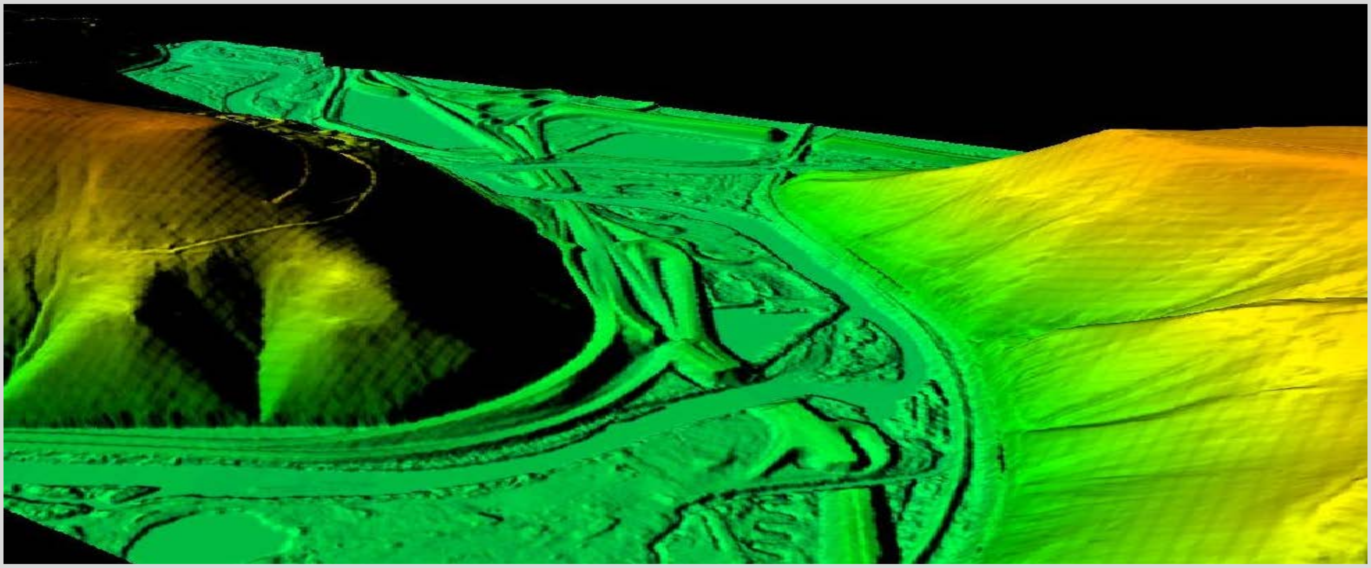
January 31, 2014

PRELIMINARY REPORT:

LiDAR Acquisition of Naches River from Hwy 410 to Mouth, Yakima River from Naches confluence to Parker Bridge



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Task Order No: EC04

Quantum Spatial Project No: 1130916

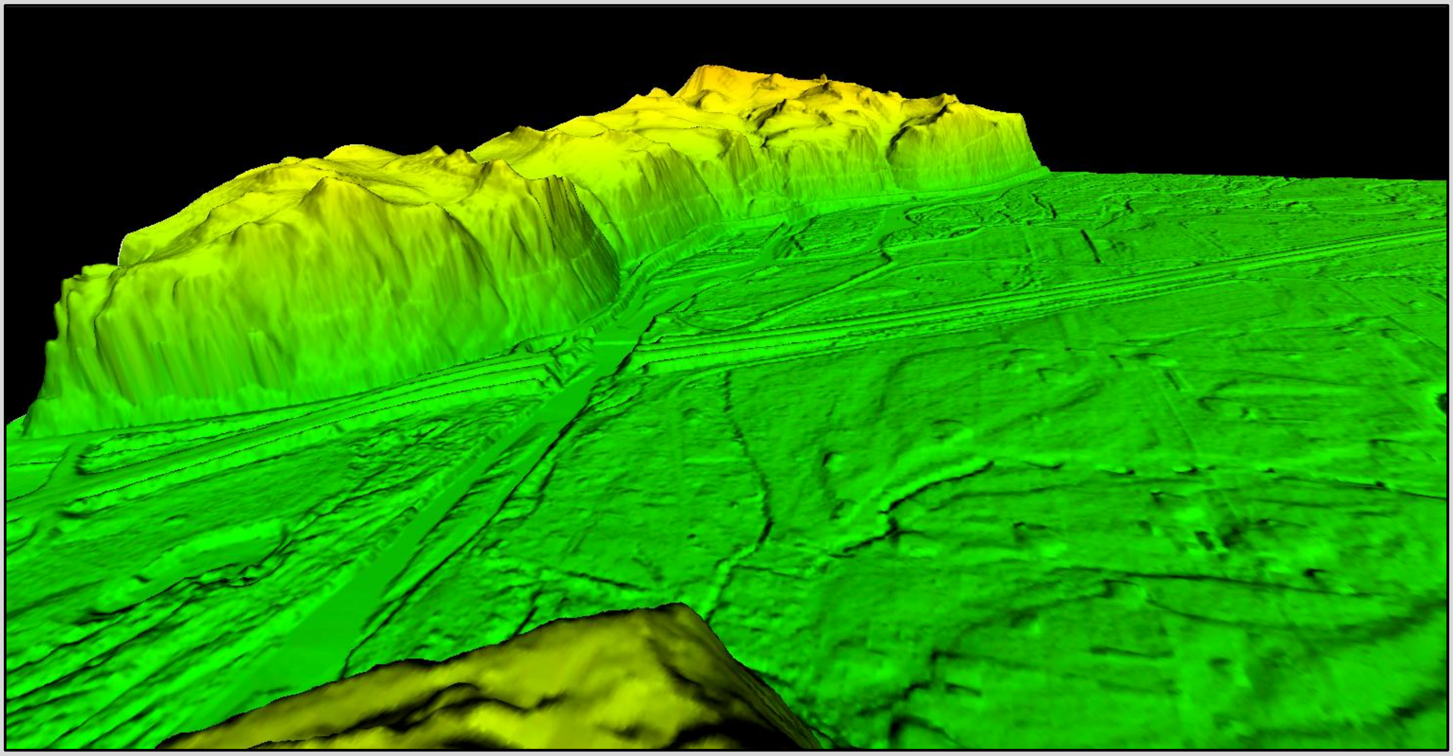
Table of Contents

Rogers Surveying, Inc.

Naches and Yakima Rivers LiDAR

1. Introduction

This report contains a summary of the Light Detection and Ranging (LiDAR) data acquisition and processing for the project area to include the Naches and Yakima Rivers. See Section 1.3 for specific areas included.



1.1 Contact Info

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1.2 Purpose

Quantum Spatial acquired high accuracy LiDAR data of the Naches and Yakima Rivers for Rogers Surveying, Inc. in accordance with requirements outlined in the Task Order Agreement, signed September 18, 2013. Rogers Surveying Inc. requires the LiDAR data to aid in analysis of Yakima County's hydraulic and geomorphic investigations of Naches and Yakima Rivers.

1.3 Project Locations

The project consists of roughly 32 square miles of the Naches and Yakima Rivers, located near central Washington. The specific areas of LiDAR acquisition were the Naches River from Hwy 410 to the Yakima confluence, and the Yakima River from the Naches confluence to the Parker Bridge. . Image 3.3a shows a graphic of the area of acquisition.

1.4 Time Period

LiDAR data acquisition for complete coverage of the project was acquired on November 14th - 15th and 19th-20th, 2013. Project data includes four (4) flight missions totaling sixty five (65) flight lines, and roughly 13 hours of flight time. An additional flight is pending due to a void in data. See image 3.3b for further information.

1.5 Project Scope

Data collection was accomplished by the staff of Quantum Spatial. Multiple flights were required to collect LiDAR data coverage. Quantum Spatial's high accuracy, dense LiDAR topographic data was requested to aid Yakima County in the engineering analysis of the specified areas of the Naches and Yakima Rivers. An additional flight is pending due to a void in the data, see Image 3.5a for relative void location in project. A revised report will be submitted when complete.

2. Geodetic Control

Control data was provided by Rogers Surveying, Inc. See section 8 for survey reports.

3. LiDAR Acquisition and Procedures

3.1 Acquisition Time Period

LiDAR data acquisition and Airborne GPS control were completed on four occasions between November 14th, 2013 and November 20th, 2013. Data from the sixty-five (65) flight lines, and four (4) flight missions are included in the project. An additional flight is pending due to a void in data, and a revise report will be submitted when complete.

