Airborne LiDAR Report

WOOLPERT

GLACIER NATIONAL PARK QL1 LIDAR

Contract Number: G16PC00022
Task Number: G16PD00549

Contractor: Woolpert, Inc.
Woolpert Project # 76750

February 2017

Airborne LiDAR Report

UNITED STATES GEOLOGICAL SURVEY

Glacier National Park QL1 Lidar

Contract Number: G16PC00022
Task Number: G16PD00549

Woolpert
4454 Idea Center Boulevard
Dayton, Ohio 45430.1500
Phone: 937.461.5660

Table of Contents

List of Figures

List of Tables

Section 1: Overview

TASK ORDER NAME: Glacier National Park QL1 Lidar

Project: # 76750

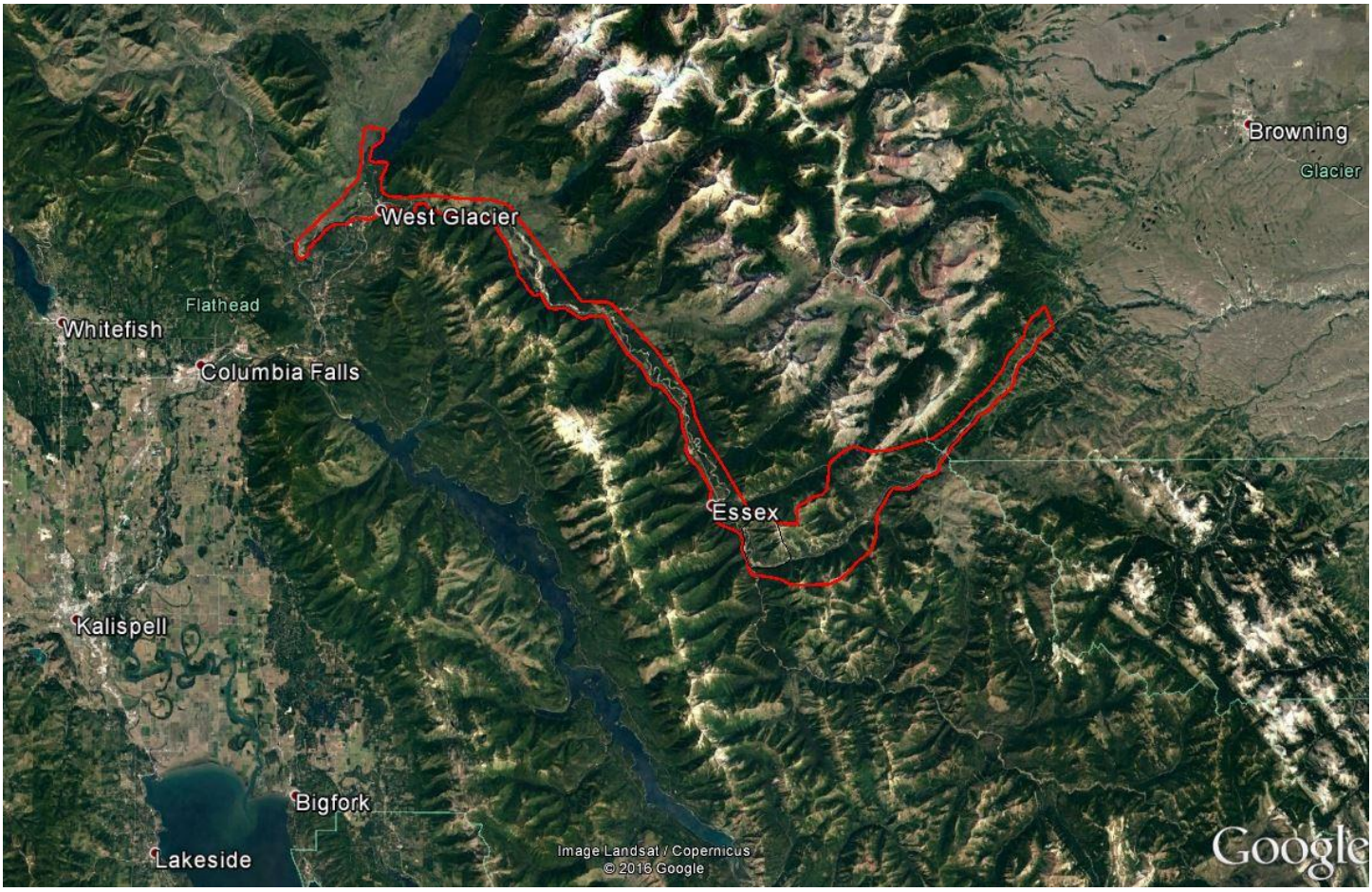
This report contains a comprehensive outline of the Glacier National Park QL1 Lidar Processing task order for the United States Geological Survey (USGS). This task is issued under USGS Contract No. G16PC00022, Task Order No. G16PD00549. This task order requires lidar data to be acquired approximately 74.27 square miles contained within Glacier National Park. The lidar was collected and processed to meet a maximum Nominal Post Spacing (NPS) of 0.35 meters. The NPS assessment is made against single swath, first return data located within the geometrically usable center portion (typically ~90%) of each swath.

The data was collected using a Dual-Head DragonEye (DE) sensor. The sensor was mounted in a Leica PAV100 gyro-stabilized mount integrated with a NovAtel SPAN GNSS and LCI-100C IMU. This sensor collects up to four returns (echo) per pulse, as well as intensity data, for the first three returns. The aerial lidar was collected at the following sensor specifications:

Table 1.1: Dual-Head DragonEye (DE) Specifications	
Post Spacing	0.35 m
AGL (Above Ground Level) average flying height	1500 m
Average Ground Speed:	125 knots
Field of View (full)	40 degrees
Pulse Rate	320 / 360
Scan Rate	50 Hz
Side Lap	15

LiDAR data was produced in NAD83(2011) UTM12N. Coordinate positions were specified in units of meters. The vertical datum used for the project was referenced to NAVD 1988, meters, GEOID12B.

Figure 1.1: Lidar Task Order AOI



Section 2: Acquisition

The LiDAR data was acquired with a Leica Leica Dual-Head DragonEye (DE) sensor, on board Woolpert's Cessna aircraft. The Leica system, developed by Leica of Herrburgg, Switzerland. The innovative dual scanner head design of the DragonEye features a unique oblique scan pattern. In one single pass, each ground target may be illuminated by four laser shots at multiple incidence angles from ±8 to ±20 degrees, maximizing vertical surface definition and minimizing shadows in the survey data. Each topographic laser operates in the infra-red spectrum at 1064nm. Up to 15 returns per pulse are acquired from each laser.

