WY Sheridan 2020 Topographic Lidar Project

Lot 6 – QL2 Delivery Report

March 31, 2021

Prepared for:

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TASK ORDER: 140G0220F0130

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Introduction

Optimal GEO, Inc. was tasked by the United States Geological Survey to acquire and process both QL1 and QL2 topographic LiDAR data for 341 and 2,630 square miles respectively covering the county of Sheridan, WY. This LiDAR data will be used to produce a high-resolution bare earth Digital Elevation Model of the entire project area. This report describes the data acquisition, ground survey, data processing, quality control, and data validation activities related to producing the final deliverables for this project.

The LiDAR data were processed in accordance with this task order's Statement of Work, as well as the USGS' NGP Lidar Base Specification version 2.1 (October 2019).

Project Team

Optimal GEO, Inc., serving as the prime contractor of this task order, was responsible for managing all project related activities. Optimal GEO was directly responsible for the topographic lidar post acquisition QA/QC, initial automated classification, manual editing of the lidar data and breakline generation and performing QA/QC on all final deliverables. All ground survey activities required to collect ground control and accuracy checkpoints were performed by Optimal GEO, Inc. and Woolpert, Inc. The data acquisition and calibration were performed by Woolpert, Inc.

Coordinate Reference System

The lidar data and derived products were delivered in the following reference system.

Horizontal Datum: North American Datum 1983, 2011 adjustment (NAD83 (2011))
Vertical Datum: North American Vertical Datum of 1988, (NAVD88)
Coordinate System: Universal Transverse Mercator (UTM) Zone 13 North
Units: Horizontal units are in meters to 2 decimal places; Vertical units are in meters to 2 decimal places.
Geoid Model: Geoid18 (used to convert ellipsoid heights to orthometric heights)

Lidar Vertical Accuracy

The tested RMSEz of the classified lidar data for checkpoints in non-vegetated terrain is 3.5 cm, within the 10 cm specification. The NVA of the classified lidar data computed using RMSEz x 1.96 is 6.9 cm, within the 19.6 cm specification.

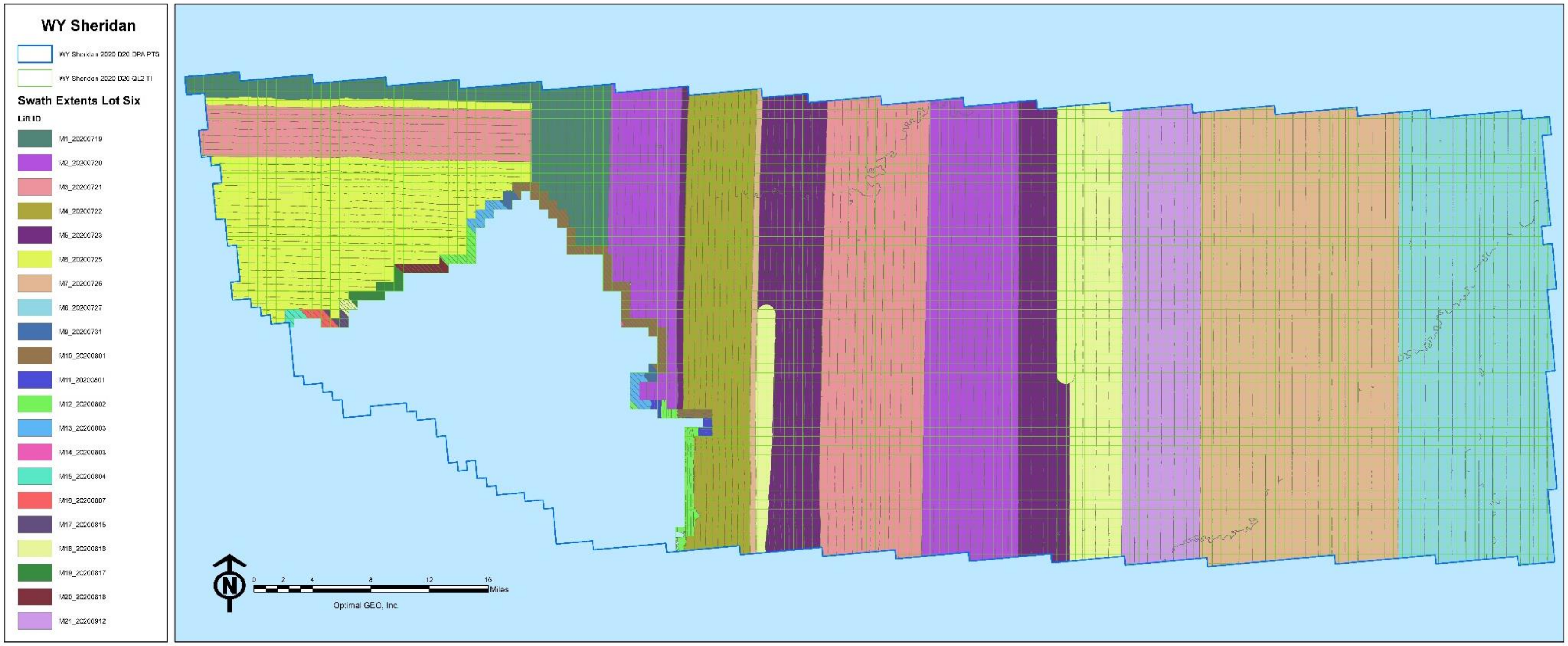
The tested VVA of the classified lidar data computed using the 95th percentile is equal to 12.6 cm, compared to the 30 cm specification.

Project Deliverables

The deliverables for the project are as follows:

1. Classified Point Cloud Data (Tiled)
2. Bare Earth Surface (Raster DEM – GeoTIFF, 32-bit floating-point format)
3. Intensity Images (8-bit gray scale, tiled, GeoTIFF format)
4. Breakline Data (ESRI GDB Feature Class Format)
5. Height Separation Rasters (modulated by intensity)
6. Independent Survey Checkpoint Data (Report, Photos, & Points)
7. Calibration Points
8. Metadata
9. Project Report (Acquisition, Processing, QC)
10. Project Extents

Project Overview Map



LiDAR Acquisition

Woolpert planned 281 passes for the WY Sheridan project area containing cross ties for the purposes of quality control. To reduce any margin for error in the flight plan, Woolpert followed FEMA's Appendix A "guidelines" for flight planning and, at a minimum, includes the following criteria:

- A digital flight line layout using mission management flight design software for direct integration into the aircraft flight navigation system.
- Planned flight lines; flight line numbers; and coverage area.
- Lidar coverage extended by a predetermined margin (100m) beyond all project borders to ensure necessary over-edge coverage appropriate for specific task order deliverables.
- Local restrictions related to air space and any controlled areas have been investigated so that required permissions can be obtained in a timely manner with respect to schedule. Additionally, Woolpert filed their flight plans as required by local Air Traffic Control (ATC) prior to each mission.

Woolpert monitored weather and atmospheric conditions and conducted lidar missions only when no conditions exist below the sensor that will affect the collection of data. These conditions include leaf-off for hardwoods, no snow, rain, fog, smoke, mist, and low clouds. Lidar systems are active sensors, not requiring light, thus missions may be conducted during night hours when weather restrictions do not prevent collection. Woolpert accesses reliable weather sites and indicators (webcams) to establish the highest probability for successful collection to position our sensor to maximize successful data acquisition.

Within 72-hours prior to the planned day(s) of acquisition, Woolpert closely monitored the weather, checking all sources for forecasts at least twice daily. As soon as weather conditions were conducive to acquisition, our aircraft mobilized to the project site to begin data collection. Once on site, the acquisition team took responsibility for weather analysis.

The lidar survey was conducted between July 19, 2020 and September 12, 2020.

Lidar System Parameters

Woolpert operated a Cessna 404 Titan - N404CP outfitted with a Leica Terrain Mapper LiDAR system during the collection of the study area.

Table 1 lists Woolpert's system parameters for lidar acquisition on this project.

Item	Parameter
System	Leica Terrain Mapper – Serial #90511
Altitude (AGL meters)	3000
Approx. Flight Speed (knots)	150
Scanner Pulse Rate (kHz)	600
Scan Frequency	52
Pulse Duration of the Scanner (nanoseconds)	5
Pulse Width of the Scanner (m)	2.5
Swath width (m)	2184
Central Wavelength of the Sensor Laser (nanometers)	1064
Did the Sensor Operate with Multiple Pulses in The Air? (yes/no)	Yes
Beam Divergence (milliradians)	0.25
Nominal Swath Width on the Ground (m)	2184
Swath Overlap (%)	25
Total Sensor Scan Angle (degree)	40
Nominal Pulse Spacing (single swath), (m)	0.71
Nominal Pulse Density (single swath) (ppsm), (m)	2.0
Aggregate NPS (m) (if ANPS was designed to be met through single coverage, ANPS and NPS will be equal)	0.71
Aggregate NPD (m) (if ANPD was designed to be met through single coverage, ANPD and NPD will be equal)	2.0
Maximum Number of Returns per Pulse	15

Table 1. Woolpert's lidar system parameters.

Acquisition Status Report and Flight Lines

Upon notification to proceed, the flight crew loaded the flight plans and validated the flight parameters. The Acquisition Manager contacted air traffic control and coordinated flight pattern requirements. Lidar acquisition began immediately upon notification that control base stations were in place. During flight operations, the flight crew monitored weather and atmospheric conditions. Lidar missions were flown only when no condition existed below the sensor that would affect the collection of data. The pilot constantly monitored the aircraft course, position, pitch, roll, and yaw of the aircraft. The sensor operator monitored the sensor, the status of PDOPs, and performed the first Q/C review during acquisition. The flight crew constantly reviewed weather and cloud locations. Any flight lines (Figure 1) impacted by unfavorable conditions were marked as invalid and re-flown immediately or at an optimal time.

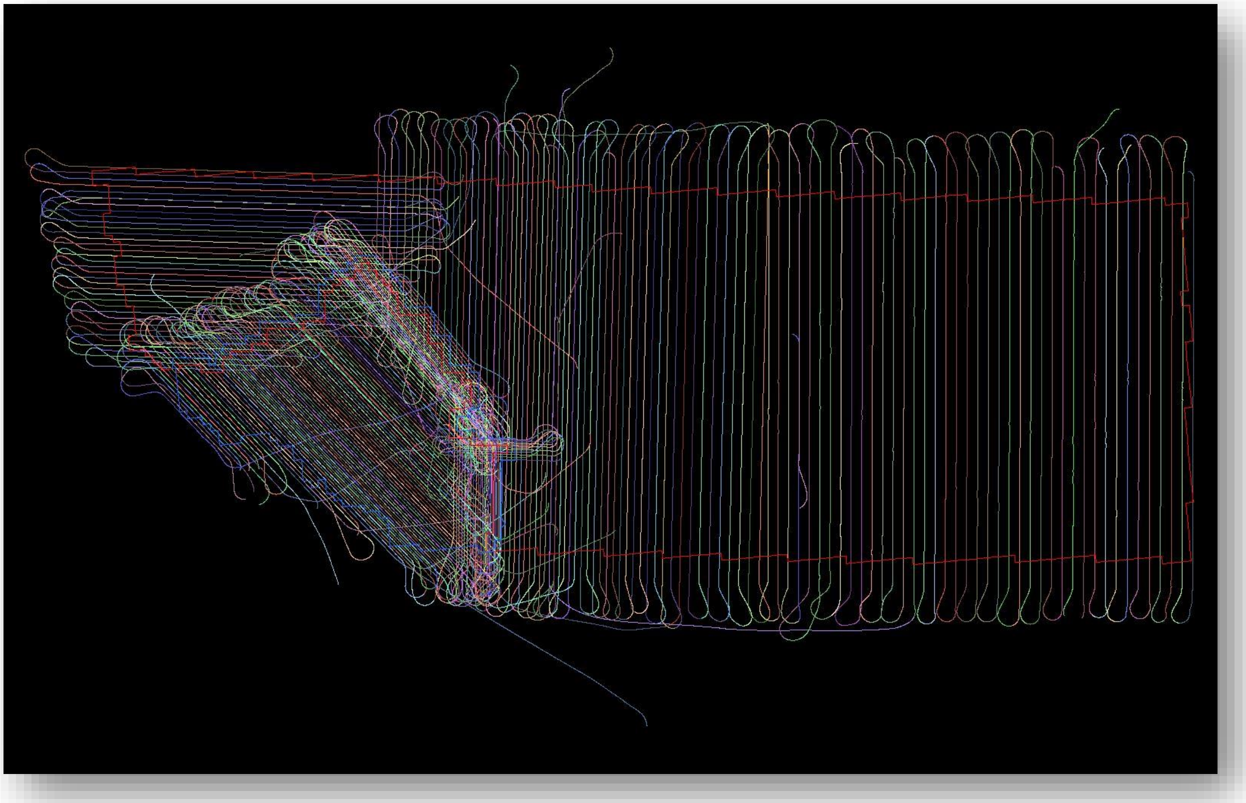


Figure 1. Trajectories as flown.

Lidar Ground Control

One LiDAR acquisition base station (Table 2) was used to control the lidar acquisition for the WY Sheridan project area. The receiver used during the survey collection, logged at 2 Hertz affixed to a 2-meter range pole served as the base station during acquisition. The coordinates of all used base station positions are provided in Table 2.

	NAD83 (2011) UTM 15		
Name	Latitude (N)	Longitude (W)	Ellipsoidal Ht (m)
WYSH_CORS	44°48'01.76953"	-107°00'35.71551"	1221.433
MTLG_CORS	45°18'44.66281"	-107°20'30.20526"	1053.075
P033_CORS	43°57'10.41596"	-107°23'15.12165"	1376.681
KSHR_CORS	44°46'22.38200"	-106°58'16.33310"	1188.685

Table 2. Listing of NGS monuments used for ground control of the lidar data.

Airborne GPS Kinematic and Flightlogs

Inertial Explorer 8.7 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. Inertial Explorer 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 data sets) certain statistical graphs and tables are generated within the Inertial Explorer 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.

Flight logs, GPS, and IMU processing reports are included in the Acquisition report: Appendix A.

Generation and Calibration of Laser Points

The initial step of calibration is to verify availability and status of all needed GPS and Laser data against field notes and compile any data if not complete.

Point clouds were then created using Leica HxMap software. The generated point cloud is the mathematical three-dimensional composite of all returns from all laser pulses as determined from the aerial mission. Laser point data are imported into GeoCue, a distributive processing software, which allows for a more manageable file size to be created in a LAS tile format.

On a project level, a supplementary coverage check is carried out to ensure no data voids unreported by Field Operations are present.

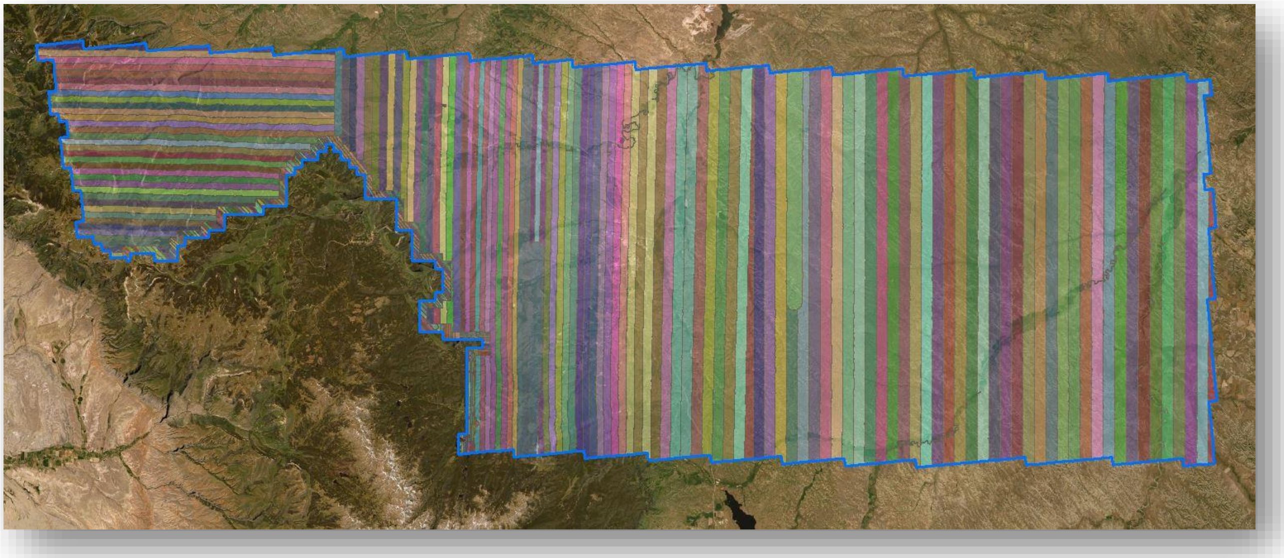


Figure 2. Lidar Swath output showing complete coverage of Lot Six

Boresight and Relative Accuracy

The initial points for each mission calibration are inspected for flight line errors, flight line overlap, slivers, or gaps in the data, point data minimums, or issues with the lidar unit or GPS. Roll, pitch, and scanner scale are optimized during the calibration process until the relative accuracy is met.

Relative accuracy and internal quality are checked using at least 3 regularly spaced QC blocks in which points from all lines are loaded and inspected. Vertical differences between ground surfaces of each line are displayed. Color scale is adjusted so that errors greater than the specifications are flagged. Cross sections are visually inspected across each block to validate point to point, flight line to flight line and mission to mission agreement. An example of this review is illustrated in Figure 3.

For this project, the specifications used are as follows:
Relative accuracy ≤ 6 cm maximum differences for smooth surface repeatability and ≤8 cm RMSDz between adjacent and overlapping swaths.

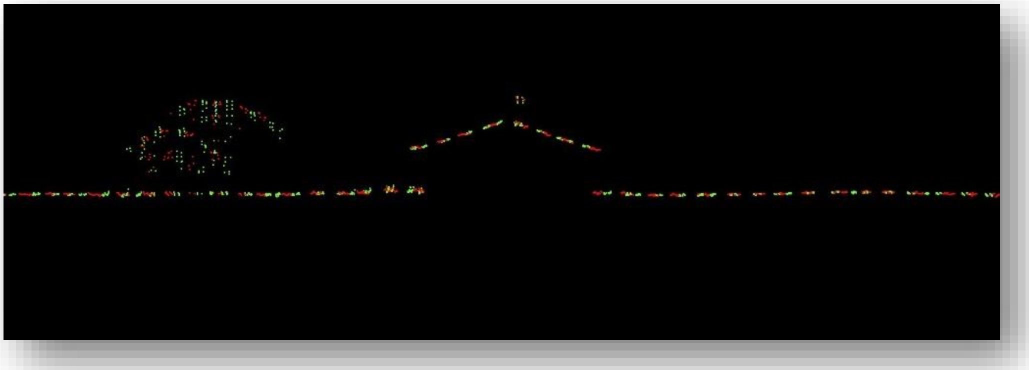


Figure 3. Profile view showing correct roll and pitch adjustments.

Lidar Processing & Quantitative Assessment

Initial Processing

Optimal GEO performed several validations on the dataset prior to starting full-scale production on the project. These validations include vertical accuracy of the swath data, inter-swath (between swath) relative accuracy validation, intra-swath (within a single swath) relative accuracy validation, verification of horizontal alignment between swaths, and confirmation of point density and spatial distribution. This initial assessment allows Optimal GEO to determine if the data are suitable for full-scale production. Addressing issues at this stage allows the data to be corrected while imposing the least disruption possible on the overall production workflow and schedule.

