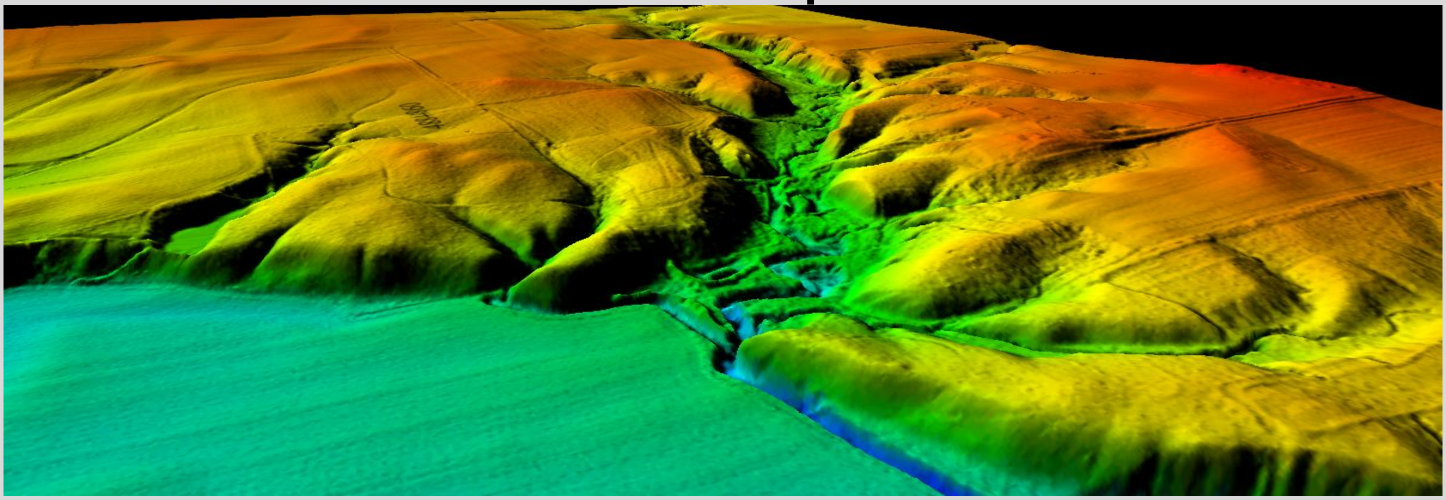
NRCS Logan County, Illinois
4ppsm
LiDAR Report



Prepared For:

United States Geological Survey
National Geospatial Technical Operations Center
1400 Independence Road
Rolla, Missouri 65401

Prepared By:

Quantum Spatial
4020 Technology Parkway
Sheboygan, WI 53083
P: 920.457.3631
F:920.457.0410

Contract ID: G10PC00025
Task Order: G13PD00885

Quantum Spatial Project No: 1130905

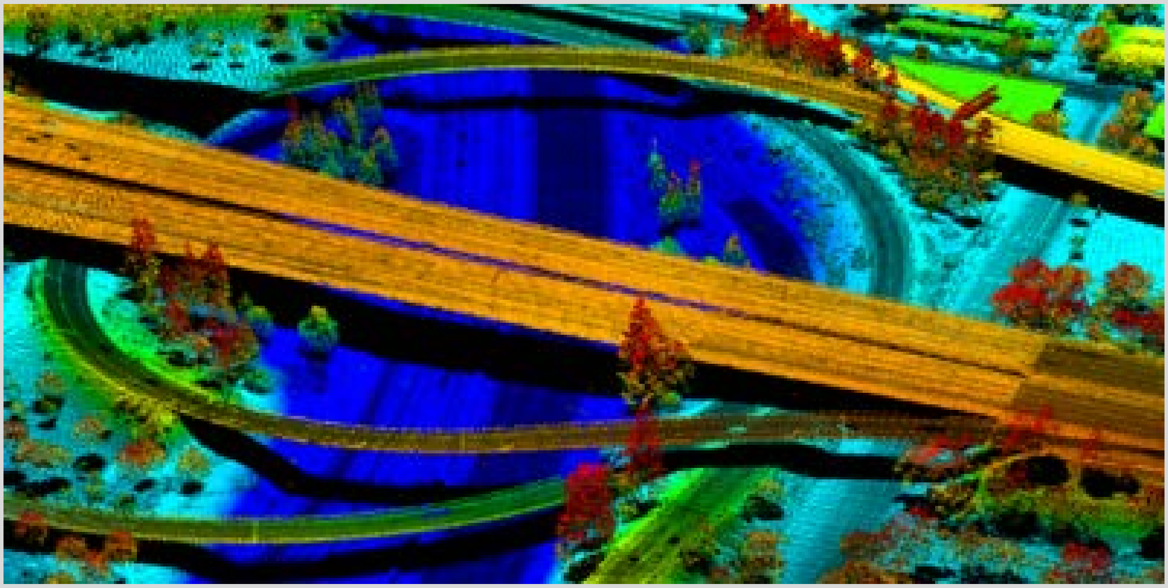
Table of Contents

United States Geological Survey

NRCS Logan County, Illinois 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 Logan County, Illinois. The United States Geological Survey (USGS) requires the LiDAR data to aid in analysis of land use, hydrologic, vegetation and recreational management.



1.1 Contact Info

Questions regarding the technical aspects of this report should be addressed to:

Quantum Spatial
4020 Technology Parkway
Sheboygan, WI 53083

Attention: Chris Guy (LiDAR Manager)
Phone: 920.457.3631
Email: cguy@quantumspatial.com

1.2 Purpose

Quantum Spatial acquired high accuracy LiDAR data of Logan County, Illinois for the USGS in accordance with requirements specified to produce such a dataset as outlined in contract ID G10PC00025 and as defined by United States Geological Survey National Geospatial Program Base LiDAR Specification, Version 1.0 (ILMF).

1.3 Project Locations

This project consisted of Logan County, Illinois. The area of acquisition is approximately 618 square miles (1600 square kilometers) located in central Illinois. Image 1.3a on the following page shows the relative location of this area.

1.4 Time Period

LiDAR data acquisition for complete coverage of the project was acquired between November 23, 2013 and November 30, 2013. See Image 3.3a and 3.3b for the project swaths collected. Flight logs can be found in Section 7 of this document.

Project data includes eight (8) flight missions totaling one hundred eleven (111) flight lines.

1.5 Project Scope

Data collection was accomplished by the staff of Quantum Spatial. Multiple flights were required to collect LiDAR data coverage of the entire county of Logan.

As documented in the Task Order, collected data was to achieve a Fundamental Vertical Accuracy (FVA) of 18.13cm (0.59 ft) at a 95% confidence level, from an RSME of 9.25cm (0.30 ft) in the open terrain land cover category based on a Triangulated Integrated Network (TIN) of the LiDAR points. And to achieve the same values from Digital Elevation Models (DEM) derived from LiDAR data.

Consolidated Vertical Accuracy (CVA) is to achieve 26.9 cm (0.88 ft) at 95th Percentile based on the DEM.

Supplemental Vertical Accuracy (SVA) has a target for each of the ground cover category of 26.9 cm (0.88ft) at 95th Percentile.

Ground cover categories are Bare Earth/Open Terrain, Urban, Tall Weeds, Brush, and Forest.

Section 5.6 contains the vertical accuracy assessment result values.

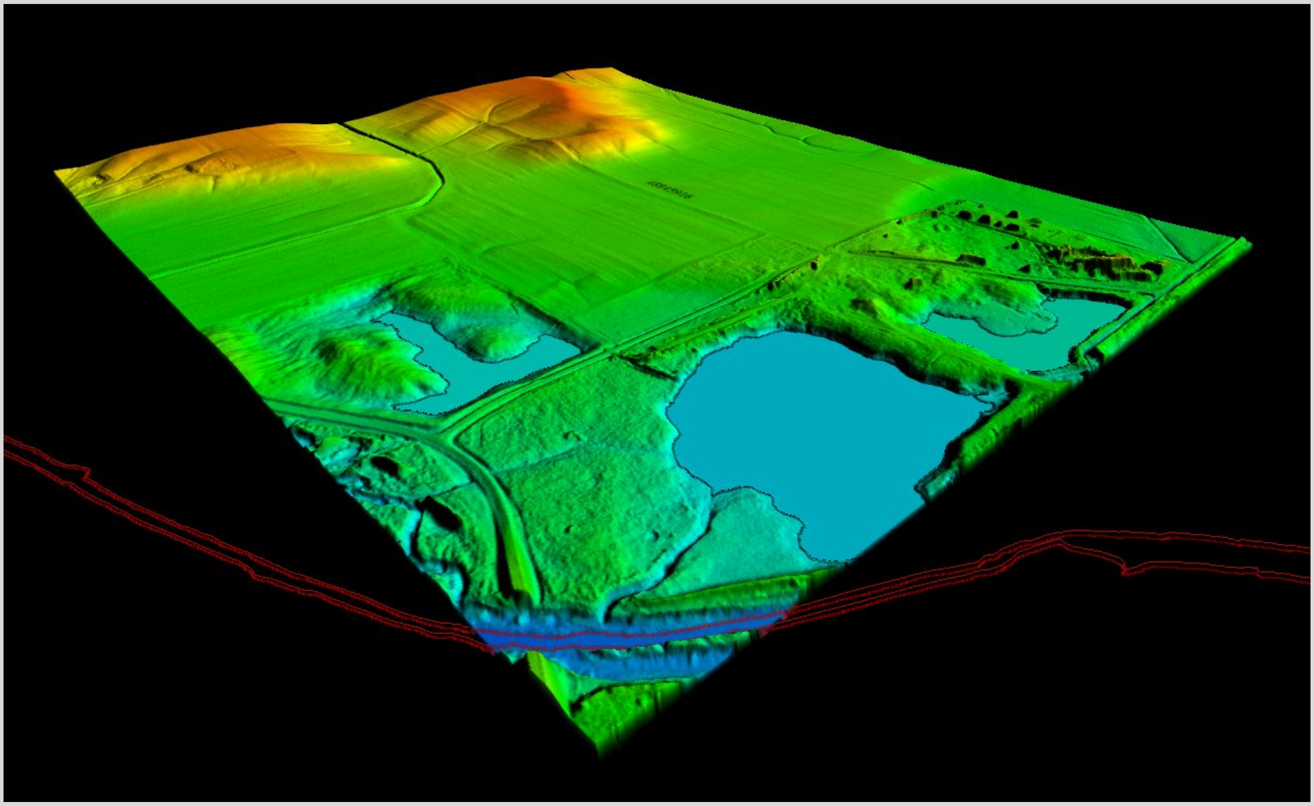
Image 1.3a: The area outlined in black shows the location of Logan County, Illinois.


Chicago
Illinois

2. Geodetic Control

The field survey report and an accuracy report are included with the project delivery. See "Final_Delivery_Report" and "Accuracy_Report" pdfs attached.

Ground survey was performed by Compass Data, Inc. between December 1, 2013 and December 12, 2013. Check points were collected in various land cover categories for data calibration and vertical assessment analysis. Ground control check points were compared to airborne data. The comparison of vertical differences provides for calculation of vertical accuracies in the various land cover categories.



3. LiDAR Acquisition and Procedures

3.1 Acquisition Time Period

LiDAR data acquisition and Airborne GPS control were completed between November 23, 2013 and November 30, 2013. Data from the eight (8) flight missions is included in the project.

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 systems as well as systems to collect GPS and IMU positioning data during flight. All flight planning was completed using Leica MissionPro software and data collection was completed using a Leica ALS70 sensor.

3.3 LiDAR Acquisition

Data acquired from eight (8) flight missions was utilized to provide project area coverage. Refer to Table 3.3a and 3.3b for acquisition parameters. Acquired swaths can be seen in Image 3.3a and 3.3b on the following page. Section 7 contains the flight logs.

A Leica sensor used on board a Piper Navajo Twin aircraft. Airborne GPS and IMU position and trajectory data of the LiDAR sensor were also acquired during the time of flight.

Before take-off, the LiDAR system and the Airborne GPS and IMU system were initialized for a period of five minutes and in operation after landing for another five minutes. 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 4ppsm

Sensor Type	Leica ALS - 70
Sensor ID	SN7220
Field of View	40°
Flying Height (Above mean sea level)	1433 - 1518m
Pulse Rate Frequency	358 kHz
Mirror Scan Rate Frequency	53.4 Hz
Scan Angle (degrees)	20°
Ground Speed	150 kts
Average Point Density	4.2 pts/m^2
Minimum Overlap	11.84%

Table 3.3b: Acquisition Parameters 8ppsm

Sensor Type	Leica ALS - 70
Sensor ID	NS7220
Field of View	36°
Flying Height (Above mean sea level)	751 - 800m
Pulse Rate Frequency	335.4 kHz
Mirror Scan Rate Frequency	56 Hz
Scan Angle (degrees)	18°
Ground Speed	150 kts
Average Point Density	8.36 pts/m^2
Minimum Overlap	19.28%

Image 3.3a: Swaths for 4ppsm data, colored by mission. Mission 20131124-135651 is orange, 20131127-144235 is blue, 20131127-213804 is yellow, 20131128-135545 is red, and 20131130-155001 is green.

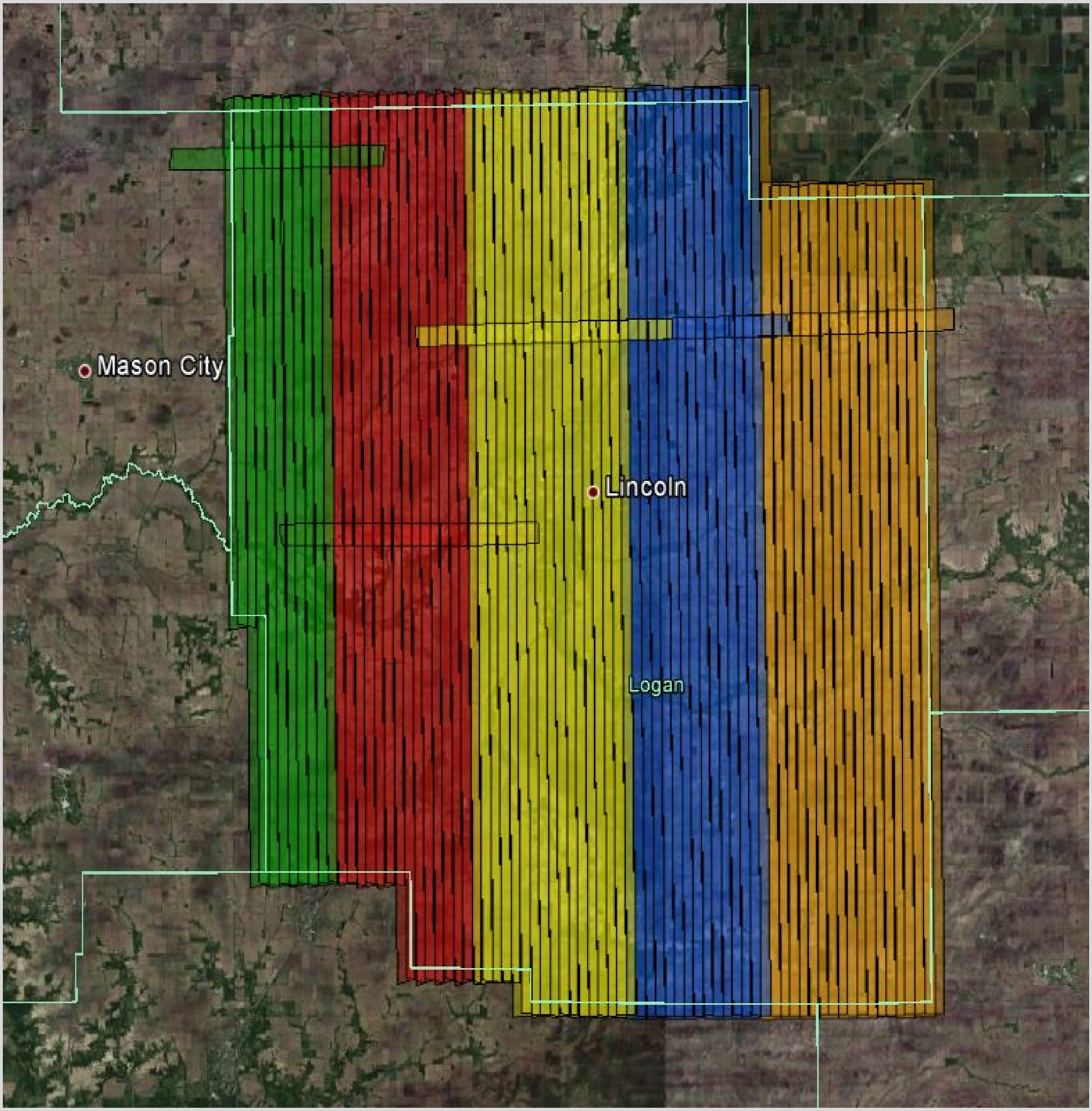
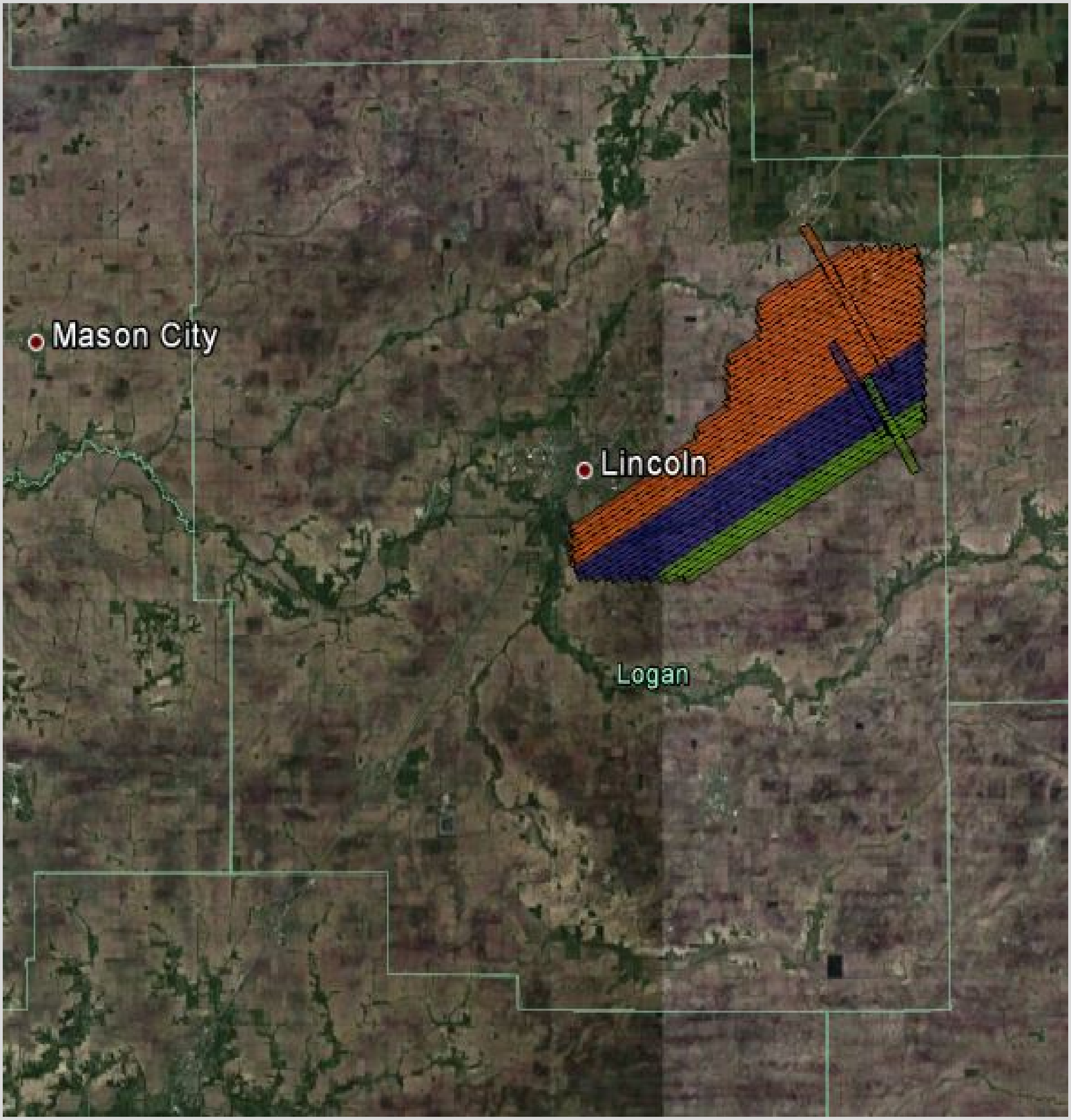


Image 3.3b: Swaths for 8ppsm data. colored by mission. Mission 20131123-223305 is orange, 20131124-191118 is purple, and 20131126-144704 is green.



