NOAA OCM Lidar for Lowndes County, GA 2015

NOAA/Charleston, SC

Table of Contents

List of Figures

List of Tables

Section 1: Overview

Project Name: NOAA OCM Lidar for Lowndes County, GA
Woolpert Project: #75271

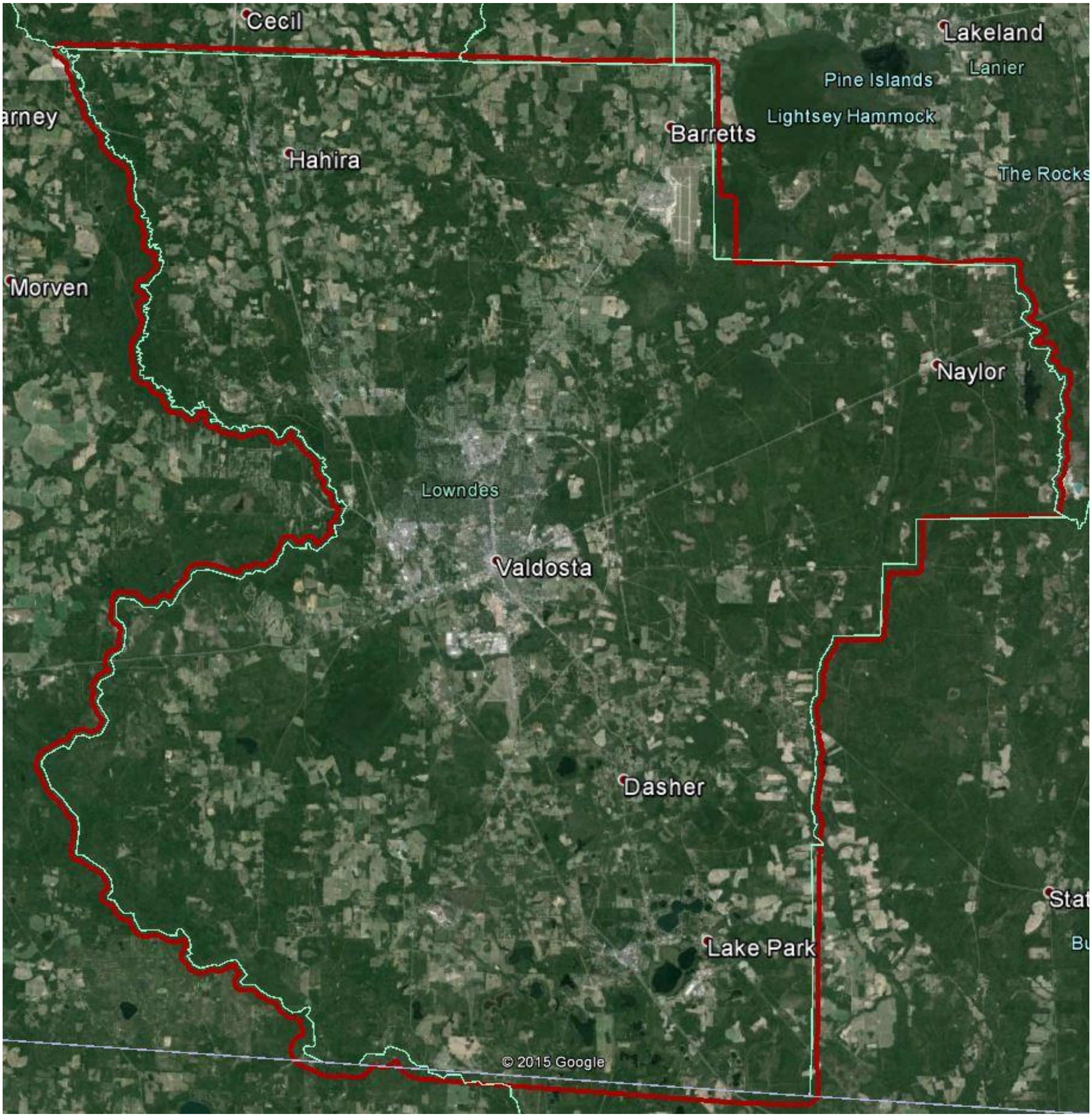
This report contains a comprehensive outline of the NOAA OCM Lidar for Lowndes County, GA Lidar task order. This task is issued under NOAA Contract Number: EA133C-11-CQ-0010 and Requisition/Reference Number: NCNA0000-15-00801. This task order requires lidar data to be acquired over Lowndes County, Georgia. The total area of the Lowndes County, Georgia Lidar AOI is approximately 500 square miles. The lidar was collected and processed to meet a maximum Nominal Post Spacing (NPS) of 0.7meter. The NPS assessment is made against single swath, first return data located within the geometrically usable center portion (typically ~90%) of each swath.

The data was collected using an Optech Gemini lidar sensor in Multi-Pulse mode. The Gemini sensor collects up to four returns per pulse, as well as 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:

Table 1.1: Lowndes County, GA Acquisition Parameters	
Post Spacing	2.3 ft / 0.7 m
AGL (Above Ground Level) average flying height	6,500 ft / 1,981 m
MSL (Mean Sea Level) average flying height	6,550 ft / 1,996 m
Average Ground Speed:	150 knots / 173 mph
Field of View (full)	40 degrees
Pulse Rate	272 kHz
Scan Rate	41.0 Hz
Side Lap	20%

The lidar data was processed and projected in State Plane Georgia West, North American Datum of 1983 (2011) in units of survey feet. The vertical datum used for the task order was referenced to NAVD 1988, GEOID12A, in units of survey feet.

Figure 1.1: Lidar Task Order AOI



Section 2: Acquisition

The existing lidar data was acquired with an Optech Gemini Multiple Pulses in Air (MPiA) Lidar Sensor System, on board a fixed-wing Cessna aircraft. The Optech Gemini lidar system, developed by Optech of Canada, includes the simultaneous first, intermediate and last pulse data capture module. The system software is operated by ALTM-NAV aboard the aircraft. Keystone Aerial Surveys Inc. of Philadelphia, PA was contracted to acquire the Lidar data.

The Optech Gemini Multiple Pulses in Air (MPiA) Lidar System has the following specifications:

Table 2.1: Optech Gemini Lidar System Specifications	
Operating Altitude	200 – 3,500 meters
Scan Angle	0 to 75° (variable)
Swath Width	0 to 1.5 X altitude (variable)
Scan Frequency	0 – 200 Hz (variable based on scan angle)
Maximum Pulse Rate	500 kHz (Effective)
Range Resolution	Better than 1 cm
Elevation Accuracy	7 - 16 cm single shot (one standard deviation)
Horizontal Accuracy	5 – 38 cm (one standard deviation)
Number of Returns per Pulse	7 (infinite)
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

Prior to mobilizing to the project site, Woolpert flight crews coordinated with the necessary Air Traffic Control personnel to ensure airspace access.

Woolpert survey crews were onsite, operating a Global Navigation Satellite System (GNSS) Base Station for the airborne GPS support.

The lidar data was collected in five (5) separate missions, flown as close together as the weather permitted, to ensure consistent ground conditions across the project area.

An initial quality control process was performed immediately on the lidar data to review the data coverage, airborne GPS data, and trajectory solution. Any gaps found in the lidar data were relayed to the flight crew, and the area was re-flown.

