



Geospatial Solutions



Terrestrial GPS setup Fundamentals of Airborne LiDAR Systems, Collection and Calibration

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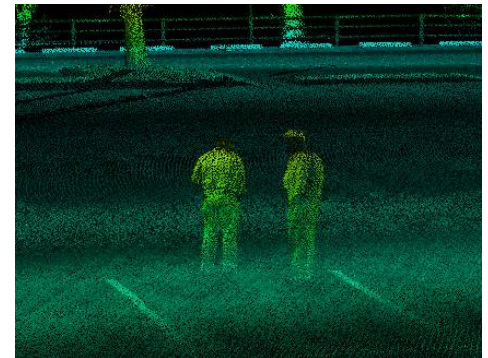
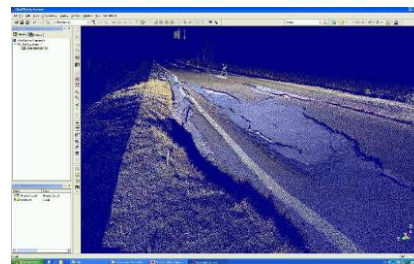
Topics

- Terrestrial GPS reference
- Planning and Collection Considerations
- Calibration
- Helicopter LiDAR
- Processing
- Survey and Accuracy



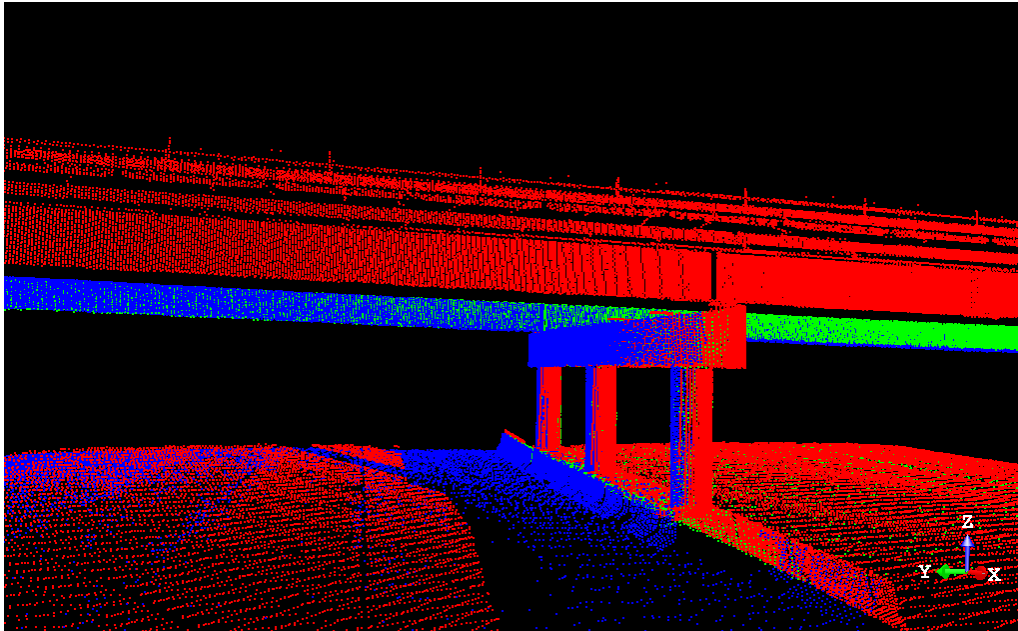
Terrestrial Setup

- Review Site location to determine Target locations
- Determine type of setup based on requirements
 - Geo-referencing required
 - Relative to itself
- Need to see everything from Scanner locations
- Similar to Survey Process
- Want to get good solution

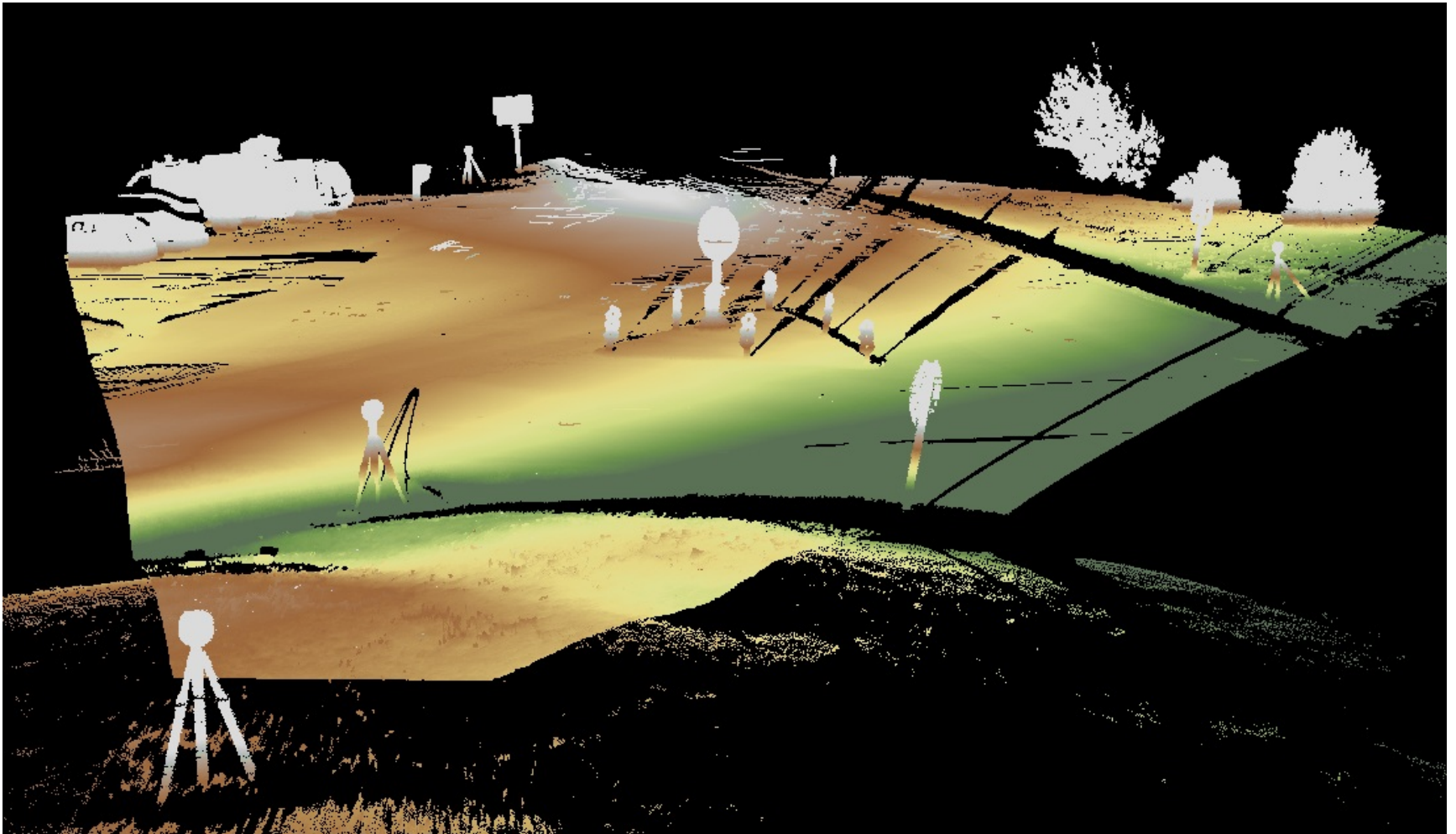


Terrestrial

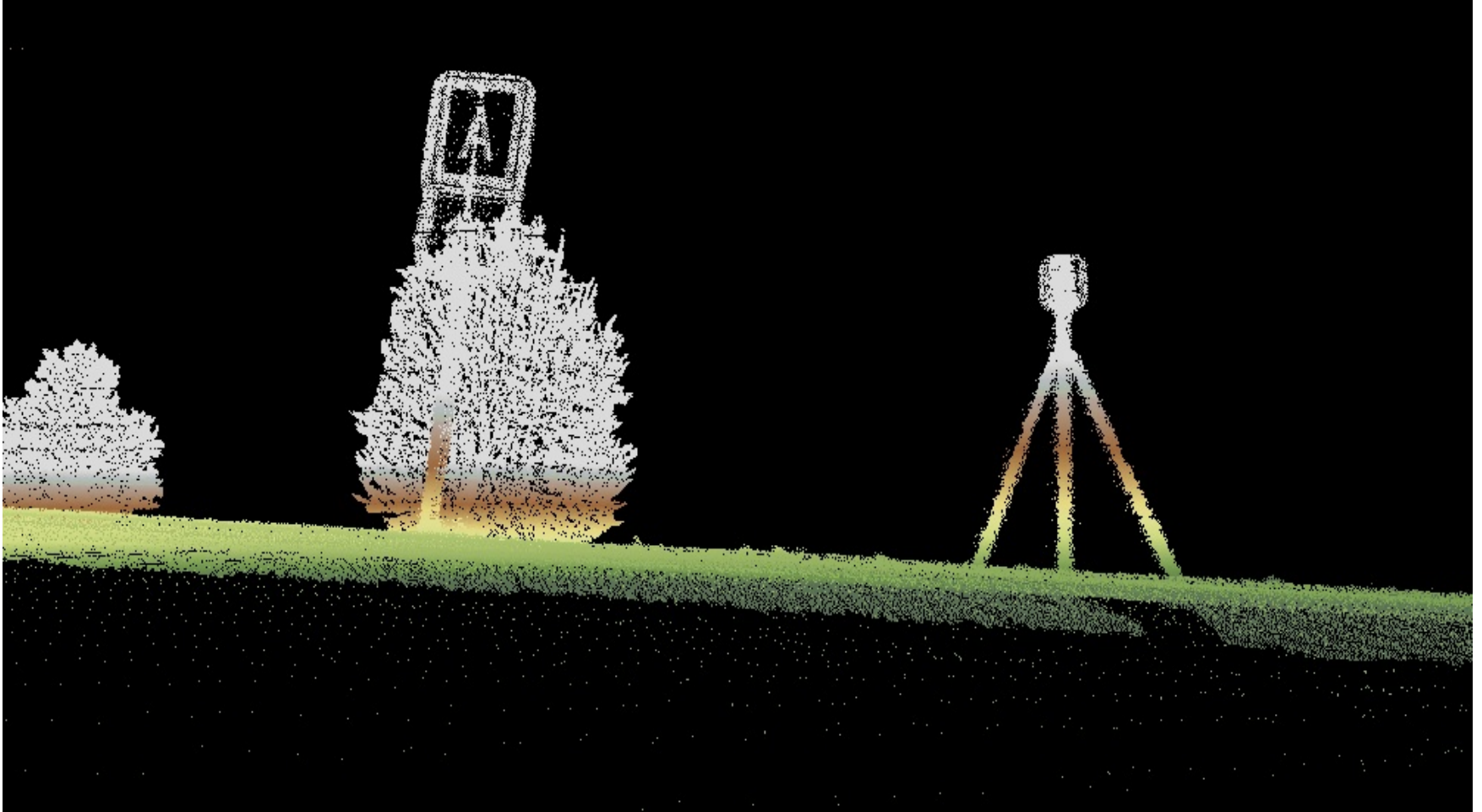
- Vertical accuracy of 3mm
- Please note that accuracy is related to Project Process
- Develop process to get better accuracy



Setup



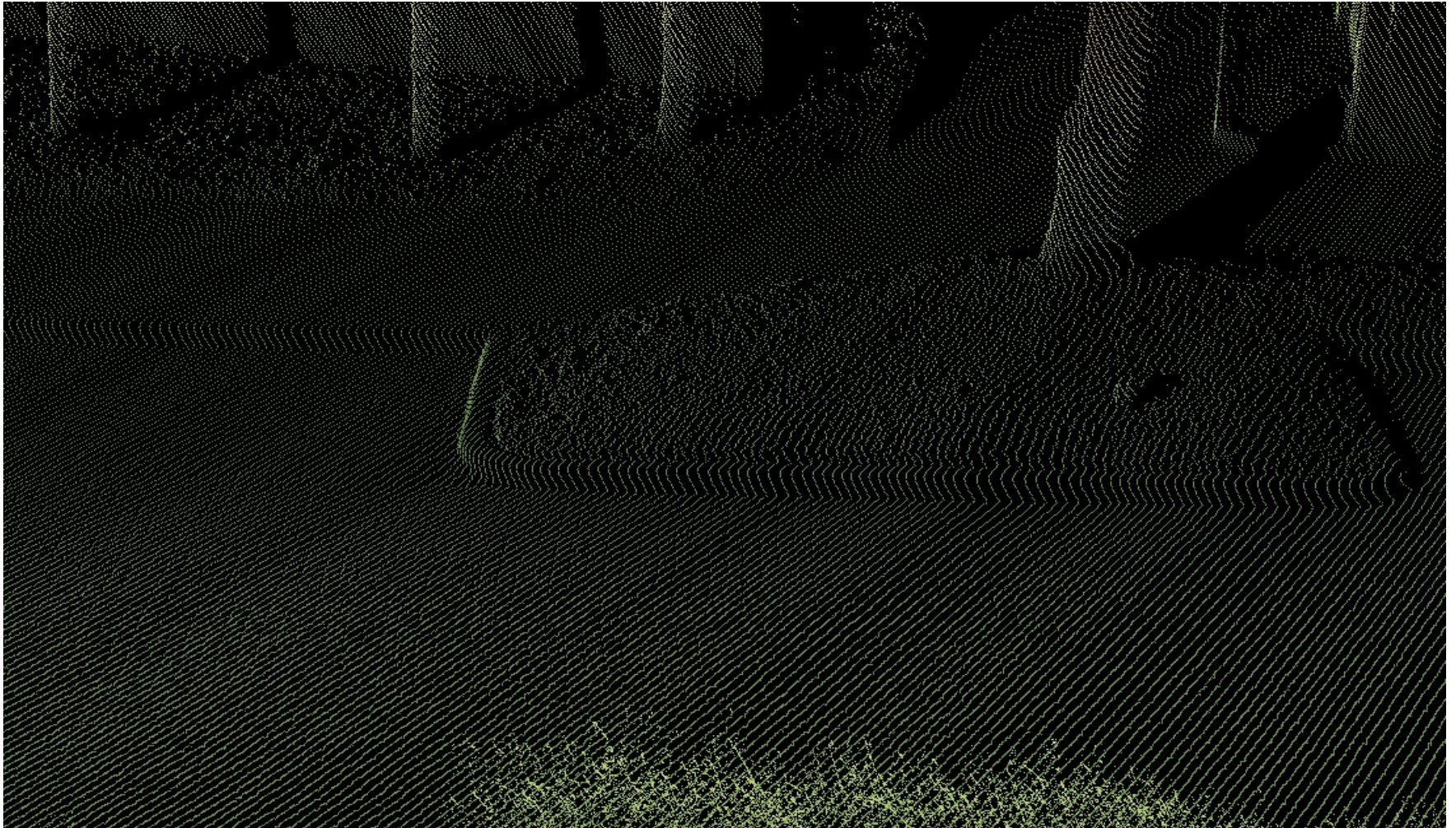
Single Set up



Location of Target locations in relationship to Area of interest

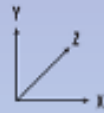


Detail

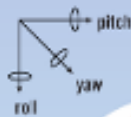


LiDAR: Light Detection and Ranging

Aerial sensor
Collects/scans data,
either photons
(reflected light) or
laser pulses

