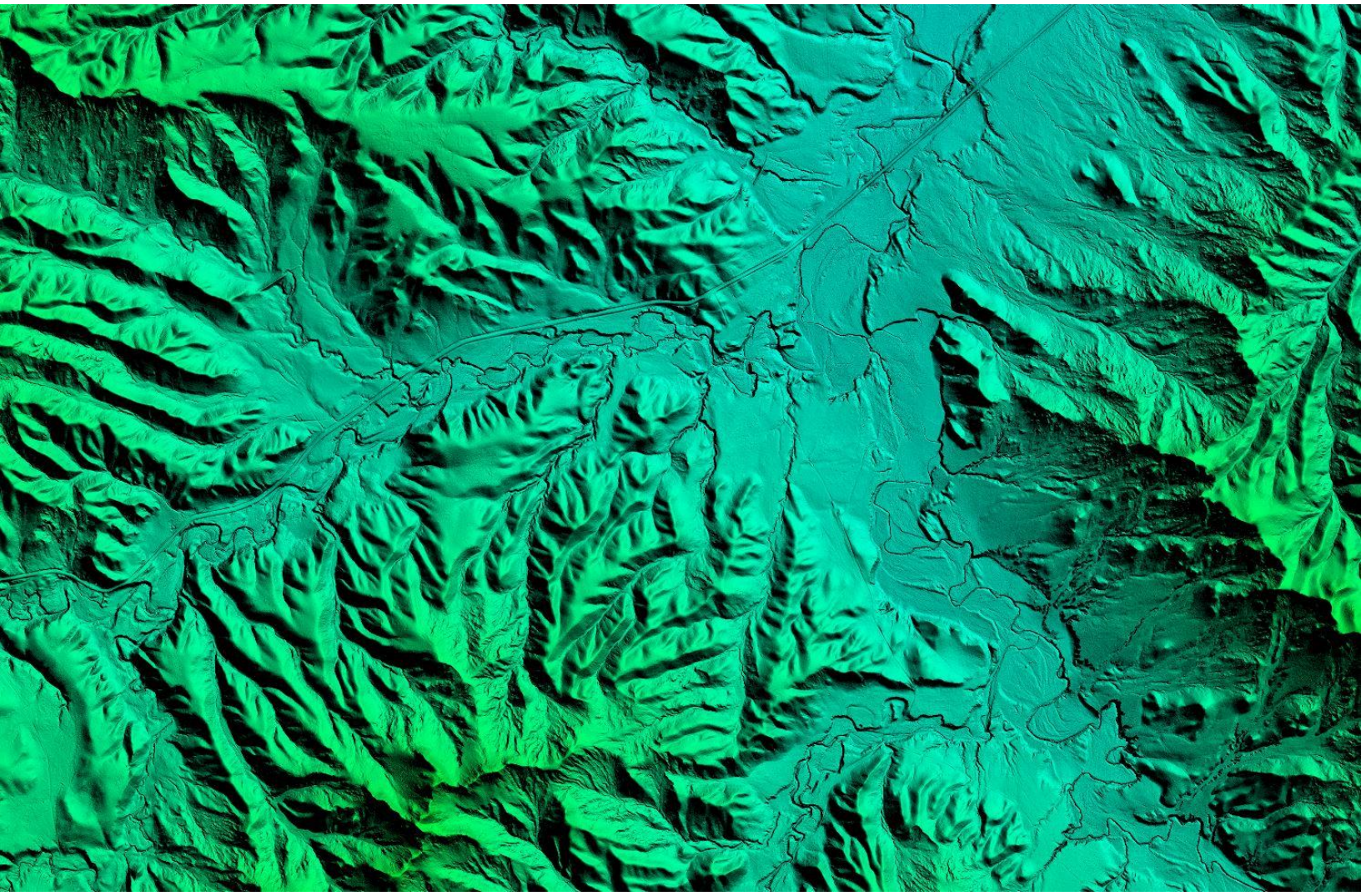

MT Statewide Phase4 B22 LIDAR PROCESSING REPORT

2023

Submitted: July 26, 2023

Project ID: 231442
Work Unit: 300248

Prepared for:

USGS
science for a changing world

Prepared by:

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1. Summary / Scope

1.1. Summary

This report contains a summary of the Montana Phase4 B22, Work Unit 300248 LiDAR acquisition task order, issued by USGS under their Contract 140G0221D0016 on May 6, 2022. This Work Unit yielded a project area covering 5349 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	1798 m	58.5°	30%	≤ 10 cm

1.3. Coverage

The Work Unit boundary covers 5349 square miles over Montana. Project extents are shown in Figure 1.

1.4. Duration

LiDAR data was acquired from August 10, 2022, to September 21, 2022, in 23 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 300248 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 Swath Separation Images • 1-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

MT Statewide Phase4 QL2
Work Unit 300248 Boundary

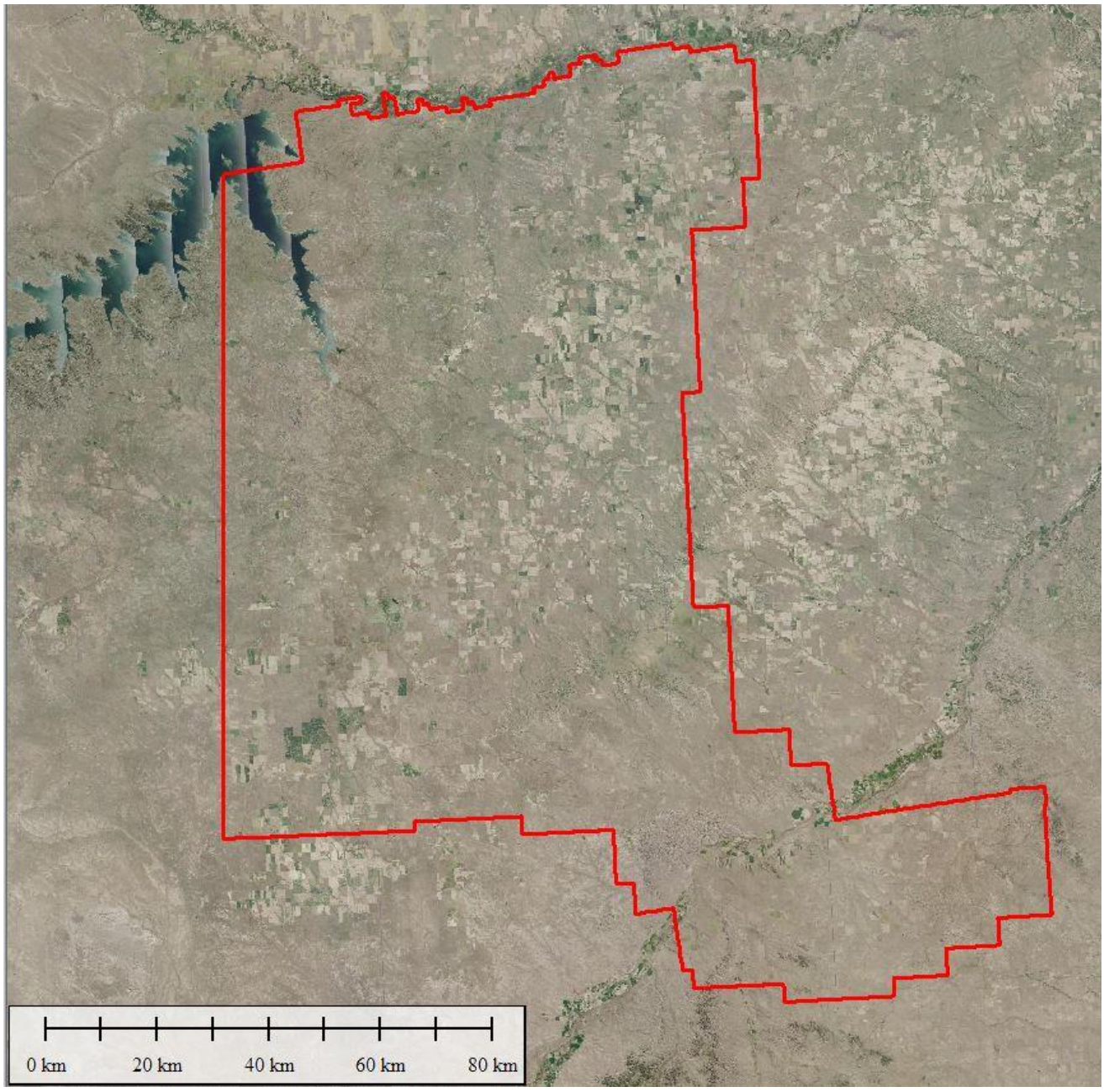

Figure 1. Work Unit Boundary

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

AXIS Geospatial utilized Riegl VQ1560i LiDAR sensors, serial number 2222593 and 2223544, 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	≤ 0.18 mrad @ 1/e [12], ≤ 0.25 mrad @ 1/e² [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	± 14° = 28°
Forward/ Backward Scan Angle in Non-Nadir Direction	± 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 Δϑ	0.006° ≤ Δϑ ≤ 0.180° [17] [18]
Angle Measurement Resolution	0.001°

Figure 3. Riegl VQ1560i LiDAR Sensor Specifications

		Riegl VQ1560i (SN2222593 and SN2223544)
Terrain and Aircraft Scanner	Flying Height	1798 m
	Recommended Ground Speed	155 kts
Scanner	Field of View	58.5°
	Scan Rate Setting Used	2 x 132 lps
Laser	Laser Pulse Rate Used	2 x 700 kHz
Coverage	Full Swath Width	2015 m
	Line Spacing	0.58 m
Point Spacing and Density	Average Point Spacing	0.71 m
	Average Point Density	2 pts / m^2

Table 2. LiDAR System Specifications

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
- Piper Navajo PA-31 (twin engine), Tail Number(s): N359RX

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)

Figure 5. AXIS Plane Piper Navajo PA-31 (N359RX)

2.4. Time Period

Project specific flights were conducted between August 10, 2022, and September 21, 2022. Twenty-three aircraft lifts were completed. Accomplished lifts are listed below.

