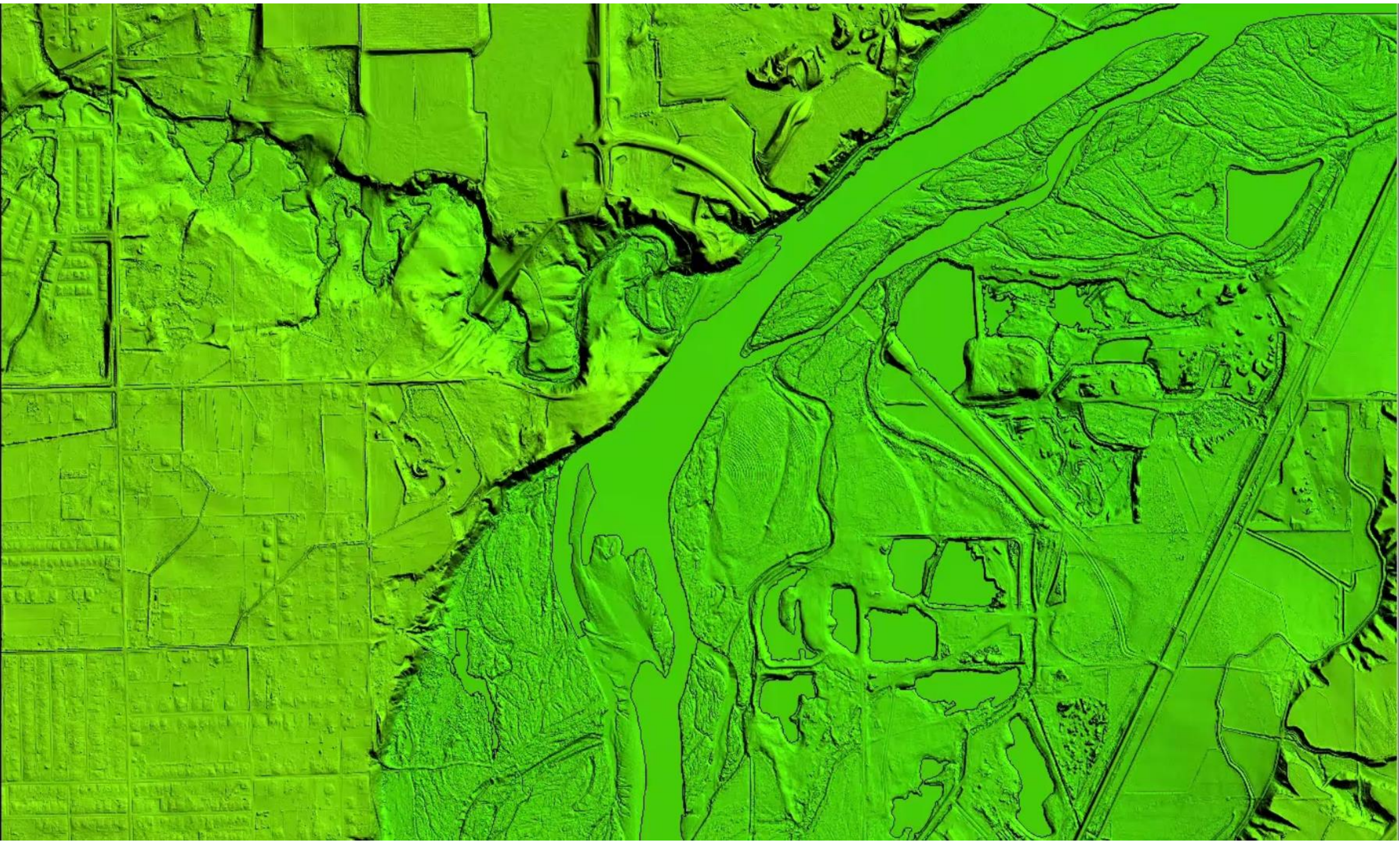

MT Statewide Phase4 B22 LIDAR PROCESSING REPORT

Project ID: 231442
Work Unit: 300197

2023

Submitted: May 12, 2023

Prepared for:

USGS science for a changing world

Prepared by:

axis geospatial

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1. Summary / Scope

1.1. Summary

This report contains a summary of the Montana Phase4 B22, Work Unit 300197 LiDAR acquisition task order, issued by USGS under their Contract 140G0221D0016 on May 6, 2022. This Work Unit yielded a project area covering 190 square miles over Montana at Quality Level 1. 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
8 pts / m2	1280 m	58.5°	55%	≤ 10 cm

1.3. Coverage

The Work Unit boundary covers 190 square miles over Montana. Project extents are shown in Figure 1.

1.4. Duration

LiDAR data was acquired from July 31, 2022, to August 3, 2022, in 3 total lifts. *See Section: 2.4. Time Period for more details.*

1.5. Issues

No issues encountered during acquisition or processing that resulted in data anomalies.

MT Statewide Phase4 B22 Work Unit 300197 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	• 0.5-meter Hydro-flattened Bare-earth Digital Elevation Model (DEM) in GeoTIFF format • 0.5-meter Intensity images in GeoTIFF format • 1-meter Swath Separation Images • 0.5-meter Maximum Surface Height Raster
Vectors *(*.shp)*	• Project Boundary • LiDAR Tile Index • Continuous Hydro-flattened Breaklines • Flightline Swath
Reports *(*.pdf)*	• LiDAR Mapping Report
Metadata *(*.xml)*	• Breaklines • Classified Point Cloud • DEM • Intensity Imagery • Contours

MT Statewide Phase4 QL1
Work Unit 300197 Boundary

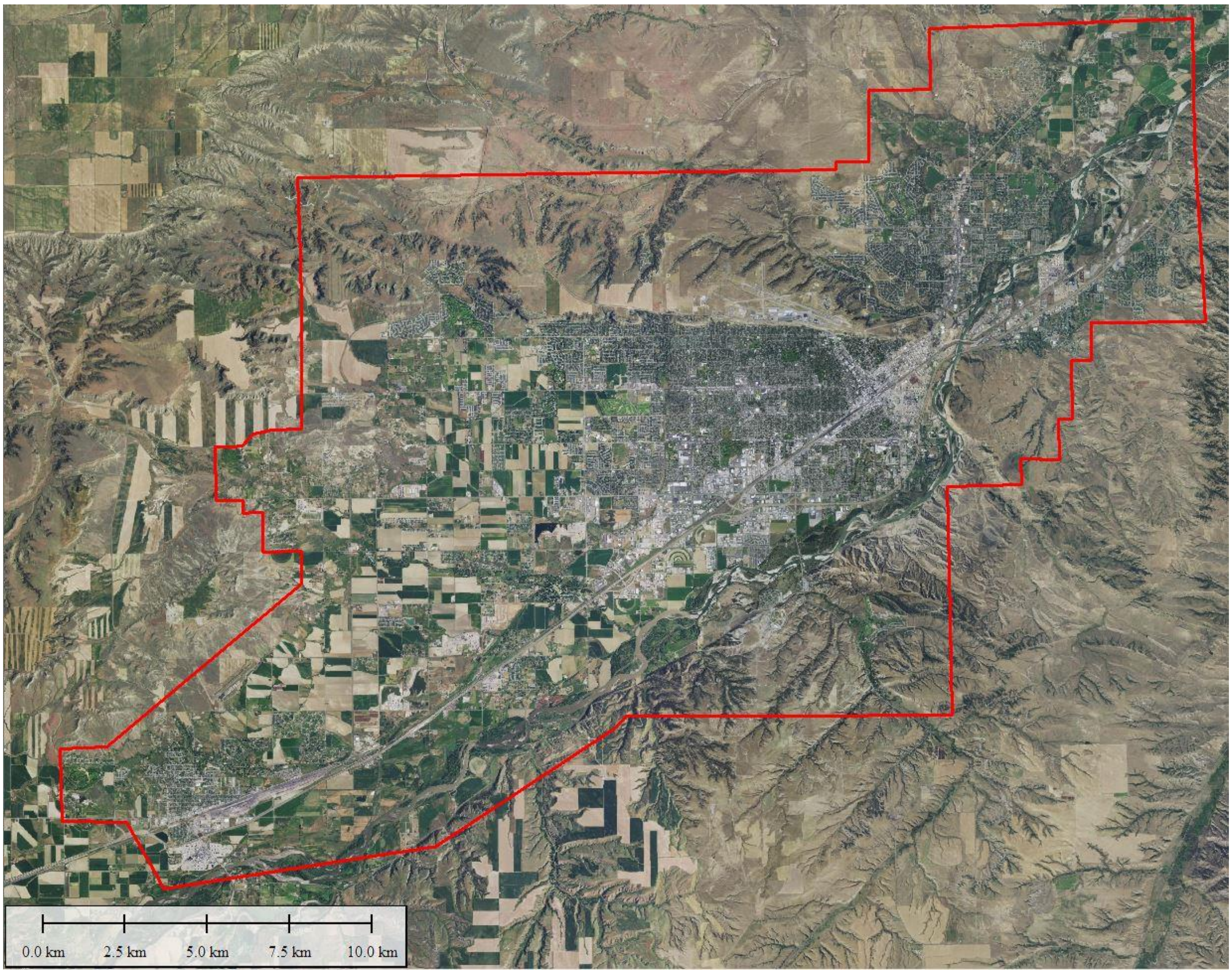


Figure 1. Work Unit Boundary

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.

