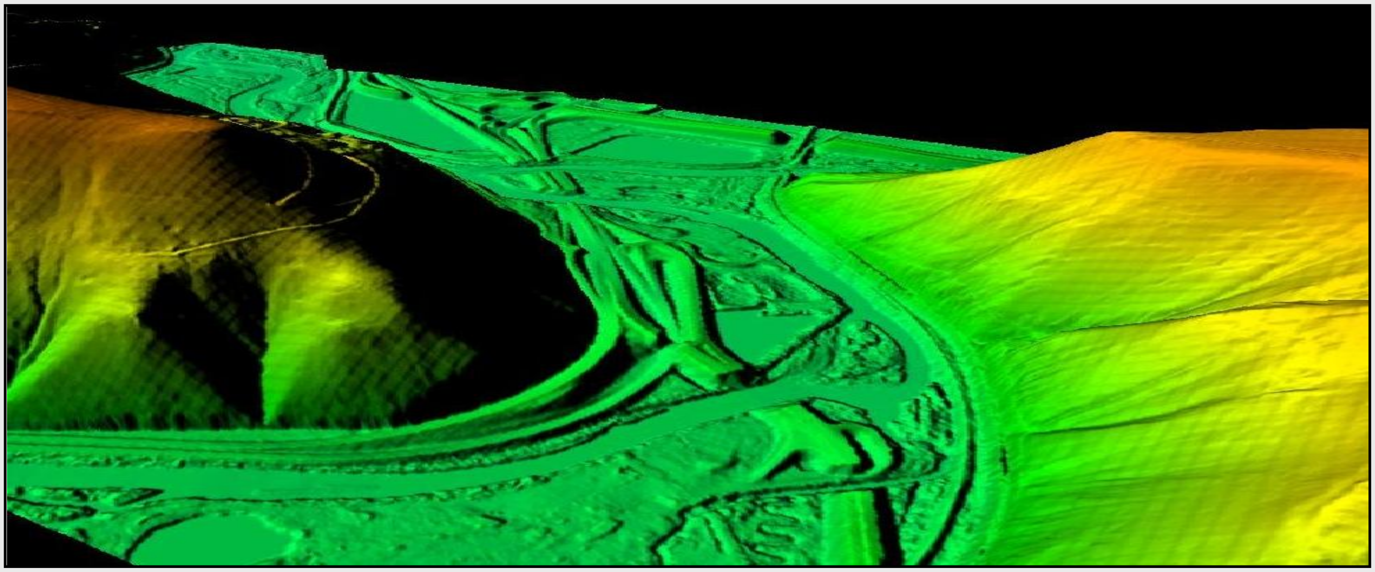
June 27, 2014

Hardin and Pope Counties Illinois, Airborne LiDAR Acquisition and Processing



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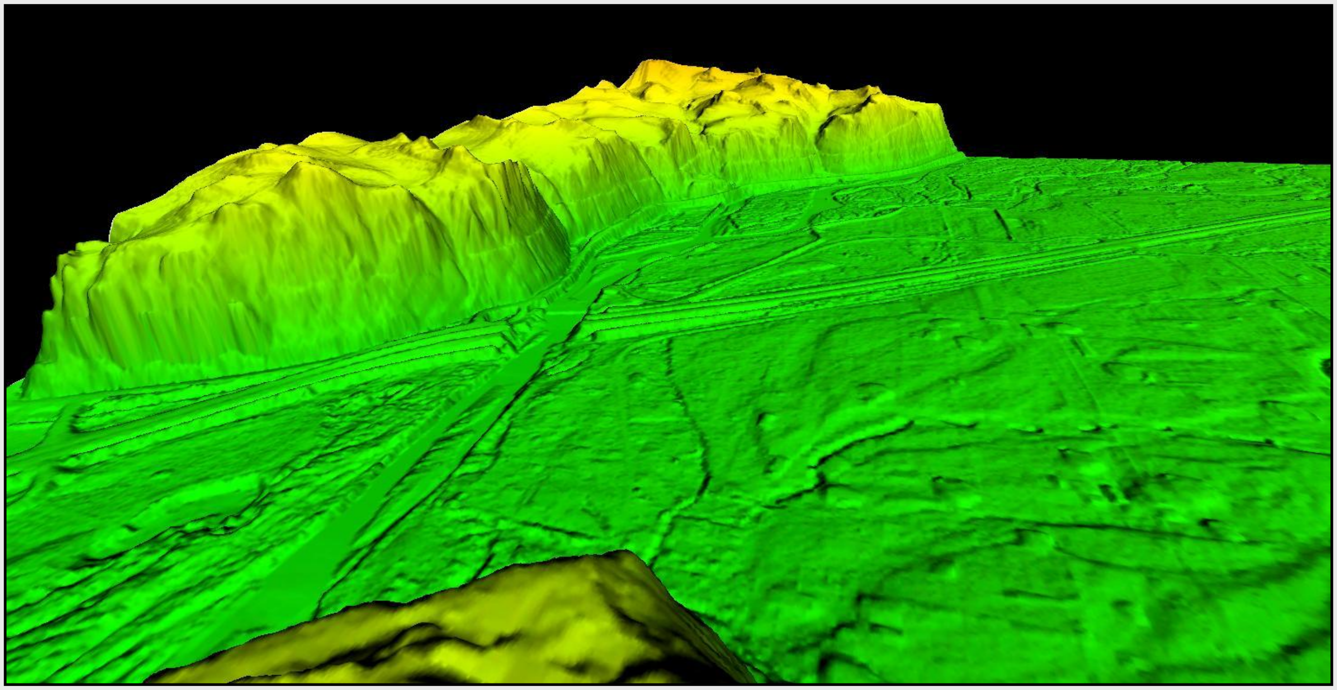
University of Illinois Urbana-Champaign

