STARR
Strategic Alliance
for Risk Reduction

ASHLAND COUNTY WI.
PRE-FLIGHT OPERATIONS PLAN

November 2014

PLANNED FLIGHT LINES

Woolpert Inc. has completed preliminary flight planning for the Ashland County Wisconsin project area. Ashland is scheduled to be acquired fall/winter 2014-2015 when the leaves are off and delivered to STARR by August 2015. The Ashland area is 976 square miles with an additional 23 square miles over Madeline Island initial planning details are depicted in Figure 1 on the following page. This Figure details that STARR expects to collect **64 flight lines covering 1,671 flight line miles**. This area warranted a "Highest" vertical accuracy requirement and will be collected with a nominal pulse spacing of 1-meter. Key components of this flight planning include:

- ✓ Generating a plan that takes all specifications into account, and the required Laser settings to meet those specs, review of terrain and water issues, along with potential base station locations at airports with sufficient services available to support the crews.
- ✓ Orientation of flight lines parallel to major terrain features and variation in flight line spacing due to terrain variation (steeper slopes generally require tighter line spacing between adjacent parallel lines to ensure point density and side overlap are maintained)
- ✓ Check Airspace issues and access issues for Base Stations.
- ✓ Safety considerations, both for flights, and Laser collection.

Acquisition (1000 sq. miles @ 1-meter nominal post spacing to meet 24.5 cm FVA, LAS point cloud delivery with metadata, pre-operations flight plan, and post flight aerial acquisition report).

PLANNED GPS STATIONS

Normally existing high accuracy monuments at airports are utilized if possible. Typically a Primary Airport Control Monument (or Secondary) is available; otherwise any other high accuracy monument can be used. We typically prefer these on the airport grounds as they can be monitored for security by airport staff. If no monument is available or an existing monument is damaged, we will set a monument with re-bar and use OPUS to control the monument. These are then used for initial field processing of the data.

PLANNED CONTROL

A minimum of twenty (20) ground control points will be surveyed to control the LiDAR data and to support a vertical test. Each of these two functions shall remain independent of each other and also be collected by independent subcontractor (CompassData). Independent check or calibration points will be three times as accurate as the surface being checked. Therefore, in order to validate a 24.5 cm LiDAR surface (consistent with 2 foot contours), STARR will collect elevation control data accurate to 8 cm. This "three times" model for collecting ground control and QA points will be used throughout the task order.

Vertical accuracy checkpoints will be located by independent STARR contractor (CompassData) to check Woolpert Inc. work in open terrain, where there is a high probability that the sensor will have detected the ground surface without influence from surrounding vegetation. Checkpoints will be located on flat or uniformly sloping terrain and will be at least five (5) meters away from any break line where there is a change in slope. This criterion applies for all QA points for the Fundamental Vertical Accuracy (FVA) Assessment as well.

Blind vertical QA points for the Consolidated Accuracy Check (CVA) will also be collected by CompassData to check Woolpert Inc. work randomly across different land use types using the ASPRS NSSDA land cover types. The points will be located in flat areas with no substantial elevation breaks within a 3-5 meter radius. We expect to normally pick one area and get 3-5 different land use classes from a single setup. We expect to normally use GPS to position an occupation and backsight point and then use a total station to get the other classes from that setup. The CVA assessment will incorporate a representative sample of the FVA assessment into the dataset to save on the total number of points collected. Figure 1 below has a location map of the flight lines and ground control points.

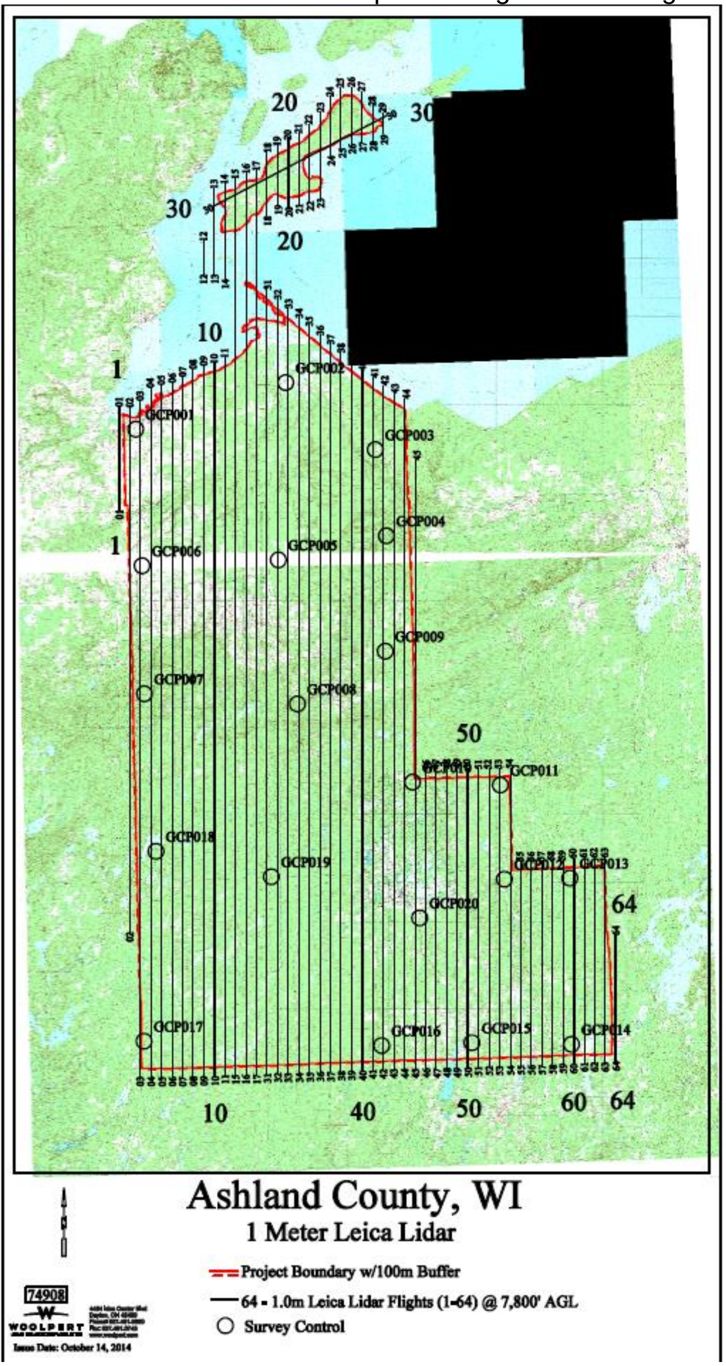


Figure 1 - Ashland County Flight Lines, Ground Control

Planned Airport Locations

Woolpert Inc. will utilize a known monument at near Ashland, Wisconsin or will set a station and tie into the control and / or generate an OPUS solution. This will involve a separate ground person if required. Aircraft will utilize KASX – John F. Kennedy Memorial Airport Ashland, Wisconsin.

Calibration Plans

Periodic detailed boresighting of the LiDAR sensor is performed at a boresight facility established in Dayton, Ohio for both our LiDAR and imagery platforms. Over 95 high-accuracy control points are located within this facility. The area also has numerous pitched roofs that are necessary in boresighting LiDAR instruments. Local boresights are also carried out at individual project sites. Typically these are established at local airports and consist of opposing and cross flights conducted at multiple flight elevations. The boresight data is processed by our Lead LiDAR Specialist with the results for all boresight parameters applied to the project acquisition.

Calibration – To accomplish the formal calibration, Woolpert has established a calibration range of an airport runway. The calibration ranges will be ground surveyed to an accuracy of better than 1 cm. The mission will consist of 3 different altitudes flown along and across the runway and opposing directions which is required in order to capture the pitch, roll, heading, and torsion errors.

Calibration of the Elevation Surface – the raw LiDAR surface is compared against ground points that are established for the calibration of the elevation surface. System biases are identified and removed during this calibration. An early statistical analysis takes place that provides an indication of the precision of the acquired data.

Quality Control Procedures for Flight Crew

Acquisition Crews

An experienced and knowledgeable acquisition crew is also critical to a successful LiDAR project. We will bring two capable crews to the project site with three more in reserve should any unexpected health issues or similar complications arise.

General Flight Mission Procedures

On a lift by lift basis the flight crew will check cloud conditions, atmospheric conditions (fog or probability of fog) and winds and turbulence. If any of those factors would make acquisition difficult they will wait a few hours and review again.

LiDAR crews can fly at night or during the day. Night flights can be smoother in some cases, but extra care must be used as it is easy to lose orientation with the ground if in very rural areas or over large expanses of water. Additionally, if there are fog probabilities then flights will not take place as fog will block the laser. It must be clear below the aircraft at all times.

The initial item is to set the base station properly over the monument, verify it is secure and running. Prior to setting the crew will have ascertained that it has storage space on the hard drives and full battery life. They will also verify that it is running with proper collection parameters. PDOP is also reviewed as collection will not take place during times of high PDOP.

The LiDAR system (controller hard drives and Laser) is connected to the flight management system and once the project plan is loaded the parameters for collection will load as well. The sensor operator will verify that everything loaded correctly before flight.

Once the LiDAR has been started the crew will taxi to the run up area and wait for the IMU, GPS and the rest of the system level out. They will collect data in a stationary position for about 5 minutes until the POS (position and orientation system) provides good level characteristics (Green Lights!).

Prior to capturing the first line of data and after the last line the flight crew will perform “S” turns to maintain IMU integrity and avoid IMU drift. Collection requires that speeds be maintained, sometimes quite slow depending on the accuracy requirements. Additionally altitudes must be watched closely.

During flights the sensor operator must monitor the laser to be sure that temperatures are consistent and within guidelines, that pulsing is taking place correctly and returns are consistent and within guidelines while watching atmospheric conditions, speeds and monitoring the pilot.

Planned ScanSet (Laser Collection Parameters)

Parameters	**1m** NPS
Flying Height	7,800
Aircraft Ground Speed (knots)	150
Pulse Rate (KHz)	230.0
Scan Rate (Hz)	34.4
Full Field of View (degrees)	40
Multi-Pulse	Yes
Full Swath Width (meters)	1,730
Swath Overlap (percentage)	25%
Max. Point Spacing Across Track (meters)	1.12
Max. Point Spacing Along Track (meters)	1.12
Across Track/Along Track Ratio	1.0
Average Point Density (M2)	1.72
Average Point Spacing (Meters)	.76
Nadir Point Density (pts/m2)	1.6
Illuminated Foot Print Diameter (meters)	.54

Acquisition (1000 sq. miles @ 1-meter nominal post spacing to meet 24.5 cm FVA, LAS point cloud delivery with metadata, pre-operations flight plan, and post flight aerial acquisition report).

Type of Aircraft

All of our LiDAR sensors are currently flown in specially modified Twin engine Cessna 310 and 404 platforms. This platform provides a very stable platform for LiDAR data acquisition, with the ability to easily achieve altitudes and speeds that are most common for LiDAR collection.

Our platforms also have significant fuel capacity, which allows us considerable time over target for performing data collection. It is also a safe platform, which is important when flying over rugged terrain. The added bonus is this is a very economical platform to fly in terms of operational and maintenance costs. Moreover, that translates to competitive rates for LiDAR data acquisition.