Final Swath Vertical Accuracy Assessment

Optimal GEO tested the vertical accuracy of the non-vegetated terrain swath data prior to additional processing. Vertical accuracy of the swath data was tested using ninety-six (96) non-vegetated (open terrain and urban) independent survey check points. The vertical accuracy is tested by comparing survey checkpoints in non-vegetated terrain to a triangulated irregular network (TIN) that is created from the raw swath points. Only checkpoints in non-vegetated terrain can be tested against raw swath data because the data has not undergone classification techniques to remove vegetation, buildings, and other artifacts from the ground surface. Checkpoints are always compared to interpolated surfaces from the lidar point cloud because it is unlikely that a survey checkpoint will be located at the location of a discrete lidar point. Optimal GEO utilized MicroStation/TerraScan software to test the classified lidar vertical accuracy, and ESRI's ArcMap to test the DEM vertical accuracy so that two different software programs are used to validate the vertical accuracy for each project. Project specifications require a NVA of 19.6 cm based on the $RMSE_z$ (10 cm) x 1.96.

The dataset for the WY Sheridan LiDAR Project satisfies these criteria. This raw lidar swath data set was tested to meet ASPRS Positional Accuracy Standards for Digital Geospatial Data (2014) for a 10 cm $RMSE_z$ Vertical Accuracy Class. Actual NVA accuracy tested to be $RMSE_z$ = 3.5 cm, equating to ± 6.9 cm at 95% confidence level. Table 3 shows all calculated statistics for the raw swath data.

Table 3: NVA at 95% Confidence Level Raw Calibrated Data.

# of Points	RMSE	RMSEz @ 95% CI	Mean (m)	Median (m)	Skew (m)	Std Dev (m)	Min (m)	Max (m)
96	**0.035**	**0.069**	**-0.003**	**0.000**	**0.163**	**0.035**	**-0.078**	**0.116**

Inter-Swath Relative Accuracy

Optimal GEO verified inter-swath or between swath relative accuracy of the dataset by creating Delta-Z (DZ) orthomosaics. According to the SOW, USGS Lidar Base Specifications v2.1, and ASPRS Positional Accuracy Standards for Digital Geospatial Data, 10 cm Vertical Accuracy Class must meet inter-swath relative accuracy of 8 cm RMSDz or less with maximum differences less than 16 cm. These measurements are to be taken in non-vegetated and flat open terrain using last returns.

Measurements are calculated in the DZ orthos on 1-meter pixels or cell sizes. Areas in the dataset where overlapping flight lines are within 8 cm of each other within each pixel are colored green, areas in the dataset where overlapping flight lines have elevation differences in each pixel between 8 cm to 16 cm are colored yellow, and DZ values above 16 cm are red. Pixels that do not contain points from overlapping flight lines are left as no data or black. Areas of vegetation and steep slopes (slopes with 16 cm or more of valid elevation change across 1 linear meter) are expected to appear yellow or red in the DZ orthos. If the project area is heavily vegetated, Optimal GEO may also create DZ Orthos from the initial ground classification only, while keeping all other parameters consistent. This allows Optimal GEO to review the ground classification relative accuracy beneath vegetation and to ensure flight line ridges or other issues do not exist in the final classified data.

Flat, open areas are expected to be green in the DZ orthos. Large or continuous sections of yellow or red pixels can indicate the data was not calibrated correctly or that there were issues during acquisition that could affect the utility of the data, especially when these yellow/red sections follow the flight lines and not the terrain or areas of vegetation. The DZ orthos for the WY Sheridan Lidar Project are shown in Figure 4; this project meets inter-swath relative accuracy specifications.

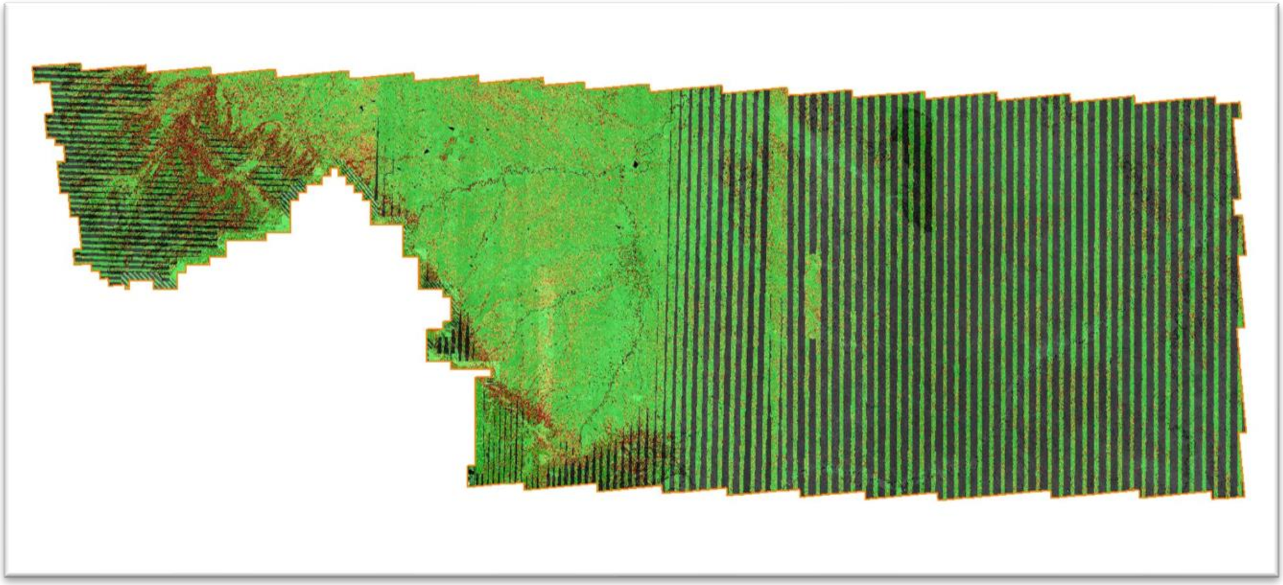


Figure 4. Delta-Z orthoimage raster generated to test inter-swath relative accuracy. Areas in the dataset where overlapping flight lines are within 8 cm of each other within each pixel are colored green, areas in the dataset where overlapping flight lines have elevation differences in each pixel between 8 cm to 16 cm are colored yellow, and DZ values greater than 16cm are colored red. Pixels that do not contain points from overlapping flight lines are left as no data or black. The yellow and red areas in this image are attributed to vegetation or steep slopes.

Intra-Swath Relative Accuracy

Optimal GEO verifies the intra-swath or within swath relative accuracy by LAStools scripting and visual reviews. Scripting is used to calculate the maximum difference of all points within each 1-meter pixel/cell size of each swath. Optimal GEO analysts then identify planar surfaces acceptable for repeatability testing and analysts review the results in those areas. According to the SOW, USGS Lidar Base Specifications v2.1, and ASPRS Positional Accuracy Standards for Digital Geospatial Data, 10 cm Vertical Accuracy Class must meet intra-swath relative accuracy of 6 cm maximum difference or less. Figure 5 shows examples of the intra-swath relative accuracy of the WY Sheridan QL2 lidar data; this project meets intra-swath relative accuracy specifications.

Figure 5. Intra-swath relative accuracy. The top image shows a close up of the project area; flat, open areas are colored green as they are within 6 cm whereas sloped terrain is colored yellow because it exceeds 6 cm maximum difference, as expected, due to actual slope/terrain change. The bottom image is a close-up of a flat area. Except for vegetated areas and around buildings (shown as yellow speckling/mottling as the elevation/height difference in vegetated areas will exceed 6 cm), this open flat area is acceptable for repeatability testing. Intra-swath relative accuracy passes specifications.

Horizontal Alignment

To ensure horizontal alignment between adjacent or overlapping flight lines, Optimal GEO uses LAStools scripting and visual reviews. LAStools scripting is used to create files similar to DZ orthos for each swath but this process highlights planar surfaces, such as roof tops. Horizontal shifts or misalignments between swaths on roof tops and other elevated planar surfaces are highlighted. Visual reviews of these features, including additional profile verifications, are used to confirm the results of this process. Figure 6 shows an example of the horizontal alignment between swaths.

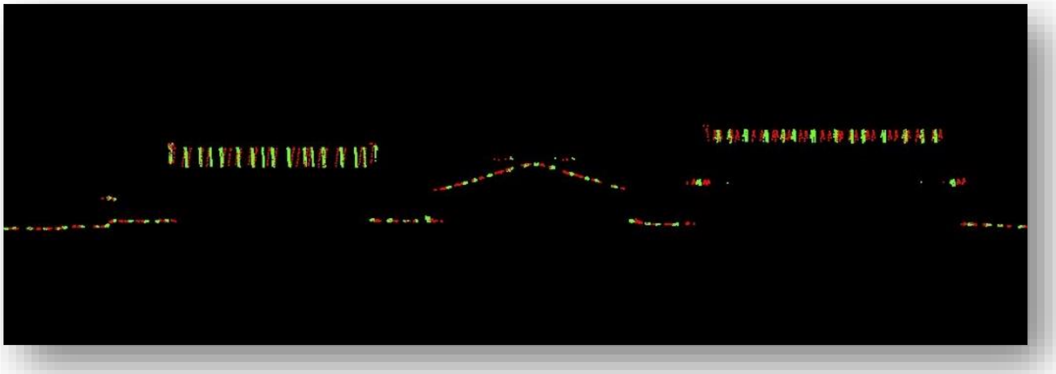


Figure 6. Profile of a lidar point cloud cross section of a buildings. Points are colorized by flight line number.

Point Density and Spatial Distribution

The required Aggregate Nominal Point Spacing (ANPS) for this project is no greater than 0.71 meters, which equates to an Aggregate Nominal Point Density (ANPD) of 2 points per square meter (ppsm) or greater for the QL2 area. For the QL1 area, the ANPS required was 0.35 meters which equates to an ANPD of 8 ppsm. Density calculations were performed using first return data only located in the geometrically usable center portion (typically ~90%) of each swath. By utilizing statistics, it was determined that the project meets the required ANPS and ANPD specifications for both the QL1 and QL2 areas.

The spatial distribution of points must be uniform and free of clustering. This specification is tested by creating a grid with cell sizes equal to the design NPS*2. LAStools scripting is then used to calculate the number of first return points of each swath within each grid cell. At least 90% of the cells must contain 1 lidar point, excluding acceptable void areas such as water or low NIR reflectivity features, i.e. some asphalt and roof composition materials.

To perform this test, Optimal GEO generated a Spatial Distribution raster grid from first return lidar points. This grid was generated for all tiles that intersect the project area. Optimal GEO did not identify any tiles where less than 90% of the cells did not contain at least one lidar point excluding acceptable void areas. Figure 7 below illustrates spatial distribution below.

Optimal GEO did identify voids in the lidar data that were larger than USGS' tolerance for acceptable data voids as defined in the task order. According to the USGS Lidar Base Specification, data voids are gaps in point cloud coverage greater or equal to $(4{*}ANPS)^2$ measured using only first returns within a single swath. The voids were identified using a density raster. Each void identified was assessed against the latest imagery in Google Earth. The types of voids found in the dataset occurred from water bodies or tall rock formations on a cliff that obscured underlying data.

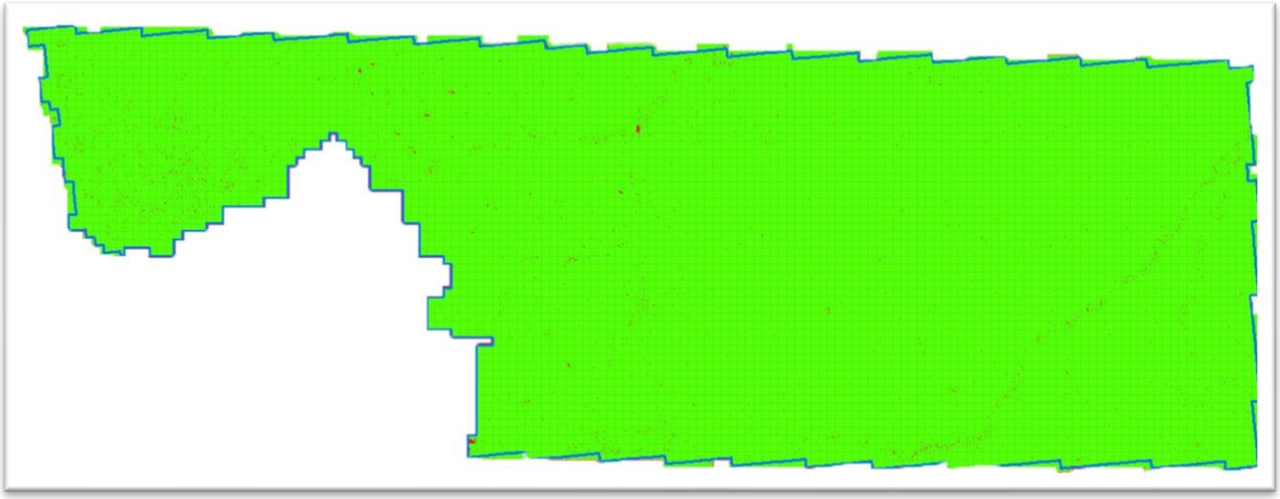


Figure 7. Spatial distribution raster generated from first return lidar pulses of the lidar data. Green pixels are areas with a count of 1 point or greater. Red pixels contain no data. The red areas are attributed to small ponds or variations in aircraft pitch that occurred during the acquisition.

Data Classification and Editing

Once the calibration, absolute swath vertical accuracy, and relative accuracy of the data was confirmed, Optimal GEO utilized a variety of software suites for data processing. The data was processed using TerraScan software. The initial step is the setup of the TerraScan project, which is done by importing a project defined tile boundary index encompassing the entire project area. The acquired 3D laser point clouds, in LAS binary format, were imported into the TerraScan project and tiled according to the project tile grid. Once tiled, the laser points were classified using a proprietary routine in TerraScan. This routine classifies any obvious low outliers in the dataset to class 7 and high outliers in the dataset to class 18. Points along flight line edges that are geometrically unusable are identified as withheld and classified to a separate class so that they will not be used in the initial ground algorithm. After points that could negatively affect the ground are removed from class 1, the ground layer is extracted from this remaining point cloud. The ground extraction process encompassed in this routine takes place by building an iterative surface model.

This surface model is generated using three main parameters: building size, iteration angle and iteration distance. The initial model is based on low points being selected by a "roaming window" with the assumption that these are the ground points. The size of this roaming window is determined by the building size parameter. The low points are triangulated, and the remaining points are evaluated and subsequently added to the model if they meet the iteration angle and distance constraints. This process is repeated until no additional points are added within iterations. A second critical parameter is the maximum terrain angle constraint, which determines the maximum terrain angle allowed within the classification model.

Each tile was then imported into TerraScan and a surface model was created to examine the ground classification. Optimal GEO analysts visually reviewed the ground surface model and corrected errors in the ground classification such as vegetation, buildings, and bridges that were present. Optimal GEO analysts employ 3D visualization techniques to view the point cloud at multiple angles and in profile to ensure that non-ground points are removed from the ground classification. After the ground classification corrections were completed, the dataset was processed through a water classification routine that utilizes breaklines compiled to automatically classify hydro features. The water classification routine selects ground points within the breakline polygons and automatically classifies them as class 9, water. During this water classification routine, points that are within 0.30 meters of the hydrographic features are moved to class 20, an ignored ground due to breakline proximity. Overage points are then identified and used in TerraScan to set the overlap bit for the overage points and the withheld bit is set on the withheld points previously identified before theground classification routine was performed.

The lidar tiles were classified to the following classification schema:

- Class 1 = Unclassified, used for all other features that do not fit into the Classes 2, 7, 9, 17, 18, 20, 21, or 22, including vegetation, buildings, etc.
- Class 2 = Bare-Earth Ground
- Class 7 = Low Noise
- Class 9 = Water, points located within collected breaklines
- Class 17 = Bridge Decks
- Class 18 = High Noise
- Class 20 = Ignored Ground due to breakline proximity
- Class 21 = Snow
- Class 22 = Temporal Exclusion

After manual classification, the LAS tiles were peer reviewed and then underwent a final QA/QC. After the final QA/QC and corrections, all headers, appropriate point data records, and variable length records, including spatial reference information, are updated in TerraScan software, and then verified using proprietary Optimal GEO tools.

Lidar Qualitative Assessment

Optimal GEO's qualitative assessment utilizes a combination of statistical analysis and interpretative methodology or visualization to assess the quality of the data for a bare-earth digital terrain model (DTM). This includes creating pseudo image products such as lidar orthos produced from the intensity returns, Triangular Irregular Network (TIN)'s, Digital Elevation Models (DEM) and 3-dimensional models as well as reviewing the actual point cloud data. This process looks for anomalies in the data, areas where man-made structures or vegetation points may not have been classified properly to produce a bare-earth model, and other classification errors. This report will present representative examples where the lidar and post processing had issues as well as examples of where the lidar performed well.

Formatting

After the final QA/QC is performed and all corrections have been applied to the dataset, all lidar files are updated to the final format requirements and the final formatting, header information, point data records, and variable length records are verified using Optimal GEO's proprietary tools. Table 4 lists some of the main lidar header fields that are updated and verified.

Classified Lidar Formatting

Parameter	Requirement	Pass/Fail
LAS Version	1.4	Pass
Point Data Format	Format 6	Pass
Coordinate Reference System	NAD83 (2011) Universal Transverse Mercator (UTM) Zone 13 North, meters and NAVD88 (Geoid 18), meters in WKT Format	Pass
Global Encoder Bit	Should be set to 17 for Adjusted GPS Time	Pass
Time Stamp	Adjusted GPS Time (unique timestamps)	Pass
System ID	Should be set to the processing system/software and is set to TerraScan	Pass
Multiple Returns	The sensor shall be able to collect multiple returns per pulse and the return numbers are recorded	Pass
Intensity	16-bit intensity values are recorded for each pulse	Pass
Classification	Required Classes include: Class 1: Unclassified Class 2: Ground Class 7: Low Noise Class 9: Water Class 17: Bridge Decks Class 18: High Noise Class 20: Ignored Ground Class 21: Snow Class 22: Temporal Exclusion	Pass, class 21 and 22 were not utilized
Overlap and Withheld Points	Overlap (Overage) and Withheld points are set to the Overlap and Withheld bits	Pass
Scan Angle	Recorded for each pulse	Pass
XYZ Coordinates	Unique Easting, Northing, and Elevation coordinates are recorded for each pulse	Pass

Table 4. Classified Lidar Formatting.

Lidar Positional Accuracy

Background

Optimal GEO quantitatively tested the dataset by testing the vertical accuracy of the lidar. The vertical accuracy is tested by comparing the discreet measurement of the survey checkpoints to that of the interpolated value within the three closest lidar points that constitute the vertices of a three-dimensional triangular face of the TIN. Therefore, the result is that only a small sample of the lidar data is actually tested. However, there is an increased level of confidence with lidar data due to the relative accuracy. This relative accuracy in turn is based on how well one lidar point "fits" in comparison to the next contiguous lidar measurement and is verified as part of the initial processing. If the relative accuracy of a dataset is within specifications and the dataset passes vertical accuracy requirements at the location of survey checkpoints, the vertical accuracy results can be applied to the whole dataset with high confidence due to the passing relative accuracy. Typically, TerraScan software to test the classified lidar vertical accuracy, and ESRI ArcMap to test the DEM vertical accuracy so that two different software programs are used to validate the vertical accuracy for each project.

Survey Vertical Accuracy Checkpoints

For the final vertical accuracy assessment, one hundred and seventy-four (174) check points were surveyed for the project and are located within bare earth/open terrain, grass/weeds/crops, and forested/fully grown land cover categories. Please see the included survey report found in the survey folder of the deliverables structure which details and validates how the survey was completed for this project.