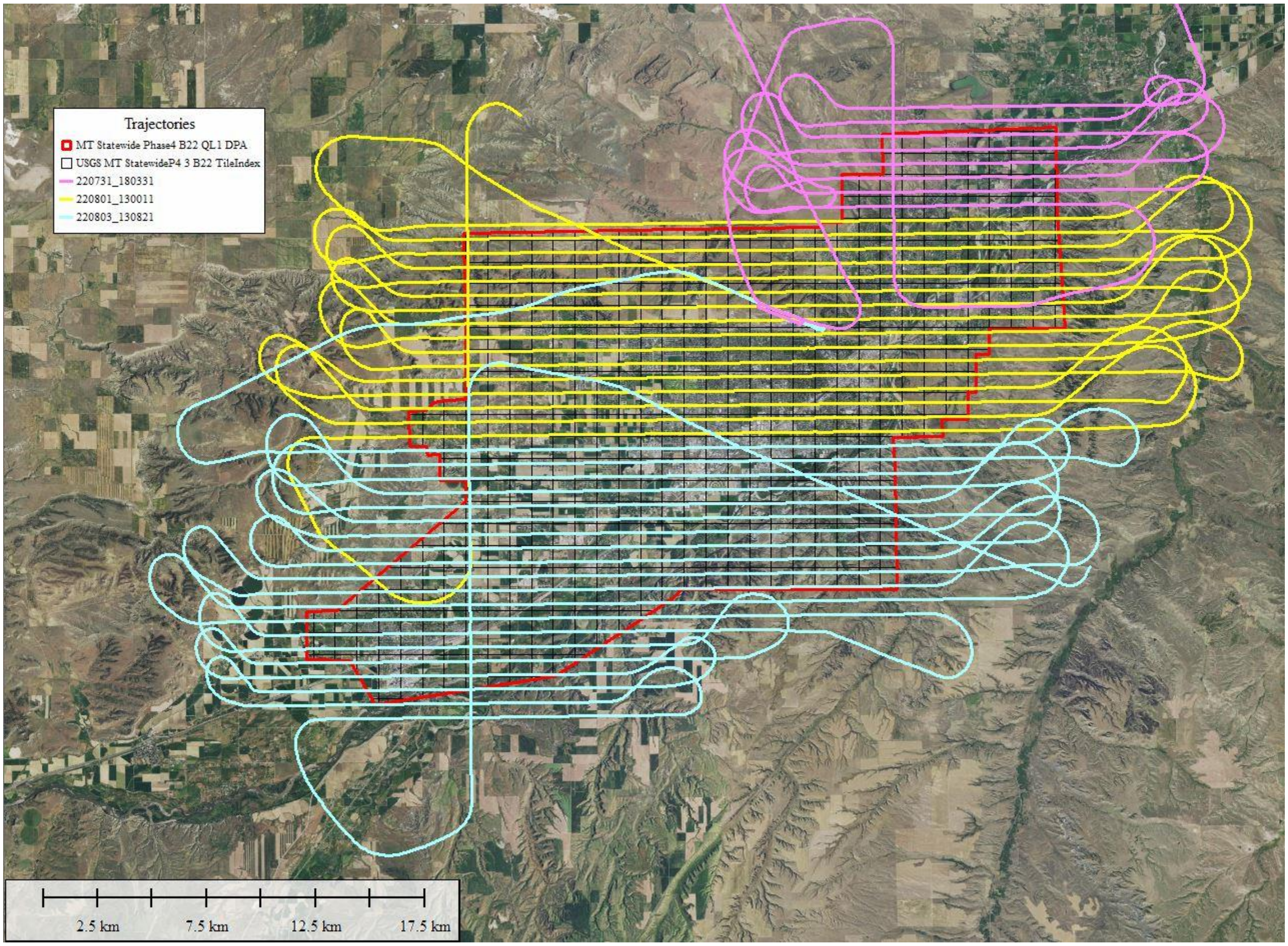


Figure 2. Billings QL1 Trajectories

2.2. LiDAR Sensor

AXIS Geospatial utilized a Riegl VQ1560i LiDAR sensor, serial number 2222593, for data acquisition.

The Riegl 1560i system is a dual channel waveform processing airborne scanning system. It has a laser pulse repetition rate of up to 2 MHz resulting in up to 600 lines per second. The system utilizes an integrated IMU/GNSS unit.

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

Minimum Range [8]	100 m
Accuracy [9][10]	20 mm
Precision [10][11]	20 mm
Laser Pulse Repetition Rate	up to 2 MHz
Effective Measurement Rate	up to 1.33 MHz @ 60° scan angle
Echo Signal Intensity	provided for each echo signal
Laser Wavelength	near infrared
Laser Beam Divergence	$\leq$ 0.18 mrad @ 1/e [12], $\leq$ 0.25 mrad @ $1/e^2$ [13]
Number of Targets per Pulse	with online waveform processing: practically unlimited [14][15] monitoring data output: first pulse
Scanner Performance	
Scanning Mechanism	rotating polygon mirror
Scan Pattern	parallel scan lines per channel, crossed scan lines between channels
Tilt Angle of Scan Lines	$\pm$ 14° = 28°
Forward/ Backward Scan Angle in Non-Nadir Direction	$\pm$ 8° at the edges
Scan Angle Range	60° total per channel, resulting in an effective FOV of 58°
Total Scan Rate	40 [16] - 600 lines/sec
Angular Step Width $\Delta\vartheta$	$0.006° \leq \Delta\vartheta \leq 0.180°$ [17][18]
Angle Measurement Resolution	0.001°

Figure 3. Riegl VQ1560i LiDAR Sensor Specifications

		Riegl VQ1560ii (SN2222593)
Terrain and Aircraft Scanner	Flying Height	1280 m
	Recommended Ground Speed	150 kts
Scanner	Field of View	58.5°
	Scan Rate Setting Used	2 x 183 lps
Laser	Laser Pulse Rate Used	2 x 1000 kHz
Coverage	Full Swath Width	1434 m
	Line Spacing	0.56 m
Point Spacing and Density	Average Point Spacing	0.35 m
	Average Point Density	8 pts / m^2

Table 2. LiDAR System Specifications for WU300197

2.3. Aircraft

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

LiDAR Collection Planes

- VulcanAir P-68C (small twin engine), Tail Number(s): N89LT

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 Riegl LiDAR system.

Figure 4. AXIS Plane VulcanAir P-68C (N89LT)

2.4. Time Period

Project specific flights were conducted between July 31, 2022, and August 03, 2022. Three aircraft lifts were completed. Accomplished lifts are listed below.

Lift	Start UTC	End UTC
20220731 (SN2222593, N89LT)	7/31/2022 1:34 PM	7/31/2022 7:42 PM
20220801 (SN2222593, N89LT)	08/01/2022 1:28 PM	08/01/2022 4:46 PM
20220803 (SN2222593, N89LT)	08/03/2022 1:38 PM	08/03/2022 4:56 PM

Table 3. Lifts for QL1 Billings

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
- Scan Rate (HZ)
- Pulse Rate Frequency (Hz)
- Ground Speed
- Altitude
- Flight Line #
- Flight Line Start and Stop Times
- Flight Line Altitude (AMSL)
- Heading
- Speed
- Notes (includes 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 includes max horizontal / vertical GPS variance, separation plot, altitude plot, PDOP plot, processing mode, number of satellite vehicles, and mission trajectory.

Project specific POSPac graphics for each mission are available in Appendix B.

Point clouds 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. The point cloud is imported into TerraSolid distributive processing software. Imported data is tiled and then calibrated using TerraMatch. Using TerraScan, the vertical accuracy of the surveyed ground control is tested, and any bias is removed from the data. TerraScan and TerraModeler are then used for automated data classification and manual cleanup.