Figure 2.1: Lidar Flight Layout, NOAA OCM Lidar for Lowndes County, GA

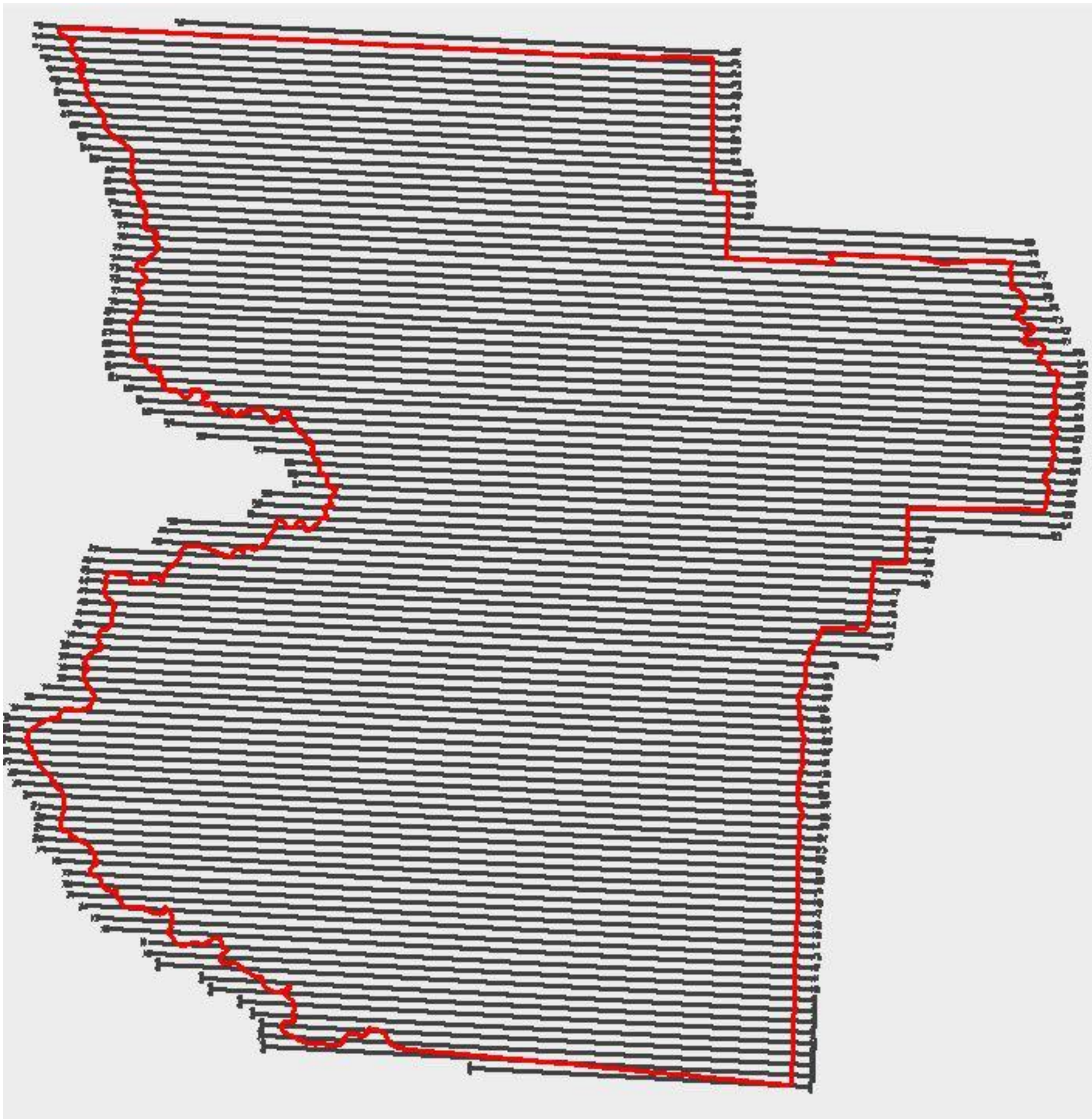


Table 2.2: Airborne Lidar Acquisition Flight Summary

Date of Mission	Lines Flown	Mission Time (UTC) Wheels Up/ Wheels Down	Mission Time (Local = EST) Wheels Up/ Wheels Down
March 16, 2015 – OP108	1-29	19:50 – 01:37	03:50PM - 09:37PM
March 17, 2015 – OP108	52-75	16:21 – 22:07	12:21PM - 06:07 PM
March 18, 2015 – OP108-A	29-35, 76-96	07:24 - 13:04	03:24AM - 09:04AM
March 18, 2015 – OP108-B	36-51	14:19 -17:56	10:19AM – 01:56PM
March 27, 2015 – OP108	10017,10020,10027,10060, 10062,10068	23:25 – 01:30	07:25PM – 09:30PM

Section 3: Lidar Data Processing

Applications and Work Flow Overview

1. Resolved kinematic corrections for three subsystems: inertial measurement unit (IMU), sensor orientation information and airborne GPS data. Developed a blending post-processed aircraft position with attitude data using Kalman filtering technology or the smoothed best estimate trajectory (SBET).
   Software: POSPac Software v. 5.3, IPAS Pro v.1.35.
2. Calculated laser point position by associating the SBET position to each laser point return time, scan angle, intensity, etc. Created raw laser point cloud data for the entire survey in LAS format. Automated line-to-line calibrations were then performed for system attitude parameters (pitch, roll, heading), mirror flex (scale) and GPS/IMU drift.
   Software: Dashmap Software v.2.75 build #25, Proprietary Software, TerraMatch v. 14.01.
3. Imported processed 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.
   Software: TerraScan v.14.011.
4. The LAS files were evaluated through a series of manual QA/QC steps to eliminate remaining artifacts from the ground class.
   Software: TerraScan v.14.011.

Global Navigation Satellite System (GNSS) – Inertial Measurement Unit (IMU) Trajectory Processing

Equipment

Flight navigation during the lidar data acquisition mission is performed using IGI CCNS (Computer Controlled Navigation System). The pilots are 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/or 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 Global Navigation Satellite System (GNSS) receivers collecting at 2 Hz.

All Woolpert aerial sensors are equipped with a Litton LN200 series Inertial Measurement Unit (IMU) operating at 200 Hz.

A base-station unit was mobilized for each acquisition missionand was operated by a member of the Woolpert acquisition team. Each base-station setup consisted of one Trimble 4000 – 5000 series dual frequency receiver, one Trimble Compact L1/L2 dual frequency antenna, one 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.

The GNSS base station operated during the Lidar acquisition missions is listed below:

Table 3.1: GNSS Base Station

Station (Name)	Latitude (DMS)	Longitude (DMS)	Ellipsoid Height (L1 Phase center) (Meters)
KVLD_Arpt_Base	30°47' 03.41489"	-83°16' 19.25889"	32.264

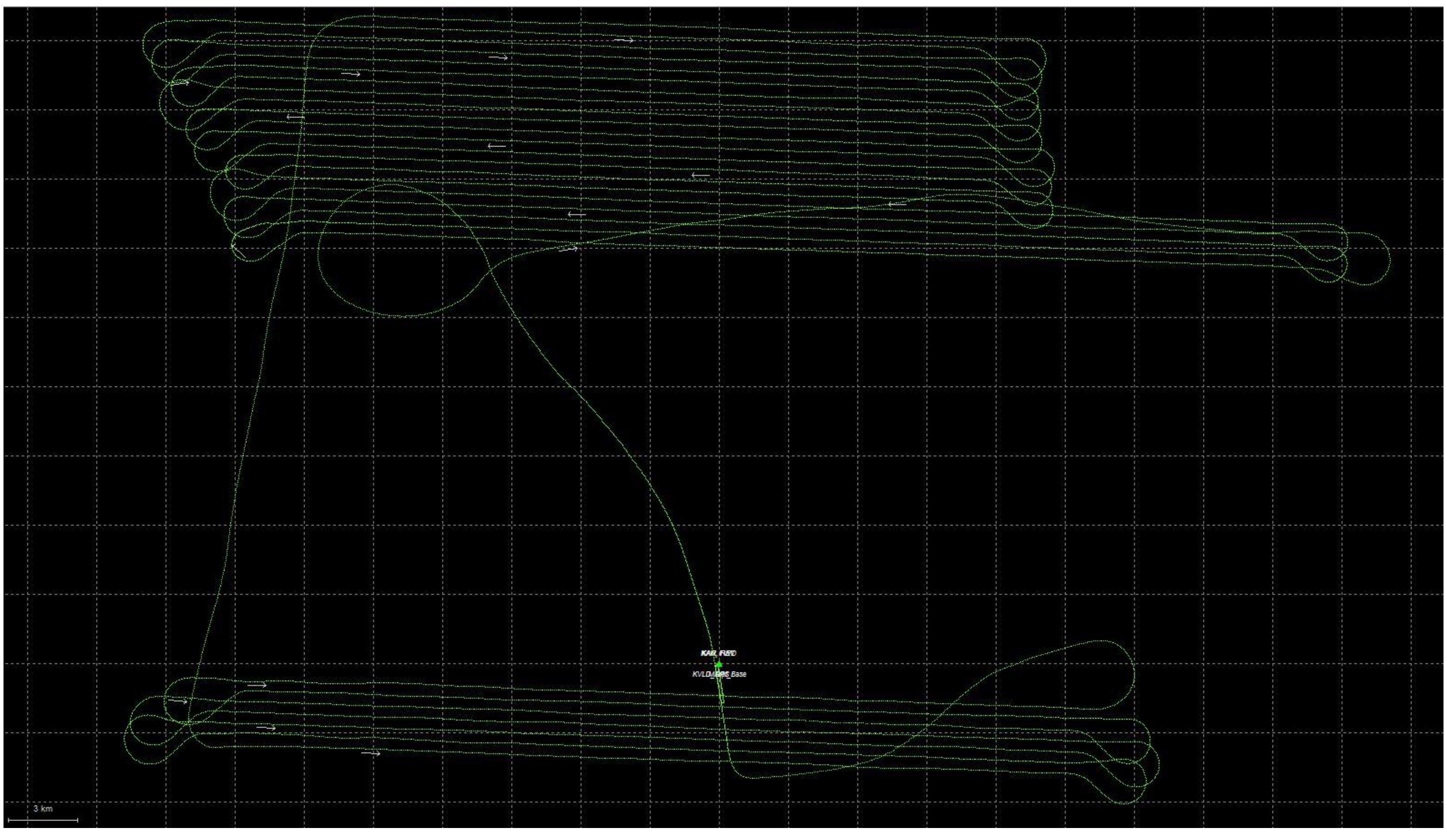
Data Processing

All airborne GNSS and IMU data was post-processed and quality controlled using Applanix MMS software. GNSS data was processed at a 1 and 2 Hz data capture rate and the IMU data was processed at 200 Hz.

