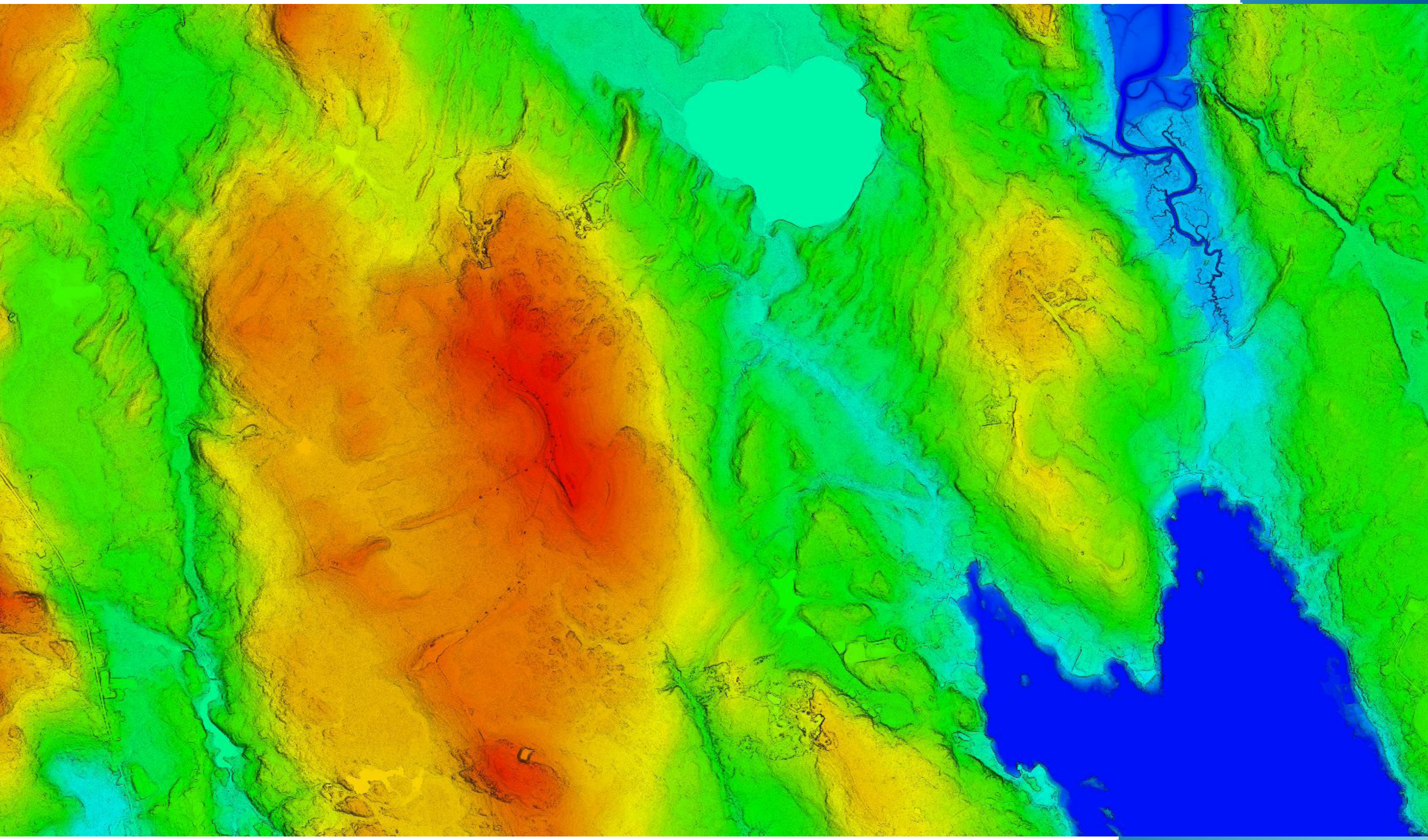
NV5 GEOSPATIAL



ME MidCoast 2021 B21 LIDAR PROCESSING REPORT

Submitted: August 31, 2023

2023

Project ID: 220048
Work Unit: 300238

Prepared for:

USGS
science for a changing world

Prepared by:

NV5 GEOSPATIAL

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1. Summary / Scope

1.1. Summary

This report contains a summary of the ME_MidCoast_2021_B21, Work Unit 300238 lidar acquisition task order, issued by USGS under their Contract G16PC00016 on May 5, 2021. The task order yielded a work unit area covering approximately 53 square miles over Maine. The intent of this document is only to provide specific validation information for the data acquisition/collection, processing, and production of deliverables completed as specified in the task order.

1.2. Scope

Aerial topographic lidar was acquired using state of the art technology along with the necessary surveyed ground control points (GCPs) and airborne GPS and inertial navigation systems. The aerial data collection was designed with the following specifications listed in Table 1 below.

Table 1. Originally Planned Lidar Specifications

Average Point Density	Flight Altitude (AGL)	Field of View	Minimum Side Overlap	RMSEz
2 pts / m^2	1900 m	58.5°	20%	≤ 10cm

1.3. Coverage

The work unit boundary covers 53 square miles over Maine. Work unit extents are shown in Figure 1.

1.4. Duration

Lidar data was acquired from May 9, 2021 to May 11, 2022 in 7 total lifts. See “Section: 2.4. Time Period” for more details.

1.5. Issues

This work unit was produced in order to cover gaps in coverage between the Maine Mid Coast task order and an older Eastern Central Maine project contracted with the State of Maine.

ME MidCoast 2021 B21 Work Unit 300238 Projected Coordinate System: UTM Zone 19 Horizontal Datum: NAD83 (2011) Vertical Datum: NAVD88 (GEOID 18) Units: Meters	
Lidar Point Cloud	Classified Point Cloud in .LAS 1.4 format
Rasters	• 1-meter Hydro-flattened Bare Earth Digital Elevation Model (DEM) in GeoTIFF format • 1-meter Intensity images in GeoTIFF format • 1-meter Swath Seperation Images • 1-meter Maximum Surface Height Raster
Vectors	Shapefiles (*.shp) • Project Boundary • Lidar Tile Index Geodatabase (*.gdb) • Continuous Hydro-flattened Breaklines • Swath Polygon
Reports	Reports in PDF format • Focus on Delivery • Survey Report • Processing Report • Work Unit Lidar Mapping Report
Metadata	XML Files (*.xml) • Breaklines • Classified Point Cloud • DEM • Intensity Imagery

