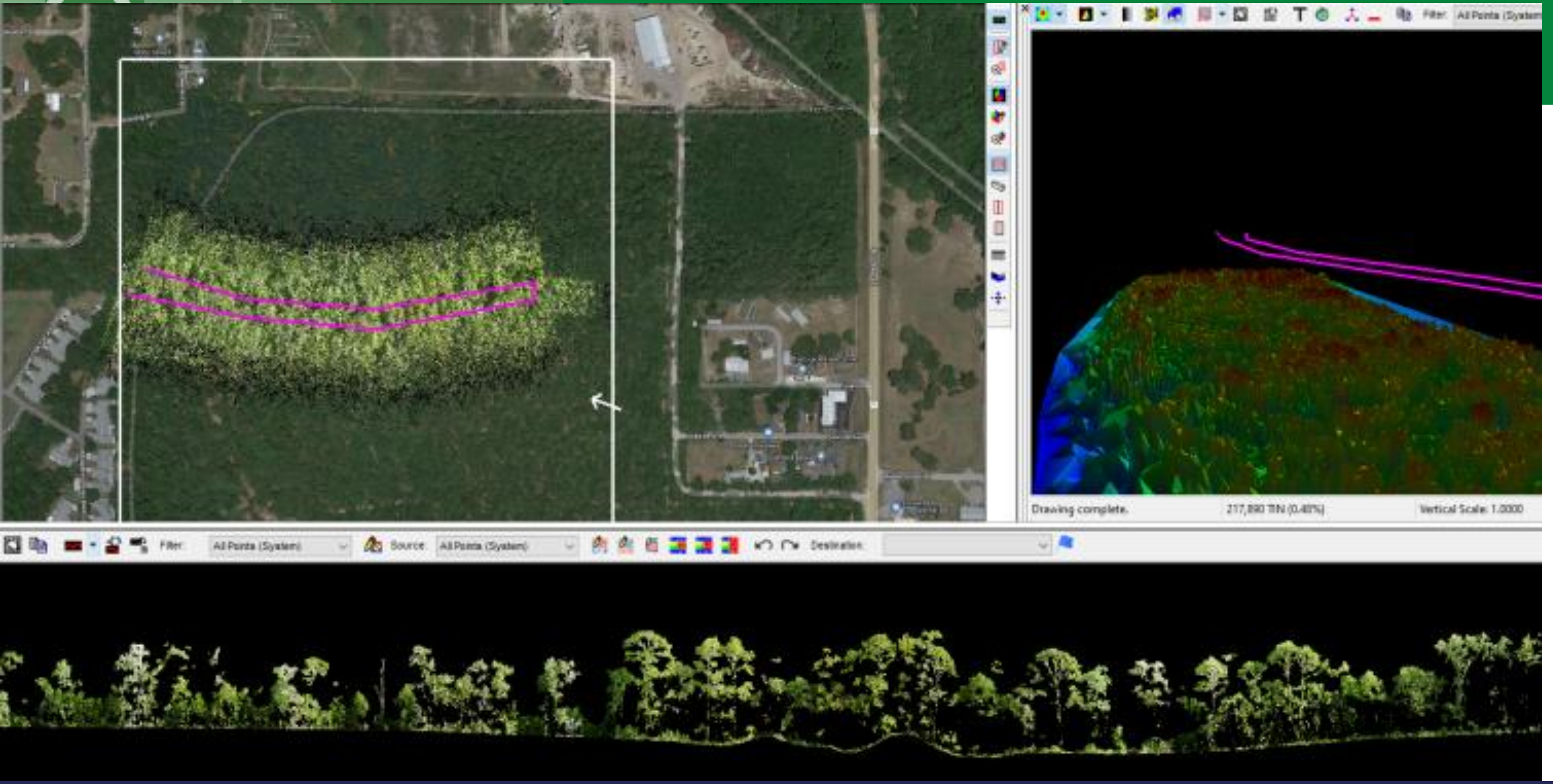



View 1 - Top, Default
View 2, Default
View 3, Default

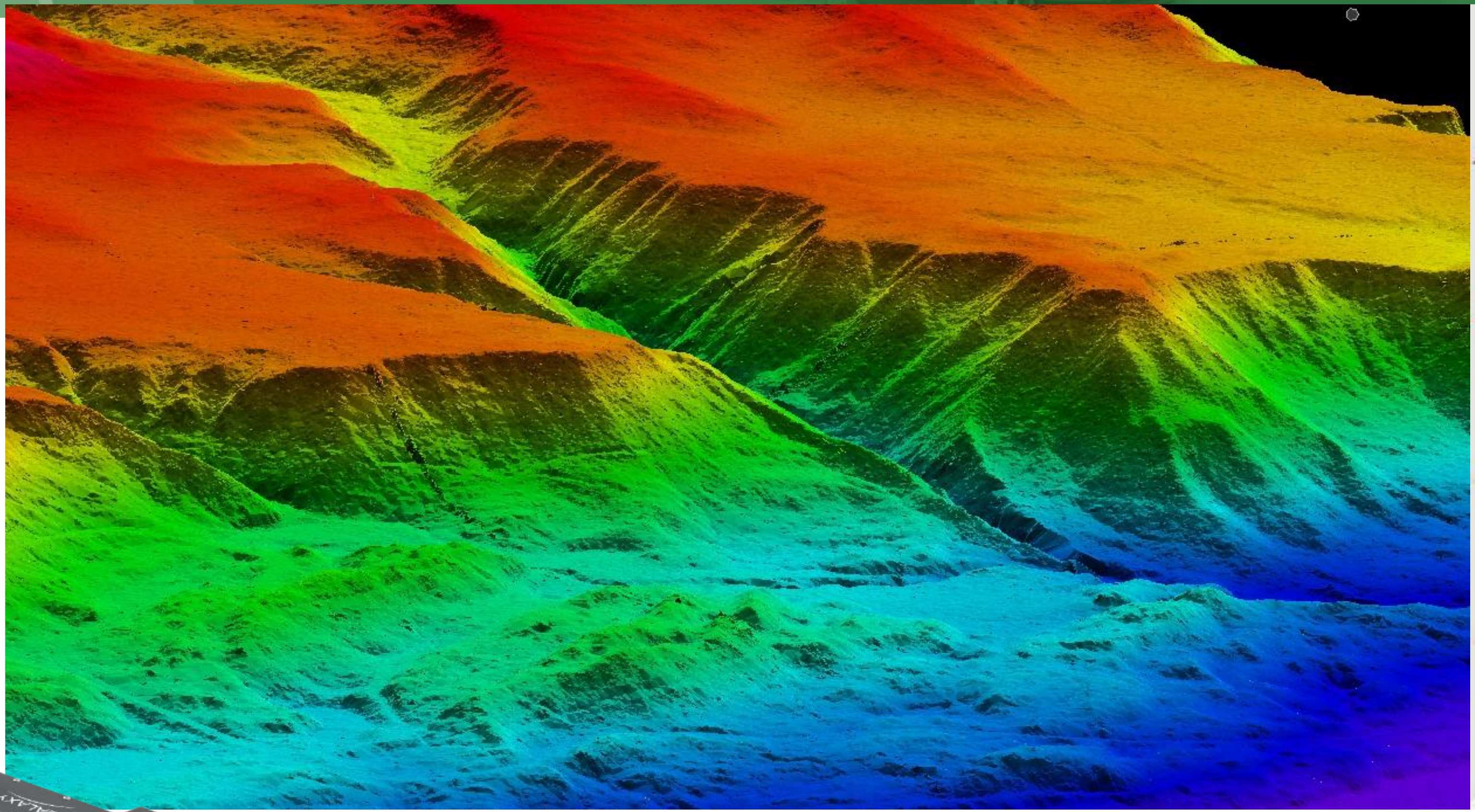
AERIAL LIDAR (UAVs)

