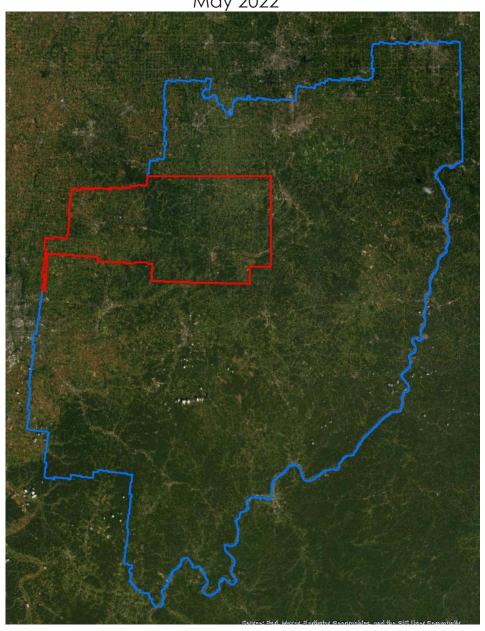
OH Statewide Phase 2 2020 B20

Lidar Mapping Report Project ID 197536 - Work Unit ID 224915

May 2022





Contract # G16PC00022 **Task Order #** 140G0220F0194



Contractor Woolpert Project # 81150

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1. Overview

About

This project contains a comprehensive outline of the 140G0220F0194 - OH Statewide Phase 2 2020 B20 task order issued by the United States Geological Survey's National Geospatial Technical Operations Center (USGS-NGTOC). This task order called for the acquisition and processing of QL0 and QL1 data covering approximately 12,101 square miles in southern Ohio (Figure 1-1).

This report encompasses the Work Unit 224915 area of interest (Figure 1-2). This AOI totals approximately 1,503 square miles and includes the following counties:

- Coshocton
- Holmes
- Knox
- Tuscarawas

Purpose

This project will support the 3DEP mission, the Natural Resources Conservation Service (NRCS) high resolution elevation enterprise program and the Federal Emergency Management Agency (FEMA) Risk Mapping.

Specifications

Data for this task order was acquired and produced to meet USGS Lidar Base Specification v2021 revision A standards and the American Society of Photogrammetry and Remote Sensing (ASPRS) Positional Accuracy Standards for Digital Geospatial Data (Edition 1, Version 1.0).

Spatial Reference

Geospatial data products were produced using the following horizontal and vertical spatial data reference system information listed in Table 1-1.

Table 1-1. Spatial Reference System

Horizontal	EPSG Code	6549
	Datumw	NAD83(2011)
	Projection	State Plane Ohio North (FIPS 3401)
	Units	US Survey Feet
Vertical	Datum	NAVD88
	Geoid	GEOID18
	Units	US Survey Feet
	Height Type	Orthometric

Figure 1-1. Project Area

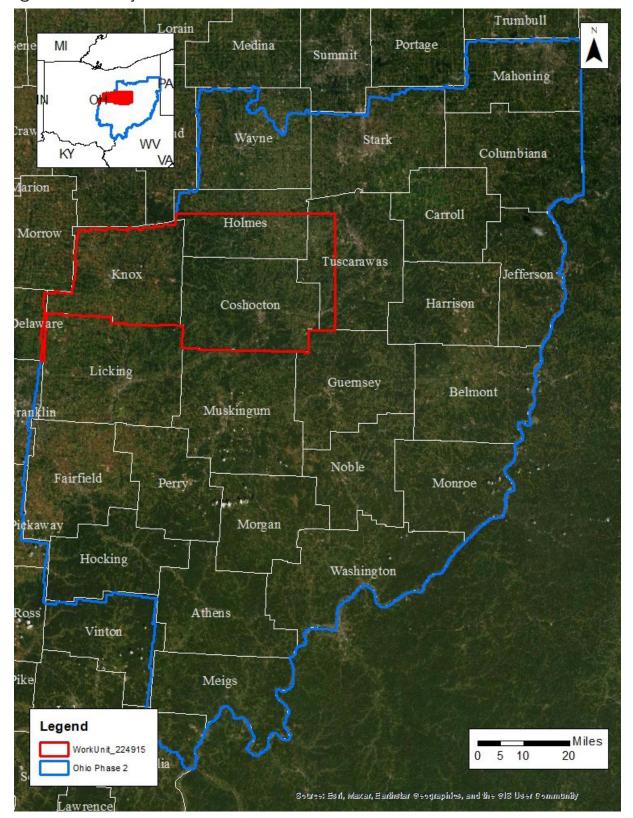


Figure 1-2. Project Area - 197536 - Work Unit 224915



Task Order Deliverables

All data products produced as part of this task order are listed in Table 1-2. All tiled deliverables had a tile of 1,250-feet x 1,250 feet. Tile names are derived from the Ohio (OGRIP) naming schema.

Example: BS20820365

This delivery's tiled dataset contains a total of 26,822 tiles. No excluded tiles from the datasets.

Table 1-2. Deliverables

Lidar Data	
Classified lidar point cloud	Tiles in LAS v1.4 format
data	Classes
	• 1 – Processed, but unclassified
	• 2 – Bare-earth ground
	• 7 – Low Noise
	• 9 – Water
	• 17 – Bridge Decks
	• 18 – High Noise • 20 – Ignored Ground
Breaklines used for hydro-	Lake and River features as feature classes in an Esri file geodatabase
flattening	Water bodies greater than 2 acres as polygon features
natterning	• Rivers 30.5 meters / 100 feet and greater in width as polyline
	features
	Bridges used in DEM generation as point features in Esri shapefile
	format
Hydro-flattened bare	1.25-foot pixel size, 32-bit floating-point; no bridges or overpass structures
earth digital elevation	GeoTIFF format
model (DEM)	
Intensity imagery	1.25-foot pixel size, 8-bit gray-scale (linear rescaling from 16-bit intensity)
	GeoTIFF format
Vertical Accuracy Data	
NVA and VVA checkpoints	Gpkg file format
Interswath and intraswath	Esri shapefile format
test results	
Spatial Metadata	
Data extent	Esri shapefile format
Tile index	Esri shapefile format
Maximum surface height	GeoTIFF format
rasters	Georgia Torringe
Swath separation images	GeoTIFF format
	Georeferenced, polygonal representation of the detailed extents of each
Swath polygons	lidar swath
	I Dolygon toature class in an Esri file goodatahase
	Polygon feature class in an Esri file geodatabase
Metadata and Reports	Polygon leature class in an Esti me geodatabase
Metadata and Reports XML metadata	Deliverable-level FGDC CSDGM/USGS MetaParser Compliant metadata in
•	

2. Acquisition

Flight Planning

Acquisition was planned based on the task order specifications listed in Table 2-1.

Table 2-1. Acquisition Requirements

Specification	Target
Resolution	8 points per square meter0.35-meter nominal point spacing
Overlap	At contractor's discretion, but enough to ensure there are no data gaps between usable portions of the swath and to ensure the aggregate nominal point density (ANPD) is achieved
Acquisition Window	Fall 2020 through Winter 2021
Data Voids	 Not allowed except Where caused by water bodies Where caused by areas of low near infra-red (NIR) reflectivity (i.e. asphalt or composition roofing) Where caused by lidar shadowing from buildings or other features Where appropriately filled-in by another swath
Data Acquisition Conditions	Atmospheric • Cloud and fog-free between the aircraft and ground Ground • Snow free • No unusual flooding or inundation, except in cases where the goal of the collection is to map the inundation Vegetation • Leaf-off is preferred Time of Day • Time of day is not of concern

Flight plans were created using Leica MissionPro software.

Lidar Sensor Information

Aerial lidar data was acquired for this project using the following lidar sensor systems:

- Terrain Mapper serial number 91511, last calibrated July 3, 2019
- Terrian Mapper serial number 91557, last calibrated July 1, 2020
- Terrian Mapper serial number 91515, last calibrated December 12, 2018
 Table 2-2 depicts a summary of sensor information. See Appendix 1 for the sensor calibration reports.

Table 2-2. Leica Terrain Mapper Sensor Info

Sensor Specifications			
Operating Altitude (m AGL)	300 - 5,500 at 10% reflective target		
Maximum Measurement Rate (kHz)	2,000		
Scan Angle	20 - 40		
Scan Width	Up to 70% of flight altitude		
Scan Frequency	Programmable up to 125 Hz (7,500 RPM), 250 scan lines per second		
Number of Returns	15		
Number of intensity measurements	15		
Pulse Mode(s)	Up to 35 pulses in air		
Laser Specifications			
Laser Beam Divergence	0.25 mrad (1/e)		
Laser Classification	Class 4 laser product		
Accuracy			
Range Resolution	< 1 cm RMS		
Elevation Accuracy	< 5 cm 1 σ		
Horizontal Accuracy	< 13 cm 1 σ		
Physical Specifications			
Size (cm), Weight (kg) • Scanner • Control Electronics	• 37 W x 68 L x 26 H cm, 47 kg • 45 W x 47 D x 25 H cm, 33 kg		
Operating Temperature • Scanner • Control Electronics	• 0 - 40°C cabin-side temperature • 0 - 40°C		
Flight Management	Leica FlightPro		
Power Consumption	922 W @ 22.0 – 30.3 VDC		

Source: Leica TerrainMapper Data Sheet

https://leica-geosystems.com/en-US/products/airborne-systems/topographic-lidar-sensors/leica-terrainmapper.

Lidar Sensor Settings

Aerial lidar was acquired using the sensors and settings listed in the Table 2-3.

Table 2-3. Lidar Sensor Settings

Settings	Terrain Mapper
Max. Number of Returns	15
Nominal Point Spacing	0.35 m
Nominal Point Density	8 ppsm
Flying Height Above Ground Level	1,372 m
Flight Speed	160 knots
Scan Angle	40°
Scan Rate Used	150 Hz
Pulse Rate Used	1,600.0 kHz
Multi-Pulse in Air	Enabled
Swath Width	1,456 m
Swath Overlap	25%

Timeline

Lidar data was collected from November 19, 2020 through April 05, 2021. A total of 112 individual flight lines were collected. Figure 2-1 shows aerial lidar coverage by lift.

For more information, see the Flight Logs in Appendix 2.

GNSS and IMU Equipment

Prior to mobilizing to the project site, flight crews coordinated with the necessary air traffic control personnel to ensure airspace access. Crews were on-site, operating a Global Navigation Satellite System (GNSS) Base Station for the airborne GPS support.

Flight navigation during acquisition was performed using Leica Flight Pro Navigation system. The pilots are skilled at maintaining their planned trajectory, while holding the aircraft steady and level. If atmospheric conditions are such that the trajectory, ground speed, roll, pitch and/or heading cannot be properly maintained, the mission is aborted until suitable conditions occur.

Base stations were set by acquisition staff and was used to support the aerial data acquisition. Table 2-3 lists the Station ID and coordinates for all base stations operated during acquisition.

For more information, see the GPS/IMU graphics in Appendix 3.

Figure 2-1. Flight Coverage

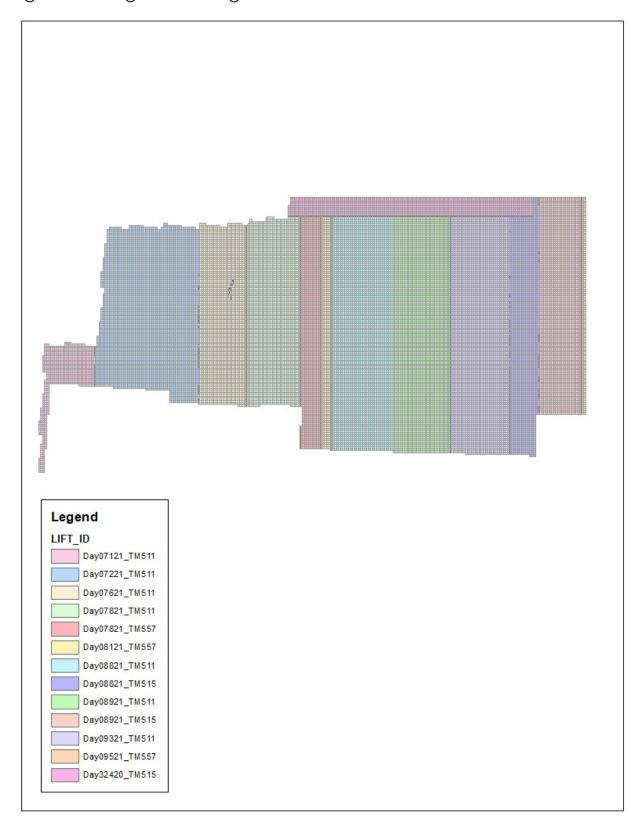


Table 2-4. GNSS Base Stations

Station Name	Longitude (DMS)	Latitude (DMS)	Ellipsoid Height L1 Phase Center (Meters)
OHAL_CORS	40°46'09.73944"	84°06'25.04574"	235.117
OHMA_CORS	40°36'49.73829"	83°04'55.32889"	257.026
OHHA_CORS	41°02'27.93405"	83°40'33.46888"	210.082
MTVR_CORS	40°22'56.57516"	82°30'38.38039"	286.605
OHRI_CORS	40°46'05.33418"	82°33'38.35490"	365.49
OHHU_CORS	41°10'36.35195"	82°33'40.91087°	254.565
OHLA_CORS	41°43'35.53476"	81°17'11.05630"	163.494
OHMN_CORS	41°01'24.70500"	80°46'21.63976"	328.747
TIFF_CORS	41°04'29.89642"	84°09'01.41466"	211.729
GARF_CORS	41°24'56.78161"	81°36'53.60423"	354.314
GUST_CORS	41°27'45.87329"	80°42'58.24972"	283.272
OHMR_CORS	40°32'45.58334"	84°37'50.63693"	236.812
OHLC_CORS	41°43'16.40562"	83°31'34.58723"	151.929
OHSB_CORS	41°38'11.21597"	82°49'47.18063"	148.449
OHAS_CORS	41°55'30.22146"	80°33'03.84441"	181 .661
OHDT_CORS	39°45'53.06211	84°10'50.33473"	196.642
GALP_CORS	38°50'39.14892"	82°16'40.09174"	169.569
STKR_CORS	39°19'33.82494"	82°06'25.62969"	178.128
MCON_CORS	39°39'39.03109"	81°49'45.12175"	272.759
PKTN_CORS	39°02'43.66599"	83°01'27.83159"	144.443
COLB_CORS	39°57'35.11256"	83°02'44.74693"	186.508
OHHO_CORS	39°32'07.27637"	82°26'37.87619"	205.271
OHLI_CORS	39°57'09.13852"	82°24'51.03107"	294.748
FREO_CORS	40°12'05.96943"	81°15'28.22082"	274.771

Acquisition Quality Assurance

An initial quality control process was immediately performed on to review the data coverage, airborne GPS data, and trajectory solution.

