Project Report

TASK ORDER NAME: GA_Central_2019_B19
TASK ORDER NUMBER: 140G0219F0277
CONTRACT NUMBER: G16PC00042
ATLANTIC PROJECT NUMBER: 19064
BLOCK NUMBER: Block 8

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SECTION 1: PROJECT OVERVIEW AND PURPOSE

1.1 Aerial LiDAR Project

1.1.1 Project Overview

USGS task order 140G0219F0277 required Winter 2019/Spring 2020 LiDAR surveys to be collected over 20,320 square miles covering part or all of 60 counties in Georgia and 6 counties in Alabama in support of the USGS 3DEP Program. Aerial LiDAR data for this task order was planned, acquired, processed, and produced at an aggregate nominal pulse spacing (ANPS) of ≤0.71 meters and in compliance with USGS National Geospatial Program LiDAR Base Specification version 1.3. The Block 08 area encompasses approximately 2,497 square miles.

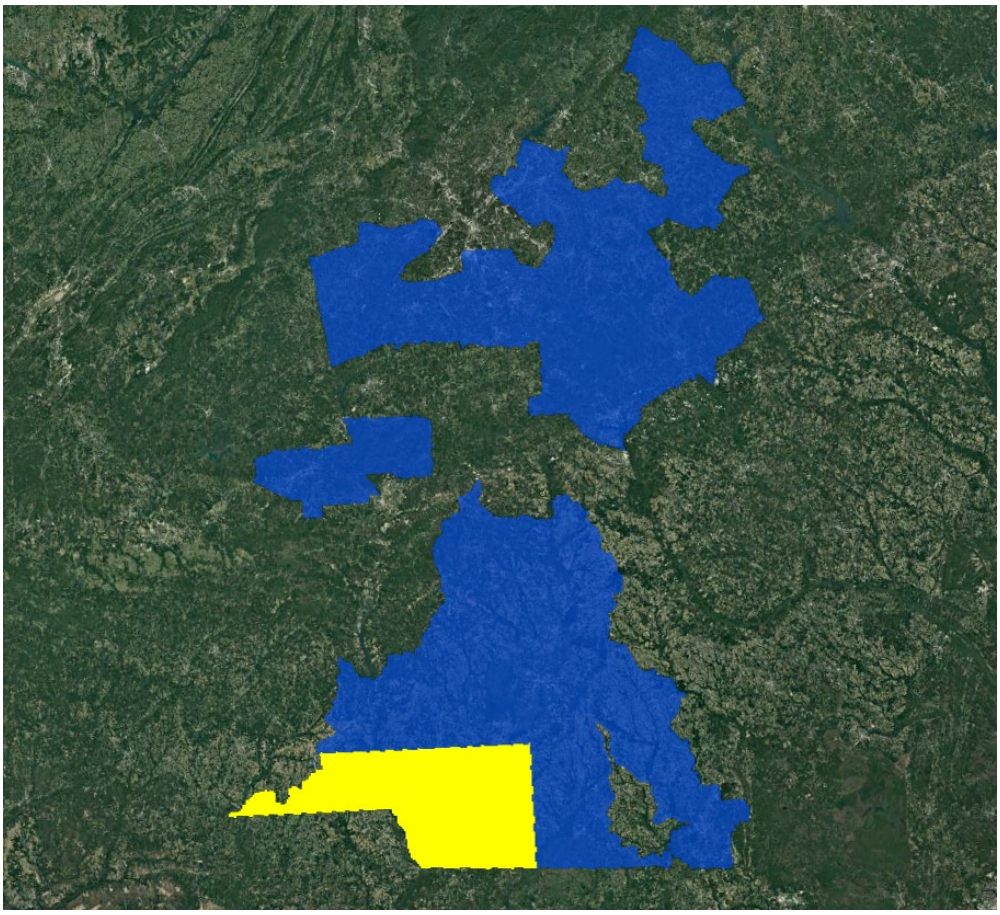

Figure 1: Aerial LiDAR Project Overview – Defined Project Area (DPA) in Yellow and Associated Areas of Interest (AOIs) in Blue

1.1.2 Project Purpose

Aerial lidar was collected to support the mapping efforts of individual counties in the State of Georgia and Alabama and the USGS 3DEP program.

1.1.3 Contract Deliverables

Item	Specification/Format
Classified Point Cloud	LAS v.14, tiled delivery
Bare Earth Surface	Raster DEM, 1m cell size, hydro flattened, GeoTIFF format
Breaklines	Hydro breaklines to BPA limit, .gdb format
Intensity Imagery	1m cell size, 8-bit, 256 gray scale, GeoTIFF format
Delivery Diagram	.gdb format
Metadata	Per product, FGDC compliant, .xml format
Project Report	Field work procedures, QC procedures and results, overall accuracy, .pdf format

Table 1: Aerial LiDAR Contract Deliverables

SECTION 2: FIELD OPERATIONS

2.1 Aerial LiDAR Project – Aerial Acquisition

2.1.1 Aircraft and Sensor Information

Atlantic operated a PACDV (N750DV) outfitted with an Optech Galaxy Prime LiDAR system during the collection of the project area. The specifications of this system are presented in the following table:

Parameter	Specification
Model	Galaxy Prime
Manufacturer	Optech
Performance Envelope	150 – 4700 m AGL, nominal
Absolute Horizontal Accuracy	1/10,000 x altitude
Absolute Elevation Accuracy	< 0.03 – 0.20 m RMSE from 150 – 4700 m AGL
Topographic Laser	1064-nm near-infrared
Laser Classification	Class IV
Pulse Repetition Frequency (Effective)	Programmable, 50 – 1000 kHz
Beam Divergence	0.25 mrad (1/e)
Laser Range Precision	< 0.008 m
Minimum Target Separation Distance	< 0.7 m (discrete)
Range Capture	Up to 8 range measurements, including last
Intensity Capture	Up to 8 intensity measurements, including last (12-bit)
Scan Angle (Fov)	10 – 60°
Swath Width	10 – 115% of altitude AGL
Scan Frequency	0 – 120 Hz advertised (0 – 240 scan lines/sec)
Scan Product	2000 maximum
Roll Compensation	±5° minimum
Data Storage	Internal solid-state drive (SSD)
Power Requirements	28 V; 300 W
Dimensions and Weight	Sensor: 0.34 x 0.34 x 0.25 m, 27 kg PDU: 0.42 x 0.33 x 0.10 m, 6.5 kg
Operation Temperature	0 to +35°C

