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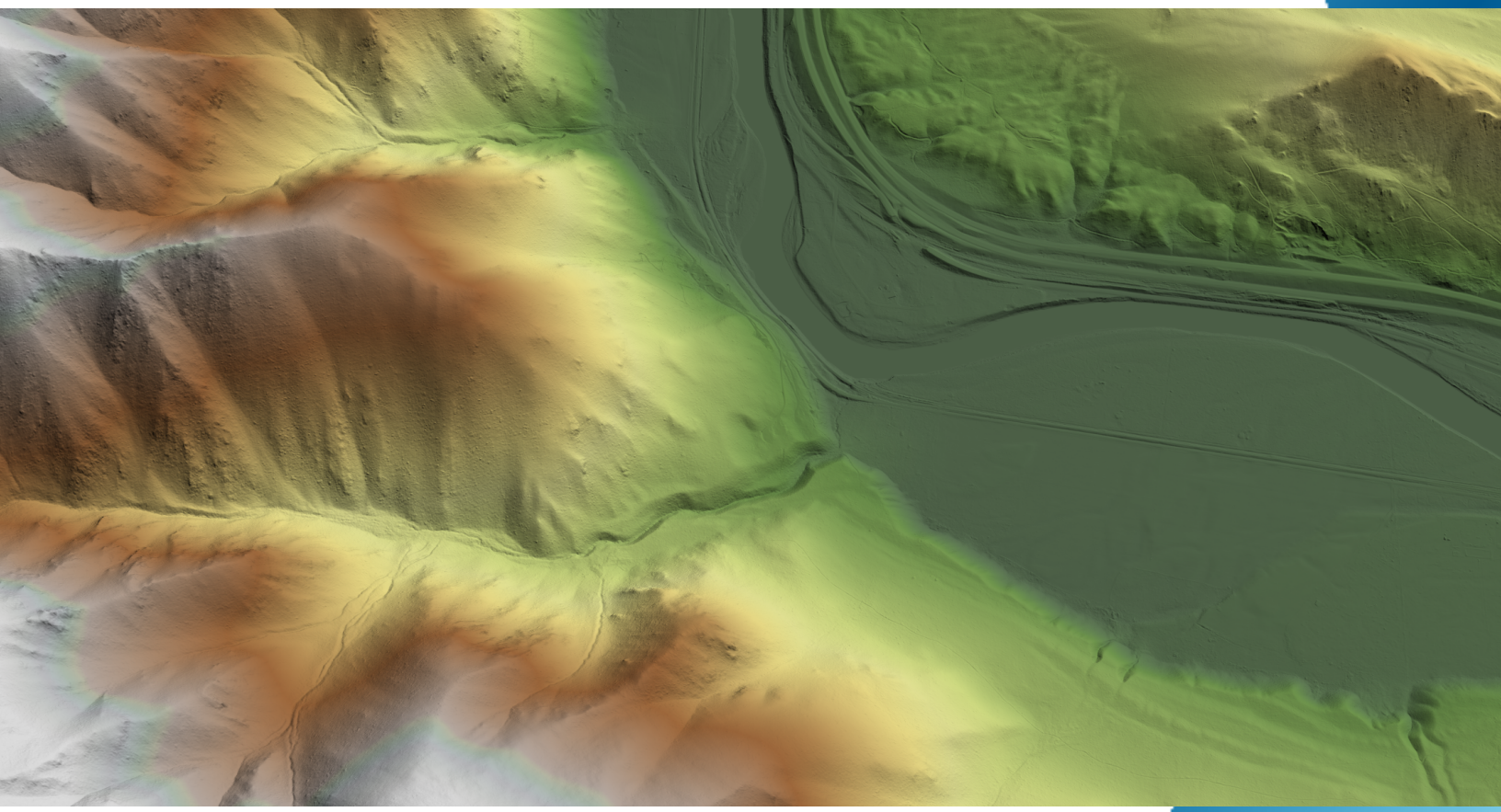

MT Statewide Phase 4 B22 LIDAR PROCESSING REPORT

2023

Submitted: May 1, 2023

Project ID: 231442
Work Unit: 300218

Prepared for:

USGS
science for a changing world

Prepared by:

NV5 GEOSPATIAL

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1. Summary / Scope

1.1. Summary

This report contains a summary of the MT Statewide Phase 4 Delivery 2, Work Unit 300218 lidar acquisition task order, issued by USGS under their Contract 140G0221D0016 on 5/27/2022. The task order yielded a work unit area covering 3850 square miles over Montana at Quality Level 2. The intent of this document is only to provide specific validation information for the data acquisition/collection, processing, and production of deliverables completed as specified in the task order.

1.2. Scope

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

Table 1. Originally Planned Lidar Specifications

Average Point Density	Flight Altitude (AGL)	Field of View	Minimum Side Overlap	RMSEz
2 pts / m2	3050 m	58.5°	30%	≤ 10 cm

1.3. Coverage

The work unit boundary covers 3850 square miles over Montana. Work unit extents are shown in Figure 1.

1.4. Duration

Lidar data was acquired from 7/30/2022 to 9/17/2022 in 15 total lifts. See “Section: 2.4. Time Period” for more details.

1.5. Issues

Tiles 432264 and 436259 are void of points; they are in open water. Additionally, tiles 436261 and 435259 are empty due to being outside the AOI.

MT Statewide Phase 4 Delivery 2 Work Unit 300218 Projected Coordinate System: State Plane Montana FIPS 2500 Horizontal Datum: NAD83 (2011) Vertical Datum: NAVD88 (GEOID 18) Units: Meters	
Lidar Point Cloud	Classified Point Cloud in .LAS 1.4 format
Rasters	• 1-meter Hydro-flattened Bare Earth Digital Elevation Model (DEM) in GeoTIFF format • 1-meter Intensity images in GeoTIFF format • 2-meter Maximum Surface Height Raster • 2-meter Swath Separation Images
Vectors	Shapefiles (*.shp) • Project Boundary • Lidar Tile Index • Contours Geodatabase (*.gdb) • Continuous Hydro-flattened Breaklines
Reports	Reports in PDF format • Focus on Delivery • Survey Report • Processing Report
Metadata	XML Files (*.xml) • Breaklines • Classified Point Cloud • DEM • Intensity Imagery • Contours

