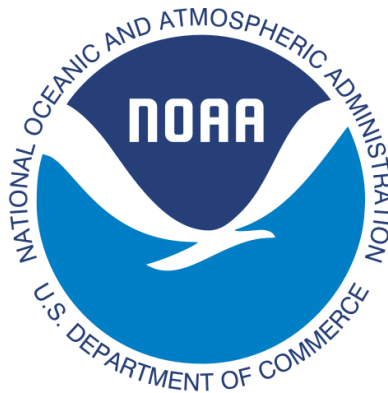


LIDAR ACQUISITION REPORT



FY 2012 GEORGIA DNR ELEVATION DATA
NOAA COASTAL SERVICES CENTER (CSC)
CONTRACT NUMBER: EA133C11CQ0010
REQUISITION ORDER NUMBER: NCNP0000-11-02615

Woolpert Project Number: 072278

Prepared by:

WOOLPERT, INC.
4454 Idea Center Boulevard
Dayton, OH 45430.1500

September 2012



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SECTION 1

SECTION 1: OVERVIEW

This report contains a comprehensive outline of the airborne LiDAR data acquisition for Floyd, Polk, Paulding, and Oconee Counties, as part of the FY 2012 Georgia Elevation Data task order; Contract Number EA133C11CQ0010; Requisition Order Number NCNP0000-11-02615, for the NOAA Coastal Services Center (CSC). The task order area for Floyd, Polk, and Paulding Counties was approximately 460.6 square miles, and the task order area for Oconee County was approximately 233.6 square miles which included a minimum buffer of 200* NPS buffer. The LiDAR data was collected and processed to meet a Nominal Post Spacing (NPS) of 1.0 meter. The NPS assessment is made against single swath, first return data located within the geometrically usable center portion (typically ~90%) of each swath.

LIDAR data was collected using a Leica ALS60 LiDAR sensor in Multi-Pulse mode. The Leica ALS60 LiDAR System collects up to four returns (echo) per pulse, recording attributes such as time stamp and intensity data, for the first three returns. If a fourth return was captured, the system does not record an associated intensity value.

The aerial LiDAR was collected at the following sensor specifications for the Oconee County Project:

Post Spacing (Minimum):	3.28 ft / 1.0 m
AGL (Above Ground Level) average flying height:	6,500 ft / 1,981 m
MSL (Mean Sea Level) average flying height:	6,940 ft / 2,115 m
Average Ground Speed:	130 knots / 149 mph
Field of View (full):	40 degrees
Pulse Rate:	115.6 kHz
Scan Rate:	41.8 Hz
Side Lap (Minimum):	25%
Flight Lines Flown at these specifications:	1 - 27 (All)

The aerial LiDAR was collected at two different sensor specifications for the Floyd, Polk, and Paulding Counties Project: Those LIDAR flight lines that entered the Atlanta Class B Airspace restriction area were flown at a lower altitude specification in order to maintain an altitude of 6500 feet MSL. These instructions were mandated by Atlanta Tracon.

Post Spacing (Minimum):	3.28 ft / 1.0 m
AGL (Above Ground Level) average flying height:	6,500 ft / 1,981 m
MSL (Mean Sea Level) average flying height:	7,075 ft / 2,156 m
Average Ground Speed:	130 knots / 149 mph
Field of View (full):	40 degrees
Pulse Rate:	115.6 kHz
Scan Rate:	41.8 Hz
Side Lap (Minimum):	25%
Flight Lines Flown at these specifications:	1 - 20

Post Spacing (Minimum):	3.28 ft / 1.0 m
AGL (Above Ground Level) average flying height:	5,925 ft / 1,825 m
MSL (Mean Sea Level) average flying height:	6,500 ft / 1,981 m
Average Ground Speed:	130 knots / 149 mph
Field of View (full):	44 degrees
Pulse Rate:	124.0 kHz
Scan Rate:	43.1 Hz
Side Lap (Minimum):	25%
Flight Lines Flown at these specifications	21 - 57

The LiDAR data was produced in Georgia State Plane West Zone, North American Datum of 1983 (NAD83). Coordinate positions were specified in units of US Survey Feet. The vertical datum used for the project was referenced to North American Vertical Datum of 1988 (NAVD88) in units of US Survey Feet.

Table 1.1: LiDAR Acquisition Specifications

Project	Post Spacing	Number of Flight Lines	Number of Collection Days	Acquisition Dates
Floyd, Polk, Paulding Counties, GA	1.0-meter Average	57	4	March 6, 2012 March 20, 2012 March 25, 2012 March 26, 2012
Oconee County, GA	1.0-meter Average	27	1	March 19, 2012

Table 1.2: LiDAR Flight Summary. 1-Meter Nominal Post Spacing

Date of Flying	Lines Flown	Time ON/Off Line (UTC)	Time On/Off Line (Local - EST/EDT)
March 6, 2012 Leica ALS60 SH6157	1 - 20 (Floyd, Polk, Paulding)	17:42 - 22:47	12:42 PM - 5:47 PM
March 19, 2012 Leica ALS60 SH6157	1-27 (Oconee)	12:14-17:01	8:14 AM - 1:01 PM
March 20, 2012 Leica ALS60 SH6157	21 - 34 (Floyd, Polk, Paulding)	13:56-16:51	9:56 AM - 12:51 PM
March 25, 2012 Leica ALS60 SH6157	39-52 (Floyd, Polk, Paulding)	11:50-14:49	7:50 AM - 10:49 AM
March 26, 2012 Leica ALS60 SH6157	33-38, 53-57 (Floyd, Polk, Paulding)	11:56-14:08	7:56 AM - 10:08 AM

Figure 1.1: LiDAR Flight Diagram of Floyd, Polk, Paulding Counties, Georgia

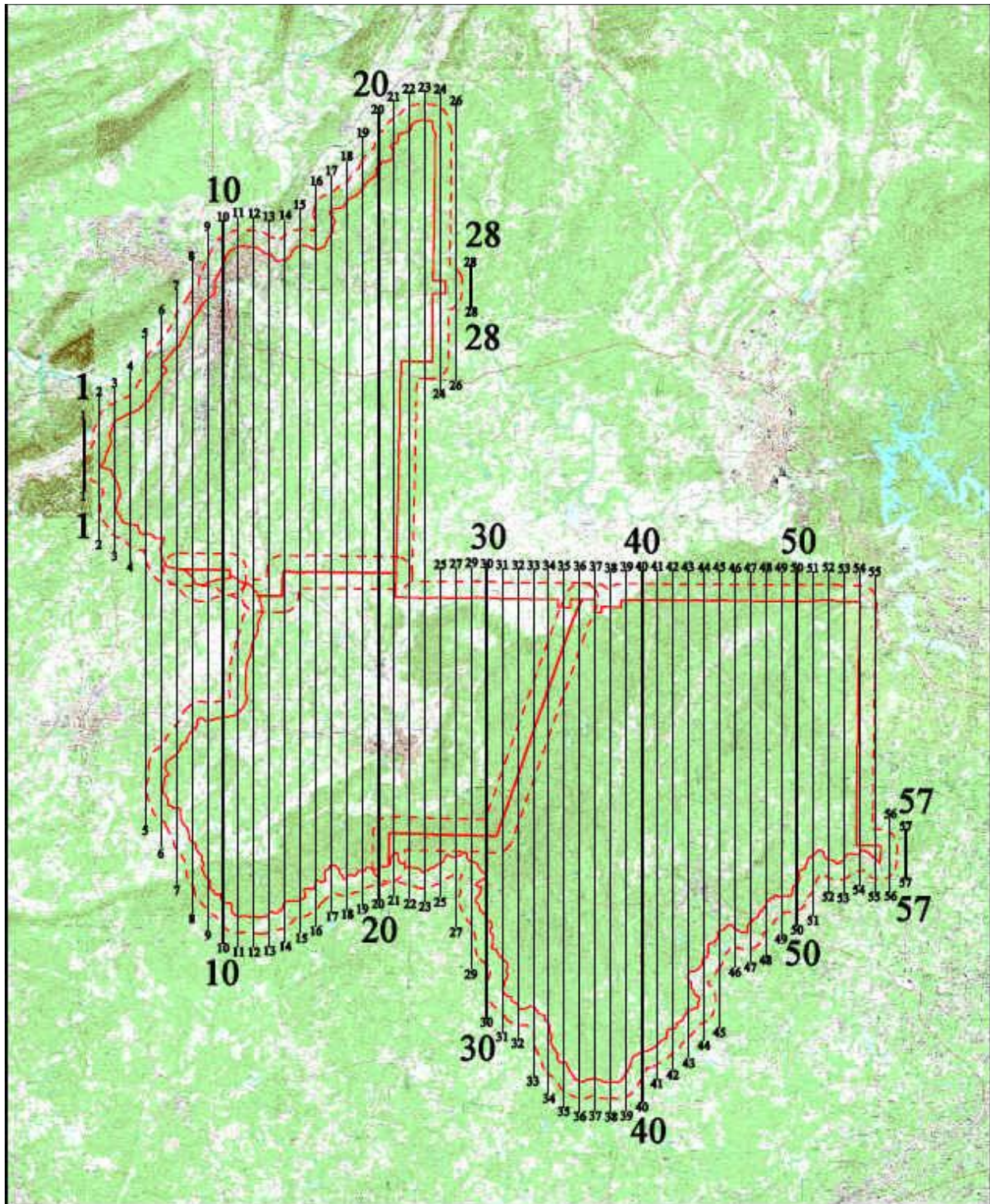
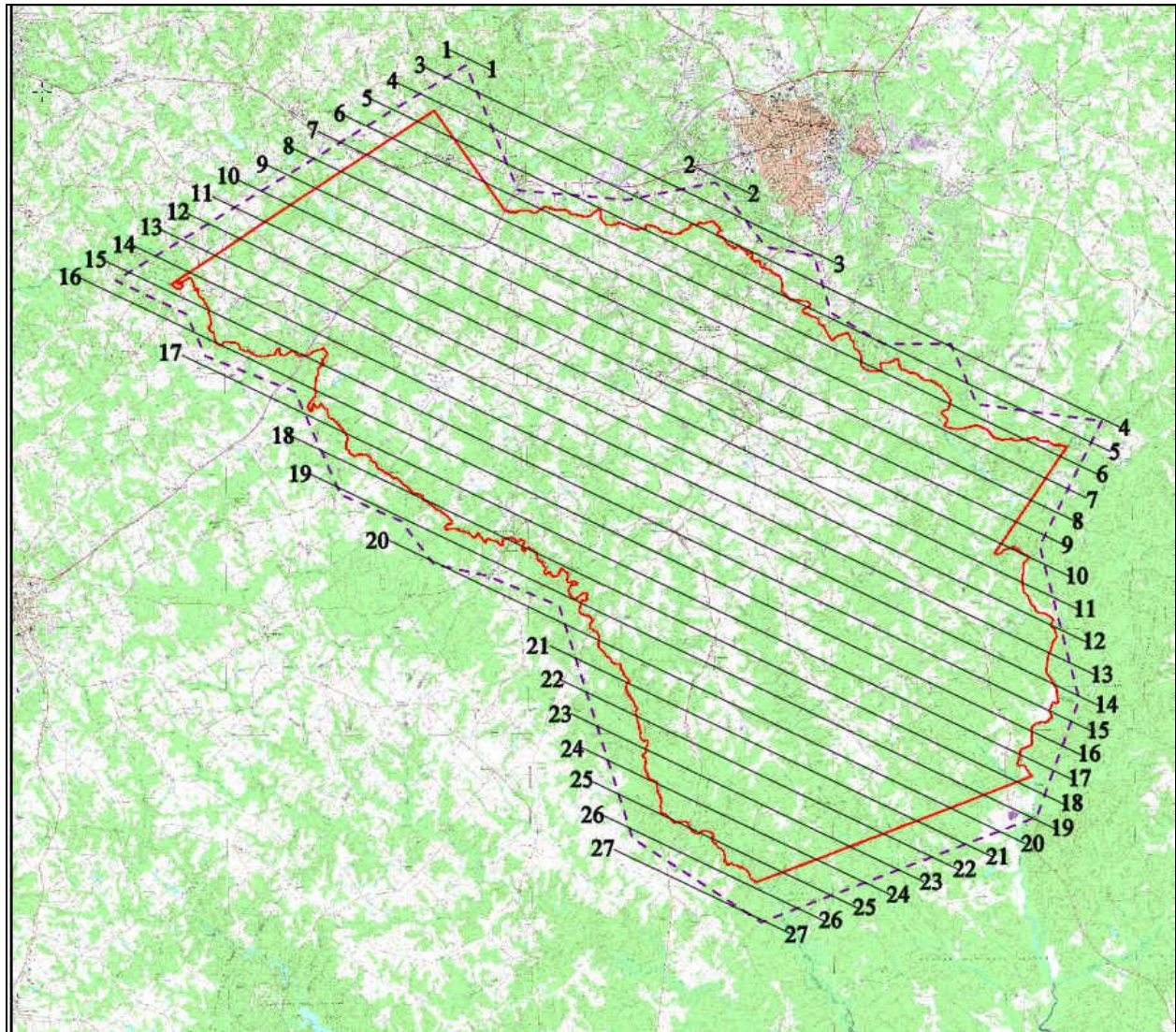