3.4 LiDAR Trajectory Processing

Missions were processed using a Continuously Operating Reference Station (CORS) station and at least one base station. The image below illustrates locations of these sites relative to the project area.

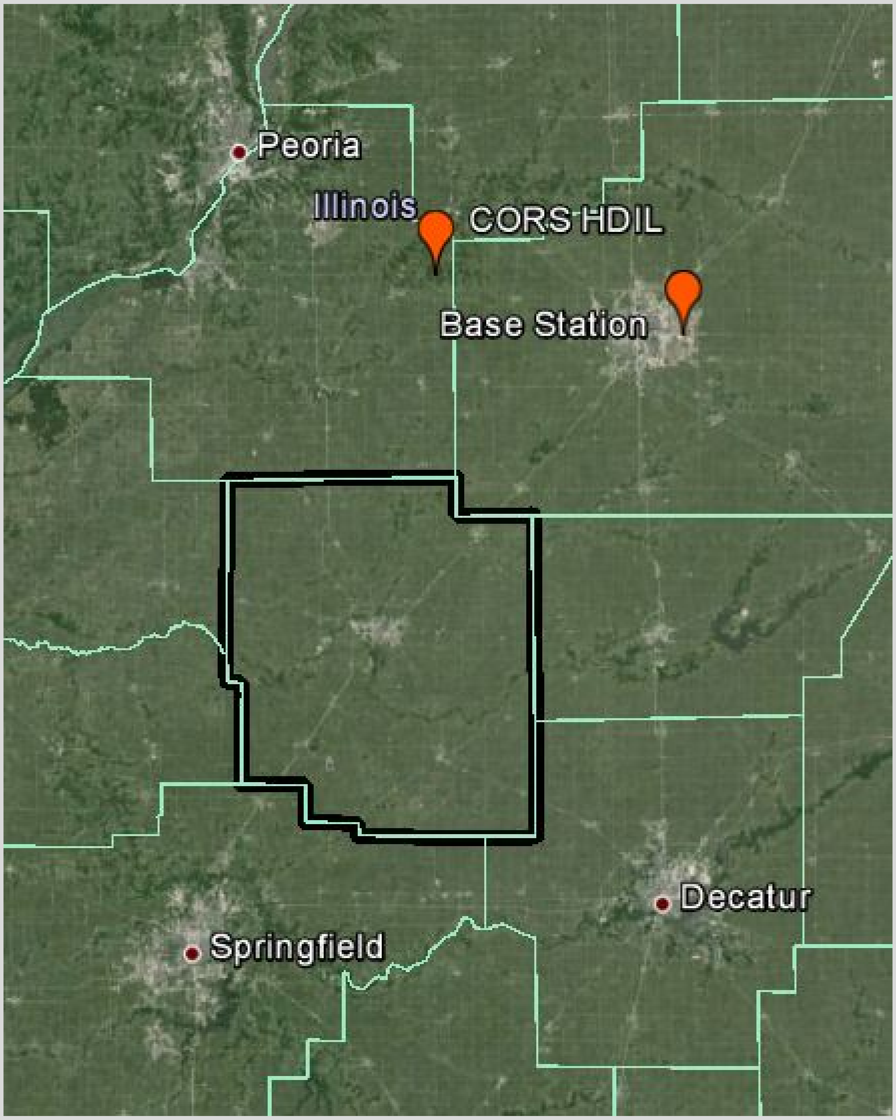
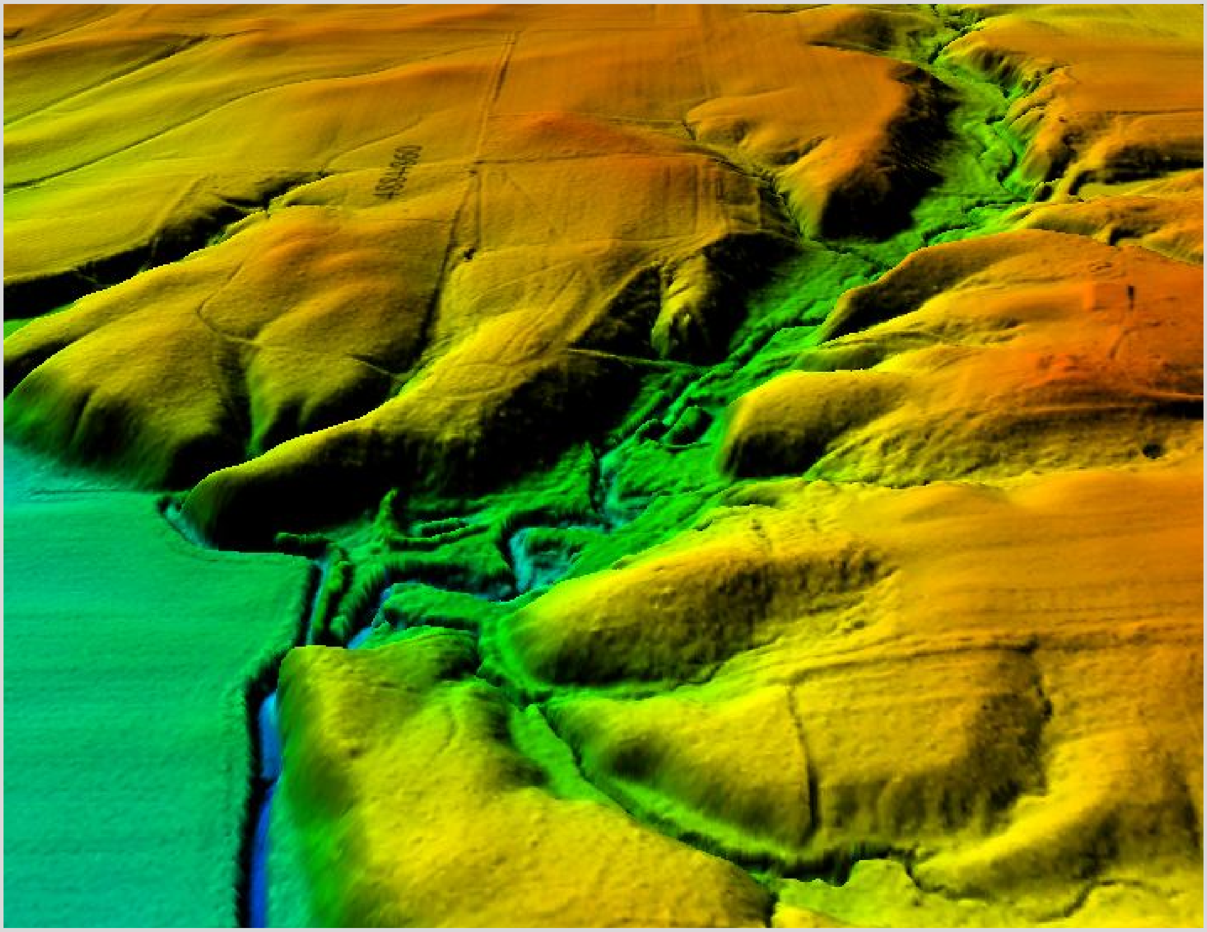


Image 3.4a: Relative location of CORS station HDIL and base station used in flight calibration.

4. Quality Control Surveys

A field survey was performed by Compass Data, Inc. between December 1, 2013 and December 12, 2013. One hundred eighty six (186) check points were collected to calibrate and evaluate airborne LiDAR data in various land coverage categories throughout Logan County.



5. Final LiDAR Processing

5.1 ABGPS and IMU Processing

Airborne GPS

Applanix - POSGPS
Utilizing carrier phase ambiguity resolution on the fly (i.e., without initialization), the solution to sub-decimeter kinematic positioning without the operational constraint of static initialization as used in semi-kinematic or stop-and-go positioning was utilized for the airborne GPS post-processing.

The processing technique used by Applanix, Inc. for achieving the desired accuracy is Kinematic Ambiguity Resolution (KAR). KAR searches for ambiguities and uses a special method to evaluate the relative quality of each intersection (RMS). The quality indicator is used to evaluate the accuracy of the solution for each processing computation. In addition to the quality indicator, the software will compute separation plots between any two solutions, which will ultimately determine the acceptance of the airborne GPS post processing.

Inertial Data
The post-processing of inertial and aiding sensor data (i.e. airborne GPS post processed data) is to compute an optimally blended navigation solution. The Kalman filter-based aided inertial navigation algorithm generates an accurate (in the sense of least-square error) navigation solution that will retain the best characteristics of the processed input data. An example of inertial/GPS sensor blending is the following: inertial data is smooth in the short term. However, a free- inertial navigation solution has errors that grow without bound with time. A GPS navigation solution exhibits short-term noise but has errors that are bounded. This optimally blended navigation solution will retain the best features of both, i.e. the blended navigation solution has errors that are smooth and bounded. The resultant processing generates the following data:

- Position: .... Latitude, Longitude, Altitude
- Velocity: .... North, East, and Down components
- 3-axis attitude:......... roll, pitch, true heading
- Acceleration: .... x, y, z components
- Angular rates:.......... x, y, z components

The Applanix software, version 4.4, was used to determine both the ABGPS trajectory and the blending of inertial data.

The airborne GPS and blending of inertial and GPS post-processing were completed in multiple steps.

1. The collected data was transferred from the field data collectors to the main computer. Data was saved under the project number and separated between LiDAR mission dates. Inside each mission date, a sub-directory was created with the aircraft's tail number and an A or B suffix was attached for the time of when the data was collected. Inside the tail number sub-directory, five sub- directories were also created EO, GPS, IMU, PROC, and RAW.

2. The aircraft raw data (IMU and GPS data combined) was run through a data extractor program. This separated the IMU and GPS data. In addition to the extracting of data, it provided the analyst the first statistics on the overall flight. The program was POSPac (POS post-processing PACkage).

3. Executing POSGPS program to derive accurate GPS positions for all flights: Applanix POSGPS

The software utilized for the data collected was PosGPS, a kinematic on- the-fly (OTF) processing software package. Post processing of the data is computed from each base station (Note: only base stations within the flying area were used) in both a forward and backward direction. This provides the analyst the ability to Quality Check (QC) the post processing, since different ambiguities are determined from different base stations and also with the same data from different directions.

The trajectory separation program is designed to display the time of week that the airborne or roving antenna traveled, and compute the differences found between processing runs. Processed data can be compared between a forward/reverse solution from one base station, a reverse solution from one base station and a forward solution from the second base station, etc. For the Applanix POSGPS processing, this is considered the final QC check for the given mission. If wrong ambiguities were found with one or both runs, the analyst would see disagreements from the trajectory plot, and re-processing would continue until an agreement was determined.

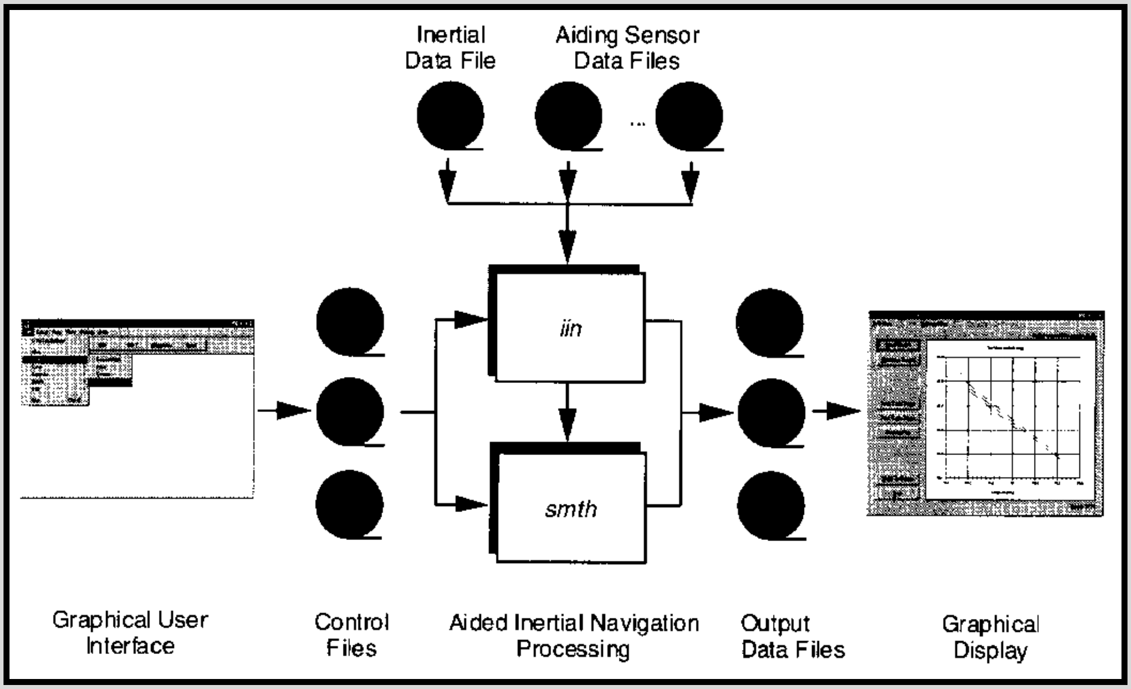
Once the analyst accepts a forward and reverse processing solution, the trajectory plot is analyzed and the combined solution is stored in a file format acceptable for the IMU post processor.

Please see Section 8 of the control report for the final accepted trajectory plots.

4. When the processed trajectory (either through POSGPS) data was accepted after quality control analysis, the combined solution is stored in a file format acceptable for the IMU post processor (i.e. POSProc).

5. Execute POS Proc. POS Proc comprises a set of individual processing interface tools that execute and provide the following functions:

The diagram below shows the organization of these tools, and is a function of the POSProc processing components.



Integrated Inertial Navigation (iin) Module.
The name *iin* is a contraction of Integrated Inertial Navigation. *iin* reads inertial data and aiding data from data files specified in a processing environment file and computes the aided inertial navigation solution. The inertial data comes from a strapdown IMU. *iin* outputs the navigation data between start and end times at a data rate as specified in the environment file. *iin* also outputs Kalman filter data for analysis of estimation error statistics and smoother data that the smoothing program *smth* uses to improve the navigation solution accuracy.

iin implements a full strapdown inertial navigator that solves Newton's equation of motion on the earth using inertial data from a strapdown IMU. The inertial navigator implements coning and sculling compensation to handle potential problems caused by vibration of the IMU.

Smoother Module (*smth*).
smth is a companion processing module to *iin*. *smth* is comprised of two individual functions that run in sequence. *smth* first runs the *smoother function* and then runs the *navigation correction function*.

The *smth* smoother function performs backwards-in-time processing of the forwards-in-time blended navigation solution and Kalman filter data generated by *iin* to compute smoothed error estimates. *smth* implements a modified Bryson-Frazier smoothing algorithm specifically designed for use with the *iin* Kalman filter. The resulting smoothed strapdown navigator error estimates at a given time point are the optimal estimates based on all input data before and after the given time point. In this sense, *smth* makes use of all available information in the input data. *smth* writes the smoothed error estimates and their RMS estimation errors to output data files.

The *smth* navigation correction function implements a feedforward error correction mechanism similar to that in the *iin* strapdown navigation solution using the smoothed strapdown navigation errors. *smth* reads in the smoothed error estimates and with these, corrects the strapdown

navigation data. The resulting navigation solution is called a Best Estimate of Trajectory (BET), and is the best obtainable estimate of vehicle trajectory with the available inertial and aiding sensor data.

The above mentioned modules provide the analyst the following statistics to ensure that the most optimal solution was achieved: a log of the *iin* processing, the Kalman filter Measurement Residuals, Smoothed RMS Estimation Errors, and Smoothed Sensor Errors and RMS,

5.2 LiDAR “Point Cloud” Processing

The ABGPS/IMU post processed data along with the LiDAR raw measurements were processed using Optech Incorporated’s ASDA software. This software was used to match the raw LiDAR measurements with the computed ABGPS/IMU positions and attitudes of the LiDAR sensor. The result was a “point cloud” of LiDAR measured points referenced to the ground control system.

5.3 LiDAR CALIBRATION

Introduction

The purpose of the LiDAR system calibration is to refine the system parameters in order for the post-processing software to produce a “point cloud” that best fits the actual ground.

The following report outlines the calibration techniques employed for this project.

Calibration Procedures

All Companies involved in collection routinely performs two types of calibrations on its airborne LiDAR system. The first calibration, system calibration, is performed whenever the LiDAR system is installed in the aircraft. This calibration is performed to define the system parameters affected by the physical misalignment of the system versus aircraft. The second calibration, in-situ calibration, is performed for each mission using that missions data. This calibration is performed to refine the system parameters that are affected by the on site conditions as needed.

System Calibration

The system calibration is performed whenever the LiDAR system is installed in the aircraft. This calibration is performed to define the system parameters affected by the physical misalignment of the system versus aircraft. The main system parameters that are affected are the heading, pitch, roll, and mirror scale.

The system calibration is performed by collecting data over a known test site that incorporates a flat surface and a large, flat roofed building. A ground survey is completed to define the flat surface and the building corners. The processed LiDAR data and ground survey data is input into TerraSolid's TerraMatch software to determine the systematic errors. The system parameters are then corrected according to the determined errors and used in the processing of future LiDAR acquisition missions.

In-situ Calibration

The in-situ calibration is performed as needed using the mission’s data. This calibration is performed to refine the system parameters that are affected by the on site conditions.

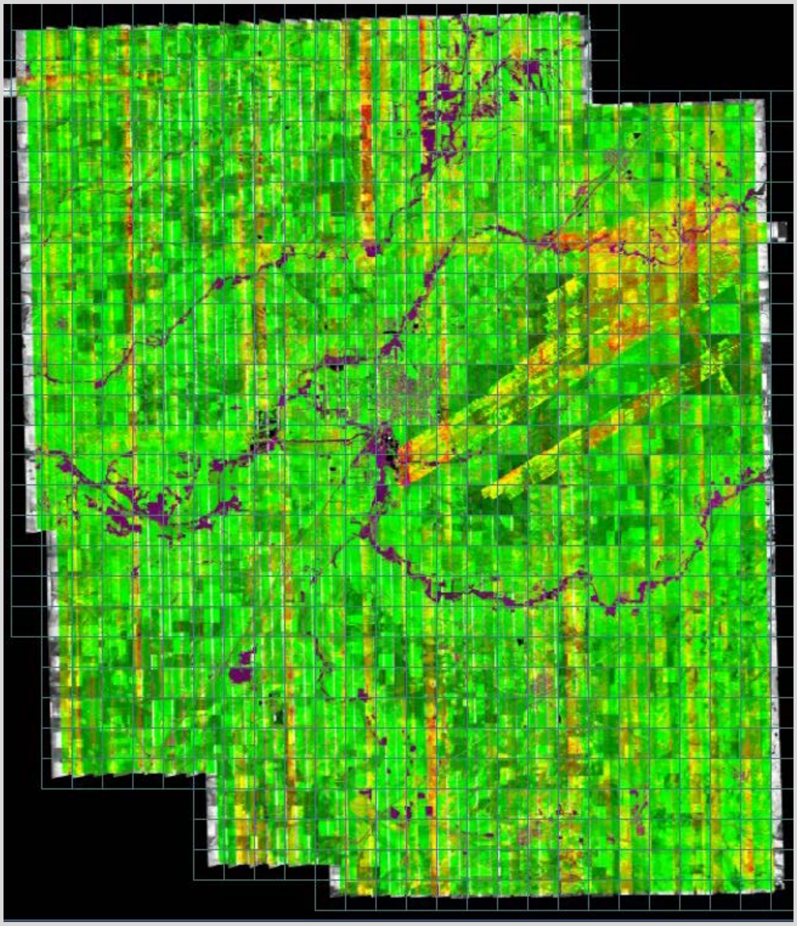
For each mission, LiDAR data for at least one cross flight is acquired over the mission’s acquisition site. The processed data of the cross flight is compared to the perpendicular flight lines using either the Optech proprietary software or TerraSolid's TerraMatch software to determine if any systematic errors are present. In this calibration, the data of individual flight lines are compared against each other and their systematic errors are corrected in the final processed data.