Lift	Start UTC	End UTC
08102022 (SN2223544, N359RX)	08/10/2022 13:56 PM	08/10/2022 20:54 PM
08122022 (SN2223544, N359RX)	08/12/2022 16:32 PM	08/12/2022 18:17 PM
08132022 (SN2223544, N359RX)	08/13/2022 15:12 PM	08/13/2022 18:55 PM
08142022 (SN2223544, N359RX)	08/14/2022 15:23 PM	08/14/2022 18:55 PM
08162022 (SN2222593, N89LT)	08/16/2022 16:25 PM	08/16/2022 18:20 PM
08182022 (SN2222593, N89LT)	08/18/2022 9:02 AM	08/18/2022 10:32 AM
08192022 (SN2222593, N89LT)	08/19/2022 9:20 AM	08/19/2022 10:55 AM
08192022 (SN2223544, N359RX)	08/19/2022 14:38 PM	08/19/2022 17:41 PM
08202022 (SN2222593, N89LT)	08/20/2022 8:59 AM	08/20/2022 12:32 PM
08202022 (SN2222593, N89LT)	08/20/2022 13:51 PM	08/20/2022 14:48 PM
08202022 (SN2223544, N359RX)	08/20/2022 14:30 PM	08/20/2022 21:00 PM
08212022 (SN2222593, N89LT)	08/21/2022 9:04 AM	08/21/2022 12:38 PM
08212022 (SN2223544, N359RX)	08/21/2022 14:39 PM	08/21/2022 18:59 PM
08262022 (SN2223544, N359RX)	08/26/2022 15:36 PM	08/26/2022 18:43 PM
08272022 (SN2223544, N359RX)	08/27/2022 15:15 PM	08/27/2022 18:13 PM
08282022 (SN2222593, N89LT)	08/28/2022 9:10 AM	08/28/2022 10:30 AM
08292022 (SN2223544, N359RX)	08/29/2022 14:42 PM	08/29/2022 19:37 PM
08302022 (SN2223544, N359RX)	08/30/2022 15:51 PM	08/30/2022 19:18 PM
08312022 (SN2223544, N359RX)	08/31/2022 6:51 AM	08/31/2022 9:52 AM
09012022 (SN2223544, N359RX)	09/01/2022 6:43 AM	09/01/2022 10:22 AM
09022022 (SN2223544, N359RX)	09/02/2022 15:15 PM	09/02/2022 18:58 PM
09212022 (SN2223544, N359RX)	09/21/2022 9:54 AM	09/21/2022 12:41 PM
09212022 (SN2223544, N359RX)	09/21/2022 15:53 PM	09/21/2022 18:45 PM

Table 3. Lifts for 300248

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 1 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.

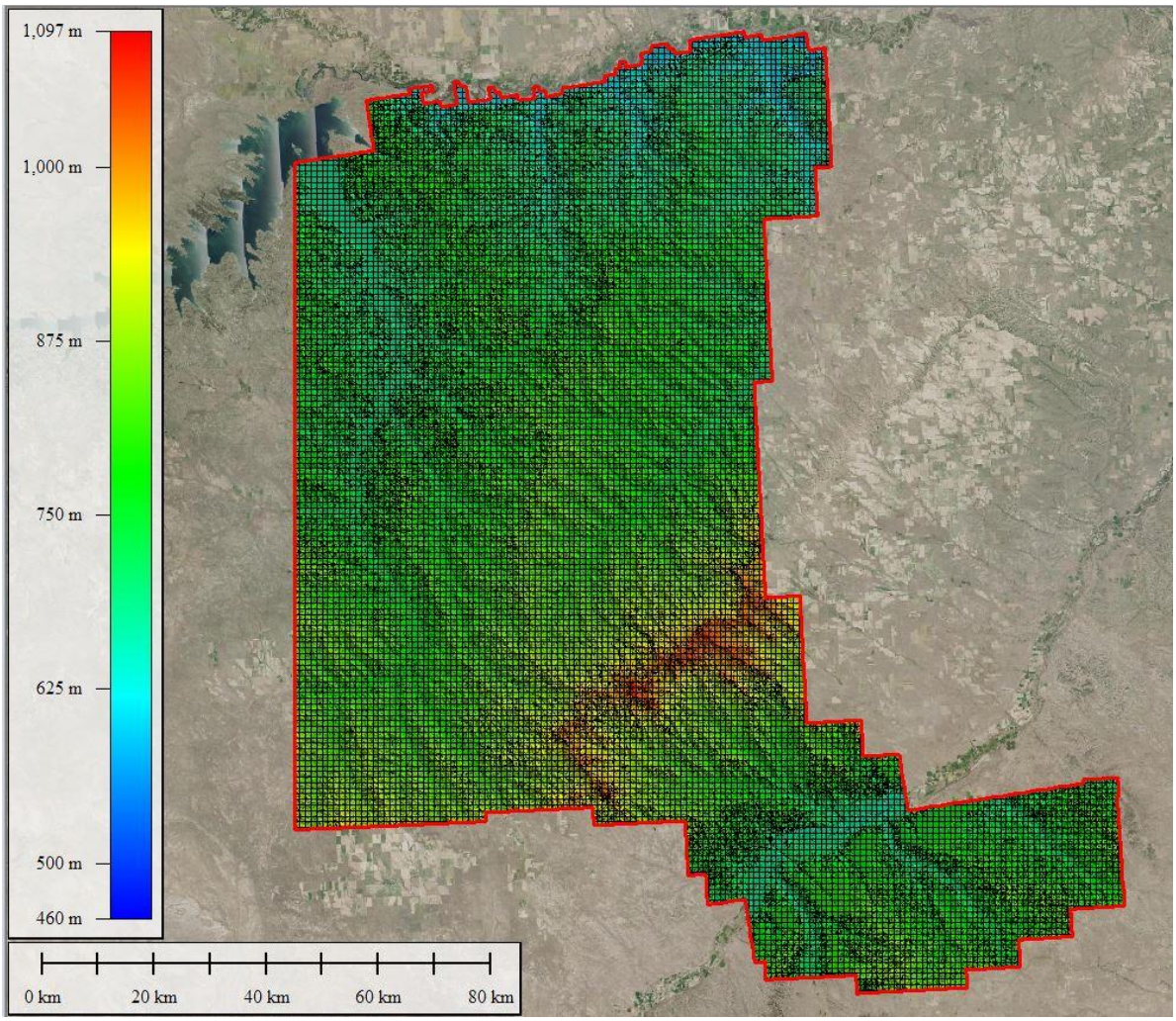

Figure 6. Work Unit 300248 Bare-Earth DEM

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 1 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.

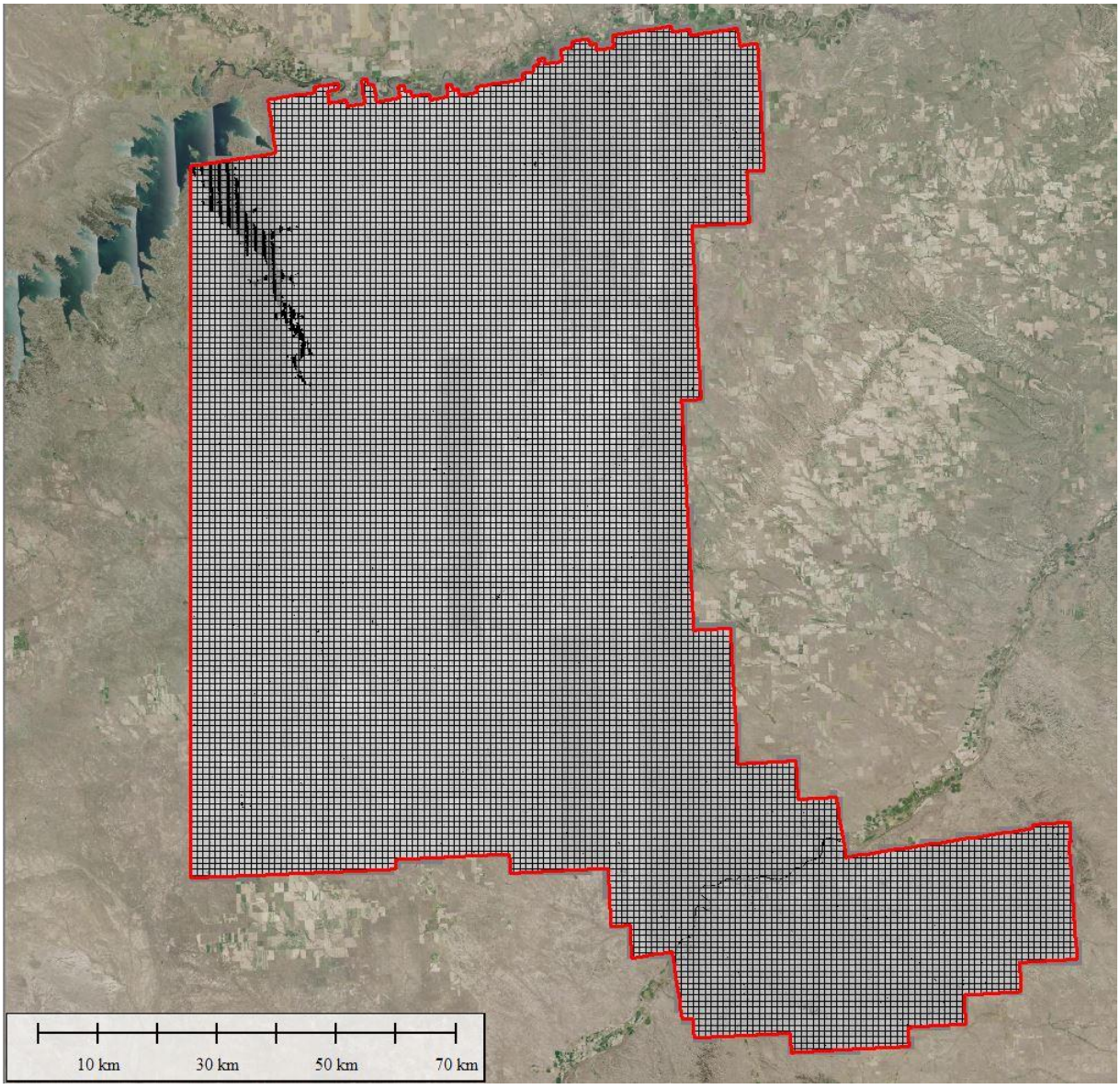

Figure 7. Work Unit 300248 Intensity Images

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 2 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.