Pope and Hardin Counties Illinois

Airborne 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 Hardin and Pope Counties in Illinois.



1.1 Contact Info

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1.2 Purpose

Quantum Spatial acquired high accuracy LiDAR data of Pope and Hardin counties in accordance with needs outlined by the Facilities and Services, Planning Division of the University of Illinois Urbana-Champaign. Data provided to Facilities and Services will aid in analysis, planning and management of Hardin and Pope Counties.

1.3 Project Locations

The project area is located in southern Illinois and borders a portion of the Ohio River. The acquisition area includes all of Pope county and Hardin county in Illinois.

1.4 Time Period

LiDAR data acquisition for complete coverage of the project was acquired on March 20th and 21st of 2014. Data collection includes three (3) flight missions totaling eighty-three (83) flight lines accomplished over two consecutive days.

1.5 Project Scope

Data acquired with aircraft and sensor operated by Quantum Spatial, Inc. is high accuracy LiDAR topographic data and is complete for the surface of Pope and Hardin counties. The project consists of approximately 710 square miles.

The data set is suitable to produce standard one foot contours. LiDAR is planned for collection of surface data to produce point density and derived surface models as specified in the project proposal to reveal surface features and terrain needed.

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2. Geodetic Control

Ground surveys and ground control point readings are conducted to provide control and calibration points used in establishing position of the LiDAR data set.

Additional survey points are collected in specific ground cover categories which are found throughout the project area for further accuracy assessments.

A report detailing equipment and ground point survey collection process is included with this document. A list of the Control Points with elevation differences is in Section 8 of this document.

QC surveys and control were completed between March 24th and April 4th, 2014.

2.1 Network Scope

Base horizontal control for the check point survey consisted of two NGS CORS stations: **KYTB**, **MOCH**; and eleven NGS Order 0 stations: **COSBY R 9 14 (HB1860), FLAT (HB1604), GPS 6 (HB1864), HOHMAN R 9 22 AZ MK (HB1868), MIDWAY R 9 20 (HB1879), PARIS R 9 12 (HB1883), PHARAOH R 9 07 AZ MK (HB1886), PHARAOH R 9 07 (HB1887), ROAICALRE R 9 15 (HB1890), STEWART R 9 21 (HB1895), WAMBLE R 9 06 (HB1897)**. The NGS stations **CONCORD R 9 1 (HB1858)** and **GPS 7 (HB1865)** were also observed, but not constrained in the final adjustment.

Horizontal control is referenced to the Illinois State Plane Coordinate System – East Zone, based on the North American Datum of 1983/2011 (NAD83/11). Final coordinates are published in US Survey Foot.

Base vertical control for the check point survey consisted of ten NGS Second Order stations: **COSBY R 9 14 (HB1860), WM 081 (DO4333), WM 095 (DO4337), WM 088 (DO4340), WM 093 (DO4345), WM 094 (DO4348). WM 098 (DO4352), WM 109 (DO4364), WM 117 (DO4372), WM 136 (DO4312)**; and ten NGS Fourth Order stations: **FLAT (HB1604), GPS 6 (HB1864), HOHMAN R 9 22 AZ MK (HB1868), MIDWAY R 9 20 (HB1879), PARIS R 9 12 (HB1883), PHARAOH R 9 07 AZ MK (HB1886), PHARAOH R 9 07 (HB1887), ROAICALRE R 9 15 (HB1890), STEWART R 9 21 (HB1895), WAMBLE R 9 06 (HB1897)**. The NGS stations **CONCORD R 9 1 (HB1858)** and **GPS 7 (HB1865)** were also observed, but not constrained in the final adjustment due to large vertical misclosures. The NGS Model GEOID12A was applied to the derived ellipsoid heights to approximate the North American Vertical Datum of 1988.

Vertical control is based on the North American Vertical Datum of 1988 (NAVD88).

