Project Report

TASK ORDER NAME: AZ_GrandCanyonNP_2019_B19
TASK ORDER NUMBER: 140G0219F0272
CONTRACT NUMBER: G16PC00042
ATLANTIC PROJECT NUMBER: 19057
BLOCK NAME: Base

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1.1 Aerial LiDAR Project

1.1.1 Project Overview

USGS task order 140G0219F0272 required summer 2019 LiDAR surveys to be collected over 833 square miles covering part or all of Grand Canyon National Park in Arizona in support of the National Park Service. Aerial LiDAR data for this task order was planned, acquired, processed, and produced at an aggregate nominal pulse spacing (ANPS) of ≤ 0.35 meters and in compliance with USGS National Geospatial Program LiDAR Base Specification version 2021 Revision A. Base AOI for this deliverable covers approximately 514 square miles.

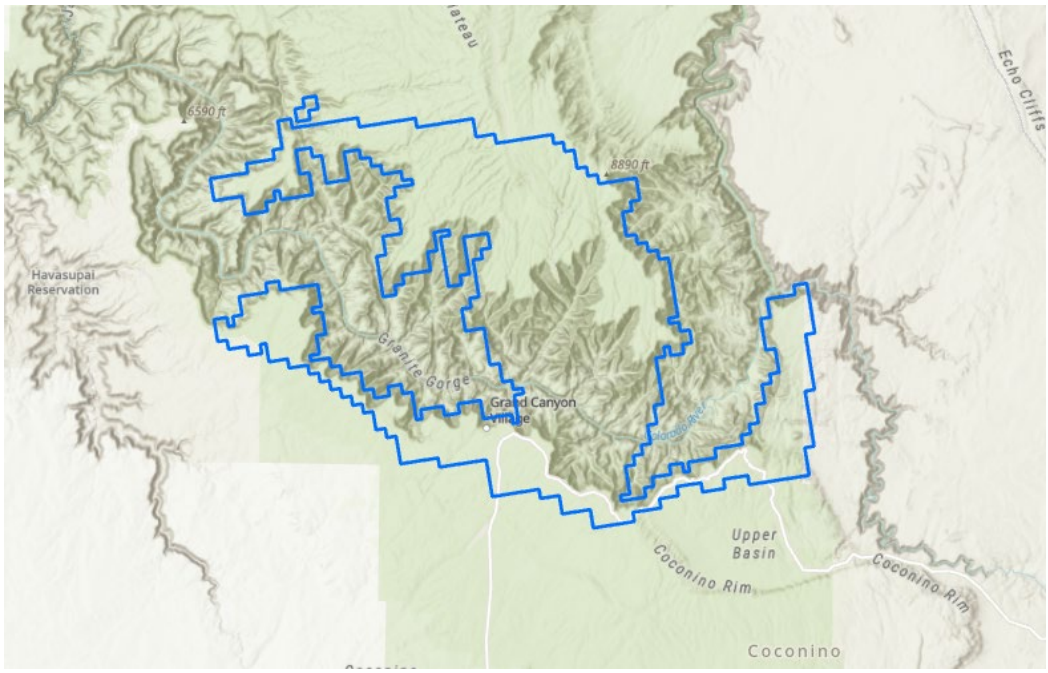

Figure 1: Aerial LiDAR Project Overview – Defined Project Area (DPA) and Associated Areas of Interest (AOIs)

1.1.2 Project Purpose

This project will support the National Park Service's goal of acquiring high quality elevation data in Grand Canyon National Park for use in dam safety assessments, engineering design and design reviews, conservation planning, research, delivery, floodplain mapping, habitat analysis and modeling, fire effects and fuel modeling, and hydrologic modeling utilizing lidar technology, as well as the USGS's National Cooperative Geologic Mapping Program's (NCGMP) goal of producing seamless multi-scales geological maps of the region, and the 3DEP mission.