5.4 LiDAR Processing

The LAS files are imported, verified, and parsed into manageable, tiled grids using GeoCue version 2012.1.27.7. GeoCue allows for ease of data management and process tracking. Relative accuracy of flightline to flightline alignment is assessed. Image 5.4a illustrates relative vertical alignment of flightlines.

- Green indicates a flightline difference of less than 0.16 feet;
- Yellow…. 0.16 – 0.33 feet;
- Orange… 0.33 – 0.48 feet;
- Red…….. 0.48 – 0.64 feet;
- Magenta.. 0.64 feet or greater.

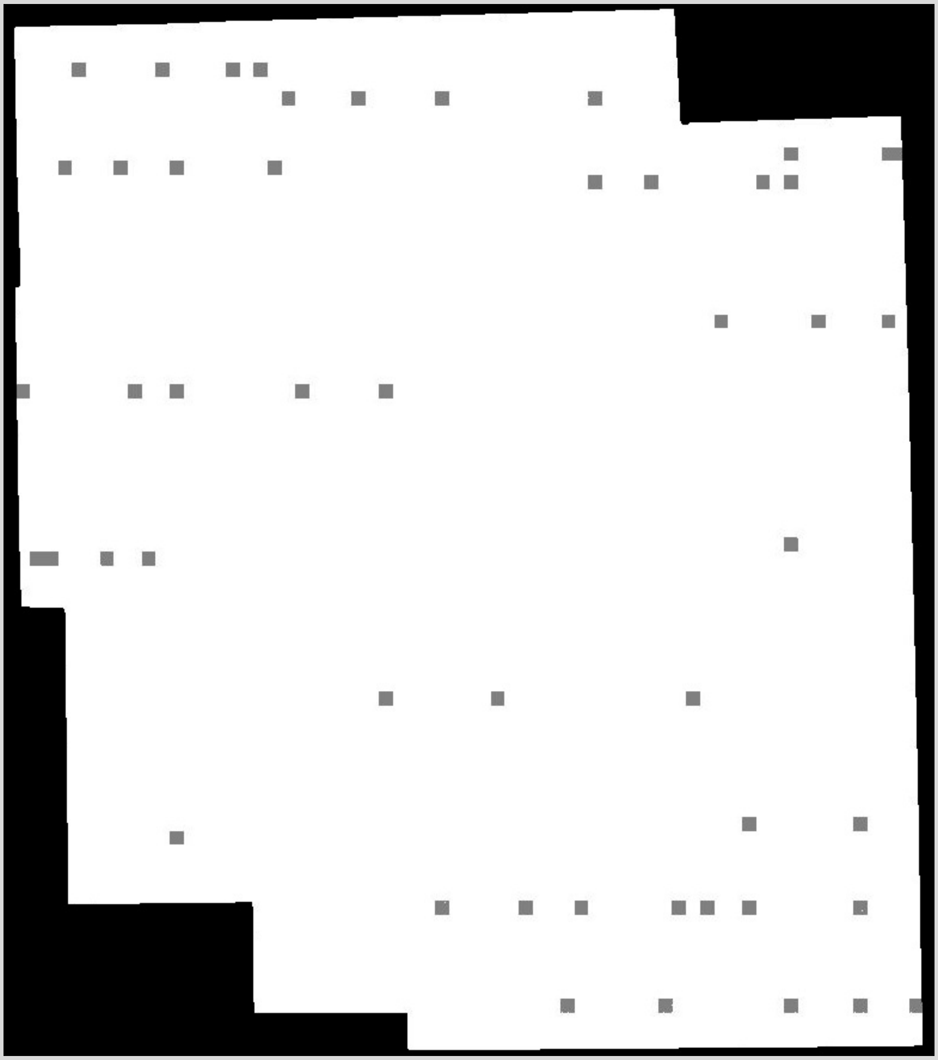
Image 5.4a: Relative Accuracy Assessment



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.

A few tiles are evaluated to ensure that the desired point density has been met. Image 5.4b illustrates tiles analyzed for point density. 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.

Image 5.4b: Locations of sample tiles in point density analysis.

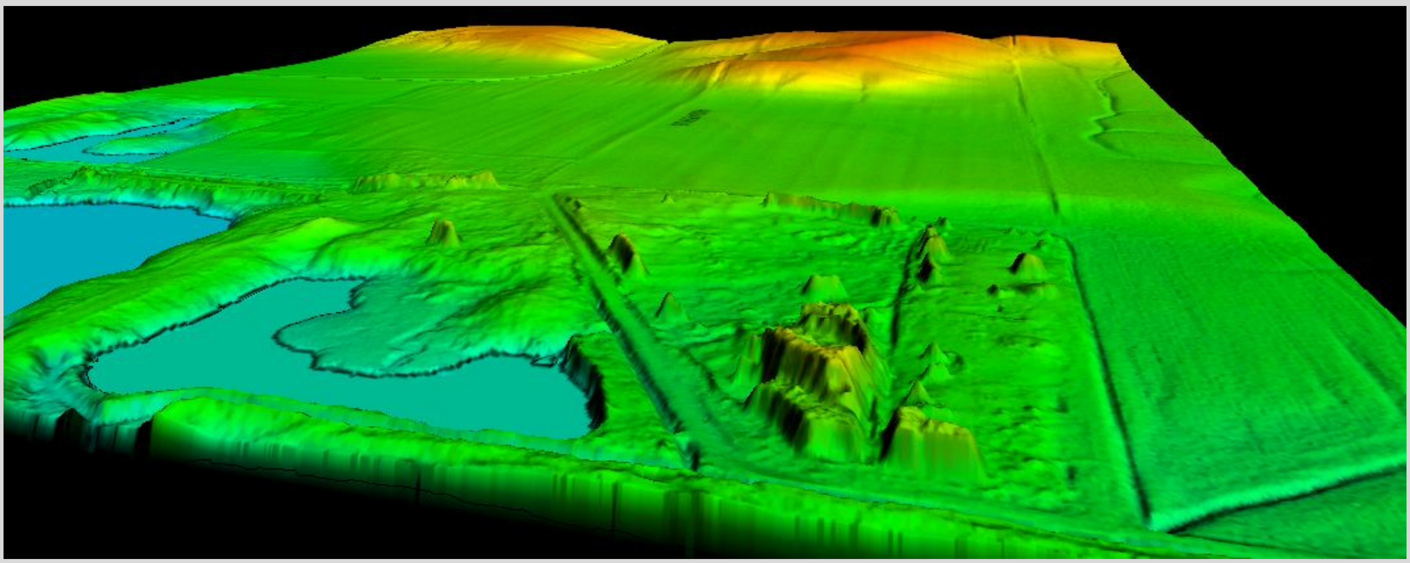


Fifty eight tiles were analyzed.

3.2 foot grid size/point spacing
Total number of cells: 24050487
Total number of cells with one or more points: 23601542
Percentage of cells with 1 point or more: 98.13%

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



5.5 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 9, of this report.

Forty five (45) ground check points were made across the project area to be used in adjusting the data to position. These forty five points were collected by Quantum Spatial, as part of the one hundred eighty six (186) control points collected for the project as described in Section 4, acquired from December 1, 2013 and December 12, 2013.

5.6 Vertical Accuracy Assessment

Vertical accuracy assessment is conducted by comparing ground survey check point z values to processed LiDAR data z values by horizontal proximity. Differences in z values are calculated to express an RMSEz value.

The Fundamental Vertical Accuracy (FVA) of the LAS data achieved 6.51 cm at a 95% confidence level with an RMSE of 3.35 cm utilizing twenty-one (21) Open Terrain ground survey check points compared to a Triangulated Integrated Network (TIN) of the LiDAR points.

See attached **"**Final_Delivery_Report" and "Accuracy_Report" for details of the ground survey control data.

FVA Data Compared to TIN

	Ground Cover Category	Number of Checkpoints	Result cm (ft.)
FVA	Open Terrain	26	6.51 (0.2156)
$RMSE_z$	Open Terrain	26	3.35 (0.110)

The Supplemental Vertical Accuracy (SVA) and Consolidated Vertical Accuracy (CVA) results are in the following table. Ground survey check points made in various ground cover categories are compared to Digital Elevation Models (DEM) derived from the LiDAR data.

Accuracy Results

	Ground Cover Category	Number of Checkpoints	Result cm (ft.)
FVA	Open Terrain	26	7.96 (0.261)
CVA	All categories	119	13.26 (0.435)
SVA	Open Terrain	26	7.16 (0.235)
SVA	Urban	30	9.42 (0.309)
SVA	Tall Grass	20	11.70 (0.384)
SVA	Brush	20	18.81 (0.617)
SVA	Forest	23	13.29 (0.436)

5.7 LiDAR Data Delivery

Raw point cloud data supplied is in the following format:

- LAS, version 1.2
- GPS times adjusted to GPS Absolute
- Full swaths and delivered as 1 file per swath which did not exceed 2 gigabytes.

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

- LAS, version 1.2 in 5280 foot grid
- GPS times adjusted to GPS Absolute
- 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)

Deliverables:

Break line polygons are collected in a Microstation environment to the project specifications using heads up and stereo techniques for collection of drainage and hydro features. They are checked for QC/QA. Upon acceptance the breaklines, either polygons or lines, are translated into ARC and imported to the final geo-database as separate features in ESRI standard.

Ground survey point locations in ESRI shapefile format.

Calibrated LiDAR points as full swaths per flightline.

Classified points as LAS following the standard established by The American Society for Photogrammetry and Remote Sensing (ASPRS) for LAS data on a per tile basis.

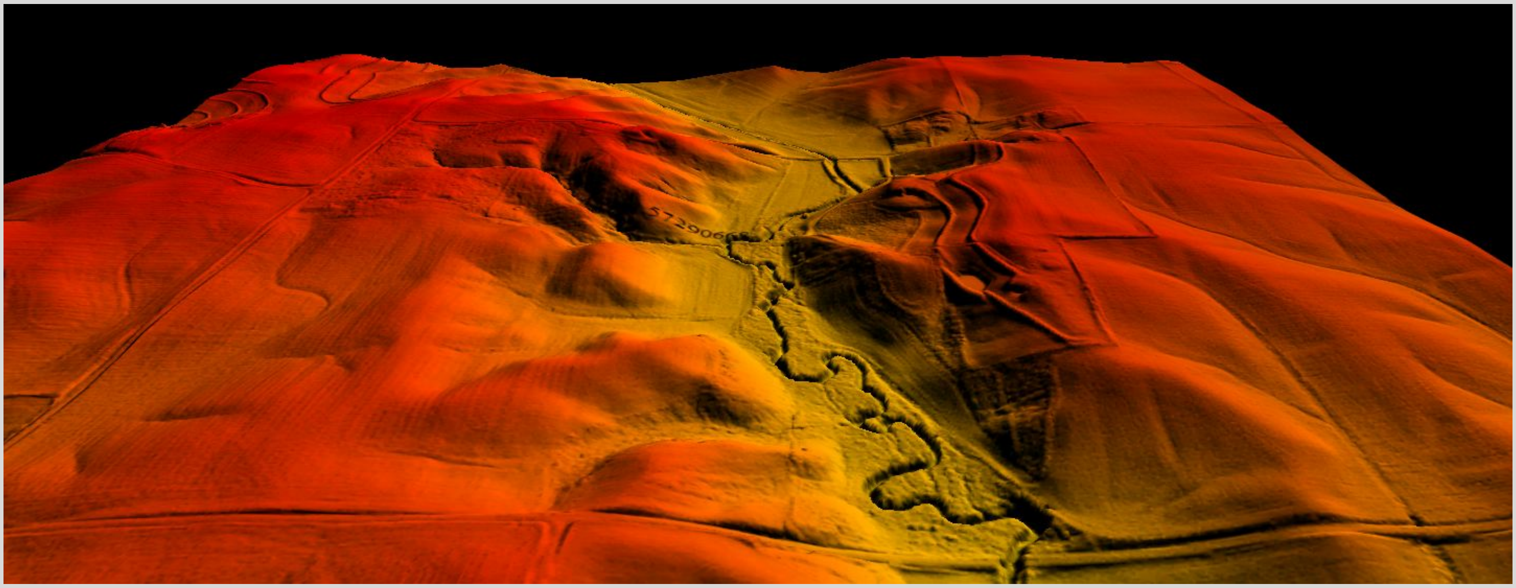
Bare earth Digital Elevation Models (DEM), hyrdo flattened on a per tile basis.

Intensity raster images are produced for each tile through GeoCue, in GeoTIFF format.

Metadata

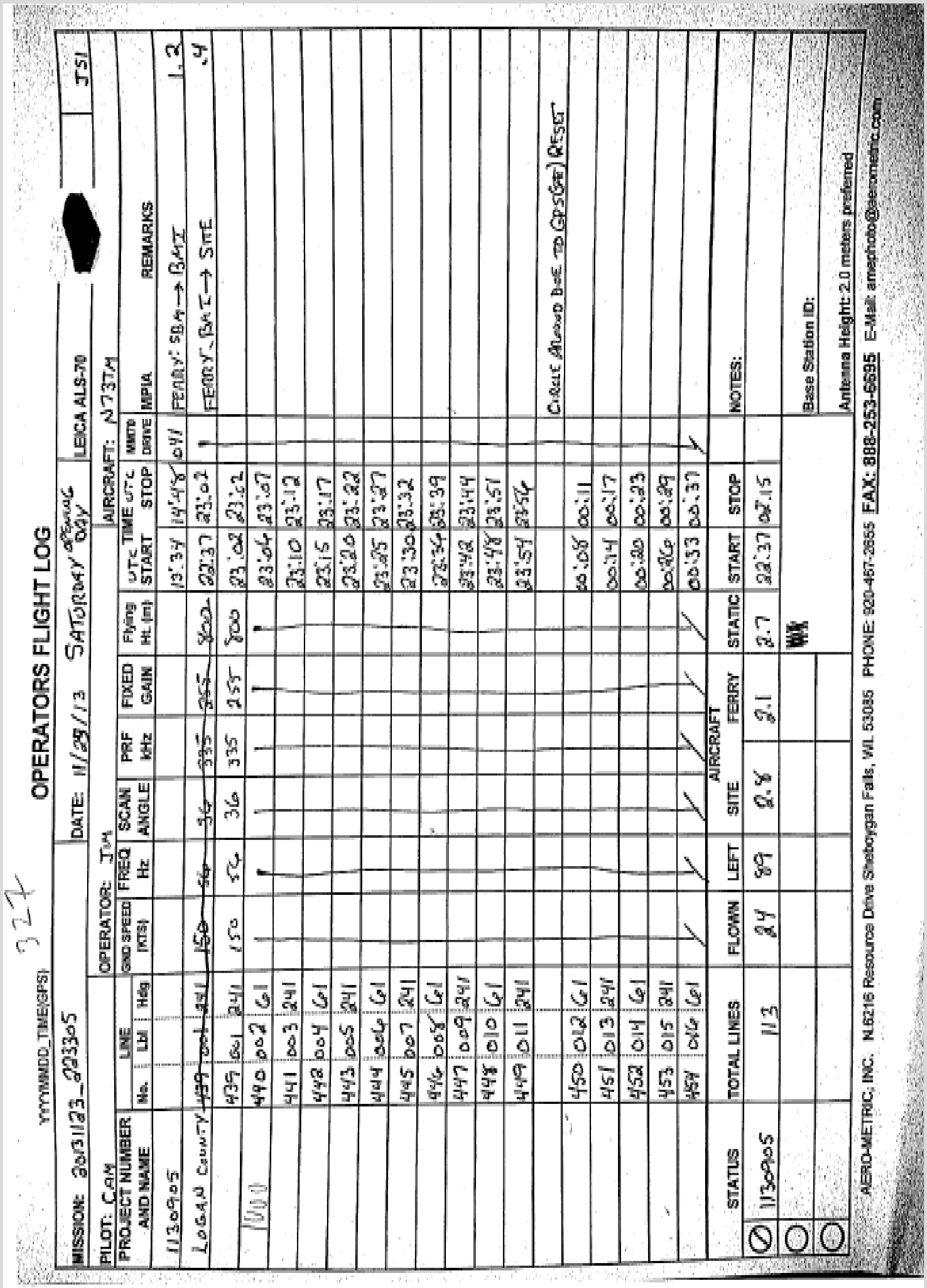
6. Conclusion

Sound procedures and use of new technologies ensure this project data will serve the United States Geological Survey 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 on Logan County, Illinois.



7. Flight Logs and Opus Solutions

Mission 20131123_223305, page 1



327

OPERATORS FLIGHT LOG

YYYYMMDD_TIME(GPS)

MISSION: 20131123_223305 | DATE: 11/23/13 SATURDAY OPENING DAY | LEICA ALS-70 [redacted] | JSI

PILOT: CAM | OPERATOR: JIM | AIRCRAFT: N73TM

PROJECT NUMBER AND NAME	LINE No.	LINE Lbl	LINE Hdg	GND SPEED (KTS)	FREQ Hz	SCAN ANGLE	PRF kHz	FIXED GAIN	Flying Ht. (m)	UTC TIME START	UTC TIME STOP	MMTD DRIVE	MPIA	REMARKS
1130905										13:34	14:48	041	FERRY: SBM → BMI	1.2
LOGAN COUNTY	~~439~~	~~001~~	~~241~~	~~150~~	~~56~~	~~36~~	~~335~~	~~255~~	~~800~~	22:37	23:02		FERRY BMI → SITE	.4
	439	001	241	150	56	36	335	255	800	23:02	23:02			
1000	440	002	61							23:04	23:07			
	441	003	241							23:10	23:12			
	442	004	61							23:15	23:17			
	443	005	241							23:20	23:22			
	444	006	61							23:25	23:27			
	445	007	241							23:30	23:32			
	446	008	61							23:34	23:39			
	447	009	241							23:42	23:44			
	448	010	61							23:48	23:51			
	449	011	241							23:54	23:56			
													CIRCLE AROUND BOE TO GPS(GPE) RESET	
	450	012	61							00:08	00:11			
	451	013	241							00:14	00:17			
	452	014	61							00:20	00:23			
	453	015	241							00:26	00:29			
	454	016	61							00:33	00:37			

STATUS	TOTAL LINES	FLOWN	LEFT	AIRCRAFT SITE	AIRCRAFT FERRY	STATIC	START	STOP	NOTES:
Ø 1130905	113	24	89	2.8	2.1	2.7	22:37	02:15	
O						WK			Base Station ID:
O									Antenna Height: 2.0 meters preferred

AERO-METRIC, INC. N.6216 Resource Drive Sheboygan Falls, WI. 53085 PHONE: 920-457-2655 FAX: 888-253-6695 E-Mail: amephoto@aerometric.com

Mission 20131123_223305, page 2.