MT Statewide Phase 4 Delivery 2
Work Unit 300218 Boundary

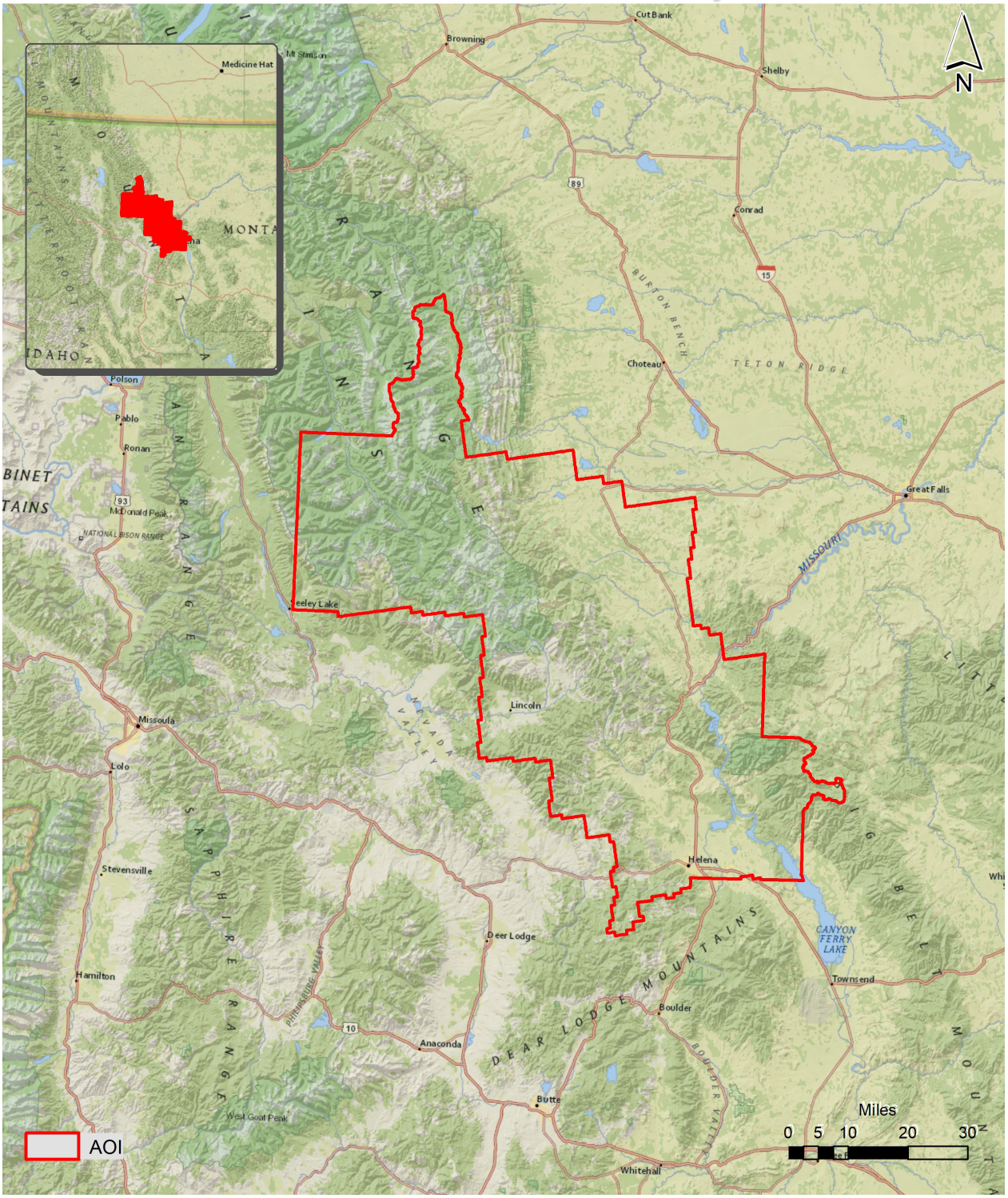


Figure 1. Work Unit Boundary

2. Planning / Equipment

2.1. Flight Planning

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

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

2.2. Lidar Sensor

NV5 Geospatial utilized Riegl VQ-1560ii lidar sensors (Figure 2), serial number(s) 3061, 4046, and 4892 for data acquisition.

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

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

Table 2. Lidar System Specifications

		Riegl VQ1560ii (SN3061)	Riegl VQ1560ii (SN4046)	Riegl VQ1560ii (SN4892)
Terrain and Aircraft Scanner	Flying Height	3050 m	3050 m	3050 m
	Recommended Ground Speed	145 kts	145 kts	145 kts
Scanner	Field of View	58.5°	58.5°	58.5°
	Scan Rate Setting Used	2 x 130 lps	2 x 130 lps	2 x 130 lps
Laser	Laser Pulse Rate Used	2 x 780 kHz	2 x 780 kHz	2 x 780 kHz
	Multi Pulse in Air Mode	YES	YES	YES
Coverage	Full Swath Width	3416 m	3416 m	3416 m
	Line Spacing	0.56 m	0.56 m	0.56 m
Point Spacing and Density	Average Point Spacing	0.71 m	0.71 m	0.71 m
	Average Point Density	2 pts / m^2	2 pts / m^2	2 pts / m^2

Figure 2. Riegl VQ-1560ii Lidar Sensor

2.3. Aircraft

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

Lidar Collection Planes

- CESSNA 208B, Tail Numbers: N704MD, N22TE
- CESSNA 208, Tail Number: N840JA

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

Figure 3. NV5 Geospatial's Aircraft

2.4. Time Period

Project specific flights were conducted between 7/30/2022 and 9/17/2022. Fifteen aircraft lifts were completed. Accomplished lifts are listed below.

Lift	Start UTC	End UTC
07302022A (SN3061, N704MD) 7/30/2022 UTC	7/30/2022 5:09:41 PM	7/30/2022 7:27:13 PM
07312022A (SN3061, N704MD) 7/31/2022 UTC	7/31/2022 4:59:50 PM	7/31/2022 6:37:39 PM
08022022A (SN3061, N704MD) 8/2/2022 UTC	8/02/2022 5:28:18 PM	8/02/2022 5:32:56 PM
08032022A (SN3061, N704MD) 8/3/2022 UTC	8/03/2022 3:17:44 PM	8/03/2022 6:14:38 PM
08092022A (SN4892, N22TE) 8/9/2022 UTC	8/09/2022 4:26:29 PM	8/09/2022 7:59:33 PM
08142022A (SN4892, N22TE) 8/14/2022 UTC	8/14/2022 7:22:24 PM	8/14/2022 8:44:33 PM
08152022A (SN4892, N22TE) 8/15/2022 UTC	8/15/2022 3:06:19 PM	8/15/2022 8:15:32 PM
08162022A (SN4892, N22TE) 8/16/2022 UTC	8/16/2022 2:56:37 PM	8/16/2022 8:11:15 PM
08172022A (SN4892, N22TE) 8/17/2022 UTC	8/17/2022 2:51:56 PM	8/17/2022 7:45:33 PM
08182022A (SN4892, N22TE) 8/18/2022 UTC	8/18/2022 4:26:59 PM	8/18/2022 6:57:21 PM
08192022A (SN4892, N22TE) 8/19/2022 UTC	8/19/2022 2:32:33 PM	8/19/2022 6:17:37 PM
08202022A (SN4892, N22TE) 8/20/2022 UTC	8/20/2022 5:48:35 PM	8/20/2022 6:51:13 PM
08222022A (SN4892, N22TE) 8/22/2022 UTC	8/22/2022 1:33:30 PM	8/22/2022 4:53:11 PM
08312022A (SN4046, N840JA) 8/31/2022 UTC	8/31/2022 8:55:34 PM	8/31/2022 9:20:51 PM
09172022A (SN4046, N840JA) 9/17/2022 UTC	9/17/2022 5:10:09 PM	9/17/2022 5:26:56 PM