Aircraft Name	**Engine Configuration**	**ABGPS**	**Flight Management System**	**Ceiling Feet**
Cessna 310-H	Twin	Yes	Yes	18,000
Cessna T310-P	Twin	Yes	Yes	26,000
Cessna 404	Twin	Yes	Yes	26,000

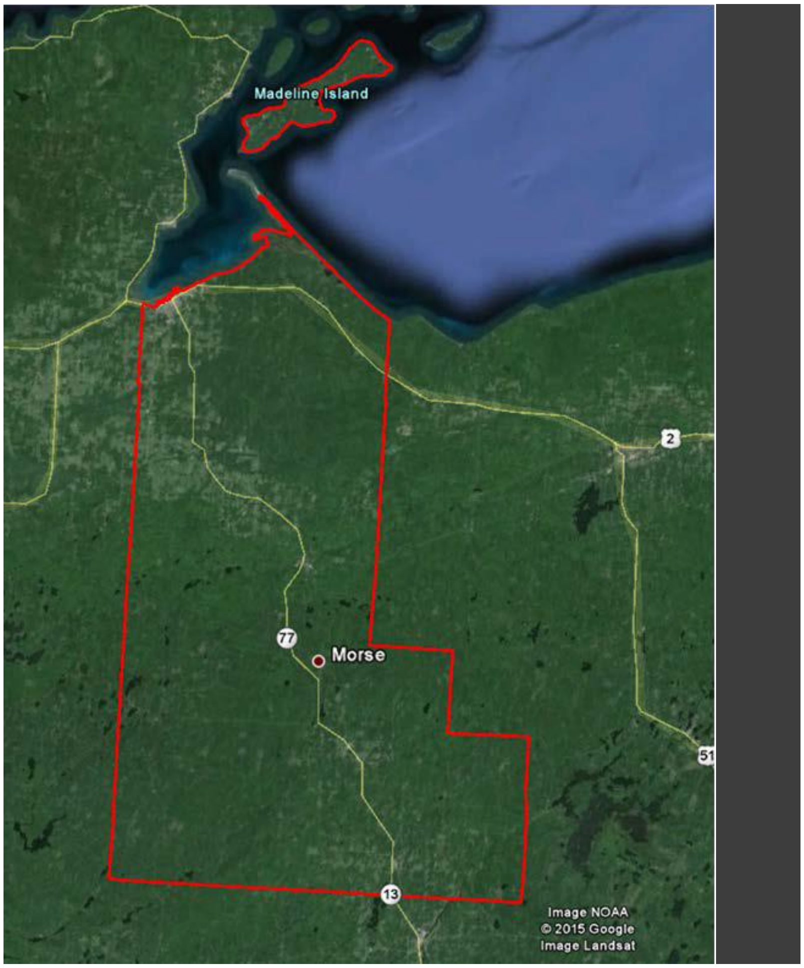
Procedure for Tracking, Executing, and Checking Re-flights

All daily flights are tracked with specific logs for each area. The field crew performs nightly backups of all data collected. This includes mission logs indicating the lines, date flown etc. as well as specific information concerning the lift, weather conditions, times, speeds and other criteria critical to the performance of the laser. The mission flight logs, GPS ground base station data and raw mission data are copied to two external hard drives as two separate copy procedure from the sensor solid state drive. One copy is shipped to our Dayton facility for processing and QC and the second copy remain in the field until acceptance from the processing center. Daily Flight Blogs are posted to the company Intranet site detailing the daily operation sensor health lodging location and plans for the following day. The flight blog serves as a database for tracking purposes. This helps determine where next to move crews and overall project status.

The flight crews do not leave the area of collection until all data has been shipped for verification. During rare incidences it may be necessary to relocate the crew if the forecast weather conditions display extend downtime usually four or five days.

Considerations for Terrain, Cover, and Weather

Terrain is not an issue for flight planning on this project. The area is very flat. Cover has been considered and collection is scheduled for the Fall of 2014 during leaf-off conditions. Traditional LiDAR weather conditions will be observed for this area.



FEMA Task Order Number HSFE05-14-J-0037
STARR Project Number 400000254
Woolpert Project #74908

FEMA STARR Ashland County Wisconsin Federal Emergency Management Agency (FEMA) September 2015

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Section 1: Overview

Project Name: FEMA STARR ASHLAND COUNTY WISCONSIN LIDAR

Woolpert Project: #74908

This report contains a comprehensive outline of the FEMA STARR Ashland County Lidar task order. This task is issued under FEMA Task Order Number: HSFE05-14-J-0037, and STARR Project Number: 400000254. This task order requires lidar data to be acquired over Ashland County, Wisconsin. The total area of the Ashland County Lidar AOI is approximately 1,011 square miles. The lidar was collected and processed to meet a maximum Nominal Post Spacing (NPS) of 1 meter. 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 Leica ALS70 500 kHz Multiple Pulses in Air (MPiA) lidar sensor. The ALS70 sensor collects up to four returns per pulse, as well as intensity data, for the first three returns. If a fourth return was captured, the system does not record an associated intensity value. The aerial lidar was collected at the following sensor specifications:

Table 1.1:

Sensor Specifications	
Post Spacing	3.3 ft / 1 m
AGL (Above Ground Level) average flying height	7,800 ft / 2,377 m
MSL (Mean Sea Level) average flying height	variable
Average Ground Speed:	150 knots / 173 mph
Field of View (full)	40 degrees
Pulse Rate	230 kHz
Scan Rate	34.4 Hz
Side Lap	25%

The lidar data was processed and projected in UTM, Zone 15, North American Datum of 1983 (2011) in units of meters. The vertical datum used for the task order was referenced to NAVD 1988, GEOID12A, in units of survey feet.

Figure 1.1: Lidar Task Order AOI and Base Station Locations

Section 2: Acquisition

The existing lidar data was acquired with a Leica ALS70 500 kHz Multiple Pulses in Air (MPiA) Lidar Sensor System, on board Woolpert Cessna aircraft. The ALS70 lidar system, developed by Leica Geosystems of Heerbrugg, Switzerland, includes the simultaneous first, intermediate and last pulse data capture module, the extended altitude range module, and the target signal intensity capture module. The system software is operated on an OC50 Operation Controller aboard the aircraft.

The ALS70 500 kHz Multiple Pulses in Air (MPiA) Lidar System has the following specifications:

Table 2.1:

ALS Lidar System Specifications	
Operating Altitude	200 – 3,500 meters
Scan Angle	0 to 75° (variable)
Swath Width	0 to 1.5 X altitude (variable)
Scan Frequency	0 – 200 Hz (variable based on scan angle)
Maximum Pulse Rate	500 kHz (Effective)
Range Resolution	Better than 1 cm
Elevation Accuracy	7 - 16 cm single shot (one standard deviation)
Horizontal Accuracy	5 – 38 cm (one standard deviation)
Number of Returns per Pulse	7 (infinite)
Number of Intensities	3 (first, second, third)
Intensity Digitization	8 bit intensity + 8 bit AGC (Automatic Gain Control) level
MPiA (Multiple Pulses in Air)	8 bits @ 1nsec interval @ 50kHz
Laser Beam Divergence	0.22 mrad @ $1/e^2$ (~0.15 mrad @ 1/e)
Laser Classification	Class IV laser product (FDA CFR 21)
Eye Safe Range	400m single shot depending on laser repetition rate
Roll Stabilization	Automatic adaptive, range = 75 degrees minus current FOV
Power Requirements	28 VDC @ 25A
Operating Temperature	0-40°C
Humidity	0-95% non-condensing
Supported GNSS Receivers	Ashtech Z12, Trimble 7400, Novatel Millenium

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

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

The lidar data was collected in three (3) separate 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. Any gaps found in the lidar data were relayed to the flight crew, and the area was re-flown.

Figure 2.1: Lidar Flight Layout, Ashland County Wisconsin Lidar

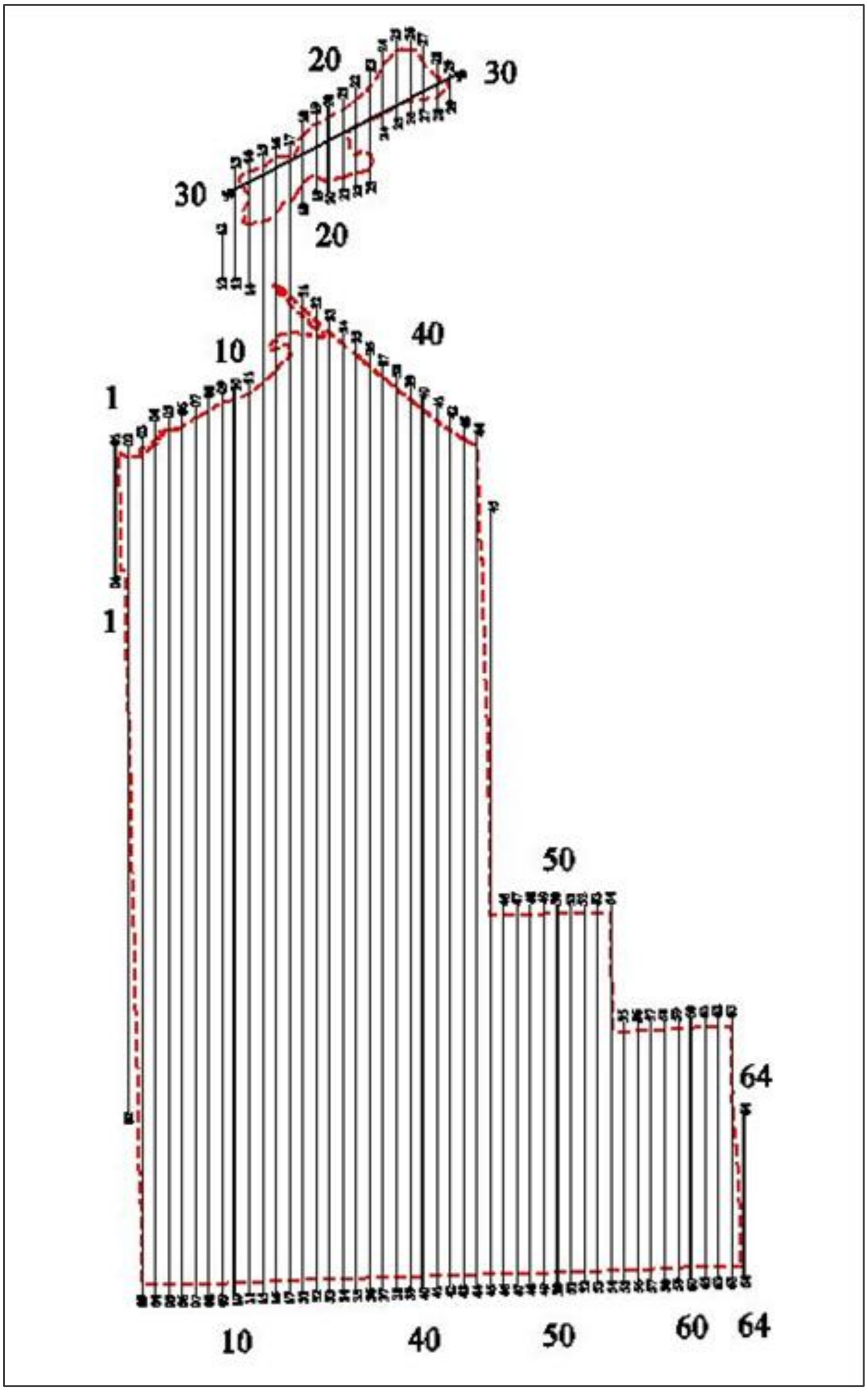


Table 2.2: Airborne Lidar Acquisition Flight Summary

Date of Mission	**Lines Flown**	**Mission Time (UTC) Wheels Up/ Wheels Down**	**Mission Time (Local = EDT) Wheels Up/ Wheels Down**
November 1, 2014 – Sensor 7177	1-11, 14-25, 31-38	16:25 – 0:13	11:25AM – 07:13PM
November 2, 2014 - Sensor 7177	12-13,26-30,39-64	13:45 – 20:57	08:45AM - 03:57PM
April 17, 2015 – SH7108	49	13:35 – 17:25	08:35AM – 12:25PM

Section 3: Lidar Data Processing

Applications and Work Flow Overview

1. Resolved kinematic corrections for three subsystems: inertial measurement unit (IMU), sensor orientation information and airborne GPS data. Developed a blending post-processed aircraft position with attitude data using Kalman filtering technology or the smoothed best estimate trajectory (SBET).
   Software: POSPac Software v. 5.3, IPAS Pro v.1.35.
2. Calculated laser point position by associating the SBET position to each laser point return time, scan angle, intensity, etc. Created raw laser point cloud data for the entire survey in LAS format. Automated line-to-line calibrations were then performed for system attitude parameters (pitch, roll, heading), mirror flex (scale) and GPS/IMU drift.
   Software: ALS Post Processing Software v.2.75 build #25, Proprietary Software, TerraMatch v. 14.01.
3. Imported processed LAS point cloud data into the task order tiles. Resulting data were classified as ground and non-ground points with additional filters created to meet the task order classification specifications. Statistical absolute accuracy was assessed via direct comparisons of ground classified points to ground RTK survey data. Based on the statistical analysis, the lidar data was then adjusted to reduce the vertical bias when compared to the survey ground control.
   Software: TerraScan v.14.011.
4. The LAS files were evaluated through a series of manual QA/QC steps to eliminate remaining artifacts from the ground class.
   Software: TerraScan v.14.011.

