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MN_LAKESUPERIOR_2021_B21 LIDAR PROCESSING REPORT

2022

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Project ID: 218910 Work Unit: 218907

Prepared for:



Prepared by:



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1. Summary / Scope

1.1. Summary

This report contains a summary of the MN_LakeSuperior_2021_B21, Work Unit 218907 lidar acquisition task order, issued by USGS under their Contract G16PC00016 on April 19, 2021. The task order yielded a project area covering 4,976 square miles over Minnesota. The intent of this document is only to provide specific validation information for the data acquisition/collection, processing, and production of deliverables completed as specified in the task order.

1.2. Scope

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

Table 1. Originally Planned Lidar Specifications

Average Point Density	Flight Altitude (AGL)	Field of View	Minimum Side Overlap	RMSEz
8 pts / m2	1,998 m	58.5°	20%	≤ 10 cm

1.3. Coverage

The project boundary covers 4,976 square miles over Minnesota. Project extents are shown in Figure 1.

1.4. Duration

Lidar data was acquired from April 25, 2021 to May 2, 2021 in 12 total lifts. See "Section: 2.4. Time Period" for more details.

1.5. Issues

There were no issues to report. There are 16 empty LAS files. Fifteen of them are fully covered by Lake Superior and one is completely inside an inland lake.

MN_LakeSuperior_2021_B21 Work Unit 218907 Projected Coordinate System: 2011 Universal Transverse Mercator Zone 15N Horizontal Datum: NAD83(2011) Vertical Datum: NAVD88 (GEOID 18) Units: Meters		
Lidar Point Cloud	Classified Point Cloud in .LAS 1.4 format	
Rasters	 0.5-meter Hydro-flattened Bare Earth Digital Elevation Model (DEM) in GeoTIFF format 0.5-meter Intensity images in GeoTIFF format 	
Vectors	 Shapefiles (*.shp) Project Boundary Lidar Tile Index Calibration and QC Checkpoints (NVA/VVA) Building Footprint Polygons Geodatabase (*.gdb) Continuous Hydro-flattened Breaklines 	
Reports	 Reports in PDF format Focus on Delivery Processing Report 	
Metadata	 XML Files (*.xml) Breaklines Classified Point Cloud DEM Intensity Imagery 	

MN_LakeSuperior_2021_B21 Work Unit 218907 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 and FMS Planner planning software.

2.2. Lidar Sensor

NV5 Geospatial utilized Riegl VQ1560i and VQ1560ii as well as Optech Galaxy T2000 lidar sensors (Figure 3), serial number(s) 3544, 4051, and 413, 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.

The Optech Galaxy T2000 is a wide-area lidar sensor. This sensor is enhanced with a continuous operating envelope, a dynamic field of view, real-time sensor protocol, and a high-performance scanner. This sensor has 2 MHz "on-ground" collection rates and is capable of 8 returns per emitted pulse.

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

Table 2	2. Lidar	System	Specifications
---------	----------	--------	----------------

		Riegl VQ1560i (3544)	Riegl VQ1560ii (4051)	Optech Galaxy T2000 (413)
Terrain and	Flying Height	1,326 m	1,500 m	1,828 m
Aircraft Scanner	Recommended Ground Speed	180 kts	160 kts	145 kts
	Field of View	58.5°	60°	38°
Scanner	Scan Rate Setting Used	2 x 200 (lps)	350 Hz	95 Hz
	Laser Pulse Rate Used	2 x 1000 kHz	2000 kHz	1100 kHz
Laser	Multi Pulse in Air Mode	6-11	Yes	Yes
6	Full Swath Width	1,484 m	1,700 m	1342 m
Coverage	Line Spacing	1,190 m	1,385 m	994 m
Point Spacing	Average Point Spacing	.459 m	0.353 m	.330 m
and Density	Average Point Density	9.70 pts / m ²	>8 pt/m2	9.12 pts / m ²

Figure 2. Riegl VQ1560i, Riegl VQ1560ii, and Optech Galaxy T2000 Lidar Sensors



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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 PA-31-310 Navajo C, Tail Number(s): C-GKSX
- Cessna 402 (twin-piston), Tail Number(s): N41GD
- Cessna 206 Stationair (piston-single), Tail Number(s): N223TC

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 state-of-the-art Riegl and Optech lidar systems. Some of NV5 Geospatial's operating aircraft can be seen in Figure 4 below.

Figure 3. Some of NV5 Geospatial's Planes



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2.4. Time Period

Project specific flights were conducted between April 25, 2021 and May 2, 2021. Twelve aircraft lifts were completed. Accomplished lifts are listed below.

Lift	Start UTC	End UTC
04252021A1 (SN3544,N223TC)	4/25/2021 1:05:22 PM	4/25/2021 5:50:00 PM
04252021A2 (SN3544,N223TC)	4/25/2021 7:16:35 PM	4/25/2021 9:45:29 PM
04282021A (SN3544,N223TC)	4/28/2021 6:19:34 PM	4/28/2021 8:31:23 PM
04282021A (SN413,N41GD)	4/28/2021 8:40:14 PM	4/29/2021 1:04:43 AM
04302021A (SN4051,C-GKSX)	4/30/2021 12:56:46 PM	4/30/2021 6:27:24 PM
04302021A (SN413,N41GD)	4/30/2021 2:38:29 PM	4/30/2021 7:20:00 PM
04302021A1 (SN3544,N223TC)	4/30/2021 1:03:58 PM	4/30/2021 3:02:27 PM
05012021A (SN4051,C-GKSX)	5/01/2021 1:27:43 PM	5/01/2021 6:51:27 PM
05012021A2 (SN3544,N223TC)	5/01/2021 7:26:41 PM	5/01/2021 8:09:02 PM
05022021A (SN4051,C-GKSX)	5/02/2021 1:01:10 PM	5/02/2021 6:00:08 PM
05022021A1 (SN3544,N223TC)	5/02/2021 1:13:49 PM	5/02/2021 4:30:50 PM
05022021A2 (SN3544,N223TC)	5/02/2021 5:57:01 PM	5/02/2021 8:17:21 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 were created using Optech LMS and 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 GeoCue distributive processing software. Imported data is tiled and then calibrated using TerraMatch and proprietary software. Using TerraScan, the vertical accuracy of the surveyed ground control is tested and any bias is removed from the data. TerraScan and TerraModeler software packages are then used for automated data classification and manual cleanup. The data are 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
Optech LMS	4.4
Applanix + POSPac	8.6
RIPROCESS	1.8.6
GeoCue	2020.1.22.1
Global Mapper	19.1;20.1
TerraModeler	21.008
TerraScan	21.016
TerraMatch	21.007

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

3.3. LAS Classification Scheme

The classification classes are determined by Lidar Base Specifications 2020, Revision A and are an industry standard for the classification of lidar point clouds. All data starts the process as Class 1 (Unclassified), and then through automated classification routines, the classifications are determined using TerraScan macro processing.

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

	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 3. LAS Classifications

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 0.5 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 0.5 meters 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.

3.8. Hydro-Flattened Raster DEM Processing

Class 2 lidar in conjunction with the hydro breaklines were used to create a 0.5-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.

3.9. Intensity Image Processing

GeoCue software was used to create the deliverable intensity images. All withheld points were ignored during

this process. This helps to ensure a more aesthetically pleasing image. The GeoCue software was then used to verify full project coverage as well. GeoTIFF files with a cell size of 0.5-meter were then provided as the deliverable for this dataset requirement.

3.10. Height 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. Proprietary software was used to create 0.5-meter raster images in GeoTIFF format.

MN_LakeSuperior_2021_B21 Work Unit 218907 Tile Layout



Figure 4. Lidar Tile Layout

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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.

MN_LakeSuperior_2021_B21 Work Unit 218907 Lidar Coverage



Figure 5. Lidar Coverage

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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, 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 1,828 meters, an IMU error of 0.002 decimal degrees, and a GNSS positional error of 0.015 meters, this project was compiled to meet 0.20 meter horizontal accuracy at the 95% confidence level. A summary is shown below.

Horizontal Accuracy		
RMSE _r	0.38 ft	
	0.12 m	
ACC _r	0.65 ft	
	0.20 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 MN_ LakeSuperior_2021_B21 project was 0.041 feet (0.013 meters). A summary is shown below.