Trajectory Quality

The GNSS Trajectory, along with high quality IMU data are key factors in determining the overall positional accuracy of the final sensor data. Within the trajectory processing, there are many factors that affect the overall quality, but the most indicative are the Combined Separation, the Estimated Positional Accuracy, and the Positional Dilution of Precision (PDOP).

Figure 3.1: Trajectory, Day 07715_OP108_A

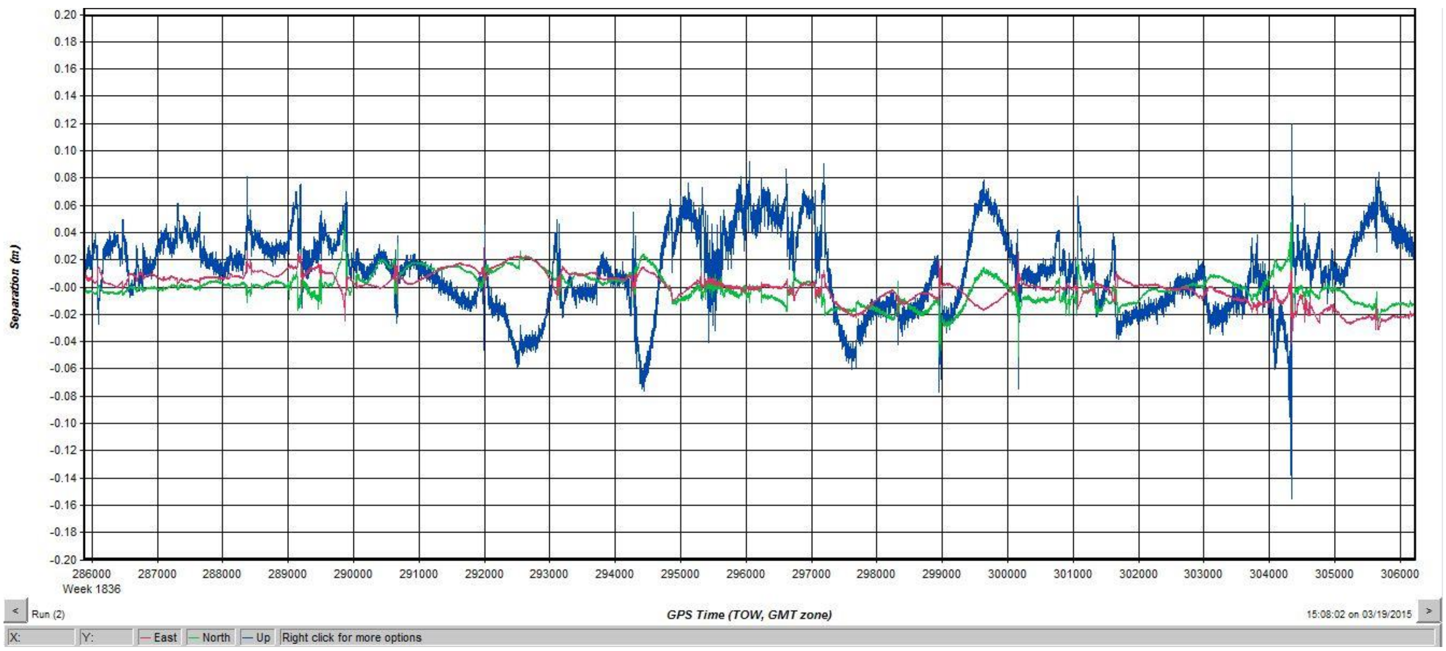


Combined Separation

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 processed in both directions to remove the combined directional anomalies. In general, when these two solutions match closely, an optimally accurate reliable solution is achieved.

Woolpert's goal is to maintain a Combined Separation Difference of less than ten (10) centimeters. In most cases we achieve results below this threshold.

Figure 3.2: Combined Separation, Day 07715_OP108_A

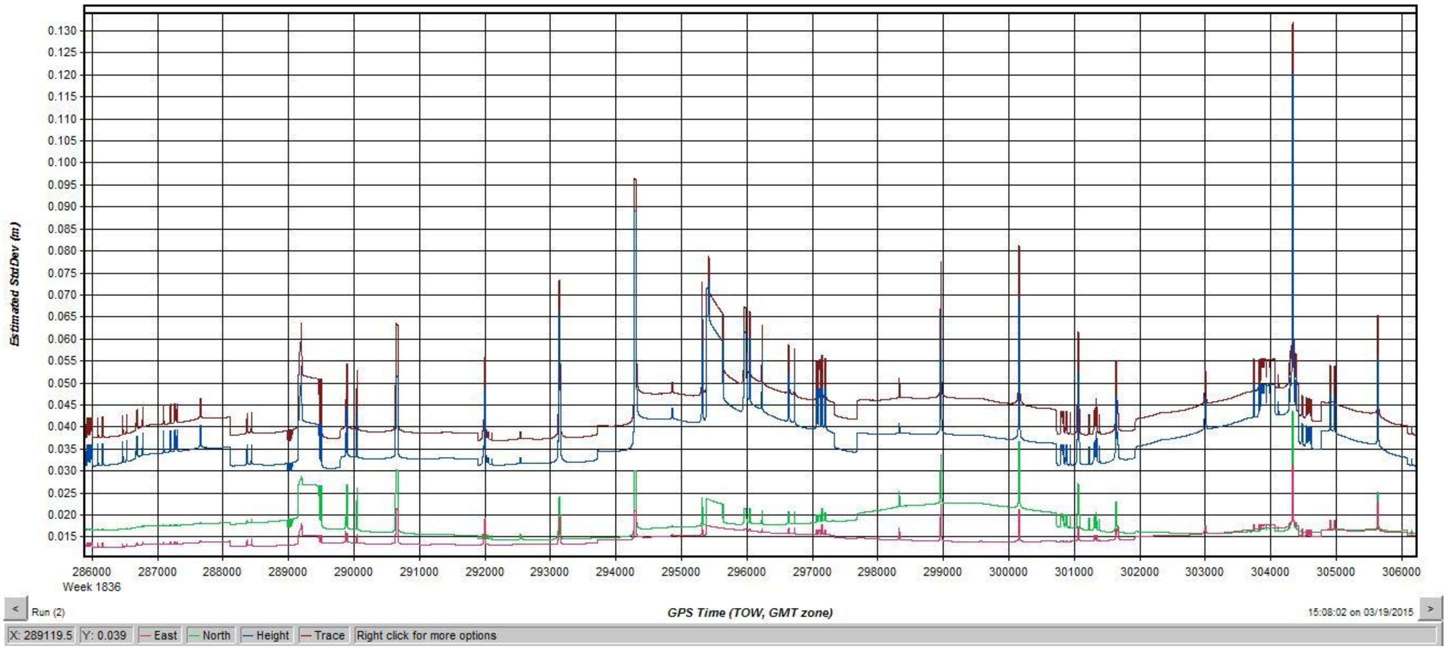


Estimated Positional Accuracy

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) centimeters, often achieving results well below this threshold.

