WOOLPERT

Martin County QL2 Lidar

Martin County/ Stuart, FL

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Section 1: Overview

Project Name: Martin County QL2 Lidar

Project: # 76001

This report contains a comprehensive outline of the Martin County QL2 Lidar Processing task order for Martin County, FL. This task is issued under Task Order No. G14PS00574. This task order requires lidar data to be acquired over approximately 566 square miles. The lidar was collected and processed to meet a maximum Nominal Post Spacing (NPS) of 0.7 meter. The NPS assessment is made against single swath, first return data located within the geometrically usable center portion (typically ~90%) of each swath.

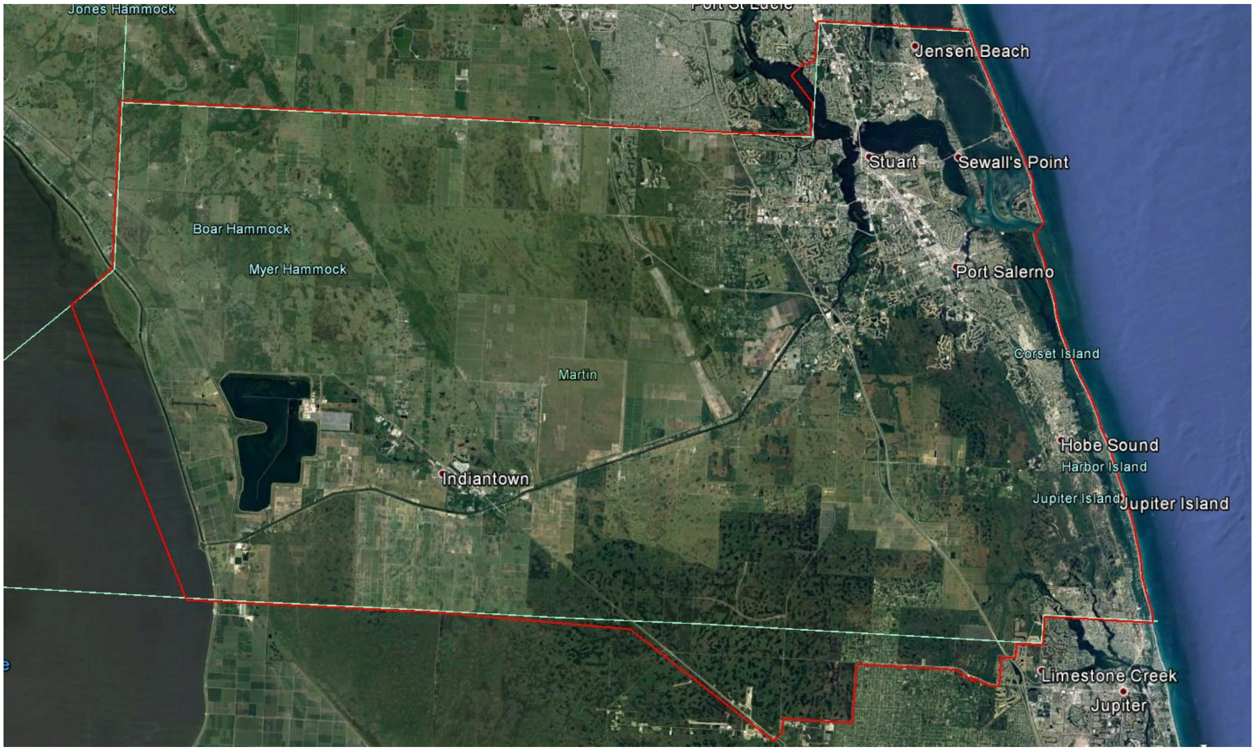
The data was collected using a Leica ALS80 1000 kHz Multiple Pulses in Air (MPiA) lidar sensor.

The ALS80 sensor collects up to an unlimited, 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: ALS80 Specifications	
Post Spacing	2.3ft / 0.7 m
AGL (Above Ground Level) average flying height	6,500 ft / 1,981 m
MSL (Mean Sea Level) average flying height	6,500 ft / 1,981 m
Average Ground Speed:	150 knots / 173 mph
Field of View (full)	40 degrees
Pulse Rate	545.0 kHz
Scan Rate	51.0 Hz
Side Lap	25%

Martin County QL2 Lidar was processed and projected in Florida State Plane East NAD83(2011). The vertical datum used for the task order was referenced to NAVD88, GEOID12B in units of Survey Feet.

Figure 1.1: Lidar Task Order AOI



Section 2: Acquisition

The existing lidar data was acquired on board Woolpert aircraft with a Leica ALS80HP 1000 kHz Multiple Pulses in Air (MPiA) Lidar Sensor System.

The ALS80HP lidar system, developed by Leica Geosystems of Heerbrugg, Switzerland, includes the simultaneous first, intermediate and last pulse data capture module, the extended altitude range module, and the target signal intensity capture module. The system software is operated on an OC80 Operation Controller aboard the aircraft.

The ALS80 1,000 kHz Multiple Pulses in Air (MPiA) Lidar System has the following specifications:

Table 2.1: ALS 80 Lidar System Specifications	
Operating Altitude	100 – 7,620 meters
Scan Angle	0 to 72° (variable)
Swath Width	0 to 1.5 X altitude (variable)
Scan Frequency	0 – 200 Hz (variable based on scan angle)
Maximum Pulse Rate	1000 kHz (Effective)
Range Resolution	Better than 1 cm
Elevation Accuracy	6 - 19 cm single shot (one standard deviation)
Horizontal Accuracy	5 – 43 cm (one standard deviation)
Number of Returns per Pulse	unlimited
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 = 72 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, 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 nine (4) 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, Martin County Lidar