1.1.3 Contract Deliverables

Item	Specification/Format
Classified Point Cloud	LAS v1.4
Hydro Flattened Bare Earth DEM	0.5m cell size, TIF format
Non- **Hydro Flattened Bare Earth DEM**	0.5m cell size, TIF format
First Return Surface DSM	0.5m cell size, TIF format
Breaklines	Esri Geodatabase
Intensity Imagery	0.5m cell size, TIF format
Control	Esri .shp
Metadata	Xml, .shp, and TIF format
Project Report	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 PACVX (N750VX) 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)	0.35
Nominal Pulse Density (pls/m²)	8
Nominal Flight Height (AGL meters)	3730
Nominal Flight Speed (kts)	140
Pass Heading (°)	Variable
Sensor Scan Angle (°)	30
Scan Frequency (Hz)	80
Pulse Rate of Scanner (kHz)	400
Pulse Width of Scanner (m)	910.9
Sensor Operated with Multiple Pulses	5
Nominal Swath Width (m)	910
Nominal Swath Overlap (%)	56

Table 3: Aerial LiDAR Sensor Acquisition Parameters

2.1.3 Flight Plan Execution

Atlantic acquired 225 passes of the AOI as a series of perpendicular and/or adjacent flight-lines executed in 9 flight missions conducted between September 27, 2019 and October 6, 2019. 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.

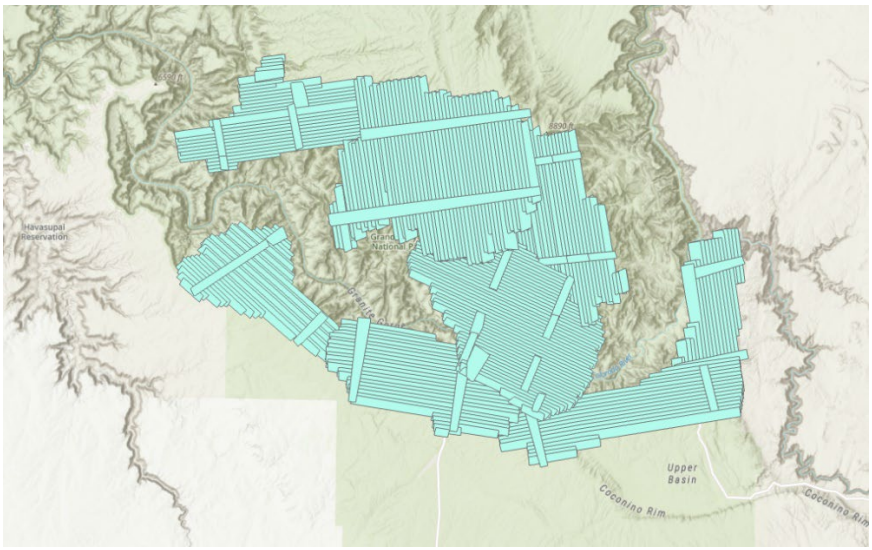

Figure 2: Orientation of Executed Flight-lines

2.1.4 GNSS Reference Stations

Fifteen (15) 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
AZDS	CORS	AZDS	N35°31'59.27673"	W114°21'33.24548"	870.669
AZFL	CORS	AZFL	N35°10'38.31362"	W111°39'25.34305"	2087.948
AZGV	CORS	AZGV	N35°15'15.74205"	W114°15'15.36563"	867.562
FERN	CORS	FERN	N35°20'30.73573"	W112°27'17.06033"	1767.848
GCES	CORS	GCES	N36°02'52.81007"	W112°07'44.95889"	2110.961
KGMN	CORS	KGMN	N35°13'51.77904"	W114°00'08.47282"	1015.642
NVLM	CORS	NVLM	N36°04'10.76768"	W114°48'47.55034"	362.043
NVWS	CORS	NVWS	N36°43'29.99460"	W114°42'55.81937"	513.78
P004	CORS	P004	N34°47'03.77117"	W112°09'07.13788"	1791.754
P006	CORS	P006	N36°09'15.07142"	W114°27'24.89044"	365.219
P008	CORS	P008	N36°08'34.15223"	W111°07'48.17867"	1522.032
P009	CORS	P009	N38°28'47.74599"	W112°13'21.78120"	1761.433
P010	CORS	P010	N34°40'02.13983"	W113°43'52.84087"	1399.033
P011	CORS	P011	N36°08'59.37697"	W109°31'09.22712"	1728.482
SGU1	CORS	SGU1	N37°06'47.49346"	W113°34'13.07877"	894.816