Actual acquired point density has been evaluated and confirmed to meet USGS standards for the relevant Quality Level. LAStools is used to calculate point density and spacing average per swath. Additional checks are made by loading LAS data directly into TerraScan and sampling open, flat areas in the acquired LAS.

After verification of accuracy and point density are complete, the calibration phase begins. Terrasolid is used to analyze and test data for discrepancies between overlapping flightlines. Tie Lines or representations of the dense lidar point cloud per scanner along every swath. Tie Lines are used to determine the best correction solution for Heading/Roll/Pitch, to eliminate or minimize discrepancies, resulting in a highly accurate and seamless transition between flight lines.

DEMs and Intensity Images are then generated using TerraScan and Global Mapper 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.

Swath Separation images at the required Quality Level are generated to confirm the calibration corrections that have been applied and data meets USGS standards. Overlapping flightlines are used to compare the elevation differences between flightlines and colorized to show any differences larger than the tolerances described in the latest Lidar Base Specification. This colorization is overlaid onto the existing Intensity images for each tile.

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

Software	Version
Applanix + POSPac	8.6
RiPROCESS	1.8.6
Global Mapper	23.1;24.1
TerraModeler	21.008
TerraScan	22.007
TerraMatch	22.008

Table 4. Software Versions

3.3. LAS Classification Scheme

Classification is determined by LiDAR Base Specification 2022, Revision A and are an industry standard for the processing of LiDAR point clouds. All data start the process as Class 1 (Unclassified). Then classification is determined through automated classification routines utilizing TerraScan macro processing.

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

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

Table 5. LAS Classifications

3.4. Classified LAS Processing

The bare-earth class is then manually reviewed to ensure correct classification of Class 2 (Ground) points. Individual TerraScan routines are combined to form an overall macro to segment and classify the LiDAR point cloud. The key focus of these routines is the accurate classification of bare earth ground points. Automated macros are run that classify most of the point cloud. Visual QC and edits are performed to ensure automated techniques worked properly and that data confirms to USGS Quality Level standards. After the initial automated bare earth surface is established, hydro collection begins through heads up digitizing, utilizing the bare earth surface and intensity information.

All ground (ASPRS Class 2) LiDAR data inside of the lake / ponds and Double Line Drain hydro flattening breaklines were classified to water (ASPRS Class 9) using TerraScan macro functionality. A buffer of 0.5 meters was used around each hydro flattened feature to classify these ground (ASPRS Class 2) points to ignored ground (ASPRS Class 20). All lake / ponds Island and Double Line Drain Island features were checked to ensure that the ground (ASPRS Class 2) points were reclassified to the correct class of Water after the automated classification was completed. These classes were created through automated processes only and were verified for classification accuracy via visual inspection.

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 as withheld bit for those points.

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. TerraScan was then used to create the deliverable industry standard LAS files for all point cloud data. Global Mapper, along with LP360 software, was used to perform final statistical analysis of the classes in the LAS files, on a per tile level to verify final classification metrics and full LAS header information.

3.5. Hydro-Flattened Breakline Processing

Using heads-up digitization, all hydro breaklines are collected for lakes/ponds greater than 2 acres in size and inland streams and rivers with a width of 30 meters or greater. Islands greater than 1 acre in size within a collected hydro feature were also captured. LiDAR intensity imagery and bare-earth surface models are used to ensure appropriate and complete collection of these features.

Breakline vector data was then draped to the ground surface elevation. Lakes/ponds were set 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 features to ensure all breaklines match the LiDAR within acceptable tolerances. Some deviation is expected between breaklines and LiDAR elevations due to monotonicity, connectivity, and flattening rules that are enforced on the breaklines. Once completeness, horizontal placement, and vertical variances are reviewed, all breaklines are evaluated for topological consistency and data integrity using a combination of ESRI's ArcGIS, Global Mapper, 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.

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. Global Mapper 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 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 ensuring no overlapping cells remain across the project area. A 32-bit floating point GeoTIFF DEM is generated for each tile with a pixel size of 0.5 meters. AXIS Geospatial's proprietary software is then 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. AXIS Geospatial uses a proprietary tool to check all formatting requirements of the DEMs to meet specifications.

GDAL version 3.1.4, was used to populate and verify that the correct CRS was applied to all files.

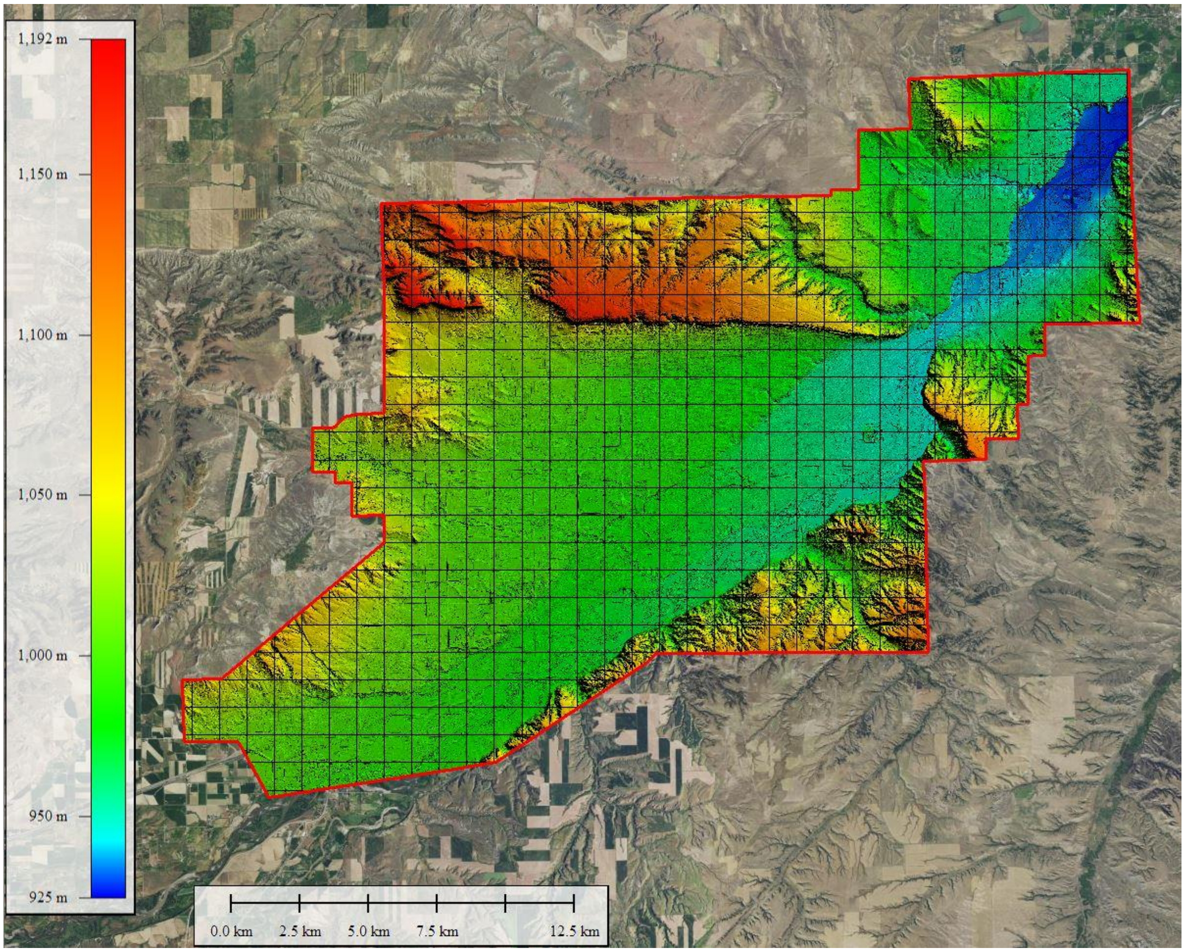


Figure 5. Work Unit 300197 Bare-Earth DEM

3.7. Intensity Image Processing

Intensity images represent reflectivity values collected by the LiDAR sensor during acquisition. TerraScan was used to export intensity images at 0.5 meter resolution. Intensity images were produced as 8-bit, 256 grayscale images in GeoTiff format. Appropriate horizontal projection information as well as applicable header values were written during product generation.