Checkpoints were evenly distributed throughout the project area to cover as many flight lines as possible using the “dispersed method” of placement.

Table 5 lists the location of the QA/QC checkpoints used to test the positional accuracy of the dataset.

Table 5. Ground Surveyed Vertical Accuracy Check Points.

Point ID	NAD83(2011), UTM Zone 13N		Elevation (m; NAVD88 Geoid18
	Easting X (m)	Northing Y (m)	
2001_2020_WY	418058.353	4980125.875	1131.943
2002_2020_WY	321277.530	4971586.937	1195.047
2003_2020_WY	412794.121	4936575.390	1137.311
2004_2020_WY	345052.839	4964334.634	1133.866
2005_2020_WY	328074.834	4943251.892	2338.848
2006_2020_WY	342186.954	4949300.187	1244.550
2007_2020_WY	318430.717	4965912.823	1432.322
2008_2020_WY	340789.954	4945406.133	1304.605
2009_2020_WY	279673.649	4963408.396	2776.551
2010_2020_WY	377626.060	4935263.292	1245.640
2011_2020_WY	272156.632	4986560.480	2725.007
2012_2020_WY	319822.275	4983074.896	1259.557
2013_2020_WY	365686.607	4966579.298	1367.040
2014_2020_WY	346613.486	4958684.622	1173.168
2015_2020_WY	374171.633	4945370.946	1355.469
2016_2020_WY	349693.694	4937390.726	1548.685
2017_2020_WY	331401.601	4957254.543	1245.073

Table 5. Ground Surveyed Vertical Accuracy Check Points continued.

2018_2020_WY	328280.258	4974838.044	1152.260
2019_2020_WY	336702.812	4965771.386	1249.803
2020_2020_WY	390387.196	4943664.080	1193.281
2020A_2020_WY	390412.353	4943709.655	1193.595
2020B_2020_WY	390438.396	4943639.831	1192.537
2021_2020_WY	286879.761	4965564.777	2770.081
2022_2020_WY	349179.051	4947677.332	1310.373
2023_2020_WY	353818.188	4979250.195	1072.823
2024_2020_WY	346298.524	4956398.547	1177.527
2025_2020_WY	398166.795	4970715.543	1293.493
2026_2020_WY	343109.575	4971828.900	1111.192
2027_2020_WY	373426.359	4974070.286	1163.631
2028_2020_WY	353460.187	4942320.884	1336.518
2029_2020_WY	344908.454	4981785.779	1136.889
2030_2020_WY	346405.442	4960887.975	1150.373
2031_2020_WY	282931.227	4975604.880	2592.209
2032_2020_WY	344567.622	4953654.719	1195.414
2033_2020_WY	324598.597	4965283.212	1291.215
2034_2020_WY	343051.073	4963197.180	1187.863
2035_2020_WY	413049.743	4959133.188	1089.832
2036_2020_WY	351909.539	4940312.362	1396.819
2037_2020_WY	362081.940	4954549.258	1192.411
2038_2020_WY	344213.936	4959704.929	1201.172
2039_2020_WY	389993.019	4980452.540	1147.300
2040_2020_WY	340355.128	4960189.067	1171.988
2041_2020_WY	378213.016	4957394.573	1420.996
2042_2020_WY	344396.537	4962344.134	1144.024
2043_2020_WY	301396.262	4982387.872	1566.073
2044_2020_WY	353972.266	4939732.381	1415.092
2045_2020_WY	371479.334	4952973.815	1260.297
2046_2020_WY	364280.168	4937800.249	1343.530
2047_2020_WY	311481.820	4980349.542	1397.237
2048_2020_WY	352715.062	4952523.547	1240.379
2049_2020_WY	419694.580	4974816.592	1057.615
2050_2020_WY	411444.260	4949848.005	1122.789
2051_2020_WY	361847.633	4945097.193	1287.865
2052_2020_WY	329192.650	4975070.216	1147.357
2053_2020_WY	380761.066	4951655.153	1375.369
2054_2020_WY	346703.213	4979164.385	1089.532
2055_2020_WY	392585.440	4962297.446	1243.728

Table 5. Ground Surveyed Vertical Accuracy Check Points continued.

2056_2020_WY	355239.055	4966476.407	1140.196
2057_2020_WY	404586.887	4979004.287	1284.786
2058_2020_WY	359913.717	4942028.240	1403.275
2058A_2020_WY	359271.826	4942519.251	1364.473
2059_2020_WY	395306.217	4951027.826	1158.981
2060_2020_WY	345628.337	4972196.406	1156.284
2060A_2020_WY	345638.524	4972133.141	1154.457
2061_2020_WY	418522.315	4942848.780	1147.001
2062_2020_WY	385694.320	4937854.055	1214.913
2062A_2020_WY	387489.657	4940482.743	1210.031
2062B_2020_WY	386281.772	4938110.273	1214.464
2063_2020_WY	354793.424	4959971.428	1188.176
2064_2020_WY	399467.205	4952376.053	1150.634
2064A_2020_WY	399531.565	4952400.820	1149.929
2065_2020_WY	365965.954	4970557.488	1358.991
2066_2020_WY	294637.068	4959618.333	2466.744
2067_2020_WY	308951.470	4944668.423	2797.222
2068_2020_WY	282637.899	4960209.844	2798.882
2069_2020_WY	305484.527	4971141.495	2412.293
2070_2020_WY	300747.304	4960509.956	2464.006
2071_2020_WY	309844.161	4954652.769	2671.256
2072_2020_WY	297044.295	4960113.555	2450.357
2073_2020_WY	306634.546	4959235.099	2415.621
2074_2020_WY	291725.742	4959018.196	2505.551
2075_2020_WY	305154.239	4954165.057	2544.557
2076_2020_WY	287197.835	4958306.701	2622.127
2077_2020_WY	297026.773	4964489.252	2424.403
2078_2020_WY	302335.076	4951547.242	2628.542
2079_2020_WY	307057.489	4948526.451	2632.940
2080_2020_WY	304617.135	4960381.303	2342.632
2081_2020_WY	310555.195	4959049.834	2452.826
2082_2020_WY	298727.236	4960004.385	2448.158
2083_2020_WY	317250.056	4942279.918	2580.213
2084_2020_WY	302106.970	4953038.538	2600.851
2085_2020_WY	324174.983	4940915.881	2348.030
2086_2020_WY	289786.973	4957215.004	2566.526
2087_2020_WY	319569.434	4942366.344	2537.244
2088_2020_WY	302083.600	4948334.329	2698.084
2089_2020_WY	313331.039	4944430.202	2738.651
2190_2020_WY	318911.173	4940913.517	2648.154

Table 5. Ground Surveyed Vertical Accuracy Check Points continued.

3001_2020_WY	351414.295	4967803.108	1133.751
3002_2020_WY	397312.475	4953158.238	1160.615
3003_2020_WY	272389.931	4986167.437	2727.166
3004_2020_WY	414351.231	4965662.670	1107.849
3004A_2020_WY	415241.422	4968633.657	1087.085
3005_2020_WY	340465.289	4948629.767	1291.845
3006_2020_WY	347473.463	4980417.090	1084.613
3007_2020_WY	323032.205	4973372.569	1188.269
3008_2020_WY	365779.361	4966660.408	1364.569
3009_2020_WY	331392.418	4957523.374	1245.712
3010_2020_WY	353785.708	4950423.261	1248.652
3011_2020_WY	364757.811	4979324.427	1114.501
3012_2020_WY	390709.015	4944086.528	1189.759
3013_2020_WY	301411.045	4982362.895	1565.424
3014_2020_WY	357473.040	4965421.471	1130.316
3015_2020_WY	364482.394	4937625.108	1330.093
3016_2020_WY	320071.656	4984268.381	1299.806
3017_2020_WY	337099.342	4965079.356	1229.664
3018_2020_WY	325488.973	4963022.876	1302.061
3019_2020_WY	325058.247	4940797.911	2355.888
3020_2020_WY	393571.337	4960768.317	1200.427
3021_2020_WY	378373.285	4936246.334	1246.077
3022_2020_WY	344784.259	4962998.349	1160.450
3023_2020_WY	402762.642	4955985.750	1125.322
3024_2020_WY	368030.500	4955331.595	1221.321
3025_2020_WY	342128.808	4974572.771	1111.153
3026_2020_WY	334876.511	4952593.239	1378.459
3027_2020_WY	344612.469	4956040.689	1193.280
3028_2020_WY	280922.322	4975430.902	2687.330
3029_2020_WY	350082.724	4947542.596	1306.143
3030_2020_WY	354377.600	4979726.052	1069.869
3031_2020_WY	386029.066	4942707.970	1222.360
3032_2020_WY	412241.586	4965730.184	1092.324
3032A_2020_WY	406161.510	4963712.600	1122.617
3033_2020_WY	330115.997	4976103.215	1189.001
3034_2020_WY	383216.081	4959222.706	1293.514
3035_2020_WY	397966.628	4970672.440	1280.724
3036_2020_WY	389327.421	4979765.915	1190.866
3037_2020_WY	385431.765	4960716.487	1287.130
3038_2020_WY	413664.535	4949088.196	1167.877

Table 5. Ground Surveyed Vertical Accuracy Check Points continued.

3039_2020_WY	280337.885	4963115.400	2755.983
3040_2020_WY	360145.211	4942120.523	1405.003
3041_2020_WY	318141.950	4966445.099	1433.073
3041A_2020_WY	317861.527	4966269.810	1421.330
3042_2020_WY	325140.398	4978211.679	1190.821
3043_2020_WY	335751.799	4976652.937	1192.631
3044_2020_WY	377993.171	4944572.159	1309.655
3045_2020_WY	410591.671	4943126.336	1162.382
3046_2020_WY	413133.382	4937464.849	1155.777
3047_2020_WY	352545.082	4955630.296	1304.113
3048_2020_WY	360462.720	4952085.794	1233.844
3049_2020_WY	386173.080	4967177.463	1381.849
3050_2020_WY	276971.357	4975579.708	2865.001
3051_2020_WY	300137.148	4982583.530	1536.401
3052_2020_WY	347323.353	4937837.278	1597.613
3052A_2020_WY	347299.308	4937835.773	1598.493
3053_2020_WY	334415.355	4942570.488	2069.464
3054_2020_WY	337054.411	4959540.038	1191.000
3055_2020_WY	281070.466	4965976.543	2637.705
3056_2020_WY	328909.273	4944450.752	2359.428
3057_2020_WY	300626.289	4960541.707	2462.135
3058_2020_WY	301059.775	4946460.138	2745.586
3059_2020_WY	301632.577	4944982.665	2725.410
3060_2020_WY	311500.821	4953590.215	2782.624
3061_2020_WY	306889.131	4959107.643	2434.840
3061A_2020_WY	306884.080	4959116.804	2434.541
3062_2020_WY	305862.306	4954220.633	2545.784
3062A_2020_WY	305872.188	4954186.290	2544.769
3063_2020_WY	297976.779	4964713.654	2463.556
3064_2020_WY	314499.787	4944314.309	2691.337
3065_2020_WY	323067.636	4941595.421	2391.649
3066_2020_WY	310104.739	4961227.770	2439.647
3066A_2020_WY	310350.252	4960762.088	2444.140
3067_2020_WY	307442.049	4946283.814	2721.082
3068_2020_WY	317753.922	4942492.719	2578.821
3069_2020_WY	294592.628	4959525.561	2471.474
3070_2020_WY	303928.974	4961366.762	2332.711

Vertical Accuracy Test Procedures

Non-vegetated Vertical Accuracy

NVA (Non-vegetated Vertical Accuracy) is determined with check points located only in non-vegetated terrain, including open terrain (grass, dirt, sand, and/or rocks) and urban areas, where there is a very high probability that the lidar sensor will have detected the bare-earth ground surface and where random errors are expected to follow a normal error distribution. The NVA determines how well the calibrated lidar sensor performed. With a normal error distribution, the vertical accuracy at the 95% confidence level is computed as the vertical root mean square error (RMSEz) of the checkpoints x 1.9600. For the WY Sheridan Lidar Project, vertical accuracy must be 19.6 cm or less based on an RMSEz of 10 cm x 1.9600.

Vegetated Vertical Accuracy

VVA (Vegetated Vertical Accuracy) is determined with all checkpoints in vegetated land cover categories, including tall grass, weeds, crops, brush and low trees, and fully forested areas, where there is a possibility that the lidar sensor and post-processing may yield elevation errors that do not follow a normal error distribution. VVA at the 95% confidence level equals the 95th percentile error for all checkpoints in all vegetated land cover categories combined. The WY Sheridan lidar project VVA standard is 30 cm based on the 95th percentile. Here, Accuracy_z differs from VVA because Accuracy_z assumes elevation errors follow a normal error distribution where RMSE procedures are valid, whereas VVA assumes lidar errors may not follow a normal error distribution in vegetated categories, making the RMSE process invalid. The relevant testing criteria are summarized in Table 6.

Quantitative Criteria	Measure of Acceptability
Non-Vegetated Vertical Accuracy (NVA) in open terrain and urban land cover categories using RMSE_z *1.9600	19.6 cm (based on RMSE_z (10 cm) * 1.9600)
Vegetated Vertical Accuracy (VVA) in all vegetated land cover categories combined at the 95% confidence level	30 cm (based on 95th percentile)

Table 6. Acceptance Criteria

The primary QA/QC vertical accuracy testing steps used by Optimal GEO are summarized as follows:

1. The ground team surveyed QA/QC vertical checkpoints in accordance with the project's specifications.
2. Next, Optimal GEO interpolated the bare-earth lidar DTM to provide the z-value for every checkpoint.
3. Optimal GEO then computed the associated z-value differences between the interpolated z-value from the lidar data and the ground truth survey checkpoints and computed NVA, VVA, and other statistics.
4. The data were analyzed by Optimal GEO to assess the accuracy of the data. The review process examined the various accuracy parameters as defined by the scope of work. The overall descriptive statistics of each dataset were computed to assess any trends or anomalies. This report provides tables, graphs, and figures to summarize and illustrate data quality.

Vertical Accuracy Results

Table 7 summarizes the tested vertical accuracy resulting from a comparison of the surveyed checkpoints to the elevation values present within the fully classified lidar LAS files.

Land Cover Category	# of Points	NVA — Non-vegetated Vertical Accuracy ($RMSE_z$ x 1.9600) Spec=19.6 cm	VVA — Vegetated Vertical Accuracy (95th Percentile) Spec=29.4 cm NVA
NVA	72	6.9 cm	
VVA	59		12.6 cm

Table 7. Tested NVA and VVA

This lidar dataset was tested to meet ASPRS Positional Accuracy Standards for Digital Geospatial Data (2014) for a 10 cm RMSEz Vertical Accuracy Class. Actual NVA accuracy was found to be $RMSE_z$ =3.5 cm, equating to ± 6.9 cm at 95% confidence level. Actual VVA accuracy was found to be ± 12.6 cm at the 95th Percentile.

Table 8 provides overall descriptive statistics.

100 % of Totals	# of Points	RMSEz (m) @95% CL	Mean (m)	Median (m)	Skew	Std Dev (m)	Min (m)	Max (m)
NVA	72	0.069	-0.007	-0.002	-0.320	0.035	-0.078	0.059
VVA	59	N/A	0.019	0.025	0.164	0.062	-0.095	0.187

Table 8. Overall Descriptive Statistics

Based on the vertical accuracy testing conducted by Optimal GEO, the lidar dataset for the WY Sheridan Lidar Project QL2 Delivery satisfies the project's pre-defined vertical accuracy criteria.

Breakline Production & Qualitative Assessment Report

Breakline Production Methodology

Optimal GEO digitized the project's hydrographic breaklines from the lidar utilizing the TIN and intensity for visualization and placement. This technique enables Optimal GEO to produce accurate 3D hydrographic breaklines for features that are consistent with the lidar data at the time of airborne survey. All drainage breaklines are monotonically enforced to show downhill flow. Water bodies are at a constant elevation where the water body has been captured at the lowest elevation. Bridge deck breaklines are compiled directly from the project's DEMs. Bridge Breaklines are used where necessary to show the logical flow of the terrain beneath bridge decks and to prevent bridge saddles in the bare earth DEMs. All features were compiled in accordance with the project's Data Dictionary.

Breakline Qualitative Assessment

Completeness and horizontal placement are verified through visual reviews against lidar intensity imagery. Automated checks are applied on all breakline features to validate topology, including the 3D connectivity of features, enforced monotonicity on linear hydrographic breaklines, and flatness on water bodies. After all corrections and edits to the breakline features, the breaklines are imported into the final GDB and verified for correct formatting.

Breakline Data Dictionary

The following data dictionary was used for this project.

Horizontal and Vertical Datum

The horizontal datum shall be North American Datum of 1983, 2011 adjustment (NAD83 2011), Units in Meters. The vertical datum shall be referenced to the North American Vertical Datum of 1988, Units in Meters. Geoid18 shall be used to convert ellipsoidal heights to orthometric heights.

Coordinate System and Projection

All data shall be projected to Universal Transverse Mercator (UTM) Zone 13 North, Horizontal Units in Meters and Vertical Units in Meters.

Inland Streams and Rivers

Feature Class: BREAKLINES
Feature Type: Polyline
Contains Z Values: Yes
XY Resolution: Accept Default Setting
XY Tolerance: 0.003

Contains M Values: No
Annotation Subclass: None
Z Resolution: Accept Default Setting
Z Tolerance: 0.001

Description

This polygon feature class will depict linear hydrographic features with a width greater than 100 feet.

Table Definition

Field Name	Data Type	Allow Null Values	Default Value	Domain	Precision	Scale	Length	Responsibility
OBJECTID	Object ID							Assigned by Software
SHAPE	Geometry							Assigned by Software
SHAPE_LENGTH	Double	Yes			0	0		Calculated by Software
Type	String	Yes			0	0	25	Assigned by Analyst

Feature Definition

Description	Definition	Capture Rules
Streams and Rivers	Linear hydrographic features such as streams, rivers, canals, etc. with an average width greater than 100 feet. In the case of embankments, if the feature forms a natural dual line channel, then capture it consistent with the capture rules. Other natural or manmade embankments will not qualify for this project.	Capture features showing dual line (one on each side of the feature). Average width shall be greater than 100 feet to show as a double line. Each vertex placed should maintain vertical integrity. Generally, both banks shall be collected to show consistent downhill flow. There are exceptions to this rule where a small branch or offshoot of the stream or river is present. The banks of the stream must be captured at the same elevation to ensure flatness of the water feature. If the elevation of the banks appears to be different see the task manager or PM for further guidance. Breaklines must be captured at or just below the elevations of the immediately surrounding terrain. Under no circumstances should a feature be elevated above the surrounding lidar points. Acceptable variance in the negative direction will be defined for each project individually. These instructions are only for docks or piers that follow the coastline or water's edge, not for docks or piers that extend perpendicular from the land into the water. If it can be reasonably determined where the edge of water most probably falls, beneath the dock or pier, then the edge of water will be collected at the elevation of the water where it can be directly measured. If there is a clearly-indicated headwall or bulkhead adjacent to the dock or pier and it is evident that the waterline is most probably adjacent to the headwall or bulkhead, then the water line will follow the headwall or bulkhead at the elevation of the water where it can be directly measured. If there is no clear indication of the location of the water's edge beneath the dock or pier, then the edge of water will follow the outer edge of the dock or pier as it is adjacent to the water, at the measured elevation of the water. Every effort should be made to avoid breaking a stream or river into segments. Dual line features shall break at road crossings (culverts). In areas where a bridge is present the dual line feature shall continue through the bridge. Islands: The double line stream shall be captured around an island if the island is greater than 1 acre. In this case a segmented polygon shall be used around the island to allow for the island feature to remain as a "hole" in the feature.