327

YYYYMMDD_TIME(GPS)

OPERATORS FLIGHT LOG

MISSION: 20131123-223305 | DATE: 11/23/13 SAT. OPENING DAY | LEICA ALS-70 [redacted] | J52

PILOT: CAM | OPERATOR: JIM | AIRCRAFT: N73TM

PROJECT NUMBER AND NAME	LINE No.	LINE Lbl	LINE Hdg	GND SPEED (KTS)	FREQ Hz	SCAN ANGLE	PRF kHz	FIXED GAIN	Flying Ht. (m)	UTC TIME START	UTC STOP	MM70 DRIVE	MPIA	REMARKS
1130905	455	017	241	150	56	36	335	255	800	00:40	00:43	041		
LOGAN COUNTY	456	018	61							00:47	00:52			
	457	019	241							00:56	01:01			
	458	020	61							01:04	01:09			
	459	021	241							01:13	01:17			
	460	022	61							01:21	01:26			
	461	023	241							01:29	01:34			
	462	024	61							01:38	01:42			
	CROSS		241							01:46	01:48			
											02:15		FERRY: SITE → BMI	.5

STATUS	TOTAL LINES	FLOWN	LEFT	AIRCRAFT SITE	AIRCRAFT FERRY	STATIC	START	STOP	NOTES:
○									
○						WK			Base Station ID:
○									Antenna Height: 2.0 meters preferred

AERO-METRIC, INC. N.6216 Resource Drive Sheboygan Falls, WI. 53085 PHONE: 920-467-2655 **FAX: 888-253-6695** E-Mail: amephoto@aerometric.com

Mission 20131124_135651, page 1.

YYYYMMDD_TIME(GPS) 328

OPERATORS FLIGHT LOG

MISSION: 20131124_ | DATE: 11/24/13 PACKER SUNDAY | LEICA ALS-70 | JSI

PILOT: CAM | OPERATOR: JIM | AIRCRAFT: N737M

PROJECT NUMBER AND NAME	LINE No.	LINE Lbl	LINE Hdg	GND SPEED (KTS)	FREQ Hz	SCAN ANGLE	PRF kHz	FIXED GAIN	Flying Ht. (m)	UTC TIME START	UTC TIME STOP	DRIVE	MPIA	REMARKS
113095S										14:00	14:24	041		FERRY: BMI → SITE VIA BLOM CORS -4
LOGAN COUNTY	435	A73	182	150	53	40	358	255	1500	14:24	14:33			
	434	A72	001							14:37	14:46			
2000	433	A71	181							14:50	14:59			
	432	A70	001							15:03	15:13			
	431	A69	181							15:16	15:26			
	430	A68	001							15:29	15:39			
	429	A67	181							15:43	15:52			
	428	A66	001							15:56	16:05			
	427	A65	181							16:09	16:18			
	426	A64	001							16:22	16:31			
	425	A63	181							16:35	16:44			
	424	A62	001							16:48	16:57			
	423	A61	181							17:01	17:10			
	422	A60	001							17:13	17:22			
	421	A59	181							17:26	17:35			
	420	A58	001							17:39	17:48			
	419	A57	181							17:52	18:01			
	418	A56	001							18:04	18:14			

STATUS	TOTAL LINES	FLOWN	LEFT	AIRCRAFT SITE	AIRCRAFT FERRY	STATIC	START	STOP	NOTES
113095S	111 [illegible]	54/19	69	4.0	.8	4.8	14:00	18:45	
		42				[illegible]			Base Station ID: B…
									Antenna Height: 2.0 meters preferred 2.0

AERO-METRIC, INC. N 6216 Resource Drive Sheboygan Falls, WI 53085 PHONE: 920-467-2655 FAX: 888-253-6695 E-Mail: amephoto@aerometric.com

Mission 20131124_135651, page 2.

YYYYMMDD_TIME(GPS) 328

OPERATORS FLIGHT LOG

MISSION: 20131124- DATE: 11/24/13 PACKER SUNDAY LEICA ALS-70 J52

PILOT: CAM OPERATOR: JIM AIRCRAFT: N737M

PROJECT NUMBER AND NAME	LINE No.	LINE Lbl	LINE Hdg	GND SPEED (KTS)	FREQ Hz	SCAN ANGLE	PRF kHz	FIXED GAIN	Flying Ht. (m)	UTC TIME UTC START	STOP	MM70 DRIVE	MPIA	REMARKS
1130905	4PPMBlock		90	150	53	40	358	255	1500	18:19	18:22	041		
LOGAN COUNTY											18:45			FERRY: SITE → BMI VIA BLAM CORS .4

STATUS	TOTAL LINES	FLOWN	LEFT	AIRCRAFT SITE	FERRY	STATIC	START	STOP	NOTES:
⊘ 1130905	111								
○						WX			Base Station ID:
○									Antenna Height: 2.0 meters preferred

AERO-METRIC, INC. N.6216 Resource Drive Sheboygan Falls, WI. 53085 PHONE: 920-467-2655 FAX: 888-253-6695 E-Mail: amephoto@aerometric.com

Mission 20131124_191118

YYYYMMDD_TIME(GPS)

OPERATORS FLIGHT LOG

MISSION: 20131124_ | DATE: 11/24/13 Packer Sunday | LEICA ALS-70 [redacted] | J53

PILOT: CAM | OPERATOR: JIM | AIRCRAFT: N737A

PROJECT NUMBER AND NAME	LINE No.	LINE Lbl	LINE Hdg	GND SPEED (KTS)	FREQ Hz	SCAN ANGLE	PRF kHz	FIXED GAIN	Flying Ht. (m)	UTC TIME START	UTC TIME STOP	MMTO DRIVE	MPIA	REMARKS
1130905										19:15	19:42	041		FERRY: BHI → SITE VIA BLAM CORS .4
LOGAN COUNTY	463	025	241	150	56	36	335	255	800	19:42	19:46			
	464	026	61							19:50	19:55			
9000	465	027	241							19:58	20:03			
	466	028	61							20:06	20:11			
	467	029	241							20:14	20:19			
	468	030	61							20:22	20:27			
	469	031	241							20:31	20:35			
	470	032	61							20:38	20:42			OIL PRESSURE DROPPED - RIGHT ENGINE
	X													
	471	033	241							20:46	20:50			
	472	034	61							20:54	20:57			
	X	UL01	332							21:00	21:02			
											21:27			FERRY: SITE → BHI VIA BLAM CORS .5

STATUS	TOTAL LINES	FLOWN	LEFT	AIRCRAFT SITE	AIRCRAFT FERRY	STATIC	START	STOP	NOTES:
Ø 1130905	111	42/10	59	1.3	.9	2.2	19:15	21:27	
O		52							Base Station ID:
O									Antenna Height: 2.0 meters preferred

AERO-METRIC, INC. N.6216 Resource Drive Sheboygan Falls, WI. 53085 PHONE: 920-467-2655 FAX: 888-253-6695 E-Mail: amephoto@aerometric.com

Mission 20131126_144704

330

YYYYMMDD_TIME(GPS)

OPERATORS FLIGHT LOG

MISSION: V 20131126-144704 | DATE: 11/26/13 TUE | LEICA ALS-70 [redacted] | TSI

PILOT: CAM | OPERATOR: JIM | AIRCRAFT: N73TM

PROJECT NUMBER AND NAME	LINE No.	LINE Lbl	LINE Hdg	GND SPEED (KTS)	FREQ Hz	SCAN ANGLE	PRF kHz	FIXED GAIN	Flying Ht. (m)	UTC TIME START	UTC TIME STOP	MM30 DRIVE	REMARKS (MPIA-Disabled/Enabled) (WF Settings)
1130905										14:51	15:16	041	FERRY: BMI → SITE VIA BLOOM CORS .5
LOGAN COUNTY	473	035	241	150	56	36	335	255	800	15:16	15:20		
	474	036	61							15:23	15:27		
4600	475	037	241							15:30	15:34		
	476	038	61							15:37	15:40		
	X	4601	333							15:43	15:49		
											16:09		FERRY: SITE → BMI VIA BLOOM CORS .4

STATUS	TOTAL LINES	FLOWN	LEFT	AIRCRAFT SITE	AIRCRAFT FERRY	STATIC	START	STOP	NOTES: FLT. #4
Ø 1130905	111	53/4	55	.4	.9	1.3	14:51	16:09	UNABLE TO FLY THE HIGH STUFF
○		56				WX OVC 34 VIS ±5			[redacted]
○									

AERO-METRIC, INC. N6216 Resource Drive Sheboygan Falls, WI. 53085 PHONE: 920-467-2855 FAX: 888-253-6695 E-Mail: amephoto@aerometric.com

Mission 20131127_144235

351

OPERATORS FLIGHT LOG

MISSION (YYYYMMDD_TIME(GPS)): 20131127_144235 | DATE: 11/27/13 WED | LEICA ALS-70 | JS1

PILOT: CAM | OPERATOR: JIM | AIRCRAFT: N73TM | ALS-70 7220

PROJECT NUMBER AND NAME	LINE No.	LINE Lbl	LINE Hdg	GND SPEED (KTS)	FREQ Hz	SCAN ANGLE	PRF kHz	FIXED GAIN	Flying Ht. (m)	UTC TIME START	UTC TIME STOP	MM/0 DRIVE	REMARKS (MPIA-Disabled/Enabled) (WF Settings)
1130905										14:46	15:10	039	FERRY: BMI → SITE via Bloomington .4
LOGAN COUNTY	417	A55	182	150	53	40	358	345	1500	15:10	15:20		
5001	416	A54	001							15:24	15:35		
	415	A53	181							15:39	15:49		
	414	A52	001							15:53	16:04		
	413	A51	181							16:08	16:17		
	412	A50	001							16:21	16:32		
	411	A49	181							16:36	16:46		
	410	A48	001							16:50	17:00		
	409	A47	181							17:04	17:14		
	408	A46	001							17:18	17:29		
	407	A45	181							17:33	17:43		
	406	A44	001							17:46	17:57		
	405	A43	181							18:01	18:11		
	404	A42	001							18:15	18:25		
	X	Loc'd	90							18:30	18:33		
											18:59		FERRY: SITE → BMI via Bloomington .5

STATUS		TOTAL LINES	FLOWN	LEFT	AIRCRAFT SITE	AIRCRAFT FERRY	STATIC	START	STOP	NOTES: FLT #5
Ø	1130905	111	56/14	41	3.3	.9	4.2	14:46	18:59	OVE STARTING TO PDP 15:40 _ DISARMED
O			70				WX SKC VIS 9-10			
O										

AERO-METRIC, INC. N.6216 Resource Drive Sheboygan Falls, WI. 53085 PHONE: 920-467-2655 FAX: 888-253-6695 E-Mail: amephoto@aerometric.com

Mission 20131127_213804

YYYYMMDD_TIME(GPS) 337

OPERATORS FLIGHT LOG

MISSION: 20131127 - 213804 | DATE: 11/27/13 WED | LEICA ALS-70 7220 | J32

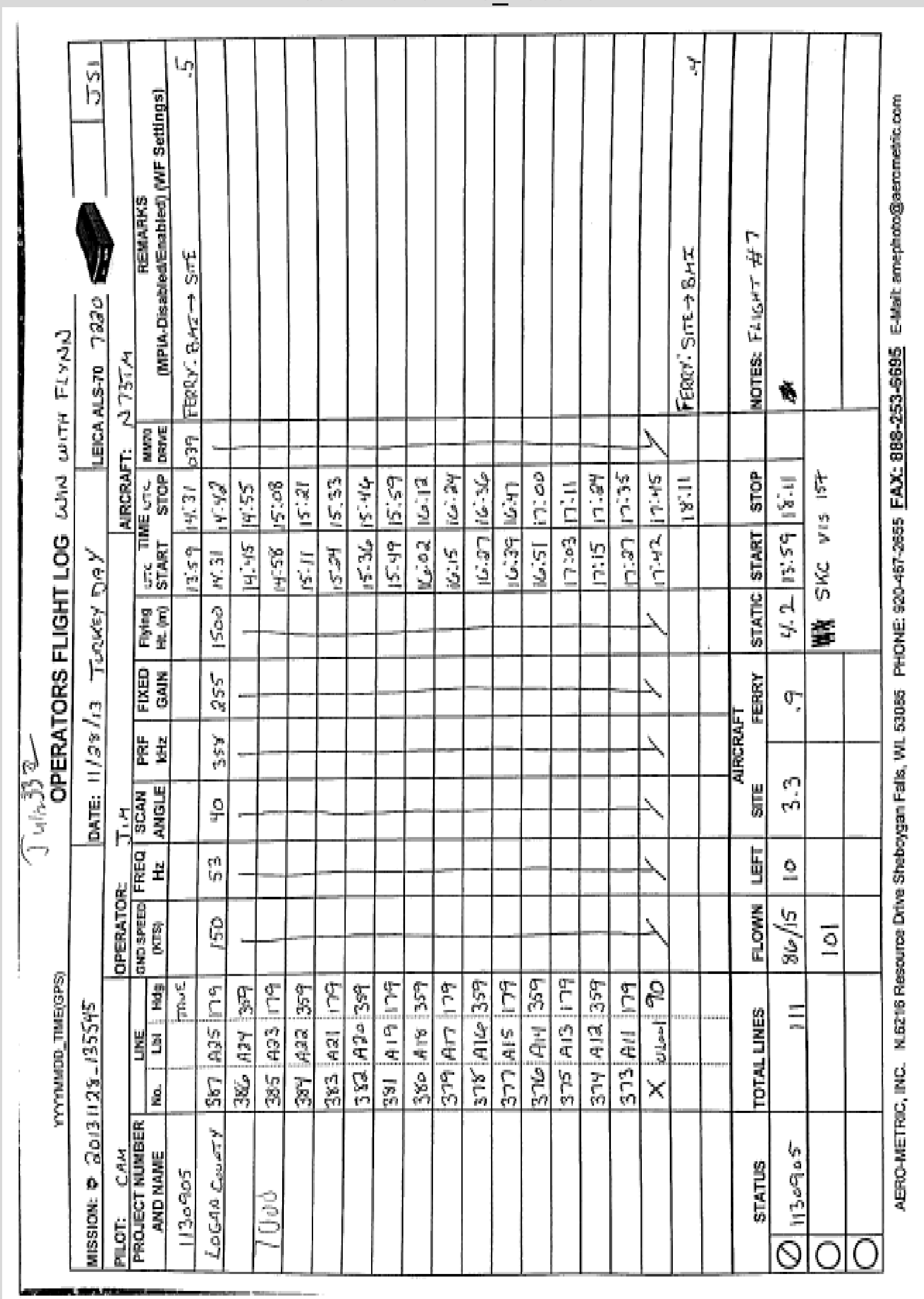
PILOT: CAM | OPERATOR: TIM | AIRCRAFT: N73TM

PROJECT NUMBER AND NAME	LINE No.	LINE Lbl	LINE Hdg	GND SPEED (KTS)	FREQ Hz	SCAN ANGLE	PRF kHz	FIXED GAIN	Flying Ht. (m)	UTC TIME START	UTC TIME STOP	MMTS DRIVE	REMARKS
1130905										21:42	22:06	041	FERRY: BMI → SITE via Bloom coas .4
LOGAN COUNTY	403	A41	181	150	53	40	358	255	1500	22:06	22:16		
OHIO	402	A40	001							22:20	22:30		
	401	A39	181							22:34	22:44		
	400	A38	001							22:48	22:58		
	399	A37	181							23:02	23:12		
	398	A36	001							23:16	23:27		
	397	A35	181							23:30	23:40		
	396	A34	001							23:44	23:54		
	395	A33	181							23:58	00:08		
	394	A32	001							00:12	00:22		
	393	A31	181							00:26	00:36		
	392	A30	001							00:40	00:50		
	391	A29	181							00:54	01:03		
	390	A28	001							01:07	01:17		
	389	A27	181							01:21	01:31		
	~~X~~	~~Loch~~	~~90~~										
	388	A26	001							01:33	01:43		
	X	Loch	90	✓	✓	✓	✓	✓	✓	01:48	01:51	✓	FERRY: SITE → BMI (STOP: 02:17) .4

STATUS		TOTAL LINES	FLOWN	LEFT	AIRCRAFT SITE	AIRCRAFT FERRY	STATIC	START	STOP	NOTES: FLT. #6
⊘	1130905	111	70/16	25	3.8	.8	4.6	21:42	02:17	
○			86				WX SKC VIS 9-10			
○										

AERO-METRIC, INC. N.6216 Resource Drive Sheboygan Falls, WI. 53085 PHONE: 920-467-2655 FAX: 888-253-6695 E-Mail: amephoto@aerometric.com

Mission 20131128_135545



YYYYMMDD_TIME(GPS) Julia332

OPERATORS FLIGHT LOG WIN WITH FLYNN

MISSION: 20131128_135545 DATE: 11/28/13 TURKEY DAY LEICA ALS-70 7220 JSI

PILOT: CAM OPERATOR: JIM AIRCRAFT: N73TM

PROJECT NUMBER AND NAME	LINE No.	LINE Lbl	LINE Hdg	GND SPEED (KTS)	FREQ Hz	SCAN ANGLE	PRF kHz	FIXED GAIN	Flying Ht. (m)	TIME UTC START	TIME UTC STOP	MM70 DRIVE	REMARKS (MPIA-Disabled/Enabled) (WF Settings)
1130905			TRUE							13:59	14:31	039	FERRY: BAZ → SITE .5
LOGAN COUNTY	387	A25	179	150	53	40	358	255	1500	14:31	14:42		
	386	A24	359							14:45	14:55		
7000	385	A23	179							14:58	15:08		
	384	A22	359							15:11	15:21		
	383	A21	179							15:24	15:33		
	382	A20	359							15:36	15:46		
	381	A19	179							15:49	15:59		
	380	A18	359							16:02	16:12		
	379	A17	179							16:15	16:24		
	378	A16	359							16:27	16:36		
	377	A15	179							16:39	16:47		
	376	A14	359							16:51	17:00		
	375	A13	179							17:03	17:11		
	374	A12	359							17:15	17:24		
	373	A11	179							17:27	17:35		
	X	ulool	90							17:42	17:45		
											18:11		FERRY: SITE → BAZ .4

STATUS	TOTAL LINES	FLOWN	LEFT	AIRCRAFT SITE	AIRCRAFT FERRY	STATIC	START	STOP	NOTES: FLIGHT #7
Ø 1130905	111	86/15	10	3.3	.9	4.2	13:59	18:11	
O		101				--- SKC VIS 15+			
O									

AERO-METRIC, INC. N.6216 Resource Drive Sheboygan Falls, WI. 53085 PHONE: 920-457-2655 FAX: 888-253-6695 E-Mail: amephoto@aerometric.com

Mission 20131130_155001

334

YYYYMMDD_TIME(GPS)

OPERATORS FLIGHT LOG

MISSION: 20131130-155001 | DATE: 11/30/13 | LEICA ALS-70 7220 [redacted] | JSI

PILOT: CAM | OPERATOR: JIM | AIRCRAFT: N73TM

PROJECT NUMBER AND NAME	LINE No.	LINE Lbl	LINE Hdg	GND SPEED (KTS)	FREQ Hz	SCAN ANGLE	PRF kHz	FIXED GAIN	Flying Ht. (m)	UTC TIME START	UTC TIME STOP	MIRROR DRIVE	REMARKS
1130905			TRUE							15:54	16:26	036	FERRY: BMI → SITE VIA BLOG CARS .5
LOGAN COUNTY	372	A10	179	150	53	40	358	255	1500	16:24	16:35		
	371	A09	359							16:39	16:47		
8000	370	A08	179							16:51	17:00		
	369	A07	359							17:04	17:13		
	368	A06	179							17:16	17:25		
	367	A05	359							17:29	17:37		
	366	A04	179							17:41	17:49		
	365	A03	359							17:53	18:02		
	364	A02	179							18:05	18:11		
	363	A01	359							18:15	18:21		
	X	UL01	90							18:24	18:27		
											18:52		FERRY: SITE → BMI VIA BLOG CARS .4