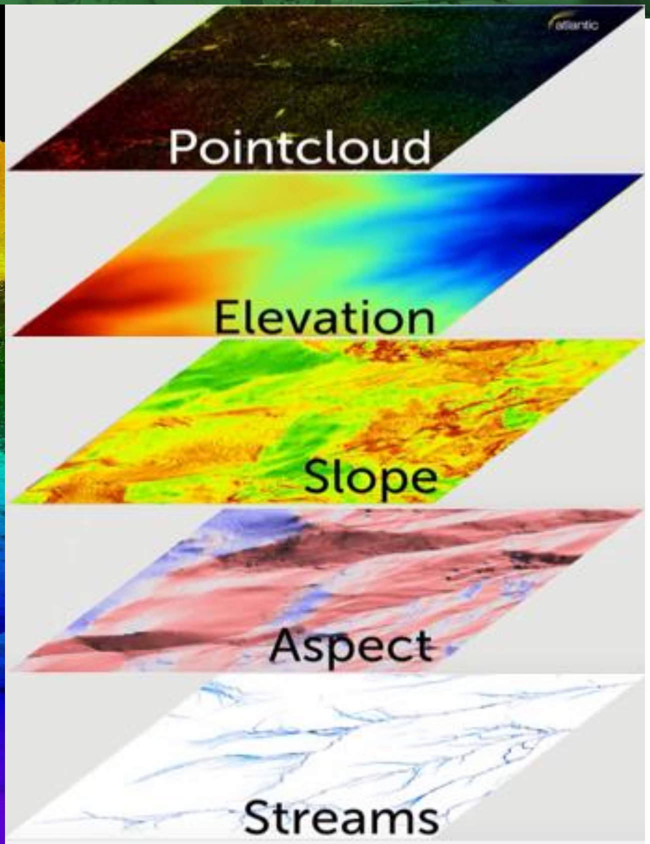
- Fixed wing aircraft or helicopter mounted; downward facing configuration
- Collection of millions of points per second
- Utilizes GPS positioning systems, inertial measurement, and targeting if precise collection is required
- Ideal for large coverage areas and remote areas
- Riegl Sensor with Sound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




Drawing complete.
217,890 TIN (0.48%)
Vertical Scale: 1.0000
Filter:
All Points (System)
Source:
All Points (System)
Destination

AERIAL LIDAR

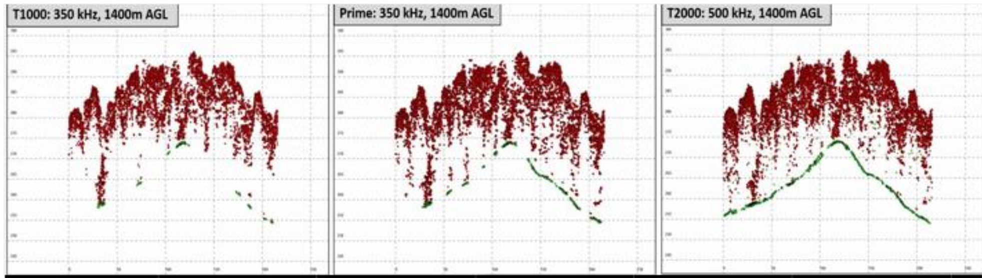


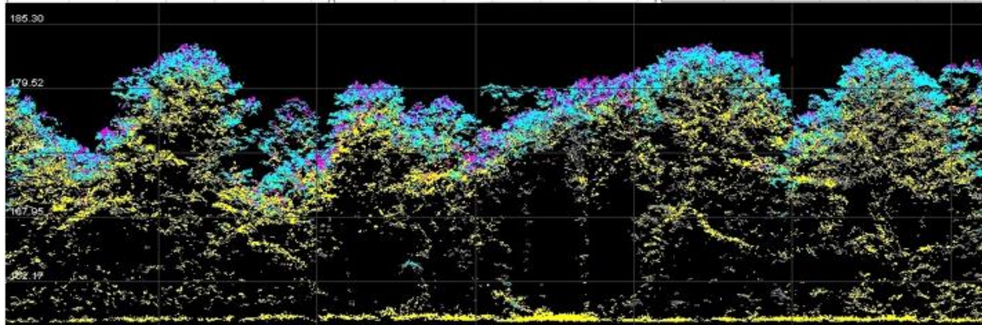


Teledyne Geospatial, Galaxy T2000

- 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

SPECIALIZED AERIAL LIDAR





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

NOMINAL PULSE DENSITY	AGGREGATE POINT DENSITY (90% OF 1M SAMPLES)	POINT DENSITY - MODE	BEAM FOOTPRINT DIAMETER, (MEAN ELEV - NADIR)	NOMINAL PULSE SPACING	AGGREGATE NOMINAL PULSE SPACING
70.4 pls/m²	244.4 pts/m²	244.1 pls/m²	6.1" (1/e²), 4.3" (1/e)	11.9 cm - 4.7"	6.4cm - 2.5"