Inland Ponds and Lakes

Feature Class: BREAKLINES
Feature Type: Polygon
Contains Z Values: Yes
XY Resolution: Accept Default Setting
XY Tolerance: 0.003

Contains M Values: No
Annotation Subclass: None
Z Resolution: Accept Default Setting
Z Tolerance: 0.001

Description

This polygon feature class will depict closed water body features that are at a constant elevation.

Table Definition

Field Name	Data Type	Allow Null Values	Default Value	Domain	Precision	Scale	Length	Responsibility
OBJECTID	Object ID							Assigned by Software
SHAPE	Geometry							Assigned by Software
SHAPE_LENGTH	Double	Yes			0	0		Calculated by Software
TYPE	String	Yes					25	Assigned by Analyst
SHAPE_AREA	Double	Yes			0	0		Calculated by Software

Feature Definition

Description	Definition	Capture Rules
Ponds and Lakes	Land/Water boundaries of constant elevation water bodies such as lakes, reservoirs, ponds, etc. Features shall be defined as closed polygons and contain an elevation value that reflects the best estimate of the water elevation at the time of data capture. Water body features will be captured for features 2 acres in size or greater. "Donuts" will exist where there are islands within a closed water body feature.	Water bodies shall be captured as closed polygons with the water feature to the right. The compiler shall take care to ensure that the z-value remains consistent for all vertices placed on the water body. Breaklines must be captured at or just below the elevations of the immediately surrounding terrain. Under no circumstances should a feature be elevated above the surrounding lidar points. Acceptable variance in the negative direction will be defined for each project individually. An Island within a Closed Water Body Feature that is 1 acre in size or greater will also have a "donut polygon" compiled. These instructions are only for docks or piers that follow the coastline or water's edge, not for docks or piers that extend perpendicular from the land into the water. If it can be reasonably determined where the edge of water most probably falls, beneath the dock or pier, then the edge of water will be collected at the elevation of the water where it can be directly measured. If there is a clearly-indicated headwall or bulkhead adjacent to the dock or pier and it is evident that the waterline is most probably adjacent to the headwall or bulkhead, then the water line will follow the headwall or bulkhead at the elevation of the water where it can be directly measured. If there is no clear indication of the location of the water's edge beneath the dock or pier, then the edge of water will follow the outer edge of the dock or pier as it is adjacent to the water, at the measured elevation of the water.

DEM Production & Qualitative Assessment

DEM Production Methodology

Optimal GEO generates a DEM from a TIN using points and breaklines utilizing a combination of TerraSolid (v20) and GDAL (2.4.0) software packages. Once the DEM is created, it is reviewed in ArcGIS for any issues requiring corrections, including remaining lidar misclassifications, erroneous breakline elevations, poor hydro-flattening or hydro-enforcement, and processing artifacts. After corrections are applied, the DEM is then split into individual tiles in accordance with the project tiling scheme. The tiles are verified for final formatting and then loaded into Global Mapper to ensure no missing or corrupt tiles and to ensure seamlessness across tile boundaries.

DEM Qualitative Assessment

Optimal GEO performed a comprehensive qualitative assessment of the bare earth DEM deliverables to ensure that all tiled DEM products were delivered with the proper extents, were free of processing artifacts, and contained the proper referencing information. This process was performed in ArcGIS software with the use of a tool set Optimal GEO has developed to verify that the raster extents match those of the tile grid and contain the correct projection information. The DEM data was reviewed at a scale of 1:5000 to review for artifacts caused by the DEM generation process and to review the hydro-flattened features. To perform this review Optimal GEO creates hillshade models and overlays a partially transparent colorized elevation model to review for these issues. All corrections are completed using

Optimal GEO's proprietary correction workflow. Upon completion of the corrections, the DEM data is loaded into Global Mapper for its second review and to verify corrections. Once the DEMs are tiled out, the final tiles are again loaded into Global Mapper to ensure coverage, extents, and that the final tiles are seamless.

DEM Vertical Accuracy Results

One hundred and thirty-one (131) checkpoints that were used to test the vertical accuracy of the lidar were used to validate the vertical accuracy of the final DEM products. Accuracy results may vary between the source lidar and final DEM deliverable. DEMs are created by averaging several lidar points within each pixel which may result in slightly different elevation values at each survey checkpoint when compared to the source LAS, which does not average several lidar points together but may interpolate (linearly) between three points to derive an elevation value. The vertical accuracy of the DEM is tested by extracting the elevation of the pixel that contains the x/y coordinates of the checkpoint and comparing these DEM elevations to the surveyed elevations. Optimal GEO typically uses TerraScan software to test the swath lidar vertical accuracy, to test the classified lidar vertical accuracy, and ESRI ArcMap to test the DEM vertical accuracy so that two different software programs are used to validate the vertical accuracy for each project.

Table 10 summarizes the tested vertical accuracy results from a comparison of the surveyed checkpoints to the elevation values present within the final DEM dataset.

Land Cover Category	# of Points	NVA — Non-vegetated Vertical Accuracy ($RMSE_z$ x 1.9600) Spec=19.6 cm	VVA — Vegetated Vertical Accuracy (95th Percentile) Spec=30 cm
NVA	72	7.7 cm	
VVA	59		10.7 cm

Table 10. DEM tested NVA and VVA

This DEM dataset was tested to meet ASPRS Positional Accuracy Standards for Digital Geospatial Data (2014) for a 10 cm RMSEz Vertical Accuracy Class. Actual NVA accuracy was found to be $RMSE_z$ = 3.9 cm, equating to +/- 7.7 cm at 95% confidence level. Actual VVA accuracy was found to be +/- 10.7 cm at the 95th percentile.

Table 11 provides overall descriptive statistics.

100 % of Totals	# of Points	RMSEz (m) @95% CL	Mean (m)	Median (m)	Skew	Std Dev (m)	Min (m)	Max (m)
NVA	72	0.077	-0.006	0.001	-0.232	0.039	-0.085	0.073
VVA	59	N/A	0.016	0.028	0.121	0.063	-0.107	0.209

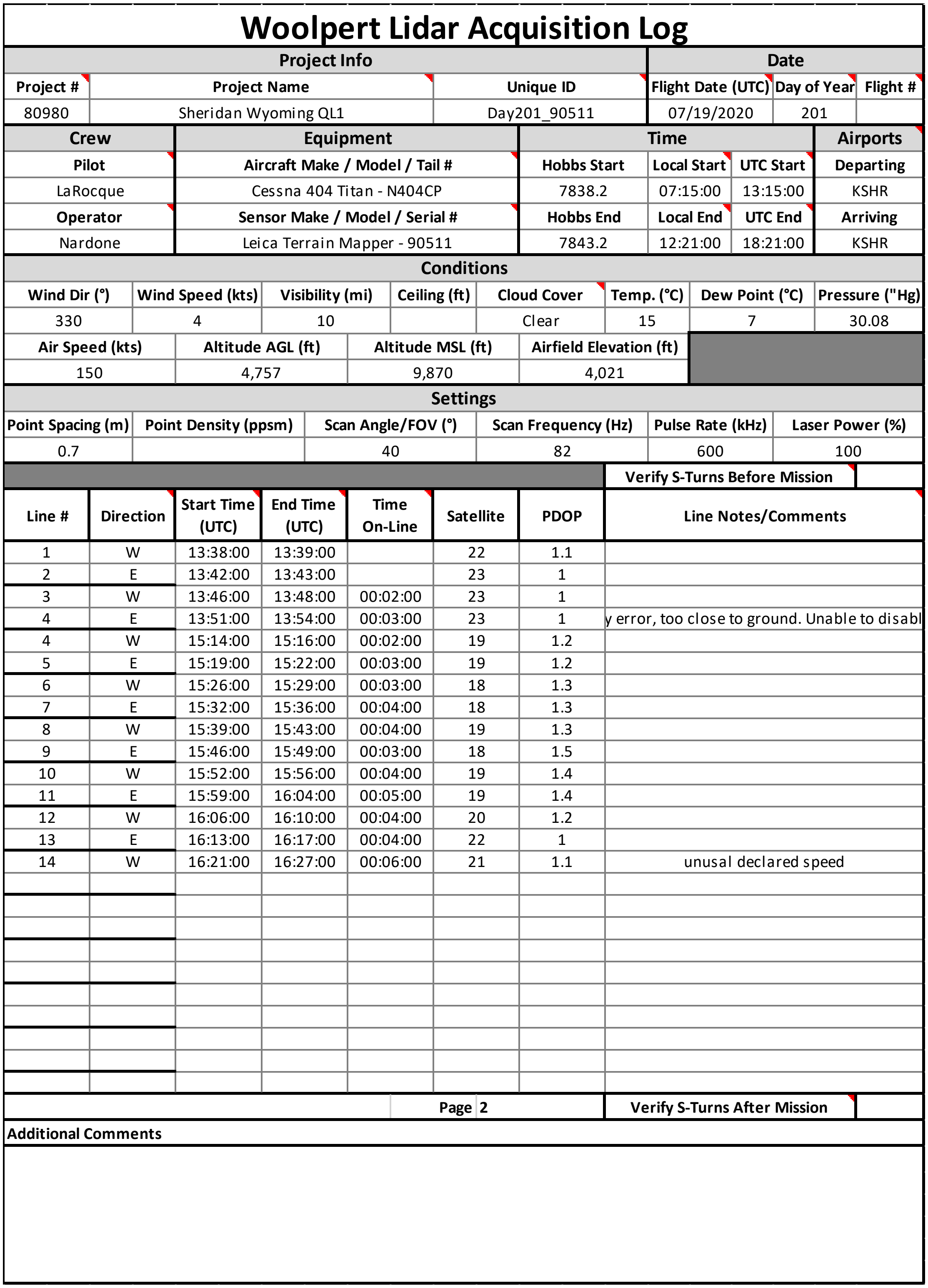
Table 11. Overall Descriptive Statistics

Based on the vertical accuracy testing conducted by Optimal GEO, the DEM dataset for the WY Sheridan Lidar Project QL2 Delivery satisfies the project's pre-defined vertical accuracy criteria.

Appendix A: Flightlogs, IMU, and GPS Processing Reports

Mission 1 (20100719)

Flight Log



Woolpert Lidar Acquisition Log

Project Info			Date		
Project #	**Project Name**	**Unique ID**	**Flight Date (UTC)**	**Day of Year**	**Flight #**
80980	Sheridan Wyoming QL1	Day201_90511	07/19/2020	201	

Crew	Equipment	Time			Airports
Pilot	**Aircraft Make / Model / Tail #**	**Hobbs Start**	**Local Start**	**UTC Start**	**Departing**
LaRocque	Cessna 404 Titan - N404CP	7838.2	07:15:00	13:15:00	KSHR
Operator	**Sensor Make / Model / Serial #**	**Hobbs End**	**Local End**	**UTC End**	**Arriving**
Nardone	Leica Terrain Mapper - 90511	7843.2	12:21:00	18:21:00	KSHR

Conditions

Wind Dir (°)	Wind Speed (kts)	Visibility (mi)	Ceiling (ft)	Cloud Cover	Temp. (°C)	Dew Point (°C)	Pressure ("Hg)
330	4	10		Clear	15	7	30.08

Air Speed (kts)	Altitude AGL (ft)	Altitude MSL (ft)	Airfield Elevation (ft)
150	4,757	9,870	4,021

Settings

Point Spacing (m)	Point Density (ppsm)	Scan Angle/FOV (°)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power (%)
0.7		40	82	600	100

Verify S-Turns Before Mission

Line #	Direction	Start Time (UTC)	End Time (UTC)	Time On-Line	Satellite	PDOP	Line Notes/Comments
1	W	13:38:00	13:39:00		22	1.1	
2	E	13:42:00	13:43:00		23	1	
3	W	13:46:00	13:48:00	00:02:00	23	1	
4	E	13:51:00	13:54:00	00:03:00	23	1	y error, too close to ground. Unable to disabl
4	W	15:14:00	15:16:00	00:02:00	19	1.2	
5	E	15:19:00	15:22:00	00:03:00	19	1.2	
6	W	15:26:00	15:29:00	00:03:00	18	1.3	
7	E	15:32:00	15:36:00	00:04:00	18	1.3	
8	W	15:39:00	15:43:00	00:04:00	19	1.3	
9	E	15:46:00	15:49:00	00:03:00	18	1.5	
10	W	15:52:00	15:56:00	00:04:00	19	1.4	
11	E	15:59:00	16:04:00	00:05:00	19	1.4	
12	W	16:06:00	16:10:00	00:04:00	20	1.2	
13	E	16:13:00	16:17:00	00:04:00	22	1	
14	W	16:21:00	16:27:00	00:06:00	21	1.1	unusal declared speed

Page 2

Verify S-Turns After Mission

Additional Comments

Mission 1 (20100719) continued

Woolpert Lidar Acquisition Log

Project Info			Date		
Project #	**Project Name**	**Unique ID**	**Flight Date (UTC)**	**Day of Year**	**Flight #**
80980	Sheridan Wyoming QL1	Day201_90511	07/19/2020	201	

Crew	Equipment	Time			Airports
Pilot	**Aircraft Make / Model / Tail #**	**Hobbs Start**	**Local Start**	**UTC Start**	**Departing**
LaRocque	Cessna 404 Titan - N404CP	7838.2	07:15:00	13:15:00	KSHR
Operator	**Sensor Make / Model / Serial #**	**Hobbs End**	**Local End**	**UTC End**	**Arriving**
Nardone	Leica Terrain Mapper - 90511	7843.2	12:21:00	18:21:00	KSHR

Conditions

Wind Dir (°)	Wind Speed (kts)	Visibility (mi)	Ceiling (ft)	Cloud Cover	Temp. (°C)	Dew Point (°C)	Pressure ("Hg)
330	4	10		Clear	15	7	30.08

Air Speed (kts)	Altitude AGL (ft)	Altitude MSL (ft)	Airfield Elevation (ft)
150	9,842	13,278	4,021

Settings

Point Spacing (m)	Point Density (ppsm)	Scan Angle/FOV (°)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power (%)
0.7		40	82	600	100

Verify S-Turns Before Mission

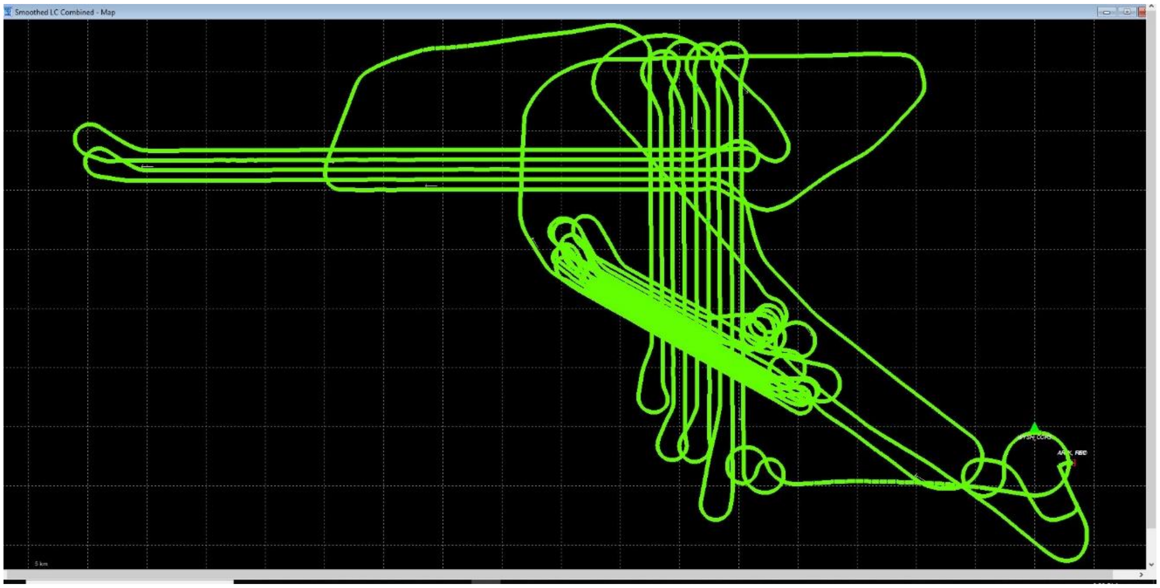
Line #	Direction	Start Time (UTC)	End Time (UTC)	Time On-Line	Satellite	PDOP	Line Notes/Comments
1	W	14:15:00	14:25:00		21	1.1	QL2_BLK 1
2	E	14:28:00	14:38:00		23	1	
3	W	14:41:00	14:51:00	00:10:00	23	0.9	
4	E	14:53:00	15:02:00	00:09:00	23	0.9	Clouds forming
5	W	16:42:00	16:52:00	00:10:00	21	1.1	
1	S	16:56:00	17:00:00	00:04:00	22	1.2	QL2_BLK 2
2	N	17:03:00	17:07:00	00:04:00	23	1.2	
3	S	17:10:00	17:15:00	00:05:00	23	1.1	
4	N	17:18:00	17:23:00	00:05:00	23	1.1	
5	S	17:26:00	17:30:00	00:04:00	23	1.1	
6	N	17:33:00	17:38:00	00:05:00	23	1.1	
7	S	17:41:00	17:46:00	00:05:00	23	1.1	
8	N	17:50:00	17:56:00	00:06:00	22	1.3	
9	S	17:59:00	18:05:00	00:06:00	23	1.1	Clouds south end

