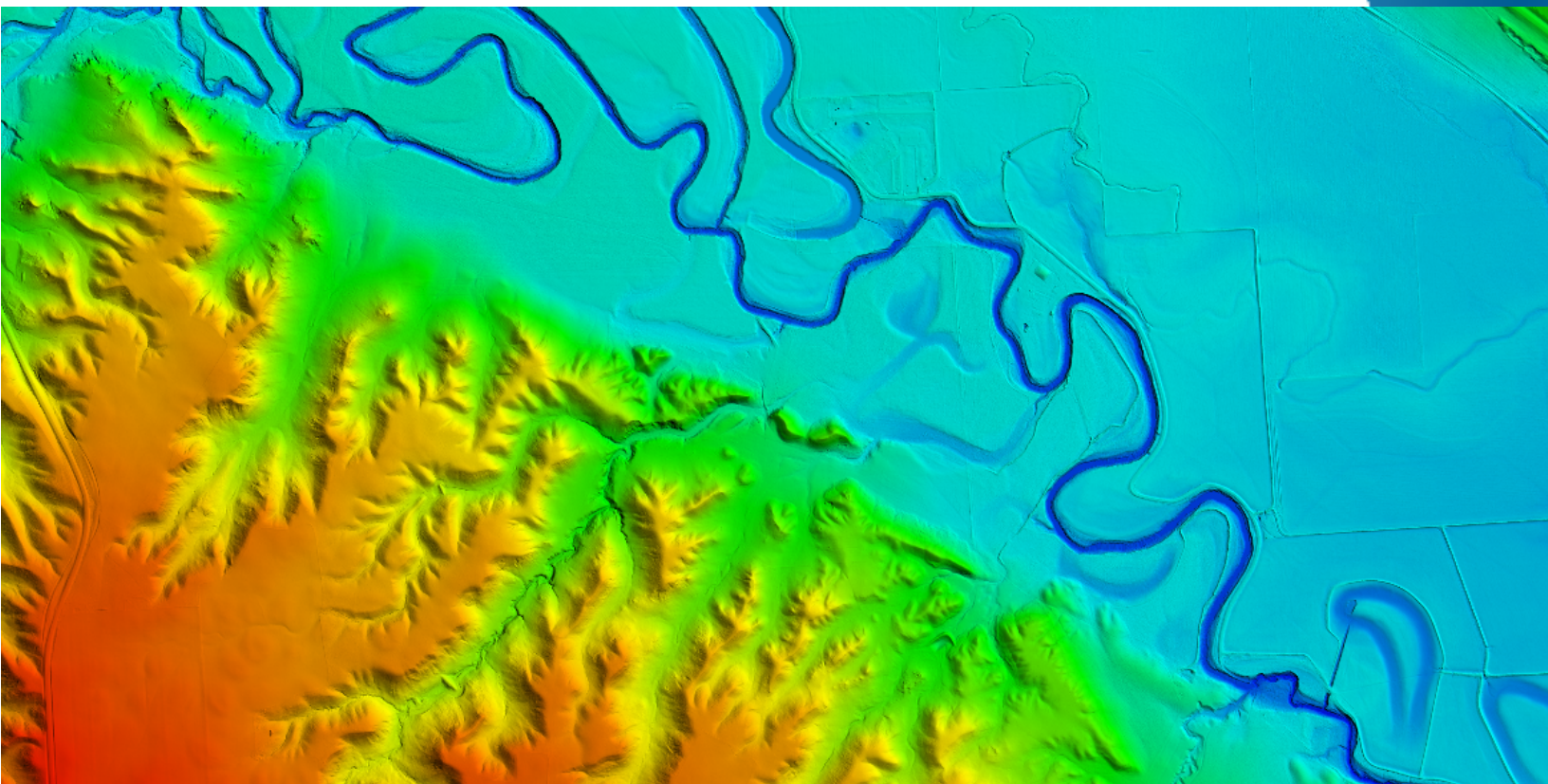




MT Statewide Phase2 2020 B20 LIDAR PROCESSING REPORT

Project ID: 197114
Work Unit: 300021

2023

Submitted: May 18, 2023

Prepared for:



tnm_help@usgs.gov

Prepared by:

N|V|5 GEOSPATIAL

Contents

1. Summary / Scope	1
1.1. Summary	1
1.2. Scope	1
1.3. Coverage.....	1
1.4. Duration.....	1
1.5. Issues	1
2. Planning / Equipment	4
2.1. Flight Planning	4
2.2. Lidar Sensor	4
2.3. Aircraft.....	6
2.4. Time Period	7
3. Processing Summary	8
3.1. Flight Logs.....	8
3.2. Lidar Processing.....	9
3.3. LAS Classification Scheme	10
3.4. Classified LAS Processing.....	11
3.5. Hydro-Flattened Breakline Processing.....	11
3.6. Hydro-Flattened Raster DEM Processing.....	12
3.7. Intensity Image Processing.....	12
3.8. Height Separation Raster Processing.....	12
4. Project Coverage Verification	14
5. Geometric Accuracy.....	16
5.1. Horizontal Accuracy.....	16
5.2. Relative Vertical Accuracy.....	17
Project Report Appendices	xviii
Appendix A.....	xix
Flight Logs.....	xix

List of Figures

Figure 1. Work Unit Boundary	3
Figure 2. Riegl VQ1560i and1560ii Lidar Sensor.....	5
Figure 3. NV5 Geospatial’s Planes	6
Figure 4. Lidar Tile Layout.....	13
Figure 5. Lidar Coverage	15

List of Tables

Table 1. Originally Planned Lidar Specifications.....	1
Table 2. Lidar System Specifications	5
Table 3. LAS Classifications	10

List of Appendices

Appendix A: Flight Logs

1. Summary / Scope

1.1. Summary

This report contains a summary of the MT_Statewide_Phase2_2020_B20 , Work Unit 300021 lidar acquisition task order, issued by USGS under their Contract G16PC0016 on 08/12/2020. The task order yielded a project area covering 2,748 square miles over Montana. 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	2500 m	58.5°	20%	≤ 10 cm

1.3. Coverage

The project boundary covers 2,748 square miles over Montana. Project extents are shown in Figure 1.