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 are all configured with a NovAtel Millennium 12-channel, L1/L2 dual frequency Global Navigation Satellite System (GNSS) receivers collecting at 2 Hz.

All Woolpert aerial sensors are equipped with a Litton LN200 series Inertial Measurement Unit (IMU) operating at 200 Hz.

A base-station unit was mobilized for each acquisition mission where a CORS station was not utilized, and was operated by a member of the Woolpert acquisition team. Each base-station setup consisted of one Trimble 4000 – 5000 series dual frequency receiver, one Trimble Compact L1/L2 dual frequency antenna, one 2-meter fixed-height tripod, and essential battery power and cabling. Ground planes were used on the base-station antennas. Data was collected at 1 or 2 Hz.

The GNSS base station operated during the Lidar acquisition missions is listed below:

Table 3.1: GNSS Base Station

Station (Name)	Latitude (DMS)	Longitude (DMS)	Ellipsoid Height (L1 Phase center) (Meters)
MIIW CORS Base	46° 28' 12.86538"	-90°09' 56.56048"	420.172
PID RM0890	46° 33' 05.94204"	-90°54' 57.26501"	219.273

Data Processing

All airborne GNSS and IMU data was post-processed and quality controlled using Applanix MMS software. GNSS data was processed at a 1 and 2 Hz data capture rate and the IMU data was processed at 200 Hz.

Trajectory Quality

The GNSS Trajectory, along with high quality IMU data are key factors in determining the overall positional accuracy of the final sensor data. Within the trajectory processing, there are many factors that affect the overall quality, but the most indicative are the Combined Separation, the Estimated Positional Accuracy, and the Positional Dilution of Precision (PDOP).

Figure 3.1: Trajectory, Day 30514_ SH7177

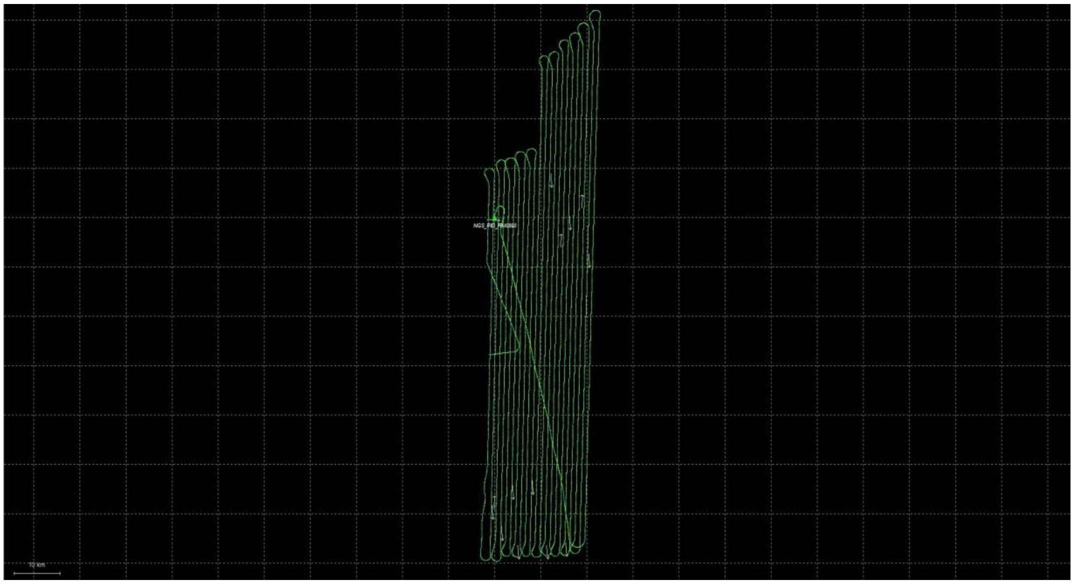


Figure 3.2: Trajectory, Day30614_ SH7177

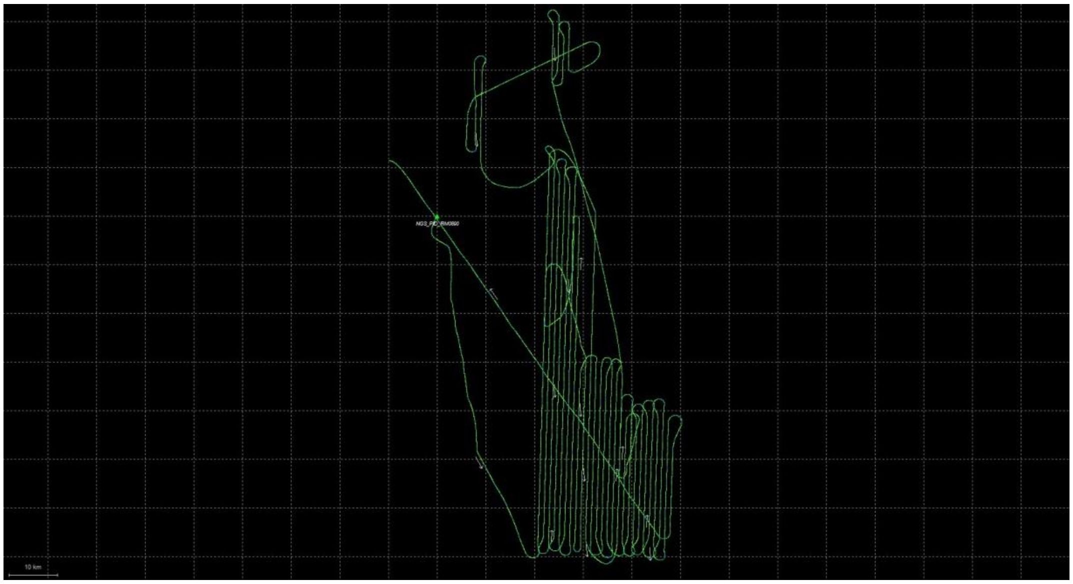
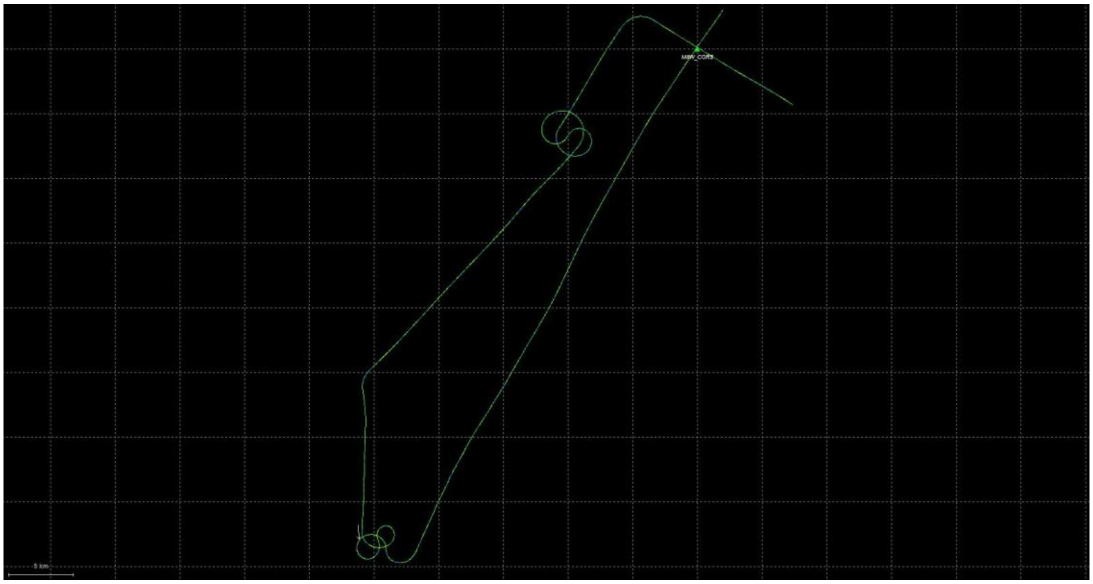


Figure 3.3: Trajectory, Day 10715_ SH7108



Combination Separation

The Combined Separation is a measure of the difference between the forward run and the backward run solution of the trajectory. The Kalman filter is processed in both directions to remove the combined directional anomalies. In general, when these two solutions match closely, an optimally accurate reliable solution is achieved.

Woolpert's goal is to maintain a Combined Separation Difference of less than ten (10) centimeters. In most cases we achieve results below this threshold.