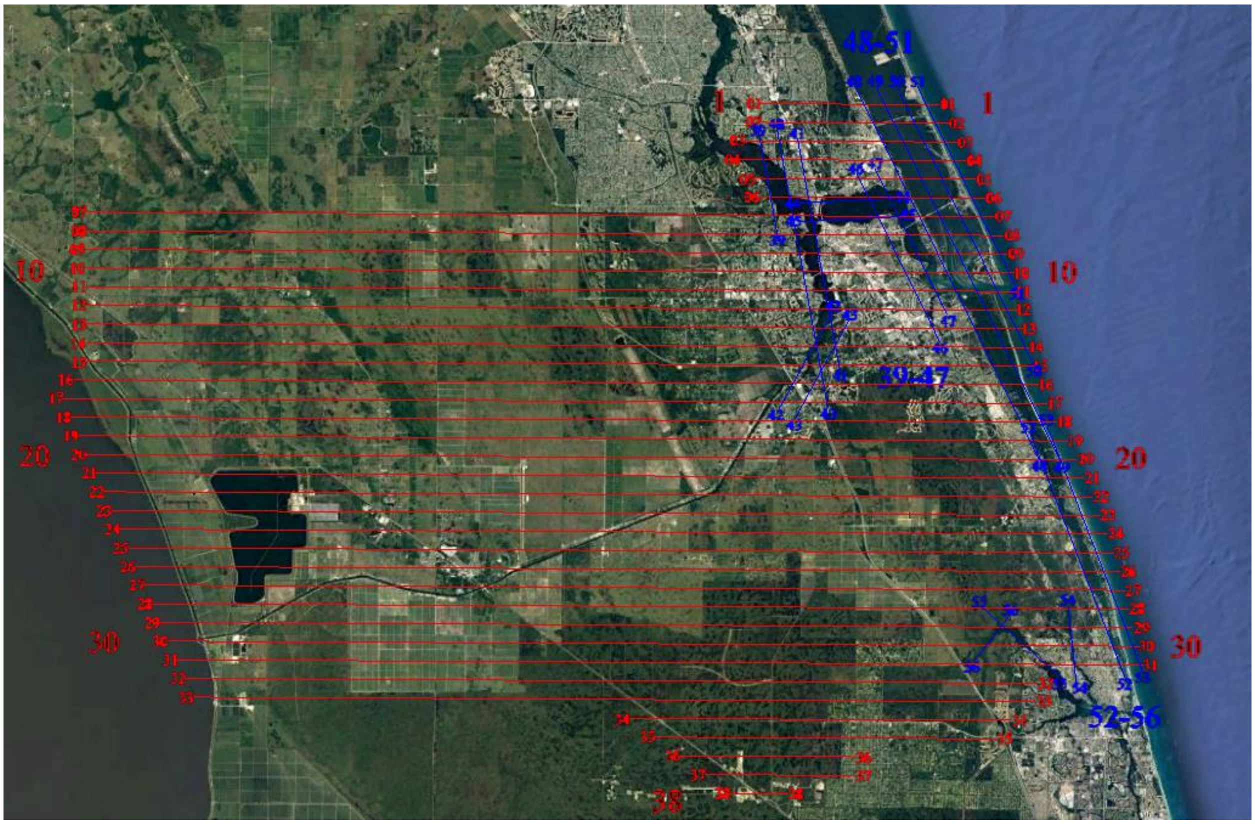


Table 2.2: Airborne Lidar Acquisition Flight Summary Woolpert			
Date of Mission	Lines Flown	Mission Time (UTC) Collect Start/ Collect End	Mission Time (Local = EDT) Collect Start/ Collect End
January 16, 2016 SH8170 A	1-16	14:11 – 21:21	09:11AM – 04:21PM
January 16, 2016 SH8170 B	17-26	14:11 – 21:21	09:11AM – 04:21PM
January 18, 2016 SH8170	27-56	14:08 – 19:21	09:08 AM – 02:21 PM
January 23, 2016 SH8170	28-29	22:44 – 23:33	05:44 PM – 06:33 PM

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: ALS Post Processing Software v.2.75 build #25, Proprietary Software, TerraMatch v. 16.01., Leica Lidar Survey Studio (LSS)
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.16.01.
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.16.01.

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 was utilized for each mission and is listed below.

Table 3.1: GNSS Base Station

Station (Name)	Latitude (DMS)	Longitude (DMS)	Ellipsoid Height (L1 Phase center) (Meters)
KSUA Airport Base	27°10'30.12576"	-80°13'27.42637"	-23.381