STATUS	TOTAL LINES	FLOWN	LEFT	AIRCRAFT SITE	AIRCRAFT FERRY	STATIC	START	STOP	NOTES: FLT. #8
⊗ 1130905	111	105/10	Ø	2.1	.9	3.0	15:54	18:26	
O		111				SKC VIS 10-11			
O									

AERO-METRIC, INC. N.6216 Resource Drive Sheboygan Falls, WI. 53085 PHONE: 920-467-2655 **FAX: 888-253-6695** E-Mail: amephoto@aerometric.com

12/12/13 Quantum Spatial Mail - OPUS solution : 00083270.13O OP1386857367313

quantum SPATIAL

Tyler Stentz <tstentz@quantumspatial.com>

OPUS solution : 00083270.13O OP1386857367313

1 message

opus <opus@ngs.noaa.gov> Thu, Dec 12, 2013 at 8:13 AM
Reply-To: ngs.opus@noaa.gov
To: tstentz@aerometric.com

20131123_223305

```
FILE: 00083270.13O OP1386857367313

                     NGS OPUS SOLUTION REPORT
                     ========================

All computed coordinate accuracies are listed as peak-to-peak values.
For additional information: http://www.ngs.noaa.gov/OPUS/about.jsp#accuracy

      USER: tstentz@aerometric.com             DATE: December 12, 2013
RINEX FILE: 0008327w.13o                       TIME: 14:13:12 UTC

  SOFTWARE: page5  1209.04 master90.pl 072313      START: 2013/11/23  22:06:00
 EPHEMERIS: igs17676.eph [precise]                  STOP: 2013/11/24  02:20:00
  NAV FILE: brdc3270.13n                        OBS USED: 10725 / 11593   :  93%
  ANT NAME: NOV702GG          NONE             # FIXED AMB:    58 /    61   :  95%
ARP HEIGHT: 2.00                              OVERALL RMS: 0.014(m)

 REF FRAME: NAD_83(2011)(EPOCH:2010.0000)             IGS08 (EPOCH:2013.8959)

         X:       91221.168(m)   0.001(m)          91220.354(m)   0.001(m)
         Y:    -4857042.668(m)   0.004(m)       -4857041.287(m)   0.004(m)
         Z:     4119464.705(m)   0.003(m)        4119464.616(m)   0.003(m)

       LAT:   40 29 15.52852      0.004(m)    40 29 15.55571      0.004(m)
     E LON:  271  4 33.44851      0.001(m)   271  4 33.41506      0.001(m)
     W LON:   88 55 26.55149      0.001(m)    88 55 26.58494      0.001(m)
    EL HGT:          227.940(m)   0.003(m)           226.821(m)   0.003(m)
 ORTHO HGT:          259.973(m)   0.012(m) [NAVD88 (Computed using GEOID12A)]

                        UTM COORDINATES    STATE PLANE COORDINATES
                         UTM (Zone 16)         SPC (1201 IL E)
Northing (Y) [meters]     4483661.604           424314.556
Easting (X)  [meters]      336933.722           249918.868
Convergence  [degrees]    -1.24952476          -0.38354574
Point Scale                0.99992732           1.00000586
Combined Factor            0.99989157           0.99997010

US NATIONAL GRID DESIGNATOR: 16TCK3693383661(NAD 83)

                             BASE STATIONS USED
PID       DESIGNATION                        LATITUDE    LONGITUDE DISTANCE(m)
```

https://mail.google.com/mail/u/0/?ui=2&ik=cc5c30ab23&view=pt&search=inbox&th=142e727bc91e5d20 1/2

DL6165 BLOM CITYBLOOMINGTONIL CORS ARP N402944.282 W0885959.461 6488.1
DL7697 HDIL MACKINAWFWIL2006 CORS ARP N403321.161 W0891738.330 32252.4
DK4053 KA12 KARA CO 12 CORS ARP N395225.338 W0885531.988 68172.9

NEAREST NGS PUBLISHED CONTROL POINT
LC0434 854.93 N402916. W0885528. 37.1

This position and the above vector components were computed without any knowledge by the National Geodetic Survey regarding the equipment or field operating procedures used.

quantum SPATIAL

Tyler Stentz <tstentz@quantumspatial.com>

OPUS solution : 00083280.13O OP1386860283436

1 message

opus <opus@ngs.noaa.gov>
Reply-To: ngs.opus@noaa.gov
To: tstentz@aerometric.com

Thu, Dec 12, 2013 at 8:59 AM

20131124_135651

```
FILE: 00083280.13O OP1386860283436

                     NGS OPUS SOLUTION REPORT
                     ========================

All computed coordinate accuracies are listed as peak-to-peak values.
For additional information: http://www.ngs.noaa.gov/OPUS/about.jsp#accuracy

     USER: tstentz@aerometric.com            DATE: December 12, 2013
RINEX FILE: 0008328n.13o                     TIME: 14:59:50 UTC

 SOFTWARE: page5  1209.04 master93.pl 072313    START: 2013/11/24  13:34:00
EPHEMERIS: igr17680.eph [rapid]                  STOP: 2013/11/24  17:06:00
 NAV FILE: brdc3280.13n                      OBS USED:  7928 /  8354   :  95%
 ANT NAME: NOV702GG        NONE             # FIXED AMB:    44 /    45   :  98%
ARP HEIGHT: 2.00                          OVERALL RMS: 0.013(m)

 REF FRAME: NAD_83(2011)(EPOCH:2010.0000)            IGS08 (EPOCH:2013.8976)

        X:     91221.169(m)   0.001(m)          91220.355(m)   0.001(m)
        Y:  -4857042.677(m)   0.008(m)       -4857041.296(m)   0.008(m)
        Z:   4119464.712(m)   0.008(m)        4119464.623(m)   0.008(m)

      LAT:  40 29 15.52851      0.004(m)      40 29 15.55570      0.004(m)
    E LON:  271  4 33.44855      0.001(m)     271  4 33.41509      0.001(m)
    W LON:   88 55 26.55145      0.001(m)      88 55 26.58491      0.001(m)
   EL HGT:         227.952(m)   0.010(m)            226.832(m)   0.010(m)
ORTHO HGT:         259.985(m)   0.021(m) [NAVD88 (Computed using GEOID12A)]

                        UTM COORDINATES    STATE PLANE COORDINATES
                         UTM (Zone 16)         SPC (1201 IL E)
Northing (Y) [meters]     4483661.604           424314.555
Easting (X)  [meters]      336933.723           249918.869
Convergence  [degrees]    -1.24952475          -0.38354574
Point Scale                0.99992732           1.00000586
Combined Factor            0.99989157           0.99997010

US NATIONAL GRID DESIGNATOR: 16TCK3693383661(NAD 83)

                        BASE STATIONS USED
PID       DESIGNATION                        LATITUDE    LONGITUDE DISTANCE(m)
```

DG9099 KAR4 KARA CO 4 COOP CORS ARP N400753.797 W0881723.849 66847.4
DL6165 BLOM CITYBLOOMINGTONIL CORS ARP N402944.282 W0885959.461 6488.1
DK4053 KA12 KARA CO 12 CORS ARP N395225.338 W0885531.988 68172.9

NEAREST NGS PUBLISHED CONTROL POINT
LC0434 854.93 N402916. W0885528. 37.1

This position and the above vector components were computed without any knowledge by the National Geodetic Survey regarding the equipment or field operating procedures used.

12/12/13 Quantum Spatial Mail - OPUS solution : 00083300.13O OP1386864376498

quantum SPATIAL

Tyler Stentz <tstentz@quantumspatial.com>

OPUS solution : 00083300.13O OP1386864376498

1 message

opus <opus@ngs.noaa.gov> Thu, Dec 12, 2013 at 10:08 AM
Reply-To: ngs.opus@noaa.gov
To: tstentz@aerometric.com

20131126_144704

```
FILE: 00083300.13O OP1386864376498

                    NGS OPUS SOLUTION REPORT
                    ========================

All computed coordinate accuracies are listed as peak-to-peak values.
For additional information: http://www.ngs.noaa.gov/OPUS/about.jsp#accuracy

      USER: tstentz@aerometric.com                DATE: December 12, 2013
RINEX FILE: 0008330o.13o                          TIME: 16:08:23 UTC

  SOFTWARE: page5  1209.04 master92.pl 072313      START: 2013/11/26  14:15:00
 EPHEMERIS: igr17682.eph [rapid]                    STOP: 2013/11/26  16:21:00
  NAV FILE: brdc3300.13n                        OBS USED:  4640 /  4848  :  96%
  ANT NAME: NOV702GG          NONE              # FIXED AMB:    36 /    39  :  92%
ARP HEIGHT: 2.00                               OVERALL RMS: 0.013(m)

 REF FRAME: NAD_83(2011)(EPOCH:2010.0000)            IGS08 (EPOCH:2013.9031)

         X:     91221.194(m)   0.001(m)           91220.380(m)   0.001(m)
         Y:  -4857042.640(m)   0.015(m)        -4857041.259(m)   0.015(m)
         Z:   4119464.686(m)   0.016(m)         4119464.597(m)   0.016(m)

       LAT:   40 29 15.52863      0.004(m)    40 29 15.55582      0.004(m)
     E LON:  271  4 33.44964      0.002(m)   271  4 33.41618      0.002(m)
     W LON:   88 55 26.55036      0.002(m)    88 55 26.58382      0.002(m)
    EL HGT:        227.907(m)   0.022(m)            226.788(m)   0.022(m)
 ORTHO HGT:        259.940(m)   0.039(m) [NAVD88 (Computed using GEOID12A)]

                        UTM COORDINATES    STATE PLANE COORDINATES
                         UTM (Zone 16)         SPC (1201 IL E)
Northing (Y) [meters]     4483661.607           424314.559
Easting (X)  [meters]      336933.749           249918.894
Convergence  [degrees]    -1.24952455          -0.38354554
Point Scale                0.99992732           1.00000586
Combined Factor            0.99989157           0.99997011

US NATIONAL GRID DESIGNATOR: 16TCK3693383661(NAD 83)

                           BASE STATIONS USED
PID       DESIGNATION                        LATITUDE    LONGITUDE DISTANCE(m)
```

1/2

https://mail.google.com/mail/u/0/?ui=2&ik=cc5c30ab23&view=pt&search=inbox&th=142e791119348318

DG9099 KAR4 KARA CO 4 COOP CORS ARP		N400753.797	W0881723.849	66847.4
DL7697 HDIL MACKINAWFWIL2006 CORS ARP		N403321.161	W0891738.330	32252.4
DK4053 KA12 KARA CO 12 CORS ARP		N395225.338	W0885531.988	68172.9

NEAREST NGS PUBLISHED CONTROL POINT

LC0434	854.93	N402916.	W0885528.	37.1

This position and the above vector components were computed without any knowledge by the National Geodetic Survey regarding the equipment or field operating procedures used.

Tyler Stentz <tstentz@quantumspatial.com>

OPUS solution : 00083310.13O OP1386868997305

1 message

opus <opus@ngs.noaa.gov> Thu, Dec 12, 2013 at 11:29 AM
Reply-To: ngs.opus@noaa.gov
To: tstentz@aerometric.com

20131127_144235

FILE: 00083310.13O OP1386868997305

```
                    NGS OPUS SOLUTION REPORT
                    ========================

All computed coordinate accuracies are listed as peak-to-peak values.
For additional information: http://www.ngs.noaa.gov/OPUS/about.jsp#accuracy

   USER: tstentz@aerometric.com              DATE: December 12, 2013
RINEX FILE: 0008331n.13o                     TIME: 17:28:54 UTC

 SOFTWARE: page5  1209.04 master93.pl 072313      START: 2013/11/27  13:33:00
EPHEMERIS: igr17683.eph [rapid]                    STOP: 2013/11/28  02:22:00
 NAV FILE: brdc3310.13n                        OBS USED: 29123 / 32349   :  90%
 ANT NAME: NOV702GG          NONE            # FIXED AMB:   196 /   201  :  98%
ARP HEIGHT: 2.00                            OVERALL RMS: 0.014(m)

 REF FRAME: NAD_83(2011)(EPOCH:2010.0000)              IGS08 (EPOCH:2013.9064)

        X:      91221.191(m)   0.004(m)          91220.377(m)   0.004(m)
        Y:   -4857042.636(m)   0.000(m)       -4857041.255(m)   0.000(m)
        Z:    4119464.689(m)   0.001(m)        4119464.600(m)   0.001(m)

      LAT:   40 29 15.52879      0.001(m)   40 29 15.55598      0.001(m)
    E LON:  271  4 33.44951      0.004(m)  271  4 33.41606      0.004(m)
    W LON:   88 55 26.55049      0.004(m)   88 55 26.58394      0.004(m)
   EL HGT:         227.906(m)   0.001(m)         226.787(m)   0.001(m)
 ORTHO HGT:        259.939(m)   0.011(m) [NAVD88 (Computed using GEOID12A)]

                         UTM COORDINATES    STATE PLANE COORDINATES
                          UTM (Zone 16)         SPC (1201 IL E)
Northing (Y) [meters]     4483661.612          424314.564
Easting (X)  [meters]      336933.746          249918.892
Convergence  [degrees]    -1.24952458         -0.38354556
Point Scale                0.99992732          1.00000586
Combined Factor            0.99989157          0.99997011

US NATIONAL GRID DESIGNATOR: 16TCK3693383661(NAD 83)

                       BASE STATIONS USED
PID       DESIGNATION                        LATITUDE    LONGITUDE DISTANCE(m)
```

DK4053 KA12 KARA CO 12 CORS ARP	N395225.338	W0885531.988	68172.9
DL6165 BLOM CITYBLOOMINGTONIL CORS ARP	N402944.282	W0885959.461	6488.1
DL2304 KA21 WOODFORD CORS ARP	N404729.312	W0891145.766	40839.6

NEAREST NGS PUBLISHED CONTROL POINT

LC0434	854.93	N402916.	W0885528.	37.1

This position and the above vector components were computed without any knowledge by the National Geodetic Survey regarding the equipment or field operating procedures used.

Tyler Stentz <tstentz@quantumspatial.com>

OPUS solution : 00083320.13O OP1386880194713

1 message

opus <opus@ngs.noaa.gov> Thu, Dec 12, 2013 at 2:34 PM
Reply-To: ngs.opus@noaa.gov
To: tstentz@aerometric.com

20131128_135545

```
 FILE: 00083320.13O OP1386880194713

                 NGS OPUS SOLUTION REPORT
                 ========================

All computed coordinate accuracies are listed as peak-to-peak values.
For additional information: http://www.ngs.noaa.gov/OPUS/about.jsp#accuracy

     USER: tstentz@aerometric.com              DATE: December 12, 2013
RINEX FILE: 0008332m.13o                       TIME: 20:34:15 UTC


 SOFTWARE: page5  1209.04 master53.pl 072313      START: 2013/11/28  12:56:00
EPHEMERIS: igr17684.eph [rapid]                    STOP: 2013/11/28  20:25:00
 NAV FILE: brdc3320.13n                        OBS USED: 16025 / 16999  :  94%
 ANT NAME: NOV702GG         NONE           # FIXED AMB:    89 /    92  :  97%
ARP HEIGHT: 2.00                            OVERALL RMS: 0.012(m)


 REF FRAME: NAD_83(2011)(EPOCH:2010.0000)              IGS08 (EPOCH:2013.9087)

        X:      91221.191(m)   0.002(m)          91220.377(m)   0.002(m)
        Y:   -4857042.634(m)   0.004(m)       -4857041.253(m)   0.004(m)
        Z:    4119464.684(m)   0.005(m)        4119464.595(m)   0.005(m)

      LAT:   40 29 15.52871      0.003(m)     40 29 15.55590      0.003(m)
    E LON:  271  4 33.44952      0.002(m)    271  4 33.41606      0.002(m)
    W LON:   88 55 26.55048      0.002(m)     88 55 26.58394      0.002(m)
   EL HGT:          227.901(m)   0.005(m)           226.782(m)   0.005(m)
 ORTHO HGT:         259.934(m)   0.014(m) [NAVD88 (Computed using GEOID12A)]

                         UTM COORDINATES    STATE PLANE COORDINATES
                          UTM (Zone 16)        SPC (1201 IL E)
Northing (Y) [meters]     4483661.609           424314.561
Easting (X)  [meters]      336933.746           249918.892
Convergence  [degrees]    -1.24952458          -0.38354556
Point Scale                0.99992732           1.00000586
Combined Factor            0.99989157           0.99997011

US NATIONAL GRID DESIGNATOR: 16TCK3693383661(NAD 83)


                          BASE STATIONS USED
PID       DESIGNATION                        LATITUDE    LONGITUDE DISTANCE(m)
```

DG9099 KAR4 KARA CO 4 COOP CORS ARP	N400753.797	W0881723.849	66847.4
DK4053 KA12 KARA CO 12 CORS ARP	N395225.338	W0885531.988	68172.9
DL7697 HDIL MACKINAWFWIL2006 CORS ARP	N403321.161	W0891738.330	32252.4

NEAREST NGS PUBLISHED CONTROL POINT

LC0434	854.93	N402916.	W0885528.	37.1

This position and the above vector components were computed without any knowledge by the National Geodetic Survey regarding the equipment or field operating procedures used.

8. LiDAR GPS Processing Plots

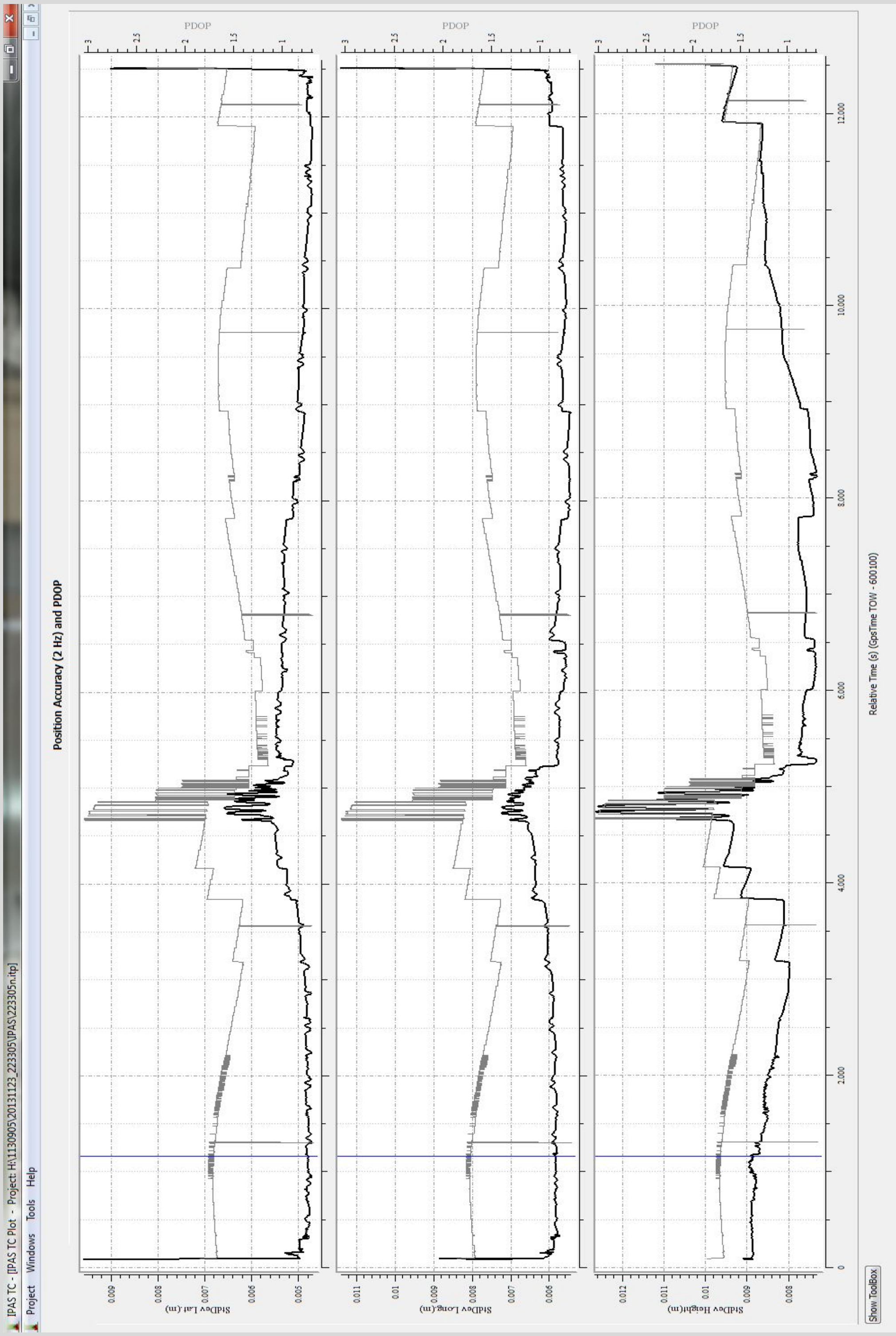


Image 8.1a: PDOP Plot for mission 20131123_223305.