Figure 3.4: Combined Separation, Day 30514_SH7177

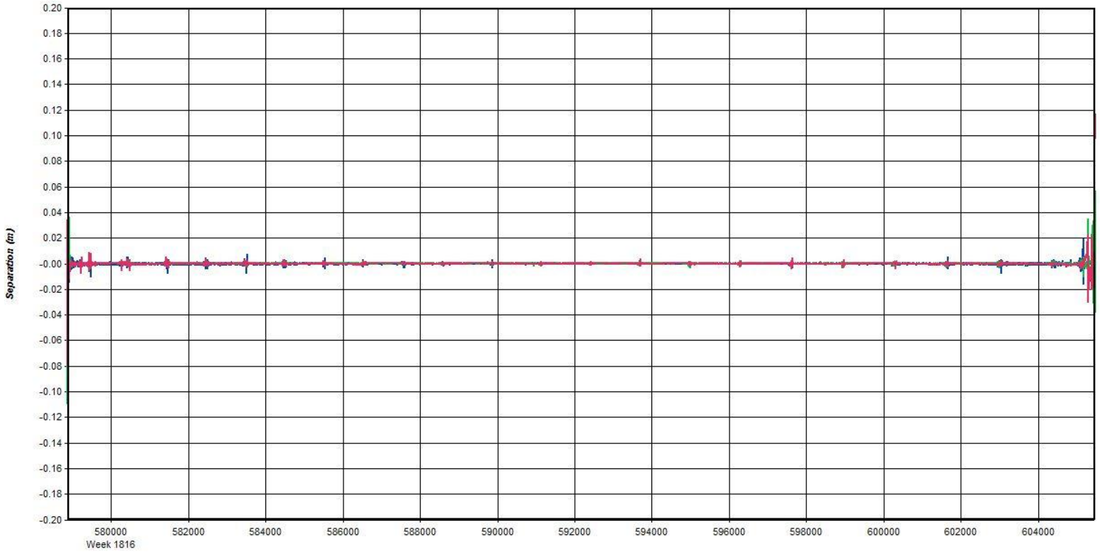


Figure 3.5: Combined Separation, Day 30614_SH7177

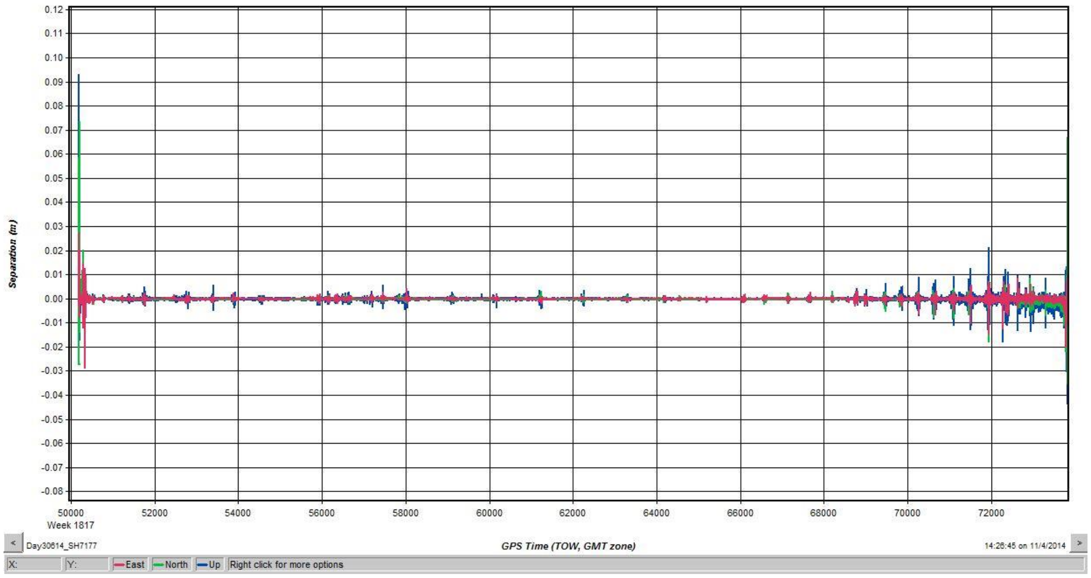
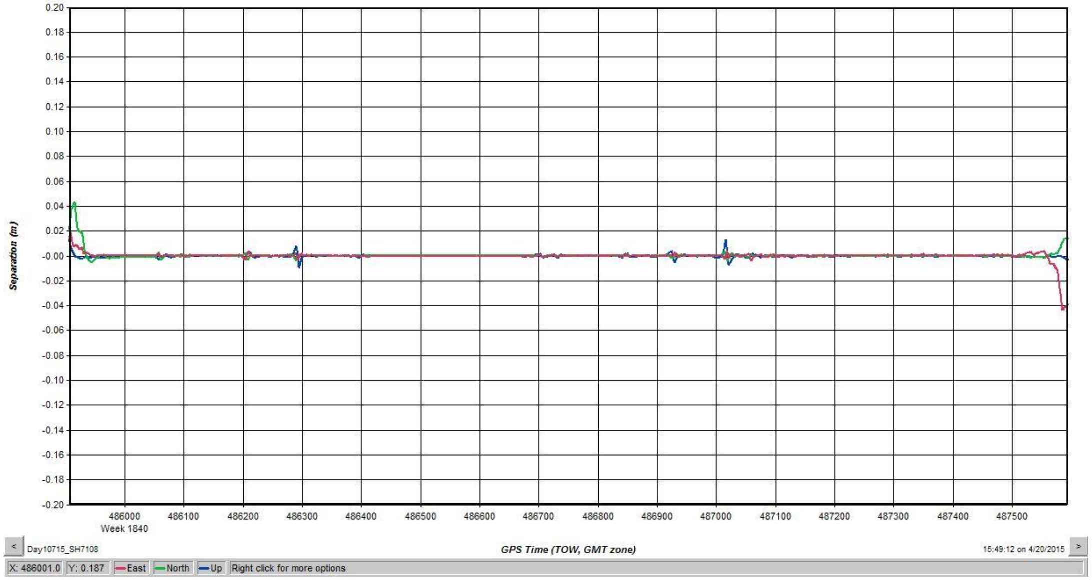


Figure 3.6: Combined Separation, Day 10715_SH7108



The Estimated Positional Accuracy plots the standard deviations of the east, north, and vertical directions along a time scale of the trajectory. It illustrates loss of satellite lock issues, as well as issues arising from long baselines, noise, and/or other atmospheric interference.

Woolpert's goal is to maintain an Estimated Positional Accuracy of less than ten (10) centimeters, often achieving results well below this threshold.

Figure 3.7: Estimated Positional Accuracy, Day 30514_SH7177

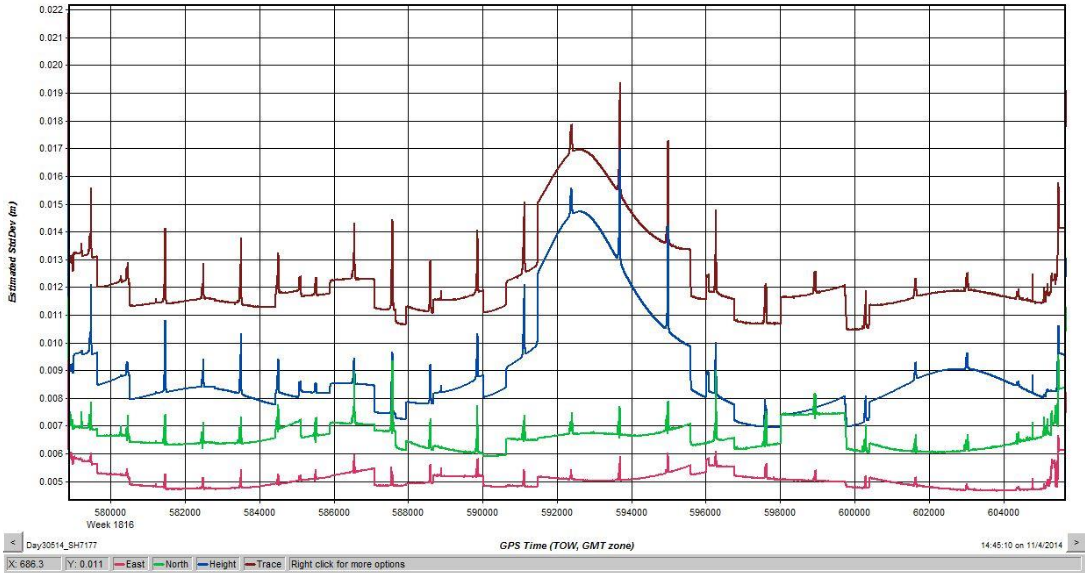


Figure 3.8: Estimated Positional Accuracy, Day 30614_SH7177

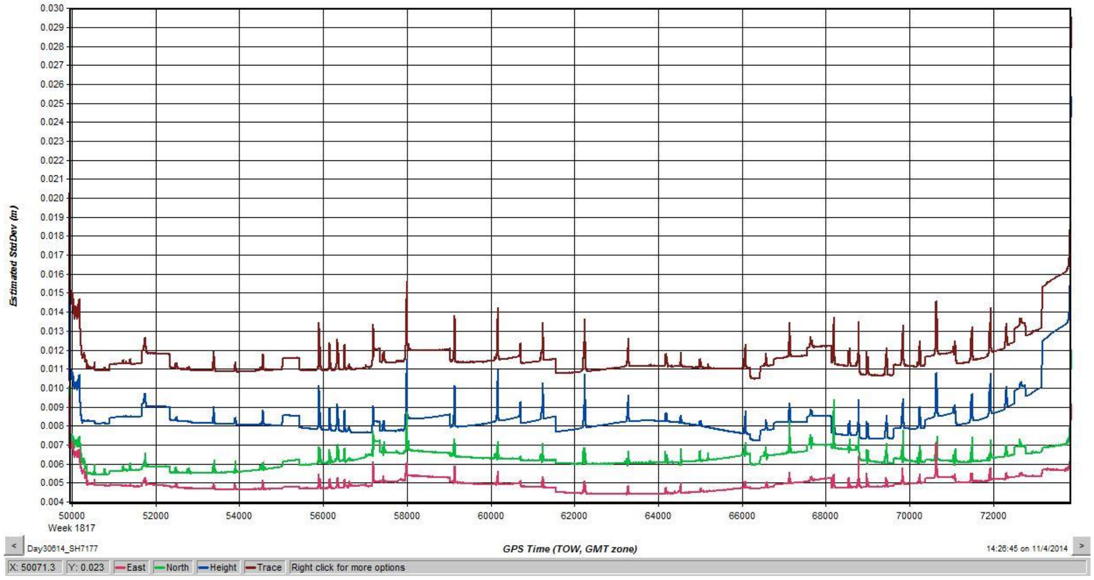
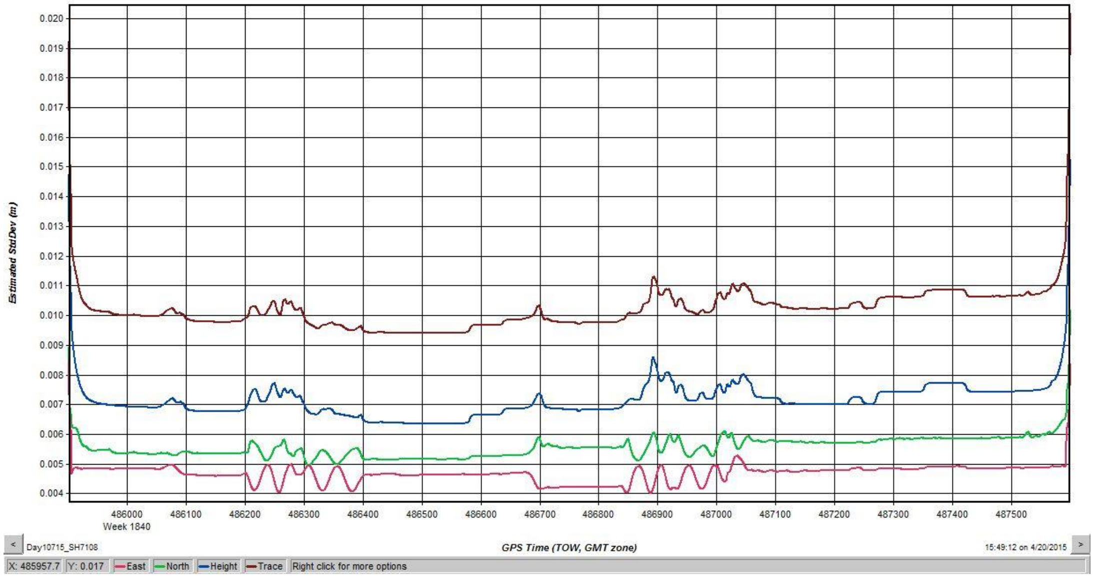


Figure 3.9: Estimated Positional Accuracy, Day 10715_SH7108



The PDOP measures the precision of the GPS solution in regards to the geometry of the satellites acquired and used for the solution.

Woolpert's goal is to maintain an average PDOP value below 3.0. Brief periods of PDOP over 3.0 are acceptable due to the calibration and control process if other metrics are within specification.

