AIRBORNE LIDAR TASK ORDER REPORT

LONG ISLAND NEW YORK SANDY LIDAR
UNITED STATES GEOLOGICAL SURVEY (USGS)

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PROJECT REPORT

USGS LONG ISLAND NEW YORK SANDY LIDAR PROCESSING

WOOLPERT PROJECT #74257

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SECTION 1: OVERVIEW

PROJECT NAME: LONG ISLAND NEW YORK SANDY LIDAR

WOOLPERT PROJECT #74257

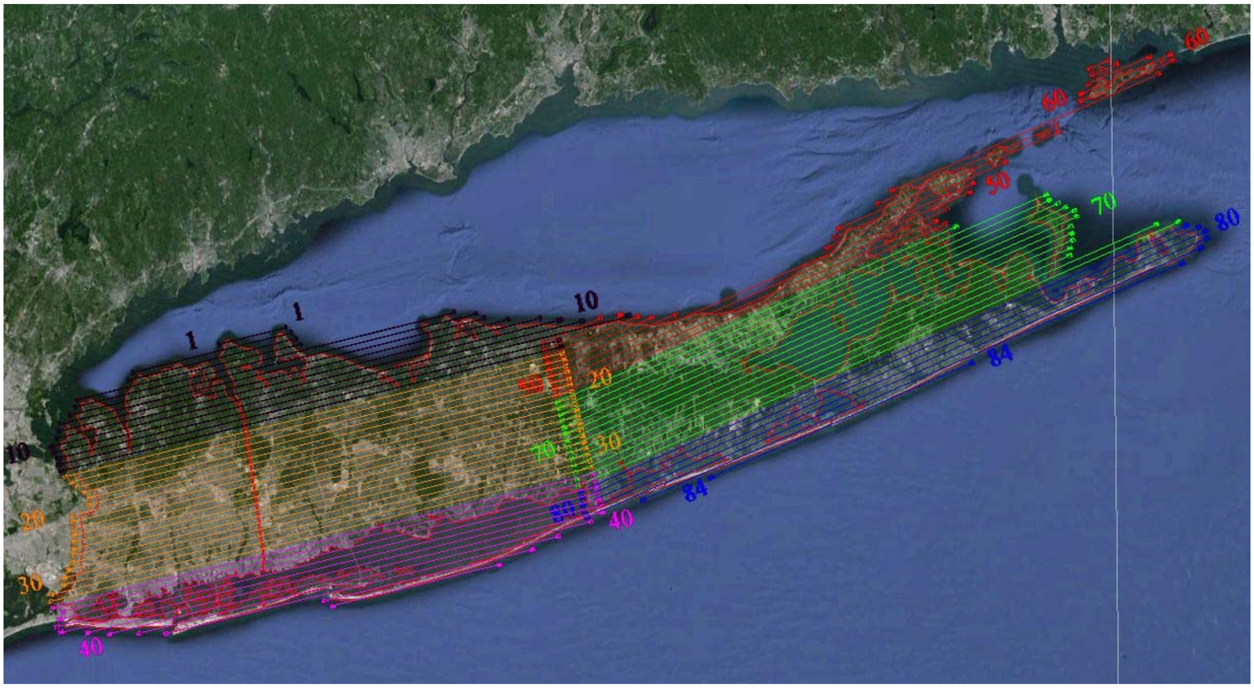
This report contains a comprehensive outline of the Long Island New York Sandy Lidar Processing task order for the United States Geological Survey (USGS). This task order requires lidar data to be acquired over two counties in New York State; Suffolk and Nassau. The total area of the Long Island Sandy Lidar AOI is approximately 1,225 square miles. The lidar was collected and processed to meet a maximum Nominal Post Spacing (NPS) of 0.7 meters. The NPS assessment is made against single swath, first return data located within the geometrically usable center portion (typically ~90%) of each swath. This acquisition was part of a larger effort designed to capture one other USGS task order AOI in New York

The data was collected using a Leica ALS70 500 kHz Multiple Pulses in Air (MPiA) lidar sensor installed in a Leica gyro-stabilized PAV30 mount. The ALS70 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:

Post Spacing (Minimum):	2.3 ft / 0.7m
AGL (Above Ground Level) average flying height:	7,500 ft / 2,286 m
MSL (Mean Sea Level) average flying height:	variable
Average Ground Speed:	150 knots / 173 mph
Field of View (full):	32 degrees
Pulse Rate:	239 kHz
Scan Rate:	41.6 Hz
Side Lap (Average):	25%

The AOI for this task order crosses UTM Zones 18 and 19. Tiles falling within either zone including any tile that contains the UTM boundary were provided in their appropriate UTM zones. With this in consideration, the lidar data was processed and projected in UTM, Zone 18, North American Datum of 1983 (2011) in units of meters as well as UTM, Zone 19, North American Datum of 1983 (2011) in units of meters. The vertical datum used for the task order was referenced to NAVD 1988, GEOID12A, in units of meters.

Figure 1.1 Lidar Task Order AOI



SECTION 2: ACQUISITION

The existing lidar data was acquired with a Leica ALS70 500 kHz Multiple Pulses in Air (MPiA) lidar sensor system, on board a Cessna 404 and Cessna 310 aircraft. The ALS70 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 OC50 Operation Controller aboard the aircraft.

Table 2.1: ALS70 Lidar System Specifications

The ALS70 500 kHz Multiple Pulses in Air (MPiA) Lidar System has the following specifications:

Specification	
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 seven (7) separate missions, flown as close together as the weather permitted, to ensure consistent ground conditions across the project area. Some missions of this acquisition were part of a larger effort designed to capture one other USGS task order AOI in New York.