Relative Vertical Accuracy		
Sample	150 flight line surfaces	
Average	.048 ft	
Average	.015 m	
Madian	.048 ft	
Median	.015 m	
RMSE	.048 ft	
	.015 m	
Standard Deviation (1σ)	.006 ft	
	.002 m	
1.05-	.011 ft	
1.960	.003 m	



Lake Superior Delivery 1, Minnesota Relative Vertical Accuracy (ft)

Project Report Appendices

The following section contains the appendices as listed in the MN_LakeSuperior_2021_B21 Lidar Project Report.

Appendix A

Flight Logs

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Julian Day 12	0 Flight A			-	-IDAR	Flight	: Log				
Date April 3	30th, 2021	Aircraft	C-GKSX	S.	stem F	Riegl VQ-	1560ii A	dditional Notes		AIR	BORNE
Project 3221_QS	LakeSuperior	Pilot	L. Bastien	0 U	nit	51		CP780.423-476		A Clean	A G I N G Harbors Company
Location	KDLH	Operator	R. Gemmel	I	u A _l	oplanix A	P60	VERY STRONG	WINDS* DRAF	TS ST	
Mission Objective				GF	S Rx 7	Frimble G	NSS17	OTHER SURVE	Y AIRCRAFT IN	7	
-Holding +02.00 p	itch O/S as per m	lanagemen	ŗ	Sc	anner 1 D	rive	B1	AREA/SAME AL	TITUDE		
				S	anner 2 D	rive	B1	Time to next mainte	ance: <u>43.6 +/-</u>	• 50 hr O 100 hr	
	Aircraft Block Tir	me				Missid	on Plan		Ctatio	6PS	Time
Ending On 17.75	Takeoff 17.10			VCI Ho	t t	500 m	Dulco Pato		Alignment	Ctort	End
					- IIIII				,	Oldi l	
Engine Off 18:59	Landing 18:50			Target S	Speed 1	60 kts	Scan Rate 17.	2/179plane	Pre Mission	12:38	12:43
Total 6.6 hrs	Total 6.0 hrs			Laser C	urrent	100 %	FOV 6() degs	Post Mission	18:53	18:58
	I iDAR	Flight	GPS	S Time		Line	e Aborted	Mission ID			
Flight Line	File Name C	Direction	Start	Ъ	р	Time	nmi to End	Time Stamp 210	430	Comments	
								210430_123	359		
Test Strip		N/A	12:56	12:	57			210430_125	345 DC e	rror, quick test.	No issues.
Figure 8		8	13:01	13:	06					6000 ft +/	
X-Tie_1001-1	512112001 (-/+ 00 [.] C	13:08	13:	13			130832		6000 ft +/	
1001	512112002	273.0	13:17	13:	39			131727	6609	ft a few low clo	uds around
1002	512112003	091.0	13:42	14:	02			134218		6099 ft	
1003	512112004	273.0	14:06	14:	27			140602		6099 ft	
1004	512112005	091.0	14:30	14:	50			143023	6099 ft	; had to turn qu	ck for traffic.
1005	512112006	273.0	14:53	15:	14			145302		6099 ft	
1006	512112007	091.0	15:17	15:	37			151744		6099 ft	
1007	512112008	273.0	15:41	16:	02			154131		6099 ft	
1008	512112009	091.0	16:05	16:	26			160533		6099 ft	
1009	512112010	273.0	16:29	16:	50			162943		6099 ft Getting	rough
1010	512112011	091.0	16:54	17:	14			165400		6099 ft	
1011	512112012	273.0	17:17	17:	39			171758		6099 ft	
v 20200520										Ра	ge 1 of 2

Julian Day 12	0 Flight A				LIDAR	Elight	: Log				
Date April :	30th, 2021	Aircraft	C-GKSX		iystem	Riegl VQ-	1560ii A	dditional Notes		AL	RORNE
Project 3221_Q5	SI_LakeSuperior	Pilot	L. Bastien		Jnit	51		CP780.423-476		A Clear	A G I N G
Location	KDLH	Operator	R. Gemmel	_	MU A	pplanix A	P60	VERY STRON	G WINDS* DRAF	TS ST	
Mission Objective					SPS Rx	Trimble G	NSS17	OTHER SURV	EY AIRCRAFT II	7	
-Holding +02.00 p	itch O/S as per rr	ıanagemen	÷	σ	canner 1 [Drive	B1	AREA/SAME AI	-TITUDE		
				S	canner 2 [Drive	B1	Time to next mainte	enance: <u>43.6 +/-</u>	• 50 hr O 100 hr	
	Aircraft Block Ti	me				Missid	on Plan		Static	GP	S Time
Engine On 12:25	Takeoff 12:49			AGL H	eight .	1500 m	Pulse Rate	1000 KHz	Alignment	Start	End
Engine Off 18:59	Landing 18:50			Target	Speed	160 kts	Scan Rate 17	2/179plane	Pre Mission	12:38	12:43
Total 6.6 hrs	Total 6.0 hrs			Laser (Current	100 %	FOV 6() degs	Post Mission	18:53	18:58
		Flicht	GPS	S Time		Lin	e Aborted	Mission II	0		
Flight Line	File Name	Direction	Start	Ш	End	Time	nmi to End	Time Stamp 210	0430	Comment	~
1012	512112013	6.060	17:42	18	3:02			210430_174	1217	9099 ft	
1013	512112014	272.9	18:06	18	3:27			180629		6099 ft	
Figure 8		8	18:27	18	3:32					6100 ft+/	
v 20200520										ä	ige 2 of 2

	AIRBORNE		DS* DRAFTS	CRAFT IN	Ш	<u>43.6 +/-</u> • 50 hr O 100 hr	tatic GPS Time	jnment Start End	sion 12:38 12:43	ission 18:53 18:58		Comments								Page 3 of 2
	Additional Notes	CP780 423-476	*VERY STRONG WINI	*OTHER SURVEY AIR	AREA/SAME ALTITUD	Time to next maintenance:		1000 KHz Ali	'2/179plane Pre Mi	0 degs Post N	Mission ID	Time Stamp 210430								
Flight Log	iegl VQ-1560ii	51	planix AP60	imble GNSS17	ve B1	ve B1	Mission Plan	00 m Pulse Rate	30 kts Scan Rate 17	00 % FOV 6	Line Aborted	Time nmi to End								
LIDAR	System Ri	Unit	IMU Apr	GPS Rx Tr	Scanner 1 Dri	Scanner 2 Dri		AGL Height 15	Target Speed 16	Laser Current 1	S Time	End								
	C-GKSX	L. Bastien	r R. Gemmel		ent.						GP	Start								
	Aircraft	Pilot	Operato	-	nanageme		ime				Flicht	Direction								
Flight A	th, 2021	LakeSuperior	(DLH		:h O/S as per n		ircraft Block Ti	Takeoff 12:49	Landing 18:50	Total 6.0 hrs	I iDAR	-ile Name								
Julian Day 120	Date April 30	Project 3221_QSI_	Location K	Mission Objective	-Holding +02.00 pitc		A	Engine On 12:25	Engine Off 18:59	Total 6.6 hrs		Flight Line F								v 20200520

Julian Day 12	0 Flight A			LIDA	R Flight	Log				
Date April 3	30th, 2021	Aircraft	C-GKSX	System	Riegl VQ-	1560ii A	dditional Notes		AIR	BORNE
Project 3221_QS	I_LakeSuperior	Pilot	L. Bastien	Unit	51		3P780 423-476			AGING
Location	KDLH	Operator	R. Gemmel	NMI	Applanix AF		VERY STRONG	3 WINDS* DRAF1	LS A Clean	
Mission Objective		-		GPS Rx	Trimble GI	NSS17 *	OTHER SURVI	EY AIRCRAFT IN		
-Holding +02.00 p	itch O/S as per r	managemer	ıt.	Scanner 1	Drive	B1	AREA/SAME AL	TITUDE		
				Scanner 2	: Drive	B1	Time to next mainte	nance: <u>43.6 +/-</u> (• 50 hr O 100 hr	
	Aircraft Rlock T	ime			Missic	n Plan		:	505	Time
Endine On 12-25	Takenff 12.49			AGI Heinht	1500 m	Pulse Rate	000 KH2	Alignment	Start	End
Engine Off 18:50	l anding 18-50			Tarnet Sneed	160 kts	Scan Rate 173	200 IS IS	Pre Mission	17.38	12.43
Total 6.6 hrs	Total 6.0 hr	s 0		Laser Current	100 %	FOV 60	degs	Post Mission	18:53	18:58
							,			
		Flinht	GPS	Time	Line	Aborted	Mission IC			
Flight Line	File Name	Direction	Start	End	Time	nmi to End	Time Stamp 210	430	Comments	
v 20200520									Ра	ige 4 of 2

