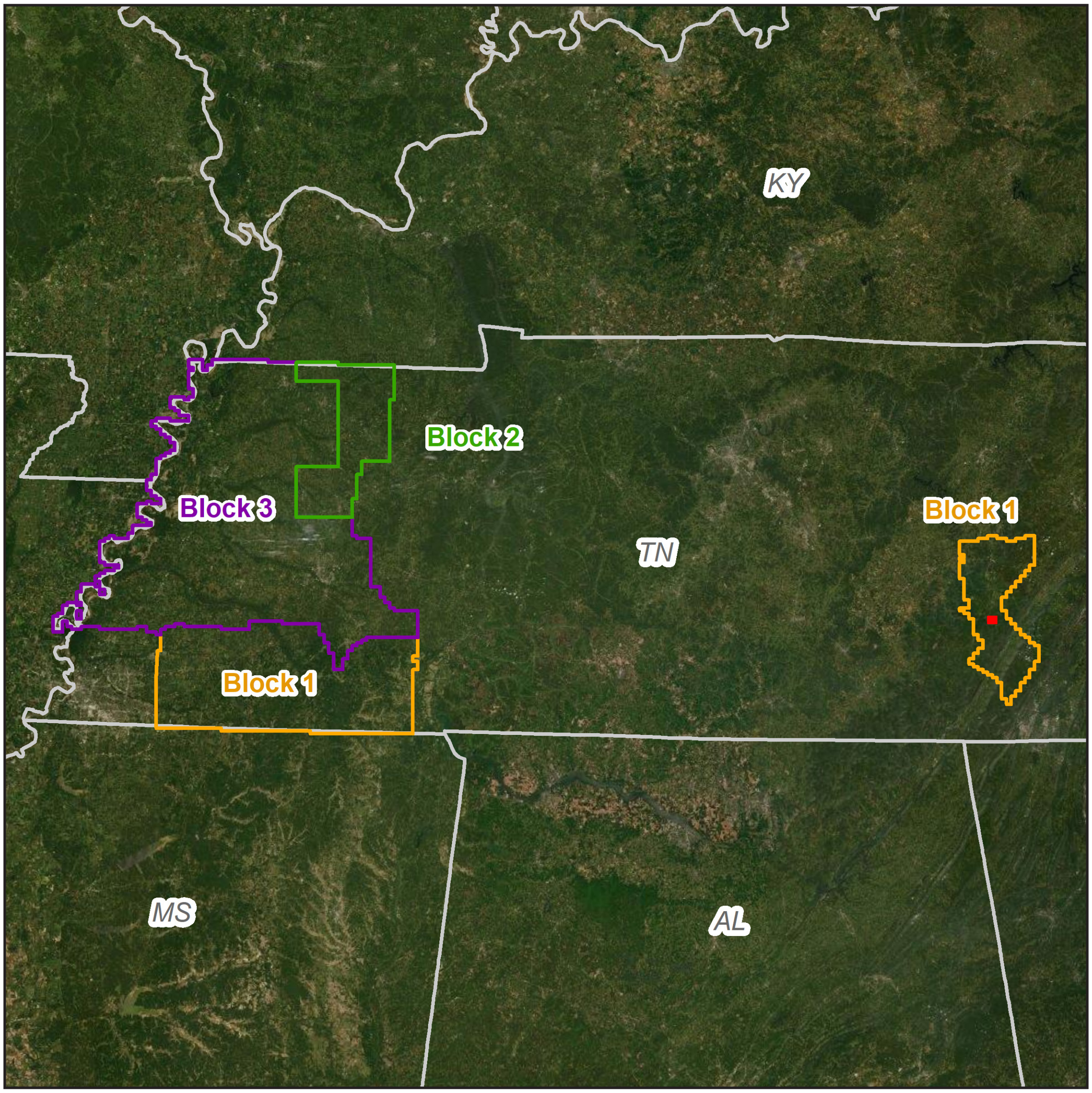
TN West TN Lidar 2019 D19

Lot 6 Block 2

Airborne Lidar Report

June 2020



Contract # G16PC00022

Task Order # 140G0219F0060

Contractor Woolpert

Project # 79576

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1. Overview

About

This project contains a comprehensive outline of the 140G0219F0060TN West TN Lidar 2019 D19 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 QL2 data over three blocks that total approximately 7,961 square miles in western Tennessee.

This report encompasses the Lot 6 Block 2 area of interest. This AOI totals approximately 729 square miles and includes the following counties:

- Gibson
- Weakley

Purpose

The purpose of this project was to collect data to be used for the following: terrain mapping, conservation planning and design, support of easement/land stewardship programs, support of special emphasis programs, support of soil projects, fill gaps in existing lidar, and water resource management.