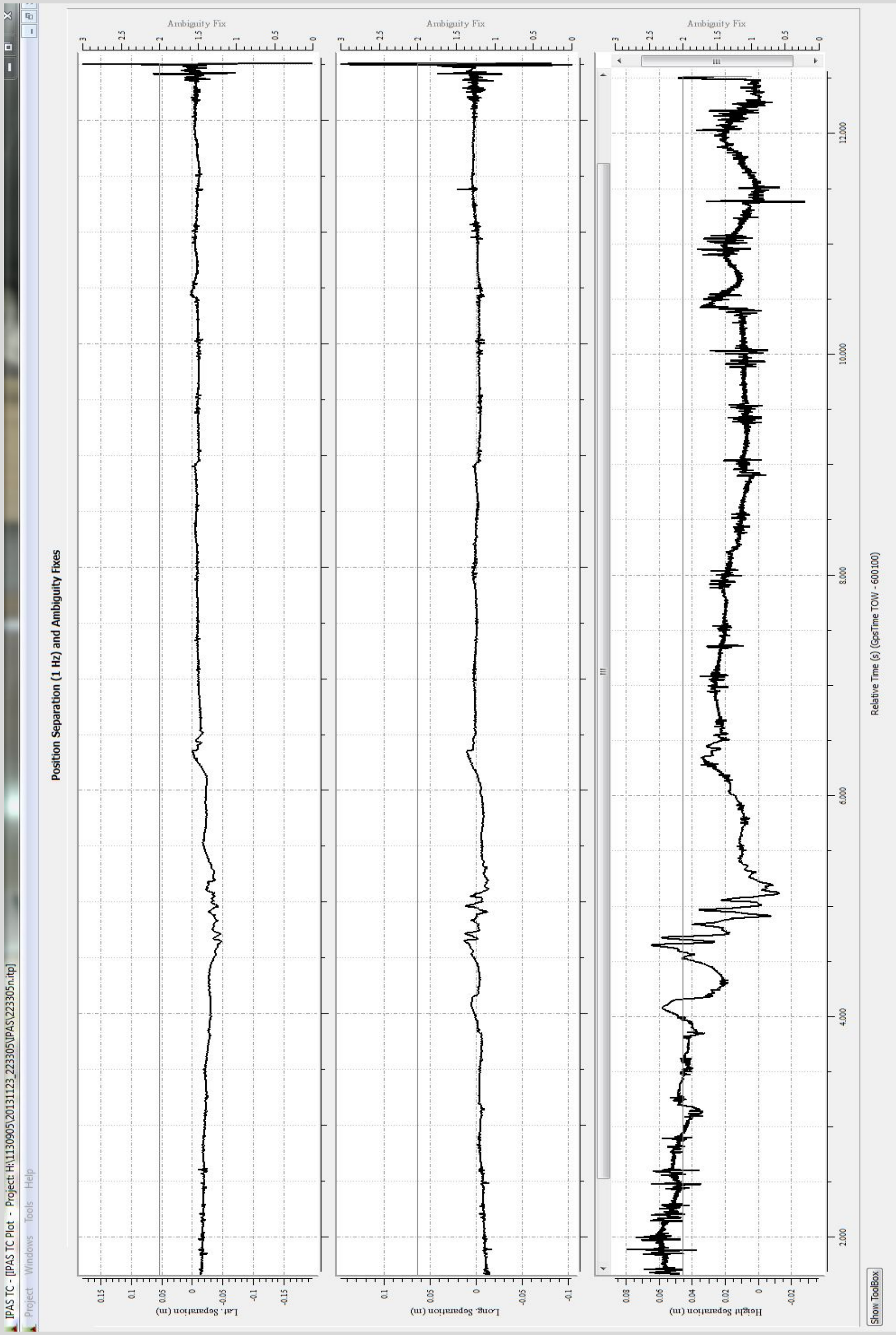


Image 8.1b: Separation Plot for mission 20131123_223305.

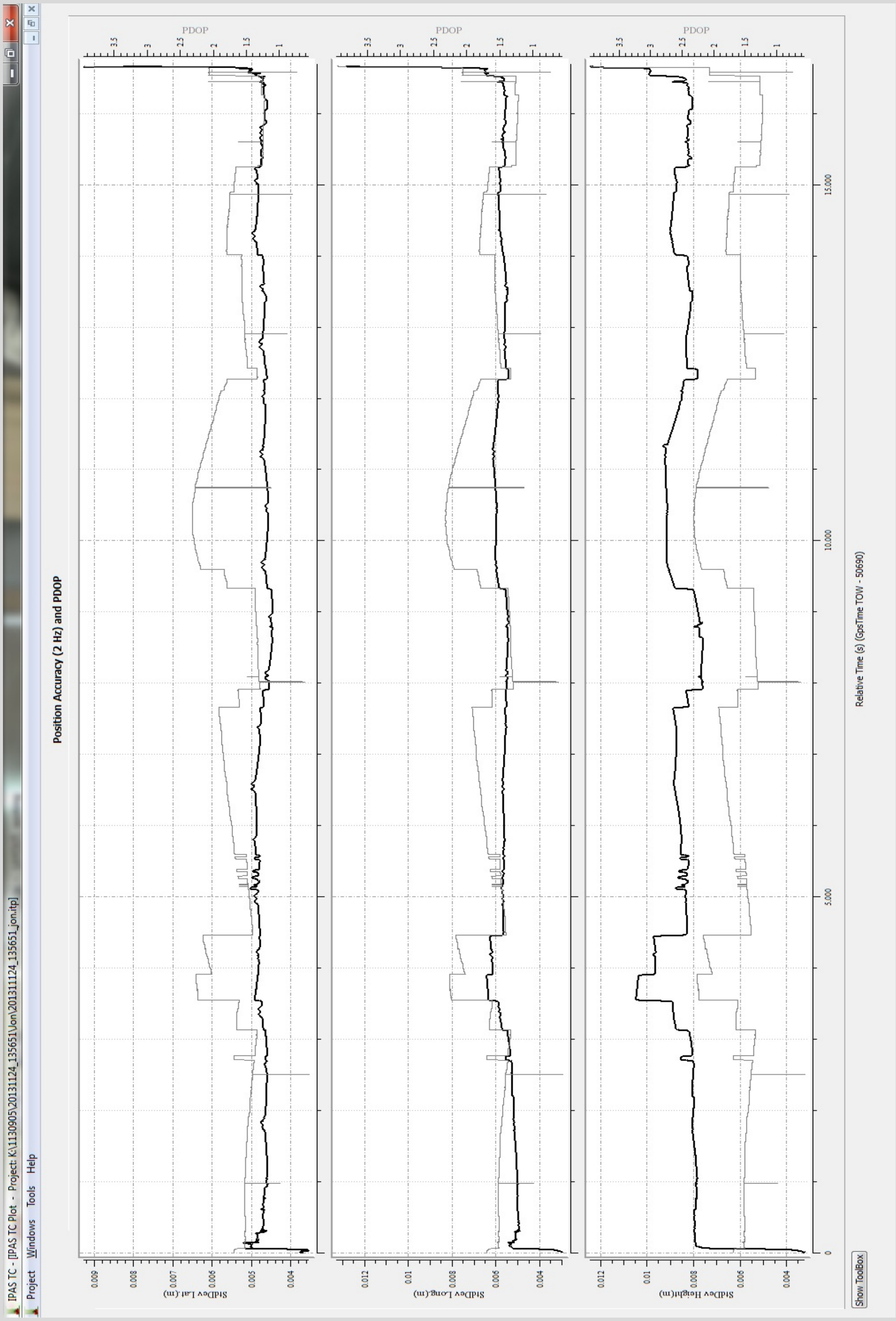


Image 8.2a: PDOP Plot for mission 20131124_135651

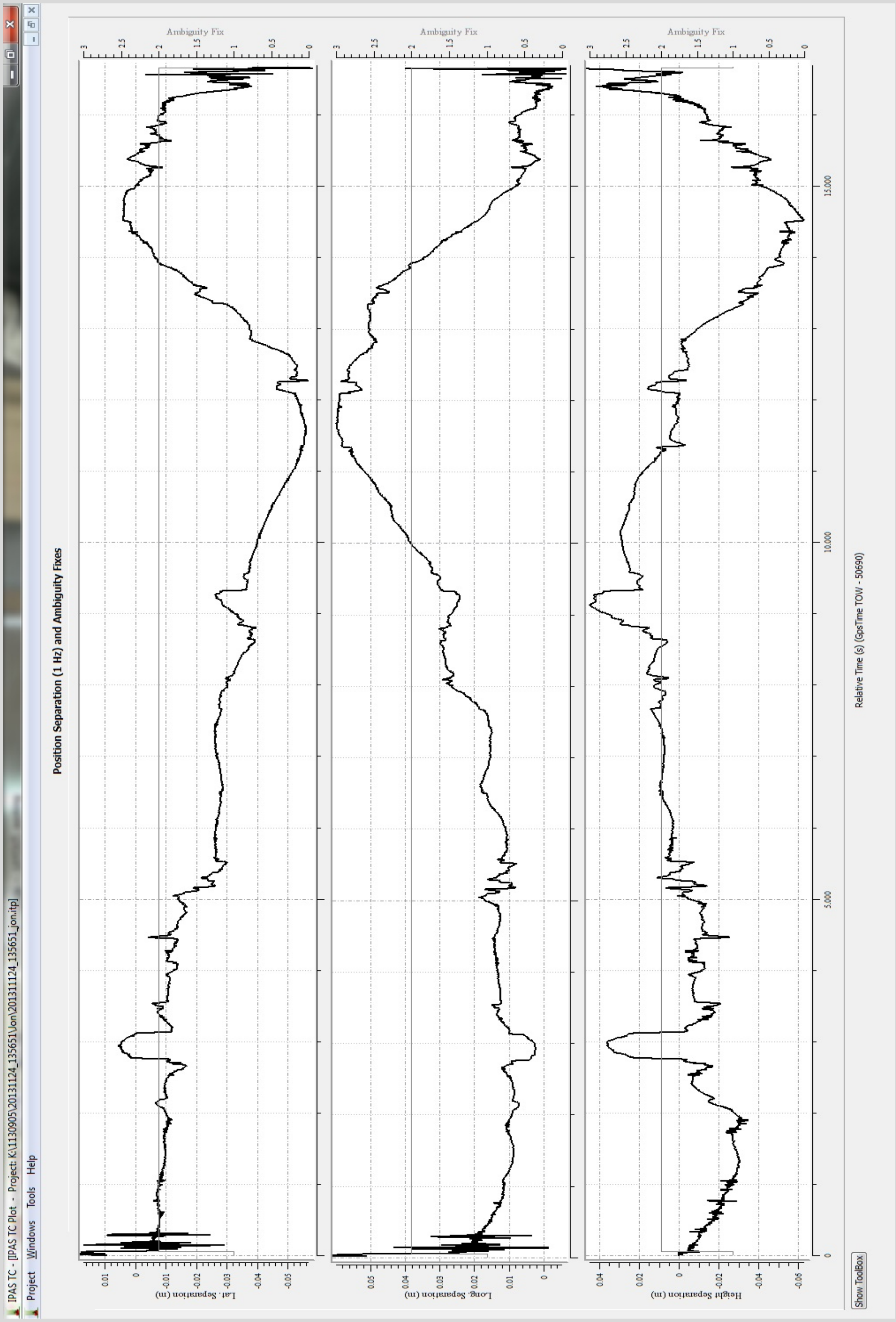


Image 8.2b: Separation Plot for mission 20131124_135651.

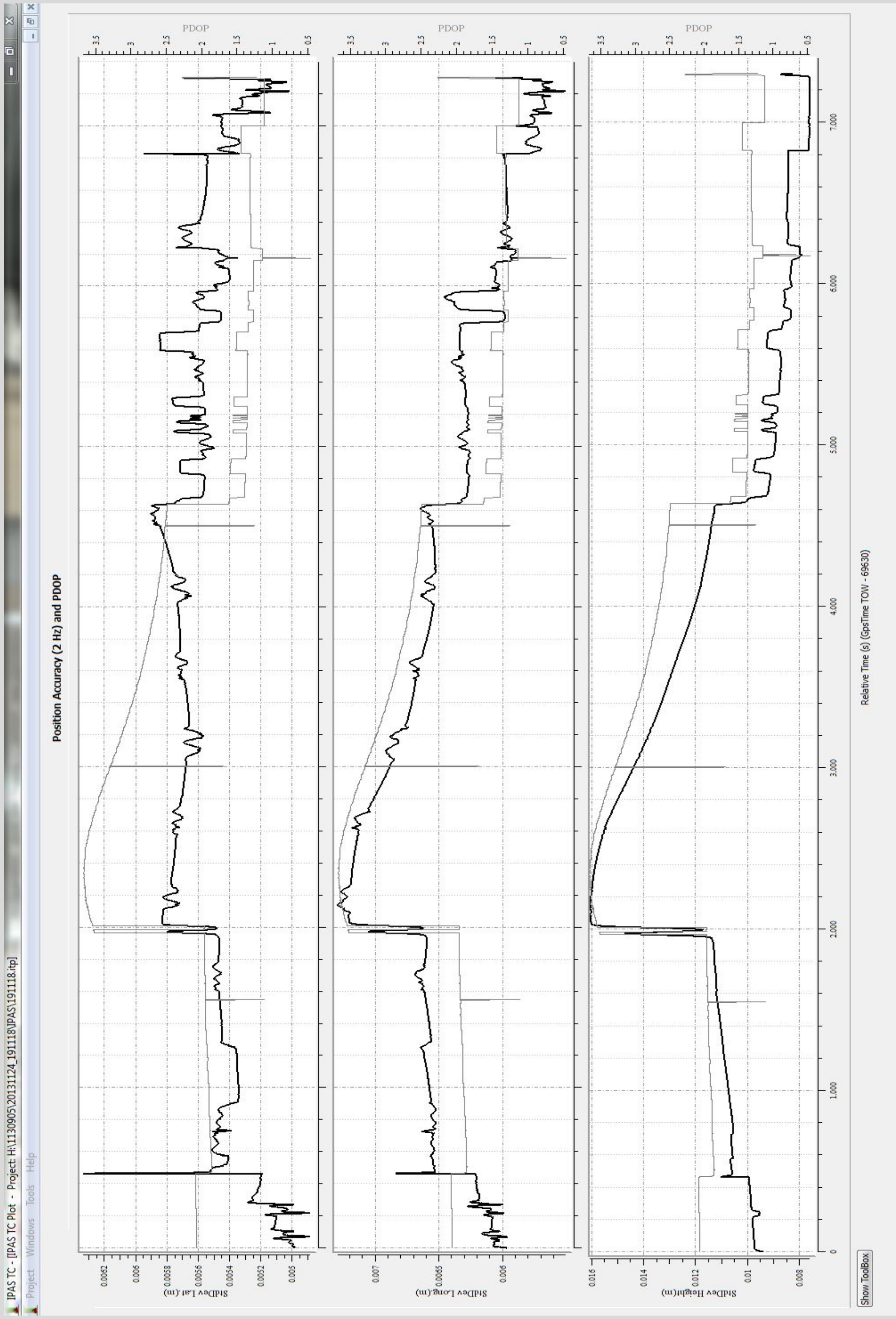


Image 8.3a: PDOP Plot for mission 20131124_191118.

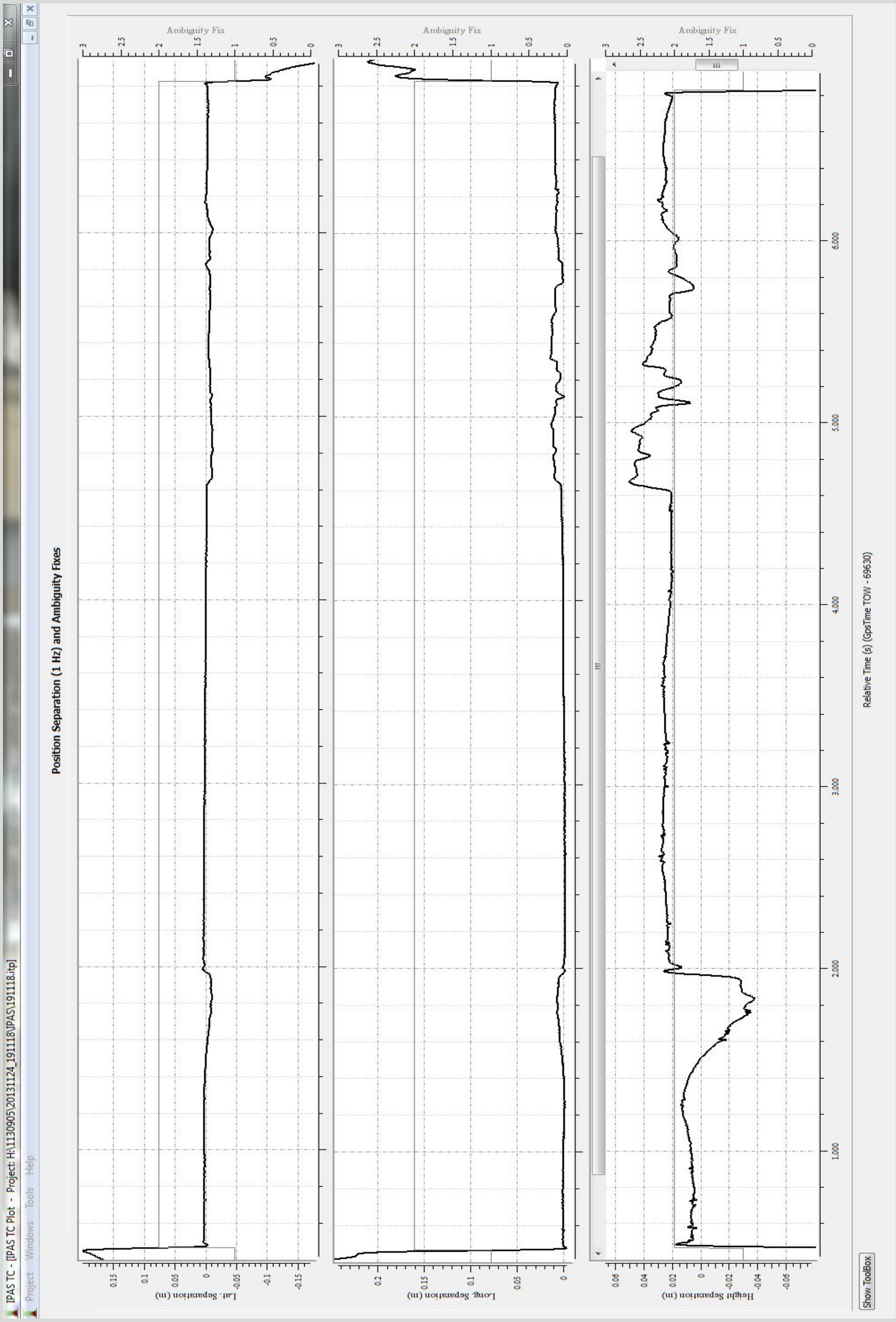


Image 8.3b: Separation Plot for mission 20141124_191118.