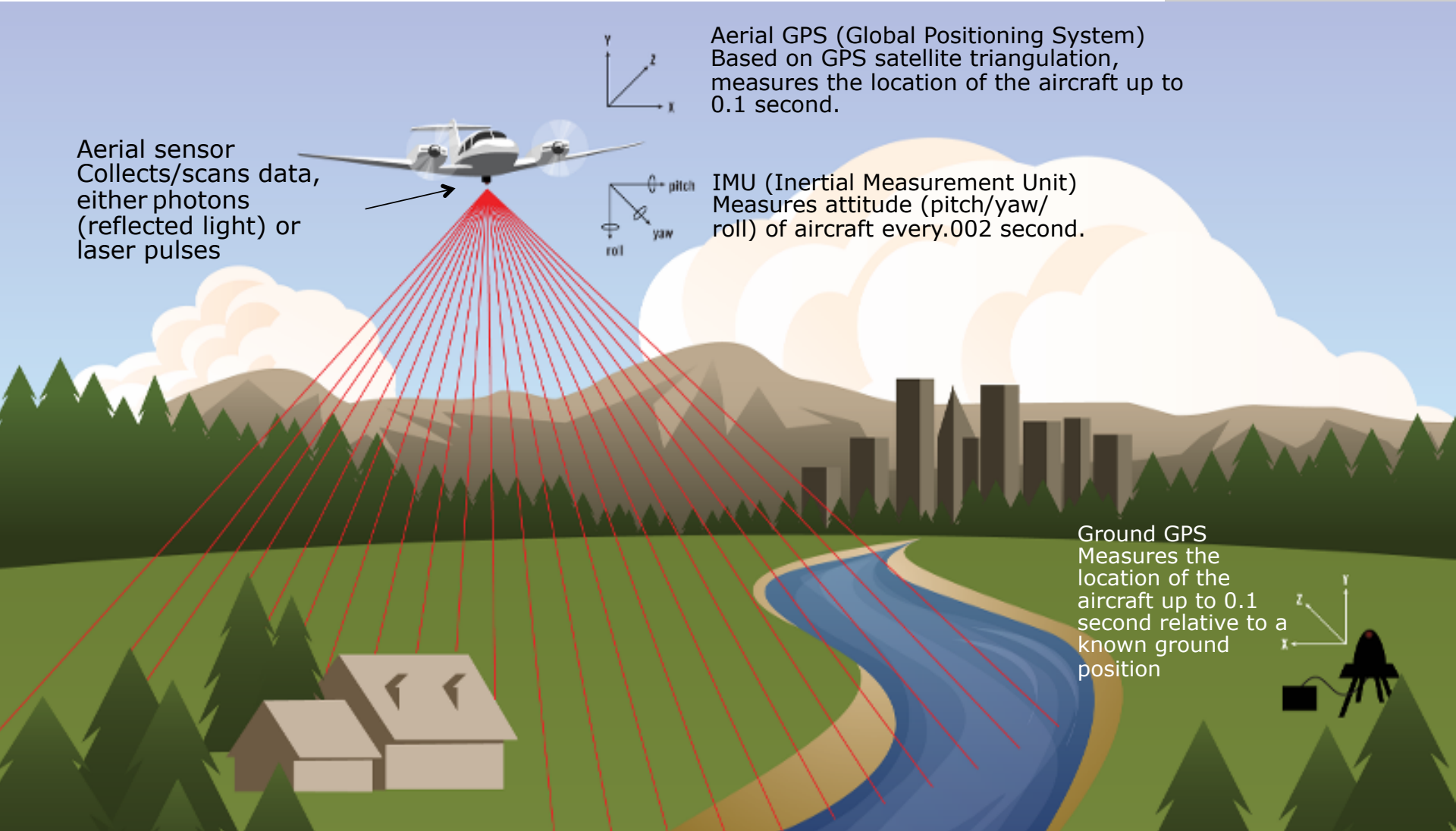


Aerial GPS (Global Positioning System)
Based on GPS satellite triangulation,
measures the location of the aircraft up to
0.1 second.



IMU (Inertial Measurement Unit)
Measures attitude (pitch/yaw/
roll) of aircraft every 0.002 second.

Ground GPS
Measures the
location of the
aircraft up to 0.1
second relative to a
known ground
position



LiDAR Collection Sensors



- Optech
- Leica
- Trimble
- Reigl

- 167Khz = 167,000 points per second
- Multi-pulse system = 2 pulse in air
- Scan-frequency function = 1000
- Can be full waveform

- 500Khz = 500,000 points per second
- Multi-pulse system = 2 pulses in air
- Laser beam split
- Scan angle up 75 degrees
- Full waveform on 1 channel

Please note that just because you can run at 500Khz does not mean you can collect at all elevations at 500khz

Flight planning

AeroPlan 70

Computation | Accuracy Settings | Image Sensor | Hardware Configuration

Application: Manual setup

Parameters

Field of View: 40.0 degrees

Reference Height Min: 0 m Max: 0 m

Flying Height above min. Elevation (AGL): 2400 m

Aircraft Speed over Ground: 160 kts

Minimum Flying Height AGL: 200 m

Maximum Altitude AMSL: 6000 m

☐ Allowed worst case Accuracy XY: 0.05 m Z: 0.05 m

☒ Use MPIA Effective Pulse Rate: 228800 Hz ☒ Auto Adjust

Scan Rate: 36.6 Hz

Scan Pattern: Triangle

☒ Auto Adjust for: Square Spacing Across/Along Track Ratio: 1.00

Max Along Track Spacing: 1.00 m Max Across Track Spacing: 1.00 m

Desired average point density: 1.00 pts/m²

Pulse rate 228.8 kHz Laser power 100 % MPIA ☒

Scan rate Commanded 36.6 Hz Maximum 53.4 Hz

Field of View 40 ° Scan pattern Triangle

Gain settings 3 3

Ground speed 160 kts / 296 km/h

Full swath width 1747 m / 1.18 mi

Average point density 1.6 pts/m²

Nadir point density 1.6 pts/m²

Max. point spacing along track 1.12 m 3.69 ft

Max. point spacing 1.13 m across track 3.71 ft

Average point spacing 0.8 m / 2.6 ft

Altitude AMSL 2400 m / 7874 ft

Minimum range gate 1502 m / 4929 ft

Eyesafe naked eye 125 m / 409 ft

Eyesafe binocular 805 m / 2640 ft

Flying height AGL 2400 m / 7874 ft

Terrain height 0 m / 0 ft

Maximum range gate 2600 m / 8529 ft

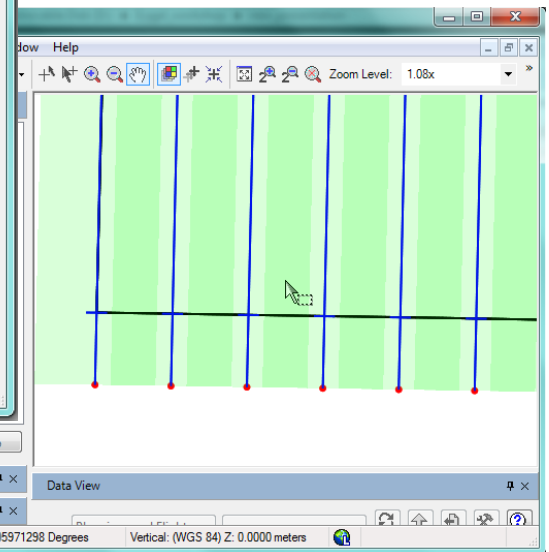
Sea level 0 m / 0 ft

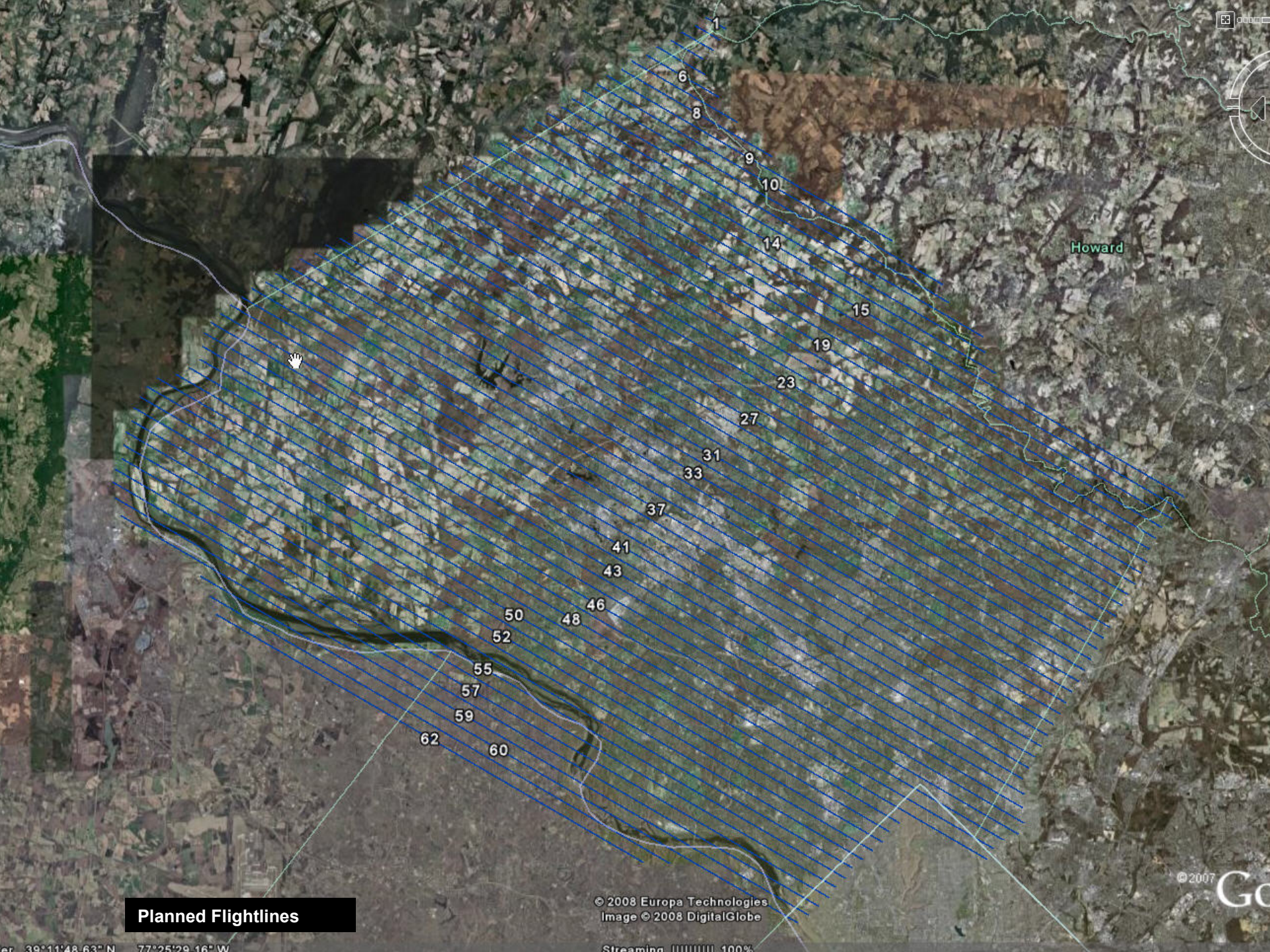
Height Range 898 m 2945 ft

Output

Description	Computed	Target	Unit
Range margin above hills	897.72		m
Range margin below valleys	42.80		m
Recommended Laser Power	100		%
Coverage			
Full Swath Width	1747.06		m
Coverage Rate (No line optimization)	469.83		km ² /h
Recommended Line Spacing (No DTM)	1585.56		m
Minimum Sidelap (No DTM, lower)	9.24		%
Minimum Sidelap (upper)	9.24		%
Point Spacing and Density			
Maximum Point Spacing Across Track	1.13		m
Maximum Point Spacing Along Track	1.12		m
Across Track/Along Track Ratio	1.01	1.00	
Average Point Density	1.6	1.0	pts / m ²
Average Point Spacing	0.79		m
Nadir Point Density	1.6		pts / m ²

OK Cancel Compute Help About...





Planned Flightlines

© 2008 Europa Technologies
Image © 2008 DigitalGlobe

Streaming 100%

39°11'48.63" N 77°25'29.16" W

LiDAR Accuracy

Things to Consider

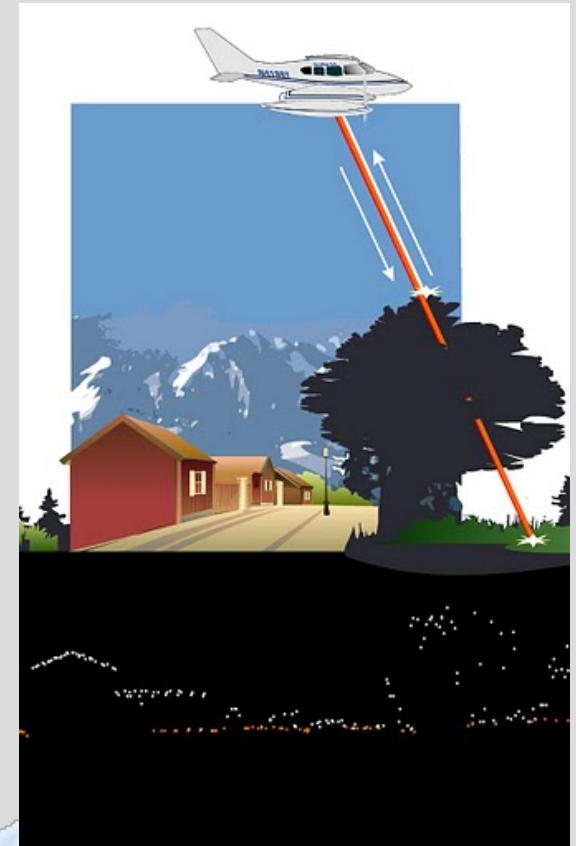
Accuracy is dependent on:

- Flying height
- Sensor parameters
 - Rep Rate
 - **Scan Angle – 40 degree of scan angle?**
 - Scan frequency
- System accuracy
- Terrain
- Vegetation
- Baseline distance
 - Location of base station to Aircraft



LiDAR Project Planning

- Day or Night
 - Safety considerations
- Leaf on or Leaf off
 - Application dependent
- Summer, Spring, Fall, or Winter
 - Most collects done in the spring and fall
 - Summer collects take place for special applications such as forestry
 - Winter collects based on geographic location
- Weather
- Smoke

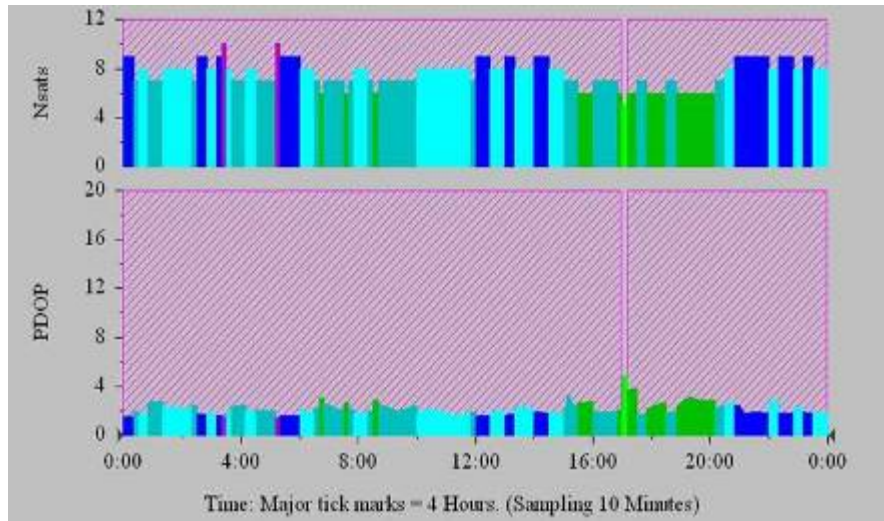


Establishing Control

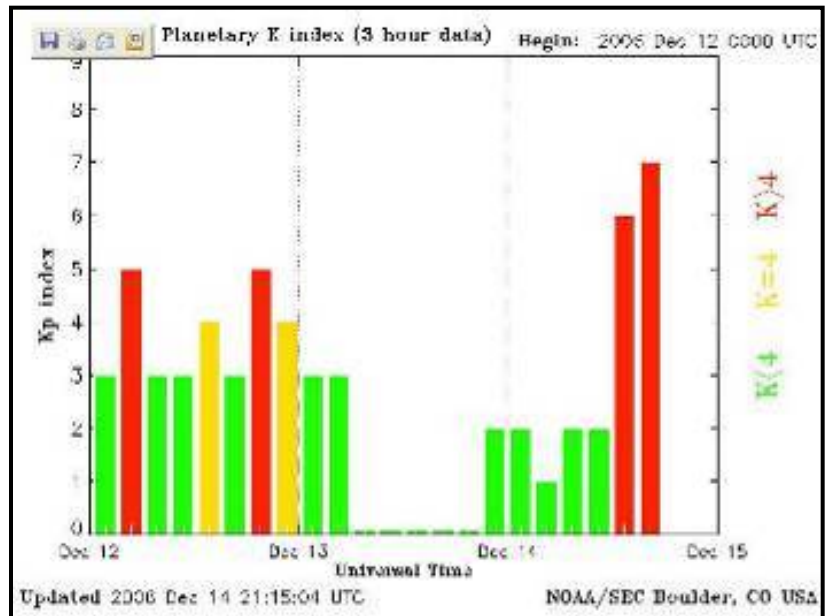
- Establish control for entire mapping program prior to collection using a minimum of two Horizontal and/or CORS stations and a minimum of three Vertical Bench Marks
- Perform Fully Constrained Network Adjustment
- Apply ITRF corrections to published or as applicable
- Adjustment supports a mapping operation not a survey
- Provide adjustment to all LiDAR providers involved in the program



