Quality Assurance Report

CHESAPEAKE BAY SHORELINE MAPPING
MD2201-TB-C
TOPO BATHY LIDAR, ORTHO, STEREO COMPILATION

Prepared For:

National Oceanic and Atmospheric Administration

NOAA Contract: 1305M220DNCNL0065
NOAA Task Order: MD2201-TB-C, VA2203-TB-C
Woolpert Project Number: 10010368

Revision	Date	Written	Project Manager	Distributed to	Comments
0	September 25, 2024	M. Christy	V. Akbay	NOAA (Digital)	

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. Introduction

Woolpert was contracted by the National Oceanic and Atmospheric Administration's National Geodetic Survey (NGS) Remote Sensing Division (RSD) Coastal Mapping Program (CMP) to provide airborne topographic and bathymetric lidar data and digital imagery to enable accurate and consistent measurement of the national shoreline for 1106 square kilometers of Chincoteague Bay (MD2201-TB-C). All data were acquired using Woolpert's Leica HawkEye 4X system to meet the requirements of the project. This report covers acquisition and processing for MD2201-TB-C.

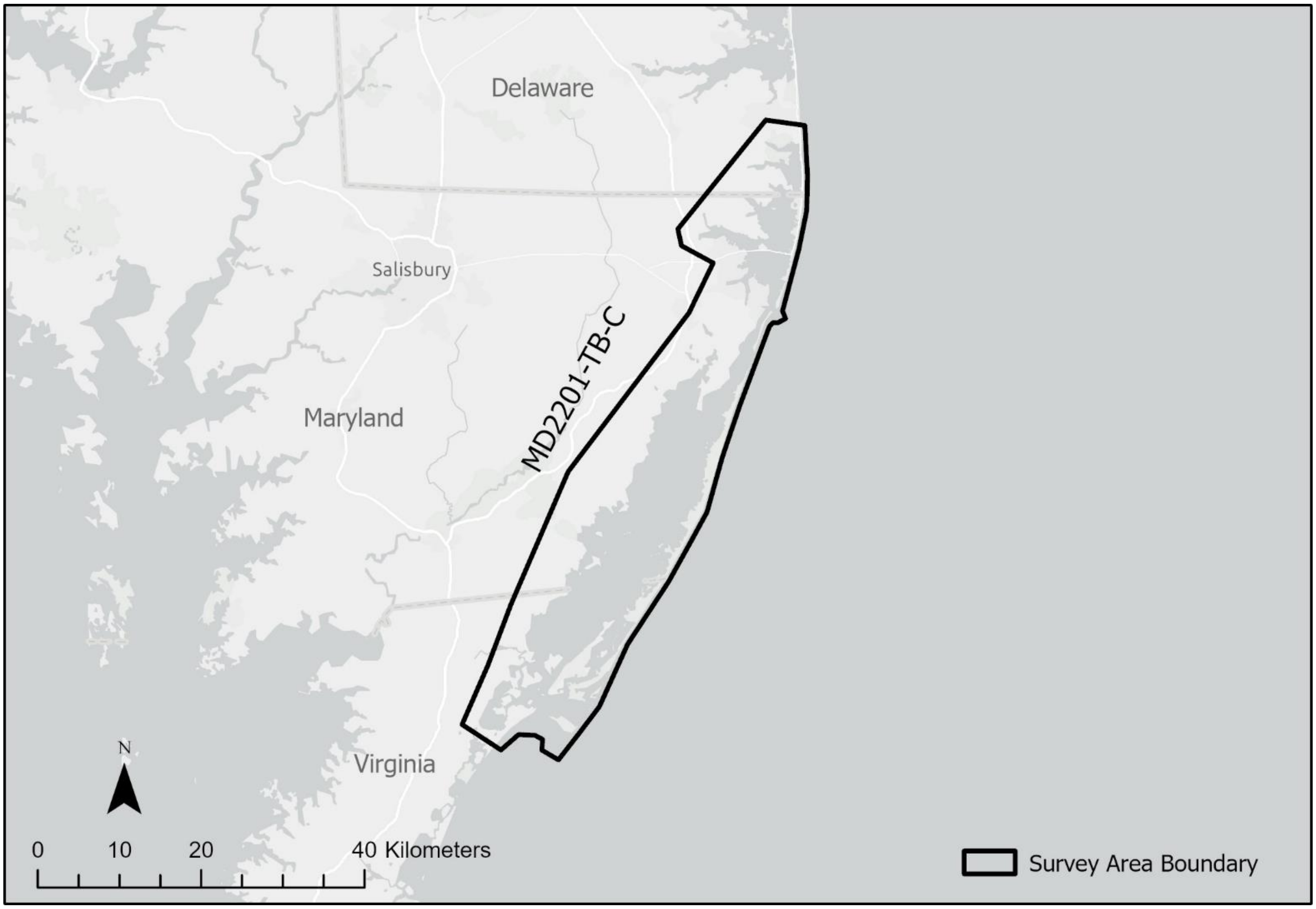

Figure 1: Survey Area

Details of the survey, data processing, quality control (QC), and product creation are provided in detail within this report.

1.1 Survey Area

The MD2201 project area covers approximately 1106 square kilometers of topographic and bathymetric lidar and digital imagery collection.

The project area was split into survey areas, subareas, and survey blocks, allowing flight lines to be planned in the most efficient manner. Bathymetric lidar data was collected to support 100% coverage and to meet QL2b specifications.

Table 1. Survey Blocks

Survey Area	Survey Subarea	Area (km^2)	Survey Block(s)
MD2201	MD2201A	258	BL31 – BL33, BL35, BL36, BL40
MD2201	MD2201B	242	BL30 – BL36, BL40, BL41

Survey Area	Survey Subarea	Area (km²)	Survey Block(s)
MD2201	MD2201C	278	BL30, BL33, BL34, BL36, BL41
MD2201	MD2201D	327	BL30, BL33, BL34, BL36, BL41

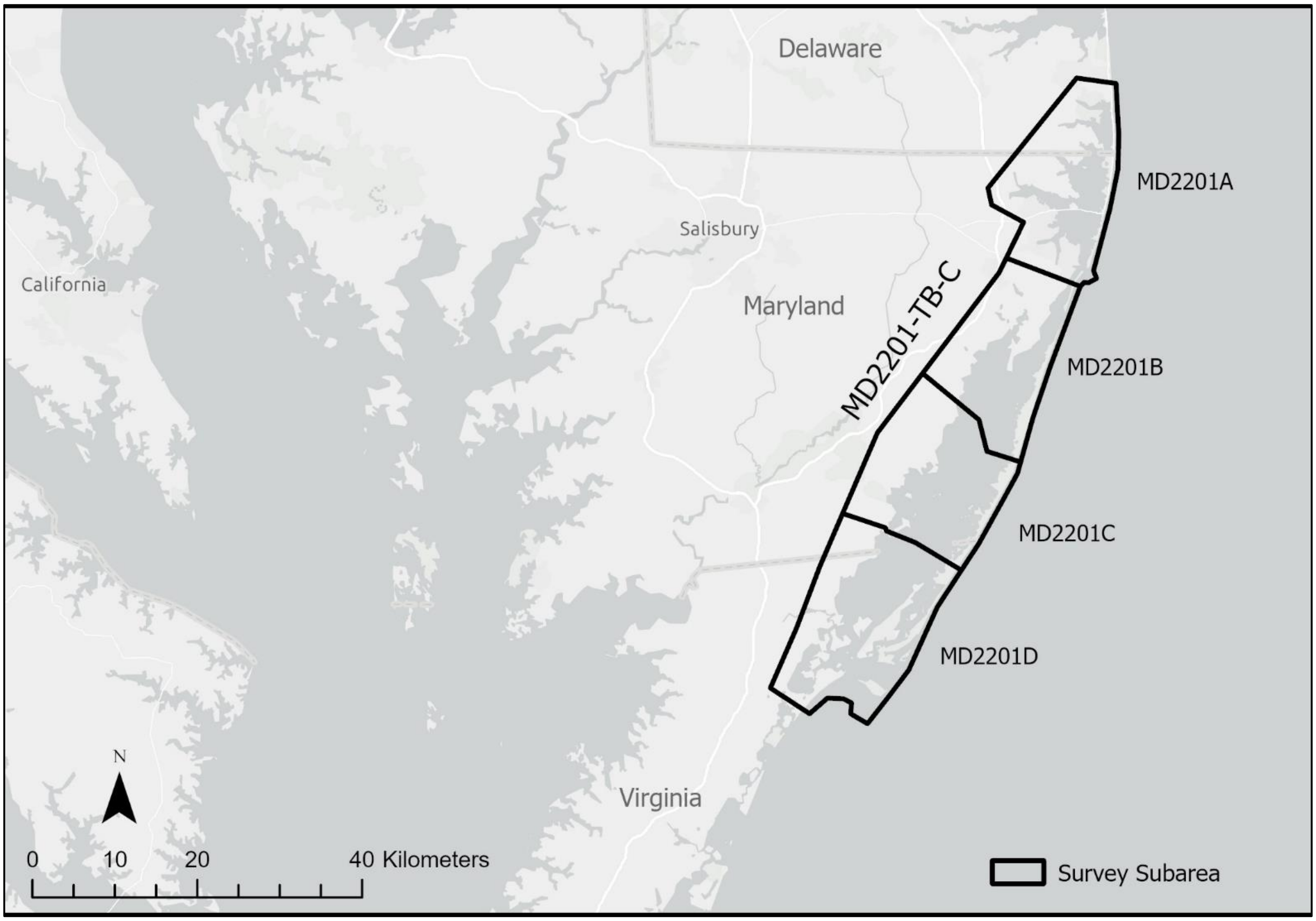

Figure 2. Survey Subareas

2. Lidar Data Acquisition

All lidar data were acquired using a Chiroptera 4X (CH4X) sensor, with an additional Leica 40 kHz deep bathymetric channel. The combination of these sensors is referred to as a Leica HawkEye 4X (HE4X) system. The CH4X sensor head, which contains the topographic laser, shallow bathymetric laser and camera, was mounted in a Leica PAV100 gyro-stabilized mount integrated with a NovAtel SPAN GNSS and LCI-100C IMU. The deep channel sensor head was mounted over a second hatch, with an additional IMU. Real-time navigation and GNSS/IMU data logging were provided by Leica FlightPro software. Lidar data was logged on the Airborne Hydrography, AB (AHAB) operator console.

2.1 Mobilization

The HE4X sensor was installed in a Cessna 404 (N7079F) and a full calibration flight was collected over Stennis International Airport (HSA) on October 30, 2022 for survey operations.

Figure 3: Mobilized Survey Aircraft N7079F

2.1.1 Aircraft Offset Survey

Physical mounting offsets between the GNSS antenna, IMU and gyro-stabilized mount were determined through a combination of manual measurements and iterative processing in NovAtel Inertial Explorer software.

Manual measurements were taken from the GNSS antenna to the reference point on the IMU in the HE4x sensor head. These measurements are added to the known offset between the IMU reference point and the rotation center of the gyro-stabilized mount to calculate the preliminary offset between the GNSS antenna and sensor reference point. This preliminary value was then used to seed the post-processing software which, through an iterative computation, uses the dynamic accelerations and rotations during flight to refine the offsets. Once the solution converges, the final offsets are entered into the flight management software and used in subsequent post-processing of the GNSS/IMU data for final trajectories.

Final offsets, shown in the Leica reference frame, are presented in Table 2.

Table 2: Aircraft Offsets for October 30, 2022 Calibration (N7079F)

Sensor Head	Lever Arm	X (forward)	Y (right)	Z (down)
CHII (Topo and Shallow Channel)	Reference to GNSS Antenna L1 Phase Center	-0.022 m	0.007 m	0.958 m
	Reference to IMU	-0.003 m	-0.006 m	-0.296 m
	Reference to IMU Rotation	0°	180°	0°
Deep Channel	IMU to GNSS Antenna L1 Phase Center	-0.081 m	0.744 m	0.876 m
	Reference to IMU Rotation	-90°	0°	180°

2.1.2 System Calibration Checks

Field calibration of the HE4X system was carried out to eliminate systematic errors by calculating corrections for boresight errors, scanner angle errors, remaining IMU angle errors, and any necessary internal timing errors. To verify or compute the field calibration, the lines shown in **Figure 4** were flown.

a. 2 x Line A over mixed terrain with flat or gentle slopes and features such as peaked roof buildings (1 x each direction)
b. 1 x Line B offset + 50% from Line A in one direction
c. 1 x Line C offset - 50% from Line A in the same direction as Line B

d. 2 x Line D orthogonal to previous lines (1 x each direction)

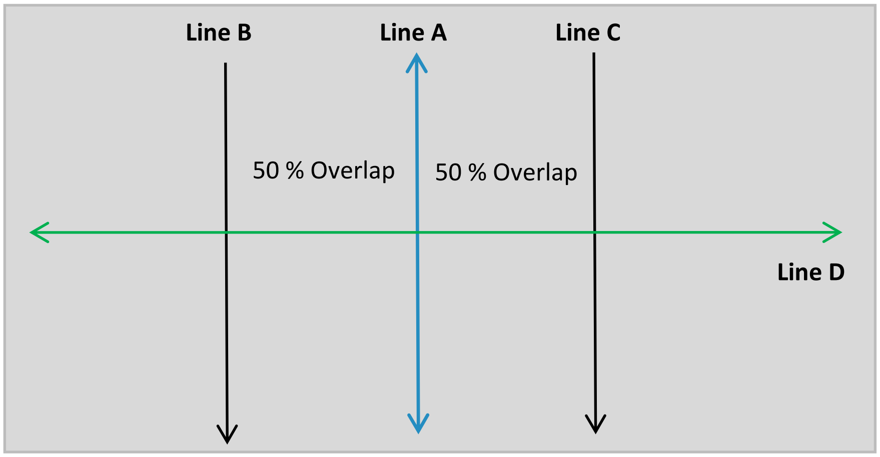

Figure 4. Schematic of HE4X Calibration Lines

A set of calibration lines were acquired at 800m, 500m and 400m altitude over Stennis on October 30th.

Calibration values were calculated using the automatic calibration routine within the Leica Lidar Survey Studio (LSS) software. This utility first identified patches or areas of gentle slope within the overlap region of all the lines to use for calibration. Patch selection prevented areas of vegetation, side of cars, or buildings from being used in the calibration process. Next, the utility compared the front side and back side of the elliptical scan within the same line, as well as comparing all lines to each other, to identify suitable calibration parameters such that data within the patches match. The procedure was iterative and continued until the best possible solution is computed.

Calibration for each channel (topographic, shallow, and deep) was done independently. Topographic channel calibration was computed using the 500 m altitude lines. The 400 m lines were then used for verification. Calibration of the shallow channel and deep channel were computed using 500 m altitude data. The lower altitude data was used for verification.