2.2 Network Computations

GPS measurements were collected using the RTK survey method. Passive NGS control stations were observed in the field and active NGS CORS stations were added in the office. GPS measurement computations were done in two stages. Initial computations were done with LEICA Geo Office (LGO), version 8.3. LGO permits the conversion of raw satellite data collected by the receivers to a meaningful coordinate difference between points (baseline solutions). Once the baseline solutions were determined, they were input into the GeoSurv-GeoLab2 series of programs (Geolab version 2.4d). A network adjustment was performed for analysis and quality closure holding the position and elevation of station **COSBY R 9 14 (HB1860)** fixed as follows:

HORIZONTAL CLOSURES (in meters)

STATION	NORTHING	EASTING	LINEAR	DISTANCE	PROPORTION
FLAT	0.036	0.125	0.130	20388.9	1: 156000
GPS 6	0.038	0.025	0.045	19717.3	1: 433000
HOHMAN R 9...	0.017	0.103	0.104	28506.5	1: 273000
MIDWAY R 9 20	0.012	0.090	0.091	22038.1	1: 242000
PARIS R 9 12	0.024	0.011	0.026	14109.0	1: 534000
PHARAOH R 9...	0.031	0.002	0.031	20827.1	1: 670000
PHARAOH R 9 07	0.034	0.010	0.035	22388.6	1: 631000
ROAICALRE R...	0.072	0.041	0.083	9574.7	1: 115000
STEWEART R...	0.015	0.082	0.083	19444.9	1: 233000

VERTICAL CLOSURES (in meters)

STATION	ADJUSTED ELEVATION	PUBLISHED ELEVATION	DIFFERENCE	DISTANCE	ALLOWABLE 3rd ORDER CLOSURE
FLAT	217.293*	217.236*	0.057	20388.9	0.054
GPS 6	136.344*	136.397*	0.053	19717.3	0.053
HOHMAN R 9...	118.906*	118.913*	0.007	28506.5	0.064
MIDWAY R 9 20	148.660*	148.646*	0.014	22038.1	0.056
PARIS R 9 12	161.737*	161.682*	0.055	14109.0	0.045
PHARAOH R 9...	140.685*	140.632*	0.053	20827.1	0.055
PHARAOH R 9 07	182.286*	182.221*	0.065	22388.6	0.057
ROAICALRE R...	75.563*	75.572*	0.009	9574.1	0.037
STEWEART R...	76.300*	76.299*	0.001	19444.9	0.053

WM 081	171.973	171.955	0.018	31007.4	0.067
WM 085	136.640	136.628	0.012	26806.7	0.062
WM 088	141.447	141.432	0.015	22673.2	0.057
WM 093	130.874	130.852	0.022	16755.0	0.049
WM 094	134.488	134.470	0.018	13453.2	0.044
WM 098	148.891	148.868	0.023	8519.1	0.035
WM 109	166.384	166.384	0.000	7889.3	0.034
WM 117	170.554	170.551	0.003	16057.5	0.048
WM 136	148.868	148.894	0.026	16821.8	0.049

* indicates ellipsoid height.

The above control was held in the fully constrained scaled least squares network adjustment to derive the ground control checkpoint values.

Table 2.1: Ground Survey Check Points	
Surveyor:	
Quantum Spatial, Inc.	March 20, 2014
	April 4. 2014
GPS RTK measurements	Leica
Indexing Points	24 points
Specific Ground Cover Categories	
Open Terrain	20 points
Urban	20 points
Tall Grass	20 points
Brush	20 points
Forest	20 points

3. LiDAR Acquisition and Procedures

Before take-off, the LiDAR system, the GPS and IMU systems were initialized for a period of five minutes and kept in operation after landing for another five minutes to ensure optimal operation and data integrity.

Flight planning and flights are completed using Leica's Mission Pro (v.11) software

LiDAR data are acquired following the flightlines and specifications predetermined in the flight plan. Missions include cross flights made perpendicular to acquisition flightlines to provide data for in-situ calibration of the LiDAR sensor. Also, during acquisition aircraft positional data is collected though the GPS unit and the IMU. This data provides for calculation of Smoothed Best Estimate Trajectory information and calibration of each LiDAR swath and in matching each swath as they are assembled.

3.1 LiDAR Planning

Missions are planned in accordance with the project objects. Missions are planned to assure complete coverage with flight lines best suited to terrain type and to achieve the point density required.

Flight planning and flights are completed using Leica's Mission Pro (v.11) software. The flight plan is accessed by the aircraft navigation system to achieve the predetermined flight and sensor specifications.

3.2 Acquisition Time Period

LiDAR data acquisition and Airborne GPS control were completed in a two day period, March 20th and March 21st, 2014. The project area is acquired with eighty-three flight lines.

Mission Parameters			
Sensor ID		Leica ALS 70	
Flight date		March 20, 2014	
		March 21, 2014	
Missions	3	Flight Lines	83

3.3 LiDAR Acquisition

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Table 3.1: Acquisition Parameters	
Sensor ID	SN7178_FOV60
Field of View	40°
Flying Height (Above mean sea level)	1970 – 2100 meters
Pulse Rate Frequency	261 kHz
Mirror Scan Rate Frequency	39.11Hz
Ground Speed	150 kts
Nominal Point Spacing	0.7 m
Flight Line Overlap	51 %

3.4 LiDAR Trajectory Processing

Smoothed Best Estimate Trajectories are resolved for each flight line from the aircraft's GPS position data and from collected data by IMU of the aircraft's attitude through the flight line. This is applied to LiDAR data points of each swath and establishes position for each LiDAR point. Swath strips are joined side by side with overlap and tested for relative accuracy against each other and against ground survey check points to establish vertical accuracy. Overlap is trimmed to specification and points are evaluated through calculation and comparison routines to determine point classification.