1.4. Duration

Lidar data was acquired from September 11, 2020 and June 3, 2021 in 13 total lifts. See “Section: 2.4. Time Period” for more details.

1.5. Issues

There were no issues to report.

MT_Statewide_Phase2_2020_B20 Work Unit 300021 Projected Coordinate System: NAD_1983_2011_StatePlane_Montana_FIPS_2500 Horizontal Datum: NAVD83 (2011) Vertical Datum: NAVD88 (GEOID 18) Units: Meter	
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 1-meter Maximum Surface Height Raster 1-meter Swath Separation Images
Vectors	Shapefiles (*.shp) - Project Boundary - Lidar Tile Index - Calibration and QC Checkpoints (NVA/VVA) Geodatabase (*.gdb) - Continuous Hydro-flattened Breaklines - Flightlines Swath
Reports	Reports in PDF format - Focus on Delivery - Focus on Accuracy - Survey Report - Processing Report
Metadata	XML Files (*.xml) - Breaklines - Classified Point Cloud - DEM - Intensity Imagery

MT Statewide Phase2 2020 B20 Work Unit 300021 Boundary

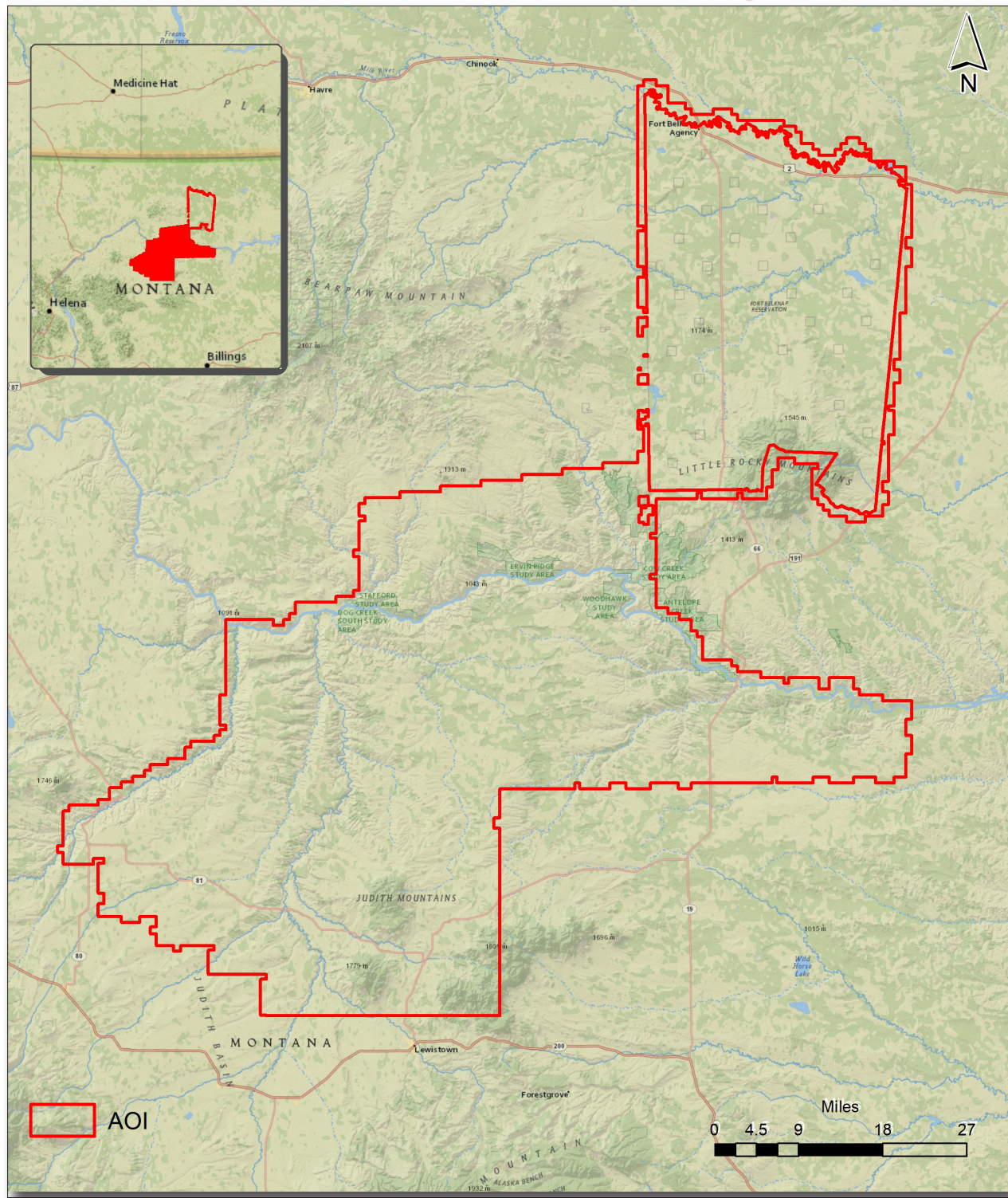


Figure 1. Work Unit Boundary

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 VQ1560i and 1560ii lidar sensors (Figure 2), serial number(s) 3546, 3061, 4040, for data acquisition.

The Riegl 1560i 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.

The Riegl 1560II system is a dual channel waveform processing airborne scanning system. It has a laser pulse repetition rate of up to 4 MHz resulting in up to 2.66 million measurements per second. The system utilizes a Multi-Pulse in the Air option (MPIA) and an integrated IMU/GNSS unit.