Figure 1.2: LiDAR Flight Diagram of Oconee County, Georgia



SECTION 2: ACQUISITION

The LiDAR data was acquired with a Leica ALS60 LiDAR system (SH6157) in Multiple Pulse in Air (MPiA) mode, on board a Cessna 404 (N475RC). Woolpert owns all the equipment used for the ground control and ABGNSS missions with the exception of CORS stations.

Table 2.1 lists the specifications and the requirements of the Leica ALS60, serial number SH6157

Table 2.1: System Specifications	
Specification	
Operating Altitude	200 - 6,000 feet
Scan Angle	0 to 75° (variable)
Swath Width	0 to 1.5 X altitude (variable)
Scan Frequency	0 - 100 Hz (variable based on scan angle)
Maximum Pulse Rate	200 kHz
Range Resolution	Better than 1 cm
Elevation Accuracy	8 - 24 cm single shot (one standard deviation)
Horizontal Accuracy	7 - 64 cm (one standard deviation)
Number of Returns per Pulse	4 (first, second, third, last)
Number of Intensities	3 (first, second, third)
Intensity Digitization	8 bit intensity + 8 bit AGC (Automatic Gain Control) level
MPiA (Multiple Pulses in Air)	8 bits @ 1nsec interval @ 50kHz
Laser Beam Divergence	0.22 mrad @ $1/e^2$ (-0.15 mrad @ $1/e$)
Laser Classification	Class IV laser product (FDA CFR 21)
Eye Safe Range	400m single shot depending on laser repetition rate
Roll Stabilization	Automatic adaptive, range = 75 degrees minus current FOV
Power Requirements	28 VDC @ 25A
Operating Temperature	0-40°C
Humidity	0-95% non-condensing
Supported GNSS Receivers	Ashtech Z12, Trimble 7400, Novatel Millenium
Attitude Error after GNSS Processing	Roll: $\pm 0.005^\circ$, Pitch: $\pm 0.005^\circ$ Heading: $\pm 0.023^\circ$

Woolpert's Aerial Acquisition Team coordinated with the necessary Air Traffic Control personnel prior to flying to ensure access.

SECTION 2

Flight navigation is performed using IGI CCNS (Computer Controlled Navigation System). The pilots are thoroughly trained and highly skilled at maintaining their planned trajectory, while holding the aircraft steady and level. If atmospheric conditions are such that the trajectory, ground speed, roll, pitch and heading cannot be properly maintained, the mission is aborted until suitable conditions occur.

The aircraft are all configured with a NovAtel Millennium 12-channel, L1/L2 dual frequency GNSS receivers collecting at 2 Hz.

All Woolpert aerial sensors are equipped with Litton LN200 series IMU's operating at 200 Hz.

A base-station unit was mobilized for the imagery acquisition mission, and was operated by a member of the Woolpert survey and/or flight crew. Each base-station setup consisted of one (1) Trimble 5000 series dual frequency receiver, one (1) Trimble Zephyr Geodetic L1/L2 dual frequency antenna, one (1) 2-meter fixed-height tripod, and essential battery power and cabling. Ground planes were used on the base-station antennas. Data was collected at 1 or 2 Hz.

GNSS Base Station operated during the acquisition mission is listed below.

All GNSS base station data and point locations were tied together, along with the ground control.

Weather

No significant weather issues occurred during the flight mission.

Ground Conditions

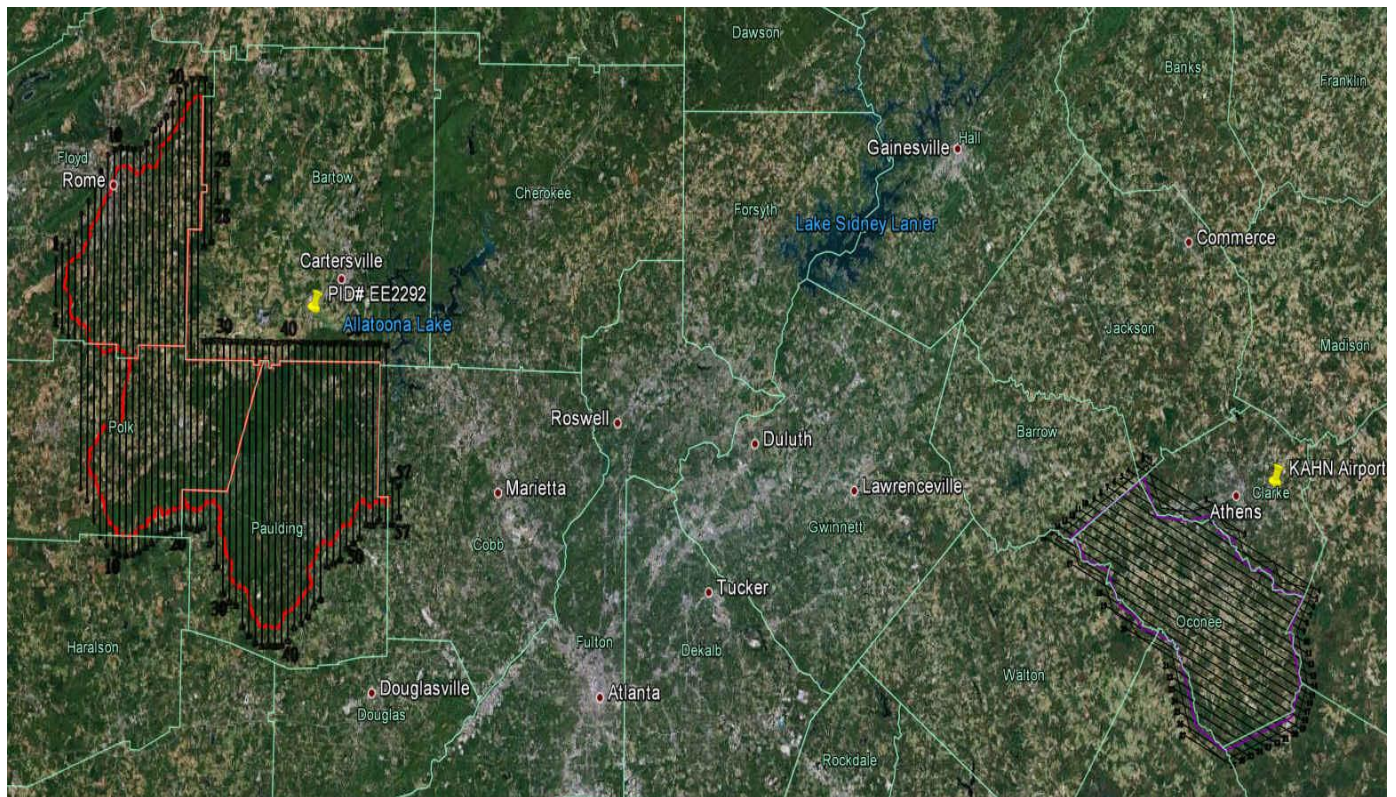
The project area was relatively flat terrain, so the project area was able to be flown at one flight altitude throughout Floyd, Polk, and Paulding Counties and one altitude for Oconee County. No flood or ponding occurred.