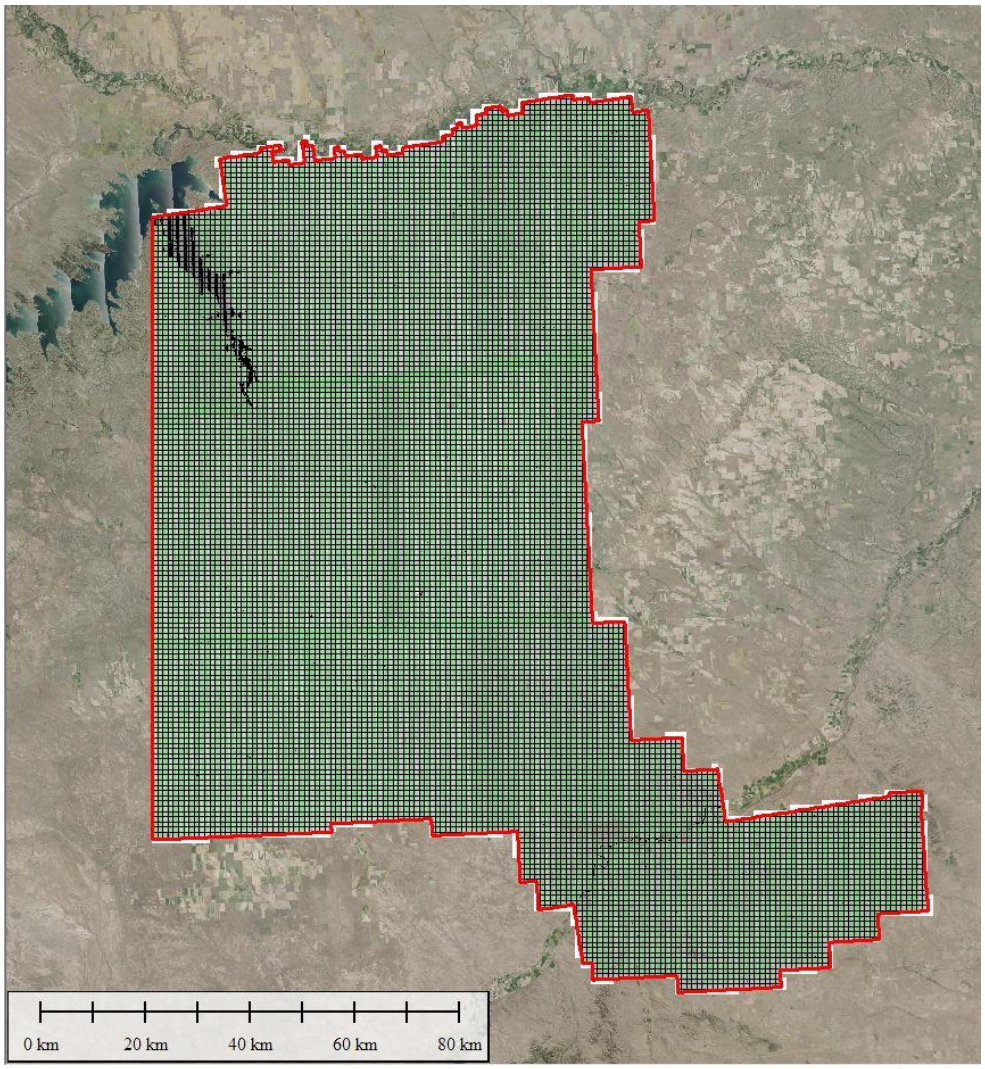

Figure 8. Work Unit 300248 Swath Separation Images

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 1 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.

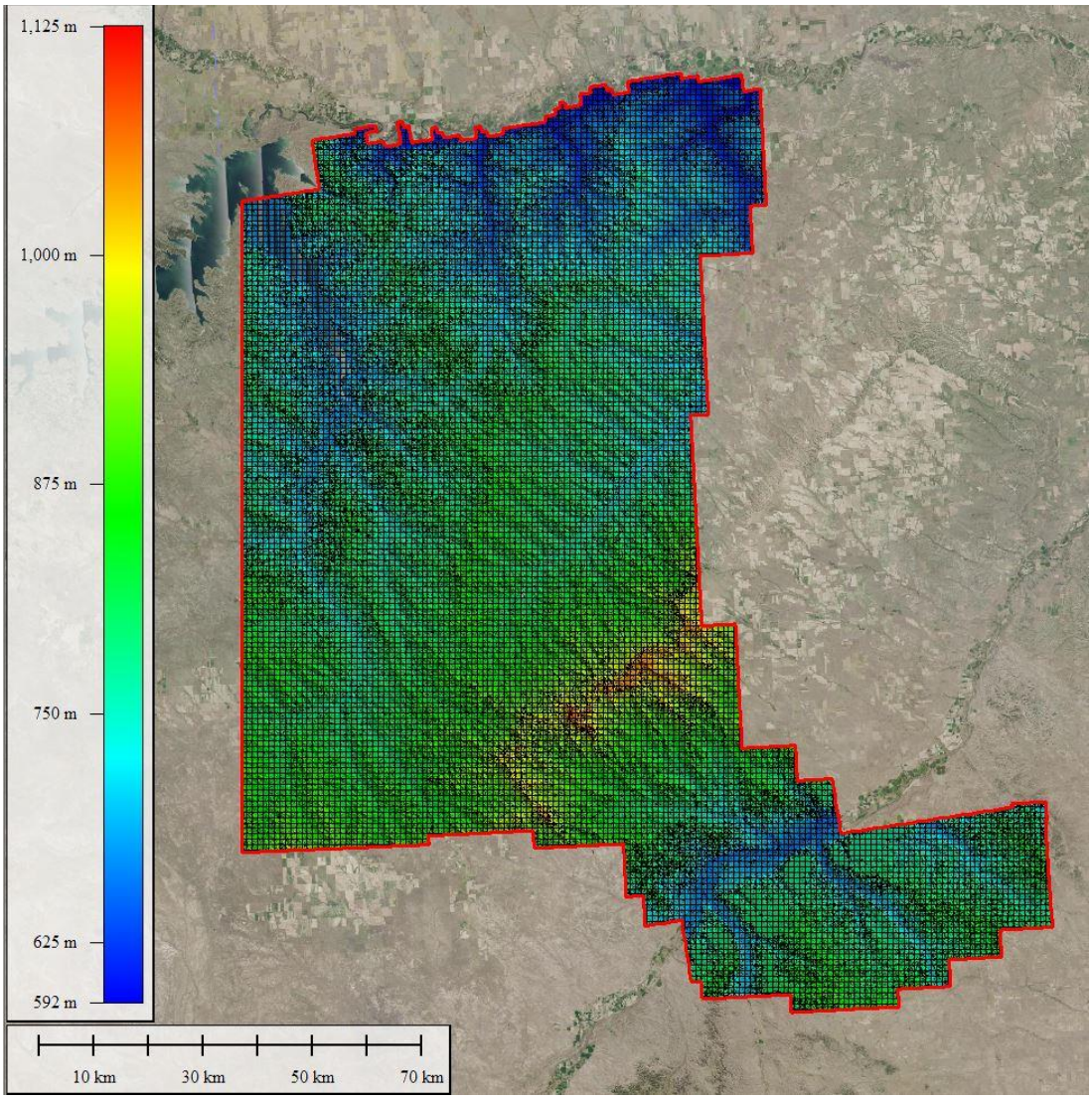

Figure 9. Work Unit 300248 MSHR Images

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 300248 Tile Layout

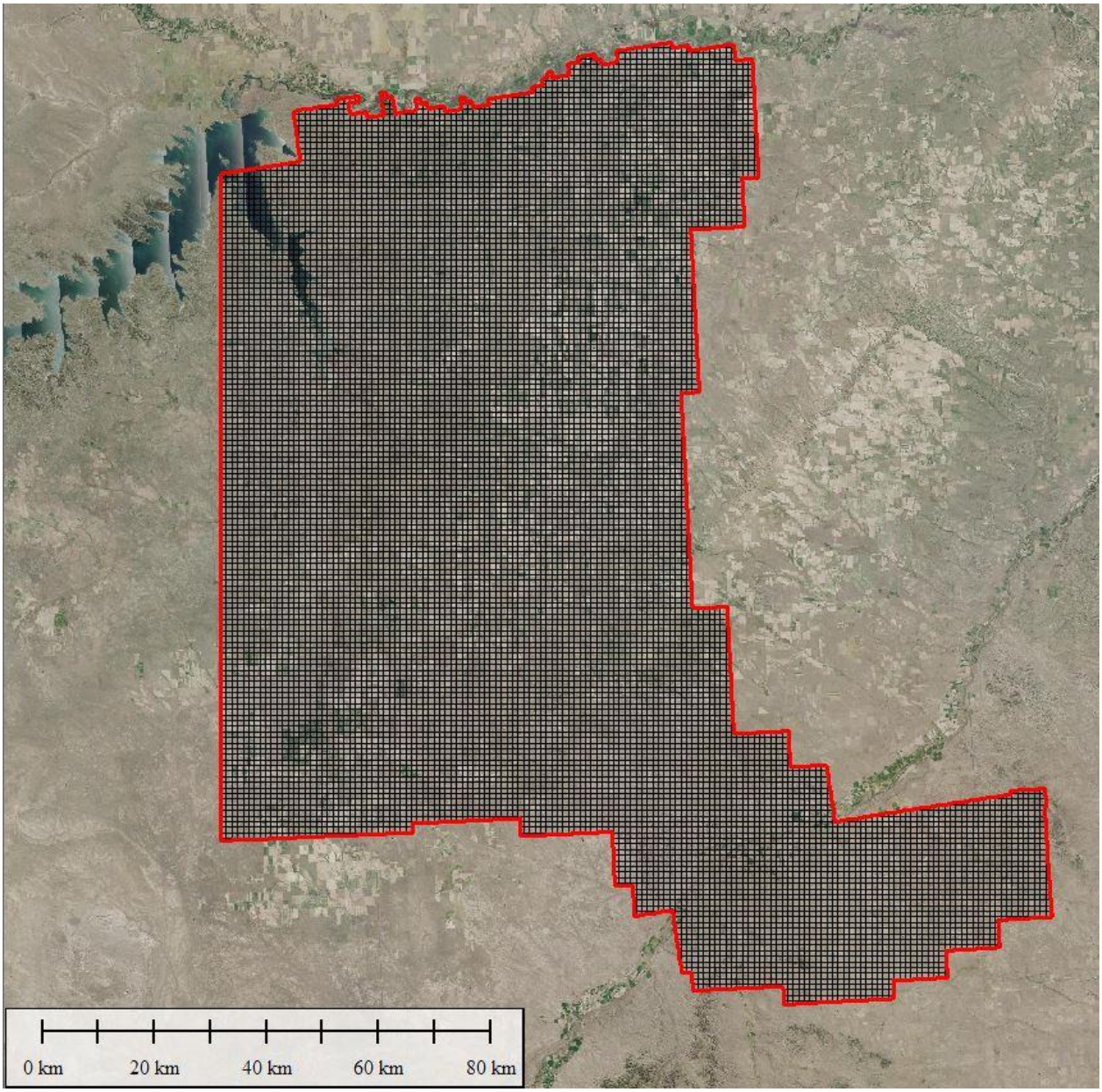

Figure 10. LiDAR Tile Layout

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 11*.