Figure 2.1: The Leica DragonEye LiDAR System has the following specifications:

Laser Characterization	
Laser wavelength [6]	1064 nm
Laser divergence	0.5 mrad (1/e²)
Pulse repetition frequency (PRF)	Up to 1 MHz
Return pulses	Programmable up to 15 returns, with full waveform record option
Operation altitude [1]	300 – 1600 m AGL
Scanner pattern	Dual head oblique scanner
Scanner speed	Programmable up to 70 RPS per scanner (i.e., 280 scans/second)
Field of view	±8° and ±20° front/back, ±20° left/right
Swath width	70 % of AGL
Point density [2]	> 16 pts/m²
Ranging accuracy [2], [3], [4]	2 cm (1σ)
Vertical accuracy [2], [3], [5]	6 cm (1σ)
Horizontal accuracy [2], [3], [5]	25 cm (1σ)

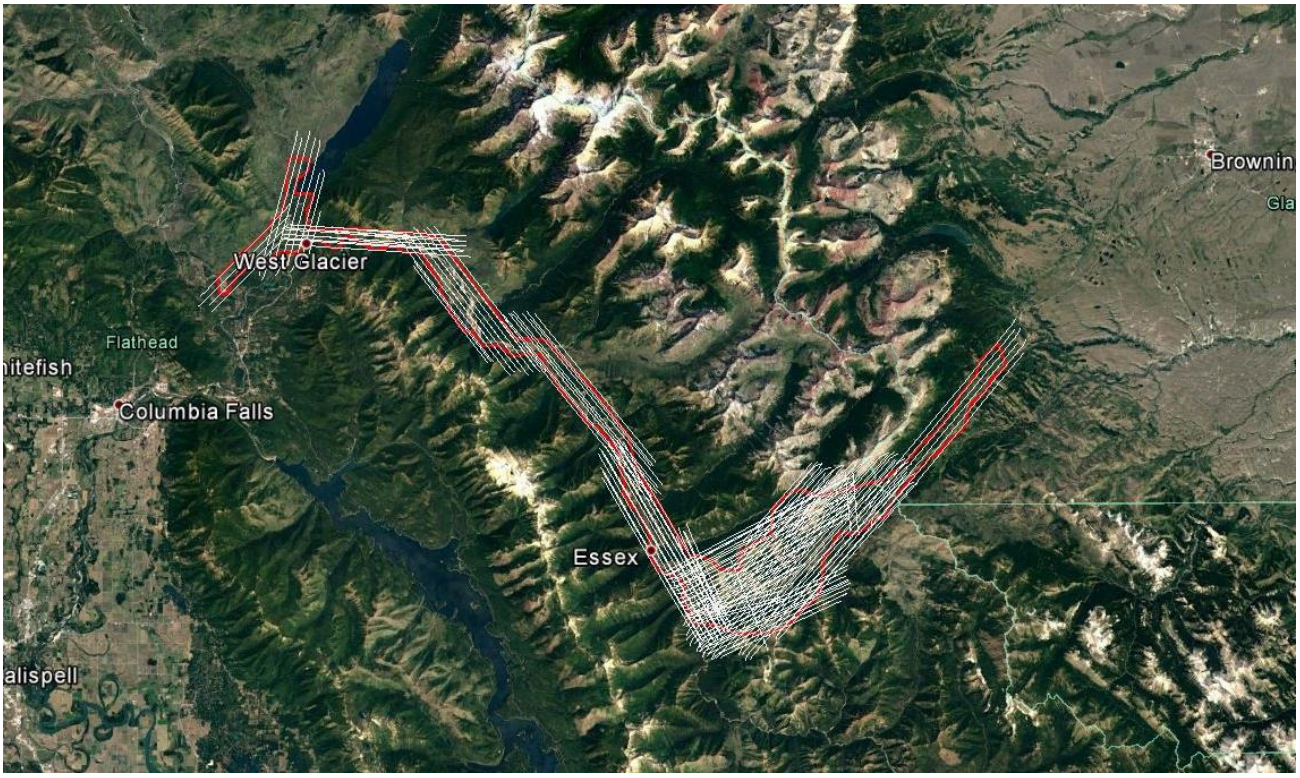
Prior to mobilizing to the project site, flight crews coordinated with the necessary Air Traffic Control personnel to ensure airspace access.

Crews were onsite, operating a Global Navigation Satellite System (GNSS) Base Station for the airborne GPS support.

The LiDAR data was collected in five (5) missions, flown as close together as the weather permitted, to ensure consistent ground conditions across the project area. An initial quality control process was performed immediately on the lidar data to review the data coverage, airborne GPS data, and trajectory solution.

Table 2.1: Airborne Lidar Acquisition Flight Summary		
Date of Mission	Lines Flown	Mission Time (UTC) Wheels Up/Wheels Down
July 29, 2016	**1-26**	**12:52 – 17:57**
July 30, 2016	**31-59, 77-84**	**12:48 – 17:47**
July 31, 2016	**60-76**	**12:39 – 15:50**
August 4, 2016	**13-27, 32-41**	**21:17 – 00:44**
August 5, 2016	**1-14, 28-31, 42-44**	**12:25 - 15:03**

Figure 2.2: LiDAR Flight Layout, Glacier National Park QL1 Lidar



Section 3: LiDAR Data Processing

Applications and Work Flow Overview

Initial data coverage analysis and quality checks to ensure there were no potential system issues were carried out in the field prior to demobilization of the sensor. In general, data were initially processed in Leica's Lidar Survey Studio (LSS) using final processed trajectory information. LAS files from LSS were imported to a Terrascan project where spatial algorithms were used to remove gross system noise and a basic ground classification was conducted per flight line for Terra Match use. TMatch was then run on the project, and a comparison to the lidar control points was conducted. Final trajectory data were post processed in NovAtel Inertial Explorer. Base station data were converted to GPB format and imported with aircraft GNSS and IMU data. Inertial Explorer accounts for the fixed offset between the reference point and IMU and uses a multi-pass algorithm to compute a tightly-coupled solution. Lidar processing was conducted using the Leica Lidar Survey Studio (LSS) software. Calibration information, along with processed trajectory information were combined with the raw laser data to create an accurately georeferenced lidar point cloud for the entire survey in LAS v1.2 format. All points from the topographic lasers include 16-bit intensity values. Additional QC steps were then performed in LSS prior to import to Terrascan. For example, spot checks were made on the data to ensure the front and back of the scans remained in alignment and no calibration or system issues were apparent prior to further data editing in Terrascan.