Figure 3.3: Estimated Positional Accuracy, Day 07715_OP108_A

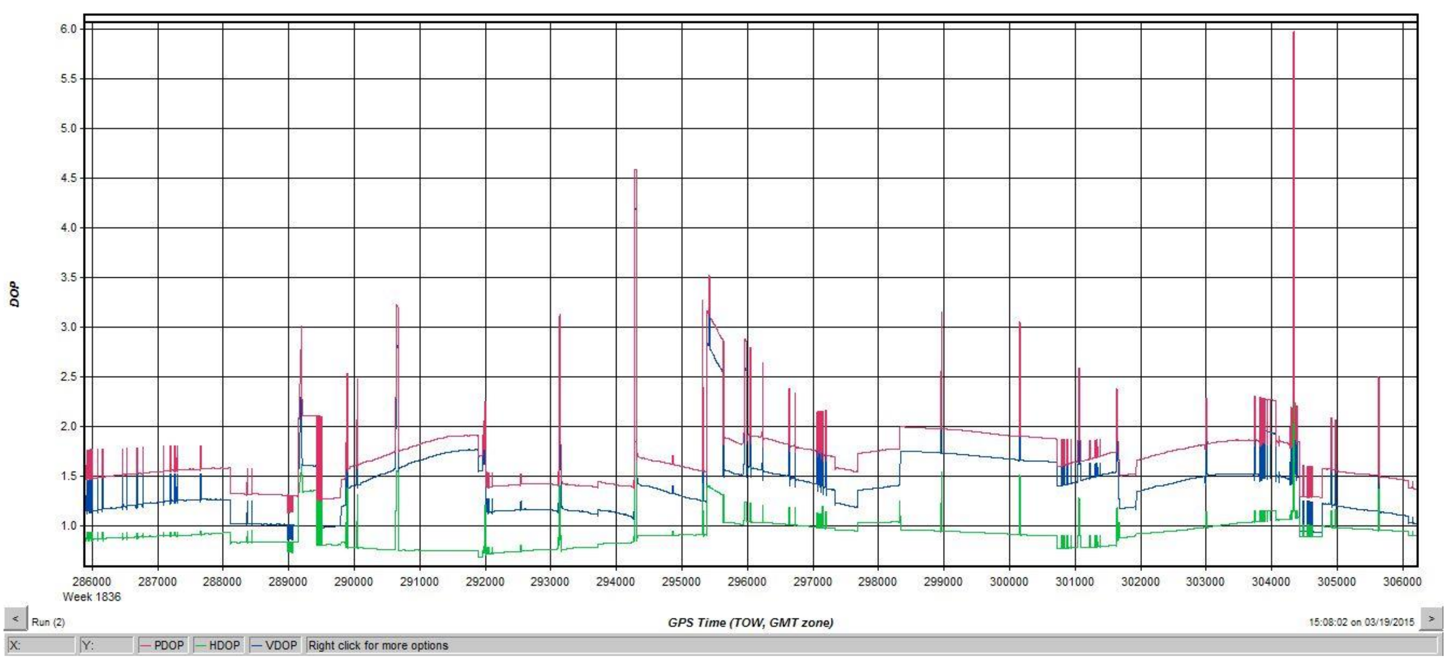


PDOP

The PDOP measures the precision of the GPS solution in regards to the geometry of the satellites acquired and used for the solution.

Woolpert's goal is to maintain an average PDOP value below 3.0. Brief periods of PDOP over 3.0 are acceptable due to the calibration and control process if other metrics are within specification.

Figure 3.4: PDOP, Day 07715_OP108_A



Lidar Data Processing

When the sensor calibration, data acquisition, and GPS processing phases were complete, the formal data reduction processes by Woolpert lidar specialists included:

- Processed individual flight lines 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.
- Calibrated LAS files were imported into the task order tiles and initially filtered to create a ground and non-ground class. Then additional classes were filtered as necessary to meet client specified classes.
- Once all project data was imported and classified, survey ground control data was imported and calculated for an accuracy assessment. As a QC measure, Woolpert has developed a routine to generate accuracy statistical reports by comparisons against the TIN and the DEM using surveyed ground control of higher accuracy. The lidar is adjusted accordingly to meet or exceed the vertical accuracy requirements.
- The lidar tiles were reviewed using a series of proprietary QA/QC procedures to ensure it fulfills the task order requirements. A portion of this requires a manual step to ensure anomalies have been removed from the ground class.
- The lidar LAS files are classified into the Default (Class 1), Ground (Class 2), Noise (Class 7), Water (Class 9), Ignored Ground (Class 10), Overlap default (Class 17), and Overlap Ground (Class 18) classifications.
- FGDC Compliant metadata was developed for the task order in .xml format for the final data products.
- The horizontal datum used for the task order was referenced to StatePlane Georgia West, North American Datum of 1983 (2011). The vertical datum used for the task order was referenced to NAVD 1988, US Survey Feet, GEOID12A. Coordinate positions were specified in units of US Survey Feet.

Section 4: Hydrologic Flattening

HYDROLOGIC FLATTENING OF LIDAR DEM DATA

NOAA OCM Lidar for Lowndes County, GA Lidar processing task order required the compilation of breaklines defining water bodies and rivers. The breaklines were used to perform the hydrologic flattening of water bodies, and gradient hydrologic flattening of double line streams and rivers. Lakes, reservoirs and ponds, at a minimum size of 2-acre or greater, were compiled as closed polygons. The closed water bodies were collected at a constant elevation. Rivers and streams, at a nominal minimum width of 30 meters (100 feet), were compiled in the direction of flow with both sides of the stream maintaining an equal gradient elevation.

LIDAR DATA REVIEW AND PROCESSING

Woolpert utilized the following steps to hydrologically flatten the water bodies and for gradient hydrologic flattening of the double line streams within the existing lidar data.

1. Woolpert used the newly acquired lidar data to manually draw the hydrologic features in a 2D environment using the lidar intensity and bare earth surface. Open Source imagery was used as reference when necessary.
2. Woolpert utilizes an integrated software approach to combine the lidar data and 2D breaklines. This process “drapes” the 2D breaklines onto the 3D lidar surface model to assign an elevation. A monotonic process is performed to ensure the streams are consistently flowing in a gradient manner. A secondary step within the program verifies an equally matching elevation of both stream edges. The breaklines that characterize the closed water bodies are draped onto the 3D lidar surface and assigned a constant elevation at or just below ground elevation.
3. The lakes, reservoirs and ponds, at a minimum size of 2-acre or greater and streams at a minimum size of 30 meters (100 feet) nominal width, were compiled to meet task order requirements. **Figure 4.1** illustrates an example of 30 meters (100 feet) nominal streams identified and defined with hydrologic breaklines. The breaklines defining rivers and streams, at a nominal minimum width of 30 meters (100 feet), were draped with both sides of the stream maintaining an equal gradient elevation.
4. All ground points were reclassified from inside the hydrologic feature polygons to water, class nine (9).
5. All ground points were reclassified from within a buffer along the hydrologic feature breaklines to buffered ground, class ten (10).
6. The lidar ground points and hydrologic feature breaklines were used to generate a new digital elevation model (DEM).

Figure 4.1: Example Hydrologic Breaklines

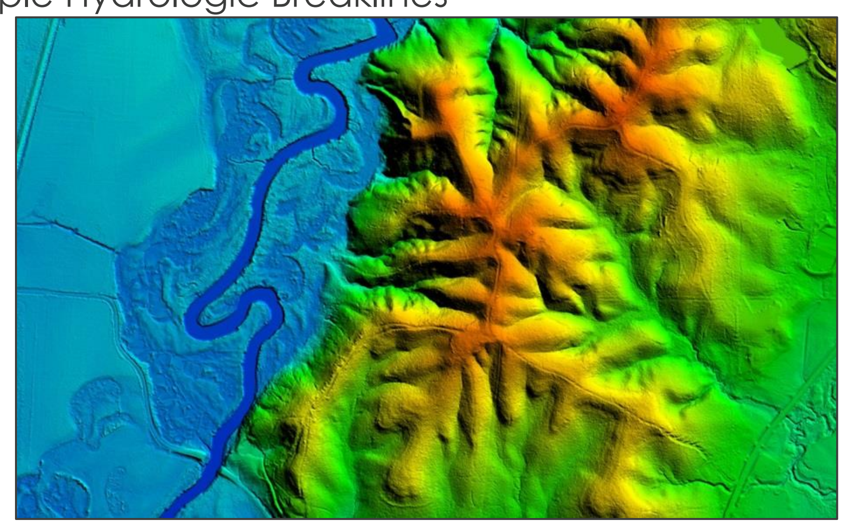


Figure 4.2 reflects a DEM generated from original lidar bare earth point data prior to the hydrologic flattening process. Note the "tinning" across the lake surface.