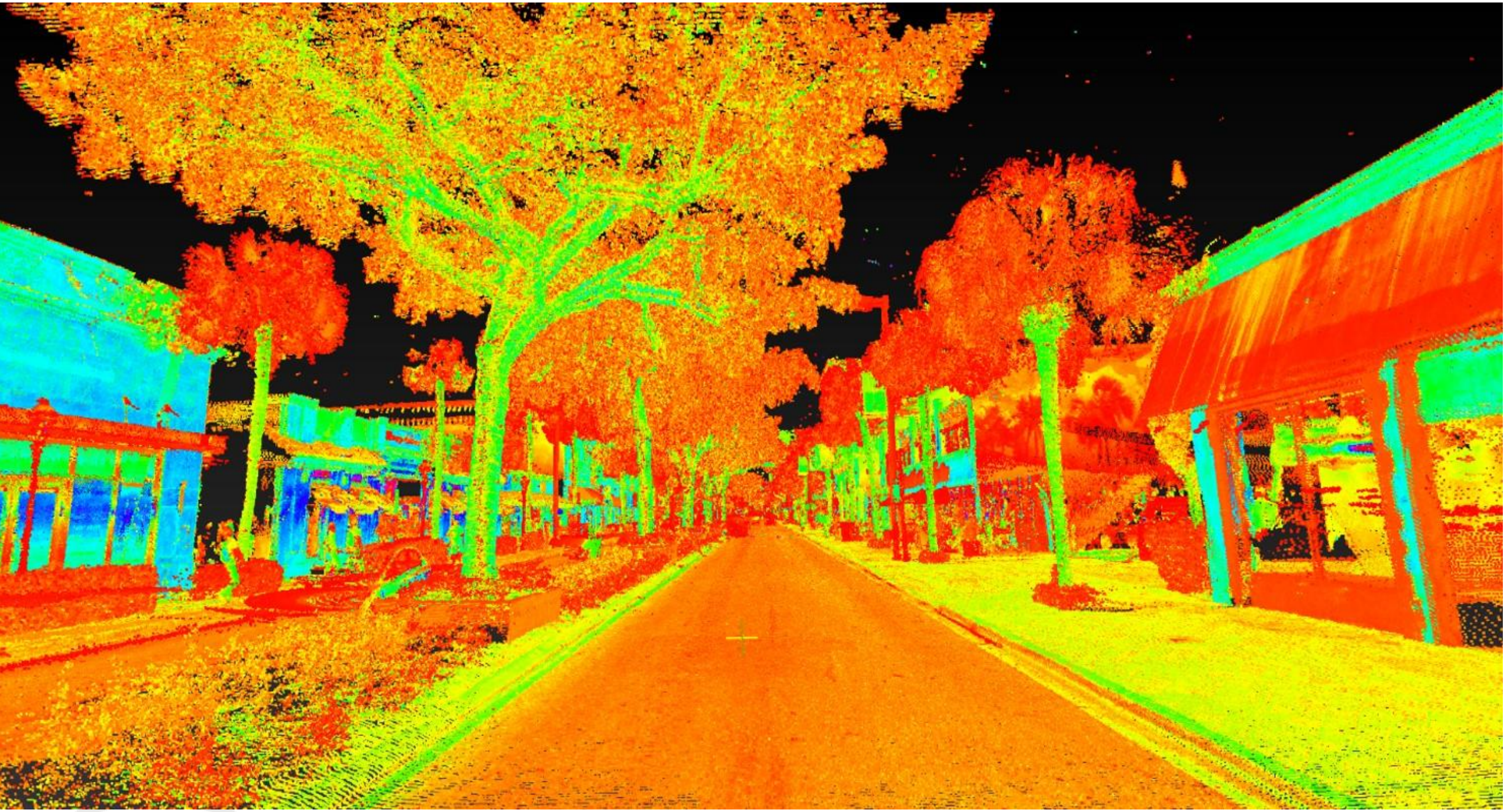
Lidar Accuracy and Precision Stats

CONTROL PANEL SAMPLE SIZE	DZ TO CONTROL (MIN, MAX)	MEAN DZ TO CONTROL	REALTIVE INTERSWATH DZ	STANDARD DEVIATION TO CONTROL (1σ)	INTRASWATH PRECISION – SMOOTH SURFACE REPEATABILITY	ABSOLUTE RMSEZ – 95% CI
110 – Hard Surface	-0.102' +0.098'	+0.015'	90% <0.131'	0.040'	0.14'	0.042' – 0.082'

Efficiency and Image Stats

AOI SIZE (AREA, LENGTH)	LIDAR BUFFER WIDTH OFF AOI	FLIGHT LINES	TIME OF ACQUISITION (INCLUDES TURNS, NO TRANSIT)	CORRIDOR LINE EFFICIENCY	IMAGE GSD (MIN, MAX)	MEAN IMAGE GSD
0.45mi², 4.3mi	+/- 700'	5 + 1 Cross	29min	8.9 corridor miles / hr.	1.71" – 1.77"	1.75" / pix.

LAS OLAS BOULEVARD – FORT LAUDERDALE



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**

FDOT SURVEYING AND MAPPING HANDBOOK

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.

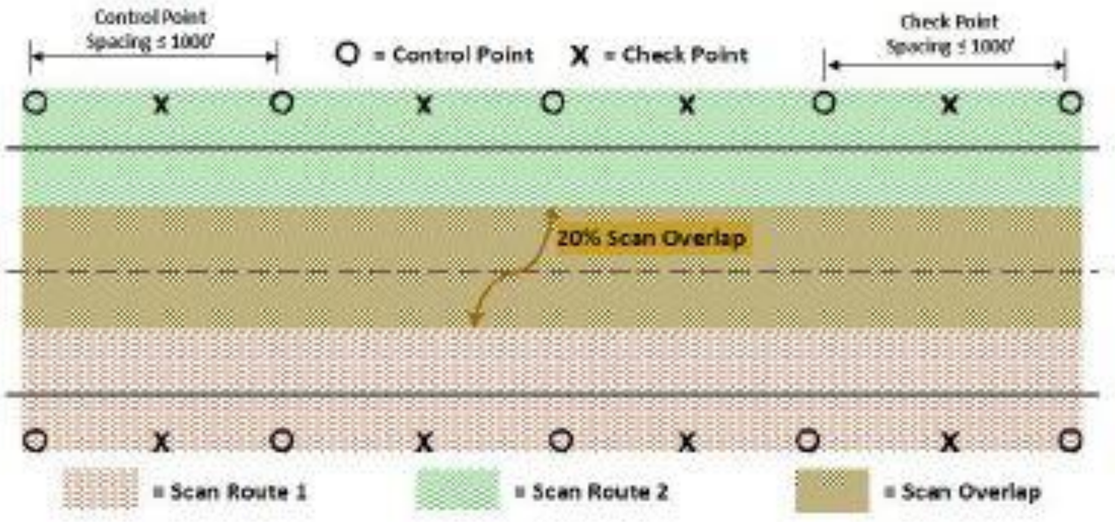
The collection rate (epoch) of the TML system sensors must be sufficient to meet project accuracy and point density requirements.