Global Navigation Satellite System (GNSS)–Inertial Measurement Unit (IMU) Trajectory Processing

Equipment

Flight navigation during the LiDAR data acquisition mission is performed using IGI CCNS (Computer Controlled Navigation System). The pilots are skilled at maintaining their planned trajectory, while holding the aircraft steady and level. If atmospheric conditions are such that the trajectory, ground speed, roll, pitch and/or heading cannot be properly maintained, the mission is aborted until suitable conditions occur.

The aircraft is configured with a NovAtel SPAN GNSS and LCI-100C IMU.

Base stations were set by acquisition staff and were used to support the LiDAR data acquisition. The base stations used during the LiDAR acquisition missions are listed below:

Table 3.1: GNSS Base Station

Station (Name)	Latitude (DMS)	Longitude (DMS)	Ellipsoid Height (L1 Phase center) (Meters)
GPI1	48 18 34.46590	114 15 9.15691	888.903
TM0733	48 14 0.36632	113 33 25.93414	1184.182

LiDAR Data Processing

When the sensor calibration, data acquisition, and GPS processing phases were complete, the formal data reduction processes by Woolpert lidar specialists included:

- Processed individual flight lines to derive a raw “Point Cloud” LAS file. Matched overlapping flight lines, generated statistics for evaluation comparisons, and made the necessary adjustments to remove any residual systematic error.
- Calibrated LAS files were imported into the task order tiles and initially filtered to create a ground and non-ground class. Then additional classes were filtered as necessary to meet client specified classes.
- Once all project data was imported and classified, survey ground control data was imported and calculated for an accuracy assessment. As a QC measure, Woolpert has developed a routine to generate accuracy statistical reports by comparisons against the TIN and the DEM using surveyed ground control of higher accuracy. The lidar is adjusted accordingly to meet or exceed the vertical accuracy requirements.
- The lidar tiles were reviewed using a series of proprietary QA/QC procedures to ensure it fulfills the task order requirements. A portion of this requires a manual step to ensure anomalies have been removed from the ground class.
- The lidar LAS files are classified into the Default (Class 1), Ground (Class 2), Low noise (Class 7), Water (Class 9), Ignored ground (Class 10), Bridge Decks (Class 17), High Noise (Class 18) classifications.
- FGDC Compliant metadata was developed for the task order in .xml format per product.
- The horizontal datum used for the task order was referenced to NAD83(2011) UTM12N meters. The vertical datum used for the task order was referenced to NAVD 1988, meters, GEOID12B.

Section 4: Hydrologic Flattening

HYDROLOGIC FLATTENING OF LIDAR DEM DATA

Glacier National Park QL1 Lidar processing task order required the compilation of breaklines defining water bodies and rivers. The breaklines were used to perform the hydrologic flattening of water bodies, and gradient hydrologic flattening of double line streams and rivers. Lakes, reservoirs and ponds, at a minimum size of 2-acre or greater, were compiled as closed polygons. The closed water bodies were collected at a constant elevation. Rivers and streams, at a nominal minimum width of 30 meters (100 feet), were compiled in the direction of flow with both sides of the stream maintaining an equal gradient elevation.

LIDAR DATA REVIEW AND PROCESSING

Woolpert utilized the following steps to hydrologically flatten the water bodies and for gradient hydrologic flattening of the double line streams within the existing lidar data.

1. Woolpert used the newly acquired lidar data to manually draw the hydrologic features in a 2D environment using the lidar intensity and bare earth surface. Open Source imagery was used as reference when necessary.
2. Woolpert utilizes an integrated software approach to combine the lidar data and 2D breaklines. This process “drapes” the 2D breaklines onto the 3D lidar surface model to assign an elevation. A monotonic process is performed to ensure the streams are consistently flowing in a gradient manner. A secondary step within the program verifies an equally matching elevation of both stream edges. The breaklines that characterize the closed water bodies are draped onto the 3D lidar surface and assigned a constant elevation at or just below ground elevation.
3. The lakes, reservoirs and ponds, at a minimum size of 2-acre or greater and streams at a minimum size of 30 meters (100 feet) nominal width, were compiled to meet task order requirements. **Figure 4.1** illustrates an example of 30 meters (100 feet) nominal streams identified and defined with hydrologic breaklines. The breaklines defining rivers and streams, at a nominal minimum width of 30 meters (100 feet), were draped with both sides of the stream maintaining an equal gradient elevation.
4. All ground points were reclassified from inside the hydrologic feature polygons to water, class nine (9).
5. All ground points were reclassified from within a buffer along the hydrologic feature breaklines to buffered ground, class ten (10).
6. The lidar ground points and hydrologic feature breaklines were used to generate a new digital elevation model (DEM).

Figure 4.1: Example Hydrologic Breaklines

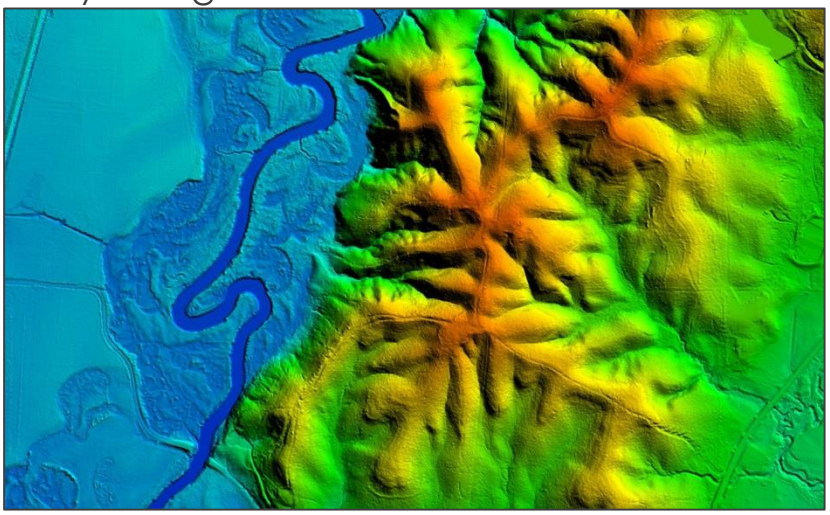


Figure 4.2 reflects a DEM generated from original lidar bare earth point data prior to the hydrologic flattening process. Note the "tinning" across the lake surface.

Figure 4.3 reflects a DEM generated from lidar with breaklines compiled to define the hydrologic features. This figure illustrates the results of adding the breaklines to hydrologically flatten the DEM data. Note the smooth appearance of the lake surface in the DEM.

Figure 4.2

Figure 4.3

Terrascan was used to add the hydrologic breakline vertices and export the lattice models. The hydrologically flattened DEM data was provided to USGS in ERDAS .IMG format.