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: Long Island New York Sandy Lidar

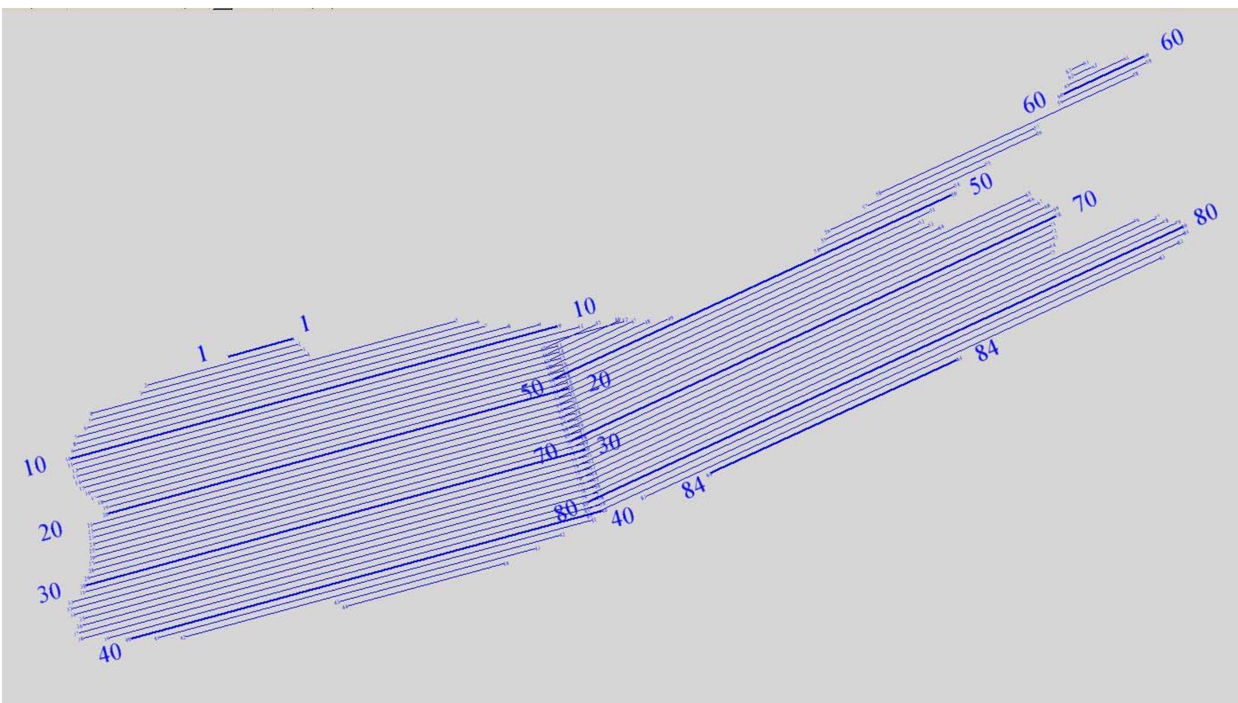


Table 2.2: Airborne Lidar Acquisition Flight Summary

Airborne Lidar Acquisition Flight Summary			
Date of Mission	Lines Flown	Mission Time (UTC) Wheels Up/ Wheels Down	Mission Time (Local = EDT) Wheels Up/ Wheels Down
April 3, 2014 – Sensor 7108	1-22	10:45-17:36	6:45AM-1:36PM
April 6, 2014 – Sensor 7108 A	23-32	10:24 – 20:14	08:24AM – 4:14PM
April 6, 2014 – Sensor 7108 B	33-44	00:34 - 01:20	8:34PM – 9:20PM
April 7, 2014 – Sensor 7108	45-49, 54-64	20:05 – 22:44	4:05PM – 6:44PM
April 10, 2014 – Sensor 7108	50-53, 65-75	14:40 – 22:03	12:40PM – 6:03PM
April 12, 2014 – Sensor 7108	23, 26, 76-84	15:40 – 00:24	11:40AM – 8:24PM
April 21, 2014 – Sensor 7177	76-77	16:08 – 16:49	12:08PM – 4:49PM

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. 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 mission, and 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.

Woolpert's acquisition team was on site, operating GNSS base stations at the Trenton Mercer Airport (KTTN), along with utilizing NJJ2, NJTP, NYBP, and NJTR CORS stations.

The GNSS base station operated during the lidar acquisition missions are listed below:

Table 3.1: GNSS Base Station

Station	Latitude	Longitude	Ellipsoid Height (L1 Phase center)
Name	(DMS)	(DMS)	(Meters)
KTTN Airport	40°16'51.15372"	74°48'34.15158"	25.786
NJTR CORS	40°15'27.46258"	74°47'48.07184"	41.360
NYCI CORS	40°45'38.23688"	73°11'51.78728"	-13.783
KGON Airport	41°20'03.47125"	72°02'38.36448"	-27.610
CTGR CORS	41°20'07.03552"	72°02'58.96932"	-18.342
KGON Airport	41°20'03.47125"	72°02'38.36448"	-27.610
ZNY1 CORS	40°47'03.54973"	73°05'49.78083"	7.709
NYCI CORS	40°45'38.23688"	73°11'51.78728"	-13.783

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

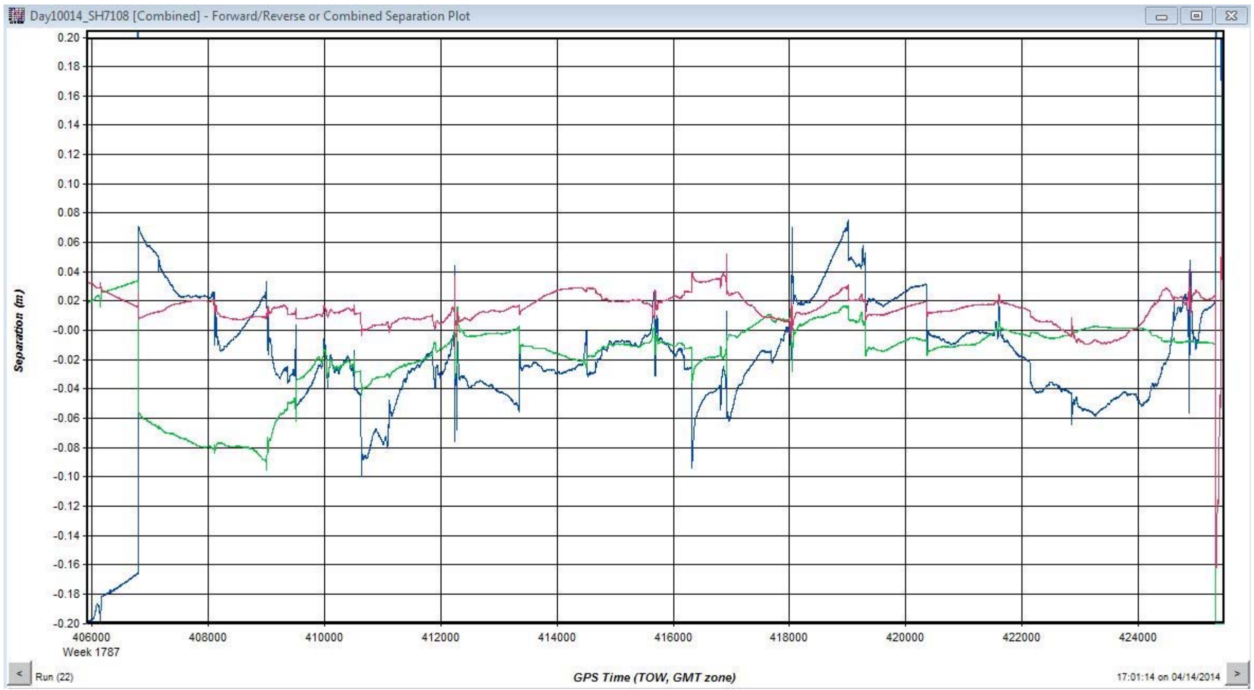
The GNSS Trajectory, along with high quality IMU data are key factors in determining the overall positional accuracy of the final sensor data. Within the trajectory processing, there are many factors that affect the overall quality, but the most indicative are the Combined Separation, the Estimated Positional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