PDOP and KP-Index

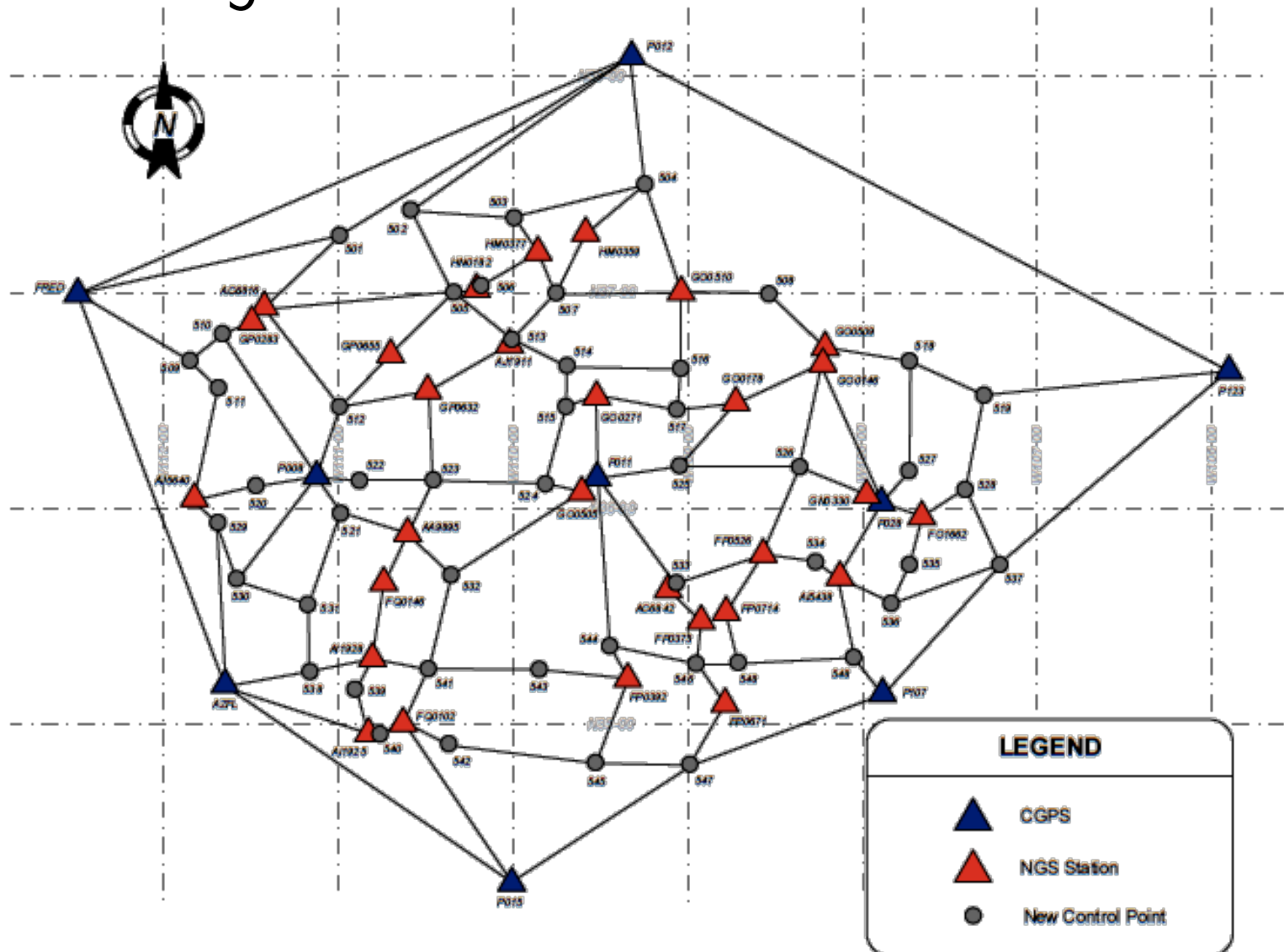


PDOP and # of Satellites

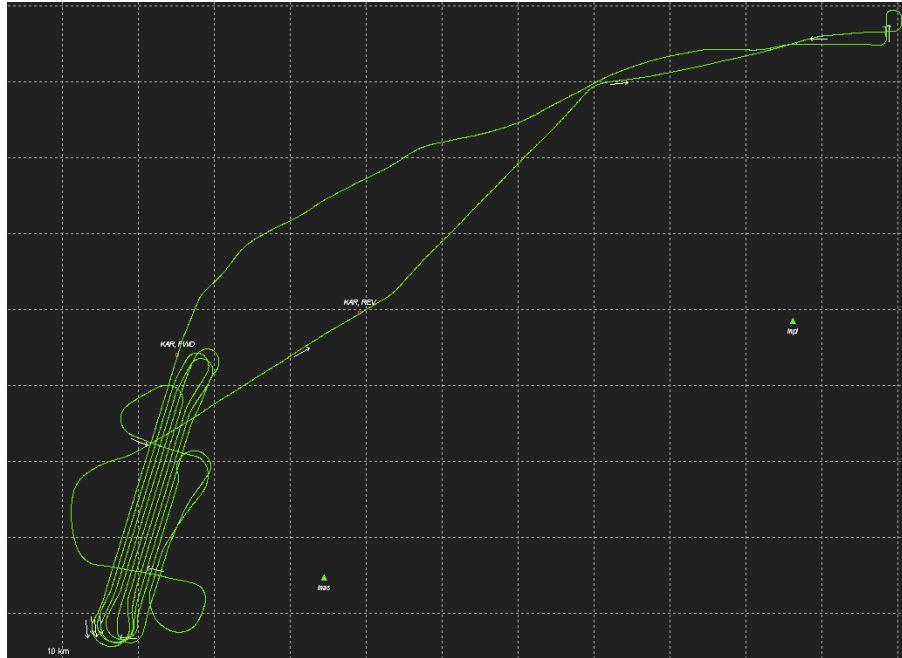


KP-index is a measure of the Geomagnetic activity from the Sun on the earth's atmosphere

Establishing Control

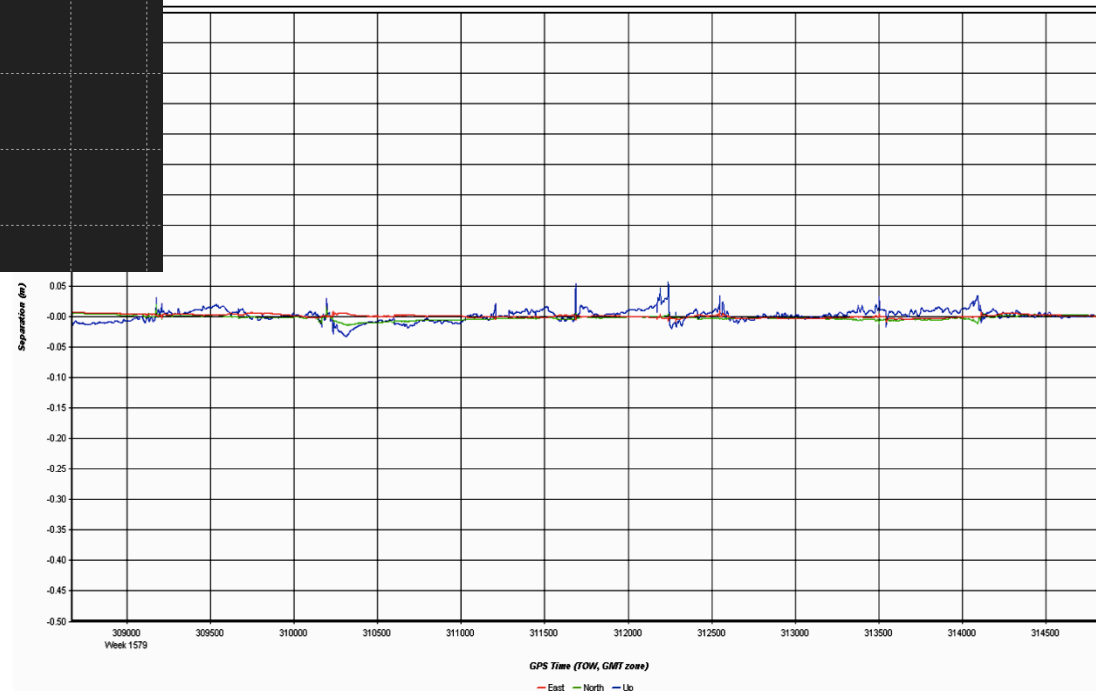


GPS

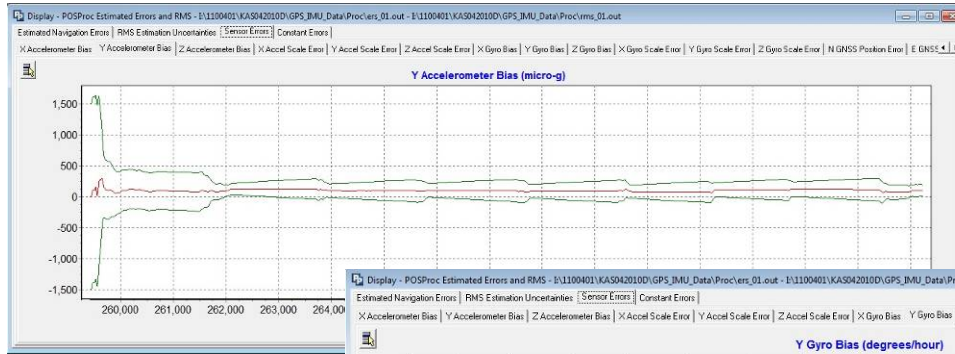


- Static initialization at start
- Static session at end
- PDOP less than 3

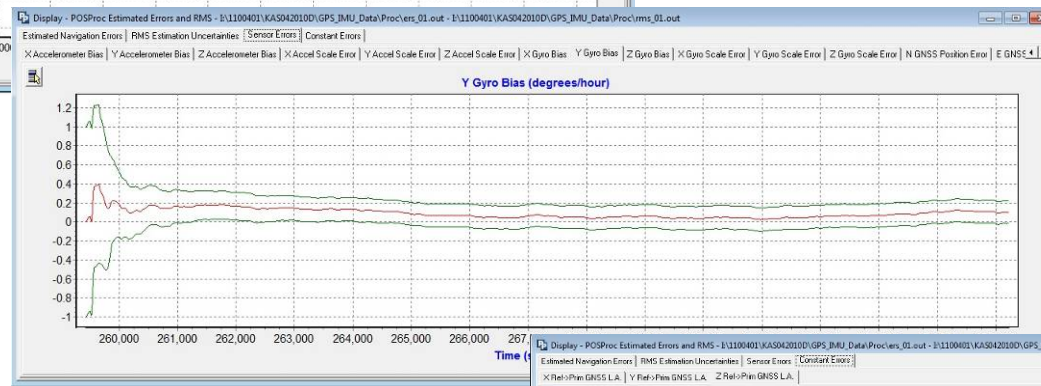
- Processing is easier
- Achieve under 5 cm combined solution



IMU data

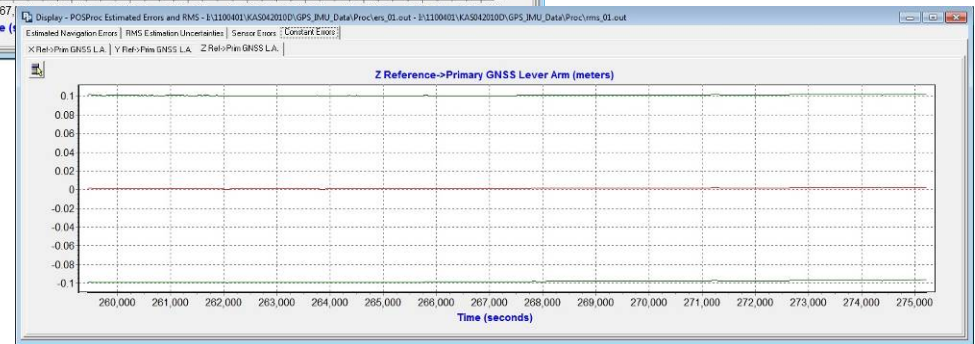


Accelerometer

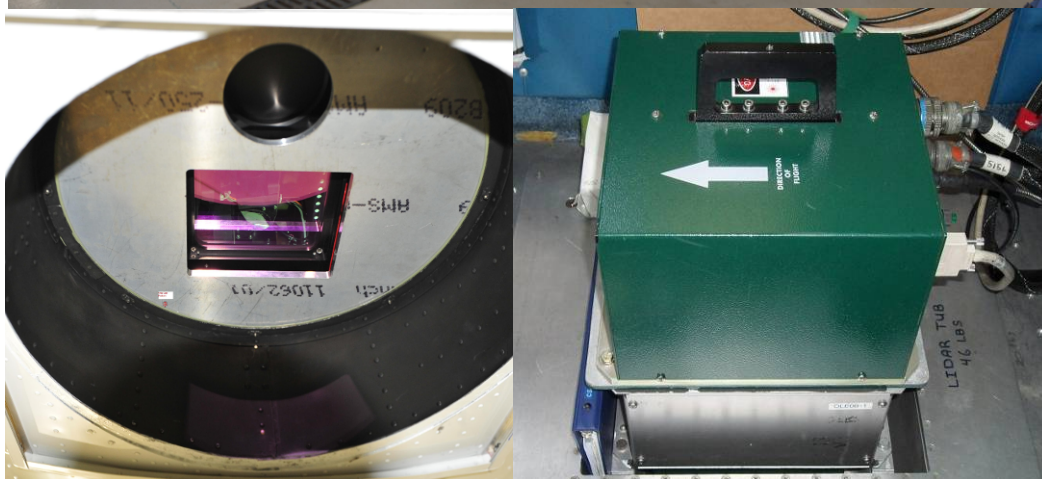


Gyro

Lever arms

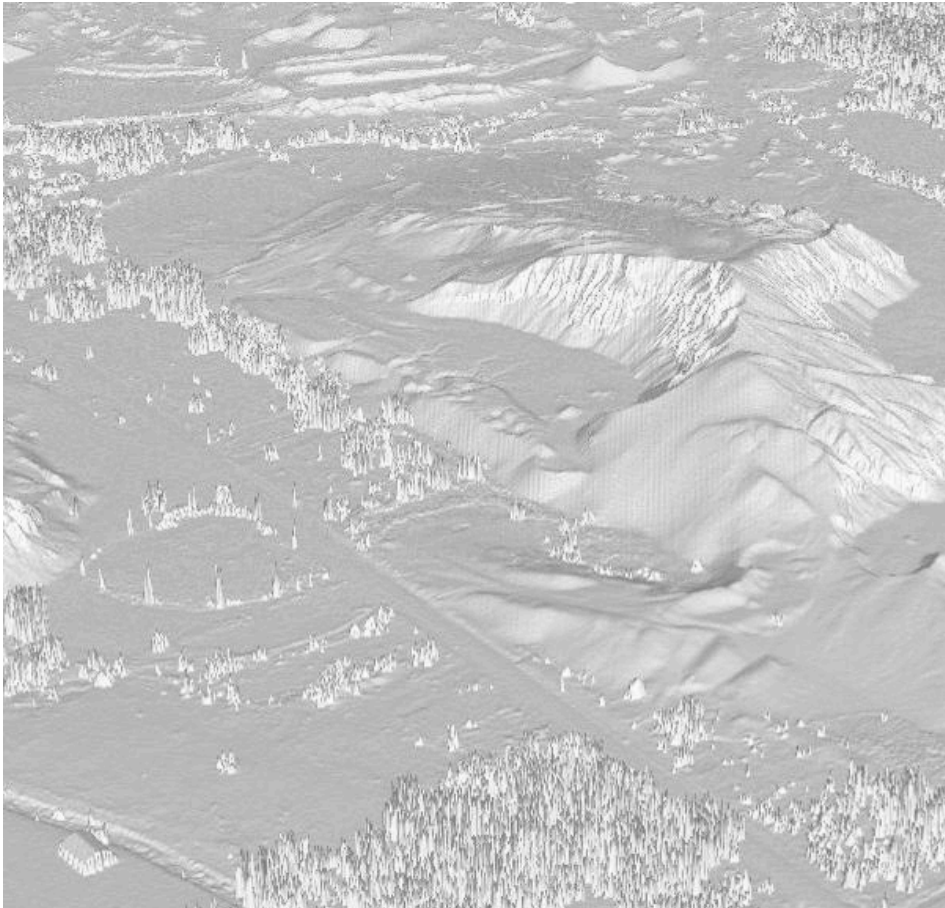


Lidar Calibration - Critically Important



- Optech, Reigl, Leica and Trimble have calibration procedures
- Proprietary sensors have custom procedures
- Proper installation and lever arm
- Survey standardization
 - GPS survey of antenna
 - Total station survey of antenna
 - PosPAC location of antenna