GPS Base Station Information

GPS Base Station Used: PID# EE2292 (Floyd, Polk, Paulding Counties) and KAHN Airport (Oconee County)

Table 2.2: GNSS Base Stations			
Station Name	Latitude (DMS)	Longitude (DMS)	Ellipsoid Height (L1 Phase Center) Feet
PID# EE2292	N 34° 07' 25.18053"	W 84° 50' 54.35887"	197.502
KAHN Airport	N 33° 57' 03.74261"	W 83° 19' 36.76747"	212.504

Figure 2.1: GPS Base Station Locations



Maps

Map of the project location is provided in shapefile format.

SECTION 3

SECTION 3

SECTION 3: LIDAR DATA PROCESSING

DATA INITIAL PROCESSING AND DATA VERIFICATION

The collected data was shipped back to the Woolpert Dayton, Ohio office for processing and quality control. All data was downloaded into a standard Woolpert directory structure. The data was immediately checked for missing files, corrupt files, etc. Once verified, the GPS data was processed using Applanix PosPac 5.3 and PosGNSS 5.1 software packages, combining airborne GPS data with base station data. The GPS quality control process includes checking the data to within specs in regards to data integrity, time gaps, positional accuracy (<10cm), combined separation (< 10cm), PDOP (<3), etc.

The LiDAR data was processed with ALS Post Processor v2.74 by Leica. The processed LiDAR data was immediately checked against the flight line layout via MicroStation V8, using TerraScan. Each flight data was checked for spatial accuracy and completeness, data quality, any data voids, clarity of the intensity imagery, point spacing specs, etc.

The results of the data analysis were immediately provided back to the flight crew. Any re-flight areas were immediately re-flown.

A Maximum Position Dilution of Precision (PDOP) of < 3.0 was achieved.

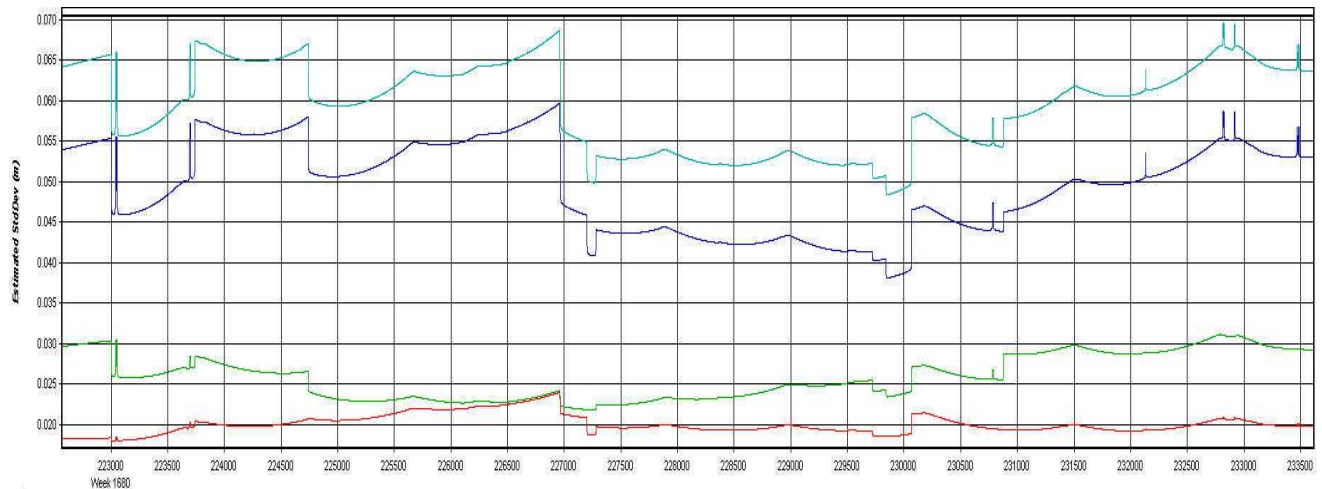
GPS/IMU Processing Summary

Table 3.1: Mission Specific Base Stations, Combined Separation, Estimated Positional Accuracy and PDOP					
Date Sensor Head	Base Station(s)	Combined Separation: Average Difference (Feet)	PDOP Average	Maximum Horizontal Positional Accuracy: (Feet)	Maximum Vertical Positional Accuracy: (Feet)
March 6, 2012 SH6157	PID# EE2292	0.06	1.6	0.03	0.07
March 19, 2012 SH6157	KAHN Airport	0.04	2.2	0.03	0.08
March 20, 2012 SH6157	PID# EE2292	0.04	1.6	0.03	0.07
March 25, 2012 SH6157	PID# EE2292	0.04	2.4	0.03	0.08
March 26, 2012 SH6157	PID# EE2292	0.02	2.4	0.03	0.07

The Estimated Positional Accuracy plots the standard deviations of the east, north, and vertical directions along a time scale of the trajectory. It illustrates loss of satellite lock issues, as well as issues arising from long baselines, noise, and/or other atmospheric interference.

Woolpert's goal is to maintain an Estimated Positional Accuracy of less than ten (10) centifeet, often achieving results well below this threshold.

Figure 3.1: Horizontal and Vertical Positional Accuracies from Day 080:



The Combined Separation is a measure of the difference between the forward run and the backward run solution of the trajectory. The Kalman filter is run in both directions to remove directional specific anomalies. The closer these two solutions match; in general, the better is the overall reliability of the solution. Woolpert's goal is to maintain a Combined Separation Difference of < 10cm, often achieving results well below this cap.

Figure 3.2: GPS Combined Separation from Day 080:

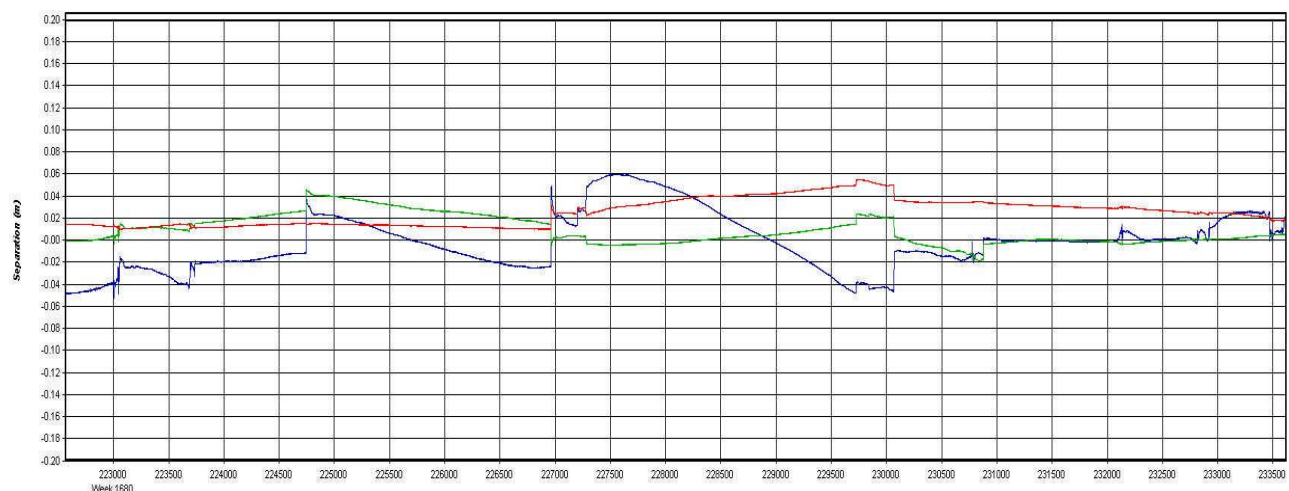


Figure 3.3: GPS Altitude Plot from Day 080:

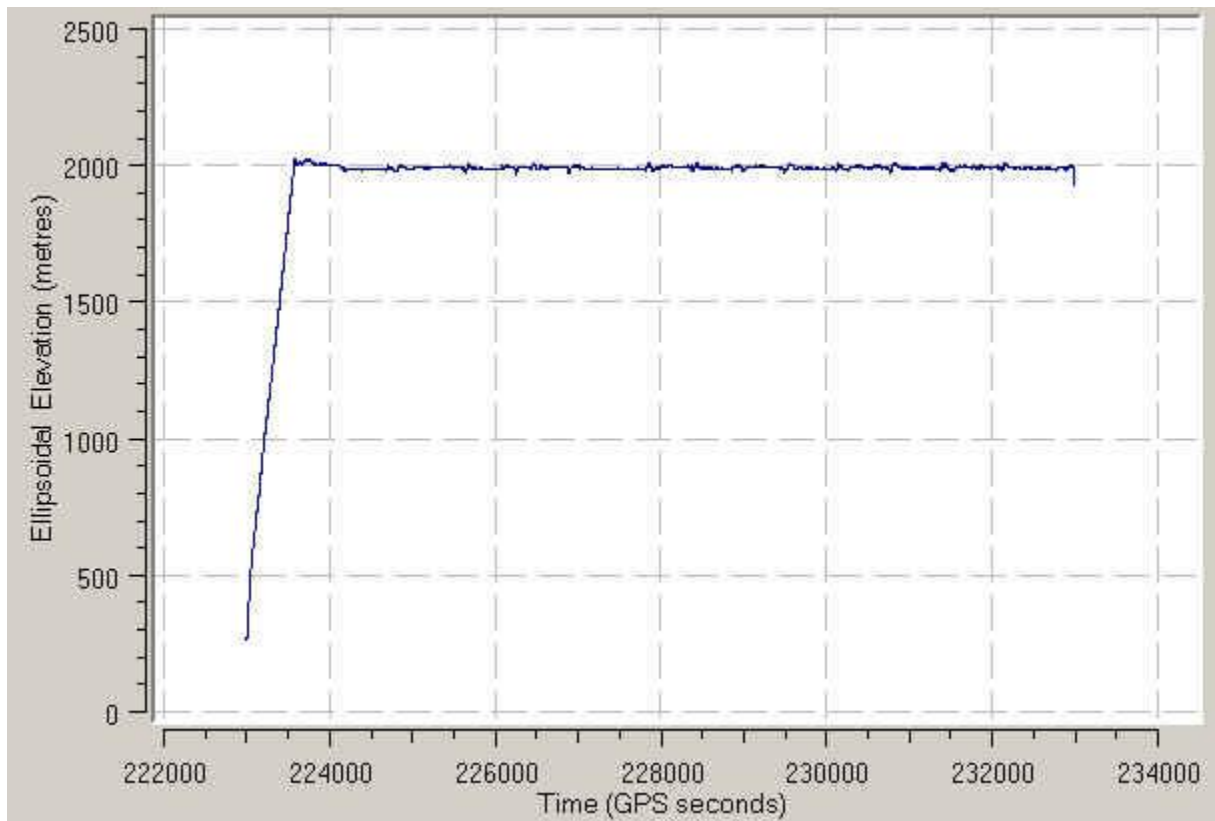
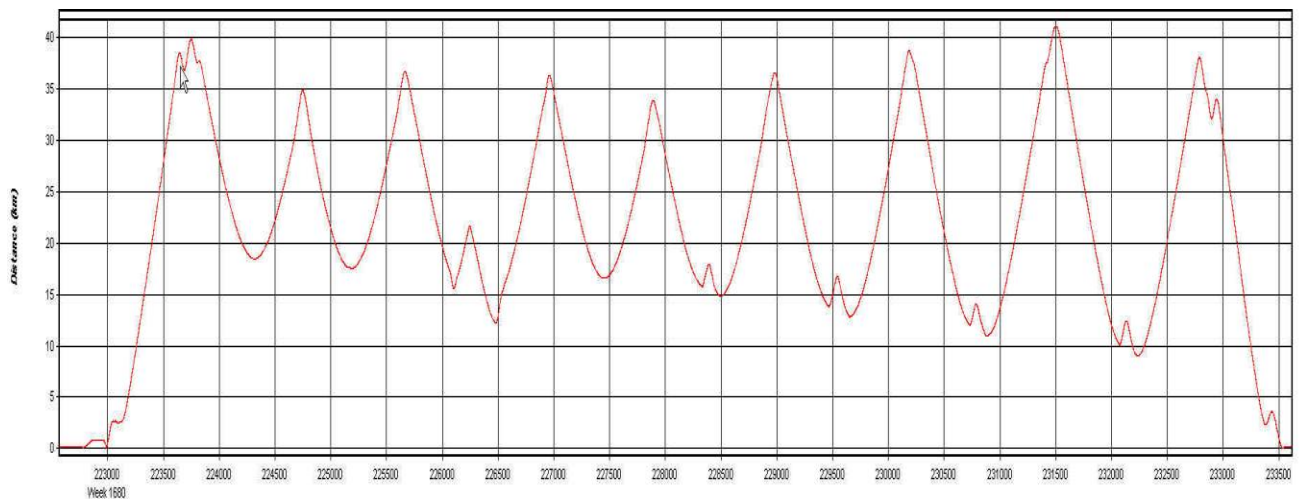


Figure 3.4: Horizontal GPS Distance from Base Station from Day 080:



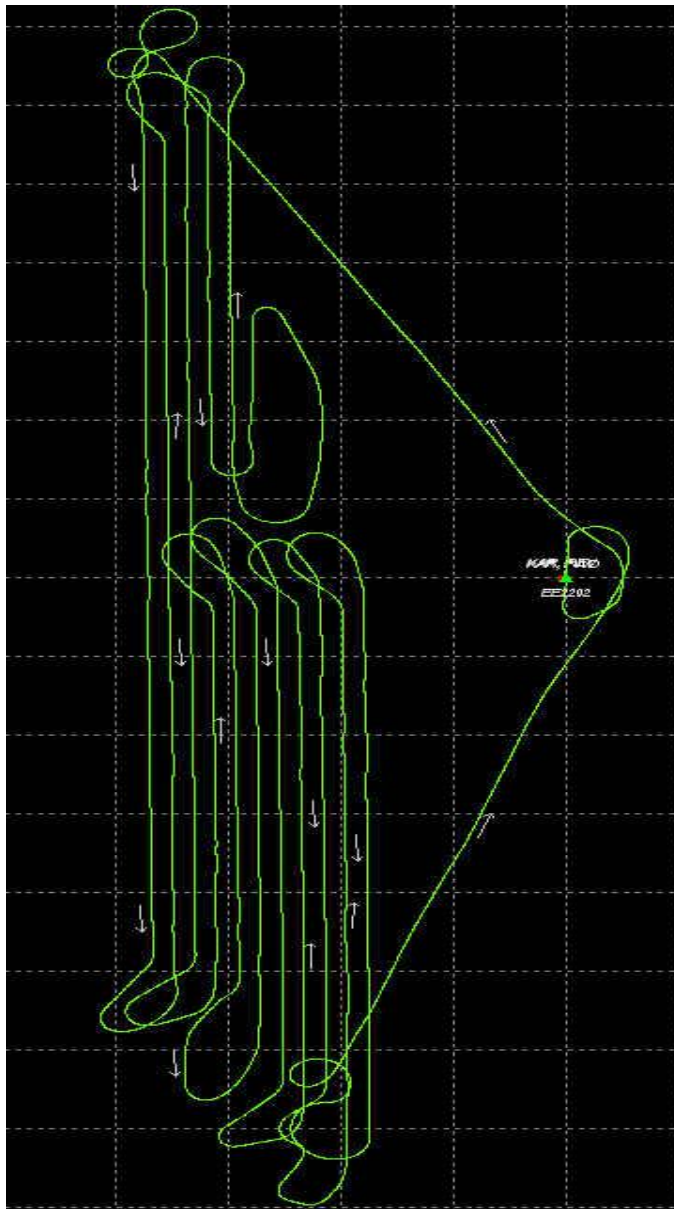
Coverage Checks

Project verification coverage are provided in shapefile format.

Flights

The GNSS Trajectory, along with high quality IMU data, is a key factor in determining the overall positional accuracy of the final sensor data.

Figure 3.5: Flight Trajectory from Day 080



Each mission “As-flown” trajectories were provided in shapefile format.

LIDAR PROCESSING APPLICATIONS AND WORK FLOW OVERVIEW

Individual flight lines processed to derive a raw “Point Cloud” LAS file. Matched overlapping flight lines, generated statistics for evaluation comparisons, and made the necessary adjustments to remove any residual systematic error.

Software: TerraScan v.12.005, TerraMatch v.12.01, Proprietary Software

Imported calibrated LAS point cloud data into the task order tiles. Resulting data were classified as ground and non-ground points with additional filters created to meet the task order classification specifications. Statistical absolute accuracy was assessed via direct comparisons of ground classified points to ground RTK survey data. Based on the statistical analysis, the LiDAR data was then adjusted to reduce the vertical bias when compared to the survey ground control. The LiDAR LAS files for this task order have been classified into the Default (Class 1), Ground (Class 2), Noise (Class 7), Water (Class 9), Ignored Ground (Class 10) and Overlap (Class 12) classifications. Note: FY 12 data will continue to use class 12 for overlap. Beginning in fy13, the USGS v.1.0 standard classes of class (+16) will be included.

Software: TerraScan v.12.005, Microstation v8

The LAS files were evaluated through a series of manual QA/QC steps to eliminate remaining artifacts and small undulations from the ground class.

Software: TerraScan v.12.005.

All water bodies greater than two acres and all rivers with a nominal 100 foot width or larger were collected as break lines using 2-d digitizing methods and lidar intensity as a base map.

Software: ESRI v10.0, Microstation v8, TerraScan v.12.005.

The bare earth DEM surface was hydrologically flattened for water body features that were greater than 2 acres and rivers and streams of 30.5 feet (100 feet) and greater nominal width.

Software: LP360 v.2011.1.54.1, Microstation v8, ESRI v.10.0, Proprietary Software

SECTION 4

SECTION 4



SECTION 4: SENSOR CALIBRATION

Calibration flights were performed prior to arriving on the project site. The calibration was performed at Greene County Airport in Xenia, OH. To accomplish the formal calibration, Woolpert has established a calibration range of an airport runway. The calibration ranges has been ground surveyed to an accuracy of better than 1 cm. The mission consisted of 3 different altitudes flown along and across the runway and opposing directions which is required in order to capture the pitch, roll, heading, and torsion errors. A factory-certified calibration was performed by Leica at their factory, attached is the certification from Leica.