Figure 4.3 reflects a DEM generated from lidar with breaklines compiled to define the hydrologic features. This figure illustrates the results of adding the breaklines to hydrologically flatten the DEM data. Note the smooth appearance of the lake surface in the DEM.

Figure 4.2

Figure 4.3

Terrascan was used to add the hydrologic breakline vertices and export the lattice models. The hydrologically flattened DEM data was provided to NOAA in ERDAS .IMG format.

The hydrologic breaklines compiled as part of the flattening process were provided to NOAA as an ESRI Geodatabase. The breaklines defining the water bodies greater than 2-acre and for the gradient flattening of all rivers and streams at a nominal minimum width of 30 meters (100 feet) were provided as a Polygon-Z feature class.

DATA QA/QC

Initial QA/QC for this task order was performed in Global Mapper v15, by reviewing the grids and hydrologic breakline features. Additionally, ESRI software and proprietary methods were used to review the overall connectivity of the hydrologic breaklines.

Edits and corrections were addressed individually by tile. If a water body breakline needed to be adjusted to improve the flattening of the DEM data, the area was cross referenced by tile number, corrected accordingly, a new DEM file was regenerated and reviewed.

Section 5: ACCURACY ASSESSMENT

Accuracy Assessment

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

Table 5.1: Overall Vertical Accuracy Statistics,		
Average error	0.184	feet
Minimum error	-0.081	feet
Maximum error	0.420	feet
Average magnitude	0.192	feet
Root mean square	0.222	feet
Standard deviation	0.127	feet

Table 5.2: Raw Swath Quality Check Point Analysis FVA

Point ID	Easting (feet)	Northing (feet)	Laser Elevation (feet)	Dz (feet)
2001	2599379.343	372294.56	229.99	0.066
2002	2526033.495	371622.805	240.47	0.201
2003	2570549.864	348467.885	170.53	0.081
2004	2637851.76	332321.259	192.1	0.054
2005	2532464.474	343020.642	235.71	0.262
2006	2624292.353	302855.605	171.06	0.16
2007	2579480.532	289912.439	185.51	0.06
2008	2528547.208	281081.541	179.82	0.267
2009	2563221.435	270631.576	214.88	0.285
2010	2589811.51	259552.214	178.52	0.353
2011	2609104.811	233596.773	153.73	0.064
2012	2591665.067	249270.551	171.08	0.245
2013	2563740.602	241163.242	118.03	0.189
2014	2548421.631	251010.742	160.21	0.279
2015	2529087.642	267528.409	157.84	0.235
2016	2618620.176	281213.73	153.9	0.405
2017	2540873.541	299623.662	149.1	0.18
2018	2604818.346	314743.984	208.22	0.082
2019	2588409.464	319619.4	218.82	0.152
2020	2554313.084	347536.518	206.74	-0.012
2021	2574178.026	368571.52	207.13	0.254
2022	2581360.053	340774.773	203.92	0.292
2023	2597725.719	333908.264	217.52	0.42
2024	2559806.431	328243.027	154.24	0.116
2025	2637052.654	342062.119	198.22	-0.081

VERTICAL ACCURACY CONCLUSIONS

Raw LAS Swath Fundamental Vertical Accuracy (FVA) Tested 0.435 feet fundamental vertical accuracy at a 95 percent confidence level, derived according to NSSDA, in open terrain using (RMSEz) x 1.96000 as defined by the National Standards for Spatial Data Accuracy (NSSDA); assessed and reported using National Digital Elevation Program (NDEP)/ASPRS Guidelines and tested against the TIN using all points.

LAS Swath Fundamental Vertical Accuracy (FVA) Tested 0.376 feet fundamental vertical accuracy at a 95 percent confidence level, derived according to NSSDA, in open terrain using (RMSEz) x 1.96000 as defined by the National Standards for Spatial Data Accuracy (NSSDA); assessed and reported using National Digital Elevation Program (NDEP)/ASPRS Guidelines and tested against the TIN using ground points.

Bare-Earth DEM Fundamental Vertical Accuracy (FVA) Tested 0.384 feet fundamental vertical accuracy at a 95 percent confidence level, derived according to NSSDA, in open terrain using (RMSEz) x 1.96000 as defined by the National Standards for Spatial Data Accuracy (NSSDA); assessed and reported using National Digital Elevation Program (NDEP)/ASPRS Guidelines and tested against the DEM.

SUPPLEMENTAL VERTICAL ACCURACY ASSESSMENTS

Table 5.3: Urban Quality Check Point Analysis SVA

Point ID	Easting (feet)	Northing (feet)	DEM Elevation (feet)	Dz (feet)
3001	2599363.143	365329.527	245.390	-0.082
3002	2550310.416	362963.471	215.450	-0.139
3003	2589570.216	350819.888	250.741	0.07
3004	2637738.108	332374.904	192.900	-0.024
3005	2569370.059	322381.985	232.010	0.018
3006	2588195.843	300943.903	186.970	0.131
3007	2579577.333	289877.619	187.450	-0.022
3008	2530105.355	282646.643	182.530	0.184
3009	2556118.709	295134.935	216.050	-0.024
3010	2597469.913	257293.924	179.080	-0.152
3011	2604211.017	235783.615	165.480	0.406
3012	2592721.997	248720.177	168.040	0.082
3013	2562625.712	253009.134	181.040	0.014
3014	2548476.028	250966.262	162.430	0.073
3015	2529130.602	267554.882	158.690	0.083
3016	2618372.692	282272.832	159.160	0.351
3017	2540027.498	299681.943	149.920	0.004
3018	2583971.054	307451.806	210.450	0.079
3019	2588522.701	319686.230	219.120	-0.468
3020	2554382.718	347528.563	207.000	0.131
3021	2574456.783	366707.911	196.650	0.062
3022	2581328.907	340700.868	205.820	-0.02
3023	2596136.634	333500.125	215.190	0.069
3024	2559818.181	328160.107	155.400	-0.024
3025	2636921.016	342119.874	199.290	-0.195

VERTICAL ACCURACY CONCLUSIONS

Urban Land Cover Classification Supplemental Vertical Accuracy (SVA) Tested 0.395 feet supplemental vertical accuracy at the 95th percentile in the Urban supplemental class reported using National Digital Elevation Program (NDEP)/ASPRS Guidelines and tested against the DEM. Urban Errors larger than 95th percentile include:

- Point 3011, Easting 2604211.017, Northing 235783.615, Z-Error 0.406 feet
- Point 3019, Easting 2588522.701, Northing 319686.230, Z-Error 0.468 feet

Table 5.4: Tall Weeds and Crops Quality Check Point Analysis SVA

Point ID	Easting (feet)	Northing (feet)	DEM Elevation (feet)	Dz (feet)
4001	2598543.163	366938.082	240.800	0.436
4002	2525990.673	371655.042	241.810	-0.065
4003	2570456.187	348501.119	172.680	0.253
4004	2644432.076	336352.790	194.430	0.72
4005	2532460.988	342973.317	236.080	0.488
4006	2624038.131	302770.679	171.320	0.376
4007	2581190.025	288382.195	194.620	0.468
4008	2530306.396	281037.720	189.260	0.386
4009	2564742.448	270637.107	210.980	0.189
4010	2589350.875	259628.701	180.660	0.679
4011	2605289.986	236561.023	153.080	0.431
4012	2591671.838	249298.635	171.660	0.538
4013	2562390.222	252825.160	171.130	0.713
4014	2553072.287	252588.184	162.980	0.638
4015	2529310.164	267498.998	160.570	0.263
4016	2618557.991	281608.603	158.680	0.548
4017	2540878.886	299702.926	146.800	0.353
4018	2583988.606	306889.991	203.220	0.469
4019	2588380.865	319766.562	218.090	-0.029
4020	2554247.504	347682.533	211.790	0.172
4021	2574149.405	368372.794	211.960	0.29
4022	2581410.828	340735.791	203.970	0.404
4023	2597585.741	333747.270	216.590	0.198
4024	2559702.288	327989.720	156.080	0.35
4025	2636797.318	342221.285	197.200	0.01

VERTICAL ACCURACY CONCLUSIONS

Tall Weeds and Crops Land Cover Classification Supplemental Vertical Accuracy (SVA) Tested 0.706 feet supplemental vertical accuracy at the 95th percentile in the Tall Weeds and Crops supplemental class reported using National Digital Elevation Program (NDEP)/ASPRS Guidelines and tested against the DEM. Tall Weeds and Crops Errors larger than 95th percentile include:

- Point 4004, Easting 2644432.076, Northing 336352.79, Z-Error 0.720 feet
- Point 4013, Easting 2562390.222, Northing 252825.16, Z-Error 0.713 feet