Page 2

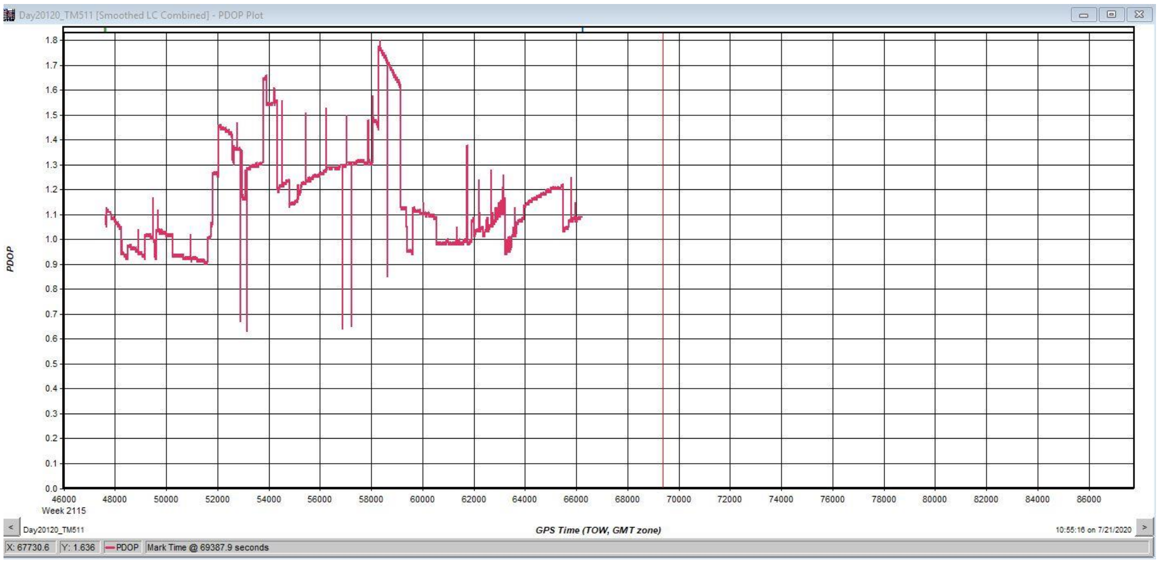
Verify S-Turns After Mission

Additional Comments

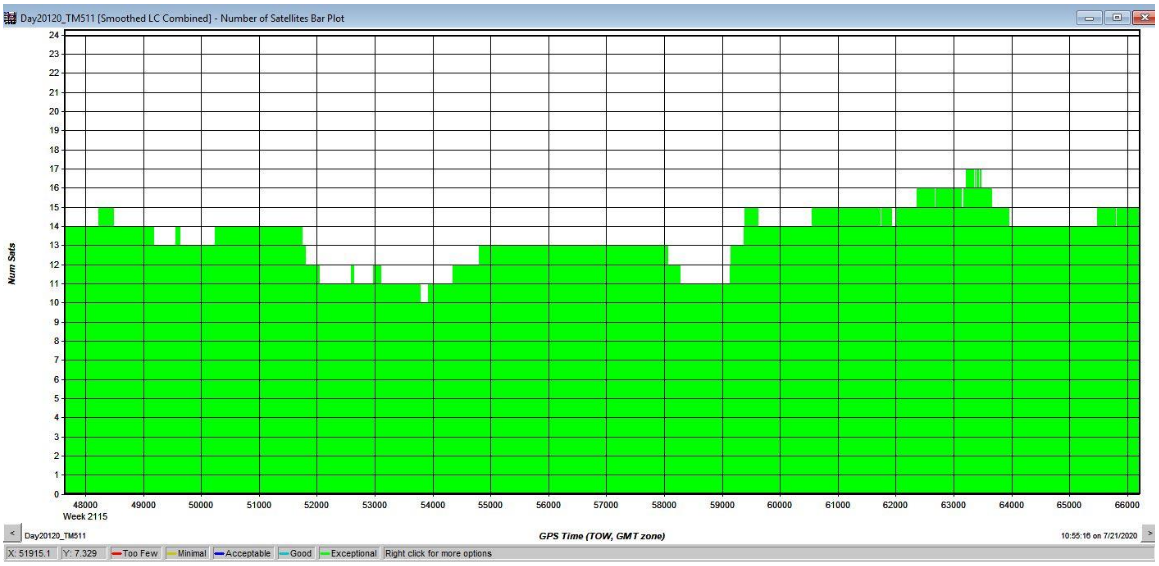
Mission Trajectory



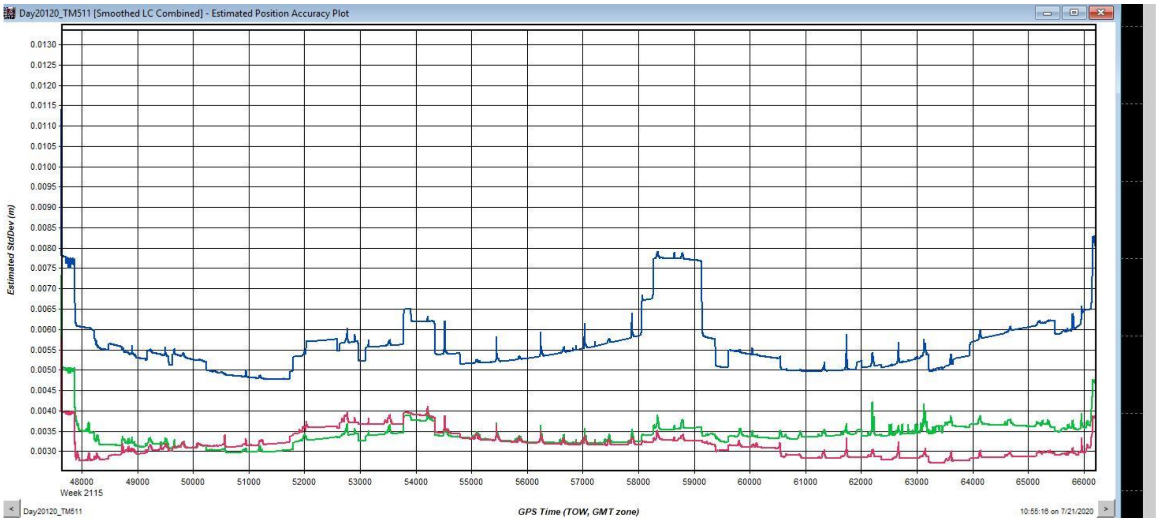
PDOP



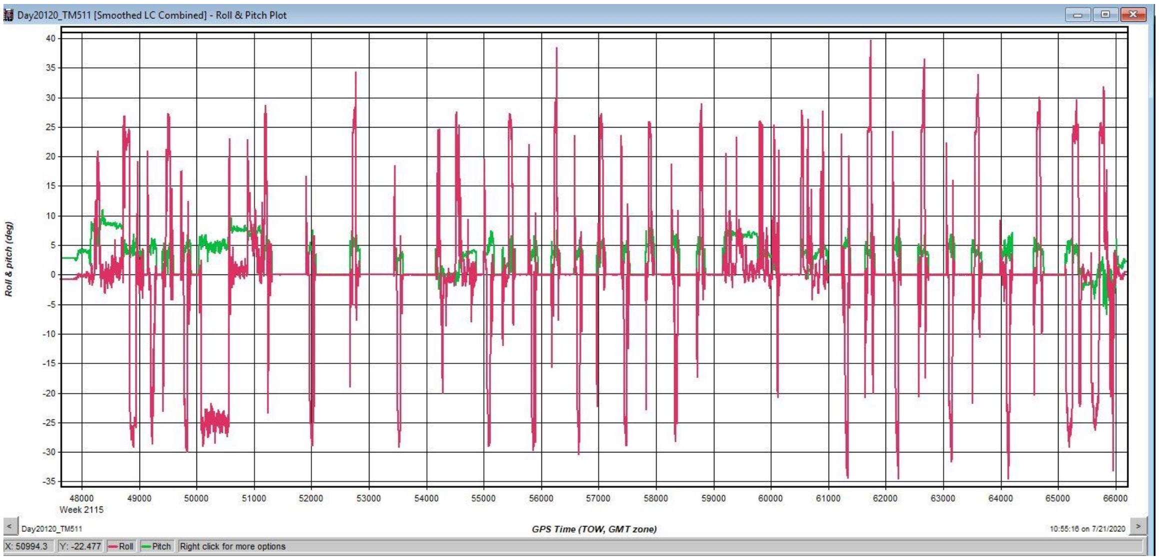
Satellites



RMS (m)

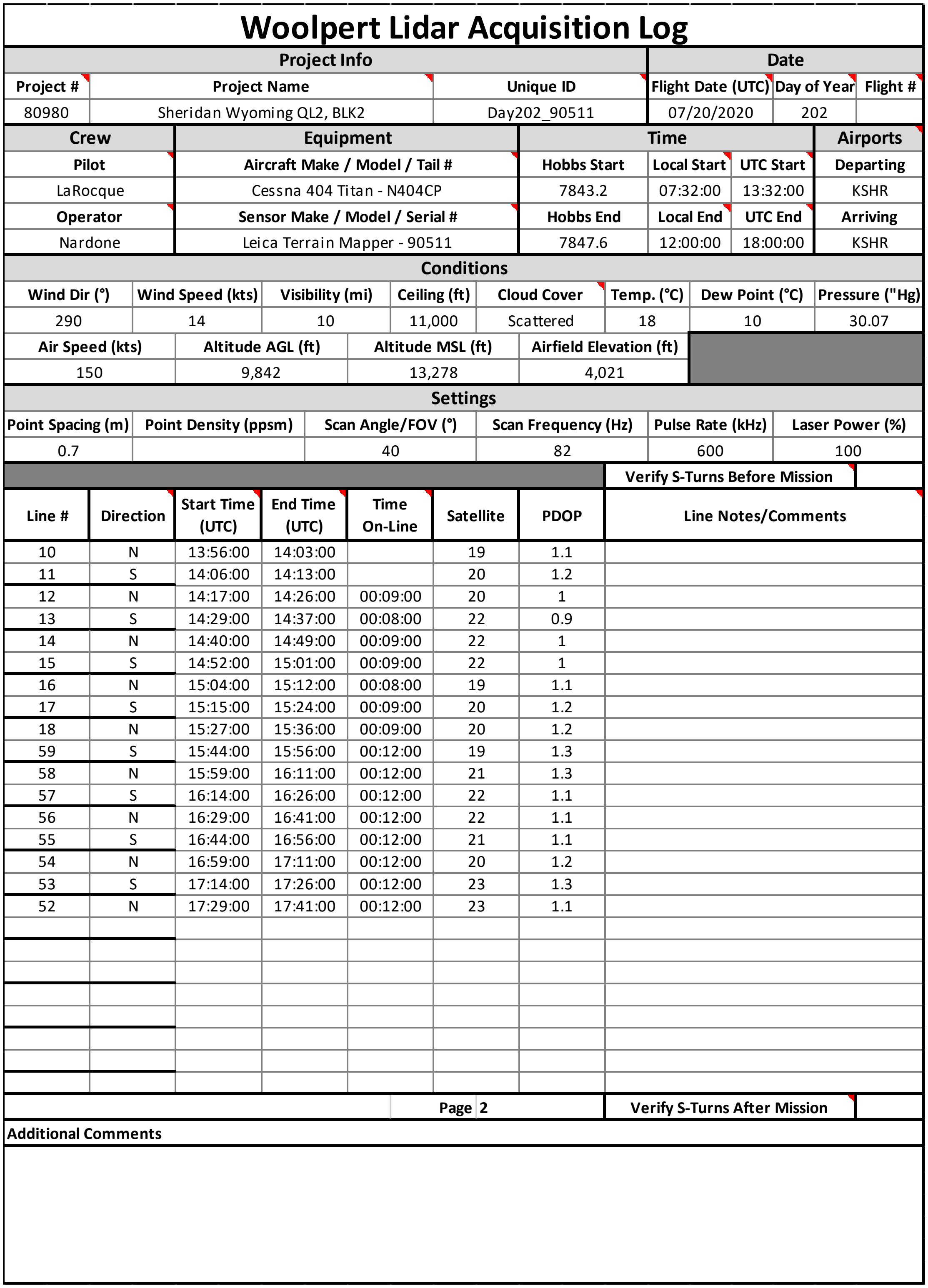


RPH (deg)


Day20120_TM511 [Smoothed LC Combined] - Roll & Pitch Plot
Roll & pitch (deg)
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
48000
Week 2115
49000
50000
51000
52000
53000
54000
55000
56000
57000
58000
59000
60000
61000
62000
63000
64000
65000
66000
<
Day20120_TM511
GPS Time (TOW, GMT zone)
10:55:16 on 7/21/2020
>
X: 50994.3
Y: -22.477
Roll
Pitch
Right click for more options

Mission 2 (20200720)

Flight Log



Woolpert Lidar Acquisition Log

Project Info			Date		
Project #	**Project Name**	**Unique ID**	**Flight Date (UTC)**	**Day of Year**	**Flight #**
80980	Sheridan Wyoming QL2, BLK2	Day202_90511	07/20/2020	202	

Crew	Equipment	Time			Airports
Pilot	**Aircraft Make / Model / Tail #**	**Hobbs Start**	**Local Start**	**UTC Start**	**Departing**
LaRocque	Cessna 404 Titan - N404CP	7843.2	07:32:00	13:32:00	KSHR
Operator	**Sensor Make / Model / Serial #**	**Hobbs End**	**Local End**	**UTC End**	**Arriving**
Nardone	Leica Terrain Mapper - 90511	7847.6	12:00:00	18:00:00	KSHR

Conditions

Wind Dir (°)	Wind Speed (kts)	Visibility (mi)	Ceiling (ft)	Cloud Cover	Temp. (°C)	Dew Point (°C)	Pressure ("Hg)
290	14	10	11,000	Scattered	18	10	30.07

Air Speed (kts)	Altitude AGL (ft)	Altitude MSL (ft)	Airfield Elevation (ft)
150	9,842	13,278	4,021

Settings

Point Spacing (m)	Point Density (ppsm)	Scan Angle/FOV (°)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power (%)
0.7		40	82	600	100

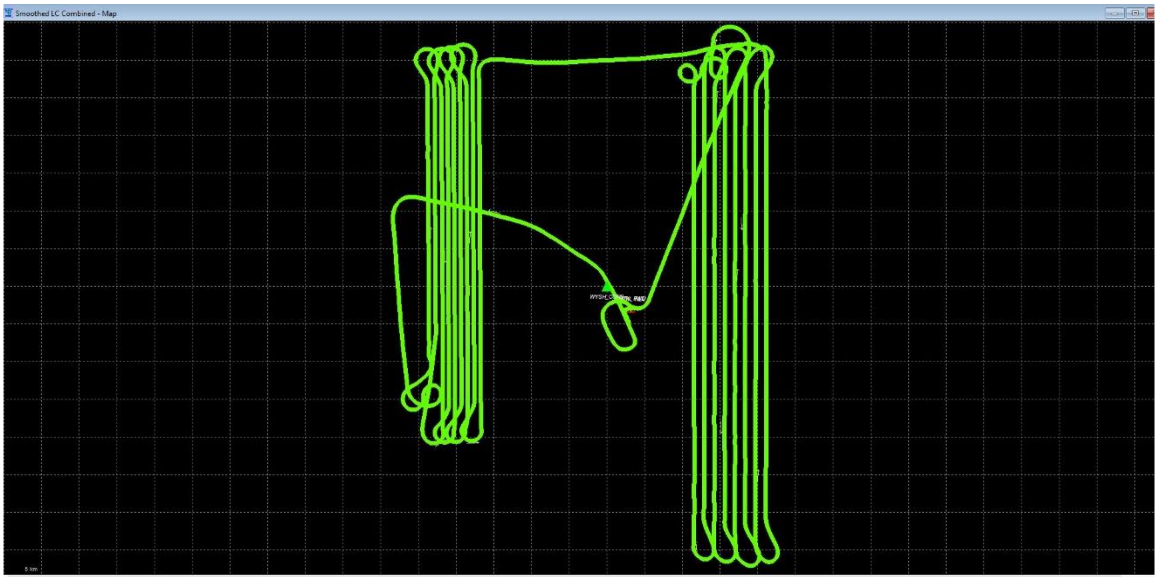
Verify S-Turns Before Mission

Line #	Direction	Start Time (UTC)	End Time (UTC)	Time On-Line	Satellite	PDOP	Line Notes/Comments
10	N	13:56:00	14:03:00		19	1.1	
11	S	14:06:00	14:13:00		20	1.2	
12	N	14:17:00	14:26:00	00:09:00	20	1	
13	S	14:29:00	14:37:00	00:08:00	22	0.9	
14	N	14:40:00	14:49:00	00:09:00	22	1	
15	S	14:52:00	15:01:00	00:09:00	22	1	
16	N	15:04:00	15:12:00	00:08:00	19	1.1	
17	S	15:15:00	15:24:00	00:09:00	20	1.2	
18	N	15:27:00	15:36:00	00:09:00	20	1.2	
59	S	15:44:00	15:56:00	00:12:00	19	1.3	
58	N	15:59:00	16:11:00	00:12:00	21	1.3	
57	S	16:14:00	16:26:00	00:12:00	22	1.1	
56	N	16:29:00	16:41:00	00:12:00	22	1.1	
55	S	16:44:00	16:56:00	00:12:00	21	1.1	
54	N	16:59:00	17:11:00	00:12:00	20	1.2	
53	S	17:14:00	17:26:00	00:12:00	23	1.3	
52	N	17:29:00	17:41:00	00:12:00	23	1.1	