	AIRBORNE	I W A G I N G	A Clean Harbors Company VINDS* DRAFTS	AIRCRAFT IN	rude	ice: <u>43.6 +/-</u> © 50 hr O 100 hr	C C C C C C C C C C C C C C C C C C C	Alignment Start Fnd	Mission 10:30 10:40	e mission 12.30 12.40 set Mission 18.53 18.58			0 Comments								
	Additional Notes	CP780 423-476	*VERY STRONG W	*OTHER SURVEY	AREA/SAME ALTIT	Time to next maintenan		1000 KHz		60 dens Po	offenn on	Mission ID	Time Stamp 210430								
Flight Log	iegl VQ-1560ii	51	planix AP60	rimble GNSS17	ive B1	ive B1	Mission Plan	500 m Pulse Rate	SO Lto Scan Dato 1	DO % FOV	N	Line Aborted	Time nmi to End								
LIDAR	System Ri	Unit	IMU Apr	GPS Rx Tr	Scanner 1 Dri	Scanner 2 Dri		AGI Heicht 15	Target Chood 16	larger Current		S Time	End								
	ft C-GKSX	L. Bastien	tor R. Gemmel		nent.							Ğ	Start								
Flight A	, 2021 Aircra	akeSuperior Pilot	LH Opera	-	O/S as per manager		raft Block Time	kenff 12·49	10.E0	tal 6.0 hrs	0.0	IDAR Flight	Pirection								
Julian Day 120	Date April 30th,	Project 3221_QSI_Ls	Location KD	Mission Objective	-Holding +02.00 pitch		Airc	Endine On 12-25 Ta	Engine Off 18:60 1.2	Total 6.6 hrs To			Flight Line File								

			Project Info
Project #		Р	roject Name
20210171:1A-1		Lak	eSuperior_QL1
· ·	Crew		Equipment
	Pilot		Aircraft Make/Model
	Rvan		Cessna 401
0	nerator		Sensor Make/Model
	Chris		Ontech Galaxy T2000
	Cinis		opteen dalaxy 12000
Wind Dir (ייע ויי	Wind Speed (kts)	Visibility (mi)
150		o	10
150	`no od (kto)	0	
Airs		Aitit	
	145		6,000
			I
Point Spacing	(m)	Point Density (ppsm)	
0.33		9.12	
Line #	Direction	Start Time	End Time
LINE #	Direction	(UTC)	(UTC)
119	70	20:40:12	20:49:42
1	182	20:53:40	20:54:28
2	2	20:58:56	21:00:15
3	182	21:03:44	21:04:59
4	2	21:08:31	21:10:02
5	182	21:13:17	21:14:59
6	2	21:19:24	21:21:05
7	182	21:25:03	21:26:56
8	2	21:31:42	21:33:49
9	182	21:37:40	21:39:48
10	2	21:44:34	21:46:42
11	182	21:50:06	21:52:25
12	2	21:56:39	21:59:16
13	182	22:03:01	22:05:44
14	2	22:09:34	22:12:36
15	182	22:16:03	22:18:57
16	2	22:22:50	22:26:04
17	182	22:30:17	22:33:28
18	2	22:38:03	22:41:33
19	182	22:45:25	22:49:02
20	2	22:52:45	22:56:33
21	182	22:59:54	23:07:09
22	2	23:11:18	23:18:31
23	182	23:21:56	23:29:04
24	2	23:32:52	23:40:07

Additional Comments

Drive 1

Survtech Lidar Acquisition Log

			Unique ID			Flight Date (UTC)
			Day118_5060413	_1		04/28/2021
					Time	
	Aircraft Ta	ail #	Hobbs	Start	Loca	l Start
	N41GD)	1295	5.2	03:	13:00
	Sensor Ser	rial #	Hobbs	End	Loca	al End
	506041	3	1300).4	08:	25:00
	Conditions				•	
	Ceiling (ft)		Cloud Cover	Temp.	(°C)	De
	12,000		Clear	12.2	2	
A	ltitude MSL (ft)		Airf	ield Elevation (ft)		
	7.400			1.428		
	Settings			· -		
Scan Angle/FOV	(°)		Scan Frequenc	v (Hz)		Pulse Rate (kHz)
38			95	<u>, , , , , , , , , , , , , , , , , , , </u>		1100
						Verify S-Turns Bef
ті	me					
On	-Line	Satellite	PDOP			Line Notes
00:0	09:30	26	0.94			G
00:0	00:48	26	0.96			G
00:0	01:19	26	0.95			G
00:0	01:15	26	0.94			G
00:0	01:31	25	1.01			G
00:0	01:42	24	1.04			G
00:0	01:41	24	1.02			G
00:0	01:53	25	0.9			G
00:0	U2:U7	24	0.98			G
00:0	02:08 02:08	25	0.93			6
00:0	02.00	28	0.82			G
00:0	02:37	26	0.89			G
00:0	02:43	26	0.9			G
00:0	03:02	26	0.9			G
00:0	02:54	27	0.89			G
00:0	03:14	27	0.89			G
00:0	03:11	27	0.93			G
00:0	03:30	25	1.01			G
	U3:37 N3:48	27	0.91			6
00.0	07:15	20	1			<u>ل</u>
00:0	07:13	26	1.05			G
00:0	07:08	26	0.95			G
00:0	07:15	24	1.14			G
		Page 1				Verify S-Turns Aft

Date			
Dute	Da	v of Year	Elight #
		118	1
		Airports	-
	Start	Departing	
20.1	2.00		•
20.1	5.00		
		Arriving	
01:2	5:00	KDLH	
		- ///:	
ew Point (°C)		Pressure ("F	lg)
2.8		29.96	
		_	_
		Laser Power (%)	
		100	
ore Mission			Yes
/Comments			
ood			
bod			
boc			
boc			
bod			
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ood			
and			
ood			
ood			
bod			
boc			
bod			
			Vac
er iviission			Yes