ME MidCoast 2021 B21
Work Unit 300238 Boundary

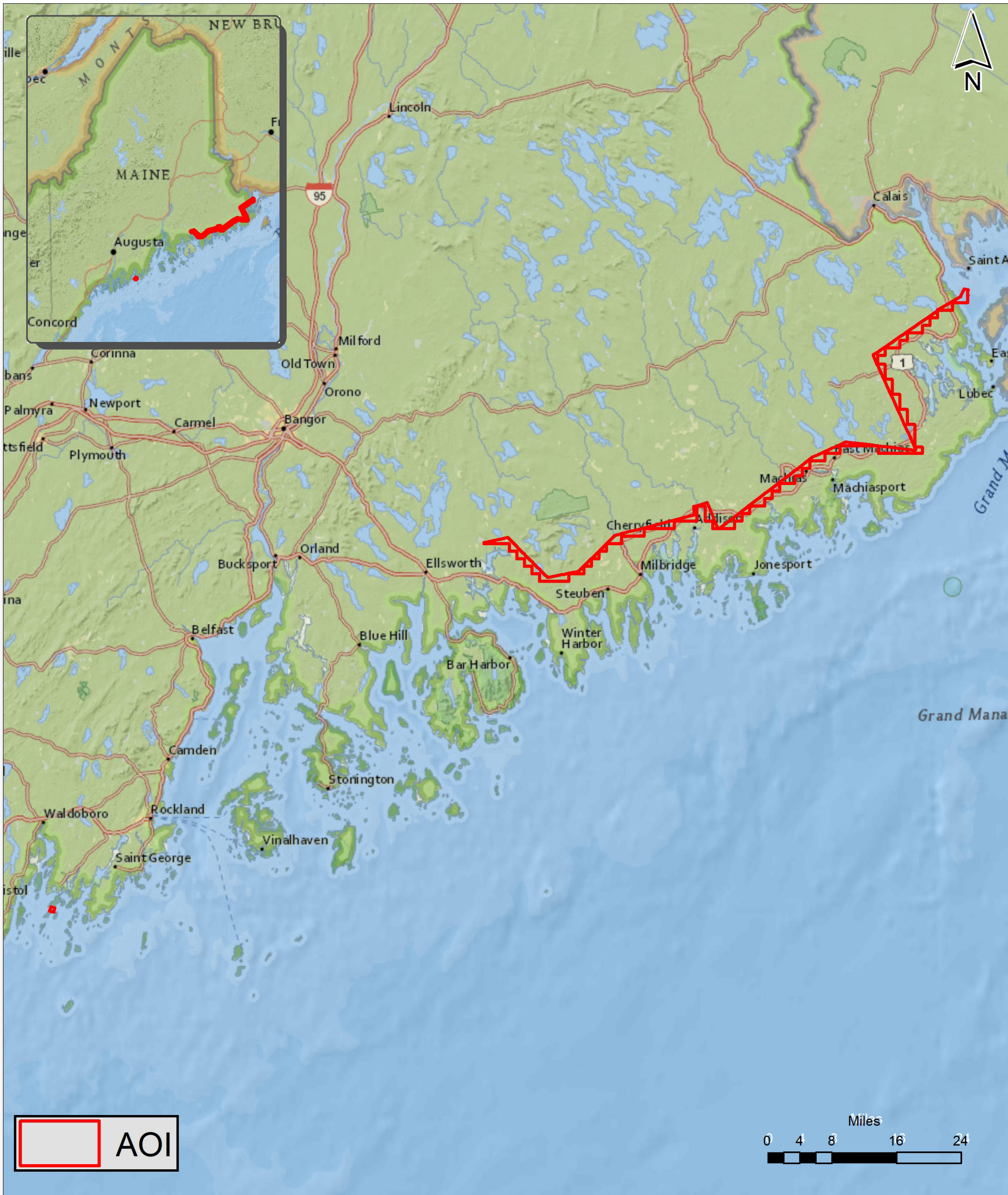

Figure 1. Work Unit Boundary

2. Planning / Equipment

2.1. Flight Planning

Flight planning was based on the unique project requirements and characteristics of the project site. The basis of planning included: required accuracies, type of development, amount / type of vegetation within project area, required data posting, and potential altitude restrictions for flights in project vicinity.

Detailed project flight planning calculations were performed for the project using RiPARAMETER planning software.

2.2. Lidar Sensor

NV5 Geospatial utilized Riegl VQ1560i lidar sensors (Figure 2), serial number(s) 3541 for data acquisition.

The Riegl 1560i system has a laser pulse repetition rate of up to 2 MHz resulting in more than 1.3 million measurements per second. The system utilizes a Multi-Pulse in the Air option (MPIA). The sensor is also equipped with the ability to measure up to an unlimited number of targets per pulse from the laser.

A brief summary of the aerial acquisition parameters for the project are shown in the lidar System Specifications in Table 2.

Table 2. Lidar System Specifications

		Riegl VQ1560i (SN3541)
Terrain and Aircraft Scanner	Flying Height	1900 m
	Recommended Ground Speed	140 kts
Scanner	Field of View	58°
	Scan Rate Setting Used	160 Hz
Laser	Laser Pulse Rate Used	350 kHz
	Multi Pulse in Air Mode	yes
Coverage	Full Swath Width	2110 m
	Line Spacing	1690 m
Point Spacing and Density	Average Nominal Point Spacing	0.58 m
	Average Point Density	3 pts / m^2

Figure 2. Riegl VQ1560i Lidar Sensor

2.3. Aircraft

All flights for the project were accomplished through the use of customized aircraft. Plane type and tail numbers are listed below.

Lidar Collection Planes

- Piper Aztec (twin-piston), Tail Number(s): N62756

These aircraft provided an ideal, stable aerial base for lidar acquisition. These aerial platforms have relatively fast cruise speeds, which are beneficial for project mobilization / demobilization while maintaining relatively slow stall speeds, proving ideal for collection of high-density, consistent data posting using a state-of-the-art lidar system. NV5 Geospatial's operating aircraft can be seen in Figure 3 below.

Figure 3. NV5 Geospatial's Aircraft

2.4. Time Period

Project specific flights were conducted between May 9, 2021 and May 11, 2022. Seven aircraft lifts were completed. Accomplished lifts are listed below.

Lift	Start UTC	End UTC
05092021A (SN3541,N62756)	5/09/2021 8:52:23 PM	5/09/2021 10:36:17 PM
05142021A (SN3541,N62756)	5/14/2021 9:51:55 PM	5/15/2021 12:52:52 AM
05152021A (SN3541,N62756)	5/16/2021 12:05:14 AM	5/16/2021 1:47:46 AM
05172021A (SN3541,N62756)	5/17/2021 12:00:21 PM	5/17/2021 3:17:03 PM
05192021A (SN3541,N62756)	5/19/2021 3:47:17 PM	5/19/2021 5:06:20 PM
05202021A (SN3541,N62756)	5/20/2021 2:02:43 PM	5/20/2021 5:38:56 PM
05112022A (SN3541, N62756)	5/112022 2:52:56 AM	5/11/2022 2:53:01 AM

3. Processing Summary

3.1. Flight Logs

Flight logs were completed by Lidar sensor technicians for each mission during acquisition. These logs depict a variety of information, including:

- Job / Project #
- Flight Date / Lift Number
- FOV (Field of View)
- Scan Rate (HZ)
- Pulse Rate Frequency (Hz)
- Ground Speed
- Altitude
- Base Station
- PDOP avoidance times
- Flight Line #
- Flight Line Start and Stop Times
- Flight Line Altitude (AMSL)
- Heading
- Speed
- Returns
- Crab

Notes: (Visibility, winds, ride, weather, temperature, dew point, pressure, etc). Project specific flight logs for each sortie are available in Appendix A.

3.2. Lidar Processing

Applanix + POSPac software was used for post-processing of airborne GPS and inertial data (IMU), which is critical to the positioning and orientation of the lidar sensor during all flights. Applanix POSPac combines aircraft raw trajectory data with stationary GPS base station data yielding a “Smoothed Best Estimate Trajectory” (SBET) necessary for additional post processing software to develop the resulting geo-referenced point cloud from the lidar missions.

During the sensor trajectory processing (combining GPS & IMU datasets) certain statistical graphs and tables are generated within the Applanix POSPac processing environment which are commonly used as indicators of processing stability and accuracy. This data for analysis include: max horizontal / vertical GPS variance, separation plot, altitude plot, PDOP plot, base station baseline length, processing mode, number of satellite vehicles, and mission trajectory.

Point clouds in flightline swath format were created using the RiPROCESS software. The generated point cloud is the mathematical three dimensional composite of all returns from all laser pulses as determined from the aerial mission. Each flightline swath point cloud was calibrated using Strip Align software that corrects systematic geometric errors and improves the relative and absolute accuracy of the flightline swath point cloud. The calibrated point cloud swaths were imported into GeoCue distributive processing software and the imported data was then tiled so further processing could take place in TerraScan software. Using TerraScan, the vertical accuracy of the surveyed ground control was tested and any vertical bias was removed from the data. TerraScan and TerraModeler software packages were then used for automated data classification and manual cleanup. The data were manually reviewed and any remaining artifacts removed using functionality provided by TerraScan and TerraModeler.

DEMs and Intensity Images are then generated using proprietary software. In the bare earth surface model, above-ground features are excluded from the data set. Global Mapper is used as a final check of the bare earth dataset.

Finally, proprietary software is used to perform statistical analysis of the LAS files.

Software	Version
Applanix + POSPac	8.6
RiPROCESS	1.8.6
Microstation Connect	10.16.02.34
GeoCue	2020.1.22.1
Global Mapper	19.1;20.1
TerraModeler	21.008
TerraScan	21.016
TerraMatch	21.007
StripAlign	2.21

3.3. LAS Classification Scheme

The classification classes are determined by Lidar Base Specifications 2020 Rev. A and are an industry standard for the classification of lidar point clouds. All data starts the process as Class 1 (Unclassified), and then through automated classification routines, the classifications are determined using TerraScan macro processing.