Specifications

Data for this task order was acquired and produced to meet USGS Lidar Base Specification v1.3 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.

Table 1-1. Spatial Reference System

Area of Interest		
Horizontal	**EPSG Code**	6576
	Datum	NAD83 (2011)
	Projection	State Plane Tennessee (FIPS Zone 4100)
	Units	US Survey Feet
Vertical	**Datum**	NAVD88
	Geoid	GEOID12B
	Units	US Survey Feet
	Height Type	Orthometric

Task Order Deliverables

All data products produced as part of this task order are listed below. All tiled deliverables had a tile size of 7,000-feet x 4,000-feet. Tile names are derived from the guidance provided by the State of Tennessee Department of Finance and Administration.

Table 1-2. Deliverables

Lidar Data	
Classified lidar point cloud data	Tiles in .las v1.4 format Classes • 1 – Processed, not Classified • 2 – Ground • 6 – Buildings • 7 – Noise • 9 – Water • 17 – Bridge Decks • 18 – High Noise • 20 – Ignored Ground

Breaklines used for hydro-flattening	• Lake and River features as feature classes in an Esri file geodatabase
	    • Water bodies greater than 2 acres as PolygonZ feature classes
	    • Rivers 30.5 meters / 100 feet and greater in width as PolylineZ features
	• Bridges used in DEM generation as PointZ feature classes in Esri shapefile format

Hydro-flattened bare earth digital elevation model (DEM)	2.5-foot pixel size, 32-bit floating-point; no bridges or overpass structures ERDAS .img format
Intensity Imagery	2.5-foot pixel size, 8-bit gray-scale (linear rescaling from 16-bit intensity) GeoTIFF format
Flight Line Index	Polygon feature classes in an Esri file geodatabase
Control Data	
Lidar calibration points	Esri shapefile format
Lidar NVA checkpoints	Esri shapefile format
Lidar VVA checkpoints	Esri shapefile format
Other Data	
Tile Index	Esri shapefile format
Metadata and Reports	
Metadata	Product-level FGDC CSDGM/USGS MetaParser Compliant metadata in .xml format
Lidar Project Report	Project report with flight logs in .pdf format
Survey Report	Survey report in .pdf format