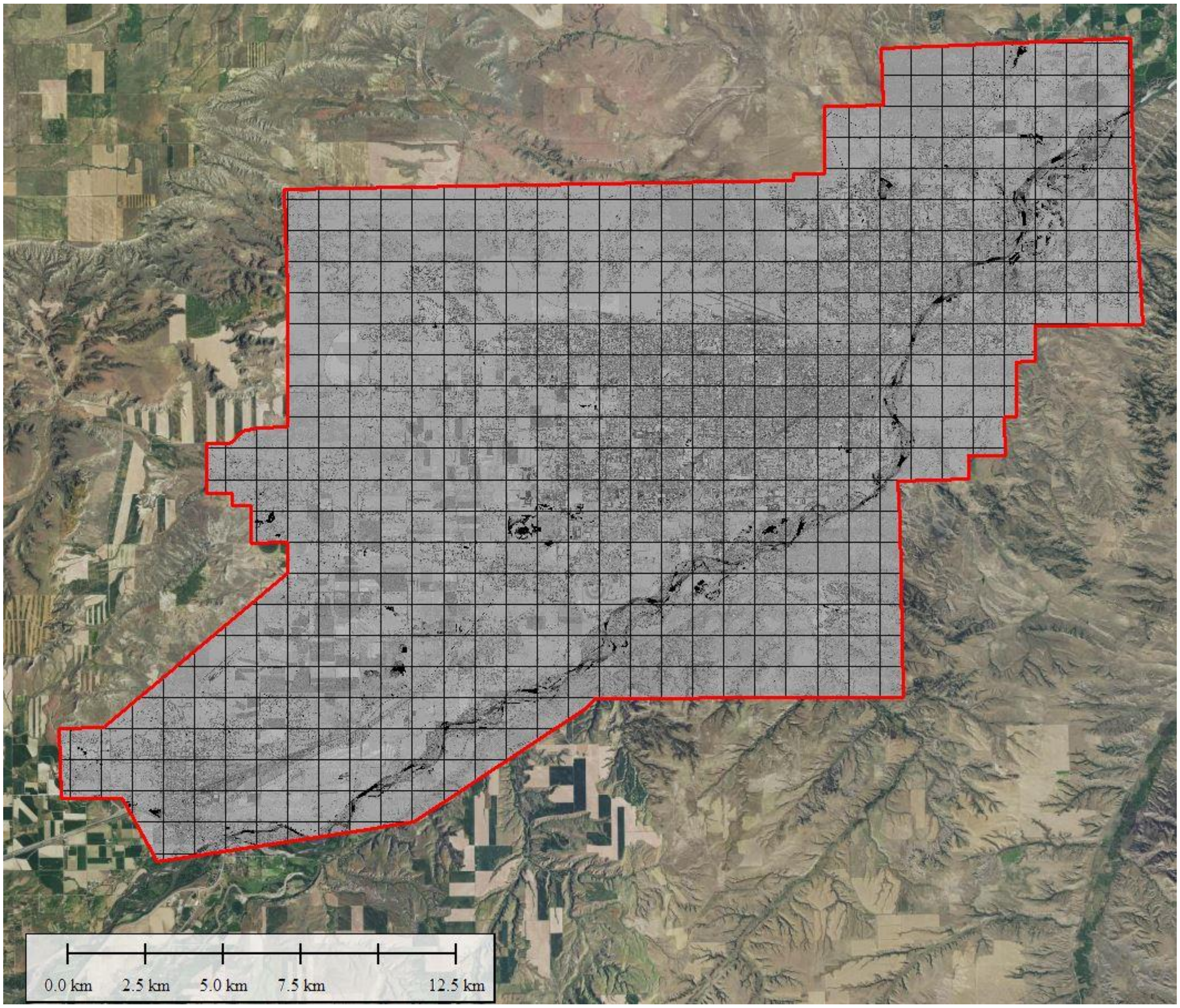


Figure 6. Work Unit 300197 Intensity Images

3.8. Swath Separation Raster Processing

Swath Separation Imagery was produced for the entire project area. Swath separation images use color-coding to illustrate differences in elevation (z-) values where swaths overlap. The color-coded images are semi-transparent and overlay the LiDAR intensity image. They are ancillary data used as visual aids to identify regions more easily within point cloud datasets that may have suspect interswath alignment or other geometric issues. Imagery was created using last returns with all classification and bit flags, except for noise and withheld bit flag are included. Images are derived from a TIN and have a 50% transparent RGB layer over lidar intensity. Color intervals are as follows for QL2 data: 0-8cm, green; 8-16cm, yellow; >16cm, red. These files were produced as GeoTIFF tiles using a cell size of 1 meter. SSI are generated from the point cloud data and will not be altered after creation, nor will there be further maintenance on this product. Appropriate horizontal projection information as well as applicable header values are written to the file during product generation. AXIS Geospatial uses a proprietary tool to check all formatting requirements of the images against specifications.

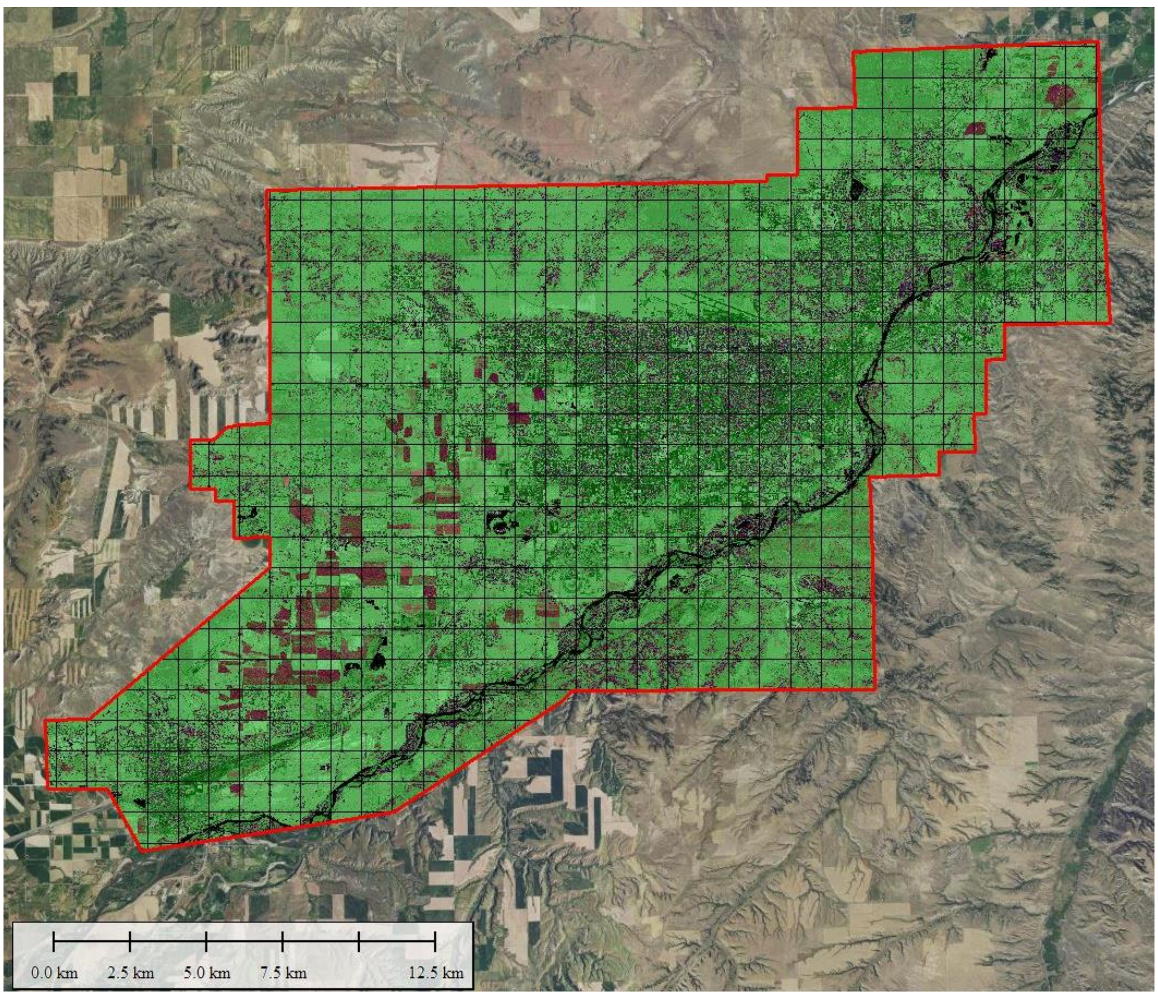


Figure 7. Work Unit 300197 Swath Separation Images

3.9. Maximum Surface Height Raster Processing

Maximum Surface Height rasters (topographic) represent a LiDAR-derived product illustrating natural and built-up features. Global Mapper is used to take all first-return classified LiDAR points, excluding those flagged with a withheld bit, to 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 is generated for each tile with a pixel size of 0.5 meter. GDAL was used to write appropriate horizontal and vertical projection information as well as applicable header values into the file after product generation. Each maximum surface height raster was reviewed in Global Mapper to check for any anomalies and to ensure a seamless dataset. AXIS Geospatial uses a proprietary tool to check all formatting requirements of the DEMs against specifications.