3.2 LiDAR Planning

The LiDAR data for this project was collected with aircraft operated by Quantum Spatial. The aircraft is equipped with LiDAR sensor system as well as a system to collect GPS and IMU positioning data during flight. All flight planning was done with Leica Mission Pro Software, and flights were completed using a Leica ALS60 sensor.

3.3 LiDAR Acquisition

Data acquired from four (4) flight missions was utilized to provide project area coverage. Refer to Table 3.3a for acquisition parameters. See Image 3.3a on the following page for a graphic of the acquisition missions completed. See Image 3.3b for a graphic of the relative void area.

A Leica ALS60 sensor was used on board a Cessna Caravan to collect airborne GPS, IMU position, and trajectory data. The Airborne GPS and IMU system was initialized for a period of five minutes before takeoff and after landing. The missions acquired data according to the planned flight lines and included a minimum of one (usually two) cross flights. The cross flights were flown perpendicular to the planned flight lines and their data used in the in-situ calibration of the sensor.

Table 3.3a: Acquisition Parameters

Sensor ID	SN6105
Field of View	30°
Flying Height (Above mean sea level)	900m
Pulse Rate Frequency	105.9kHz
Mirror Scan Rate Frequency	61.1Hz
Ground Speed	105kts
Nominal Point Spacing/meter	4.06pts/m^2
Flight Line Overlap	50%

Image 3.3a: Acquisition areas indicating flight lines relative to the surface. The colors represent separate missions.

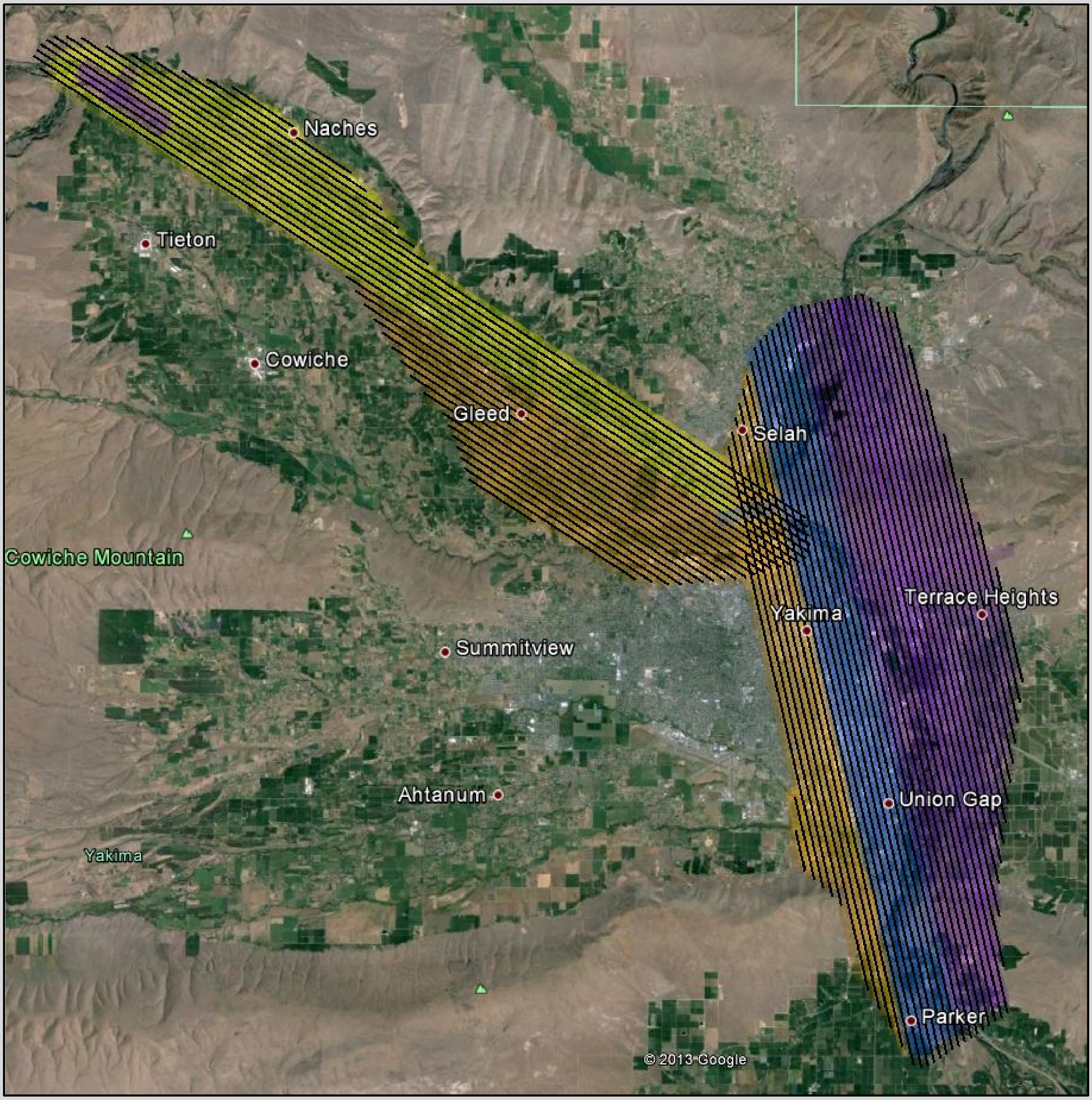
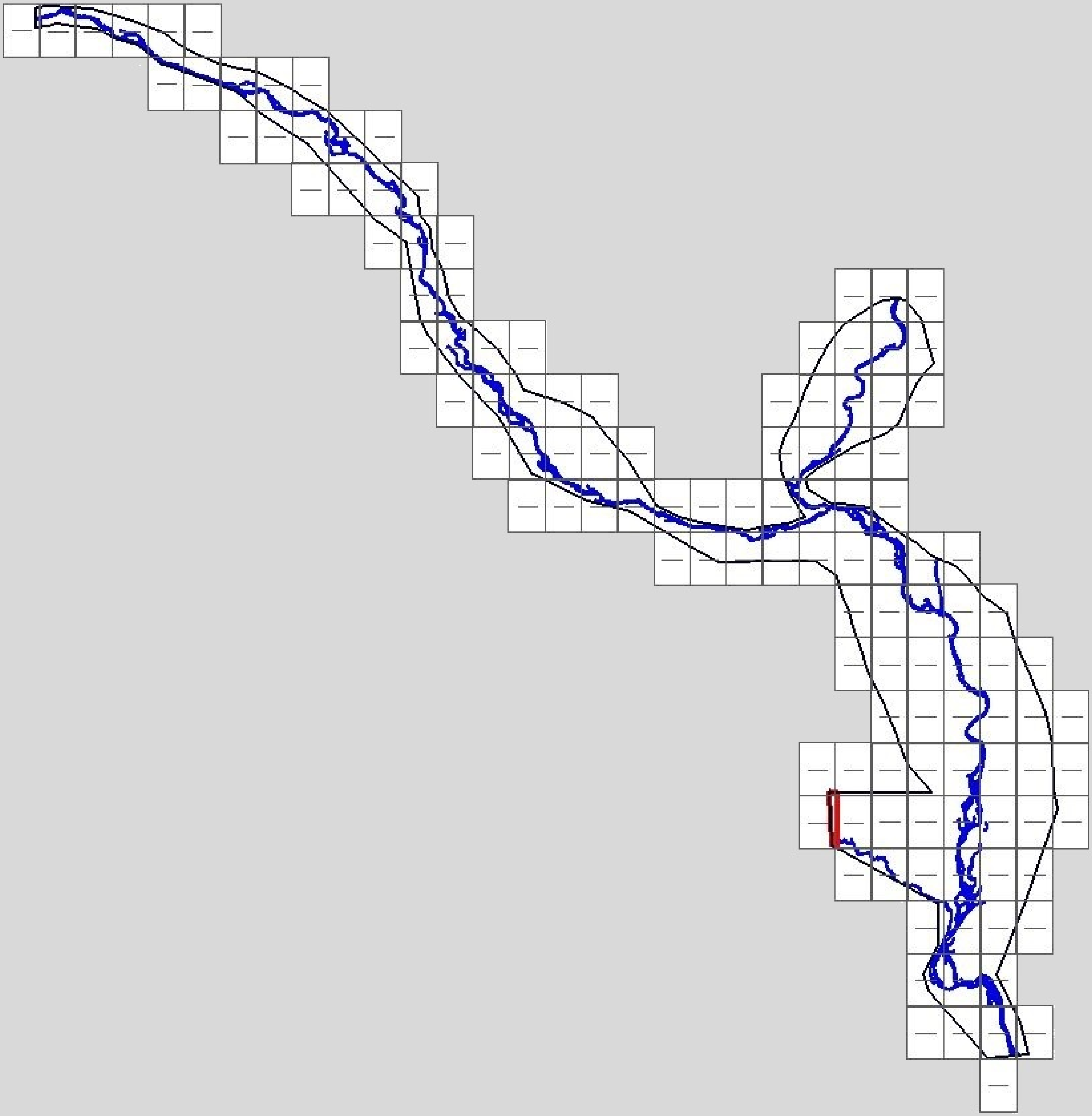


Image 3.3b: Below is the project boundary. The void area to be re-flown is outlined in red. The 1/100th USGS 7.5 minute quadrangles containing the void are q46120e5224, q46120e5225, q46120e5404, and q46120e5405. The 1/4th USGS 7.5 minute quadrangles containing the void are q46120e52 and q46120e54.