FDOT SURVEYING AND MAPPING HANDBOOK

Operation/Specification	TML Survey		
	Type A	Type B	Type C
TML positional accuracy requirements relative to Project Control Points and Validation Points	V ≤ 0.06 ft	V ≤ 0.10 ft	See Note 5
Maximum post-processed baseline length	5 miles		10 miles
Minimum number of common healthy satellites in view for GNSS base stations and mobile scanner	See Notes 1 thru 4		
Maximum PDOP during TML data acquisition	5		
Allow sufficient time between overlapping collection passes to ensure change in satellite constellation. Recommend at least 3 different satellites in view.	Each Overlapping Pass		
Minimum overlapping coverage between adjacent runs	20%		
Minimum number of project transformation points required	4		
LiDAR point density requirements (see note 8)	(≥ 20 pts/ft²)	(≥ 10 pts/ft²)	See note 9
Recommended maximum spacing for Project Control Point pairs along the project corridor. Project Control Points should be located on each side of scanned roadway.	1000 ft intervals See Note 5	1500 ft intervals See Note 5	See note 5
Recommended maximum Validation Point spacing along the project corridor for QA purposes as safety conditions permit. (See Note 3)	1000 ft intervals See Note 5	1000-2500 ft intervals See Note 5	See Note 5
Minimum NSSDA Horizontal and Vertical Check Points	20 points - see note 7		

FDOT SURVEYING AND MAPPING HANDBOOK

39.6.1. TYPICAL TML TYPE "A" PROJECT CONTROL AND VALIDATION POINT LAYOUT



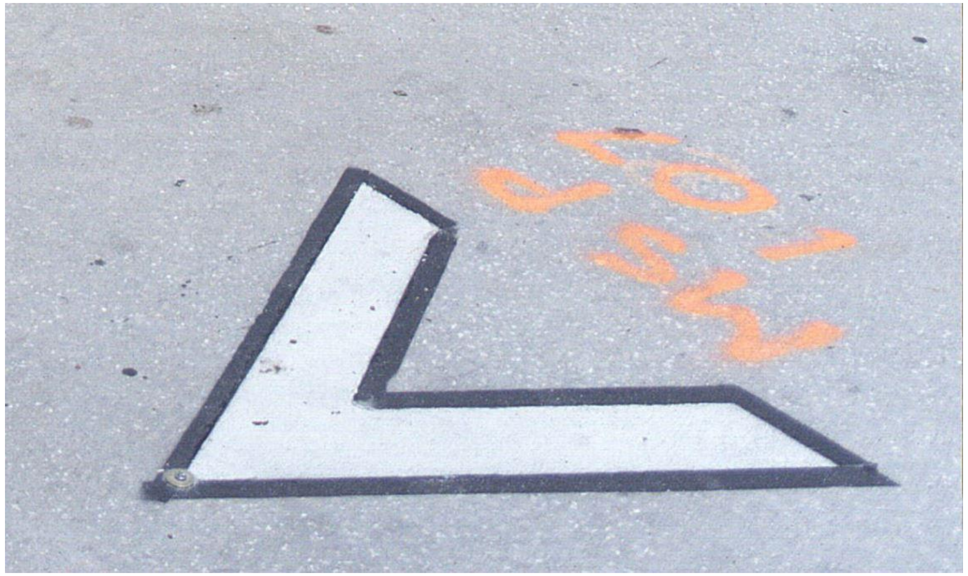
Note: Since all projects are different, these are only recommendations. The Surveyor & Mapper in responsible charge of the TML must choose the appropriate accuracy and geometry of the Project Control Points and Validation Points to insure the TML survey data and products meet or surpass accuracy requirements of the project.

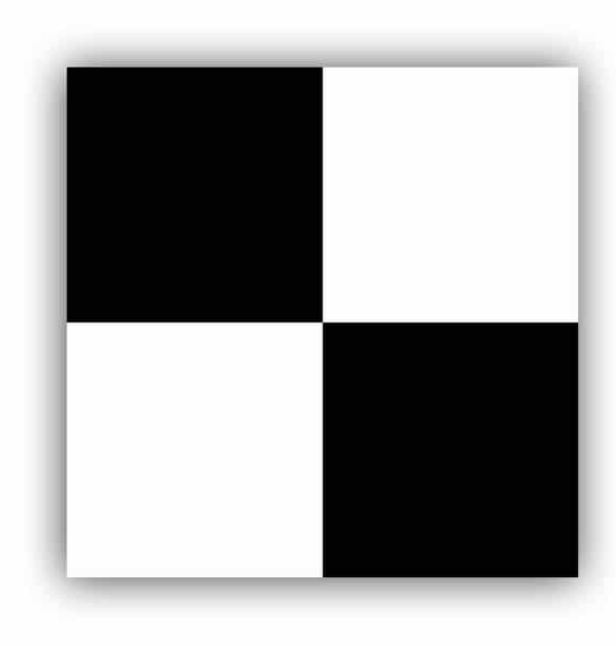
Validation Points may also serve as NSSDA check points to meet the requirements of this section.

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.