The hydrologic breaklines compiled as part of the flattening process were provided to the USGS in ESRI geodatabase format. The breaklines defining the water bodies greater than 2-acre and for the gradient flattening of all rivers and streams at a nominal minimum width of 30 meters (100 feet) were provided as a Polygon-Z and Polyline-Z in ESRI geodatabase format, respectively.

DATA QA/QC

Initial QA/QC for this task order was performed in Global Mapper v15, by reviewing the grids and hydrologic breakline features. Additionally, ESRI software and proprietary methods were used to review the overall connectivity of the hydrologic breaklines.

Edits and corrections were addressed individually by tile. If a water body breakline needed to be adjusted to improve the flattening of the DEM data, the area was cross referenced by tile number, corrected accordingly, a new DEM file was regenerated and reviewed.

Section 5: Accuracy Assessment

Final Vertical Accuracy Assessment

The vertical accuracy statistics were calculated by comparison of the LiDAR bare earth points to the ground surveyed QA/QC points.

Table 5.1: Overall Vertical Accuracy Statistics		
Average error	-0.019	meter
Minimum error	-0.094	meter
Maximum error	0.067	meter
Average magnitude	0.033	meter
Root mean square	0.041	meter
Standard deviation	0.037	meter

Table 5.2: RAW Swath Quality Check Point Analysis NVA

Point ID	Easting (meter)	Northing (meter)	Elevation (meter)	TIN Elevation (meter)	Dz (meter)
1002	309404.345	5347196.163	1223.593	1223.580	-0.013
1012	310860.718	5345343.840	1217.506	1217.520	0.014
1015	319151.108	5349592.911	1357.623	1357.590	-0.033
1052	284398.730	5375721.912	1021.491	1021.450	-0.041
1055	287424.919	5374870.016	1044.923	1044.940	0.017
1096	304714.933	5355209.284	1150.069	1150.070	0.001
2001	279633.610	5381484.356	981.240	981.150	-0.090
2002	273057.441	5372588.786	947.535	947.490	-0.045
2003	277118.747	5374952.441	995.515	995.500	-0.015
2004	281776.137	5375392.131	1016.070	1016.020	-0.050
2005	286284.253	5375269.809	1042.404	1042.310	-0.094
2006	289875.125	5373068.992	1009.878	1009.840	-0.038
2007	291230.227	5370900.860	1014.876	1014.890	0.014
2008	294852.584	5367204.454	1033.920	1033.920	0.000
2009	299108.530	5364455.871	1085.385	1085.390	0.005
2010	300494.917	5362578.067	1107.197	1107.220	0.023
2011	302274.959	5360652.979	1131.766	1131.730	-0.036
2012	326910.761	5355852.887	1570.471	1570.490	0.019
2013	305469.744	5353984.004	1165.818	1165.780	-0.038
2014	306224.292	5352103.201	1168.077	1168.020	-0.057
2015	307645.777	5349136.949	1177.559	1177.520	-0.039
2017	310861.184	5345333.233	1216.583	1216.590	0.007
2018	312087.666	5345696.871	1249.633	1249.590	-0.043
2019	313456.208	5345961.560	1275.687	1275.610	-0.077

2020	334521.782	5364227.181	1464.450	1464.440	-0.010
2021	332168.941	5361707.136	1525.946	1525.980	0.034
2022	329403.822	5358067.851	1526.483	1526.550	0.067
2023	323500.622	5352394.934	1511.010	1510.990	-0.020
2024	320879.830	5351477.993	1411.049	1411.020	-0.029
2025	317798.689	5348089.245	1333.252	1333.240	-0.012

VERTICAL ACCURACY CONCLUSIONS

Raw Swath Non-Vegetated Vertical Accuracy (NVA) Tested 0.098 Meter Non vegetated vertical accuracy at a 95 percent confidence level, derived according to NSSDA, in open terrain using (RMSEz) x 1.96000 as defined by the National Standards for Spatial Data Accuracy (NSSDA); assessed and reported using National Digital Elevation Program (NDEP)/ASPRS Guidelines and tested against the TIN using all points.

LAS Swath Non-Vegetated Vertical Accuracy (NVA) Tested 0.080 Meter Non vegetated vertical accuracy at a 95 percent confidence level, derived according to NSSDA, in open terrain using (RMSEz) x 1.96000 as defined by the National Standards for Spatial Data Accuracy (NSSDA); assessed and reported using National Digital Elevation Program (NDEP)/ASPRS Guidelines and tested against the TIN using ground points

Table 5.3: NVA Check Point Analysis DEM

Point ID	Easting (meter)	Northing (meter)	Elevation (meter)	DEM Elevation (meter)	Dz (meter)
1002	309404.345	5347196.163	1223.593	1223.600	-0.007
1012	310860.718	5345343.840	1217.506	1217.480	0.026
1015	319151.108	5349592.911	1357.623	1357.620	0.003
1052	284398.730	5375721.912	1021.491	1021.440	0.051
1055	287424.919	5374870.016	1044.923	1044.890	0.033
1096	304714.933	5355209.284	1150.069	1150.070	-0.001
2001	279633.610	5381484.356	981.240	981.160	0.080
2002	273057.441	5372588.786	947.535	947.490	0.045
2003	277118.747	5374952.441	995.515	995.490	0.025
2004	281776.137	5375392.131	1016.070	1015.980	0.090
2005	286284.253	5375269.809	1042.404	1042.320	0.084
2006	289875.125	5373068.992	1009.878	1009.860	0.018
2007	291230.227	5370900.860	1014.876	1014.870	0.006
2008	294852.584	5367204.454	1033.920	1033.920	0.000
2009	299108.530	5364455.871	1085.385	1085.400	-0.015
2010	300494.917	5362578.067	1107.197	1107.190	0.007
2011	302274.959	5360652.979	1131.766	1131.750	0.016
2012	326910.761	5355852.887	1570.471	1570.500	-0.029
2013	305469.744	5353984.004	1165.818	1165.830	-0.012
2014	306224.292	5352103.201	1168.077	1168.000	0.077
2015	307645.777	5349136.949	1177.559	1177.530	0.029

2017	310861.184	5345333.233	1216.583	1216.680	-0.097
2018	312087.666	5345696.871	1249.633	1249.590	0.043
2019	313456.208	5345961.560	1275.687	1275.620	0.067
2020	334521.782	5364227.181	1464.450	1464.420	0.030
2021	332168.941	5361707.136	1525.946	1525.980	-0.034
2022	329403.822	5358067.851	1526.483	1526.540	-0.057
2023	323500.622	5352394.934	1511.010	1510.970	0.040
2024	320879.830	5351477.993	1411.049	1411.010	0.039
2025	317798.689	5348089.245	1333.252	1333.230	0.022

VERTICAL ACCURACY CONCLUSIONS

Bare-Earth DEM Non-Vegetated Vertical Accuracy (NVA) Tested 0.088 Meter Non-Vegetated vertical accuracy at a 95 percent confidence level, derived according to NSSDA, in open terrain using (RMSEz) x 1.96000 as defined by the National Standards for Spatial Data Accuracy (NSSDA); assessed and reported using National Digital Elevation Program (NDEP)/ASPRS Guidelines and tested against the DEM.