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 3.1: Combined Separation, Day10014 SH7108

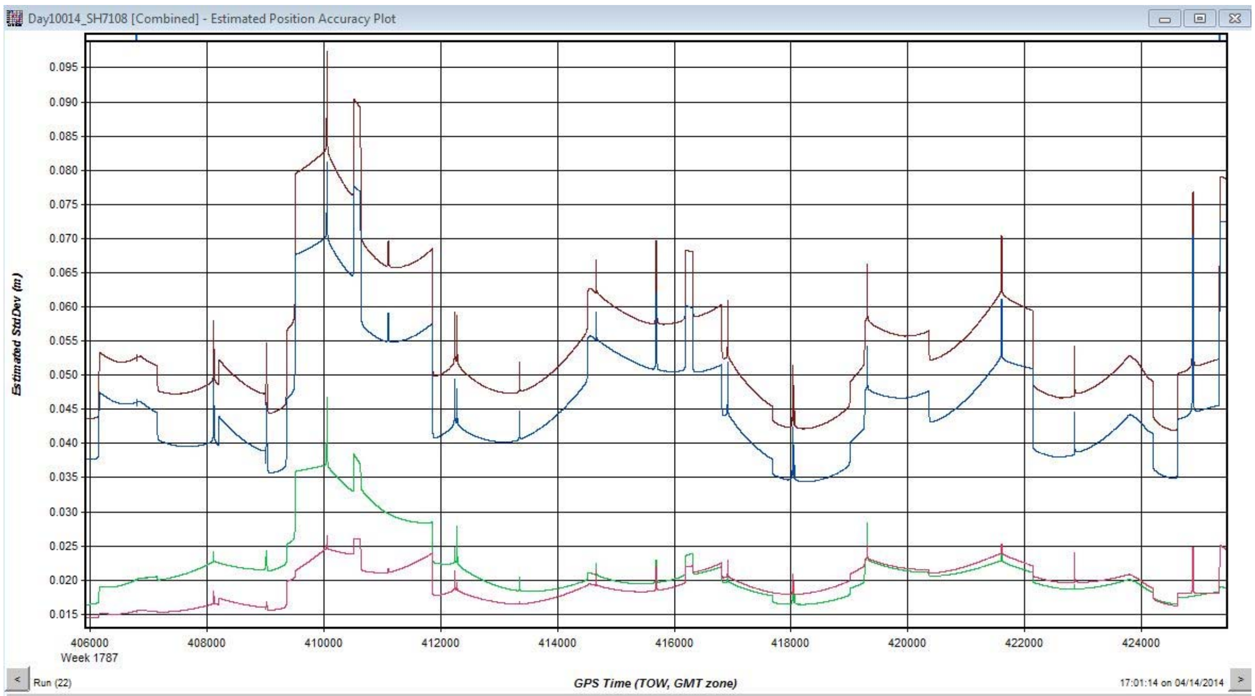


Estimated Positional Accuracy

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 3.2: Estimated Positional Accuracy, Day10014 SH7108

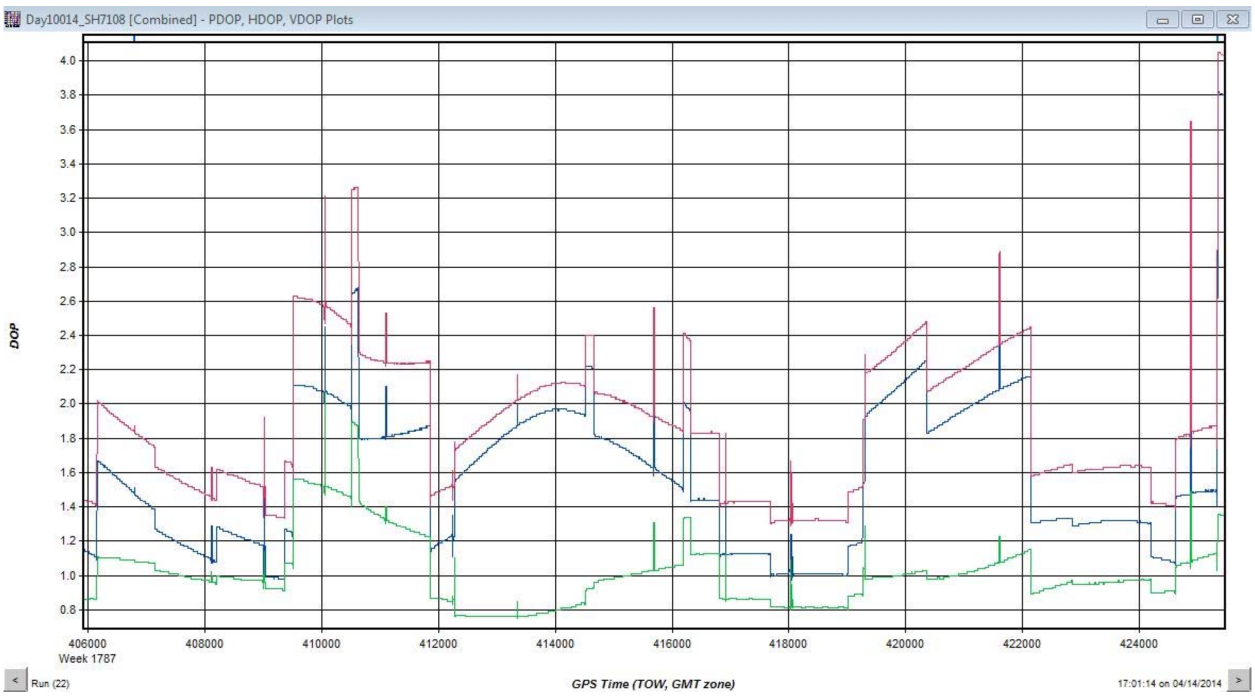


PDOP

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 3.3: PDOP, Day10014 SH7108



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.