FDOT

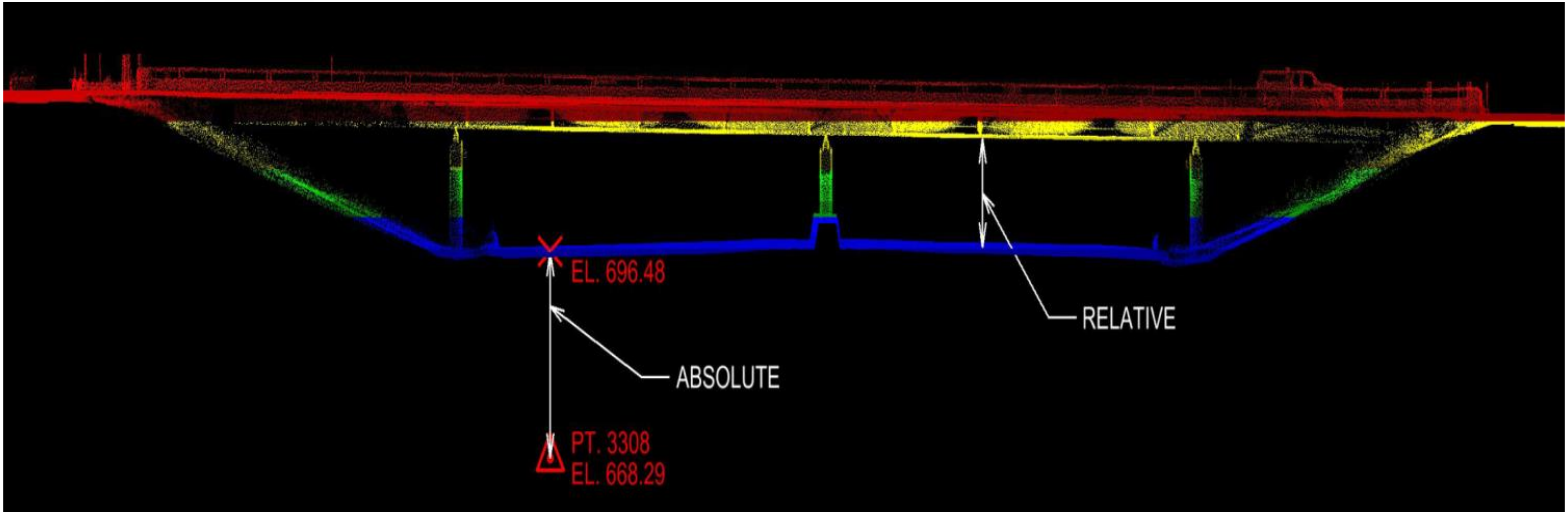
TYPES OF TARGETS





TARGET LAYOUTS

RELATIVE VS. ABSOLUTE POSITION



- Absolute – Location
  - Point cloud in relation to established coordinate system
- Relative – Distance
  - Point to point distance within cloud

LEICA PEGASUS BACKPACK

Process Trajectory -

Import/Unzip LiDAR files

Extract image files

Time alignment (Specific for Pegasus)

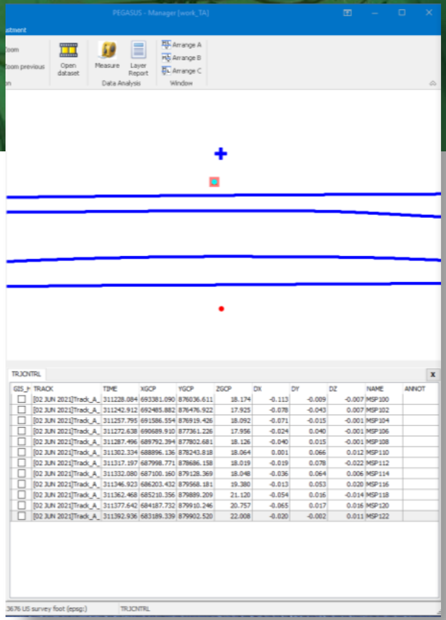
Generate point clouds

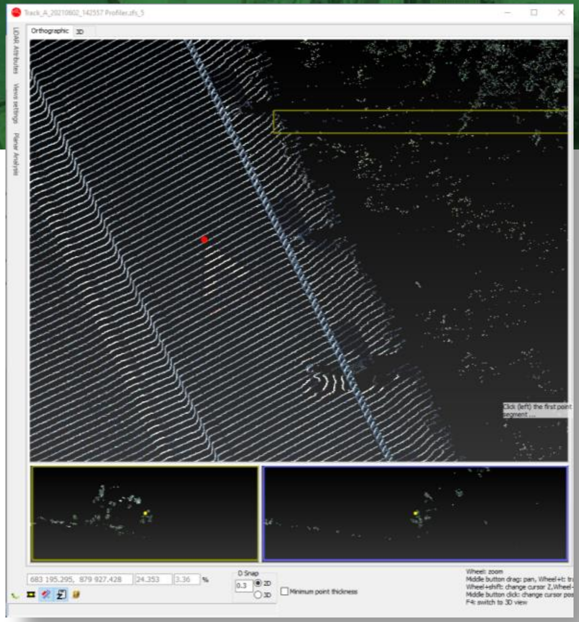
Filter point clouds

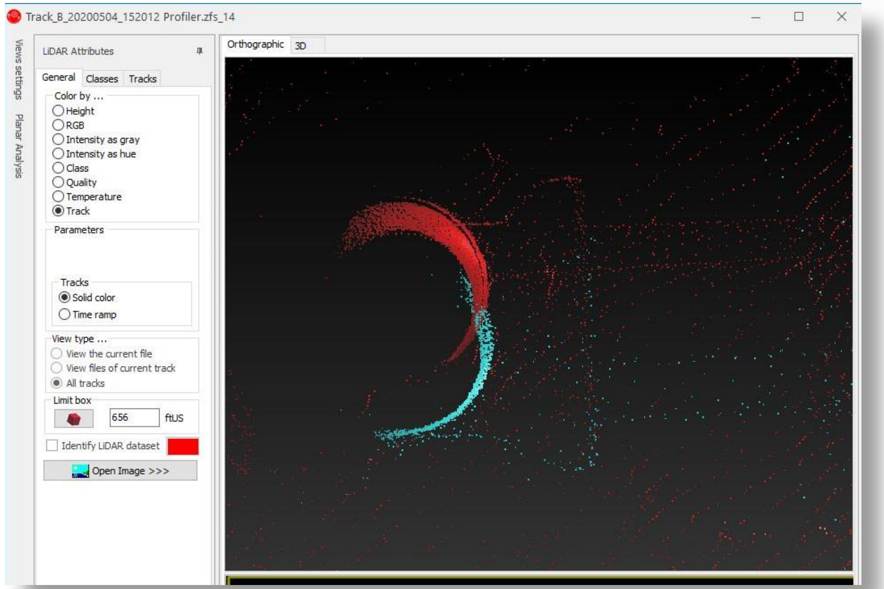
Adjust to control or itself – Manual, Vertical averaging, Target recognition, Multipass/SLAM

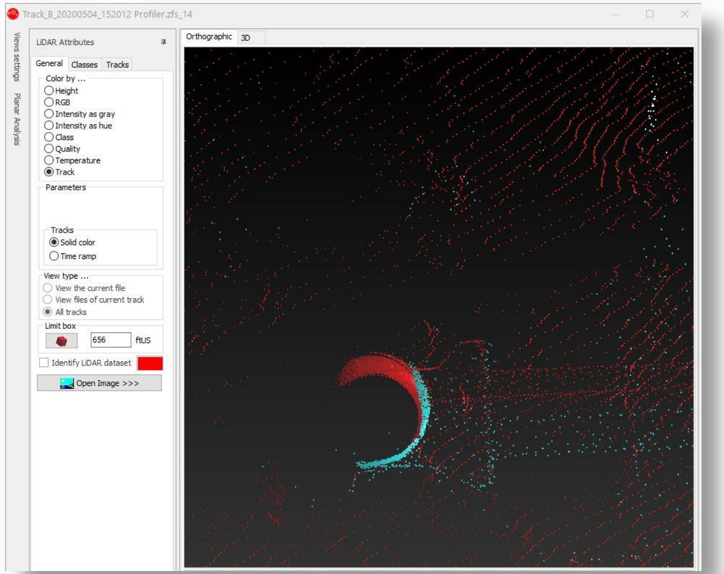
QC

Host – Orbit, TopoDot









QC – CONTROL POINT REPORT EXAMPLE

Leica Pegasus:Two Ultimate
Mobile Reality Capture

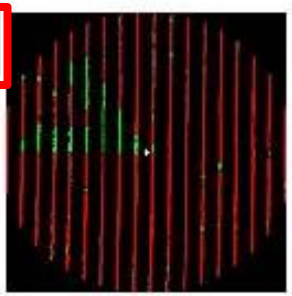
Leica Geosystems

Name: MSP508	ID: 14	Class: Control Point
Track Data: [05 MAY 2020]THEA_A_20200505_122718 Profilerzfs_13|12653613.gps		