Figure 1-1. Project Area

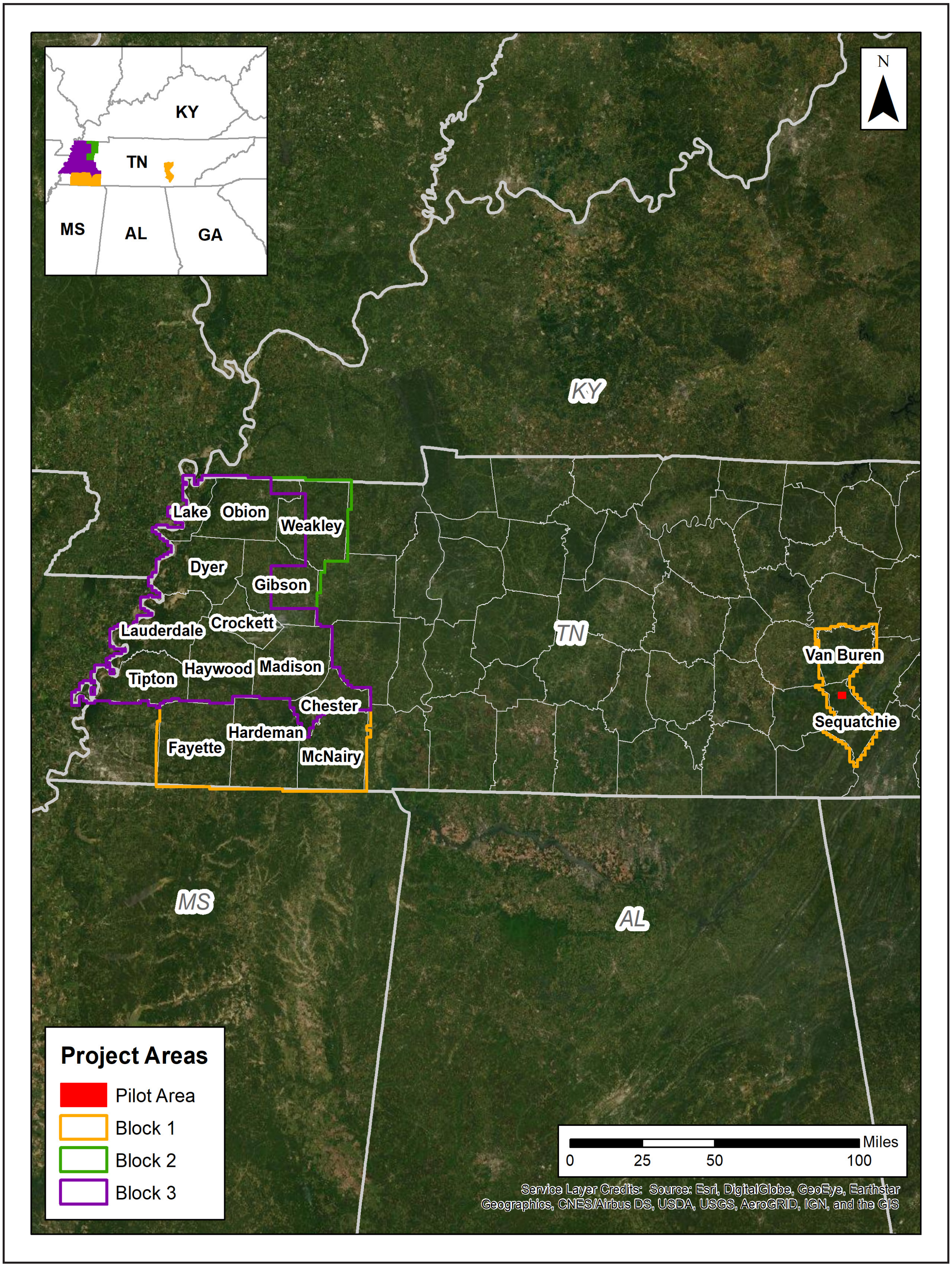
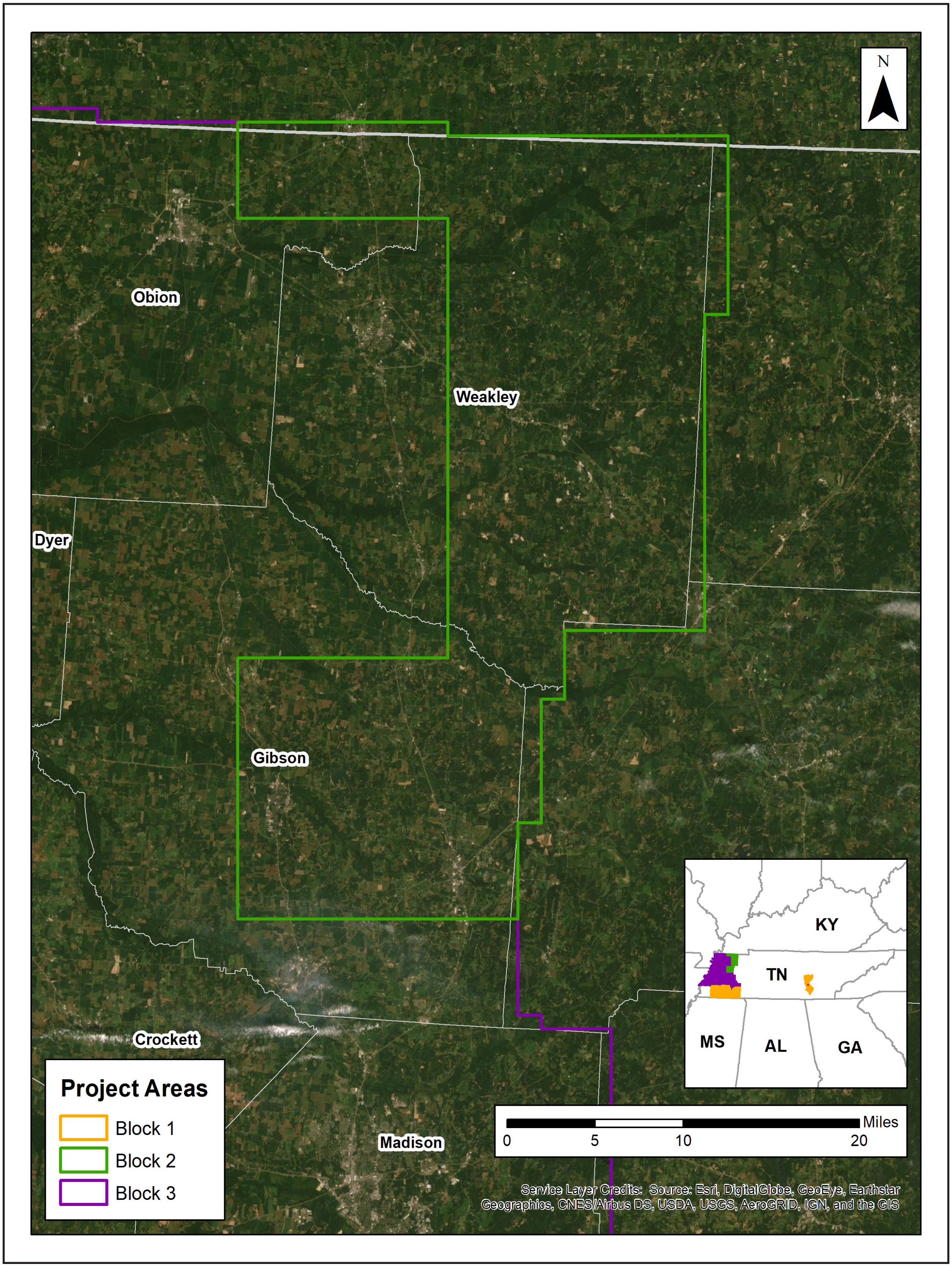