Figure 3.10: PDOP, Day 30514_SH7177

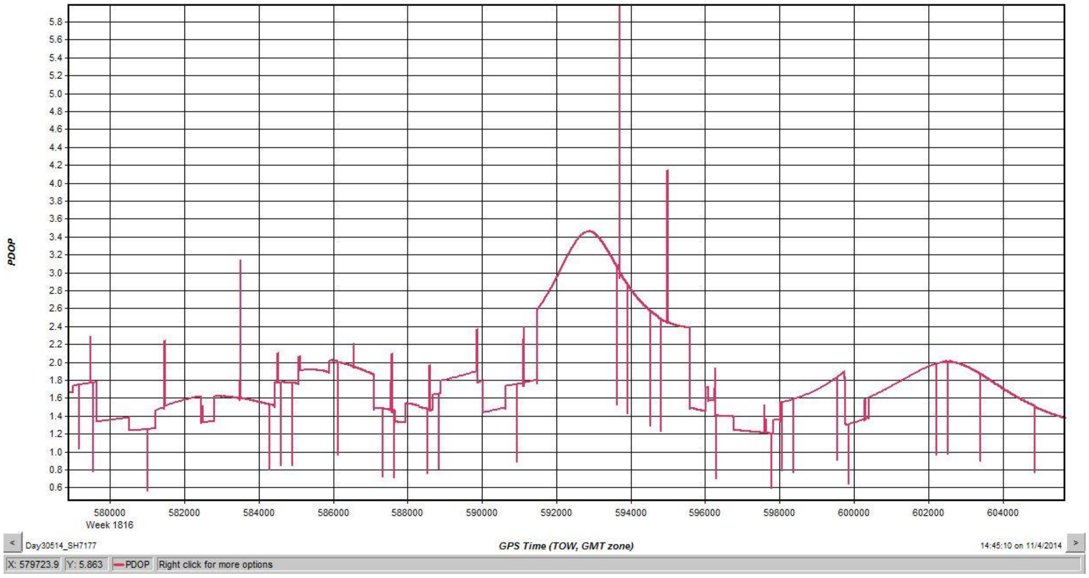


Figure 3.11: PDOP, Day 30614_SH7177

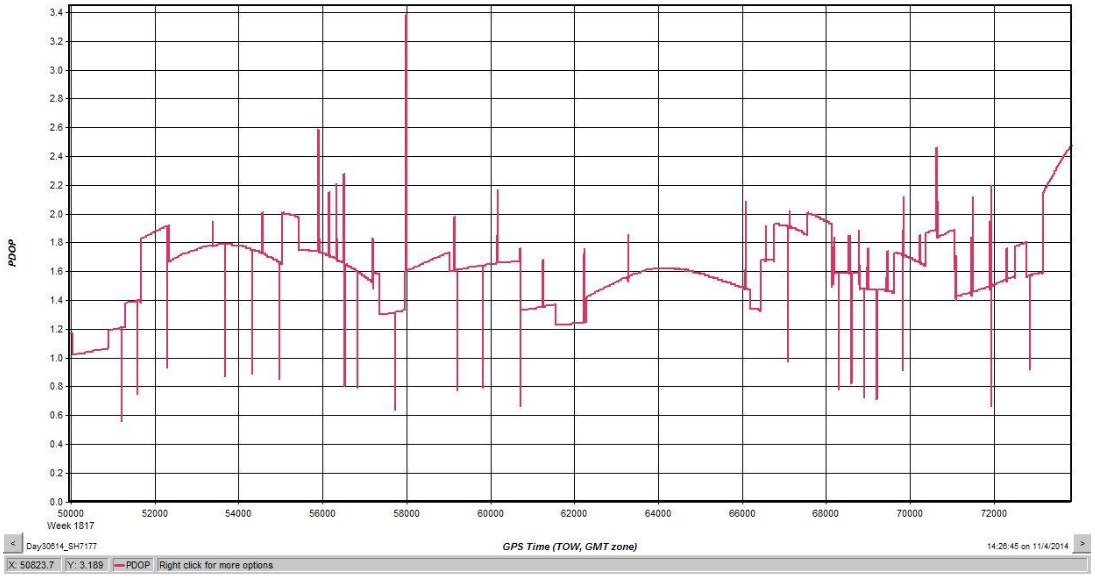


Figure 3.12: PDOP, Day 10715_SH7108

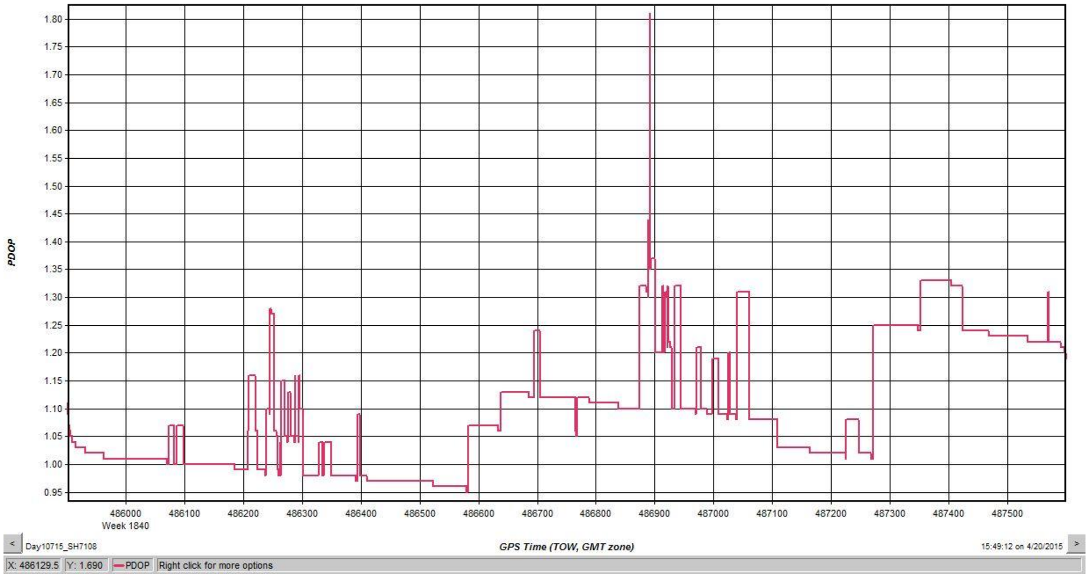


Figure 3.13: Altitude, Day30514_SH7177

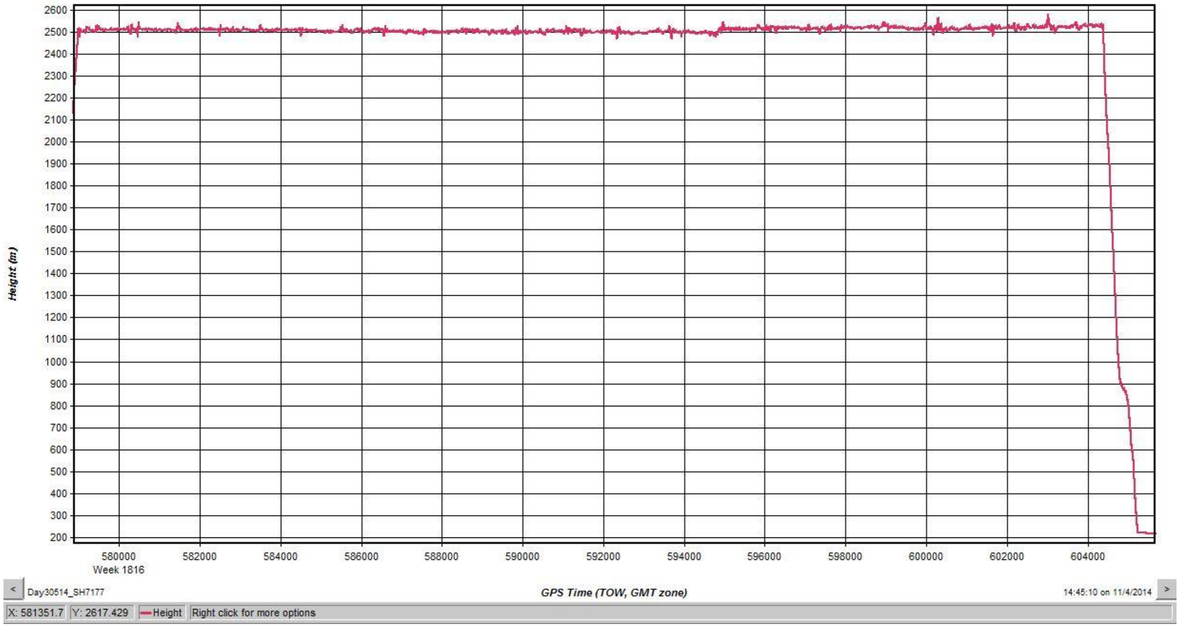


Figure 3.14: Altitude, Day30614_SH7177

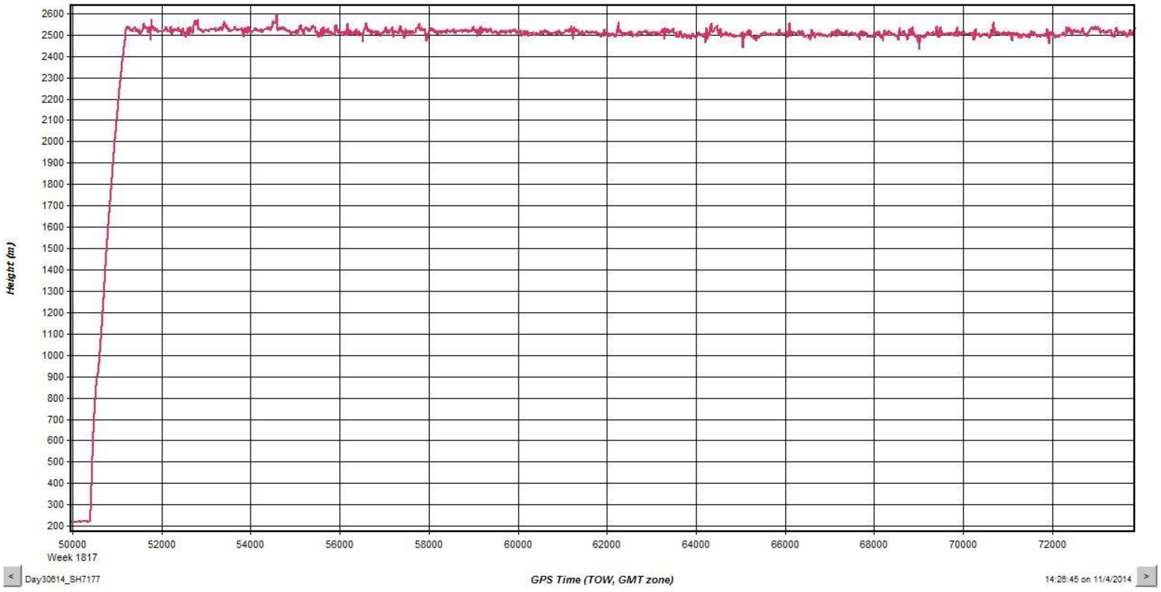
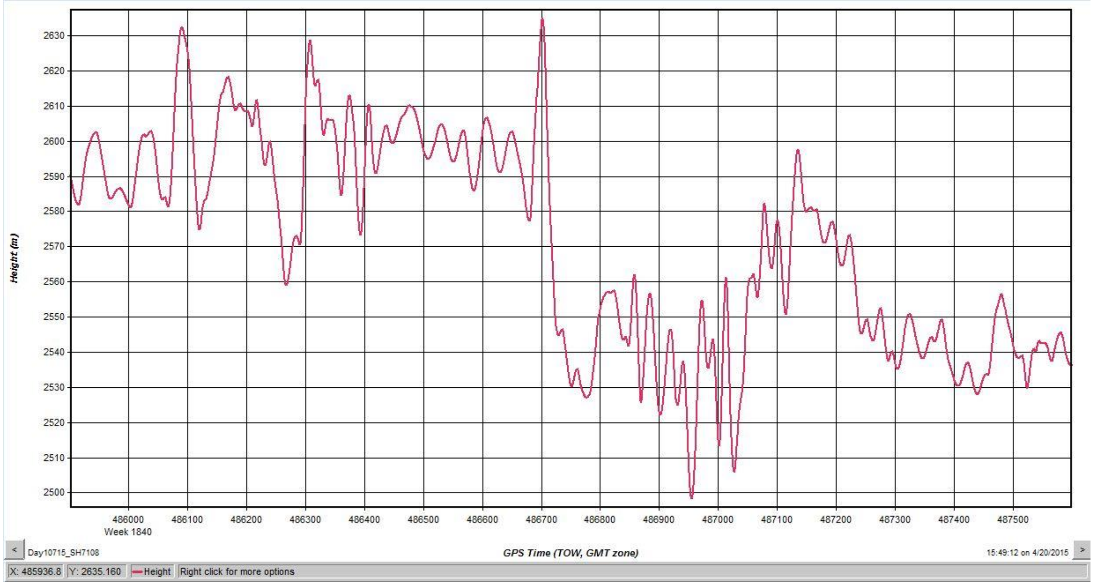


Figure 3.15: Altitude, Day10715_SH7108



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:

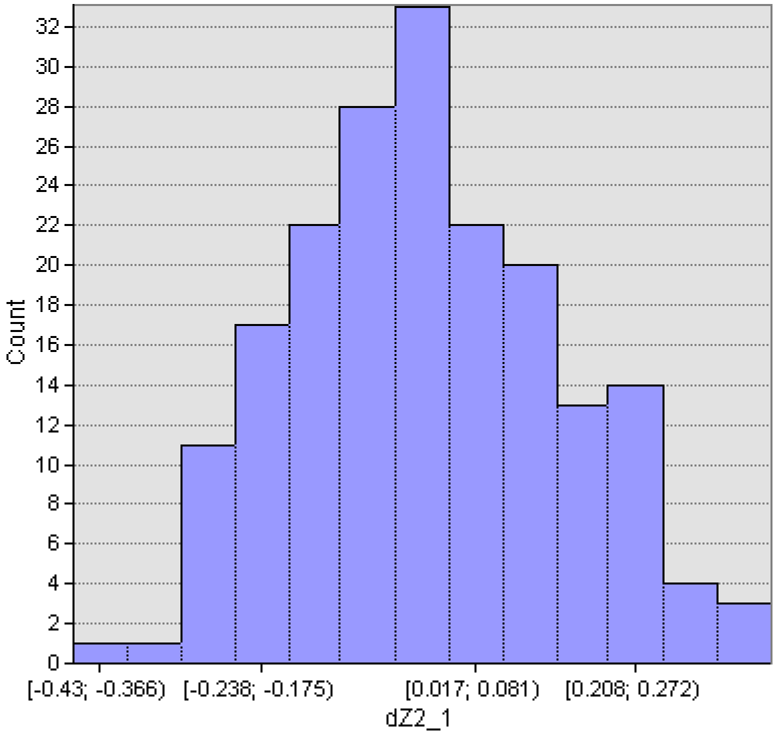
- Processed individual flight lines to derive a raw "Point Cloud" LAS file. Matched overlapping flight lines, generated statistics for evaluation comparisons, and made the necessary adjustments to remove any residual systematic error.
- Calibrated LAS files were imported into the task order tiles and 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), FGDC Compliant metadata was developed for the task order in .xml format for the final data products.
- The horizontal datum used for the task order was referenced to in UTM, Zone 15, North American Datum of 1983 (2011) in units of meters. The vertical datum used for the task order was referenced to NAVD 1988, GEOID12A, in units of survey feet.
- Relative vertical accuracy refers to the internal geometric quality of a lidar dataset, without regard to surveyed ground control. Overlap consistency (interswath) was tested at 20 locations all over the project area. Overlap consistency is a measure of geometric alignment of two overlapping swaths; the principles used with swaths can be applied to overlapping lifts and projects as well. Overlap consistency will be assessed at multiple locations within overlap in nonvegetated areas of only single returns. The overlap areas that will be tested are those between the following:

  Adjacent, overlapping parallel swaths within a project,
  Cross-tie swaths and the intersecting project swaths, and
  Adjacent, overlapping lifts.

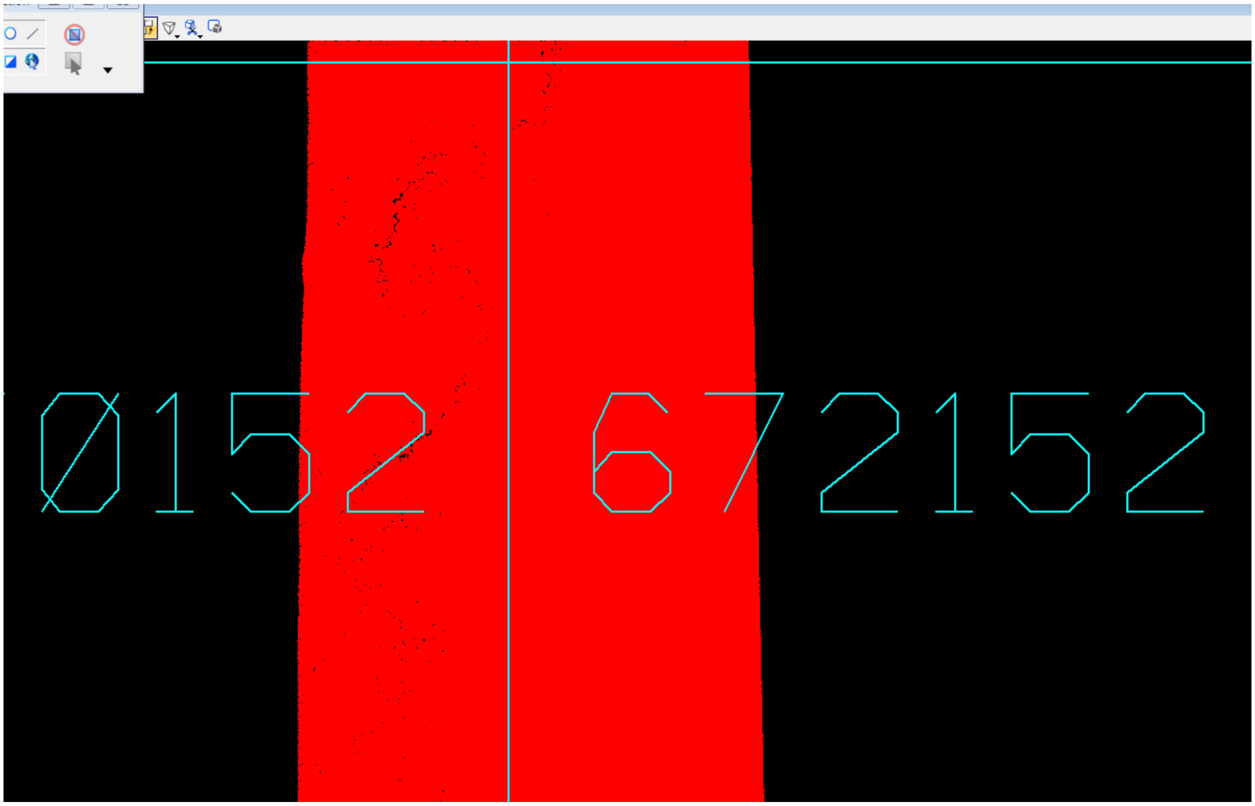
  The average line to line difference was tested at -0.010 survey feet. The RMSDz of line to line difference is 0.162 survey feet. The number of samples is 189. The Frequency of relative vertical accuracy between flightlines is shown as following.

Figure 3.16: Histogram Interswath Accuracy



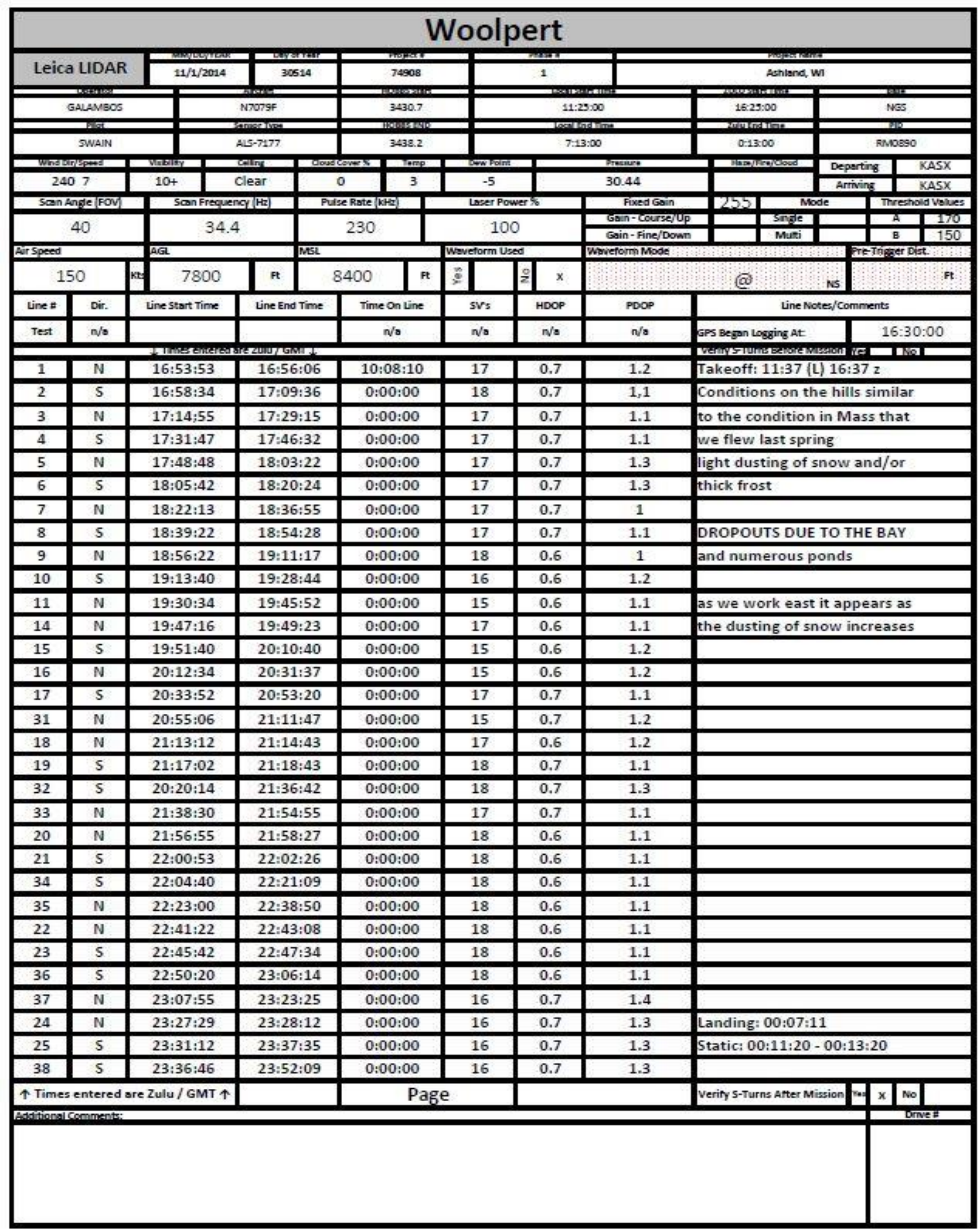
- This LAS 1.2 dataset contains return numbers beyond a 5th return(6th, 7th, 8th, etc). A fully compliant LAS 1.2 file only supports the encoding of up to and including 5 returns in the LAS header information. Any subsequent returns (6th, 7th, 8th, etc) cannot be encoded in the header and most lidar processing software will generate a warning stating "Number of points by return not equal point record count".
- The vertical scale factor of this lidar dataset is 0.01. The LAS generating software defaults the vertical scale factor to 0.001 so the Z-value of a lidar point at 50.53 ft is stored by the software as 50.530 ft. This is what is known as “fluff”. There is nothing wrong with the data only that most lidar processing softwares are able to detect this “fluff” and display a warning.
- The scan angle rank in point data record is the angle at which the laser point was output from the laser system includes roll of the aircraft added by roll compensation. Due to the tiled nature of the LAS data, some LAS files may exhibit a lower scan angle rank than what the overall project was acquired at and/or contain only negative or positive scan angle ranks. This is due to the fact that when swath data is imported to a tiled format that tile assumes whatever scan angle rank values that fall within that tile boundary. See figure 3.17- Assuming that nadir of the swath falls roughly on the tile boundary it could be expected that tile 672152 might only contain negative scan angle ranks or have lower scan angle ranks than anticipated.