3. Processing Summary

3.1. Flight Logs

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

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

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

3.2. Lidar Processing

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

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

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

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

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

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

3.3. LAS Classification Scheme

The classification classes are determined by Lidar Base Specifications 2021, Revision A and are an industry standard for the classification of lidar point clouds. All data starts the process as Class 1 (Unclassified), and then through automated classification routines, the classifications are determined using TerraScan macro processing.

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

Table 3. LAS Classifications

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

3.4. Classified LAS Processing

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

All ground (ASPRS Class 2) lidar data inside of the Lake Pond and Double Line Drain hydro flattening breaklines were then classified to water (ASPRS Class 9) using proprietary tools. A buffer of 3 feet/1 meter was also used around each hydro flattened feature to classify these ground (ASPRS Class 2) points to Ignored ground (ASPRS Class 20). All Lake Pond Island and Double Line Drain Island features were checked to ensure that the ground (ASPRS Class 2) points were reclassified to the correct classification after the automated classification was completed.

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

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

3.5. Hydro-Flattened Breakline Processing

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

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

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

3.6. Hydro-Flattened Raster DEM Processing

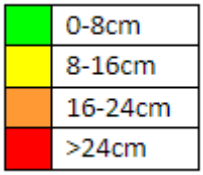
Hydro-Flattened DEMs (topographic) represent a lidar-derived product illustrating the grounded terrain and associated breaklines (as described above) in raster form. NV5 Geospatial's proprietary software was used to take all input sources (bare earth lidar points, bridge and hydro breaklines, etc.) and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

3.7. Intensity Image Processing

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

3.8. Swath Separation Raster Processing

Swath Separation Images are rasters that represent the interswath alignment between flight lines and provide a qualitative evaluation of the positional quality of the point cloud. NV5 Geospatial proprietary software generated 1-meter cell size raster images in GeoTIFF format using last returns, excluding points flagged with the withheld bit, and using a point-in-cell algorithm. Images are generated with a 75% intensity opacity and (4) absolute 8-cm intervals, see below for interval coloring. Intensity images are linearly scaled to a value range specific to the project area to standardize the images and reduce differences between individual tiles. Appropriate horizontal projection information as well as applicable header values are written to the file during product generation. NV5 Geospatial uses a proprietary tool called FOCUS on Delivery to check all formatting requirements of the images against what is required before final delivery.



3.9. Maximum Surface Height Raster Processing

Maximum Surface Height rasters (topographic) represent a lidar-derived product illustrating natural and built-up features. NV5 Geospatial's proprietary software was used to take all first-return classified lidar points, excluding those flagged with a withheld bit, and create a raster on a tile-by-tile basis. Data extending past the tile edge is incorporated in this process so that proper gridding can occur. The raster product is then clipped back to the tile edge so that no overlapping cells remain across the project area. A 32-bit floating point GeoTIFF was generated for each tile with a pixel size of 2 meter cell size. NV5 Geospatial's proprietary software was used to write appropriate horizontal and vertical projection information as well as applicable header values into the file during product generation. Each maximum surface height raster is reviewed in Global Mapper to check for any anomalies and to ensure a seamless dataset. NV5 Geospatial uses a proprietary tool called FOCUS on Delivery to check all formatting requirements of the DEMs against what is required before final delivery.

3.10. Contour Processing

Automated routines within TerraScan and TerraModeler generate an educated, thinned subset of bare earth points (ASPRS Class 8, Model Key). Model Key points and hydro-flattened breaklines were used to generate a terrain surface from which 1-foot contours could be generated. Using proprietary software, all tiled contour shapefiles were combined into one, continuous dataset within an Esri File Geodatabase. All lines have their elevations as their attributes and there are no spot elevations or depressions on separate layers.,