Table 5.5: Brushlands and Trees Quality Check Point Analysis SVA

Point ID	Easting (feet)	Northing (feet)	DEM Elevation (feet)	Dz (feet)
5001	2599511.313	372288.342	229.940	0.891
5002	2527626.373	372883.335	222.100	0.211
5003	2570959.458	345053.039	152.730	0.524
5004	2643151.034	344970.786	196.850	0.374
5005	2543805.444	346633.273	185.850	1.118
5006	2624273.619	302699.754	171.540	0.959
5007	2584787.412	288435.652	193.920	0.133
5008	2531048.936	282795.121	158.260	0.954
5009	2553738.580	270319.831	183.890	0.956
5011	2608535.953	234316.010	153.890	0.893
5012	2591605.068	249208.137	171.340	0.968
5013	2562545.789	254150.728	203.890	0.612
5014	2541623.718	249772.068	98.740	0.774
5015	2529259.782	267717.629	158.790	0.572
5016	2608244.905	273981.671	160.700	0.305
5017	2540035.162	299754.779	151.570	0.772
5018	2604844.953	314819.308	208.700	0.571
5019	2588350.516	319786.047	217.860	0.144
5020	2556015.900	348625.267	203.500	0.135
5021	2574810.105	367980.034	216.820	0.463
5022	2576085.549	336600.971	173.300	0.259
5023	2597666.862	333813.106	216.110	1.211
5024	2558466.442	326881.765	154.150	1.063
5025	2636874.143	342072.975	197.250	0.377

VERTICAL ACCURACY CONCLUSIONS

Brushlands and Trees Land Cover Classification Supplemental Vertical Accuracy (SVA) Tested 1.110 feet supplemental vertical accuracy at the 95th percentile in the Brushlands and Trees Land supplemental class reported using National Digital Elevation Program (NDEP)/ASPRS Guidelines and tested against the DEM. Brushlands and Trees Land Errors at the 95th percentile include:

- Point 5005, Easting 2543805.444, Northing 346633.273, Z-Error 1.118 feet
- Point 5023, Easting 2597666.862, Northing 333813.106, Z-Error 1.211 feet

Table 5.6: Forested and Fully Grown Quality Check Point Analysis SVA				
Point ID	**Easting (feet)**	**Northing (feet)**	**DEM Elevation (feet)**	**Dz (feet)**
6001	2602823.979	374319.064	224.960	0.176
6002	2525840.479	372019.720	238.560	-0.26
6003	2570582.857	348042.484	166.950	0.258
6004	2638074.279	331856.159	190.270	-0.486
6005	2532433.781	342943.045	235.590	0.002
6006	2624081.193	302888.662	171.400	-0.1
6007	2585969.219	288226.241	194.290	0.332
6008	2528470.866	281096.395	179.110	0.091
6009	2563275.357	270705.296	215.000	0.369
6010	2588781.293	259661.441	179.970	1.284
6011	2605249.089	236737.318	153.210	0.231
6012	2591382.051	248780.861	166.270	0.395
6013	2563055.762	254355.386	206.120	0.166
6014	2541819.540	252988.838	157.280	0.307
6015	2529062.500	267626.962	159.620	0.454
6016	2618642.360	281129.825	153.160	0.195
6017	2540857.266	299528.080	151.090	0.349
6018	2613628.629	320542.244	202.080	-0.042
6019	2588535.633	319732.465	217.230	0.021
6020	2554467.876	347718.401	209.880	0.419
6021	2574184.055	368429.761	209.530	0.328
6022	2581341.464	340612.075	207.340	-0.103
6023	2597714.448	334099.923	216.620	0.199
6024	2558599.824	326853.436	152.030	-0.163
6025	2636981.408	342282.455	197.510	-0.05
6002A	2527560.506	372988.717	222.440	-0.111
6019A	2584298.401	317710.188	197.140	-0.388
6020A	2554028.142	347544.733	206.980	0.071

VERTICAL ACCURACY CONCLUSIONS

Forested and Fully Grown Land Cover Classification Supplemental Vertical Accuracy (SVA) Tested 0.475 feet supplemental vertical accuracy at the 95th percentile in the Forested and Fully Grown supplemental class reported using National Digital Elevation Program (NDEP)/ASPRS Guidelines and tested against the DEM. Forested and Fully Grown Errors at the 95th percentile include:

- Point 6004, Easting 2638074.279, Northing 331856.159, Z-Error 0.486 feet
- Point 6010, Easting 2588781.293, Northing 259661.441, Z-Error 1.284 feet

Table 5.7: Swamplands Quality Check Point Analysis SVA				
Point ID	Easting (feet)	Northing (feet)	DEM Elevation (feet)	Dz (feet)
7001	2597410.759	370365.620	196.740	-0.116
7002	2519824.418	372612.960	198.430	0.178
7003	2591541.245	355452.605	217.190	0.225
7004	2574307.927	368666.431	203.190	0.215
7005	2565186.766	348365.254	181.900	0.08
7006	2591577.788	335711.423	204.770	0.363
7007	2558523.477	326824.329	152.170	0.177
7008	2616962.564	340424.631	200.590	-0.063
7009	2647948.733	335677.768	168.280	0.285
7010	2630294.547	323697.375	174.690	0.083
7011	2584265.102	317656.312	195.930	0.056
7012	2621347.196	303466.151	168.360	0.177
7013	2620510.033	264621.401	121.500	0.341
7014	2606350.014	248511.534	151.650	0.509
7015	2607116.202	234294.226	154.250	0.284
7016	2563232.347	243451.745	134.970	0.501
7017	2562690.722	253432.613	182.760	0.291
7018	2542376.483	252806.999	165.910	0.298
7019	2530750.012	285126.476	134.950	0.194
7020	2541049.737	299865.694	134.980	0.187
7021	2553827.249	270338.602	184.390	0.58
7022	2573508.027	290494.008	179.360	-0.066
7023	2554017.423	292137.151	202.650	0.862
7024	2585716.467	308226.578	194.810	-0.113
7025	2613565.059	313740.361	188.070	0.355

VERTICAL ACCURACY CONCLUSIONS

Swamp Land Cover Classification Supplemental Vertical Accuracy (SVA) Tested 0.566 feet supplemental vertical accuracy at the 95th percentile in the Swamp supplemental class reported using National Digital Elevation Program (NDEP)/ASPRS Guidelines and tested against the DEM. Swamp Errors at the 95th percentile include:

- Point 7023, Easting 2554017.423, Northing 292137.151, Z-Error 0.862 feet

CONSOLIDATED VERTICAL ACCURACY ASSESSMENT AND CONCLUSION

Consolidated Vertical Accuracy (CVA) Tested 0.920 feet consolidated vertical accuracy at the 95th percentile level; reported using National Digital Elevation Program (NDEP)/ASPRS Guidelines and tested against the DEM. CVA is based on the 95th percentile error in all land cover categories combined.

- Point 5005, Easting 2543805.444, Northing 346633.273, Z-Error 1.118 feet
- Point 5006, Easting 2624273.619, Northing 302699.754, Z-Error 0.959 feet
- Point 5008, Easting 2531048.936, Northing 282795.121, Z-Error 0.954 feet
- Point 5009, Easting 2553738.580, Northing 270319.831, Z-Error 0.956 feet
- Point 5012, Easting 2591605.068, Northing 249208.137, Z-Error 0.968 feet

- Point 5023, Easting 2597666.862, Northing 333813.106, Z-Error 1.211 feet
- Point 5024, Easting 2558466.442, Northing 326881.765, Z-Error 1.063 feet
- Point 6010, Easting 2588781.293, Northing 259661.441, Z-Error 1.284 feet

Approved by:	Name	Signature	Date
Associate Member, Lidar Specialist Certified Photogrammetrist #1381	Qian Xiao		August 2015

Section 6: Flight Logs

Flight logs for the project are shown on the following pages:

Woolpert

Optech LIDAR

MM/DD/YYYY	Day of Year	Project #	Phase #	Project Name
3/16/2015	75	75271	2	NOAA_Lowndes_GA_Optech

Operator	Aircraft #	HOBBS Start	Local Start Time	ZULU Start Time	Base
BURKE	N111SD	42.6	15:50:00	19:50:00	WOOLPERT PIN
Pilot	**Sensor Type**	**HOBBS END**	**Local End Time**	**Zulu End Time**	**PID**
Voris	Optech- Gemini 108	48.1	9:37:40	1:37:40	