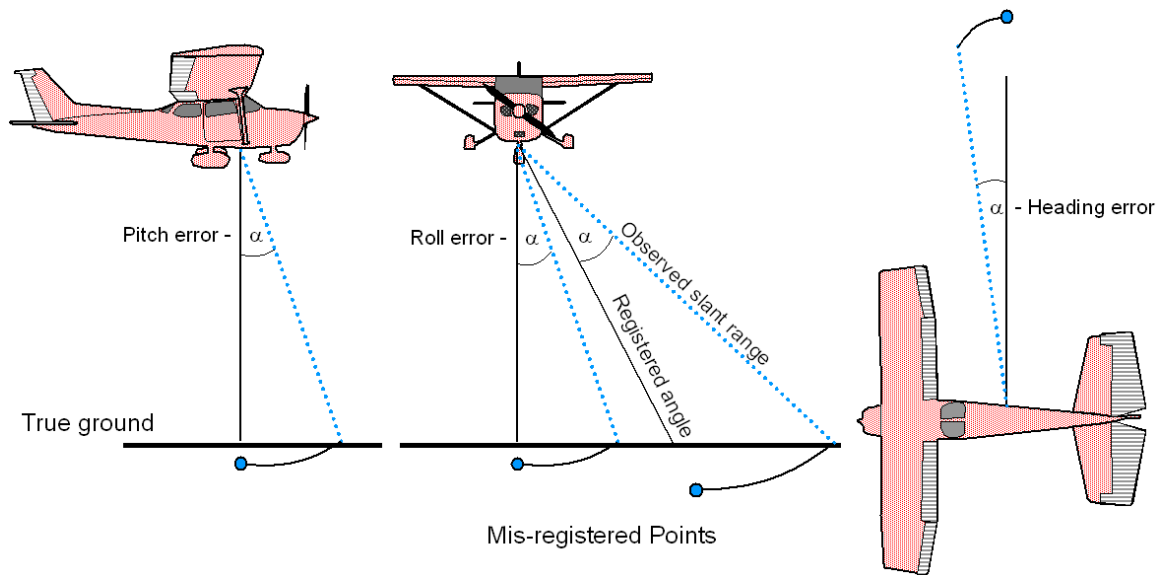
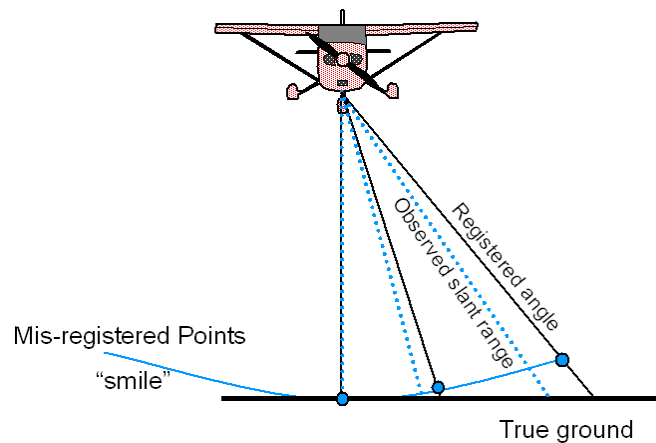
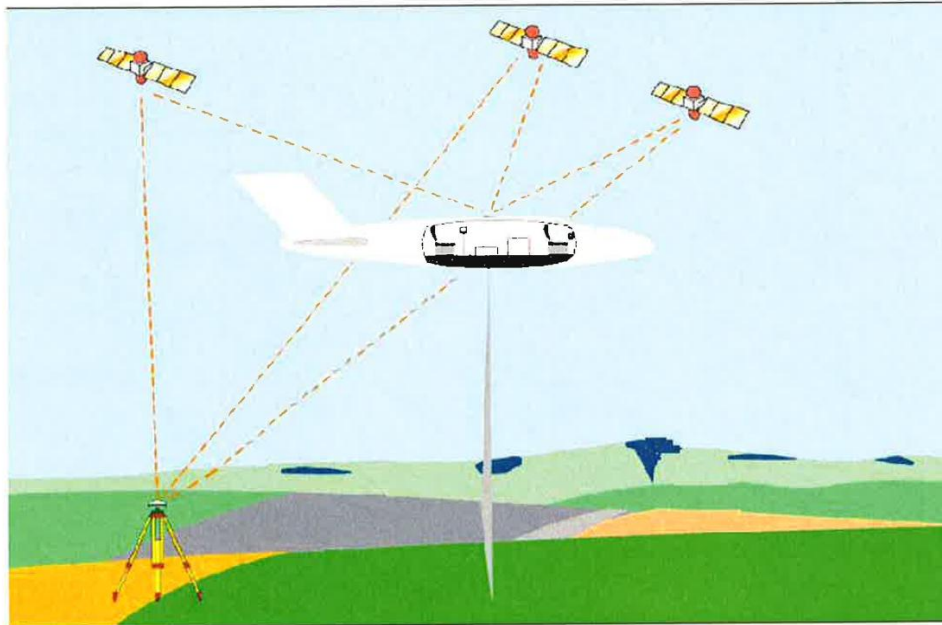


Figure 4.1: Misalignment Errors



ALS Calibration Certificate



This certificate is valid for

Model
ALS60

Serial Number
SN6157

Calibration certificate issued on
by

17 December 2010

Junyu Mao

Certificate and calibration data ID

**SN6157 ALS60 Calibration
Report 20101217**

Leica Geosystems AG
Heinrich-Wild-Strasse
9435 Heerbrugg
Switzerland



Components of ALS

Component	Device	Type	Serial Number
LS60	Laser Scanner		6157
IPAS	INS System (3.0 Build 1)	10	1378
IMU	Inertial Measurement unit	DUS5 "LN200"	408096
DL60	Data Logger	XP embedded	0252378002
GC60	Galvo Controller	"ALS_60"	X 10111803 Y
		performance	
SC60	System Controller		6157

Calibration process

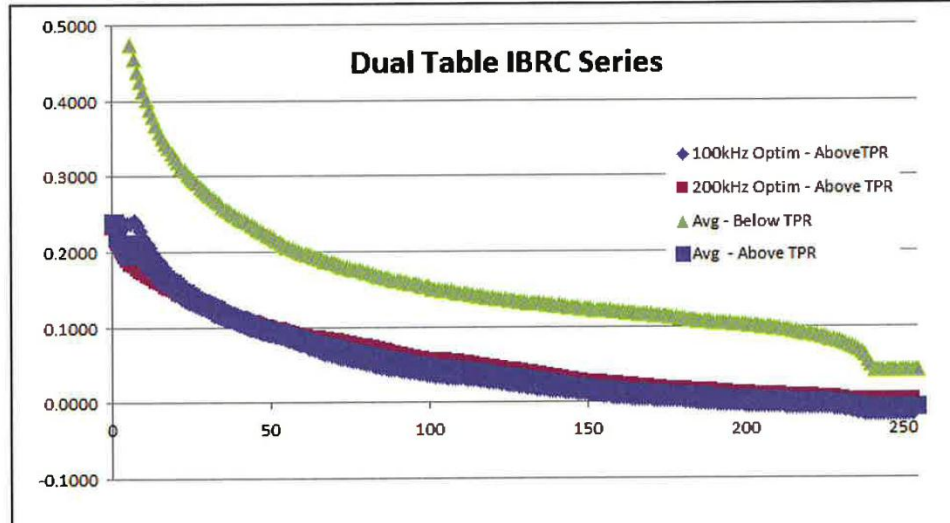
Intensity based range correction (IBRC)

	Passed	Date	Inspector
RIVIT (raw IBRC) measurements	ok	05-Nov-10	Production
IBRC table	ok	05-Nov-10	Heierli René

File **SN6157_20101105_DUAL_IBRC_Default.csv**

Objective To correct for the effect of varying range based on return signal strength.

Note The range biases are in meters. The bias values derived from test data above and below the TPR are for intensity values of 0 (low intensity) to 255 (high intensity) in that order.



Dual Intensity based range correction (Dual-IBRC) - curve

Flight and data processing

	Passed	Date	Inspector
Test flight	ok	10 Dec 10	Norbert Lämmer
Data Quality Check	ok	13 Dec 10	Junyu Mao
(Boresight) Calibration	ok	14 Dec 10	Junyu Mao

File **ALS6157_Calibration_20101210.reg**

Objective To correct for systematic effects of this ALS System.

Validation A complete "on-site" calibration should be performed *after system delivery* to verify factory calibration and establish a final set of correction parameters.**IPAS Processing – FCMS Guidance and Sensor Control Operation**

Parameter [Units]	Value
IMU Type	DUS5-"LN200"
IMU Lever Arm X [m]	-0.450
IMU Lever Arm Y [m]	0.119
IMU Lever Arm Z [m]	-0.203
Omega Rotation Angle	90.00000
Phi Rotation Angle	0.00000
Kappa Rotation Angle	0.00000
User Frame Lever Arm X [m]	-0.167
User Frame Lever Arm Y [m]	0.001
User Frame Lever Arm Z [m]	-0.175
Leica Locarno Test Airplane – Pilatus HB-FKL	
GPS Lever Arm X [m]	0.630
GPS Lever Arm Y [m]	0.370
GPS Lever Arm Z [m]	-1.370
Required: IPAS Pro v1.35 b0005+, IPAS TC 3.0+ ALS Post Processor v2.70#14+, IPAS SUP file required	

ALS Calibration Summary – Key Parameters for use in the ALS Post Processor

Parameter [Units]	Value
Encoder Scale Factor [encoder counts per revolution]	8388608
Encoder Offset, "Scan Angle Correct" [encoder counts]	-10300
Roll [rad]	-0.002978143
Pitch [rad]	0.006446347
Heading [rad]	-0.003676788
Pitch Error Slope [rad/deg]	6.516e-006
Torsion Constant [Nm/rad]	40000
Nominal Range Offset [m]	-6.064
R1 [m] BankA / BankB	-6.064 / -6.084
R2 [m] BankA / BankB	-6.065 / -6.050
R3 [m] BankA / BankB	-6.046 / -6.070
R4 [m] BankA / BankB	-6.110 / -6.075
TPR [Hz]	100000
TPR Offset [m]	0
Elevation Offset [m]	0
PPS Correction [μs]	0
Encoder Latency [μs]	0.2
IMU Latency [μs]	-1000
Waveform Trigger Delay - below TPR [ps]	7513
Waveform Trigger Delay - above TPR [ps]	9460
ALS Post Processor v2.70#14+ is required!	