Figure 1-1. Project Area - Block 2



2. Acquisition

Flight Planning

Aerial lidar data was collected using the specifications listed below.

Table 2-1. Acquisition Requirements

Specification	Target
Resolution	• 2 points per square meter • 0.7-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 nominal point density is achieved
Acquisition Window	At a period of annual minimal water level in the spring 2019 leaf off window
Acquisition Conditions	• Cloud and fog-free between the aircraft and ground • Snow free • Ground has no unusual flooding or inundation, except in cases where the goal of the collection is to map the inundation • Preference of vegetation is leaf-off
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 appropriately filled-in by another swath
Control	Airborne Global Positioning System (ABGPS) and Inertial Measurement Unit (IMU) data to be used along with differentially-corrected GPS ground control points

Lidar Sensor Information

Aerial lidar data was acquired using the Leica ALS70 and Leica TerrainMapper lidar sensor systems. A total of 57 flight lines were collected for the Block 2 AOI.

Table 2-2. Leica ALS70 Sensor Info

System Performance	
Maximum Flying Height (m AGL)	3,500
Maximum Measurement Rate (kHz)	500
Field of view (degrees)	0 - 75 (full angle, user adjustable)
Roll stabilization (automatic adaptive, degrees)	70 - active FOV
Scan patterns (user selectable)	sine, triangle raster
Maximum Scan Rate (Hz) • Scan • Triangle • Raster	• 200 • 158 • 120
Number of Returns	unlimited
Number of intensity measurements	3 (first, second, third)
Physical Specifications	
Size (cm), Weight (kg) • Scanner • Control Electronics	• 45 W x 47 D x 36 H • 45 kg
Operating Temperature Scanner Control Electronics	0 - 40°C
Flight Management	FCMS
Power Consumption	910 W @ 22.0 – 30.3 VDC

Source: Leica ALS70-HP Product Specifications
https://w3.leica-geosystems.com/downloads123/zz/airborne/ALS70/brochures/Leica_ALS70_6P_BRO_en.pdf

Table 2-3. 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

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 IGI CCNS (Computer Controlled 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. See the table below for stations operated during acquisition.

Table 2-4. GNSS Base Stations

Station Name	Latitude (DMS)	Longitude (DMS)	Ellipsoid Height L1 Phase Center (Meters)
COLB_CORS	39° 57’ 35.11256"	83° 02’ 44.74693"	186.508
PAR_KCHA_Base	35° 01’ 56.91115"	85° 12’ 23.60732"	177.269
TN22_CORS	35° 23’ 25.71880"	84° 22’ 40.97004"	207.543
TN23_CORS	35° 55’ 10.68490"	84° 59’ 57.56518"	527.522
TN24_CORS	36° 08’ 03.69715"	85° 29’ 57.81747"	309.655
TN26_CORS	35° 26’ 35.11875"	84° 37’ 48.33555"	258.117
TN28_CORS	35° 42’ 05.60618"	85° 44’ 43.51172"	271.52
TN40_CORS	35° 38’ 50.61711"	88° 24’ 04.31175"	126.737
TN43_CORS	35° 13’ 42.85127"	88° 36’ 14.10607"	122.415
TN44_CORS	35° 38’ 25.50233"	88° 55’ 08.62787"	92.437

Timeline

Lidar data was collected from December 11, 2019 through February 2, 2020 for the Block 2 AOI. Acquisition specifications are listed in the table below. An initial quality control process was immediately performed on to review the data coverage, airborne GPS data, and trajectory solution.

Table 2-4. Project Acquisition Specifications

Settings	Leica ALS70	Leica TerriainMapper
Max. Number of Returns	4	15
Nominal Point Spacing	0.71 m	0.71 m
Nominal Point Density	2.56 ppsm	2 ppsm
Flying Height Above Ground Level	1,392 m	2,500 m
Flight Speed	120 knots	150 knots
Scan Angle	40°	40°
Scan Rate Used	52.2 Hz	90 Hz
Pulse Rate Used	190.8 kHz	600 kHz
Multi-Pulse in Air	Enabled	Enabled
Swath Width	1,013 m	1,819 m
Swath Overlap	35%	25.5%

For more information, see the Flight Logs in Appendix 1.