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 VQ1560i (3546)	Riegl VQ1560i (3061)	Riegl VQ1560ii (4040)
Terrain and Aircraft Scanner	Flying Height	2,305 m	2,305 m	2,305 m
	Recommended Ground Speed	145 kts	145 kts	145 kts
Scanner	Field of View	60°	60°	60°
	Scan Rate Setting Used	74 lps	74 lps	81 lps
Laser	Laser Pulse Rate Used	350 kHz	350 kHz	350 kHz
	Multi Pulse in Air Mode	yes	yes	yes
Coverage	Full Swath Width	2,583 m	2,583 m	2,583 m
	Line Spacing	2,066 m	2,066 m	2,066 m
Point Spacing and Density	Average Point Spacing	0.64 m	0.64 m	0.64 m
	Average Point Density	2.45 pts / m ²	2.45 pts / m ²	2.45 pts / m ²

Figure 2. Riegl VQ1560i and 1560ii Lidar Sensor



2.3. Aircraft

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

Lidar Collection Planes

- Piper Navajo (twin-piston), Tail Number(s): N6GR
- Cessna Caravan (single-turboprop), Tail Number(s): N840JA
- 1977 Piper PA-31-325 (fixed wing multi engine), Tail Number(s): N22GE

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 VQ1560i and VQ1560ii lidar systems. NV5 Geospatial's operating aircraft can be seen in Figure 3 below.

Figure 3. NV5 Geospatial's Planes



2.4. Time Period

Project specific flights were conducted between September 11, 2020 and June 3, 2021. Thirteen aircraft lifts were completed. Accomplished lifts are listed below.

Lift	Start UTC	End UTC
09112020A (SN4040,N22GE)	9/11/2020 3:41:13 PM	9/11/2020 6:58:46 PM
09162020A (SN4040,N22GE)	9/16/2020 5:11:19 PM	9/16/2020 7:41:09 PM
09212020A (SN4040,N22GE)	9/21/2020 3:42:27 PM	9/21/2020 7:46:45 PM
09212020B (SN4040,N22GE)	9/21/2020 9:42:22 PM	9/21/2020 10:09:52 PM
11042020A (SN3061,N840JA)	11/04/2020 4:35:03 PM	11/04/2020 9:31:36 PM
05192021A (SN3546,N6GR)	5/19/2021 5:49:29 PM	5/19/2021 7:55:25 PM
05272021A (SN3546,N6GR)	5/27/2021 6:49:11 PM	5/27/2021 9:49:33 PM
05292021A (SN3546,N6GR)	5/29/2021 2:44:03 PM	5/29/2021 5:28:01 PM
05302021A (SN3546,N6GR)	5/30/2021 2:27:19 PM	5/30/2021 5:20:56 PM
05312021A (SN3546,N6GR)	5/31/2021 1:54:15 PM	5/31/2021 6:17:04 PM
06012021A (SN3546,N6GR)	6/01/2021 2:08:22 PM	6/01/2021 3:52:08 PM
06022021A (SN3546,N6GR)	6/02/2021 3:03:04 PM	6/02/2021 6:34:31 PM
06032021A (SN3546,N6GR)	6/03/2021 2:17:22 PM	6/03/2021 4:11:59 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.

Software	Version
Applanix + POSPac	8.6
RiPROCESS	1.8.6
Microstation Connect	10.16.02.34
GeoCue	2020.1.22.1
Global Mapper	19.1;20.1
TerraModeler	21.008
TerraScan	21.016
TerraMatch	21.007
StripAlign	2.21

3.3. LAS Classification Scheme

The classification classes are determined by Lidar Base Specifications 2.1 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 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.

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. GeoCue was then used to create the deliverable industry-standard LAS files for all point cloud data. NV5 Geospatial's proprietary 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

Class 2 lidar was used to create a bare earth surface model. The surface model was then used to heads-up digitize 2D breaklines of Inland Streams and Rivers with a 100 foot nominal width and Inland Ponds and Lakes of 2 acres or greater surface area.

Elevation values were assigned to all Inland streams and rivers using NV5 Geospatial's proprietary software.

All ground (ASPRS Class 2) lidar data inside of the collected inland breaklines were then classified to water (ASPRS Class 9) using TerraScan macro functionality. A buffer of 3 feet was also used around each hydro-flattened feature. These points were moved from ground (ASPRS Class 2) to Ignored Ground (ASPRS Class 20).

The breakline files were then translated to Esri file geodatabase format using Esri conversion tools.

Breaklines are reviewed against lidar intensity imagery to verify completeness of capture. All breaklines are then compared to TINs (triangular irregular networks) created from ground only points prior to water classification. The horizontal placement of breaklines is compared to terrain features and the breakline elevations are compared to lidar elevations 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 completeness, horizontal placement, and vertical variance is reviewed, all breaklines are reviewed for topological consistency and data

integrity using a combination of Esri Data Reviewer tools and proprietary tools.

3.6. Hydro-Flattened Raster DEM Processing

Class 2 lidar in conjunction with the hydro breaklines were used to create a 1-meter Raster DEM. Using automated scripting routines within proprietary software, a GeoTIFF file was created for each tile. Each surface is reviewed using Global Mapper to check for any surface anomalies or incorrect elevations found within the surface.

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 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.