SECTION 4: HYDROLOGIC FLATTENING

HYDROLOGIC FLATTENING OF LIDAR DEM DATA

Long Island New York 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-acres 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 30.5 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-acres or greater and streams at a minimum size of 30.5 (100 feet) nominal width, were compiled to meet task order requirements. **Figure 4.1** illustrates an example of 30.5 meters (100 feet) nominal streams identified and defined with hydrologic breaklines. The breaklines defining rivers and streams, at a nominal minimum width of 30.5 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

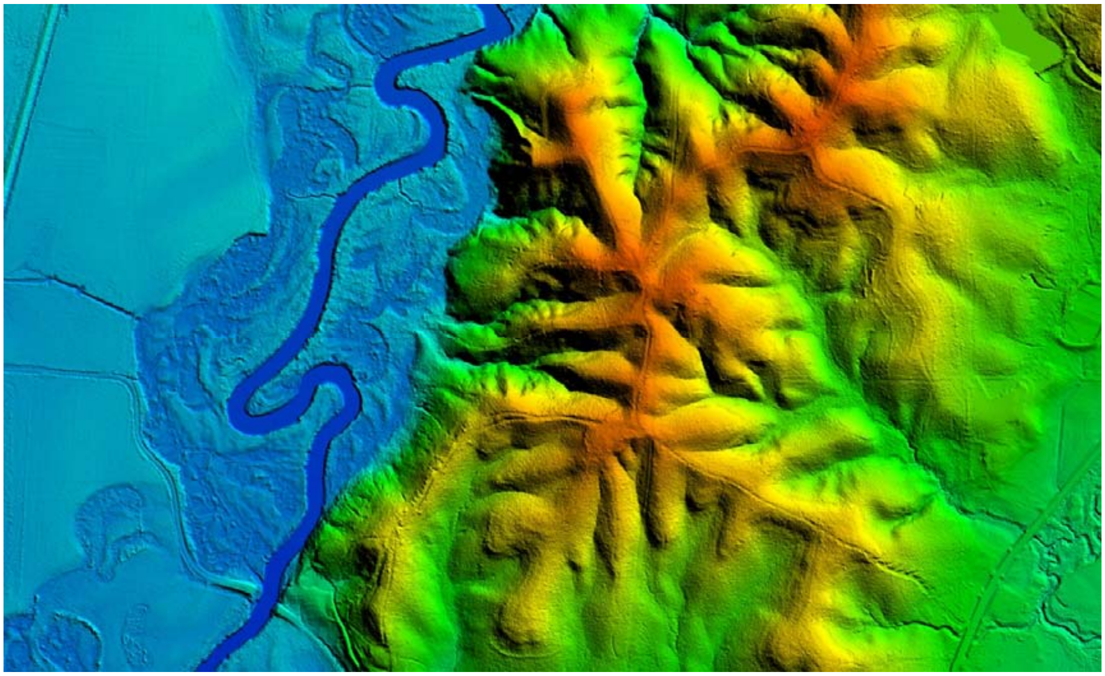
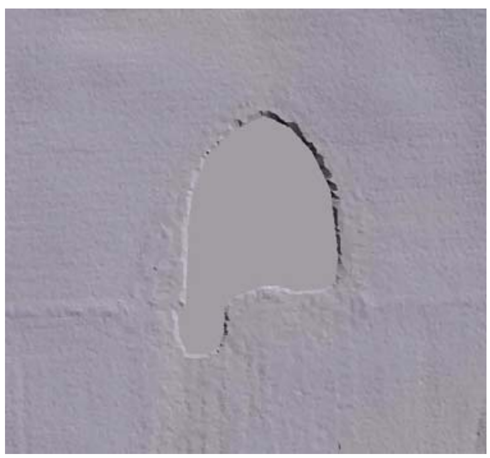


Figure 4.2 reflects a DEM generated from original lidar bare earth point data prior to the hydrologic flattening process. Note the "tinning" across the lake surface.

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 USGS in ERDAS .IMG format at a 1-meter cell size.

The hydrologic breaklines compiled as part of the flattening process were provided to the USGS as an ESRI shapefile. The breaklines defining the water bodies greater than 2-acres were provided as a PolygonZ file. The breaklines compiled for the gradient flattening of all rivers and streams at a nominal minimum width of 30.5 meters (100 feet) were provided as a PolylineZ file.

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: FINAL ACCURACY ASSESSMENT

FINAL VERTICAL ACCURACY ASSESSMENT

The vertical accuracy statistics were calculated by comparison of the lidar bare earth points to the ground surveyed quality check points.

Table 5.1: Overall Vertical Accuracy Statistics

Average error	0.022	meters
Minimum error	-0.07	meters
Maximum error	0.12	meters
Root mean square	0.058	meters
Standard deviation	0.055	meters

Table 5.2: Swath Quality Check Point Analysis, FVA, UTM 18N, NAD83, NAVD88 GEOID12A, Long Island New York Sandy Lidar

Point ID	Easting (UTM meters)	Northing (UTM meters)	TIN Elevation (meters)	Dz (meters)
2001	750404.7	4571625	11.75	0.07
2002	752972.5	4573956	5.05	0.1
2003	722416.3	4557223	14.48	0.12
2004	710791.1	4543864	8.85	0
2005	673331.1	4534535	43.89	-0.03
2006	646920.7	4526114	36.99	-0.01
2007	628161.6	4533425	1.85	0.04
2008	623775.5	4524734	17.27	-0.04
2009	609287.5	4516218	7.1	0.09
2010	613910.7	4508129	23.23	0.04
2011	615819.1	4499581	3.61	-0.03
2012	649349.2	4499156	4.75	0.06
2013	679613.3	4512127	0.87	0.05
2014	674866.6	4528218	28.33	-0.05

Point ID	Easting (UTM meters)	Northing (UTM meters)	TIN Elevation (meters)	Dz (meters)
2015	726714.7	4532367	5.7	0.02
2016	756925.7	4551270	2.17	0.06
2017	727346.9	4542257	0.71	0.06
2018	711091.5	4529918	13.81	0.04
2019	654411.1	4507981	1.24	-0.06
2020	679918.8	4518948	17.47	-0.07
2021	639589.7	4530844	12.21	0

VERTICAL ACCURACY CONCLUSIONS

LAS Swath Fundamental Vertical Accuracy (FVA) Tested 0.113 meters 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.