The classes used in the dataset are as follows and have the following descriptions:

Table 3. LAS Classifications

	Classification Name	Description
1	Processed, but Unclassified	Laser returns that are not included in the ground class, or any other project classification
2	Bare earth	Laser returns that are determined to be ground using automated and manual cleaning algorithms
7	Low Noise	Laser returns that are often associated with scattering from reflective surfaces, or artificial points below the ground surface
9	Water	Laser returns that are found inside of hydro features
17	Bridge Deck	Laser returns falling on bridge decks
18	High Noise	Laser returns that are often associated with birds or artificial points above the ground surface
20	Ignored Ground	Ground points that fall within the given threshold of a collected hydro feature.

3.4. Classified LAS Processing

The bare earth surface is then manually reviewed to ensure correct classification on the Class 2 (Ground) points. After the bare- earth surface is finalized; it is then used to generate all hydro-breaklines through heads-up digitization.

All ground (ASPRS Class 2) lidar data inside of the Lake Pond and Double Line Drain hydro flattening breaklines were then classified to water (ASPRS Class 9) using proprietary tools. A buffer of 1 meter was also used around each hydro flattened feature to classify these ground (ASPRS Class 2) points to Ignored ground (ASPRS Class 20). All Lake Pond Island and Double Line Drain Island features were checked to ensure that the ground (ASPRS Class 2) points were reclassified to the correct classification after the automated classification was completed.

Any noise that was identified either through manual review or automated routines was classified to the appropriate class (ASPRS Class 7 and/or ASPRS Class 18) followed by flagging with the withheld bit.

All data was manually reviewed and any remaining artifacts removed using functionality provided by TerraScan and TerraModeler. Global Mapper is used as a final check of the bare earth dataset. GeoCue was then used to create the deliverable industry-standard LAS files for all point cloud data. NV5 Geospatial's proprietary software was used to perform final statistical analysis of the classes in the LAS files, on a per tile level to verify final classification metrics and full LAS header information.

3.5. Hydro-Flattened Breakline Processing

Using heads-up digitization, all Lake-Ponds, Double Line Drains, and Islands are manually collected that are within the project size specification. This includes Lake-Ponds greater than 2 acres in size, Double Line Drains with greater than a 100 foot nominal width, and Islands greater than 1 acre in size within a collected hydro feature. Lidar intensity imagery and bare-earth surface models are used to ensure appropriate and complete collection of these features.

Elevation values are assigned to all collected hydro features via NV5 Geospatial's proprietary software. This software sets Lake-Ponds to an appropriate, single elevation to allow for the generation of hydro-flattened digital elevation models (DEM). Double Line Drain elevations are assigned based on lidar elevations and surrounding terrain feature to ensure all breaklines match the lidar within acceptable tolerances. Some deviation is expected between breakline and lidar elevations due to monotonicity, connectivity, and flattening rules that are enforced on the breaklines. Once complete, horizontal placement, and vertical variances are reviewed, all breaklines are evaluated for topological consistency and data integrity using a combination of proprietary tools and manual review of hydro-flattened DEMs.

Breaklines are combined into one seamless shapefile, clipped to the project boundary, and imported into an Esri file geodatabase for delivery.

3.6. Hydro-Flattened Raster DEM Processing

Hydro-Flattened DEMs (topographic) represent a lidar-derived product illustrating the grounded terrain and associated breaklines (as described above) in raster form. NV5 Geospatial's proprietary software was used to take all input sources (bare earth lidar points, bridge and hydro breaklines, etc.) and create a Triangulated Irregular Network (TIN) on a tile-by-tile basis. Data extending past the tile edge is incorporated in this process so that proper triangulation can occur. From the TIN, linear interpolation is used to calculate the cell values for the raster product. The raster product is then clipped back to the tile edge so that no overlapping cells remain across the project area. A 32-bit floating point GeoTIFF DEM was generated for each tile with a pixel size of 1-meter. NV5 Geospatial's proprietary software was used to write appropriate horizontal and vertical projection information as well as applicable header values into the file during product generation. Each DEM is reviewed in Global Mapper to check for any surface anomalies and to ensure a seamless dataset. NV5 Geospatial ensures there are no void or no-data values (-999999) in each derived DEM. This is achieved by using propriety software checking all cell values that fall within the project boundary. NV5 Geospatial uses a proprietary tool called FOCUS on Delivery to check all formatting requirements of the DEMs against what is required before final delivery.

3.7. Intensity Image Processing

Intensity images represent reflectivity values collected by the lidar sensor during acquisition. Proprietary software generates intensity images using first returns and excluding those flagged with a withheld bit. Intensity images are linearly scaled to a value range specific to the project area to standardize the images and reduce differences between individual tiles. Appropriate horizontal projection information as well as applicable header values are written during product generation.

3.8. Maximum Surface Height Raster Processing

Maximum Surface Height rasters (topographic) represent a lidar-derived product illustrating natural and built-up features. NV5 Geospatial's proprietary software was used to take all first-return classified lidar points, excluding those flagged with a withheld bit, and create a raster on a tile-by-tile basis. Data extending past the tile edge is incorporated in this process so that proper gridding can occur. The raster product is then clipped back to the tile edge so that no overlapping cells remain across the project area. A 32-bit floating point GeoTIFF was generated for each tile with a pixel size of 1-meter. NV5 Geospatial's proprietary software was used to write appropriate horizontal and vertical projection information as well as applicable header values into the file during product generation. Each maximum surface height raster is reviewed in Global Mapper to check for any anomalies and to ensure a seamless dataset. NV5 Geospatial uses a proprietary tool called FOCUS on Delivery to check all formatting requirements of the DEMs against what is required before final delivery.

3.9. Swath Separation Raster Processing

Swath Separation Images are rasters that represent the interswath alignment between flight lines and provide a qualitative evaluation of the positional quality of the point cloud. NV5 Geospatial proprietary software generated 2-foot raster images in GeoTIFF format using last returns, excluding points flagged with the withheld bit, and using a point-in-cell algorithm. Images are generated with a 75% intensity opacity and (4) absolute 8-cm intervals, see below for interval coloring. Intensity images are linearly scaled to a value range specific to the project area to standardize the images and reduce differences between individual tiles. Appropriate horizontal projection information as well as applicable header values are written to the file during product generation. NV5 Geospatial uses a proprietary tool called FOCUS on Delivery to check all formatting requirements of the images against what is required before final delivery.

Green	0-8cm
Yellow	8-16cm
Orange	16-24cm
Red	>24cm

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Work Unit 300238 Tile Layout

Figure 4. Lidar Tile Layout

4. Project Coverage Verification

A proprietary tool (FOCUS on Flight) produces grid-based polygons of each flightline, depicting exactly where lidar points exist. These swath polygons are reviewed against the project boundary to verify adequate project coverage. Please refer to Figure 5.