MT Statewide Phase 4 Delivery 2
Work Unit 300218 Tile Layout

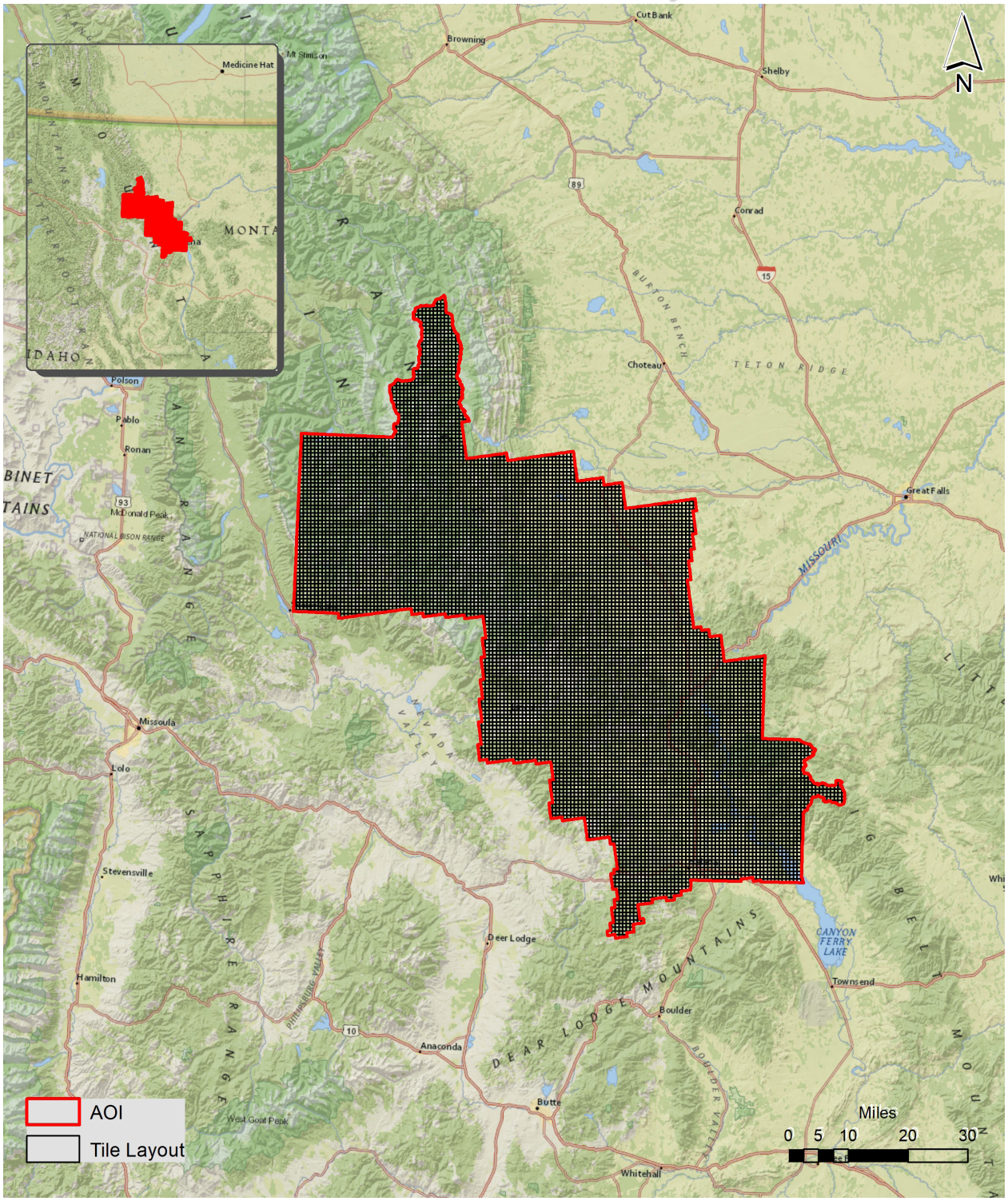


Figure 4. Tile Layout

4. Project Coverage Verification

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

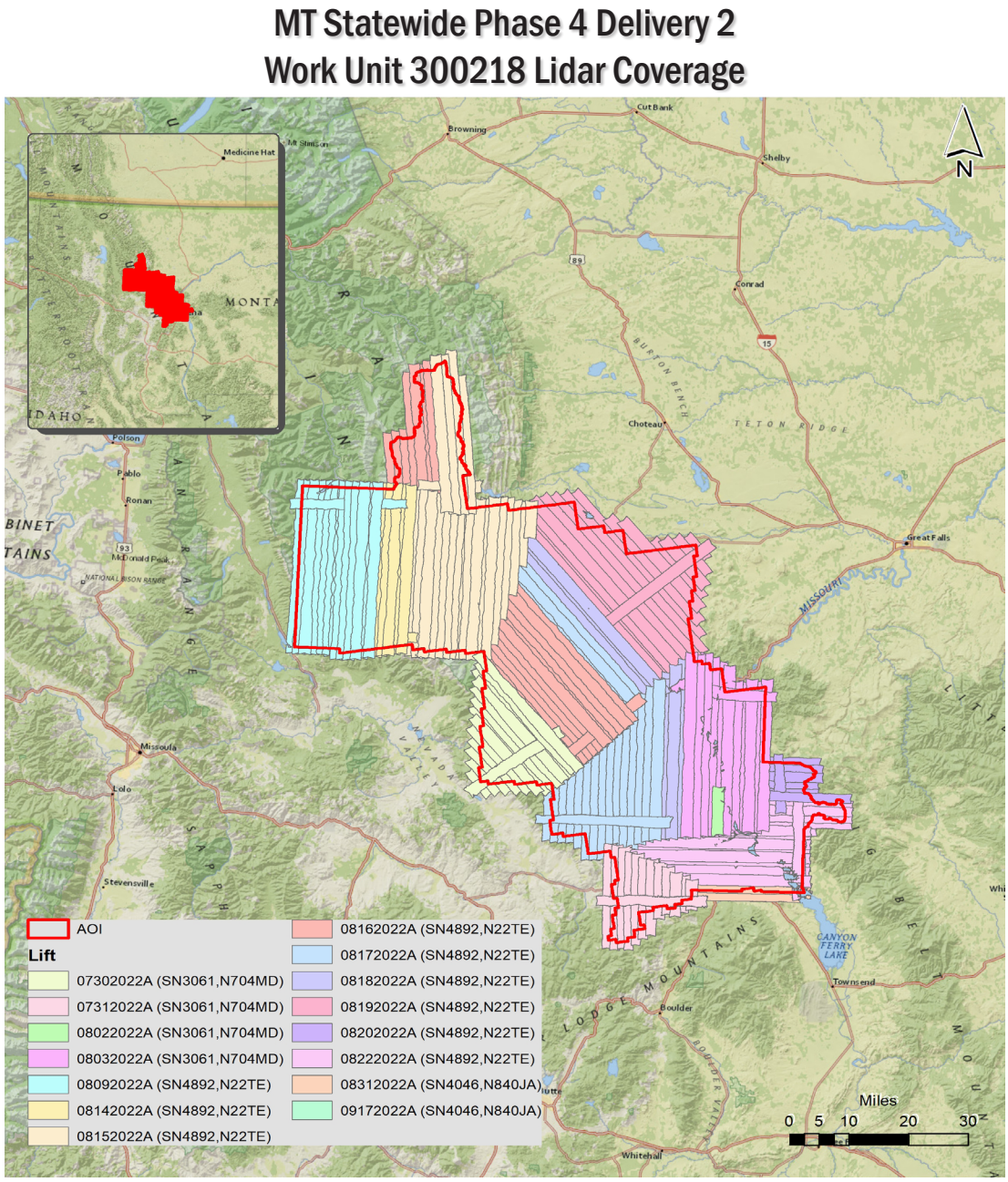


Figure 5. Lidar Coverage

5. Geometric Accuracy

5.1. Horizontal Accuracy

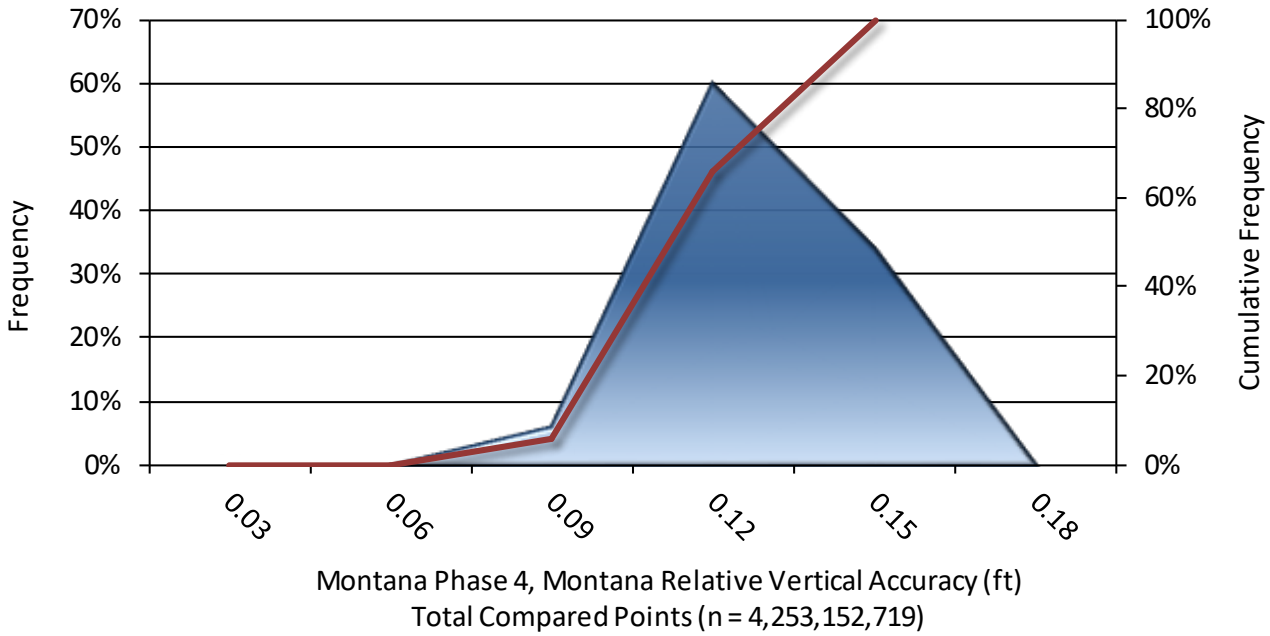
Lidar horizontal accuracy is a function of Global Navigation Satellite System (GNSS) derived positional error, flying altitude, and INS derived attitude error. The obtained $RMSE_r$ value is multiplied by a conversion factor of 1.7308 to yield the horizontal component of the National Standards for Spatial Data Accuracy (NSSDA) reporting standard where a theoretical point will fall within the obtained radius 95% of the time. Based on a flying altitude of 3050 meters, an IMU error of 0.002 decimal degrees, and a GNSS positional error of 0.019 meters, this project was compiled to meet 0.19 meter horizontal accuracy at the 95% confidence level. A summary is shown below.

Horizontal Accuracy	
$RMSE_r$	0.63 ft
	0.19 m
ACC_r	1.09 ft
	0.33 m

5.2. Relative Vertical Accuracy

Relative vertical accuracy refers to the internal consistency of the data set as a whole: the ability to place an object in the same location given multiple flight lines, GPS conditions, and aircraft attitudes. When the lidar system is well calibrated, the swath-to-swath vertical divergence is low (<0.10 meters). The relative vertical accuracy was computed by comparing the ground surface model of each individual flight line with its neighbors in overlapping regions. The average (mean) line to line relative vertical accuracy for the MT Statewide Phase 4 Delivery 2 project was 0.110 feet (0.034 meters). A summary is shown below.

Relative Vertical Accuracy	
Sample	152 flight line surfaces
Average	0.110 ft
	0.034 m
Median	0.117 ft
	0.036 m
RMSE	0.114 ft
	0.035 m
Standard Deviation (1σ)	0.012 ft
	0.004 m
1.96σ	0.023 ft
	0.007 m



Project Report Appendices

The following section contains the appendices as listed in the MT Statewide Phase 4 Delivery 2 Lidar Project Report.

Appendix A

Flight Logs

Project	947122-R040220.00	MT_Statewide_Phase4