Wind Dir/Speed	Visibility	Ceiling	Cloud Cover %	Temp	Dew Point	Pressure	Haze/Fire/Cloud		
var / 03	clr	12	0	28	4	0.083	Haze	Departing	KVLD
								Arriving	KVLD

Frequency	Half-Angle	System PRF	Roll Compensation	Divergence Mode	Multipulse	k	DIGITIZER
48	11	125	ON [X] OFF [ ]	WD [ ] NR [X]	OFF [ ] ON [ ] FIX [X]	OFF [X] ON [ ] SAMPLE [ ] BOUNDARY [ ]	Range Gate [ ] Threshold [ ] Laser Trigger Edge [ ] 1 PPS edge [ ]

Air Speed	AGL	MSL	Avg. Elev.	Adj. AGL	Max Range
130	5000	5000			

Line #	Dir.	Mission ID#	Line End Time	Time On Line	ALT	KTS	PDOP	Line Notes/Comments	
Test	n/a			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	92	20:14:29	20:18:46	0:04:17	1520	138	2		
2	272	20:22:33	20:29:00	0:06:27	1541	119	2.4		
3	92	20:31:48	20:38:13	0:06:25	1523	130	1.7		
4	272	20:40:49	20:47:02	0:06:12	1550	129	1.8		
5	92	20:49:33	20:56:06	0:06:33	1521	131	1.7		
6	272	20:58:52	21:05:20	0:06:28	1516	132	1.8		
7	92	21:07:44	21:14:27	0:06:43	1514	127	1.9		
8	272	21:17:03	21:23:57	0:06:54	1539	136	1.9		
9	92	21:26:01	21:33:13	0:07:13	1534	141	1.6		
10	272	21:35:20	21:43:00	0:07:40	1527	134	1.6		
11	92	21:45:12	21:52:43	0:07:31	1511	134	1.6		
12	272	21:54:55	22:02:53	0:07:58	1524	139	1.6		
13	92	22:05:03	22:12:53	0:07:50	1531	138	1.5		
14	272	22:14:56	22:23:18	0:08:22	1543	122	1.4		
15	92	22:25:38	22:33:40	0:08:01	1496	144	1.4		
16	272	22:35:48	22:44:19	0:08:32	1525	122	1.8		
17	92	22:46:22	22:54:37	0:08:15	1521	138	1.7		
18	272	22:56:46	23:05:34	0:08:48	1506	129	1.6		
19	92	23:07:51	23:15:58	0:08:07	1523	138	1.4		
20	272	23:18:10	23:26:50	0:08:40	1528	127	1.6		
21	92	23:29:10	23:37:31	0:08:21	1518	143	1.5		
22	272	23:39:43	23:48:23	0:08:40	1514	135	1.6		
23	92	23:50:38	23:58:59	0:08:21	1516	144	1.5		
24	272	0:01:11	0:10:11	0:09:00	1516	118	1.6		
25	92	0:12:29	0:21:13	0:08:44	1528	142	1.6		
26	272	0:23:36	0:32:45	0:09:09	1524	121	1.6		
27	92	0:35:15	0:44:22	0:09:07	1529	146	1.6		
28	272	0:46:30	0:55:53	0:09:22	1510	110	1.3		
29	92	0:58:03	1:07:15	0:09:12	1510	122	15	Laser would not turn off	
				0:00:00					
↑ Times entered are Zulu / GMT ↑				Page	1			Verify S-Turns After Mission	Yes x No

Additional Comments:	Drive #
Temperature inversion haze trapped at 5000MSL Laser would not turn off on line 29, shut down laser pump RTB	

Woolpert

Optech LIDAR	MM/DD/YYYY	Day of Year	Project #	Phase #	Project Name
	3/17/2015	76	75271	2	NOAA_Lowndes_GA_Optech

Operator	Aircraft #	HOBBS Start	Local Start Time	Zulu Start Time	Base
BURKE	N111SD	48.1	12:21:00	16:21:00	WOOLPERT PIN
Pilot	**Sensor Type**	**HOBBS END**	**Local End Time**	**Zulu End Time**	**PID**
Voris	Optech- Gemini 108	53.7	18:07:51	22:07:51	

Wind Dir/Speed	Visibility	Ceiling	Cloud Cover %	Temp	Dew Point	Pressure	Haze/Fire/Cloud		
var / 03	10	5k	0	28	13	30.04	Haze	Departing	KVLD
								Arriving	KVLD

Frequency	Half-Angle	System PRF	Roll Compensation	Divergence Mode	Multipulse	k	DIGITIZER
48	11	125	ON X OFF	WD NR X	OFF ON FIX X	OFF X ON SAMPLE BOUNDARY	Range Gate Threshold Laser Trigger Edge 1 PPS edge

Air Speed	AGL	MSL	Max. Elev.	Adj. AGL	Max Range
130	5000	5000			

Line #	Dir.	Mission ID#	Line End Time	Time On Line	ALT	KTS	PDOP	Line Notes/Comments
Test	n/a			n/a	n/a	n/a	n/a	GPS Began Logging At:
		↕ Times entered are Zulu / GMT ↕						Verify S-Turns Before Mission Yes No
52	272	16:42:38	16:50:58	0:08:20	1538	122		
53	92	16:53:18	17:02:12	0:08:54	1533	133		
54	272	17:04:28	17:14:10	0:09:42	1527	120		
55	92	17:16:16	17:24:58	0:08:42	1513	135		
56	272	17:27:02	17:36:36	0:09:33	1517	122		
57	92	17:38:23	17:47:20	0:08:57	1515	136		
58	272	17:49:30	18:00:03	0:10:33	1528	114		
59	92	18:01:32	18:11:30	0:09:58	1504	135		Plan progress showed gap from 58
60	272	18:13:43	18:24:45	0:11:02	1507	115		
60	92	18:26:41	18:28:32	0:01:51	1500	134		
61	92	18:34:59	18:45:33	0:10:34	1500	127		
62	272	18:47:41	18:58:41	0:11:00	1551	129		
63	92	19:00:15	19:10:57	0:10:42	1588	134		
64	272	19:13:03	19:24:14	0:11:10	1561	115		
65	92	19:26:00	19:36:37	0:10:37	1554	126		
66	272	19:38:53	19:49:52	0:10:59	1549	129		
67	92	19:51:51	20:02:44	0:10:53	1544	125		
68	272	20:04:30	20:15:48	0:11:18	1538	121		
69	92	20:17:52	20:28:28	0:10:35	1593	133		
70	272	20:30:57	20:41:56	0:10:59	1583	123		
71	92	20:43:51	20:54:14	0:10:23	1567	135		
72	272	20:56:36	21:07:23	0:10:46	1600	128		
73	92	21:09:25	21:19:43	0:10:18	1579	136		
74	272	21:22:05	21:33:05	0:11:00	1578	123		
75	92	21:35:01	21:45:26	0:10:25	1596	137		
58.5		21:53:01	21:55:35	0:02:34	1576	126		Fly patch based on plan progress
				0:00:00				
				0:00:00				
				0:00:00				
				0:00:00				
↑ Times entered are Zulu / GMT ↑				Page	1			Verify S-Turns After Mission Yes x No

Additional Comments:	Drive #
Low ceiling at 5k MSL at start of mission	

Woolpert

Optech LIDAR

MM/DD/YEAR	Day of Year	Project #	Phase #	Project Name
3/18/2015	77	75271	2	NOAA_Lowndes_GA_Optech

Operator	Aircraft	HOBBS Start	Local Start Time	ZULU Start Time	
BURKE	N111SD	53.7	3:24:30	7:24:30	WOOLPE
Pilot	**Sensor Type**	**HOBBS END**	**Local End Time**	**Zulu End Time**	
Voris	Optech- Gemini 108	59.1	9:04:00	13:04:00	

Wind Dir/Speed	Visibility	Ceiling	Cloud Cover %	Temp	Dew Point	Pressure	Haze/Fire/Cloud	
calm	10	CLR	0	16	13	29.97		Departing Arriving

Frequency	Half-Angle	System PRF	Roll Compensation	Divergence Mode	Multipulse	k	DIGITIZER
48	11	125	ON X OFF	WD NR X	OFF ON FIX X	OFF X ON SAMPLE BOUNDARY	Range Gate Threshold Laser Trigger Edge 1 PPS edge