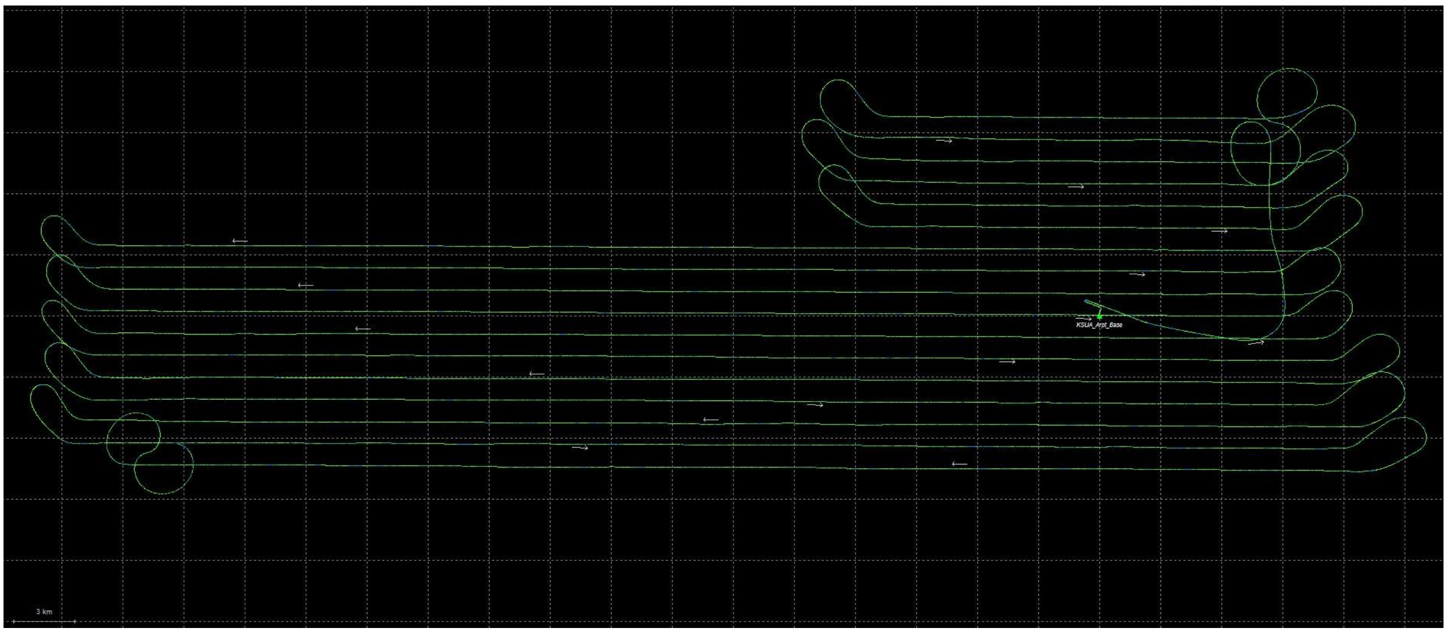
Data Processing

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, Day01616_SH8170_A

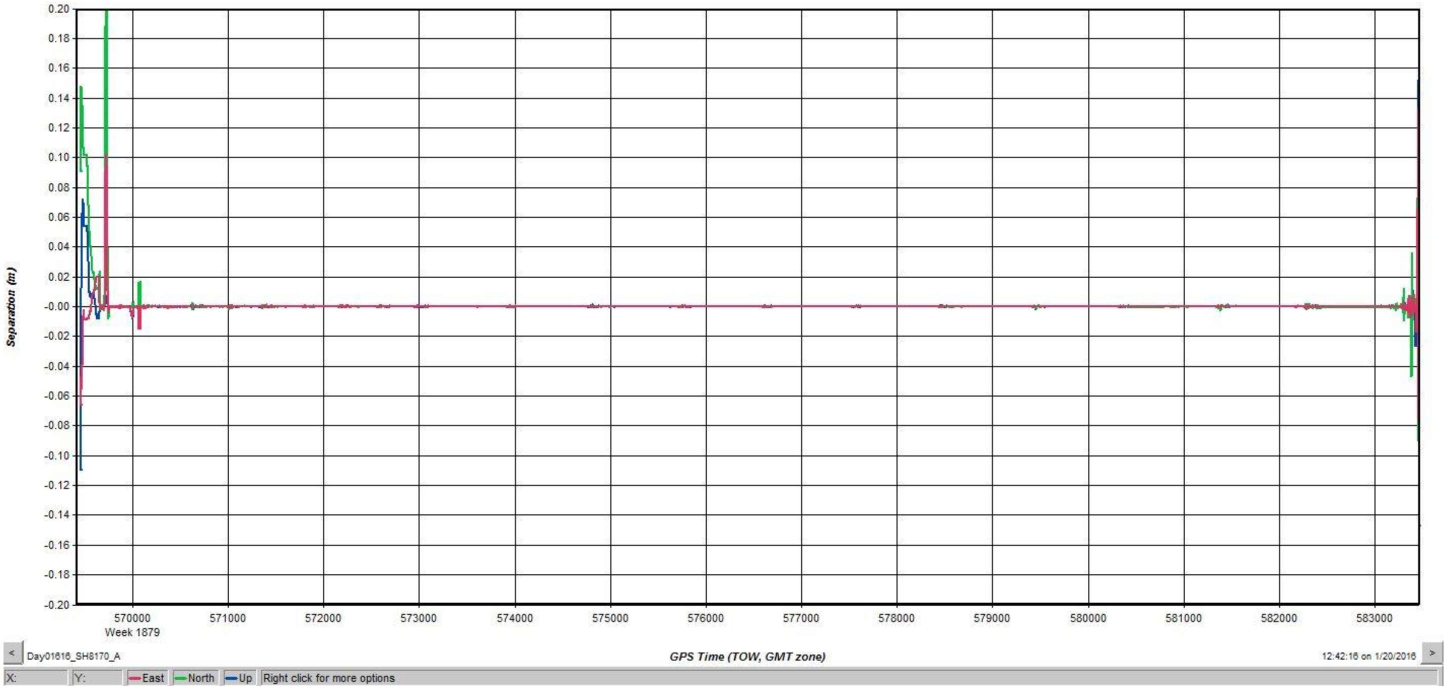


Combination Separation

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, Day01616_SH8170_A

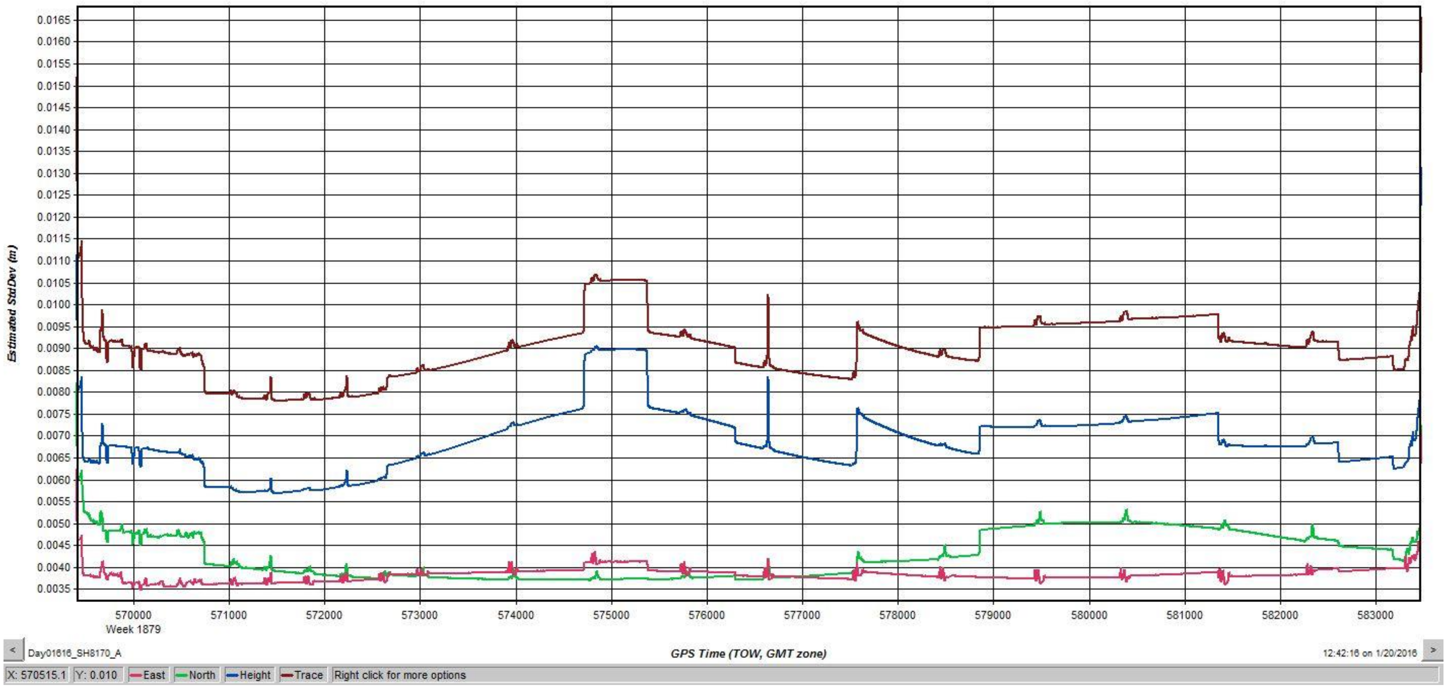


Estimated Positional Accuracy

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, Day01616_SH8170_A

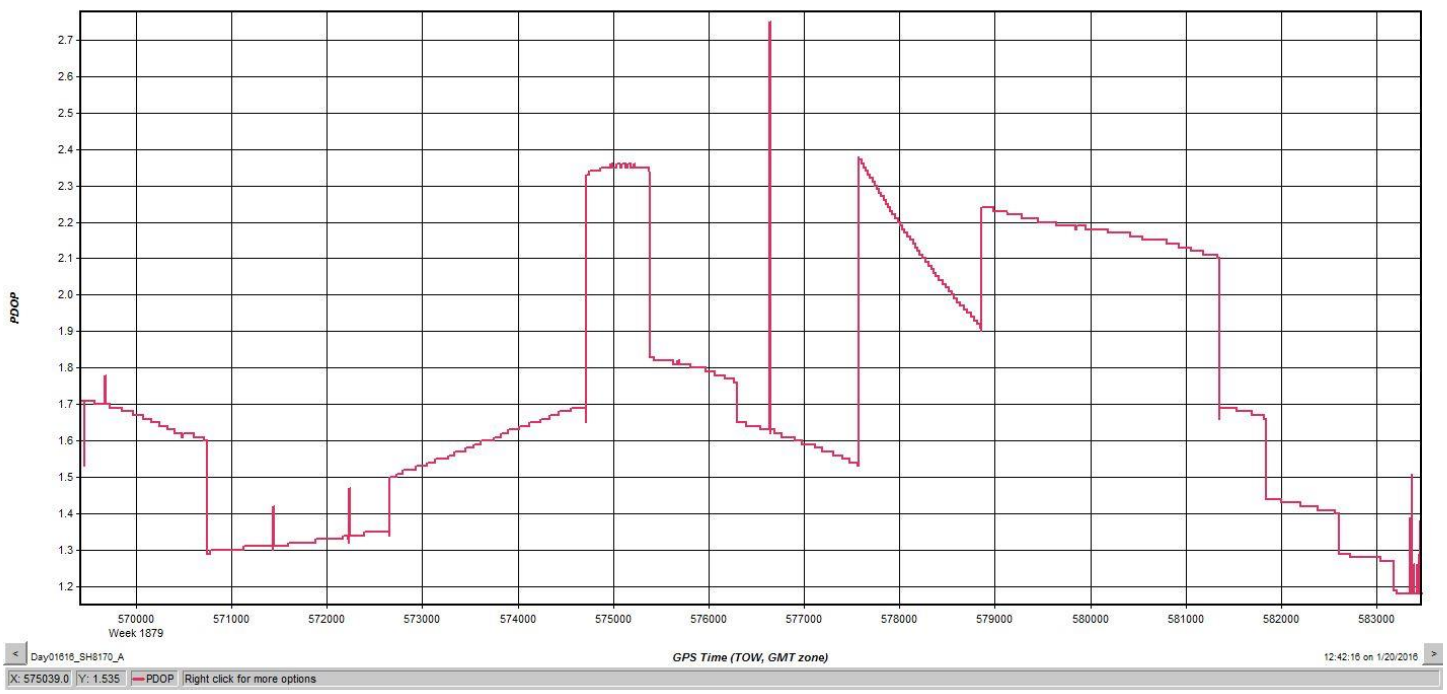


PDOP

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, Day01616_SH8170_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), Low Noise (Class 7), Water (Class 9), Ignored Ground (Class 10), Bridge Decks (Class 17) and High Noise (Class 18) classifications.
- FGDC Compliant metadata was developed for the task order in .xml format for the final data products.
- The horizontal datum used was referenced to NAD83(2011) Florida State Plane East, Survey Feet. The vertical datum used for the task order was referenced to NAVD88, GEOID12B in units of Survey Feet.