XGCP	YGCP	ZGCP	DX	DY	DZ
541879.859	1307881.817	40.876	0.049	0.042	-0.023

TIME	SIMMETRY	TYPE	IDLINK
218357.559	33.119	7	113

Manually reacquired

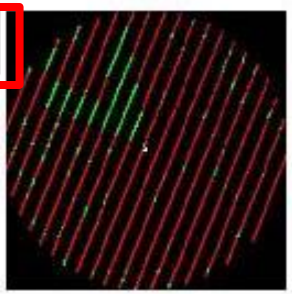


Name: MSP509	ID: 15	Class: Control Point
Track Data: [05 MAY 2020]THEA_A_20200505_122718 Profilerzfs_12|12653613.gps		

XGCP	YGCP	ZGCP	DX	DY	DZ
541106.046	1308523.694	28.895	0.080	0.050	-0.068

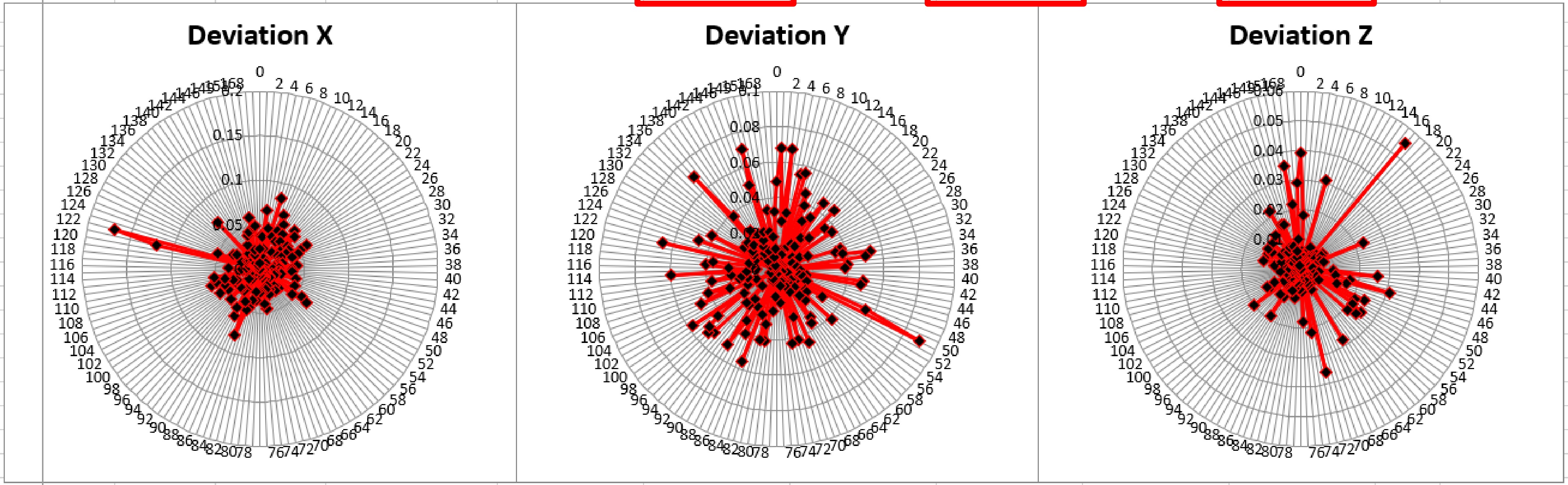
TIME	SIMMETRY	TYPE	IDLINK
218342.079	32.532	7	109

Manually reacquired



QC – MOBILE LIDAR TARGETS REPORT EXAMPLE

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Index	Point	Easting	Northing	Elevation	Abs(Deviation X)	Deviation X	Abs(Deviation Y)	Deviation Y	Abs(Deviation Z)	Deviation Z	Dist XY	Template Name
150	149	MSP601	548585.85	1307096.96	40.136	0.022	0.022	0.007	-0.007	0.001	0.001	0.024	60¯
151	150	MSP602	547743.01	1306922.31	54.397	0.059	-0.059	0.021	0.021	0.006	-0.006	0.062	60¯
152	151	MSP603	548598.79	1305181.5	33.958	0.047	-0.047	0.033	-0.033	0.035	-0.035	0.057	60¯
153	152	MSP604	548480.56	1306116.58	37.142	0.049	-0.049	0.018	0.018	0.022	-0.022	0.052	60¯
154	168	MSP620	537392.82	1314479.67	29.776	0.007	-0.007	0.011	0.011	0.01	-0.01	0.013	60¯
155	174	MSP627	522611.08	1316082.31	16.64	0.023	-0.023	0.032	-0.032	0.029	-0.029	0.04	60¯
156													
157					AVG		-0.0109		-0.0049		-0.0044		
158					RMSE		0.0371		0.0319		0.0124		
159					Within Tolerance (%)		100		100		100		