Table 5.4: VVA Quality Check Point Analysis DEM

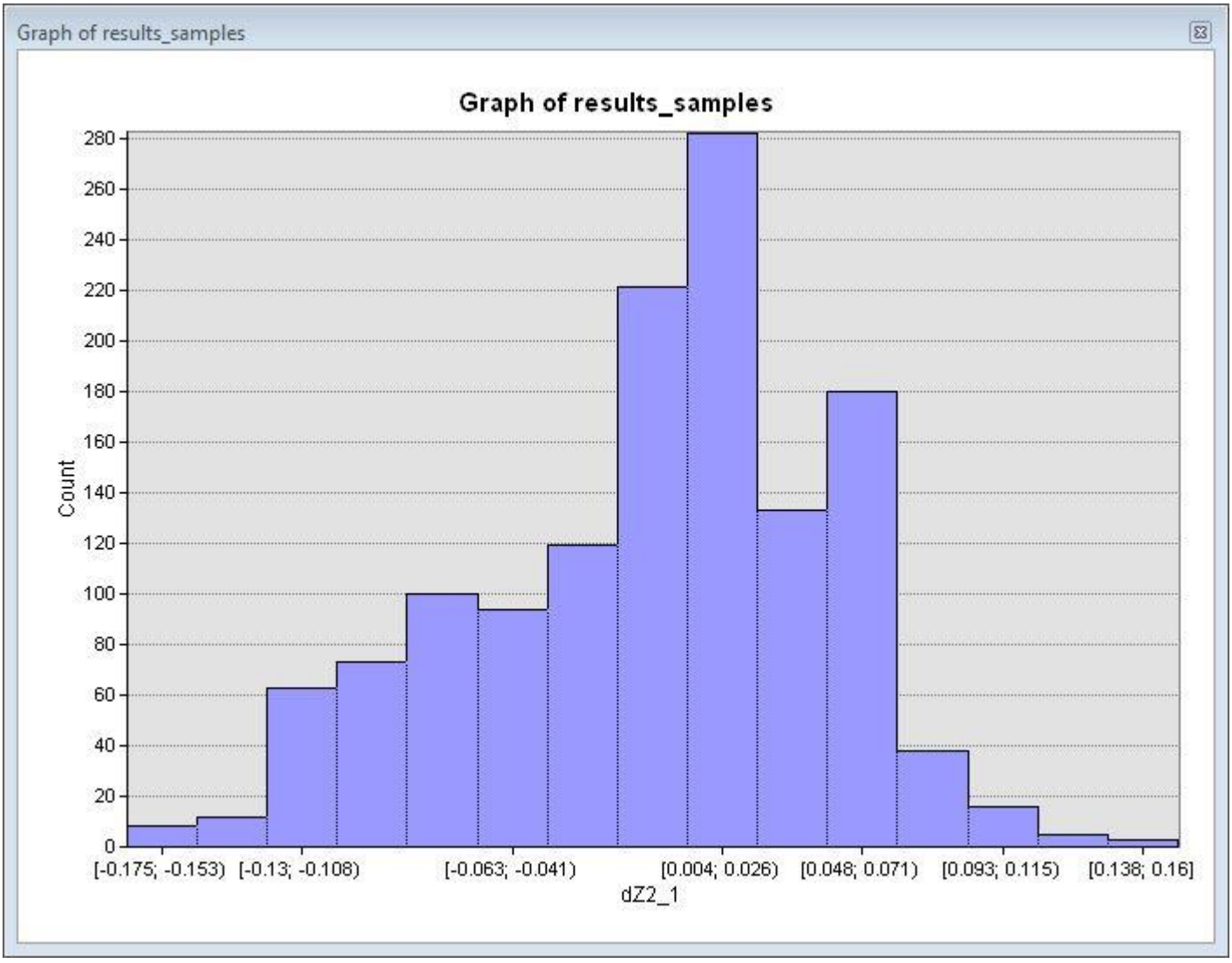
Point ID	Easting (meter)	Northing (meter)	Elevation (meter)	DEM Elevation (meter)	Dz (meter)
1056	287392.391	5374890.019	1043.582	1043.560	0.022
1092	313467.176	5345934.822	1274.360	1274.320	0.040
3001	279642.676	5381465.646	980.763	980.660	0.103
3002	273059.020	5372607.136	947.823	947.820	0.003
3003	278667.100	5376298.734	963.843	963.800	0.043
3004	288599.308	5374835.771	1021.103	1021.100	0.003
3005	294830.295	5367205.756	1033.212	1033.500	-0.288
3006	302105.398	5360627.680	1149.493	1149.500	-0.007
3007	305444.604	5353971.217	1166.063	1166.040	0.023
3008	313429.113	5345971.797	1273.542	1273.570	-0.028
3009	324955.844	5353460.068	1598.161	1598.120	0.041
3010	333074.986	5362917.339	1518.748	1518.820	-0.072

Vertical Accuracy Conclusions

Vegetated Vertical Accuracy (VVA) Tested 0.186 Meter at the 95th percentile reported using National Digital Elevation Program (NDEP)/ASPRS Guidelines and tested against the DEM. VVA Errors larger than 95th percentile include:

Point 3005, Easting 294830.295, Northing 5367205.756, Z-Error 0.288 Meter

Figure 5.1: LIDAR Relative Accuracy Histogram for Glacier National Park QL1 Lidar



Relative Accuracy Assessment and Conclusion

Relative accuracy also known as "between swath" accuracy was tested through a series of well distributed flight line overlap locations. The relative accuracy for the Glacier National Park QL1 Lidar measured at 0.057 meters RMSDz.

Approved by:	Name	Signature	Date
Associate Member, Lidar Specialist Certified Photogrammetrist #1381	Qian Xiao		February 2017

Section 6: LiDAR Acquisition Flight Logs

This section contains the Flight Log(s) covering the project. Flight Logs list mission specific details such as crew members, airports, weather conditions, real time PDOP values and document any issues encountered during the mission. Flight Logs are filled out by the sensor operator during the acquisition flight.