3.4 LiDAR Relative Swath Locations

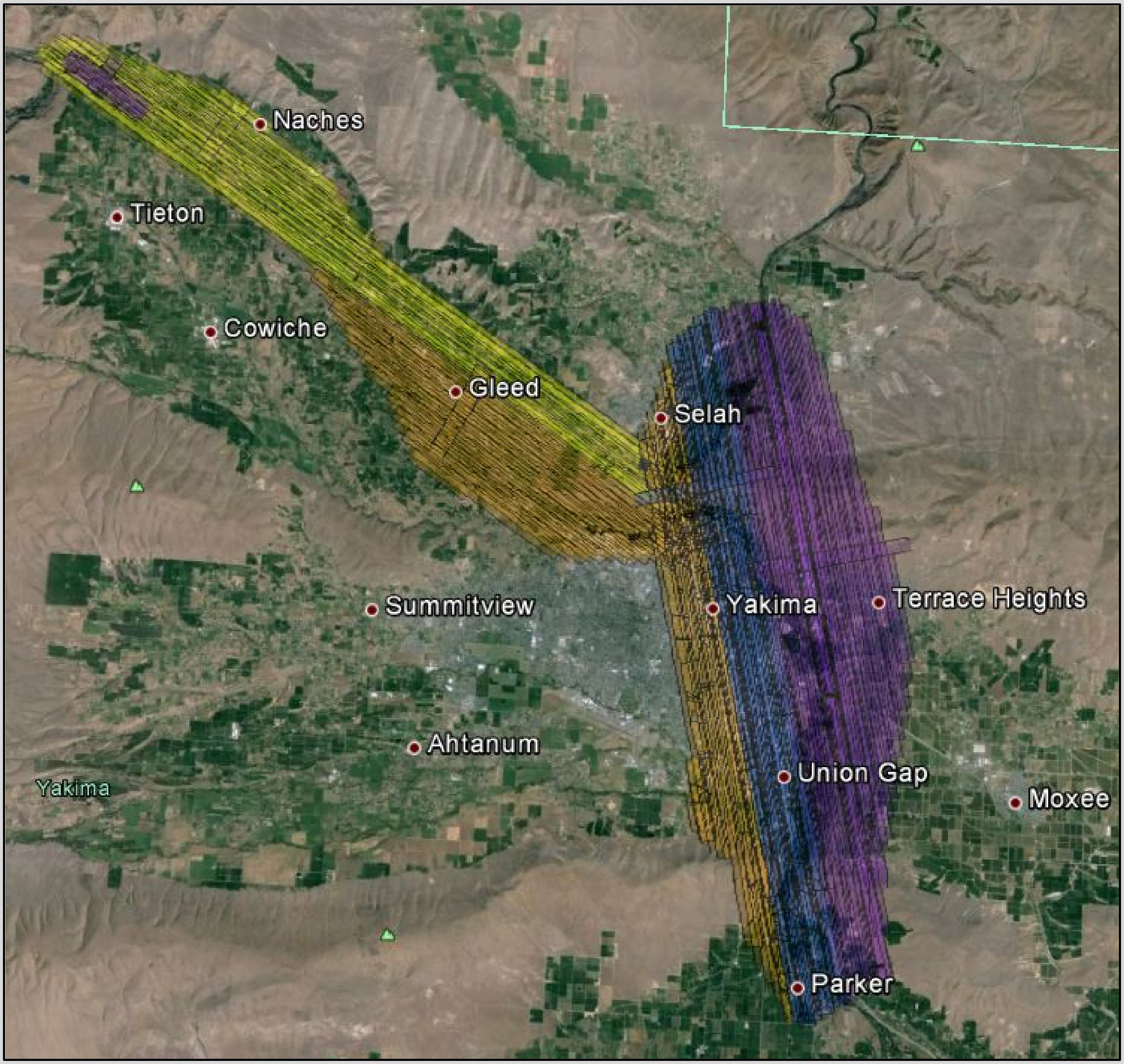


Image 3.4a: Swath locations by mission. Mission 2013.11.14_SN6105 is orange, 2013.15.14_SN6105 is yellow, 2013.19.14_SN6105 is blue, and 2013.20.14_SN6105 is purple.

4 Quality Control Surveys

A field survey was performed by Rogers Surveying, Inc.

See Section 8 for further details of the ground survey control data.

5 LiDAR Processing

Quantum Spatial LiDAR Calibration Steps	Software Used
Resolve GPS kinematic corrections for aircraft position and aligns all source data by time and filters. Smoothes the data, and provides a trajectory file indicating the latitude, longitude, ellipsoidal height, roll, pitch and heading of the scanner at intervals of 1/200 second in .sol format.	Leica IPAS TC v. 3.2
Calculate laser point position by associating .sol file information to each laser point return time, with offsets relative to scan angle, intensity, etc. included. As part of this process, correction for atmospheric refraction (bending) of the light path and correction for variations in the speed of light over the path are made. The post processor also provides inputs for various alignment coefficients (e.g., roll, pitch, heading, range offsets, etc.).This process creates the raw laser point cloud data for the entire survey in *.las (ASPRS v1.2) format, in which each point maintains the corresponding scan angle, return number (echo), intensity, and x, y, z information.	Leica ALS Post Processor v. 2.75 Build #25
Import .las strips from ALS Post Processer into GeoCue for calibration. Populate relative bin layout of mission extent. Filter bins for noise and run ground by flight line macro for calibration.	GeoCue v. 2013.1.45.1
Test relative accuracy using ground classified points per each flight line. Perform automated line-to-line calibrations for system attitude parameters (pitch, roll, heading), mirror flex (scale). Calibrations are performed on ground-classified points from paired flight lines. Every flight line is used for relative accuracy calibration.	TerraMatch v. 13, TerraScann v.13, GeoCue v. 2013.1.45.1
QC each mission line-to-line calibration by running DZ-orthos for each mission and after each mission is merged together for final project coverage.	GeoCue v. 2013.1.45.1
Assess Fundamental vertical accuracy via direct comparisons of ground-classified points to ground survey data.	TerraScan v.13

See Section 7 of the report for the final accepted trajectory plots.