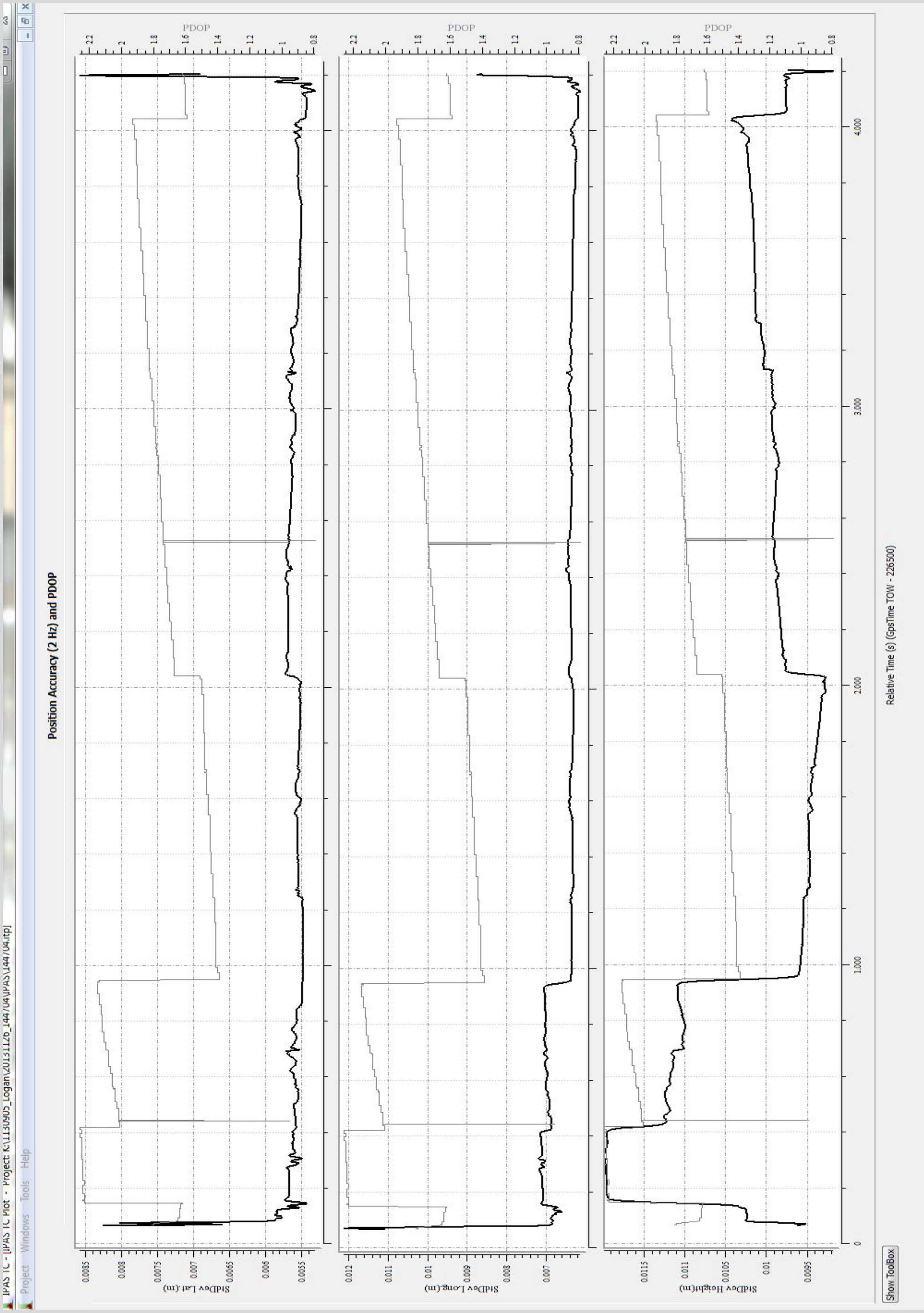


Image 8.4a: PDOP Plot for mission 20131126_144704.

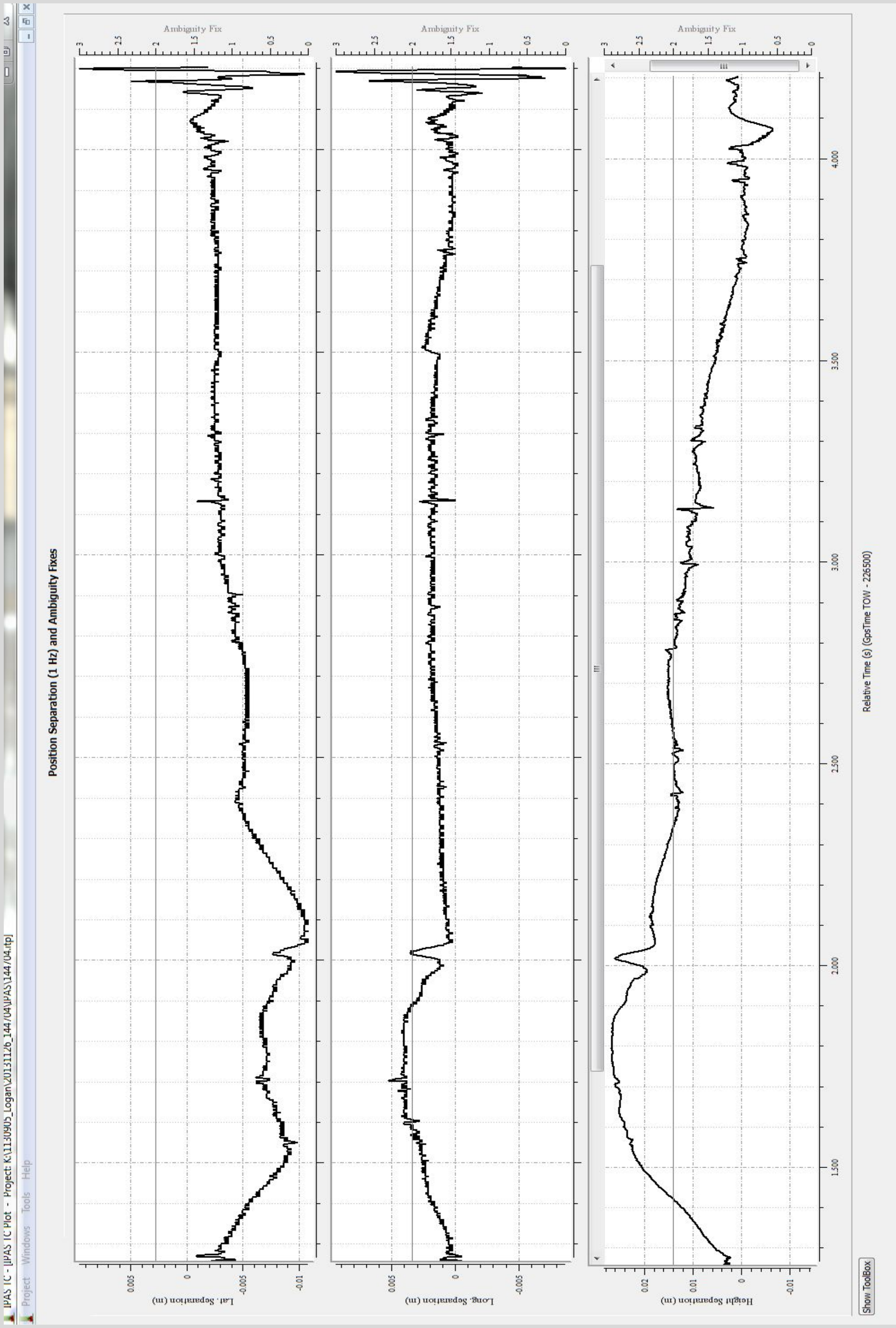


Image 8.4b: Separation Plot for mission 20131126_144704.

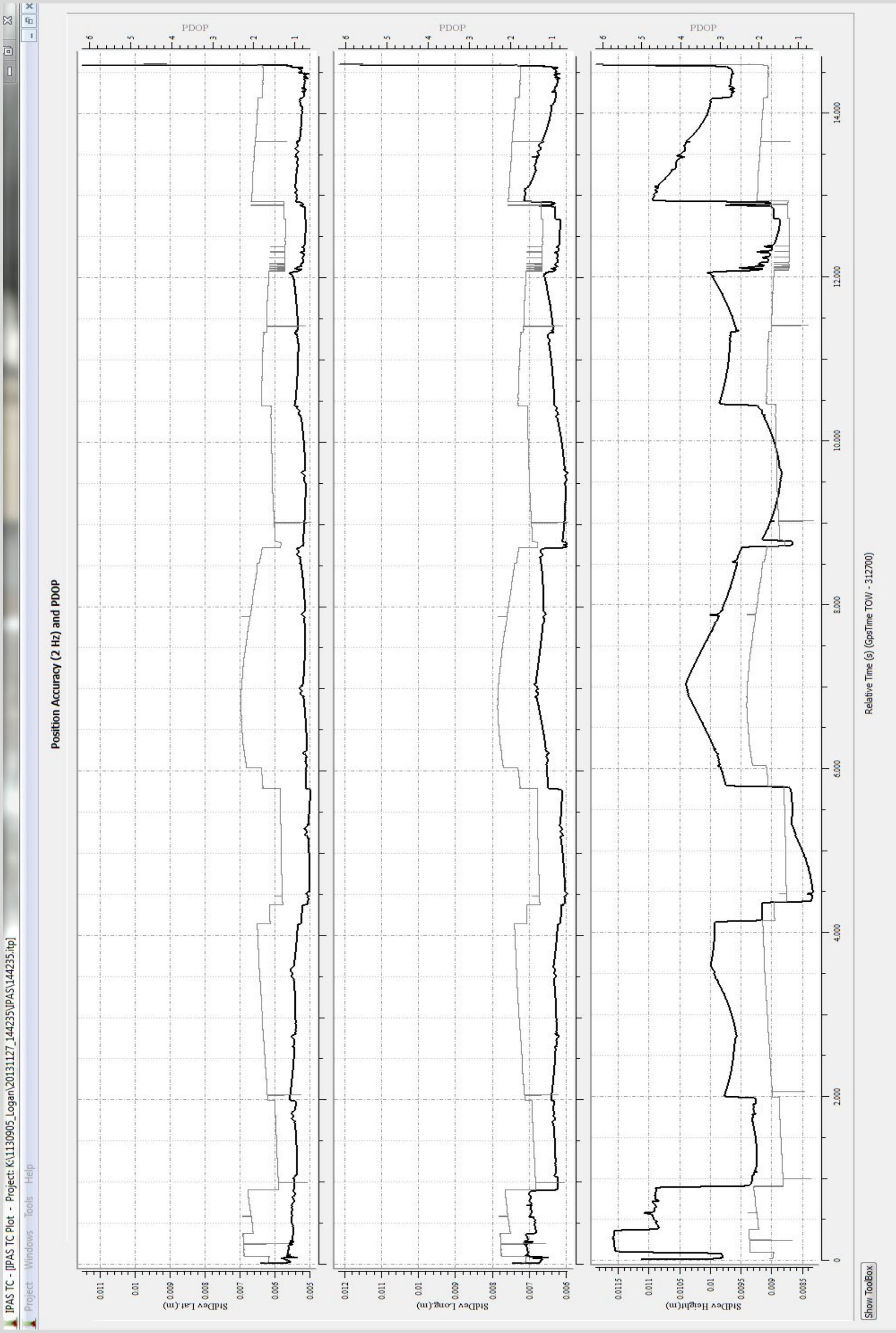


Image 8.5a: PDOP Plot for mission 20131127_144235.

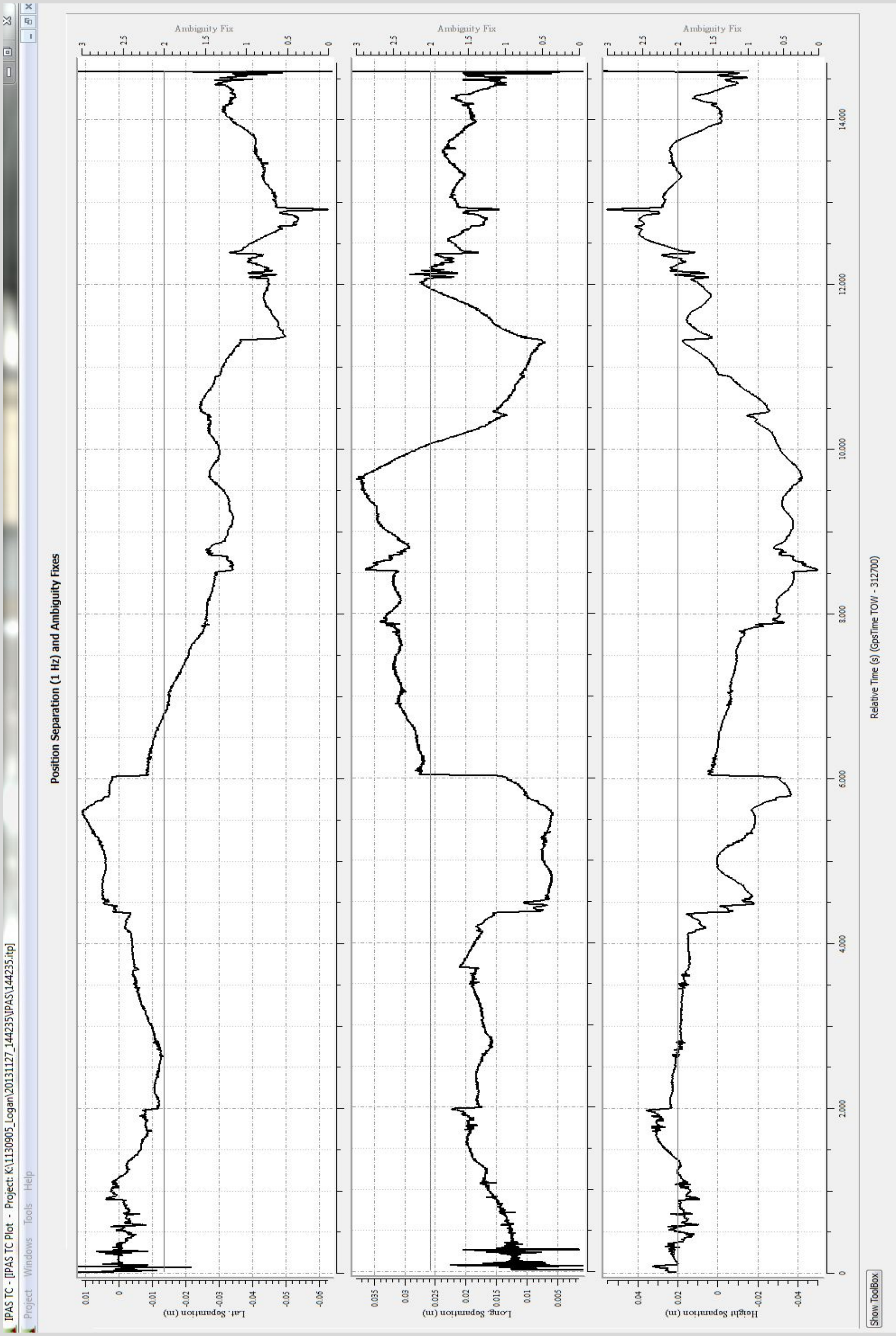


Image 8.5b: Separation Plot for mission 20131127_144235.

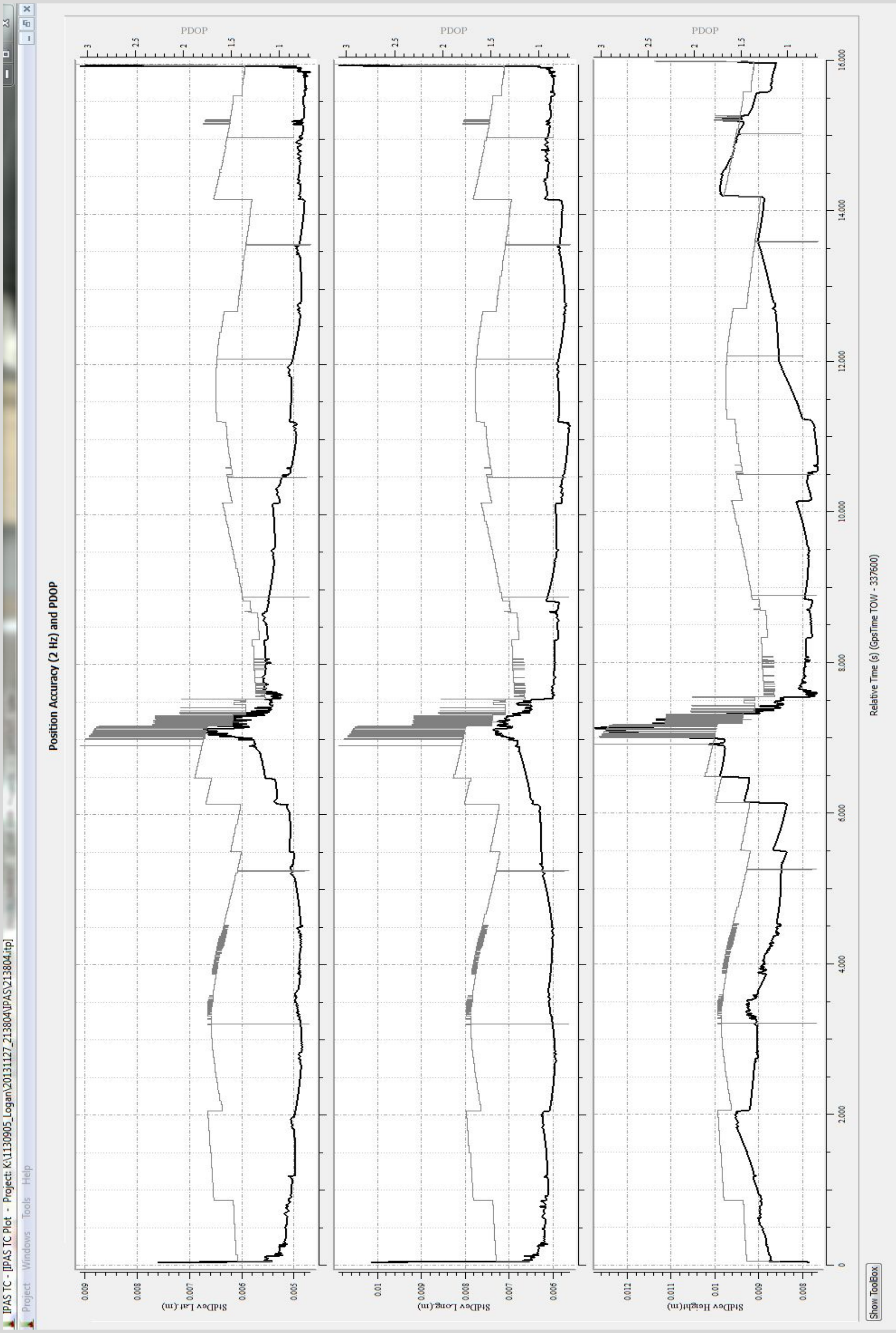


Image 8.6a: PDOP Plot for mission 20131127_213804.