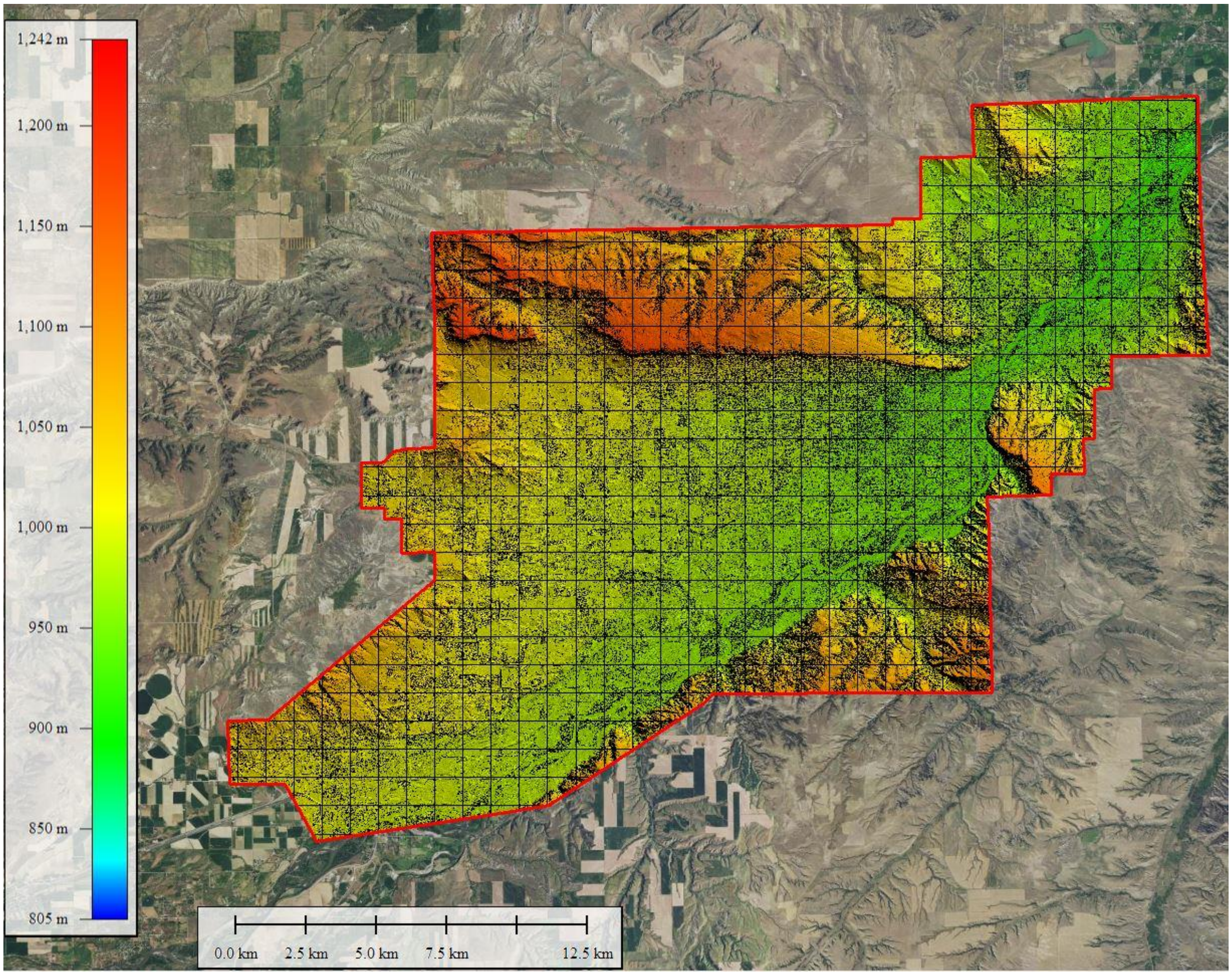


Figure 8. Work Unit 300197 MSHR Images

3.10. Contour Processing

The LAS Ground Class, along with breakline data, was used to create a surface of hydro flattened bare-earth DEMs. Contours were produced at 1-foot intervals in shapefile format using Global Mapper. Automated smoothing techniques were applied. No manual editing of contours was performed. Contours were attributed with every fifth contour as Index and all others as Intermediate. Contours were cut into 1000 m by 1000 m tiles to match the LAS and Bare-earth DEM deliverables. Tiled contour shapefiles were combined into one continuous dataset within an Esri File Geodatabase. There are no spot elevations or depressions on separate layers.

MT Statewide Phase4 B22
Work Unit 300197 Tile Layout

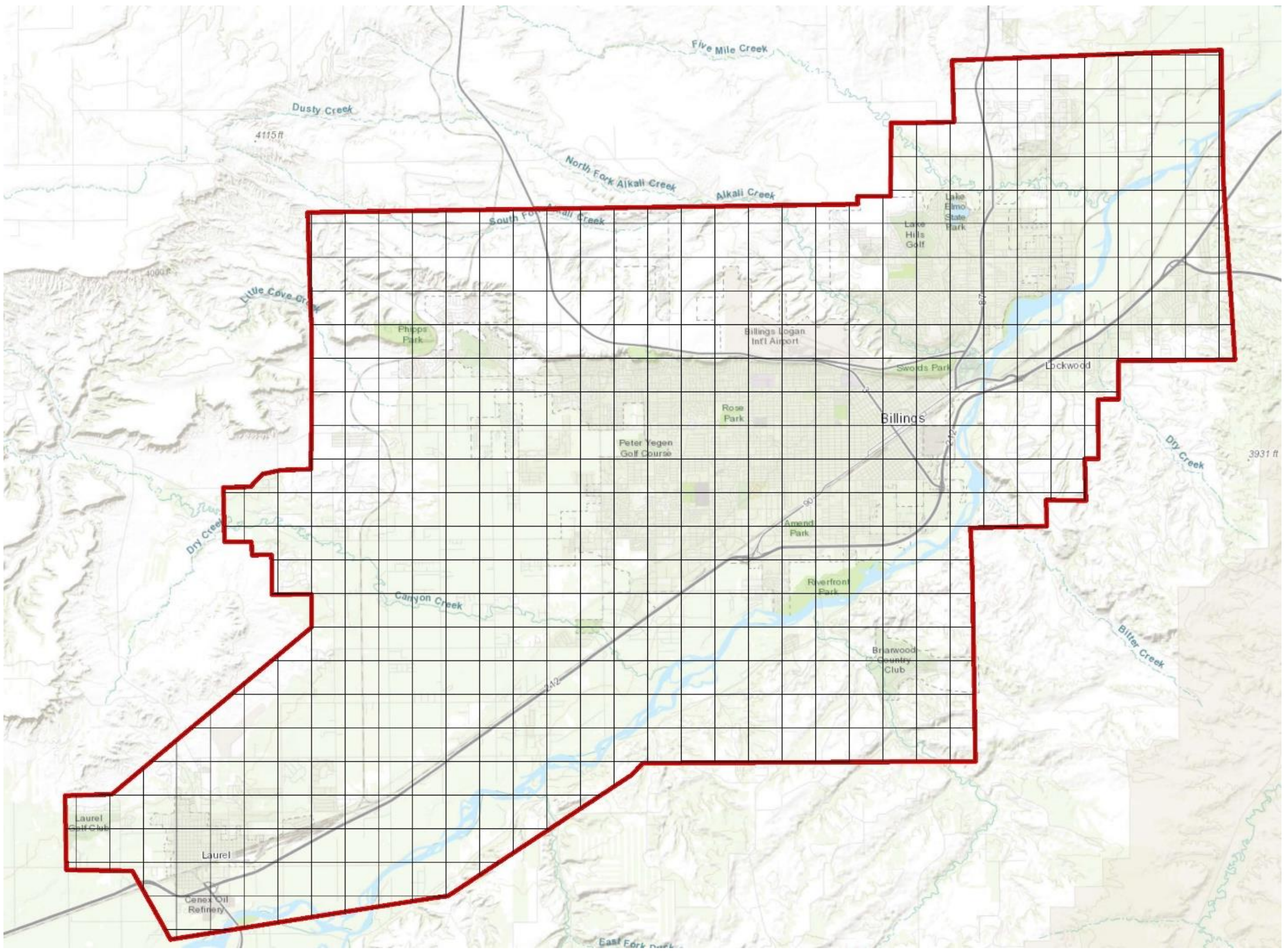


Figure 9. LiDAR Tile Layout

4. Project Coverage Verification

4.1. Swath Polygon Boundaries

Swath polygons of each flightline, depicting the boundary of LiDAR points, are exported using LAStools. These swath polygons were reviewed against the project boundary to verify adequate project coverage. *Please refer to Figure 5*.