Figure 3.17: Scan Angle Rank



Section 4: Flight Logs

Flight logs for the project are shown on the following pages:



Woolpert

Leica LIDAR	MM/DD/YEAR 11/1/2014	Day of Year 30514	Project # 74908	Phase # 1	Project Name Ashland, WI
Operator GALAMBOS	Aircraft N7079F	HOBBS START 3430.7	Local Start Time 11:25:00	Zulu Start Time 16:25:00	Base NGS
Pilot SWAIN	Sensor Type ALS-7177	HOBBS END 3438.2	Local End Time 7:13:00	Zulu End Time 0:13:00	PID RM0890

Wind Dir/Speed	Visibility	Ceiling	Cloud Cover %	Temp	Dew Point	Pressure	Haze/Fire/Cloud		
240 7	10+	Clear	0	3	-5	30.44		Departing Arriving	KASX KASX

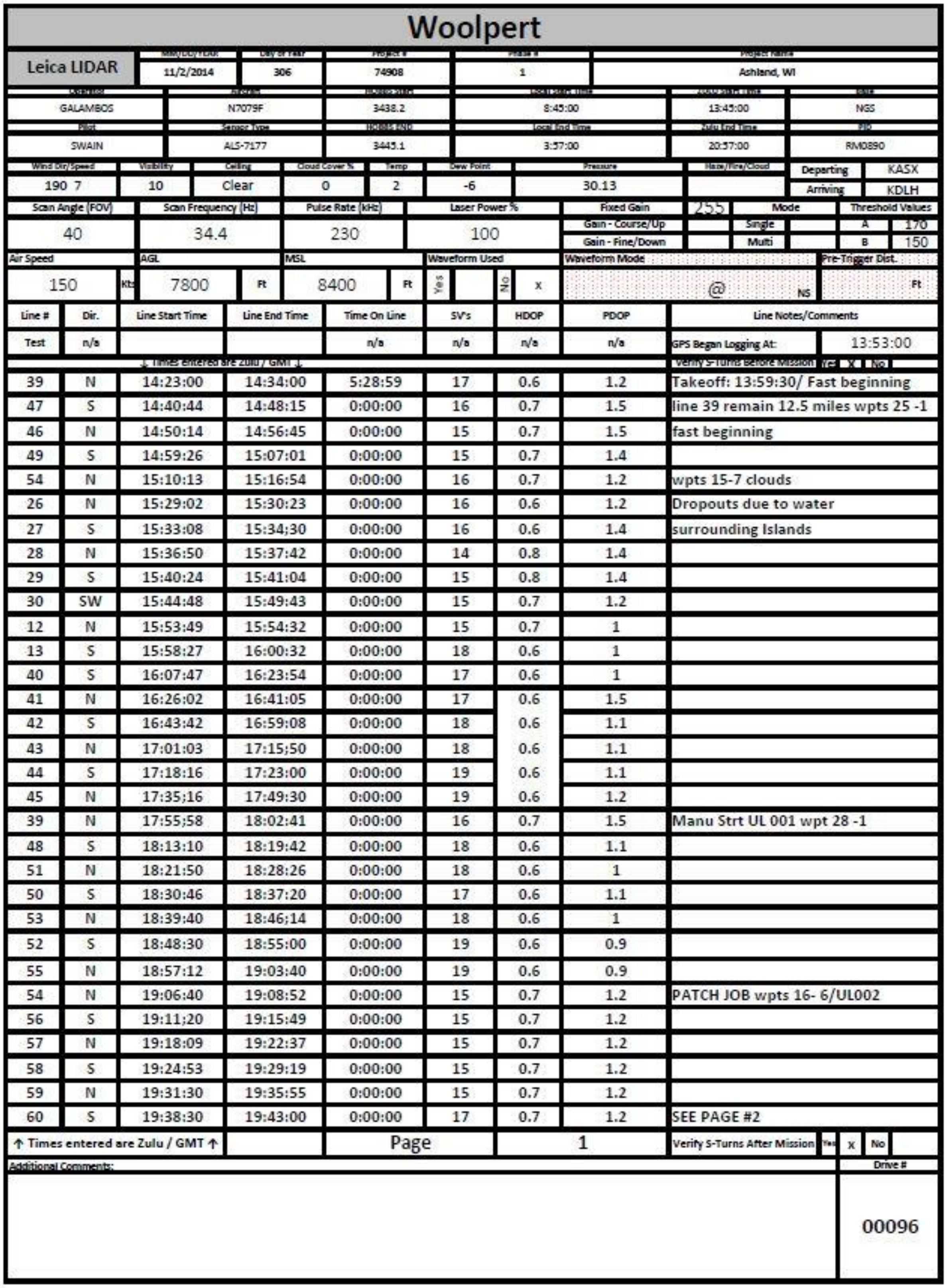
Scan Angle (FOV)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power %	Fixed Gain	255	Mode		Threshold Values	
40	34.4	230	100	Gain - Course/Up		Single		A	170
				Gain - Fine/Down		Multi		B	150

Air Speed		AGL		MSL		Waveform Used				Waveform Mode	Pre-Trigger Dist.
150	Kts	7800	Ft	8400	Ft	Yes		No	x	@ NS	Ft

Line #	Dir.	Line Start Time	Line End Time	Time On Line	SV's	HDOP	PDOP	Line Notes/Comments	
Test	n/a			n/a	n/a	n/a	n/a	GPS Began Logging At:	16:30:00
		↓ Times entered are Zulu / GMT ↓						Verify S-Turns Before Mission Yes ☐ No ☐	
1	N	16:53:53	16:56:06	10:08:10	17	0.7	1.2	Takeoff: 11:37 (L) 16:37 z	
2	S	16:58:34	17:09:36	0:00:00	18	0.7	1,1	Conditions on the hills similar	
3	N	17:14;55	17:29:15	0:00:00	17	0.7	1.1	to the condition in Mass that	
4	S	17:31:47	17:46:32	0:00:00	17	0.7	1.1	we flew last spring	
5	N	17:48:48	18:03:22	0:00:00	17	0.7	1.3	light dusting of snow and/or	
6	S	18:05:42	18:20:24	0:00:00	17	0.7	1.3	thick frost	
7	N	18:22:13	18:36:55	0:00:00	17	0.7	1		
8	S	18:39:22	18:54:28	0:00:00	17	0.7	1.1	DROPOUTS DUE TO THE BAY	
9	N	18:56:22	19:11:17	0:00:00	18	0.6	1	and numerous ponds	
10	S	19:13:40	19:28:44	0:00:00	16	0.6	1.2		
11	N	19:30:34	19:45:52	0:00:00	15	0.6	1.1	as we work east it appears as	
14	N	19:47:16	19:49:23	0:00:00	17	0.6	1.1	the dusting of snow increases	
15	S	19:51:40	20:10:40	0:00:00	15	0.6	1.2		
16	N	20:12:34	20:31:37	0:00:00	15	0.6	1.2		
17	S	20:33:52	20:53:20	0:00:00	17	0.7	1.1		
31	N	20:55:06	21:11:47	0:00:00	15	0.7	1.2		
18	N	21:13:12	21:14:43	0:00:00	17	0.6	1.2		
19	S	21:17:02	21:18:43	0:00:00	18	0.7	1.1		
32	S	20:20:14	21:36:42	0:00:00	18	0.7	1.3		
33	N	21:38:30	21:54:55	0:00:00	17	0.7	1.1		
20	N	21:56:55	21:58:27	0:00:00	18	0.6	1.1		
21	S	22:00:53	22:02:26	0:00:00	18	0.6	1.1		
34	S	22:04:40	22:21:09	0:00:00	18	0.6	1.1		
35	N	22:23:00	22:38:50	0:00:00	18	0.6	1.1		
22	N	22:41:22	22:43:08	0:00:00	18	0.6	1.1		
23	S	22:45:42	22:47:34	0:00:00	18	0.6	1.1		
36	S	22:50:20	23:06:14	0:00:00	18	0.6	1.1		
37	N	23:07:55	23:23:25	0:00:00	16	0.7	1.4		
24	N	23:27:29	23:28:12	0:00:00	16	0.7	1.3	Landing: 00:07:11	
25	S	23:31:12	23:37:35	0:00:00	16	0.7	1.3	Static: 00:11:20 - 00:13:20	
38	S	23:36:46	23:52:09	0:00:00	16	0.7	1.3		
↑ Times entered are Zulu / GMT ↑				Page				Verify S-Turns After Mission Yes x No	

Additional Comments:

Drive #



Woolpert

Leica LIDAR

MM/DD/YEAR	Day of Year	Project #	Phase #	Project Name
11/2/2014	306	74908	1	Ashland, WI

Operator	Aircraft	Hobbs Start	Local Start Time	Zulu Start Time	Base
GALAMBOS	N7079F	3438.2	8:45:00	13:45:00	NGS
Pilot	**Sensor Type**	**Hobbs END**	**Local End Time**	**Zulu End Time**	**PID**
SWAIN	ALS-7177	3445.1	3:57:00	20:57:00	RM0890

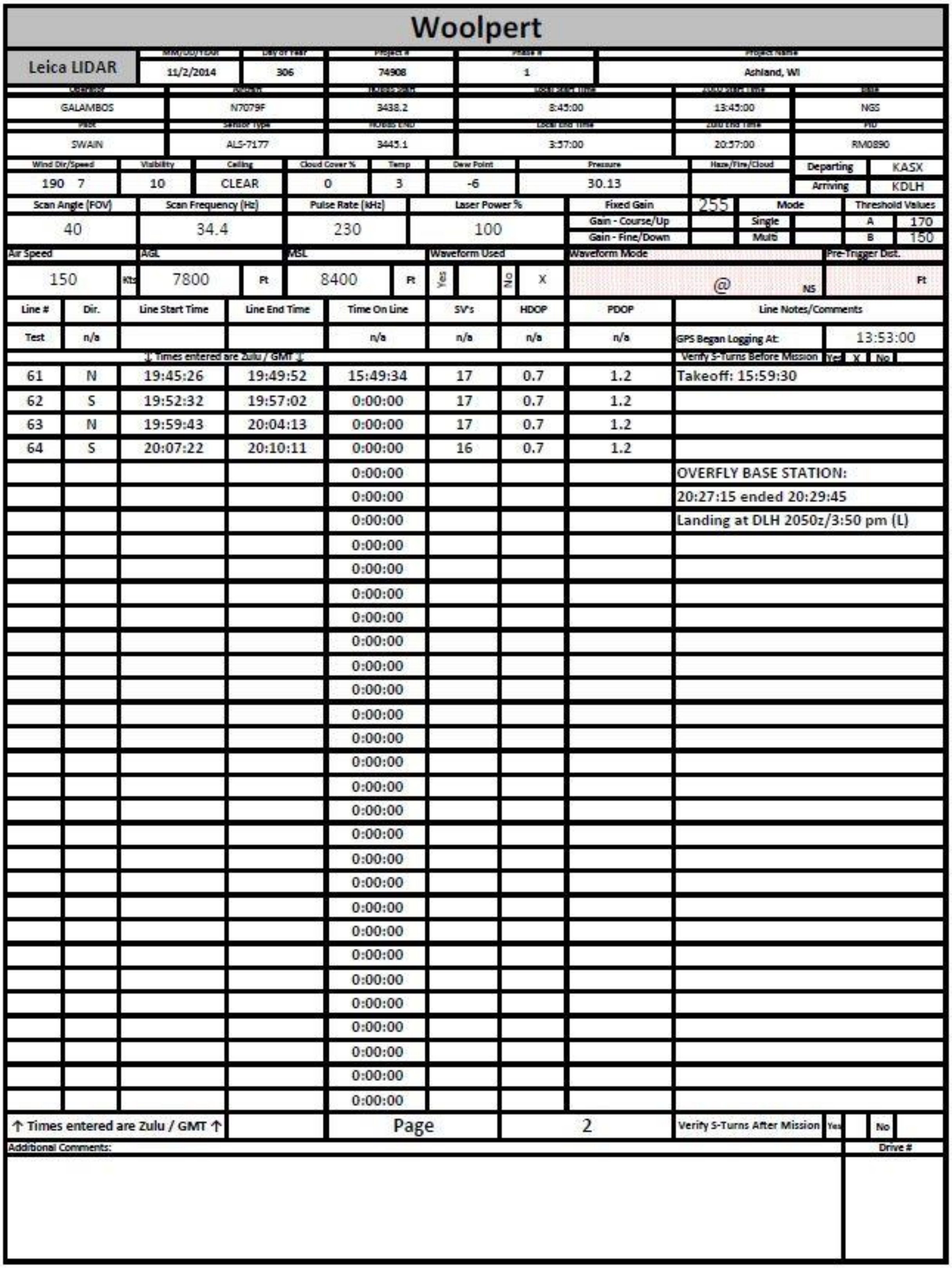
Wind Dir/Speed	Visibility	Ceiling	Cloud Cover %	Temp	Dew Point	Pressure	Haze/Fire/Cloud	Departing	KASX
190 7	10	Clear	0	2	-6	30.13		Arriving	KDLH

Scan Angle (FOV)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power %	Fixed Gain	255	Mode		Threshold Values	
40	34.4	230	100	Gain - Course/Up		Single		A	170
				Gain - Fine/Down		Multi		B	150

Air Speed		AGL		MSL		Waveform Used				Waveform Mode	Pre-Trigger Dist.
150	Kts	7800	Ft	8400	Ft	Yes		No	x	@ NS	Ft