Bare-Earth DEM Fundamental Vertical Accuracy (FVA) Tested 0.115 meters 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: Quality Check Point Analysis, Urban, UTM 18N, NAD83, NAVD88 GEOID12A, Long Island New York Sandy Lidar

Point ID	Easting (UTM meters)	Northing (UTM meters)	DEM Elevation (meters)	Abs. Dz (meters)
3001	750665.890	4571937.67	1.79	0.06
3002	752758.990	4573691.15	4.8	0.13
3003	722425.180	4557213.8	14.6	0.05
3004	711542.420	4542960.31	8.74	0.08
3005	673316.400	4534650.74	43.58	0.05
3006	647121.610	4527110.9	50.82	0.1

Point ID	Easting (UTM meters)	Northing (UTM meters)	DEM Elevation (meters)	Abs. Dz (meters)
3007	632586.790	4525974.69	9.11	0.13
3008	623479.930	4523924.16	27.55	0.07
3009	610405.490	4516525.37	33.45	0
3010	613349.190	4506977.69	15.69	0.05
3011	614977.380	4499596.41	3.96	0.07
3012	647294.110	4500060.38	5.2	0
3013	679680.140	4513340.82	2.31	0.14
3014	674899.880	4528243.83	28.09	0.04
3015	726687.850	4532383.13	5.69	0.07
3016	757089.580	4551641.84	2.72	0.05
3017	727358.030	4542427.64	1.27	0.01
3018	710608.960	4529969.19	1.95	0.01
3019	653997.900	4510812.55	6.19	0.14
3020	679956.030	4518966.37	16.95	0.17
3021	638799.980	4531071.62	2.4	0.12

ACCURACY CONCLUSIONS

Urban Land Cover Classification Supplemental Vertical Accuracy (SVA) Tested 0.140 meters 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 3020, Easting 679956.03, Northing 4518966.37, Z-Error 0.17 meters

Table 5.4: Quality Check Point Analysis, Tall Weeds and Crops, UTM 18N, NAD83, NAVD88 GEOID12A, Long Island New York Sandy Lidar

Point ID	Easting (UTM meters)	Northing (UTM meters)	DEM Elevation (meters)	Abs. Dz (meters)
4001	750475.570	4571674.22	17.27	0.13
4002	752938.260	4573922.4	4.35	0.15
4003	722513.640	4556877.22	15.02	0.09
4004	710740.300	4543982.29	8.34	0
4005	674194.530	4534706.77	42.07	0.07
4006	646495.640	4525745.34	28.79	0.01
4007	628259.310	4532293.21	12.4	0.08
4008	623841.580	4520583.03	74.68	0.02
4009	609359.840	4515788.89	8.78	0.05
4010	613933.380	4508100.11	22.96	0.02
4011	619668.600	4494362.8	2.24	0.11
4012	649426.640	4499147.26	4.68	0.04
4013	679602.140	4512117.31	0.91	0.15
4014	674715.040	4528143.29	26.56	0.07
4015	726652.490	4532377.75	5.78	0.04
4016	725948.460	4537985.62	35.46	0.01
4017	725364.290	4537652.39	37.51	0.13
4018	701356.920	4525947.91	24.69	0.03
4019	654312.690	4509242.25	4.32	0.08
4020	678908.730	4520730.57	22.11	0.04
4021	639604.980	4530891.19	12.1	0.06

ACCURACY CONCLUSIONS

Tall Weeds/Crops Land Cover Classification Supplemental Vertical Accuracy (SVA) Tested 0.150 meters supplemental vertical accuracy at the 95th percentile in the Tall Weeds/Crops supplemental class reported using National Digital Elevation Program (NDEP)/ASPRS Guidelines and tested against the DEM. There were no Tall Weeds/Crops Errors exceeding the 95th percentile. Tall Weeds/Crops Errors at the 95th percentile include:

- Point 4002, Easting 752938.26, Northing 4573922.4, Z-Error 0.15 meters
- Point 4013, Easting 679602.14, Northing 4512117.31, Z-Error 0.15 meters

Table 5.5: Quality Check Point Analysis, Brush Lands and Trees, UTM 18N, NAD83, NAVD88 GEOID12A, Long Island New York Sandy Lidar

Point ID	Easting (UTM meters)	Northing (UTM meters)	DEM Elevation (meters)	Abs. Dz (meters)
5001	750579.850	4571955.79	1.17	0.27
5002	752990.610	4573964.21	4.66	0.25
5003	722515.930	4556907.17	15.18	0.04
5004	710831.570	4543982.26	6.77	0.06
5005	674188.450	4534664.32	41.91	0.04
5006	646562.550	4525744.2	30.81	0.02
5007	628290.210	4532276.32	14.32	0.15
5008	623857.510	4520596.08	74.22	0.07
5009	609606.030	4515885.25	7.39	0.21
5010	618417.260	4494423.78	2.3	0.25
5011	618694.220	4494430.02	2.19	0.13
5012	649373.700	4499200.63	4.53	0.06
5013	679628.160	4512117.44	0.74	0.19
5014	674688.510	4528163.97	26.24	0.02
5015	726391.450	4530942.01	5.06	0.04
5016	757041.740	4551665.66	3.78	0.1
5017	725629.620	4537785.85	33.9	0.05

Point ID	Easting (UTM meters)	Northing (UTM meters)	DEM Elevation (meters)	Abs. Dz (meters)
5018	701336.850	4525963.42	25.19	0.04
5019	654266.140	4507970.09	0.89	0.03
5020	678818.930	4520766.26	22.69	0.09
5021	639584.870	4530941.97	12.35	0.04

ACCURACY CONCLUSIONS

Brush Lands and Trees Land Cover Classification Supplemental Vertical Accuracy (SVA) Tested 0.250 meters supplemental vertical accuracy at the 95th percentile in the Brush Lands and Trees supplemental class reported using National Digital Elevation Program (NDEP)/ASPRS Guidelines and tested against the DEM. Brush Lands and Trees Errors larger than 95th percentile include:

- Point 5001, Easting 750579.85, Northing 4571955.79, Z-Error 0.27 meters

Table 5.6: Quality Check Point Analysis, Forested and Fully Grown, UTM 18N, NAD83, NAVD88 GEOID12A, Long Island New York Sandy Lidar