Project # Image: Crew Pilot Image: Crew Pilot Ryan Pilot Pilot Ryan Operator Pilot Chris Image: Crew Pilot Start Speed (kts) Mind Dir (*) Vind Speed (kts) 8 Air Speed (kts) 145 145 Point Spacing (m) Point De 0.33 Point Crew Pilot Start (trew Pilot) Line # Direction Start (trew Pilot) 25 182 233 26 2 233 27 182 000 28 2 000 29 182 003 30 2 000 31 182 000 32 2 00 32 2 00 32 2 00 32 2 00 32 2 00 32 2 00 32 2 00 33	Project Na LakeSuperior Aircraft Ce Sensor Optech Altitude AGL (1 6,000	me QL1 Equipmen Make/Model ssna 401 Make/Model Galaxy T2000 Visibility (m 10
Crew Pilot Ryan	LakeSuperior Aircraft Ce Sensor Optech Altitude AGL (1 6,000	C_QL1 Equipmen Make/Model ssna 401 Make/Model Galaxy T2000 Visibility (m 10
Crew Pilot Ryan Operator Chris Wind Dir (°) Wind Speed (kt) 145 Point Spacing (m) Point De Oirection Star Line # Direction Star 25 182 233 26 2 233 27 182 000 28 2 000 29 182 000 30 2 000 31 182 000 32 2 000 31 182 00 32 2 00 32 2 00 32 2 00 32 2 00 31 182 00 32 2 00 31 182 00 32 2 00 33 34 34 34 34 34 34 34 <td>Aircraft Ce Sensor Optech Altitude AGL (1 6,000</td> <td>Equipmen Make/Model ssna 401 Make/Model Galaxy T2000 Visibility (m 10</td>	Aircraft Ce Sensor Optech Altitude AGL (1 6,000	Equipmen Make/Model ssna 401 Make/Model Galaxy T2000 Visibility (m 10
Pilot Ryan Operator Chris Wind Speed (kt 150 8 Air Speed (kts) 8 145 9 Point Spacing (m) Point De 0.33 9 Line # Direction Star 25 182 23: 26 2 23: 27 182 00: 28 2 00: 30 2 00: 31 182 00: 32 2 00: 32 2 00: 32 2 00: 32 2 00: 32 2 00: 32 2 00: 32 2 00: 32 2 00: 33 182 00: 34 182 00: 35 182 182 36 2 00: 37 182 00: 38 182	Aircraft Ce Sensor Optech Altitude AGL (1 6,000	Make/Model ssna 401 Make/Model Galaxy T2000 Visibility (m 10
Notes Notes Wind Dir (°) Wind Speed (kts) 150 8 Air Speed (kts) 145 145 9 Point Spacing (m) Point De 0.33 9 Line # Direction Star 25 182 23: 26 2 23: 26 2 23: 27 182 00: 28 2 00: 30 2 00: 31 182 00: 32 2 00: 32 2 00: 32 2 00: 32 2 00: 32 2 00: 32 2 00: 33 182 00: 34 182 00: 35 2 0: 36 37 36 37 37 182 182 <td< td=""><td>Ce Sensor Optech Altitude AGL (1 6,000</td><td>issna 401 Make/Model Galaxy T2000 Visibility (m 10</td></td<>	Ce Sensor Optech Altitude AGL (1 6,000	issna 401 Make/Model Galaxy T2000 Visibility (m 10
Operator Chris Wind Dir (°) Wind Speed (kts) 145 8 Air Speed (kts) 145 145 90int Spacing (m) Point De 0.33	Altitude AGL (1 6,000	Galaxy T2000 Visibility (m
Wind Dir (°) Wind Speed (kt) 150 8 Air Speed (kts) 145 145 9 Point Spacing (m) Point De 0.33 1 Line # Direction Star 25 182 23: 26 2 23: 26 2 23: 27 182 00: 28 2 00: 29 182 00: 30 2 00: 31 182 00: 32 2 00: 32 2 00: 32 2 00: 32 2 00: 32 2 00: 32 2 00: 32 2 00: 34 182 14 35 36 37 36 37 38 37 38 39 38 39 39 39 30 30 <t< td=""><td>Altitude AGL (1</td><td>Galaxy T2000 Visibility (m 10</td></t<>	Altitude AGL (1	Galaxy T2000 Visibility (m 10
Wind Dir (°) Wind Speed (kt) 150 8 Air Speed (kts) 145 145 9 Point Spacing (m) Point De 0.33 9 Line # Direction Star 25 182 23 26 2 23 26 2 23 27 182 00 28 2 00 29 182 00 30 2 00 31 182 00 32 2 00 32 2 00 32 2 00 32 2 00 32 2 00 32 2 00 32 2 00 33 182 00 34 182 00 35 2 00 36 2 00 37 30 30 30 30 30 30 30	Altitude AGL (6,000	Visibility (m 10
Wind Dir () Wind Speed (kt 150 8 Air Speed (kts) 145 145 9 0.33 9 Line # Direction (t 25 182 23: 26 2 23: 27 182 00: 28 2 00: 30 2 00: 31 182 00: 32 2 00: 31 182 00: 32 2 00: 32 2 00:	Altitude AGL (1 6,000	10
S Air Speed (kts) Point Spacing (m) Point De 145 0.33	Altitude AGL (6,000	10
Air speed (kts) 145 Point Spacing (m) Point De 0.33 Direction Star Line # Direction (Line # 25 182 233 26 2 233 26 2 233 27 182 000 28 2 000 30 2 000 31 182 000 32 2 000 31 182 000 32 2 000 31 182 000 32 2 000 34 182 000 35 2 000 31 182 000 32 2 000 34 34 34 34 36 37 38 39 31 33 39 30 30 32 33 30 30 30 30 37 38	6,000	£+)
Point Spacing (m) Point De 0.33	6,000	11)
Point Spacing (m) Point De 0.33 0.33 Line # Direction Star 25 182 23 26 2 23 26 2 23 27 182 000 28 2 00 29 182 00 30 2 00 31 182 00 32 2 00 32 2 00 30 2 00 31 182 00 32 2 0 33 1 1 34 1 1 35 2 0 1 36 2 0 1 37 1 1 1 39 1 1 1 30 2 1 1 31 1 1 1 35 1 1 1 36 1 1 1 37		
Line # Direction Star (U 25 182 23 26 2 23 27 182 00 28 2 00 29 182 00 30 2 00 31 182 00 32 2 00	sity (ppsm)	
Line # Direction Star (I 25 182 23 26 2 23 27 182 00 28 2 00 29 182 00 30 2 00 31 182 00 32 2 00	12	
Line # Direction Star (I 25 182 23 26 2 23 27 182 00 28 2 00 29 182 00 30 2 00 31 182 00 32 2 00		
Line # Direction (l 25 182 23 26 2 23 27 182 00 28 2 00 29 182 00 30 2 00 31 182 00 32 2 00	Time	End Time
25 182 23 26 2 23 27 182 00 28 2 00 29 182 00 30 2 00 31 182 00 32 2 00 32 2 00	C)	(UTC)
26 2 23 27 182 00 28 2 00 29 182 00 30 2 00 31 182 00 32 2 00	3:22	23:50:30
27 182 00: 28 2 00: 29 182 00: 30 2 00: 31 182 00: 32 2 00:	4:28	00:01:42
28 2 00 29 182 00 30 2 00 31 182 00 32 2 00	5:09	00:12:12
29 182 00: 30 2 00: 31 182 00: 32 2 00:	5:06	00:23:06
	5:46	00:33:26
	7:49	00:44:23
	5:05	00:54:19
		01.04.47
	1	
	I	
·		
ional Comments		

Survtech Lidar Acquisition Log

			Unique ID			light Date (UTC)
			Day118_5060413	_1		04/28/2021
					Time	
	Aircraft Ta	ail #	Hobbs	Start	Loca	l Start
	N41GE)	1295	5.2	03::	13:00
	Sensor Ser	rial #	Hobbs	End	Loca	al End
	506041	.3	1300).4	08:2	25:00
	Conditions					
	Ceiling (ft)		Cloud Cover	Temp.	(°C)	De
	12,000		Clear	12.2	2	
A	ltitude MSL (ft)		Airf	ield Elevation (ft)		
	7,400			1,428		
	Settings					
Scan Angle/FOV	/ (°)		Scan Frequenc	y (Hz)		Pulse Rate (kHz)
38			95			1100
						Verify S-Turns Bef
Ti	me					
On	-Line	Satellite	PDOP			Line Notes
00:0	07:08	26	1			G
00:0	07:14	28	0.95			G
00:0	07:03	28	0.96			G
00:0	07:00	27	0.96			G
00:0	06:40	30	0.85			G
00:0	06:34 06:1 <i>1</i>	30	0.86			G
00:0	06:54	30	0.87			G
						Dri
		Page 1				Verify S-Turns Aft

Date			
	Da	y of Year	Flight #
		118	1
		Airports	
UTC	Start	Departing	
20:1	3:00	KDLH	
υтс	End	Arriving	
01:2	5:00	KDI H	
0 = 1 =			
ew Point (°C)		Pressure ("H	g)
2.8		29.96	Б/
2.0		25.50	
			_
		aser Power (%)	
	L	100	
ana Deliacian		100	¥
ore Mission			Yes
;/Comments			
ood			
000			
000			
ve 1			
er Mission			Yes

			Project Info
Project #		Р	roject Name
20210171:1A-1		Lak	eSuperior_QL1
C	rew		Equipment
F	Pilot		Aircraft Make/Model
F	Rvan		Cessna 401
On	erator		Sensor Make/Model
40	`hric		Optech Galaxy T2000
			Opteen Galaxy 12000
Wind Dir (°)		Wind Speed (kts)	Visibility (mi)
220		10	10
520	(1+)	10	
Air Sp		Altiti	ude AGL (π)
	145		6,000
Point Spacing (m)	Point Density (ppsm)	
0.33		9.12	
Lino #	Direction	Start Time	End Time
Line #	Direction	(UTC)	(UTC)
33	182	14:38:27	14:45:08
34	2	14:50:00	14:56:56
35	182	15:00:28	15:07:58
36	2	15:12:47	15:20:30
37	182	15:24:26	15:32:34
38	2	15:36:46	15:45:26
39	182	15:49:35	15:57:55
40	2	16:02:00	16:10:38
41	182	16:14:36	16:23:01
42	2	16:27:09	16:35:49
43	182	16:38:45	16:46:59
44	2	16:55:41	17:10:09
45	182	17:13:24	17:27:19
46	2	17:31:43	17:46:13
47	182	17:49:12	18:03:08
48	2	18:07:13	18:21:30
49	182	18:24:27	18:38:49
50	2	18:43:01	18:57:34
Manuel Tie		19:16:17	19:20:03

Additional Comments

Named This Missions IMU (210430B)