Woolpert developed a quality assurance and validation plan to ensure the acquired lidar data meets the USGS Base Specification requirements. For quality assurance purposes, the lidar data was processed immediately following acquisition to verify the coverage has appropriate density, distribution, and no unacceptable data voids. Accompanying GPS data was post processed using differential and Kalman filter algorithms to derive a best estimate of trajectory. The quality of the solution was verified to be consistent with the accuracy requirements of the task order. Any required re-flights were scheduled at the earliest opportunity.

The spatial distribution of the geometrically usable first return lidar points was reviewed for density requirements as well as regular and uniform point distribution - verifying the lidar data is spaced so that 90% of the cells in a 2*NPS grid placed over the data contain at least one lidar point. The NPS assessment is made against single swath, first return data located within the geometrically usable center portion (typically ~90%) of each swath. Additionally, the data was reviewed for unacceptable data voids – verifying no area greater than or equal to $(4 \times ANPS)^2$ exhibited data coverage gaps.

3. Processing

Processing Summary

Once the lidar data passed initial QC, the dataset was corrected for aircraft orientation and movement. This process used airborne inertial, orientation, and GPS data collected during acquisition along with ground-based GPS data. The data went through a geometric calibration that further corrected each laser point. This calibrated data set was used to create the LAS point cloud. The LAS point data was initially classified into "ground" and "non-ground", then further refined using the classes specified in this task order. Breaklines were drawn to denote hydrological features. After the hydro-flattening process, the final deliverables products were created.

GPS-IMU Trajectory Processing

Kinematic corrections for the aircraft position were resolved using aircraft GPS and static ground GPS (1-Hz) for each geodetic control (base station) for three subsystems: inertial measurement unit (IMU), sensor orientation information, and airborne GPS data.

Post-processing of the IMU system data and aircraft position with attitude data was completed to compute an optimally accurate, blended navigation solution based on Kalman filtering technology, or the smoothed best estimate of trajectory (SBET).

For more information, see the GPS/IMU graphics in Appendix 3.

Software: Novatel Inertial Explorer v8.70.6129

Trajectory Quality

The GNSS trajectory and high-quality IMU data are key factors in determining the overall positional accuracy of the final sensor data. Within the trajectory processing, there are many factors that affect the overall quality, but the most indicative are the combined separation, the estimated positional accuracy, and the positional dilution of precision (PDOP).

Combination Separation

Combined separation is a measure of the difference between the forward-run and the backward-run solution of the trajectory. The Kalman filter was processed in both directions to remove the combined directional anomalies. In general, when these two solutions match closely, an optimally accurate and reliable solution is achieved.

The data for this task order was processed with a goal to maintain a combined separation difference of less than ten (10) centimeters.

Estimated Positional Accuracy

Estimated positional accuracy plots the standard deviations of the east, north, and vertical directions along a time scale of the trajectory. It illustrates loss of satellite lock issues, as well as issues arising from long baselines, noise, and/or other atmospheric interference.

PDOP

The PDOP measures the precision of the GPS solution in regard to the geometry of the satellites acquired

and used for the solution.

The data for this task order was processed with a goal to maintain an average PDOP value below 3.0. Brief periods of PDOP over 3.0 are acceptable due to the calibration and control process if other metrics are within specification.

Geometric Calibration

After the initial phase was complete, a formal reduction process was performed on the data. Laser point position was calculated by associating the SBET position to each laser point return time, scan angle, intensity, etc. Raw laser point cloud data was created for the whole project area in LAS format. Automated line-to-line calibrations were then performed for system attitude parameters (pitch, roll, heading), GPS/IMU drift. Statistical reports were generated for comparison and used to make the necessary adjustments to remove any residual systematic error.

For more information, see the Sensor Calibration Report(s) in Appendix 1.

Software: Proprietary Software, TerraMatch v21.002, HxMap 3.4

Relative Accuracy: Interswath (Overlap) Consistency

Interswath or overlap consistency was assessed at multiple locations within overlap in non-vegetated areas containing only single returns and located in areas with slopes of less than 10 degrees. To the extent allowed by the data, test areas were chosen where the full width of the overlap was represented. These overlap areas include adjacent, overlapping parallel swaths within a project, cross-tie swaths and a sample of intersecting project swaths in both flight directions, and adjacent, overlapping lifts.

This project required the interswath accuracy to meet ≤ 8 cm RMSDz. Accuracy was assessed in accordance with the USGS Base Specification v2021 revision A.

The interswath consistency results were produced as polygon features in Esri shapefile format. Table 3-1 lists the interswath test results. Figure 3-1 depicts the location of the interswath test locations.

Table 3-1. Interswath Results

Minimum (m)	Maximum (m)	RMSDz (m)
-0.06200000000	0.0700000000	0.05160000000
-0.07300000000	0.10000000000	0.06290000000
-0.0300000000	0.07300000000	0.04190000000
-0.05500000000	0.0500000000	0.03270000000
-0.07000000000	0.11000000000	0.06600000000

Figure 3-1. Interswath Testing Locations



Relative Accuracy: Intraswath Precision

Intraswath precision (or smooth surface precision) was performed on hard surfaces with areas consisting of approximately 100 pixels (ex.: parking lots, large rooftops) and containing only single return lidar points. Sample areas were selected where full width of the swath(s) (left, center, and right) were represented to the extent the data allowed.

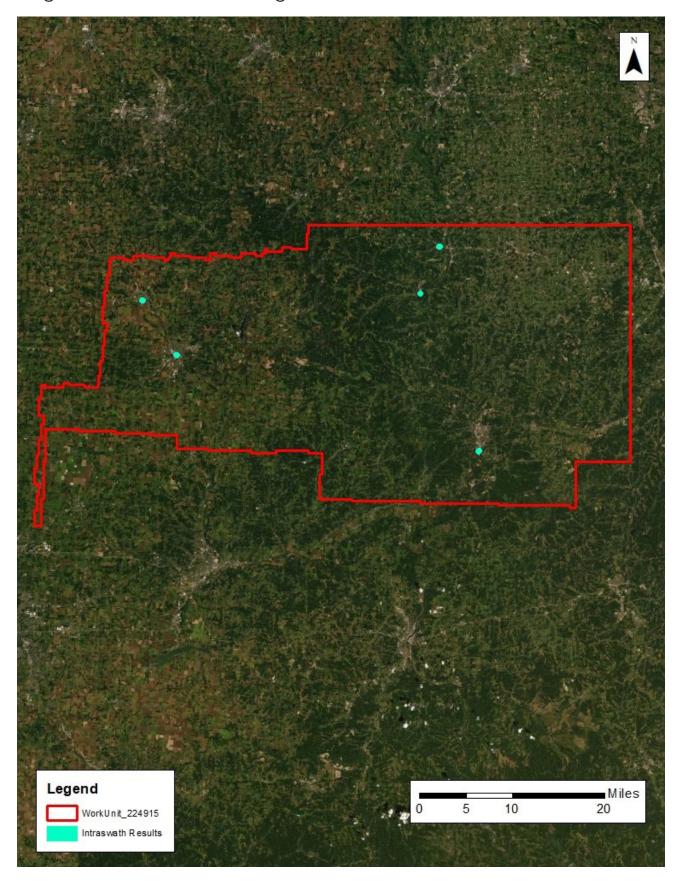
This project required the intraswath accuracy to meet ≤ 6 cm RMSDz. Accuracy was assessed in accordance with the USGS Base Specification v2020 revision A.

The intraswath precision results were produced as polygon features in Esri shapefile format. Table 3-2 lists the intraswath test results. Figure 3-2 depicts the location of the intraswath test locations.

Table 3-2. Intraswath Results

Minimum (m)	Maximum (m)	RMSDz (m)
-0.29900000000	0.52200000000	0.0490000000
-0.17900000000	0.36000000000	0.0600000000
-0.22600000000	0.35100000000	0.08600000000
-0.17200000000	0.46400000000	0.0400000000
-0.12000000000	0.13200000000	0.0370000000

Figure 3-2. Intraswath Testing Locations



Lidar Data Classification

LAS data was initially classified as ground and non-ground points "first and only" as well as "last of many" lidar returns. Additional filters were created to meet the task order classification specifications. Statistical absolute accuracy was assessed via direct comparisons of ground classified points to ground RTK survey data. Based on the statistical analysis, the lidar data was then adjusted to reduce the vertical bias when compared to the survey ground control of higher accuracy.

The bare-earth (Class 2 - Ground) lidar points underwent a manual QA/QC step to verify the quality of the DEM as well as a peer-based QC review. This included a review of the DEM surface to remove artifacts and ensure topographic quality. After the bare-earth surface is finalized, it is then used to generate all hydro-breaklines through a semi-automated process.

All ground (Class 2) lidar data inside of the Lake Pond and Double Line Drain hydro flattening breaklines were then classified to water (Class 9) using TerraScan/LP360 macro functionality. A buffer of 0.7 meters was also used around each hydro-flattened feature to classify these ground (Class 2) points to Ignored Ground (Class 20). All Lake Pond Island and Double Line Drain Island features were checked to ensure that the ground (Class 2) points were reclassified to the correct classification after the automated classification was completed.

All data was manually reviewed and any remaining artifacts removed using functionality provided by TerraScan and TerraModeler. Global Mapper was used as a final check of the bare earth dataset. GeoCue was then used to create the deliverable industry-standard LAS files. Woolpert proprietary software and LP360 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.

Table 3-3 lists the point classifications used.

Table 3-3. Classified Point Breakdown

Class Number	Class Name	
Class 1	Processed, but unclassified	
Class 2	Bare earth	
Class 7	Low noise	
Class 9	Water	
Class 17	Bridge deck	
Class 18	High noise	
Class 20 Ignored ground		

Hydrologic Flattening

The lidar task order required compilation of breaklines defining the following types of water body features:

Lakes, reservoirs, ponds	Minimum of 2-acres or greater Compiled as closed polygons, collected at a constant elevation
Rivers, streams	Nominal width of 30.5 meters / 100 feet Compiled in direction of flow, with both sides maintaining an equal elevation gradient
Bridge breaklines	Breaklines used to enforce a logical terrain surface below a bridge

Woolpert utilized the following steps to hydrologically flatten the water bodies and for gradient hydrologic flattening of the double line streams within the existing lidar data:

- 1. The newly acquired lidar data was utilized to manually compile the hydrologic features in a 2D environment using the lidar intensity and bare earth surface. Open Source imagery was used as reference when necessary.
- 2. An integrated software approach was applied to combine the lidar data and 2D breaklines. This process "drapes" the 2D breaklines onto the 3D lidar surface model to assign an elevation. A monotonic process is performed to ensure the streams are consistently flowing in a gradient manner. A secondary step within the program verifies an equally matching elevation of both stream edges. The breaklines that characterize the closed water bodies are draped onto the 3D lidar surface and assigned a constant elevation at or just below ground elevation.
- 3. All classified ground points from inside the hydrologic feature polygons were reclassified to water, class nine (9).
- 4. All classified ground points were reclassified from within a buffer along the hydrologic feature breaklines to buffered ground, class twenty (20). The buffer distance was approximately the task order designed nominal pulse spacing distance.
- 5. Breaklines used for bridge removal during the hydrologic flattening were included with the hydrologic breakline geodatabase deliverable.
- 6. The lidar ground points and breaklines were used to generate a digital elevation model (DEM).
- 7. QA/QC for this task was performed by reviewing the hydrologically flattened DEM and hydrologic breakline features. Additionally, a combined approach utilizing commercial off the shelf software and proprietary methods were used to review the overall connectivity of the hydrologic breaklines.

TerraScan was used to add the hydrologic breakline vertices and export the lattice models.

Breaklines defining the water bodies greater than 2-acres were provided as polygon features. Rivers and streams with a nominal minimum width of 30.5 meters (100 feet) were provided as polyline features. All lake and river breaklines compiled as part of the flattening process were provided in an Esri file geodatabase.

Breaklines used for DEM generation were provided as point features in Esri shapefile format.

Software: TerraScan v20, TerraModeler v20, Esri ArcMap v10.7, LP360 v2019.1.30.4

Digital Elevation Model

TerraScan was used to add the hydrologic breakline vertices and export the lattice models. Class 2 (ground) lidar points in conjunction with the hydro breaklines and bridge breaklines were used to create 1.25-foot hydro-flattened bare-earth raster DEM files. Using automated scripting routines within ArcMap, a 32-bit floating point raster GeoTIFF file was created for each tile. Files were produced to the full extents of the tile boundaries. Each surface is reviewed using Global Mapper to check for any surface anomalies or incorrect elevations found within the surface.

Software: TerraScan v20, GDAL 2.4.0, Esri ArcMap v10.7, Global Mapper v20.0

Intensity Imagery

Lidar intensity data derived from the acquired lidar data was linearly rescaled from 16-bit intensity and provided as 1.25-foot pixel, 8-bit, 256 gray scale GeoTIFF files. Files were produced to the full extents of the tile boundaries.