Line #	Dir.	Line Start Time	Line End Time	Time On Line	SV's	HDOP	PDOP	Line Notes/Comments	
Test	n/a			n/a	n/a	n/a	n/a	GPS Began Logging At:	13:53:00
		↓ Times entered are Zulu / GMT ↓						Verify S-Turns Before Mission	Yes X No
39	N	14:23:00	14:34:00	5:28:59	17	0.6	1.2	Takeoff: 13:59:30/ Fast beginning	
47	S	14:40:44	14:48:15	0:00:00	16	0.7	1.5	line 39 remain 12.5 miles wpts 25 -1	
46	N	14:50:14	14:56:45	0:00:00	15	0.7	1.5	fast beginning	
49	S	14:59:26	15:07:01	0:00:00	15	0.7	1.4		
54	N	15:10:13	15:16:54	0:00:00	16	0.7	1.2	wpts 15-7 clouds	
26	N	15:29:02	15:30:23	0:00:00	16	0.6	1.2	Dropouts due to water	
27	S	15:33:08	15:34;30	0:00:00	16	0.6	1.4	surrounding Islands	
28	N	15:36:50	15:37:42	0:00:00	14	0.8	1.4		
29	S	15:40:24	15:41:04	0:00:00	15	0.8	1.4		
30	SW	15:44:48	15:49:43	0:00:00	15	0.7	1.2		
12	N	15:53:49	15:54:32	0:00:00	15	0.7	1		
13	S	15:58:27	16:00:32	0:00:00	18	0.6	1		
40	S	16:07:47	16:23:54	0:00:00	17	0.6	1		
41	N	16:26:02	16:41:05	0:00:00	17	0.6	1.5		
42	S	16:43:42	16:59:08	0:00:00	18	0.6	1.1		
43	N	17:01:03	17:15;50	0:00:00	18	0.6	1.1		
44	S	17:18:16	17:23:00	0:00:00	19	0.6	1.1		
45	N	17:35;16	17:49:30	0:00:00	19	0.6	1.2		
39	N	17:55;58	18:02:41	0:00:00	16	0.7	1.5	Manu Strt UL 001 wpt 28 -1	
48	S	18:13:10	18:19:42	0:00:00	18	0.6	1.1		
51	N	18:21:50	18:28:26	0:00:00	18	0.6	1		
50	S	18:30:46	18:37:20	0:00:00	17	0.6	1.1		
53	N	18:39:40	18:46;14	0:00:00	18	0.6	1		
52	S	18:48:30	18:55:00	0:00:00	19	0.6	0.9		
55	N	18:57:12	19:03:40	0:00:00	19	0.6	0.9		
54	N	19:06:40	19:08:52	0:00:00	15	0.7	1.2	PATCH JOB wpts 16- 6/UL002	
56	S	19:11;20	19:15:49	0:00:00	15	0.7	1.2		
57	N	19:18:09	19:22:37	0:00:00	15	0.7	1.2		
58	S	19:24:53	19:29:19	0:00:00	15	0.7	1.2		
59	N	19:31:30	19:35:55	0:00:00	15	0.7	1.2		
60	S	19:38:30	19:43:00	0:00:00	17	0.7	1.2	SEE PAGE #2	
↑ Times entered are Zulu / GMT ↑				Page		1		Verify S-Turns After Mission	Yes x No

Additional Comments:	Drive #
	00096



Woolpert

Leica LIDAR	MM/DD/YEAR	Day of Year	Project #	Phase #	Project Name
	11/2/2014	306	74908	1	Ashland, WI

Operator	Aircraft	HOBBS Start	Local Start Time	Zulu Start Time	Base
GALAMBOS	N7079F	3438.2	8:45:00	13:45:00	NGS
Pilot	Sensor Type	HOBBS END	Local End Time	Zulu End Time	PID
SWAIN	ALS-7177	3445.1	3:57:00	20:57:00	RM0890

Wind Dir/Speed	Visibility	Ceiling	Cloud Cover %	Temp	Dew Point	Pressure	Haze/Fire/Cloud	Departing	KASX
190 7	10	CLEAR	0	3	-6	30.13		Arriving	KDLH

Scan Angle (FOV)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power %	Fixed Gain	255	Mode		Threshold Values	
40	34.4	230	100	Gain - Course/Up		Single		A	170
				Gain - Fine/Down		Multi		B	150

Air Speed		AGL		MSL		Waveform Used				Waveform Mode	Pre-Trigger Dist.
150	Kts	7800	Ft	8400	Ft	Yes		No	X	@ NS	Ft

Line #	Dir.	Line Start Time	Line End Time	Time On Line	SV's	HDOP	PDOP	Line Notes/Comments
Test	n/a			n/a	n/a	n/a	n/a	GPS Began Logging At: 13:53:00
		↓ Times entered are Zulu / GMT ↓						Verify S-Turns Before Mission Yes X No
61	N	19:45:26	19:49:52	15:49:34	17	0.7	1.2	Takeoff: 15:59:30
62	S	19:52:32	19:57:02	0:00:00	17	0.7	1.2	
63	N	19:59:43	20:04:13	0:00:00	17	0.7	1.2	
64	S	20:07:22	20:10:11	0:00:00	16	0.7	1.2	
				0:00:00				OVERFLY BASE STATION:
				0:00:00				20:27:15 ended 20:29:45
				0:00:00				Landing at DLH 2050z/3:50 pm (L)
				0:00:00				
				0:00:00				
				0:00:00				
				0:00:00				
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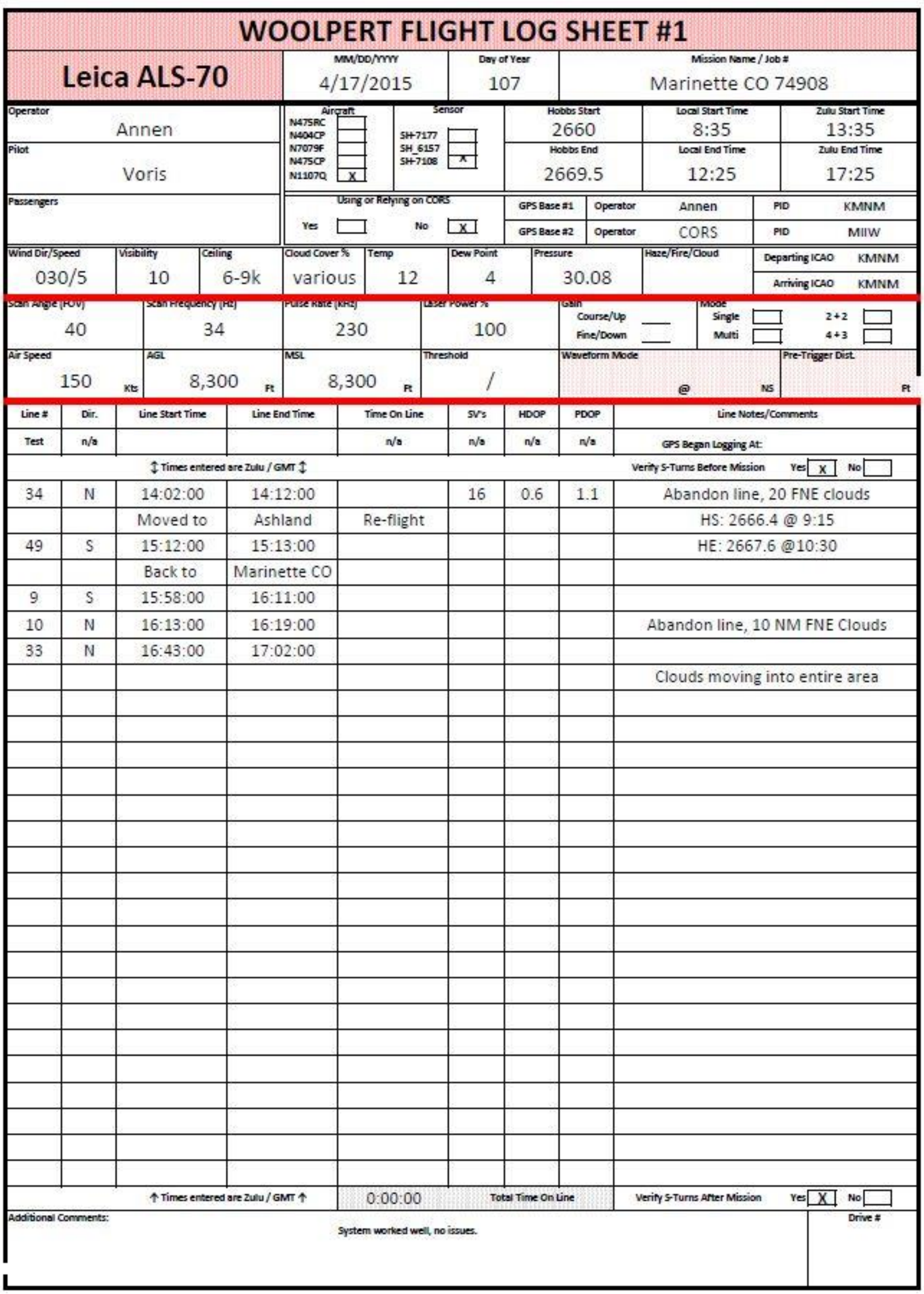
↑ Times entered are Zulu / GMT ↑		Page	2	Verify S-Turns After Mission	Yes		No

Additional Comments:	Drive #



WOOLPERT FLIGHT LOG SHEET #1

Leica ALS-70

MM/DD/YYYY 4/17/2015	Day of Year 107	Mission Name / Job # Marinette CO 74908

Operator: Annen
Pilot: Voris
Passengers:

Aircraft: N475RC ☐ N404CP ☐ N7079F ☐ N475CP ☐ N1107Q ☒
Sensor: SH-7177 ☐ SH_6157 ☐ SH-7108 ☒

Hobbs Start 2660	Local Start Time 8:35	Zulu Start Time 13:35
Hobbs End 2669.5	Local End Time 12:25	Zulu End Time 17:25

Using or Relying on CORS: Yes ☐ No ☒

GPS Base #1	Operator	Annen	PID	KMNM
GPS Base #2	Operator	CORS	PID	MIIW

Wind Dir/Speed	Visibility	Ceiling	Cloud Cover %	Temp	Dew Point	Pressure	Haze/Fire/Cloud
030/5	10	6-9k	various	12	4	30.08	

Departing ICAO: KMNM
Arriving ICAO: KMNM

Scan Angle (FOV)	Scan Frequency (Hz)	Pulse Rate (KHz)	Laser Power %
40	34	230	100

Gain: Course/Up ___ Fine/Down ___
Mode: Single ☐ Multi ☐ 2+2 ☐ 4+3 ☐

Air Speed	AGL	MSL	Threshold
150 Kts	8,300 Ft	8,300 Ft	/

Waveform Mode: @ NS
Pre-Trigger Dist.: Ft

Line #	Dir.	Line Start Time	Line End Time	Time On Line	SV's	HDOP	PDOP	Line Notes/Comments
Test	n/a			n/a	n/a	n/a	n/a	GPS Began Logging At:
		↕ Times entered are Zulu / GMT ↕						Verify S-Turns Before Mission Yes ☒ No ☐
34	N	14:02:00	14:12:00		16	0.6	1.1	Abandon line, 20 FNE clouds
		Moved to	Ashland	Re-flight				HS: 2666.4 @ 9:15
49	S	15:12:00	15:13:00					HE: 2667.6 @10:30
		Back to	Marinette CO					
9	S	15:58:00	16:11:00					
10	N	16:13:00	16:19:00					Abandon line, 10 NM FNE Clouds
33	N	16:43:00	17:02:00					
								Clouds moving into entire area
		↑ Times entered are Zulu / GMT ↑		0:00:00	Total Time On Line			Verify S-Turns After Mission Yes ☒ No ☐

Additional Comments:
System worked well, no issues.

Drive #

Section 5: Final Deliverables

The final lidar deliverables are listed below.

- LAS v1.2 unclassified point cloud.
- FGDC compliant project level metadata in XML format
- Post-flight aerial acquisition and calibration report
- Lidar certificate of compliance