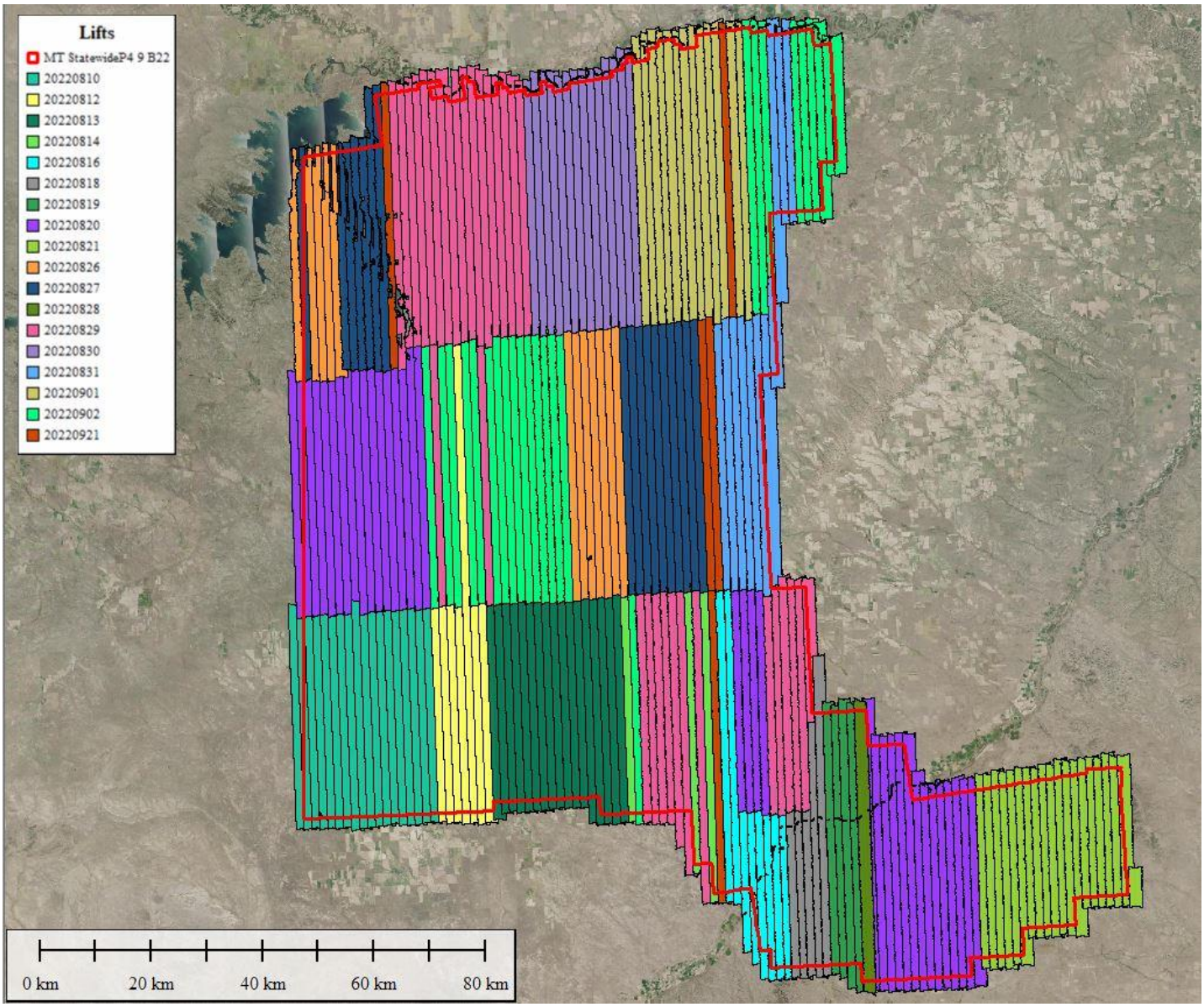

Figure 11. Work Unit 300248 LiDAR Coverage

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 1798 meters, an IMU error of 0.0025 decimal degrees, and a GNSS positional error of 0.05 meters, this project was compiled to meet 0.25 meter horizontal accuracy at 95% confidence level. A summary is shown below.

Horizontal Accuracy	
$RMSE_r$	0.49 ft
	0.15 m
ACC_r	0.82 ft
	0.25 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 -0.00454 feet (-0.00138 meters). *A summary is shown below*.

Relative Vertical Accuracy	
Sample	50 flight line surfaces
Average	-0.00454 ft
	-0.00138 m
Median	0.0000 ft
	0.0000 m
RMSE	0.24279 ft
	0.074 m
Standard Deviation (1σ)	0.19402 ft
	0.05913 m
1.96σ	0.02694 ft
	0.00821 m

Project Report Appendices

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

Flight Logs

axis geospatial				LiDAR and Imagery Flight Report				Project(s):		2007821B MONTANT QL2 FT PECK			
Pilot:		ES		Project Number(s):		2007821B MONTANT QL2 FT PECK				Date:		8/10/2022	
Operator:		AC		Project Name(s):						Mission Start (LT):		1239.9 / 1245.2	
Aircraft:		N359RX		Hobbs Start:	1239.0 / 1244.7	Hobbs Stop:	1244.7 / 1247.4			Mission End (LT):		1244.4 / 1246.6	
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):	5985		Lateral Overlap (%):	30%			Lens:			
Laser Power (%):	100		Point Spacing (m):	0.321		Forward Overlap (%):				Point Density (ppms):		5.88	
	Camera Counter		Line Start/Stop	MOB:	2.5	MSN:	5.9	TOT:	8.4				

Line #	Direction	Camera Counter To	Camera Counter From	Line Start/Stop Start Time UTC	Line Start/Stop Stop Time UTC	Altitude (Planned)	Altitude (Actual)	Remarks	Clouds	Aperture	Shutter Speed
163	N			13:56	14:04	9570+-		FT PECK			
165	S			14:09	14:18						
XTIE	E			14:22	14:24						
221	N			14:29	14:38						
224	S			14:45	14:53						
227	N			14:56	15:05						
230	S			15:07	15:18						
233	N			15:20	15:30						
236	S			15:33	15:42						
239	N			15:46	15:56						
242	S			15:59	16:10						
245	N			16:12	16:21						
248	S			16:26	16:24						
251	N			16:32	16:41						
254	S			16:43	16:58						
258	N			17:02	17:11						
259	S			17:14	17:25						
263	N			17:28	17:36						
266	S			17:39	17:47						
XTIE	W			17:55	18:00						
269	N			19:33	19:44						
272	S			19:47	19:57						
275	N			19:59	20:09						
278	S			20:11	20:20						
281	N			20:23	20:33						
284	S			20:37	20:46						
XTIE	W			20:50	20:54						

LiDAR and Imagery Flight Report				Project(s):	2007821B MONTANT QL2 FT PECK		
Pilot:	ES	Project Number(s):	2007821B MONTANT QL2 FT PECK			Date:	8/12/2022
Operator:	AC	Project Name(s):				Mission Start (LT):	1248.0
Aircraft:	N359RX	Hobbs Start:	1247.4	Hobbs Stop:	1252.7	Mission End (LT):	1251.7

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):	5985	Lateral Overlap (%):	30%	Lens:	
Laser Power (%):	100	Point Spacing (m):	0.321	Forward Overlap (%):		Point Density (ppms):	5.88

MOB: 2.5 MSN: 5.9 TOT: 8.4

		Camera Counter		Line Start/Stop							
Line #	Direction	To	From	Start Time UTC	Stop Time UTC	Altitude (Planned)	Altitude (Actual)	Remarks	Clouds	Aperture	Shutter Speed
64	W			14:38	14:45	10825+-		BILLINGS W REFLIGHTS			
65	E			14:49	14:56	10824+-					
66	W			15:00	15:08	10824+-					
67	E			15:11	15:18	10840-					
68	N			15:25	15:27	11214+-		CROSSTIE			
287	N			16:32	16:42	9284+-		FT PECK			
291	S			16:45	16:54	9284+-					
293	N			16:59	17:07	9284+-					
296	S			17:12	17:21	9284+-					
299	N			17:29	17:39	9284+-		ine not cut in FP, Shortened line to fly need complete N en			
302	S			17:43	17:52	9284+-					
304	N			17:57	18:06	9284+-					
9487	XTIE			18:12	18:17	9284+-					

LiDAR and Imagery Flight Report				Project(s):	2007821B MONTANT QL2 FT PECK		
Pilot:	ES	Project Number(s):	2007821B MONTANT QL2 FT PECK			Date:	8/13/2022
Operator:	AC	Project Name(s):				Mission Start (LT):	1253.7
Aircraft:	N359RX	Hobbs Start:	1252.7	Hobbs Stop:		Mission End (LT):	1257.5

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):	5985	Lateral Overlap (%):	30%	Lens:	
Laser Power (%):	100	Point Spacing (m):	0.321	Forward Overlap (%):		Point Density (ppms):	5.88