Software: TerraScan v20, Esri ArcMap v10.7

Swath Separation Image

A swath separation image is generated to visualize the DZ between the overlapping areas of the flight lines. To generate this surface a point insertion method is used as the primary algorithm. All returns for all point classes except classes 7 and 18 are used in the calculation for each cell. GSD and color ramp values are dependent on the Quality Level and point spacing for the project. The GSD for the surface is no more then 4 times the NPS of the lidar data rounded to an appropriate whole number. The color ramp for the following QL levels are as follows:

QL1 + QL2

- Less than 8 cm Green
- 8 cm to 16 cm Yellow
- Greater than 16 cm Red

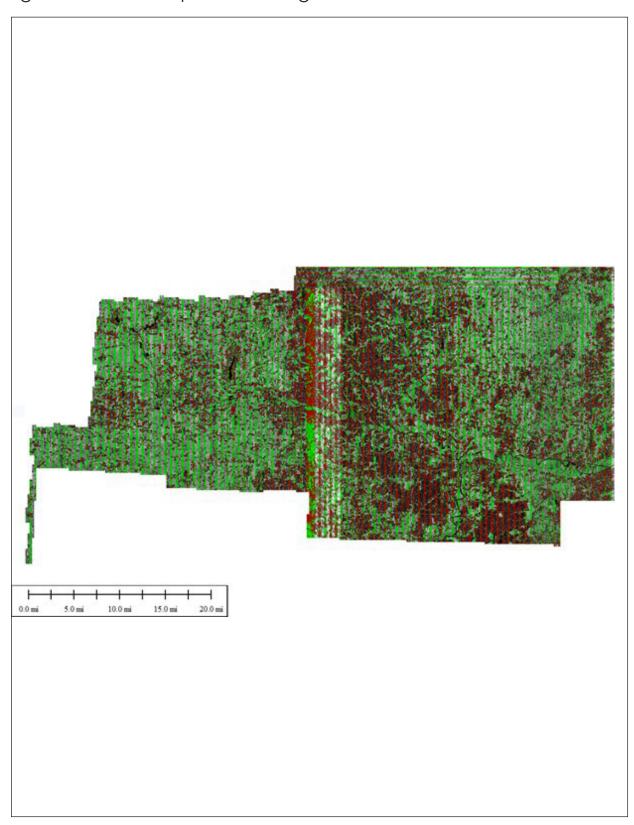
QL0

- Less than 4 cm Green
- 4 cm to 8 cm Yellow
- Greater than 8 cm Red

Intensity values are modulated to 50% to ensure that there is no oversaturation of intensities values throughout the surface.

Software: LP360 v2018.2.59.5

Figure 3-3. Svath Separation Image



Metadata

FGDC CSDGM/USGS MetaParser-compliant metadata was produced in XML format. The metadata includes a complete description of the task order client information, contractor information, project purpose, lidar acquisition and ground survey collection parameters, lidar acquisition and ground survey collection dates, spatial reference system information, data processing including acquisition quality assurance procedures, GPS and base station processing, geometric calibration, lidar classification, hydrologic flattening, intensity imagery development, and final product development.

Other metadata deliverables included Esri shapefiles of the ground control and QA/QC points, interswath and intraswath test results, data extent, and tile index. A georeferenced, polygonal representation of the detailed extents of each acquired lidar swath was produced as a polygon feature class in an Esri file geodatabase. Swath separation images were produced in GeoTIFF format. Maximum height separation rasters were produced in GeoTIFF format.

4. Accuracy Assessment

Horizontal Accuracy

The data set was produced to meet ASPRS "Positional Accuracy Standards for Digital Geospatial Data" (2014) for a 0.148 m RMSEx / RMSEy Horizontal Accuracy Class which equates to Positional Horizontal Accuracy = +/- 0.363 m at a 95% confidence level.

Classified Lidar Point Cloud Testing

This project required Non-Vegetated Vertical Accuracy (NVA) and Vegetated Vertical Accuracy (VVA) to be tested on the classified lidar point cloud data. The dataset was required to meet a target NVA value of 19.6 cm at a 95% confidence level using an RMSEz target value of 10 cm x 1.9600 and a target VVA value of 30 cm at the 95th percentile. Testing was assessed and reported using guidelines developed by the National Digital Elevation Program (NDEP) and the American Society for Photogrammetry and Remote Sensing (ASPRS).

The NVA and VVA values were calculated using independent checkpoints that were not used in the calibration or post processing of the lidar point cloud data. Checkpoints were distributed throughout the project area. NVA checkpoints were located in bare earth and urban (non-vegetated) land cover classes. VVA checkpoints were located in brush/tall grass/weeds (vegetated) land cover classes. These checkpoints were surveyed using GPS techniques. See the survey report for acquisition methodologies.

Testing was performed using TINs created from the final calibrated and controlled swath data. For each NVA checkpoint, an elevation value was derived from the TIN at the point's x,y location. This value was compared to the checkpoint's surveyed elevation value.

The classified lidar point cloud accuracy test results are listed below in Table 4-1.

	Result	Points Used
NVA	0.059 m RMSEz 0.030 m at 95% CL	26
VVA	0.255 m at 95th Percentile	23

Table 4-1. Classified Point Cloud Vertical Accuracy

Digital Elevation Model Testing

This project required Non-Vegetated Accuracy (NVA) and Vegetated Vertical Accuracy (VVA) testing of the digital elevation model (DEM) dataset. The calculated NVA value was required to meet 19.6 cm at a 95% confidence level using an RMSEz target value of 10 cm x 1.9600. VVA was required to meet 0.30 cm at the 95th percentile error. Testing was assessed and reported using guidelines developed by the National Digital Elevation Program (NDEP) and the American Society for Photogrammetry and Remote Sensing (ASPRS).

Testing was performed using the bare earth DEM created as part of this task order. For each checkpoint, an elevation value was derived from the DEM at the point's x,y location. This value was compared to the checkpoint's surveyed elevation value.

The NVA and VVA values were calculated using independent checkpoints that were not used in the calibration or post processing of the lidar point cloud data. Checkpoints were distributed throughout the project area. NVA checkpoints were located in bare earth and urban (non-vegetated) land cover classes. VVA checkpoints were located in brush/tall grass/weeds (vegetated) land cover classes. These checkpoints were surveyed using GPS techniques. See the survey report for acquisition methodologies.

The classified lidar point cloud accuracy test results are listed below in Table 4-2.

Table 4-2. DEM Accuracy

	Result	Points Used
NVA	0.032 m RMSEz 0.063m at 95% CL	26
VVA	0.254 m at 95th Percentile	23

Appendix 1: Sensor Calibration Report

- when it has to be **right**



Leica Geosystems Leica TerrainMapper-LN Calibration Certificate

Product Leica TerrainMapper-LN

Serial Number 91511

Date 03 July 2019 Inspector Mark O'Neal



Leica Geosystems AG

Heinrich-Wild-Strasse CH-9435 Heerbrugg Schweiz

www.leica-geosystems.com

1. System Components

Component	Туре	Serial Number
Pod	TerrainMapper Pod	91511
GNSS/IMU	Litef LCI-100C 500 Hz	1139
LiDAR Unit	Hyperion2 LiDAR Unit	5511
Camera Head	CH82	82659
Lens	NAT-D 2.8/80	80254

2. Estimation Process

		Passed	Date	Inspector
Image Flight	completed	ok	10.05.2019	Philip Benz
Image Quality Check	checked	ok	16.05.2019	Philip Benz
Image Calibration	completed	ok	18.05.2019	Xu Wang
Image Misalignment Update	completed	ok	02.07.2019	Mark O'Neal
LiDAR Flight	completed	ok	10.17.2018	Deniz Arslan
LiDAR Quality Check	checked	ok	23.10.2018	Rene Heirli
LiDAR Calibration and Accuracy	completed	ok	24.10.2018	Robert Bosch
LiDAR Misalingment Update	completed			

3. Inspectors

Name Position	Bernhard Riedl Production Manager	15.11.2018	Rud Benlard
Name Position	Robert Bosch Support Engineer	23.05.2019	Xu Wang
Name Position	Michael Vetter Support Engineer	03.07.2019	h.Bodi

4. Remarks

5. LiDAR Calibration Results

The calibration results for the LiDAR Unit are only valid for:

• IMU and Pod as listed in the System Components section

5.1 LiDAR Geometric Calibration Results

IMU Misalignment		Value	Unit
	ω	-0.138877	degree
	Φ	0.130994	degree
	К	-0.006412	degree
Boresight		Value	Unit
	Θ	0.001052	degree
	Φ	-0.001885	degree
Receiver 1		Value	Unit
Range	Δ Offset	0.000000	meters
Wedge 0		Value	Unit
Wedge	Δ Alpha	0.001241	degree
Wedge Position	Δ Offset	-0.426898	degree
Position Correction	X	-0.019523	degree
	Υ	0.007883	degree
Mount	Roll	-0.020901	degree
	Pitch	0.107683	degree
Rotation Axis	Roll	0.103712	degree
	Pitch	0.124140	degree
Wedge 1		Value	Unit
Wedge	Δ Alpha	-0.009545	degree
Wedge Position	Δ Offset	0.412993	degree
Position Correction	X	0.004000	degree
	Υ	0.011085	degree
Mount	Roll	0.102859	degree
	Pitch	0.025756	degree
	Speed Pitch	1.50E-06	degree/rps ²
Rotation Axis	Roll	0.114811	degree
	Pitch	-0.080531	degree

LiDAR Geometric Calibration File

HYPERION_GEOMETRY_LIDARUNIT-5511-C-855570-DATETIME-20181023-153458.XML

	Date	23.10.2018
LiDAR Misalingment Flight	Date	-
LiDAR Misalingment Update Completed	Date	-

5.2 LiDAR Unit Accuracy Check

Accuracy checks:

- Deviation of two perpendicular lines to GCP's
- Difference of two perpendicular lines
- Difference of forward and backward scan of one line

5.2.1 Multi-line accuracy of two perpendicular lines to ground control points

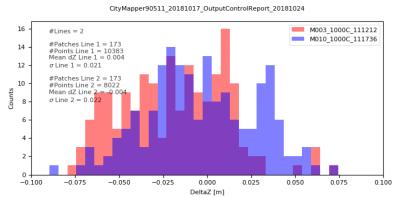


Figure 1 Vertical distance to ground control points at 1000 m AGL.

5.2.2 Difference of forward and backward scan of one line

Color	Limits [m]	Number of patches	Proportion of total number of patches [%]
	<=0.04	293823	93.48
	0.04-0.07	20386	6.49
	0.07-0.1	89	0.03
	>0.1	16	0.01

Figure 2 Vertical difference betweeen forward and backward scan at 1000 m AGL.

5.2.3 Multi-line accuracy between two perpendicular lines

M003_1000C_111212_vs_M010_1000C_111736

39940 valid patches with size of 2 m found. Only patches with standard deviation < 0.05 m and minimum of 5 points are included.

Color	Limits [m]	Number of patches	Proportion of total number of patches [%]
	<=0.04	32066	80.29
	0.04-0.07	7841	19.63
	0.07-0.1	21	0.05
	>0.1	12	0.03



Figure 3 Vertical difference betweeen two perpendicular lines at 1000 m AGL.

6. Imaging Sensors Estimation Results

The estimation results for the camera head and lens combination are only valid for:

- IMU and Pod as listed in the System Components section.
- Camera Head, lens and specified position as listed in the Estimation Results sections.

6.1 Camera Model of distortion free images

All factory calibration results contain fixed nominal focal lengths and zero principal point offsets. Leica HxMap applies the grid to create distortion-free images of nominal focal length and pixel size.

6.1.1 CH8x Model

			Component
Camera Head Lens			CH82 NAT-D 2.8/80
Camera Model			
Focal Length			Distance [mm]
	С		83.00
Radial Symmetric Distorsion			Distance [mm]
	k ₀ k ₁ k ₂		0.0000 0.0000 0.0000
Decentering Distortion	P ₁ p ₂		Distance [mm] 0.0000 0.0000
Non-Orthogonality Distortion			Distance [mm]
Pixel Size (Height and Width)	b ₁ b ₂		0.0000 0.0000 Distance [mm]
	RGB NIR		0.0052 0.0120
Rows and Columns		Rows	Columns
	Active RGB Raw RGB Active NIR Raw NIR	7752 7788 3654 3366	10320 10336 4478 4500

6.2 Results of Geometric Calibration

6.2.1 Calibration method for Green Reference Band

Estimation of additional parameters (focal length, principal point, radial symmetric distortion, correction grid) and IMU misalignment in simultaneous bundle adjustment

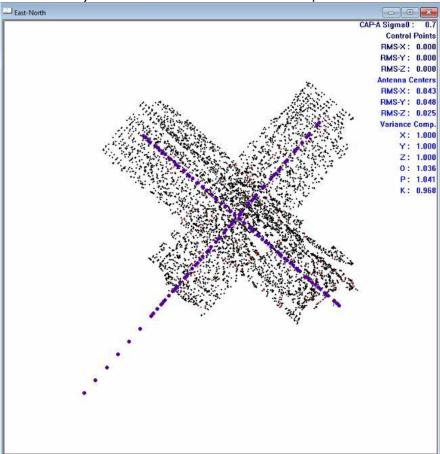
Reference band (green)

Distance [mm]

Resulting sigma naught of bundle adjustment:

0.0007

Final bundle adjustment results after elimination of tie point blunders:



6.2.2 Calibration method for Other Spectral Bands

Estimation of additional parameters (correction grid), based on the result for green in simultaneous bundle adjustment

Other Spectral Bands

Distance [mm]

Co-registration to green better than:

0.002

Leica HxMap applies the grid to create distortion-free images of nominal focal length and fixed pixel size of 0.0052 mm.