Processing Software	
Title	Version
Leica IPAS TC	3.2
Leica ALS Post Processor	2.75 Build#25
TerraScan	14.003
TerraModeler	14.001
TerraMatch	14.003
Intergraph MicroStation	08.05.02.70
GeoCue	13.1.45.1

4 Quality Control Surveys

Ground survey points were collected by Quantum Spatial, Inc. The point measurements are used in calibration and evaluation of LiDAR data position.

Accompanying documents, Hardin Pope Indexing Point Report.pdf and HardinPope_Vertical Accuracy points Rept.pdf, contain photographs and survey point coordinates.

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. 14, TerraScan v.14, 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.14

5.1 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.

5.2 Classification

Once both the accuracy between swaths and data density is accepted classification algorithms are performed using TerraScan to determine point classification as bare-earth and other classes.

The classified data is examined and further classified using manual techniques. The manual editing largely 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).

Depending on the project requirements and unique surface conditions, various quality checks are performed.

5.3 Fundamental Vertical Accuracy of RAW LiDAR

Check points surveyed within the project area provide calibration checks for indexing the LiDAR point cloud. A report indicating comparative positional statistics is produced when LiDAR has been adjusted to these indexing points. The results can be found in Section 5.4 LiDAR Trajectory Processing.

The ground check points made in open terrain areas across the project area are used in establishing the accuracy of the RAW swath LiDAR prior to classification. The RMSE is determined by comparison of the vertical position of a TIN of the RAW LiDAR points to elevations measured at the locations of the set of open terrain ground survey points. Differences in vertical values are calculated to express a RMSEz value. The FVA is determined by multiplying the RSMEz value by 1.96 to express a 95% confidence level.

Elevation of RAW LiDAR points compared to elevation of Open Terrain check points FVA is at 95% confidence level (RSME x 1.96)		
	Feet	Meters
RAW RMSE	0.220	0.067
RAW FVA	0.431	0.131

5.4 Vertical Accuracy Assessment of Classified Points

Vertical accuracy of the Classified points is tested against surveyed ground points. Ground survey check points are collected in various ground cover categories across the project area.

Vertical accuracy assessment is made by comparing ground survey check point elevation values to elevation values of the DEM produced from the Ground Classed LiDAR points by horizontal proximity. Differences in vertical values are calculated to express a RMSEz value. The FVA is determined by multiplying the RSMEz value by 1.96 to express a 95% confidence level.

Elevation values of DEM compared to elevation of Open Terrain check points FVA is at 95% confidence level (RSME x 1.96)		
	Feet	Meters
RMSE of DEM	0.166	0.051
FVA based on DEM	0.325	0.099

Supplemental Vertical Accuracy (SVA) values are determined for each ground cover category collected in the ground survey. Elevations of ground survey check points of the various ground cover categories are compared to elevation values of the DEM derived from Ground Classed LiDAR points. The differences are tabulated to determine the 95th percentile of differences in each ground cover category.

Elevation values of DEM compared to elevation of Open Terrain check points SVA is the 95th percentile of differences		
Ground Cover Category	Feet	Meters
Open Terrain	0.094	0.029
Urban	0.278	0.085
Tall Grass	0.354	0.108
Brush	0.611	0.186
Forest	0.428	0.130
All Categories (CVA)	0.474	0.144

5.5 LiDAR Data Deliveries

Unclassified LiDAR points

LAS version 1.2 in 2000 foot grid

Classified LiDAR points

LAS, version 1.2 in 2000 foot grid

Classification scheme to ASPRS Standards

- 1 – Processed, but unclassified
- 2 – Bare Earth, Ground
- 3 – Low Vegetation
- 4 – Medium Vegetation
- 5 – High Vegetation
- 6 – Building
- 7 – Noise (Low or High, Manually identified, if needed)
- 8 – Model Key
- 9 – Water
- 10 – Ignored Ground (Breakline proximity)

Surface Models

Delivered on a per tile basis of 2000 foot grid:

- DAT files
- TIN files
- Bare Earth Digital Elevation Model, hydro flattened, in DEM format