MOB: -1256.5 MSN: 3.8 TOT: -1252.7

		Camera Counter		Line Start/Stop							
Line #	Direction	To	From	Start Time UTC	Stop Time UTC	Altitude (Planned)	Altitude (Actual)	Remarks	Clouds	Aperture	Shutter Speed
307	N			15:12	15:21	9450+-		FT PECK			
310	S			15:25	15:34						
313	N			15:39	15:47						
316	S			15:52	16:00						
319	N			16:04	16:13						
322	S			16:18	16:26						
325	N			16:31	16:39						
328	S			16:43	16:51						
331	N			16:55	17:04						
334	S			17:09	17:17						
337	N			17:21	17:30						
340	S			17:33	17:42						
343	N			17:46	17:55						
346	S			17:58	18:10						
349	N			18:13	18:22						
352	S			18:25	18:35						
355	N			18:36	18:46						
XTIE	W			18:50	18:55						

LiDAR		Project(s):	MONTANA FT PECK

Pilot:	ES	Project Number(s):	2007821B	Date:	8/14/2022
Operator:	CT/AC	Project Name(s):	MONTANA FT PECK	Mission Start (LT):	1259.1 / 1262.5
Aircraft:	N359RX	Hobbs Start: 1258.3 / 1262.1	Hobbs Stop: 1262.1 / 1264.9	Mission End (LT):	1261.6 / 1264.0

LiDAR Unit:	VQ1560i (3)	Scan Rate:		Camera Unit:	Phase One	Drive:	VQ III L 1
MTA Zones:		Grnd Spd Max (kts):	155	FOV (deg):	58.52	Sun Angle:	> 30º
PRR (kHz):	700	Altitude (feet AMT):	5950	Lateral Overlap (%):	30%	Lens:	50mm
Laser Power (%):	100%	Point Spacing (m):	0.593	Forward Overlap (%):		Point Density (ppms):	5.76
GSM 4000	Camera Counter	Line Start/Stop					

				HOBBS		II		HOBBS		III				IV	
Engine Start	1258.3	1258.3		TOT	3.8	1262.1		TOT	2.8	0:00	1264.9	6.6		0:00	0.0
t on station	1259.1	1259.1		MSN	3.4	1262.5		MSN	1.5			4.9			
t off station	1262.5	1262.5		MOB	0.4	1264.0		MOB	1.3			1.7			
engines off	1262.1	1262.1				1264.9									

Line #	Direction	Start	End	Start Time	Stop Time	Altitude (Planned)	Altitude (Actual)	Remarks	Clouds	Aperture	Shutter Speed
									FEW >0-2/8	5.6	1/1600
20078_21B MONTANA FT PECK											
358	N			15:23	15:33	5950+-					
362	S			15:38	15:47						
364	N			15:52	16:01						
367	S			16:05	16:15			LIGHT CHOP START			
370	N			16:19	16:28						
373	S			16:32	16:41						
376	N			16:45	16:56						
379	S			16:59	17:11						
XTIE	W			17:19	17:23						
382	N			19:00	19:11						
385	S			19:16	19:30						
388	N			19:34	19:47						
391	S			19:51	20:04						
XTIE	W			20:09	20:12						

LiDAR		Project(s):	MONTANA FT PECK

Pilot:	ES	Project Number(s):	2007821B	Date:	8/16/2022
Operator:	CT/AC	Project Name(s):	MONTANA FT PECK	Mission Start (LT):	53.5
Aircraft:	N359RX	Hobbs Start: 3252.1	Hobbs Stop:	Mission End (LT):	55.7

LiDAR Unit:	VQ1560i (2)	Scan Rate:		Camera Unit:	Phase One	Drive:	VQII L2
MTA Zones:		Grnd Spd Max (kts):	155	FOV (deg):	58.52	Sun Angle:	> 30º
PRR (kHz):	700	Altitude (feet AMT):	5950	Lateral Overlap (%):	30%	Lens:	50mm
Laser Power (%):	100%	Point Spacing (m):	0.593	Forward Overlap (%):		Point Density (ppms):	5.76
GSM 4000	Camera Counter	Line Start/Stop					

				HOBBS		II		HOBBS		III				IV	
Engine Start	3252.1			TOT				TOT	0.0	0:00	0.0	5.3		0:00	0.0
t on station				MSN				MSN	0.0			2.2			
t off station				MOB				MOB	0.0			3.1			
engines off															

Line #	Direction	Start	End	Start Time	Stop Time	Altitude (Planned)	Altitude (Actual)	Remarks	Clouds	Aperture	Shutter Speed
									FEW >0-2/8	5.6	1/1600
20078_21B MONTANA FT PECK											
394	N			16:25	16:39	5950+-					
397	S			16:43	16:58						
400	N			17:04	17:10						
404	S			17:15	17;22						
408	N			17:26	17:34			LIGHT CHOP START			
412	S			17:37	17:45						
416	N			17:48	17:56						
420	S			17:58	18:06						
XTIE	W			18:16	18:20						

LiDAR and Imagery Flight Report

Project(s): 20220818_LT_II_STTC_DF

Pilot:	JT	Project Number(s):	see below			Date:	20220818_LT_II_STTC_DF
Operator:	PM	Project Name(s):	see below			Mission Start (LT):	9:00
Aircraft:	N89LT	Hobbs Start:	3258.6	Hobbs Stop:	3260.2	Mission End (LT):	10:35

LiDAR Unit:	VQ-1560i - II	Scan Rate:		Camera Unit:	Phase One	Drive:	VQ II L 3		
MTA Zones:		Grnd Spd Max (kts):	155 kts	FOV (deg):	58.52	Sun Angle:	> 30°		
PRR (kHz):	700 x 2	Altitude (feet AMT):	5950'	Lateral Overlap (%):	30%	Lens:	50mm		
Laser Power (%):	100%	Point Spacing (m):		Forward Overlap (%):		Point Density (ppms):			
	Camera Counter	Line Start/Stop							

	Time	Hobbs	20078-21b			Time	Hobbs	20078-21b			Time	Hobbs			Time
MOB START	7:35	3257.2	BIL	PECK		13:30	3261.6	BIL	PECK		0:00	0.0			0:00
t on station	9:00	3258.6		TOT	4.4				TOT	-3261.6				TOT	0.0
t off station	10:35	3260.2		MSN	1.6				MSN	0.0				MSN	0.0
MOB END	11:55	3261.6	BIL	MOB	2.8			BIL	MOB	-3261.6				MOB	0.0

Line #	Direction	Start	End	Start Time	Stop Time	Altitude (Planned)	Altitude (Actual)	Remarks	0	0				Clouds	Aperture	Shutter Speed
				MTN ZONE		8996										
20078: Montana: Fort Peck																
								700 X 2	100%	5900'	155 kts	134 LPS				
424	N350			9:02	9:11											
428	s173			9:14	9:23											
431	N353			9:25	9:33											
434	S173			9:42	9:53											
437	N353			9:56	10:13			cloud starting to pop in vacinity								
x9491	E82			10:26	10:32			clouds popped below msn alt								

LiDAR and Imagery Flight Report

Project(s): 20220819_LT_II_STTC_DF

Pilot:	JT	Project Number(s):	see below			Date:	20220819_LT_II_STTC_DF
Operator:	DF	Project Name(s):	see below			Mission Start (LT):	9:20
Aircraft:	N89LT	Hobbs Start:	3263.0	Hobbs Stop:	3264.7	Mission End (LT):	11:00

LiDAR Unit:	VQ-1560i - II	Scan Rate:		Camera Unit:	Phase One	Drive:	VQ II L 3		
MTA Zones:		Grnd Spd Max (kts):	155 kts	FOV (deg):	58.52	Sun Angle:	> 30°		
PRR (kHz):	700 x 2	Altitude (feet AMT):	5950'	Lateral Overlap (%):	30%	Lens:	50mm		
Laser Power (%):	100%	Point Spacing (m):		Forward Overlap (%):		Point Density (ppms):			
	Camera Counter	Line Start/Stop							

	Time	Hobbs	20078-21b			Time	Hobbs	20078-21b			Time	Hobbs			Time
MOB START	8:10	3261.6	BIL	PECK		12:20	3265.0	GDV	PECK		14:00	3266.7			0:00
t on station	9:20	3263.0		TOT	3.4				TOT	1.7				TOT	-3266.7
t off station	11:00	3264.7		MSN	1.7				MSN	0.0				MSN	0.0
MOB END	11:30	3265.0	GDV	MOB	1.7	14:00	3266.7	BIL	MOB	1.7				MOB	-3266.7

Line #	Direction	Start	End	Start Time	Stop Time	Altitude (Planned)	Altitude (Actual)	Remarks	0	0				Clouds	Aperture	Shutter Speed
				MTN ZONE		8996										
20078: Montana: Fort Peck																
								700 X 2	100%	5900'	155 kts	134 LPS				
439	N350			9:20	9:37											
441	S173			9:40	9:51											
443	N350			9:55	10:10											
445	S173			10:11	10:23											
447	N350			10:26	10:41			Cloud cover below MSN ALT								
9491	E83			10:52	10:55											

LiDAR and Imagery Flight Report

Project(s): 20220819_RX_III_GSM_CT

Pilot:	ES	Project Number(s):	20078-21B MT			Date:	20220819_RX_III_GSM_CT
Operator:	CT	Project Name(s):	see below			Mission Start (LT):	0:00
Aircraft:	N89LT	Hobbs Start:		Hobbs Stop:	1270.2	Mission End (LT):	0:00

LiDAR Unit:	VQ- III	Scan Rate:		Camera Unit:	Phase One	Drive:	VQ II L 3
MTA Zones:		Grnd Spd Max (kts):	155 kts	FOV (deg):	58.52	Sun Angle:	> 30°
PRR (kHz):	700 x 2	Altitude (feet AMT):	5950'	Lateral Overlap (%):	30%	Lens:	50mm
Laser Power (%):	100%	Point Spacing (m):		Forward Overlap (%):		Point Density (ppms):	

Camera Counter | Line Start/Stop

	Time	Hobbs	20078-21b			Time	Hobbs	20078-21b			Time	Hobbs			Time
MOB START		1265.9	BIL	PECK			1270.6	GGW	PECK		0:00	1271.8			0:00
t on station		1267.0		TOT	4.7				TOT	1.2				TOT	-1271.8
t off station		1270.2		MSN	3.2				MSN	0.0				MSN	0.0
MOB END		1270.6	GGW	MOB	1.5		1271.8	BIL	MOB	1.2				MOB	-1271.8