ME MidCoast 2021 B21
Work Unit 300238 Lidar Coverage

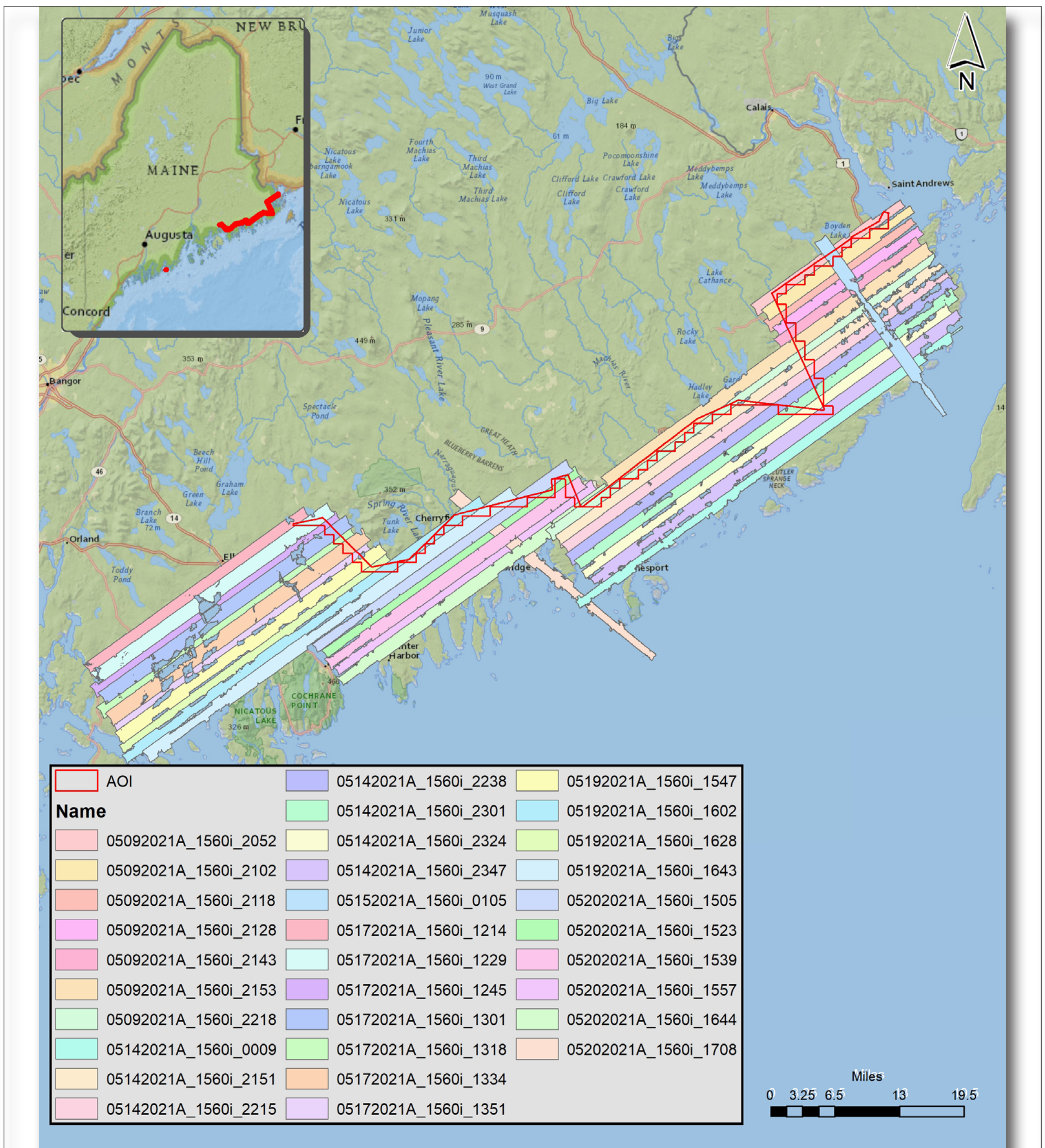


Figure 5. Lidar Coverage

5. Accuracy Testing

5.1. Calibration Control Point Testing

Figure 6 shows the location of each bare earth calibration point for the project area. TerraScan was used to perform a quality assurance check using the lidar bare earth calibration points. The results of the surface calibration are not an independent assessment of the accuracy of these project deliverables, but the statistical results do provide additional feedback as to the overall quality of the elevation surface.

5.2. Point Cloud Testing

The project specifications require that only Non-Vegetated Vertical Accuracy (NVA) be computed for raw lidar point cloud swath files. The required accuracy (ACCz) is: 19.6 cm at a 95% confidence level, derived according to NSSDA, i.e., based on RMSE of 10 cm in the "bare earth" and "urban" land cover classes. The NVA was tested with 107 checkpoints located in bare earth and urban (non-vegetated) areas. These check points were not used in the calibration or post processing of the lidar point cloud data. The checkpoints were distributed throughout the project area and were surveyed using GPS techniques. See survey report for additional survey methodologies.

Elevations from the unclassified lidar surface were measured for the x,y location of each check point. Elevations interpolated from the lidar surface were then compared to the elevation values of the surveyed control points. AccuracyZ has been tested to meet 19.6 cm or better Non-Vegetated Vertical Accuracy at 95% confidence level using RMSE(z) x 1.9600 as defined by the National Standards for Spatial Data Accuracy (NSSDA); assessed and reported using National Digital Elevation Program (NDEP)/ASPRS Guidelines.

5.3. Digital Elevation Model (DEM) Testing

The project specifications require the accuracy (ACCz) of the derived DEM be calculated and reported in two ways:

1. The required NVA is: 19.6 cm at a 95% confidence level, derived according to NSSDA, i.e., based on RMSE of 10 cm in the "bare earth" and "urban" land cover classes. This is a required accuracy. The NVA was tested with 107 checkpoints located in bare earth and urban (non-vegetated) areas. See Figure 7.
2. Vegetated Vertical Accuracy (VVA): VVA shall be reported for "brushlands/low trees" and "tall weeds/crops" land cover classes. The target VVA is: 29.4 cm at the 95th percentile, derived according to ASPRS Guidelines, Vertical Accuracy Reporting for lidar Data, i.e., based on the 95th percentile error in all vegetated land cover classes combined. This is a target accuracy. The VVA was tested with 83 checkpoints located in tall weeds/crops and brushlands/low trees (vegetated) areas. The checkpoints were distributed throughout the project area. See Figure 8.

AccuracyZ has been tested to meet 19.6 cm or better Non-Vegetated Vertical Accuracy at 95% confidence level using RMSE(z) x 1.9600 as defined by the National Standards for Spatial Data Accuracy (NSSDA); assessed and reported using National Digital Elevation Program (NDEP)/ASRPS Guidelines.

A brief summary of results are listed below.

Table 4. Accuracy Results

	Target	Measured	Point Count
Raw NVA	0.196 m	0.0716	107
NVA	0.196 m	0.07	107
VVA	0.294 m	0.1627	83