Section 4: Hydrologic Flattening

HYDROLOGIC FLATTENING OF LIDAR DEM DATA

Martin County QL2 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

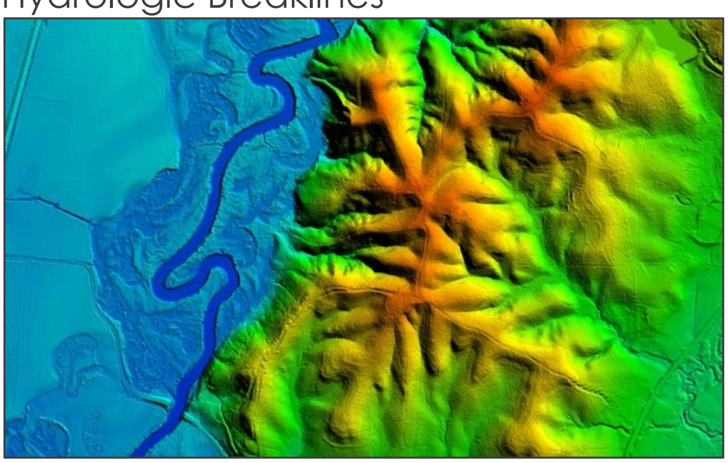


Figure 4.2 reflects a DEM generated from original lidar bare earth point data prior to the hydrologic flattening process. Note the “tinning” across the lake surface.

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 Martin County in ERDAS .IMG format.

The hydrologic breaklines compiled as part of the flattening process were provided 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. Polygon-Z hydro breaklines contain islands as “donut-holes”. Some areas of this project are located in areas exhibiting swamp-like and/or heavily vegetated conditions. In such areas, placement of hydrographic features developed as part of the hydrologic breakline dataset may appear ambiguous.

DATA QA/QC

Initial QA/QC for this task order was performed in Global Mapper v16, 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

This section contains accuracy assessments for Martin County QL2 Lidar. The vertical accuracy statistics were calculated by comparison of the lidar bare earth points to the ground surveyed QA/QC points. Data deliverables were delivered in NAD1983(2011) State Plane Florida East, NAVD88 Geoid12B Survey Feet.

Table 5.1: Overall Vertical Accuracy Statistics		
Average error	0.044	feet
Minimum error	-0.276	feet
Maximum error	0.279	feet
Average magnitude	0.096	feet
Root mean square	0.125	feet
Standard deviation	0.118	feet

Table 5.2: Raw Swath Quality Check Point Analysis NVA

Point ID	Easting (US Feet)	Northing (US Feet)	TIN Elevation (US Feet)	Dz (US Feet)
2001	915631.625	1065605.617	4.010	0.054
2002	916145.075	1044070.023	3.490	-0.015
2003	918977.608	1022078.101	7.300	0.046
2004	939208.541	999034.032	3.050	0.004
2005	943688.523	993813.465	11.870	0.146
2006	953722.432	958059.639	19.540	-0.009
2007	908457.562	953909.352	17.650	-0.276
2008	888260.329	956788.478	24.140	-0.049
2009	896151.854	980673.248	20.510	0.106
2010	889346.743	1010073.504	16.360	0.037
2011	891249.948	1037243.399	7.950	0.158
2012	890998.814	1058192.464	10.630	-0.168
2013	854296.842	1036623.184	26.930	0.014
2014	824762.948	1044256.97	30.060	0.21
2015	856591.259	1023290.565	32.780	0.071
2016	824838.992	1011132.541	28.170	0.059
2017	877746.316	996598.321	23.650	0.15
2018	848335.294	979468.991	26.290	0.036
2019	786187.569	964722.249	21.160	-0.099
2020	824316.914	980154.767	33.670	0.087
2021	782000.586	1007048.697	26.930	0.221
2022	772286.493	988327.982	16.650	-0.037

2023	761485.823	1028295.486	27.720	-0.101
2024	774273.053	1028332.028	33.920	-0.124
2025	805626.409	1022877.861	33.230	-0.007
2026	824724.06	1028430.548	28.170	-0.004
2027	800159.733	995989.863	34.180	0.019
2028	813924.585	974637.348	26.250	0.033
2029	881137.779	1033271.661	15.000	-0.035
2030	840694.294	1028510.112	29.790	-0.038
2030A	853910.741	1043468.139	26.990	0.209
2031	919419.09	985929.238	15.780	0.151
2031A	914502.988	985977.53	16.260	0.058
2032	877553.797	1008545.48	21.780	0.262
2033	813339.905	1010463.111	37.130	0.14
2034	905572.945	1039200.349	12.110	0.279
2035	907064.704	986012.237	17.520	0.169
2036	909474.264	1018985.455	16.500	-0.144
2037	934750.65	959477.039	12.820	-0.044
2038	888358.619	936803.009	23.690	-0.054
2039	910170.195	1054052.012	3.440	0.016
2040	945699.797	978531.489	34.150	0.245
2041	775253.195	1038075.07	33.630	0.115
2042	915574.308	1006408.146	17.010	0.053
2043	923252.113	947474.636	16.730	0.028
2044	831849.73	979775.953	37.940	0.049

VERTICAL ACCURACY CONCLUSIONS

Raw Swath Non-Vegetated Vertical Accuracy (NVA) Tested 0.245 US feet Non vegetated 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 Non-Vegetated Vertical Accuracy (NVA) Tested 0.243 US feet Non vegetated 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.

Table 5.3: Non-Vegetated Vertical Accuracy Quality Check Point Analysis NVA

Point ID	Easting (US Feet)	Northing (US Feet)	DEM Elevation (US Feet)	Dz (US Feet)
2001	915631.625	1065606	3.98	-0.024
2002	916145.075	1044070	3.48	0.025
2003	918977.608	1022078	7.29	-0.036
2004	939208.541	999034	3.02	0.026
2005	943688.523	993813.5	11.87	-0.146
2007	908457.562	953909.4	17.57	0.356