Point ID	Easting (UTM meters)	Northing (UTM meters)	DEM Elevation (meters)	Abs. Dz (meters)
6001	750436.970	4571612.95	17.84	0.16
6002	752924.330	4573968.83	4.91	0.21
6003	722453.250	4556836.2	15.69	0.15
6004	710778.970	4543978.22	7.9	0
6005	674166.440	4534689.37	42.15	0.1
6006	646434.010	4525722.8	28.76	0.03
6007	628225.350	4533326.61	8.73	0.13
6008	623867.780	4520575.67	73.94	0.02
6009	609607.000	4515902.66	7.7	0.01
6010	679535.690	4514083.23	4.19	0.01
6011	679550.260	4514085.29	4.1	0.03

Point ID	Easting (UTM meters)	Northing (UTM meters)	DEM Elevation (meters)	Abs. Dz (meters)
6012	679542.520	4514108.73	4.23	0.01
6013	679526.050	4514109.21	4.16	0
6014	674717.440	4528169.23	27.86	0.04
6015	654519.510	4507928.81	1.1	0.1
6016	757102.040	4551570.91	2.79	0.11
6017	726002.250	4538016.13	35.13	0.1
6018	701324.230	4525970.63	25.21	0.07
6019	654249.570	4507998.32	0.82	0.07
6020	678897.720	4520786.96	22.07	0.07
6021	639631.620	4530855.81	12.87	0.06

ACCURACY CONCLUSIONS

Forested and Fully Grown Land Cover Classification Supplemental Vertical Accuracy (SVA) Tested 0.160 meters supplemental vertical accuracy at the 95th percentile in the Forested/Fully Grown supplemental class reported using National Digital Elevation Program (NDEP)/ASPRS Guidelines and tested against the DEM. Forested/Fully Grown Errors larger than 95th percentile include:

- Point 6002, Easting 752924.33, Northing 4573968.83, Z-Error 0.21 meters

CONSOLIDATED VERTICAL ACCURACY ASSESSMENT

ACCURACY CONCLUSIONS

Consolidated Vertical Accuracy (CVA) Tested 0.186 meters 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 5001, Easting 750579.85, Northing 4571955.79, Z-Error 0.27 meters
- Point 5002, Easting 752990.61, Northing 4573964.21, Z-Error 0.25 meters
- Point 5009, Easting 609606.03, Northing 4515885.25, Z-Error 0.21 meters
- Point 5010, Easting 618417.26, Northing 4494423.78, Z-Error 0.25 meters
- Point 5013, Easting 679628.16, Northing 4512117.44, Z-Error 0.19 meters
- Point 6002, Easting 752924.33, Northing 4573968.83, Z-Error 0.21 meters

Approved By:			
Title	Name	Signature	Date
Associate Lidar Specialist Certified Photogrammetrist #1281	Qian Xiao		November 2014

SECTION 6: FLIGHT LOGS

FLIGHT LOGS

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

WOOLPERT FLIGHT LOG SHEET #1

Leica ALS-70	MM/DD/YYYY	Day of Year	Mission Name / Job #
	4/3/2014	93	74257

Operator	Aircraft	Sensor	Hobbs Start	Local Start Time	Zulu Start Time
Annen	N475RC [X], N404CP [ ], N7079F [ ], N475CP [ ], N1107Q [ ]	SH-7177 [ ], SH_6157 [ ], SH-7108 [X]	5029	645	10:45
Pilot			**Hobbs End**	**Local End Time**	**Zulu End Time**
Albers			5035.6	13:36	17:36

Passengers	Using or Relying on CORS	GPS Base #1	Operator	PID
Simmons	Yes [ ] No [X]		Annen	KTTN
		GPS Base #2	Operator	PID

Wind Dir/Speed	Visibility	Ceiling	Cloud Cover %	Temp	Dew Point	Pressure	Haze/Fire/Cloud	Departing ICAO / Arriving ICAO
Calm	10/Clr	fw 8k	80	9	1	30.1		

Scan Angle (FOV)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power %	Gain	Mode
32	41.6	239	100	Course/Up ___ Fine/Down ___	Single [ ] Multi [ ] 2+2 [ ] 4+3 [ ]

Air Speed	AGL	MSL	Threshold	Waveform Mode	Pre-Trigger Dist.
150 Kts	7500 Ft	7500 Ft	/	@ 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 [ ]
A01	E	11:27:00	11:29:00					
A02	W	11:31:00	11:36:00					
A03	E	11:39:00	11:44:00					
A04	W	11:47:00	11:54:00					
A05	E	11:56:00	12:07:00					
A06	W	12:09:00	12:22:00					
A07	E	12:24:00	12:38:00					Manual start, UL001
A08	W	12:40:00	12:55:00					
A09	E	12:57:00	13:12:00					
A10	W	13:14:00	13:30:00					
A11	E	13:32:00	13:48:00					
A12	W	13:52:00	14:09:00					
A13	E	14:12:00	14:27:00					
A14	W	14:30:00	14:45:00					
A15	E	14:47:00	15:03:00					
A16	W	15:05:00	15:20:00					
A17	E	15:22:00	15:38:00					
A18	W	15:41:00	15:56:00					
A19	E	15:58:00	16:12:00					
A20	W	16:15:00	16:29:00					
A21	E	16:38:00	16:54:00					
A22	W	16:57:00	17:12:00					Manual start line UL002
† Times entered are Zulu / GMT †				0:00:00	Total Time On Line			Verify S-Turns After Mission Yes [ ] No [ ]

Additional Comments: System required 2 manual starts. GUI screen locked up several times in flight. Seems like a buffer issue.