ME MidCoast 2021 B21
Calibration Points

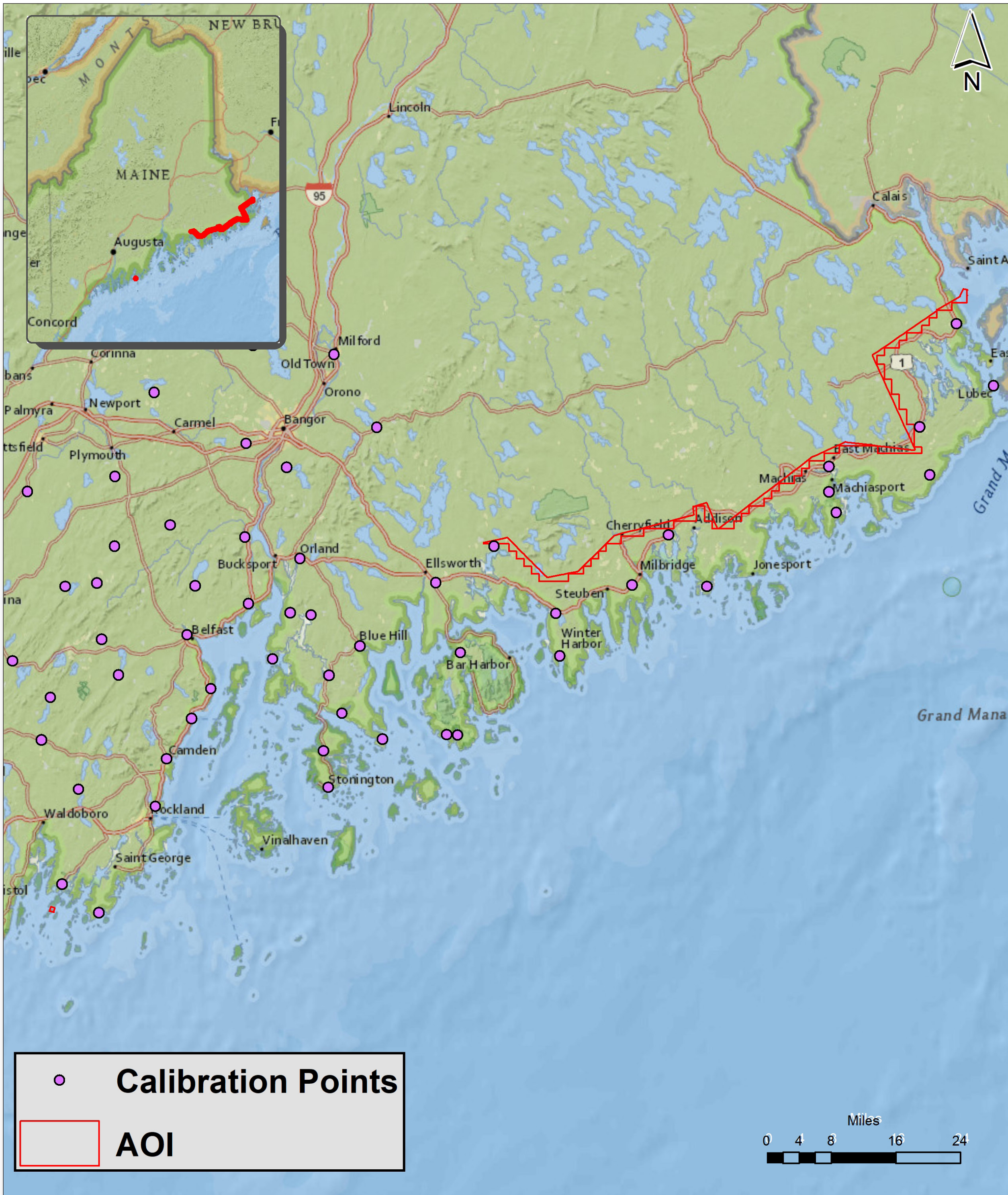


Figure 6. Calibration Control Point Locations

ME MidCoast 2021 B21
NVA Points

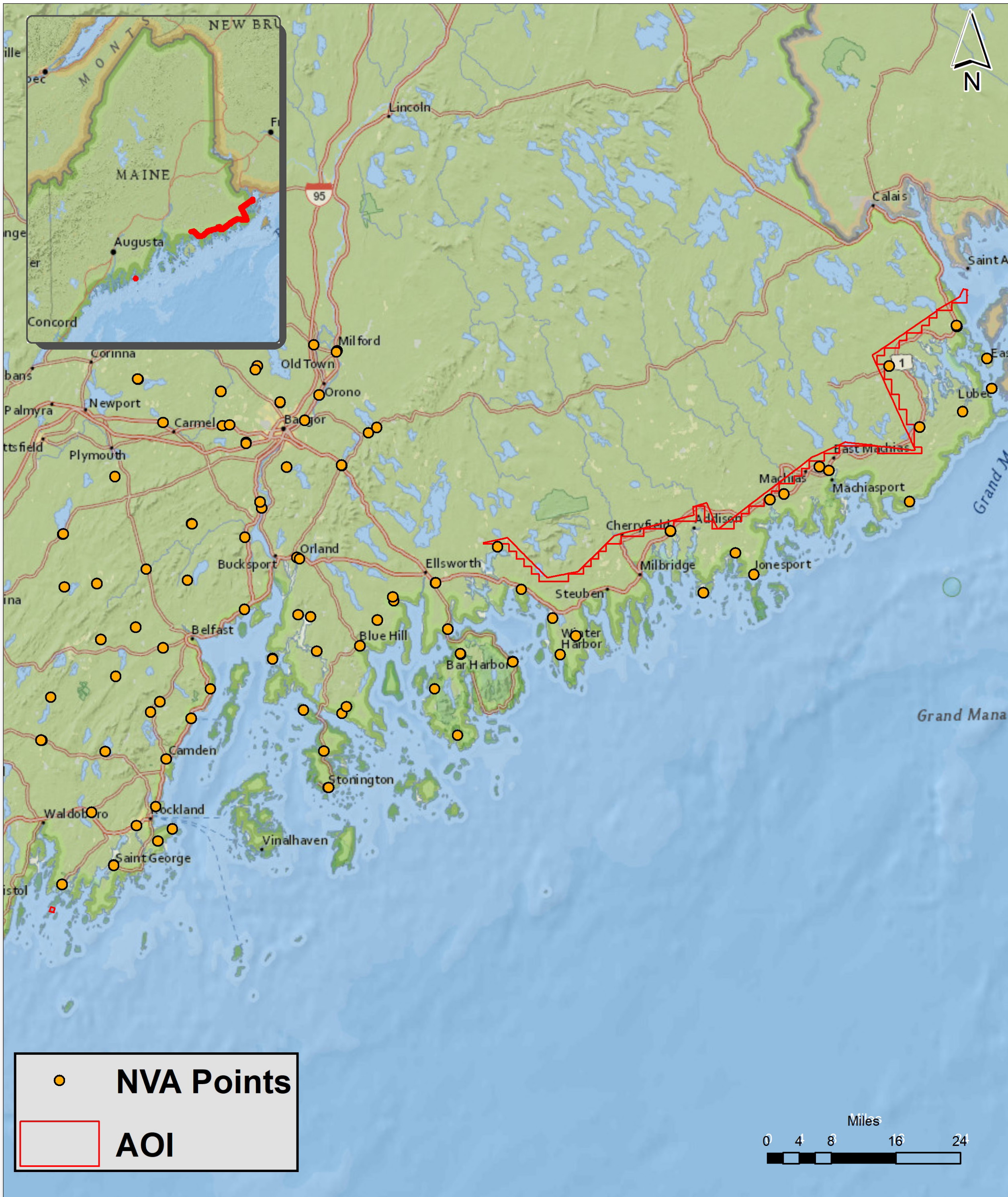


Figure 7. QC Checkpoint Locations - NVA

ME MidCoast 2021 B21
VVA Points

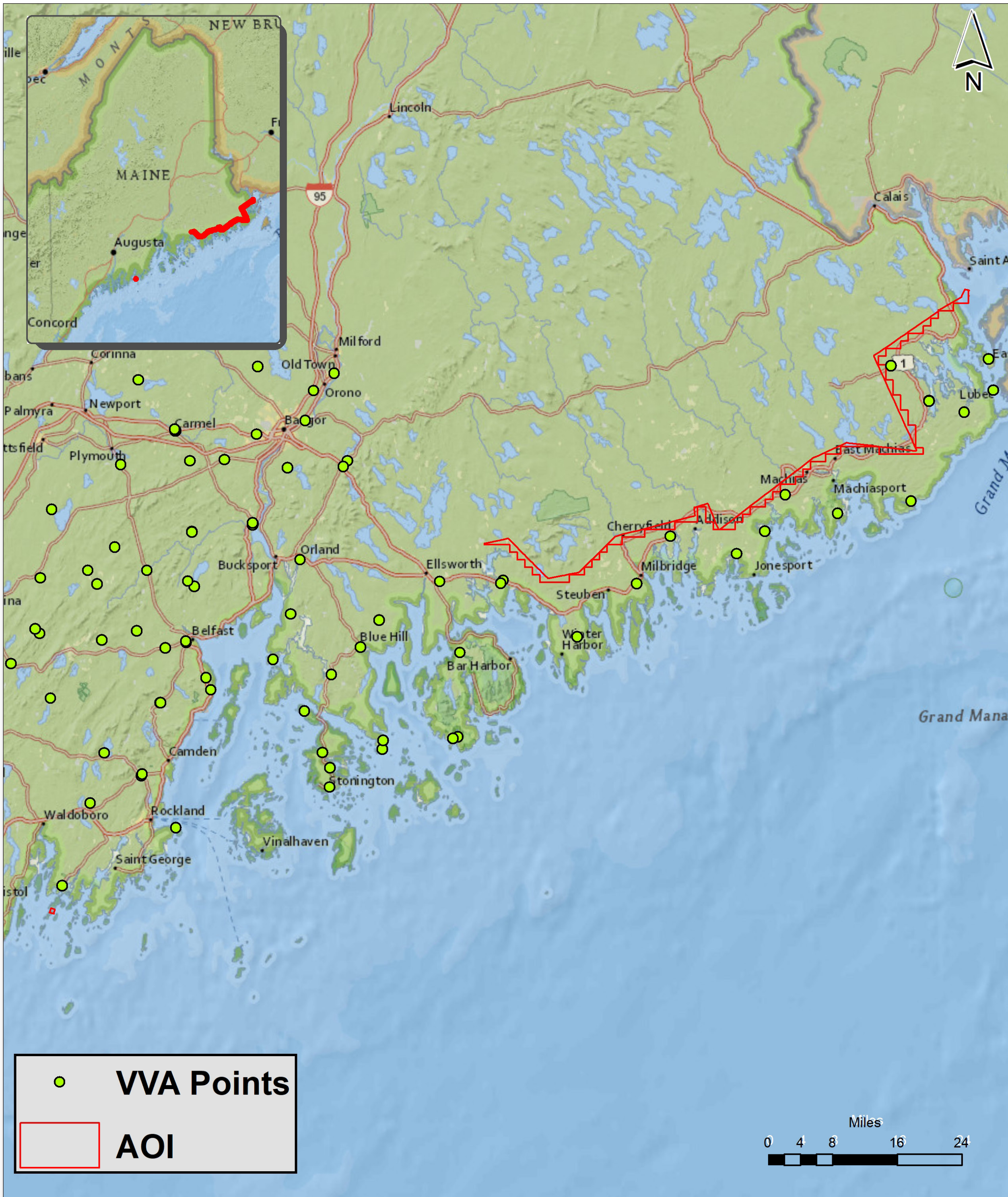


Figure 8. QC Checkpoint Locations - VVA

6. Geometric Accuracy

6.1. Horizontal Accuracy

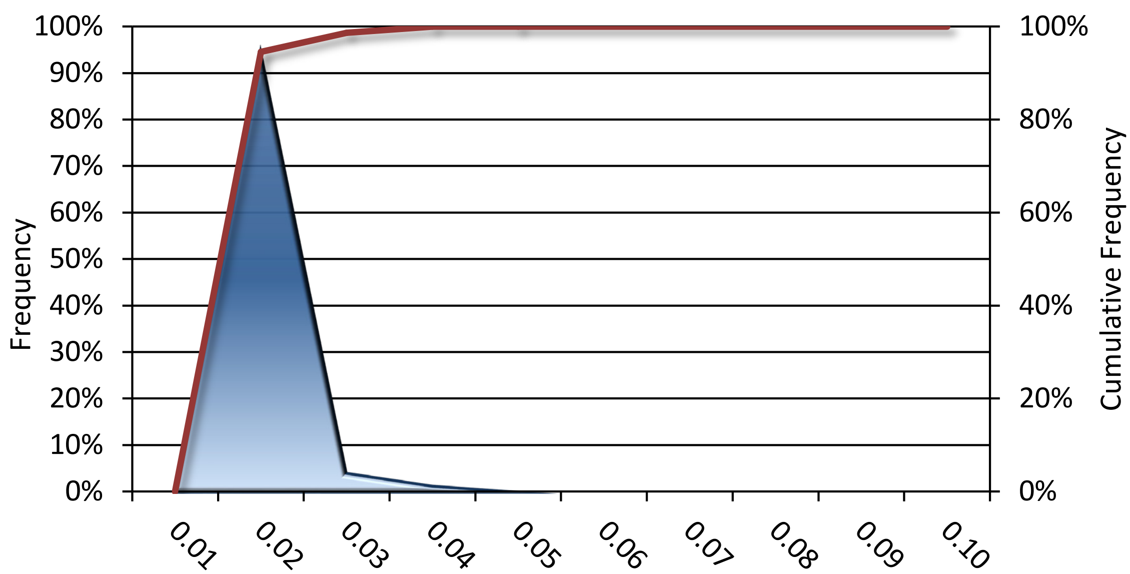
Lidar horizontal accuracy is a function of Global Navigation Satellite System (GNSS) derived positional error, flying altitude, and INS derived attitude error. The obtained $RMSE_r$ value is multiplied by a conversion factor of 1.7308 to yield the horizontal component of the National Standards for Spatial Data Accuracy (NSSDA) reporting standard where a theoretical point will fall within the obtained radius 95% of the time. Based on a flying altitude of 1900 meters, an IMU error of 0.002 decimal degrees, and a GNSS positional error of 0.019 meters, this project was compiled to meet 0.21 meter horizontal accuracy at the 95% confidence level. A summary is shown below.

Horizontal Accuracy	
$RMSE_r$	0.12 m
	0.39 ft
ACC_r	0.21 m
	0.68 ft

6.2. Relative Vertical Accuracy

Relative vertical accuracy refers to the internal consistency of the data set as a whole: the ability to place an object in the same location given multiple flight lines, GPS conditions, and aircraft attitudes. When the lidar system is well calibrated, the swath-to-swath vertical divergence is low (<0.10 meters). The relative vertical accuracy was computed by comparing the ground surface model of each individual flight line with its neighbors in overlapping regions. The average (mean) line to line relative vertical accuracy for the ME_MidCoast_2021_B21 project was 0.052 feet (0.016 meters). A summary is shown below.

Relative Vertical Accuracy	
Sample	73 flight line surfaces
Average	0.052 ft
	0.016 m
Median	0.053 ft
	0.016 m
RMSE	0.056 ft
	0.017 m
Standard Deviation (1σ)	0.009 ft
	0.003 m
1.96σ	0.017 ft
	0.005 m



Maine Mid Coast, Maine Relative Vertical Accuracy (m)
Total Compared Points (n = 1,662,917,149)

6.3. Intraswath Precision (Smooth Surface Precision)