Table 4: GNSS Reference Stations

2.2 9Aerial LiDAR Project – Ground Acquisition

2.2.1 Ground Control Survey

A total of seventy one (71) ground survey points were collected in support of this project, including twenty-one (21) LiDAR Control Points (LCPs), thirty (30) Non-vegetated Vertical Accuracy (NVA) and twenty (20) 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:

Point ID	Easting	Northing	Elevation
ABYSS_PIN	393480.1900	3991111.0730	2076.8450
CAPE	414538.4340	3998068.3400	2406.6870
DESERT_VIEW	425208.7000	3988789.4000	2286.5670
LCP101A	393395.4180	3991090.5120	2071.5350
LCP102A	389380.5130	3988731.2120	1948.6860
LCP103A	375801.4230	4003207.6260	1981.2980
LCP104A	387563.3370	4006676.4850	2273.7410
LCP105A	396719.2410	4014331.8850	2490.1170
LCP106A	400797.0350	4013320.5280	2488.9590
LCP107A	399949.0070	4020957.3450	2682.3270

Point ID	Easting	Northing	Elevation
LCP108A	412132.2520	4015355.4350	2693.2030
LCP209	429934.4960	3999432.7350	1847.3900
LCP210	410045.2750	3989997.4980	1153.2700
LCP211	401838.4440	4002600.5200	1996.2310
LCP551	430671.4600	4003160.8330	1806.1570
LCP701	421874.6840	3985701.6510	2190.4440
LCP702	409873.2570	4013020.7270	2502.2040
LCP703	378226.9930	4024333.5790	2303.7900
LCP704	389401.5530	4023439.2660	2547.9100
SIGNAL_HILL	377922.4250	4003703.8010	2065.4950
XLCP701	415169.4790	3999107.1570	2431.8260