Table 2: System Specifications – Galaxy Prime

2.1.2 Sensor Acquisition Information

The following table illustrates project specific system parameters for LiDAR acquisition on this project:

Parameter	Specification
System	Optech Galaxy Prime
Nominal Pulse Spacing (m)	.64

Parameter	Specification
Nominal Pulse Density (pls/m²)	2.44
Nominal Flight Height (AGL meters)	2000
Nominal Flight Speed (kts)	150
Pass Heading (°)	E-W
Sensor Scan Angle (°)	45
Scan Frequency (Hz)	60
Pulse Rate of Scanner (kHz)	350
Line Spacing (m)	1325.48
Pulse Width of Scanner (m)	1664
Central Wavelength of Sensor Laser (nm)	1064
Sensor Operated with Multiple Pulses	6
Beam Divergence (mrad)	.25
Nominal Swath Width (m)	1657
Nominal Swath Overlap (%)	20
Scan Pattern	TRIANGLE

Table 3: Aerial LiDAR Sensor Acquisition Parameters

2.1.3 Flight Plan Execution

Atlantic acquired 81 passes of the AOI as a series of perpendicular and/or adjacent flight-lines executed in 10 flight missions conducted between February 14, 2020 and March 27, 2020. Onboard differential Global Navigation Satellite System (GNSS) unit(s) recorded sample aircraft positions at 2 hertz (Hz) or more frequency. LiDAR data was only acquired when a minimum of six (6) satellites were in view.

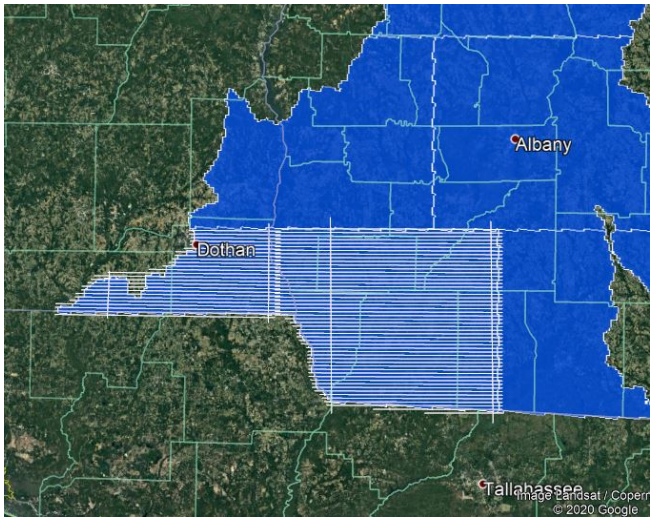

Figure 2: Orientation of Executed Flight-lines and LiDAR DPA

2.1.4 GNSS Reference Stations

Twenty-one (21) Continuously Operating Reference Stations (CORS) were used to control the LiDAR acquisition for the defined project area. The coordinates provided in below are in NAD83 (2011), Geographic Coordinate System, Ellipsoid, Meters.

Designation	Type	PID	Latitude (N)	Longitude (W)	Elevation
AL76	CORS	AL76	N31°52'29.95916"	W85°13'32.48372"	100.108
ALA1	CORS	ALA1	N32°35'55.88601"	W85°30'14.13664"	184.083
ALDO	CORS	ALDO	N31°14'22.17261"	W85°26'24.71347"	79.679
ALNB	CORS	ALNB	N31°22'38.98303"	W85°54'57.77491"	106.888
CRST	CORS	CRST	N30°43'33.87320"	W86°30'22.22010"	32.546
FL75	CORS	FL75	N30°36'45.11280"	W83°08'48.07588"	23.165
FLCB	CORS	FLCB	N29°50'33.38184"	W84°41'42.55870"	-21.079
GAAE	CORS	GAAE	N33°25'38.07519"	W82°04'04.06900"	124.363
GAAY	CORS	GAAY	N31°39'40.91991"	W84°16'29.65339"	55.889
GABY	CORS	GABY	N31°22'39.31821"	W84°56'06.69099"	63.548
GACC	CORS	GACC	N33°32'44.73033"	W82°08'01.72591"	98.476
GACL	CORS	GACL	N30°52'20.86185"	W84°23'55.88567"	56.406
GACR	CORS	GACR	N32°22'51.45821"	W83°20'46.43164"	97.765
GALC	CORS	GALC	N31°14'37.74079"	W84°55'13.36665"	38.441
GATF	CORS	GATF	N31°27'06.88711"	W83°30'32.85618"	96.077
GATH	CORS	GATH	N30°57'42.69491"	W84°54'54.64152"	23.768
GAVA	CORS	GAVA	N30°50'35.11386"	W83°16'18.44513"	45.409
GAWD	CORS	GAWD	N31°02'51.98946"	W84°12'16.58543"	82.181
TALH	CORS	TALH	N30°23'47.50413"	W84°21'21.06143"	-7.292
XCTY	CORS	XCTY	N29°37'51.63332"	W83°06'29.36128"	-15.299
ZTL4	CORS	ZTL4	N33°22'46.87805"	W84°17'48.21673"	260.681

Table 4: GNSS Reference Stations

2.2 Aerial LiDAR Project – Ground Acquisition

2.2.1 Ground Control Survey

A total of 103 ground survey points were collected in support of this project, including 23 LiDAR Control Points (LCP), 49 Non-vegetated Vertical Accuracy (NVA) and 31 Vegetated Vertical Accuracy (VVA).