Acquisition Quality Assurance

Woolpert developed a quality assurance and validation plan to ensure the acquired lidar data meets the USGS Base Specification Version 1.3. 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.

Note: Data from this new dataset was referenced to existing USGS projects in Tennessee as tie-edges.

GNSS-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).

Software: POSPac Software v. 5.3, IPAS Pro v.1.35., Novatel Inertial Explorer v8.60.6129

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), mirror flex (scale) and GPS/IMU drift. Statistical reports were generated for comparison and used to make the necessary adjustments to remove any residual systematic error.

Software: Proprietary Software, TerraMatch v20, Leica CloudPro 1.2.4

Lidar Data Classification

LAS data was classified as ground and non-ground points with additional filters 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.

Calibrated LAS files were imported into the task order tiles and initially filtered to create a ground and non-ground class. Then additional classes were filtered as necessary to meet the following client-specified classes:

- Class 1 – Default / Processed, but not Classified
- Class 2 – Bare Earth Ground
- Class 6 – Buildings
- Class 7 – Low Noise
- Class 9 – Water
- Class 17 – Bridge Decks
- Class 18 – High Noise
- Class 20 – Ignored Water

Classified LAS files were evaluated through a series of manual QA/QC steps as well as a peer-based review to eliminate remaining artifacts from the ground class. This included a review of the DEM surface to remove artifacts and ensure topographic quality.

Software: Proprietary Software, TerraScan v20

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. The purpose of these breaklines is for a more aesthetically pleasing DEM appearance.
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 a PolygonZ feature class. Rivers and streams with a nominal minimum width of 30.5 meters (100 feet) were provided as a PolylineZ feature class. 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 PointA features in Esri shapefile format.

Software: TerraScan v18, TerraModeler v18, Esri ArcMap v10.4, LP360 v2018.1.57.4

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 2.5-foot hydro-flattened bare-earth raster DEM files. Using automated scripting routines within ArcMap, an 32-bit floating point raster ERDAS .img file was created for each tile. Files were produced to the full tile extents. Each surface is reviewed using Global Mapper to check for any surface anomalies or incorrect elevations found within the surface.

Software: TerraScan v20

Intensity Imagery

Lidar intensity data derived from the acquired lidar data was linearly rescaled from 16-bit intensity and provided as 2.5-foot pixel, 8-bit, 256 gray scale GeoTIFF format intensity imagery files. Files were produced to the full tile extents.

Software: TerraScan v20

Building Footprints

Automated feature extraction was performed using proprietary Woolpert software. The raw lidar and bare earth model datasets were processed to extract and attribute building and vegetation features. Automated extraction was followed by detailed Q/C to verify completeness and accuracy of extraction. Final Q/C'ed features were attributed with geometrically derived attributes based on feature extents, reflective surface DEM and bare earth DEM. Extracted and attributed features were reviewed for completeness and consistency. Projection information and metadata were added to final vector data files.

Software: Proprietary Software, Esri ArcMap v10.7

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 and delivery 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.

4. Accuracy Statement

Horizontal Accuracy

The data sets was produced to meet ASPRS "Positional Accuracy Standards for Digital Geospatial Data" (2014) for a 18.6 cm RMSEx / RMSEy Horizontal Accuracy Class which equates to Positional Horizontal Accuracy = +/- 45.4 cm at a 95% confidence level.

Raw Lidar Swath Testing

This project required the lidar point cloud swath to be produced to meet a Non-Vegetated Vertical Accuracy (NVA) value of 19.6 cm at a 95% confidence level using an RMSEz target value of 10 cm x 1.9600.

Digital Elevation Model Testing

This project required DEM data to be produced to meet a Non-Vegetated Vertical Accuracy (NVA) value of 19.6 cm at a 95% confidence level using an RMSEz target value of 10 cm x 1.9600 and a Vegetated Vertical Accuracy (VVA) value of 0.294 cm at the 95th percentile error.