2008	888260.329	956788.5	24.11	0.079
2009	896151.854	980673.2	20.51	-0.106
2010	889346.743	1010074	16.43	-0.107
2011	891249.948	1037243	7.89	-0.098
2012	890998.814	1058192	10.64	0.158
2013	854296.842	1036623	26.87	0.046
2014	824762.948	1044257	30.05	-0.2
2015	856591.259	1023291	32.77	-0.061
2016	824838.992	1011133	28.25	-0.139
2017	877746.316	996598.3	23.63	-0.13
2018	848335.294	979469	26.27	-0.016
2019	786187.569	964722.2	21.15	0.109
2020	824316.914	980154.8	33.63	-0.047
2021	782000.586	1007049	26.97	-0.261
2022	772286.493	988328	16.45	0.237
2023	761485.823	1028295	27.61	0.211
2024	774273.053	1028332	33.9	0.144
2025	805626.409	1022878	33.21	0.027
2026	824724.06	1028431	28.08	0.094
2027	800159.733	995989.9	34.24	-0.079
2028	813924.585	974637.3	26.23	-0.013
2029	881137.779	1033272	14.97	0.065
2030	840694.294	1028510	29.81	0.018
2030A	853910.741	1043468	27.01	-0.229
2031	919419.09	985929.2	15.75	-0.121
2031A	914502.988	985977.5	16.23	-0.028
2032	877553.797	1008545	21.76	-0.242
2033	813339.905	1010463	37.07	-0.08
2034	905572.945	1039200	11.93	-0.099
2035	907064.704	986012.2	17.51	-0.159
2036	909474.264	1018985	16.47	0.174
2037	934750.65	959477	12.8	0.064
2038	888358.619	936803	23.64	0.104
2039	910170.195	1054052	3.41	0.014
2040	945699.797	978531.5	34.14	-0.235
2041	775253.195	1038075	33.64	-0.125
2042	915574.308	1006408	17.02	-0.063
2043	923252.113	947474.6	16.69	0.012
2044	831849.73	979776	37.96	-0.069

VERTICAL ACCURACY CONCLUSIONS

Bare-Earth DEM Non-Vegetated Vertical Accuracy (NVA) Tested 0.264 US feet Non-Vegetated 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.

Table 5.4: Vegetated Vertical Accuracy Quality Check Point Analysis VVA				
Point ID	**Easting (US Feet)**	**Northing (US Feet)**	**DEM Elevation (US Feet)**	**Dz (US Feet)**
3001	916522.481	1063733	3.79	-0.103
3002	943605.01	993953.8	11.25	0.026
3003	945646.89	978575.7	33.56	-0.169
3004	928516.67	986067.3	12.67	-0.235
3005	891342.797	965652.1	20.38	-0.226
3006	881493.766	955889.8	23.2	-0.49
3007	896202.386	980823.7	18.08	-0.339
3008	892073.14	1010641	7.34	0.167
3009	893301.158	1037929	4.4	0.008
3010	890915.011	1058757	9.89	0.092
3011	896253.527	1047178	7.93	-0.485
3012	909547.105	1043758	9.55	-0.12
3013	854200.757	1036549	27.35	-0.145
3014	824935.136	1044394	30.57	-0.424
3016	824643.282	1012664	28.67	-0.296
3017	878647.22	995565.8	27.71	0.143
3018	849090.29	980567.2	25.38	-0.309
3019	786096.643	964767.1	19.61	-0.307
3020	824338.081	980241.2	34.36	-0.164
3021	782264.13	1006943	26.83	-0.172
3022	772273.286	988395.6	14.7	-0.078
3023	761568.448	1028271	27.16	-0.998
3024	786454.3	1028755	37.55	-0.057
3025	805953.283	1022828	29.62	-0.326
3026	824844.095	1028455	27.87	-0.179
3027	813313.124	1010434	37.01	-0.183
3027A	800141.813	996244.8	30.84	0.072
3028	866959.961	983681.2	25.22	-0.29
3030	934340.804	969054.1	8.24	0.106
3031	913326.157	1004540	13.8	-0.447
3032	946394.212	964668.2	12.75	-0.282
3033	856681.026	1025690	33.67	-0.183
3034	884441.301	1025584	16.76	-0.134