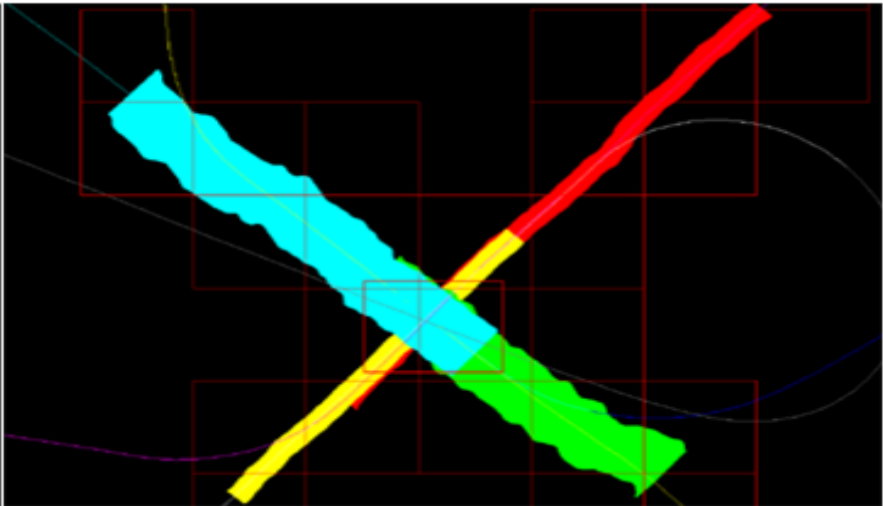
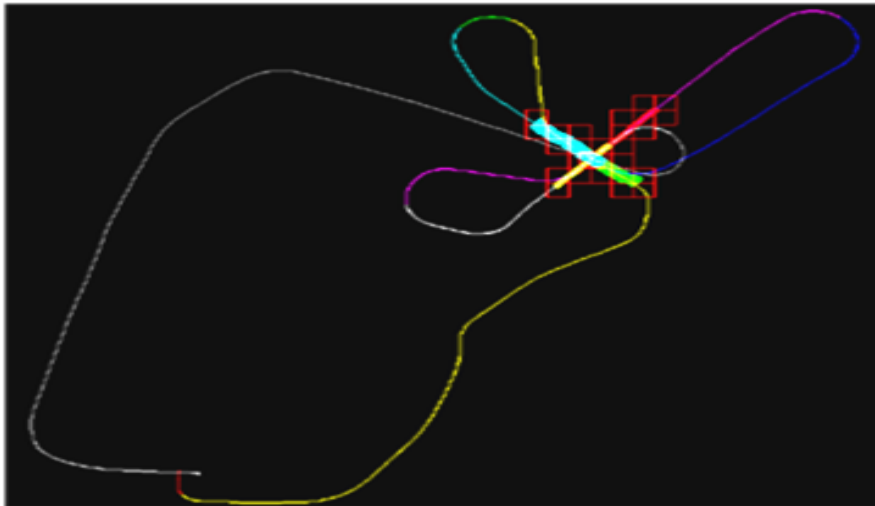
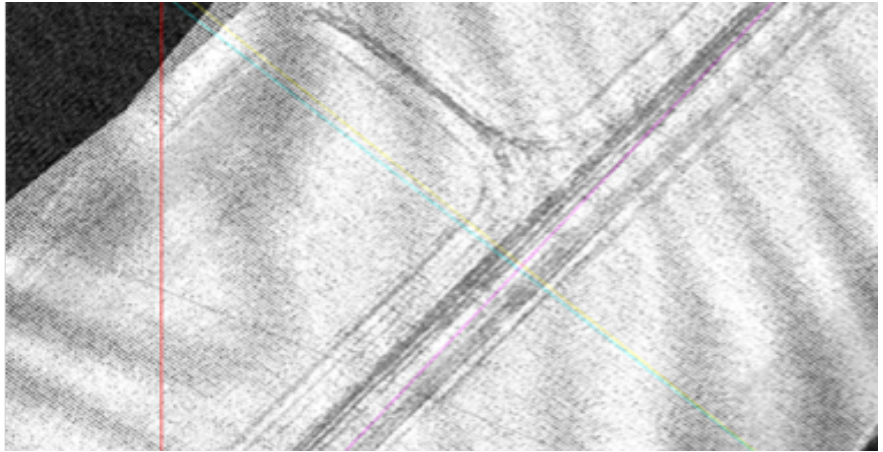
Lidar Calibration: Why Is It Important?



- Calibration after every installation
 - Required to make sure the system is operating correctly
- Calibration every mission
 - Provides necessary information in case of unforeseen occurrences
 - Fly a minimum of 1 perpendicular line to flight lines collected for that mission
 - Ensure ability to correct for roll, pitch, heading, scan scale and other potential biases
- 90% of problems are a result of improper installation

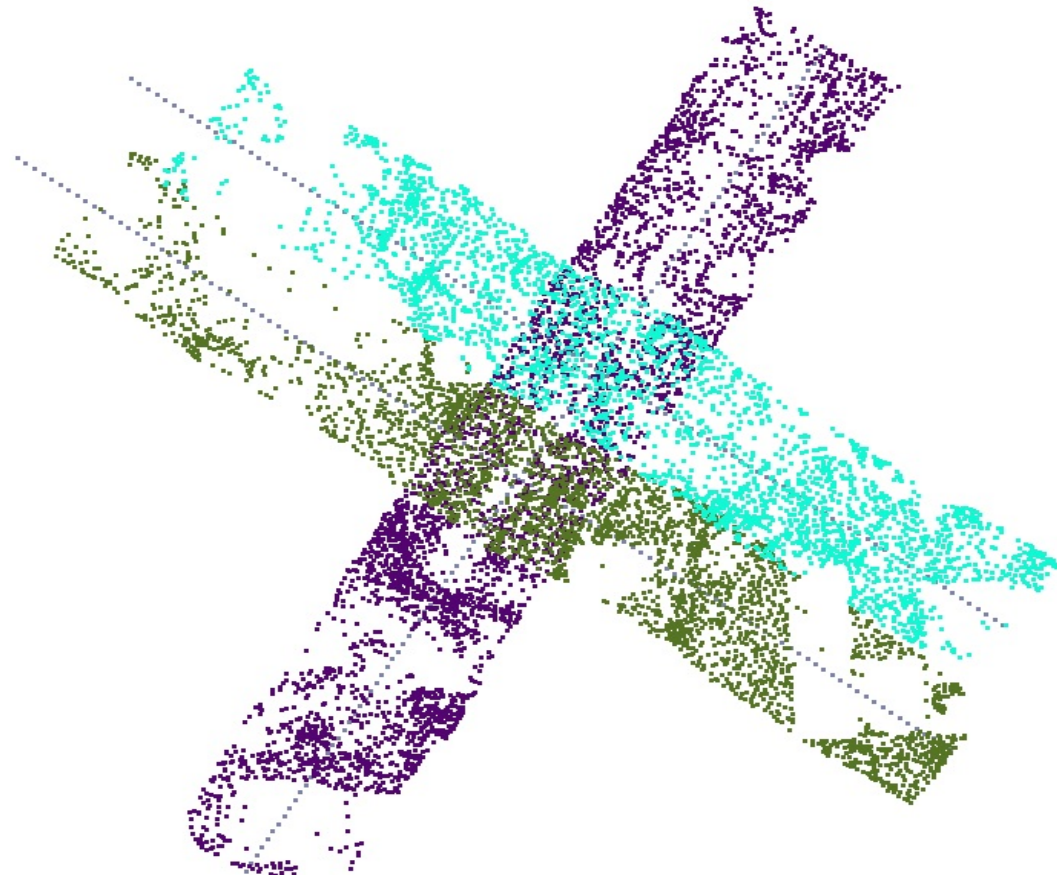
Lidar Calibration

- Flying lines perpendicular
- Flying lines parallel
- Calibration every mission



Planar Surface

Calibration process finds planar surfaces



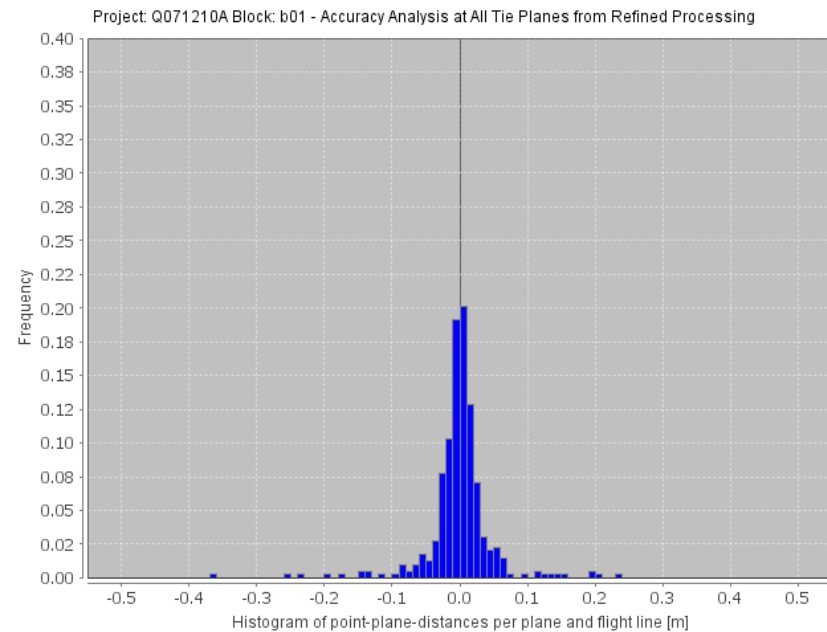
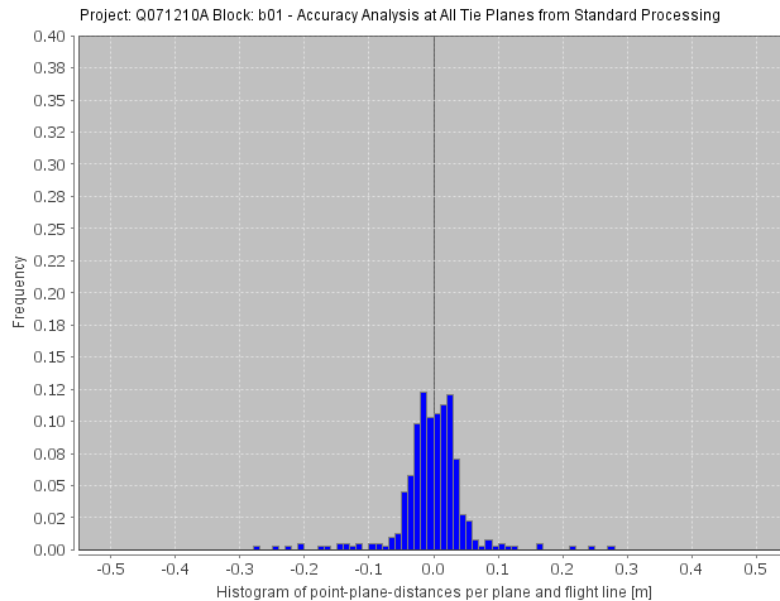
Lidar Calibration