Air Speed	AGL	MSL	Avg. Elev.	Adj. AGL	Max Range
130	5000	5150	150		

↓ Times entered are Zulu / GMT ↓

Line #	Dir.	Mission ID#	Line End Time	Time On Line	ALT	KTS	PDOP	Line Notes/Comments
Test	n/a			n/a	n/a	n/a	n/a	GPS Began Logging At:
						Verify S-Turns Before Mission		Yes / No
76	272	7:55:33	8:05:50	0:10:17	1601	134	1.6	
77	92	8:08:17	8:18:28	0:10:11	1568	118	1.4	
78	272	8:20:35	8:30:56	0:10:22	1605	123	1.4	
79	92	8:33:07	8:43:06	0:10:00	1575	131	1.6	
80	272	8:45:15	8:55:32	0:10:17	1586	126	1.7	
81	92	8:57:52	9:05:23	0:07:31	1601	130	1.8	
82	272	9:07:17	9:15:02	0:07:46	1594	121	1.8	
83	92	9:16:52	9:24:28	0:07:36	1603	121	1.8	
84	272	9:26:22	9:34:07	0:07:45	1606	122	1.8	
85	92	9:36:11	9:43:42	0:07:31	1597	125	1.7	
86	272	9:45:54	9:53:21	0:07:28	1578	124	1.6	
87	92	9:55:21	10:02:53	0:07:32	1588	130	1.4	
88	272	10:04:56	10:12:35	0:07:39	1585	120	1.5	
89	92	10:14:58	10:22:26	0:07:28	1598	132	1.5	
90	272	10:24:31	10:32:13	0:07:42	1586	128	1.9	
91	92	10:34:14	10:41:53	0:07:40	1611	127	2	
92	272	10:43:55	10:51:49	0:07:54	1598	123	1.9	
93	92	10:53:49	11:01:38	0:07:49	1606	132	1.8	
94	272	11:03:40	11:11:28	0:07:48	1616	129	2.1	
95	92	11:13:40	11:21:25	0:07:44	1603	135	2.1	
96	272	11:23:25	11:29:46	0:06:21	1605	134	2	
29	92	11:37:42	11:46:20	0:08:39	1626	136	1.8	Re-Flight due to laser not powe
30	272	11:48:26	11:57:25	0:08:59	1608	122	1.9	
31	92	11:59:45	12:08:42	0:08:56	1621	134	2	
32	272	12:11:02	12:19:47	0:08:46	1624	134	2.4	
33	92	12:22:06	12:30:54	0:08:48	1607	133	1.7	
34	272	12:33:04	12:41:31	0:08:28	1610	129	1.7	
35	92	12:44:04	12:52:27	0:08:23	1610	135	1.5	
				0:00:00				
				0:00:00				

↑ Times entered are Zulu / GMT ↑		Page	1	Verify S-Turns After Mission	Yes	x	No

Additional Comments:

Sled drive 00860 DC buffer overflow error shut down system swap drive to 00366 reboot no errors.

Woolpert

Optech LIDAR	MM/DD/YEAR	Day of Year	Project #	Phase #	Project Name
	3/18/2015	77	75271	2	NOAA_Lowndes_GA_Optech

Operator	Aircraft	HOBBS Start	Local Start Time	ZULU Start Time	
BURKE	N111SD	59.1	10:19:00	14:19:00	WOOLPE
Pilot	**Sensor Type**	**HOBBS END**	**Local End Time**	**Zulu End Time**	
Voris	Optech- Gemini 108	62.5	14:56:30	17:56:30	

Wind Dir/Speed	Visibility	Ceiling	Cloud Cover %	Temp	Dew Point	Pressure	Haze/Fire/Cloud	
calm	10	CLR	0	18	12	30.05		Departing / Arriving

Frequency	Half-Angle	System PRF	Roll Compensation	Divergence Mode	Multipulse	k	DIGITIZER
48	11	125	ON X / OFF	WD / NR X	OFF / ON / FIX X	OFF X / ON / SAMPLE / BOUNDARY	Range Gate / Threshold / Laser Trigger Edge / 1 PPS edge

Air Speed	AGL	MSL	Avg. Elev.	Adj. AGL	Max Range
130	5000	5150	150		

Line #	Dir.	Mission ID#	Line End Time	Time On Line	ALT	KTS	PDOP	Line Notes/Comments
Test	n/a			n/a	n/a	n/a	n/a	GPS Began Logging At:
		↓ Times entered are Zulu / GMT ↓				Verify S-Turns Before Mission		Yes Y No
36	272	14:38:33	14:47:18	0:08:45	1588	127	1.5	
37	92	14:49:42	14:58:06	0:08:24	1603	126	1.5	14:57 Received DC Buffer O
38	272	15:00:13	15:08:54	0:08:41	1602	124	1.3	
39	92	15:11:23	15:19:54	0:08:32	1579	123	1.3	
40	272	15:22:07	15:30:43	0:08:36	1582	119	1.5	
41	92	15:33:05	15:41:52	0:08:48	1593	126	1.6	
42	272	15:43:59	15:52:50	0:08:52	1580	131	1.6	
43	92	15:55:16	16:03:54	0:08:37	1594	132	1.4	
44	272	16:06:09	16:14:52	0:08:44	1573	129	1.4	
45	92	16:17:15	16:26:13	0:08:58	1584	125	1.3	
46	272	16:28:18	16:37:09	0:08:51	1597	128	1.8	
47	92	16:39:41	16:48:22	0:08:41	1597	129	1.9	
48	272	16:50:16	16:58:37	0:08:21	1601	130	1.9	
49	92	17:00:57	17:09:21	0:08:24	1594	133	1.8	
50	272	17:11:39	17:19:51	0:08:12	1621	132	1.6	
51	92	17:23:03	17:30:27	0:07:24	1595	135	1.5	
37	272	17:33:38	17:41:58	0:08:21	1583	136	1.5	Re-Fly line 37 due to Bu
				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				
↑ Times entered are Zulu / GMT ↑				Page	1		Verify S-Turns After Mission	Yes x No

Additional Comments:

Tried again Sled drive 00860 DC buffer overflow error and rolling message "Trying SCSI" shut down system swap drive to 00366 reboot no errors.

Woolpert

Optech LIDAR	MM/DD/YYYY	Day of Year	Project #	Phase #	Project Name
	3/27/2015	86	75271	2	Lowndes County, GA

Operator	Aircraft	HOBBS Start	Local Start Time	ZULU Start Time	Base
SIMMONS	N111SD	69.1	19:25:00	23:25:00	WOOLPERT PIN
Pilot	**Sensor Type**	**HOBBS END**	**Local End Time**	**Zulu End Time**	**PID**
Other	Optech- Gemini 108	70.6	21:30:00	1:30:00	

Wind Dir/Speed	Visibility	Ceiling	Cloud Cover %	Temp	Dew Point	Pressure	Haze/Fire/Cloud		
VAR @ 04	10 SM	CLR		14	7	2985		Departing	KVLD
								Arriving	KVLD

Frequency	Half-Angle	System PRF	Roll Compensation	Divergence Mode	Multipulse	ARF	DIGITIZER
			ON X	WD	OFF	OFF X ON	Range Gate Threshold
			OFF	NR X	ON	SAMPLE	Laser Trigger Edge
					FIX X	BOUNDARY	1 PPS edge

Air Speed	AGL	MSL	Avg. Elev.	Adj. AGL	Max Range
130	5000		20		

Line #	Dir.	Mission ID#	Line End Time	Time On Line	SV's	HDOP	PDOP	Line Notes/Comments
Test	n/a			n/a	n/a	n/a	n/a	GPS Began Logging At:
↓ Times entered are Zulu / GMT ↓						Verify S-Turns Before Mission	Yes	No
60.5	E	23:48:13	23:58:37	0:10:24				
62.5	W	0:01:40	0:14:20	0:12:41				
68.5	W	0:24:52	0:35:58	0:11:06				
27.5	E	0:41:09	0:50:12	0:09:03				
20.5	W	0:52:45	1:02:06	0:09:21				
17.5	E	1:04:19	1:12:37	0:08:17				
				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				
				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				
↑ Times entered are Zulu / GMT ↑			Page	1		Verify S-Turns After Mission	Yes	No

Additional Comments:	Drive #

Section 7: Final Deliverables

The final lidar deliverables are listed below.

- LAS v1.2 classified point cloud
- Digital Elevation Model in ESRI Grid Format
- Tile layout and data extent provided in ESRI .GDB
- Control Points provided in ESRI .GDB
- Flightline vectors provided in ESRI .GDB
- Breaklines used in hydrologic flattening provided in ESRI .GDB
- FGDC compliant metadata per product in XML format
- Lidar processing report in pdf format
- Survey report in pdf format