Accuracy Check

	Value	Std Dev	Inspector
Avg Dz to Control. Locarno Test Site. 35 check points (Line 095532, AGL 2300m)	0.008	0.029	Junyu Mao
Shot to Shot noise check (Line 100029 @1300m AGL)	-	0.011	Junyu Mao
Summary Calibration check	ok	-	Junyu Mao

Nominal Laser Characteristics

	Value
Beam diameter ($1/e$ and $1/e^2$, mm)	5.6, 8.0
Beam divergence ($1/e$ and $1/e^2$, mr)	0.15, 0.22
Pulse width (maximum, Full Width Half Max, ns)	9
Maximum single-pulse energy (mJ)	0.2
Emitted wavelength (nm)	1064

Inspection

Inspectors

Name	Junyu Mao
Position	Airborne Systems Support Engineer
Name	Bernhard Riedl
Position	Production Manager - Hardware

The following measurements were calculated in the lab at Leica and will remain constant.

Table 4.1: ALS60 S/N 6157 IMU Lever Arm Values

User to IMU Lever Arm (POS/AV)	
X	-0.450 m
Y	0.119 m
Z	-0.203 m

The positioning of the GPS antenna on the aircraft was field surveyed by Woolpert using a total station to $\pm 0.02\text{m}$.

Table 4.2: N475RC: Cessna 404 with ALS60 S/N 6157 installed Lever Arm Values

Reference Point to GPS Antenna	
X	0.530 m
Y	0.60 m
Z	-1.480 m

SECTION 5: FLIGHT LOGS

This section contains the Flight Log(s) covering the project. Flight Logs list mission specific details such as crew members, airports, weather conditions, real time PDOP values and document any issues encountered during the mission. Flight Logs are filled out by the sensor operator during the acquisition flight.

SECTION 5



WOOLPERT FLIGHT LOG SHEET #1																																																																																																																																																																																																																																																																																																													
Leica ALS-50/60			MM/DD/YYYY 03/06/2012		Day of Year 66		Mission Name / Job # 72278-Polk/Floyd/Paulding -Flight_1																																																																																																																																																																																																																																																																																																						
Operator Burton			Aircraft N404CP ☐		Sensor SH-46 ☐		Hobbs Start 4288.7		Local Start Time 12:42:45		Zulu Start Time 17:42																																																																																																																																																																																																																																																																																																		
Pilot Rader			N475RC ☒		SH-77 ☐		Hobbs End 4293.6		Local End Time 17:47:44		Zulu End Time 22:47																																																																																																																																																																																																																																																																																																		
Passengers			Using or Relying on CORS Yes ☐ No ☒		GPS Base #1 Operator Burton		GPS Base #2 Operator		PID EE2292		PID																																																																																																																																																																																																																																																																																																		
Wind Dir/Speed 098/16		Visibility 10+	Ceiling clear	Cloud Cover %	Temp 13	Dew Point -6	Pressure 3053		Haze/Fire/Cloud		Departing ICAO KVPC																																																																																																																																																																																																																																																																																																		
Scan Angle (FOV) 40		Scan Frequency (Hz) 41.8		Pulse Rate (kHz) 115.6		Laser Power % 87		Gain Course/Up 6 Fine/Down 12		Mode Single ☐ 2 + 2 ☐ Multi ☒ 4 + 3 ☒																																																																																																																																																																																																																																																																																																			
Air Speed 130 Kts		AGL 6500 Ft		MSL 7075 Ft		Avg. Elev. Ft		Waveform Mode @ NS		Pre-Trigger Dist. Rt																																																																																																																																																																																																																																																																																																			
<table border="1"> <thead> <tr> <th>Line #</th> <th>Dir.</th> <th>Line Start Time</th> <th>Line End Time</th> <th>Time On Line</th> <th>SVs</th> <th>HDOP</th> <th>PDOP</th> <th>Line Notes/Comments</th> </tr> </thead> <tbody> <tr> <td>Test</td> <td>n/a</td> <td>17:59:09</td> <td>17:59:28</td> <td>n/a</td> <td>n/a</td> <td>n/a</td> <td>n/a</td> <td>GPS Began Logging At:</td> </tr> <tr> <td colspan="9"> ⬆ Times entered are Zulu / GMT ⬆ Verify S-Turns Before Mission Yes ☒ No ☐ </td> </tr> <tr><td>1</td><td>N</td><td>18:09:35</td><td>18:10:45</td><td>0:01:10</td><td>18</td><td>0.8</td><td>1.4</td><td></td></tr> <tr><td>2</td><td>S</td><td>18:14:45</td><td>18:15:55</td><td>0:01:10</td><td>19</td><td>0.8</td><td>1.4</td><td></td></tr> <tr><td>3</td><td>N</td><td>18:19:09</td><td>18:21:36</td><td>0:02:27</td><td>19</td><td>0.7</td><td>1.1</td><td></td></tr> <tr><td>4</td><td>S</td><td>18:24:55</td><td>18:27:45</td><td>0:02:50</td><td>19</td><td>0.7</td><td>1.1</td><td></td></tr> <tr><td>5</td><td>N</td><td>18:34:33</td><td>18:41:55</td><td>0:07:22</td><td>20</td><td>0.6</td><td>1</td><td></td></tr> <tr><td>6</td><td>S</td><td>18:45:40</td><td>18:53:39</td><td>0:07:59</td><td>21</td><td>0.5</td><td>1</td><td></td></tr> <tr><td>7</td><td>N</td><td>18:57:25</td><td>19:06:25</td><td>0:09:00</td><td>20</td><td>0.6</td><td>1</td><td></td></tr> <tr><td>8</td><td>S</td><td>19:10:06</td><td>19:15:34</td><td>0:05:28</td><td>19</td><td>0.6</td><td>1</td><td>Aborted - Skydivers</td></tr> <tr><td>8</td><td>S</td><td>19:28:58</td><td>19:33:55</td><td>0:04:57</td><td>17</td><td>0.6</td><td>1.2</td><td>Manual re-start</td></tr> <tr><td>9</td><td>N</td><td>19:36:41</td><td>19:47:11</td><td>0:10:30</td><td>17</td><td>0.6</td><td>1.2</td><td></td></tr> <tr><td>18</td><td>S</td><td>19:52:10</td><td>20:03:38</td><td>0:11:28</td><td>17</td><td>0.6</td><td>1.1</td><td></td></tr> <tr><td>19</td><td>N</td><td>20:06:49</td><td>20:18:23</td><td>0:11:34</td><td>15</td><td>0.8</td><td>1.4</td><td></td></tr> <tr><td>20</td><td>S</td><td>20:22:11</td><td>20:34:13</td><td>0:12:02</td><td>15</td><td>0.8</td><td>1.4</td><td></td></tr> <tr><td>17</td><td>N</td><td>20:37:50</td><td>20:48:57</td><td>0:11:07</td><td>16</td><td>0.7</td><td>1.2</td><td></td></tr> <tr><td>16</td><td>S</td><td>20:52:19</td><td>21:03:34</td><td>0:11:15</td><td>16</td><td>0.7</td><td>1.2</td><td></td></tr> <tr><td>15</td><td>N</td><td>21:06:42</td><td>21:17:38</td><td>0:10:56</td><td>16</td><td>0.7</td><td>1.1</td><td></td></tr> <tr><td>14</td><td>S</td><td>21:12:03</td><td>21:32:05</td><td>0:20:02</td><td>16</td><td>0.7</td><td>1.2</td><td></td></tr> <tr><td>13</td><td>N</td><td>21:35:16</td><td>21:46:05</td><td>0:10:49</td><td>16</td><td>0.8</td><td>1.3</td><td></td></tr> <tr><td>12</td><td>S</td><td>21:49:14</td><td>22:00:19</td><td>0:11:05</td><td>16</td><td>0.8</td><td>1.4</td><td></td></tr> <tr><td>11</td><td>N</td><td>22:03:10</td><td>22:14:11</td><td>0:11:01</td><td>15</td><td>0.8</td><td>1.4</td><td></td></tr> <tr><td>10</td><td>S</td><td>22:17:15</td><td>22:28:10</td><td>0:10:55</td><td>17</td><td>0.7</td><td>1.1</td><td></td></tr> <tr><td></td><td></td><td></td><td></td><td>0:00:00</td><td></td><td></td><td></td><td></td></tr> <tr><td></td><td></td><td></td><td></td><td>0:00:00</td><td></td><td></td><td></td><td></td></tr> <tr><td></td><td></td><td></td><td></td><td>0:00:00</td><td></td><td></td><td></td><td></td></tr> <tr><td></td><td></td><td></td><td></td><td>0:00:00</td><td></td><td></td><td></td><td></td></tr> <tr><td></td><td></td><td></td><td></td><td>0:00:00</td><td></td><td></td><td></td><td></td></tr> <tr><td></td><td></td><td></td><td></td><td>0:00:00</td><td></td><td></td><td></td><td></td></tr> <tr> <td colspan="4"> ↑ Times entered are Zulu / GMT ↑ Verify S-Turns After Mission Yes ☒ No ☐ </td> <td colspan="2">Total Time On Line 3:05:07</td> <td colspan="2"></td> <td colspan="2"></td> </tr> <tr> <td colspan="8">Additional Comments:</td> <td colspan="2">Drive #</td> </tr> </tbody> </table>												Line #	Dir.	Line Start Time	Line End Time	Time On Line	SVs	HDOP	PDOP	Line Notes/Comments	Test	n/a	17:59:09	17:59:28	n/a	n/a	n/a	n/a	GPS Began Logging At:	⬆ Times entered are Zulu / GMT ⬆ Verify S-Turns Before Mission Yes ☒ No ☐									1	N	18:09:35	18:10:45	0:01:10	18	0.8	1.4		2	S	18:14:45	18:15:55	0:01:10	19	0.8	1.4		3	N	18:19:09	18:21:36	0:02:27	19	0.7	1.1		4	S	18:24:55	18:27:45	0:02:50	19	0.7	1.1		5	N	18:34:33	18:41:55	0:07:22	20	0.6	1		6	S	18:45:40	18:53:39	0:07:59	21	0.5	1		7	N	18:57:25	19:06:25	0:09:00	20	0.6	1		8	S	19:10:06	19:15:34	0:05:28	19	0.6	1	Aborted - Skydivers	8	S	19:28:58	19:33:55	0:04:57	17	0.6	1.2	Manual re-start	9	N	19:36:41	19:47:11	0:10:30	17	0.6	1.2		18	S	19:52:10	20:03:38	0:11:28	17	0.6	1.1		19	N	20:06:49	20:18:23	0:11:34	15	0.8	1.4		20	S	20:22:11	20:34:13	0:12:02	15	0.8	1.4		17	N	20:37:50	20:48:57	0:11:07	16	0.7	1.2		16	S	20:52:19	21:03:34	0:11:15	16	0.7	1.2		15	N	21:06:42	21:17:38	0:10:56	16	0.7	1.1		14	S	21:12:03	21:32:05	0:20:02	16	0.7	1.2		13	N	21:35:16	21:46:05	0:10:49	16	0.8	1.3		12	S	21:49:14	22:00:19	0:11:05	16	0.8	1.4		11	N	22:03:10	22:14:11	0:11:01	15	0.8	1.4		10	S	22:17:15	22:28:10	0:10:55	17	0.7	1.1						0:00:00									0:00:00									0:00:00									0:00:00									0:00:00									0:00:00					↑ Times entered are Zulu / GMT ↑ Verify S-Turns After Mission Yes ☒ No ☐				Total Time On Line 3:05:07						Additional Comments:								Drive #	
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WOOLPERT FLIGHT LOG SHEET #1													
Leica ALS-50/60			MM/DD/YYYY 3/19/2012		Day of Year 79		Mission Name / Job # Oconee County, GA/072279						
Operator Bart Galambos			Aircraft N404CP ☐		Sensor SH-46 ☐		Hobbs Start 4317.5		Local Start Time 8:14		Zulu Start Time 12:14		
Pilot Leo Rader			N475RC ☒		SH-77 ☐		Hobbs End 4322.3		Local End Time 1:01		Zulu End Time 17:01		
Passengers N/A			Using or Relying on CORS Yes ☐ No ☒		GPS Base #1 Operator Bart		GPS Base #2 Operator		PID ASI				
Wind Dir/Speed 90@10		Visibility 3 Mist		Ceiling 0		Cloud Cover % Clear		Temp 14		Dew Point 13		Pressure 3019	
Haze/Fire/Cloud		Departing ICAO KAHN		Arriving ICAO KAHN									
Scan Angle (FOV) 40		Scan Frequency (Hz) 41.8		Pulse Rate (kHz) 115.6		Laser Power % 87		Gain Course/Up 6 Fine/Down 12		Mode Single ☐ 2 + 2 ☐ Multi ☒ 4 + 3 ☒			
Air Speed 130 Kts		AGL 6500 Ft		MSL 6940 Ft		Avg. Elev. 440 Ft		Waveform Mode @ NS		Pre-Trigger Dist. Rt			
Line #	Dir.	Line Start Time	Line End Time	Time On Line	SVs	HDOP	PDOP	Line Notes/Comments					
Test	n/a			n/a	n/a	n/a	n/a	GPS Began Logging At: 8:04(L) / 12:04z					
⚡ Times entered are Zulu / GMT ⚡ Verify S-Turns Before Mission Yes ☒ No ☐													
27	NW	12:29:06	12:30:59	0:01:53	15	0.7	1.2						
26	SE	12:34:09	12:36:30	0:02:21	16	0.6	1.1						
25	NW	12:39:52	12:42:43	0:02:51	16	0.6	1.2						
24	SE	12:46:02	12:49:21	0:03:19	16	0.6	1.1						
23	NW	12:53:14	12:56:57	0:03:43	16	0.6	1.1						
22	SE	13:00:09	13:04:27	0:04:18	15	0.7	1.3						
21	NW	13:07:51	13:12:50	0:04:59	14	0.7	1.3						
20	SE	13:17:36	13:24:22	0:06:46	14	0.7	1.3						
19	NW	13:28:01	13:35:52	0:07:51	14	0.7	1.3						
18	SE	13:39:34	13:47:38	0:08:04	15	0.7	1.1						
17	NW	13:50:29	14:00:00	0:09:31	16	0.8	1.2						
16	SE	14:04:57	14:15:33	0:10:36	19	0.6	1						
15	NW	14:18:22	14:28:51	0:10:29	19	0.6	1.1						
14	SE	14:31:45	14:41:53	0:10:08	18	0.6	1.2						
13	NW	14:44:36	14:54:30	0:09:54	16	0.6	1.4						
12	SE	14:57:41	15:07:10	0:09:29	18	0.6	1.1						
11	NW	15:10:00	15:19:03	0:09:03	19	0.6	1.2						
10	SE	15:22:02	15:30:41	0:08:39	19	0.6	1.1						
9	NW	15:34:08	15:42:36	0:08:28	20	0.6	1.1						
8	SE	15:45:19	15:53:35	0:08:16	21	0.6	1						
7	NW	15:55:51	16:03:55	0:08:04	20	0.6	1.1						
6	SE	16:06:34	16:14:30	0:07:56	20	0.6	1.1						
5	NW	16:17:15	16:24:52	0:07:37	19	0.6	1.2						
4	SE	16:27:47	16:35:22	0:07:35	18	0.7	1.3						
3	NW	16:39:49	16:44:07	0:04:18	18	0.7	1.1						
1	SE	16:47:10	16:47:33	0:00:23	18	0.7	1.4						
2	SE	16:49:44	16:50:22	0:00:38	18	0.7	1.4						
↑ Times entered are Zulu / GMT ↑ Total Time On Line 2:57:09 Verify S-Turns After Mission Yes ☒ No ☐													
Additional Comments:										Drive #			
Static End :170410Z/1:04 (I)										#5			