- Flying a cross flight during collection

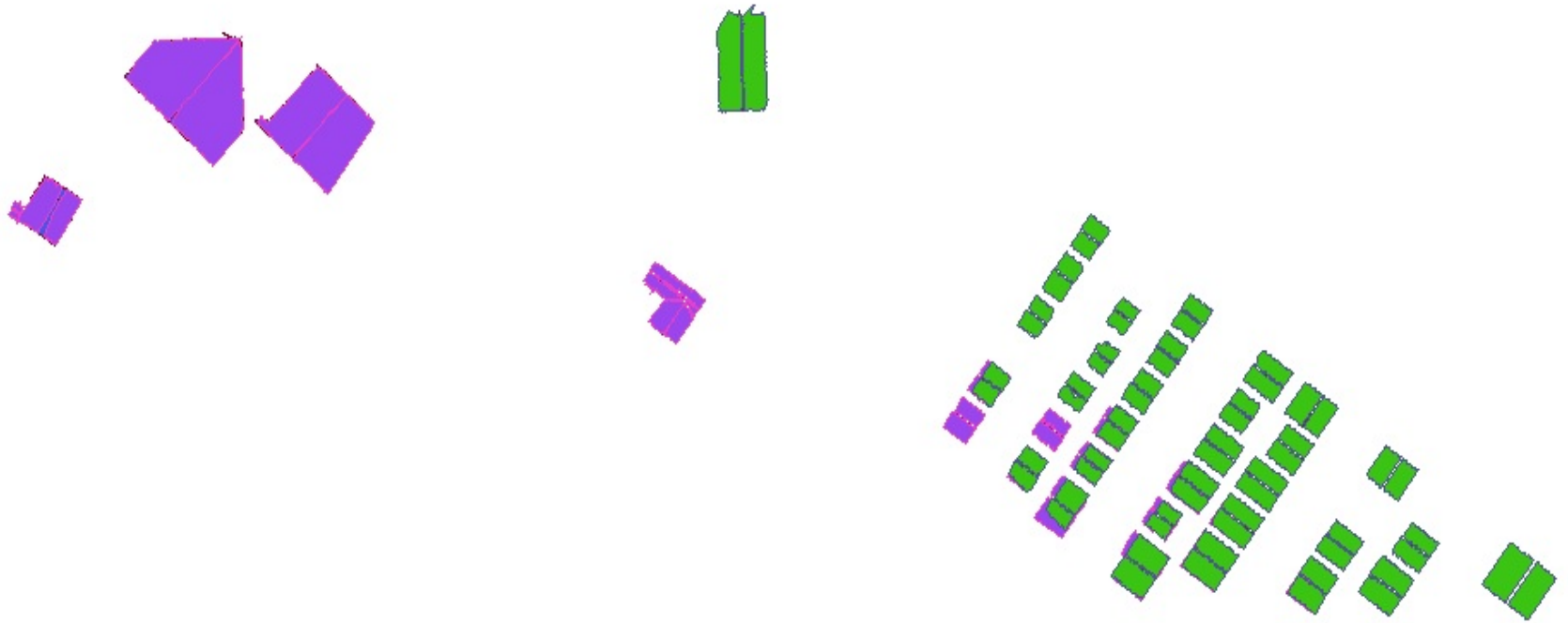


The Plane Results

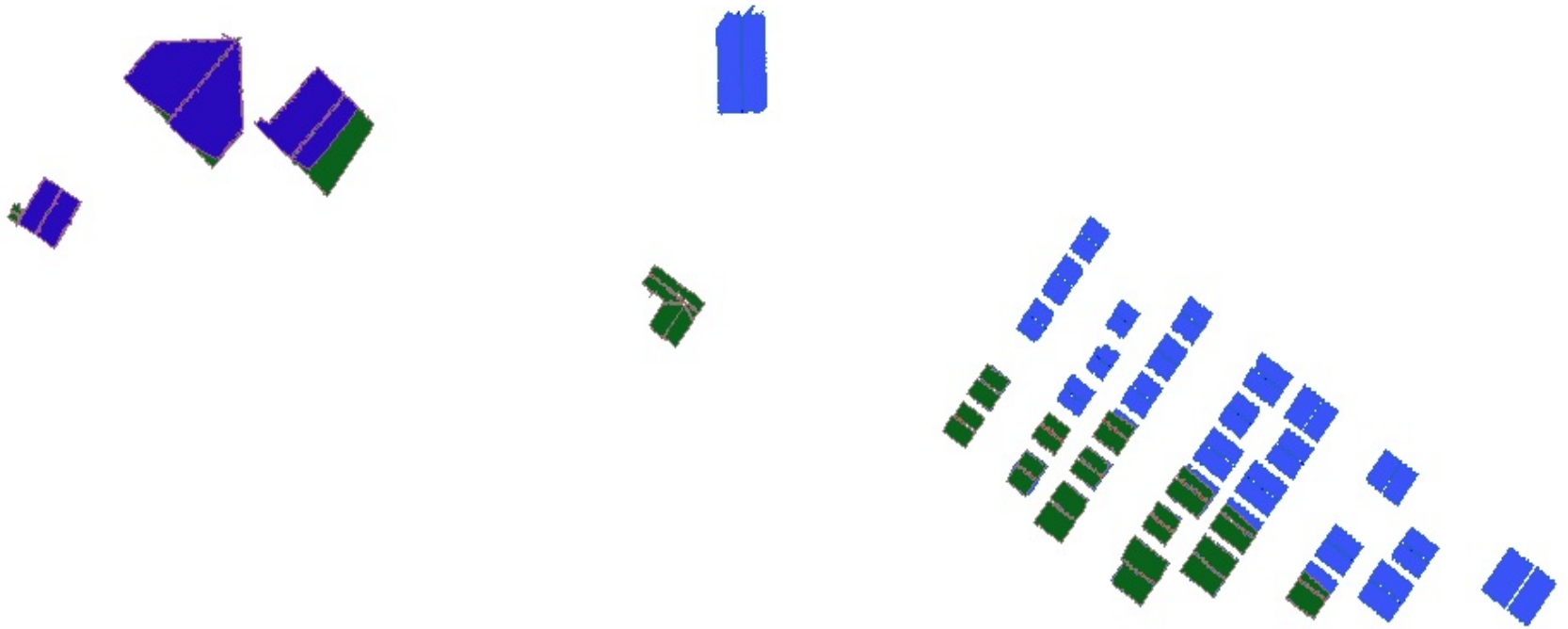
Graphically speaking



Roof Line Correction

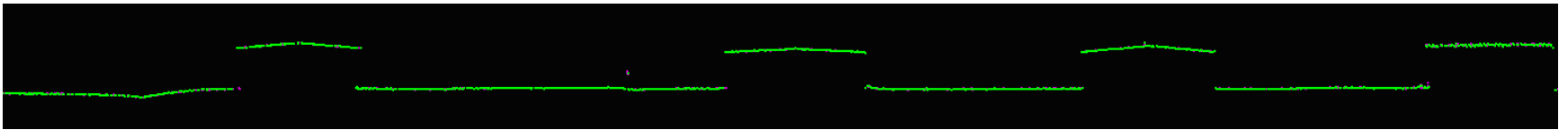


Roof Line Correction

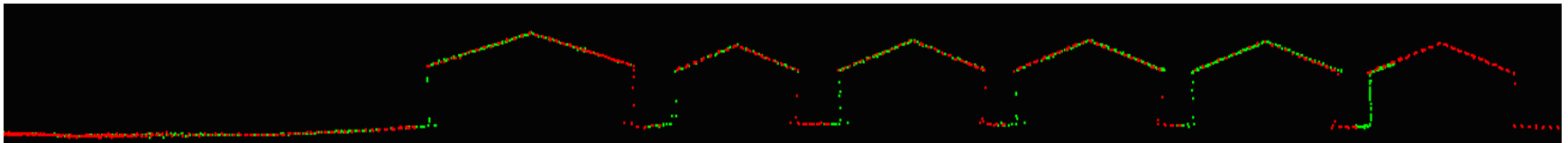


Roof Line Correction

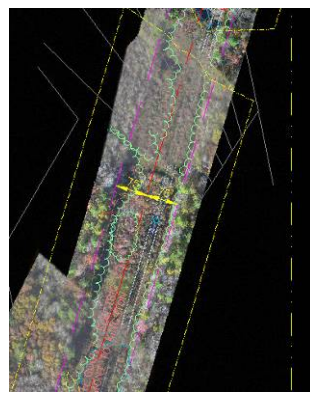
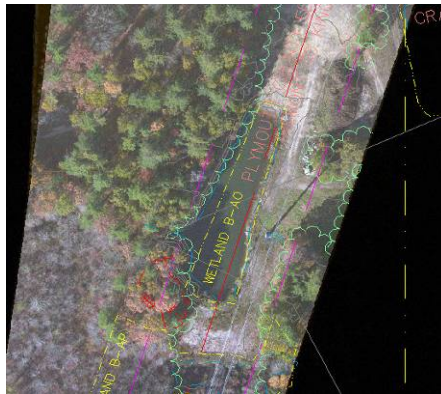
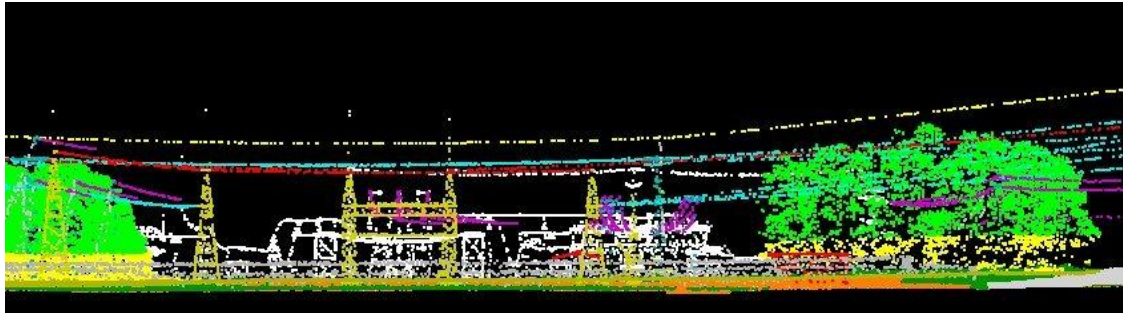
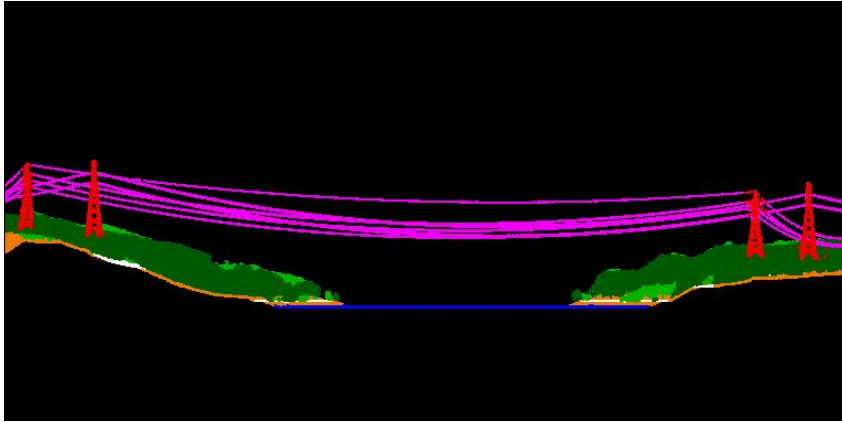
Profile of perpendicular lines at edge of scan on E-W line



Profile of parallel lines at edge of scan



Helicopter LiDAR



Collection rates (Helicopter)

- Collect 80-160 linear kilometers a day
- Flying Height is 120 to 230 meters
- Used mostly for corridor mapping
 - Transmission mapping
 - Roadway mapping
 - Pipeline mapping
- 20 – 40 PPM



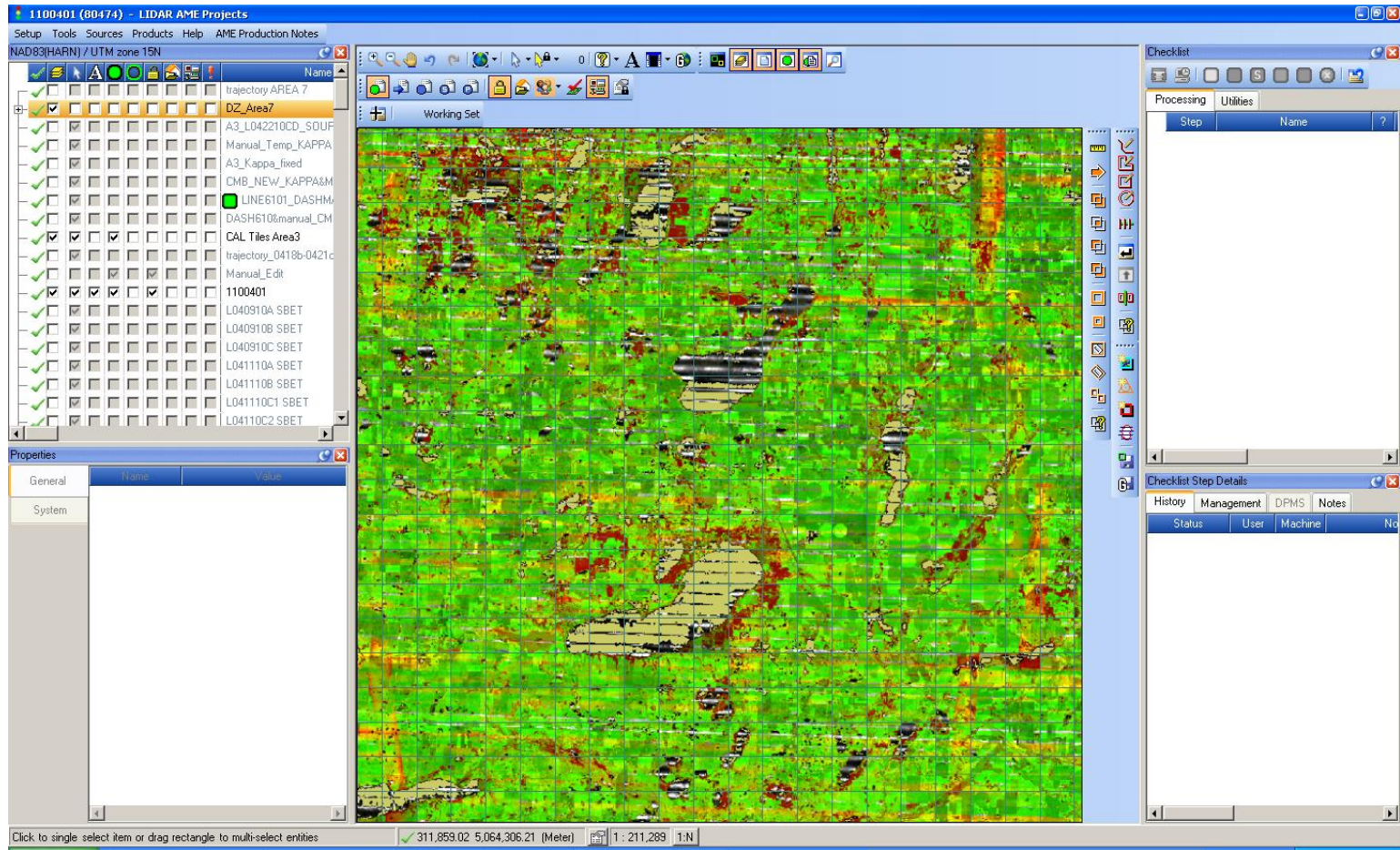
Multi-Sensor configurations

- Ortho- Applanix DSS or Leica RCD30 Digital Camera
- Multi-Spectral and Hyper-Spectral
- Video -FLIR ULTRA MEDIA II 36X RGB
- Nikon D-200 (10.3 megapixel) digital camera
 - GPS referencing
- LiDAR Sensors
 - Low Altitude
 - High Altitude
 - Both?