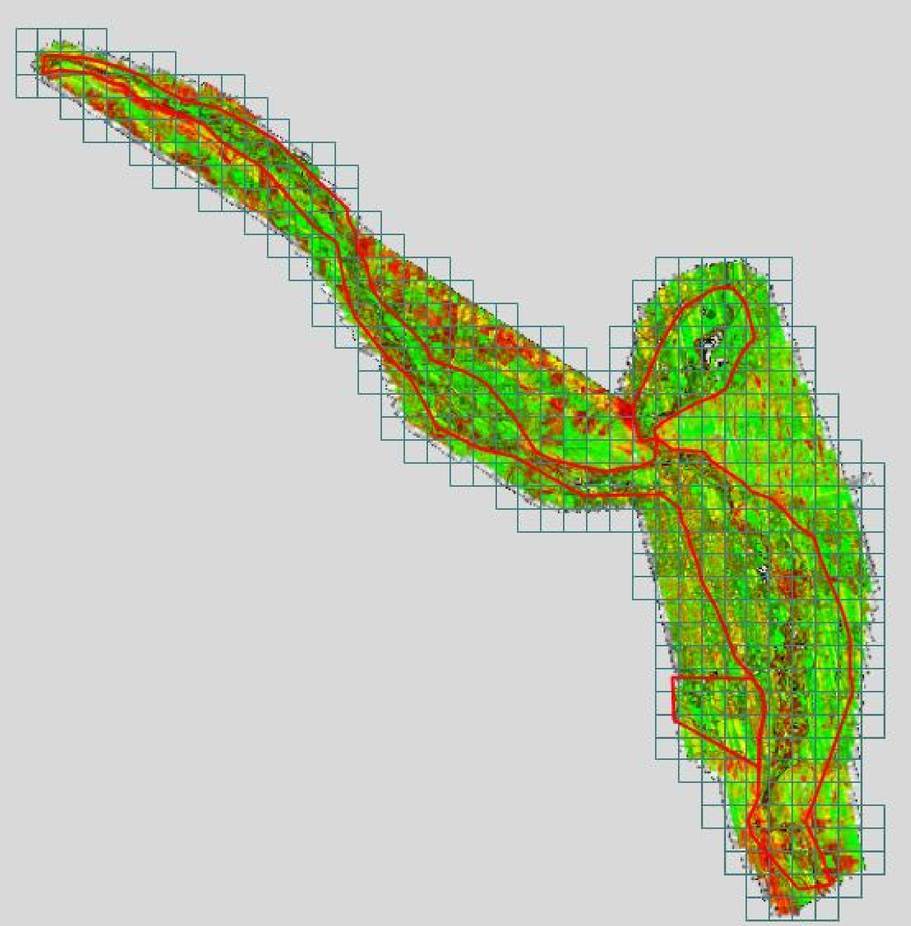
5.1 LiDAR Processing Quality Control

Relative accuracy of flightline to flightline alignment is assessed. Image 5.1a illustrates relative vertical alignment of flightlines.

- Green indicates a flightline comparison of less than 0.05 m / 0.16ft;
- Yellow…. 0.05 – 0.1 meters / 0.16 – 0.32 feet;
- Orange… 0.1 – 0.15 meters / 0.32 – 0.5 feet;
- Red…….. 0.15 – 0.20 meters / 0.5 – 0.66 feet;

Areas containing dense vegetation coverage or inundation from water will show a greater elevation offset then is actually present in the ground data. This is due to these regions having a high number of returns from vegetation or non-ground objects and few returns from the ground causing the elevation offset to be exaggerated in the relative accuracy assessment procedure. Relative accuracy for DZ-ortho rasters can be skewed when multiple flight line coverage occurs due the extra point density of the multiple overlaying flight lines.

Image 5.1a: Relative Accuracy Assessment



A few tiles are evaluated to ensure that the desired point density has been met. Quantum Spatial utilizes proprietary software to complete this task. A grid, sized according to the USGS version 13 specifications, based on the nominal post spacing, is used for point analysis. The USGS version 13 specification allows that a grid size up to 2 times the nominal post spacing be used. Point density is analyzed on the basis of this grid space size or cell and the result indicates the point density of the sampled tiles.

Once both the accuracy between swaths and data density is accepted an automated classification algorithm is performed using TerraSolid's TerraScan, version 013.011. This produces the majority of the bare-earth datasets. Further, the data is processed to classify specific vegetation classes and man-made structures.

The remainder of the data is classified using manual classification techniques. The majority of the manual editing involves changing points initially classified as ground (class 2), to unclassified or non-ground (class 1). Erroneous low points and high points, including clouds, are classified to Noise (class 7).

5.2 Check Point Validation

To ensure position of the assembled data it is verified against surveyed ground control data. TerraScan computes the vertical differences between surveyed ground control points and LiDAR collected points.

Check points are surveyed within the project area to provide calibration checks of the LiDAR point cloud. A report indicating comparative positional statistics is produced when LiDAR has been adjusted to control and can be found in Section 8 of this report.

5.3 LiDAR Data Deliveries

Classified point cloud data is being supplied using the following criteria.

- LAS, version 1.2 in 1500 meter grid
- Classification scheme:
  - 1 – Processed, but unclassified
  - 2 – Bare Earth, Ground
  - 7 – Noise (Low or High, Manually identified, if needed)
  - 9 – Water
  - 10 – Ignored Ground (Breakline proximity)
  - 15 – Bridge

Deliverables:

Delivered on a per tile basis following the 1/100th USGS 7.5 minute quadrangle:

- Bare Earth ASCII files
- Classified LAS following the standard established by The American Society for Photogrammetry and Remote Sensing (ASPRS) for LAS data on a per tile basis

Delivered on a per tile basis following the 1/4th USGS 7.5 minute quadrangle:

- Bare Earth Digital Elevation Models (DEM), hyrdo flattened
- First Return Digital Elevation Models (DEM)
- One foot and two foot contours in ESRI shapefile
- First Return Intensity raster images in .tiff format with world files

Aircraft Trajectory files in ACII format

Metadata, FGDC standard

6 Conclusion

Sound procedures and use of new technologies ensure this project data will serve Rogers Surveying, Inc. and all users of the provided LiDAR derivative products well into the future. The models produced are accurate and representative of surface conditions at the time of data acquisition.