GEOMATICS DATA SOLUTIONS

FLIGHT LOG

PROJECT NAME:	P2016.011 - Glacier NP - QL1 Lidar	**BASE AIRPORT:**	Glacier Park Int. (GPI)
LOCATION / AREA:	Glacier National Park, MT / BL01, 02, 04 to 08	**DATE:**	29 July 2016
AIRCRAFT:	Cessna 401 - N6255Q	**PILOT:**	Dave S.
SYSTEM:	Dual DragonEye	**OPERATOR:**	Dushan A.
MISSION ID:	P2016-011_GlacierNP_900m & 1500m	**CLOUDS:**	Clear
BASE STATION:	GPI1	**WIND:**	5-10kts @ 120°

ENGINE START:	12:38	**ENGINE OFF:**	18:02	**ENGINE TIME:**	05:24
GNSS START:	12:42	**GNSS STOP:**	17:59		
TAKEOFF:	12:52	**TOUCHDOWN:**	17:57	**AIR TIME**	05:05

FL #	START TIME	END TIME	TOPO PRF | PWR		BATHY PWR CHII	REMARKS
	12:39:00					AHAB Computer Time Sync
	12:39:00					Load Camera Cal File
	12:42:00					Initialize GNSS at GPI1
	12:58:00					Dataset: 900m_20160729_125815
000_FL1	12:58:27	13:01:19	280	35	-	Start BL01
001_FL2	13:03:47	13:06:37	280	35	-	
002_FL3	13:09:12	13:11:53	280	35	-	
003_FL4	13:14:41	13:17:04	280	35	-	
004_FL5	13:19:41	13:23:05	280	35	-	Start BL02
005_FL6	13:25:18	13:28:27	280	35	-	
006_FL7	13:30:50	13:34:03	280	35	-	
007_FL8	13:36:46	13:39:54	280	35	-	
008_FL9	13:42:00	13:44:52	280	35	-	
009_FL10	13:47:37	13:49:54	280	35	-	
010_FL11	13:52:03	13:54:21	280	35	-	
011_FL12	13:57:21	13:58:45	280	35	-	
	14:00:00					AHAB System Crash (UI Camera)
	14:20:00					Disable UI Camera
	14:24:00					Dataset: 1500m_20160729_142430
000_FL1	14:24:42	14:28:26	180	55	-	Start BL04
001_FL2	14:30:31	14:34:29	180	55	-	
002_FL3	14:36:30	14:40:19	180	55	-	
003_FL4	14:42:44	14:46:36	180	55	-	
004_FL5	14:48:43	14:52:38	180	55	-	
005_FL6	14:57:54	14:59:37	180	55	-	Start BL05
006_FL7	15:02:00	15:03:50	180	55	-	
007_FL8	15:05:58	15:07:39	180	55	-	
008_FL9	15:11:22	15:14:03	180	55	-	Start BL06

GEOMATICS DATA SOLUTIONS

FLIGHT LOG

PROJECT NAME:	P2016.011 - Glacier NP - QL1 Lidar	**BASE AIRPORT:**	Glacier Park Int. (GPI)
LOCATION / AREA:	Glacier National Park, MT / BL01, 02, 04 to 08	**DATE:**	29 July 2016
AIRCRAFT:	Cessna 401 - N6255Q	**PILOT:**	Dave S.
SYSTEM:	Dual DragonEye	**OPERATOR:**	Dushan A.
MISSION ID:	P2016-011_GlacierNP_900m & 1500m	**CLOUDS:**	Clear
BASE STATION:	GPI1	**WIND:**	5-10kts @ 120°

ENGINE START:	12:38	**ENGINE OFF:**	18:02	**ENGINE TIME:**	05:24
GNSS START:	12:42	**GNSS STOP:**	17:59		
TAKEOFF:	12:52	**TOUCHDOWN:**	17:57	**AIR TIME**	05:05

FL #	START TIME	END TIME	TOPO PRF	TOPO PWR	BATHY PWR CHII	REMARKS
009_FL10	15:16:54	15:20:17	180	55	-	
010_FL11	15:22:35	15:26:15	180	55	-	
011_FL12	15:29:11	15:32:50	180	55	-	
012_FL13	15:35:17	15:39:01	180	55	-	
013_FL14	15:41:53	15:45:45	180	55	-	
014_FL15	15:48:20	15:52:08	180	55	-	
015_FL16	15:54:47	15:58:31	180	55	-	
016_FL17	16:00:57	16:04:50	180	55	-	
017_FL18	16:09:05	16:13:56	180	55	-	Start BL07
018_FL19	16:16:57	16:21:52	180	55	-	
019_FL20	16:24:11	16:29:01	180	55	-	
020_FL21	16:32:01	16:36:45	180	55	-	
021_FL22	16:39:07	16:43:46	180	55	-	
022_FL23	16:46:29	16:50:39	180	55	-	
023_FL24	16:52:57	16:57:00	180	55	-	
024_FL25	17:01:40	17:05:46	180	55	-	Start BL08
025_FL26	17:08:02	17:12:18	180	55	-	

GEOMATICS DATA SOLUTIONS

FLIGHT LOG

PROJECT NAME:	P2016.011 - Glacier NP - QL1 Lidar	**BASE AIRPORT:**	Glacier Park Int. (GPI)
LOCATION / AREA:	Glacier National Park, MT / BL08, 09, 10, 13	**DATE:**	30 July 2016
AIRCRAFT:	Cessna 401 - N6255Q	**PILOT:**	Dave S.
SYSTEM:	Dual DragonEye	**OPERATOR:**	Dushan A.
MISSION ID:	P2016-011_GlacierNP_900m & 1500m	**CLOUDS:**	Cloudy
BASE STATION:	GPI1 & AB7736	**WIND:**	20-25kts @ 240°

ENGINE START:	12:37	**ENGINE OFF:**	17:51	**ENGINE TIME:**	05:14
GNSS START:	12:40	**GNSS STOP:**	17:49		
TAKEOFF:	12:48	**TOUCHDOWN:**	17:47	**AIR TIME**	04:59