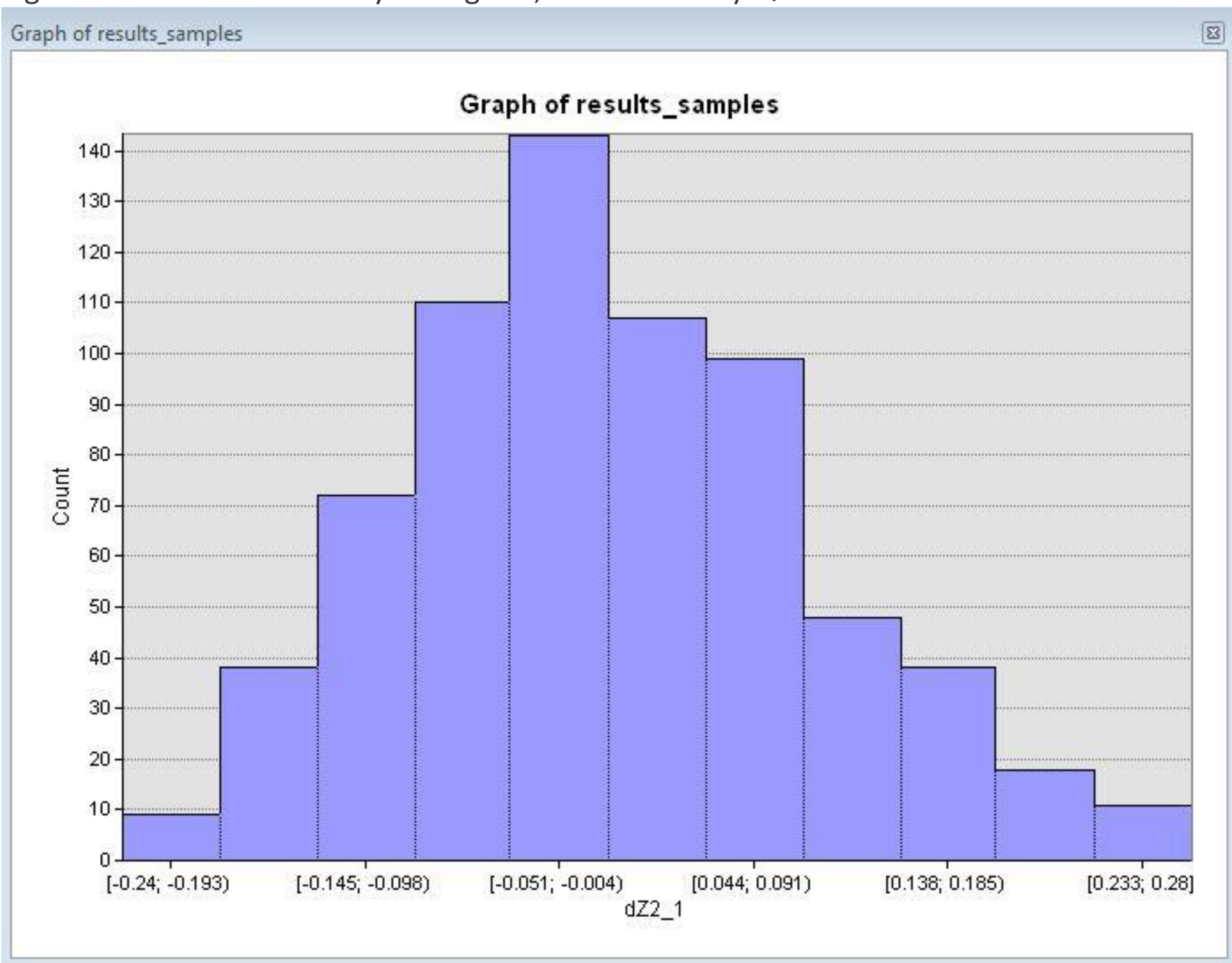
VERTICAL ACCURACY CONCLUSIONS

Vegetated Vertical Accuracy (VVA) Tested 0.642 US feet at the 95th percentile reported using National Digital Elevation Program (NDEP)/ASPRS Guidelines and tested against the DEM. VVA Errors larger than 95th percentile include:
Point 3023, Easting 761568.448, Northing 1028270.720, Z-Error 0.998 US feet

RELATIVE ACCURACY ASSESSMENT AND CONCLUSION

Relative accuracy also known as "between swath" accuracy was tested through a series of well distributed flight line overlap locations. The relative accuracy for the Martin County QL2 Lidar tested at 0.099 feet RMSDz.

Figure 5.1: Relative Accuracy Histogram, Martin County QL2 Lidar



Approved by:	Name	Signature	Date
Associate Member, Lidar Specialist Certified Photogrammetrist #1381	Qian Xiao		June 2016

Section 6: Flight Logs

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

Woolpert

Leica LIDAR	1/16/2016	16	76001		martin co

SMITH	N7079F	228.9	9:11:00	14:11:00	
GEBHART	OTHER	235.8	4:21:00	21:21:00	

calm	10			15	15	2994		Departing	SUB
								Arriving	SUB

Scan Angle (FOV)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power %	Fixed Gain		Mode		Threshold Values	
40	51	545	100	Gain - Course/Up		Single		A	
				Gain - Fine/Down		Multi	x	B	

Air Speed		AGL		MSL		Waveform Used				Waveform Mode	Pre-Trigger Dist.	
150	Kts	6500	Ft	6500	Ft	Yes		No		@ NS		Ft

Line #	Dir.	Line Start Time	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 x No
1	w	14:33:00	14:36:00		15	0.7	1.3	
2	e	14:39:00	14:41:00		16	0.7	1.2	
3	w	14:45:00	14:48:00		16	0.7	1.2	
4	e	14:52:00	14:55:00		16	0.7	1.3	
5	w	14:58:00	15:01:00		16	0.7	1.3	
6	e	15:05:00	15:08:00		17	0.7	1.3	
7	w	15:12:00	15:24:00		17	0.7	1.3	
8	e	15:27:00	15:39:00		16	0.7	1.2	
9	w	15:42:00	15:54:00		16	0.7	1.3	
10	e	15:57:00	16:09:00		19	0.7	1.2	
11	w	16:12:00	16:24:00		18	0.7	1.3	
12	e	16:27:00	16:39:00		19	0.7	1.1	
13	w	16:43:00	16:56:00		19	0.7	1.1	
14	e	16:59:00	17:11:00		18	0.7	1.2	
15	w	17:14:00	17:28:00		18	0.7	1.5	
16	e	17:31:00	17:43:00		20	0.7	1.2	
17	w	17:47:00	18:01:00		21	0.7	1.1	** reboot system
17	w	18:28:00	18:42:00		20	0.7	1.2	
18	e	18:45:00	18:57:00		19	0.7	1.2	
19	w	19:00:00	19:14:00		18	0.7	1.3	
20	e	19:17:00	19:29:00		18	0.7	1.2	
21	w	19:33:00	19:47:00		15	0.7	1.2	
22	e	19:51:00	20:02:00		17	0.7	1.1	
23	w	20:06:00	20:20:00		16	0.7	1.2	
24	e	20:23:00	20:35:00		16	0.7	1.2	
25	w	20:39:00	20:52:00		16	0.7	1.2	
26	e	20:55:00	21:07:00		16	0.7	1.3	
				0:00:00				
↑ Times entered are Zulu / GMT ↑				Page		1		Verify S-Turns After Mission Yes x No

Additional Comments: | Drive #

** ais warning -sow is not being updated error-sc has not recieved proper recovery message(tm1b) from ins/gnss module

Woolpert

Leica LIDAR

MM/DD/YYYY	Day of Year	Project #	Phase #	Project Name
1/18/2016	18	76001		martin co

Operator	Aircraft	HOBBS Start	Local Start Time	ZULU Start Time	Base
SMITH	N7079F	235.8	9:08:00	14:08:00	

Pilot	Sensor Type	HOBBS Stop	Local End Time	Zulu End Time	FBO
GEBHART	OTHER	241.1	2:21:00	19:21:00	

Wind Dir/Speed	Visibility	Ceiling	Cloud Cover %	Temp	Dew Point	Pressure	Haze/Fire/Cloud	Departing	SUB
								Arriving	SUB

Scan Angle (FOV)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power %	Fixed Gain		Mode		Threshold Values	
40	51	545	100	Gain - Course/Up		Single		A	
				Gain - Fine/Down		Multi	x	B	

Air Speed		AGL		MSL		Waveform Used				Waveform Mode	Pre-Trigger Dist.
150	Kts	6500	Ft	6500	Ft	Yes		No		@ NS	Ft