Point cloud data accuracy was tested against a Triangulated Irregular Network (TIN) constructed from LiDAR points in clear and open areas. A clear and open area can be characterized with respect to topographic and ground cover variation such that a minimum of five (5) times the Nominal Pulse Spacing (NPS) exists with less than 1/3 of the RMSEZ deviation from a low-slope plane. Slopes that exceed ten (10) percent were avoided.

Each land cover type representing ten (10) percent or more of the total project area were tested and reported with a VVA. In land cover categories other than dense urban areas, the tested points did not have obstructions forty-five (45) degrees above the horizon to ensure a satisfactory TIN surface. The VVA value is provided as a target. It is understood that in areas of dense vegetation, swamps, or extremely difficult terrain, this value may be exceeded.

The NVA value is a requirement that must be met, regardless of any allowed "busts" in the VVA(s) for individual land cover types within the project. Checkpoints for each assessment (NVA and VVA) are required to be well-distributed throughout the land cover type, for the entire project area.

The following tables and figures outline the coordinate values and distribution of LCP, NVA and VVA points collected in support of this project:

ID	Easting	Northing	Elevation
LCP301	993438.583	943355.75	71.979
LCP302	1017584.996	963429.955	92.651
LCP303	975328.973	937465.28	68.492
LCP304	978979.201	936852.28	59.359
LCP305	1005399.979	961723.104	97.852
LCP310	1009946.026	953944.558	78.039
LCP311	1030396.146	942865.438	55.615
LCP313	1052227.573	942278.672	48.836
LCP314	1052128.79	952190.28	51.706
LCP315	1039828.666	955699.759	42.16
LCP316	1018226.112	952114.772	53.662
LCP318	1036156.626	967684.002	55.821
LCP320	1063998.601	960142.959	45.633
LCP321	1075823.732	939994.874	33.487
LCP323	1057464.531	930808.53	38.553
LCP325	1062816.169	920259.176	24.16
LCP326	1093632.876	923698.705	82.746
LCP327	1101938.08	922200.008	87.445
LCP901	1110257.105	943808.306	88.893

ID	Easting	Northing	Elevation
LCP902	1097273.164	944640.87	39.601
LCP903	1088794.898	960039.786	46.502
LCP904	1099433.184	956375.973	44.711
LCP905	1080842.702	962903.986	45.033

Table 5: LiDAR Control Point Coordinates

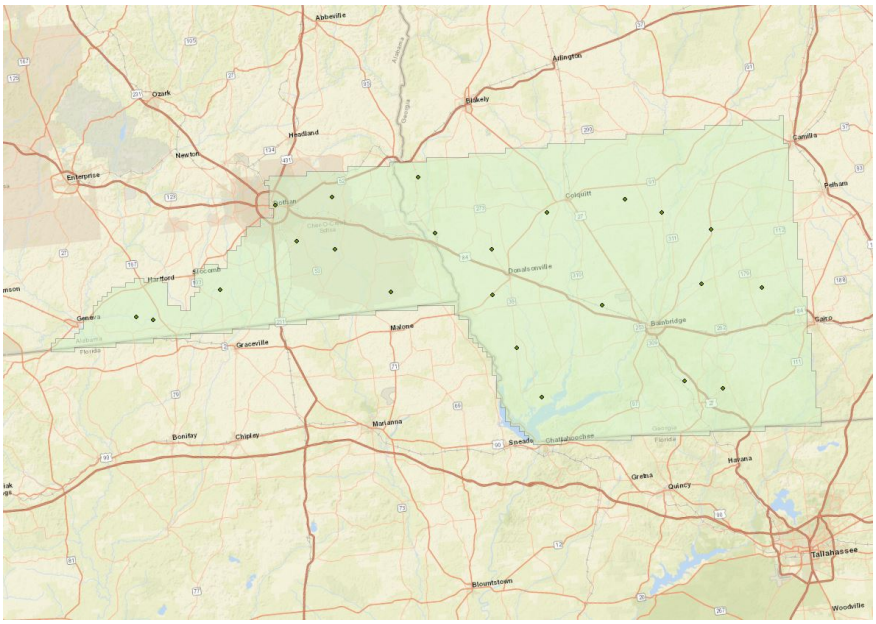

Figure 3: LiDAR Control Point Distribution

ID	Easting	Northing	Elevation
BE101	1088808.512	960041.484	46.257
BE102	1063997.469	960132.943	45.711
BE103	1039837.292	955682.382	42.02
BE104	1018214.312	952119.417	53.892
BE105	993439.871	943343.32	72.201
BE106	975325.061	937482.838	68.133
BE107	1005694.545	940121.203	54.925
BE108	1030414.836	942867.648	56.038
BE109	1052241.025	942274.183	49.197
BE110	1075813.697	940008.734	32.205
BE111	1110236.715	943799.84	89.106
BE113	1062831.585	920250.779	24.331
BE114	1093619.436	923699.772	82.512

ID	Easting	Northing	Elevation
BE309	1016428.512	942877.041	43.256
BE319	1046450.639	963630.989	58.044
BE901	1097011.198	944113.886	39.938
OT84	1017576.279	963434.569	92.416
OT85	1046454.417	963613.685	58.748
OT86	1093352.16	971111.16	46.411
OT87	1075037.051	965483.3	55.561
OT95	1105517.847	953573.952	38.962
OT96	1060027.297	940413.017	36.072
OT97	1071987.551	927882.158	35.685
OT98	1102816.809	928914.255	84.167
OT101	1003565.458	949939.848	68.671
OT102	1028618.407	955698.741	70.803
OT103	1067151.116	972559.575	56.993
OT306	993455.318	943349.834	71.836
OT308	1009960.754	953928.106	77.623
OT322	1057463.583	930786.51	36.765
UR87	1116103.467	918870.128	58.225
UR88	1081868.752	917634.234	92.18
UR89	1063733.082	930300.398	28.884
UR90	1064052.278	945912.711	51.138
UR91	1087716.269	945760.802	41.879
UR92	1090308.954	932876.954	31.812
UR94	1107583.939	965366.23	44.415
UR101	1036163.528	967680.563	55.722
UR102	1044209.386	948594.576	37.556
UR103	1056702.828	964723.155	54.101
UR104	1016434.899	942856.382	43.444
UR107	995902.147	938872.035	72.525
UR108	969999.551	934276.906	73.718
UR117	1077883.221	953801.562	42.798
UR118	1095535.352	942713.264	40.439
UR119	1112968.025	930326.292	86.642
UR901	1099324.409	955094.942	43.186
UR902	1112105.255	922653.954	78.964
UR903	1051269.781	972491.257	69.482