FL #	START TIME	END TIME	TOPO PRF | PWR		BATHY PWR CHII	REMARKS
	12:40:00					Initialize GNSS at GPI1
	13:00:00					Initialize GNSS over AB7736
	13:06:00					Dataset: 1500m_20160730_130621
000_FL77	13:06:33	13:09:46	180	55	-	Start BL13
001_FL78	13:12:24	13:16:05	180	55	-	
002_FL79	13:21:00	13:24:24	180	55	-	
003_FL80	13:28:55	13:32:20	180	55	-	
004_FL81	13:36:46	13:40:09	180	55	-	
005_FL82	13:44:34	13:47:52	180	55	-	
006_FL83	13:52:17	13:55:26	180	55	-	
007_FL84	13:59:44	14:02:33	180	55	-	
008_FL31	14:07:57	14:12:38	180	55	-	Start BL08
009_FL32	14:15:02	14:19:42	180	55	-	
010_FL33	14:22:27	14:27:02	180	55	-	
011_FL56	14:30:26	14:32:33	180	55	-	Start BL10
012_FL57	14:34:44	14:36:56	180	55	-	
013_FL58	14:39:22	14:41:27	180	55	-	
014_FL59	14:43:56	14:46:02	180	55	-	
015_FL34	14:53:00	14:55:23	180	55	-	Start BL09
016_FL35	14:57:53	15:00:12	180	55	-	
017_FL36	15:03:44	15:08:17	180	55	-	
018_FL37	15:10:28	15:14:48	180	55	-	
019_FL38	15:17:51	15:22:29	180	55	-	
020_FL39	15:24:44	15:29:27	180	55	-	
021_FL40	15:32:19	15:37:29	180	55	-	
022_FL41	15:39:41	15:44:30	180	55	-	
023_FL42	15:46:45	15:52:02	180	55	-	
024_FL43	15:54:19	15:59:29	180	55	-	

GEOMATICS DATA SOLUTIONS

FLIGHT LOG

PROJECT NAME:	P2016.011 - Glacier NP - QL1 Lidar	**BASE AIRPORT:**	Glacier Park Int. (GPI)
LOCATION / AREA:	Glacier National Park, MT / BL08, 09, 10, 13	**DATE:**	30 July 2016
AIRCRAFT:	Cessna 401 - N6255Q	**PILOT:**	Dave S.
SYSTEM:	Dual DragonEye	**OPERATOR:**	Dushan A.
MISSION ID:	P2016-011_GlacierNP_900m & 1500m	**CLOUDS:**	Cloudy
BASE STATION:	GPI1 & AB7736	**WIND:**	20-25kts @ 240°

ENGINE START:	12:37	**ENGINE OFF:**	17:51	**ENGINE TIME:**	05:14
GNSS START:	12:40	**GNSS STOP:**	17:49		
TAKEOFF:	12:48	**TOUCHDOWN:**	17:47	**AIR TIME**	04:59

FL #	START TIME	END TIME	TOPO PRF | PWR		BATHY PWR CHII	REMARKS
025_FL44	16:01:46	16:07:31	180	55	-	
026_FL45	16:09:42	16:15:07	180	55	-	
027_FL46	16:17:18	16:23:25	180	55	-	
028_FL47	16:26:01	16:31:33	180	55	-	
029_FL48	16:33:59	16:39:25	180	55	-	
030_FL49	16:41:38	16:46:46	180	55	-	
031_FL50	16:49:11	16:54:40	180	55	-	
032_FL51	16:56:48	17:01:52	180	55	-	
033_FL52	17:04:12	17:09:41	180	55	-	
034_FL53	17:11:49	17:16:45	180	55	-	
035_FL54	17:19:06	17:23:33	180	55	-	
036_FL55	17:25:25	17:29:32	180	55	-	
	17:33:00					Close GNSS over AA7736
	17:49:00					Close GNSS at GPI1

GEOMATICS DATA SOLUTIONS

FLIGHT LOG

PROJECT NAME:	P2016.011 - Glacier NP - QL1 Lidar	**BASE AIRPORT:**	Glacier Park Int. (GPI)
LOCATION / AREA:	Glacier National Park, MT / BL11, 12	**DATE:**	31 July 2016
AIRCRAFT:	Cessna 401 - N6255Q	**PILOT:**	Dave S.
SYSTEM:	Dual DragonEye	**OPERATOR:**	Dushan A.
MISSION ID:	P2016-011_GlacierNP_900m & 1500m	**CLOUDS:**	Cloudy
BASE STATION:	GPI1 & TM0733	**WIND:**	35-40kts @ 230°

ENGINE START:	12:24	**ENGINE OFF:**	15:53	**ENGINE TIME:**	03:29
GNSS START:	12:32	**GNSS STOP:**	15:52		
TAKEOFF:	12:39	**TOUCHDOWN:**	15:50	**AIR TIME**	03:11

FL #	START TIME	END TIME	TOPO PRF | PWR		BATHY PWR CHII	REMARKS
	12:32:00					Initialize GNSS at GPI1
	12:50:00					Initialize GNSS over TM0733
	13:00:00					Dataset: 1500m_20160731_130026
000_FL60	13:00:38	13:05:01	180	55	-	Start BL11
001_FL61	13:07:38	13:11:39	180	55	-	Speed & Altitude off
002_FL61	13:15:01	13:19:30	180	55	-	
003_FL62	13:24:46	13:29:06	180	55	-	
004_FL63	13:34:17	13:38:35	180	55	-	
005_FL64	13:43:51	13:48:13	180	55	-	
006_FL65	13:53:03	13:57:19	180	55	-	
007_FL66	14:02:19	14:06:25	180	55	-	
008_FL67	14:11:29	14:15:40	180	55	-	
009_FL68	14:20:31	14:24:31	180	55	-	
010_FL69	14:29:33	14:33:28	180	55	-	
011_FL70	14:37:58	14:40:57	180	55	-	
012_FL71	14:45:16	14:48:11	180	55	-	
013_FL72	14:52:56	14:55:30	180	55	-	
014_FL73	14:59:41	15:02:12	180	55	-	
015_FL74	15:06:46	15:08:48	180	55	-	
016_FL75	15:15:25	15:17:33	180	55	-	Start BL12
017_FL76	15:22:14	15:24:26	180	55	-	
	15:28:00					Close GNSS over TM0733
	15:52:00					Close GNSS at GPI1

GEOMATICS DATA SOLUTIONS

FLIGHT LOG

PROJECT NAME:	P2016.011 - Glacier NP - QL1 Lidar	**BASE AIRPORT:**	Glacier Park Int. (GPI)
LOCATION / AREA:	Glacier National Park, MT / BL03, 09, 11	**DATE:**	04 August 2016
AIRCRAFT:	Cessna 401 - N6255Q	**PILOT:**	Dave S.
SYSTEM:	Dual DragonEye	**OPERATOR:**	Dushan A.
MISSION ID:	P2016-011_GlacierNP_900m & 1500m	**CLOUDS:**	Cloudy
BASE STATION:	GPI1 & TM0733	**WIND:**	5-10kts @ 200°

ENGINE START:	21:04	**ENGINE OFF:**	00:50	**ENGINE TIME:**	03:46
GNSS START:	21:08	**GNSS STOP:**	00:48		
TAKEOFF:	21:17	**TOUCHDOWN:**	00:44	**AIR TIME**	03:37