6.3 Estimation Results for Nadir Camera Head and Lens

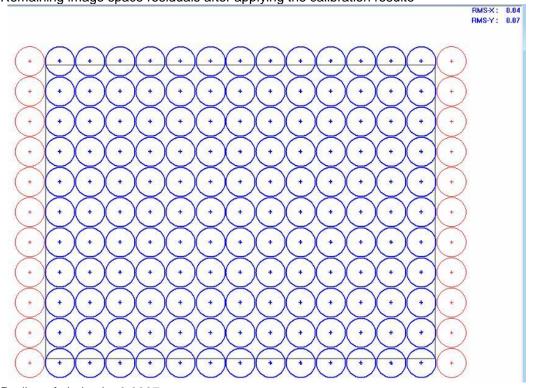
		Component	Serial Number
Camera Head Lens View Direction in Pod Position		CH82 NAT-D 2.8/80 Nadir	82659 80254
IMU Misalignment		Angle [degree]	
	ω Φ κ	-0.00815 0.00028 -0.26654	
Principal Point		Distance [mm]	
	x y	0.0000 0.0000	
Focal Length		Distance [mm]	
	С	83.00	

Geometric Calibration File

RCD30_Geometry_CameraHead-82659-E-798528_LensSystem-80254-B-785423_DateTime-20190518-214751.xml

Geometric Calibration Date	Date	18.05.2019
Radiometric Calibration Date	Date	05.02.2019
Misalingment Flight	Date	23.06.2019
Misalingment Update Completed	Date	02.07.2019

Remaining image space residuals after applying the calibration results



Radius of circles is 0.0007 mm

- when it has to be right



Leica Geosystems Leica TerrainMapper-L Calibration Certificate

Product Leica TerrainMapper-L

Serial Number 90515

Date 12 December 2018

Inspector Robert Bosch



Leica Geosystems AG

Heinrich-Wild-Strasse CH-9435 Heerbrugg Schweiz

www.leica-geosystems.com

1. System Components

Component	Туре	Serial Number
Pod	Terrainmapper Pod	90515
GNSS/IMU	Litef LCI-100C 500 Hz	1226
LiDAR Unit	Hyperion2 LiDAR Unit	5516

2. Estimation Process

		Passed	Date	Inspector
LiDAR Flight	completed	ok	29.11.2018	Philip Benz
LiDAR Quality Check	checked	ok	06.12.2018	Rene Heierli
LiDAR Calibration and Accuracy	completed	ok	12.12.2018	Robert Bosch
LiDAR Misalignment Update	completed			

3. Inspectors

Name	Bernhard Riedl	12.12.2018	Rud Benlard
Position	Production Manager		must remaid
Name	Robert Bosch	12.12.2018	6.Bod
Position	Support Engineer		67.5001

4. Remarks

5. LiDAR Calibration Results

The calibration results for the LiDAR Unit are only valid for:

• IMU and Pod as listed in the System Components section

5.1 LiDAR Geometric Calibration Results

IMU Misalignment		Value	Unit
	ω	-0.022555	degree
	Φ	0.056357	degree
	К	0.000504	degree
Boresight		Value	Unit
	Θ	0.015419	degree
	Φ	-0.001923	degree
Receiver 1		Value	Unit
Range	Δ Offset	0.000000	meters
Wedge 0		Value	Unit
Wedge	Δ Alpha	-0.043014	degree
Wedge Position	Δ Offset	0.442789	degree
Position Correction	X	-0.012826	degree
	Υ	0.000012	degree
Mount	Roll	0.045379	degree
	Pitch	0.210132	degree
Rotation Axis	Roll	0.031087	degree
	Pitch	0.076675	degree
Wedge 1		Value	Unit
Wedge	Δ Alpha	-0.005517	degree
Wedge Position	Δ Offset	0.559649	degree
Position Correction	X	0.030760	degree
	Υ	-0.001169	degree
Mount	Roll	0.012366	degree
	Pitch	0.054254	degree
	Speed Pitch	1.50E-06	degree/rps ²
Rotation Axis	Roll	0.032485	degree
	Pitch	-0.029191	degree

LiDAR Geometric Calibration File

HYPERION_GEOMETRY_LIDARUNIT-5516-C-855570-DATETIME-20181204-161828.XML

	Date	04.12.2018
LiDAR Misalignment Flight	Date	-
LiDAR Misalignment Update Completed	Date	-

5.2 LiDAR Unit Accuracy Check

Accuracy checks:

- Deviation of two perpendicular lines to GCP's
- Difference of two perpendicular lines
- Difference of forward and backward scan of one line

5.2.1 Multi-line accuracy of two perpendicular lines to ground control points

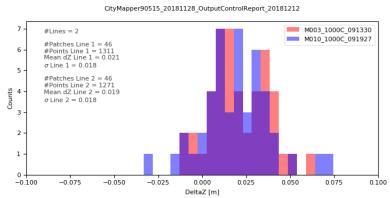


Figure 1 Vertical distance to ground control points at 1000 m AGL.

5.2.2 Difference of forward and backward scan of one line

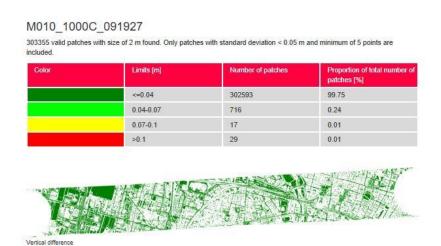


Figure 2 Vertical difference betweeen forward and backward scan at 1000 m AGL.

5.2.3 Multi-line accuracy between two perpendicular lines

M003_1000C_091330_vs_M010_1000C_091927

 $29588 \ valid \ \textbf{patches with size of 2 m found. Only patches with standard deviation} < 0.05 \ m \ and \ minimum \ of 5 \ points \ are included.$

Color	Limits [m]	Number of patches	Proportion of total number of patches [%]
	<=0.04	29546	99.86
	0.04-0.07	38	0.13
	0.07-0.1	1	0.00
	>0.1	3	0.01



Figure 3 Vertical difference betweeen two perpendicular lines at 1000 m AGL.

- when it has to be **right**



Leica Geosystems Leica TerrainMapper-LN Calibration Certificate

Product Leica TerrainMapper-LN

Serial Number 91557

Date 01 July 2020 Inspector Ivan Belchev



Leica Geosystems AG

Heinrich-Wild-Strasse CH-9435 Heerbrugg Schweiz www.leica-geosystems.com

1. System Components

Component	Туре	Serial Number
Pod	TerrainMapper Pod	91557
GNSS/IMU	Litef LCI-100C 500 Hz	1346
LiDAR Unit	Hyperion2 LiDAR Unit	5561
Camera Head Lens	CH82 NAT-D 2.8/80	82673 80264

2. Estimation Process

		Passed	Date	Inspector
Image Flight	completed	ok	23.06.2020	Deniz Arslan
Image Quality Check	checked	ok	29.06.2020	Bernhard Riedl
Image Calibration	completed	ok	29.06.2020	Zoltan Poth
Image Misalingment Update	completed			
LiDAR Flight	completed	ok	23.06.2020	Deniz Arslan
LiDAR Quality Check	checked	ok	26.06.2020	Rene Heierli
LiDAR Calibration and Accuracy	completed	ok	25.06.2020	Michael Vetter
LiDAR Misalingment Update	completed			

3. Inspectors

Name Position	Bernhard Riedl Production Manager	01.07.2020	Ried Benlard
Name Position	Ivan Belchev Workflow Specialist	01.07.2020	Utres
Name Position	Michael Vetter Support Engineer	01.07.2020	Vete Schlad

4. Remarks

5. LiDAR Calibration Results

The calibration results for the LiDAR Unit are only valid for:

• IMU and Pod as listed in the System Components section

5.1 LiDAR Geometric Calibration Results

IMU Misalignment		Value	Unit
	ω	-0.063987	degree
	Φ	-0.049738	degree
	К	-0.005305	degree
Boresight		Value	Unit
	Θ	-0.001796	degree
	Φ	-0.003034	degree
Receiver 1		Value	Unit
Range	Δ Offset	0.000000	meters
Wedge 0		Value	Unit
Wedge	Δ Alpha	-0.045434	degree
Wedge Position	Δ Offset	0.352942	degree
Position Correction	X	-0.014623	degree
	Υ	0.020330	degree
Mount	Roll	0.210896	degree
	Pitch	0.426854	degree
Rotation Axis	Roll	0.232742	degree
	Pitch	0.169968	degree
Wedge 1		Value	Unit
Wedge	Δ Alpha	0.003457	degree
Wedge Position	Δ Offset	0.393122	degree
Position Correction	X	0.019198	degree
	Υ	-0.002307	degree
Mount	Roll	0.020583	degree
	Pitch	0.038667	degree
	Speed Pitch	1.50E-06	degree/rps ²
Rotation Axis	Roll	0.061823	degree
	Pitch	0.034555	degree

LiDAR Geometric Calibration File

HYPERION_GEOMETRY_LIDARUNIT-5561-D-855570-DATETIME-20200625-085747.XML

	Date	25.06.2020
LiDAR Misalingment Flight	Date	-
LiDAR Misalingment Update Completed	Date	-

5.2 LiDAR Unit Accuracy Check

Accuracy checks:

- Deviation of two perpendicular lines to GCP's
- Difference of two perpendicular lines
- Difference of forward and backward scan of one line

5.2.1 Multi-line accuracy of two perpendicular lines to ground control points

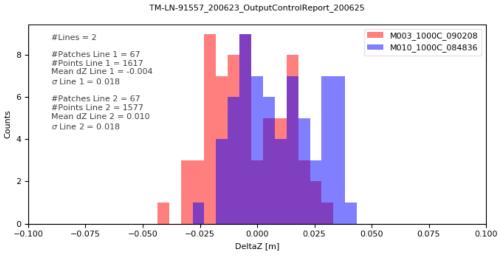


Figure 1 Vertical distance to ground control points at 1000 m AGL.

5.2.2 Difference of forward and backward scan of one line

M003_1000C_090208

377750 valid patches with size of 2 m found. Only patches with standard deviation < 0.05 m and minimum of 5 points are included.

Color	Limits [m]	Number of patches	Proportion of total number of patches [%]
	<=0.04	372019	98.48
	0.04-0.07	5529	1.46
	0.07-0.1	169	0.04
	>0.1	33	0.01



Figure 2 Vertical difference betweeen forward and backward scan at 1000 m AGL.

5.2.3 Multi-line accuracy between two perpendicular lines

$M003_1000C_090208_vs_M010_1000C_084836$

50693 valid patches with size of 2 m found. Only patches with standard deviation < 0.05 m and minimum of 5 points are included.

Color	Limits [m]	Number of patches	Proportion of total number of patches [%]
	<=0.04	50354	99.33
	0.04-0.07	327	0.65
	0.07-0.1	6	0.01
	>0.1	6	0.01



Figure 3 Vertical difference betweeen two perpendicular lines at 1000 m AGL.

6. Imaging Sensors Estimation Results

The estimation results for the camera head and lens combination are only valid for:

- IMU and Pod as listed in the System Components section.
- Camera Head, lens and specified position as listed in the Estimation Results sections.

6.1 Camera Model of distortion free images

All factory calibration results contain fixed nominal focal lengths and zero principal point offsets. Leica HxMap applies the grid to create distortion-free images of nominal focal length and pixel size.

6.1.1 CH8x Model

			Component
Camera Head			CH82
Lens			NAT-D 2.8/80
Camera Model			
Focal Length			Distance [mm]
	С		83.00
Radial Symmetric Distorsion			Distance [mm]
	k_0		0.0000
	k ₁		0.0000
	k ₂		0.0000
Decentering Distortion			Distance [mm]
3	p ₁		0.0000
	р ₂		0.0000
Non-Orthogonality Distortion			Distance [mm]
	b ₁		0.0000
	b_2		0.0000
Pixel Size (Height and Width)			Distance [mm]
	RGB		0.0052
	NIR		0.0120
Rows and Columns		Rows	Columns
	Active RGB	7752	10320
	Raw RGB	7788	10336
	Active NIR	3654	4478
	Raw NIR	3366	4500

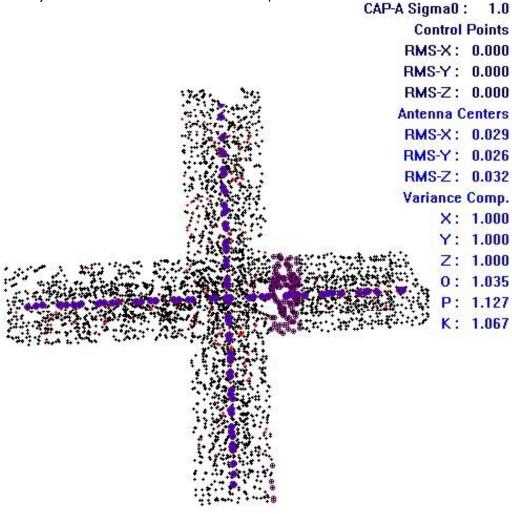
6.2 Results of Geometric Calibration

6.2.1 Calibration method for Green Reference Band

Estimation of additional parameters (focal length, principal point, radial symmetric distortion, correction grid) and IMU misalignment in simultaneous bundle adjustment

Reference band (green) Resulting sigma naught of bundle adjustment: 0.0010

Final bundle adjustment results after elimination of tie point blunders:



6.2.2 Calibration method for Other Spectral Bands

Estimation of additional parameters (correction grid), based on the result for green in simultaneous bundle adjustment

Other Spectral Bands	Distance [mm]
Co-registration to green better than:	0.002

Leica HxMap applies the grid to create distortion-free images of nominal focal length and fixed pixel size of 0.0052 mm.