7 LiDAR GPS Processing Plots

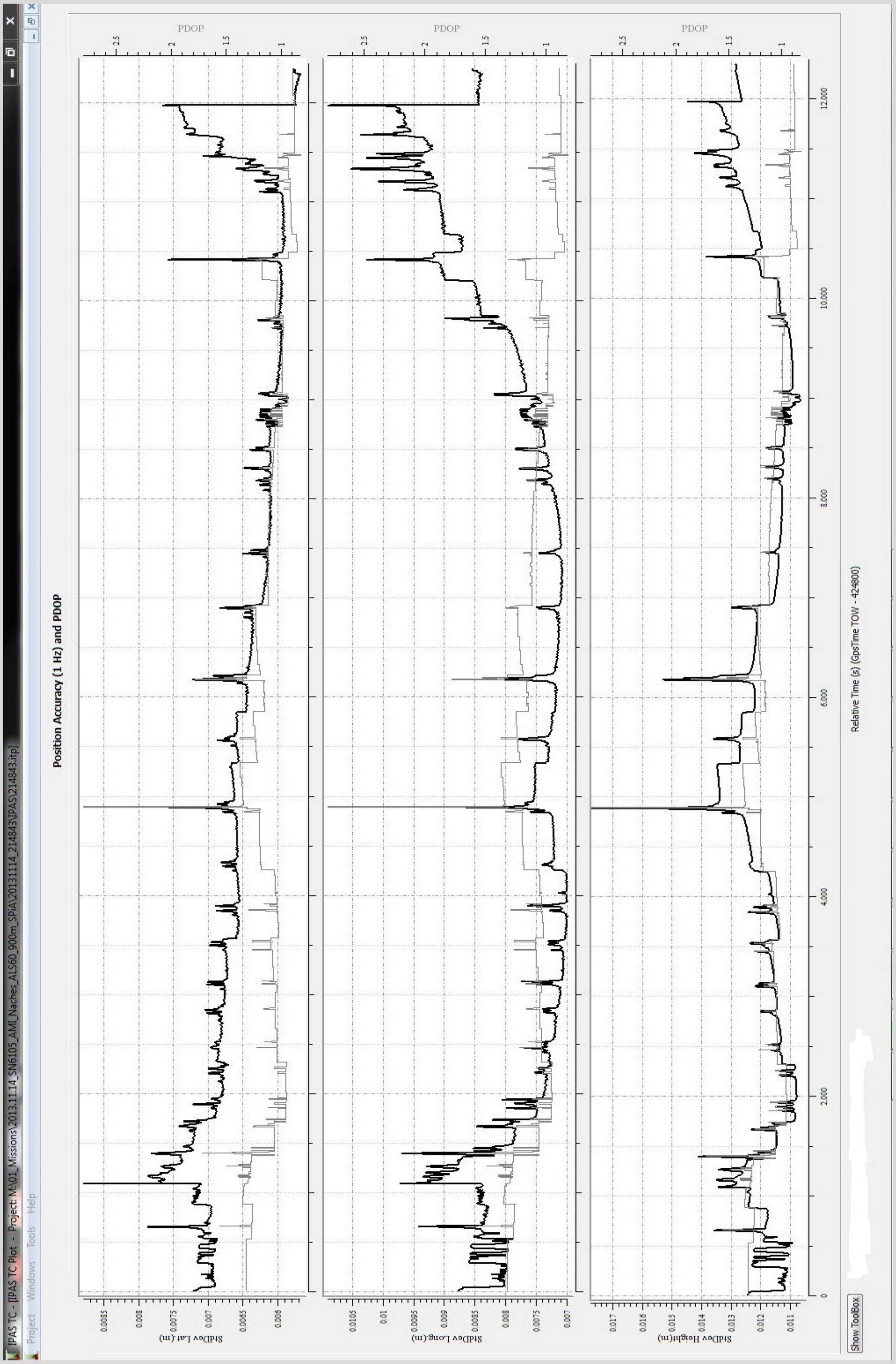


Image 7a: 20131114 PDOP Plot

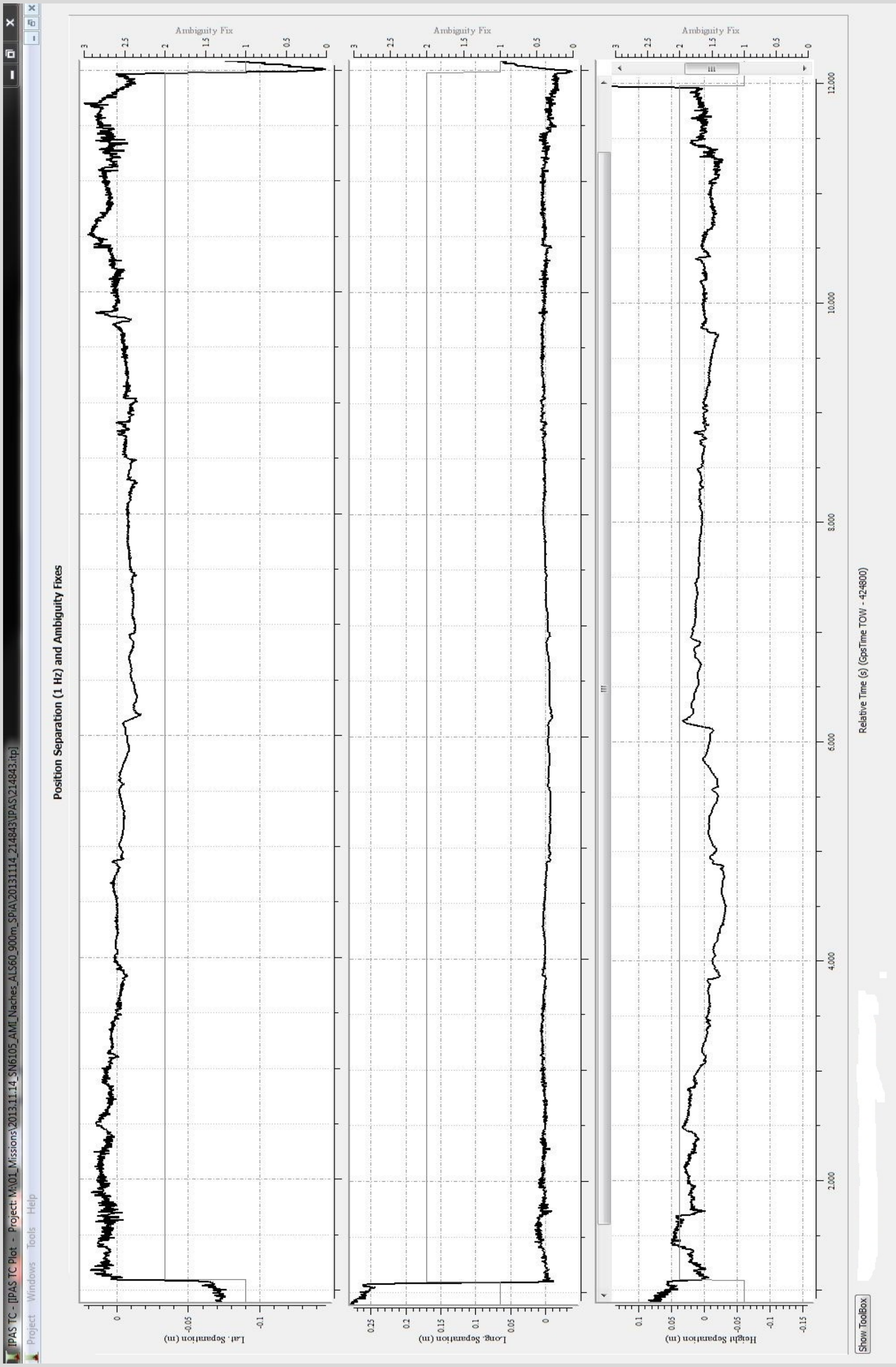


Image 7b: 20131114 Separation Plot

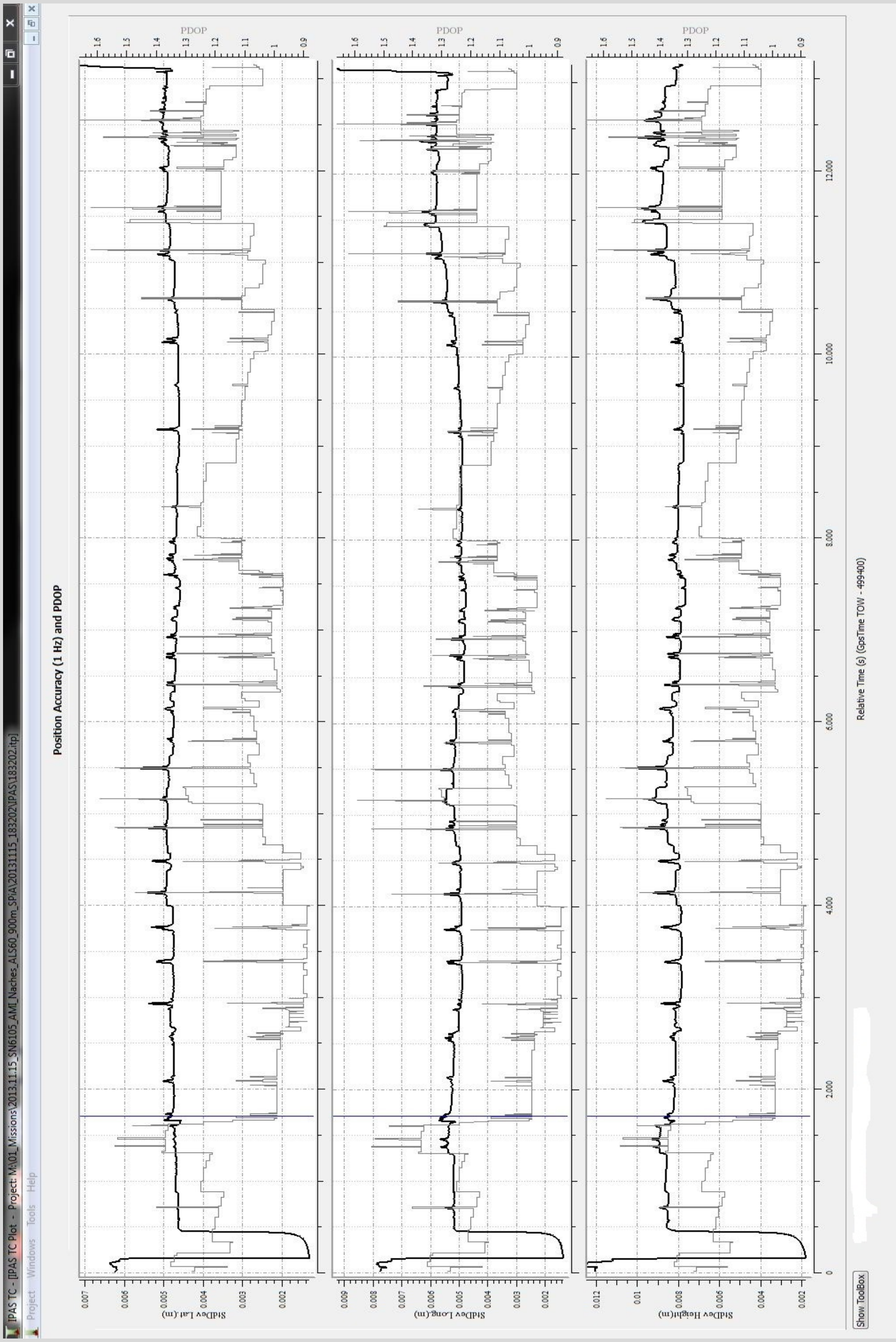


Image 7c: 20131115 PDOP Plot

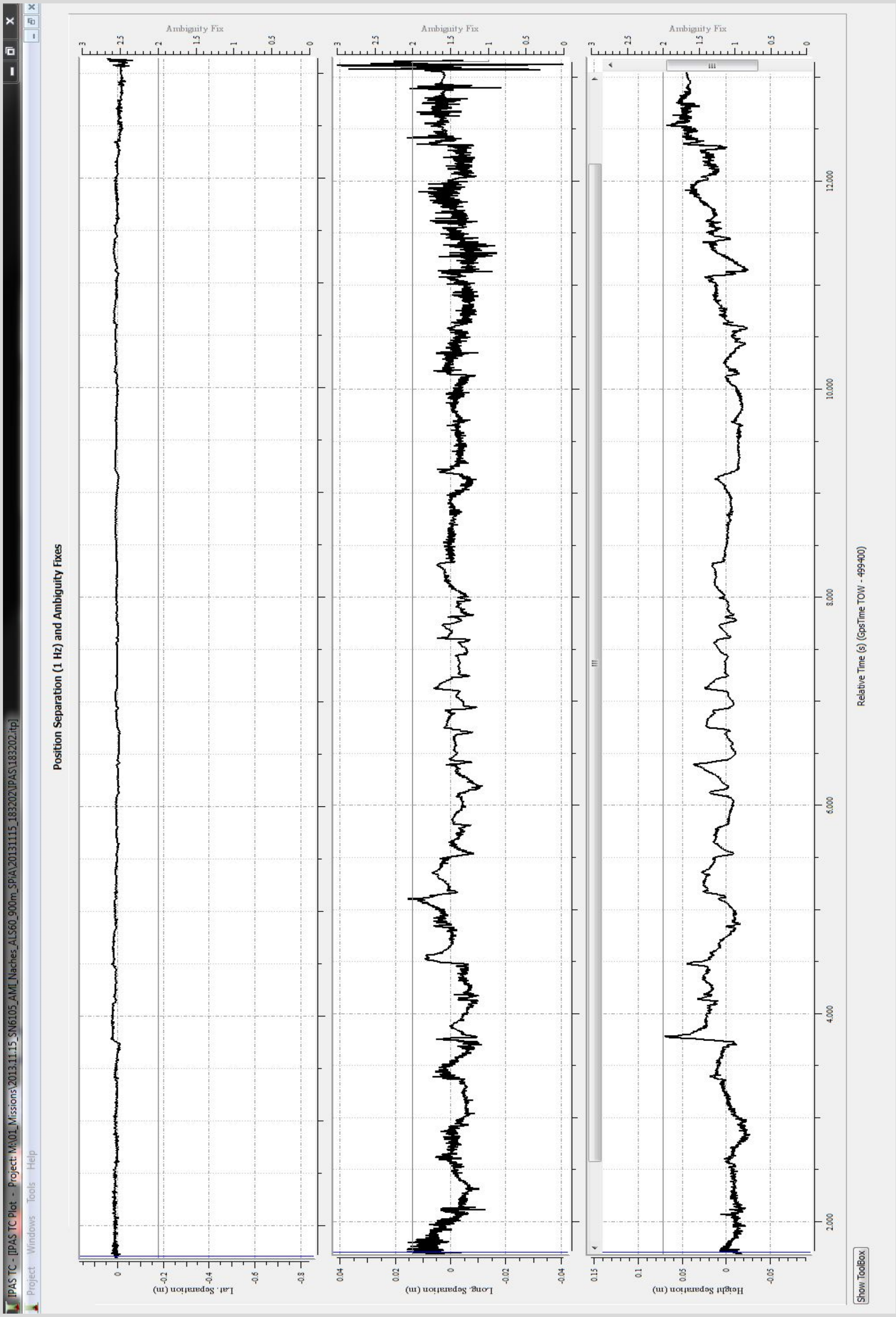


Image 7d: 20131115 Separation Plot

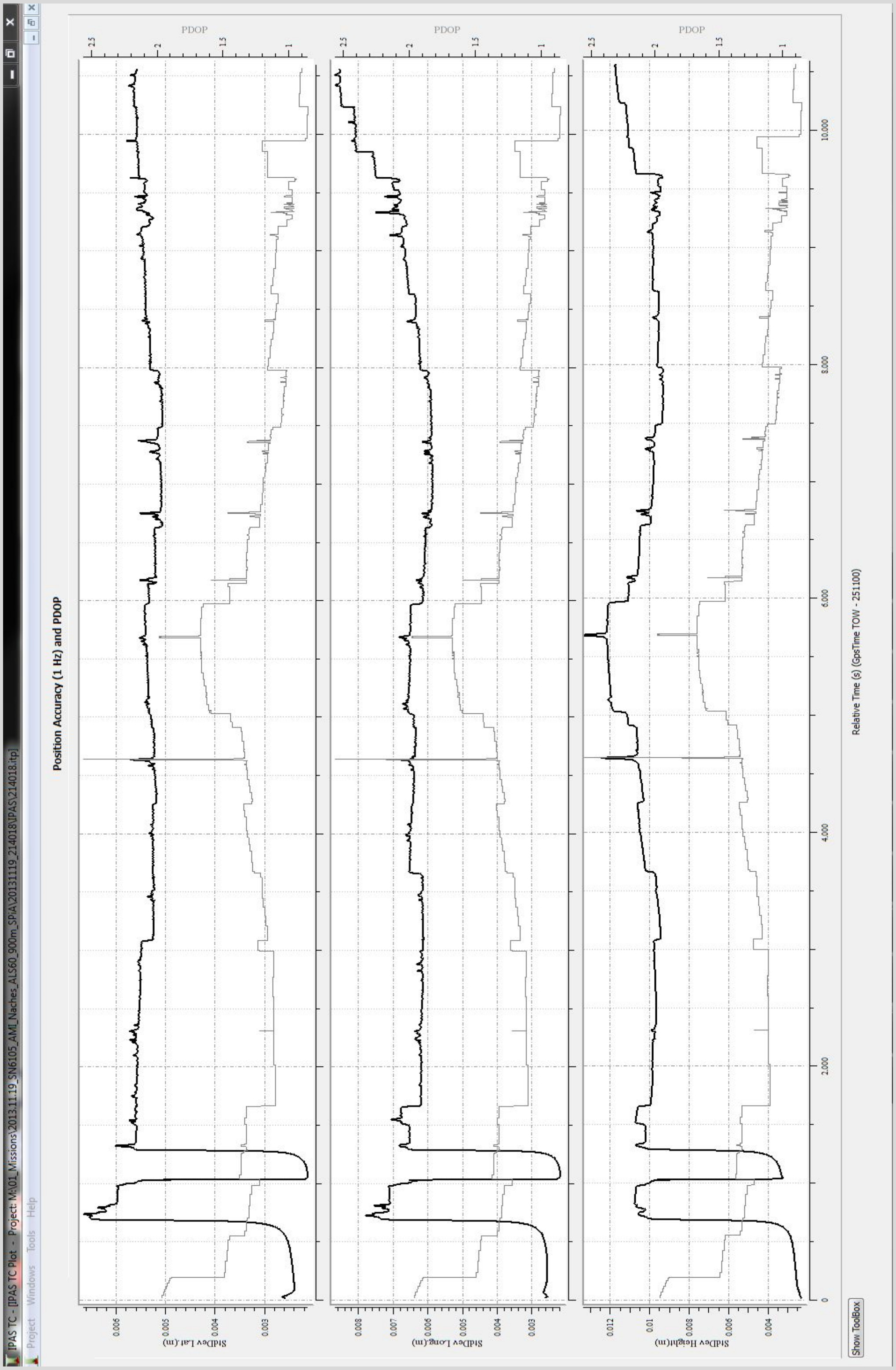


Image 7e: 20131119 PDOP Plot

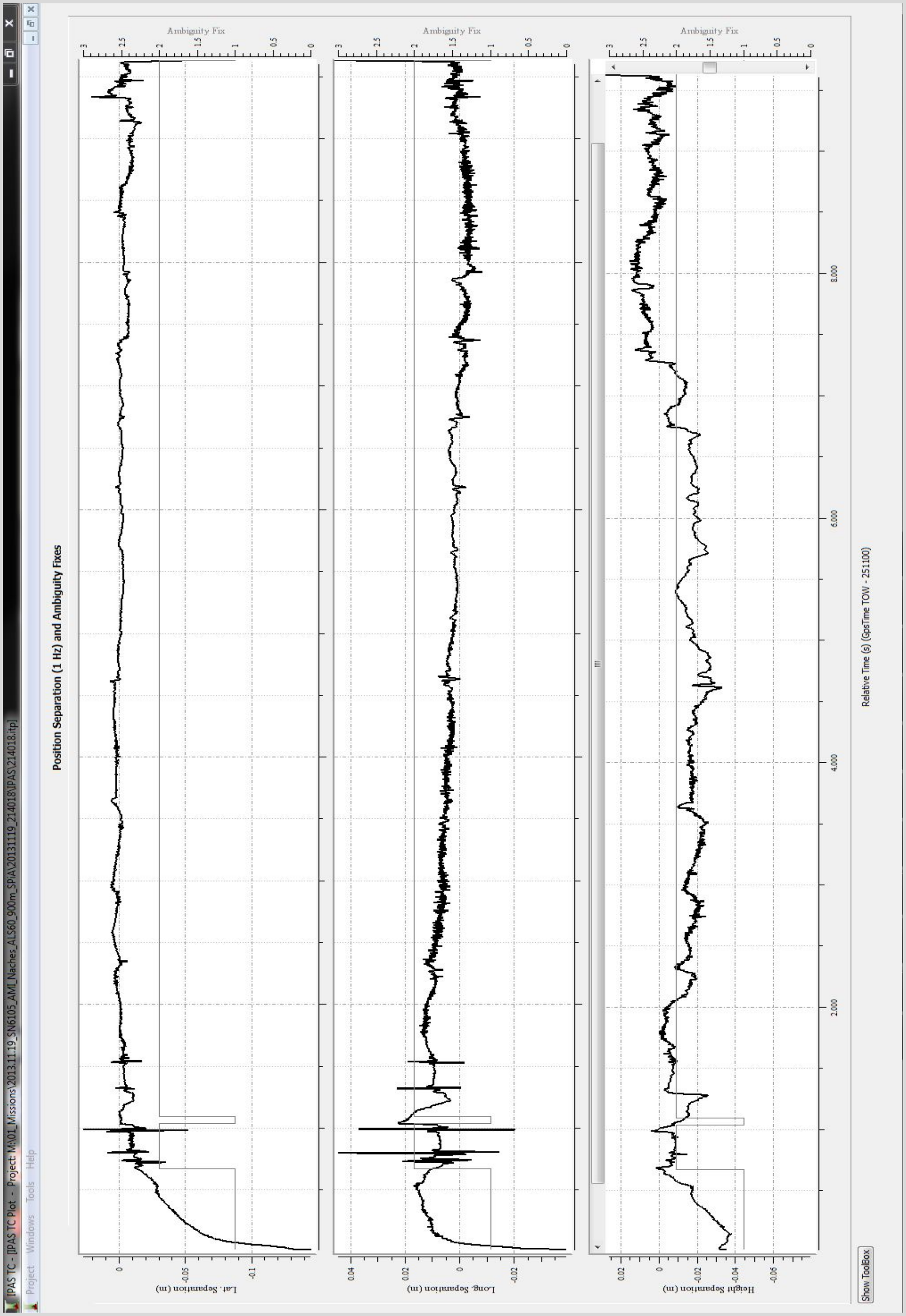


Image 7f: 20131119 Separation Plot

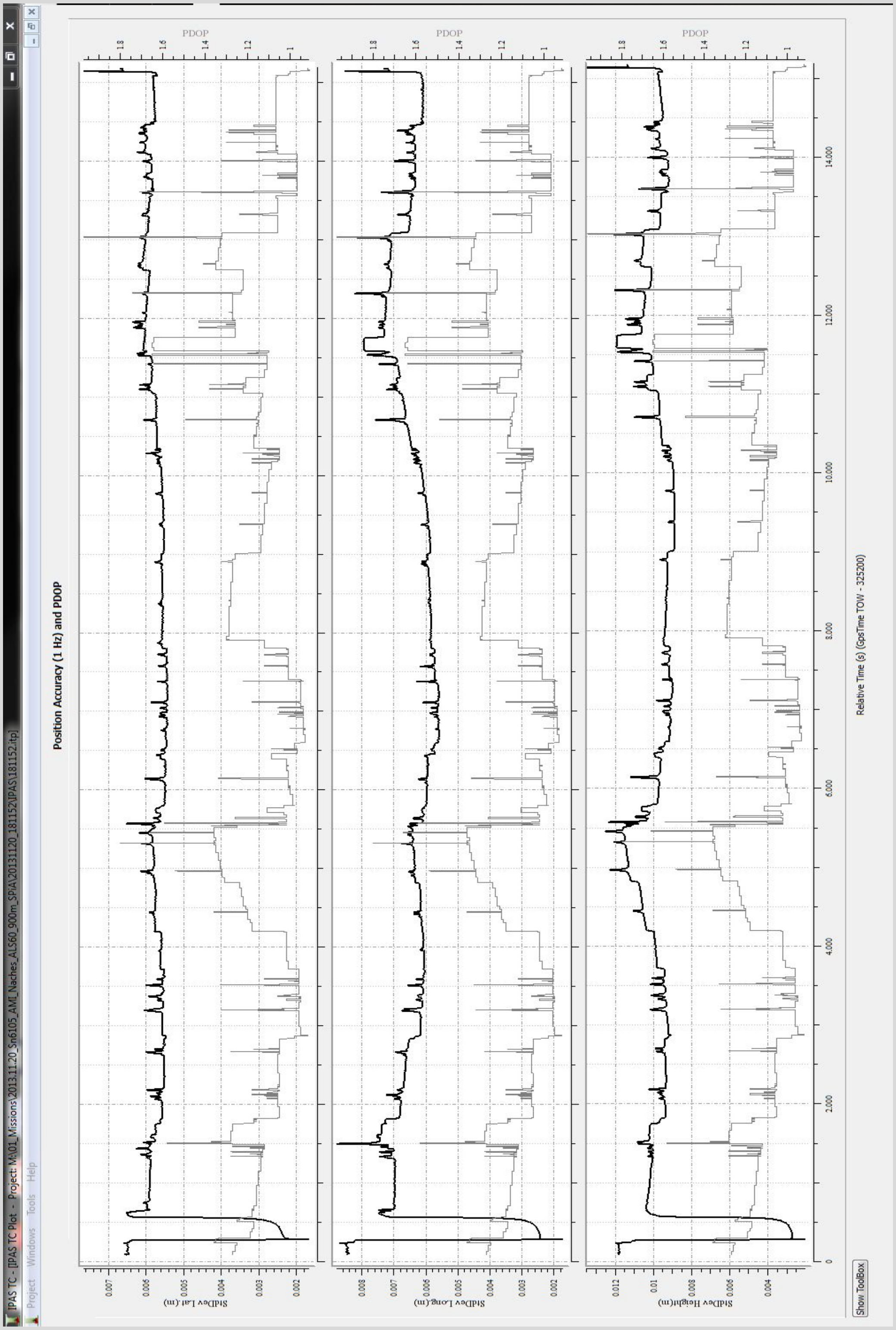


Image 7g: 20131120 PDOP Plot

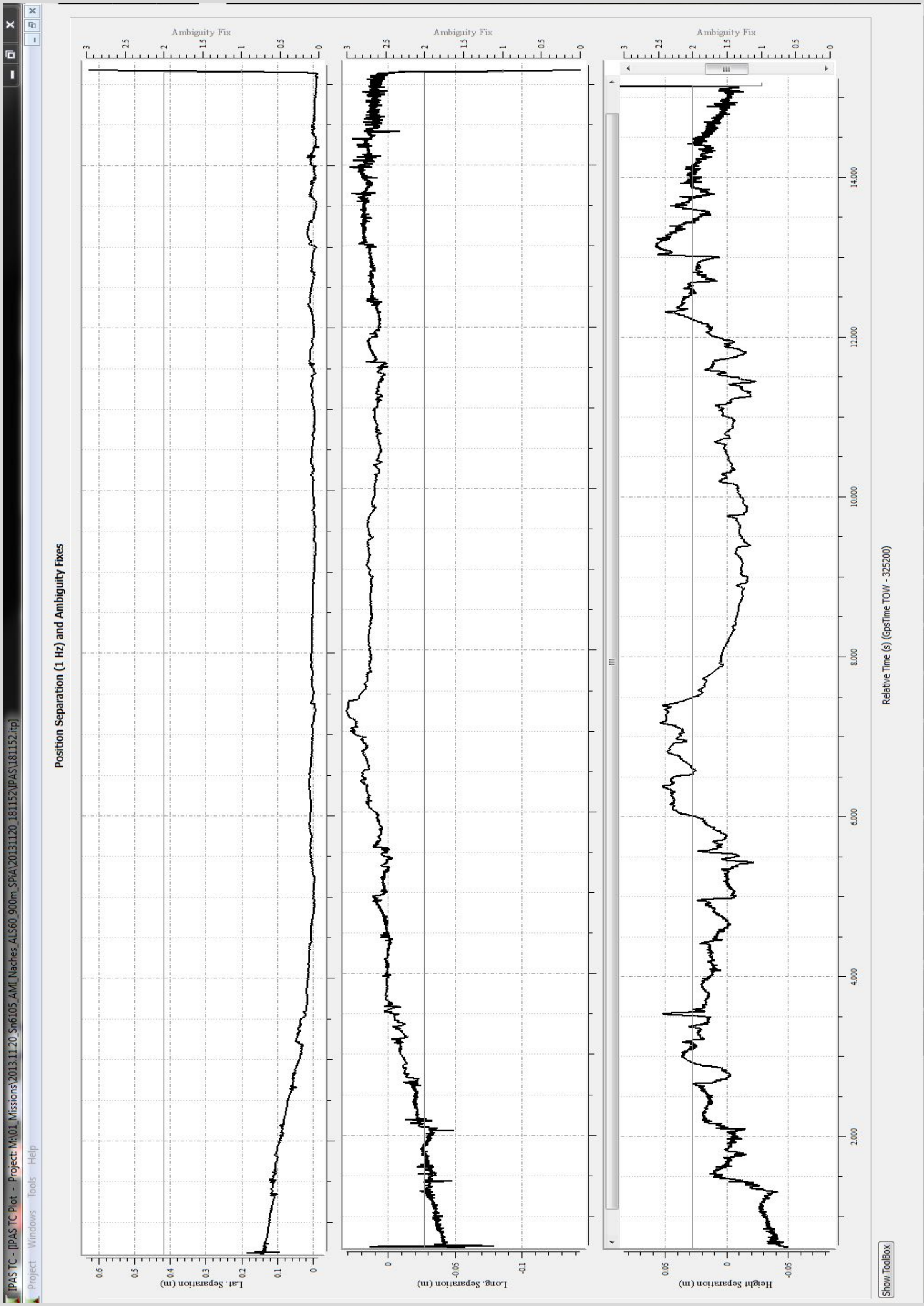


Image 7h: 20131120 Separation Plot

8 QA/QC Output Control Report

See below for Control Report. The check points were collected across the Naches and Yakima Rivers project area and used to calibrate LiDAR data position.

Naches and Yakima Rivers Control Report					
Control	Easting	Northing	Known Z	Laser Z	Dz
100	1646314.0720	462954.4300	1031.5500	1031.3100	-0.2400
101	1646326.2090	462846.1310	1030.3400	1030.1100	-0.2300
102	1646332.0280	462740.9300	1030.0480	1029.8900	-0.1580
103	1646338.4160	462634.1520	1029.5840	1029.3700	-0.2140
104	1646351.3330	462519.3120	1029.0110	1028.8500	-0.1610
105	1646618.5610	462671.3720	1043.4690	1043.1400	-0.3290
106	1646572.0780	462760.1670	1041.4460	1041.2200	-0.2260