	0-8cm
	8-16cm
	16-24cm
	>24cm

MT Statewide Phase2 2020 B20 Work Unit 300021 Tile Layout

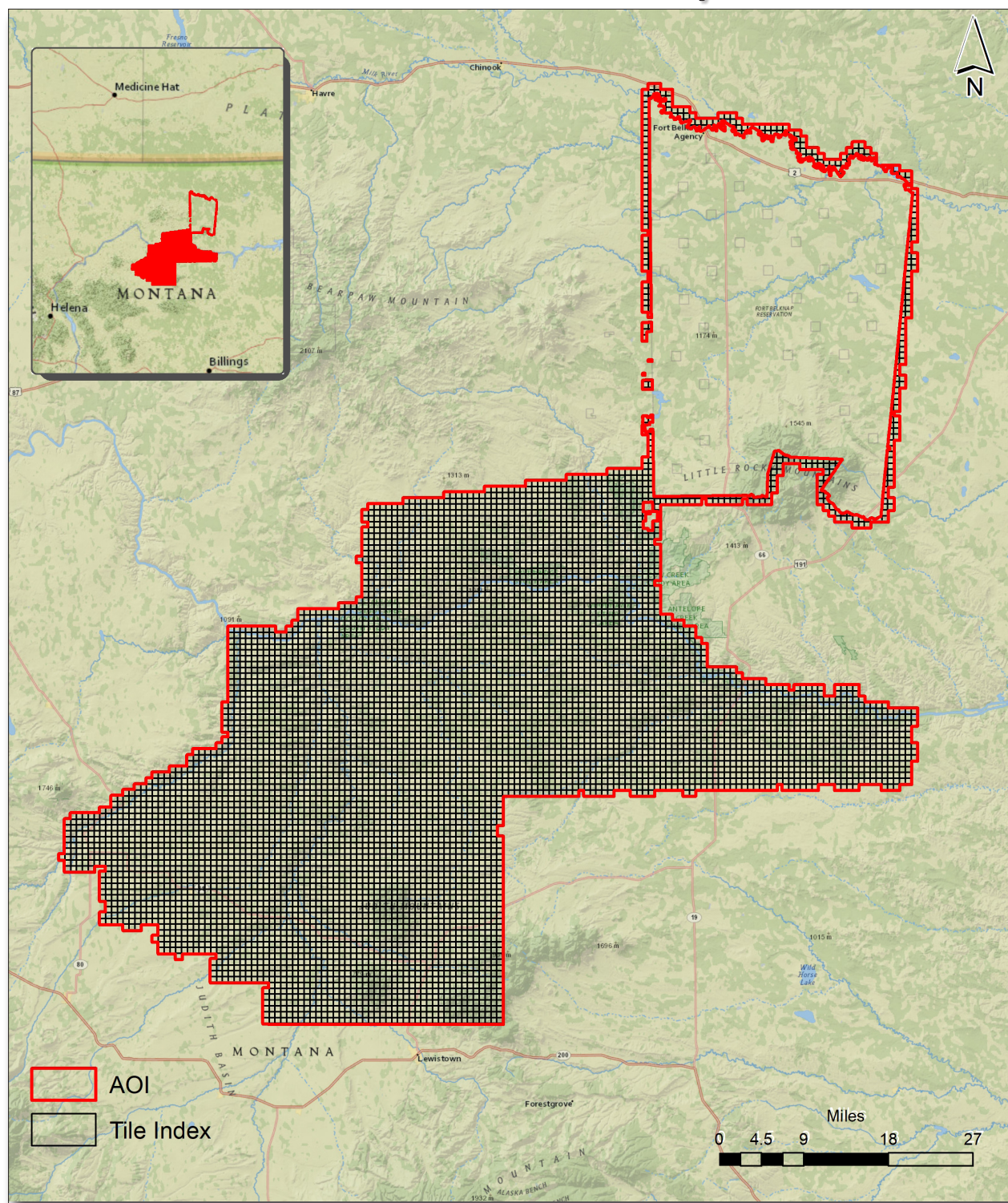


Figure 4. Lidar Tile Layout

4. Project Coverage Verification

Coverage verification was performed by comparing coverage of processed .LAS files captured during project collection to generate project shape files depicting boundaries of specified project areas. Please refer to Figure 5.