WOOLPERT FLIGHT LOG SHEET #1													
Leica ALS-50/60			MM/DD/YYYY 3/20/2012		Day of Year 80		Mission Name / Job # Three Counties_GA/72278						
Operator Bart Galambos			Aircraft N404CP ☐		Sensor SH-46 ☐		Hobbs Start 4317.5		Local Start Time 8:14		Zulu Start Time 12:14		
Pilot Leo Rader			N475RC ☒		SH-77 ☐		Hobbs End 4322.3		Local End Time 1:01		Zulu End Time 17:01		
Passengers N/A			Using or Relying on CORS Yes ☐ No ☒		GPS Base #1		Operator Bart		PID ASI				
					GPS Base #2		Operator		PID				
Wind Dir/Speed 90@10		Visibility 10		Ceiling 0		Cloud Cover % Clear		Temp 19		Dew Point 15		Pressure 3017	
Haze/Fire/Cloud		Departing ICAO KVPC		Arriving ICAO KVPC									
Scan Angle (FOV) 44		Scan Frequency (Hz) 43.1		Pulse Rate (kHz) 123.6		Laser Power % 78		Gain Course/Up 6 Fine/Down 12		Mode Single ☐ 2 + 2 ☐ Multi ☒ 4 + 3 ☒			
Air Speed 130 Kts		AGL 5925 Ft		MSL 6500 Ft		Avg. Elev. 575 Ft		Waveform Mode @		Pre-Trigger Dist. NS			
Line #	Dir.	Line Start Time	Line End Time	Time On Line	SVs	HDOP	PDOP	Line Notes/Comments					
Test	n/a			n/a	n/a	n/a	n/a	GPS Began Logging At: 9:49 (L)					
⚡ Times entered are Zulu / GMT ⚡ Verify S-Turns Before Mission Yes ☒ No ☐													
21	S	14:11:55	14:24:00	0:12:05	15	0.7	1.2						
22	N	14:27:15	14:39:24	0:12:09	16	0.7	1.3						
24	S	14:42:46	14:47:18	0:04:32	16	0.7	1.5						
28	N	14:49:35	14:50:15	0:00:40	18	0.6	1.1						
26	N	14:56:18	15:00:30	0:04:12	18	0.6	1.1						
23	S	15:04:02	15:16:21	0:12:19	18	0.6	1.2						
25	N	15:20:00	15:24:04	0:04:04	19	0.6	1.2						
27	S	15:28:21	15:33:47	0:05:26	19	0.6	1.1						
29	N	15:37:54	15:44:00	0:06:06	20	0.6	1.1						
30	S	15:47:46	15:54:30	0:06:44	19	0.6	1.1						
31	N	15:58:01	16:05:04	0:07:03	20	0.6	1						
32	S	16:08:18	16:15:27	0:07:09	20	0.6	1.2						
33	N	16:19:51	16:27:26	0:07:35	18	0.7	1.4	Waypoint 22 Cloud					
34	S	16:30:49	16:38:52	0:08:03	18	0.7	1.4	Waypoint 9 29, 30 Cloud					
		0:00:00	0:00:00	0:00:00				Engine shutdown, on restart IPAS and					
		0:00:00	0:00:00	0:00:00				IMU errors.					
		0:00:00	0:00:00	0:00:00									
		0:00:00	0:00:00	0:00:00									
		0:00:00	0:00:00	0:00:00									
		0:00:00	0:00:00	0:00:00									
		0:00:00	0:00:00	0:00:00									
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		0:00:00	0:00:00	0:00:00									
		0:00:00	0:00:00	0:00:00									
↑ Times entered are Zulu / GMT ↑ Total Time On Line 1:38:07								Verify S-Turns After Mission Yes ☒ No ☐					
Additional Comments:										Drive #			
										#3			

SECTION 6

SECTION 6: VERTICAL ACCURACY ASSESMENT

The vertical accuracy statistics were calculated by comparison of the LiDAR bare earth points to the ground surveyed QA/QC points.