Table 6: Non-Vegetated Vertical Accuracy (NVA) Point Coordinates

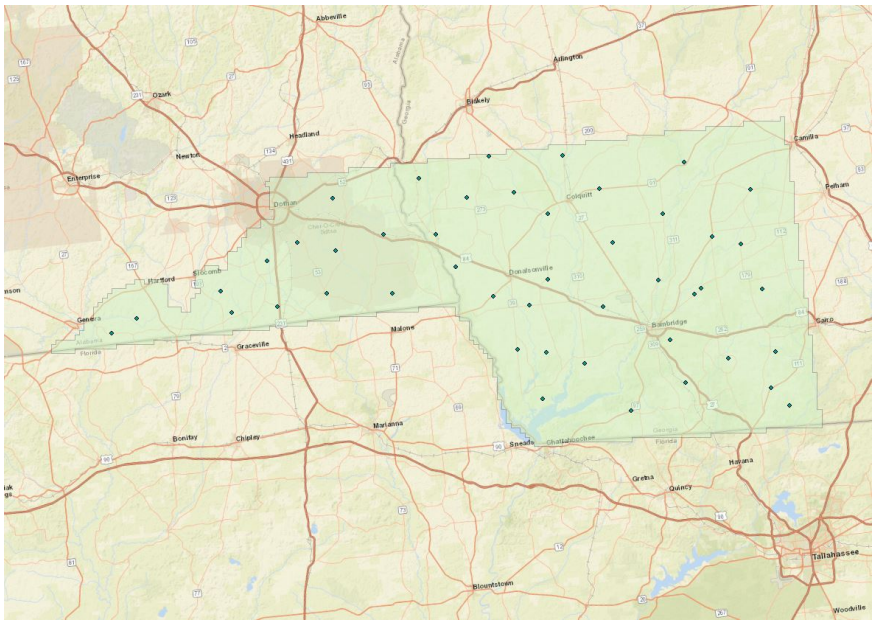

Figure 4: Non-Vegetated Vertical Accuracy (NVA) Point Distribution

ID	Easting	Northing	Elevation
BR67	1116914.132	955520.267	104.127
BR68	1099135.937	958192.006	41.71
BR69	1083487.559	965502.931	44.306
BR70	1073349.489	947617.616	38.939
BR71	1057444.43	930793.229	37.049
BR72	1087085.738	917295.06	84.789
BR77	1105391.745	970640.703	43.281
BR78	1067814.686	964811.94	44.738
BR79	1027412.223	965345.159	82.72
BR80	1023539.578	948830.485	50.198
BR81	991261.685	937255.105	70.96
HG58	1111509.374	973345.827	48.454
HG59	1083798.697	974983.178	52.272
HG60	1083359.859	950762.428	38.946
HG61	1083945.855	937051.479	30.066
HG62	1084657.705	922199.476	94.113
HG63	1117805.723	938967.665	86.612
HG70	980189.098	936260.956	60.387
HG71	1007793.214	944417.353	62.504
HG72	1009522.067	962178.38	80.68
HG73	1037170.663	945184.303	40.539

ID	Easting	Northing	Elevation
HG75	1112178.337	922691.991	78.767
HG77	1099136.821	937190.78	52.283
HG312	1030401.734	942857.286	56.093
HG901	1114956.939	922853.419	72.254
TR77	1101948.244	922207.058	87.448
TR78	1077254.521	931353.61	34.825
TR79	1052108.551	952190.257	51.266
TR83	1009962.882	953939.794	77.847
TR307	978975.826	936845.484	59.519
TR317	1018202.315	952106.963	53.151
TR324	1063739.977	930285.37	27.531

Table 7: Vegetated Vertical Accuracy (VVA) Point Coordinates

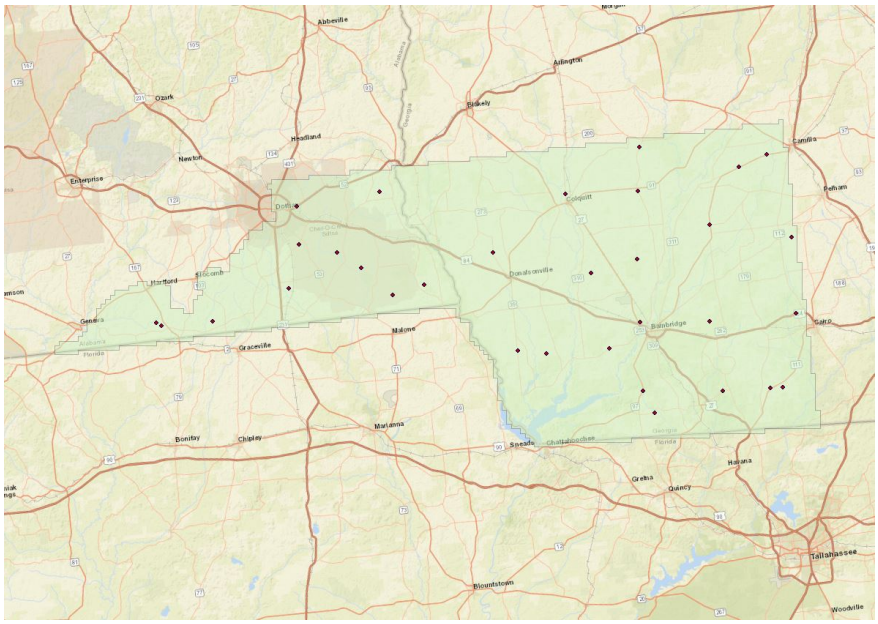

Figure 5: Vegetated Vertical Accuracy (VVA) Point Distribution

SECTION 3: DATA PRODUCTION

3.1 Aerial LiDAR Project – Calibration/Classification

3.1.1 LiDAR Point Cloud Generation

Atlantic used Leica software products to download the IPAS ABGNSS/IMU data and raw laser scan files from the airborne system. Waypoint Inertial Explorer is used to extract the raw IPAS ABGNSS/IMU data, which is further processed in combination with controlled base stations to provide the final Smoothed Best Estimate Trajectory (SBET) for each mission. The SBETs are combined with the raw laser scan files to export the LiDAR ASCII Standard (*.las) formatted swath point clouds.