Drive #

WOOLPERT FLIGHT LOG SHEET #1

Leica ALS-70	MM/DD/YYYY	Day of Year	Mission Name / Job #
	4/6/2014	96	74257

Operator	Annen	Pilot	Albers
Passengers			
Aircraft	N475RC [X], N404CP [ ], N7079F [ ], N475CP [ ], N1107Q [ ]	Sensor	SH-7177 [ ], SH_6157 [ ], SH-7108 [X]
Hobbs Start	5035.6	Hobbs End	5042.2
Local Start Time	6:24	Local End Time	16:14
Zulu Start Time	10:24	Zulu End Time	20:14
Using or Relying on CORS	Yes [ ] No [X]		
GPS Base #1	Operator: Annen	PID	KTTN
GPS Base #2	Operator: NYCI	PID	DI0446

Wind Dir/Speed	Visibility	Ceiling	Cloud Cover %	Temp	Dew Point	Pressure	Haze/Fire/Cloud	Departing ICAO / Arriving ICAO
320/9	10	Clr	0	34f	21f	30.17		

Scan Angle (FOV)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power %	Gain	Mode
32	41.6	239	100	Course/Up —; Fine/Down —	Single [ ] Multi [ ] 2+2 [ ] 4+3 [ ]

Air Speed	AGL	MSL	Threshold	Waveform Mode	Pre-Trigger Dist.
150 Kts	7500 Ft	7500 Ft	/	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 [ ]
C42	N	10:57:00	11:04:00					New York
C43	S	11:09:00	11:10:00					
C44	N	11:12:00	11:14:00					
C45	S	11:16:00	11:18:00					
C4	E	11:33:00	11:37:00					
B67	S	11:43:00	11:50:00					
B68	N	11:53:00	12:02:00					
B69	S	12:05:00	14:14:00					
A42	S	12:16:00	12:25:00					
A43	N	12:28:00	12:37:00					
A44	S	12:39:00	12:48:00					
A45	N	12:51:00	13:00:00					
A77	N	13:11:00	13:20:00					
								Long Island
23	E	13:31:00	13:47:00					
24	W	13:49:00	14:05:00					
25	E	14:07:00	14:22:00					
26	W	14:25:00	14:40:00					
27	E	14:42:00	14:57:00					
28	W	15:00:00	15:16:00					
29	E	15:18:00	15:34:00					
30	W	15:37:00	15:53:00					
31	E	15:56:00	16:12:00					MANUAL START UL001
32	W	16:14:00	16:31:00					
31	E	16:34:00	16:35:00					GAP FILL
C2	W	16:41:00	16:44:00					NEW YORK
C3	E	16:46:00	16:49:00					
† Times entered are Zulu / GMT †				0:00:00 Total Time On Line				Verify S-Turns After Mission Yes [ ] No [ ]

Additional Comments:	Drive #

WOOLPERT FLIGHT LOG SHEET #1

Leica ALS-70	MM/DD/YYYY	Day of Year	Mission Name / Job #
	4/6/2014	96	74257

Operator	Aircraft	Sensor	Hobbs Start	Local Start Time	Zulu Start Time
Annen	N475RC X	SH-7177	5042.2	20:34	0:34
Pilot	N404CP	SH_6157	**Hobbs End**	**Local End Time**	**Zulu End Time**
Albers	N7079F	SH-7108 X	5047	21:20	1:20
	N475CP				
	N1107Q				

Passengers	Using or Relying on CORS	GPS Base #1	Operator	Annen	PID	KTNN
	Yes ☐ No X	GPS Base #2	Operator	NYCI	PID	D10446

Wind Dir/Speed	Visibility	Ceiling	Cloud Cover %	Temp	Dew Point	Pressure	Haze/Fire/Cloud	Departing ICAO / Arriving ICAO
var/6	10	clr	0	14c	6	30.16		

Scan Angle (FOV)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power %	Gain	Mode
32	41.6	239	100	Course/Up ___ Fine/Down ___	Single ☐ Multi ☐ 2+2 ☐ 4+3 ☐
Air Speed	**AGL**	**MSL**	**Threshold**	**Waveform Mode**	**Pre-Trigger Dist.**
150 Kts	7500 Ft	7500 Ft	/		Ft

Line #	Dir.	Line Start Time	Line End Time	Time On Line	SV's	HDOP	PDOP	Line Notes/Comments
Test	n/a	21:39:00	21:41:00	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 ☐
33	E	21:45:00	22:01:00					Inflight restart TDC error
34	W	22:04:00	22:20:00					
35	E	22:23:00	22:39:00					
36	W	22:41:00	22:57:00					
37	E	22:59:00	23:16:00					
38	W	23:18:00	23:34:00					
39	E	23:37:00	23:53:00					
40	W	23:55:00	0:10:00					
41	E	0:13:00	0:27:00					
42	W	0:30:00	0:42:00					
43	E	0:47:00	0:54:00					
44	W	0:57:00	1:02:00					
		† Times entered are Zulu / GMT †		0:00:00	Total Time On Line			Verify S-Turns After Mission Yes X No ☐

Additional Comments:
We had an ALS warning Fetch Data TDC error at the start of our first line. We did an inflight restart and overflew CORS PID D10446
The test fire showed that everything was working correctly so we continued the mission.

Drive #

WOOLPERT FLIGHT LOG SHEET #1

Leica ALS-70	MM/DD/YYYY	Day of Year	Mission Name / Job #
	04/07/2-14	97	74257

Operator	Aircraft	Sensor	Hobbs Start	Local Start Time	Zulu Start Time
Annen	N475RC X	SH-7177	5047.9	16:05	20:05
	N404CP	SH_6157			
	N7079F	SH-7108 X			
	N475CP				
	N1107Q				
Pilot			**Hobbs End**	**Local End Time**	**Zulu End Time**
Albers			5050.1	18:44	22:44

Passengers	Using or Relying on CORS	GPS Base #1	Operator	PID
	Yes [ ] No [X]		ANNEN	KGON
		GPS Base #2	Operator	PID

Wind Dir/Speed	Visibility	Ceiling	Cloud Cover %	Temp	Dew Point	Pressure	Haze/Fire/Cloud	Departing ICAO / Arriving ICAO
210/4	8	9k	100	8	3	30.24		

Scan Angle (FOV)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power %	Gain	Mode
32	41.6	239	100	Course/Up — Fine/Down —	Single [ ] 2+2 [ ] Multi [ ] 4+3 [ ]

Air Speed	AGL	MSL	Threshold	Waveform Mode	Pre-Trigger Dist.
150 Kts	7500 Ft	7500 Ft	/	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 [ ]
63	E	16:31:00	16:31:00					
62	W	16:34:00	16:35:00					
61	E	16:37:00	16:39:00					
60	W	16:42:00	16:45:00					
59	E	16:47:00	16:50:00					
58	W	16:54:00	17:02:00					
57	E	17:06:00	17:11:00					
56	W	17:14:00	17:21:00					
55	E	17:25:00	17:31:00					
54	W	17:34:00	17:39:00					
49	W	17:44:00	17:48:00					
48	E	17:50:00	17:54:00					
47	W	17:57:00	18:00:00					
46	E	18:03:00	18:06:00					
45	W	18:09:00	18:11:00					
64	E	18:15:00	18:28:00					
↑ Times entered are Zulu / GMT ↑				0:00:00 Total Time On Line				Verify S-Turns After Mission Yes [X] No [ ]