At each step of the calibration process, quality assurance was conducted to ensure values being calculated were valid. This was done using the Leica LSS Quality Control Utility. Two types of checks were performed. First, the front scan was compared to the back scan for every line. Next, a single line was chosen as a baseline and was compared to every other line. As expected, the average errors from both checks were small. Additionally, the data was visually reviewed. In particular, features were studied to ensure lines from different directions show structures in the same position, verifying horizontal accuracy was maintained. These tests all provided assurance of relative accuracy.

Results from the calibration verification checks are provided in **Table 3**. Results are good and indicate that calibrations were successful. Calibration values computed were used for all project data collected until the date of the next calibration.

Table 3: Calibration QA Results for October 30, 2022

Test		Topo 800m	Topo 500m	Topo 400m	Shallow 500m	Shallow 400m	Deep 500m	Deep 400m
Front to Back Scan Comparison	Average Error (m)	-0.0113	-0.0004	-0.0003	-0.0005	-0.0033	0.0004	0.0107
	Std. Dev. of Error	0.0007	0.0005	0.0003	0.0013	0.0011	0.0054	0.0010
Line to Line Comparison	Average Error (m)	-0.0025	-0.0033	-0.0057	-0.0044	-0.0067	-0.0045	-0.0051
	Std. Dev. of Error	0.0029	0.0008	0.0010	0.0008	0.0018	0.0066	0.0075

Woolpert acquired a detailed set of ground truth data at Stennis International Airport. The ground truth was acquired using Trimble R10 GNSS receivers, Real Time Kinematic (RTK) and Post-Processed Kinematic (PPK) survey techniques.

Ground truth is not used within the automatic calibration routine. However, a comparison to the lidar data was used to verify absolute accuracy. Results presented in **Table 4** show data is well within required accuracy specifications.

Table 4: Calibration Ground Truth Comparisons for October 30, 2022

	Topo			Shallow		Deep	
	800m	500m	400m	500m	400m	500m	400m
Average dz (m)	-0.0073	0.0075	0.0092	0.0032	0.0032	0.0203	0.0030
Root Mean Square (m)	0.0082	0.0110	0.0109	0.0096	0.0072	0.0218	0.0069

2.2 Survey Operations

For ease of operations and data management, the survey area was split into survey blocks. Actual flight lines flown, including start and end date and unique line ID, are provided in the trajectory database included with the project deliverables in SHP format.

A summary of the daily operations is shown in **Table 5**. Detailed Flight Logs for each day are provided in section 8.1. Aerial operations were conducted out of four airports: Cambridge-Dorchester (CGE), Ocean City Municipal Airport (OXB), Salisbury Regional (SBY), and Easton Airport (ESN).

Eighteen cross lines were acquired across the areas of interest during the survey for quality purposes. Crosslines were planned perpendicular to main scheme survey lines and used to verify the relative accuracy of the data where bottom coverage allowed.

Table 5: Summary of Daily Operations

Flight	Engine Time	Air Time	Flown km | %		Reflown km | %	
2022-10-30A	2:19:00	1:42:00	123.5	0.5%		
2022-11-03A	5:07:00	4:32:00	549.8	2.4%		
2022-11-04A	5:07:00	4:32:00	549.8	2.4%		
2022-11-05A	5:37:00	4:48:00	502.4	2.2%		
2022-11-08A	1:50:00	1:00:00	46.1	0.2%		
2022-11-09A	2:53:00	2:24:00	145.0	0.6%		
2022-11-10A	5:34:00	4:58:00	695.5	3.0%	31.9	0.1%
2022-11-29A	4:02:00	3:32:00	85.6	0.4%	42.0	0.2%
2022-11-29B	4:02:00	3:32:00	24.5	0.1%	20.0	0.1%
2022-12-01A	5:22:00	4:57:00				
2022-12-01B	5:22:00	4:57:00	367.6	1.6%	55.1	0.2%
2022-12-02A	6:34:00	5:54:00	635.9	2.7%	41.5	0.2%
2022-12-02B	6:34:00	5:54:00	120.3	0.5%		
2022-12-08A	6:41:00	6:13:00	658.8	2.8%	26.1	0.1%
2022-12-09A	6:36:00	6:02:00	1053.7	4.5%		
2022-12-10A	4:27:00	3:45:00	588.4	2.5%		
2022-12-14A	6:31:00	5:55:00	873.4	3.7%		
2022-12-19A	6:21:00	4:45:00	606.8	2.6%	93.7	0.4%
2022-12-21A	4:46:00	3:42:00	409.7	1.8%	55.4	0.2%
2023-02-02A	4:48:00	4:18:00	214.1	0.9%		
2023-02-05A	5:50:00	5:04:00	197.4	0.8%		

2.2.1 The HawkEye 4X

All lidar data was acquired using a HE4X sensor. The system provides denser data than previous traditional bathymetric lidar systems. It is unique in its ability to acquire bathymetric lidar, topographic lidar, and 4-band digital camera imagery simultaneously.

The HE4X provided 500 kHz topographic data, an effective 140 kHz shallow bathymetric data, and 40 kHz deep bathymetric data.

The bathymetric and topographic lasers are independent and do not share an optical chain or receivers, so they are optimized for their specific function. As with any bathymetric lidar, maximum depth penetration is a function of water clarity and seabed reflectivity. The HE4X is designed to penetrate to 3 times the secchi depth. This is also represented as Dmax = 4/K, where K is the diffuse attenuation coefficient, and assuming K is between 0.1 and 0.3, a normal sea state and 15% seabed reflectance.

Both the topographic and bathymetric sub-systems use a palmer scanner to produce an elliptical scan pattern of laser points with a degree of incidence ranging from ± 14° (front and back) to ± 20° (sides), providing a 40° field of view. This has the benefit of providing multiple look angles on a single pass and helps to eliminate shadowing effects. This can be of particular use in urban areas, where all sides of a building are illuminated, or for bathymetric features such as the sides of narrow water channels or features on the seafloor, such as smaller objects and wrecks. It also assists with penetration in the surf zone where the back scan passes the same ground location a couple of seconds after the front scan, allowing the areas of whitewater to shift.

The bathymetric laser is a diode pumped class 4 laser which operates in the green spectrum. Full waveform data is acquired for every pulse. The topographic laser operates in the infra-red spectrum at 1064 nm. Up to 4 returns per pulse are acquired from each lidar.

For this project, the flight parameters shown in **Table 6** were used to provide 100% coverage. Flight parameters used exceed the requirements for the survey to meet QL2b.

Table 6. HE4X Survey Flight Parameters

	Topo-Bathy Flight Lines
Topographic PRF (kHz)	500
Topographic Points per m^2	>16.7
Shallow Bathy PRF (kHz)	140
Shallow Bathy Points per m^2	4.7
Deep Bathy PRF (kHz)	40
Deep Bathy Points per m^2	1.3
Swath Width (m)	350
Flight Line Sidelap (%)	20
Altitude (m)	480
Survey Speed (knots)	125

During acquisition, flight lines were shown on a pilot's display, and the aircraft was controlled by the pilot at all times. The HE4X system includes a NovAtel SPAN GNSS system with an LCI-100C IMU for aircraft position and orientation. One IMU is in the main Chiroptera sensor head, which includes the topographic channel, shallow channel, and RCD30 camera. Data from this IMU is also used in real-time by the PAV100 gyro-stabilized mount to compensate for deviations in pitch and roll.

A second IMU is contained within the deep channel sensor head, installed over a second hatch in the aircraft. This head does not include a gyro-stabilized mount. Aircraft bank angles were restricted to 25° to avoid any potential GNSS dropouts. No flights were planned if the PDOP was expected to go above 3.0.

Data were monitored for quality during acquisition using the Operators Console running on the AHAB collection computer. The operator monitored the system status of the scanners and receivers, waveforms, camera images, data coverage, flight lines and the health of the navigation system.

All data was recorded to a removable solid-state hard disk. At the end of each flight, the hard disk was removed and taken to the field office, where data was copied onto backup disks for transmission back to the main processing office. Preliminary data was reviewed daily in the field for quality and coverage.

2.2.2 Positioning

Position and orientation data was acquired in the aircraft using a NovAtel SPAN with LCI-100C IMU. All data was post-processed using NovAtel Inertial Explorer software to provide a tightly coupled position and orientation trajectory solution.

Calibration data were processed using single-base Post Processed Kinematic (PPK) techniques. A GNSS base station was set up at Stennis International Airport. The data collected from GNSS base station provided the reference station data used to control trajectory processing.

To provide accurate coordinates for comparison, a control point (JX10) was established which served as the base for RTK observations. GNSS observations were used to compute an accurate coordinate for the control point (**Table 7)**.

Table 7. GNSS Base Summary for Calibration

Control Point	Latitude	Longitude	Height (m)	Datum
JX10	30° 22’ 23.25998” N	089° 26’ 54.19218” W	-22.853	NAD83-2011

All project data were acquired using Precise Point Positioning (PPP) techniques. Logs for the base station and trajectory processing are provided in **Section 8.2**.

3. Ground Survey Operations

Ground control surveys were conducted to assist with final point cloud calibration and to perform quality assurance checks on the final LiDAR point cloud.

3.1 LiDAR Survey Points

The purpose of this survey was to establish three-dimensional coordinates for 9 topographic lidar control points, 3 bathymetric lidar check points, 20 vegetated check points, and 20 non-vegetated check points. The points were uniformly dispersed over the project areas. Further discussion of the results is presented in **Section 5.4.3**.

3.2 Lidar Ground Check Points (RTK)

For quality control purposes, a daily QC flight line was acquired over the same location nearly every day just south of Ocean City, MD for MD2201.Topographic control and check point data were collected with a Trimble R-10 GNSS receiver using RTK GNSS techniques over the area covered by the daily lidar QC line. Further discussion of the processing and results is presented in **Section 5.4.3**.

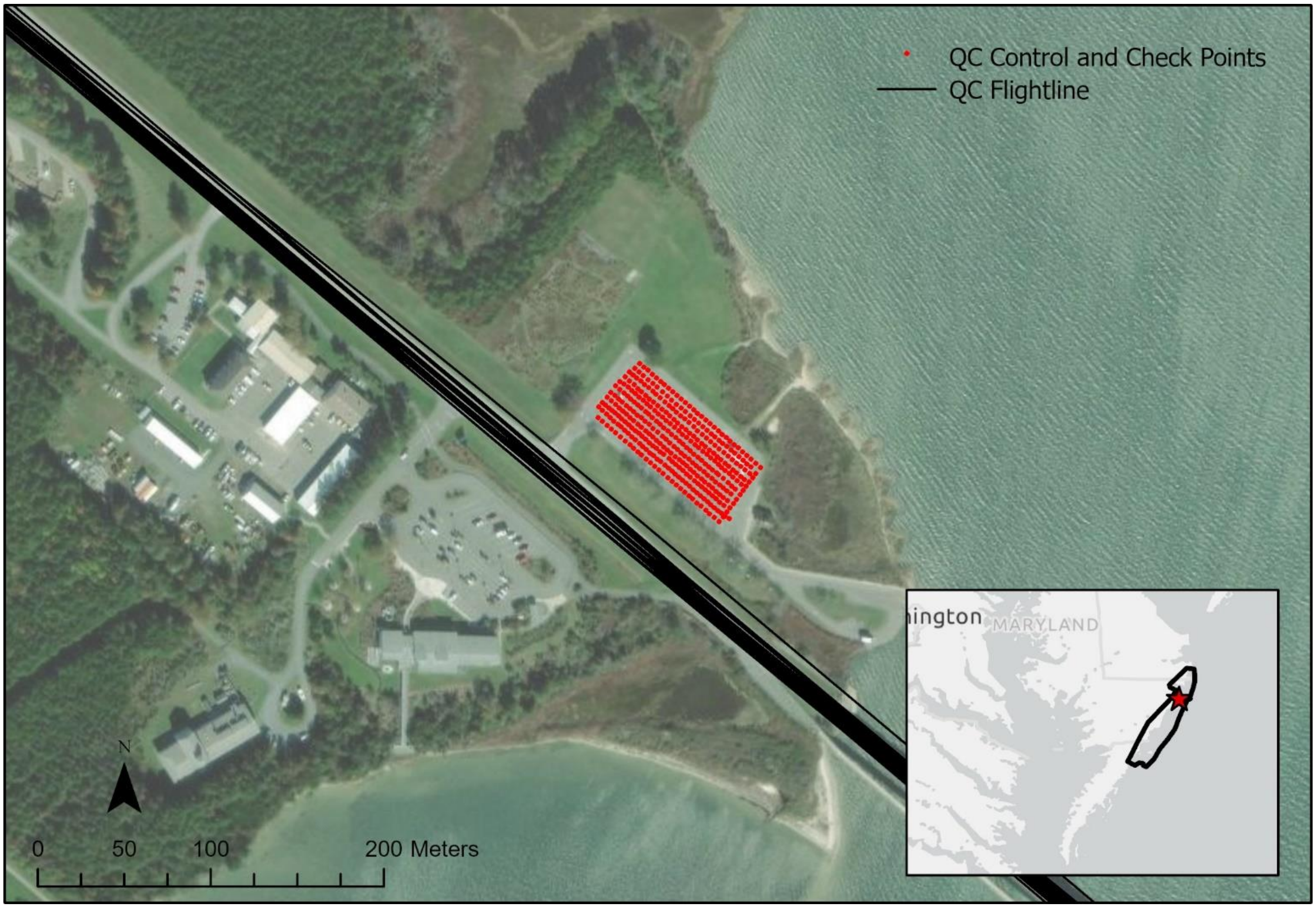

Figure 5: Daily MD2201 QC Line Control and Check Point Survey

4. Data Processing

Initial data coverage analysis and quality checks to ensure there were no potential system issues were carried out in the field and office prior to final demobilization of the sensor. Final processing was conducted in Woolpert's offices.

In general, data were initially processed in Leica's Lidar Survey Studio (LSS) using final processed trajectory information. LAS files from LSS were then imported to a TerraScan project, where spatial algorithms were used to remove gross noise. Manual review and further QC were conducted in TerraScan prior to product creation.

4.1 Position

Final trajectory data were post processed in NovAtel Inertial Explorer. Lever arms, shown in the NovAtel reference frame, are presented in **Table 2**. Inertial Explorer accounts for the fixed offset between the reference point and IMU and uses a multi-pass algorithm to compute a tightly coupled solution. Trajectory processing logs are provided in **Section 8.2**. Average Forward and Reverse Separation RMS for the project was 0.026 m in Easting and Northing, and 0.037 m in Height.