3.1.2 Coordinate Reference System

Parameter	Specification
Horizontal Datum	Albers Equal Area
Coordinate System	NAD83 2011
Vertical Datum	NAVD88
Geoid Model	12B
EPSG Code	6350
Units of Reference	Meter

Table 1: Coordinate Reference System

3.1.3 LiDAR Point Cloud Statistics

Category	Value
Total Points	22,873,008,320
Nominal Pulse Spacing (m)	0.4250
Nominal Pulse Density (pls/m²)	5.5355
Aggregate Total Points	22,873,008,320
Aggregate Nominal Pulse Spacing (m)	0.5613
Aggregate Nominal Pulse Density (pls/m²)	3.1740

Table 2: LiDAR Point Cloud Statistics

3.1.4 Smooth Surface Repeatability (Interswath)

Departures from planarity of first returns within single swaths in non-vegetated areas were assessed at multiple locations with hard surface areas (parking lots or large rooftops) inside the project area. Each area was evaluated using signed difference rasters (maximum elevation – minimum elevation) at a cell size equal to 2 x ANPS, rounded to the next integer.

3.1.5 LiDAR Calibration

Using a combination of GeoCue, TerraScan and TerraMatch; overlapping swath point clouds are corrected for any orientation or linear deviations to obtain the best fit swath-to-swath calibration. Relative calibration was evaluated using advanced plane-matching analysis and parameter corrections derived. This process was repeated interactively until residual errors between overlapping swaths, across all project missions, was reduced to ≤2cm.

A final analysis of the calibrated lidar is preformed using a TerraMatch tie line report for an overall statistical model of the project area. Individual control point assessments for this project can be found in Section VI of this report.

Upon completion of the data calibration, a complete set of elevation difference intensity rasters (dZ Orthos) are produced. A user-defined color ramp is applied depicting the offsets between overlapping swaths based on project specifications. The dZ orthos provide an opportunity to review the data calibration in a qualitative manner. Atlantic assigns green to all offset values that fall below the required RMSDz requirement of the project. A yellow color is assigned for offsets that fall between the RMSDz value and 1.5x of that value. Finally, red values are assigned to all values that fall beyond 1.5x of the RMSDz requirements of the project.

3.1.6 LiDAR Classification

Multiple automated filtering routines are applied to the calibrated LiDAR point cloud identifying and extracting bare-earth and above ground features. GeoCue, TerraScan, and TerraModeler software was used for the initial batch processing, visual inspection and any manual editing of the LiDAR point clouds. Atlantic utilized collected breakline data to preform classification for class 9 (Water).

Code	Description
1	Processed but unclassified
2	Bare-earth ground
3	Low Vegetation (0.5 – 5 feet)
4	Medium Vegetation (5 – 20 feet)
5	High Vegetation (>20 feet)
6	Buildings
7	Low Noise
9	Water
17	Bridge Decks
18	High Noise
20	Ignored Ground (breakline proximity)
21	Snow (where reliable identifiable)
22	Temporal Exclusion (typically non-favored data in intertidal zones)

Table 3: LiDAR Point Classification Codes and Descriptions

3.1.7 LiDAR Intensity Imagery

LiDAR intensity imagery was created from the final calibrated and classified lidar point cloud. Intensity images were produced from all classified points and posted to a 1.0-meter cell size. Intensity images were cut to match the tile index and its corresponding tile names and delivered in GeoTIFF format.

3.1.8 Hydro-line Collection/Conflation

Hydro breaklines were compiled using LiDAR intensity data and surface terrain models of the entire project area. After the collection, all delineated hydro features were validated for monotonicity and vertical variance. This procedure ensures that no points were floating above ground. Hydro-lines were then encoded into the LiDAR

surface and used to hydro-enforce/flatten all significant water bodies. These final hydro-lines were then used in the production of bare Earth digital models to hydro flatten significant water bodies. This product was delivered as an ESRI geodatabase for the entire project area.

3.1.9 Bare-Earth Surface – Digital Elevation Model (DEM)

Bare earth Digital Elevation Models (DEMs) were derived using the hydro-lines and bare earth (ground) LiDAR points. All DEMs were created with a grid spacing of 1 meter. DEMs for this project were cut to match the tile index and its corresponding tile names and delivered in 32-bit floating point GeoTIFF format.

SECTION 4: ACCURACY ASSESSMENT

4.1 Aerial LiDAR Project – Vertical Accuracy Assessment

4.1.1 Requirements

Per the table below, the Vertical Accuracy Assessment utilized the required parameters for Vertical Data Accuracy Class IV.

Vertical Data Accuracy Class	RMSEz in Non-Vegetated Terrain (cm)	Non-Vegetated Vertical Accuracy (NVA) at 95% Confidence Level (cm)	Vegetated Vertical Accuracy (VVA) at 95th Percentile (cm)
I	1.0	2.0	2.9
II	2.5	4.9	7.4
III	5.0	9.8	14.7
IV	10.0	19.6	29.4
V	12.5	24.5	36.8
VI	20.0	39.2	58.8
VII	33.3	65.3	98.0
VIII	66.7	130.7	196.0
IX	100.0	196.0	294.0
X	333.3	653.3	980.0

Table 4: Vertical Accuracy Standards, Source: ASPRS Positional Accuracy Standards for Digital Geospatial Data v1.0 (2014)

*The terms NVA and VVA are from the American Society for Photogrammetry and Remote Sensing (ASPRS) Positional Accuracy Standards for Digital Geospatial Data v1.0 (2014). The term NVA refers to assessments in clear, open areas (which typically produce only single LiDAR returns); the term VVA refers to assessments in vegetated areas (typically characterized by multiple return LiDAR).