Appendix 1: Flight Logs

Woolpert Lidar Acquisition Log

Project Info			Date		
Project #	Project Name	Unique ID	Flight Date (UTC)	Day of Year	Flight #
79576	West TN North Block	Day345_90511_A	12/11/2019	345	A

Crew	Equipment	Time			Airports
Pilot	Aircraft Make / Model / Tail #	Hobbs Start	Local Start	UTC Start	Departing
Nico	Cessna 404 Titan - N532NM	444.3	11:33:00	17:33:00	NQA
Operator	Sensor Make / Model / Serial #	Hobbs End	Local End	UTC End	Arriving
Ryan	Leica Terrain Mapper - 90511	451.3	17:14:00	23:14:00	NQA

Conditions

Wind Dir (°)	Wind Speed (kts)	Visibility (mi)	Ceiling (ft)	Cloud Cover	Temp. (°C)	Dew Point (°C)	Pressure ("Hg)
210	4	10		Clear	5	-4	3059

Air Speed (kts)	Altitude AGL (ft)	Altitude MSL (ft)	Airfield Elevation (ft)
150	8,200	8,379	319

Settings

Point Spacing (m)	Point Density (ppsm)	Scan Angle/FOV (°)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power (%)
0.7		40	90	600	100

Verify S-Turns Before Mission: Yes

Line #	Direction	Start Time (UTC)	End Time (UTC)	Time On-Line	Satellite	PDOP	Line Notes/Comments
89	N	17:33:00	17:37:00	00:04:00	20	1.4	
88	S	17:40:00	17:50:00	00:10:00	21	1.1	
87	N	17:53:00	18:03:00	00:10:00	24	1	
86	S	18:06:00	18:16:00	00:10:00	22	1.1	
85	N	18:19:00	18:29:00	00:10:00	20	1.2	
84	S	18:31:00	18:41:00	00:10:00	19	1.3	
83	N	18:44:00	18:54:00	00:10:00	19	1.3	
82	S	18:57:00	19:06:00	00:09:00	22	1.2	
81	N	19:10:00	19:20:00	00:10:00	21	1.2	
80	S	19:23:00	19:33:00	00:10:00	19	1.2	
79	N	19:35:00	19:45:00	00:10:00	16	1.4	
78	S	19:48:00	19:59:00	00:11:00	18	1.2	
77	N	20:02:00	20:13:00	00:11:00	18	1.2	
76	S	20:15:00	20:28:00	00:13:00	19	1.1	
75	N	20:31:00	20:45:00	00:14:00	19	1.1	
74	S	20:48:00	21:01:00	00:13:00	18	1.2	
73	N	21:04:00	21:18:00	00:14:00	18	1.2	
72	S	21:21:00	21:34:00	00:13:00	15	1.6	
71	N	21:37:00	21:50:00	00:13:00	16	1.2	
70	S	21:53:00	22:06:00	00:13:00	19	1.1	
69	N	22:09:00	22:23:00	00:14:00	19	1.1	
68	S	22:26:00	22:39:00	00:13:00	19	1.2	
67	N	22:42:00	22:58:00	00:16:00	19	1.3	
66	S	23:00:00	23:14:00	00:14:00	22	1.2	

Verify S-Turns After Mission: Yes

Additional Comments

Woolpert Lidar Acquisition Log

Project Info			Date		
Project #	Project Name	Unique ID	Flight Date (UTC)	Day of Year	Flight #
79576	West TN South Block	Day357_90513_1	12/23/2019	357	1

Crew	Equipment	Time			Airports
Pilot	Aircraft Make / Model / Tail #	Hobbs Start	Local Start	UTC Start	Departing
LaRocque	Cessna 404 Titan - N7079F	2474.2	11:49:00	17:49:00	MKL
Operator	Sensor Make / Model / Serial #	Hobbs End	Local End	UTC End	Arriving
Kennedy	Leica Terrain Mapper - 90513	2478.3	15:56:00	21:56:00	MKL

Conditions

Wind Dir (°)	Wind Speed (kts)	Visibility (mi)	Ceiling (ft)	Cloud Cover	Temp. (°C)	Dew Point (°C)	Pressure ("Hg)
40	7	10		Clear	16	8	30.06

Air Speed (kts)	Altitude AGL (ft)	Altitude MSL (ft)	Airfield Elevation (ft)
150	8,200	8,397	434

Settings

Point Spacing (m)	Point Density (ppsm)	Scan Angle/FOV (°)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power (%)
0.7		40	90	600	100

Verify S-Turns Before Mission: Yes

Line #	Direction	Start Time (UTC)	End Time (UTC)	Time On-Line	Satellite	PDOP	Line Notes/Comments
81	N	18:07:00	18:20:00	00:13:00	19	1.2	
82	S	18:23:00	18:35:00	00:12:00	20	1.1	
83	N	18:38:00	18:51:00	00:13:00	19	1.1	
84	S	18:54:00	19:06:00	00:12:00	18	1.2	
85	N	19:09:00	19:22:00	00:13:00	18	1.4	
86	S	19:25:00	19:37:00	00:12:00	17	1.4	
87	N	19:40:00	19:53:00	00:13:00	20	1.1	
88	S	19:56:00	20:09:00	00:13:00	19	1.3	
89	N	20:11:00	20:24:00	00:13:00	18	1.2	
90	S	20:27:00	20:39:00	00:12:00	16	1.6	
91	N	20:42:00	20:55:00	00:13:00	16	1.7	
92	S	20:58:00	21:11:00	00:13:00	18	1.3	
93	N	21:14:00	21:27:00	00:13:00	18	1.2	
94	S	21:30:00	21:42:00	00:12:00	20	1.1	