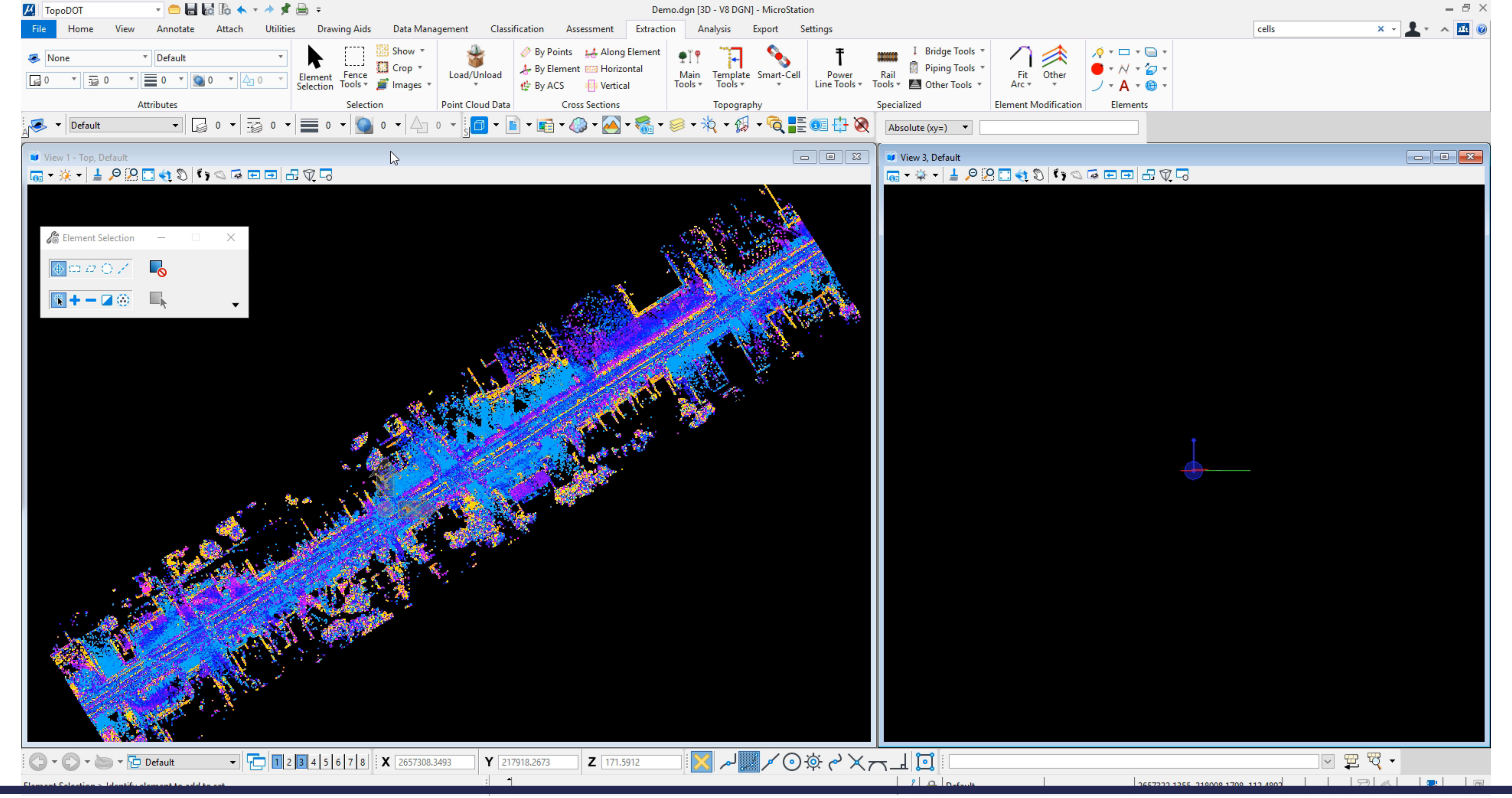
HAWAII SAMPLE BACKPACK DATA

Open your phone camera app and scan the QR Code to access Orbit Demo data

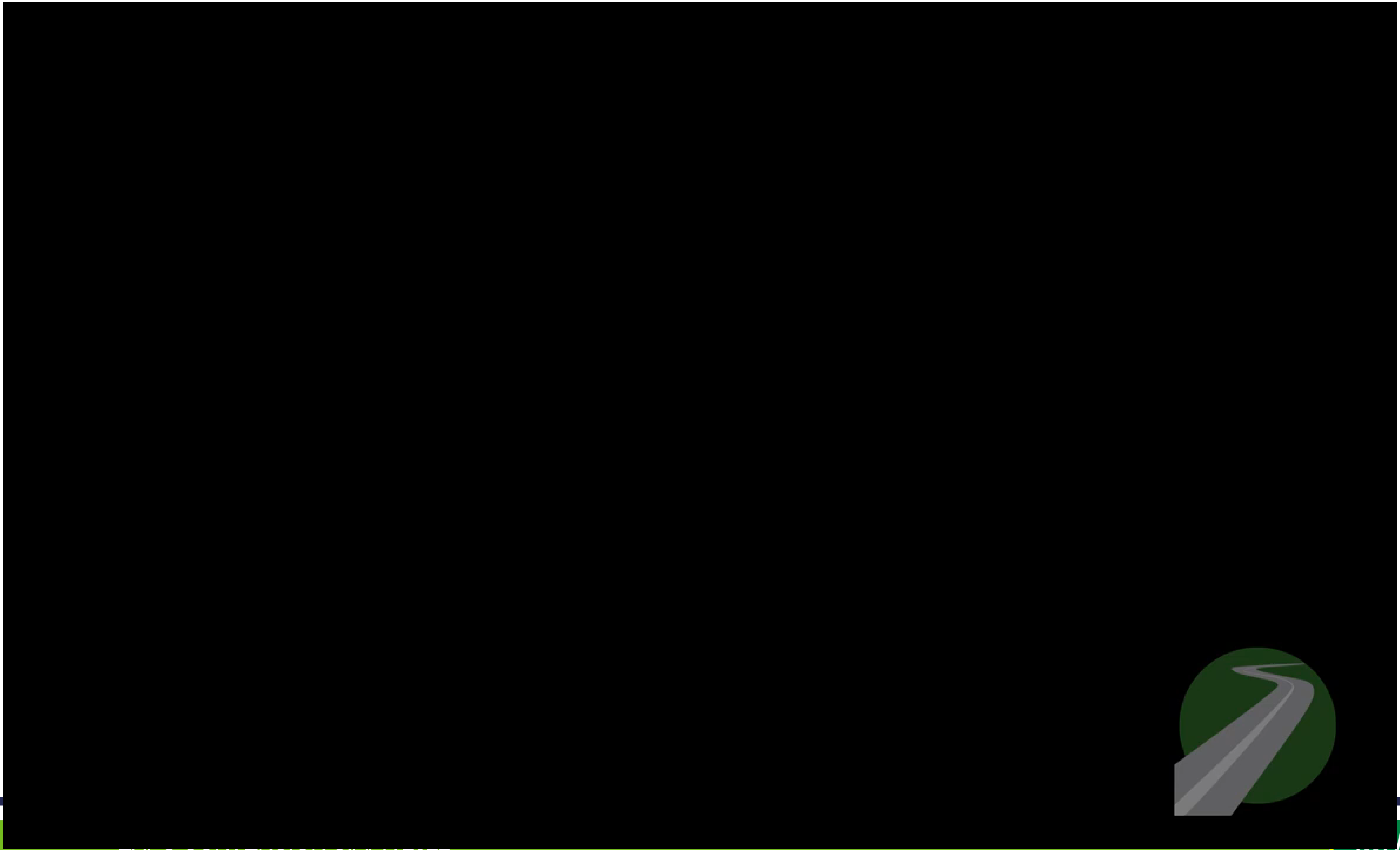
https://publication.wgigeo.tech/publication/BPExample