4.1.2 Results

An overall statistical assessment of the check points can be found in the following two tables (values provided in meters):

Broad Land Cover Type	Points (#)	RMSEz	Confidence Level (95%)	Percentile (95th)
NVA (Point Cloud)	48	0.0520	0.1019	0.0762
NVA (DEM)	48	0.0751	0.1472	0.1306
VVA (Point Cloud)	32	0.0963	0.1887	0.2073
VVA (DEM)	32	0.1235	0.2421	0.1503

Table 5: NVA/VVA Accuracies

SECTION 5: CERTIFICATION STATEMENTS

5.1 Aerial LiDAR Project

This accuracy assessment confirms that the data may be used for the intended applications stated in Section I of this document. This dataset may also be used as a topographic input for other applications, but the user should be aware that this LiDAR dataset was designed with a specific purpose and was not intended to meet specifications and/or requirements of users outside of the United States Geological Survey.

It should also be noted that LiDAR points do not represent a continuous surface model. LiDAR points are discrete measurements of the surface and any values derived within a triangle of three LiDAR points are interpolated. As such, the user should not use the resultant LiDAR dataset for vertical placement of a planimetric feature such as a headwall, building footprint or any other planimetric feature unless there is an associated LiDAR point that can be reasonably located on this structure.

Consideration should be given by the end user of this dataset to the fact that this LiDAR dataset was developed differently and separately than previous LiDAR datasets that may be available for this geographic location. It is likely that the data in this project was created using different geodetic control, a different Geoid, newer LiDAR technology and more up-to-date processing techniques. As such, any direct comparative analysis performed between this dataset and previous datasets could result in misleading or inaccurate results. Users are encouraged to proceed with caution while performing this type of comparative analysis and to completely understand the variables that make each of these datasets unique and not corollary.

It is encouraged that the user refers to the full FGDC Metadata and project reports for a complete understanding on the content of this dataset.

I, hereby, certify to the extent of my knowledge that the statements and statistics represented in this document are true and factual.

James C. Cannon, ASPRS Certified Photogrammetrist #R1594CP

SECTION 6: CONTROL POINT ASSESSMENTS

6.1 Aerial LiDAR Project

6.1.1 Point Cloud Check Point Assessment

Point ID	Given (X)	Given (Y)	Given (Z)	Laser (Z)	Delta (Z)	Report Point Type
BE101	1088808.5120	960041.4840	46.2570	46.2480	-0.0090	NVA
BE102	1063997.4690	960132.9430	45.7110	45.7820	0.0710	NVA
BE103	1039837.2920	955682.3820	42.0200	42.0360	0.0160	NVA
BE104	1018214.3120	952119.4170	53.8920	53.9340	0.0420	NVA
BE105	993439.8710	943343.3200	72.2010	72.1630	-0.0380	NVA
BE106	975325.0610	937482.8380	68.1330	68.0590	-0.0740	NVA
BE107	1005694.5450	940121.2030	54.9250	54.9570	0.0320	NVA
BE108	1030414.8360	942867.6480	56.0380	56.0670	0.0290	NVA
BE109	1052241.0250	942274.1830	49.1970	49.2760	0.0790	NVA
BE110	1075813.6970	940008.7340	32.2050	32.1590	-0.0460	NVA
BE111	1110236.7150	943799.8400	89.1060	89.1010	-0.0050	NVA
BE113	1062831.5850	920250.7790	24.3310	24.3260	-0.0050	NVA
BE114	1093619.4360	923699.7720	82.5120	82.4470	-0.0650	NVA
BE309	1016428.5120	942877.0410	43.2560	43.2240	-0.0320	NVA
BE319	1046450.6390	963630.9890	58.0440	57.9830	-0.0610	NVA
BE901	1097011.1980	944113.8860	39.9380	40.1020	0.1640	NVA
BR67	1116914.1320	955520.2670	104.1270	104.2150	0.0880	VVA
BR68	1099135.9370	958192.0060	41.7100	41.7730	0.0630	VVA
BR69	1083487.5590	965502.9310	44.3060	44.3020	-0.0040	VVA
BR70	1073349.4890	947617.6160	38.9390	38.9840	0.0450	VVA
BR71	1057444.4300	930793.2290	37.0490	37.1560	0.1070	VVA
BR72	1087085.7380	917295.0600	84.7890	84.9190	0.1300	VVA
BR77	1105391.7450	970640.7030	43.2810	43.2920	0.0110	VVA
BR78	1067814.6860	964811.9400	44.7380	44.9340	0.1960	VVA
BR79	1027412.2230	965345.1590	82.7200	82.6990	-0.0210	VVA
BR80	1023539.5780	948830.4850	50.1980	50.2580	0.0600	VVA
BR81	991261.6850	937255.1050	70.9600	70.9370	-0.0230	VVA
HG312	1030401.7340	942857.2860	56.0930	56.1050	0.0120	VVA
HG58	1111509.3740	973345.8270	48.4540	48.6370	0.1830	VVA
HG59	1083798.6970	974983.1780	52.2720	52.3630	0.0910	VVA
HG60	1083359.8590	950762.4280	38.9460	38.9260	-0.0200	VVA