Flightplan	MT_Statewide4_1560iiS_QL2_200	

Mission Name	S2223061_20220730_F1
Mission Date	7/30/2022
Aircraft	N704MD
Pilot	Creston Saul
Co-Pilot	
Operator	Stephanie Cohee
Co-Operator	
Vendor	NV5 Geospatial
Base Airport	KMSO
Departure (Local Time)	7:59:00 AM
Arrival (Local Time)	1:54:00 PM

Mission Notes

Successful acq of priority lines. once finished with those we moved E of Missoula and acquired until turbulence was to much.

Line	Heading	Start Time (UTC)	Stop Time (UTC)	Speed (kt)	Notes
00231	SE	14:30:28	14:44:17	137.6	
00230	NW	14:46:30	15:01:08	127.3	
00229	SE	15:03:13	15:16:47	137.3	
00228	NW	15:18:51	15:33:13	129.5	
00227	SE	15:35:52	15:49:24	137.8	
00226	NW	15:51:22	16:05:54	128.2	
00225	SE	16:07:48	16:20:20	139.2	
00224	NW	16:22:46	16:29:33	131.0	xline 163235 record09
00223	E	16:32:35	16:36:56	144.9	
00249	SE	17:09:40	17:11:44	140.0	
00250	NW	17:14:12	17:17:24	125.5	
00251	SE	17:20:29	17:24:18	143.4	
00252	NW	17:26:55	17:32:13	125.2	
00253	SE	17:35:35	17:41:29	137.2	
00254	NW	17:44:01	17:51:27	125.5	
00255	SE	17:54:15	18:01:48	140.2	
00256	NW	18:03:48	18:12:51	124.3	
00257	SE	18:15:18	18:24:06	138.0	
00258	NW	18:26:28	18:36:07	129.4	moderate turbulence
00259	SE	18:38:59	18:48:46	136.1	Refly 11-15 statute miles FNE due to loss of density from turbulence.
00260	NW	18:50:56	19:01:37	126.2	moderate turbulence
00261	SE	19:04:15	19:14:33	138.6	Refly 0-21 statute miles FNE due to loss of density from turbulence. xline 192000 record023
00262	SW	19:20:00	19:27:13	137.5	

Project	947122-R040220.00	MT_Statewide_Phase4
Flightplan	MT_Statewide4_1560iiS_QL2_200	

Mission Name	S2223061_20220731_F1
Mission Date	7/31/2022
Aircraft	N704MD
Pilot	Creston Saul
Co-Pilot	
Operator	Stephanie Cohee
Co-Operator	
Vendor	NV5 Geospatial
Base Airport	KBZN
Departure (Local Time)	7:50:00 AM
Arrival (Local Time)	1:05:00 PM

Mission Notes

Mobed to south AOI from KMSO and started on a block south of Butte, MT. There was heavy smoke from local wildfires on the south half of the line, but the returns were still good. We eventually ran into heavy turbulence on that block and then moved to a block located right over Butte and finished that block. Good day of acq.