Verify S-Turns After Mission: Yes

Additional Comments

Woolpert Lidar Acquisition Log

Project Info			Date		
Project #	Project Name	Unique ID	Flight Date (UTC)	Day of Year	Flight #
79576	West TN South Block	Day358_90513_1	12/24/2019	358	1

Crew	Equipment	Time			Airports
Pilot	Aircraft Make / Model / Tail #	Hobbs Start	Local Start	UTC Start	Departing
LaRocque	Cessna 404 Titan - N7079F	2478.7	10:00:00	16:00:00	MKL
Operator	Sensor Make / Model / Serial #	Hobbs End	Local End	UTC End	Arriving
Kennedy	Leica Terrain Mapper - 90513	2482.7	14:15:00	20:15:00	MKL

Conditions

Wind Dir (°)	Wind Speed (kts)	Visibility (mi)	Ceiling (ft)	Cloud Cover	Temp. (°C)	Dew Point (°C)	Pressure ("Hg)
0	0	10		Clear	9	6	30.12

Air Speed (kts)	Altitude AGL (ft)	Altitude MSL (ft)	Airfield Elevation (ft)
150	8,200	8,397	434

Settings

Point Spacing (m)	Point Density (ppsm)	Scan Angle/FOV (°)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power (%)
0.7		40	90	600	100

Verify S-Turns Before Mission: Yes

Line #	Direction	Start Time (UTC)	End Time (UTC)	Time On-Line	Satellite	PDOP	Line Notes/Comments
95	N	16:19:00	16:33:00	00:14:00	21	1.2	
96	S	16:35:00	16:49:00	00:14:00	21	1.1	
97	N	16:52:00	17:07:00	00:15:00	21	1	
98	S	17:10:00	17:25:00	00:15:00	19	1.1	
99	N	17:29:00	17:46:00	00:17:00	18	1.2	
100	S	17:49:00	18:06:00	00:17:00	20	1.2	
101	N	18:08:00	18:25:00	00:17:00	21	1.1	
102	S	18:28:00	18:45:00	00:17:00	20	1.1	
103	N	18:48:00	19:05:00	00:17:00	16	1.4	
104	S	19:07:00	19:24:00	00:17:00	16	1.5	
105	N	19:27:00	19:44:00	00:17:00	17	1.4	
106	S	19:46:00	20:06:00	00:20:00	17	1.3	

Verify S-Turns After Mission: Yes

Additional Comments

Woolpert Lidar Acquisition Log

Project Info			Date		
Project #	Project Name	Unique ID	Flight Date (UTC)	Day of Year	Flight #
79576	West TN South Block	Day364_90513_1	12/30/2019	364	1

Crew	Equipment	Time			Airports
Pilot	Aircraft Make / Model / Tail #	Hobbs Start	Local Start	UTC Start	Departing
LaRocque	Cessna 404 Titan - N7079F	2487.3	13:01:00	19:01:00	MKL
Operator	Sensor Make / Model / Serial #	Hobbs End	Local End	UTC End	Arriving
Kennedy	Leica Terrain Mapper - 90513	2488.9	14:34:00	20:34:00	MKL

Conditions

Wind Dir (°)	Wind Speed (kts)	Visibility (mi)	Ceiling (ft)	Cloud Cover	Temp. (°C)	Dew Point (°C)	Pressure ("Hg)
240	16	10		Clear	9	2	29.9

Air Speed (kts)	Altitude AGL (ft)	Altitude MSL (ft)	Airfield Elevation (ft)
150	8,200	8,397	434

Settings

Point Spacing (m)	Point Density (ppsm)	Scan Angle/FOV (°)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power (%)
0.7		40	90	600	100

Verify S-Turns Before Mission: Yes

Line #	Direction	Start Time (UTC)	End Time (UTC)	Time On-Line	Satellite	PDOP	Line Notes/Comments
107	N	19:20:00	19:37:00	00:17:00	17	1.3	
108	S	19:40:00	19:52:00	00:12:00	18	1.2	
69	N	20:08:00	20:21:00	00:13:00	15	1.6	frequent clouds/flooding on the ground

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Verify S-Turns After Mission: Yes