Point ID	Given (X)	Given (Y)	Given (Z)	Laser (Z)	Delta (Z)	Report Point Type
HG61	1083945.8550	937051.4790	30.0660	30.1400	0.0740	VVA
HG62	1084657.7050	922199.4760	94.1130	94.1170	0.0040	VVA
HG63	1117805.7230	938967.6650	86.6120	86.6850	0.0730	VVA
HG70	980189.0980	936260.9560	60.3870	60.4540	0.0670	VVA
HG71	1007793.2140	944417.3530	62.5040	62.5370	0.0330	VVA
HG72	1009522.0670	962178.3800	80.6800	80.9250	0.2450	VVA
HG73	1037170.6630	945184.3030	40.5390	40.6300	0.0910	VVA
HG75	1112178.3370	922691.9910	78.7670	78.8810	0.1140	VVA
HG77	1099136.8210	937190.7800	52.2830	52.5040	0.2210	VVA
HG901	1114956.9390	922853.4190	72.2540	72.3110	0.0570	VVA
OT101	1003565.4580	949939.8480	68.6710	68.6860	0.0150	NVA
OT102	1028618.4070	955698.7410	70.8030	70.9140	0.1110	NVA
OT103	1067151.1160	972559.5750	56.9930	56.9760	-0.0170	NVA
OT306	993455.3180	943349.8340	71.8360	71.7350	-0.1010	NVA
OT308	1009960.7540	953928.1060	77.6230	77.6040	-0.0190	NVA
OT322	1057463.5830	930786.5100	36.7650	36.6990	-0.0660	NVA
OT84	1017576.2790	963434.5690	92.4160	92.4650	0.0490	NVA
OT85	1046454.4170	963613.6850	58.7480	58.6970	-0.0510	NVA
OT86	1093352.1600	971111.1600	46.4110	46.4100	-0.0010	NVA
OT87	1075037.0510	965483.3000	55.5610	55.5010	-0.0600	NVA
OT95	1105517.8470	953573.9520	38.9620	39.0060	0.0440	NVA
OT96	1060027.2970	940413.0170	36.0720	36.0820	0.0100	NVA
OT97	1071987.5510	927882.1580	35.6850	35.6550	-0.0300	NVA
OT98	1102816.8090	928914.2550	84.1670	84.2210	0.0540	NVA
TR307	978975.8260	936845.4840	59.5190	59.5250	0.0060	VVA
TR317	1018202.3150	952106.9630	53.1510	53.1650	0.0140	VVA
TR324	1063739.9770	930285.3700	27.5310	27.6250	0.0940	VVA
TR77	1101948.2440	922207.0580	87.4480	87.4820	0.0340	VVA
TR78	1077254.5210	931353.6100	34.8250	34.7450	-0.0800	VVA
TR79	1052108.5510	952190.2570	51.2660	51.2600	-0.0060	VVA
TR83	1009962.8820	953939.7940	77.8470	77.7960	-0.0510	VVA
UR101	1036163.5280	967680.5630	55.7220	55.7520	0.0300	NVA
UR102	1044209.3860	948594.5760	37.5560	37.5190	-0.0370	NVA
UR103	1056702.8280	964723.1550	54.1010	54.1060	0.0050	NVA
UR104	1016434.8990	942856.3820	43.4440	43.3630	-0.0810	NVA
UR107	995902.1470	938872.0350	72.5250	72.5130	-0.0120	NVA

Point ID	Given (X)	Given (Y)	Given (Z)	Laser (Z)	Delta (Z)	Report Point Type
UR108	969999.5510	934276.9060	73.7180	73.7380	0.0200	NVA
UR117	1077883.2210	953801.5620	42.7980	42.7930	-0.0050	NVA
UR118	1095535.3520	942713.2640	40.4390	40.4840	0.0450	NVA
UR119	1112968.0250	930326.2920	86.6420	86.7000	0.0580	NVA
UR87	1116103.4670	918870.1280	58.2250	58.2220	-0.0030	NVA
UR88	1081868.7520	917634.2340	92.1800	92.1750	-0.0050	NVA
UR89	1063733.0820	930300.3980	28.8840	28.9400	0.0560	NVA
UR90	1064052.2780	945912.7110	51.1380	51.1350	-0.0030	NVA
UR901	1099324.4090	955094.9420	43.1860	43.2110	0.0250	NVA
UR902	1112105.2550	922653.9540	78.9640	79.0280	0.0640	NVA
UR91	1087716.2690	945760.8020	41.8790	41.9310	0.0520	NVA
UR92	1090308.9540	932876.9540	31.8120	31.7740	-0.0380	NVA
UR94	1107583.9390	965366.2300	44.4150	44.4360	0.0210	NVA

Table 13: Point Cloud Check Point Assessment

6.1.2 Digital Elevation Model (DEM) Check Point Assessment

Point ID	Given (X)	Given (Y)	Given (Z)	DEM (Z)	DEM (DZ)	Point Type
BE101	1088808.5120	960041.4840	46.2570	46.2650	-0.0080	NVA
BE102	1063997.4690	960132.9430	45.7110	45.7940	-0.0830	NVA
BE103	1039837.2920	955682.3820	42.0200	42.0340	-0.0140	NVA
BE104	1018214.3120	952119.4170	53.8920	53.9570	-0.0650	NVA
BE105	993439.8710	943343.3200	72.2010	72.0690	0.1320	NVA
BE106	975325.0610	937482.8380	68.1330	68.0190	0.1140	NVA
BE107	1005694.5450	940121.2030	54.9250	55.0280	-0.1030	NVA
BE108	1030414.8360	942867.6480	56.0380	56.0310	0.0070	NVA
BE109	1052241.0250	942274.1830	49.1970	49.2550	-0.0580	NVA
BE110	1075813.6970	940008.7340	32.2050	32.1230	0.0820	NVA
BE111	1110236.7150	943799.8400	89.1060	89.0880	0.0180	NVA
BE113	1062831.5850	920250.7790	24.3310	24.3020	0.0290	NVA
BE114	1093619.4360	923699.7720	82.5120	82.4590	0.0530	NVA
BE309	1016428.5120	942877.0410	43.2560	43.1880	0.0680	NVA
BE319	1046450.6390	963630.9890	58.0440	57.8810	0.1630	NVA
BE901	1097011.1980	944113.8860	39.9380	40.0910	-0.1530	NVA
OT101	1003565.4580	949939.8480	68.6710	68.7150	-0.0440	NVA
OT102	1028618.4070	955698.7410	70.8030	70.9680	-0.1650	NVA
OT103	1067151.1160	972559.5750	56.9930	56.9930	0.0000	NVA
OT306	993455.3180	943349.8340	71.8360	71.6340	0.2020	NVA