Line #	Direction	Start	End	Start Time	Stop Time	Altitude (Planned)	Altitude (Actual)	Remarks	0	0	Clouds	Aperture	Shutter Speed
				MTN ZONE									
20078: Montana: FORT PECK													
180	N			14:38	14:48			LINE ALREADY FLOWN. DNU					
192	S			14:56	15:06								
195	N			15:11	15:19								
198	S			15:23	15:33								
201	N			15:36	15:46								
204	S			15:49	15:58								
207	N			16:01	16:11								
210	S			16:13	16:23								
213	N			16:26	16:36								
216	S			16:38	16:48								
219	N			16:51	17:00								
X-TIE	E			17:08	17:13			LIGHT CHOP ON BEGINNING OF X-TIE					
222	S			17:19	17:29			CLOUDS BUILDING IN IMMEDIATE AREA					
225	N			17:32	17:41								

LiDAR and Imagery Flight Report

Project(s): 20220820_LT_II_STTC_PM

Pilot:	JT	Project Number(s):	see below	Date:	20220820_LT_II_STTC_PM
Operator:	PM	Project Name(s):	see below	Mission Start (LT):	8:50
Aircraft:	N89LT	Hobbs Start:	3268.0	Hobbs Stop:	3271.7	Mission End (LT):	12:35

LiDAR Unit:	VQ-1560i - II	Scan Rate:		Camera Unit:	Phase One	Drive:	VQ II L 2
MTA Zones:		Grnd Spd Max (kts):	155 kts	FOV (deg):	58.52	Sun Angle:	> 30°
PRR (kHz):	700 x 2	Altitude (feet AMT):	5950'	Lateral Overlap (%):	30%	Lens:	50mm
Laser Power (%):	100%	Point Spacing (m):		Forward Overlap (%):		Point Density (ppms):	

MTN ZONE | Camera Counter | Line Start/Stop

	Time	Hobbs	20078-21b				Time	Hobbs	20078-21b				Time	Hobbs					Time
MOB START	7:30	3266.7	BIL	PECK			13:25	3272.1	MLS	PECK			16:00	3274.6					0:00
t on station	8:50	3268.0		TOT	5.4		13:50	3272.6		TOT	2.5					TOT	-3274.6		
t off station	12:35	3271.7		MSN	3.7		14:50	3273.5		MSN	0.9					MSN	0.0		
MOB END	13:05	3272.1	MLS	MOB	1.7		16:00	3274.6	BIL	MOB	1.6					MOB	-3274.6		

Line #	Direction	Start	End	Start Time	Stop Time	Altitude (Planned)	Altitude (Actual)	Remarks	0	0				Clouds	Aperture	Shutter Speed
				MTN ZONE												
20078: Montana: PECK																
								700 X 2	100%	5900'	155 kts	134 LPS				
449	N 351			8:54	XX		8992	sensor did not fire - op error								
449	N 351			8:59	9:12		8992	YAW ANGLE - + / - 12°								
450	S 171			9:16	9:31		8982	wind vs aircraft: challenge to control pitch / alt: +9°						82 airspeed / pitch		
450	N 351			9:36	9:47		8982	refly 450								
451	S 171			9:50	10:02		8848	good								
452	N 351			10:04	10:15		8838									
453	S 171			10:17	10:29		8963									
454	N 351			10:32	10:42		8940									
455	S 171			10:46	10:57		8963									
456	N 351			10:59	11:08		8923	clouds building to the north and east								
457	S 171			11:11	11:21		8960									
458	N 351			11:23	11:31		8966	rough southern start, got much better								
459	S 171			11:34	11:44		9084									
460	N 351			11:46	11:54		9130									
461	S 171			11:57	12:08		9153									
462	N 351			12:11	12:19		9176									
X 9490	W 263			12:25	12:32		8992	clouds building to the north and east								
								rough ride on the descent								
401	N 351			13:51	14:00		9268	some mild chop // 152 NB								
405	S 171			14:03	14:14		9242	some mild chop - not too bad								
409	N 351			14:17	14:26		9179									
413	S 171			14:29	14:41		9163	increased turb, may have low pd in areas								
X 9489	W			14:44	14:48		8960									

LiDAR and Imagery Flight Report

Project(s): 20220820_RX_III_GSM_CT

Pilot:	ES	Project Number(s):	20078-21B MT			Date:	20220820_RX_III_GSM_CT
Operator:	CT	Project Name(s):	see below			Mission Start (LT):	0:00
Aircraft:	N359RX	Hobbs Start:	1270.6	Hobbs Stop:	1276.6	Mission End (LT):	0:00

LiDAR Unit:	VQ- III	Scan Rate:		Camera Unit:	Phase One			Drive:	A
MTA Zones:		Grnd Spd Max (kts):	155 kts	FOV (deg):	58.52			Sun Angle:	> 30°
PRR (kHz):	700 x 2	Altitude (feet AMT):	5950'	Lateral Overlap (%):	30%			Lens:	50mm
Laser Power (%):	100%	Point Spacing (m):		Forward Overlap (%):				Point Density (ppms):	
	Camera Counter	Line Start/Stop							

	Time	Hobbs	20078-21b			Time	Hobbs	20078-21b			Time	Hobbs				Time
MOB START		1270.6	BIL	PECK			1277.1	GGW	PECK		0:00	1279.4				0:00
t on station		1272.7		TOT	6.5		1277.6		TOT	2.3				TOT	-1279.4	
t off station		1276.6		MSN	3.9		1278.5		MSN	0.9				MSN	0.0	
MOB END		1277.1	GGW	MOB	2.6		1279.4	BIL	MOB	1.4				MOB	-1279.4	

Line #	Direction	Start	End	Start Time	Stop Time	Altitude (Planned)	Altitude (Actual)	Remarks	0	0				Clouds	Aperture	Shutter Speed
				MTN ZONE												
20078: Montana: FORT PECK																
228	N			14:30	14:41											
231	S			14:43	14:53											
234	N			14:56	15:05											
237	S			15:08	15:18											
240	N			15:21	15:30											
243	S			15:33	15:43			LIGHT CHOP ON THIS LINE								
246	N			15:46	15:55											
249	S			15:58	16:08											
252	N			16:12	16:21											
255	S			16:24	16:35											
256	N			16:38	16:47											
260	S			16:51	17:01											
264	N			17:05	17:14											
267	S			17:17	17:27											
270	N			17:30	17:39											
273	S			17:43	17:53											
276	N			17:56	18:06											
XTIE	W			18:13	18:20											
279	S			20:13	20:24			LIGHT CHOP STARTING								
282	N			20:28	20:39											
285	S			20:42	20:50											
XTIE	W			20:58	21:00											

LiDAR and Imagery Flight Report

Project(s): 20221820_RX_III_GSM_CT

Pilot:	ES	Project Number(s):	20078-21B MT			Date:	20221820_RX_III_GSM_CT
Operator:	CT	Project Name(s):	see below			Mission Start (LT):	0:00
Aircraft:	N359RX	Hobbs Start:	1270.6	Hobbs Stop:	1284.9	Mission End (LT):	0:00

LiDAR Unit:	VQ- III	Scan Rate:		Camera Unit:	Phase One	Drive:	A
MTA Zones:		Grnd Spd Max (kts):	155 kts	FOV (deg):	58.52	Sun Angle:	> 30°
PRR (kHz):	700 x 2	Altitude (feet AMT):	5950'	Lateral Overlap (%):	30%	Lens:	50mm
Laser Power (%):	100%	Point Spacing (m):		Forward Overlap (%):		Point Density (ppms):	

Camera Counter | Line Start/Stop

	Time	Hobbs	20078-21b			Time	Hobbs	20078-21b			Time	Hobbs				Time
MOB START		1279.4	BIL	PECK			1285.3	MLS	PECK		0:00	1286.4				0:00
t on station		1280.5					0.0		TOT	1.1				TOT	-1286.4	
t off station		1284.9					0.0		MSN	0.0				MSN	0.0	
MOB END		1285.3	MLS				*1286*	BIL	MOB	1.1				MOB	-1286.4	

Line #	Direction	Start	End	Start Time	Stop Time	Altitude (Planned)	Altitude (Actual)	Remarks	0	0	Clouds	Aperture	Shutter Speed
				MTN ZONE									
20078: Montana: FORT PECK													
288	N			14:39	14:50	5950+/-		WINDY FIRST LINE					
291	S			14:53	15:03								
294	N			15:08	15:19								
297	S			15:22	15:32								
299	N			15:36	15:47			UNCUT LINE, NORTH SECTION.					
302	S			15:51	16:01								
305	N			16:05	16:16								
308	S			16:18	16:29								
311	N			16:33	16:44								
314	S			16:47	16:57								
317	N			17:00	17:11								
320	S			17:14	17:25								
323	N			17:28	17:38								
326	S			17:41	17:52								
329	N			17:55	18:06								
332	S			18:09	18:19								
335	N			18:22	18:32								
338	S			18:36	18:46								
XTIE	W			18:51	18:59								

LiDAR and Imagery Flight Report

Project(s): 20220821_LT_II_STTC_DF

Pilot:	JT	Project Number(s):	see below	Date:	20220821_LT_II_STTC_DF
Operator:	DF	Project Name(s):	see below	Mission Start (LT):	9:04
Aircraft:	N89LT	Hobbs Start: 3276.1	Hobbs Stop: 3279.8	Mission End (LT):	12:39

LiDAR Unit:	VQ-1560i - II	Scan Rate:		Camera Unit:	Phase One	Drive:	VQ II L 2
MTA Zones:		Grnd Spd Max (kts):	155 kts	FOV (deg):	58.52	Sun Angle:	> 30°
PRR (kHz):	700 x 2	Altitude (feet AMT):	5950'	Lateral Overlap (%):	30%	Lens:	50mm
Laser Power (%):	100%	Point Spacing (m):		Forward Overlap (%):		Point Density (ppms):	

MTN ZONE — Camera Counter — Line Start/Stop

	Time	Hobbs	20078-21b			Time	Hobbs	20078-21b			Time	Hobbs				Time
MOB START	7:40	3274.6	BIL	PECK			0.0	MLS	PECK							0:00
t on station	9:04	3276.1		TOT					TOT					TOT	0.0	
t off station	12:39	3279.8		MSN					MSN	0.0				MSN	0.0	
MOB END			MLS	MOB	0.0		3274.6	BIL	MOB	0.0				MOB	0.0	