Line	Heading	Start Time (UTC)	Stop Time (UTC)	Speed (kt)	Notes
00478	S	14:24:13	14:40:05	129.4	heavy smoke on south half of lines
00479	N	14:42:26	14:58:01	131.6	
00480	S	15:00:44	15:16:05	133.7	
00481	N	15:18:13	15:34:26	128.0	
00482	S	15:37:23	15:53:51	131.2	
00483	N	15:56:10	16:13:09	127.0	
00484	S	16:15:40	16:31:11	138.1	
00485	N	16:34:23	16:51:54	122.6	Refly 15-20 statute miles FNE due to density loss from turbulence. heavy turb on midline to north end
00541	N	16:59:49	17:07:52	123.8	
00542	S	17:10:16	17:17:40	134.6	
00543	N	17:19:35	17:27:04	129.3	
00544	S	17:29:13	17:35:59	137.6	
00545	N	17:37:59	17:44:58	124.7	
00546	S	17:46:35	17:52:34	127.9	
00547	N	17:54:19	18:00:07	124.4	
00548	S	18:02:34	18:06:29	130.8	
00549	N	18:08:20	18:11:54	125.5	moderate turbulence
00550	S	18:14:19	18:17:28	129.8	
00551	N	18:19:05	18:21:50	128.2	
00552	S	18:23:51	18:25:52	140.3	
00553	SW	18:29:54	18:37:39	122.9	xline 182954W record021

Project	947122-R040220.00	MT_Statewide_Phase4
Flightplan	MT_Statewide4_1560iiS_QL2_200	

Mission Name	S2223061_20220802_F1
Mission Date	8/2/2022
Aircraft	N704MD
Pilot	Creston Saul
Co-Pilot	
Operator	Stephanie Cohee
Co-Operator	
Vendor	NV5 Geospatial
Base Airport	KBZN
Departure (Local Time)	8:32:00 AM
Arrival (Local Time)	12:08:00 PM

Mission Notes

Poor weather conditions today. We flew what we could that was cloud and snow free. Attempted north block near Helena, but down drafts, turbulence and clouds kick us out.

Line	Heading	Start Time (UTC)	Stop Time (UTC)	Speed (kt)	Notes
00501	SW	15:02:18	15:09:20	125.1	
00502	NE	15:12:04	15:17:47	154.6	
00502	SW	15:21:16	15:28:41	118.7	refly. too fast
00503	NE	15:30:46	15:40:05	140.8	
00538	SE	15:48:45	16:04:09	136.5	
00539	NW	16:06:51	16:24:06	114.8	
00540	SE	16:26:00	16:37:21	138.0	
00541	NE	16:41:45	16:43:56	151.2	xline 164145 E record08
00642	N	17:28:17	17:32:55	95.5	slow due to heavy down draft. turb. aborted. refly

Project	947122-R040220.00	MT_Statewide_Phase4
Flightplan	MT_Statewide4_1560iiS_QL2_200	

Mission Name	S2223061_20220803_F1	**Mission Notes**
Mission Date	8/3/2022	One lift today under good conditions.
Aircraft	N704MD	
Pilot	Creston Saul	
Co-Pilot		
Operator	Steve Krohn	
Co-Operator		
Vendor	NV5 Geospatial	
Base Airport	KBZN	
Departure (Local Time)	8:38:00 AM	
Arrival (Local Time)	12:50:00 PM	

Line	Heading	Start Time (UTC)	Stop Time (UTC)	Speed (kt)	Notes
00638	N	12:00:00	12:30:00		175137 348 degrees
00639	N	12:00:00	12:30:00		173431 168 degrees
00640	N	12:00:00	12:30:00		171809 348 degrees
00641	N	12:00:00	12:30:00		170220 168 degrees
00642	N	12:00:00	12:30:00		Refly 0-15 statute miles FNE due to Channel 2 dropout causing lack of density. 164550 348 degrees Reflight of partial line flown on 08-2
00643	N	12:00:00	12:30:00		162954 168 degrees
00644	N	12:00:00	12:30:00		161448 348 degrees
00645	N	12:00:00	12:30:00		160048 168 degrees
00646	N	12:00:00	12:30:00		154600 348 degrees
00647	N	12:00:00	12:30:00		153209 168 degrees
00648	N	12:00:00	12:30:00		151743 348 degrees

Project	947122-R040220.00	MT_Statewide_Phase4
Flightplan	MT_Statewide4_1560iiS_QL2_200	

Mission Name	SN4892_20220809_F1
Mission Date	8/9/2022
Aircraft	N22TE
Pilot	Mikhail Dekanu
Co-Pilot	
Operator	Justen Maxey
Co-Operator	
Vendor	NV5 Geospatial
Base Airport	KSFF
Departure (Local Time)	8:15:00 AM
Arrival (Local Time)	2:05:00 PM

Mission Notes

Good flight. Only issue is that there is still oil leaking down the belly and getting on the back lens during flight.

Line	Heading	Start Time (UTC)	Stop Time (UTC)	Speed (kt)	Notes
00585	N	16:26:28	16:38:51	134.2	
00586	S	16:41:43	16:53:57	135.9	
00587	N	16:57:29	17:09:55	133.6	
00588	S	17:13:08	17:25:24	135.4	
00589	N	17:29:37	17:42:10	132.5	
00590	S	17:45:54	17:58:10	135.7	
00591	N	18:01:22	18:13:48	135.1	
00592	S	18:16:45	18:29:22	135.2	
00593	N	18:32:35	18:45:25	132.7	
00594	S	18:48:29	19:01:16	133.4	
00595	N	19:04:23	19:17:08	133.0	
00596	S	19:19:50	19:32:28	133.7	
00597	N	19:35:25	19:48:00	133.1	
xline	SW	19:52:02	19:59:34	134.2	

Project	947122-R040220.00	MT_Statewide_Phase4
Flightplan	MT_Statewide4_1560iiS_QL2_200	

Mission Name	SN4892_20220814_F1	**Mission Notes**
Mission Date	8/14/2022	We mob'd over from NE WA and flew Phase 4 until fuel was low
Aircraft	N22TE	
Pilot	Mikhail Dekanu	
Co-Pilot		
Operator	Justen Maxey	
Co-Operator	Joel Riggs	
Vendor	NV5 Geospatial	
Base Airport	KMSO	
Departure (Local Time)	8:40:00 AM	
Arrival (Local Time)	3:04:00 PM	

Line	Heading	Start Time (UTC)	Stop Time (UTC)	Speed (kt)	Notes
00598	S	19:22:24	19:35:20	128.8	
00599	N	19:37:41	19:50:39	127.7	
00600	S	19:53:15	20:06:23	125.2	
00601	N	20:09:18	20:22:13	126.4	
00602	S	20:25:14	20:38:01	125.6	
xline	SW	20:41:12	20:44:34	137.3	

Project	947122-R040220.00	MT_Statewide_Phase4
Flightplan	MT_Statewide4_1560iiS_QL2_200	