Additional Comments: EVERYTHING WORKED FINE TODAY, NO ISSUES

Drive #

WOOLPERT FLIGHT LOG SHEET #1

Leica ALS-70	MM/DD/YYYY	Day of Year	Mission Name / Job #
	4/10/2014	100	73714

Operator	Aircraft	Sensor	Hobbs Start	Local Start Time	Zulu Start Time
Annen	N475RC X N404CP N7079F N475CP N1107Q	SH-7177 SH_6157 SH-7308 X	5050.1	12:40	14:40
Pilot			**Hobbs End**	**Local End Time**	**Zulu End Time**
Swain			5055.3	18:03	22:03

Passengers	Using or Relying on CORS			
	Yes ☐ No X	GPS Base #1	Operator Annen	PID KGON
		GPS Base #2	Operator	PID

Wind Dir/Speed	Visibility	Ceiling	Cloud Cover %	Temp	Dew Point	Pressure	Haze/Fire/Cloud	Departing ICAO / Arriving ICAO
9	10	Clear	0	9	-2	30.21		

Scan Angle (FOV)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power %	Gain	Mode
32	41.6	239	100	Course/Up ___ Fine/Down ___	Single ☐ 2+2 ☐ Multi ☐ 4+3 ☐
Air Speed	**AGL**	**MSL**	**Threshold**	**Waveform Mode**	**Pre-Trigger Dist.**
150 Kts	7500 Ft	7500 Ft	/	@ 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 ☐
50	W	17:05:00	17:20:00					
51	E	17:23:00	17:36:00					
52	W	17:38:00	17:52:00					
53	E	17:54:00	18:08:00					
65	W	18:12:00	18:29:00					
66	E	18:32:00	18:47:00					
67	W	18:50:00	19:07:00					
68	E	19:10:00	19:26:00					
69	W	19:29:00	19:47:00					
70	E	19:49:00	20:05:00					
71	W	20:08:00	20:26:00					
72	E	20:28:00	20:44:00					
73	W	20:47:00	21:04:00					
74	E	21:07:00	21:22:00					
75	E	21:25:00	21:42:00					
† Times entered are Zulu / GMT †				0:00:00 Total Time On Line				Verify S-Turns After Mission Yes X No ☐

Additional Comments:	Drive #
Everything worked fine	

WOOLPERT FLIGHT LOG SHEET #1

Leica ALS-70	MM/DD/YYYY	Day of Year	Mission Name / Job #
	4/12/2014	102	73714

Operator	Aircraft	Sensor	Hobbs Start	Local Start Time	Zulu Start Time
Annen	N475RC [X] N404CP [ ] N7079F [ ] N475CP [ ] N1107Q [ ]	SH-7177 [ ] SH_6157 [ ] SH-7308 [X]	5055.3	11:40	15:40
Pilot			**Hobbs End**	**Local End Time**	**Zulu End Time**
Swain			5059.8	20:24	0:24

Passengers	Using or Relying on CORS	GPS Base #1	Operator	PID
	Yes [ ] No [X]		Annen	KGON
		GPS Base #2	Operator	PID

Wind Dir/Speed	Visibility	Ceiling	Cloud Cover %	Temp	Dew Point	Pressure	Haze/Fire/Cloud	Departing ICAO / Arriving ICAO
Var/5	10	Clear	0	17	1	30.2		

Scan Angle (FOV)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power %	Gain	Mode
32	41.6	239	100	Course/Up ___ Fine/Down ___	Single [ ] 2+2 [ ] Multi [ ] 4+3 [ ]

Air Speed	AGL	MSL	Threshold	Waveform Mode	Pre-Trigger Dist.
150 Kts	7500 Ft	7500 Ft	/	@ 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 [ ]
76	W	16:07:00	16:27:00					
77	E	16:30:00	16:50:00					
78	W	16:53:00	17:14:00					
79	E	17:17:00	17:37:00					
80	W	17:40:00	18:03:00					
81	E	18:05:00	18:26:00					
82	W	18:29:00	18:52:00					
83	E	18:56:00	19:14:00					
84	W	19:25:00	19:33:00					
26	W	19:40:00	19:42:00					
23	W	19:50:00	19:52:00					
† Times entered are Zulu / GMT †				0:00:00 Total Time On Line				Verify S-Turns After Mission Yes [ ] No [ ]

Additional Comments:	Drive #

Woolpert

Leica LIDAR	4/21/2014	111	74257	2	Long Island, NY
GALAMBOS	N111SD	2550.4	12:08:00	16:08:00	CORS
LaROCQUE	ALS-7177	2552.0	12:49:00	16:49:00	2NY1

Wind Dir/Speed	Visibility	Ceiling	Cloud Cover %	Temp	Dew Point	Pressure	Haze/Fog/Cloud		
calm	10	clear		11	2	30.18		Departing	KHYA
								Arriving	KHYA

Scan Angle (FOV)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power %	Fixed Gain		Mode		Threshold Values	
32	41.6	239	100	Gain - Course/Up	6	Single		A	180
				Gain - Fine/Down	12	Multi	X	B	170

Air Speed		AGL		MSL		Waveform Used				Waveform Mode		Pre-Trigger Dist.	
150	Kts	7500	Ft	7420	Ft	Yes		No	X	@	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 Begun Logging At:	15:05z
↓ Times entered are Zulu / GMT ↓								Verify S-Turns Before Mission	Yes X No
				0:00:00				Take off: 15:10z	
				0:00:00				Overfly CORS: 16:01:28	
76	E	16:08:05	16:26:25	0:00:00	14	0.7	1.3		
77	W	16:29:36	16:48:50	0:00:00	14	0.8	1.2	Overfly CORS: 16:52:35	
				0:00:00				LANDING HYA: 1:43 EDT	
				0:00:00					
				0:00:00					
				0:00:00					
				0:00:00					
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↑ Times entered are Zulu / GMT ↑				Page		1		Verify S-Turns After Mission	Yes X No

Additional Comments:	Drive #
	783516

SECTION 7: FINAL DELIVERABLES

FINAL DELIVERABLES

The final lidar deliverables are listed below.

- LAS v1.2 classified point cloud
- LAS v1.2 raw unclassified point cloud flight line strips no greater than 2GB. Long swaths greater than 2GB will be split into segments)
- Hydrologically flattened Polygon z and Polyline z shapefiles
- Hydrologically flattened bare earth 1-meter DEM in ERDAS .IMG format
- 8-bit gray scale intensity images
- 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

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