107	1646531.1490	462855.7920	1038.7260	1038.4500	-0.2760
108	1646460.3230	462931.7130	1034.0850	1033.9300	-0.1550
109	1646359.1490	462973.3970	1031.7310	1031.4600	-0.2710
110	1646251.6490	462977.1460	1031.6420	1031.4100	-0.2320
111	1647677.909	448785.119	984.769	984.58	-0.189
112	1647675.292	448688.528	984.235	984.03	-0.2050
113	1647792.02	448565.873	983.882	983.65	-0.2320
114	1647849.988	448488.291	982.031	981.84	-0.1910
115	1647934.096	448441.265	980.625	980.51	-0.1150
116	1648044.565	448441.247	978.835	978.64	-0.1950
117	1648148.962	448444.902	978.551	978.32	-0.2310
118	1648251.559	448449.426	978.814	978.78	-0.034
119	1648353.901	448446.427	979.615	979.63	0.015
120	1648454.685	448441.788	979.791	979.58	-0.211
121	1648434.033	448542.591	979.204	979.08	-0.124
122	1648352.896	448570.254	978.67	978.6	-0.07
123	1648363.228	448648.053	977.573	977.57	-0.003
124	1648305.724	448737.068	979.737	979.68	-0.057
125	1648312.829	448635.325	978.565	978.5	-0.065

Naches and Yakima Rivers Control Report					
Control	Easting	Northing	Known Z	Laser Z	Dz
126	1648284.073	448534.798	978.52	978.59	0.07
127	1644012.619	488733.694	1123.701	1123.8	0.099
128	1643954.489	488627.956	1122.876	1122.68	-0.196
129	1643895.631	488521.104	1122.233	1122.13	-0.103
130	1643832.245	488399.601	1121.807	1121.83	0.023