6.3 Estimation Results for Nadir Camera Head and Lens

		Component	Serial Number
Camera Head Lens View Direction in Pod Position		CH82 NAT-D 2.8/80 Nadir	82673 80264
IMU Misalignment		Angle [degree]	
	ω Φ κ	0.03017 -0.01221 -0.25213	
Principal Point		Distance [mm]	
	x y	0.0000 0.0000	
Focal Length		Distance [mm]	
	С	83.00	

Geometric Calibration File

RCD30_Geometry_CameraHead-82673---798528_LensSystem-80264-B-785423_DateTime-20200629-142416.xml

RMS-X: 0.13 RMS-Y: 0.11

Geometric Calibration Date	Date	29.06.2020
Radiometric Calibration Date	Date	30.01.2020
Misalingment Flight	Date	-
Misalingment Update Completed	Date	-

Remaining image space residuals after applying the calibration results

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Radius of circles is 0.0010 mm

Appendix 2: Flight Logs

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				Pro	oject li	nfo							[Date		
Project #			Project	Name	e		\top	U	nique ID		Flight	Date	(UTC)	Day o	f Year	Flight #
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48	w	,	15:31:00	15:4	6:00			22	1							
47	е		15:49:00	15:5	9:00	00:10:00	1	.8	1.2							
46	W	,	16:03:00	16:1	9:00	00:16:00	1	.9	1.1							
45	е		16:23:00		3:00	00:10:00	_	20	1.3							
44	w	'	16:37:00		2:00	00:15:00		20	1.3							
43	е		16:54:00		4:00	00:10:00		20	1.2							
42	W		17:09:00		2:00	00:13:00	_	22	1							
41	e w	,	17:25:00 17:39:00		5:00 4:00	00:10:00 00:15:00	_	23 22	1.3							
39	e		18:03:00		3:00	00:10:00		24	1.2							
38	w	,	18:17:00		1:00	00:14:00		23	1.3							
37	е		18:34:00		4:00	00:10:00	_	23	1.2							
36	w	,	18:48:00	19:0	1:00	00:13:00	2	24	1.2							
35	е		19:04:00	19:1	6:00	00:12:00	2	22	1.2							
34	W	'	19:20:00	19:3	9:00	00:19:00	2	23	1.3							
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40		(UTC)		TC)	On-Line			4.2							
13 12	S	17:37:00		0:00 5:00	00:03:0		6	1.2							
11	n s	17:42:00 17:47:00		0:00	00:03:0		8 8	1.1			n	av roll	limit		
10	S	17:53:00		5:00	00:03:0		9	1.1			Р	avion	mmc		
9	n	17:57:00		8:00	00:02:0		8	1.2							
8	S	18:02:00		3:00	00:01:0		9	1							
7	e	18:06:00		8:00	00:02:0		0	1							
6	w	18:11:00	18:1	.3:00	00:02:0	0 1	9	1							
5	е	18:16:00	18:1	.8:00	00:02:0	0 1	9	1							
4	S	18:21:00		2:00	00:01:0		6	1.3							
3	n	18:25:00		6:00	00:01:0	_	6	1.3							
2	е	18:30:00		2:00	00:02:0		6	1.4							
1	W	18:34:00	18:3	6:00	00:02:0	0 1	6	1.4							
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11111 1 2	·					Page			V	erify S-	iurns	Aiter	IVIISSIO	11	
dditional C	omments														

					ject In					<u>uisitio</u>				Г	ate		
Project #			Project		jeet iii	110	П			nique ID		Eliabt	· Data	(UTC)		f Voor	Flight
81150			Ohio lida		2		-			71 90511 1			/12/20	` '	07		_
			Official						Dayu	/1_90511_1			/12/20	21	07		1
	ew				Equip							Time	_				rports
	lot					Model		#		Hobbs S		Local Sta		UTC S			parting
Gib	ilaro			Cessna	404 Ti	tan - N4	04CP			8243.	9	14:3	2:00	19:3	2:00		DAY
Ope	rator		Sei	nsor M	ake / N	/lodel	Seria	l #		Hobbs E	ind	Loca	l End	UTC	End	Aı	rriving
Ken	nedy		Le	eica Tei	rain M	lapper -	9051	1		8247.	5	18:1	1:00	23:1	1:00		OSU
							C	onditi	ons								
Wind Dir	(°)	Wind	Speed (kts)	Visi	bility (ı	mi)	Ceilin	g (ft)	Clo	ud Cover	Tem	p. (°C)	Dew	/ Point	(°C)	Press	ure ("F
350			7		10					Clear		4		-2	•		30.36
Air Spe	ed (kts)	Altitude	AGI (f		Δl+i	tude	MSL (f	t)	Airfield El							
	60 (Kt3	,	6,5		-/	Aiti	7,2		-1		009	. ()					
1	-		0,3	J_					~c	Ι,	509						
Dalat C	- /:: >	<u> </u>	4 Dag -14 /	I				Settin		- Fua	/1.1=\	D !	D-1	/Ial != \			[0/]
Point Spacii	ng (m)	Poir	nt Density (pp	sm)	Sca	n Angle	/ FOV	(*)	Sca	n Frequency	(HZ)	Pulse	Rate	(KHZ)	Las		ver (%)
			8			40				150			1600			100	
											Ve	erify S-1	Turns l	Before	Missic	n	Yes
Line #	Direc	ction	Start Time (UTC)	End 1 (U1		Tim On-Li		Sate	llite	PDOP			Line N	otes/C	omme	ents	
1	N	J	19:59:00	20:0	-	00:01		1	8	1.5							
2	9		20:03:00	20:0		00:03		1		1.5							
3	N		20:09:00	20:1		00:03		1		1.5							
4	9	5	20:19:00	20:2		00:07		2		1.3							
5	١	١	20:29:00	20:3	9:00	00:10	:00	2	0	1.3							
6	9	5	20:42:00	20:5	2:00	00:10	:00	2	1	1.2							
7	N	١	20:55:00	21:0	5:00	00:10	:00	2	1	1.1							
8	9	5	21:08:00	21:1	3:00	00:10	:00	2	1	1.2							
9	١	١	21:21:00	21:3		00:10	$\overline{}$	2		1.2							
10	9		21:34:00	21:4		00:10	:00	2		1.2							
11	N		21:48:00	21:5		00:10		2		1.1							
12	9		22:01:00	22:1		00:10	_	2		1.2							
13	N		22:14:00	22:2		00:10		2		1.2							
14	5		22:31:00	22:4		00:10		2		1.2							
15	N	N	22:44:00	22:5	5:00	00:11	:00	2	T	1.1							
					\dashv		\dashv										
					-		\dashv										
								Page	1		٧	erify S-	Turns	After I	Vissio	n	Yes
	ommei	_						_			-						

				Wo	olp	ert L	.ida	ar A	cq	uisitio	n L	og					
				Pro	oject l	nfo									ate		
Project #			Project	Name	e				U	nique ID		Flight	Date ((UTC)	Day o	f Year	Flight #
81150			Ohio lida	r blocl	κ 3		\neg		Day0	72_90511_1		03,	/13/20	21	0	72	1
	ew					ment			<u>'</u>			Time	<u> </u>				rports
Pi	lot		Ai	rcraft		/ Model /	/ Tail	#		Hobbs St	art	Local	Start	UTC S	Start		parting
	ilaro					itan - N4(8248		09:4		14:4			DAY
	rator					Model /		1#		Hobbs E	nd	Local		UTC			riving
	nedy				-	lapper - !				8255.4		17:0		22:0			DAY
Ken	leuy		LC	ica re	II alli iv	паррет - :		onditio		0233.4	•	17.0	3.00	22.0	3.00		DAT
Wind Di	/0\	\A/!l	C / -+-\	\ /! = !	· - • • • • •	···· · · · · · ·						- (96)	D	D = 1 4	/0C)	D	(!!!!=\
Wind Dir	(')	Wind	Speed (kts)	VIS	ibility (mi) C	Ceilin		Cic	oud Cover	_	o. (°C)	Dew	Point	(°C)		ure ("Hg)
80			7		10		10,0			Few		3		-6		3	30.48
Air Spe	ed (kts)	Altitude	AGL (ft)	Altit	tude I	MSL (ft	:)	Airfield Ele	evation	ո (ft)					
1	60		6,5	62			7,29	93		1,0	009						
								Setting	gs								
Point Spacia	ng (m)	Poir	nt Density (pp	sm)	Sca	n Angle/	/FOV	(°)	Sca	n Frequency	(Hz)	Pulse	Rate ((kHz)	Las	ser Pov	wer (%)
			8			40				150			1600			100	<u> </u>
											Ve	rify S-1	Turns E	Before	Missi	on	Yes
			Start Time	End	Time	Time	<u> </u>										<u></u>
Line #	Direc	tion	(UTC)		TC)	On-Lin		Satel	lite	PDOP			Line N	otes/C	comm	ents	
16	N	1	15:14:00	-	8:00	00:14:0	00	20)	1.2							
17	S	;	15:32:00	15:4	7:00	00:15:0		23	;	1.1							
18	N	1	15:50:00	16:0	5:00	00:15:0	00	24		1.2							
19	S	5	16:08:00	16:2	3:00	00:15:0	00	22		1.3							
20	N	1	16:26:00	16:4	1:00	00:15:0	00	22		1.2							
21	S		16:44:00		9:00	00:15:0	_	18		1.5							
22	N		17:02:00		7:00	00:15:0		19		1.4							
23	S		17:20:00		5:00	00:15:0		19		1.3							
24	N		17:39:00		4:00	00:15:0	_	20		1.1							
25 26	S		17:57:00 18:16:00		0:00	00:15:0		19 20		1.3							
27	S		18:33:00		8:00	00:14:0	_	21		1.1							
28	N		18:51:00		7:00	00:15:0	_	20		1.1							
29	S		19:10:00		5:00	00:15:0		21		1							
30	N		19:28:00		3:00	00:15:0		19		1.2							
31	S	5	19:46:00		3:00	00:17:0	00	18		1.3							
32	N	I	20:06:00	20:2	4:00	00:18:0	00	16	5	1.7							
33	S	5	20:27:00		4:00	00:17:0	_	17	'	1.4							
34	N		20:47:00		5:00	00:18:0	_	17		1.2							
35	S	5	21:08:00	21:2	5:00	00:17:0	00	18	<u> </u>	1.2							
							\dashv										
							\dashv										
							\dashv										
							\dashv										
								Page 1	1		V	erify S-	Turns	After I	Missin	n	Yes
Additional C	ommo	nts						. 450	-			, 5	. 41113		5510		. 03
Additional C	Jiiiiie	1163															

			1	Vo	olp	ert	Lid	ar A	Acq	uisitio	on L	og					
				Pro	ject I	nfo									Date		
Project #			Project	Name	•				U	nique ID		Flight	Date	(UTC)	Day o	f Year	Flight #
81150			Ohio lida	r blocl	3				Day0	76_90511_:	1	03	/17/20	21	07	76	1
Cr	ew				Equip	ment						Time				Aiı	rports
Pi	lot		Ai	rcraft I	Make ,	/ Mode	el / Tai	l #		Hobbs	Start	Local	Start	UTC	Start	De	parting
Gib	ilaro			Cessna	404 T	itan - N	1404CF)		8255	.7	12:4	7:00	16:4	7:00		DAY
Ope	rator		Ser	nsor M	ake /	Model	/ Seria	al #		Hobbs	End	Loca	l End	UTC	End	Ar	riving
	nedy					/lapper	-			8260	.4	+	8:00		8:00		DAY
						- 1-1		Condit	ions								
Wind Dir	· (°)	Wind	Speed (kts)	Visi	bility (mi)		ng (ft)		oud Cover	Tem	p. (°C)	Dew	Point	(°C)	Press	ure ("Hg)
130	()	*******	9	¥13	3	,		00		cattered		8		5	()		0.01
Air Spe	od (kts	١	Altitude	VCI (٨١		MSL (1		Airfield E		_		_			0.01
-		,			ι,	AI			11,			11 (11)					
1	60		6,5	02			1,2	93 Satti		1	,009						
D-1-1-C	, , , ,	<u> </u>	1 D - 11 /				- /=-:	Settir		- F	. (1.1.)	·	D :	(1.1.			10()
Point Spacio	ng (m)	Poir	t Density (pp	sm)	Sca	n Angl		/ (~)	Sca	n Frequenc	y (Hz)	Pulse	Rate	(KHZ)	Las		ver (%)
			8			4	U			150		1.5	1600			100	
											V	erify S-	Turns E	Before	Missi	on	Yes
Line #	Direc	tion	Start Time (UTC)		Time TC)	Tin On-I		Sate	ellite	PDOP			Line N	otes/0	Commo	ents	
36	N		17:25:00		4:00	00:1		1	.8	1.2							
37	5		17:47:00		7:00	00:2		1		1.4							
38	N		18:10:00		9:00	00:1			2	1.1	+						
39	5		18:32:00		1:00	00:1			0	1.1	+						
40 41	5		18:54:00 19:17:00		4:00 6:00	00:2 00:1			2	1.1	+						
42	N		19:39:00		8:00	00:1		1		1.3	+-						
43			20:01:00		1:00	00:2		1		1.2	+-						
44	N	1	20:24:00		3:00	00:1			9	1.2	\top						
											-						
											+						
								Page	1		\ \	erify S	Turns	After I	Missio	n	Yes
Additional C	omme	nts						J				•					

			1	Wo	olp	ert l	Lid	ar A	A cq	uisit	tio	n Lo	og					
				Pro	oject li	nfo										ate		
Project #			Project	Name	•				U	nique ID	<u> </u>		Flight	Date	(UTC)	Day o	f Year	Flight #
81150			Ohio lida							 78_9051				/19/20		07		1
Cre	ew.				Equip	ment			7	_	_		Time					ports
	ot		Δί	rcraft		/ Model	l / Tai	il #		Hob	bs Sta		Local	Start	UTC S	Start		parting
	laro					itan - N					260.9		10:3		14:3		-	OSU
														_				
Opei						Model /					obs Er		Local	_	UTC			riving
Kenr	nedy		Le	eica Te	rrain N	1apper -				8	266.4		16:0	8:00	20:0	8:00		OSU
								Condit										
Wind Dir	(°)	Wind	Speed (kts)	Vis	ibility (mi)	Ceilir	ng (ft)	Clo	ud Cove	er	Temp	o. (°C)	Dew	Point	(°C)	Press	ure ("Hg)
40			13		10							2	2		-8		3	0.35
Air Spe	ed (kts)	Altitude	AGL (ft)	Alt	itude	MSL (ft)	Airfie	ld Ele	vatior	(ft)					
16	50		6,5	62			7,2	293			90)5						
								Settir	ıgs									
Point Spacin	ng (m)	Poin	nt Density (pp	sm)	Sca	n Angle	e/FO\			n Freque	encv ((Hz)	Pulse	Rate	(kHz)	Las	er Pov	ver (%)
•	J. 7		8			40				150		,		1600	` /		100	• •
			,									Ve	rify S-1		Before	Missi	_	Yes
			Start Time	End	Time	Tim	0					• •	, 5	L	2.016			103
Line #	Direc	tion	(UTC)		TC)	On-Li		Sate	llite	PDO	P			Line N	otes/C	commo	ents	
45	S		15:06:00		6:00	00:20		2	2	1								
45			15:30:00		0:00	00:20		2		1.1								
47	S		15:53:00		3:00	00:20		2		1.3								
48	N		16:17:00		6:00	00:20		1		1.5								
49	S		16:40:00		9:00	00:19		2		1.4								
50	N		17:05:00		3:00	00:18		2		1.3								
51	S	;	17:27:00	17:4	6:00	00:19	00:	2	0	1.4								
52	Ν	ı	17:50:00	18:1	0:00	00:20	0:00	2	3	1.2	!							
53	S	,	18:13:00	18:3	2:00	00:19	00:	2	4	1.2								
54	N	I	18:36:00	18:5	5:00	00:19	00:	2	2	1.3	1							
55	S		18:58:00						3	1.2			Accider	ntal en	nergen	cy sto	p, refly	line
55	S		19:18:00	19:3	8:00	00:20	0:00	2	1	1.3	1							
											-							
- • • •								Page	1			Ve	erify S-	Turns	After I	Vissio	n	Yes
Additional C	omme	nts																