MT Statewide Phase2 2020 B20 Work Unit 300021 Lidar Coverage

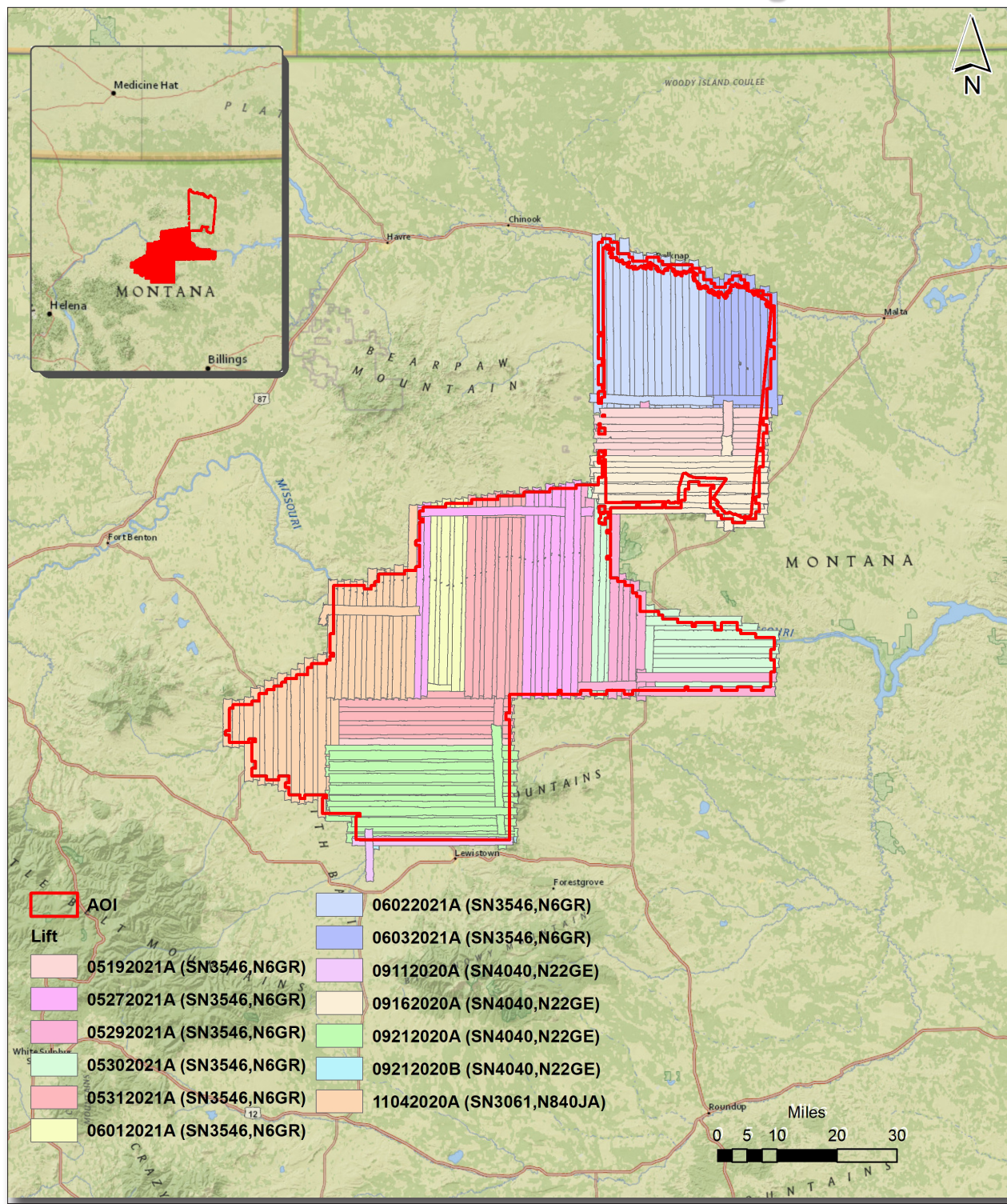


Figure 5. Lidar Coverage

5. Geometric Accuracy

5.1. Horizontal Accuracy

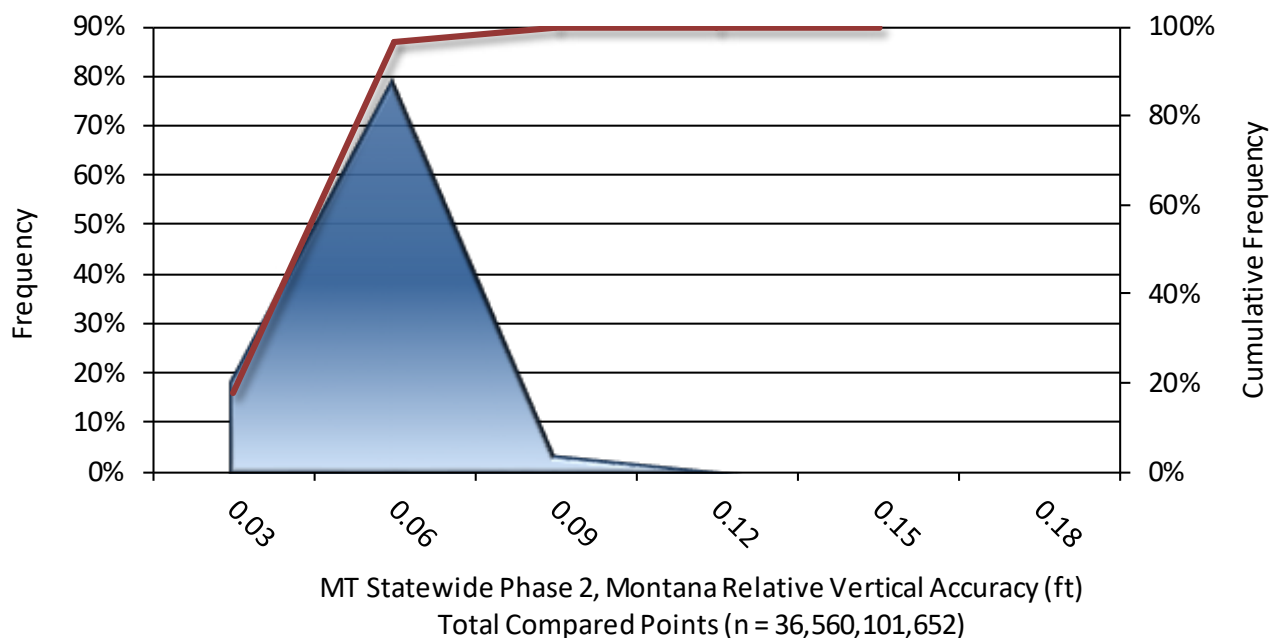
Lidar horizontal accuracy is a function of Global Navigation Satellite System (GNSS) derived positional error, flying altitude, and INS derived attitude error. The obtained $RMSE_r$ value is multiplied by a conversion factor of 1.7308 to yield the horizontal component of the National Standards for Spatial 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 2,305 meters, an IMU error of 0.002 decimal degrees, and a GNSS positional error of 0.015 meters, this project was compiled to meet 0.25 meter horizontal accuracy at the 95% confidence level. A summary is shown below.

Horizontal Accuracy	
$RMSE_r$	0.47 ft
	0.14 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 (<0.10 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_Phase2_2020_B20 project was 0.034 feet (0.010 meters). A summary is shown below.

Relative Vertical Accuracy	
Sample	184 flight line surfaces
Average	0.034 ft
	0.010 m
Median	0.038 ft
	0.012 m
RMSE	0.041 ft
	0.013 m
Standard Deviation (1 σ)	0.010 ft
	0.003 m
1.96 σ	0.019 ft
	0.006 m



Project Report Appendices

The following section contains the appendices as listed in the Lidar Project Report.