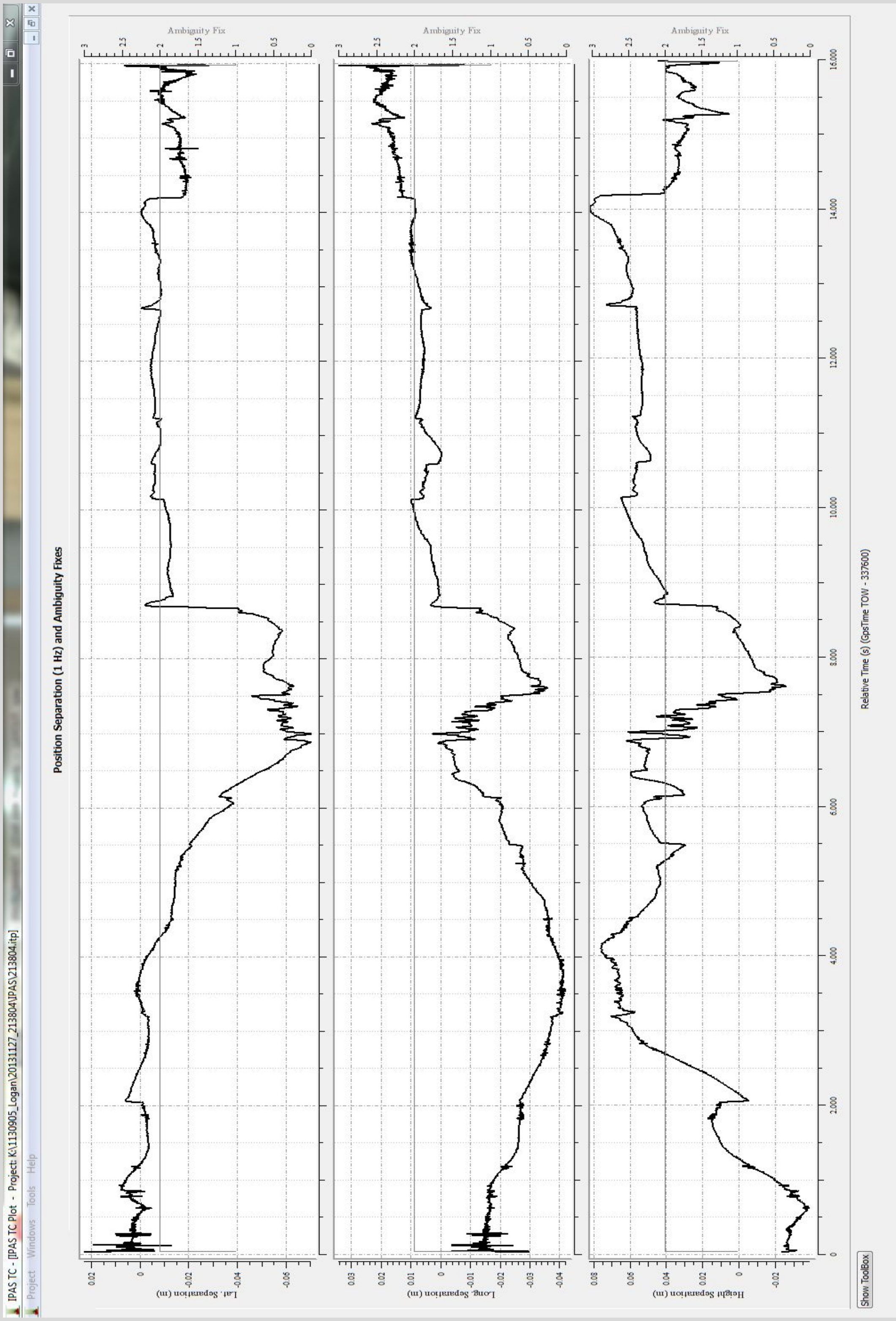


Image 8.6b: Separation Plot for mission 20131127_213804.

Image 8.7a: PDOP Plot for mission 20131128_135545.

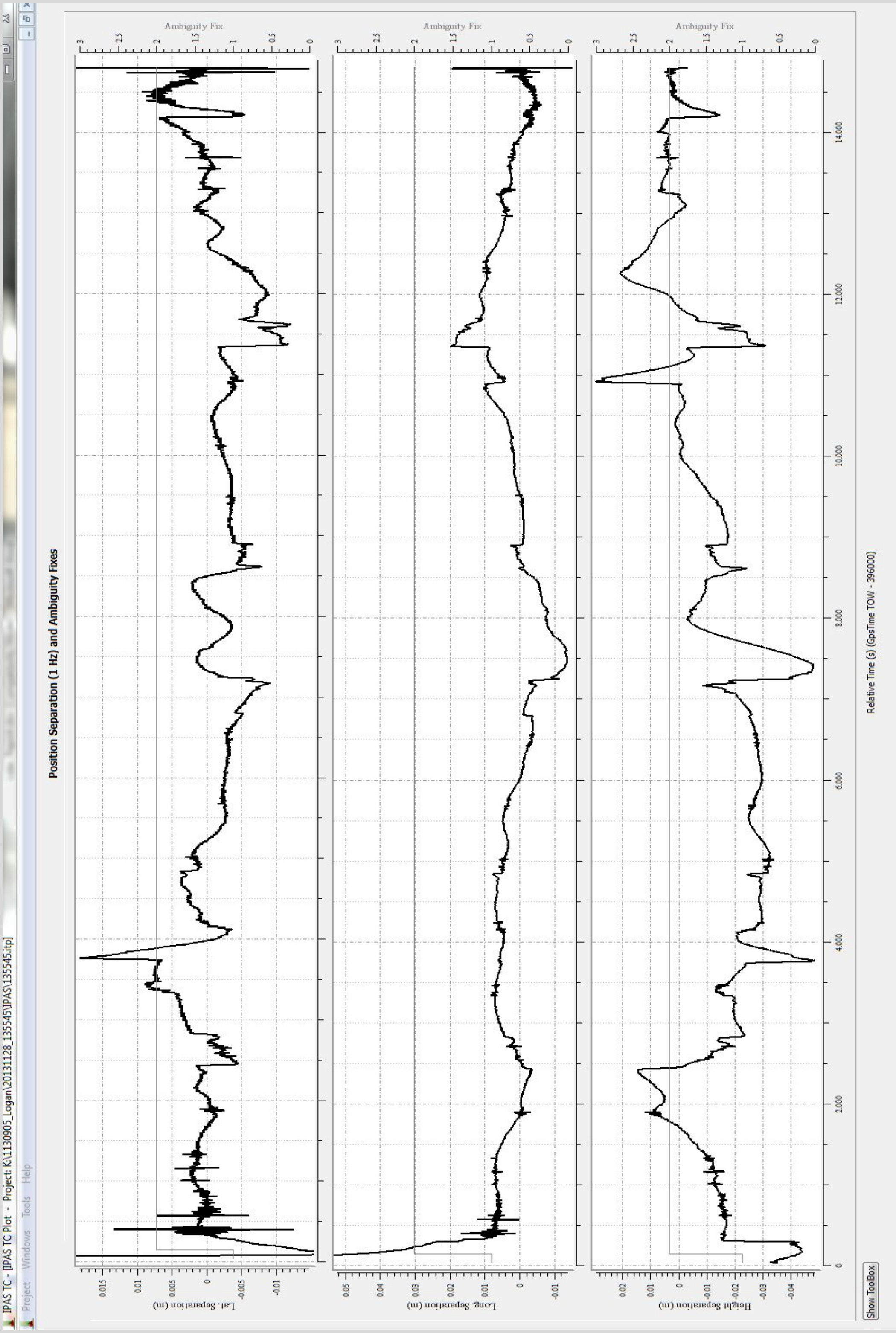


Image 8.7b: Separation Plot for mission 20131128_135545.

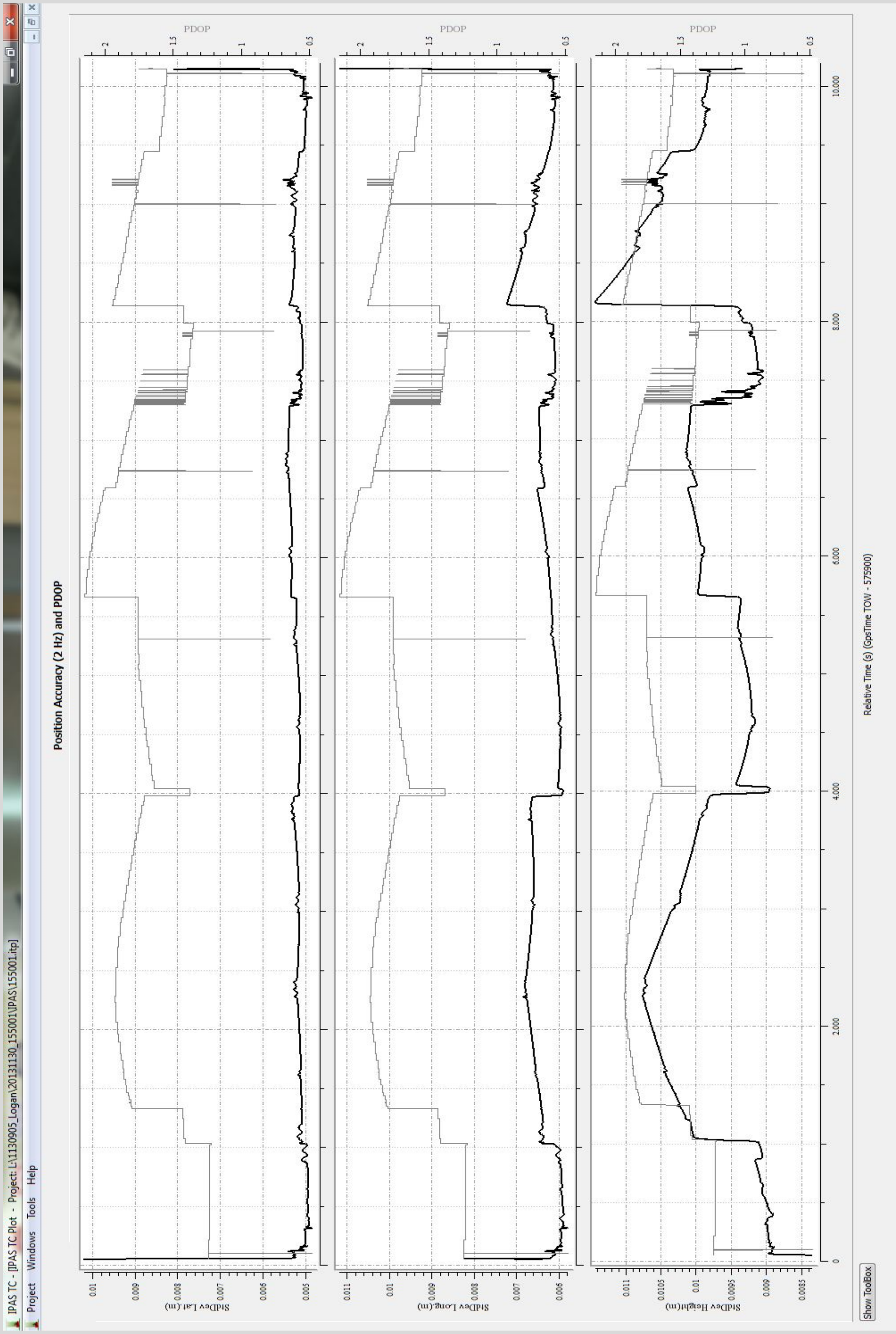


Image 8.8a: PDOP Plot for mission 20131130_155001.

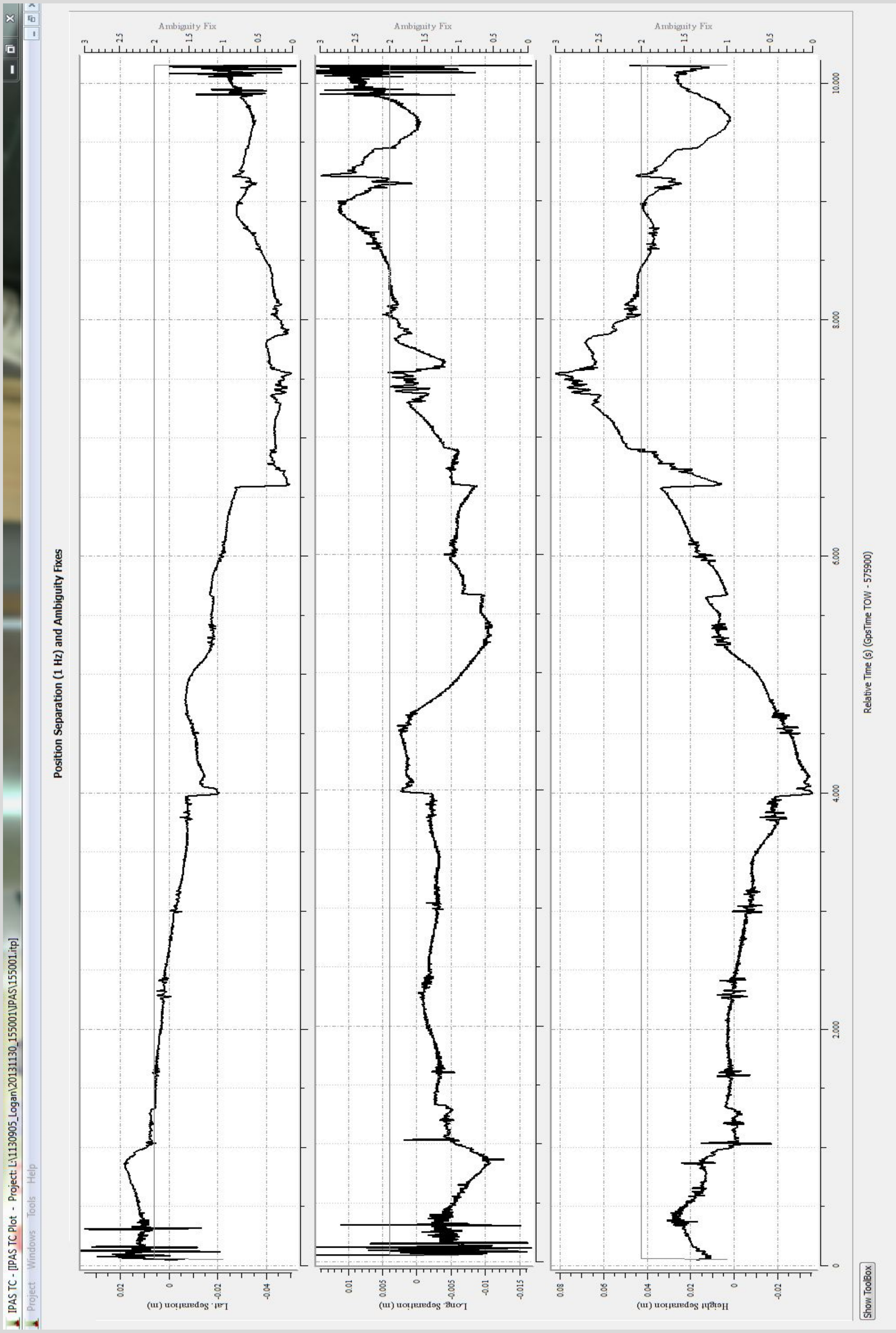


Image 8.8b: Separation Plot for mission 20131130_155001.

9. QA/QC Output Control Report

Output Control Report on check points collected across the Logan County project area and used to calibrate LiDAR data position.

Logan County Control Report

	Control	Easting	Northing	Known Z	Laser Z	Dz
1	CTR100	2455329.592	1325738.183	602.367	602.55	0.183
2	CTR101	2460000.602	1299335.012	543.922	544.16	0.238
3	CTR101a	2460083.659	1299348.657	544.887	545.1	0.213
4	CTR103	2486066.839	1321643.967	581.473	581.52	0.047
5	CTR103a	2486142.884	1321632.372	581.441	581.4	-0.041
6	CTR104	2568334.416	1283203.336	627.822	627.9	0.078
7	CTR105	2486620.057	1290668.383	551.531	551.48	-0.051
8	CTR105a	2486544.719	1290662.713	551.23	551.14	-0.09
9	CTR106	2512704.266	1331560.379	695.045	694.79	-0.255
10	CTR107	2514137.179	1290800.82	587.147	586.95	-0.197
11	CTR107a	2514191.991	1290799.036	586.601	586.39	-0.211
12	CTR108	2543132.941	1330796.029	666.182	666.36	0.178
13	CTR108a	2543115.248	1330838.181	665.994	666.05	0.056
14	CTR109	2568750.464	1267635.848	642.623	642.67	0.047
15	CTR110	2558620.357	1312517.125	709.613	709.83	0.217
16	CTR111	2574128.79	1309359.698	696.444	696.54	0.096
17	CTR112	2544639.073	1294592.231	598.922	598.85	-0.072
18	CTR113	2541147.039	1269769.265	608.025	607.83	-0.195
19	CTR114	2530461.601	1317313.244	601.091	601.07	-0.021
20	CTR115	2514374.991	1273711.076	578.34	578.15	-0.19
21	CTR116	2499521.97	1306438.253	607.517	607.62	0.103
22	CTR116a	2499516.994	1306370.878	606.076	605.88	-0.196
23	CTR117	2486851.29	1276490.06	568.549	568.6	0.051
24	CTR117a	2486847.151	1276406.488	567.056	567.18	0.124
25	CTR118	2460493.787	1281182.693	554.539	554.55	0.011
26	CTR118a	2460411.838	1281115.211	553.562	553.99	0.428
27	CTR119	2460644.826	1266571.056	525.278	525.52	0.242
28	CTR119a	2460547.23	1266570.921	524.085	524.18	0.095
29	CTR120	2512509.89	1260805.233	555.941	555.73	-0.211

Logan County Control Report

	Control	Easting	Northing	Known Z	Laser Z	Dz
30	CTR121	2543484.429	1237889.019	595.486	595.47	-0.016
31	CTR122	2571880.55	1243543.696	609.265	609.29	0.025
32	CTR123	2512048.396	1222224.369	618.632	618.44	-0.192
33	CTR123a	2512766.059	1222022.723	605.077	605.03	-0.047
34	CTR124	2544257.99	1221760.885	636.271	636.08	-0.191
35	CTR125	2499087.565	1239653.155	589.799	589.61	-0.189
36	CTR126	2467611.821	1242908.444	598.623	598.91	0.287
37	CTR126a	2467615.109	1242966.371	598.68	598.79	0.11
38	CTR127	2482826.193	1221969.873	598.136	598.29	0.154
39	CTR127a	2482823.664	1222061.465	598.11	598.06	-0.05
40	CTR128	2511649.013	1192040.637	597.394	597.28	-0.114
41	CTR128a	2511627.463	1192144.923	597.916	598	0.084
42	CTR129	2548845.648	1195519.751	580.681	580.69	0.009
43	CTR129a	2548766.98	1195531.224	579.48	579.6	0.12
44	CTR130	2573091.332	1187644.065	600.556	600.83	0.274
45	CTR130a	2573111.212	1187571.777	601.448	601.84	0.392

Average dz	0.03
Minimum dz	-0.255
Maximum dz	0.428
Average magnitude	0.142
Root mean square	0.172
Std deviation	0.172

10. Ground Control Survey Reports

Refer to “Final_Delivery_Report” and “Accuracy_Report” for ground control survey results.