Survtech Lidar Acquisition Log

			Unique ID		F	light Date (UTC)
			Day120_5060413	_1		04/30/2021
					Time	
	Aircraft Ta	ail #	Hobbs	Start	Loca	Start
	N41GD)	1301	7	09:1	.3:00
	Sensor Ser	ial #	Hobbs	End	Loca	l End
	506041	3	1307	.1	02:3	37:00
	Conditions					
	Ceiling (ft)		Cloud Cover	Temp.	(°C)	De
	12,000		Clear	-0.6		
A	ltitude MSL (ft)	I	Airf	ield Elevation (ft)		
	7,430			1,428		
	Settings		I	·		
Scan Angle/FOV	(°)		Scan Frequenc	v (Hz)		Pulse Rate (kHz)
38	()		95	,,,,		1100
					· · · · · ·	/erifv S-Turns Bef
Ti	me					,
On-	12,000 Altitude MSL (ft) 7,430 Settings le/FOV (°) 8 Time On-Line Satellite	Satellite	PDOP			Line Notes
00:0	06:41	28	0.97			G
00:0	06:56	28	0.98			G
00:0	07:30	31	0.86			G
00:0	07:43	32	0.84			G
00:0	08:08	31	0.84			G
00:0	08:40	30	0.88			G
00:0	08:20	31	0.85			G
00:0	J8:38	32	0.8			6
00.0	J8:25	30 29	0.87			6
00:0)8:14	30	0.91			6
00:1	14:28	30	0.95			G
00:1	13:55	30	0.93			G
00:1	14:30	28	0.91			G
00:1	13:56	29	0.82			G
00:1	14:17	30	0.78			G
00:1	14:22	28	0.8			G
00:1	14:33	28	0.81			G
00.0	JS.40	27	0.85			G
						Dr
1						
		Dama 1				V
		Page 1				verity S-Turns Aft

Date			
	Da	y of Year	Flight #
		120	1
		Airports	
UTC	Start	Denarting	
14.1	3.00	RDI H	
14.1	5.00 Fad	Arriving	
010	End 7.00	Arriving	
19:3	7:00	KDLH	
		- ///	
ew Point (°C)		Pressure ("H	g)
-5.6		30.19	
	I	aser Power (%)	
		100	
ore Mission			Yes
;/Comments			
ood			
000			
ood			
ive 3			
er Mission			Yes

Julian Day 12	0 Flight A			-	-IDAR	Flight	: Log				
Date April 3	30th, 2021	Aircraft	C-GKSX	S.	stem F	Riegl VQ-	1560ii A	dditional Notes		AIR	BORNE
Project 3221_QS	LakeSuperior	Pilot	L. Bastien	0 U	nit	51		CP780.423-476		A Clean	A G I N G Harbors Company
Location	KDLH	Operator	R. Gemmel	I	u A _l	oplanix A	P60	VERY STRONG	WINDS* DRAF	TS ST	
Mission Objective				GF	S Rx 7	Frimble G	NSS17	OTHER SURVE	Y AIRCRAFT IN	7	
-Holding +02.00 p	itch O/S as per m	lanagemen	ŗ	Sc	anner 1 D	rive	B1	AREA/SAME AL	TITUDE		
				S	anner 2 D	rive	B1	Time to next mainte	ance: <u>43.6 +/-</u>	• 50 hr O 100 hr	
	Aircraft Block Tir	me				Missid	on Plan		Ctatio	6PS	Time
Ending On 17.75	Takeoff 17.10			VCI Ho	t t	500 m	Dulco Pato		Alignment	Ctort	End
					- IIIII				,	Oldi l	
Engine Off 18:59	Landing 18:50			Target S	Speed 1	60 kts	Scan Rate 17.	2/179plane	Pre Mission	12:38	12:43
Total 6.6 hrs	Total 6.0 hrs			Laser C	urrent	100 %	FOV 6() degs	Post Mission	18:53	18:58
	I iDAR	Flight	GPS	S Time		Line	e Aborted	Mission ID			
Flight Line	File Name C	Direction	Start	Ъ	р	Time	nmi to End	Time Stamp 210	430	Comments	
								210430_123	359		
Test Strip		N/A	12:56	12:	57			210430_125	345 DC e	rror, quick test.	No issues.
Figure 8		8	13:01	13:	06					6000 ft +/	
X-Tie_1001-1	512112001 (-/+ 00 [.] C	13:08	13:	13			130832		6000 ft +/	
1001	512112002	273.0	13:17	13:	39			131727	6009	ft a few low clo	uds around
1002	512112003	091.0	13:42	14:	02			134218		6099 ft	
1003	512112004	273.0	14:06	14:	27			140602		6099 ft	
1004	512112005	091.0	14:30	14:	50			143023	6099 ft	; had to turn qu	ck for traffic.
1005	512112006	273.0	14:53	15:	14			145302		6099 ft	
1006	512112007	091.0	15:17	15:	37			151744		6099 ft	
1007	512112008	273.0	15:41	16:	02			154131		6099 ft	
1008	512112009	091.0	16:05	16:	26			160533		6099 ft	
1009	512112010	273.0	16:29	16:	50			162943		6099 ft Getting	rough
1010	512112011	091.0	16:54	17:	14			165400		6099 ft	
1011	512112012	273.0	17:17	17:	39			171758		6099 ft	
v 20200520										Ра	ge 1 of 2

Julian Day 12	0 Flight A				LIDAR	Elight	: Log				
Date April :	30th, 2021	Aircraft	C-GKSX		iystem	Riegl VQ-	1560ii A	dditional Notes		AL	RORNE
Project 3221_Q5	SI_LakeSuperior	Pilot	L. Bastien		Jnit	51		CP780.423-476		A Clear	A G I N G
Location	KDLH	Operator	R. Gemmel	_	MU A	pplanix A	P60	VERY STRON	G WINDS* DRAF	TS ST	
Mission Objective					SPS Rx	Trimble G	NSS17	OTHER SURV	EY AIRCRAFT II	7	
-Holding +02.00 p	itch O/S as per rr	ıanagemen	÷	σ	canner 1 [Drive	B1	AREA/SAME AI	-TITUDE		
				S	canner 2 [Drive	B1	Time to next mainte	enance: <u>43.6 +/-</u>	• 50 hr O 100 hr	
	Aircraft Block Ti	me				Missid	on Plan		Static	GP	S Time
Engine On 12:25	Takeoff 12:49			AGL H	eight .	1500 m	Pulse Rate	1000 KHz	Alignment	Start	End
Engine Off 18:59	Landing 18:50			Target	Speed	160 kts	Scan Rate 17	2/179plane	Pre Mission	12:38	12:43
Total 6.6 hrs	Total 6.0 hrs			Laser (Current	100 %	FOV 6() degs	Post Mission	18:53	18:58
		Flicht	GPS	S Time		Lin	e Aborted	Mission II	0		
Flight Line	File Name	Direction	Start	Ш	End	Time	nmi to End	Time Stamp 210	0430	Comment	~
1012	512112013	6.060	17:42	18	3:02			210430_174	1217	9099 ft	
1013	512112014	272.9	18:06	18	3:27			180629		6099 ft	
Figure 8		8	18:27	18	3:32					6100 ft+/	
v 20200520										ä	ige 2 of 2

	AIRBORNE		DS* DRAFTS	CRAFT IN	Ш	<u>43.6 +/-</u> • 50 hr O 100 hr	tatic GPS Time	jnment Start End	sion 12:38 12:43	ission 18:53 18:58		Comments								Page 3 of 2
	Additional Notes	CP780 423-476	*VERY STRONG WINI	*OTHER SURVEY AIR	AREA/SAME ALTITUD	Time to next maintenance:		1000 KHz Ali	'2/179plane Pre Mi	0 degs Post N	Mission ID	Time Stamp 210430								
Flight Log	iegl VQ-1560ii	51	planix AP60	imble GNSS17	ve B1	ve B1	Mission Plan	00 m Pulse Rate	30 kts Scan Rate 17	00 % FOV 6	Line Aborted	Time nmi to End								
LIDAR	System Ri	Unit	IMU Apr	GPS Rx Tr	Scanner 1 Dri	Scanner 2 Dri		AGL Height 15	Target Speed 16	Laser Current 1	S Time	End								
	C-GKSX	L. Bastien	r R. Gemmel		ent.						GP	Start								
	Aircraft	Pilot	Operato	-	nanageme		ime				Flicht	Direction								
Flight A	th, 2021	LakeSuperior	(DLH		:h O/S as per n		ircraft Block Ti	Takeoff 12:49	Landing 18:50	Total 6.0 hrs	I iDAR	-ile Name								
Julian Day 120	Date April 30	Project 3221_QSI_	Location K	Mission Objective	-Holding +02.00 pitc		A	Engine On 12:25	Engine Off 18:59	Total 6.6 hrs		Flight Line F								v 20200520