				ject In		J. /		uisitio		- 8)ata		
Dua: a a 4	I	Duninal		•	то			minus ID		Flimba	Data (Date	. V	. =1: 1 .
Project #		Project						nique ID					Day of		-
81150		OH Lidar Block					Dayu	78_91557_A			/19/20	21	07		A
	ew			Equipr						Time	_				irports
	lot	Ai			Model / Tai	I #		Hobbs S		Local		UTC :			parting
Dar	Perl				- N406SD			722.2		11:1	3:00	15:1	7:00		KDAY
Ope	rator	Sei	nsor M	ake / N	/lodel / Seria	al#		Hobbs E	ind	Loca	l End	UTC	End	Α	rriving
Ry	/an	Le	eica Tei	rain Ma	apper - 9155	57		728.9)	15:4	6:00	19:4	6:00		KDAY
					(Conditi	ons								
Wind Dir	r (°) Wind	Speed (kts)	Visi	bility (n	ni) Ceilir	ng (ft)	Clo	oud Cover	Tem	o. (°C)	Dew	Point	(°C)	Pres	sure ("H
40		17		10				Clear		1		-7			3038
Air Spe	ed (kts)	Altitude	AGL (f	t)	Altitude	MSL (f	t)	Airfield El	evation	ո (ft)					
	50		62			16	<u> </u>		009						
						Settin	σς								
oint Spacii	ng (m) Poi	nt Density (pr	nsm)	Scar	n Angle/FOV			n Frequency	(H ₇)	Dulce	Rate	/kH2/	Lace	ar Po	wer (%)
Onit Spacii	ing (iii) Foii	it Delisity (pp	J3111 <i>j</i>	Jean	40	()	JCa	150	(112)	Fuise	1600	KIIZJ	Las	10	
_				_	40		_	150				\- .	D 411-		
				_					Ve	erify S-	urns E	setore	IVIISSIO	n	Yes
Line #	Direction	Start Time	End 1		Time	Sate	llite	PDOP			Line N	otes/C	omme	nts	
		(UTC)	(UI	-	On-Line										
36	S	15:13:00	15:2		00:09:00	20		1.1	-			reflig	ht		
81	S	15:35:00	15:4		00:13:00	19		1.3	-						
82	N	15:53:00	16:0		00:13:00	19		1.3							
83	S N	16:10:00 16:22:00	16:1 16:3		00:08:00	2:		1.1 1.6	-						
84 85	S	16:34:00	16:3		00:09:00	19		1.6							
86	N	16:46:00	16:5		00:09:00	13		1.5							
87	S	16:59:00	17:0		00:03:00	20		1.3							
88	N	17:11:00	17:2		00:09:00	2		1.1							
89	S	17:24:00	17:3		00:08:00	2		1.1							
90	N	17:37:00	17:4		00:05:00	20)	1.3							
91	S	17:46:00	17:4	3:00	00:02:00	2:	1	1.3							
92	N	17:52:00	17:5	4:00	00:02:00	2:	1	1.3							
93	S	17:57:00	17:5	9:00	00:02:00	2:	2	1.2							
94	N	18:03:00	18:0	4:00	00:01:00	2:	2	1.2							
											BLOC	K 4 7	'139 M	SL	
1	N	18:18:00	18:3	_	00:19:00	2:		1.2							
2	S	18:40:00	18:5	_	00:19:00	2:		1.1	-						
3	N	19:05:00	19:2	_	00:18:00	2:		1.2	-						
4	S	19:27:00	19:4	5:00	00:19:00	2:	L	1.3	-						
				\rightarrow					-						
				+					+						
				$\overline{}$											
				-+											
						Page	1		V	erify S	Turns	After I	Vissior	1	Yes
dditional C	Comments								-						

			•	Wo	olp	ert Li	dar	Acq	uisitio	n L	og					
				Pro	oject I	nfo							[Date		
Project #			Project	Nam	е			U	nique ID		Flight	t Date	(UTC)	Day o	f Year	Flight #
81150			OH Lidar BLK	7 and	BLK 4	ļ		Day0	81_91557_A		03	/22/20)21	081		Α
Cr	ew				Equip	ment					Time				Aiı	rports
Pi	lot		Ai	rcraft		/ Model / T	ail#	il # Hobbs Start					UTC			parting
	Perl					5 - N406SD			744.6			3:00	16:2			(DAY
	rator		Sai			Model / Se	rial #		Hobbs E			l End		End	riving	
•									750	illu						
ĸy	/an		Lt	eica re	rrain i	/lapper - 91	Condi	tions.	750		16:1	.0:00	20:1	0:00	ľ	(DAY
Wind Di	. (0)	\ A / !	C / -+-\	\ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \	: I- : I : 4 /	/!\		1		T	- (96)	D	. D - ! 4	(96)	D	(!!!!=\
Wind Dir	(1)	Wind	Speed (kts)	VIS	ibility ((mi) Cei	ling (ft)	Cic	oud Cover	-	o. (°C)	Dew	v Point	(°C)		ure ("Hg)
0			0		10				Clear		.6		-3			3028
Air Spe	ed (kts)		Altitude		ft)		de MSL (ft)	Airfield El		າ (ft)					
1	60		6,5	62		(5,965		1,0	009						
							Setti	ngs								
Point Spacia	ng (m)	Poir	nt Density (pp	osm)	Sca	n Angle/F0	OV (°)	Sca	n Frequency	(Hz)	Pulse	e Rate	(kHz)	Las	ser Pov	ver (%)
						40			150			1600			100)
										Ve	erify S-	Turns I	Before	Missi	on	Yes
Line #	Direc	tion	Start Time (UTC)		Time TC)	Time On-Line	Sate	ellite	PDOP			Line N	otes/C	Comme	ents	
5	E		16:23:00	_	6:00	00:13:00	1	19	1.6							
6	W		16:39:00		3:00	00:13:00	_	L9	1.9							
7	E		16:56:00		1:00	00:15:00	_	20	1.6							
8	w		17:15:00		9:00	00:14:00	_	21	1.3							
9	Е		17:33:00		6:00	00:13:00	_	22	1.2							
10	W	,	17:50:00	18:0	4:00	00:14:00	2	24	1.1							
11	Е		18:08:00	18:2	2:00	00:14:00	2	24	1.1							
12	W	'	18:25:00	18:3	9:00	00:14:00	2	21	1.1							
13	E		18:45:00		1:00	00:16:00	2	22	1.1							
14	W	'	19:05:00	19:2	2:00	00:17:00	1 2	20	1.2							
												BLOC	CK 4 7	′139 N	1SL	
5	N		19:30:00		8:00	00:18:00	_	L7	1.8							
6	S		19:52:00	20:1	.0:00	00:18:00	1 2	L8	1.6							
							+									
										1						
							Page	1		V	erify S	-Turns	After I	Missio	n	Yes
Additional C	Commer	its														
İ																

			1	Wo	olp	ert	Lid	ar A	∤cq	uisitio	n L	og					
				Pro	oject l	nfo								D	ate		
Project #			Project	Name	2				U	nique ID		Flight	Date (UTC)	Day o	f Year	Flight #
81150			Ohio lida	r blocl	< 4				Day0	88_90511_:	L		/29/20	_		38	1
Cr	ew				Equip	ment						Time				Ai	rports
Pi	lot		Ai	rcraft		/ Model	l / Tai	l #		Hobbs 9	Start	Local	Start	UTC S	Start	parting	
Sto	rck			Cessna	404 Ti	itan - N	404CF)		826	3	10:4	8:00	14:48	3:00		OSU
	rator		Sei	nsor N	lake / I	Model /	/ Seria	al #		Hobbs		Loca		UTC			riving
	nedy					/lapper				8273		16:0		20:00			OSU
TCTT.	icay			, roa re		паррел		onditi	ons	0270	.5	10.0	0.00	20.0	3.00		-
Wind Dir	(°)	Wind	Speed (kts)	Vis	ibility (mi)	Ceilir			oud Cover	Temi	p. (°C)	Dew	Point	(°C)	Press	ure ("Hg)
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Air Spe	ad (kts	١	Altitude	VCI (ΔI+	ituda	MSL (f	+1	Airfield E							0.20
-	60 (Kts	,	6,5		,	Ait	7,1		ι,		905	(10)					
11	JU		0,3	02			/,1	Settin	are		503						
Doint Cassin	ng /ms\	De:	t Donaite /	sem)	C	n Anala	/EOV			n Eroauss	, (µ-\	Dulas	Data 4	LU-1	100	or Do	vor (0/)
Point Spacir	ig (m)	POIR	nt Density (pp)SIII)	Sca	n Angle		()	эcа	n Frequenc	y (mz)	Pulse	1600	KHZ)	Las		ver (%)
			8		40					150	.,	:6	1600) - f - :	NA:- ·	100	
											Ve	erify S-1	urns E	erore	IVIISSI	υn	Yes
Line #	Direc	tion	Start Time		Time	Tim		Sate	llite	PDOP			Line No	otes/C	omm	ents	
7			(UTC)		TC)	On-L		20		4.2							
7 8	5		15:17:00 15:39:00		6:00 9:00	00:19		1		1.3 1.5			overs	peed n	ortn e	ena	
9	5		16:02:00					1		1.5							
10	N		16:23:00	16:4	0:00 00:18:00 2:00 00:19:00			2		1.3							
11	5		16:45:00		3:00			1		1.4							
12	N		17:06:00		5:00			2		1.2							
13	9	,	17:27:00	17:4	6:00			2	4	1.1							
14	N	I	17:49:00	18:0	7:00	00:18	3:00	2	2	1.1							
15	5		18:10:00		8:00	00:18		2		1.1							
16	N	I	18:31:00		9:00	00:18		2		1.1							
17	5		18:52:00		1:00	00:19		2		1.3	-						
18 19	N 9		19:14:00 19:35:00	19:3	2:00	00:18	s:UU	1	9	1.4	DAV	motor	Overla	ad fli	tht ov	ocutio:	n restart
13		,	15.55.00								PAV		art did				
												11030	ar t uiu	3		Jac, 111	
											+						
											+						
											+						
								Page	1		V	erify S-	Turns	After N	∕lissio	n	Yes
Additional C	omme	nts									<u> </u>	-					

				Wo	olp	ert Lid	lar /	Acq	uisitio	n L	og					
				Pro	oject I	nfo							[Date		
Project #			Project	t Nam	е			U	nique ID		Flight	Date	(UTC)	Day o	f Year	Flight
81150			Ohio Lidar B	lock 7	and 5			Day0	88_90515_A		03,	88	Α			
Cr	ew				Equip	ment					Time				Ai	rports
Pi	lot		Ai	rcraft	Make ,	/ Model / Ta	il#		Hobbs St	art	Local	Start	UTC	Start	parting	
На	gen			Cessna	404 Ti	itan - N475R0	2		2437.8	3	11:0	2:00	15:0	2:00	(DAY	
Ope	rator		Sei	nsor N	lake /	Model / Seri	al#		Hobbs E	nd	Local	l End	UTC	End	riving	
•	/an					/lapper - 905			2444.3	3	15:4	8:00	19:4	8:00		(DAY
,							Condit	ions								
Wind Dir	· (°)	Wind	Speed (kts)	Vis	ibility (ng (ft)		oud Cover	Temr	o. (°C)	Dev	/ Point	(°C)	Press	ure ("H
0	()	vviiid	0	V13		iiii) Ceiiii	18 (14)	Cic	Clear		3	Devi	-3	()		3027
	a al /lata	`	_	ACL /	10			:+1			_		-5		•	0027
Air Spe)	Altitude		It)	Altitude		τ)	Airfield El		1 (π)					
1	60		6,5	62		6,9	965		1,0	009						
					ı		Settir				ı					
Point Spaci	ng (m)	Poir	nt Density (pp	osm)	Sca	in Angle/FO\	/ (°)	Sca	n Frequency	(Hz)	Pulse	Rate	(kHz)	Las		ver (%)
						40			150			1600			100)
										Ve	erify S-1	Turns l	Before	Missi	on	Yes
Line #	Direc	tion	Start Time (UTC)		Time TC)	Time On-Line	Sate	llite	PDOP			Line Notes/Comments				
39	E		15:02:00	15:1	4:00	00:12:00	2	0	1.3		BLOCK 7				SL	
40	W	/	15:19:00	15:3	3:00	00:14:00	2	0	1.2							
41	E		15:39:00	15:5	2:00	00:13:00	1	8	1.5							
42	W	/	15:56:00	16:1	3:00	00:17:00			1.6							
43	E		16:16:00	16:3	0:00	00:14:00	2	1	1.3							
44	W	/	16:32:00		9:00	00:17:00	2	1	1.1							
45	E		16:52:00		5:00	00:13:00	2		1.4	(1-						
53	W	/	17:08:00	17:2	7:25:00 00:17		2	3	1.2	refi		reflig	ht			
												BLOCK 5 7169MSL		CI		
1	N		17:34:00	17.5	4:00	00:20:00	2	5	1.1			БЕО		TOSIVI	3L	
2	S		17:56:00	_	3:00	00:20:00	25 23		1.1							
3	N		18:16:00		5:00	00:17:00	2		1.1							
4	S		18:41:00		1:00	00:20:00	2		1.3							
5	N		19:03:00		25:00	00:22:00	1		1.7							
6	S		19:27:00	19:4	8:00	00:21:00	2	0	1.2							
	1						Page	1		V	erify S	Turns	After I	Missio	n	Yes
Additional C	Comme	nts														