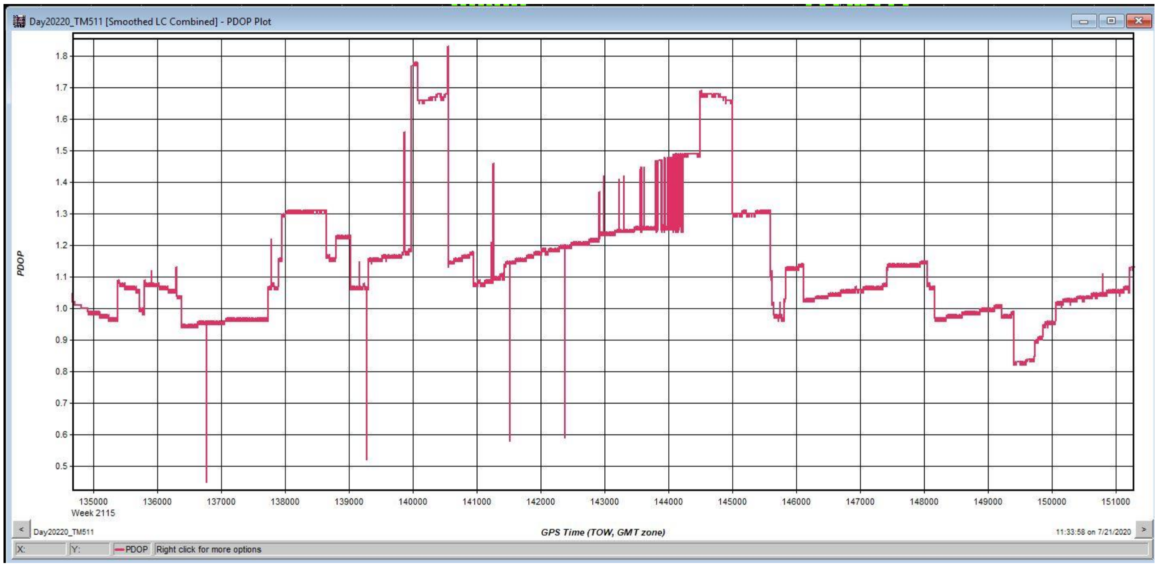
Page 2 **Verify S-Turns After Mission**

Additional Comments

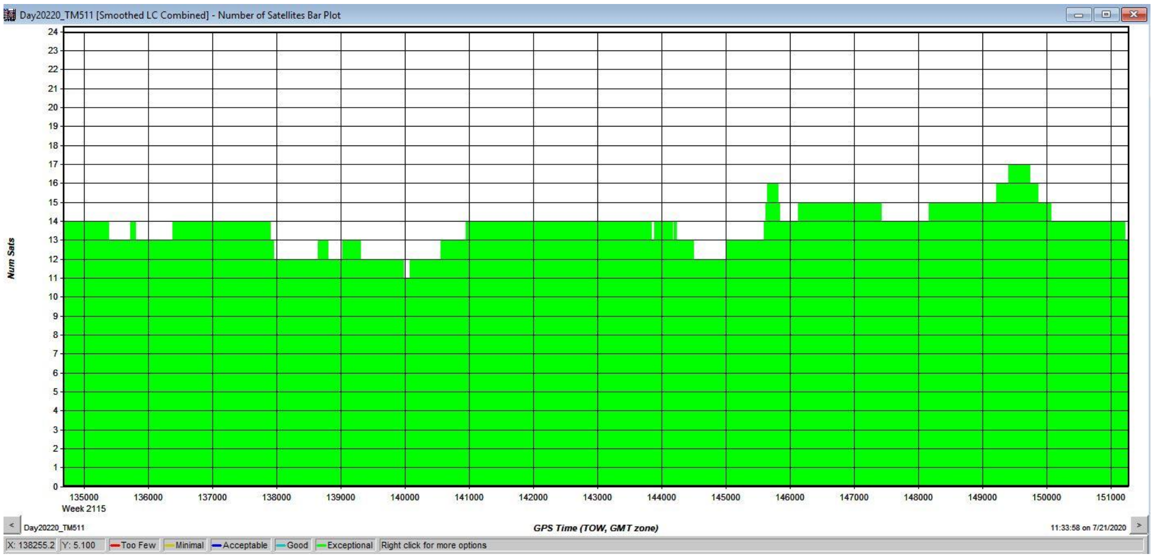
Mission Trajectory



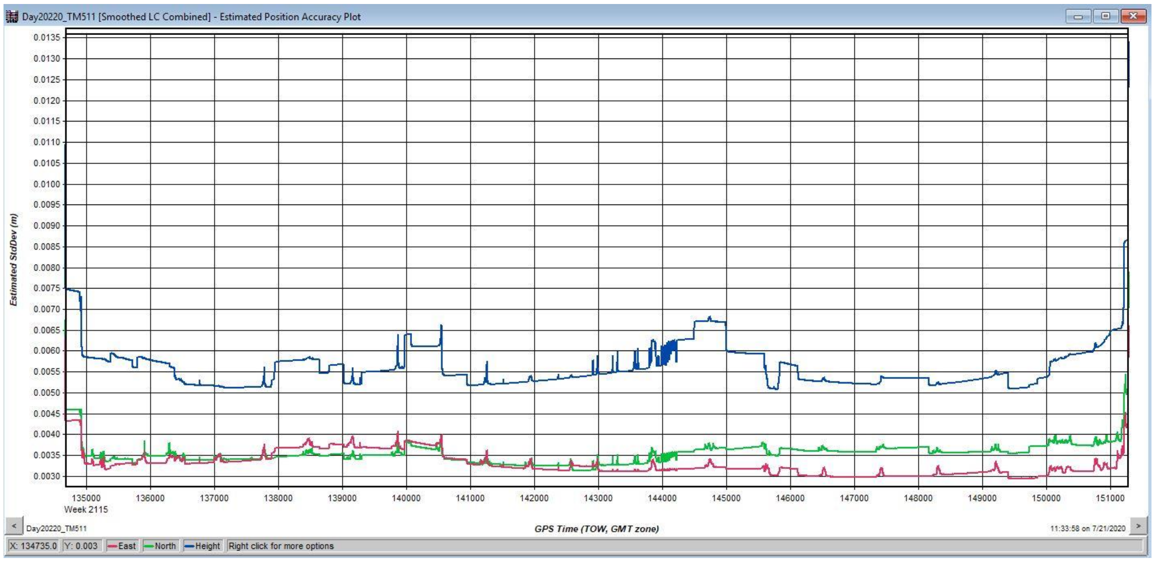
PDOP



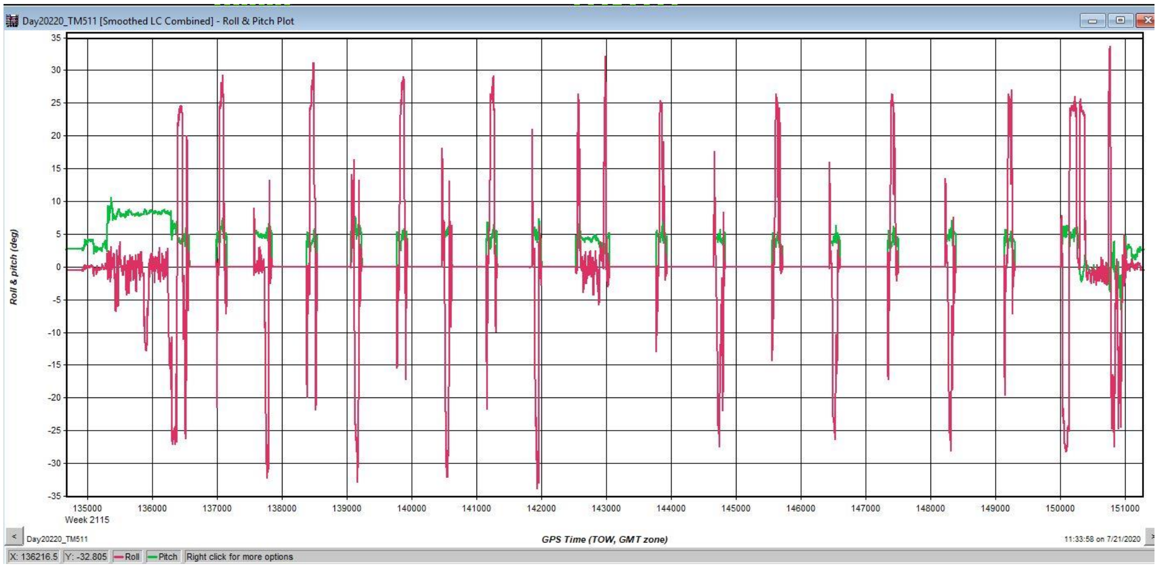
Satellites



RMS (m)



RPH (deg)


Day20220_TM511 [Smoothed LC Combined] - Roll & Pitch Plot
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
Roll & pitch (deg)
135000
Week 2115
136000
137000
138000
139000
140000
141000
142000
143000
144000
145000
146000
147000
148000
149000
150000
151000
Day20220_TM511
GPS Time (TOW, GMT zone)
11:33:58 on 7/21/2020
X: 136216.5
Y: -32.805
Roll
Pitch
Right click for more options

Mission 3 (20200721)

Flight Log

Woolpert Lidar Acquisition Log

Project Info			Date		
Project #	**Project Name**	**Unique ID**	**Flight Date (UTC)**	**Day of Year**	**Flight #**
80980	Sheridan Wyoming QL2, BLK2	Day203_90511	07/21/2020	203	

Crew	Equipment	Time			Airports
Pilot	**Aircraft Make / Model / Tail #**	**Hobbs Start**	**Local Start**	**UTC Start**	**Departing**
LaRocque	Cessna 404 Titan - N404CP	7847.6	07:15:00	13:15:00	KSHR
Operator	**Sensor Make / Model / Serial #**	**Hobbs End**	**Local End**	**UTC End**	**Arriving**
Nardone	Leica Terrain Mapper - 90511	7853.3	01:00:00	19:00:00	KSHR

Conditions

Wind Dir (°)	Wind Speed (kts)	Visibility (mi)	Ceiling (ft)	Cloud Cover	Temp. (°C)	Dew Point (°C)	Pressure ("Hg)
290	5	10	9,500		16	9	30.1

Air Speed (kts)	Altitude AGL (ft)	Altitude MSL (ft)	Airfield Elevation (ft)
150	9,842	13,278	4,021

Settings

Point Spacing (m)	Point Density (ppsm)	Scan Angle/FOV (°)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power (%)
0.7		40	82	600	100

Verify S-Turns Before Mission

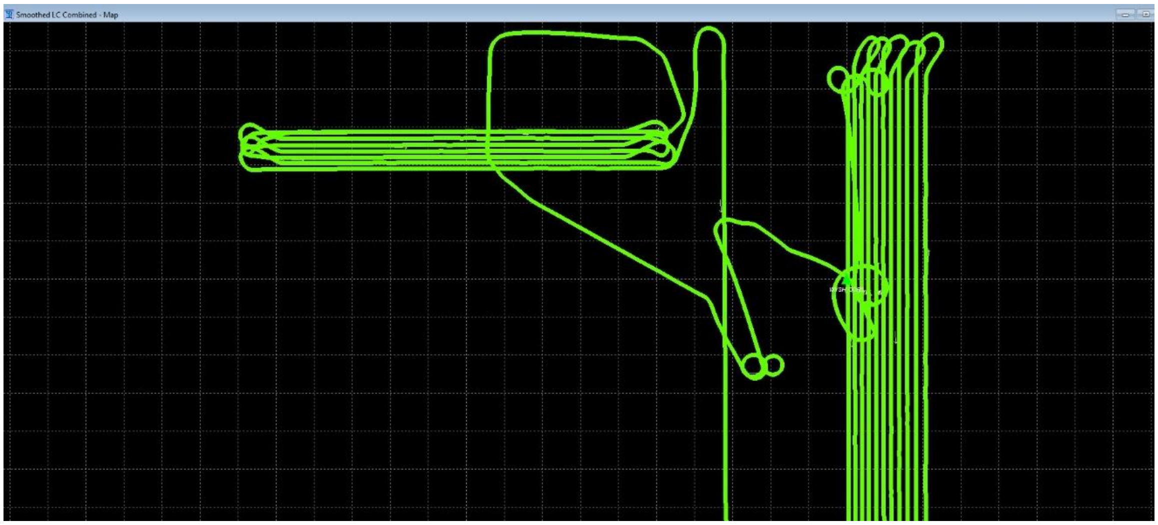
Line #	Direction	Start Time (UTC)	End Time (UTC)	Time On-Line	Satellite	PDOP	Line Notes/Comments
27	W	13:36:00	13:41:00		21	1.1	QL1 - BLK1: test speed flight
							Sensor didn't shut off but had low returns
							25-75% returns
6	W	13:54:00	14:04:00	00:10:00	20	1.2	QL2 - BLK1
6	E	14:08:00	14:18:00	00:10:00	21	1.1	
7	W	14:21:00	14:31:00	00:10:00	22	0.9	
8	E	14:34:00	14:44:00	00:10:00	24	0.9	
9	W	14:47:00	14:57:00	00:10:00	20	1.2	
10	E	14:59:00	15:08:00	00:09:00	20	1.1	
11	W	15:12:00	15:22:00	00:10:00	20	1.2	
12	E	15:24:00	15:33:00	00:09:00	20	1.2	Clouds West end 2 miles in
							QL2 - BLK2
19	S	15:40:00	15:52:00	00:12:00	20	1.3	Clouds south end last 6 miles
51	N	15:59:00	16:11:00	00:12:00	19	1.3	
50	S	16:14:00	16:26:00	00:12:00	20	1.1	
49	N	16:29:00	16:41:00	00:12:00	22	1.1	
48	S	16:44:00	16:56:00	00:12:00	21	1.1	
47	N	16:59:00	17:11:00	00:12:00	20	1.2	
46	S	17:14:00	17:26:00	00:12:00	22	1.2	
45	N	17:29:00	17:41:00	00:12:00	22	1.2	
44	S	17:44:00	17:56:00	00:12:00	23	1.2	
43	N	17:59:00	18:11:00	00:12:00	23	1.1	
42	S	18:14:00	18:26:00	00:12:00	25	1.1	
41	N	18:29:00	18:41:00	00:12:00	24	1.1	

Page 2

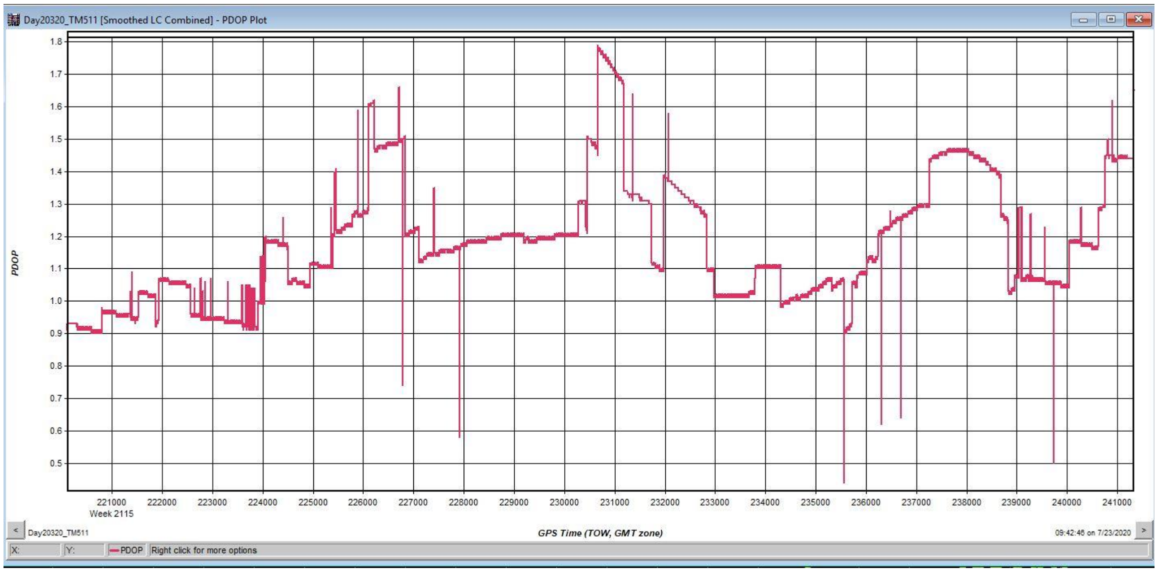
Verify S-Turns After Mission

Additional Comments

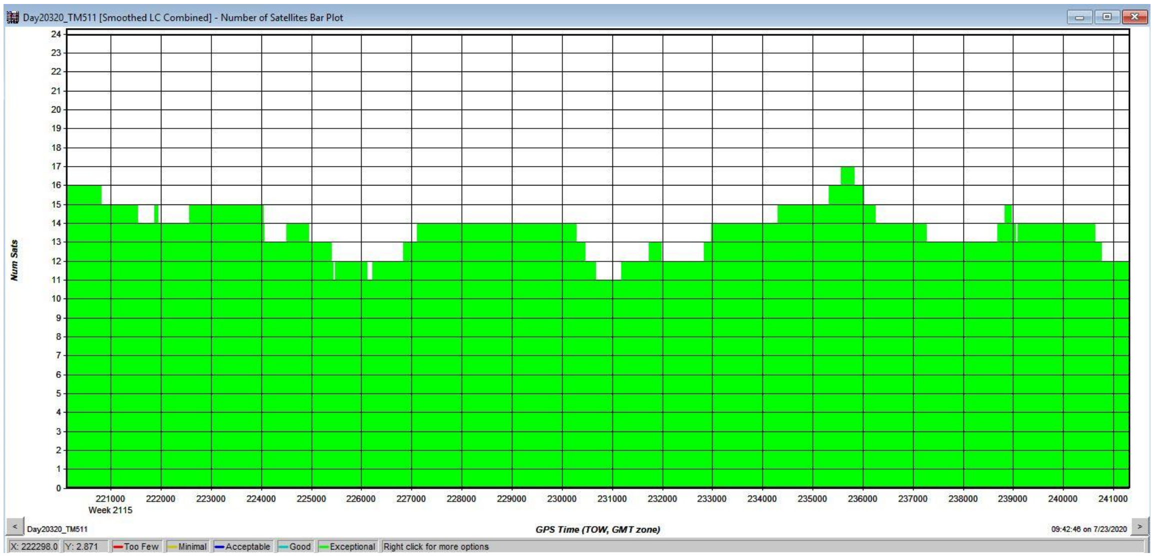
Mission Trajectory



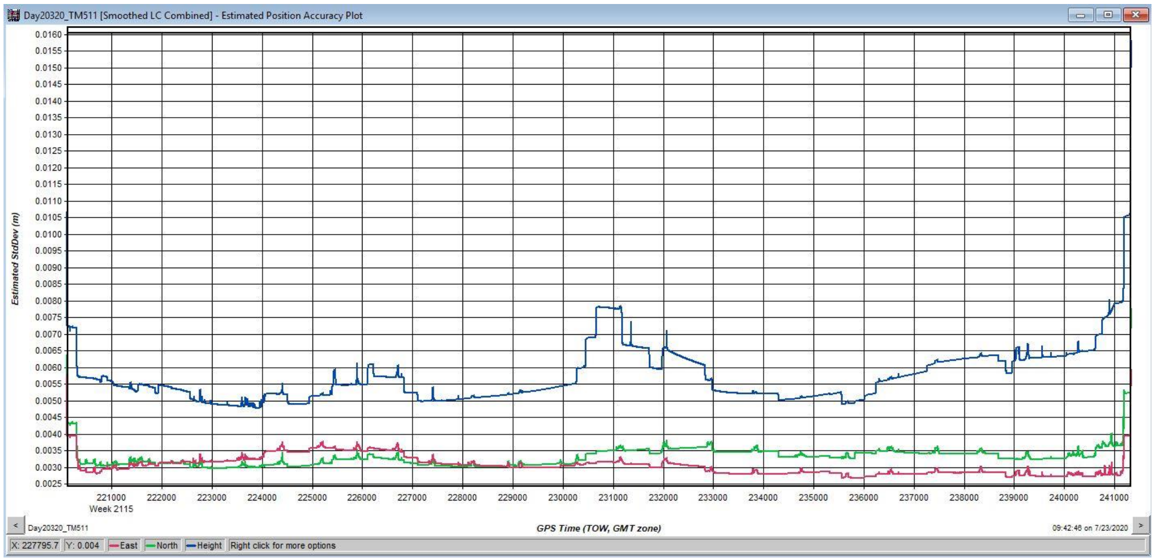
PDOP



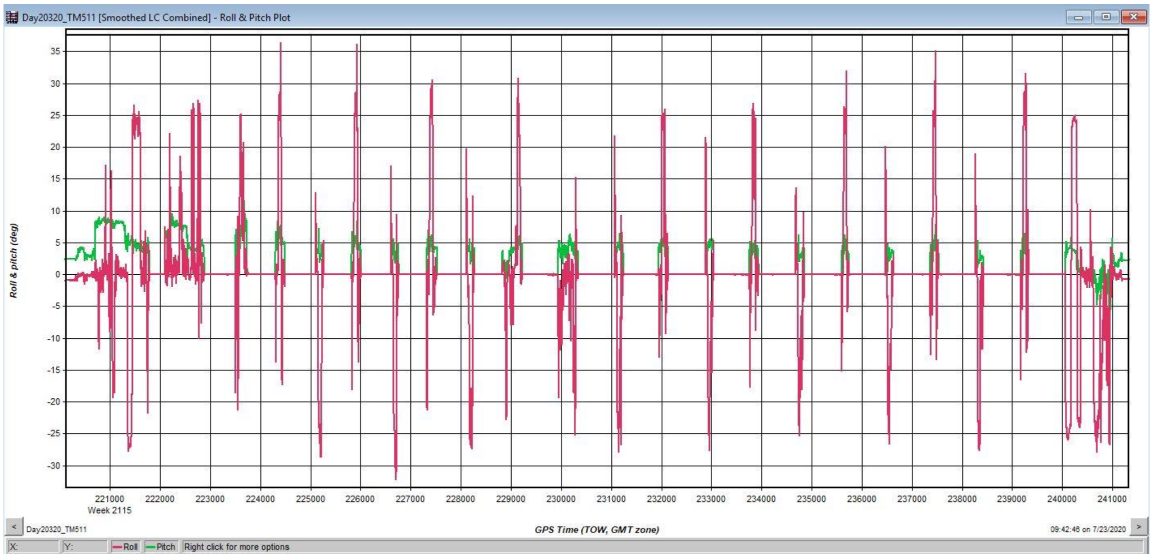
Satellites



RMS (m)