Appendix A

Flight Logs

QUENTUM

(email log daily to flight_log_distribution_list@quantumspatial.com)

Lift: A B C D E Pg. of 2

Lift: A B C D E Pg. of 2

[illegible]

Total Prod Lines:	Lines Flown:	Lines Remain:	Online Time:	Mob Time:	Notes:
-------------------	--------------	---------------	--------------	-----------	--------

Airborne LiDAR Data Collection Log Sheet :: Quantum Spatial, Inc

Date: 8-30-20

(email log daily to flight_log_distribution_list@quantumspatial.com)

Lift: A (B) C D E

Pg 2 of 2

[illegible]

(email log daily to flight_log_distribution_list@quantumspatial.com)

Lift: A B C D E Pg 1 of 1

Line #	Hdg	Start (UTC)	End (UTC)	Gd Spd	PDOP/sats	GPS Altitude	Crab	Turb (0...+)	FLIGHT LINE NOTES - visibility, clouds, smoke, partial, etc.
166	345	1505	1518	152	1/24	10006			turbulence
165	165	1521	1532	147	1/24	10259			
164	345	1536	1549	153	1/24	10265			
163	165	1552	1603	130	1/28	10269			
162	345	1607	1619	150	1/29	10344			
161	165	1622	1633	150	1/28	10544			
160	345	1637	1651	145	1/29	10928			
159	165	1654	1706	134	1/30	11052			
158	345	1709	1722	150	1/29	11180			
157	165	1726	1737	142	1/30	10797			
156	345	1740	Aborted	137	1/32	10610			- Cant Hold ^{or} Speed Altitude / $\pm 1000'$ Altitude X tie 1752 - 1754
	Retly	156							(A) H ₀₆₆₅ = 3.6 online = 2.6 M ₀₆₆ = 1.0

Total Proj Lines:	Lines Flown:	Lines Remain:	Online Time:	Mob Time:	Notes:
-------------------	--------------	---------------	--------------	-----------	--------

Airborne LIDAR Data Collection Log Sheet :: Quantum Spatial, Inc

(email log daily to flight_log_distribution_list@quantumspatial.com)

Date: 9-03-20

Lit: A B C D E Pg 1 of 2

Project: MT LIDAR Q12	Proj #: 36170	Flight Mgmt File: 20200903A
Aircraft: N226E	Begin Hobbs: 10805.5	End Hobbs: 10809.9 Total: 4.4
Pilot: Simmonds	Co-Pilot: —	Tech: Swan
Dep Apt: MSO	Dep Time (Lcl): 850 (Z): MDT	Arr Apt: MSO
Arr Time (Local): 1319 (Z): MDT	Tot Time Aloft:	
CORS: Y / N	Sta 1:	Sta 2:
Flyovers: Y / N	If Y, times: Sta1	Sta2)
GPS Unit: Y / N	Sta 1:	Sta 2:
Flyovers: Y / N	If Y, times: Sta1	Sta2)
Gd Temp beg: °C	End: °C	OAT beg: °C
End: °C	Altimeter begin: end:	
LIDAR Type: 1560i	Serial #: 4040	Alt AGL
Alt AMSL	Avg Terr Ht	Max Gdsd
Avg Pt Spacing	Power	PPSM
FOV	Scan Freq	MpiA Y / N
Pulses In Air	Pulse Rate	
deg GB	End GB	Tot GB
Storage Name#		

Line #	Hdg	Start (UTC)	End (UTC)	Gd Spd	PDOP/Sats	GPS Altitude	Crab	Turb [0..+]	FLIGHT LINE NOTES - visibility, clouds, smoke, partial, etc.
156	345	1519	1533	126	1/24	10610			
155	165	1536	1547	150	1/25	10561			
154	345	1550	1602	139	1/26	10318			
153	165	1605	1616	150	1/26	10183			
152	345	1619	1631	139	1/29	10167			
151	165	1634	1644	150	1/29	10036			
150	345	1648	1659	139	1/28	9957			
149	165	1702	1711	138	1/27	9957			
148	345	1713	1724	132	1/30	9957			* possible reply on northern END*
147	165	1730	1740	150	1/30	9941			
146	345	1743	1756	133	1/31	9941			
145	165	1801	1814	150	1/31	9941			
144	345	1818	1833	132	1/26	9927			
143	165	1836	1849	128	1/28	10000			

x tie - 1855 - 1857

(A) Hobbs = 4.4
on line = 3.5
mob = 0.9

Total Proj Lines:	Lines Flown:	Lines Remain:	Online Time:	Mob Time:	Notes:
-------------------	--------------	---------------	--------------	-----------	--------

Airborne LIDAR Data Collection Log Sheet :: Quantum Spatial, Inc

Date: 9-3-20

(email log daily to flight_log_distribution_list@quantumspatial.com)

Lift: A B C D E Pg 2 of 2

Project:	MT LIDAR Q22		Proj #:	36170		Flight Mgmt File:	20200903R	
Aircraft:	N22GE		Begin Hobbs:	10809.9		End Hobbs:	10813.5 Total: 3.6	
Pilot:	Simonds		Co-Pilot:	✓		Tech:	Swan	
Dep Apt:	MSO		Dep Time (Lcl):	1435 (Z): MDT		Arr Apt:	MSO	
Arr Time (Local):	1819 (Z): MDT		Tot Time Aloft:					
CORS:	Y / N		Sta 1:	Sta 2:		Flyovers:	Y / N If Y, times: Sta1) Sta2)	
GPS Unit:	Y / N		Sta 1:	Sta 2:		Flyovers:	Y / N If Y, times: Sta1) Sta2)	
Gd Temp beg:	°c End: °c		OAT beg:	°c End: °c		Altimeter begin:	end:	
LIDAR	Type	Serial #	Alt	Alt	Avg Terr	Max	Avg Pt	beg GB End GB Tot GB
FOV	156011	4040	AGL	AMSL	Ht	Gdspd	Spacing	
	Scan		MpIA	Pulses	Pulse	Power	PPSM	Storage
	Freq		Y / N	In Air	Rate			Name/s