Mission Name	SN4892_20220815_F1	**Mission Notes**
Mission Date	8/15/2022	Good flight. No issues.
Aircraft	N22TE	
Pilot	Mikhail Dekanu	
Co-Pilot		
Operator	Joel Riggs	
Co-Operator	Justen Maxey	
Vendor	NV5 Geospatial	
Base Airport	KMSO	
Departure (Local Time)	8:30:00 AM	
Arrival (Local Time)	2:45:00 PM	

Line	Heading	Start Time (UTC)	Stop Time (UTC)	Speed (kt)	Notes
00603	N	15:06:19	15:19:04	126.3	
00604	S	15:21:53	15:34:54	123.7	
00605	N	15:37:53	15:50:49	123.4	
00606	S	15:55:15	16:08:13	122.1	
00607	N	16:11:17	16:23:47	125.1	
00608	S	16:27:04	16:39:38	123.4	
00609	N	16:42:17	16:54:25	126.8	
00610	S	16:57:57	17:10:23	122.9	
00611	N	17:13:18	17:25:30	124.9	
00612	S	17:28:34	17:41:04	123.0	
00613	N	17:44:31	17:56:53	125.1	
00614	S	17:59:59	18:12:40	121.8	
00615	N	18:16:08	18:27:20	126.2	
00616	S	18:29:55	18:39:39	119.6	
00617	N	18:43:05	18:50:15	126.7	
00618	S	18:53:07	18:58:22	117.8	
00619	N	19:02:07	19:04:50	127.6	
00584	N	19:11:03	19:21:38	125.2	
00583	S	19:23:16	19:37:53	123.2	
00582	N	19:40:17	19:52:26	125.7	
00581	S	19:55:12	20:07:12	125.0	
xline	SW	20:11:17	20:15:32	127.5	

Project	947122-R040220.00	MT_Statewide_Phase4
Flightplan	MT_Statewide4_1560iiS_QL2_200	

Mission Name	SN4892_20220816_F1	**Mission Notes**
Mission Date	8/16/2022	Smooth day.
Aircraft	N22TE	
Pilot	Mikhail Dekanu	
Co-Pilot		
Operator	Joel Riggs	
Co-Operator	Justen Maxey	
Vendor	NV5 Geospatial	
Base Airport	KMSO	
Departure (Local Time)	8:20:00 AM	
Arrival (Local Time)	2:40:00 PM	

Line	Heading	Start Time (UTC)	Stop Time (UTC)	Speed (kt)	Notes
00580	N	14:56:36	15:07:59	125.4	
00579	S	15:10:28	15:21:29	124.8	
00578	N	15:24:54	15:35:49	123.8	
00577	S	15:38:26	15:48:31	125.2	
00576	N	15:52:04	15:57:35	126.3	
00575	S	16:00:49	16:05:59	127.6	
00574	N	16:08:35	16:13:48	118.5	
00259	SE	16:33:06	16:43:36	125.4	
00261	NW	16:46:53	16:58:33	121.2	
00262	SE	17:01:32	17:13:10	126.6	
00263	NW	17:15:41	17:28:07	121.7	
00264	SE	17:30:43	17:43:04	125.2	
00265	NW	17:45:48	17:58:57	120.2	
00266	SE	18:01:34	18:14:27	125.5	
00267	NW	18:16:57	18:30:29	122.6	
00268	SE	18:33:32	18:46:53	127.1	
00269	NW	18:49:43	19:03:56	122.2	
00270	SE	19:07:05	19:21:12	125.7	
00271	NW	19:25:20	19:40:17	121.1	
00272	SE	19:43:22	19:58:10	125.0	
xline	SW	20:02:18	20:11:15	118.6	xline

Project	947122-R040220.00	MT_Statewide_Phase4
Flightplan	MT_Statewide4_1560iiS_QL2_200	

Mission Name	SN4892_20220817_F1
Mission Date	8/17/2022
Aircraft	N22TE
Pilot	Mikhail Dekanu
Co-Pilot	
Operator	Joel Riggs
Co-Operator	Justen Maxey
Vendor	NV5 Geospatial
Base Airport	KMSO
Departure (Local Time)	8:10:00 AM
Arrival (Local Time)	2:20:00 PM

Mission Notes

A couple misfires and loss of GPS, a couple clouds in our first block, but otherwise a productive smooth day.

Line	Heading	Start Time (UTC)	Stop Time (UTC)	Speed (kt)	Notes
00273	SE	14:51:56	15:06:48	126.8	
00274	NW	15:09:55	15:26:05	118.5	
00275	SE	15:31:05	15:46:34	127.1	
00620	S	15:57:20	16:02:26	124.8	
00621	N	16:05:13	16:11:01	124.3	
00622	NW	16:11:39	16:11:59	121.7	
00622	S	16:14:37	16:20:51	126.3	
00623	N	16:23:41	16:30:37	123.6	
00624	NW	16:31:19	16:31:31	131.1	
00624	S	16:33:48	16:39:23	124.3	
00624	N	16:44:18	16:52:09	125.1	
00625	NW	16:52:48	16:52:54	129.1	
00625	S	16:55:26	17:04:36	125.7	
00626	N	17:07:21	17:17:20	122.6	
00627	S	17:20:54	17:31:14	124.0	
00628	N	17:34:41	17:45:25	124.0	
00629	S	17:48:34	17:55:16	125.7	
00629	N	18:02:52	18:03:03	130.4	
00629	N	18:08:39	18:19:36	124.9	
00630	S	18:22:50	18:33:53	126.3	
00631	N	18:37:11	18:48:27	126.1	
00632	S	18:51:31	19:02:52	126.6	
00633	N	19:06:09	19:18:08	123.7	
00634	NW	19:18:44	19:18:49	144.8	
00634	S	19:21:21	19:33:23	127.4	
xline	SW	19:36:25	19:45:34	128.3	xline

Project	947122-R040220.00	MT_Statewide_Phase4
Flightplan	MT_Statewide4_1560iiS_QL2_200	

Mission Name	SN4892_20220818_F1
Mission Date	8/18/2022
Aircraft	N22TE
Pilot	Ethan Hillmer
Co-Pilot	
Operator	Joel Riggs
Co-Operator	
Vendor	NV5 Geospatial
Base Airport	KHLN
Departure (Local Time)	9:30:00 AM
Arrival (Local Time)	1:15:00 PM

Mission Notes

Ethan Hillmer rotated in as pilot. Had a later start and came back a little early. Got a little turbulent. Otherwise, sky was clear. Finished off the remainder of one block and began another N of Helena.