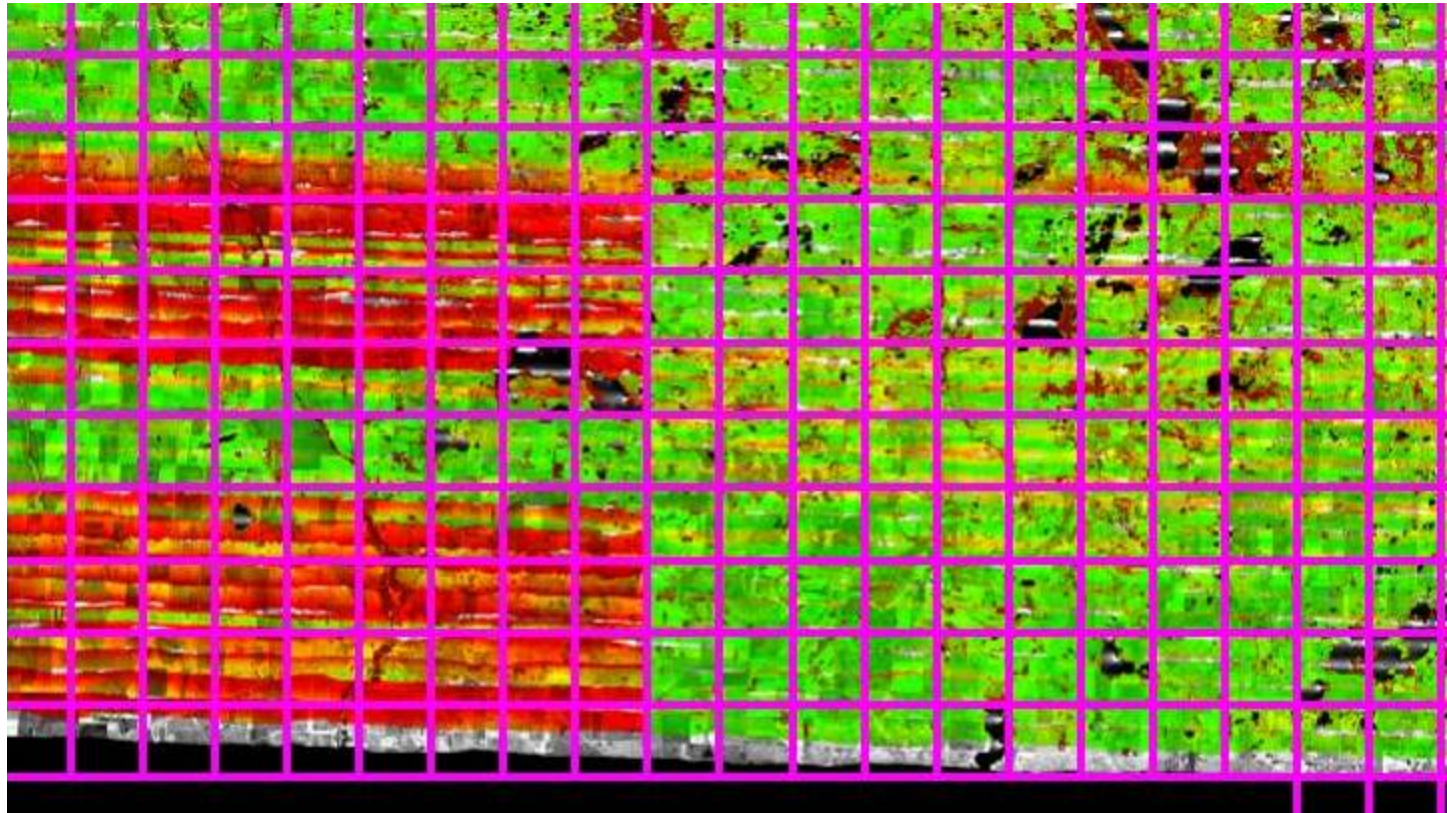
Checking Calibration

DZ ortho from several missions



Checking Calibration

Differences between bad calibration and correct calibration



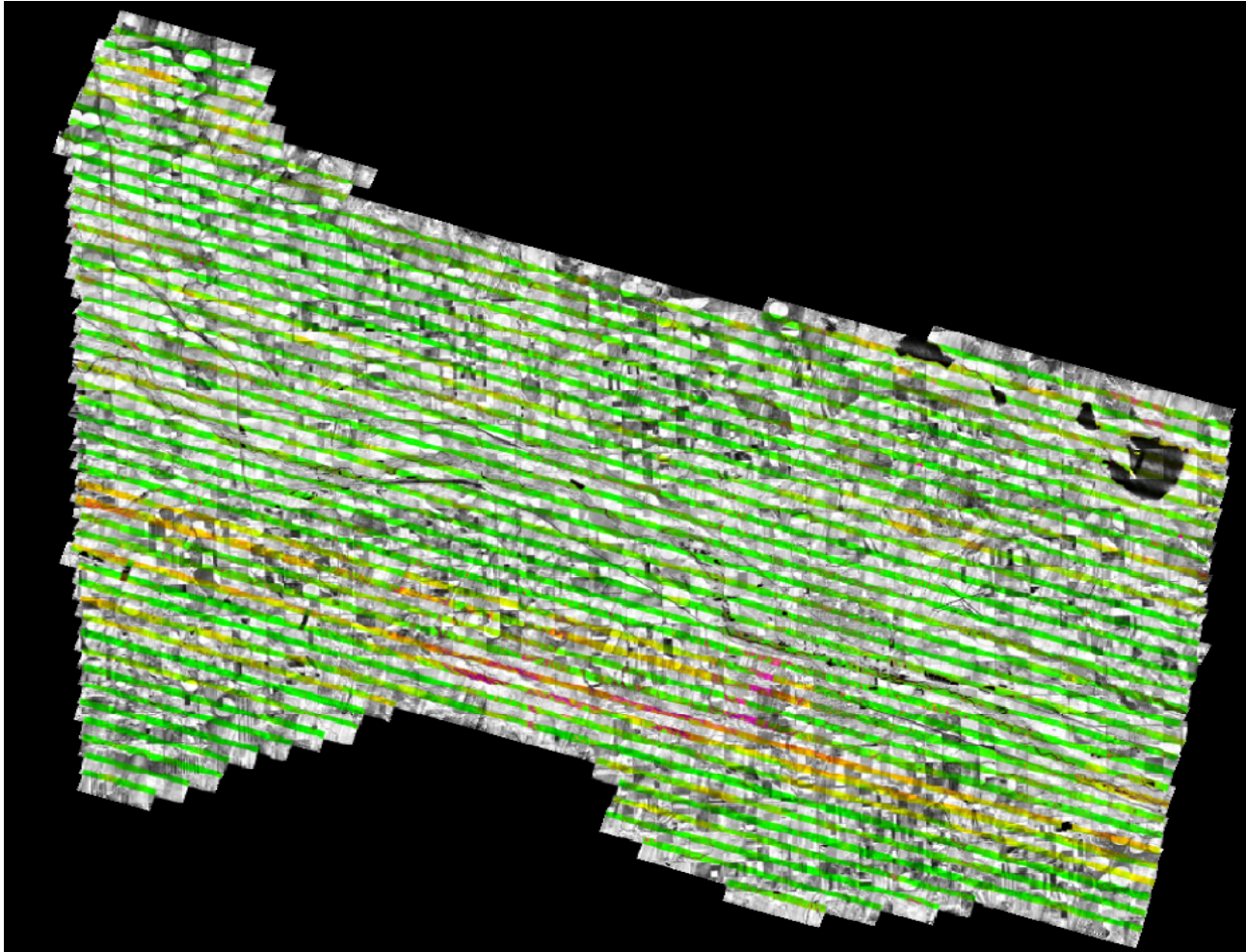
Unresolved Area

Resolved Area

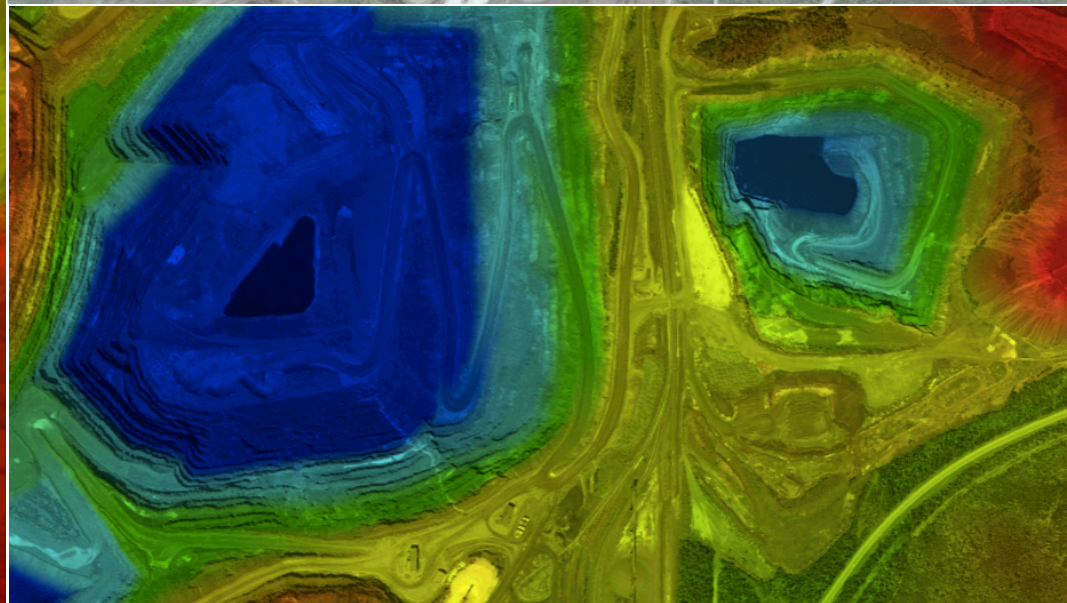
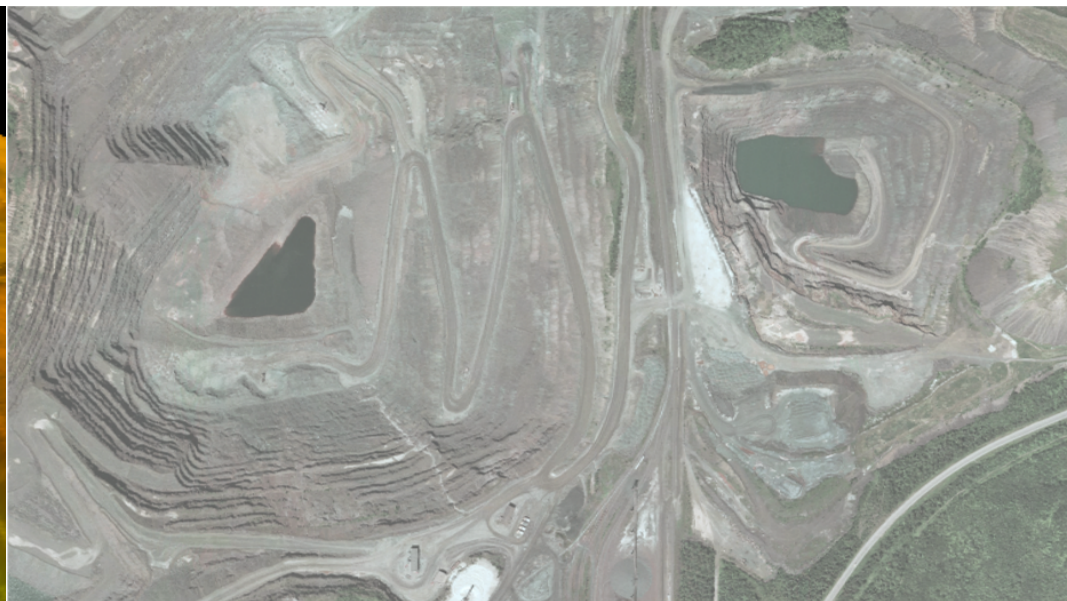
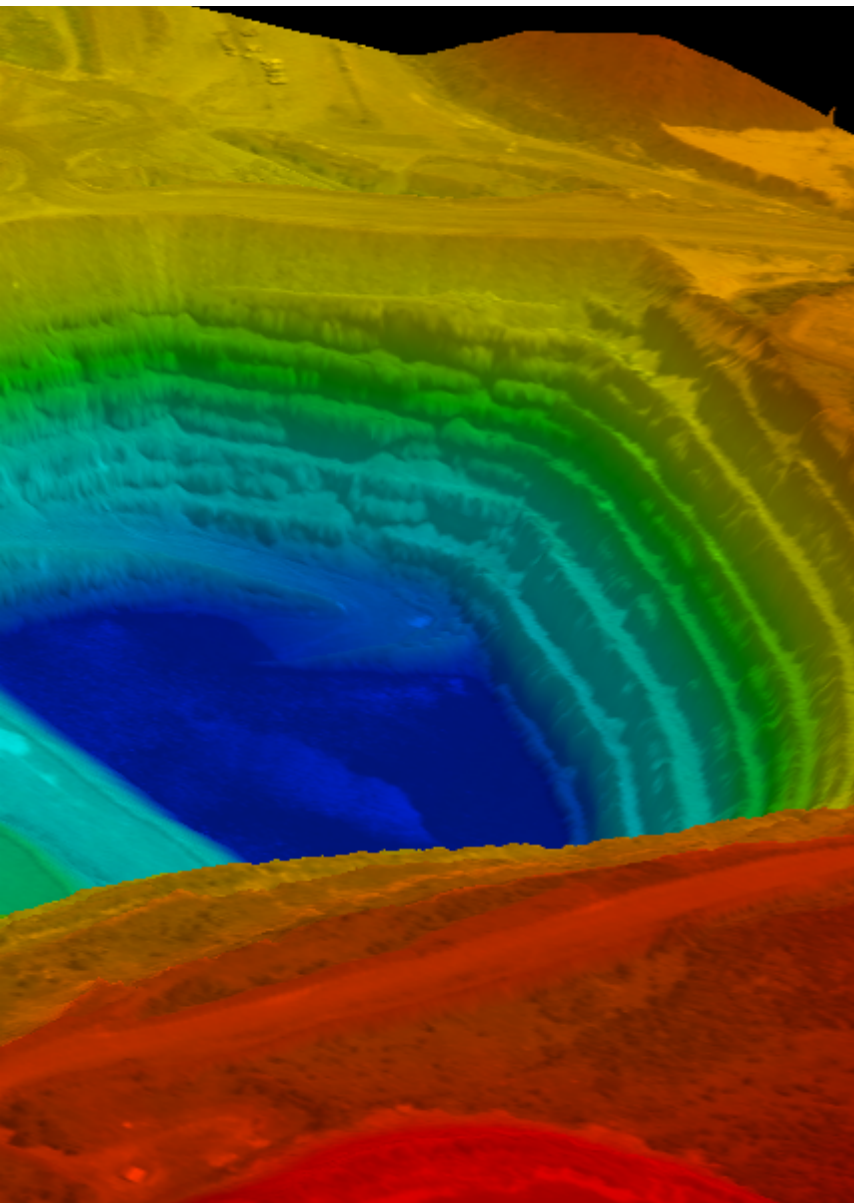


Checking Calibration

4 missions - old calibration method



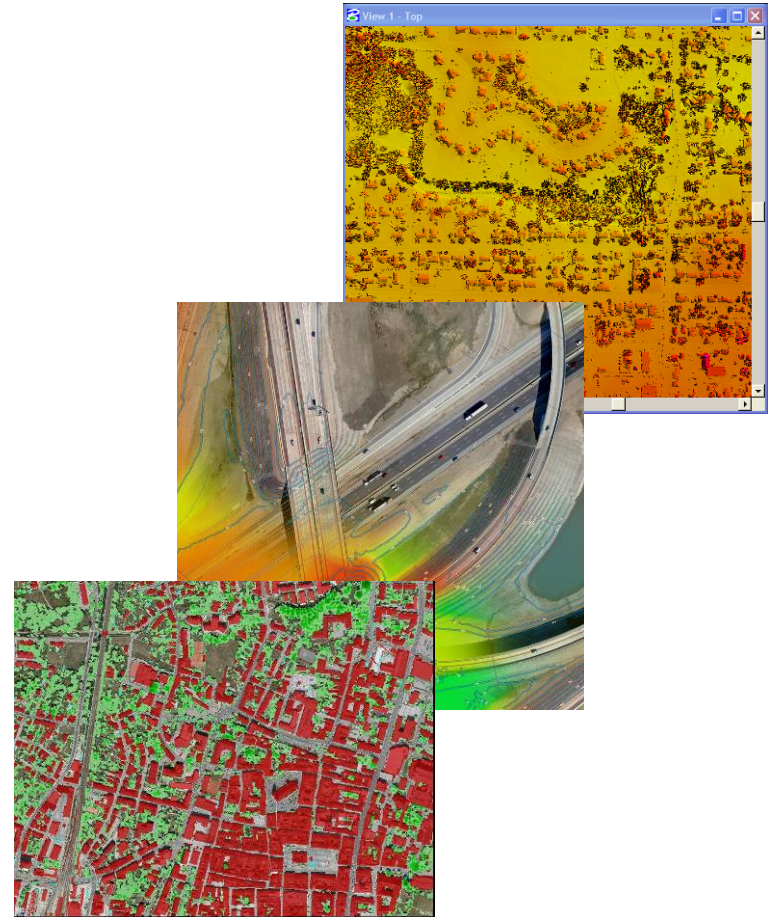
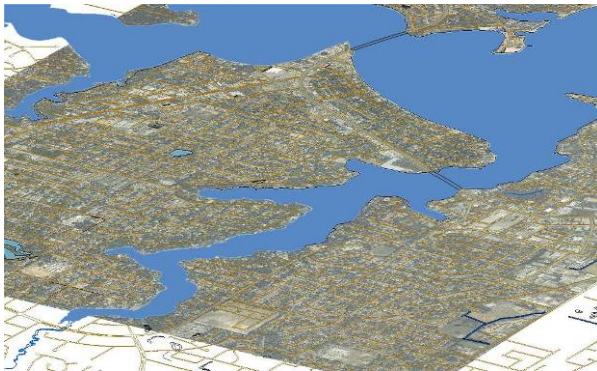
Difficult Collections and Data



Processing Steps

1. GPS Processing
2. IMU Processing
3. Calibration
4. LAS point Cloud Output
5. Classification
6. QC Manual Editing
7. Generation products