Intraswath Precision (smooth surface precision) is the measure of reliability of the lidar point cloud elevations along a planar surface. This measurement is performed on hard surfaces against a single flightline. NV5 digitized several large parking lots as polygons across the project area. These polygons were then used to calculate precision on a single FL basis using the below formula:

Precision = Range – (Slope x Cellsize x 1.414)

Range – Is the difference between the highest and lowest lidar points in each cell
Slope – is the maximum slope of the cell to its 8 neighbors
Cellsize – is set to the ANPS, rounded up to the next integer, and then doubled

NV5 calculated the RMSDz to be 3.98 cm, minimum slope-corrected range to be 0.12 cm, and the maximum slope-corrected range to be 198.0 cm.

Project Report Appendices

The following section contains the appendices as listed in the ME MidCoast 2021 B21 Lidar Project Report.

Appendix A

Flight Logs

Project	2021-2383-4859-NV5_Maine-LiDAR
Mission ID	756_21_129_A
Date	9-May-21
Julian Day	129
Aircraft	Aztec - N62756
Sensor	VQ-1560i - S2223541
Pilot(s)	Peter Durudogan
Operator	Greg Ring
Planned AGL	1900 m
Planned Speed	140 knots

Time

Up (UTC)	Down (UTC)	Hobbs (Hours)	Air (Hours)
20:21	23:20	4.6	2.98

Lines

Plan ID	Run	Altitude (m)	Speed (knots)	Start	Stop	Note
R1_MENV01_1900m_140kn_350khz_2ppm_\	1	1970.652	159.5115104	2021-05-09 20:35:24	5/9/2021 20:36	test
R1_MENV01_1900m_140kn_350khz_2ppm_\	2	1969.86	132.6865184	2021-05-09 20:50:31	5/9/2021 20:50	test
R1_MENV01_1900m_140kn_350khz_2ppm_\	3000	1942.551	137.2428794	2021-05-09 20:52:21	5/9/2021 20:59	
R1_MENV01_1900m_140kn_350khz_2ppm_\	3001	1943.256	115.2366667	2021-05-09 21:02:32	5/9/2021 21:10	
R1_MENV01_1900m_140kn_350khz_2ppm_\	3002	1926.213	125.1794083	2021-05-09 21:13:42	5/9/2021 21:13	
R1_MENV01_1900m_140kn_350khz_2ppm_\	3	1938.391	135.9288435	2021-05-09 21:17:56	5/9/2021 21:18	test
R1_MENV01_1900m_140kn_350khz_2ppm_\	3002	1936.269	136.7996838	2021-05-09 21:18:26	5/9/2021 21:25	
R1_MENV01_1900m_140kn_350khz_2ppm_\	3003	1933.521	109.6053622	2021-05-09 21:28:49	5/9/2021 21:37	
R1_MENV01_1900m_140kn_350khz_2ppm_\	3004	1923.268	138.9923354	2021-05-09 21:43:51	5/9/2021 21:50	
R1_MENV01_1900m_140kn_350khz_2ppm_\	3005	1970.605	122.862351	2021-05-09 21:53:45	5/9/2021 22:12	
R1_MENV01_1900m_140kn_350khz_2ppm_\	3006	1943.528	130.334472	2021-05-09 22:18:14	5/9/2021 22:36	