Table 5: LiDAR Control Point Coordinates

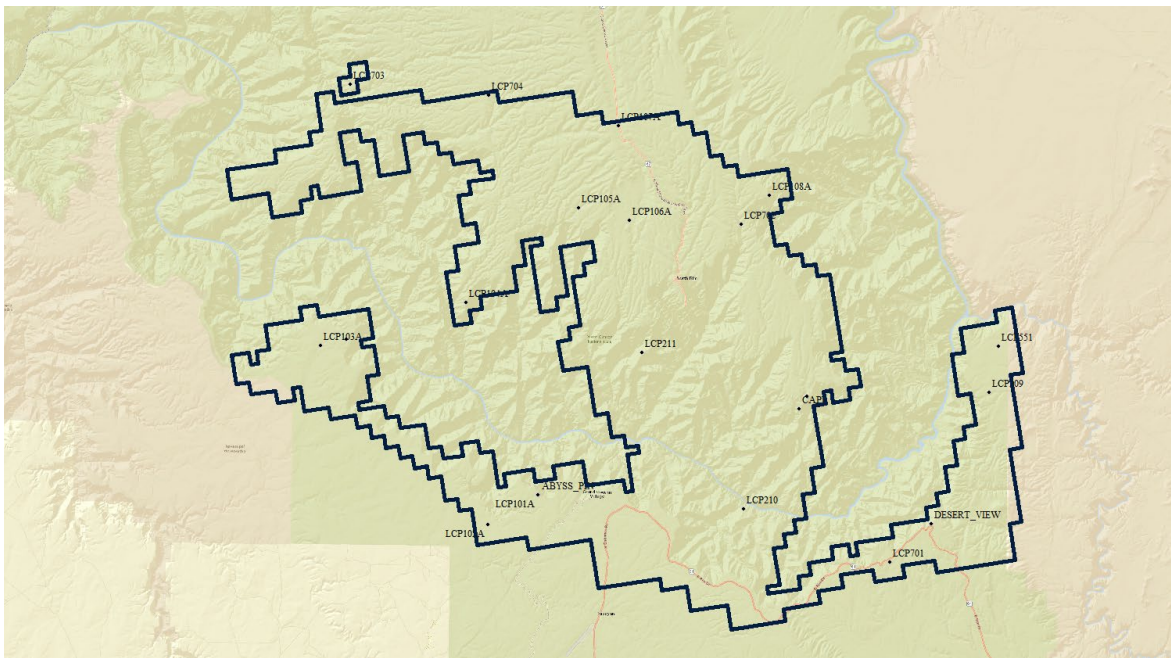

Figure 3: LiDAR Control Point Distribution

Point ID	Easting	Northing	Elevation
BE02	389264.9950	3988786.8620	1946.8500
BE03	421831.2140	3985708.5860	2189.7060
BE04	412148.3860	4015334.5420	2693.2720
BE06	378235.9270	4024310.7730	2304.7340
BE08	396640.8260	4014313.3640	2490.5700
BE09	399957.8570	4020937.2920	2682.1520
BE204	428030.8600	4004099.6270	1870.4340
BE208	401900.8200	4002567.5640	1996.0910
BE209	402442.6350	3995648.4740	744.3590
BE210	410048.4370	3989994.3790	1153.1270
OT01	397526.7280	3990213.5150	2111.0780
OT02	411967.2720	4015426.0390	2689.9050
OT03	376202.1050	4005206.0560	2026.3410
OT05	414536.7080	3997986.6290	2409.1140
OT06	378850.5600	4022025.5940	2292.2170
OT08	402918.6410	4010942.7510	2520.3810
OT10	404267.2270	4009312.7280	2466.1560
OT202	430712.5730	4003062.6440	1806.6170
OT208	412973.0960	3994542.2380	1934.8590
OT210	407227.6200	4004948.7190	1382.7630
UR01A	391018.3420	3991526.9260	2031.7140
UR02	398914.8530	3984220.8410	2071.1970
UR04	425638.7010	3988899.6860	2280.3680

Point ID	Easting	Northing	Elevation
UR06	405320.5960	4014218.7870	2525.3690
UR08	405082.0960	4008603.4100	2518.4300
UR09	404821.2150	4008096.9460	2542.8880
UR10	405181.9520	3985438.4940	2202.0080
UR208	401419.8000	3998243.3520	1181.7500
UR209	405256.4890	3992592.9460	1490.2020
XNVA701	415180.0340	3999111.7400	2432.3410