Line #	Direction	Start	End	Start Time	Stop Time	Altitude (Planned)	Altitude (Actual)	Remarks	0	0				Clouds	Aperture	Shutter Speed
				MTN ZONE												
20078: Montana: PECK																
								700 X 2	100%	5900'	155 kts	134 LPS				
463	N 349			9:04	9:13	9176	9175	bumpy								
464	S 174			9:15	9:24	9124	9120	bit choppy but should be fine								
465	N 353			9:27	9:36	9058	9066									
466	S 174			9:40	9:48	9035	9047									
467	N 353			9:51	9:59	9038	9025									
468	S 174			10:02	10:10	9091	9106									
469	N 353			10:15	10:22	9114	9112									
470	S 174			10:25	10:32	9127	9135									
471	N 353			10:35	10:42	9150	9153									
472	S 174			10:45	10:52	9173	9180									
473	N 353			10:55	11:03	9196	9207									
474	S 174			11:05	11:13	9212	9215									
475	N 354			11:15	11:23	9225	9222									
476	S 174			11:27	11:34	9130	9121									
477	N 353			11:36	11:43	9114	9111									
478	S 174			11:45	11:51	9107	9096									
479	N 354			11:53	12:01	9114	9144									
480	S 174			12:03	12:09	9153	9163									
481	N 354			12:11	12:18	9183	9187									
482	S 174			12:23	12:26	9353	9346									
xx9491	W			12:30	12:38	8920	8917									

LiDAR and Imagery Flight Report

Project(s): 20220826_RX_III_GSM_CT

Pilot:	ES	Project Number(s):	20078-21B MT			Date:	20220826_RX_III_GSM_CT
Operator:	CT	Project Name(s):	see below			Mission Start (LT):	0:00
Aircraft:	N359RX	Hobbs Start:	1270.6	Hobbs Stop:	1291.0	Mission End (LT):	0:00

LiDAR Unit:	VQ- III	Scan Rate:		Camera Unit:	Phase One	Drive:	A
MTA Zones:		Grnd Spd Max (kts):	155 kts	FOV (deg):	58.52	Sun Angle:	> 30°
PRR (kHz):	700 x 2	Altitude (feet AMT):	5950'	Lateral Overlap (%):	30%	Lens:	50mm
Laser Power (%):	100%	Point Spacing (m):		Forward Overlap (%):		Point Density (ppms):	

Camera Counter | Line Start/Stop

	Time	Hobbs	20078-21b			Time	Hobbs	20078-21b			Time	Hobbs				Time
MOB START		1279.4	BIL	PECK					PECK		0:00	0.0				0:00
t on station		1287.8		TOT	12.7				TOT	0.0				TOT	0.0	
t off station		1291.0		MSN	3.2				MSN	0.0				MSN	0.0	
MOB END		1292.1	BIL	MOB	9.5				MOB	0.0				MOB	0.0	

Line #	Direction	Start	End	Start Time	Stop Time	Altitude (Planned)	Altitude (Actual)	Remarks	0	0				Clouds	Aperture	Shutter Speed
				MTN ZONE												
20078: Montana: FORT PECK																
341				15:36	15:48											
344				15:51	ABTD			Line aborted Lost GPS								
344				16:05	16:15											
347				16:18	16:29											
350				16:32	16:43											
353				16:47	16:58											
356				17:01	17:12			CLOUDS FORMING BELOW MISSION ALT								
359				17:16	17:27											
X-TIE				17:33	17:36											
247				17:48	17:56											
250				18:00	18:11			Moving west due to clouds								
253				18:14	18:22			Possible cloud, QC this line								
257				18:25	18:35											
X-TIE				18:41	18:43			T-Storms forming at FBO, RTB								

axis geospatial		AXIS GeoAviation		LiDAR and Imagery Flight Report								Project(s):		20220827_RX_III_GSM_CT						
Pilot:		ES				Project Number(s):		20078-21B MT						Date:		20220827_RX_III_GSM_CT				
Operator:		CT				Project Name(s):		see below						Mission Start (LT):		0:00				
Aircraft:		N359RX				Hobbs Start:	1270.6		Hobbs Stop:	1296.3				Mission End (LT):		0:00				
LiDAR Unit:		VQ- III		Scan Rate:				Camera Unit:		Phase One				Drive:		A				
MTA Zones:				Grnd Spd Max (kts):		155 kts		FOV (deg):		58.52				Sun Angle:		> 30°				
PRR (kHz):		700 x 2		Altitude (feet AMT):		5950'		Lateral Overlap (%):		30%				Lens:		50mm				
Laser Power (%):		100%		Point Spacing (m):				Forward Overlap (%):						Point Density (ppms):						
		Camera Counter		Line Start/Stop																
	Time	Hobbs	20078-21b			Time	Hobbs	20078-21b				Time	Hobbs							Time
MOB START		1292.1	BIL	N359RX					N359RX			0:00	0.0							0:00
t on station		1293.2		TOT	5.1				TOT	0.0						TOT	0.0			
t off station		1296.3		MSN	3.1				MSN	0.0						MSN	0.0			
MOB END		1297.2	BIL	MOB	2.0				MOB	0.0						MOB	0.0			
Line #	Direction	Start	End	Start Time	Stop Time	Altitude (Planned)		Altitude (Actual)			Remarks	0	0				Clouds	Aperture	Shutter Speed	
				MTN ZONE																
20078: Montana: FORT PECK																				
362	N			15:15	15:25															
365	S			15:29	15:40															
368	N			15:44	15:55						BIT OF CRAB TODAY									
371	S			15:59	16:09															
374	N			16:12	16:23															
377	S			16:26	16:38															
380	N			16:41	16:51															
383	S			16:55	17:06															
386	N			17:08	17:19						CHOP BEGINNING…									
389	S			17:23	17:34						CHOP AND CLOUDS INCREASING									
392	N			17:37	17:47															
395	S			17:51	18:02						HEAVY CHOP/SWAY									
XTIE	W			18:07	18:13															

LiDAR and Imagery Flight Report

Project(s): 20220828_LT_II_STTC_DF

Pilot:	JT	Project Number(s):	see below			Date:	20220828_LT_II_STTC_DF
Operator:	DF	Project Name(s):	see below			Mission Start (LT):	9:10
Aircraft:	N89LT	Hobbs Start:	3294.0	Hobbs Stop:	3294.6	Mission End (LT):	10:30

LiDAR Unit:	VQ-1560i - II	Scan Rate:		Camera Unit:	Phase One	Drive:	VQ II L 2
MTA Zones:		Grnd Spd Max (kts):	155 kts	FOV (deg):	58.52	Sun Angle:	> 30°
PRR (kHz):	700 x 2	Altitude (feet AMT):	5950'	Lateral Overlap (%):	30%	Lens:	50mm
Laser Power (%):	100%	Point Spacing (m):		Forward Overlap (%):		Point Density (ppms):	

MTN ZONE | Camera Counter | Line Start/Stop

	Time	Hobbs	20078-21b				Time	Hobbs	20078-21b				Time	Hobbs				Time
MOB START	8:10	3292.6	BIL	PECK				3295.9	BIL	PECK								0:00
t on station	9:10	3294.0		TOT						TOT						TOT	0.0	
t off station	10:30	3294.6		MSN						MSN	0.0					MSN	0.0	
MOB END	11:15	3295.9	BIL	MOB					BIL	MOB	0.0					MOB	0.0	

Line #	Direction	Start	End	Start Time	Stop Time	Altitude (Planned)	Altitude (Actual)	Remarks	0	0				Clouds	Aperture	Shutter Speed
				MTN ZONE												
20078: Montana: PECK																
								700 X 2	100%	5900'	155 kts	134 LPS				
401	N 350			9:10	9:20			Heavy cloud cover below MSN ALT ABORTED.								
447	S 173			10:15	10:30											
X9491	W															

LiDAR and Imagery Flight Report

Project(s): 20220829_RX_III_GSM_CT

Pilot:	ES	Project Number(s):	20078-21B MT			Date:	20220829_RX_III_GSM_CT
Operator:	CT	Project Name(s):	see below			Mission Start (LT):	0:00
Aircraft:	N359RX	Hobbs Start:	1270.6	Hobbs Stop:	1305.7	Mission End (LT):	0:00

LiDAR Unit:	VQ- III	Scan Rate:		Camera Unit:	Phase One	Drive:	A
MTA Zones:		Grnd Spd Max (kts):	155 kts	FOV (deg):	58.52	Sun Angle:	> 30°
PRR (kHz):	700 x 2	Altitude (feet AMT):	5950'	Lateral Overlap (%):	30%	Lens:	50mm
Laser Power (%):	100%	Point Spacing (m):		Forward Overlap (%):		Point Density (ppms):	

Camera Counter | Line Start/Stop

	Time	Hobbs	20078-21b			Time	Hobbs	20078-21b			Time	Hobbs				Time
MOB START		1299.7	BIL	N359RX			1306.1	GLA	N359RX		0:00	1307.4				0:00
t on station		1300.7		TOT	6.4				TOT	1.3				TOT	-1307.4	
t off station		1305.7		MSN	5.0				MSN	0.0				MSN	0.0	
MOB END		1306.1	GLA	MOB	1.4		1307.4	BIL	MOB	1.3				MOB	-1307.4	