Project	2021-2383-4859-NV5_Maine-LiDAR
Mission ID	756_21_133_A
Date	13-May-21
Julian Day	133
Aircraft	Aztec - N62756
Sensor	VQ-1560i - S2223541
Pilot(s)	Peter Durudogan
Operator	Greg Ring
Planned AGL	1900 m
Planned Speed	140 knots

Time

Up (UTC)	Down (UTC)	Hobbs (Hours)	Air (Hours)
20:33	0:20	5.7	3.78

Lines

Plan ID	Run	Altitude (m)	Speed (knots)	Start	Stop	Note
R1_MENV02_1900m_140kn_350khz_2ppm_\	1	1800.539	125.1444192	2021-05-13 21:41:26	5/13/2021 21:41	test
R1_MENV02_1900m_140kn_350khz_2ppm_\	2	1980.732	129.3100683	2021-05-13 21:46:55	5/13/2021 21:47	test
R1_MENV02_1900m_140kn_350khz_2ppm_\	2000	1980.133	131.3452688	2021-05-13 21:48:04	5/13/2021 21:49	
R1_MENV02_1900m_140kn_350khz_2ppm_\	2001	2024.777	123.4999306	2021-05-13 21:53:26	5/13/2021 21:56	
R1_MENV02_1900m_140kn_350khz_2ppm_\	2002	2012.235	133.2891088	2021-05-13 21:59:30	5/13/2021 22:03	
R1_MENV02_1900m_140kn_350khz_2ppm_\	2003	1982.113	127.7763786	2021-05-13 22:06:11	5/13/2021 22:07	
R1_MENV02_1900m_140kn_350khz_2ppm_\	2031	2073.782	128.5344762	2021-05-13 22:18:40	5/13/2021 22:27	
R1_MENV02_1900m_140kn_350khz_2ppm_\	2032	2078.302	124.3474448	2021-05-13 22:30:12	5/13/2021 22:38	
R1_MENV02_1900m_140kn_350khz_2ppm_\	2047	1861.952	133.9947227	2021-05-13 22:48:13	5/13/2021 22:49	
R1_MENV02_1900m_140kn_350khz_2ppm_\	2046	1856.722	127.7822101	2021-05-13 22:55:20	5/13/2021 23:00	
R1_MENV02_1900m_140kn_350khz_2ppm_\	2045	1913.952	131.2305822	2021-05-13 23:03:37	5/13/2021 23:08	
R1_MENV02_1900m_140kn_350khz_2ppm_\	2026	1900.086	131.003153	2021-05-13 23:12:26	5/13/2021 23:23	
R1_MENV02_1900m_140kn_350khz_2ppm_\	2027	1894.782	119.194325	2021-05-13 23:27:09	5/13/2021 23:40	
R1_MENV02_1900m_140kn_350khz_2ppm_\	2028	1875.222	136.6655589	2021-05-13 23:43:54	5/13/2021 23:53	
R1_MENV02_1900m_140kn_350khz_2ppm_\	2029	1868.95	123.6515501	2021-05-13 23:56:45	5/14/2021 0:07	
R1_MENV02_1900m_140kn_350khz_2ppm_\	2025	1986.962	141.8653309	2021-05-14 00:12:33	5/14/2021 0:24	
R1_MENV02_1900m_140kn_350khz_2ppm_\	2030	1867.801	116.8053456	2021-05-14 00:27:24	5/14/2021 0:30	
R1_MENV02_1900m_140kn_350khz_2ppm_\	2024	1977.288	114.1228464	2021-05-14 00:39:47	5/14/2021 0:52	
R1_MENV02_1900m_140kn_350khz_2ppm_\	2003	1981.662	118.1543706	2021-05-14 01:05:10	5/14/2021 1:11	

Project	2021-2383-4859-NV5_Maine-LiDAR
Mission ID	756_21_134_A
Date	14-May-21
Julian Day	134
Aircraft	Aztec - N62756
Sensor	VQ-1560i - S2223541
Pilot(s)	Peter Durudogan
Operator	Greg Ring
Planned AGL	1900 m
Planned Speed	140 knots

Time

Up (UTC)	Down (UTC)	Hobbs (Hours)	Air (Hours)
20:20	00:31:00	5.5	4.18

Lines

Plan ID	Run	Altitude (m)	Speed (knots)	Start	Stop	Note
R1_MENV03_1900m_140kn_350khz_2ppm_\	3007	1932.621	131.7729136	5/14/2021 21:51	5/14/2021 22:11	
R1_MENV03_1900m_140kn_350khz_2ppm_\	3008	1972.102	128.8182768	5/14/2021 22:15	5/14/2021 22:35	
R1_MENV03_1900m_140kn_350khz_2ppm_\	3009	1946.745	127.3934421	5/14/2021 22:38	5/14/2021 22:58	
R1_MENV03_1900m_140kn_350khz_2ppm_\	3010	1954.927	122.3958294	5/14/2021 23:01	5/14/2021 23:21	
R1_MENV03_1900m_140kn_350khz_2ppm_\	3011	1944.817	131.8681618	5/14/2021 23:24	5/14/2021 23:43	
R1_MENV03_1900m_140kn_350khz_2ppm_\	3012	1933.593	125.9375059	5/14/2021 23:47	5/15/2021 0:06	
R1_MENV03_1900m_140kn_350khz_2ppm_\	3013	1934.489	127.0727085	5/15/2021 0:09	5/15/2021 0:29	
R1_MENV03_1900m_140kn_350khz_2ppm_\	3014	1930.608	127.3370707	5/15/2021 0:32	5/15/2021 0:52	
R1_MENV03_1900m_140kn_350khz_2ppm_\	3020	1861.179	126.2679587	2021-05-15 00:56:04	5/15/2021 0:58	

Project	2021-2383-4859-NV5_Maine-LiDAR
Mission ID	756_21_135_A
Date	15-May-21
Julian Day	135
Aircraft	Aztec - N62756
Sensor	VQ-1560i - S2223541
Pilot(s)	Peter Durudogan
Operator	Greg Ring
Planned AGL	1900 m
Planned Speed	140 knots

Time

Up (UTC)	Down (UTC)	Hobbs (Hours)	Air (Hours)
22:47	00:20:00	3.2	2.55

Lines

Plan ID	Run	Altitude (m)	Speed (knots)	Start	Stop	Note
R1_MENV03_1900m_140kn_350khz_2ppm_\	3019	1863.514	136.0532493	5/16/2021 0:05	5/16/2021 0:17	
R1_MENV03_1900m_140kn_350khz_2ppm_\	3021	1869.669	119.0096602	5/16/2021 0:20	5/16/2021 0:23	
R1_MENV03_1900m_140kn_350khz_2ppm_\	3023	1911.244	113.5241437	5/16/2021 0:26	5/16/2021 0:35	
R1_MENV03_1900m_140kn_350khz_2ppm_\	3018	1877.397	136.4614557	5/16/2021 0:48	5/16/2021 1:01	
R1_MENV03_1900m_140kn_350khz_2ppm_\	3022	1941.307	112.6610787	5/16/2021 1:05	5/16/2021 1:15	
R1_MENV03_1900m_140kn_350khz_2ppm_\	3017	1919.518	112.1070843	5/16/2021 1:25	5/16/2021 1:47	

Project	2021-2383-4859-NV5_Maine-LiDAR
Mission ID	756_21_137_A
Date	17-May-21
Julian Day	137
Aircraft	Aztec - N62756
Sensor	VQ-1560i - S2223541
Pilot(s)	Peter Durudogan
Operator	Greg Ring
Planned AGL	1900 m
Planned Speed	140 knots