Project Datum are provided in **Table 8**. Data were delivered in UTM Zone 18N NAD83(2011) epoch 2010.0 with elevations in NAVD88 GEOID18 except for the classified lidar point cloud which was delivered with ellipsoid heights.

Table 8. Project Spatial Reference Systems

Name	Processing and Deliverable Datum
Horizontal Datum	NAD83(2011) epoch 2010
Horizontal Projection	UTM 18N
Horizontal Units	Meters

Vertical Datum	Ellipsoid or NAVD88 GEOID18
Vertical Units	Meters

4.2 Imagery

For more details about the imagery acquisition and processing see the following reports:

MD2201:

Airborne Positioning and Orientation Report (APOR): Submitted June 1, 2023

Acquisition Summary: Submitted on June 1, 2023

A/T Report: Submitted on June 8, 2023

4.3 Lidar

4.3.1 Raw Data Processing

Lidar processing was conducted using the Leica Lidar Survey Studio (LSS) software. Calibration information, along with processed trajectory information were combined with the raw laser data to create an accurately georeferenced lidar point cloud for the entire survey in LAS v1.4 format. All points from the topographic and bathymetric laser include 16-bit intensity values.

During the LSS processing stage, an automatic land/water discrimination was made for the bathymetric waveforms. This allowed the bathymetric (green) pulses over water to be automatically refracted for the pulse hitting the water surface and travelling through the water column, producing the correct depth. Another advantage of the automatic land/water discrimination was that it permitted calculation of an accurate water surface over smaller areas, allowing simple bathymetric processing of smaller, narrower streams and drainage channels. Sloping water surfaces were also handled correctly.

Prior to processing, the hydrographer adjusted waveform sensitivity settings dependent on the environment encountered and entered a value for the refraction index to be used for bathymetry. The index of refraction was an indication of the water type. Values used for sensitivity settings and the index of refraction are included in the LSS processing settings files. A value of 1.3423 was used for the index of refraction, indicating salt water.

To determine the optimal waveform sensitivity settings for final processing, sample areas were selected and processed with multiple different settings, to iteratively converge on the best possible settings. This was done by reviewing the processed point cloud and waveforms within sample areas. A sample waveform is provided in **Figure 6**. Settings affected which waveform peaks were classified as valid seabed, and which peaks were classified as noise.

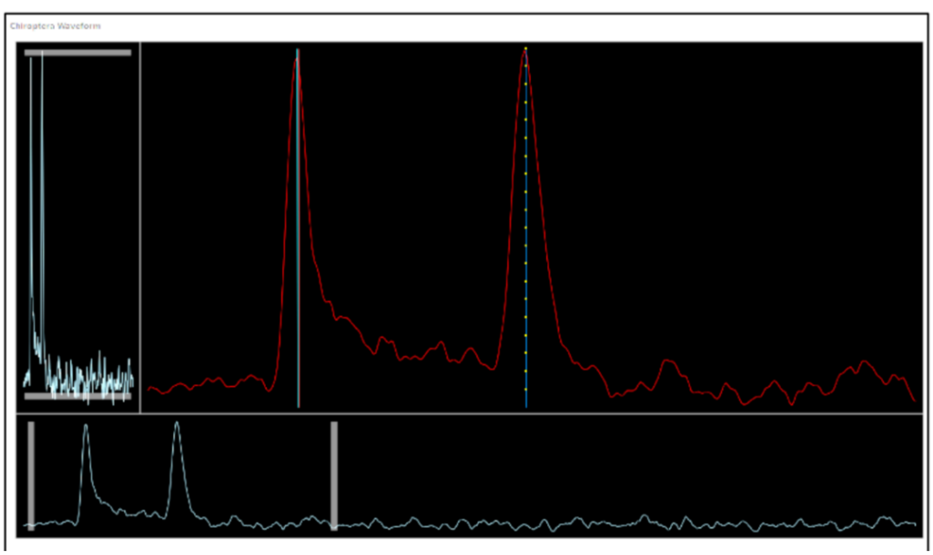

Figure 6. Sample Waveform in Shallow Water

Optimal settings struck a balance between the amount of valid data that was classified as seabed bottom, and the amount of noise that was incorrectly classified due to peaks in the waveforms. All valid data was selected, while only a small amount of noise remained to be edited out. Once optimal threshold settings were chosen, they were used for the entire project.

It is important to note that all digitized waveform peaks were available to be reviewed by the hydrographer; both valid seabed bottom and peaks classed as noise. This allowed the hydrographer to review data during TerraScan editing for valid data such as objects that may have been misclassified as noise.

Woolpert developed proprietary routines implemented in our in-house GTools software to run further checks on the lidar data prior to import to Terrascan project tiles. These checks automatically identified areas where Multiple Pulse in Air (MPIA) errors occurred, as well as invalid derived water surface data, and deleted the erroneous data from the dataset. In addition, GTools merged the multiple small files per flight line generated by LSS into a single LAS file per flight line. Data in each LAS file was also classed into a standard LAS class structure in preparation for data editing.

4.3.2 Lidar Data Classification/Editing

After data were processed through LSS and the data integrity reviewed, data were organized into tiles within a TerraScan project. Data classification and spatial algorithms were applied in Terrasolid's TerraScan software. Customized spatial algorithms, such as isolated points and low point filters, were run to remove gross fliers in the bathymetric and topographic data.

All data were reviewed manually to reclassify any valid bathy points incorrectly identified by the automated routines in LSS as invalid, and vice versa. In addition, any topographic points remaining over the water were reclassified to a Topographic Water class to correct the ground representation. Manual editing was conducted in TerraScan. Product grids and TIN models were used at the required product resolution to assist in data editing and QC results. Steps conducted during the manual editing phase included:

- Removing noise from the unclassified topographic class to leave only valid data (e.g., vegetation, buildings, real temporary objects in the environment such as cars, people, etc.);
- Removing any topographic unclassified, topographic ground, and valid seabed class data from the water surface to a water surface class, including along the shoreline;
- Filling gaps in the topographic ground and seabed classes, including potential objects such as rocks on the coast; and
- Removing any remaining noise from the topographic ground and seabed classes.

4.3.3 Reflectance

Once all lidar data were edited, final seabed class data were used to compute project specific correction parameters and normalize the raw intensity data for depth. Corrected values were then written back into the LAS files.

Although the bathymetric data includes intensity values, these are raw values. For intensity (reflectance) to correctly represent the reflectance of the seabed, the intensities must be normalized for any losses in signal as the light travels through the water column, so that the intensity value better reflects the intensity of the seabed itself.

One of the fundamental issues that exists with reflectance imagery is the variance in return due to water clarity differences occurring spatially along line, and temporally from day to day. This is challenging for any bathymetric lidar sensor.

If water clarity is relatively consistent along a line, then it is possible to achieve an overall homogenous reflectance image for an area. To a certain extent, variation in reflectivity intensity can be minimized by limiting the size of flight blocks and trying to ensure similar environmental parameters exist within a single flight block. In other words, where changes in water clarity or environment may be expected, flight blocks should be split to allow different normalization parameters to be used per block for the reflectance processing. Where this is not possible and water clarity varies significantly along a line, variation in reflective intensity will be seen in the output imagery. While this imagery can still be analyzed and used for manual seabed classification, it prohibits the use of unsupervised, or semiautomated classification.

Woolpert used proprietary in-house scripts to compute project specific correction parameters and normalize the raw intensity data for depth. This provided intensities that more closely represent the reflectance of the actual seabed. Corrected values were used to create reflectance images per flight line using LASTools. Individual flight line reflectance images were then used in Trimble's OrthoVista software to create a final reflectance image for the entire area.

OrthoVista was used to improve radiometric balancing between lines and the seamline editor was used to improve the joins between lines to remove as much line-to-line edge matching and cloud artifact issues as possible. As well as delivering the reflectance raster mosaics themselves, the processed reflectance data was used to correct the intensity values within the LAS files for delivery.

4.3.4 LiDAR Datum Conversions

All editing was conducted with the LiDAR data elevations on the ellipsoid. Once editing was completed, data were transformed from ITRF2014 (Current Epoch) to NAD83(2011) epoch:2010 with ellipsoid heights using TerraScan.

Terrascan was then used to compare the LiDAR data to known ground control points. For each known location a small TIN was created from the surrounding LiDAR points and the elevation difference from the TIN plane to the point computed.

5. Quality Control

Quality control was carried out through every phase of the project. Several checks were used to ensure data integrity and quality was maintained. Specific statistics were generated during cross line analysis and from direct comparison to topographic control.

5.1 Calibration

Calibration, which is fundamental to ensuring good data accuracy, is discussed in detail in **Section 2.1.2**.

5.2 Online Checks

The airborne operator monitored the system status of the scanners and receivers, waveforms, data coverage, flight lines, and navigation system during data acquisition. Flight logs were maintained during data acquisition. Logs not only tracked lines acquired, but also any relevant information on weather or water clarity, instances when sensor issues occurred, and so on. These logs were a valuable resource during processing. Flight logs are provided in **Section 8.1**.

5.3 Positioning

During acquisition, aircraft bank angles were restricted to 25 degrees to avoid any potential GNSS dropouts. No flights were planned if the PDOP was expected to go above 3.0. Position processing and results are discussed in **Section 2.2.2**.

5.4 Accuracy Checks

5.4.1 Comparison to Adjacent Lines (Relative Accuracy)

Throughout data editing, adjacent survey lines of data were compared to ensure there were no data busts or system artifacts. During processing, TerraSolid's TMatch software was run to examine the Delta Z differences between overlapping lines, then a simple Z correction was applied per flight line to remove any vertical differences between flight lines. Using TMatch to move all the lines into the same relative plane reduced any remaining small differences caused by the limitations of the trajectory accuracy.

Woolpert's in-house software, GTools, was used to generate dZ grids representing flight line to flight line differences in areas of overlap. Any results within areas of slope greater than 10 degrees were removed, and final dZ statistics generated for the project. This provided a measure of inter-swath accuracy.

Interswath or overlap consistency for the topographic laser was assessed in all areas of overlap with slopes of less than 10 degrees. The topographic RMSDz average for the project is 0.028 m. This meets the required accuracy of ± 8 cm.

Interswath or overlap consistency for the bathymetric laser was assessed in all areas of overlap with slopes of less than 10 degrees. The bathymetric RMSDz average for the project lines is 0.055 m. This meets the required QL2b accuracy.

Results are presented in **Table 9**.

Table 9. Line to Line Relative Accuracy

Survey Area	Topographic Laser RMSDz (m)	Bathymetric Laser RMSDz (m)
MD2201	0.028	0.055

5.4.2 Cross Line Analyses

Cross lines were run in a direction perpendicular to main scheme lines across the entire survey area, providing a good representation for analysis of consistency. All cross lines were used for cross line comparisons. Only bathymetric point returns were used for the analysis. Cross line analysis was performed using ArcGIS Pro. A 2m mean gridded surface of cross line point data were compared to a 2m gridded surface of the main scheme survey lines and statistics generated. A summary of the results is provided in **Table 10**. The result of the analysis meets the required QL2b depth accuracy requirements.

Table 10. Cross Line Surface to Main Scheme Surface Results

	MD2201
No. of Nodes Compared	2733851
Mean Difference (m)	0.000
Standard Deviation (Std. Dev)	0.055
Mean + 2*Std. Dev	0.109

5.4.3 Comparison to Topographic Control

Topographic control data were acquired using RTK GNSS techniques. (**Section 3.1**). This area was covered by the daily lidar QC line used to account for any potential trajectory shifts between each acquisition survey day. In addition, survey control and check points were acquired throughout the survey area to shift the lidar data to the project datum and to assess absolute accuracy.

5.4.3.1 Precise Point Positioning Shifts

Due to the remote location of the project areas, Precise Point Positioning (PPP) was used for survey acquisition. To account for any potential trajectory shift between each acquisition survey day a daily QC line was acquired and compared to topographic control data and a shift computed.

To ensure the highest accuracy possible in this scenario, the daily QC line was established on south of Ocean City, MD for MD2201 and this same line was collected on every survey flight. Control points were acquired for this daily QC line. The control was compared to each lidar daily QC line, and a mean shift computed. During lidar calibration, any line-to-line vertical mismatches were removed. Thus, an average PPP shift per project area was computed and applied to remove any remaining errors in the ellipsoid height due to the use of PPP processing of the trajectories.

A static shift was determined to be appropriate to account for PPP trajectory shift for both survey areas. Results of calculated data shifts comparing the QC lines and RTK control points are provided in **Table 11**.

Table 11. Precise Point Positioning Shifts

	Static Shift Applied (m)
MD2201	0.121

5.4.3.2 Primary Ellipsoid Height Control

A ground survey was collected by Woolpert throughout the survey area. The survey consisted of 9 topographic lidar control points, 3 bathymetric lidar check points, 20 vegetated check points, and 20 non-vegetated check points. The points were uniformly dispersed over the project area. Once all manual classification was completed and the PPP shift applied, data were compared to topographic lidar control to compute an average vertical shift to be applied. Results are noted in **Table 12**.

Table 12. Static Shifts Applied to Align Ellipsoid Heights to Topographic Lidar Control Points

	Static Shift Applied (m)
MD2201	-0.019

Absolute vertical accuracy for the lidar points was then calculated using the acquired check points. A summary of results is provided in **Table 13**, **Table 14**, and **Table 15**. The check points were observed in three different land cover types to assess absolute vertical accuracy: non-vegetated (NVA), vegetated (VVA), and bathymetric (BVA). The results indicate that the project meets the required vertical accuracy of 10cm RMSE or 19.6cm at a 95% confidence level for NVA.

This data set tested 0.071 meters fundamental vertical accuracy at the 95th percent confidence level in open terrain using RMSE(z) x 1.96.

Table 13. Ellipsoid LiDAR Comparison to NVA Check Point Results

Area	Count	Average dZ (m)	Std. Deviation	RMSE (m)	Accuracy (95% Confidence)
MD2201	20	0.016	0.033	0.036	0.071

Table 14. Ellipsoid LiDAR Comparison to VVA Check Point Results

Area	Count	Average dZ (m)	Std. Deviation	95th Percentile
MD2201	20	0.136	0.069	0.235

Table 15. Ellipsoid LiDAR Comparison to BVA Check Point Results

Area	Count	Average dZ (m)	Std. Deviation	RMSE (m)
MD2201	3	0.011	0.028	0.026

5.4.3.3 Ellipsoid to Orthometric Corrections Applied

Once the data were vertical shifted and checked using the Woolpert acquired ground survey the GEOID18 geoid model was applied in SAFE's FME software to convert the ellipsoid elevation data to the final orthometric datum for product creation and delivery.

Terrascan was used to compare the LiDAR data to known ground control points after the transformation. For each location a small TIN was created from the surrounding LiDAR points and elevation difference from the TIN plane to the known point computed. Results are provided in **Table 16** and indicate the transformation was applied correctly.