			1	Wo	olp	ert L	ida	ar A	\cq	uisitic	n L	og					
				Pro	oject l	nfo									ate		
Project #			Project	: Name	2				U	nique ID		Flight	Date	(UTC)	Day o	f Year	Flight #
81150			Ohio lida	ır blocl	< 4				Day0	89_90511_1		03,	/30/20	2021		39	1
Cr	ew				Equip	ment						Time				Ai	irports
Pi	lot		Ai	rcraft	Make /	/ Model /	Tail	#		Hobbs S	tart	Local	Start	UTC	Start	parting	
Sto	rck			Cessna	404 Ti	itan - N40	 04CP			8274		10:2	9:00	14:2	9:00		CMH
	rator		Sei	nsor IV	lake / I	Model / S	Serial	l #		Hobbs	nd	Loca		UTC			rriving
	nedy					1apper - 9				8278.		15:1		19:1			CMH
Ken	icuy			ica ic	TT GITT IV	паррет		onditi	onc	0270.	<i></i>	15.1	7.00	13.1	7.00		CIVIII
Wind Dir	(°)	Wind	Speed (kts)	Vic	ibility (mi) C	eiling			oud Cover	Tomi	o. (°C)	Dow	Point	(°C)	Dross	sure ("Hg)
200	()	vviiiu	12	VIS	10	1111)	eiiiiį	g (11)	Cit	Juu Covei	+ -	.3	Dew	-1	()	FIES	30.1
	1 /1 - 1 -	`		A C1 //		A 14:4-		NACL /S	•)	A:				-1			30.1
Air Spe)	Altitude		rt)	Altiti		MSL (f	t)	Airfield E		1 (π)					
10	50		6,5	62			7,13			[15						
						_		Settin				I -					
Point Spacir	ng (m)	Poir	nt Density (pp	osm)	Sca	n Angle/I	FOV	(°)	Sca	n Frequency	(Hz)	Pulse	Rate	(kHz)	Las		wer (%)
			8			40				150			1600			10	0
										Ve	rify S-1	Turns E	Before	Missi	on	Yes	
Line #	Line # Direction Start Time End T						e	Satellite		PDOP			Line N	otes/C	Commo	ents	
19	9	5	14:53:00	15:1	4:00	00:21:0	21		1.4								
20	١	1	15:16:00	15:3	5:00	00:19:0	00	2:	1	1.3							
21	5	5	15:38:00	15:5	9:00	00:21:0	00	19	9	1.6							
22	١		16:01:00		9:00			19		1.9							
23	5		16:22:00		12:00 00:20			20		1.5							
24	N		16:45:00		03:00 00:18			21		1.2							
25	5		17:06:00		6:00	00:20:0	_			1.2	-						
26 27	N 9		17:28:00 17:49:00		6:00 0:00	00:18:0 00:21:0		20		1.1							
28	N		18:12:00		0:00	00:21:0		2:		1.1							
29	9		18:33:00		4:00	00:21:0		17		1.3							
							\neg										
							\bot										
							\dashv				1						
							\dashv				1						
							+				+						
							+				+						
							\dashv				+-						
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							\dashv				1						
								Page	1		V	erify S-	Turns	After I	Vissio	n	Yes
Additional C	omme	nts															

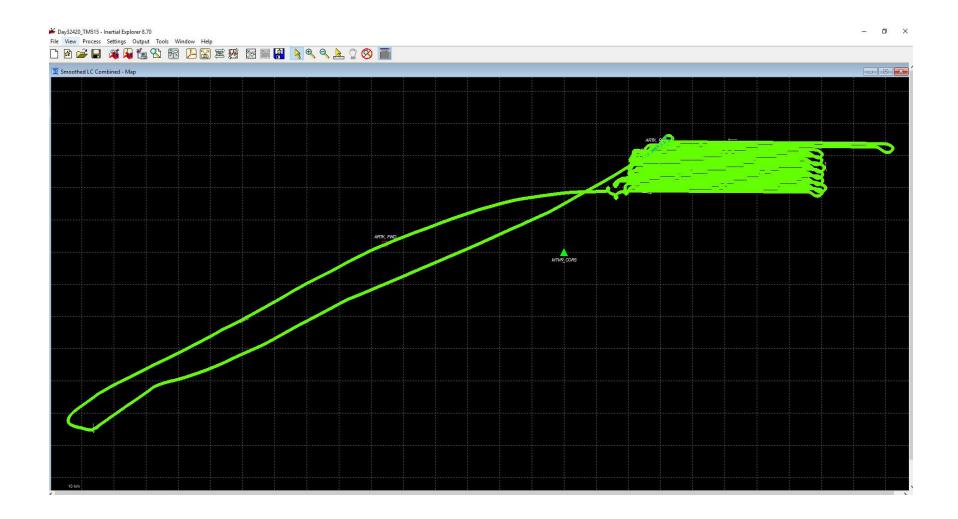
			1	Wо	olp	ert Li	dar /	Acq	uisitio	n Lo	og					
				Pro	oject Ir	nfo							[Date		
Project #			Project	Name	e			U	nique ID		Flight	Date	(UTC)	Day o	f Year	Flight #
81150			Ohio LiDA	R Pha	se II			Day	089_90515		03,	/30/20)21	08	39	
Cre	ew				Equip	ment					Time				Aiı	rports
Pil	lot		Ai	rcraft	Make /	/ Model / T	Γail #		Hobbs St	tart	Local	Start	UTC	Start	Der	parting
Нає	gan		,	 Cessna	404 Ti	itan - N475	RC		2444.3	3	09:4	5:00	13:4	5:00	(DAY	
	rator		Ser	nsor N	lake / I	Model / Se	erial #		Hobbs E	nd	Loca	l End	UTC			riving
Narc						ларрег - 90			2449.5		-	5:00	19:1			MGY
							Condit	tions								
Wind Dir	(°)	Wind	Speed (kts)	Vis	ibility ((mi) Ce	iling (ft)	_	oud Cover	Temr	p. (°C)	Dev	v Point	(°C)	Press	ure ("Hg)
190	`		22		10				Clear	-	12		-3	· - /		30.36
Air Spe	ed (kts	1	Altitude	AGL (Altitu	de MSL (/f+)	Airfield Ele							0.55
16			6,5		-		7,169	,		98	1 (1.5)					
				02			Settii	ngs		JC						
Point Spacin	29 (m)	Poir	nt Density (pp	nem)	Sca	an Angle/F0			n Frequency	(H ₇)	Dulse	e Rate	(LH2)	Las	er Pov	ver (%)
0.35	8 (1117)	10	8	3111)	300	40	Jv ()	J.C.	150	(114)	ruisc	1600	(KIIZ)	Lus	100	
0.55			0			40			130	Ve	erify S-1		Pofore	Missi		Yes
			C. Time		=:		-			Ve	rily 3-	unis	Seluie	Milooid)II	Yes
Line #	Direc	tion	Start Time (UTC)	(U	Time TC)	Time On-Line	Sate	ellite	PDOP			Line N	lotes/C		ents	
7	N		14:45:00		05:00		工						Block	¢ 5		
8	S	_	15:07:00		34:00		\bot			<u> </u>						
9	N		15:36:00			00:20:00			<u> </u>							
10 11	S N	_	15:58:00 16:26:00	::00 15:56:00 ::00 16:24:00		00:26:00	_			_						
12	S		16:26:00		16:00 L6:00	00:20:00	_			-						
13	N		17:18:00		37:00	00:20:00				\vdash						
14	S		17:41:00		06:00	00:25:00	_			\vdash						
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							Page	: 1		V	erify S-	·Turns	After I	Missio	n	
Additional Co	ommer	nts														

				Wo	olp	ert	Lid	ar A	\cq	ļυ	isitio	n Lo	og					
				Pro	oject l	nfo										ate		
Project #			Project	Name	2				U	Jniq	que ID		Flight	Date ((UTC)	Day o	f Year	Flight #
81150			Ohio lidar	block	4/5				Day0	93_	_90511_1			/03/20		09		1
Cr	ew				Equip	ment			•				Time		<u> </u>		Ai	rports
Pi	lot		Ai	rcraft		/ Model	l / Tai	l #		T	Hobbs St	art	Local	Start	UTC S	Start		parting
Sw	ain					itan - N				t	8279.6		10:0	3:00	14:0	3:00		DAY
	rator					Model /				H	Hobbs Er		Local		UTC			riving
	nedy					lapper -				H	8286.2		16:3		20:3			DAY
Ken	icuy			ica ic	i i a ii i v	таррст		onditi	ions	_	0200.2		10.5	0.00	20.5	0.00		DAT
Wind Dir	/ °\	Wind	Speed (kts)	Vic	ibility (mil	Ceilir				d Cover	Tomr	o. (°C)	Dow	Point	(°C)	Drocc	ure ("Hg)
210	()	vviiiu	10	VIS	10	,1111)					oken		3. (C)	Dew	-8	()		30.42
		,		101/				000		_			-		-8		3	10.42
Air Spe)	Altitude		rt)	Alt		MSL (f	rt)	_	Airfield Ele		ı (ft)					
1	50		6,5	62			7,1				1,0	09						
								Settin										
Point Spacir	ng (m)	Poir	nt Density (pp	sm)	Sca	n Angle		/ (°)	Sca	n F	requency	(Hz)	Pulse	Rate	(kHz)	Las		wer (%)
			8		40				150			1600			100)		
												Ve	rify S-1	Turns E	Before	Missi	on	Yes
Line #	Direc	rtion	Start Time	End	Time	Tim	ie	Sate	llita		PDOP			Line N	otes/C	omm	onts	
Lille #	Direc	Lion	(UTC)	(U	TC)	On-L	ine	Sate	ilite		PDOP			Lille IV	otes/ C	Ommo	ents	
40	N	1	14:49:00	15:0	8:00	00:19	9:00	1	9		1.3							
39	5	<u> </u>	15:10:00		9:00	00:19		1	9		1.4							
38	N		15:31:00		0:00			2		1.9								
37	5		15:52:00		1:00			2		-	1.2							
36	N		16:13:00		1:00			2		\vdash	1.1							
35 34	S N		16:33:00 16:53:00		1:00				23 26		1.4							
33	5		17:14:00		2:00	00:18		2		\vdash	1.1							
32	N		17:35:00		3:00	00:18		2		\vdash	1.2							
31	9		17:55:00		3:00	00:18		2		T	1.1							
30	N	1	18:16:00	18:3	4:00	00:18	3:00	2	2	Т	1.2							
44	5	<u> </u>	18:45:00		0:00	00:15		1	7		1.7		St	tart Blo	ock 5 @	7169	MSL	
43	N		19:02:00		7:00	00:15			8	L	1.3							
42	5	5	19:19:00	19:3	4:00	00:15	5:00	1	9	-	1.2							
										+								
										\vdash								
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										L								
								Page	1			V	erify S-	Turns	After I	Vissio	n	Yes
Additional C	omme	nts																
		_		_				_		_		_						

					ject l			ar A	•							Date			
Project #			Project		-	1110				nique ID	<u> </u>		Elight	Date			r Flight		
81150			oh b							ilique ib			04/05/202			JTC) Day of Y 095		1	
	ew		Offic		Eauin	ment							Time			0.		irports	
	lot		Λi	rcraft N			ıl / Tai	1 #		Hobi	hc Sta		Local	Start	LITC			eparting	
	hart		All			5 - N40		1 #		Hobbs Start 782.4			11:1		15:18:00				
			Co.	nsor M				-l #				۵.	Local		UTC End		— ,	day	
-	rator																		
311	nith		Lt	eica Ter	rain iv	паррег		onditi		/	80.4		03:1	8:00	19:1	8:00		day	
Min d Din	. /0\	\	Conned (late)	\/:-:	L:1:4/	·:\					T	T	(%C)	Da	D=:4	(%C)	Duna	/!!!!	
Wind Dir	(1)	wina	Speed (kts)	VISI	bility (mı)	Cellir	ng (ft)	Cic	ud Cove	er	Temp		Dew	Point	(°C)	Pres	sure ("H	
190			5		10						Few 1				4			3013	
Air Spe)	Altitude		t)	Al		MSL (f	t)	Airfiel			(ft)						
1	60		6,5	62			7,1	L69			1,00)9							
								Settin											
Point Spacii	ng (m)	Poir	t Density (pp	sm)	Sca					n Frequency (Hz)			Pulse	Rate 1603	(kHz)				
				40						150					100				
												Ve	rify S-T	Turns E	Before	re Mission Yes			
Line #	Direc	tion	Start Time (UTC)		End Time (UTC)					Line N	otes/0	Commo	ents						
15	n		16:14:00	16:3				20		1.1									
16	S		16:37:00		55:00			19		1.2									
17	n		16:58:00	17:1		00:19:00		2		1.1									
18 19	s n		17:20:00 17:42:00	17:39 18:00		00:19:00		2		1.1	-								
20	n s		18:03:00	18:2		00:1		2		1.2	\rightarrow								
			20.00.00				-				\neg								
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								Page	1			Ve	erify S-	Turns	After	Missio	n	Yes	
Additional C	Comme	nts																	