Metadata, FGDC standard

Vertical Accuracy Assessment Report in PDF format

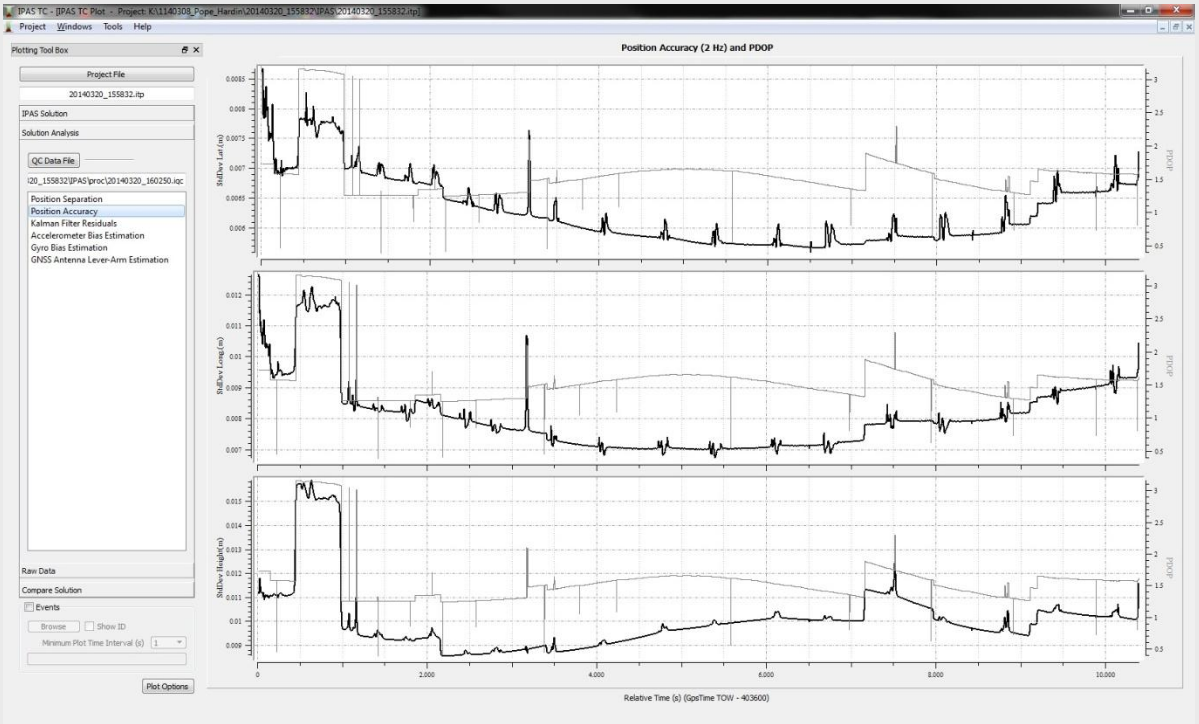
Ground Survey Check Points in ASCII file format

6 Conclusion

Sound procedures and use of new technologies ensure this project data will serve The University of Illinois at Urbana-Champaign. and all users of the provided LiDAR derivative products as accurate models. The models produced are representative of surface conditions at the time of data acquisition.