131	1643777.811	488295.635	1121.576	1121.54	-0.036
132	1643728.737	488183.99	1122.779	1122.86	0.081
133	1643671.27	488077.219	1122.357	1123.04	0.683
134	1643613.183	487967.538	1123.387	1123.2	-0.187
135	1643556.434	487864.016	1122.811	1122.54	-0.271
136	1643500.259	487765.292	1123.646	1123.54	-0.106
137	1629582.163	470293.506	1115.618	1115.38	-0.238
138	1629473.118	470316.068	1115.413	1115.32	-0.093
139	1629364.722	470330.701	1116.085	1116.13	0.045
140	1629255.723	470347.913	1116.548	1116.41	-0.138
141	1629149.569	470365.468	1117.657	1117.55	-0.107
142	1629057.53	470380.579	1118.587	1118.83	0.243
143	1628952.256	470397.485	1118.703	1118.95	0.247
144	1628853.93	470415.898	1118.522	1119.21	0.688
145	1628731.083	470419.647	1125.42	1125.18	-0.24
146	1628622.416	470436.137	1126.142	1125.99	-0.152
147	1628518.265	470479.239	1119.596	1119.81	0.214
148	1618317.689	473877.407	1180.225	1180.19	-0.035
149	1618220.888	473948.057	1178.963	1178.83	-0.133
150	1618105.283	474010.591	1179.059	1178.96	-0.099
151	1618015.921	474054.328	1179.622	1179.48	-0.142
152	1617909.608	474109.026	1181.267	1181.14	-0.127
153	1617825.875	474151.737	1182.177	1182.03	-0.147
154	1617732.836	474198.978	1182.151	1181.97	-0.181
155	1617604.826	474268.004	1181.434	1181.31	-0.124