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

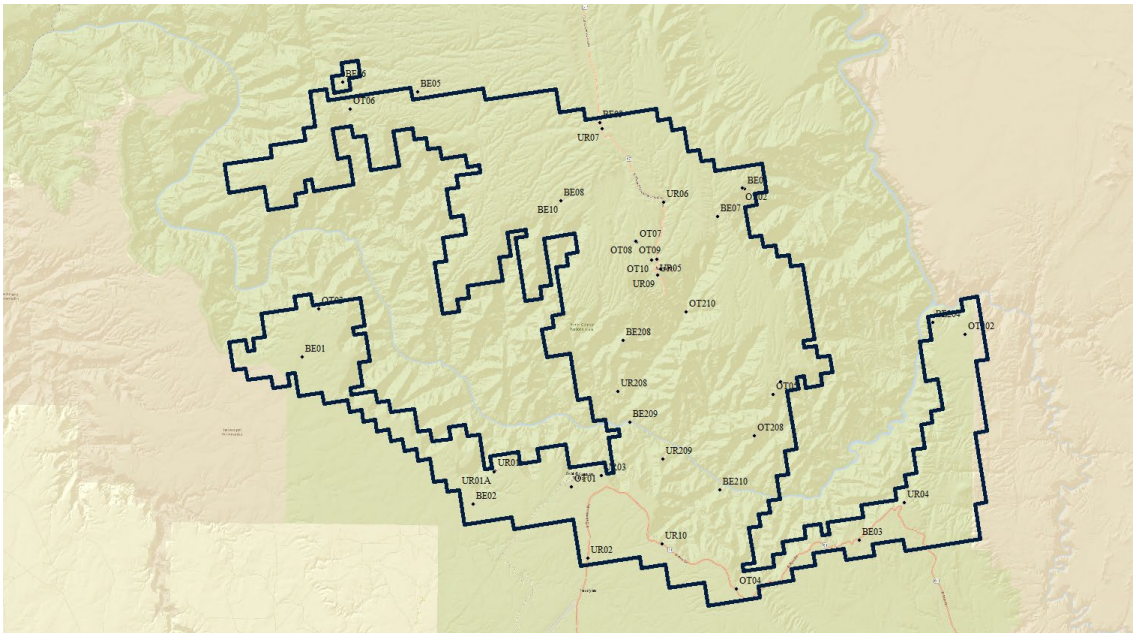

Figure 4: Non-Vegetated Vertical Accuracy (NVA) Point Distribution

Point ID	Easting	Northing	Elevation
BR01	375374.2820	4002323.8590	1962.3320
BR02	427144.2920	3988356.8310	2199.1650
BR05	410934.0730	3983904.7630	2273.2460

Point ID	Easting	Northing	Elevation
BR06	414550.0600	3998012.2530	2409.7800
BR07	389868.1400	4022537.0130	2455.8280
BR206	430385.1000	3994931.6910	1885.6380
BR701	402462.8250	3995645.6330	744.3460
HG01	395014.5200	3992443.4600	2125.7670
HG02	403928.7730	3986484.6990	2182.4250
HG03	400327.9990	4013562.8260	2499.8070
HG05	422842.4140	3986796.8070	2215.9560
HG06	391497.3540	3988359.4150	2015.6270
HG07	374490.4910	4000093.8470	1926.2010
TR01	414515.4060	3997996.3380	2408.8540
TR02	375800.3070	4003216.1270	1981.6320
TR03	379778.2300	4021832.3620	2315.9250
TR05	399070.5540	3986236.6820	2089.5740
TR07B	395098.6250	4014563.2700	2512.1260
TR201	429918.9920	3999410.7920	1848.0720
VVA551	401399.5080	3998257.3250	1182.5850