Julian Day 12	0 Flight A			LIDA	R Flight	Log				
Date April 3	30th, 2021	Aircraft	C-GKSX	System	Riegl VQ-	1560ii A	dditional Notes		AIR	BORNE
Project 3221_QS	I_LakeSuperior	Pilot	L. Bastien	Unit	51		3P780 423-476			AGING
Location	KDLH	Operator	R. Gemmel	NMI	Applanix AF		VERY STRONG	3 WINDS* DRAF1	LS A Clean	
Mission Objective		-		GPS Rx	Trimble GI	NSS17 *	OTHER SURVI	EY AIRCRAFT IN		
-Holding +02.00 p	itch O/S as per r	managemer	ıt.	Scanner 1	Drive	B1	AREA/SAME AL	TITUDE		
				Scanner 2	: Drive	B1	Time to next mainte	nance: <u>43.6 +/-</u> (• 50 hr O 100 hr	
	Aircraft Rlock T	ime			Missic	n Plan		:	505	Time
Endine On 12-25	Takenff 12.49			AGI Heinht	1500 m	Pulse Rate	000 KH2	Alignment	Start	End
Engine Off 18:50	l anding 18-50			Tarnet Sneed	160 kts	Scan Rate 173	200 IS IS	Pre Mission	17.38	12.43
Total 6.6 hrs	Total 6.0 hr	s 0		Laser Current	100 %	FOV 60	degs	Post Mission	18:53	18:58
							,			
		Flinht	GPS	Time	Line	Aborted	Mission IC			
Flight Line	File Name	Direction	Start	End	Time	nmi to End	Time Stamp 210	430	Comments	
v 20200520									Ра	ige 4 of 2

	AIRBORNE	I W A G I N G	A Clean Harbors Company VINDS* DRAFTS	AIRCRAFT IN	rude	ice: <u>43.6 +/-</u> © 50 hr O 100 hr	C C C C C C C C C C C C C C C C C C C	Alignment Start Fnd	Mission 10:30 10:40	e mission 12.30 12.40 set Mission 18.53 18.58			0 Comments								
	Additional Notes	CP780 423-476	*VERY STRONG W	*OTHER SURVEY	AREA/SAME ALTIT	Time to next maintenan		1000 KHz		60 dens Po	offenn on	Mission ID	Time Stamp 210430								
Flight Log	iegl VQ-1560ii	51	planix AP60	rimble GNSS17	ive B1	ive B1	Mission Plan	500 m Pulse Rate	SO Lto Scan Dato 1	DO % FOV	N	Line Aborted	Time nmi to End								
LIDAR	System Ri	Unit	IMU Apr	GPS Rx Tr	Scanner 1 Dri	Scanner 2 Dri		AGI Heicht 15	Target Chood 16	larger Current		S Time	End								
	ft C-GKSX	L. Bastien	tor R. Gemmel		nent.							Ğ	Start								
Flight A	, 2021 Aircra	akeSuperior Pilot	LH Opera	-	O/S as per manager		raft Block Time	kenff 12·49	10.E0	tal 6.0 hrs	0.0	IDAR Flight	Pirection								
Julian Day 120	Date April 30th,	Project 3221_QSI_Ls	Location KD	Mission Objective	-Holding +02.00 pitch		Airc	Endine On 12-25 Ta	Engine Off 18:60 1.2	Total 6.6 hrs To			Flight Line File								

Julian Day 12	21 Flight A			LIDA	R Flight	Log			•	
		7		[[•	•••
Date Ma	y 1, 2021	Aircraft	C-GKSX	System	Riegl VQ-1	1560ii A	dditional Notes		ALK	2 B O R N E
Project 3221_Q	SI_LakeSuperior	Pilot	L. Bastien	Unit	51		:P780.477-526			A G I N G
Location	KDLH	Operator	R. Gemmel	IMU	Applanix AF	* 090	VERY STRONG W	INDS* 50NM		
Mission Objective				GPS Rx	Trimble GI	VSS17 *	SPEED VARIES W	/ DIRECTION		
-Holding +02.00	pitch O/S as per r	nanagemer	rt.	Scanner '	I Drive	<u>-</u>	30/170+/- hard to r	naintain		
1014+				Scanner 2	2 Drive	5	Fime to next maintenand	e: <u>37.6 +/-</u> (⊙ 50 hr O 100 hr	
]						
	Aircraft Block T	ime			Missio	n Plan		Static	3d9	S Time
Engine On 12:56	Takeoff 13:13	~		AGL Height	1500 m	Pulse Rate 1	000 KHz	Alignment	Start	End
Engine Off 19:15	Landing 19:06	6		Target Speed	160 kts	Scan Rate 172	/179plane Pre	Mission	13:03	13:08
Total 6.3 hrs	Total 5.9 hrs			Laser Current	100 %	FOV 60	degs	st Mission	19:09	19:14
	-									
	I iDAR	Flight	Sd9	Time	Line	Aborted	Mission ID			
Flight Line	File Name	Direction	Start	End	Time	nmi to End	Time Stamp 210501		Comments	
							210501_130315		Traffic	
Figure 8		8	13:20	13:24				ln	ascent 4800-	6000 ft
X-Tie_14-25	512112101	-/+ 0.0	13:27	13:31			210501_132743		6200 ft +/	
1014	512112102	273.0	13:36	14:01			133638		6099 ft	
1015	512112103	091.0	14:04	14:24			140435	6099 ft hi	it gust start of	line, looks fine
1016	512112104	273.0	14:28	14:53			142842		6099 ft	
1017	512112105	091.0	14:56	15:16			145640		6099 ft	
1018	512112106	273.0	15:20	15:45			152036	6609	ft PCS error	end of line
								Did not a	uto stop. Look	s okay though
1019	512112107	091.0	15:49	16:09			154912		6099 ft	
1020	512112108	273.1	16:13	16:37			161300		6099 ft	
1021	512112109	091.0	16:40		16:51	23 NM +/-	164011	609	9 ft Glitch quit	t mid line
								displayir	ng strange line	e on snapshot
1021	512112110	092.1	16:58	17:07			165826		6099 ft east 2	4 NM
1022	512112111	272.3	17:10	17:35			171026		6099 ft	
v 20200520									Pa	ige 1 of 2

Julian Day 12	21 Flight A			LID	AR Fligh	ıt Log				
Date Ma	iy 1, 2021	Aircraft	C-GKSX	Systen	n Riegl VC	-1560ii	Additional Notes		AIR	BORNE
Project 3221_Q	SI_LakeSuperior	Pilot	L. Bastien	Unit	51		CP780.477-526		A Clean	A G I N G
Location	KDLH	Operator	R. Gemmel	IMU	Applanix ,	4P60	*VERY STRON	3 WINDS* 50NM		
Mission Objective				GPS R	x Trimble	GNSS17	*SPEED VARIE	S W/ DIRECTION		
-Holding +02.00	pitch O/S as per n	nanagemen	īt.	Scanne	er 1 Drive	C1	130/170+/- hard	to maintain		
1014+				Scann	er 2 Drive	5	Time to next mainte	enance: <u>37.6 +/-</u>	0 50 hr O 100 hr	
								-		
	Aircraft Block Ti	ime			Miss	sion Plan		Static	GPS	Time
Engine On 12:56	Takeoff 13:13	~		AGL Height	1500	n Pulse Rate	1000 KHz	Alignment	Start	End
Engine Off 19:15	Landing 19:06			Target Spee	d 160 kt	s Scan Rate 17	2/179plane	Pre Mission	13:03	13:08
Total 6.3 hrs	Total 5.9 hrs			Laser Curre	nt 100 %	FOV 6	0 degs	Post Mission	19:09	19:14
	LIDAR	Flicht	GPS	Time		ne Aborted	Mission II			
Flight Line	File Name	Direction	Start	End	Time	nmi to End	Time Stamp 210	1501	Comments	
1023	512112112	091.0	17:38	17:58			210501_173	802	6099 ft	
1024	512112113	273.0	18:03	18:27			180303		6099 ft	
1025	512112114	091.0	18:30	18:51			183012		6000 ft	
Figure 8		ω	18:51	18:55					6000 ft	
v 20200520									Ра	ge 2 of 2