7 LiDAR GPS Processing Plots

20140320_155832 PDOP plot



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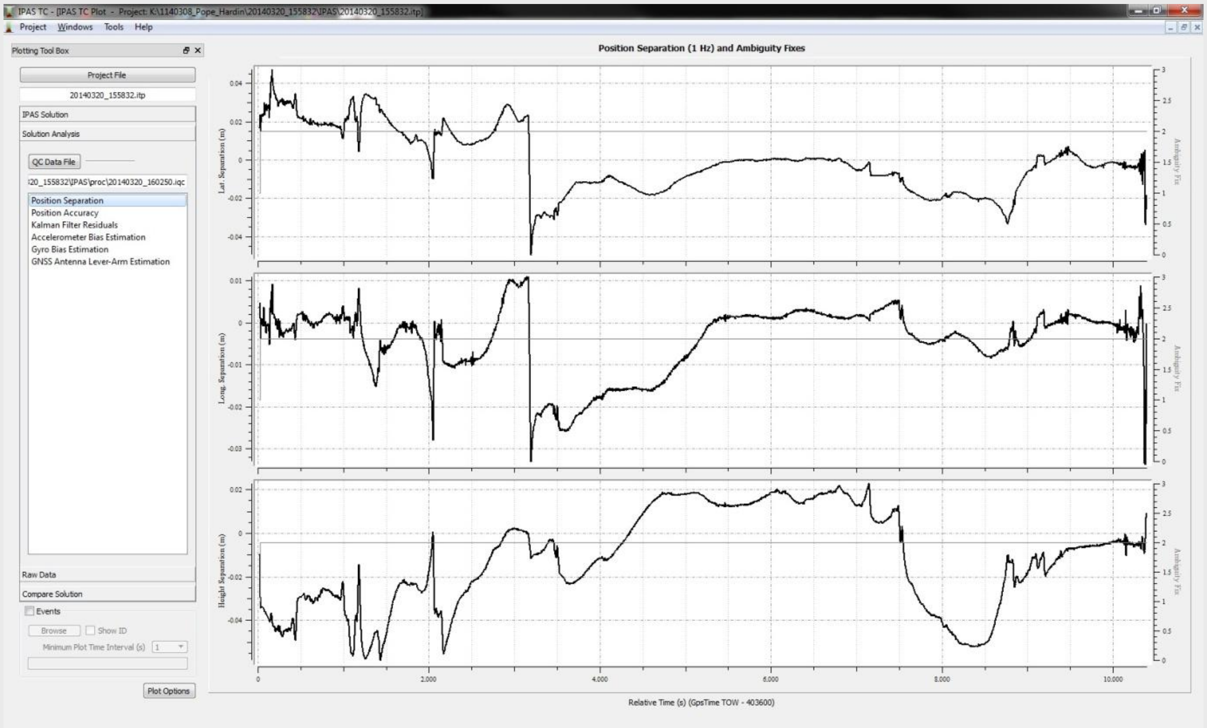
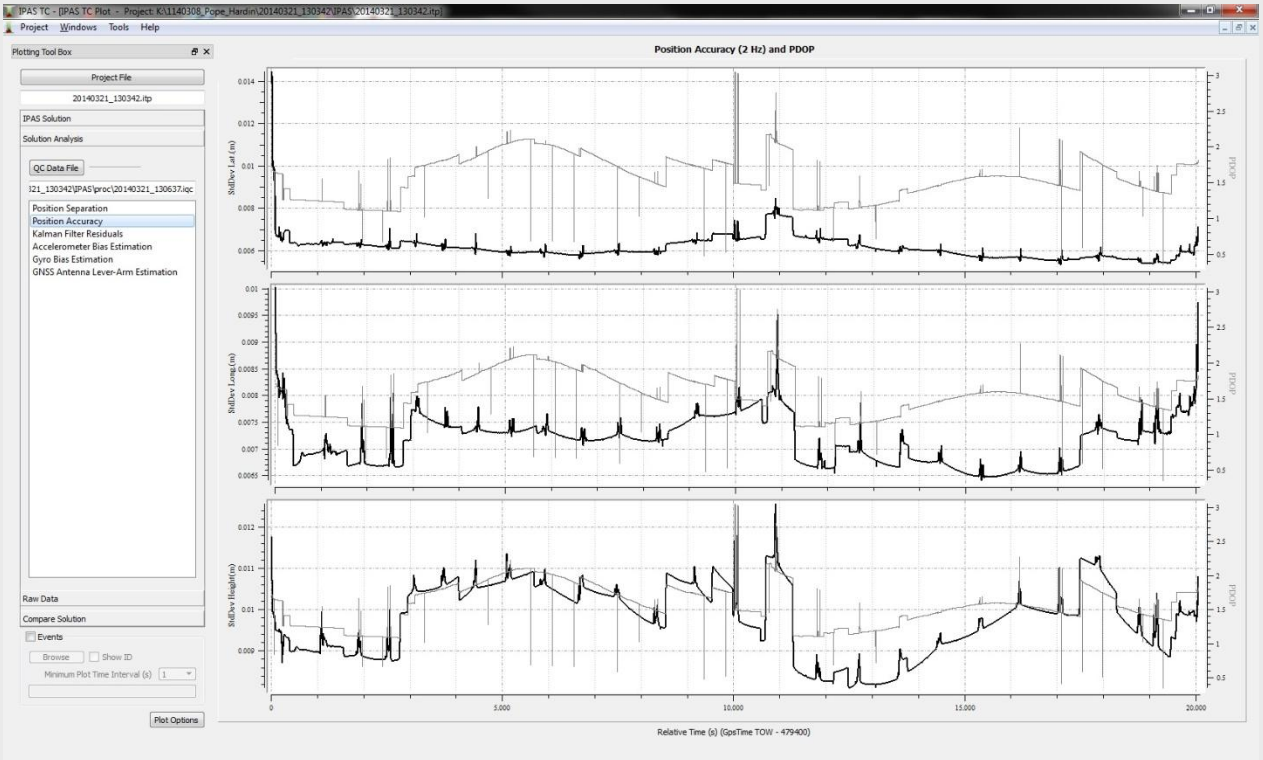
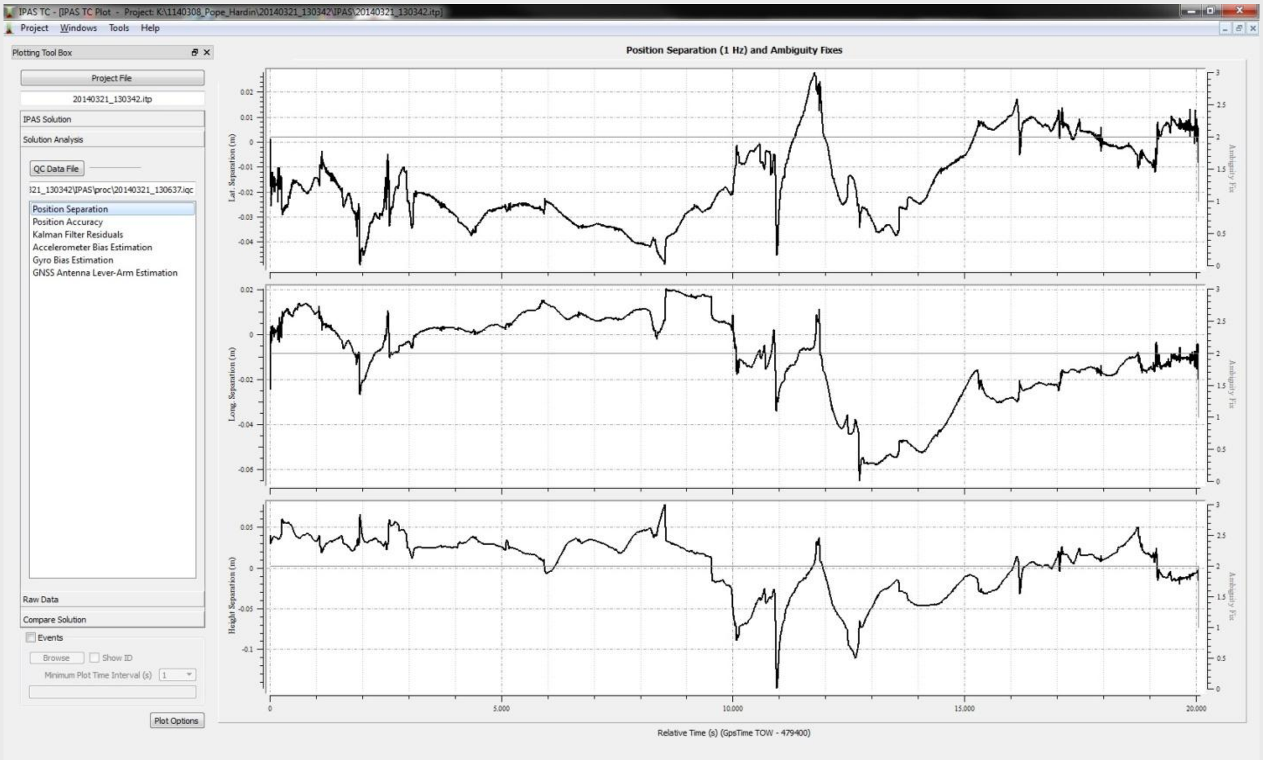