Table 7: Vegetated Vertical Accuracy (VVA) Point Coordinates

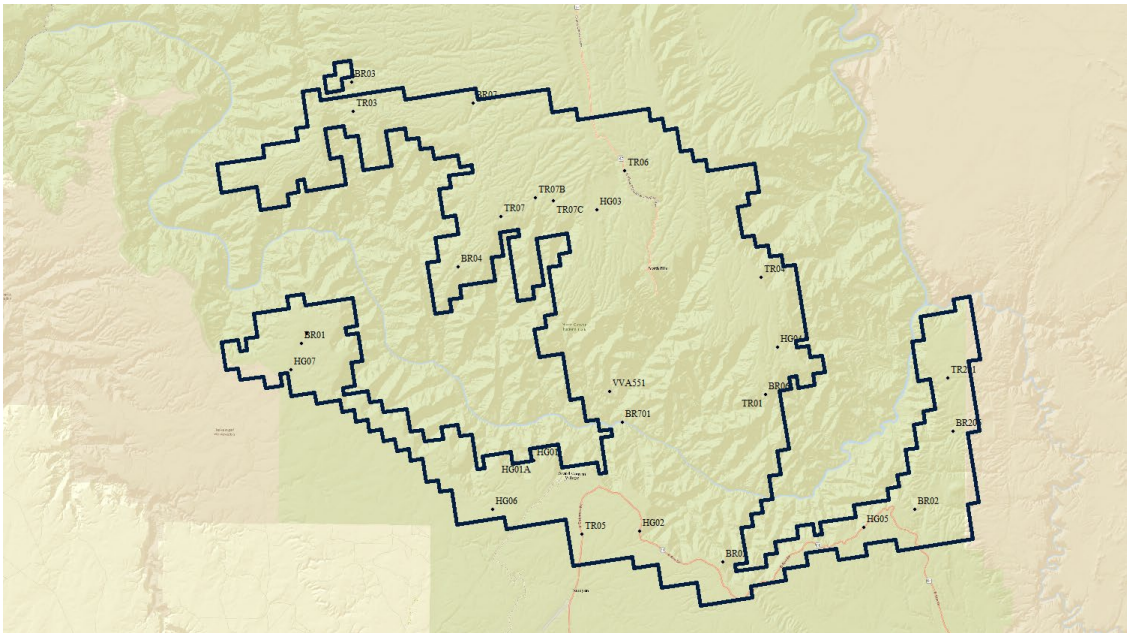

Figure 5: Vegetated Vertical Accuracy (VVA) Point Distribution

SECTION 3: DATA PRODUCTION

3.1 Aerial LiDAR Project – Calibration/Classification

3.1.1 LiDAR Point Cloud Generation

Atlantic used Optech software products to download the IPAS ABGNSS/IMU data and raw laser scan files from the airborne system. Applanix PosPac 8.5 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	NAD 1983 2011
Coordinate System	UTM Zone 12 North
Vertical Datum	NAVD88
Geoid Model	12B
EPSG Code	6341
Units of Reference	Meters

Table 1: Coordinate Reference System

3.1.3 LiDAR Point Cloud Statistics

Category	Value
Total Points	18,437,418,809
Nominal Pulse Spacing (m)	0.3789
Nominal Pulse Density (pls/m²)	6.9645
Aggregate Total Points	17,115,522,999
Aggregate Nominal Pulse Spacing (m)	0.2917
Aggregate Nominal Pulse Density (pls/m²)	11.7502

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	Unclassified
2	Ground
7	Low Point (“Low Noise”)
9	Water
17	Bridge Decks
18	High Noise
20	Ignored Ground
21	Snow
22	Temporal exclusion

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 0.5-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)

Two sets of bare earth Digital Elevation Models (DEMs) were derived using the hydro-lines and bare earth (ground) LiDAR points and using only the bare earth (ground) LiDAR points. All DEMs were created with a grid spacing of 0.5 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.

3.1.10 Surface-Digital Elevation Model (DSM)

Surface digital elevation models (DSMs) were derived using all first return LiDAR points, excluding LiDAR points classified as high or low noise. All DSMs were created with a grid spacing of 0.5 meter. DSMs 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)	30	0.0779	0.1526	0.1538
NVA (DEM)	30	0.0924	0.1811	0.1492
VVA (Point Cloud)	20	0.0920	0.1803	0.1855
VVA (DEM)	20	0.0783	0.1535	0.1246

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.

Brian J. Mayfield, ASPRS Certified Photogrammetrist #R1276

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
BE02	389264.9950	3988786.8620	1946.8500	1947.0430	0.1930	NVA
BE03	421831.2140	3985708.5860	2189.7060	2189.7500	0.0440	NVA
BE04	412148.3860	4015334.5420	2693.2720	2693.2500	-0.0220	NVA
BE06	378235.9270	4024310.7730	2304.7340	2304.8300	0.0960	NVA
BE08	396640.8260	4014313.3640	2490.5700	2490.6010	0.0310	NVA
BE09	399957.8570	4020937.2920	2682.1520	2682.1930	0.0410	NVA
BE204	428030.8600	4004099.6270	1870.4340	1870.4030	-0.0310	NVA
BE208	401900.8200	4002567.5640	1996.0910	1996.1530	0.0620	NVA
BE209	402442.6350	3995648.4740	744.3590	744.5420	0.1830	NVA
BE210	410048.4370	3989994.3790	1153.1270	1153.2160	0.0890	NVA
BR01	375374.2820	4002323.8590	1962.3320	1962.3000	-0.0320	VVA
BR02	427144.2920	3988356.8310	2199.1650	2199.1870	0.0220	VVA
BR05	410934.0730	3983904.7630	2273.2460	2273.3070	0.0610	VVA
BR06	414550.0600	3998012.2530	2409.7800	2409.9640	0.1840	VVA
BR07	389868.1400	4022537.0130	2455.8280	2455.9910	0.1630	VVA
BR206	430385.1000	3994931.6910	1885.6380	1885.6320	-0.0060	VVA
BR701	402462.8250	3995645.6330	744.3460	744.5600	0.2140	VVA
HG01	395014.5200	3992443.4600	2125.7670	2125.7830	0.0160	VVA
HG02	403928.7730	3986484.6990	2182.4250	2182.4220	-0.0030	VVA
HG03	400327.9990	4013562.8260	2499.8070	2499.9210	0.1140	VVA
HG05	422842.4140	3986796.8070	2215.9560	2216.0110	0.0550	VVA