Time

Up (UTC)	Down (UTC)	Hobbs (Hours)	Air (Hours)
10:24	14:39:00	5	4.25

Lines

Plan ID	Run	Altitude (m)	Speed (knots)	Start	Stop	Note
R1_MENV02_1900m_140kn_350khz_2ppm_\	1	888.436	115.0733842	5/17/2021 11:28	5/17/2021 11:29	Test Shot
R1_MENV02_1900m_140kn_350khz_2ppm_\	2004	2041.078	125.6400984	5/17/2021 12:00	5/17/2021 12:11	
R1_MENV02_1900m_140kn_350khz_2ppm_\	2005	2144.554	130.0681659	5/17/2021 12:14	5/17/2021 12:26	
R1_MENV02_1900m_140kn_350khz_2ppm_\	2006	2060.286	126.1765982	5/17/2021 12:29	5/17/2021 12:41	
R1_MENV02_1900m_140kn_350khz_2ppm_\	2007	1974.291	130.0662221	5/17/2021 12:45	5/17/2021 12:57	
R1_MENV02_1900m_140kn_350khz_2ppm_\	2008	2025.593	125.6051093	5/17/2021 13:01	5/17/2021 13:14	
R1_MENV02_1900m_140kn_350khz_2ppm_\	2009	2080.064	127.9940886	5/17/2021 13:18	5/17/2021 13:30	Refly
R1_MENV02_1900m_140kn_350khz_2ppm_\	2010	2178.489	122.9051155	5/17/2021 13:34	5/17/2021 13:48	
R1_MENV02_1900m_140kn_350khz_2ppm_\	2011	1992.912	131.6971038	5/17/2021 13:51	5/17/2021 14:04	
R1_MENV03_1900m_140kn_350khz_2ppm_\	3015	1932.573	129.3917096	5/17/2021 14:14	5/17/2021 14:32	
R1_MENV03_1900m_140kn_350khz_2ppm_\	3016	1934.22	125.7139643	5/17/2021 14:36	5/17/2021 14:56	
R1_MENV02_1900m_140kn_350khz_2ppm_\	2039	1914.646	126.6664459	5/17/2021 15:07	5/17/2021 15:17	

Project	2021-2383-4859-NV5_Maine-LiDAR
Mission ID	756_21_139_A
Date	19-May-21
Julian Day	139
Aircraft	Aztec - N62756
Sensor	VQ-1560i - S2223541
Pilot(s)	Peter Durudogan
Operator	Greg Ring
Planned AGL	1900 m
Planned Speed	140 knots

Time

Up (UTC)	Down (UTC)	Hobbs (Hours)	Air (Hours)
14:23:00	16:30:00	3.4	2.12

Lines

Plan ID	Run	Altitude (m)	Speed (knots)	Start	Stop	Note
R1_MENV02_1900m_140kn_350khz_2ppm_\	1	1012.219	114.2511398	2021-05-19 15:28:53	5/19/2021 15:29	test shot
R1_MENV02_1900m_140kn_350khz_2ppm_\	2012	1977.051	146.0892952	2021-05-19 15:47:14	5/19/2021 15:59	
R1_MENV02_1900m_140kn_350khz_2ppm_\	2014	1997.334	106.2872274	2021-05-19 16:02:26	5/19/2021 16:23	
R1_MENV02_1900m_140kn_350khz_2ppm_\	2013	1977.785	136.9027074	2021-05-19 16:28:37	5/19/2021 16:40	
R1_MENV02_1900m_140kn_350khz_2ppm_\	2015	2031.471	105.6166026	2021-05-19 16:43:58	5/19/2021 17:06	

Project	2021-2383-4859-NV5_Maine-LiDAR
Mission ID	756_21_140_A
Date	20-May-21
Julian Day	139
Aircraft	Aztec - N62756
Sensor	VQ-1560i - S2223541
Pilot(s)	Peter Durudogan
Operator	Greg Ring
Planned AGL	1900 m
Planned Speed	140 knots

Time

Up (UTC)	Down (UTC)	Hobbs (Hours)	Air (Hours)
12:50:00	17:03:00	4.9	4.22

Lines

Plan ID	Run	Altitude (m)	Speed (knots)	Start	Stop	Note
R1_MENV02_1900m_140kn_350khz_2ppm_\	1	1140.341	109.5062264	2021-05-20 13:54:47	5/20/2021 13:55	Test Fire
R1_MENV02_1900m_140kn_350khz_2ppm_\	2049	2297.22	131.2791782	2021-05-20 14:02:42	5/20/2021 14:15	
R1_MENV02_1900m_140kn_350khz_2ppm_\	2033	2247.745	104.2928475	2021-05-20 14:24:50	5/20/2021 14:35	
R1_MENV02_1900m_140kn_350khz_2ppm_\	2034	2310.605	134.1113531	2021-05-20 14:37:56	5/20/2021 14:46	
R1_MENV02_1900m_140kn_350khz_2ppm_\	2035	2319.327	101.0855115	2021-05-20 14:49:59	5/20/2021 15:00	
R1_MENV02_1900m_140kn_350khz_2ppm_\	2016	1935.913	106.5477019	2021-05-20 15:05:06	5/20/2021 15:20	
R1_MENV02_1900m_140kn_350khz_2ppm_\	2017	1945.543	133.1685907	2021-05-20 15:23:44	5/20/2021 15:35	
R1_MENV02_1900m_140kn_350khz_2ppm_\	2018	1945.074	107.7645458	2021-05-20 15:39:15	5/20/2021 15:54	
R1_MENV02_1900m_140kn_350khz_2ppm_\	2019	1954.055	135.6294922	2021-05-20 15:57:24	5/20/2021 16:09	
R1_MENV02_1900m_140kn_350khz_2ppm_\	2021	1948.792	110.4451011	2021-05-20 16:12:49	5/20/2021 16:27	
R1_MENV02_1900m_140kn_350khz_2ppm_\	2022	1963.36	136.2437456	2021-05-20 16:30:06	5/20/2021 16:41	
R1_MENV02_1900m_140kn_350khz_2ppm_\	2020	1939.958	109.5703731	2021-05-20 16:44:01	5/20/2021 17:00	
R1_MENV02_1900m_140kn_350khz_2ppm_\	2048	1947.191	122.304469	2021-05-20 17:08:54	5/20/2021 17:19	
R1_MENV02_1900m_140kn_350khz_2ppm_\	2023	1965.582	135.3942875	2021-05-20 17:27:50	5/20/2021 17:38	

Project	2021-2383-4859-NV5_Maine-LiDAR
Mission ID	756_21_144_A
Date	24-May-21
Julian Day	139
Aircraft	Aztec - N62756
Sensor	VQ-1560i - S2223541
Pilot(s)	Peter Durudogan
Operator	Greg Ring
Planned AGL	1900 m
Planned Speed	140 knots

Time

Up (UTC)	Down (UTC)	Hobbs (Hours)	Air (Hours)
13:30:00	15:30:00	2.7	2

Lines

Plan ID	Run	Altitude (m)	Speed (knots)	Start	Stop	Note
R1_MENV02_1900m_140kn_350khz_2ppm_VQ1579	1	1301.659	106.5924102	2021-05-24 17:32:30	5/24/2021 17:32	test fire
R1_MENV02_1900m_140kn_350khz_2ppm_VQ1580	2050	1922.46	135.1065992	2021-05-24 17:48:13	5/24/2021 17:56	
R1_MENV02_1900m_140kn_350khz_2ppm_VQ1581	2051	1870.057	118.7627925	2021-05-24 18:02:52	5/24/2021 18:05	
R1_MENV02_1900m_140kn_350khz_2ppm_VQ1582	2036	2188.456	122.3122443	2021-05-24 18:19:21	5/24/2021 18:28	
R1_MENV02_1900m_140kn_350khz_2ppm_VQ1583	2037	2016.96	123.0645104	2021-05-24 18:31:53	5/24/2021 18:41	
R1_MENV02_1900m_140kn_350khz_2ppm_VQ1584	2038	1953.121	124.7031675	2021-05-24 18:45:05	5/24/2021 18:55	
R1_MENV02_1900m_140kn_350khz_2ppm_VQ1585	2040	1926.343	121.1595472	2021-05-24 18:58:27	5/24/2021 19:07	
R1_MENV02_1900m_140kn_350khz_2ppm_VQ1586	2041	1931.379	123.0198021	2021-05-24 19:12:27	5/24/2021 19:23	
R1_MENV02_1900m_140kn_350khz_2ppm_VQ1587	2042	1888.646	126.8705491	2021-05-24 19:26:19	5/24/2021 19:35	
R1_MENV02_1900m_140kn_350khz_2ppm_VQ1588	2043	1926.097	123.202523	2021-05-24 19:39:06	5/24/2021 19:46	
R1_MENV02_1900m_140kn_350khz_2ppm_VQ1589	2044	1931.216	124.6545715	2021-05-24 19:49:10	5/24/2021 19:54	