FL #	START TIME	END TIME	TOPO PRF | PWR		BATHY PWR CHII	REMARKS
	21:08:00					Initialize GNSS at GPI1
	21:28:00					Initialize GNSS over TM0733
	21:35:00					Dataset: 900m_20160804_213525
000_FL13	21:35:33	21:40:23	280	35	-	Start BL03
001_FL14	21:42:27	21:47:16	280	35	-	
002_FL15	21:49:48	21:54:50	280	35	-	
003_FL16	21:56:48	22:01:34	280	35	-	
004_FL17	22:03:57	22:08:47	280	35	-	
005_FL18	22:10:47	22:15:50	280	35	-	
	22:20:00					Dataset: 1500mR_20160804_222033
000_FL25	22:20:41	22:25:07	180	55	-	Start BL09
001_FL24	22:26:44	22:31:15	180	55	-	
002_FL23	22:33:00	22:37:32	180	55	-	
003_FL22	22:39:18	22:43:58	180	55	-	
004_FL21	22:45:43	22:50:14	180	55	-	
005_FL20	22:52:21	22:56:34	180	55	-	
006_FL19	22:58:31	23:02:19	180	55	-	
007_FL18	23:04:26	23:07:57	180	55	-	
008_FL17	23:09:52	23:13:05	180	55	-	
009_FL16	23:14:46	23:17:50	180	55	-	
010_FL15	23:20:15	23:22:42	180	55	-	
011_FL27	23:29:20	23:30:43	180	55	-	
012_FL26	23:32:24	23:33:47	180	55	-	
013_FL41	23:37:02	23:38:26	180	55	-	Start BL11
014_FL40	23:40:33	23:42:04	180	55	-	
015_FL32	23:44:28	23:48:48	180	55	-	
016_FL33	23:50:55	23:55:15	180	55	-	
017_FL34	23:56:59	00:01:15	180	55	-	

GEOMATICS DATA SOLUTIONS

FLIGHT LOG

PROJECT NAME:	P2016.011 - Glacier NP - QL1 Lidar	**BASE AIRPORT:**	Glacier Park Int. (GPI)
LOCATION / AREA:	Glacier National Park, MT / BL03, 09, 11	**DATE:**	04 August 2016
AIRCRAFT:	Cessna 401 - N6255Q	**PILOT:**	Dave S.
SYSTEM:	Dual DragonEye	**OPERATOR:**	Dushan A.
MISSION ID:	P2016-011_GlacierNP_900m & 1500m	**CLOUDS:**	Cloudy
BASE STATION:	GPI1 & TM0733	**WIND:**	5-10kts @ 200°

ENGINE START:	21:04	**ENGINE OFF:**	00:50	**ENGINE TIME:**	03:46
GNSS START:	21:08	**GNSS STOP:**	00:48		
TAKEOFF:	21:17	**TOUCHDOWN:**	00:44	**AIR TIME**	03:37

FL #	START TIME	END TIME	TOPO PRF | PWR		BATHY PWR CHII	REMARKS
018_FL35	00:03:01	00:07:01	180	55	-	
019_FL36	00:08:48	00:12:45	180	55	-	
020_FL37	00:14:32	00:17:44	180	55	-	
021_FL38	00:19:52	00:22:29	180	55	-	
022_FL39	00:24:22	00:26:30	180	55	-	
	00:30:00					Close GNSS over TM0733
	00:48:00					Close GNSS at GPI1

GEOMATICS DATA SOLUTIONS

FLIGHT LOG

PROJECT NAME:	P2016.011 - Glacier NP - QL1 Lidar	**BASE AIRPORT:**	Glacier Park Int. (GPI)
LOCATION / AREA:	Glacier National Park, MT / BL04 to 10, 13	**DATE:**	05 August 2016
AIRCRAFT:	Cessna 401 - N6255Q	**PILOT:**	Dave S.
SYSTEM:	Dual DragonEye	**OPERATOR:**	Dushan A.
MISSION ID:	P2016-011_GlacierNP_900m & 1500m	**CLOUDS:**	Clear
BASE STATION:	GPI1	**WIND:**	5-10kts @ 160°

ENGINE START:	12:12	**ENGINE OFF:**	15:08	**ENGINE TIME:**	02:56
GNSS START:	12:15	**GNSS STOP:**	15:06		
TAKEOFF:	12:25	**TOUCHDOWN:**	15:03	**AIR TIME**	02:38

FL #	START TIME	END TIME	TOPO PRF | PWR		BATHY PWR CHII	REMARKS
	12:15:00					Initialize GNSS at GPI1
	12:40:00					Dataset: 1500mR_20160805_123953
000_FL1	12:40:01	12:43:42	180	55	-	Start BL04
001_FL2	12:46:02	12:49:51	180	55	-	
002_FL3	12:53:45	12:55:32	180	55	-	Start BL05
003_FL7	12:59:39	13:03:22	180	55	-	Start BL06
004_FL6	13:05:06	13:08:55	180	55	-	
005_FL5	13:10:57	13:14:39	180	55	-	
006_FL4	13:16:24	13:19:03	180	55	-	
007_FL8	13:22:18	13:27:05	180	55	-	Start BL07
008_FL9	13:28:50	13:33:34	180	55	-	
009_FL10	13:35:46	13:39:53	180	55	-	
010_FL14	13:43:33	13:48:07	180	55	-	Start BL08
011_FL13	13:50:07	13:54:44	180	55	-	
012_FL12	13:57:00	14:01:34	180	55	-	
013_FL11	14:03:23	14:07:25	180	55	-	
014_FL31	14:11:45	14:13:50	180	55	-	Start BL10
015_FL28	14:16:31	14:18:38	180	55	-	Start BL09
016_FL29	14:21:33	14:23:44	180	55	-	
017_FL30	14:26:02	14:28:09	180	55	-	
018_FL42	14:32:22	14:35:46	180	55	-	Start BL13
019_FL43	14:37:53	14:41:15	180	55	-	
020_FL44	14:43:13	14:46:11	180	55	-	
	15:06:00					Close GNSS at GPI1

Section 7: Final Deliverables

The final lidar deliverables are listed below.

- LAS v1.4 classified point cloud
- LAS v1.4 raw unclassified point cloud flight line strips.
- Hydro Breaklines as ESRI geodatabase
- Bridge Breaklines as ESRI geodaabase
- Digital Elevation Model in ERDAS .IMG format
- 8-bit gray scale intensity images in .TIF format
- Tile Index provided as ESRI shapefile
- Project boundary as ESRI shape file
- Control Points provided as ESRI shapefile
- FGDC compliant metadata per product in XML format
- Lidar processing report in pdf format
- Survey report in pdf format