Julian Day 12'	Flight A				LIDAR	Flight	Log				
Date May	1, 2021	Aircraft	C-GKSX	<u>ن</u> م	ystem	Riegl VQ-1	560ii A	dditional Notes		AL	ZBORNE
Project 3221_QSI	_LakeSuperior	Pilot	L. Bastien	>	nit	51		P780_477-526			A G I N G
Location	KDLH	Operator	R. Gemmel		A U	pplanix AF	. *	VERY STRONG	WINDS* 50NM		
Mission Objective				G	PS Rx	Trimble GN	VSS17 *	SPEED VARIES	W/ DIRECTION	7	
-Holding +02.00 pi	tch O/S as per m	lanagemen	ŗt	Ŵ	canner 1 D)rive (2	30/170+/- hard t	o maintain		
1014+				ŭ	canner 2 D)rive (5	Time to next mainten	ance: <u>37.6 +/-</u>	● 50 hr O 100 hr	
						:	i				
_	Aircraft Block Ti	me				Missio	n Plan		Static	GP	S Time
Engine On 12:56	Takeoff 13:13			AGL He	eight 1	1500 m	Pulse Rate 1	000 KHz	Alignment	Start	End
Engine Off 19:15	Landing 19:06			Target	Speed	160 kts	Scan Rate 172	//179plane	Pre Mission	13:03	13:08
Total 6.3 hrs	Total 5.9 hrs			Laser (Current	100 %	FOV 60	degs	Post Mission	19:09	19:14
	LiDAR	Fliaht	GPS	Time		Line	Aborted	Mission ID			
Flight Line	File Name	Direction	Start	ш	pu	Time	nmi to End	Time Stamp 2105	01	Comment	
v 20200520										ä	age 3 of 2

	AIRBORNE	A Clean Harbors Commany				● 50 hr O 100 hr	GPS Time	Start End	13:03 13:08	19:09 19:14		Comments								
	ditional Notes	2780.477-526	ERY STRONG WINDS* 50NM	PEED VARIES W/ DIRECTION	0/170+/- hard to maintain	me to next maintenance: $37.6 + 1/2$	Static	00 KHz Alignment	179plane Pre Mission	degs Post Mission	Mission ID	Time Stamp 210501								
light Log	ji VQ-1560ii Add	51 CF	anix AP60 *V	hble GNSS17 *S	C1 13	C1	Mission Plan) m Pulse Rate 10	kts Scan Rate 172/) % FOV 60	Line Aborted	me nmi to End								
LIDAR F	System Rieg	Unit	IMU Appla	GPS Rx Trim	Scanner 1 Drive	Scanner 2 Drive		AGL Height 1500	Target Speed 160	Laser Current 100	Time	End Ti								
	t C-GKSX	L. Bastien	or R. Gemmel		lent.						SdD	Start								
	Aircrat	r Pilot	Operat		managen		Time	13	90	ITS	Flight	Direction								
Flight A	, 2021	LakeSuperio	(DLH		sh O/S as per		ircraft Block	Takeoff 13:1	Landing 19:(Total 5.9 h	I iDAR	-ile Name								
Julian Day 121	Date May 1	Project 3221_QSI_	Location k	Mission Objective	-Holding +02.00 pitc	1014+	•	Engine On 12:56	Engine Off 19:15	Total 6.3 hrs		Flight Line								

v 20200520

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Julian Day 121	Flight A			L	LIDAR	Flight	_ 				
ate May	1, 2021	Aircraft	C-GKSX	<i>w</i>	system	Riegl VQ-1	560ii A	dditional Notes			R B O R N E
roject 3221_QSI	_LakeSuperior	Pilot	L. Bastien		Jnit	51		3P780.477-526		A Clear	Harbors Company
-ocation	KDLH	Operator	R. Gemmel	_	MU A	pplanix AP	60 *	VERY STRONG	WINDS* 50NM		
Mission Objective					PS Rx	Trimble GN	USS17 *	SPEED VARIES	W/ DIRECTION	_	
Holding +02.00 pit	ch O/S as per n	nanagemen	÷	05	scanner 1 E	Drive (5	30/170+/- hard to	o maintain		
1014+				0	scanner 2 D	Drive (Time to next maintena	ance: <u>37.6 +/-</u>	● 50 hr O 100 hr	
1	Aircraft Block Ti	me				Missio	n Plan		Static	GP	S Time
Engine On 12:56	Takeoff 13:13			AGL H	eight `	1500 m	Pulse Rate 1	000 KHz	Alignment	Start	End
Engine Off 19:15	Landing 19:06			Target	Speed	160 kts	Scan Rate 172	2/179plane F	re Mission	13:03	13:08
Total 6.3 hrs	Total 5.9 hrs			Laser	Current	100 %	FOV 60	degs	ost Mission	19:09	19:14
		_									
	I iDAR	Flight	GPS	S Time		Line	Aborted	Mission ID			
Flight Line	File Name	Direction	Start		End	Time	nmi to End	Time Stamp 2105	10	Comment	
v 20200520										ä	age 5 of 2

ð	geospatial			AXIS GEOAVIA	NOI		LiDAR a	nd Imagery	Flight F	Report	Project(s)	. 2200	30 Rainey	Lake
	Pilot:				5		Project	Number(s):		220030 Rain	ey Lake	Date:		5/2/2021
	Operator:				AC		Projec	t Name(s):		1099		Mission Start (LT):		3955.2 / 3959.
	Aircraft:			2	23TC		Hobbs S	tart: 3954.7 /	3959.0	Hobbs Stop:	3959.0 / 3962.3	Mission End (LT):		3958.6 / 3961.
Lidar	Unit:	3) V	Q-1560i S2	223544	Scan	Rate:	2	X159	Came	ra Unit:	Phase One	Drive:		В
MTA 2	ones:		8 TO 12		Grnd Spd	Max (kts):		130	FOV	(deg):	58.52	Sun Angle:		
PRR (kHz):		2×1000		Altitude (f	eet AMT):		5600	Lateral O	verlap (%):		Lens:		
Laser Po	wer (%):		100		Point Spa	acing (m):	-	0.321	Forward C	overlap (%):		Point Density (ppms):		11.6
		Camera	Counter	Line Sta	irt/Stop									
Line #	Direction	То	From	Start Time UTC	Stop Time UTC	Altitude (Pl	anned)	Altitude (Actu	al)		Remarks		Clouds	Aperture
51 XTIE	z			8:14	8:17	5655-	1				AREA 1099			
38	M			8:23	8:36						27-46			
35	Ш			9:38	9:51									
32	M			9:53	20:6									
29	Е			60:6	9:22									
28	M			9:26	9:40									
31	Ш			9:42	9:56									
34	M			9:58	10:11									
37	ш			10:13	10:26									
36	N			10:29	10:43									
33	Ш			10:45	10:59									
30	v			11:01	11:14									
27	Ш			11:16	11:30									
51 XTIE	z			12:56	12:59									
46	M			13:04	13:18									
43	Ш			13:19	13:34									
40	M			13:36	13:50									
39	Ш			13:52	14:07									
42	Page 1 of 4			14:10	14:25									

		AREA 1099														
14:42	14:58	15:16														
14:26	14:45	15:00														
ш	Μ	ш														
45	44	41														