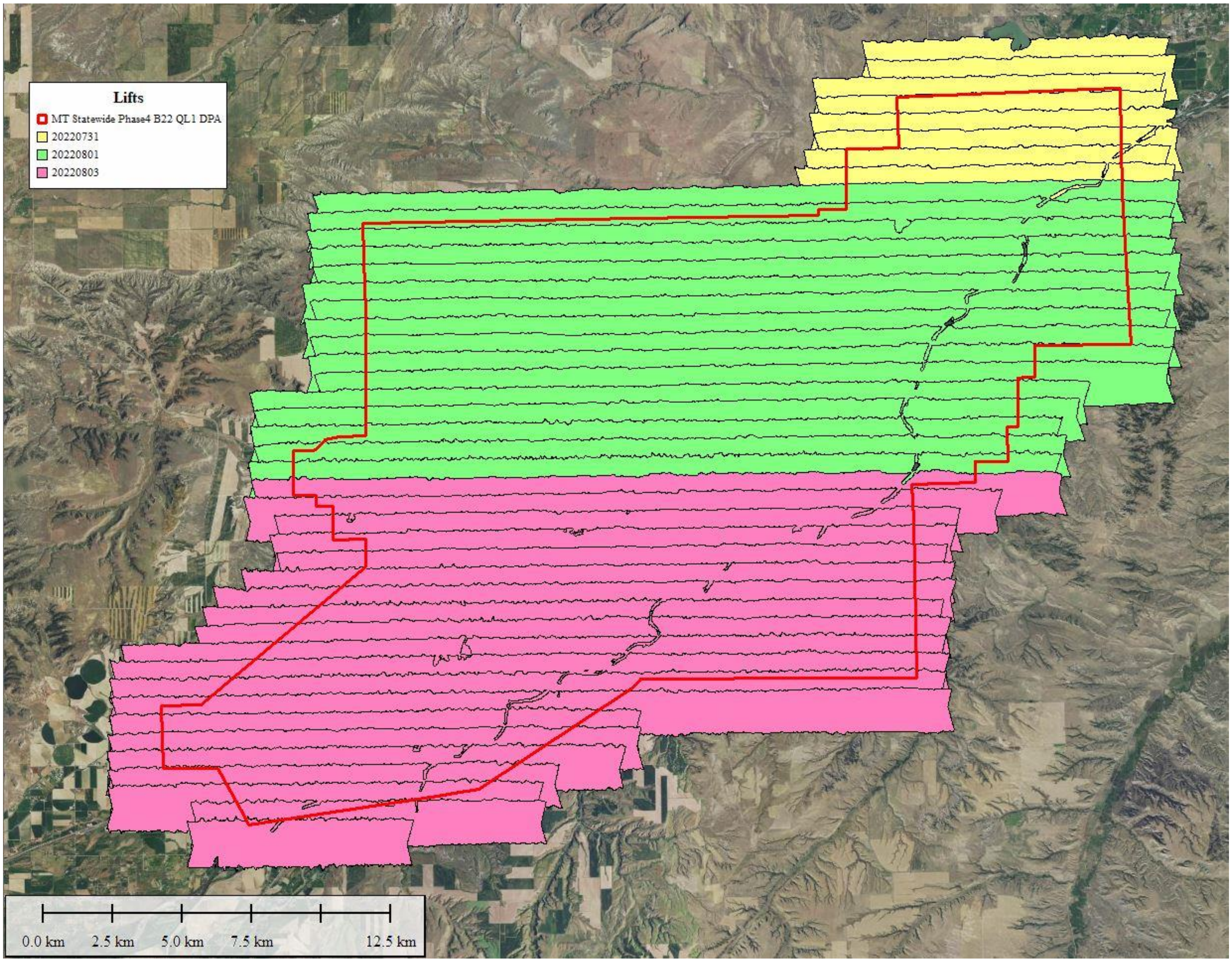


Figure 10. Work Unit 300197 LiDAR Coverage

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 1280 meters, an IMU error of 0.0025 decimal degrees, and a GNSS positional error of 0.05 meters, this project was compiled to meet 0.19 meter horizontal accuracy at 95% confidence level. A summary is shown below.

Horizontal Accuracy	
$RMSE_r$	0.36 ft
	0.11 m
ACC_r	0.62 ft
	0.19 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 (<0.08 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 Phase4 B22 project was 0.007 feet (0.002 meters). *A summary is shown below*.

Relative Vertical Accuracy	
Sample	50 flight line surfaces
Average	0.007 ft
	0.002 m
Median	-0.0016 ft
	-0.0005 m
RMSE	0.04 ft
	0.014 m
Standard Deviation (1σ)	0.089 ft
	0.015 m
1.96σ	0.001 ft
	0.0004 m

Project Report Appendices

The following section contains the appendices as listed in the MT Statewide Phase4 B22 LiDAR Project Report.

Flight Logs

LiDAR and Imagery Flight Report

Project(s): 20220731

Pilot:	ES	Project Number(s):	2007821B MONTANT			Date:	7/31/2022
Operator:	AC	Project Name(s):				Mission Start (LT):	3232.1 / 3236.5
Aircraft:	89LT	Hobbs Start:	3231.5 / 3236.0	Hobbs Stop:	3236.0 / 3237.9	Mission End (LT):	3235.7 / 3237.7
LiDAR Unit:	2) VQ-1560i S2222593	Scan Rate:	2*144	Camera Unit:	Phase One	Drive:	A 0/1
MTA Zones:	6 - 10	Grnd Spd Max (kts):	155	FOV (deg):	58.52	Sun Angle:	
PRR (kHz):	2*700	Altitude (feet AMT):	5500	Lateral Overlap (%):	55%	Lens:	
Laser Power (%):	100	Point Spacing (m):	0.321	Forward Overlap (%):		Point Density (ppms):	5.88

		Camera Counter		Line Start/Stop							
Line #	Direction	To	From	Start Time UTC	Stop Time UTC	Altitude (Planned)	Altitude (Actual)	Remarks	Clouds	Aperture	Shutter Speed
9	N			13:34	13:52	10560+-		THICK SMOKE FROM FIRE NORTH END			
XTIE	E			13:55	13:52			VERY THICK SMOKE EXAMPLE			
10	S			14:10	14:28			THICK SMOKE FROM FIRE NORTH END			
57	N			14:41	14:50	10090+-					
56	S			14:53	15:02						
55	N			15:06	15:14						
54	S			15:18	15:27						
53	N			15:30	15:30						
52	S			15:42	15:50						
51	N			15:55	16:04						
50	S			16:08	16:16						
49	N			16:20	16:29						
48	S			16:33	16:41						
47	N			16:44	16:54						
XTIE	E			16:59	16:03						
1	W			18:44	18:48	7860+-					
2	E			18:50	18:52						
3	W			18:56	18:59						
4	E			19:02	19:07						
5	W			19:09	19:12						
6	E			19:15	19:18						
7	W			19:21	19:24						
8	E			19:31	19:34						
XTIE	N			19:39	19:42						

LiDAR and Imagery Flight Report				Project(s):	20220801
Pilot:	ES	Project Number(s):	2007821B MONTANT	Date:	8/1/2022
Operator:	AC	Project Name(s):		Mission Start (LT):	3238.3
Aircraft:	89LT	Hobbs Start: 3237.9	Hobbs Stop: 3241.9	Mission End (LT):	3241.7

LiDAR Unit:	2) VQ-1560i S2222593	Scan Rate:	2*144	Camera Unit:	Phase One	Drive:	A 0/1
MTA Zones:	6 - 10	Grnd Spd Max (kts):	155	FOV (deg):	58.52	Sun Angle:	
PRR (kHz):	2*1000	Altitude (feet AMT):	5500	Lateral Overlap (%):	55%	Lens:	
Laser Power (%):	100	Point Spacing (m):	0.321	Forward Overlap (%):		Point Density (ppms):	5.88