Line #	Direction	Start	End	Start Time	Stop Time	Altitude (Planned)	Altitude (Actual)	Remarks	0	0			Clouds	Aperture	Shutter Speed
				MTN ZONE											
20078: Montana: FORT PECK															
291	N			14:42	14:54	5950AGL	5950+/-	REQUESTED REFLY COMPLETED							
308	S			14:56	15:07			REQUESTED REFLY COMPLETED							
X-TIE	W			15:14	15:17			REFLY X-TIE							
280	N			15:25	15:38										
283	S			15:43	15:52										
286	N			15:56	16:08										
289	S			16:12	16:22										
292	N			16:26	16:37										
295	S			16:41	16:51										
298	N			16:55	17:07										
300	S			17:11	17:21										
303	N			17:24	17:35										
306	S			17:38	17:49										
309	N			17:53	18:04										
312	S			18:07	18:18										
315	N			18:22	18:32										
318	S			18:35	18:45										
321	N			18:49	18:59			LIGHT CHOP							
324	S			19:03	19:12			MEDIUM CHOP							
327	N			19:16	19:26			LIGHT CHOP							
X-TIE	W			19:31	19:37										

axis geospatial		AXIS GeoAviation		LiDAR and Imagery Flight Report								Project(s):		20220830_RX_III_GSM_CT						
Pilot:		ES				Project Number(s):		20078-21B MT						Date:		20220830_RX_III_GSM_CT				
Operator:		CT				Project Name(s):		see below						Mission Start (LT):		0:00				
Aircraft:		N359RX				Hobbs Start:	1270.6	Hobbs Stop:	1312.2					Mission End (LT):		0:00				
LiDAR Unit:		VQ- III		Scan Rate:				Camera Unit:	Phase One					Drive:		A				
MTA Zones:				Grnd Spd Max (kts):		155 kts		FOV (deg):	58.52					Sun Angle:		> 30°				
PRR (kHz):		700 x 2		Altitude (feet AMT):		5950'		Lateral Overlap (%):	30%					Lens:		50mm				
Laser Power (%):		100%		Point Spacing (m):				Forward Overlap (%):						Point Density (ppms):						
		Camera Counter		Line Start/Stop																
	Time	Hobbs	20078-21b			Time	Hobbs	20078-21b				Time	Hobbs							Time
MOB START		1306.1	BIL	N359RX					N359RX			0:00	0.0							0:00
t on station		1308.7		TOT	7.1				TOT	0.0						TOT	0.0			
t off station		1312.2		MSN	3.5				MSN	0.0						MSN	0.0			
MOB END		1313.2	GLA	MOB	3.6				MOB	0.0						MOB	0.0			
Line #	Direction	Start	End	Start Time	Stop Time	Altitude (Planned)		Altitude (Actual)		Remarks	0	0				Clouds	Aperture	Shutter Speed		
				MTN ZONE																
20078: Montana: FORT PECK																				
330	N			15:51	16:01		5950+/-													
333	S			16:05	16:15															
336	N			16:17	16:29															
339	S			16:32	16:42															
342	N			16:46	16:56															
345	S			17:00	17:10															
348	N			17:13	17:23															
351	S			17:26	17:36															
354	N			17:40	17:50															
357	S			17:54	18:04															
360	N			18:09	18:20															
363	S			18:24	18:34															
366	N			18:38	18:50															
369	S			18:54	19:04															
X-TIE	W			19:13	19:18															

LiDAR and Imagery Flight Report

Project(s): 20220902RX_III_GSM_CT

Pilot:	ES	Project Number(s):	20078-21B MT			Date:	20220902RX_III_GSM_CT
Operator:	CT	Project Name(s):	see below			Mission Start (LT):	0:00
Aircraft:	N359RX	Hobbs Start:	1270.6	Hobbs Stop:	1319.1	Mission End (LT):	0:00

LiDAR Unit:	VQ- III	Scan Rate:		Camera Unit:	Phase One	Drive:	A
MTA Zones:		Grnd Spd Max (kts):	155 kts	FOV (deg):	58.52	Sun Angle:	> 30°
PRR (kHz):	700 x 2	Altitude (feet AMT):	5950'	Lateral Overlap (%):	30%	Lens:	50mm
Laser Power (%):	100%	Point Spacing (m):		Forward Overlap (%):		Point Density (ppms):	

Camera Counter | Line Start/Stop

	Time	Hobbs	20078-21b			Time	Hobbs	20078-21b			Time	Hobbs				Time
MOB START		1314.0	BIL	N359RX					N359RX		0:00	0.0				0:00
t on station		1315.2		TOT	5.8				TOT	0.0				TOT	0.0	
t off station		1319.1		MSN	3.9				MSN	0.0				MSN	0.0	
MOB END		1319.8	BIL	MOB	1.9				MOB	0.0				MOB	0.0	

Line #	Direction	Start	End	Start Time	Stop Time	Altitude (Planned)	Altitude (Actual)	Remarks	0	0				Clouds	Aperture	Shutter Speed
				MTN ZONE												
20078: Montana: FORT PECK																
326	N			15:15	15:27		5950+/-	LIGHT CHOP								
323	S			15:30	15:41			HEAVY HAZE IN AREA								
320	N			15:45	15:55											
317	S			15:59	16:10											
314	N			16:14	16:25											
311	S			16:29	16:40											
305	N			16:44	16:55											
299	S			17:00	17:13			LONGER LINE FOR OVERLAP								
302	N			17:17	17:28			LIGHT CHOP								
XTIE	S			17:37	17:48											
297	S			17:51	18:00											
294	N			18:04	18:15											
288	S			18:19	18:30											
361	S			18:40	18:49											
XTIE	W			18:55	18:58											

LiDAR and Imagery Flight Report

Project(s): 20220921RX_III_GSM_CT

Pilot:	ES	Project Number(s):	20078-21B MT			Date:	20220921RX_III_GSM_CT
Operator:	CT	Project Name(s):	see below			Mission Start (LT):	0:00
Aircraft:	N359RX	Hobbs Start:	1270.6	Hobbs Stop:	1324.2	Mission End (LT):	0:00

LiDAR Unit:	VQ- III	Scan Rate:		Camera Unit:	Phase One	Drive:	A
MTA Zones:		Grnd Spd Max (kts):	155 kts	FOV (deg):	58.52	Sun Angle:	> 30°
PRR (kHz):	700 x 2	Altitude (feet AMT):	5950'	Lateral Overlap (%):	30%	Lens:	50mm
Laser Power (%):	100%	Point Spacing (m):		Forward Overlap (%):		Point Density (ppms):	

Camera Counter | Line Start/Stop

	Time	Hobbs	20078-21b			Time	Hobbs	20078-21b			Time	Hobbs				Time
MOB START		1319.8	BIL	N359RX					N359RX		0:00	0.0				0:00
t on station		1321.3		TOT	5.2				TOT	0.0				TOT	0.0	
t off station		1324.2		MSN	2.9				MSN	0.0				MSN	0.0	
MOB END		1325.0	BIL	MOB	2.3				MOB	0.0				MOB	0.0	

Line #	Direction	Start	End	Start Time	Stop Time	Altitude (Planned)	Altitude (Actual)	Remarks	0	0				Clouds	Aperture	Shutter Speed
				MTN ZONE												
20078: Montana: FORT PECK																
						5950+/-	5950+/-									
391				15:53	16:06									SKC 0/8		
392				16:10	16:21									FEW >0-2/8		
395				16:25	16:35									FEW >0-2/8		
xtie				16:40	16:42									FEW >0-2/8		
xtie				16:47	16:48									SCT 3-4/8		
407				17:00	17:11			CLOUDS IN AREA						SCT 3-4/8		
xtie				17:20	17:21									SCT 3-4/8		
277				17:37	17:48									SCT 3-4/8		
xtie				17:53	17:54									SCT 3-4/8		
282				18:01	18:12			DO NOT USE CLOUDS BELOW MISSION ALT						BKN 5-7/8		
285				18:15	18:25									FEW >0-2/8		
282				18:28	18:39			THIS LINE IS CLEAR						FEW >0-2/8		
xtie				18:45	18:45									SKC 0/8		

LiDAR and Imagery Flight Report

Project(s): 20220921RX_III_GSM_CT

Pilot:	ES	Project Number(s):	20078-21B MT			Date:	20220921RX_III_GSM_CT
Operator:	CT	Project Name(s):	see below			Mission Start (LT):	0:00
Aircraft:	N359RX	Hobbs Start:	1319.8	Hobbs Stop:	1324.2	Mission End (LT):	0:00

LiDAR Unit:	VQ- III	Scan Rate:		Camera Unit:	Phase One	Drive:	A
MTA Zones:		Grnd Spd Max (kts):	155 kts	FOV (deg):	58.52	Sun Angle:	> 30°
PRR (kHz):	700 x 2	Altitude (feet AMT):	5950'	Lateral Overlap (%):	30%	Lens:	50mm
Laser Power (%):	100%	Point Spacing (m):	UNIFORM	Forward Overlap (%):	60%	Point Density (ppms):	

Camera Counter | Line Start/Stop

	Time	Hobbs	20078-21b			Time	Hobbs	20078-21b			Time	Hobbs				Time
MOB START		1319.8	BIL	N359RX					N359RX		0:00	0.0				0:00
t on station		1321.3		TOT	5.2				TOT	0.0				TOT	0.0	
t off station		1324.2		MSN	2.9				MSN	0.0				MSN	0.0	
MOB END		1325.0	BIL	MOB	2.3				MOB	0.0				MOB	0.0	

Line #	Direction	Start	End	Start Time	Stop Time	Altitude (Planned)	Altitude (Actual)	Remarks	0	0				Clouds	Aperture	Shutter Speed
				MTN ZONE												
20078: Montana: FORT PECK																
						5950+/-	5950+/-									
391	N			9:54	10:06									SKC 0/8		
392	N			10:09	10:21			SMALL CLOUD BELOW MISSION ALT. CHECK CAREFULLY						SKC 0/8		
395	S			10:24	10:36			CLOUDS FORMING TO EAST/WEST BELOW M ALT						FEW >0-2/8		
407	N			11:00	11:12			LIGHT CHOP						FEW >0-2/8		
277	N			11:38	11:49			LG BODY OF WATER IN THIS LINE. CLOUDS BELOW						SCT 3-4/8		
285	N			12:15	12:26			CLOUDS IN AREA / TAIL WIND						FEW >0-2/8		
282	S			12:01	12:12			CLOUDS IN THIS LINE, LIKELY UNUSEABLE WILL REFLY						SCT 3-4/8		
XTIE	W			10:41	10:42			XTIE BETWEEN CLOUDS POPPING						SCT 3-4/8		
XTIE	E			10:47	10:48									SCT 3-4/8		
XTIE	W			11:20	11:21			LIGHT CHOP						SKC 0/8		
XTIE	W			11:53	11:54									SKC 0/8		
XTIE	W			12:46	12:47											
282	S			12:29	12:41			USE THIS INSTEAD OF EARLIER LINE 282								