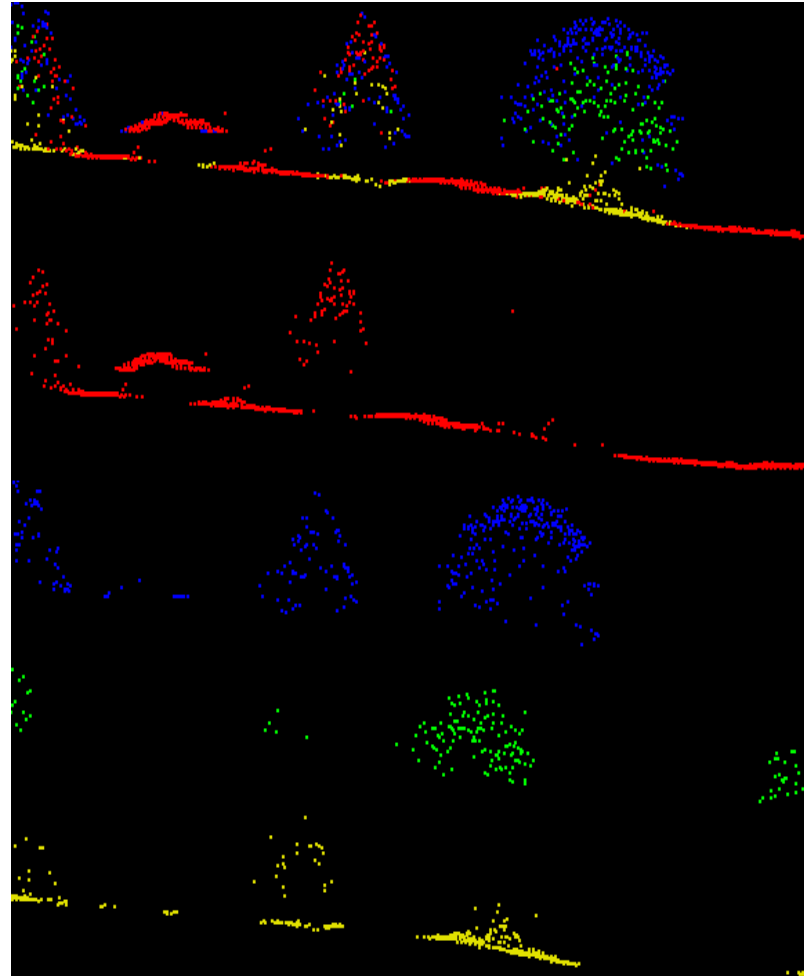
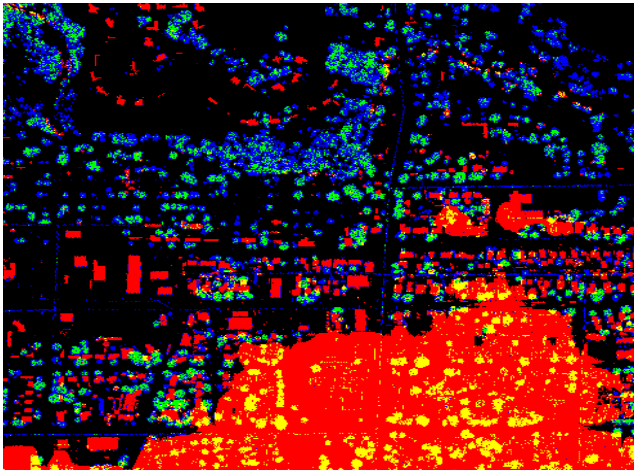
Software Packages?



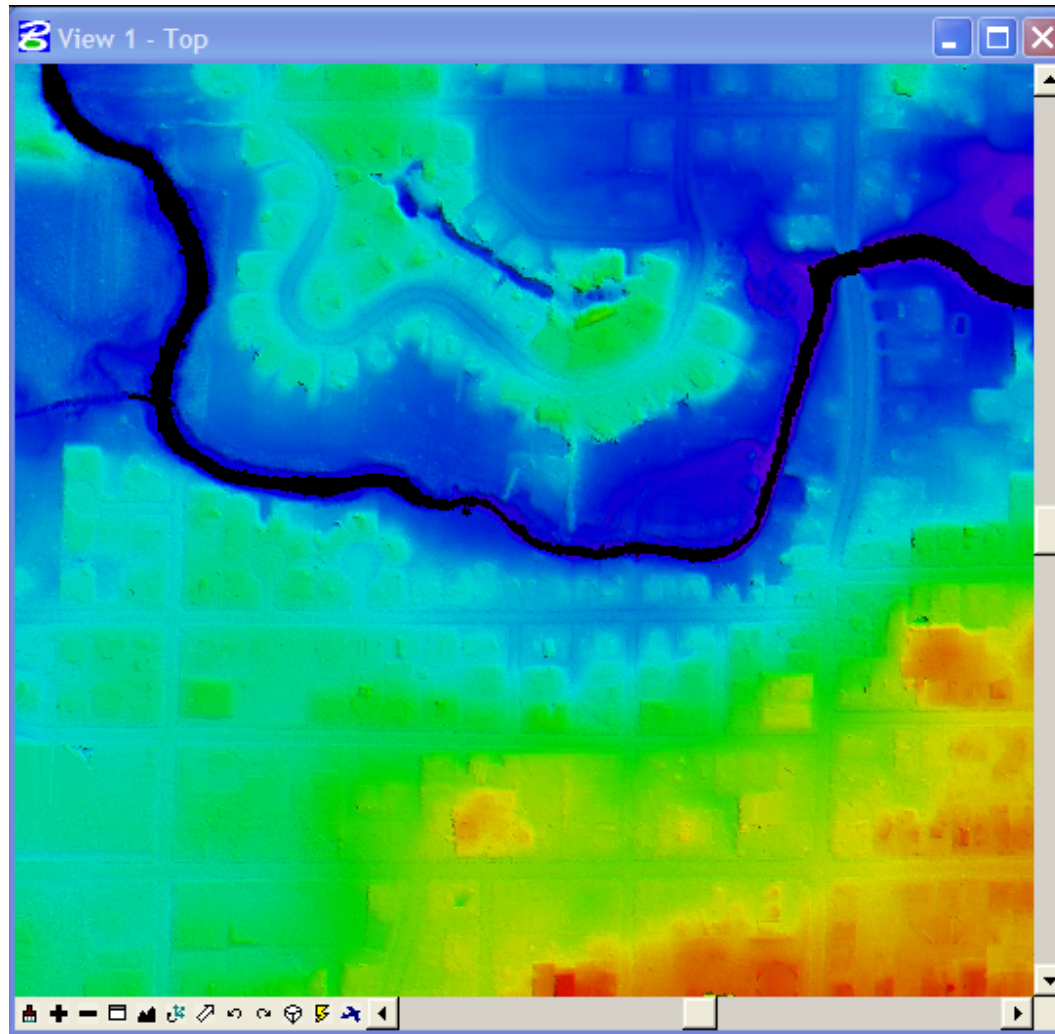
Processing - LiDAR Returns

LiDAR System Returns

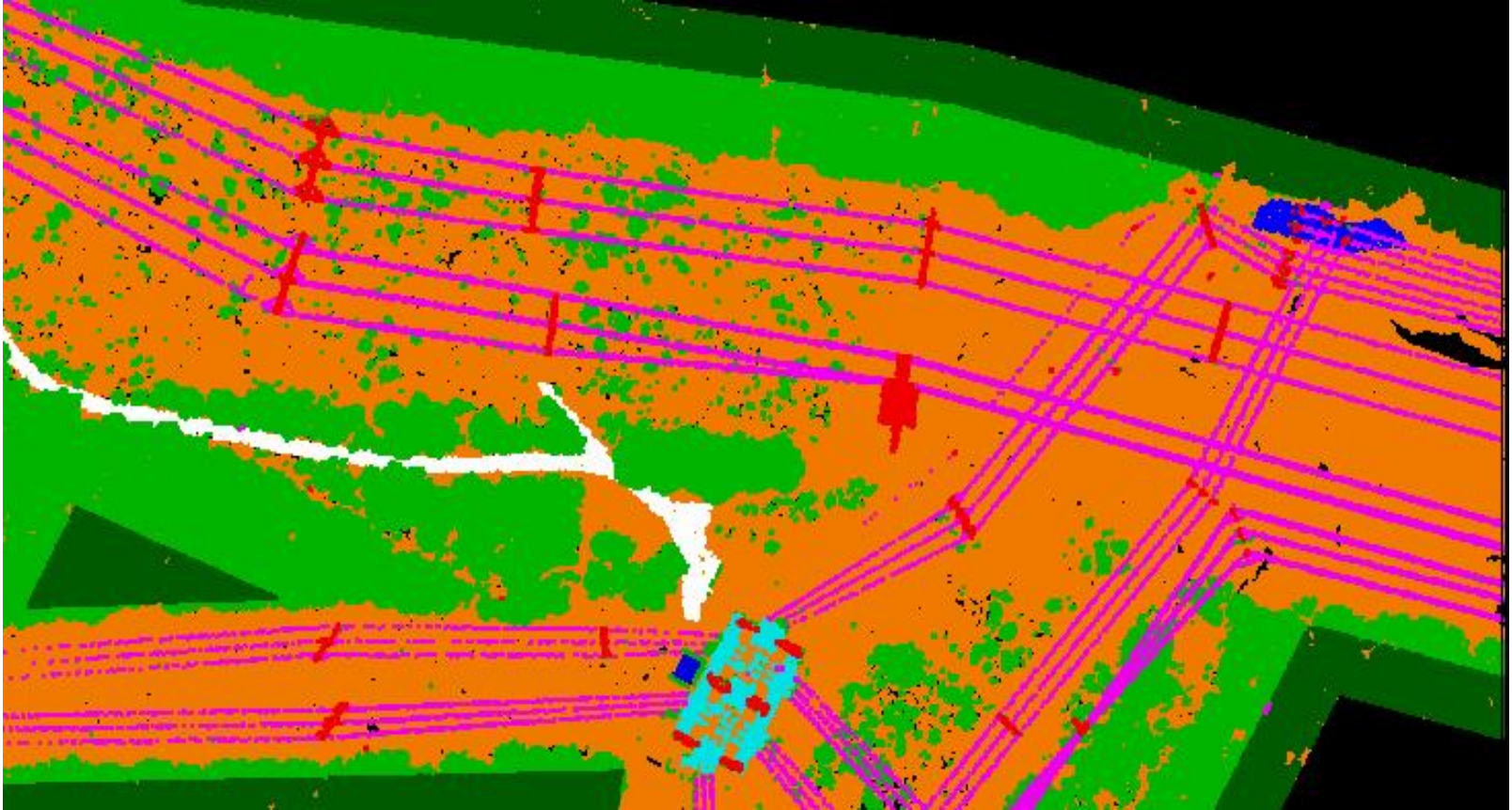
- 1st Return – Red
- 2nd Return – Blue
- 3rd Return – Green
- Last Return – Yellow
- Up to Seven



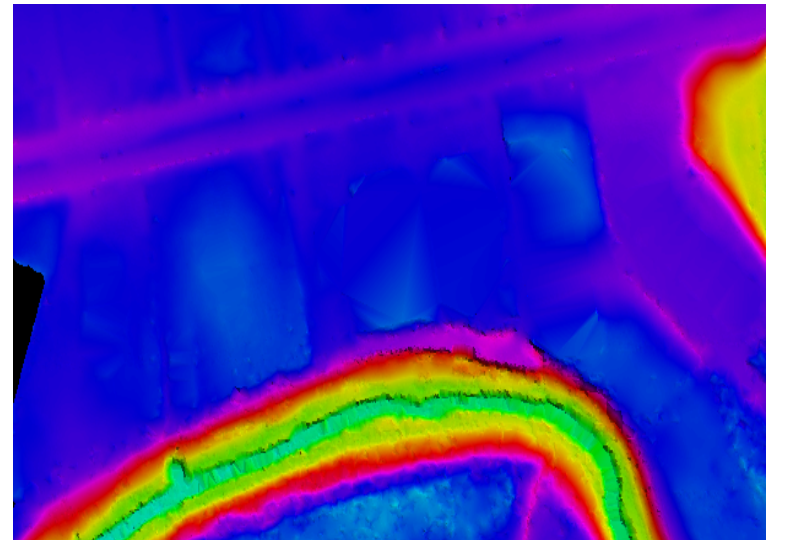
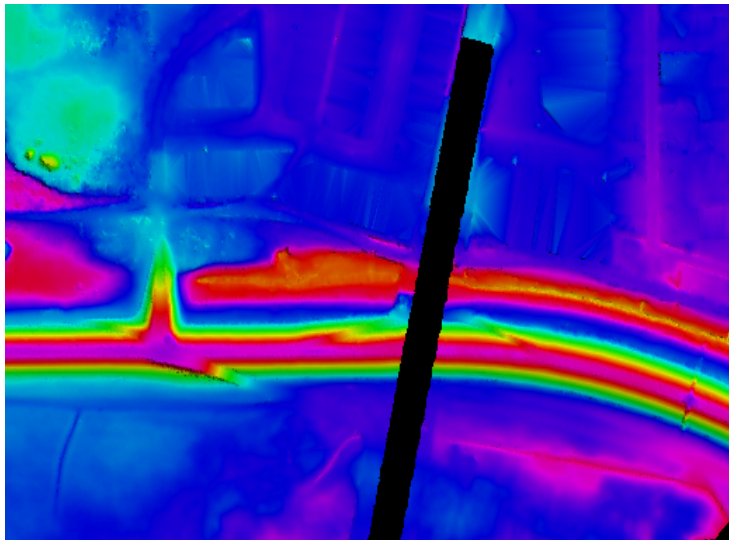
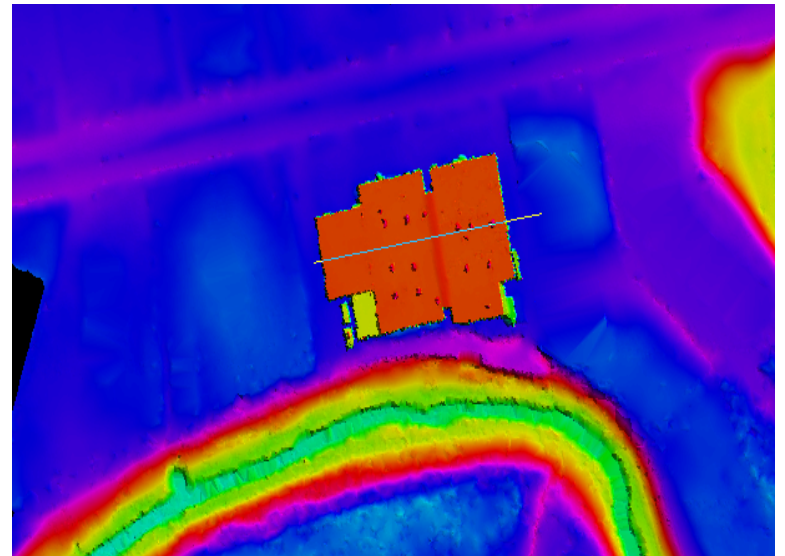
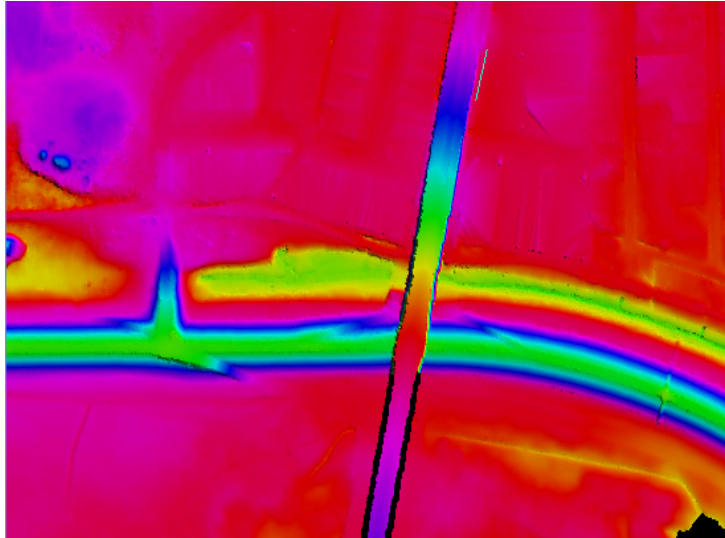
Processing – Bare Earth Model



Processing -Classification



Manual Editing

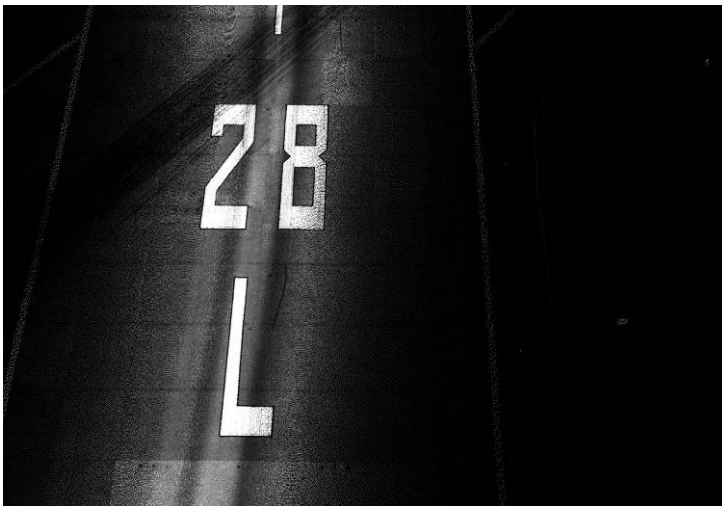


LiDAR Processing

LiDARgrammetry



Point Cloud Data Classified by Intensity



What's Important?