		Camera Counter		Line Start/Stop							
Line #	Direction	N+A32: B35	From	Start Time UTC	Stop Time UTC	Altitude (Planned)	Altitude (Actual)	Remarks	Clouds	Aperture	Shutter Speed
9	E			13:28	13:35	7860+-					
10	W			13:39	13:49						
11	E			13:52	13:59						
12	W			14:03	14:13						
13	E			14:16	14:22						
14	W			14:26	14:36						
15	E			14:39	14:46						
16	W			14:50	14:59						
17	E			15:02	15:10						
18	W			15:12	15:24						
19	E			15:27	15:33						
20	W			15:39	15:48						
21	E			15:52	15:58						
22	W			16:02	16:13			LIGHT TURBULENCE			
23	E			16:16	16:21			LIGHT TURBULENCE			
24	W			16:28	16:37			MODERATE TURBULENCE WITH UP/DOWN DRAFTS			
XTIE	N			16:41	16:46						

		LiDAR and Imagery Flight Report					**Project(s):**		20220803										

Pilot:	ES	Project Number(s):	2007821B MONTANT QL1	Date:	8/3/2022
Operator:	AC	Project Name(s):		Mission Start (LT):	3242.4
Aircraft:	89LT	Hobbs Start: 3241.9	Hobbs Stop: 3246.1	Mission End (LT):	3245.8

LiDAR Unit:	2) VQ-1560i S2222593	Scan Rate:	2*144	Camera Unit:	Phase One	Drive:	A 0/1		
MTA Zones:	6 - 10	Grnd Spd Max (kts):	150	FOV (deg):	58.52	Sun Angle:			
PRR (kHz):	2*1000	Altitude (feet AMT):	4200	Lateral Overlap (%):	55%	Lens:			
Laser Power (%):	100	Point Spacing (m):	0.321	Forward Overlap (%):		Point Density (ppms):	5.88		

		Camera Counter		Line Start/Stop							
						MOB: 0.8	MSN: 3.4	TOT: 4.2			
Line #	Direction	N+A32:B35	From	Start Time UTC	Stop Time UTC	Altitude (Planned)	Altitude (Actual)	Remarks	Clouds	Aperture	Shutter Speed
25	E			13:38	13:44	7860+-		QL1			
26	W			13:49	14:57						
27	E			14:00	14:06						
28	W			14:11	14:17						
29	E			14:21	14:26						
30	W			14:31	14:39						
31	E			14:42	14:48						
32	W			14:52	14:59						
33	E			15:02	15:10						
34	W			15:12	15:22						
35	E			15:25	15:32						
36	W			15:35	15:45						
37	E			15:48	15:56						
38	W			16:00	16:06						
39	E			16:09	16:14						
40	W			16:17	16:23						
41	E			16:25	16:28						
42	W			16:32	16:37						
43	E			16:40	16:44						
44	W			16:46	16:49						
XTIE	N			16:53	16:56						

Appendix B

POSPac Graphics

General Information

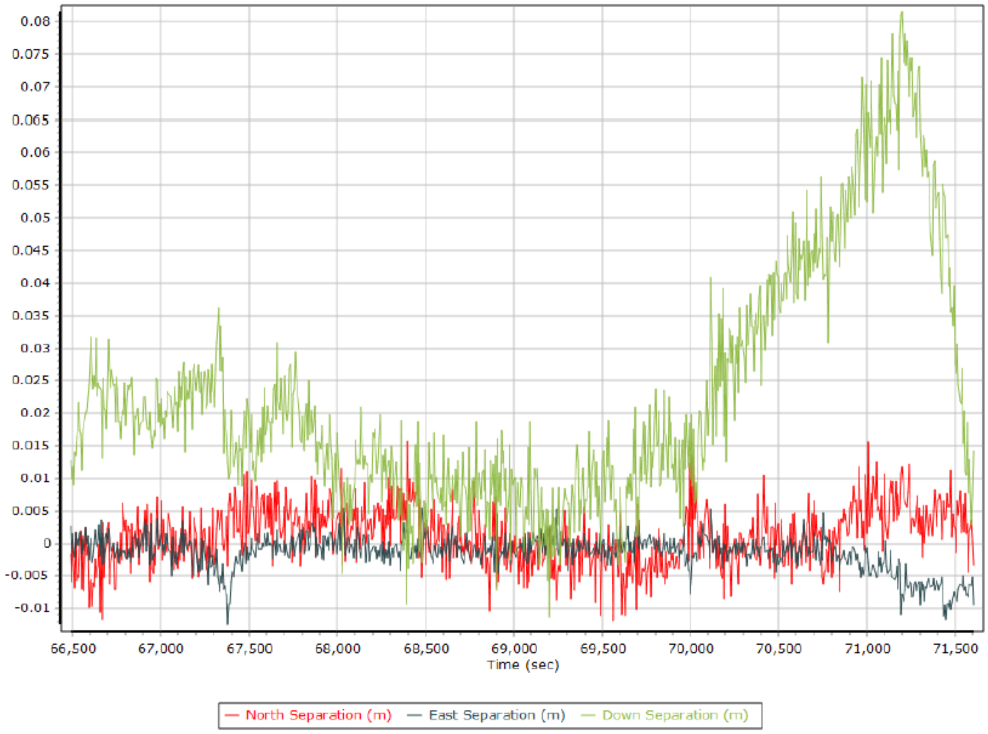
Mission Information

Project name	20078_20220731-2_LT_S2222593_STATIC_RTX
Processing date	2022-08-03 21:12:02
Mission date	2022-07-31 18:27:04
Mission duration	01:26:35.972
Processing mode	IN-Fusion PP-RTX

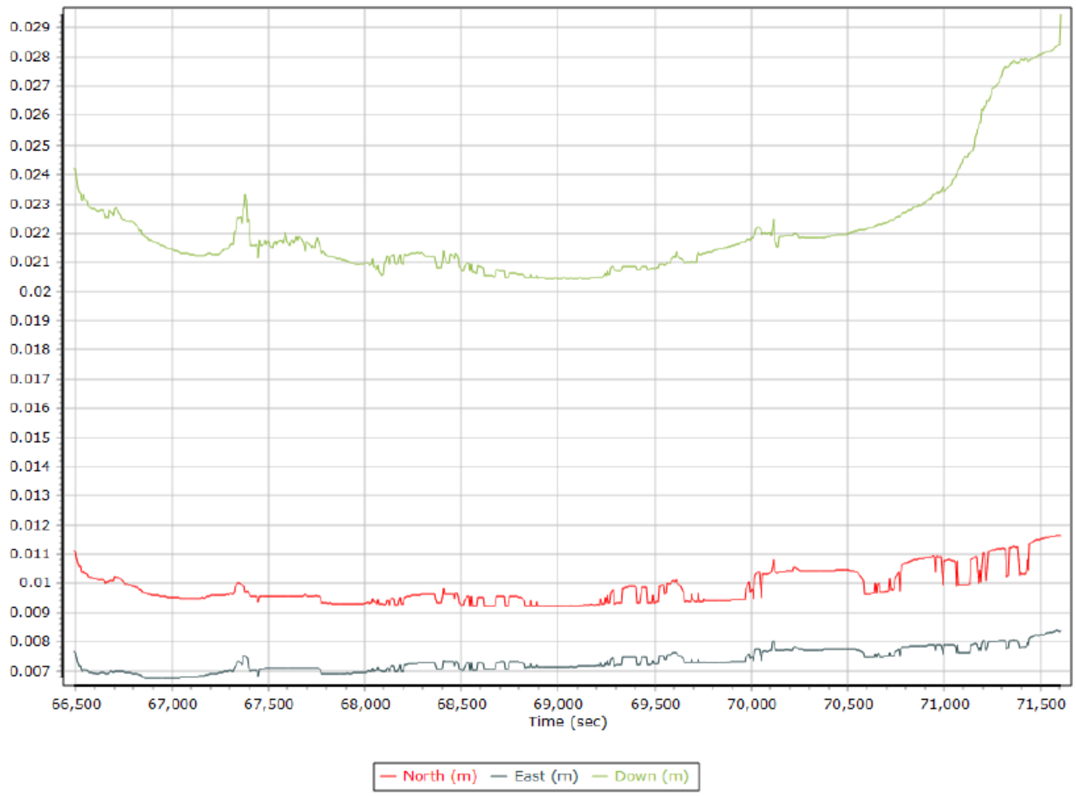
Rover Hardware Information

Product	POS AV 610 VER6 HW2.5-12
Serial number	S/N8223
IMU type	57
Receiver type	BD982
Antenna type	AV37