Line #	Dir.	Line Start Time	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 x No
48	s	14:21:00	14:26:00		14	0.7	1.4	
49	n	14:30:00	14:35:00		15	0.7	1.3	
50	s	14:38:00	14:43:00		15	0.7	1.4	
51	n	14:45:00	14:48:00		15	0.7	1.4	
52	s	14:54:00	14:58:00		16	0.7	1.5	
53	n	15:01:00	15:05:00		16	0.7	1.5	
54	s	15:10:00	15:11:00		18	0.7	1.6	
55	n	15:14:00	15:16:00		18	0.7	1.1	
56	s	15:20:00	15:21:00		16	0.7	1.2	
38	w	15:24:00	15:25:00		16	0.7	1.3	
37	e	15:28:00	15:30:00		16	0.7	1.3	
36	w	15:34:00	15:36:00		16	0.7	1.3	
35	e	15:39:00	15:44:00		17	0.7	1.2	
34	w	15:47:00	15:52:00		17	0.7	1.2	
42	n	15:57:00	15:58:00		18	0.7	1.2	
43	s	16:02:00	16:03:00		17	0.7	1.3	
41	n	16:06:00	16:09:00		17	0.7	1.3	
40	s	16:11:00	16:15:00		17	0.7	1.3	
39	n	16:19:00	16:20:00		17	0.7	1.3	
46	s	16:22:00	16:25:00		18	0.7	1.1	
47	w	16:28:00	16:30:00		18	0.7	1.1	
44	e	16:33:00	16:35:00		18	0.7	1.1	
45	w	16:38:00	16:39:00		17	0.7	1.2	
27	e	16:45:00	16:58:00		18	0.7	1.2	
28	w	17:01:00	17:13:00		19	0.7	1.1	
29	e	17:16:00	17:29:00		22	0.7	1.1	
30	w	17:31:00	17:44:00		23	0.7	1.1	
31	e	17:46:00	18:00:00		24	0.7	1.1	
32	w	18:03:00	18:14:00		23	0.7	1.1	
33	e	18:17:00	18:28:00		21	0.7	1.1	
28	w	18:36:00	18:41:00	0:00:00	20	0.7	1.1	refit wp 40 to end
↑ Times entered are Zulu / GMT ↑				Page		1		Verify S-Turns After Mission Yes x No

Additional Comments:

** ais warning -sow is not being updated error-sc has not recieved proper recovery message(tm1b) from ins/gnss module

Drive #

Woolpert

Leica LIDAR	MM/DD/YYYY	Day of Year	Project #	Phase #	Project Name
	1/18/2016	18	76001	0	martin co

Operator	Aircraft	HOBBS Start	Local Start Time	Zulu Start Time	Base
Pilot	**Sensor Type**	**HOBBS End**	**Local End Time**	**Zulu End Time**	**FBO**

Wind Dir/Speed	Visibility	Ceiling	Cloud Cover %	Temp	Dew Point	Pressure	Haze/Fire/Cloud	Departing	
								Arriving	

Scan Angle (FOV)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power %	Fixed Gain		Mode		Threshold Values	
				Gain - Course/Up		Single		A	
				Gain - Fine/Down		Multi		B	

Air Speed		AGL		MSL		Waveform Used				Waveform Mode	Pre-Trigger Dist.
	Kts		Ft		Ft	Yes		No		@ NS	Ft

Line #	Dir.	Line Start Time	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
27	w	18:43:00	18:48:00	13:43:00	20	0.07	1.1	refit wp end to 40
29	e	18:49:00	18:54:00	0:00:00	19	0.07	1.3	refit wp 40 to end
30	w	18:57:00	19:01:00	0:00:00	19	0.07	1.2	refit wp end to 40
31	e	19:04:00	19:08:00	0:00:00	19	0.07	1.2	refit wp 40 to end
				0:00:00				
				0:00:00				
				0:00:00				
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↑ Times entered are Zulu / GMT ↑				Page		2		Verify S-Turns After Mission Yes No

Additional Comments:	Drive #

Woolpert

Leica LIDAR	MM/DD/YYYY	Day of Year	Project #	Phase #	Project Name
	1/23/2016	23	76001		martin co

Operator	Aircraft #	HOBBS Start	Local Start Time	Zulu Start Time	Base
SMITH	N7079F	241.1	5:44:00	22:44:00	
Pilot	**Sensor Type**	**HOBBS End**	**Local End Time**	**Zulu End Time**	**FBO**
GEBHART	OTHER	241.9	6:33:00	23:33:00	

Wind Dir/Speed	Visibility	Ceiling	Cloud Cover %	Temp	Dew Point	Pressure	Haze/Fire/Cloud	Departing	SUS
								Arriving	SUS

Scan Angle (FOV)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power %	Fixed Gain		Mode		Threshold Values	
40	51	545	100	Gain - Course/Up		Single		A	
				Gain - Fine/Down		Multi	x	B	

Air Speed		AGL		MSL		Waveform Used				Waveform Mode	Pre-Trigger Dist.	
150	Kts	6500	Ft	6500	Ft	Yes		No		@ NS		Ft

Line #	Dir.	Line Start Time	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 x No
28	e	22:56:00	22:58:00		20	0.7	1.1	refit
29	w	23:05:00	23:09:00		19	0.7	1.2	refit
29	e	23:11:00	23:13:00		19	0.7	1.2	refit
28	e	23:17:00	23:19:00		19	0.7	1.2	refit

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

Additional Comments: Drive #

** ais warning -sow is not being updated error-sc has not recieved proper recovery message(tm1b) from ins/gnss module

Section 7: Final Deliverables

The final lidar deliverables are listed below.

- LAS v1.4 classified point cloud
- LAS v1.4 raw unclassified point cloud flight line strips.
- Hydro Breaklines as ESRI Geodatabase
- Bridge Breaklines as ESRI Geodatabase
- Digital Elevation Model in ESRI Grid format
- 8-bit gray-scale intensity images in .TIF format
- Tile layout and data extent provided as ESRI shapefile
- Control Points provided as ESRI shapefile
- FGDC compliant metadata per product in XML format
- Lidar processing report in pdf format
- Survey report in pdf format