															1 3 0 2 1



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Julian Day 12	22 Flight A				IDAR Fligh	t Log				
Date Ma	iy 2, 2021	Aircraft	C-GKSX	Sys	tem Riegl VQ	-1560ii A	dditional Notes		AL	RORNE
Project 3221_Q	SI_LakeSuperior	Pilot	L. Bastien	Unit	51		:P780 530-576			AGING
Location	KDLH	Operator	R. Gemmel	IMU	Applanix	P60	VERY STRONG	3 WINDS*	A Clean	
Mission Objective				GPS	Rx Trimble C	SNSS17	SPEED VARIE	S W/ DIRECTION	ŕ	
-Holding +02.00	pitch O/S as per I	managemer	ıt.	Sca	nner 1 Drive	A1 d	oing best to mɛ	aintain 160		
1026+				Sca	nner 2 Drive	A1	Time to next mainte	enance: <u>37.6 +/-</u>	• 50 hr O 100 hr	
	Aircraft Block T	Time			Missi	on Plan		č		2 Time
								Static Alignment	5	
Engine On 12:30	Takeoff 12:4	6		AGL Heig	ht 1500 n	Pulse Rate 1	000 KHz	Alignment	Start	End
Engine Off 18:22	Landing 18:1;	3		Target Sp	eed 160 kts	Scan Rate 172	:/179plane	Pre Mission	12:37	12:42
Total 5.9 hrs	Total 5.4 hr	S		Laser Cui	rent 100 %	FOV 60	degs	Post Mission	18:16	18:21
			Ī			-				
	I iDAR	Flight	SdD	S Time		le Aborted	Mission IC	(
Flight Line	File Name	Direction	Start	End	Time	nmi to End	Time Stamp 123	5747	Comment	0
Figure 8		8	12:54	12:5	8 (ID for	INS-GPS 1:	210502_123	747)	4000-6000 ft	climb
X-Tie_26-37	512112201	008.0 +/-	13:01	13:0	4		130109		6200 ft	
1026	512112202	273.0	13:10	13:3	0		131010		5899 ft	
1027	512112203	091.0	13:33	13:5	4		133350		5899 ft	
1028	512112204	273.1	13:57	14:1	2		135747		5899 ft	
1029	512112205	6.060	14:21	14:4	1		142107		5800 ft	
1030	512112206	273.1	14:45	15:0	5		144509		5800 ft	
1031	512112207	091.0	15:08	15:2	ი		150840		5800 ft	
1032	512112208	273.1	15:32	15:5	3		153246		5800 ft	
1033	512112209	091.0	15:56	16:1	7		155626		5600 ft	
1034	512112210	273.0	16:20	16:4	£		162042		5400 ft	
1035	512112211	091.0	16:44	17:0	4		164406		5400 ft	
1036	512112212	273.0	17:08	17:2	8		170807		5400 ft	
1037	512112213	091.0	17:31	17:5	2		173134		5400 ft	
Figure 8		8	17:53	17:5	8				5400 ft	
v 20200520									č	age 1 of 2

P Flight A 2, 2021 LakeSuperior	Aircraft Pilot L	C-GKSX Bastien		-IDAR	Riegl VQ-	t Log	Additional Notes	ι			
	Operator	R. Gemmel	M		pplanix A	P60	*VERY STROM	NG WIND	s,	A Clear	Harbors Company
m	inagement.		S S S	S Rx anner 1 D	Trimble G Drive	NSS17 A1	*SPEED VARI doing best to n	ES W/ DI naintain 1	RECTION 60		
			Sci	anner 2 D	Drive	A1	Time to next mair	ntenance:	37.6 +/- 0	9 50 hr O 100 hr	
-	ЭС				Missi	on Plan		ي م	tatic	GP	Time
1			AGL Hei	ght 1	1500 m	Pulse Rate	1000 KHz	Alig	nment	Start	End
1			Target S	beed	160 kts	Scan Rate 17	72/179plane	Pre Mis	sion	12:37	12:42
			Laser Cu	urrent	100 %	FOV 6	30 degs	Post Mi	ssion	18:16	18:21
	Eliabt	GPS	Time		Lin	e Aborted	Mission				
D	irection	Start	Ĕ	q	Time	nmi to End	Time Stamp 12	23747		Comment	
l X	0.5.0 +/-	17:58	17:5	58			123747_1	75830	5400 ft +	/- Knife island	, just in case.
	8	18:01	18:(05						5400 ft +,	
1											
I											
										ä	ige 2 of 2

Julian Day 122	2 Flight A				LIDAR	Elight	Log					
Date May	2, 2021	Aircraft	C-GKSX	<i>S</i>	ystem	Riegl VQ-1	560ii A	dditional Notes			AIR	BORNE
Project 3221_QSI	_LakeSuperior	Pilot	L. Bastien		nit	51		P780.530-576			A Clean	A G I N G
Location	KDLH	Operator	R. Gemmel		AU A	pplanix AF	.*	VERY STRON	3 WINDS*			
Mission Objective				0	PS Rx	Trimble GN	VSS17 *	SPEED VARIE	S W/ DIRECT	ION,		
-Holding +02.00 pi	tch O/S as per m	lanagemen	ŗ	σ	canner 1 [Drive /	A1 d	oing best to ma	aintain 160			
1026+				<u></u>	canner 2 [Drive ,	41	Time to next maint	enance: <u>37.6</u> +	<u>-/-</u> © 50 hr (O 100 hr	
							i					
_	Aircraft Block Ti	me				Missio	n Plan		Static		GPS	Time
Engine On 12:30	Takeoff 12:49			AGL H	eight	1500 m	Pulse Rate 1	000 KHz	Alignment	St	art	End
Engine Off 18:22	Landing 18:13			Target	Speed	160 kts	Scan Rate 172	2/179plane	Pre Mission	12	:37	12:42
Total 5.9 hrs	Total 5.4 hrs			Laser (Current	100 %	FOV 60	degs	Post Mission	18.	:16	18:21
		-										
	LiDAR	Fliaht	GPS	S Time		Line	Aborted	Mission II	- 0			
Flight Line	File Name	Direction	Start	ш	ind	Time	nmi to End	Time Stamp 123	3747	ŭ	omments	
v 20200520											Paç	Je 3 of 2

	AIRBORNE	A Clear Hardward Cambred Cambred		Ŷ		● 50 hr O 100 hr	GPS Time	Start	12.37 12.42	18:16 18:21			Comments								
	dditional Notes	CP780.530-576	VERY STRONG WINDS*	SPEED VARIES W/ DIRECTIO	doing best to maintain 160	Time to next maintenance: $37.6 +/-$		000 KHz Alignment	2/179nlane Pra Mission	Dideds Post Mission	, ,	Mission ID	Time Stamp 123747	-							
Flight Log	kiegl VQ-1560ii A	51	splanix AP60 *	rimble GNSS17 *	rive A1 C	rive A1	Mission Plan	500 m Pulse Rate 1	60 kts Scan Rate 170	100 % FOV 60		Line Aborted	Time nmi to End								
LIDAR	System F	Unit	IMU AF	GPS Rx T	Scanner 1 Di	Scanner 2 Di		AGI Heicht 1	Tarnet Sneed 1	Laser Current		S Time	End								
	t C-GKSX	L. Bastien	or R. Gemmel		nent.							GP	Start								
	Aircrat	r Pilot	Operat		⁻ managen		Time	49		S I		Fliaht	Direction								
Flight A	, 2021	LakeSuperio	CDLH		th O/S as per		ircraft Block	Takeoff 12.4	anding 18	Total 5.4 h		I iDAR	ile Name								
Julian Day 122	Date May 2	Project 3221_QSI_	Location	Mission Objective	-Holding +02.00 pitc	1026+		Fngine On 12:30	Engine Off 18-22	Total 5.9 hrs			Flight Line								

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Julian Day 122	2 Flight A				LIDAR	Flight	Log					
Date May	2, 2021	Aircraft	C-GKSX	S	ystem	Riegl VQ-1	560ii A	dditional Notes			AIR	BORNE
Project 3221_QSI	_LakeSuperior	Pilot	L. Bastien		nit	51		P780,530-576				G I N G
Location	KDLH	Operator	R. Gemmel	_	AU A	pplanix AF	09	VERY STRON	3 WINDS*			
Mission Objective				0	PS Rx	Trimble GN	ISS17 *	SPEED VARIE	S W/ DIRECT	ION,		
-Holding +02.00 pi	tch O/S as per m	anagemen	ŗt	S	canner 1 [Drive /	71 d	oing best to ma	aintain 160			
1026+				S	canner 2 [Drive ,	71	Time to next maint	enance: <u>37.6</u> +	<u>-/-</u> © 50 hr (O 100 hr	
							i					
-	Aircraft Block Ti	ne				Missio	n Plan		Static		GPS -	Time
Engine On 12:30	Takeoff 12:49			AGL H	eight `	1500 m	Pulse Rate 1	000 KHz	Alignment	Sta	Ľ	End
Engine Off 18:22	Landing 18:13			Target	Speed	160 kts	Scan Rate 172	2/179plane	Pre Mission	12:0	37	12:42
Total 5.9 hrs	Total 5.4 hrs			Laser (Current	100 %	FOV 60	degs	Post Mission	18.	16	18:21
	Lidar	Fliaht	GPS	S Time		Line	Aborted	Mission II				
Flight Line	File Name	Direction	Start	ш	pu	Time	nmi to End	Time Stamp 123	8747	ບິ	mments	
v 20200520											Pag	e 5 of 2