Table 16. Orthometric LiDAR Comparison to NVA Check Point Results

Area	Count	Average dZ (m)	Std. Deviation	RMSE (m)	Accuracy (95% Confidence)
MD2201	20	0.018	0.034	0.034	0.068

Table 17. Orthometric LiDAR Comparison to VVA Check Point Results

Area	Count	Average dZ (m)	Std. Deviation	95th Percentile
MD2201	20	0.136	0.069	0.235

Table 18. Orthometric LiDAR Comparison to BVA Check Point Results

Area	Count	Average dZ (m)	Std. Deviation	RMSE (m)
MD2201	3	0.011	0.028	0.026

5.4.3.4 Imagery Accuracy

For a detailed discussion of imagery accuracy see the Aerotriangulation Report MD2201-TB-C.pdf submitted on April 6, 2023.

6. Flight Trajectories

The flight trajectories used for the survey collection are provided in ESRI Shapefile format. The Shapefile contains the attributes, date of capture, local start time, local end time, reference station, and flight line number.

6.1 MD2201 Flight Trajectories

The MD2201 project area was surveyed between November 3, 2022 and February 5, 2023. A total of 344 flight lines were collected.

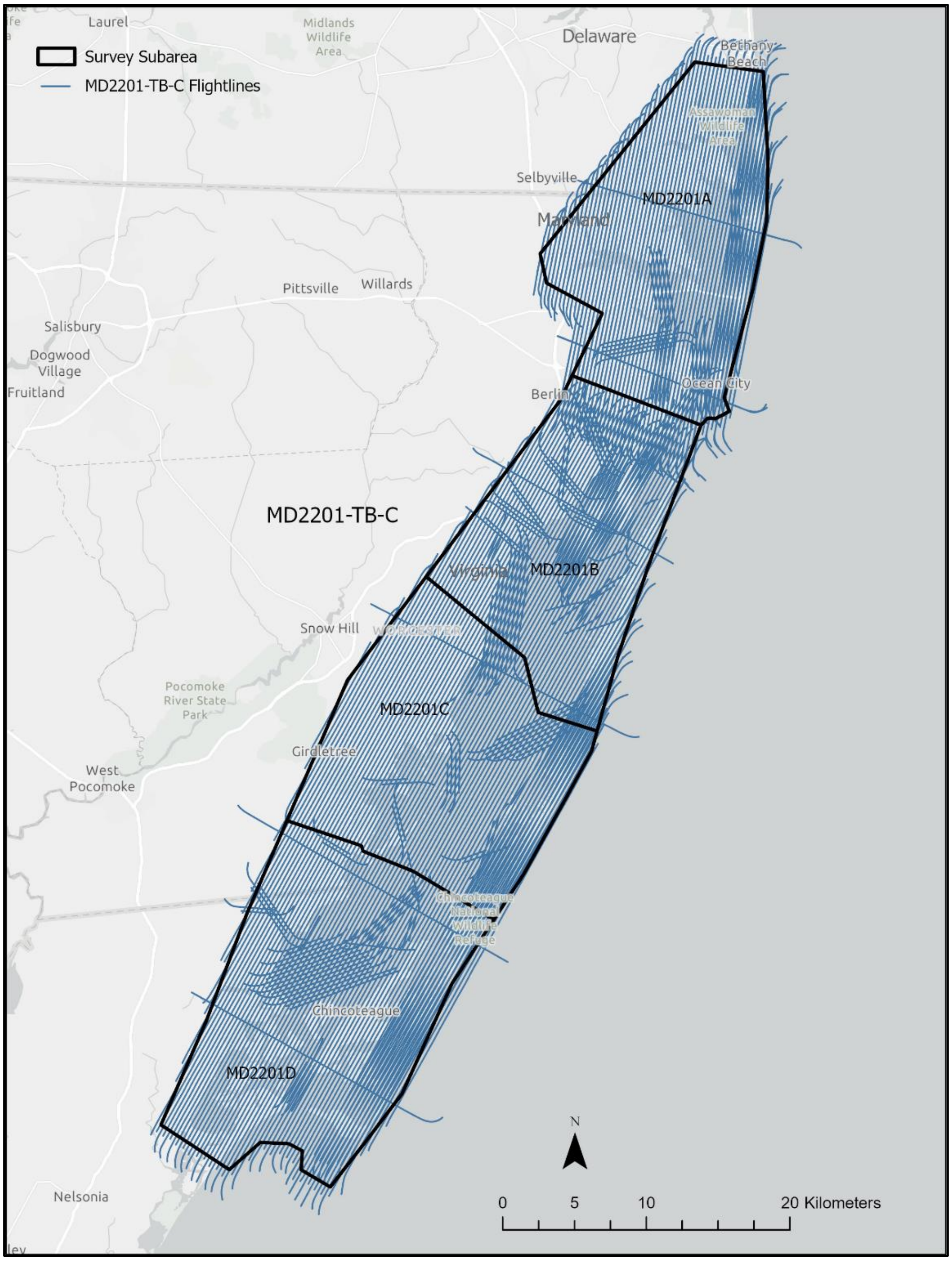

Figure 7. MD2201 Flight Trajectories

7. Products

Deliverables required for the project are listed in **Table 19**.

Table 19. Product Deliverable Structure

ID	Type	Item	Deliverable	Resolution (m)	Tiled	Note
1		Classified Lidar Point Cloud	LAS 1.4	--	✓	Vertical NAD83 (2011) epoch 2010.0
2		Topographic/Bathymetric DEM	GeoTIFF	1	✓	Classes 2 and 40. Vertical NAVD88 GEOID18
3		Bathymetric Void Layer	SHP	--		
4		Tile Index	SHP	1000 x 1000	✓	
5		TopoBathy DEM Tile Index	SHP	5000 x 5000	✓	
6		Normalized Seabed Intensity	GeoTIFF	1	✓	
7		Final Trajectory	ASCII	--	--	
8		TPU	GeoTIFF	1	✓	
9		Dz Orthos	GeoTIFF	1	✓	
10		Metadata Per Product	XML	--	--	
16		Flightline Index	SHP	--	--	

7.1 Classified Lidar Point Cloud (LAZ Files)

The LAZ data coordinate reference system applied is:

- Horizontal: UTM Zone 18N, NAD83(PA11) epoch:2010, meters
- Vertical: NAD83(2011) epoch:2010 Ellipsoid, meters

Delivered LAZ data are provided in Point Record Format 6 and include Adjusted GPS Time and 16-bit intensity values. LAZ file classes delivered are shown in **Table 20**. Classes 2 and 40 provide the ground model for the project.

Table 20. LAZ Classes

NUMBER	POINT CLASS	DESCRIPTION
1	Unclassified	Valid unclassified data from the topographic laser
2	Ground	Bare earth ground
W7	Low Noise	Spurious high/low point returns (unusable)
9	Water	Water (topographic sensor)
W18	High Noise	Spurious high/low noise points from the bathymetric laser.
40	Bathymetric Point	Submerged topography
41	Water Surface	Water surface, distinct from Point Class 9, which is used in topographic-only lidar and only designates “water,” not “water surface”
S42	Derived Water Surface	Synthetic water surface location used in computing refraction at water surface
43	Submerged object	Submerged Object, not otherwise specified (e.g., wreck, rock, submerged piling)

8. Related Information

8.1 Flight Logs

FLIGHT LOG

PROJECT NAME:	2022-10010368 Chesapeake	**BASE AIRPORT:**	Stennis (KHSA)
LOCATION / AREA:	Stennis / 400m, 500m, 800m	**DATE:**	30 October 2022
AIRCRAFT:	Cessna 404 (N70790F)	**PILOT:**	Ryan C.
SYSTEM:	HawkEye 4X	**OPERATOR:**	Richard C.

MISSION ID:	Stennis-Cal	**CLOUDS:**	Clouds @ 3000ft
BASE STATION:	JX10	**WIND:**	5-10 kts @ 280

ENGINE START:		**ENGINE OFF:**		**ENGINE TIME:**	
GNSS START:	19:07	**GNSS START:**			2:19
TAKEOFF:	19:32	**TOUCHDOWN:**		**AIR TIME**	01:42

FL #	LINE #	START TIME	END TIME	TOPO PRF	TOPO PWR	CHII PWR	REMARKS
		19:32:00					Takeoff
		19:39:27					DS: 800m_20221030_193927
000_FL1	6381	19:39:27	19:41:34	800	330	10	
001_FL1	6381	19:44:21	19:46:21	800	330	10	
002_FL3	6383	19:49:56	19:52:02	800	330	10	
003_FL4	6384	19:54:29	19:56:27	800	330	10	
004_FL5	6385	19:59:12	20:01:09	800	330	10	
005_FL6	6386	20:06:06	20:08:08	800	330	10	
		20:11:49					DS: 500m_20221030_201149
000_FL1	6351	20:11:50	20:13:27	490	500	4	BAD: Wrong settings at start of line
001_FL2	6352	20:18:31	20:20:08	490	500	4	
002_FL1	6351	20:22:20	20:23:56	490	500	4	
003_FL3	6353	20:26:52	20:28:25	490	500	4	
004_FL4	6354	20:30:49	20:32:24	490	500	4	
005_FL5	6355	20:34:33	20:36:04	490	500	4	
006_FL6	6356	20:40:16	20:41:51	490	500	4	
		20:48:15					DS: 400m_20221030_204815
000_FL1	6341	20:48:15	20:49:51	400	300	3	
001_FL2	6342	20:52:06	20:53:37	400	300	3	
002_FL3	6343	20:56:24	20:57:48	400	300	3	
003_FL4	6344	20:59:41	21:01:04	400	300	3	
004_FL5	6345	21:03:34	21:04:56	400	300	3	
005_FL6	6346	21:08:48	21:10:08	400	300	3	
		21:10:00					End survey
		21:14:00					Landing

FLIGHT LOG

PROJECT NAME:	2022-10010368 Chesapeake	**BASE AIRPORT:**	Ocean City(KOXB)
LOCATION / AREA:	Chesapeake / BL10, BL31, BL60	**DATE:**	3 November 2022
AIRCRAFT:	Cessna 404 (N70790F)	**PILOT:**	Theron C.
SYSTEM:	HawkEye 4X	**OPERATOR:**	Richard C.

MISSION ID:	ChesapeakeMain, ChesapeakeMD, ChesapeakeVA	**CLOUDS:**	Clear
BASE STATION:	NA	**WIND:**	10 kts @ 100

ENGINE START:		**ENGINE OFF:**		**ENGINE TIME:**	
GNSS START:	13:41	**GNSS START:**			5:07
TAKEOFF:	14:04	**TOUCHDOWN:**		**AIR TIME**	04:32

FL #	LINE #	START TIME	END TIME	TOPO PRF	TOPO PWR	CHII PWR	REMARKS
		14:04:00					Takeoff
		14:11:39					DS: BL60_20221103_141139
000_FL1	6001	14:11:39	14:14:06	480	500	10	
		14:35:45					DS: BL10_20221103_143545
000_FL35	1035	14:35:45	14:49:55	480	500	10	
		15:26:52					DS: BL31_20221103_152652
000_FL56	3156	15:26:52	15:30:55	480	500	10	
001_FL55	3155	15:33:28	15:38:05	480	500	10	
002_FL54	3154	15:40:25	15:45:28	480	500	10	
003_FL53	3153	15:48:01	15:53:39	480	500	10	
004_FL52	3152	15:55:51	16:01:45	480	500	10	
005_FL51	3151	16:04:17	16:10:25	480	500	10	
006_FL50	3150	16:12:44	16:19:17	480	500	10	
007_FL49	3149	16:21:21	16:28:39	480	500	10	
008_FL48	3148	16:31:07	16:38:43	480	500	10	
009_FL47	3147	16:41:15	16:48:53	480	500	10	
010_FL46	3146	16:51:02	16:58:26	480	500	10	
011_FL45	3145	17:00:50	17:08:19	480	500	10	
012_FL44	3144	17:10:18	17:17:43	480	500	10	
013_FL43	3143	17:20:06	17:27:34	480	500	10	
014_FL42	3142	17:29:54	17:37:24	480	500	10	
015_FL41	3141	17:39:38	17:47:06	480	500	10	
016_FL40	3140	17:49:27	17:56:52	480	500	10	
017_FL39	3139	17:59:07	18:06:33	480	500	10	
018_FL38	3138	18:08:52	18:16:23	480	500	10	
019_FL37	3137	18:18:29	18:25:55	480	500	10	
		18:36:00					Landing
		18:46:00					End survey

WOOLPERT

FLIGHT LOG

PROJECT NAME:	2022-10010368 Chesapeake	**BASE AIRPORT:**	Salisbury(KSBY)
LOCATION / AREA:	Chesapeake / BL31, BL60	**DATE:**	4 November 2022
AIRCRAFT:	Cessna 404 (N70790F)	**PILOT:**	Theron C.
SYSTEM:	HawkEye 4X	**OPERATOR:**	Richard C.

MISSION ID:	ChesapeakeMain, ChesapeakeMD	**CLOUDS:**	Clouds @ 3000ft
BASE STATION:	NA	**WIND:**	15 kts @ 160
LIDAR DRIVE:	HE4X-02	**RCD DRIVE:**	RCD-01

ENGINE START:	15:30	**ENGINE OFF:**	19:24	**ENGINE TIME:**	03:54
TAKEOFF:	15:48	**LANDING:**	19:11	**AIR TIME**	03:23

FL #	LINE #	START TIME	END TIME	ALTITUDE	TOPO PRF	TOPO PWR	REMARKS
		15:48:00					Takeoff
		16:03:55					DS: BL60_20221104_160355
000_FL1	6001	16:03:55	16:06:13	480	500	10	
		16:09:40					DS: BL31_20221104_160940
000_FL36	3136	16:09:40	16:16:37	480	500	10	
001_FL35	3135	16:18:58	16:26:33	480	500	10	
002_FL34	3134	16:28:59	16:36:07	480	500	10	
003_FL33	3133	16:38:37	16:45:58	480	500	10	
		17:17:43					DS: BL31_20221104_171743
000_FL32	3132	17:17:43	17:25:04	480	500	10	
001_FL31	3131	17:27:20	17:34:17	480	500	10	
002_FL30	3130	17:37:05	17:44:22	480	500	10	
003_FL29	3129	17:46:42	17:53:34	480	500	10	
004_FL28	3128	17:56:33	18:03:38	480	500	10	
005_FL27	3127	18:06:03	18:12:41	480	500	10	
006_FL26	3126	18:15:39	18:22:23	480	500	10	
007_FL25	3125	18:24:31	18:30:50	480	500	10	
008_FL24	3124	18:33:12	18:39:42	480	500	10	
009_FL23	3123	18:41:54	18:48:03	480	500	10	
010_FL22	3122	18:50:35	18:56:48	480	500	10	
		18:57:00					End survey
		19:11:00					Landing

FLIGHT LOG

PROJECT NAME:	2022-10010368 Chesapeake	**BASE AIRPORT:**	Salisbury(KSBY)
LOCATION / AREA:	Chesapeake / BL10, BL11, BL14, BL33, BL60	**DATE:**	5 November 2022
AIRCRAFT:	Cessna 404 (N70790F)	**PILOT:**	Theron C.
SYSTEM:	HawkEye 4X	**OPERATOR:**	Richard C.