Line	Heading	Start Time (UTC)	Stop Time (UTC)	Speed (kt)	Notes
00635	N	16:26:59	16:38:37	131.4	
00635	S	16:45:27	16:57:22	134.0	
00636	N	17:00:45	17:13:34	129.3	
00637	S	17:18:35	17:31:19	134.2	
00276	NW	17:44:50	18:00:24	129.9	
00277	SE	18:04:29	18:19:14	138.8	
00278	NW	18:23:40	18:39:35	131.4	
xline	E	18:53:02	18:57:21	146.7	

Project	947122-R040220.00	MT_Statewide_Phase4
Flightplan	MT_Statewide4_1560iiS_QL2_200	

Mission Name	SN4892_20220819_F1	**Mission Notes**
Mission Date	8/19/2022	Completed MT phase 4 block W of Great Falls. Returned due to to complicated visibility from haze and smoke.
Aircraft	N22TE	
Pilot	Ethan Hillmer	
Co-Pilot		
Operator	Joel Riggs	
Co-Operator		
Vendor	NV5 Geospatial	
Base Airport	KHLN	
Departure (Local Time)	8:00:00 AM	
Arrival (Local Time)	12:40:00 PM	

Line	Heading	Start Time (UTC)	Stop Time (UTC)	Speed (kt)	Notes
00279	NW	14:32:33	14:48:23	134.0	
00280	SE	14:52:49	15:08:38	136.8	
00281	NW	15:13:29	15:29:54	132.5	
00282	SE	15:34:08	15:50:09	135.3	
00283	NW	15:54:49	16:10:52	133.0	
00284	SE	16:15:30	16:31:05	133.3	
00285	NW	16:35:23	16:50:02	133.7	
00286	SE	16:54:07	17:07:17	135.1	
00287	NW	17:10:16	17:19:49	134.5	
00288	SE	17:23:11	17:31:18	134.0	
00289	NW	17:34:58	17:40:11	134.8	
00290	SE	17:44:34	17:48:54	134.1	
00291	NW	17:53:14	17:56:33	136.2	
00292	SE	18:01:13	18:03:16	135.0	
xline	SW	18:07:45	18:17:55	137.8	xline

Project	947122-R040220.00	MT_Statewide_Phase4
Flightplan	MT_Statewide4_1560iiS_QL2_200	

Mission Name	SN4892_20220820_F1
Mission Date	8/20/2022
Aircraft	N22TE
Pilot	Ethan Hillmer
Co-Pilot	
Operator	Joel Riggs
Co-Operator	
Vendor	NV5 Geospatial
Base Airport	KHLN
Departure (Local Time)	8:00:00 AM
Arrival (Local Time)	1:05:00 PM

Mission Notes

Started early, but ran into technical difficulties with Viewer/Roughbook GPS connection upon entering imaging altitude N of Helena. Pilot was concerned about visibility due to smoke and haze as well as changing weather conditions so we landed after a short imaging session.

Line	Heading	Start Time (UTC)	Stop Time (UTC)	Speed (kt)	Notes
00553	E	17:48:35	17:52:31	138.6	
00554	SW	17:58:04	18:02:20	134.1	
00555	E	18:06:43	18:10:57	136.2	
00556	SW	18:16:06	18:20:09	132.2	
00557	E	18:23:47	18:27:40	138.3	
00558	SW	18:33:59	18:40:07	133.4	
xline	S	18:47:07	18:53:03	138.8	xline

Project	947122-R040220.00	MT_Statewide_Phase4
Flightplan	MT_Statewide4_1560iiS_QL2_200	

Mission Name	SN4892_20220822_F1	**Mission Notes**
Mission Date	8/22/2022	Imaged blocks just N of and directly over Helena. Pilot observed lowering cloud levels and decided we should shift S to Butte for imaging.
Aircraft	N22TE	
Pilot	Ethan Hillmer	
Co-Pilot		
Operator	Joel Riggs	
Co-Operator		
Vendor	NV5 Geospatial	
Base Airport	KHLN	
Departure (Local Time)	7:00:00 AM	
Arrival (Local Time)	11:20:00 AM	

Line	Heading	Start Time (UTC)	Stop Time (UTC)	Speed (kt)	Notes
00559	E	13:33:29	13:39:39	135.3	
00560	SW	13:44:31	13:50:56	129.3	
00561	E	13:55:07	14:01:12	136.1	
00562	SW	14:05:45	14:12:05	130.2	
00563	E	14:15:42	14:19:31	134.6	
00564	SW	14:24:43	14:37:23	121.3	
00565	E	14:42:23	14:54:15	138.1	
00566	SW	14:59:40	15:13:29	124.9	
00567	E	15:18:33	15:31:35	137.3	
00568	SW	15:36:04	15:50:23	125.0	
00569	E	15:55:09	16:07:24	139.3	
00570	SW	16:11:10	16:23:15	129.3	
00571	E	16:26:38	16:36:50	140.8	
misfire	S	16:45:05	16:45:22	131.8	misfire
xline	S	16:45:26	16:53:12	133.3	xline

Project	947122-R040220.00	MT_Statewide_Phase4
Flightplan	MT_Statewide4_1560iiS_QL2_200	

Mission Name	S2224046_20220831_F1	**Mission Notes**
Mission Date	8/31/2022	Picked up these two line in mob from KTIW to KBZN.
Aircraft	N840JA	
Pilot	Tyler Helsom	
Co-Pilot		
Operator	Kevin Olsonawski	
Co-Operator		
Vendor	NV5 Geospatial	
Base Airport	KBZN	
Departure (Local Time)	9:55:00 AM	
Arrival (Local Time)	3:47:00 PM	

Line	Heading	Start Time (UTC)	Stop Time (UTC)	Speed (kt)	Notes
00573	E	20:55:33	21:04:16	130.4	
00572	SW	21:06:15	21:16:23	127.2	
00572	S	21:19:12	21:20:50	140.4	Crossline

Project	947122-R040220.00	MT_Statewide_Phase4
Flightplan	MT_Statewide4_1560iiS_QL2_200	

Mission Name	S2224046_20220917_F1	**Mission Notes**
Mission Date	9/17/2022	
Aircraft	N840JA	
Pilot	Tyler Helsom	
Co-Pilot		
Operator	Mark Smith	
Co-Operator		
Vendor	NV5 Geospatial	
Base Airport	KBTM	
Departure (Local Time)	9:00:00 AM	
Arrival (Local Time)	12:17:00 PM	

Line	Heading	Start Time (UTC)	Stop Time (UTC)	Speed (kt)	Notes
00401	SE	15:29:39	15:37:40	124.6	
00401	NW	15:45:04	15:59:28	125.7	
00402	SE	16:01:28	16:15:46	128.9	
00000	SW	16:18:39	16:20:35	113.3	
00642	N	17:10:08	17:23:22	124.5	
00000	SW	17:25:53	17:26:56	148.2	