Point ID	Given (X)	Given (Y)	Given (Z)	Laser (Z)	Delta (Z)	Report Point Type
HG06	391497.3540	3988359.4150	2015.6270	2015.6270	0.0000	VVA
HG07	374490.4910	4000093.8470	1926.2010	1926.2120	0.0110	VVA
OT01	397526.7280	3990213.5150	2111.0780	2111.0750	-0.0030	NVA
OT02	411967.2720	4015426.0390	2689.9050	2689.9630	0.0580	NVA
OT03	376202.1050	4005206.0560	2026.3410	2026.2980	-0.0430	NVA
OT05	414536.7080	3997986.6290	2409.1140	2409.1700	0.0560	NVA
OT06	378850.5600	4022025.5940	2292.2170	2292.3200	0.1030	NVA
OT08	402918.6410	4010942.7510	2520.3810	2520.4580	0.0770	NVA
OT09	402958.4760	4010902.8100	2520.5180	2520.5780	0.0600	NVA
OT202	430712.5730	4003062.6440	1806.6170	1806.6890	0.0720	NVA
OT208	412973.0960	3994542.2380	1934.8590	1934.9770	0.1180	NVA
OT210	407227.6200	4004948.7190	1382.7630	1382.8550	0.0920	NVA
TR01	414515.4060	3997996.3380	2408.8540	2408.9330	0.0790	VVA
TR02	375800.3070	4003216.1270	1981.6320	1981.6910	0.0590	VVA
TR03	379778.2300	4021832.3620	2315.9250	2315.9590	0.0340	VVA
TR05	399070.5540	3986236.6820	2089.5740	2089.5460	-0.0280	VVA
TR07B	395098.6250	4014563.2700	2512.1260	2512.1890	0.0630	VVA
TR201	429918.9920	3999410.7920	1848.0720	1848.0910	0.0190	VVA
UR01A	391018.3420	3991526.9260	2031.7140	2031.7200	0.0060	NVA
UR02	398914.8530	3984220.8410	2071.1970	2071.1770	-0.0200	NVA
UR04	425638.7010	3988899.6860	2280.3680	2280.3490	-0.0190	NVA
UR06	405320.5960	4014218.7870	2525.3690	2525.4440	0.0750	NVA
UR08	405082.0960	4008603.4100	2518.4300	2518.4780	0.0480	NVA
UR09	404821.2150	4008096.9460	2542.8880	2542.8930	0.0050	NVA

Point ID	Given (X)	Given (Y)	Given (Z)	Laser (Z)	Delta (Z)	Report Point Type
UR10	405181.9520	3985438.4940	2202.0080	2202.0220	0.0140	NVA
UR208	401419.8000	3998243.3520	1181.7500	1181.8300	0.0800	NVA
UR209	405256.4890	3992592.9460	1490.2020	1490.3140	0.1120	NVA
VVA551	401399.5080	3998257.3250	1182.5850	1182.7440	0.1590	VVA
XNVA701	415180.0340	3999111.7400	2432.3410	2432.3280	-0.0130	NVA

Table 63: 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)	Report Point Type
BE02	389264.995	3988786.862	1946.85	1946.9161	-0.0661	NVA
BE03	421831.2140	3985708.5860	2189.7060	2189.6363	0.0697	NVA
BE04	412148.386	4015334.542	2693.272	2693.1241	0.1479	NVA
BE06	378235.9270	4024310.7730	2304.7340	2304.7092	0.0248	NVA
BE08	396640.826	4014313.364	2490.57	2490.4879	0.0821	NVA
BE09	399957.8570	4020937.2920	2682.1520	2682.0696	0.0824	NVA
BE204	428030.86	4004099.627	1870.434	1870.2939	0.1401	NVA
BE208	401900.8200	4002567.5640	1996.0910	1996.0331	0.0579	NVA
BE209	402442.635	3995648.474	744.359	744.4338	-0.0748	NVA
BE210	410048.4370	3989994.3790	1153.1270	1153.1181	0.0089	NVA
OT01	397526.728	3990213.515	2111.078	2110.9518	0.1262	NVA
OT02	411967.2720	4015426.0390	2689.9050	2689.8362	0.0688	NVA
OT03	376202.105	4005206.056	2026.341	2026.1915	0.1495	NVA
OT05	414536.7080	3997986.6290	2409.1140	2409.0319	0.0821	NVA
OT06	378850.56	4022025.594	2292.217	2292.2694	-0.0524	NVA
OT08	402918.6410	4010942.7510	2520.3810	2520.3418	0.0392	NVA