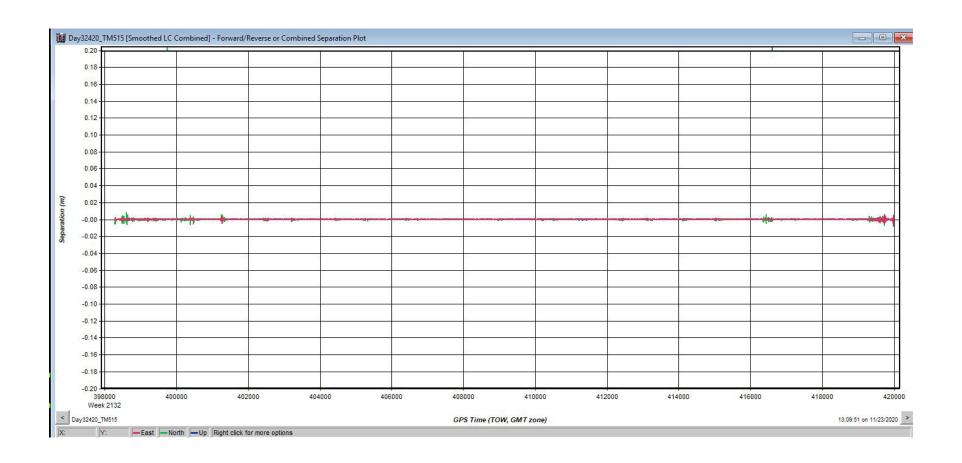
Appendix 3: GPS / IMU Graphics

Trajectory

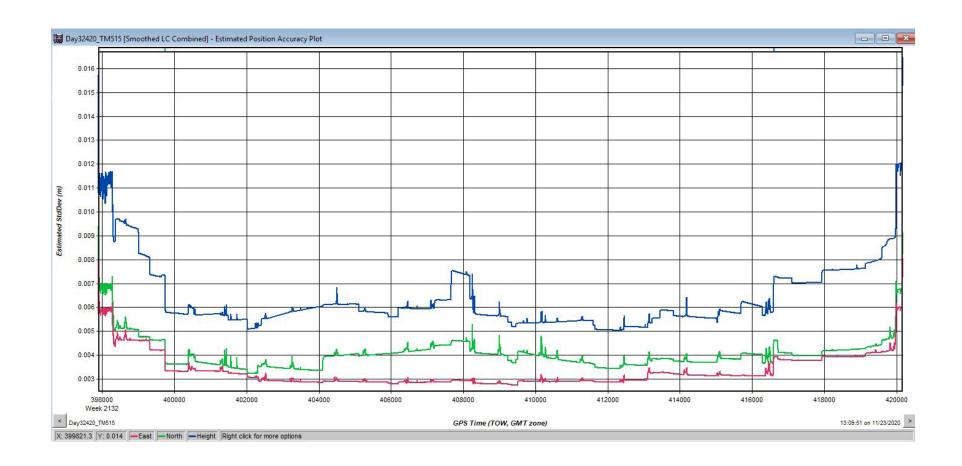


A3-2

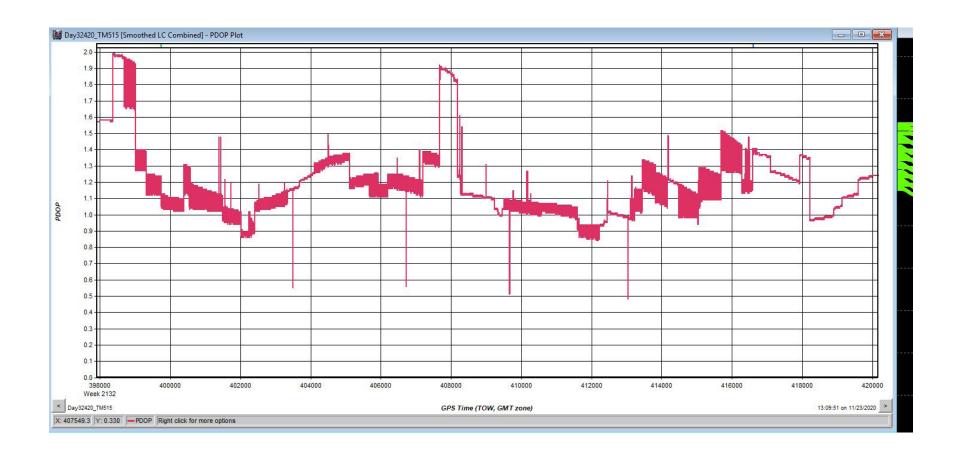
Forward/Reverse or Combined Separation Plot



Estimated Position Accuracy

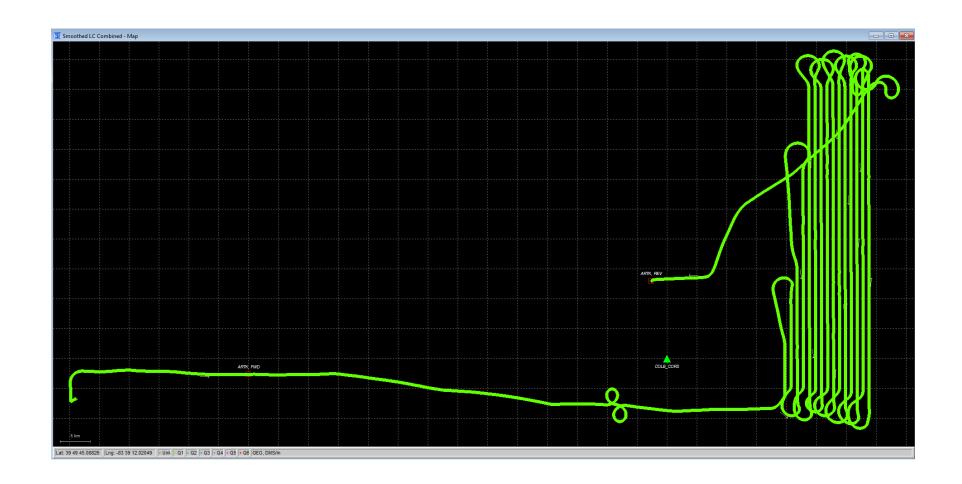


PDOP Plot



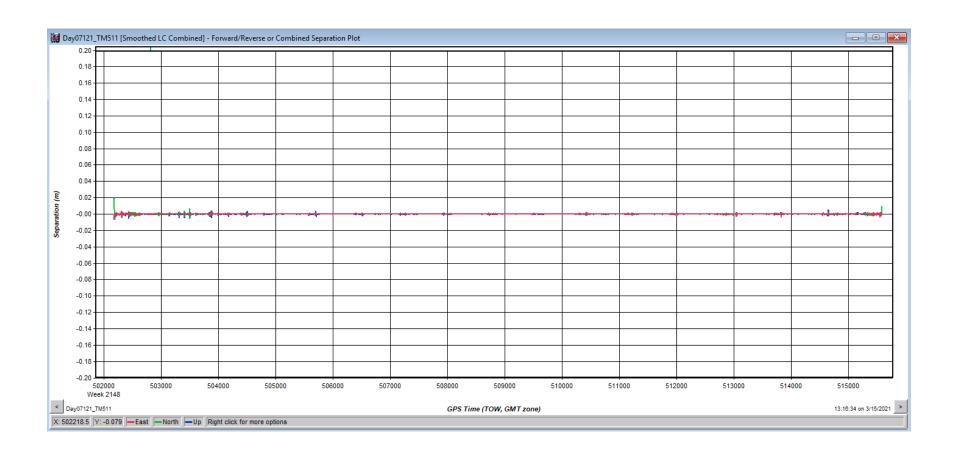
Day07121_TM511

Trajectory



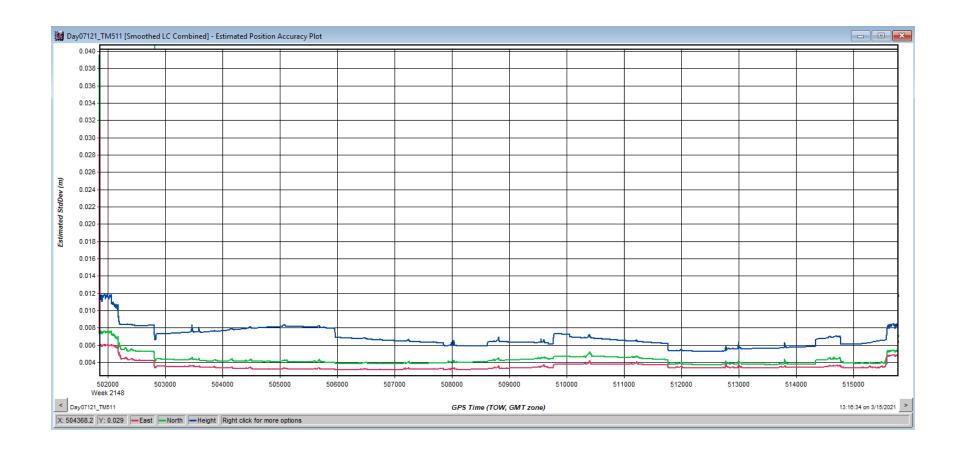
Day07121_TM511

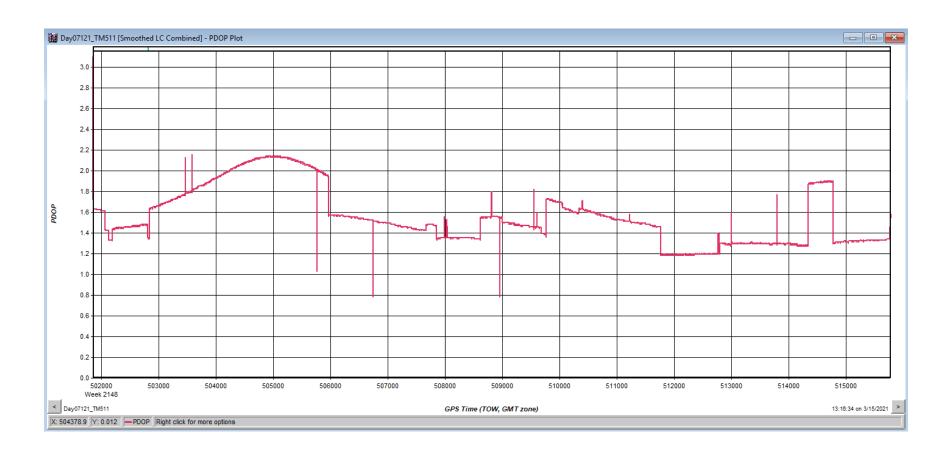
Forward/Reverse or Combined Separation Plot

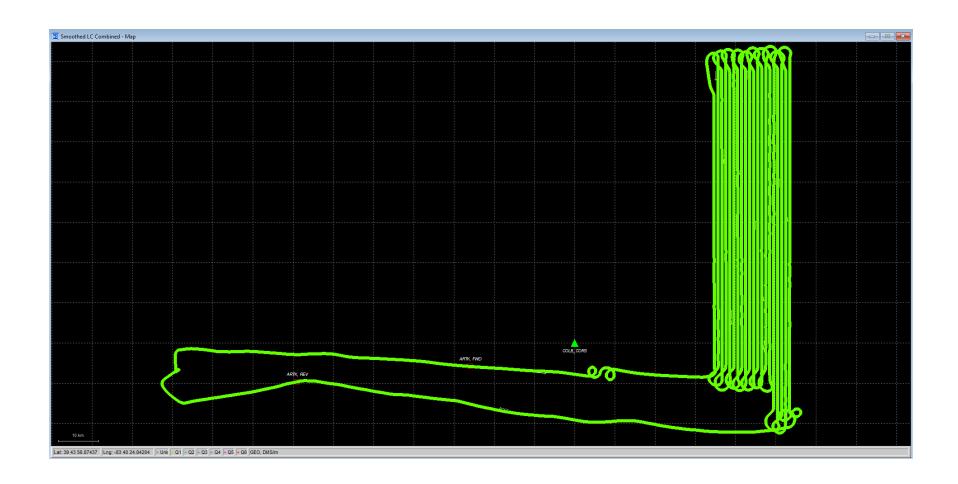


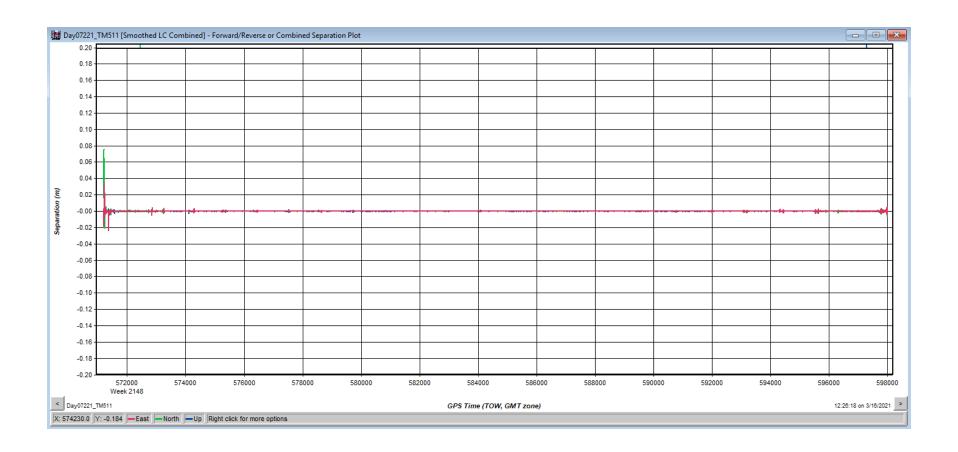
Day07121_TM511

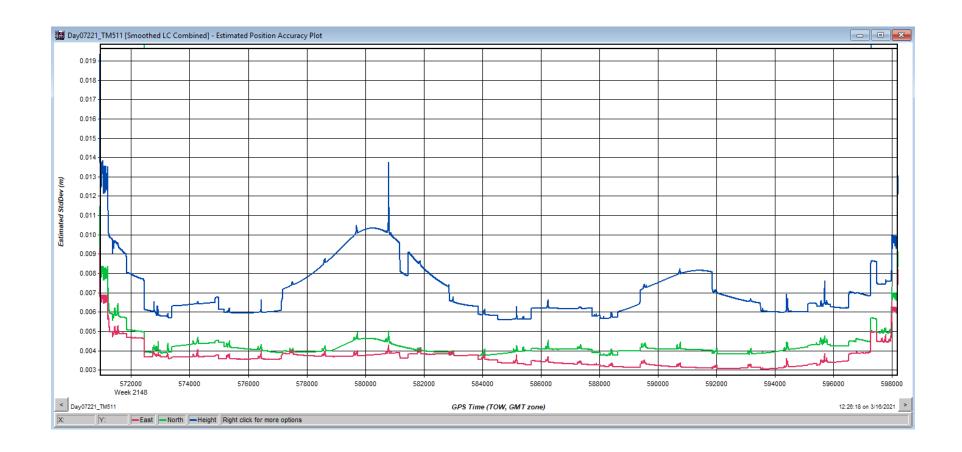
Estimated Position Accuracy



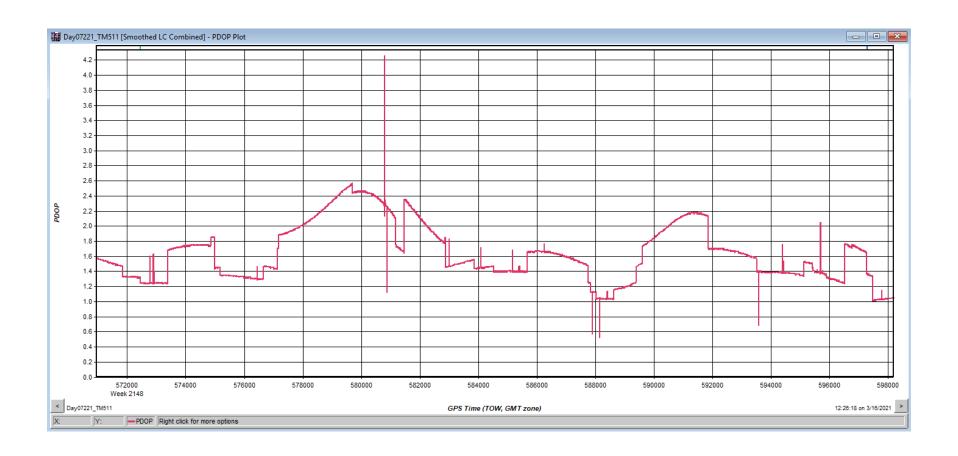








PDOP Plot



A3-13