156	1617514.064	474318.555	1181.301	1181.19	-0.111
157	1617375.082	474389.691	1182.149	1182.06	-0.089
159	1572326.421	515337.279	1576.44	1576.7	0.26
160	1572432.849	515322.867	1574.981	1575.24	0.259

Naches and Yakima Rivers Control Report					
Control	Easting	Northing	Known Z	Laser Z	Dz
161	1572533.95	515303.068	1575.693	1575.99	0.297
162	1572635.344	515271.523	1574.966	1575.2	0.234
163	1572722.249	515210.862	1575.164	1575.41	0.246
164	1572807.013	515157.202	1575.989	1576.08	0.091
165	1572919.202	515136.378	1574.189	1574.45	0.261
166	1573006.989	515172.343	1574.213	1574.34	0.127
168	1593564.259	506707.3	1444.218	1444.63	0.412
169	1593587.595	506614.83	1444.026	1444.36	0.334
170	1593628.264	506532.827	1442.197	1442.47	0.273
171	1593698.645	506470.333	1441.566	1441.88	0.314
172	1593770.099	506407.953	1441.131	1441.5	0.369
173	1593843.498	506342.151	1440.654	1440.93	0.276
174	1593924.814	506283.801	1440.633	1440.92	0.287
175	1594000.992	506216.849	1439.845	1439.98	0.135
176	1594077.952	506151.513	1439.206	1439.43	0.224
177	1594156.26	506084.603	1438.355	1438.59	0.235
178	1594233.798	506016.647	1437.734	1437.92	0.186
179	1594310.877	505951.251	1437.116	1437.31	0.194

Average Dz	0.0837
Minimum Dz	-0.2710
Maximum Dz	0.6880
Average Magnitude	0.1910
Root Mean Square	0.2250
Standard Deviation	0.2276