- Relative Accuracy
- Removal of Artifacts and Outliers
 - How do you quantify this?
- Gaps
 - Unacceptable
- Vegetation Removal & Other Classifications
 - How do you quantify this?
- Check Point Verification
- Horizontal Accuracy
- Vertical Accuracy



Check Point Surveys

Five Main Categories

- Hard Surface
- Low Grass
- High Grass
- Brush
- Forest

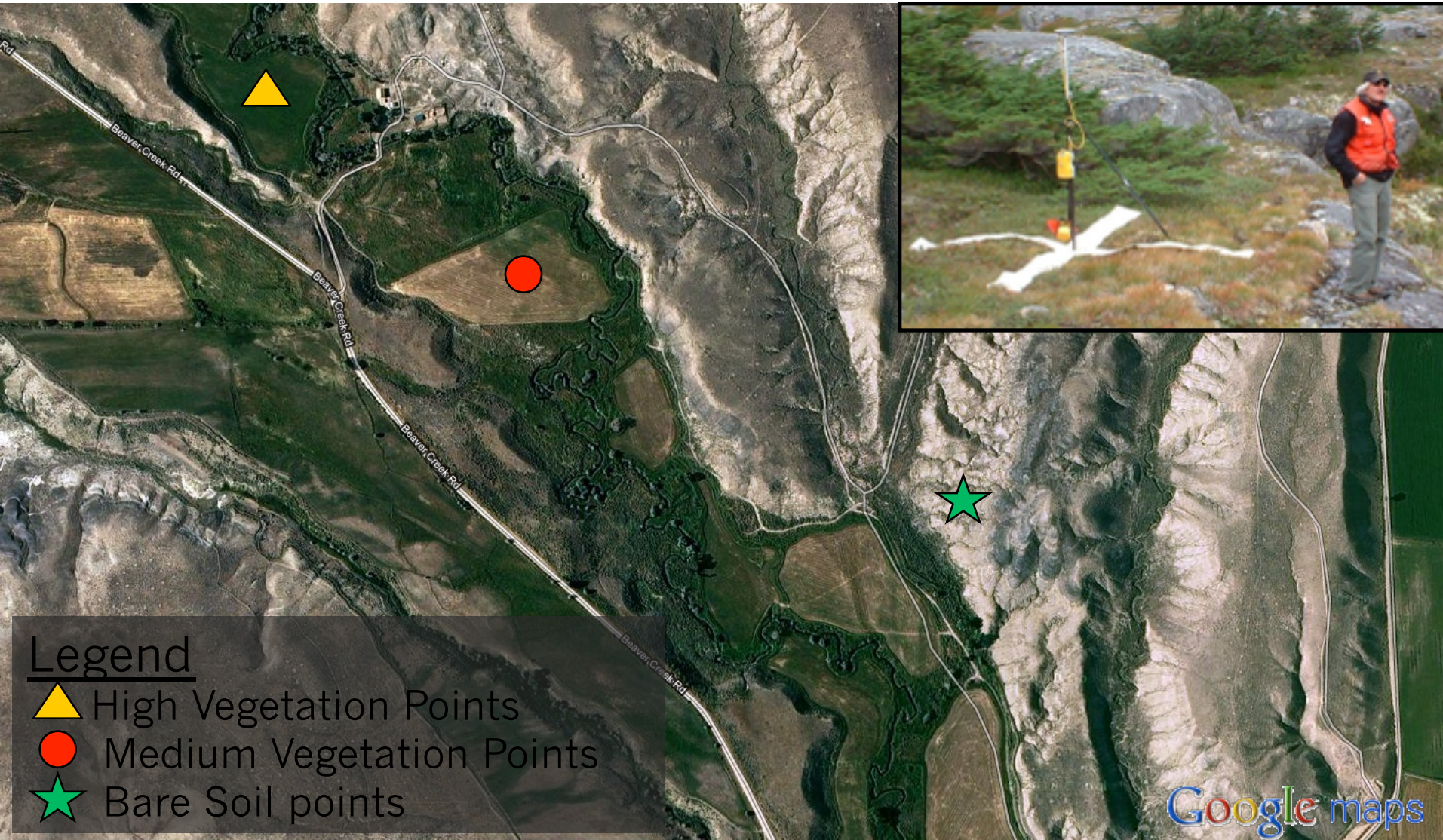
What does this mean?

By region?

Point distribution?



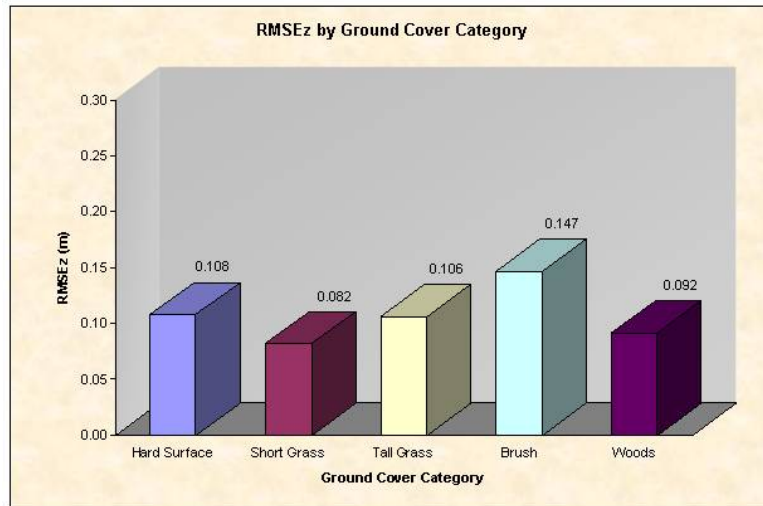
Verification of Point Class



Accuracy

What accuracy do you need?

What are you doing?



Quality Control Report (All Check Points)

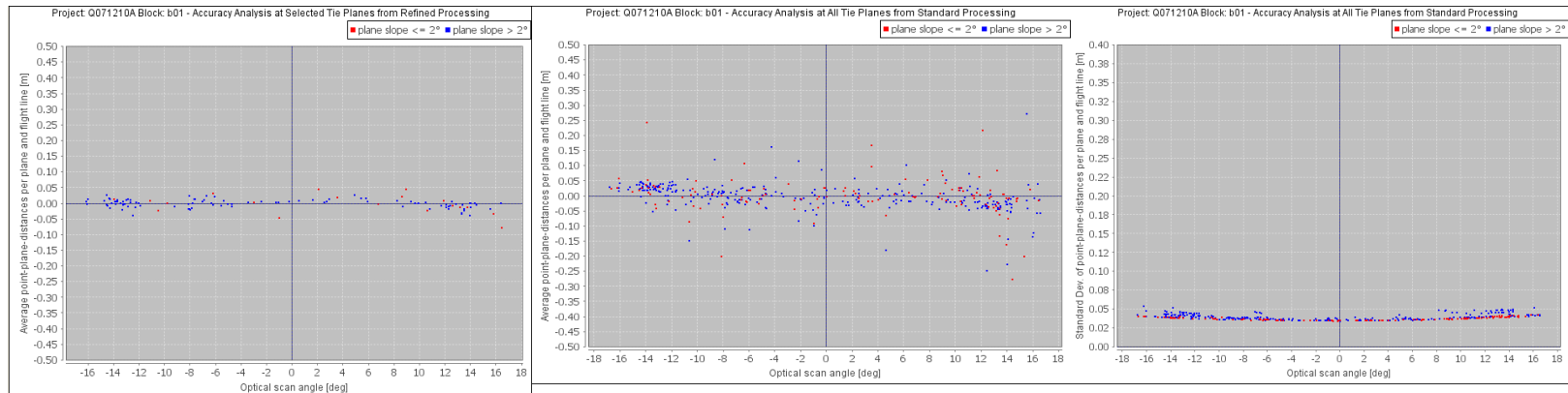
Number	Easting	Northing	Known Z	Laser Z	Dz
100	540834.061	4862280.474	391.901	391.960	+0.059
101	475506.406	4882502.397	339.050	339.040	-0.010
102	485582.255	4867963.234	382.263	382.280	+0.017
103	501136.859	4872590.172	387.736	387.670	-0.066
104	461403.811	4826690.475	390.018	389.940	-0.078
105	463346.842	4822470.654	386.420	386.370	-0.050
106	507098.434	4892184.660	360.016	359.960	-0.056
107	511287.264	4863176.906	409.482	409.580	+0.098
108	534746.004	4832525.284	423.079	423.110	+0.031
109	501478.759	4836597.598	371.967	371.900	-0.067
110	560234.546	4821511.856	403.804	403.800	-0.004
111	573316.951	4836514.746	300.922	300.920	-0.002
112	589012.207	4833472.032	344.679	344.660	-0.019
113	599379.146	4849657.186	223.972	224.120	+0.148

514	521133.612	4866397.838	349.313	349.280	-0.033
515	528133.612	4877670.838	349.313	349.280	-0.033
516	545430.927	4901148.398	331.918	331.850	-0.068
517	454263.775	4829289.264	389.563	389.460	-0.103
518	470432.122	4820366.513	371.156	371.180	+0.024
519	468669.792	4853781.788	390.864	390.870	+0.006
520	484145.763	4877613.129	374.382	374.330	-0.052
521	496331.426	4855544.460	387.599	387.520	-0.079
522	500405.293	4836787.206	373.900	373.820	-0.080
523	523731.851	4840120.258	432.643	432.500	-0.143
524	534834.946	4820643.149	394.806	394.830	+0.024
525	550736.899	4847132.421	373.429	373.370	-0.059
526	557554.021	4827902.532	408.238	408.270	+0.032
527	580423.954	4833713.623	331.643	331.620	-0.023
528	615447.986	4863138.157	408.504	408.540	+0.036
529	565088.237	4855170.949	307.314	307.260	-0.054
530	481512.950	4891211.080	354.386	354.250	-0.136
531	489886.984	4858080.057	388.762	388.780	+0.018
532	493361.018	4839013.965	385.313	385.240	-0.073
533	449990.650	4816486.635	392.661	392.610	-0.051
534	495611.402	4844116.597	392.610	392.430	-0.180

Average dz +0.001
Minimum dz -0.222
Maximum dz +0.526
Average magnitude 0.082
Root mean square 0.109
Std deviation 0.109

Typically Speaking?

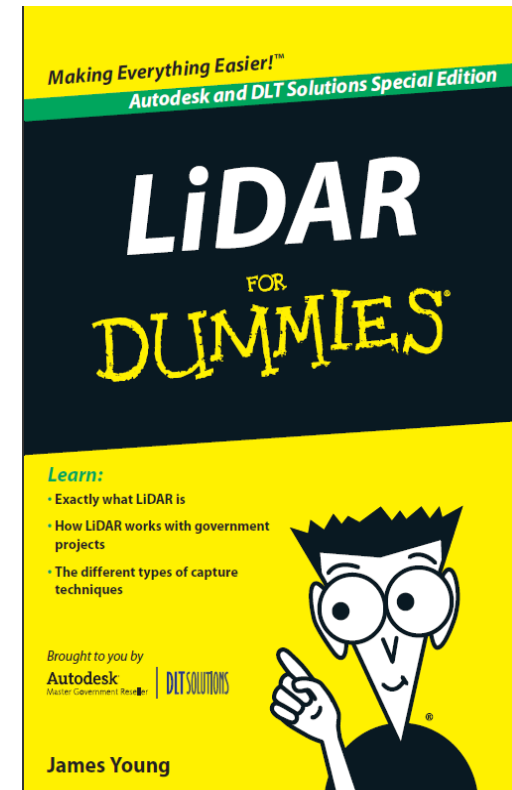
- Fixed Wing MPia, ALS-70 and GEMINI
 - Vertical accuracy achieved: 3 – 12 cm
 - Horizontal accuracy achieved: 10 – 27 cm
- Helicopter LiDAR – Reigl 680, Optech Orion and Leica ALS70-C
 - Vertical accuracy achieved: 1-2 cm
 - Horizontal accuracy achieved: 5-10 cm



Data meets accuracy specification?

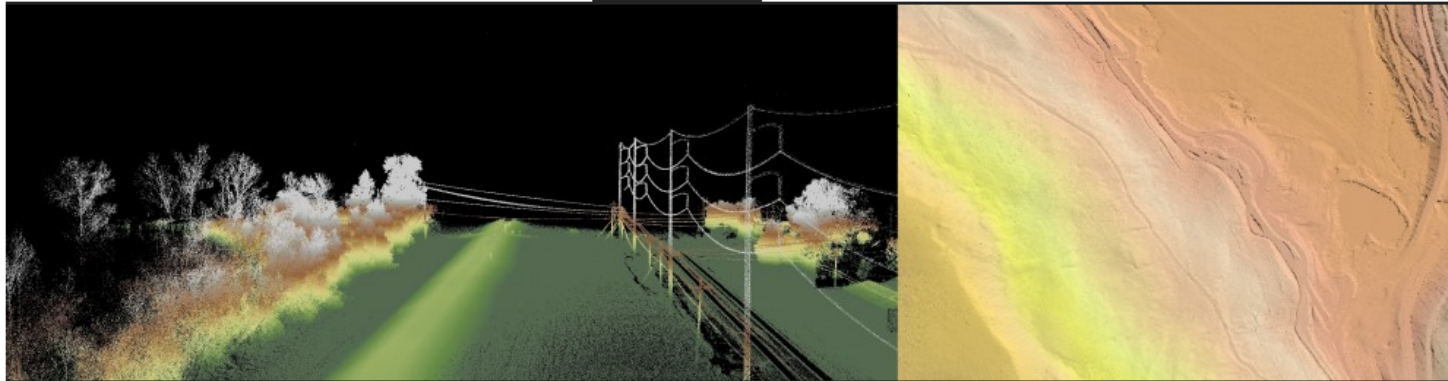
Publications

- LIDAR for Dummies
- American Surveyor – Mobile Mapping
- Professional Surveyor –Calibration Software



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James Wilder Young

Jamie Young has worked in the LiDAR industry for 15 Years. I am currently The LiDAR Solution Specialist for [AeroMetric, Inc.](#) , a professional geospatial services and mapping firm headquartered in Sheboygan, WI.

[AeroMetric website](#)

<http://bloglidar.com>

Thank You