Table 6.1: Overall Vertical Accuracy Statistics Floyd, Polk, Paulding, Counties, Georgia

Average error	-0.045	feet
Minimum error	-0.380	feet
Maximum error	+0.310	feet
Average magnitude	0.169	feet
Root mean square	0.204	feet
Standard deviation	0.206	feet

Table 6.2: QA/QC Analysis, Floyd, Polk, Paulding, NAD83 (NSRS2007) State Plane Georgia West, Survey Feet, NAVD88 Geoid 09

Point ID	Easting (survey feet)	Northing (survey feet)	Elevation (survey feet)	Laser Elevation (survey feet)	Dz (survey feet)
1001	2036749.9	1578623.41	934.7	934.49	-0.21
1002	2027882.42	1487275.56	776.34	776.5	0.16
1003	2119938.02	1484560.33	746.93	747	0.07
1004	2122776.49	1433208.75	1123.73	1123.52	-0.21
1005	2062049.92	1397573.36	1277.28	1276.99	-0.29
1006	1988454.25	1439594.16	897.72	897.6	-0.12
1007	1978845.87	1519092.68	669.28	669.28	0

Point ID	Easting (survey feet)	Northing (survey feet)	Elevation (survey feet)	Laser Elevation (survey feet)	Dz (survey feet)
1008	1997864.23	1551014.95	615.55	615.5	-0.05
1009	2089298.64	1440077.06	885.26	885.44	0.18
1010	2035315.03	1456986.26	800.3	800.49	0.19
1011	2001112.62	1491958.17	858.21	858.52	0.31
1012	2066372.57	1484510.7	851.2	851.17	-0.03
1013	2030293.53	1533465.42	690.5	690.52	0.02
1014	2104793.75	1459330.38	962.77	962.46	-0.31
1015	2049688.91	1437029.96	1269.77	1269.39	-0.38

VERTICAL ACCURACY CONCLUSIONS

Tested 0.399 feet fundamental vertical accuracy at 95 percent confidence level in open terrain using $RMSE(z) \times 1.9600$

Based on the analysis of the LiDAR data, the accuracy of the data meets the task order requirements.

Approved By:			
Title	Name	Signature	Date
Associate LiDAR Specialist Certified Photogrammetrist #1281	Qian Xiao		September 26, 2012

Table 6.3: Overall Vertical Accuracy Statistics Oconee, County, Georgia

Average error	-0.011	feet
Minimum error	-0.250	feet
Maximum error	+0.338	feet
Average magnitude	0.149	feet
Root mean square	0.180	feet
Standard deviation	0.189	feet

Table 6.4: QA/QC Analysis, Oconee, NAD83 (NSRS2007) State Plane Georgia West, Survey Feet, NAVD88 Geoid 09 (O represents Oconee Control Points)

Point ID	Easting (survey feet)	Northing (survey feet)	Elevation (survey feet)	Laser Elevation (survey feet)	Dz (survey feet)
O1001	2458623.18	1420488.12	760.72	761.1	0.38
O1002	2484717.65	1438215.45	820.2	819.95	-0.25
O1003	2528348.44	1422132.63	642.78	642.57	-0.21
O1004	2564636.78	1401628.92	690.96	690.85	-0.11
O1006	2531791.24	1359500.05	675.04	675.25	0.21
O1007	2497262.79	1389759.59	625.31	625.52	0.21
O1008	2485369.29	1412018.34	829.5	829.4	-0.1
O1009	2513611.64	1412416.96	757.19	756.98	-0.21
O1010	2522129.36	1374556.94	752.06	752.37	0.31
O1011	2539650.94	1365053.69	693.04	693.11	0.07
O1012	2547914.94	1397813.05	666.6	666.69	0.09

Point ID	Easting (survey feet)	Northing (survey feet)	Elevation (survey feet)	Laser Elevation (survey feet)	Dz (survey feet)
O1013	2468609.97	1425658.77	820.97	820.92	-0.05
O1014	2483379.73	1426526.39	833.45	833.45	0
O1015	2502854.68	1428811.84	757.27	757.14	-0.13
O1016	2474723.97	1416909.83	796.05	796.05	0
O1017	2487444.09	1395677.51	738.65	738.65	0
O1018	2508640.17	1396351.42	715.03	715.3	0.27
O1019	2505162.29	1407969.27	797.98	798.07	0.09
O1020	2529710.36	1424636.56	643.78	643.75	-0.03
O1021	2518521.77	1420634.75	653.33	653.32	-0.01
O1050	2541029.73	1357947.69	664.85	665.09	0.24
O1051	2548107.77	1371788.92	590.56	590.39	-0.17
O1052	2556265.02	1371335.47	633.15	632.97	-0.18
O1053	2553664.12	1381751.56	642.55	642.43	-0.12
O1054	2550777.59	1401889.53	623.71	623.48	-0.23
O1055	2530338.11	1404318.58	735.37	735.4	0.03
O1056	2535040.79	1395852.35	742.59	742.56	-0.03
O1057	2535098.57	1381752.89	719.03	718.8	-0.23
O1058	2529054.88	1387462.1	766.26	766.49	0.23
O1059	2518459.06	1388602.2	778.39	778.22	-0.17
O1060	2514604.43	1392064.57	761.53	761.28	-0.25

VERTICAL ACCURACY CONCLUSIONS

Tested 0.352 feet fundamental vertical accuracy at 95 percent confidence level in open terrain using $RMSE(z) \times 1.9600$

Based on the analysis of the LiDAR data, the accuracy of the data meets the task order requirements.

Approved By:			
Title	Name	Signature	Date
Associate LiDAR Specialist Certified Photogrammetrist #1281	Qian Xiao		September 26, 2012

Table 6.5: Overall Vertical Accuracy Statistics Floyd, Polk, Paulding, Oconee Counties, Georgia

Average error	-0.022	feet
Minimum error	-0.38	feet
Maximum error	+0.38	feet
Average magnitude	0.155	feet
Root mean square	0.188	feet
Standard deviation	0.085	feet

Table 6.6: QA/QC Analysis, Floyd, Polk, Paulding, Oconee, NAD83 (NSRS2007) State Plane Georgia West, Survey Feet, NAVD88 Geoid 09 (O represents Oconee Control Points)

Point ID	Easting (survey feet)	Northing (survey feet)	Elevation (survey feet)	Laser Elevation (survey feet)	Dz (survey feet)
1001	2036749.9	1578623.41	934.7	934.49	-0.21
1002	2027882.42	1487275.56	776.34	776.5	0.16
1003	2119938.02	1484560.33	746.93	747	0.07
1004	2122776.49	1433208.75	1123.73	1123.52	-0.21
1005	2062049.92	1397573.36	1277.28	1276.99	-0.29
1006	1988454.25	1439594.16	897.72	897.6	-0.12
1007	1978845.87	1519092.68	669.28	669.28	0
1008	1997864.23	1551014.95	615.55	615.5	-0.05
1009	2089298.64	1440077.06	885.26	885.44	0.18
1010	2035315.03	1456986.26	800.3	800.49	0.19
1011	2001112.62	1491958.17	858.21	858.52	0.31
1012	2066372.57	1484510.7	851.2	851.17	-0.03
1013	2030293.53	1533465.42	690.5	690.52	0.02
1014	2104793.75	1459330.38	962.77	962.46	-0.31
1015	2049688.91	1437029.96	1269.77	1269.39	-0.38
O1001	2458623.18	1420488.12	760.72	761.1	0.38
O1002	2484717.65	1438215.45	820.2	819.95	-0.25
O1003	2528348.44	1422132.63	642.78	642.57	-0.21
O1004	2564636.78	1401628.92	690.96	690.85	-0.11
O1005	2559082.81	1359666.84	469.2	outside	*
O1006	2531791.24	1359500.05	675.04	675.25	0.21
O1007	2497262.79	1389759.59	625.31	625.52	0.21

Point ID	Easting (survey feet)	Northing (survey feet)	Elevation (survey feet)	Laser Elevation (survey feet)	Dz (survey feet)
O1008	2485369.29	1412018.34	829.5	829.4	-0.1
O1009	2513611.64	1412416.96	757.19	756.98	-0.21
O1010	2522129.36	1374556.94	752.06	752.37	0.31
O1011	2539650.94	1365053.69	693.04	693.11	0.07
O1012	2547914.94	1397813.05	666.6	666.69	0.09
O1013	2468609.97	1425658.77	820.97	820.92	-0.05
O1014	2483379.73	1426526.39	833.45	833.45	0
O1015	2502854.68	1428811.84	757.27	757.14	-0.13
O1016	2474723.97	1416909.83	796.05	796.05	0
O1017	2487444.09	1395677.51	738.65	738.65	0
O1018	2508640.17	1396351.42	715.03	715.3	0.27
O1019	2505162.29	1407969.27	797.98	798.07	0.09
O1020	2529710.36	1424636.56	643.78	643.75	-0.03
O1021	2518521.77	1420634.75	653.33	653.32	-0.01
O1050	2541029.73	1357947.69	664.85	665.09	0.24
O1051	2548107.77	1371788.92	590.56	590.39	-0.17
O1052	2556265.02	1371335.47	633.15	632.97	-0.18
O1053	2553664.12	1381751.56	642.55	642.43	-0.12
O1054	2550777.59	1401889.53	623.71	623.48	-0.23
O1055	2530338.11	1404318.58	735.37	735.4	0.03
O1056	2535040.79	1395852.35	742.59	742.56	-0.03
O1057	2535098.57	1381752.89	719.03	718.8	-0.23
O1058	2529054.88	1387462.1	766.26	766.49	0.23

Point ID	Easting (survey feet)	Northing (survey feet)	Elevation (survey feet)	Laser Elevation (survey feet)	Dz (survey feet)
O1059	2518459.06	1388602.2	778.39	778.22	-0.17
O1060	2514604.43	1392064.57	761.53	761.28	-0.25

VERTICAL ACCURACY CONCLUSIONS

Tested 0.368 feet fundamental vertical accuracy at 95 percent confidence level in open terrain using $RMSE(z) \times 1.9600$

Based on the analysis of the LiDAR data, the accuracy of the data meets the task order requirements.

Approved By:			
Title	Name	Signature	Date
Associate LiDAR Specialist Certified Photogrammetrist #1281	Qian Xiao		September 26, 2012



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