MISSION ID:	ChesapeakeMain, ChesapeakeMD, ChesapeakeVA	**CLOUDS:**	Clouds @ 3000ft
BASE STATION:	NA	**WIND:**	20-25 kts @ 200
LIDAR DRIVE:	HE4X-04	**RCD DRIVE:**	RCD-02

ENGINE START:	13:16	**ENGINE OFF:**	18:53	**ENGINE TIME:**	05:37
TAKEOFF:	13:49	**LANDING:**	18:37	**AIR TIME**	04:48

FL #	LINE #	START TIME	END TIME	ALTITUDE	TOPO PRF	PWR	REMARKS
		13:49:00					Takeoff
		14:10:30					DS: BL10_20221105_141030
000_FL54	1098	14:10:30	14:20:23	480	500	10	
001_FL53	1097	14:25:25	14:35:49	480	500	10	
002_FL52	1096	14:41:35	14:51:39	480	500	10	
003_FL51	1095	14:56:56	15:03:54	480	500	10	
		15:09:40					DS: BL11_20221105_150940
000_FL17	1117	15:09:40	15:23:10	480	500	10	
001_FL50	1150	15:27:05	15:38:25	480	500	10	
		15:51:11					DS: BL14_20221105_155111
000_FL47	1497	15:51:11	15:57:33	480	500	10	
001_FL46	1496	16:01:45	16:08:55	480	500	10	
002_FL45	1495	16:15:58	16:21:00	480	500	10	
003_FL1	1401	16:29:51	16:41:16	480	500	10	
		17:07:34					DS: BL60_20221105_170734
000_FL1	6001	17:07:34	17:09:51	480	500	10	
		17:15:31					DS: BL33_20221105_171531
000_FL31	3331	17:15:31	17:18:28	480	500	10	
001_FL30	3330	17:21:57	17:26:20	480	500	10	
002_FL29	3329	17:28:54	17:33:41	480	500	10	
003_FL28	3328	17:36:42	17:42:26	480	500	10	
004_FL27	3327	17:44:54	17:51:08	480	500	10	
005_FL26	3326	17:53:40	18:00:22	480	500	10	
006_FL25	3325	18:02:49	18:09:04	480	500	10	
007_FL24	3324	18:11:43	18:18:28	480	500	10	
		18:19:00					End survey
		18:37:00					Landing

FLIGHT LOG

PROJECT NAME:	2022-10010368 Chesapeake	**BASE AIRPORT:**	Salisbury(KSBY)
LOCATION / AREA:	Chesapeake / BL60	**DATE:**	8 November 2022
AIRCRAFT:	Cessna 404 (N70790F)	**PILOT:**	Theron C.
SYSTEM:	HawkEye 4X	**OPERATOR:**	Richard C.
MISSION ID:	ChesapeakeMain	**CLOUDS:**	Clear
BASE STATION:	NA	**WIND:**	25-30kts @ 10

ENGINE START:		**ENGINE OFF:**		**ENGINE TIME:**	
GNSS START:	13:47	**GNSS START:**			1:50
TAKEOFF:	14:25	**TOUCHDOWN:**		**AIR TIME**	01:00

FL #	LINE #	START TIME	END TIME	TOPO PRF	PWR	CHII PWR	REMARKS
		14:25:00					Takeoff
		14:37:26					DS: BL60_20221108_143726
000_FL1	6001	14:37:26	14:39:38	480	500	4	Deep 240/280
001_FL1	6001	14:45:16	14:47:29	480	500	4	Deep 260/300
002_FL1	6001	14:52:56	14:55:08	480	500	4	Deep 290/300
003_FL1	6001	15:00:27	15:02:43	480	500	4	Deep 220/220
004_FL1	6001	15:08:33	15:10:46	480	500	10	Deep 190/170
		15:25:00					Landing
		15:37:00					End survey

FLIGHT LOG

PROJECT NAME:	2022-10010368 Chesapeake	**BASE AIRPORT:**	Salisbury(KSBY)
LOCATION / AREA:	Chesapeake / BL35, BL60	**DATE:**	9 November 2022
AIRCRAFT:	Cessna 404 (N70790F)	**PILOT:**	Theron C.
SYSTEM:	HawkEye 4X	**OPERATOR:**	Richard C.

MISSION ID:	ChesapeakeMain, ChesapeakeMD	**CLOUDS:**	Clouds @ 3500ft
BASE STATION:	NA	**WIND:**	10 kts @ 80
LIDAR DRIVE:	HE4X-04	**RCD DRIVE:**	RCD-01

ENGINE START:	18:08	**ENGINE OFF:**	21:01	**ENGINE TIME:**	02:53
TAKEOFF:	18:25	**LANDING:**	20:49	**AIR TIME**	02:24

FL #	LINE #	START TIME	END TIME	ALTITUDE	TOPO PRF	TOPO PWR	REMARKS
		18:25:00					Takeoff
		18:42:21					DS: BL60_20221109_184221
000_FL1	6001	18:42:21	18:44:41	480	500	4	
		18:47:36					DS: BL35_20221109_184736
000_FL16	3516	18:47:36	18:48:30	480	500	4	
001_FL15	3515	18:50:37	18:51:17	480	500	4	
002_FL13	3513	19:07:22	19:12:05	480	500	4	
003_FL12	3512	19:14:17	19:18:53	480	500	4	
004_FL11	3511	19:45:19	19:50:01	480	500	4	
005_FL10	3510	19:52:32	19:56:56	480	500	4	
006_FL9	3509	19:59:55	20:03:27	480	500	4	
007_FL8	3508	20:05:38	20:07:45	480	500	4	
008_FL7	3507	20:10:30	20:13:01	480	500	4	
009_FL6	3506	20:15:58	20:18:59	480	500	4	
010_FL5	3505	20:21:36	20:24:57	480	500	4	
011_FL4	3504	20:27:35	20:30:54	480	500	4	
012_FL3	3503	20:33:18	20:35:21	480	500	4	
		20:49:00					Landing
		21:01:00					End survey

WOOLPERT

FLIGHT LOG

PROJECT NAME:	2022-10010368 Chesapeake	**BASE AIRPORT:**	Salisbury(KSBY)
LOCATION / AREA:	Chesapeake / BL32, BL35, BL60	**DATE:**	10 November 2022
AIRCRAFT:	Cessna 404 (N70790F)	**PILOT:**	Theron C.
SYSTEM:	HawkEye 4X	**OPERATOR:**	Richard C.

MISSION ID:	ChesapeakeMain, ChesapeakeMD	**CLOUDS:**	Clear
BASE STATION:	NA	**WIND:**	10-15 kts @ 140
LIDAR DRIVE:	HE4X-02	**RCD DRIVE:**	RCD-02

ENGINE START:	13:28	**ENGINE OFF:**	19:02	**ENGINE TIME:**	05:34
TAKEOFF:	13:51	**LANDING:**	18:49	**AIR TIME**	04:58

FL #	LINE #	START TIME	END TIME	ALTITUDE	TOPO PRF	TOPO PWR	REMARKS
		13:51:00					Takeoff
		14:03:53					DS: BL60_20221110_140353
000_FL1	6001	14:03:53	14:06:08	480	500	4	
		14:10:15					DS: BL35_20221110_141015
000_FL3	3503	14:10:15	14:13:49	480	500	4	
001_FL2	3502	14:15:44	14:19:04	480	500	4	
002_FL1	3501	14:21:34	14:23:15	480	500	4	
		14:26:39					DS: BL32_20221110_142639
000_FL56	3256	14:26:39	14:30:38	480	500	4	
001_FL55	3255	14:33:13	14:37:56	480	500	4	
002_FL54	3254	14:40:10	14:45:04	480	500	4	
003_FL53	3253	14:47:35	14:53:12	480	500	4	
004_FL52	3252	14:55:18	15:00:54	480	500	4	
005_FL51	3251	15:03:09	15:09:28	480	500	4	
006_FL50	3250	15:11:30	15:17:41	480	500	4	
007_FL49	3249	15:20:09	15:27:41	480	500	4	
008_FL48	3248	15:29:41	15:36:55	480	500	4	
009_FL47	3247	15:39:24	15:47:15	480	500	4	
010_FL46	3246	15:49:19	15:56:26	480	500	4	
011_FL45	3245	15:58:50	16:06:35	480	500	4	
012_FL44	3244	16:08:36	16:15:42	480	500	4	
013_FL43	3243	16:18:04	16:25:45	480	500	4	
014_FL42	3242	16:27:43	16:35:00	480	500	4	
015_FL41	3241	16:37:20	16:44:53	480	500	4	
016_FL40	3240	16:47:03	16:54:15	480	500	4	
017_FL39	3239	16:56:46	17:04:19	480	500	4	
018_FL38	3238	17:06:22	17:13:27	480	500	4	
019_FL37	3237	17:15:51	17:23:30	480	500	4	
020_FL36	3236	17:25:58	17:33:03	480	500	4	

FLIGHT LOG

PROJECT NAME:	2022-10010368 Chesapeake	**BASE AIRPORT:**	Salisbury(KSBY)
LOCATION / AREA:	Chesapeake / BL32, BL35, BL60	**DATE:**	10 November 2022
AIRCRAFT:	Cessna 404 (N70790F)	**PILOT:**	Theron C.
SYSTEM:	HawkEye 4X	**OPERATOR:**	Richard C.

MISSION ID:	ChesapeakeMain, ChesapeakeMD	**CLOUDS:**	Clear
BASE STATION:	NA	**WIND:**	10-15 kts @ 140
LIDAR DRIVE:	HE4X-02	**RCD DRIVE:**	RCD-02

ENGINE START:	13:28	**ENGINE OFF:**	19:02	**ENGINE TIME:**	05:34
TAKEOFF:	13:51	**LANDING:**	18:49	**AIR TIME**	04:58

FL #	LINE #	START TIME	END TIME	ALTITUDE	TOPO PRF	TOPO PWR	REMARKS
021_FL35	3235	17:35:19	17:42:47	480	500	4	
022_FL34	3234	17:44:55	17:52:00	480	500	4	
023_FL33	3233	17:54:21	18:01:46	480	500	4	
024_FL32	3232	18:03:59	18:11:03	480	500	4	
025_FL31	3231	18:13:40	18:21:05	480	500	4	
026_FL30	3230	18:24:33	18:25:10	480	500	4	BAD: broke off due to traffic
027_FL30	3230	18:30:16	18:34:40	480	500	4	BAD: broke off due to storage
		18:49:00					Landing
		19:01:00					End survey

FLIGHT LOG

PROJECT NAME:	2022-10010368 Chesapeake	**BASE AIRPORT:**	Salisbury(KSBY)
LOCATION / AREA:	Chesapeake / BL32, BL60	**DATE:**	29 November 2022
AIRCRAFT:	Cessna 404 (N70790F)	**PILOT:**	Dennis C.
SYSTEM:	HawkEye 4X	**OPERATOR:**	Richard C.

MISSION ID:	ChesapeakeMain, ChesapeakeMD	**CLOUDS:**	Clouds @ 4000ft
BASE STATION:	NA	**WIND:**	10-15 kts @ 180
LIDAR DRIVE:	HE4X-03	**RCD DRIVE:**	RCD-02

ENGINE START:	17:20	**ENGINE OFF:**	21:22	**ENGINE TIME:**	04:02
TAKEOFF:	17:38	**LANDING:**	21:10	**AIR TIME**	03:32

FL #	LINE #	START TIME	END TIME	ALTITUDE	TOPO		REMARKS
					PRF	PWR	
		17:38:00					Takeoff
		17:50:56					DS: BL60_20221129_175056
000_FL1	6001	17:50:56	17:53:12	480	500	4	BAD:
		17:59:25					DS: BL32_20221129_175925
000_FL30	3230	17:59:25	18:06:25	480	500	4	
001_FL29	3229	18:10:23	18:17:18	480	500	4	
002_FL28	3228	18:23:41	18:30:53	480	500	4	
003_FL27	3227	18:34:23	18:41:15	480	500	4	
004_FL26	3226	18:44:12	18:47:42	480	500	4	BAD: Partial laser stop
		19:11:00					End survey
		21:10:00					Landing

WOOLPERT

FLIGHT LOG

PROJECT NAME: 2022-10010368 Chesapeake
BASE AIRPORT: Salisbury(KSBY)
LOCATION / AREA: Chesapeake / BL32
DATE: 29 November 2022
AIRCRAFT: Cessna 404 (N70790F)
PILOT: Dennis C.
SYSTEM: HawkEye 4X
OPERATOR: Richard C.

MISSION ID: ChesapeakeMD
CLOUDS: Clouds @ 4000ft
BASE STATION: NA
WIND: 10-15 kts @ 180
LIDAR DRIVE: HE4X-03
RCD DRIVE: RCD-02

ENGINE START: 17:20
ENGINE OFF: 21:22
ENGINE TIME: 04:02
TAKEOFF: 17:38
LANDING: 21:10
AIR TIME 03:32

FL #	LINE #	START TIME	END TIME	ALTITUDE	TOPO PRF	TOPO PWR	REMARKS
		17:38:00					Takeoff
		20:39:34					DS: BL32_20221129_203934
000_FL26	3226	20:39:34	20:46:31	480	500	4	
001_FL25	3225	20:48:53	20:53:54	480	500	4	BAD: partial line
		21:10:00					Landing
		21:20:00					End survey

FLIGHT LOG

PROJECT NAME:	2022-10010368 Chesapeake	**BASE AIRPORT:**	Salisbury(KSBY)
LOCATION / AREA:	Chesapeake / BL30, BL60	**DATE:**	1 December 2022
AIRCRAFT:	Cessna 404 (N70790F)	**PILOT:**	Dennis C.
SYSTEM:	HawkEye 4X	**OPERATOR:**	Richard C.