Point ID	Given (X)	Given (Y)	Given (Z)	DEM (Z)	DEM (DZ)	Point Type
OT308	1009960.7540	953928.1060	77.6230	77.6370	-0.0140	NVA
OT322	1057463.5830	930786.5100	36.7650	36.6960	0.0690	NVA
OT84	1017576.2790	963434.5690	92.4160	92.4590	-0.0430	NVA
OT85	1046454.4170	963613.6850	58.7480	58.6530	0.0950	NVA
OT86	1093352.1600	971111.1600	46.4110	46.4100	0.0010	NVA
OT87	1075037.0510	965483.3000	55.5610	55.4860	0.0750	NVA
OT95	1105517.8470	953573.9520	38.9620	39.0150	-0.0530	NVA
OT96	1060027.2970	940413.0170	36.0720	36.0900	-0.0180	NVA
OT97	1071987.5510	927882.1580	35.6850	35.6390	0.0460	NVA
OT98	1102816.8090	928914.2550	84.1670	84.2070	-0.0400	NVA
UR101	1036163.5280	967680.5630	55.7220	55.7450	-0.0230	NVA
UR102	1044209.3860	948594.5760	37.5560	37.4950	0.0610	NVA
UR103	1056702.8280	964723.1550	54.1010	54.0250	0.0760	NVA
UR104	1016434.8990	942856.3820	43.4440	43.3160	0.1280	NVA
UR107	995902.1470	938872.0350	72.5250	72.4990	0.0260	NVA
UR108	969999.5510	934276.9060	73.7180	73.7480	-0.0300	NVA
UR117	1077883.2210	953801.5620	42.7980	42.7410	0.0570	NVA
UR118	1095535.3520	942713.2640	40.4390	40.4510	-0.0120	NVA
UR119	1112968.0250	930326.2920	86.6420	86.7330	-0.0910	NVA
UR87	1116103.4670	918870.1280	58.2250	58.2180	0.0070	NVA
UR88	1081868.7520	917634.2340	92.1800	92.1680	0.0120	NVA
UR89	1063733.0820	930300.3980	28.8840	28.9220	-0.0380	NVA
UR90	1064052.2780	945912.7110	51.1380	51.1130	0.0250	NVA
UR901	1099324.4090	955094.9420	43.1860	43.2050	-0.0190	NVA
UR902	1112105.2550	922653.9540	78.9640	79.0400	-0.0760	NVA
UR91	1087716.2690	945760.8020	41.8790	41.9080	-0.0290	NVA
UR92	1090308.9540	932876.9540	31.8120	31.7730	0.0390	NVA
UR94	1107583.9390	965366.2300	44.4150	44.4460	-0.0310	NVA

Point ID	Given (X)	Given (Y)	Given (Z)	DEM (Z)	DEM (DZ)	Point Type
BR67	1116914.1320	955520.2670	104.1270	104.2690	-0.1420	VVA
BR68	1099135.9370	958192.0060	41.7100	41.8270	-0.1170	VVA
BR69	1083487.5590	965502.9310	44.3060	44.2840	0.0220	VVA
BR70	1073349.4890	947617.6160	38.9390	39.0570	-0.1180	VVA
BR71	1057444.4300	930793.2290	37.0490	37.0780	-0.0290	VVA
BR72	1087085.7380	917295.0600	84.7890	84.8530	-0.0640	VVA

Point ID	Given (X)	Given (Y)	Given (Z)	DEM (Z)	DEM (DZ)	Point Type
BR77	1105391.7450	970640.7030	43.2810	43.2650	0.0160	VVA
BR78	1067814.6860	964811.9400	44.7380	44.9570	-0.2190	VVA
BR79	1027412.2230	965345.1590	82.7200	82.6510	0.0690	VVA
BR80	1023539.5780	948830.4850	50.1980	50.1660	0.0320	VVA
BR81	991261.6850	937255.1050	70.9600	70.6960	0.2640	VVA
HG312	1030401.7340	942857.2860	56.0930	56.0590	0.0340	VVA
HG58	1111509.3740	973345.8270	48.4540	48.5080	-0.0540	VVA
HG59	1083798.6970	974983.1780	52.2720	52.3600	-0.0880	VVA
HG60	1083359.8590	950762.4280	38.9460	38.9090	0.0370	VVA
HG61	1083945.8550	937051.4790	30.0660	30.1040	-0.0380	VVA
HG62	1084657.7050	922199.4760	94.1130	94.1090	0.0040	VVA
HG63	1117805.7230	938967.6650	86.6120	86.7480	-0.1360	VVA
HG70	980189.0980	936260.9560	60.3870	60.5140	-0.1270	VVA
HG71	1007793.2140	944417.3530	62.5040	62.5430	-0.0390	VVA
HG72	1009522.0670	962178.3800	80.6800	80.9930	-0.3130	VVA
HG73	1037170.6630	945184.3030	40.5390	40.3950	0.1440	VVA
HG75	1112178.3370	922691.9910	78.7670	78.8840	-0.1170	VVA
HG77	1099136.8210	937190.7800	52.2830	52.5370	-0.2540	VVA
HG901	1114956.9390	922853.4190	72.2540	72.3120	-0.0580	VVA
TR307	978975.8260	936845.4840	59.5190	59.5070	0.0120	VVA
TR317	1018202.3150	952106.9630	53.1510	53.1360	0.0150	VVA
TR324	1063739.9770	930285.3700	27.5310	27.6710	-0.1400	VVA
TR77	1101948.2440	922207.0580	87.4480	87.5000	-0.0520	VVA
TR78	1077254.5210	931353.6100	34.8250	34.6670	0.1580	VVA
TR79	1052108.5510	952190.2570	51.2660	51.2000	0.0660	VVA
TR83	1009962.8820	953939.7940	77.8470	77.7550	0.0920	VVA

Table 14: DEM Check Point Assessment