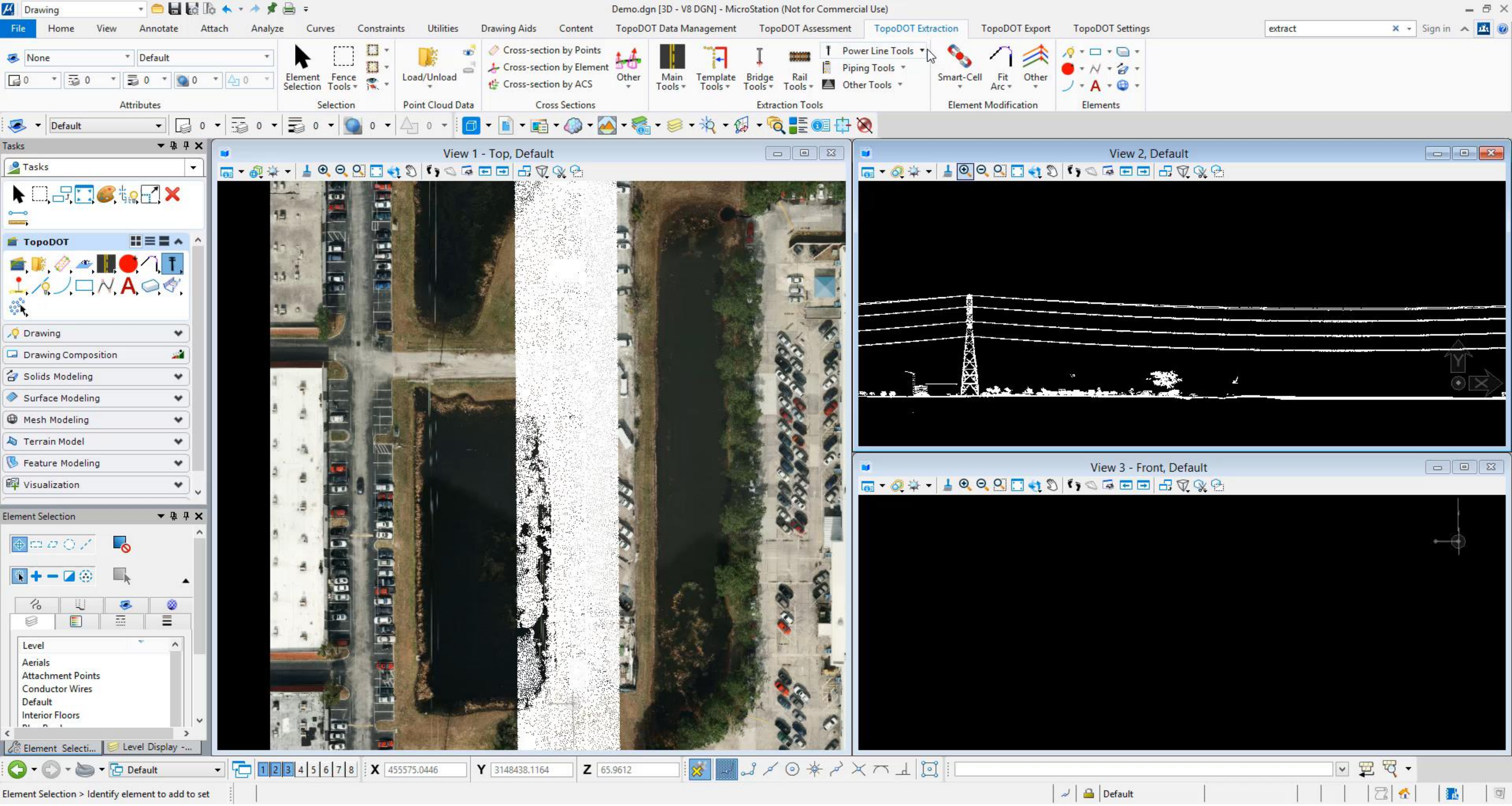
TOPODOT APPLICATIONS

- Asset Management GIS
- Breakline Extraction tool for 3D Topographic surveys
- Detailed Roadway Conditions Report tool
- Cross Slope Analysis tool
- Electric Transmition Locations
- Among Other Applications



Demo.dgn [3D - V8 DGN] - MicroStation
TopoDOT
File
Home
View
Annotate
Attach
Utilities
Drawing Aids
Data Management
Classification
Assessment
Extraction
Analysis
Export
Settings
cells
None
Default
Element Selection
Fence Tools
Show
Crop
Images
Load/Unload
By Points
By Element
By ACS
Along Element
Horizontal
Vertical
Main Tools
Template Tools
Smart-Cell
Power Line Tools
Rail Tools
Bridge Tools
Piping Tools
Other Tools
Fit Arc
Other
Attributes
Selection
Point Cloud Data
Cross Sections
Topography
Specialized
Element Modification
Elements
Absolute (xy=)
View 1 - Top, Default
View 3, Default
Element Selection
X 2657308.3493
Y 217918.2673
Z 171.5912




Demo.dgn [3D - V8 DGN] - MicroStation (Not for Commercial Use)
File
Home
View
Annotate
Attach
Analyze
Curves
Constraints
Utilities
Drawing Aids
Content
TopoDOT Data Management
TopoDOT Assessment
TopoDOT Extraction
TopoDOT Export
TopoDOT Settings
Element Selection
Fence Tools
Load/Unload
Cross-section by Points
Cross-section by Element
Cross-section by ACS
Other
Main Tools
Template Tools
Bridge Tools
Rail Tools
Power Line Tools
Piping Tools
Other Tools
Smart-Cell
Fit Arc
Attributes
Selection
Point Cloud Data
Cross Sections
Extraction Tools
Element Modification
Elements
Tasks
TopoDOT
Drawing
Drawing Composition
Solids Modeling
Surface Modeling
Mesh Modeling
Terrain Model
Feature Modeling
Visualization
Element Selection
Level
Aerials
Attachment Points
Conductor Wires
Default
Interior Floors
View 1 - Top, Default
View 2, Default
View 3 - Front, Default
X 455575.0446
Y 3148438.1164
Z 65.9612
Element Selection > Identify element to add to set

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

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