MISSION ID:	ChesapeakeMain, ChesapeakeMD	**CLOUDS:**	Clear
BASE STATION:	NA	**WIND:**	10-15 kts @ 310
LIDAR DRIVE:	HE4X-04	**RCD DRIVE:**	RCD-01

ENGINE START:	15:04	**ENGINE OFF:**	20:26	**ENGINE TIME:**	05:22
TAKEOFF:	15:21	**LANDING:**	20:18	**AIR TIME**	04:57

FL #	LINE #	START TIME	END TIME	ALTITUDE	TOPO PRF	PWR	REMARKS
		15:21:00					Takeoff
		15:40:54					DS: BL60_20221201_154054
000_FL1	6001	15:40:54	15:43:18	480	500	4	BAD: No Deep Nav
		15:50:37					DS: BL30_20221201_155037
000_FL64	3064	15:50:37	15:58:34	480	500	4	BAD: No Deep Nav
001_FL63	3063	16:01:58	16:04:47	480	500	4	BAD: No Deep Nav
		16:05:00					End survey
		20:18:00					Landing

WOOLPERT

FLIGHT LOG

PROJECT NAME:	2022-10010368 Chesapeake	**BASE AIRPORT:**	Salisbury(KSBY)
LOCATION / AREA:	Chesapeake / BL30	**DATE:**	1 December 2022
AIRCRAFT:	Cessna 404 (N70790F)	**PILOT:**	Dennis C.
SYSTEM:	HawkEye 4X	**OPERATOR:**	Richard C.

MISSION ID:	ChesapeakeMD	**CLOUDS:**	Clear
BASE STATION:	NA	**WIND:**	10-15 kts @ 310
LIDAR DRIVE:	HE4X-04	**RCD DRIVE:**	RCD-01

ENGINE START:	15:04	**ENGINE OFF:**	20:26	**ENGINE TIME:**	05:22
TAKEOFF:	15:21	**LANDING:**	20:18	**AIR TIME**	04:57

FL #	LINE #	START TIME	END TIME	ALTITUDE	TOPO PRF	TOPO PWR	REMARKS
		15:21:00					Takeoff
		17:48:43					DS: BL30_20221201_174843
000_FL63	3063	17:48:43	17:57:36	480	500	4	
001_FL62	3062	18:00:33	18:10:08	480	500	4	
002_FL61	3061	18:12:49	18:23:12	480	500	4	
003_FL60	3060	18:25:31	18:36:33	480	500	4	
004_FL59	3059	18:39:12	18:50:36	480	500	4	Missing Frame
005_FL58	3058	18:52:59	19:04:48	480	500	4	Missing Frame
006_FL57	3057	19:07:06	19:19:01	480	500	4	
007_FL56	3056	19:21:13	19:33:51	480	500	4	
008_FL55	3055	19:36:18	19:48:44	480	500	4	Missing Frame
009_FL54	3054	19:51:16	20:04:46	480	500	4	BAD: No imagery, RCD error
		20:07:14					DS: BL30_20221201_200714
000_FL53	3053	20:07:14	20:08:30	480	500	4	BAD: No imagery, ended at begining
		20:09:00					End survey
		20:18:00					Landing

FLIGHT LOG

PROJECT NAME:	2022-10010368 Chesapeake	**BASE AIRPORT:**	Salisbury(KSBY)
LOCATION / AREA:	Chesapeake / BL30, BL60	**DATE:**	2 December 2022
AIRCRAFT:	Cessna 404 (N70790F)	**PILOT:**	Dennis C.
SYSTEM:	HawkEye 4X	**OPERATOR:**	Richard C.

MISSION ID:	ChesapeakeMain, ChesapeakeMD	**CLOUDS:**	Clear
BASE STATION:	NA	**WIND:**	10 kts @ 230
LIDAR DRIVE:	HE4X-03	**RCD DRIVE:**	RCD-01

ENGINE START:	14:55	**ENGINE OFF:**	21:29	**ENGINE TIME:**	06:34
TAKEOFF:	15:26	**LANDING:**	21:20	**AIR TIME**	05:54

FL #	LINE #	START TIME	END TIME	ALTITUDE	TOPO PRF	PWR	REMARKS
		15:26:00					Takeoff
		15:39:51					DS: BL60_20221202_153951
000_FL1	6001	15:39:51	15:42:12	480	500	4	
		15:45:52					DS: BL30_20221202_154552
000_FL64	3064	15:45:52	15:54:00	480	500	4	
		16:11:26					DS: BL30_20221202_161126
000_FL54	3054	16:11:26	16:24:22	480	500	4	No Imagery
001_FL53	3053	16:27:24	16:41:18	480	500	4	No Imagery
002_FL52	3052	16:43:49	16:57:40	480	500	4	No Imagery
003_FL51	3051	17:00:30	17:15:28	480	500	4	No Imagery
004_FL50	3050	17:18:23	17:33:11	480	500	4	No Imagery
005_FL49	3049	17:35:56	17:50:59	480	500	4	No Imagery
006_FL48	3048	17:53:39	18:07:59	480	500	4	No Imagery
007_FL47	3047	18:13:38	18:28:22	480	500	4	No Imagery
008_FL46	3046	18:30:56	18:45:22	480	500	4	No Imagery
009_FL45	3045	18:49:23	19:04:28	480	500	4	No Imagery
010_FL44	3044	19:06:20	19:20:54	480	500	4	No Imagery
011_FL43	3043	19:23:34	19:35:13	480	500	4	BAD: System Error
		19:36:00					End survey
		21:20:00					Landing

FLIGHT LOG

WOOLPERT

PROJECT NAME:	2022-10010368 Chesapeake	**BASE AIRPORT:**	Salisbury(KSBY)
LOCATION / AREA:	Chesapeake / BL30, BL60	**DATE:**	2 December 2022
AIRCRAFT:	Cessna 404 (N70790F)	**PILOT:**	Dennis C.
SYSTEM:	HawkEye 4X	**OPERATOR:**	Richard C.

MISSION ID:	ChesapeakeMain, ChesapeakeMD	**CLOUDS:**	Clear
BASE STATION:	NA	**WIND:**	10 kts @ 230
LIDAR DRIVE:	HE4X-03	**RCD DRIVE:**	RCD-01

ENGINE START:	14:55	**ENGINE OFF:**	21:29	**ENGINE TIME:**	06:34
TAKEOFF:	15:26	**LANDING:**	21:20	**AIR TIME**	05:54

FL #	LINE #	START TIME	END TIME	ALTITUDE	TOPO PRF	PWR	REMARKS
		15:26:00					Takeoff
		20:26:21					DS: BL30_20221202_202621
000_FL43	3043	20:26:21	20:41:20	480	500	4	
001_FL42	3042	20:43:45	20:58:08	480	500	4	
		21:03:13					DS: BL60_20221202_210313
000_FL1	6001	21:03:13	21:05:33	480	500	4	
		21:06:00					End survey
		21:20:00					Landing

FLIGHT LOG

PROJECT NAME:	2022-10010368 Chesapeake	**BASE AIRPORT:**	Salisbury(KSBY)
LOCATION / AREA:	Chesapeake / BL12, BL32, BL60	**DATE:**	8 December 2022
AIRCRAFT:	Cessna 404 (N70790F)	**PILOT:**	Dennis C.
SYSTEM:	HawkEye 4X	**OPERATOR:**	Richard C.

MISSION ID:	ChesapeakeMain, ChesapeakeMD, ChesapeakeVA	**CLOUDS:**	Clouds @ 3000ft
BASE STATION:	NA	**WIND:**	25-30kts @ 20
LIDAR DRIVE:	HE4X-01	**RCD DRIVE:**	RCD-01

ENGINE START:	14:47	**ENGINE OFF:**	21:28	**ENGINE TIME:**	06:41
TAKEOFF:	15:01	**LANDING:**	21:14	**AIR TIME**	06:13

FL #	LINE #	START TIME	END TIME	ALTITUDE	TOPO PRF	PWR	REMARKS
		15:01:00					Takeoff
		15:14:11					DS: BL60_20221208_151411
000_FL1	6001	15:14:11	15:16:27	480	500	4	
		15:21:24					DS: BL32_20221208_152124
000_FL26	3226	15:21:24	15:28:52	480	500	4	
001_FL25	3225	15:32:28	15:38:57	480	500	4	
002_FL24	3224	15:42:05	15:48:58	480	500	4	
003_FL23	3223	15:51:33	15:57:40	480	500	4	
004_FL22	3222	16:00:29	16:07:03	480	500	4	
005_FL21	3221	16:09:36	16:15:35	480	500	4	
006_FL20	3220	16:18:21	16:24:38	480	500	4	
007_FL19	3219	16:26:37	16:32:12	480	500	4	
008_FL18	3218	16:34:49	16:40:53	480	500	4	
009_FL17	3217	16:43:12	16:48:35	480	500	4	
010_FL16	3216	16:51:21	16:56:58	480	500	4	
011_FL15	3215	16:59:34	17:04:40	480	500	4	
012_FL14	3214	17:07:16	17:12:24	480	500	4	
013_FL13	3213	17:14:48	17:19:36	480	500	4	
014_FL12	3212	17:22:44	17:25:49	480	500	4	
015_FL11	3211	17:28:19	17:31:01	480	500	4	
016_FL10	3210	17:34:08	17:36:54	480	500	4	
017_FL9	3209	17:39:18	17:41:47	480	500	4	
018_FL8	3208	17:44:19	17:46:39	480	500	4	
019_FL7	3207	17:49:15	17:51:22	480	500	4	
020_FL6	3206	17:54:23	17:56:25	480	500	4	
021_FL5	3205	17:58:54	18:00:47	480	500	4	
022_FL4	3204	18:03:36	18:05:21	480	500	4	
023_FL3	3203	18:07:33	18:09:03	480	500	4	
024_FL2	3202	18:12:05	18:13:18	480	500	4	

FLIGHT LOG

WOOLPERT

PROJECT NAME:	2022-10010368 Chesapeake	**BASE AIRPORT:**	Salisbury(KSBY)
LOCATION / AREA:	Chesapeake / BL12, BL32, BL60	**DATE:**	8 December 2022
AIRCRAFT:	Cessna 404 (N70790F)	**PILOT:**	Dennis C.
SYSTEM:	HawkEye 4X	**OPERATOR:**	Richard C.

MISSION ID:	ChesapeakeMain, ChesapeakeMD, ChesapeakeVA	**CLOUDS:**	Clouds @ 3000ft
BASE STATION:	NA	**WIND:**	25-30kts @ 20
LIDAR DRIVE:	HE4X-01	**RCD DRIVE:**	RCD-01

ENGINE START:	14:47	**ENGINE OFF:**	21:28	**ENGINE TIME:**	06:41
TAKEOFF:	15:01	**LANDING:**	21:14	**AIR TIME**	06:13

FL #	LINE #	START TIME	END TIME	ALTITUDE	TOPO PRF	PWR	REMARKS
025_FL1	3201	18:15:31	18:16:28	480	500	4	
026_FL57	3295	18:19:45	18:23:41	480	500	4	
027_FL58	3296	18:27:36	18:31:54	480	500	4	
		18:50:42					DS: BL12_20221208_185042
000_FL45	1245	18:50:42	18:51:34	480	500	4	
001_FL44	1244	18:54:13	18:55:18	480	500	4	
002_FL43	1243	18:57:34	18:58:52	480	500	4	
003_FL42	1242	19:01:56	19:03:32	480	500	4	
004_FL41	1241	19:06:14	19:08:35	480	500	4	
005_FL40	1240	19:11:08	19:13:38	480	500	4	
006_FL39	1239	19:16:26	19:18:59	480	500	4	
007_FL38	1238	19:21:08	19:24:02	480	500	4	
008_FL37	1237	19:26:15	19:29:14	480	500	4	
009_FL36	1236	19:31:36	19:34:41	480	500	4	
010_FL35	1235	19:37:17	19:40:20	480	500	4	
011_FL34	1234	19:43:32	19:51:53	480	500	4	
012_FL33	1233	19:54:24	20:02:16	480	500	4	
013_FL32	1232	20:04:50	20:13:08	480	500	4	
014_FL31	1231	20:15:26	20:23:41	480	500	4	
015_FL30	1230	20:26:17	20:34:55	480	500	4	
016_FL29	1229	20:37:19	20:45:46	480	500	4	
017_FL28	1228	20:48:14	20:57:11	480	500	4	
		20:58:00					End survey
		21:14:00					Landing

WOOLPERT

FLIGHT LOG

PROJECT NAME:	2022-10010368 Chesapeake	**BASE AIRPORT:**	Salisbury(KSBY)
LOCATION / AREA:	Chesapeake / BL30, BL60	**DATE:**	9 December 2022
AIRCRAFT:	Cessna 404 (N70790F)	**PILOT:**	Dennis C.
SYSTEM:	HawkEye 4X	**OPERATOR:**	Richard C.

MISSION ID:	ChesapeakeMain, ChesapeakeMD	**CLOUDS:**	Clouds @ 2000ft
BASE STATION:	NA	**WIND:**	15 kts @ 30
LIDAR DRIVE:	HE4X-02	**RCD DRIVE:**	RCD-01

ENGINE START:	13:44	**ENGINE OFF:**	20:20	**ENGINE TIME:**	06:36
TAKEOFF:	14:04	**LANDING:**	20:06	**AIR TIME**	06:02

FL #	LINE #	START TIME	END TIME	ALTITUDE	TOPO PRF	TOPO PWR	REMARKS
		14:04:00					Takeoff
		14:17:09					DS: BL60_20221209_141709
000_FL1	6001	14:17:09	14:19:25	480	500	4	
		14:27:17					DS: BL30_20221209_142717
000_FL41	3041	14:27:17	14:41:22	480	500	4	
001_FL40	3040	14:44:04	14:59:07	480	500	4	
002_FL39	3039	15:01:52	15:15:55	480	500	4	
003_FL38	3038	15:18:06	15:33:52	480	500	4	
004_FL37	3037	15:36:26	15:51:03	480	500	4	
005_FL36	3036	15:53:38	16:09:18	480	500	4	
006_FL35	3035	16:11:51	16:27:02	480	500	4	
007_FL34	3034	16:29:43	16:45:36	480	500	4	
008_FL33	3033	16:48:01	17:02:41	480	500	4	
009_FL32	3032	17:05:27	17:21:15	480	500	4	
010_FL31	3031	17:23:44	17:38:30	480	500	4	
011_FL30	3030	17:40:57	17:56:13	480	500	4	
012_FL29	3029	17:58:34	18:13:31	480	500	4	
013_FL28	3028	18:16:50	18:32:17	480	500	4	
014_FL27	3027	18:34:41	18:49:05	480	500	4	
015_FL26	3026	18:52:00	19:06:52	480	500	4	
		19:23:35					DS: BL30_20221209_192335
000_FL25	3025	19:23:35	19:37:59	480	500	4	
001_FL24	3024	19:40:23	19:55:13	480	500	4	
		19:56:00					End survey
		20:06:00					Landing

FLIGHT LOG

PROJECT NAME:	2022-10010368 Chesapeake	**BASE AIRPORT:**	Salisbury(KSBY)
LOCATION / AREA:	Chesapeake / BL30, BL60	**DATE:**	10 December 2022
AIRCRAFT:	Cessna 404 (N70790F)	**PILOT:**	Dennis C.
SYSTEM:	HawkEye 4X	**OPERATOR:**	Richard C.