Line #	Hdg	Start (UTC)	End (UTC)	Gd Spd	PRCP/°s	GPS Altitude	Crah	Turb (0-9)	FLIGHT LINE NOTES - visibility, clouds, smoke, partial, etc.
142	345	2111	2125	146	1/25	9914			
141	165	2128	2141	150	1/25	9927			
140	345	2152	2204	140	1/25	9934			
139	165	2207	2220	137	1/26	9918			
138	345	2223	2237	150	1/28	9918			
137	165	2240	2252	150	1/27	9914			
136	345	2255	2307	144	1/30	9977			
135	165	2310	2322	150	1/30	9944			
134	345	2325	2338	155	1/32	9918			
133	165	2340	2353	135	1/30	9918			
									X file 2355 - 2357 - R+B
									(B) Hobbs = 3.6
									online = 2.7
									mob = 0.9
									(A+B) Hobbs = 8.0
									online = 6.2
									mob = 1.8

Total Proj Lines:	Lines Flown:	Lines Remain:	Online Time:	Mob Time:	Notes:
-------------------	--------------	---------------	--------------	-----------	--------

(email log daily to flight_log_distribution_list@quantumspatial.com)

Lift: A B C D E Pg. 1 of 1

Scanned with CamScanner

(email log daily to flight_log_distribution_list@quantumspatial.com)

Lift: A B C D E Pg 7 of 2

Line #	Hdg	Start (UTC)	End (UTC)	Gd Spd	PDOF = Sats	GPS Altitude	Crab	Turb (0 - 9)
77	324	2200	2214	146	1/26	16197		
76	144	2217	2230	135	1/28	10000		
75	324	2232	2243	149	1/27	9846		
74	144	2247	2258	130	1/27	9900		
73	324	2301	2313	148	1/29	9750		
72	144	2315	2327	150	1/29	9777		
71	324	2329	2340	146	1/29	9754		
70	144	2344	2356	135	1/28	9700		
69	324	2359	0008	155	1/28	9730		
68	144	0011	0022	140	1/28	9681		

FLIGHT LINE NOTES – visibility, clouds, smoke, partial, etc.

X tie

$\odot 11.665 = 3.5$
 $on\ line = 2.4$
 $m.b = 1.1$

$\odot A+B$
 $11.665 = 7.7$
 $on\ line = 5.3$
 $m.b = 1.4$

Total Prod Lines:	Lines Flown:	Lines Remain:	Online Time:	Mob Time:	Notes:
-------------------	--------------	---------------	--------------	-----------	--------

(email log daily to flight_log_distribution_list@quantumspatial.com)

Lift: A B C D E

Pg 7 of 7

Scanned with CamScanner

(email log daily to flight_log_distribution_list@quantumspatial.com)

Lift: A B C D E

Pg 1 of 1

Scanned with CamScanner

quantum / (email log daily to flight_log_distribution_list@quantumspatial.com)

Lift: (A) B C D E Pg 1 of

Line #	Hdg	Start (UTC)	End (UTC)	Gd Spd	POOP/sats	GPS Altitude	Crab	Turb (0...9)	FLIGHT LINE NOTES - visibility, clouds, smoke, partial, etc.
14	22	1557	1559	150	1/27	1200			
13	202	1602	1603	150	1/28	12165			
12	22	1607	1608	135	1/28	12880			
11	202	1612	1614	143	1/28	12628			
10	22	1617	1619	140	1/28	11932			
9	78	1622	1624	121	1/26	12021			
8	358	1627	1630	149	1/28	12309			
7	78	1632	1634	148	1/28	12214			
6	358	1638	1640	138	1/28	11502			
5	78	1643	1645	148	1/27	11589			
4	357	1648	1650	140	1/26	11706			
3	177	1652	1654	145	1/25	12410			
2	357	1658	1659	140	1/24	11860			
1	177	1702	1704	150	1/25	11735			X tie 1707-1710
MT QL2 36170									
55	144	1725	1736	150	1/28	9668			
54	324	1739	1750	120	1/29	9668			
53	144	1753	1802	154	1/29	9622			
Total Proj Lines:		Lines Flown:		Lines Remain:		Online Time:		Mob Time:	
								Notes:	

35827
ID -
refines

36170 MT-

Airborne LIDAR Data Collection Log Sheet :: Quantum Spatial, Inc

(email log daily to flight_log_distribution_list@quantumspatial.com)

Date:

Lift: A B C D E Pg. of

Project:		Proj #:		Flight Mgmt File:	
Aircraft:	Begin Hobbs:	End Hobbs:	Total:	Pilot:	Co-Pilot:
Dep Apt:	Dep Time (Lcl):	(Z):	Arr Apt:	Arr Time (Local):	(Z):
CORS: Y / N		Sta 1:	Sta 2:	Flyovers: Y / N	If Y, times: Sta1
GPS Unit: Y / N		Sta 1:	Sta 2:	Flyovers: Y / N	If Y, times: Sta1
Gd Temp beg: °C		End: °C	OAT beg: °C	End: °C	Altimeter begin: end:
LIDAR	Type	Serial #	Alt AGL	Alt AMSL	Avg Terr Ht
	FOV	Scan Freq	MplA Y / N	Pulse Rate	Power