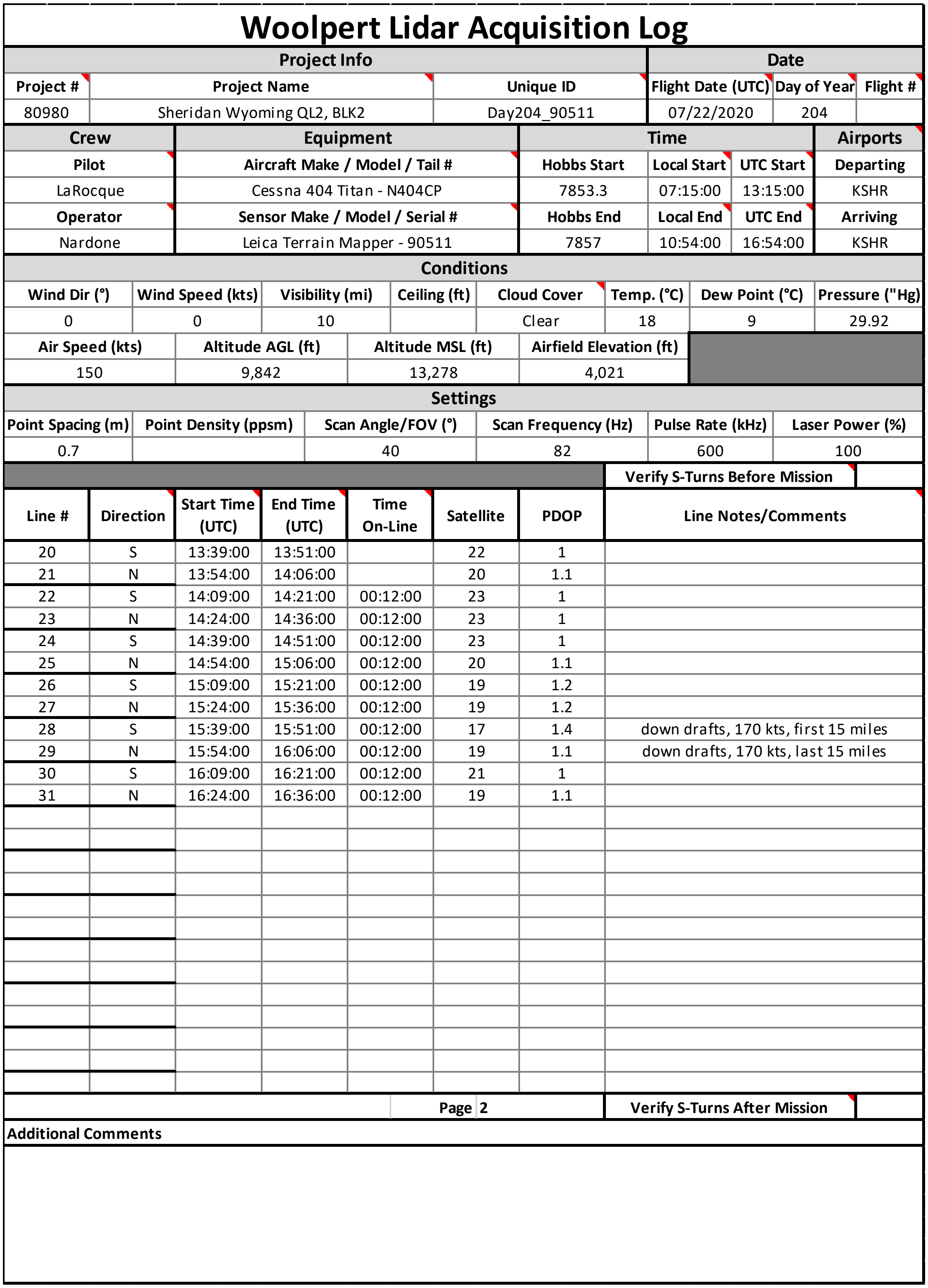


RPH (deg)


Day20320_TM511 [Smoothed LC Combined] - Roll & Pitch Plot
Roll & pitch (deg)
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
221000
Week 2115
222000
223000
224000
225000
226000
227000
228000
229000
230000
231000
232000
233000
234000
235000
236000
237000
238000
239000
240000
241000
Day20320_TM511
GPS Time (TOW, GMT zone)
09:42:46 on 7/23/2020
X:
Y:
Roll
Pitch
Right click for more options

Mission 4 (20200722)

Flight Log



Woolpert Lidar Acquisition Log

Project Info			Date		
Project #	**Project Name**	**Unique ID**	**Flight Date (UTC)**	**Day of Year**	**Flight #**
80980	Sheridan Wyoming QL2, BLK2	Day204_90511	07/22/2020	204	

Crew	Equipment	Time			Airports
Pilot	**Aircraft Make / Model / Tail #**	**Hobbs Start**	**Local Start**	**UTC Start**	**Departing**
LaRocque	Cessna 404 Titan - N404CP	7853.3	07:15:00	13:15:00	KSHR
Operator	**Sensor Make / Model / Serial #**	**Hobbs End**	**Local End**	**UTC End**	**Arriving**
Nardone	Leica Terrain Mapper - 90511	7857	10:54:00	16:54:00	KSHR

Conditions

Wind Dir (°)	Wind Speed (kts)	Visibility (mi)	Ceiling (ft)	Cloud Cover	Temp. (°C)	Dew Point (°C)	Pressure ("Hg)
0	0	10		Clear	18	9	29.92

Air Speed (kts)	Altitude AGL (ft)	Altitude MSL (ft)	Airfield Elevation (ft)
150	9,842	13,278	4,021

Settings

Point Spacing (m)	Point Density (ppsm)	Scan Angle/FOV (°)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power (%)
0.7		40	82	600	100

Verify S-Turns Before Mission

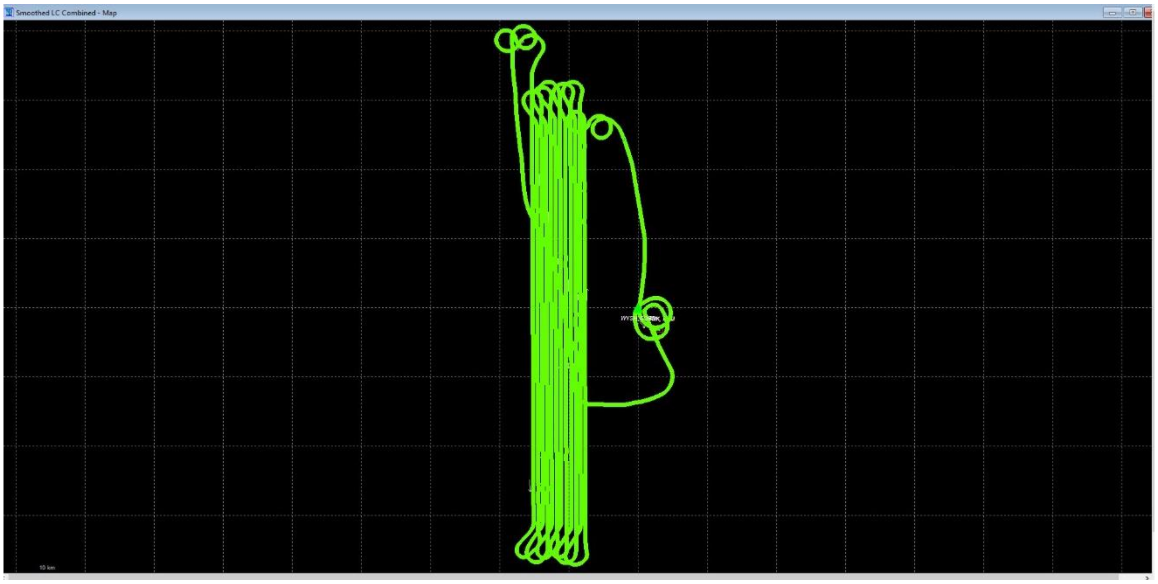
Line #	Direction	Start Time (UTC)	End Time (UTC)	Time On-Line	Satellite	PDOP	Line Notes/Comments
20	S	13:39:00	13:51:00		22	1	
21	N	13:54:00	14:06:00		20	1.1	
22	S	14:09:00	14:21:00	00:12:00	23	1	
23	N	14:24:00	14:36:00	00:12:00	23	1	
24	S	14:39:00	14:51:00	00:12:00	23	1	
25	N	14:54:00	15:06:00	00:12:00	20	1.1	
26	S	15:09:00	15:21:00	00:12:00	19	1.2	
27	N	15:24:00	15:36:00	00:12:00	19	1.2	
28	S	15:39:00	15:51:00	00:12:00	17	1.4	down drafts, 170 kts, first 15 miles
29	N	15:54:00	16:06:00	00:12:00	19	1.1	down drafts, 170 kts, last 15 miles
30	S	16:09:00	16:21:00	00:12:00	21	1	
31	N	16:24:00	16:36:00	00:12:00	19	1.1	

Page 2

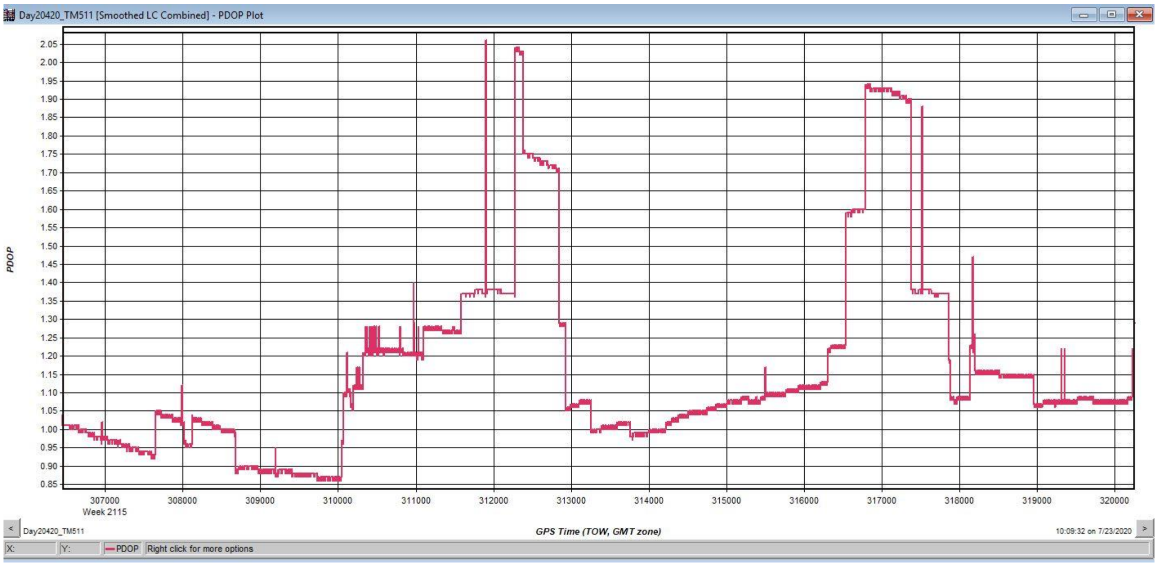
Verify S-Turns After Mission

Additional Comments

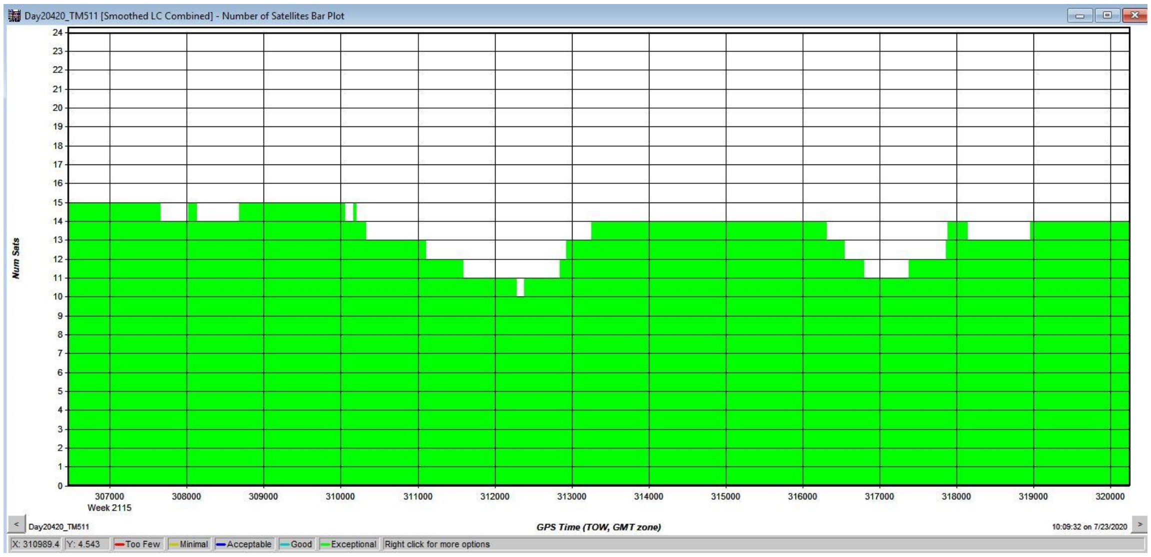
Mission Trajectory



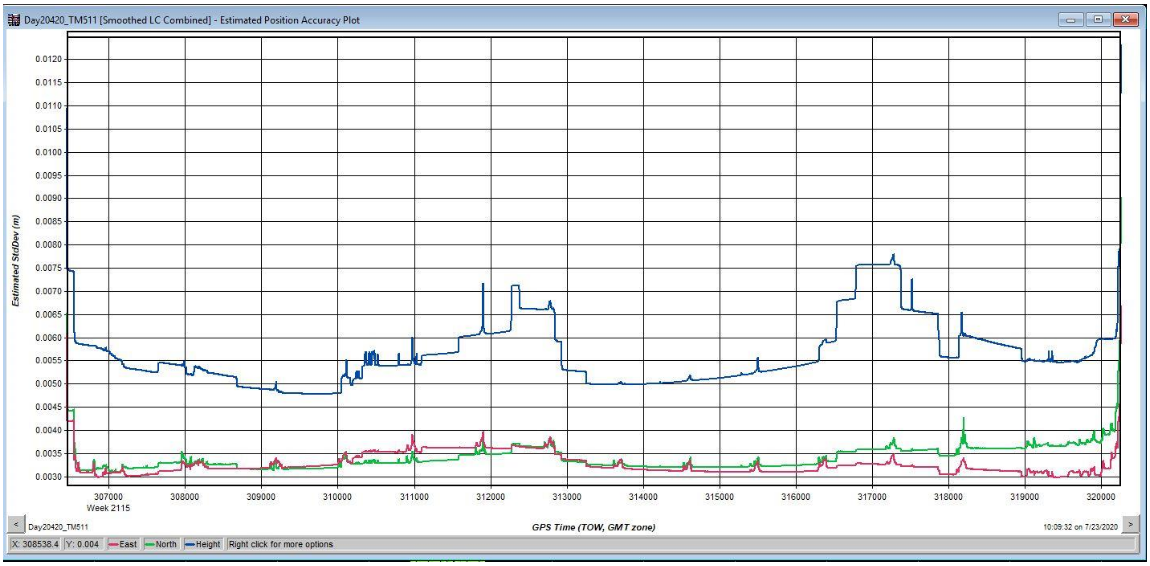
PDOP



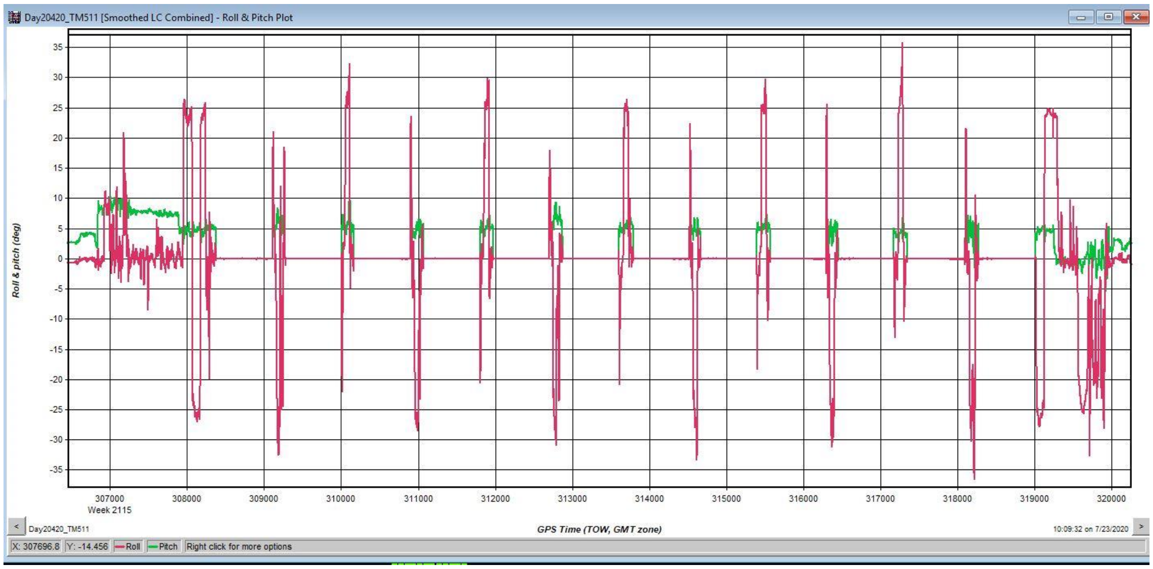
Satellites



RMS (m)

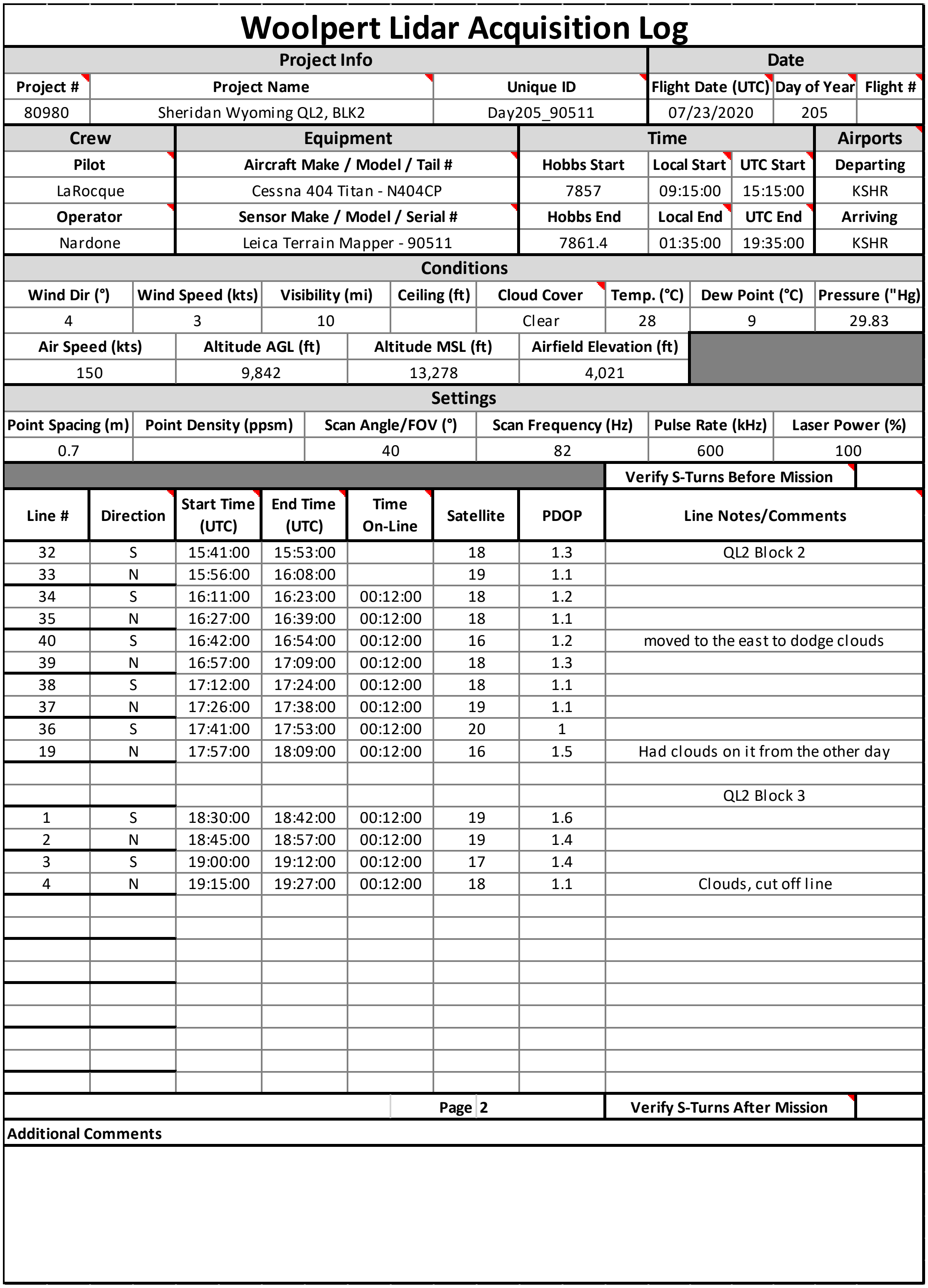


RPH (deg)