MISSION ID:	ChesapeakeMain, ChesapeakeMD	**CLOUDS:**	Clouds @ 2000ft
BASE STATION:	NA	**WIND:**	15-20 kts @ 60
LIDAR DRIVE:	HE4X-02	**RCD DRIVE:**	RCD-01

ENGINE START:	14:41	**ENGINE OFF:**	19:08	**ENGINE TIME:**	04:27
TAKEOFF:	15:18	**LANDING:**	19:03	**AIR TIME**	03:45

FL #	LINE #	START TIME	END TIME	ALTITUDE	TOPO PRF	PWR	REMARKS
		15:18:00					Takeoff
		15:32:36					DS: BL60_20221210_153236
000_FL1	6001	15:32:36	15:34:48	480	500	4	
		15:43:52					DS: BL30_20221210_154352
000_FL23	3023	15:43:52	15:58:40	480	500	4	
001_FL22	3022	16:01:17	16:17:15	480	500	4	
002_FL21	3021	16:19:39	16:34:03	480	500	4	
003_FL20	3020	16:36:46	16:52:27	480	500	4	
004_FL19	3019	16:54:55	17:09:38	480	500	4	
005_FL18	3018	17:12:15	17:27:49	480	500	4	
006_FL17	3017	17:30:27	17:44:59	480	500	4	
007_FL16	3016	17:47:10	18:02:57	480	500	4	
008_FL15	3015	18:05:20	18:20:05	480	500	4	
009_FL14	3014	18:22:11	18:37:51	480	500	4	
		18:39:00					End survey
		19:03:00					Landing

FLIGHT LOG

PROJECT NAME:	2022-10010368 Chesapeake	**BASE AIRPORT:**	Salisbury(KSBY)
LOCATION / AREA:	Chesapeake / BL30, BL33, BL60	**DATE:**	14 December 2022
AIRCRAFT:	Cessna 404 (N70790F)	**PILOT:**	Dennis C.
SYSTEM:	HawkEye 4X	**OPERATOR:**	RICHARD C.

MISSION ID:	ChesapeakeMain, ChesapeakeMD	**CLOUDS:**	Clear
BASE STATION:	NA	**WIND:**	5-10 kts @ 30
LIDAR DRIVE:	HE4X-04	**RCD DRIVE:**	RCD-01

ENGINE START:	15:24	**ENGINE OFF:**	21:55	**ENGINE TIME:**	06:31
TAKEOFF:	15:53	**LANDING:**	21:48	**AIR TIME**	05:55

FL #	LINE #	START TIME	END TIME	ALTITUDE	TOPO PRF	PWR	REMARKS
		15:53:00					Takeoff
		16:08:31					DS: BL60_20221214_160831
000_FL1	6001	16:08:31	16:10:41	480	500	4	
		16:20:00					DS: BL30_20221214_162000
000_FL13	3013	16:20:00	16:34:17	480	500	4	
001_FL12	3012	16:38:19	16:52:33	480	500	4	
002_FL11	3011	16:55:42	17:07:57	480	500	4	
003_FL10	3010	17:12:42	17:24:42	480	500	4	
004_FL9	3009	17:28:02	17:38:19	480	500	4	
005_FL8	3008	17:42:32	17:52:23	480	500	4	
006_FL7	3007	17:55:26	18:04:03	480	500	4	
007_FL6	3006	18:06:20	18:13:56	480	500	4	
008_FL5	3005	18:17:05	18:23:36	480	500	4	
009_FL4	3004	18:25:57	18:31:24	480	500	4	
010_FL3	3003	18:34:22	18:38:39	480	500	4	
011_FL2	3002	18:41:20	18:44:29	480	500	4	
012_FL1	3001	18:47:31	18:49:34	480	500	4	
013_FL65	3095	18:55:03	18:59:26	480	500	4	
014_FL66	3096	19:03:00	19:08:24	480	500	4	
015_FL67	3097	19:13:36	19:18:26	480	500	4	
016_FL68	3098	19:22:23	19:26:31	480	500	4	
		19:34:45					DS: BL33_20221214_193445
000_FL23	3323	19:34:45	19:41:45	480	500	4	
001_FL22	3322	19:45:04	19:53:49	480	500	4	
002_FL21	3321	19:56:20	20:05:36	480	500	4	
003_FL20	3320	20:08:17	20:17:58	480	500	4	
004_FL19	3319	20:20:21	20:30:10	480	500	4	
005_FL18	3318	20:33:00	20:43:24	480	500	4	
006_FL17	3317	20:45:53	20:56:13	480	500	4	

WOOLPERT

FLIGHT LOG

PROJECT NAME:	2022-10010368 Chesapeake	**BASE AIRPORT:**	Salisbury(KSBY)
LOCATION / AREA:	Chesapeake / BL30, BL33, BL60	**DATE:**	14 December 2022
AIRCRAFT:	Cessna 404 (N70790F)	**PILOT:**	Dennis C.
SYSTEM:	HawkEye 4X	**OPERATOR:**	RICHARD C.

MISSION ID:	ChesapeakeMain, ChesapeakeMD	**CLOUDS:**	Clear
BASE STATION:	NA	**WIND:**	5-10 kts @ 30
LIDAR DRIVE:	HE4X-04	**RCD DRIVE:**	RCD-01

ENGINE START:	15:24	**ENGINE OFF:**	21:55	**ENGINE TIME:**	06:31
TAKEOFF:	15:53	**LANDING:**	21:48	**AIR TIME**	05:55

FL #	LINE #	START TIME	END TIME	ALTITUDE	TOPO PRF	PWR	REMARKS
007_FL16	3316	20:58:49	21:09:46	480	500	4	
008_FL15	3315	21:12:04	21:22:59	480	500	4	
009_FL14	3314	21:25:24	21:36:50	480	500	4	
		21:39:00					End survey
		21:48:00					Landing

FLIGHT LOG

PROJECT NAME:	2022-10010368 Chesapeake	**BASE AIRPORT:**	Salisbury(KSBY)
LOCATION / AREA:	Chesapeake / BL11, BL33, BL60	**DATE:**	19 December 2022
AIRCRAFT:	Cessna 404 (N70790F)	**PILOT:**	Dennis C.
SYSTEM:	HawkEye 4X	**OPERATOR:**	RICHARD C.

MISSION ID:	ChesapeakeMain, ChesapeakeMD, ChesapeakeVA	**CLOUDS:**	Clear
BASE STATION:	NA	**WIND:**	10-15 kts @ 320
LIDAR DRIVE:	HE4X-03	**RCD DRIVE:**	RCD-02

ENGINE START:	15:16	**ENGINE OFF:**	21:37	**ENGINE TIME:**	06:21
TAKEOFF:	16:40	**LANDING:**	21:25	**AIR TIME**	04:45

FL #	LINE #	START TIME	END TIME	ALTITUDE	TOPO PRF	PWR	REMARKS
		21:12:00					End survey
		16:40:00					Takeoff
		16:52:44					DS: BL60_20221219_165244
000_FL1	6001	16:52:44	16:54:51	480	500	4	
		16:59:48					DS: BL33_20221219_165948
000_FL13	3313	16:59:48	17:01:19	480	500	4	
		17:23:17					DS: BL11_20221219_172317
000_FL50	1150	17:23:17	17:33:58	480	500	4	
001_FL49	1149	17:36:31	17:46:22	480	500	4	
002_FL48	1148	17:49:22	18:00:08	480	500	4	
003_FL47	1147	18:02:42	18:12:49	480	500	4	
004_FL46	1146	18:16:32	18:27:52	480	500	4	
005_FL45	1145	18:30:20	18:40:46	480	500	4	
006_FL44	1144	18:43:50	18:55:20	480	500	4	
007_FL43	1143	18:57:42	19:08:24	480	500	4	
008_FL42	1142	19:11:48	19:23:31	480	500	4	
009_FL41	1141	19:25:50	19:27:11	480	500	4	BAD:
010_FL41	1141	19:52:19	20:03:24	480	500	4	
011_FL40	1140	20:06:16	20:18:00	480	500	4	
012_FL39	1139	20:20:05	20:31:04	480	500	4	
013_FL38	1138	20:34:18	20:45:47	480	500	4	
014_FL37	1137	20:47:43	20:58:31	480	500	4	
015_FL36	1136	21:01:04	21:13:22	480	500	4	
		21:25:00					Landing

FLIGHT LOG

PROJECT NAME:	2022-10010368 Chesapeake	**BASE AIRPORT:**	Salisbury(KSBY)
LOCATION / AREA:	Chesapeake / BL11, BL40, BL60	**DATE:**	21 December 2022
AIRCRAFT:	Cessna 404 (N70790F)	**PILOT:**	Dennis C.
SYSTEM:	HawkEye 4X	**OPERATOR:**	RICHARD C.

MISSION ID:	ChesapeakeMain, ChesapeakeMD, ChesapeakeVA	**CLOUDS:**	Clear
BASE STATION:	NA	**WIND:**	5-10 kts @ 70
LIDAR DRIVE:	HE4X-04	**RCD DRIVE:**	RCD-02

ENGINE START:	15:37	**ENGINE OFF:**	20:23	**ENGINE TIME:**	04:46
TAKEOFF:	16:30	**LANDING:**	20:12	**AIR TIME**	03:42

FL #	LINE #	START TIME	END TIME	ALTITUDE	TOPO PRF	TOPO PWR	REMARKS
		16:30:00					Takeoff
		16:42:32					DS: BL60_20221221_164232
000_FL1	6001	16:42:32	16:44:42	480	500	4	
		16:50:37					DS: BL40_20221221_165037
000_FL1	4001	16:50:37	16:51:50	480	500	4	
001_FL2	4002	16:54:59	16:56:21	480	500	4	
002_FL3	4003	16:59:08	17:00:32	480	500	4	
003_FL4	4004	17:03:43	17:04:31	480	500	4	
004_FL5	4005	17:07:32	17:08:50	480	500	4	
005_FL6	4006	17:11:27	17:12:45	480	500	4	
006_FL7	4007	17:15:28	17:16:49	480	500	4	
007_FL8	4008	17:19:47	17:21:06	480	500	4	
008_FL9	4009	17:23:03	17:23:54	480	500	4	
		17:41:11					DS: BL11_20221221_174111
000_FL18	1118	17:41:11	17:54:47	480	500	4	
001_FL17	1117	17:57:28	18:11:02	480	500	4	
002_FL16	1116	18:13:47	18:27:29	480	500	4	
003_FL15	1115	18:30:17	18:43:51	480	500	4	
004_FL14	1114	18:46:56	19:00:34	480	500	4	
005_FL13	1113	19:03:13	19:16:58	480	500	4	
006_FL12	1112	19:23:40	19:37:13	480	500	4	
007_FL11	1111	19:39:43	19:53:32	480	500	4	
		19:54:00					End survey
		20:12:00					Landing

FLIGHT LOG

PROJECT NAME:	2022-10010368 Chesapeake	**BASE AIRPORT:**	Easton(KESN)
LOCATION / AREA:	Chesapeake / BL41, BL61	**DATE:**	2 February 2023
AIRCRAFT:	Cessna 404 (N70790F)	**PILOT:**	Dennis C.
SYSTEM:	HawkEye 4X	**OPERATOR:**	Andrew B.

MISSION ID:	ChesapeakeMain, ChesapeakeMD	**CLOUDS:**	Clouds @5000ft+
BASE STATION:	NA	**WIND:**	Calm @ 130
LIDAR DRIVE:	HE4X-04	**RCD DRIVE:**	RCD-01

ENGINE START:	15:54	**ENGINE OFF:**	20:42	**ENGINE TIME:**	04:48
TAKEOFF:	16:11	**LANDING:**	20:29	**AIR TIME**	04:18

FL #	LINE #	START TIME	END TIME	ALTITUDE	TOPO PRF	PWR	REMARKS
		16:11:00					Takeoff
		16:18:05					DS: BL61_20230202_161805
000_FL1	6101	16:18:05	16:20:09	480	500	4	
001_FL1	6101	16:20:26	16:20:50	480	500	4	BAD: Operator Error
		16:44:57					DS: BL41_20230202_164457
000_FL1	4101	16:44:57	16:46:48	480	500	4	
001_FL2	4102	16:48:56	16:51:03	480	500	4	
002_FL3	4103	16:53:32	16:55:53	480	500	4	
003_FL4	4104	16:58:14	17:00:39	480	500	4	
004_FL5	4105	17:03:06	17:05:48	480	500	4	
005_FL6	4106	17:08:06	17:10:41	480	500	4	
006_FL7	4107	17:13:03	17:15:45	480	500	4	
007_FL8	4108	17:17:57	17:20:18	480	500	4	
008_FL9	4109	17:23:04	17:25:02	480	500	4	
009_FL10	4110	17:28:40	17:29:43	480	500	4	
010_FL11	4111	17:31:52	17:32:57	480	500	4	
011_FL12	4112	17:35:33	17:36:39	480	500	4	
012_FL13	4113	17:38:21	17:40:12	480	500	4	
013_FL14	4114	17:42:30	17:44:39	480	500	4	
014_FL15	4115	17:46:58	17:49:11	480	500	4	
015_FL16	4116	17:51:40	17:53:45	480	500	4	
016_FL17	4117	17:56:09	17:57:59	480	500	4	
017_FL18	4118	18:00:22	18:01:53	480	500	4	
018_FL19	4119	18:04:23	18:05:37	480	500	4	
019_FL20	4120	18:08:24	18:09:17	480	500	4	
020_FL21	4121	18:11:21	18:12:15	480	500	4	
021_FL22	4122	18:14:33	18:15:33	480	500	4	
022_FL23	4123	18:18:06	18:19:13	480	500	4	
023_FL24	4124	18:21:40	18:22:46	480	500	4	

FLIGHT LOG

PROJECT NAME:	2022-10010368 Chesapeake	**BASE AIRPORT:**	Easton(KESN)
LOCATION / AREA:	Chesapeake / BL41, BL61	**DATE:**	2 February 2023
AIRCRAFT:	Cessna 404 (N70790F)	**PILOT:**	Dennis C.
SYSTEM:	HawkEye 4X	**OPERATOR:**	Andrew B.