Additional Comments

Woolpert Lidar Acquisition Log

Project Info			Date		
Project #	**Project Name**	**Unique ID**	**Flight Date (UTC)**	**Day of Year**	**Flight #**
79576	West TN North Block	Day365_90513_1	12/31/2019	365	1

Crew	Equipment	Time			Airports
Pilot	**Aircraft Make / Model / Tail #**	**Hobbs Start**	**Local Start**	**UTC Start**	**Departing**
LaRocque	Cessna 404 Titan - N7079F	2488.9	09:04:00	15:04:00	MKL
Operator	**Sensor Make / Model / Serial #**	**Hobbs End**	**Local End**	**UTC End**	**Arriving**
Kennedy	Leica Terrain Mapper - 90513	2491.6	11:48:00	17:48:00	MKL

Conditions

Wind Dir (°)	Wind Speed (kts)	Visibility (mi)	Ceiling (ft)	Cloud Cover	Temp. (°C)	Dew Point (°C)	Pressure ("Hg)
280	16	10		Clear	4	-3	30.1

Air Speed (kts)	Altitude AGL (ft)	Altitude MSL (ft)	Airfield Elevation (ft)
150	8,200	8,397	434

Settings

Point Spacing (m)	Point Density (ppsm)	Scan Angle/FOV (°)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power (%)
0.7		40	90	600	100

Verify S-Turns Before Mission: Yes

Line #	Direction	Start Time (UTC)	End Time (UTC)	Time On-Line	Satellite	PDOP	Line Notes/Comments
65	N	15:19:00	15:34:00	00:15:00	17	1.5	moderate flooding on ground, all lines
64	S	15:37:00	15:51:00	00:14:00	21	1.1	
63	N	15:54:00	16:08:00	00:14:00	18	1.3	
62	S	16:21:00	16:25:00	00:04:00	20	1	
61	N	16:28:00	16:43:00	00:15:00	20	1	
60	S	16:46:00	17:00:00	00:14:00	21	1	
59	N	17:03:00	17:17:00	00:14:00	18	1.3	
58	S	17:20:00	17:34:00	00:14:00	18	1.2	
	S						

Verify S-Turns After Mission: Yes

Additional Comments

Woolpert Lidar Acquisition Log

Project Info			Date		
Project #	Project Name	Unique ID	Flight Date (UTC)	Day of Year	Flight #
79576	West TN North Block	Day033_90513_1	02/02/2020	033	1

Crew	Equipment	Time			Airports
Pilot	Aircraft Make / Model / Tail #	Hobbs Start	Local Start	UTC Start	Departing
Swain	Cessna 404 Titan - N532NM	460.7	09:46:00	15:46:00	MKL
Operator	Sensor Make / Model / Serial #	Hobbs End	Local End	UTC End	Arriving
Kennedy	Leica Terrain Mapper - 90513	465.7	14:47:00	20:47:00	MKL

Conditions

Wind Dir (°)	Wind Speed (kts)	Visibility (mi)	Ceiling (ft)	Cloud Cover	Temp. (°C)	Dew Point (°C)	Pressure ("Hg)
220	12	10		Clear	12	1	29.98

Air Speed (kts)	Altitude AGL (ft)	Altitude MSL (ft)	Airfield Elevation (ft)
150	8,200	8,397	434

Settings

Point Spacing (m)	Point Density (ppsm)	Scan Angle/FOV (°)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power (%)
0.7		40	90	600	100

Verify S-Turns Before Mission: Yes

Line #	Direction	Start Time (UTC)	End Time (UTC)	Time On-Line	Satellite	PDOP	Line Notes/Comments
57	N	16:01:00	16:16:00	00:15:00	16	1.3	
56	S	16:19:00	16:34:00	00:15:00	17	1.2	
55	N	16:37:00	16:51:00	00:14:00	19	1.2	
54	S	16:54:00	17:09:00	00:15:00	19	1.3	
53	N	17:11:00	17:26:00	00:15:00	21	1.1	
52	S	17:28:00	17:43:00	00:15:00	20	1.2	
51	N	17:46:00	18:00:00	00:14:00	18	1.5	
50	S	18:03:00	18:18:00	00:15:00	21	1.2	
49	N	18:20:00	18:34:00	00:14:00	21	1.2	
48	S	18:37:00	18:51:00	00:14:00	21	1.2	
47	N	18:54:00	19:08:00	00:14:00	20	1.4	
46	S	19:11:00	19:26:00	00:15:00	23	1.1	
45	N	19:28:00	19:42:00	00:14:00	23	1.2	
44	S	19:45:00	20:00:00	00:15:00	23	1.2	
43	N	20:03:00	20:17:00	00:14:00	22	1.1	
42	S	20:19:00	20:34:00	00:15:00	21	1.1	

Verify S-Turns After Mission: Yes

Additional Comments