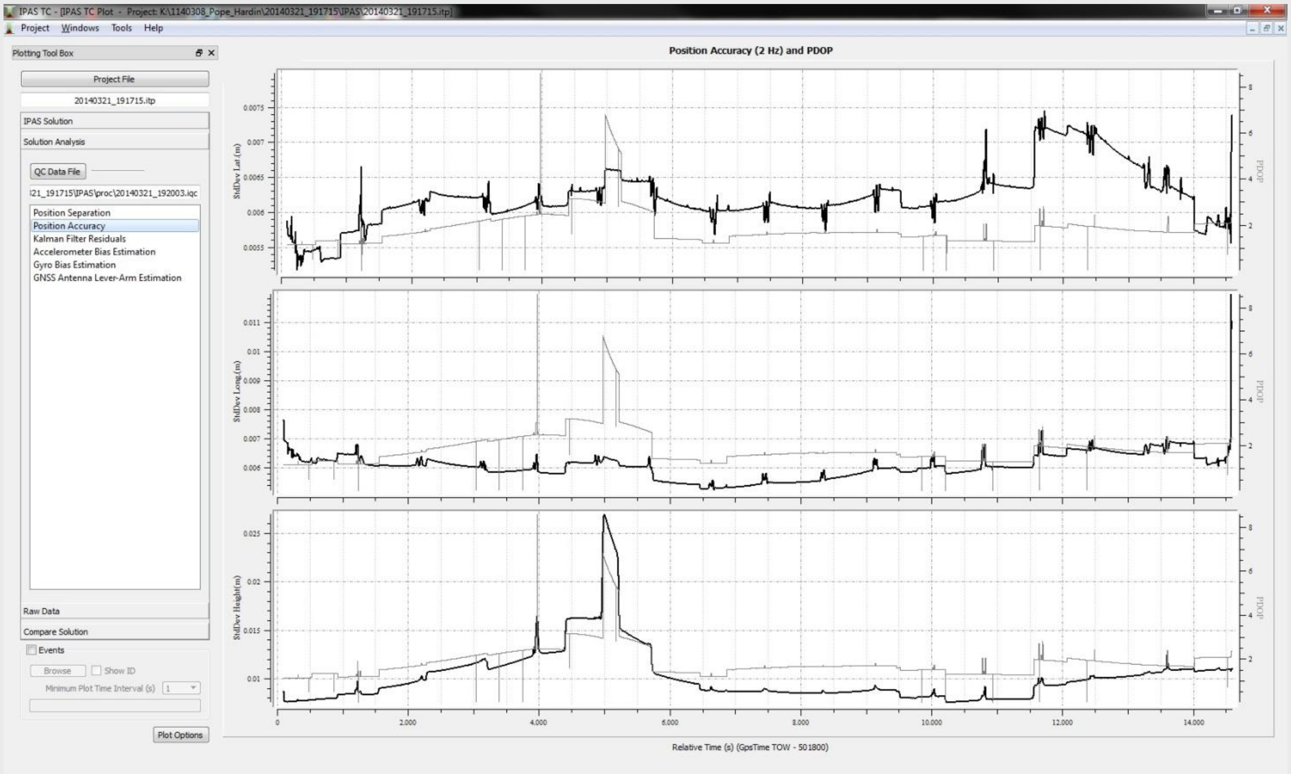
20140321_130342 PDOP plot



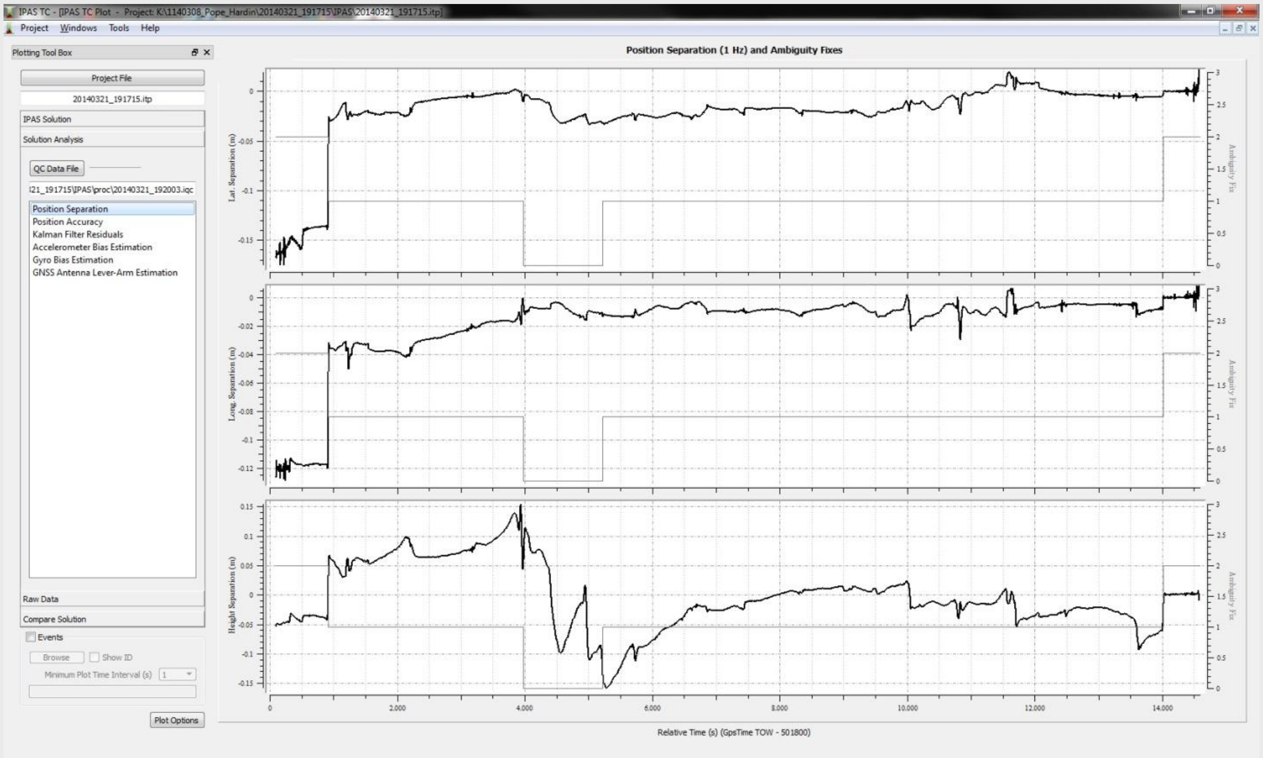
20140321_130342 Separation plot



20140321_191715 PDOP plot



20140321_191715 Separation plot



8 QA/QC Output Control Report

Check points collected across the Hardin and Pope Counties project area and used to calibrate LiDAR data position.

Hardin and Pope Counties Index Control Report					
Control	Easting	Northing	Known Z	Laser Z	Dz
1	893116.2	325673.7	746.547	746.52	-0.027
2	915209.6	332516.3	705.802	705.84	0.038
3	944400.7	324886	810.974	811.01	0.036
4	974922	333114.4	527.719	527.55	-0.169
5	963593.5	310248	459.31	459.55	0.24
6	1024051	334629.5	533.021	533.17	0.149
7	1033591	315147.3	534.999	534.95	-0.049
8	1032656	291507.9	339.107	339.12	0.013
9	1031741	300958.7	421.207	421.3	0.093
10	992081.6	283673.6	357.099	357.59	0.491
11	973688.3	273780.1	358.018	358.13	0.112
12	945168.2	283002.7	421.754	422.1	0.346
13	939414.5	251920.7	485.668	485.63	-0.038
14	908485.3	272928.8	694.861	695.03	0.169
15	932308	214760	345.849	345.77	-0.079
16	924888	254333.1	546.652	546.65	-0.002
17	886831.1	261898.7	498.473	498.44	-0.033
18	887000.4	286807.8	408.907	409.06	0.153
19	905976.5	211709.8	584.106	583.84	-0.266
20	935648.8	210952.5	372.929	372.82	-0.109
21	946464.5	179478.1	397.883	397.87	-0.013
22	954519.8	181157.3	352.506	352.42	-0.086
23	950773.6	166053.4	344.182	344.21	0.028
24	942509.3	192933.5	349.957	349.97	0.013
				Average dz	0.042
				Minimum dz	-0.266
				Maximum dz	0.491
				Average magnitude	0.115
				Root mean square	0.164
				Std deviation	0.162