MISSION ID:	ChesapeakeMain, ChesapeakeMD	**CLOUDS:**	Clouds @5000ft+
BASE STATION:	NA	**WIND:**	Calm @ 130
LIDAR DRIVE:	HE4X-04	**RCD DRIVE:**	RCD-01

ENGINE START:	15:54	**ENGINE OFF:**	20:42	**ENGINE TIME:**	04:48
TAKEOFF:	16:11	**LANDING:**	20:29	**AIR TIME**	04:18

FL #	LINE #	START TIME	END TIME	ALTITUDE	TOPO PRF	PWR	REMARKS
024_FL25	4125	18:25:11	18:26:14	480	500	4	
025_FL26	4126	18:28:34	18:29:36	480	500	4	
026_FL27	4127	18:32:46	18:33:57	480	500	4	
027_FL28	4128	18:36:21	18:37:30	480	500	4	
028_FL29	4129	18:39:39	18:40:29	480	500	4	
029_FL30	4130	18:42:47	18:43:38	480	500	4	
030_FL31	4131	18:46:28	18:48:07	480	500	4	
031_FL32	4132	18:50:15	18:51:47	480	500	4	
032_FL33	4133	18:54:17	18:56:00	480	500	4	
033_FL34	4134	18:58:20	18:59:53	480	500	4	
034_FL35	4135	19:02:42	19:03:45	480	500	4	
035_FL36	4136	19:05:51	19:07:01	480	500	4	
036_FL37	4137	19:09:18	19:10:41	480	500	4	
037_FL38	4138	19:12:46	19:14:19	480	500	4	
038_FL39	4139	19:16:56	19:18:46	480	500	4	
039_FL40	4140	19:20:57	19:22:50	480	500	4	
040_FL41	4141	19:25:23	19:27:32	480	500	4	
041_FL42	4142	19:29:34	19:31:44	480	500	4	
042_FL43	4143	19:34:36	19:36:50	480	500	4	
043_FL44	4144	19:39:13	19:41:19	480	500	4	
044_FL45	4145	19:44:06	19:46:16	480	500	4	
045_FL46	4146	19:48:28	19:50:26	480	500	4	
046_FL47	4147	19:53:26	19:55:30	480	500	4	
047_FL48	4148	19:57:50	19:59:45	480	500	4	
		20:00:00					Ended survey, restricted area active.
		20:29:00					Landing

WOOLPERT

FLIGHT LOG

PROJECT NAME:	2022-10010368 Chesapeake	**BASE AIRPORT:**	Easton(KESN)
LOCATION / AREA:	Chesapeake / BL41, BL45, BL61	**DATE:**	5 February 2023
AIRCRAFT:	Cessna 404 (N70790F)	**PILOT:**	Dennis C.
SYSTEM:	HawkEye 4X	**OPERATOR:**	Andrew B.

MISSION ID:	ChesapeakeMain, ChesapeakeMD, ChesapeakeVA	**CLOUDS:**	Clouds @5000ft+
BASE STATION:	NA	**WIND:**	30+ kts @ 240
LIDAR DRIVE:	HE4X-02	**RCD DRIVE:**	RCD-01

ENGINE START:	16:14	**ENGINE OFF:**	22:04	**ENGINE TIME:**	05:50
TAKEOFF:	16:46	**LANDING:**	21:50	**AIR TIME**	05:04

FL #	LINE #	START TIME	END TIME	ALTITUDE	TOPO PRF	PWR	REMARKS
		16:46:00					Takeoff
		17:03:25					DS: BL61_20230205_170325
000_FL1	6101	17:03:25	17:06:23	480	500	4	
		17:32:51					DS: BL41_20230205_173251
000_FL49	4149	17:32:51	17:34:39	480	500	4	
001_FL50	4150	17:38:54	17:40:02	480	500	4	
002_FL51	4151	17:43:46	17:44:53	480	500	4	
003_FL52	4152	17:49:08	17:50:24	480	500	4	
004_FL53	4153	17:54:59	17:56:11	480	500	4	
005_FL54	4154	17:59:52	18:00:59	480	500	4	
006_FL55	4155	18:05:25	18:06:12	480	500	4	
007_FL56	4156	18:10:51	18:11:41	480	500	4	
008_FL57	4157	18:15:28	18:16:21	480	500	4	
009_FL58	4158	18:20:30	18:21:30	480	500	4	
010_FL59	4159	18:23:40	18:24:30	480	500	4	
011_FL60	4160	18:29:33	18:30:29	480	500	4	
012_FL61	4161	18:34:31	18:35:21	480	500	4	
013_FL62	4162	18:39:43	18:40:36	480	500	4	
014_FL63	4163	18:44:02	18:44:55	480	500	4	
015_FL64	4164	18:48:38	18:49:25	480	500	4	
016_FL65	4165	18:59:19	19:00:07	480	500	4	
017_FL66	4166	19:03:16	19:04:07	480	500	4	
018_FL67	4167	19:08:10	19:09:11	480	500	4	
		19:10:00					Completed BL41.
		19:17:39					DS: BL45_20230205_191739
000_FL1	4501	19:17:39	19:18:35	480	500	4	
001_FL2	4502	19:24:37	19:27:18	480	500	4	
002_FL3	4503	19:31:53	19:34:50	480	500	4	
003_FL4	4504	19:37:20	19:40:02	480	500	4	

FLIGHT LOG

PROJECT NAME:	2022-10010368 Chesapeake	**BASE AIRPORT:**	Easton(KESN)
LOCATION / AREA:	Chesapeake / BL41, BL45, BL61	**DATE:**	5 February 2023
AIRCRAFT:	Cessna 404 (N70790F)	**PILOT:**	Dennis C.
SYSTEM:	HawkEye 4X	**OPERATOR:**	Andrew B.

MISSION ID:	ChesapeakeMain, ChesapeakeMD, ChesapeakeVA	**CLOUDS:**	Clouds @5000ft+
BASE STATION:	NA	**WIND:**	30+ kts @ 240
LIDAR DRIVE:	HE4X-02	**RCD DRIVE:**	RCD-01

ENGINE START:	16:14	**ENGINE OFF:**	22:04	**ENGINE TIME:**	05:50
TAKEOFF:	16:46	**LANDING:**	21:50	**AIR TIME**	05:04

FL #	LINE #	START TIME	END TIME	ALTITUDE	TOPO		REMARKS
					PRF	PWR	
004_FL5	4505	19:43:38	19:46:40	480	500	4	
005_FL6	4506	19:48:48	19:51:32	480	500	4	
006_FL7	4507	19:55:03	19:58:09	480	500	4	
007_FL8	4508	20:00:31	20:03:22	480	500	4	
008_FL9	4509	20:06:19	20:09:26	480	500	4	
009_FL10	4510	20:11:45	20:14:42	480	500	4	
010_FL11	4511	20:17:26	20:20:34	480	500	4	
011_FL12	4512	20:22:44	20:25:31	480	500	4	
012_FL13	4513	20:27:54	20:30:56	480	500	4	
013_FL14	4514	20:33:03	20:35:55	480	500	4	
014_FL15	4515	20:38:27	20:40:32	480	500	4	
015_FL16	4516	20:42:50	20:44:51	480	500	4	
016_FL17	4517	20:47:37	20:49:39	480	500	4	
017_FL18	4518	20:53:18	20:54:57	480	500	4	
018_FL19	4519	20:58:18	21:00:03	480	500	4	
019_FL20	4520	21:02:21	21:03:33	480	500	4	
020_FL21	4521	21:07:21	21:08:09	480	500	4	
021_FL22	4522	21:10:24	21:11:15	480	500	4	
022_FL23	4523	21:16:14	21:17:23	480	500	4	
023_FL24	4524	21:20:02	21:21:09	480	500	4	
024_FL25	4525	21:24:27	21:25:42	480	500	4	
025_FL26	4526	21:28:12	21:29:22	480	500	4	
		21:50:00					Landing
		22:04:00					Ended survey

8.2 Trajectory Processing Log

Project Name	Download Airborne Data	Create IE Project Directory	Copy Data to IE Project /Raw	Run Project Wizard	Base Station			Check Base Coordinate & Datum	Check Lever Arms	Process Time Window		Process TC	Review QC Plots	Separation			Solution Status	Comments
					Station ID	Receiver Type	Antenna (ARP) Height (m)			Start Time (GPS Week Time)	End Time (GPS Week Time)			East RMS (m)	North RMS (m)	Up RMS (m)		
2022-10-30A_CH4X	RC	RC	RC	RC	jx10	R10	GT	GT	GT	70124	76516	GT	GT	0.004	0.002	0.010	FINAL	CAL
2022-10-30A_HE4X	RC	RC	RC	RC	jx10	R10	RC	RC	RC	70102	76661	RC	RC	0.005	0.003	0.010	FINAL	CAL
2022-11-03A_CH4X	RC	RC	RC	RC	NA	PPP	NA	RC	RC			RC	RC	0.011	0.011	0.044	FINAL	
2022-11-03A_HE4X	RC	RC	RC	RC	NA	PPP	NA	RC	RC			RC	RC	0.043	0.059	0.089	FINAL	
2022-11-04A_CH4X	RC	GT	GT	GT	NA	PPP	NA	GT	GT			GT	GT	0.008	0.018	0.027	FINAL	
2022-11-04A_HE4X	RC	GT	GT	GT	NA	PPP	NA	GT	GT			GT	GT	0.079	0.048	0.096	FINAL	
2022-11-05A_CH4X	RC	RC	RC	RC	NA	PPP	NA	RC	RC			RC	RC	0.007	0.014	0.034	FINAL	
2022-11-05A_HE4X	RC	RC	RC	RC	NA	PPP	NA	RC	RC			RC	RC	0.072	0.055	0.109	FINAL	
2022-11-08A_CH4X	RC	RC	RC	RC	NA	PPP	NA	RC	RC			RC	RC	0.006	0.003	0.020	FINAL	
2022-11-08A_HE4X	RC	RC	RC	RC	NA	PPP	NA	RC	RC			RC	RC	0.007	0.006	0.020	FINAL	
2022-11-09A_CH4X	RC	RC	RC	RC	NA	PPP	NA	RC	RC			RC	RC	0.013	0.008	0.025	FINAL	
2022-11-09A_HE4X	RC	RC	RC	RC	NA	PPP	NA	RC	RC			RC	RC	0.015	0.010	0.025	FINAL	
2022-11-10A_CH4X	RC	RC	RC	RC	NA	PPP	NA	RC	RC			RC	RC	0.012	0.014	0.033	FINAL	
2022-11-10A_HE4X	RC	RC	RC	RC	NA	PPP	NA	RC	RC			RC	RC	0.014	0.013	0.038	FINAL	
2022-11-29A_CH4X	RC	RC	RC	RC	NA	PPP	NA	RC	RC			RC	RC	0.004	0.003	0.008	FINAL	
2022-11-29A_HE4X	RC	RC	RC	RC	NA	PPP	NA	RC	RC			RC	RC	0.005	0.004	0.008	FINAL	
2022-11-29B_CH4X	RC	RC	RC	RC	NA	PPP	NA	RC	RC			RC	RC	0.012	0.006	0.008	FINAL	
2022-11-29B_HE4X	RC	RC	RC	RC	NA	PPP	NA	RC	RC			RC	RC	0.012	0.009	0.012	FINAL	
2022-12-01A_CH4X	RC	RC	RC	RC	NA	PPP	NA	RC	RC			RC	RC	0.006	0.011	0.013	FINAL	
2022-12-01A_HE4X	RC	RC	RC	RC	NA	PPP	NA	RC	RC								FINAL	BAD FLIGHT
2022-12-01B_CH4X	RC	RC	RC	RC	NA	PPP	NA	RC	RC			RC	RC	0.011	0.010	0.028	FINAL	
2022-12-01B_HE4X	RC	RC	RC	RC	NA	PPP	NA	RC	RC			RC	RC	0.011	0.011	0.029	FINAL	
2022-12-02A_CH4X	RC	RC	RC	RC	NA	PPP	NA	RC	RC			RC	RC	0.006	0.007	0.015	FINAL	
2022-12-02A_HE4X	RC	RC	RC	RC	NA	PPP	NA	RC	RC			RC	RC	0.005	0.005	0.020	FINAL	
2022-12-02B_CH4X	RC	RC	RC	RC	NA	PPP	NA	RC	RC			RC	RC	0.006	0.004	0.012	FINAL	
2022-12-02B_HE4X	RC	RC	RC	RC	NA	PPP	NA	RC	RC			RC	RC	0.007	0.005	0.013	FINAL	
2022-12-08A_CH4X	RC	RC	RC	RC	NA	PPP	NA	RC	RC			GT	GT	0.024	0.024	0.058	FINAL	
2022-12-08A_HE4X	GT	GT	GT	GT	NA	PPP	NA	GT	GT			GT	GT	0.024	0.024	0.059	FINAL	
2022-12-09A_CH4X	RC	RC	RC	RC	NA	PPP	NA	RC	RC			RC	RC	0.011	0.023	0.023	FINAL	

2022-12-09A_HE4X	RC	RC	RC	RC	NA	PPP	NA	RC	RC			RC	RC	0.007	0.010	0.019	FINAL	
2022-12-10A_CH4X	RC	RC	RC	RC	NA	PPP	NA	RC	RC			RC	RC	0.008	0.006	0.022	FINAL	
2022-12-10A_HE4X	RC	RC	RC	RC	NA	PPP	NA	RC	RC			RC	RC	0.008	0.005	0.020	FINAL	
2022-12-14A_CH4X	RC	RC	RC	RC	NA	PPP	NA	RC	RC			RC	RC	0.025	0.015	0.043	FINAL	
2022-12-14A_HE4X	RC	RC	RC	RC	NA	PPP	NA	RC	RC			RC	RC	0.025	0.015	0.044	FINAL	
2022-12-19A_CH4X	JS	JS	JS	JS	NA	PPP	NA	JS	JS			JS	RC	0.016	0.015	0.043	FINAL	
2022-12-19A_HE4X	JS	JS	JS	JS	NA	PPP	NA	JS	JS			RC	RC	0.121	0.061	0.135	FINAL	
2022-12-21A_CH4X	RC	RC	RC	RC	NA	PPP	NA	RC	RC			RC	RC	0.008	0.009	0.015	FINAL	
2022-12-21A_HE4X	RC	RC	RC	RC	NA	PPP	NA	RC	RC			RC	RC	0.107	0.069	0.102	FINAL	
2023-02-02A_CH4X	AB	AB	AB	AB	NA	PPP	NA	AB	AB			AB	AB	0.015	0.015	0.044	FINAL	
2023-02-02A_HE4X	AB	AB	AB	AB	NA	PPP	NA	AB	AB			AB	AB	0.015	0.015	0.037	FINAL	
2023-02-05A_CH4X	AB	AB	AB	AB	NA	PPP	NA	AB	AB			AB	AB	0.013	0.014	0.050	FINAL	
2023-02-05A_HE4X	AB	AB	AB	AB	NA	PPP	NA	AB	AB			AB	AB	0.012	0.016	0.043	FINAL	