Point ID	Given (X)	Given (Y)	Given (Z)	DEM (Z)	DEM (DZ)	Report Point Type
OT09	402958.476	4010902.81	2520.518	2520.4555	0.0625	NVA
OT202	430712.5730	4003062.6440	1806.6170	1806.5953	0.0217	NVA
OT208	412973.096	3994542.238	1934.859	1934.8515	0.0075	NVA
OT210	407227.6200	4004948.7190	1382.7630	1382.7673	-0.0043	NVA
UR01A	391018.342	3991526.926	2031.714	2031.5840	0.1300	NVA
UR02	398914.8530	3984220.8410	2071.1970	2071.0480	0.1490	NVA
UR04	425638.701	3988899.686	2280.368	2280.2167	0.1513	NVA
UR06	405320.5960	4014218.7870	2525.3690	2525.3238	0.0452	NVA
UR08	405082.096	4008603.41	2518.43	2518.3368	0.0932	NVA
UR09	404821.2150	4008096.9460	2542.8880	2542.7416	0.1464	NVA
UR10	405181.952	3985438.494	2202.008	2201.9096	0.0984	NVA
UR208	401419.8000	3998243.3520	1181.7500	1181.6968	0.0532	NVA
UR209	405256.489	3992592.946	1490.202	1490.1989	0.0031	NVA
XNVA701	415180.0340	3999111.7400	2432.3410	2432.2098	0.1312	NVA

Point ID	Given (X)	Given (Y)	Given (Z)	DEM (Z)	DEM (DZ)	Report Point Type
BR01	375374.282	4002323.859	1962.332	1962.2719	0.0601	VVA
BR02	427144.2920	3988356.8310	2199.1650	2199.0683	0.0967	VVA
BR05	410934.073	3983904.763	2273.246	2273.2112	0.0348	VVA
BR06	414550.0600	3998012.2530	2409.7800	2409.7881	-0.0081	VVA
BR07	389868.14	4022537.013	2455.828	2455.8404	-0.0124	VVA
BR206	430385.1000	3994931.6910	1885.6380	1885.5141	0.1239	VVA
BR701	402462.825	3995645.633	744.346	744.3463	-0.0003	VVA
HG01	395014.5200	3992443.4600	2125.7670	2125.6423	0.1247	VVA

Point ID	Given (X)	Given (Y)	Given (Z)	DEM (Z)	DEM (DZ)	Report Point Type
HG02	403928.773	3986484.699	2182.425	2182.3043	0.1207	VVA
HG03	400327.9990	4013562.8260	2499.8070	2499.7852	0.0218	VVA
HG05	422842.414	3986796.807	2215.956	2215.8896	0.0664	VVA
HG06	391497.3540	3988359.4150	2015.6270	2015.5107	0.1163	VVA
HG07	374490.491	4000093.847	1926.201	1926.0772	0.1238	VVA
TR01	414515.4060	3997996.3380	2408.8540	2408.8082	0.0458	VVA
TR02	375800.307	4003216.127	1981.632	1981.6139	0.0181	VVA
TR03	379778.2300	4021832.3620	2315.9250	2315.8841	0.0409	VVA
TR05	399070.554	3986236.682	2089.574	2089.4494	0.1246	VVA
TR07B	395098.6250	4014563.2700	2512.1260	2512.1153	0.0107	VVA
TR201	429918.992	3999410.792	1848.072	1847.9762	0.0958	VVA
VVA551	401399.5080	3998257.3250	1182.5850	1182.5740	0.0110	VVA

Table 14: DEM Check Point Assessment