Forward/Reverse Separation



Estimated Position Accuracy



General Information

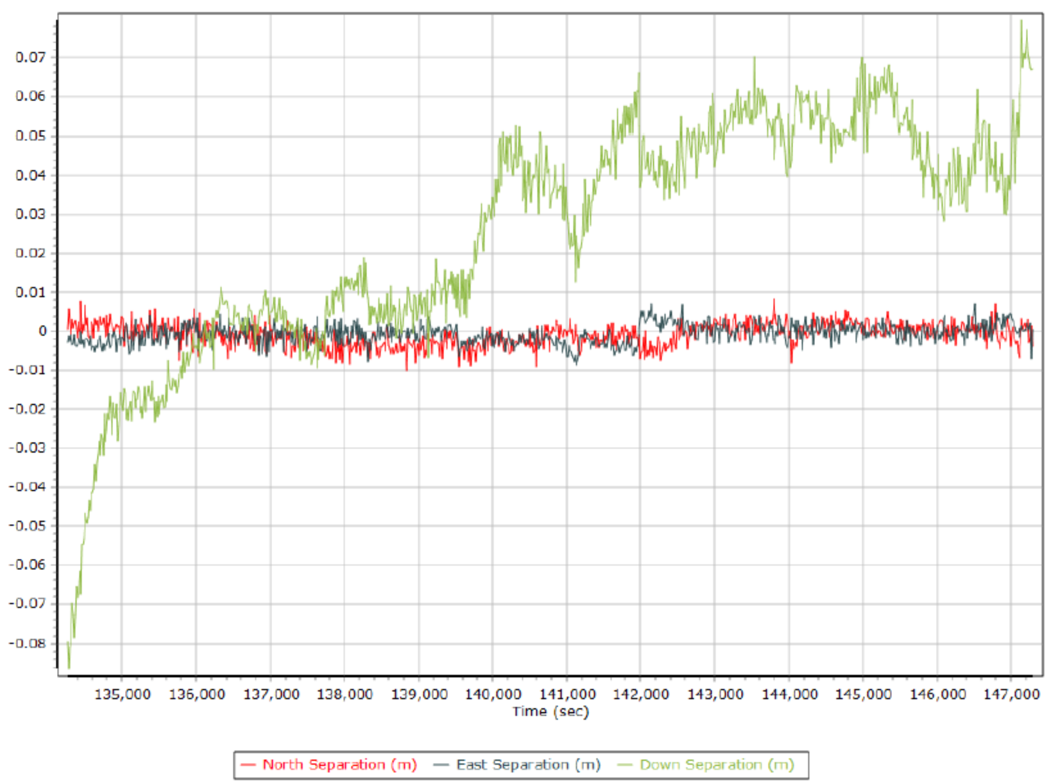
Mission Information

Project name	20078_20220801_LT_S2222593
Processing date	2023-05-11 21:37:08
Mission date	2022-08-01 13:16:38
Mission duration	03:38:35.000
Processing mode	IN-Fusion PP-RTX

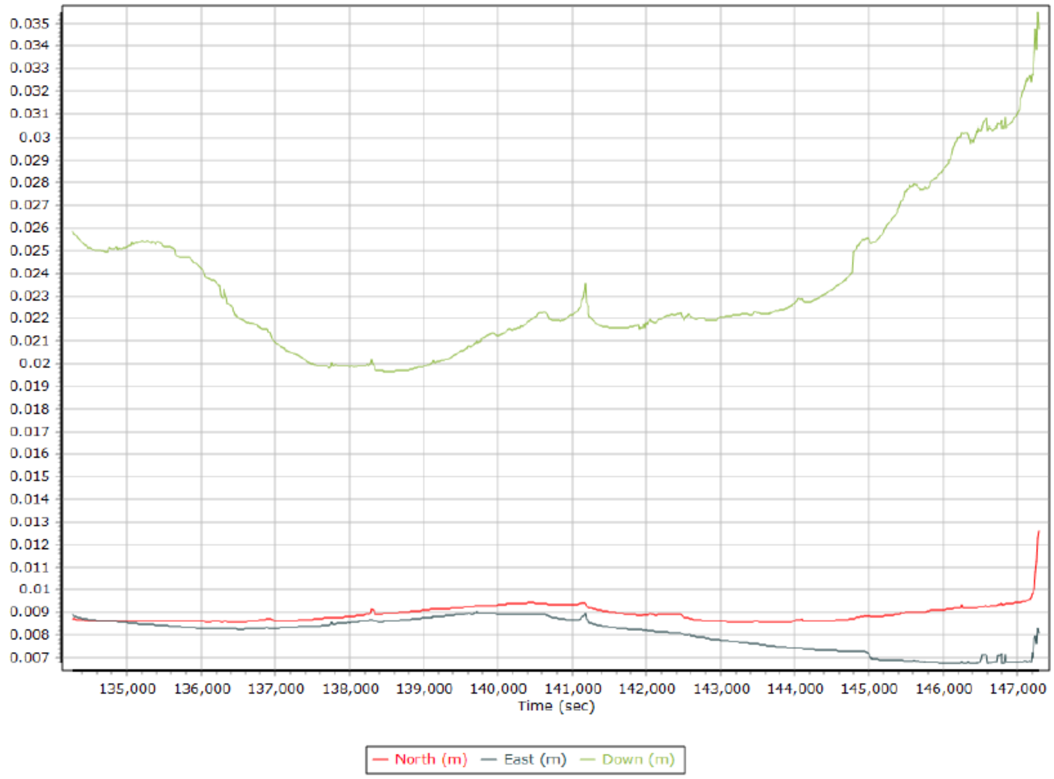
Rover Hardware Information

Product	POS AV 610 VER6 HW2.5-12
Serial number	S/N8223
IMU type	57
Receiver type	BD982
Antenna type	AV37

Forward/Reverse Separation



Estimated Position Accuracy



General Information

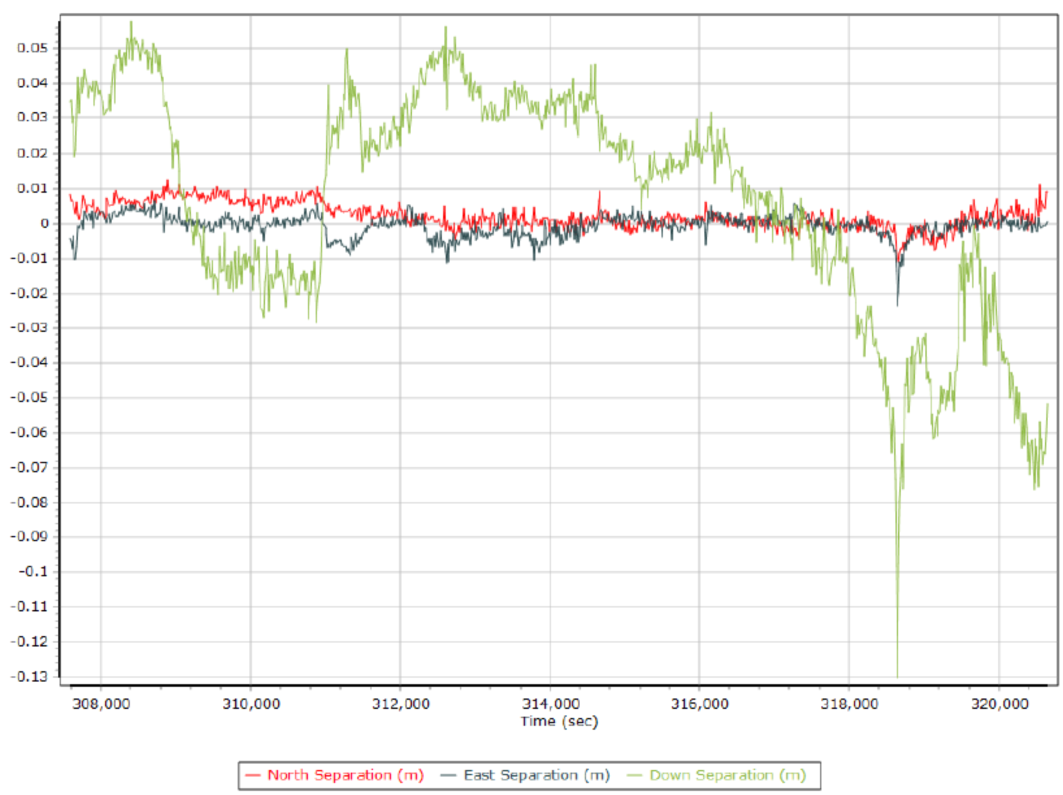
Mission Information

Project name	20078_20220803_LT_S2222593
Processing date	2022-08-09 19:29:28
Mission date	2022-08-03 13:25:18
Mission duration	03:39:19.000
Processing mode	IN-Fusion PP-RTX

Rover Hardware Information

Product	POS AV 610 VER6 HW2.5-12
Serial number	S/N8223
IMU type	57
Receiver type	BD982
Antenna type	AV37

Forward/Reverse Separation



Estimated Position Accuracy