Line #	Hdg	Start (UTC)	End (UTC)	Gd Spd	PDOP/sats	GPS Altitude	Crab	Turb (0-9)	FLIGHT LINE NOTES - visibility, clouds, smoke, partial, etc.
52	344	1806	1814	145	1.8	9600			
51	44	1816	1823	145	1.29	9600			X tie 1825-1827
									35827
									(A) Hobbs = 2.1
									Online = 1.2
									Mob = 0.9
									(A) Combined
									Hobbs = 4.2
									Online = 2.2
									Mob = 2.0
									(A) 36170
									Hobbs = 2.1
									Online = 1.0
									Mob = 1.1

Total Proj Lines:	Lines Flown:	Lines Remain:	Online Time:	Mob Time:	Notes:
-------------------	--------------	---------------	--------------	-----------	--------

Airborne LIDAR Data Collection Log Sheet :: Quantum Spatial, Inc

(email Log daily to flight_log_distribution_list@quantumspatial.com)

Date: 9-8-20

UTC: A B C D E

pg 1 of 2

Project: M7 GL2 LIDAR	Proj #: 36170	Flight Mgmt File: 20200808A
Aircraft: 226E	Begin Hobbs: 10829.8	End Hobbs: 10834.1 Total: 4.3
Pilot: J Nelson	Co-Pilot:	Tech: Swan
Dep Apt: MSb	Dep Time (Ldt): 915 (Zt) MDT	Arr Apt: MSb Arr Time (Local): 1330 (Zt) MDT
Tot Time Aloft: 4.3		
CORS: Y / N	Sta 1:	Sta 2:
Flyovers: Y / N	If Y, times: Sta1)	Sta2)
GPS Unit: Y / N	Sta 1:	Sta 2:
Flyovers: Y / N	If Y, times: Sta1)	Sta2)
Gd Temp beg: °C	End: °C	OAT beg: °C
Alt AGL	Alt AMSL	Avg Terr Ht
Max Gdsd	Avg Pt Spacing	Power
PPSM	PPSM	
Beg CB	End CB	Tot CB
Storage Name		

Line #	Hdg	Start (UTC)	End (UTC)	Gd Spd	PDOP/sats	GPS Altitude	Crab	Turb (0-5)	FLIGHT LINE NOTES - visibility, clouds, smoke, partial, etc.
50	324	1554	1601	143	1/31	9918			
49	144	1604	1609	150	1/30	10910			
48	324	1613	1615	130	1/30	10830			
13 47	129	1625	1635	141	1/30	10374			x tie 1617-1618
14	309	1639	1650	122	1/28	10415	10328		
15	129	1653	1704	153	1/33	10292			
16	309	1707	1718	132	1/33	10252			
17	129	1721	1732	145	1/33	10268			
18	309	1735	1747	150	1/34	10233			
19	129	1749	1800	145	1/32	10121			
20	309	1803	1815	150	1/29	10160			
21	129	1818	1830	150	1/30	10049			x tie
28	309	1834	1843	154	1/29	9842			
29	129	1846	1856	150	1/29	9815			x tie 1859-1903
(A) Hobbs = 4.3 all line = 3.0 mob = 1.3									

Total Proj Lines:

Lines Flown:

Lines Remain:

Online Time:

Mob Time:

Notes:

Airborne LIDAR Data Collection Log Sheet :: Quantum Spatial, Inc

(email log daily to flight_log_distribution_list@quantumspatial.com)

Date: 9-8-20

Lift: A B C D E

Page 2 of 2

Project: MT 01.2	Proj #: 36170	Flight Mgmt File: 20200908B
Aircraft: N2265	Begin Hobbs: 10834.1	End Hobbs: 10838.1 Total: 4.0
Pilot: Jaman	Co-Pilot:	Tech: Swan
Dep Apt: MSO	Dep Time (Ldt): 1500 (Z): MDT	Arr Apt: MSO Arr Time (Local): 1909 (Z): MDT
Tot Time Aloft: 4.6		
CORS: Y / N	Sta 1:	Sta 2:
Flyovers: Y / N	If Y, times: Sta1	Sta2
GPS Unit: Y / N	Sta 1:	Sta 2:
Flyovers: Y / N	If Y, times: Sta1	Sta2
Gd Temp beg: °C	End: °C	OAT beg: °C
Alt: AMSL	Alt: AMSL	Alt: AMSL
Avg Terr Ht	Max Gdspd	Avg Pt Spacing
Pulse Rate	Power	PPSM
LIDAR	Type: 1560ii	Serial #: 4040
FOV	Scan Freq	MplA Y / N
		Pulses In Air
		Power
		PPSM
		Storage Name(s)

Line #	Hdg	Start (UTC)	End (UTC)	Gd Spd	FOOF/Sec	GPS Altitude	Crab	Turb (0-5)	FLIGHT LINE NOTES - visibility, clouds, smoke, partial, etc.
30	309	2138	2147	144	1/25	9895			
31	129	2151	2201	150	1/25	9931			
32	309	2203	2213	155	1/26	9973			
33	129	2216	2225	142	1/25	10023			
34	309	2228	2238	136	1/28	10085			
35	129	2241	2249	140	1/29	10174			
36	309	2252	2308	145	1/30	10174		23.00	
37	129	2304	2318	149	1/32	10292			
38	309	2318	2322	125	1/30	10357			
39	129	2324	2331	155	1/29	10410			
40	309	2333	2339	150	1/28	10492			
41	129	2342	2347	150	1/25	10574			
42	309	2351	2357	122	1/31	10708			
43	129	0002	0007	140	1/30	10872			
44	309	0010	0014	190	1/31	11004			
45	129	0017	0021	115	1/32	11112			
46	309	0023	0025	155	1/32	11148			
47	129	0028	0029	147	1/31	11004			

(B) Hobbs = 4.0
online = 2.9
mob = 1.1

A+B Hobbs = 8.3
online = 5.9
mob = 2.4

X file 0031 - 0026

Total Proj Lines:	Lines Flown:	Lines Remain:	Online Time:	Mob Time:	Notes:
-------------------	--------------	---------------	--------------	-----------	--------