Day20420_TM511 [Smoothed LC Combined] - Roll & Pitch Plot
Roll & pitch (deg)
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
307000
Week 2115
308000
309000
310000
311000
312000
313000
314000
315000
316000
317000
318000
319000
320000
Day20420_TM511
GPS Time (TOW, GMT zone)
10:09:32 on 7/23/2020
X: 307696.8
Y: -14.456
Roll
Pitch
Right click for more options

Mission 5 (20200723)

Flight Log



Woolpert Lidar Acquisition Log

Project Info			Date		
Project #	**Project Name**	**Unique ID**	**Flight Date (UTC)**	**Day of Year**	**Flight #**
80980	Sheridan Wyoming QL2, BLK2	Day205_90511	07/23/2020	205	

Crew	Equipment	Time			Airports
Pilot	**Aircraft Make / Model / Tail #**	**Hobbs Start**	**Local Start**	**UTC Start**	**Departing**
LaRocque	Cessna 404 Titan - N404CP	7857	09:15:00	15:15:00	KSHR
Operator	**Sensor Make / Model / Serial #**	**Hobbs End**	**Local End**	**UTC End**	**Arriving**
Nardone	Leica Terrain Mapper - 90511	7861.4	01:35:00	19:35:00	KSHR

Conditions

Wind Dir (°)	Wind Speed (kts)	Visibility (mi)	Ceiling (ft)	Cloud Cover	Temp. (°C)	Dew Point (°C)	Pressure ("Hg)
4	3	10		Clear	28	9	29.83

Air Speed (kts)	Altitude AGL (ft)	Altitude MSL (ft)	Airfield Elevation (ft)
150	9,842	13,278	4,021

Settings

Point Spacing (m)	Point Density (ppsm)	Scan Angle/FOV (°)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power (%)
0.7		40	82	600	100

Verify S-Turns Before Mission

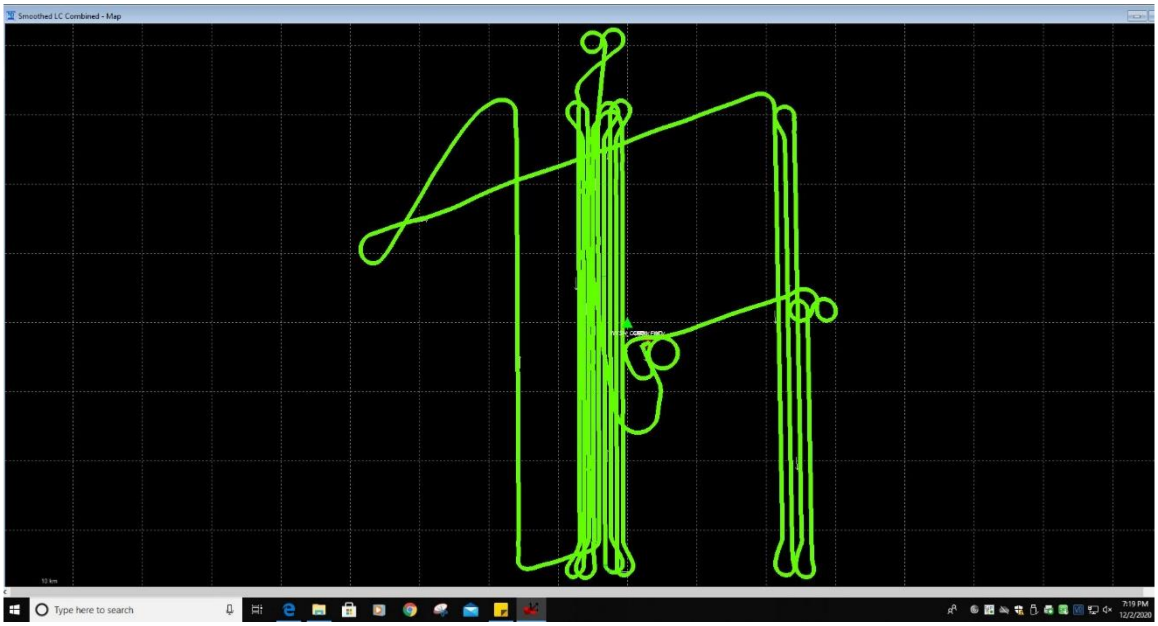
Line #	Direction	Start Time (UTC)	End Time (UTC)	Time On-Line	Satellite	PDOP	Line Notes/Comments
32	S	15:41:00	15:53:00		18	1.3	QL2 Block 2
33	N	15:56:00	16:08:00		19	1.1	
34	S	16:11:00	16:23:00	00:12:00	18	1.2	
35	N	16:27:00	16:39:00	00:12:00	18	1.1	
40	S	16:42:00	16:54:00	00:12:00	16	1.2	moved to the east to dodge clouds
39	N	16:57:00	17:09:00	00:12:00	18	1.3	
38	S	17:12:00	17:24:00	00:12:00	18	1.1	
37	N	17:26:00	17:38:00	00:12:00	19	1.1	
36	S	17:41:00	17:53:00	00:12:00	20	1	
19	N	17:57:00	18:09:00	00:12:00	16	1.5	Had clouds on it from the other day
							QL2 Block 3
1	S	18:30:00	18:42:00	00:12:00	19	1.6	
2	N	18:45:00	18:57:00	00:12:00	19	1.4	
3	S	19:00:00	19:12:00	00:12:00	17	1.4	
4	N	19:15:00	19:27:00	00:12:00	18	1.1	Clouds, cut off line

Page 2

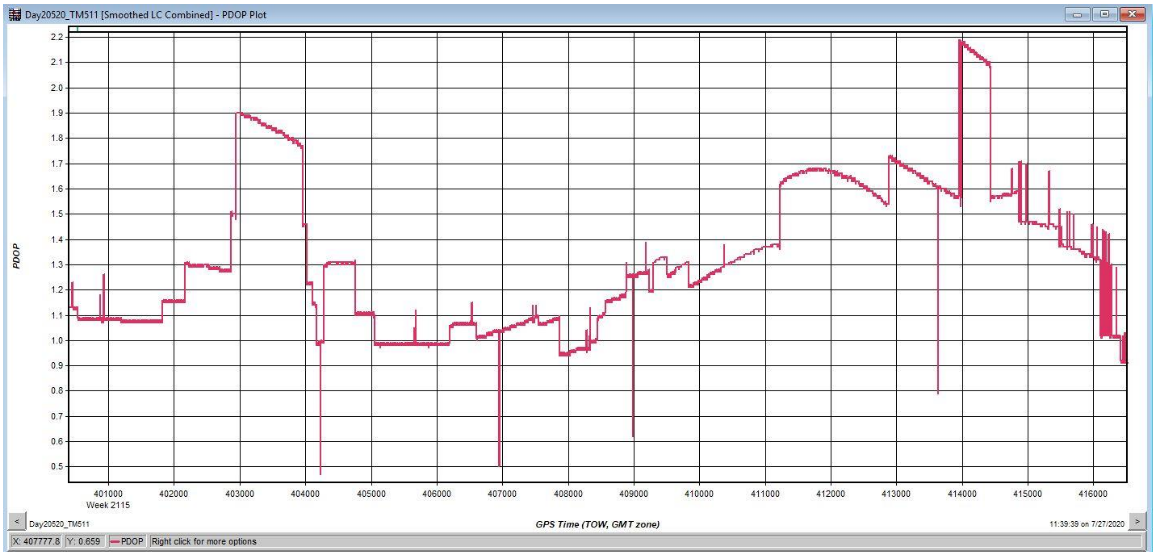
Verify S-Turns After Mission

Additional Comments

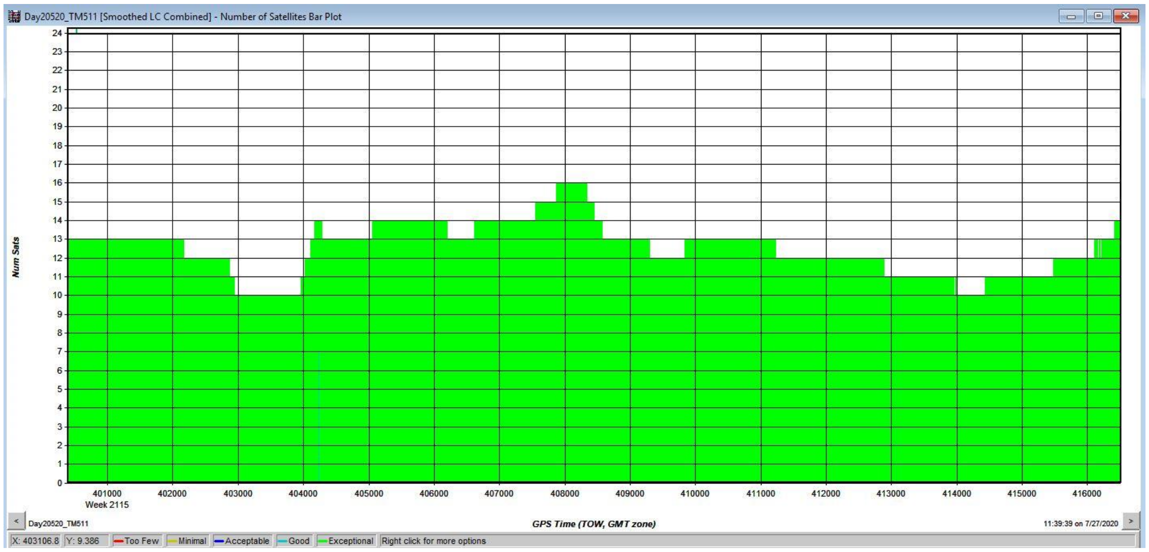
Mission Trajectory



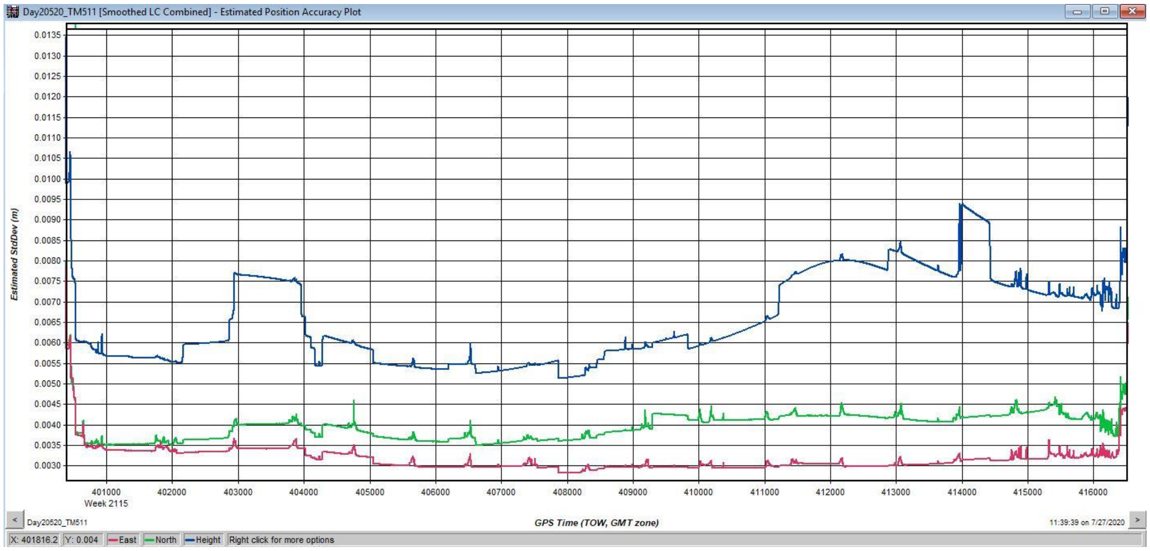
PDOP



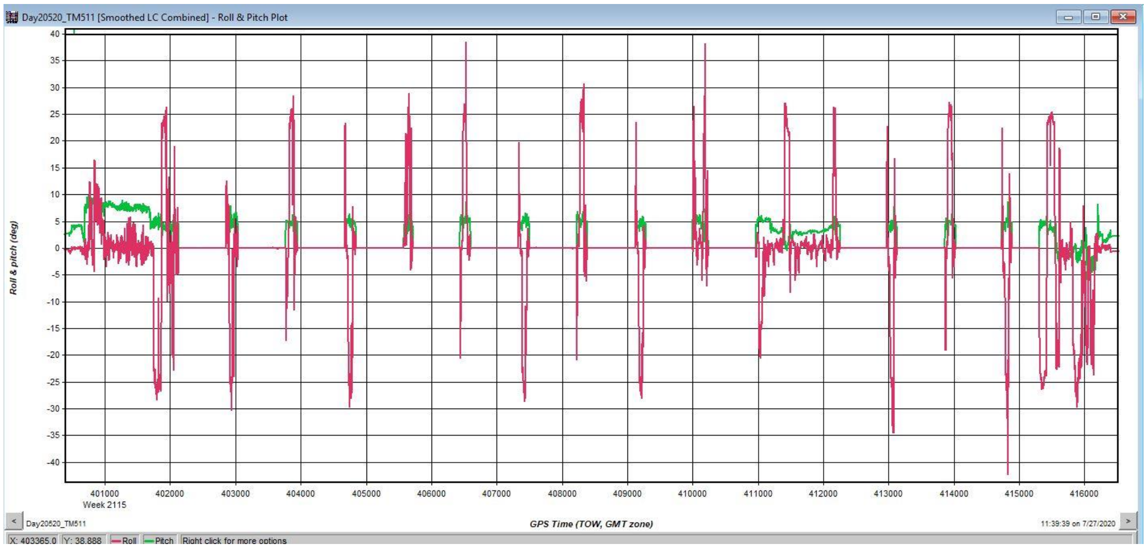
Satellites



RMS (m)

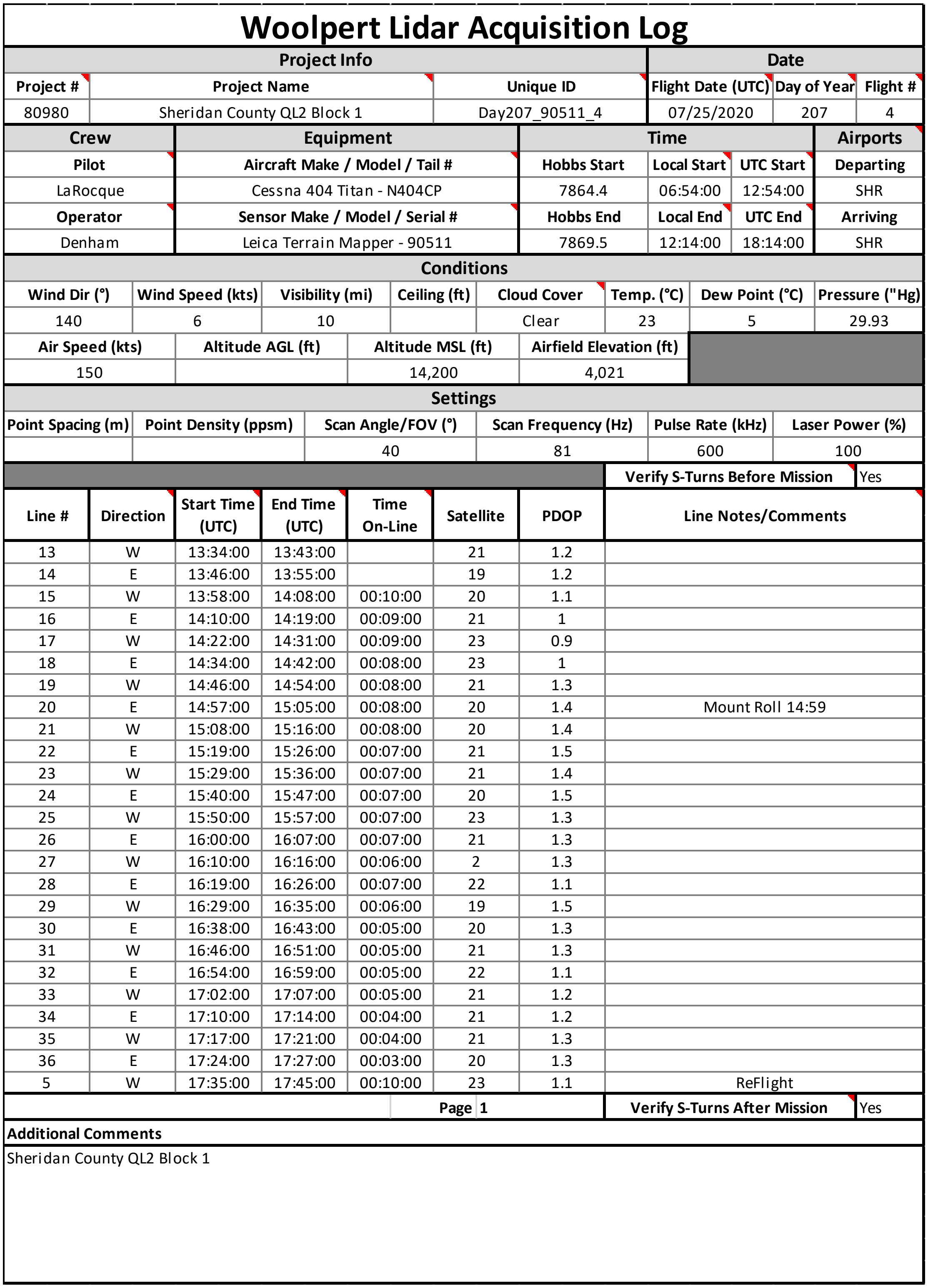


RPH (deg)


Day20520_TM511 [Smoothed LC Combined] - Roll & Pitch Plot
Roll & pitch (deg)
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
401000
Week 2115
402000
403000
404000
405000
406000
407000
408000
409000
410000
411000
412000
413000
414000
415000
416000
Day20520_TM511
GPS Time (TOW, GMT zone)
11:39:39 on 7/27/2020
X: 403365.0
Y: 38.888
Roll
Pitch
Right click for more options

Mission 6 (20200725)

Flight Log



Woolpert Lidar Acquisition Log

Project Info			Date		
Project #	**Project Name**	**Unique ID**	**Flight Date (UTC)**	**Day of Year**	**Flight #**
80980	Sheridan County QL2 Block 1	Day207_90511_4	07/25/2020	207	4

Crew	Equipment	Time			Airports
Pilot	**Aircraft Make / Model / Tail #**	**Hobbs Start**	**Local Start**	**UTC Start**	**Departing**
LaRocque	Cessna 404 Titan - N404CP	7864.4	06:54:00	12:54:00	SHR
Operator	**Sensor Make / Model / Serial #**	**Hobbs End**	**Local End**	**UTC End**	**Arriving**
Denham	Leica Terrain Mapper - 90511	7869.5	12:14:00	18:14:00	SHR

Conditions

Wind Dir (°)	Wind Speed (kts)	Visibility (mi)	Ceiling (ft)	Cloud Cover	Temp. (°C)	Dew Point (°C)	Pressure ("Hg)
140	6	10		Clear	23	5	29.93

Air Speed (kts)	Altitude AGL (ft)	Altitude MSL (ft)	Airfield Elevation (ft)
150		14,200	4,021

Settings

Point Spacing (m)	Point Density (ppsm)	Scan Angle/FOV (°)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power (%)
		40	81	600	100

Verify S-Turns Before Mission Yes

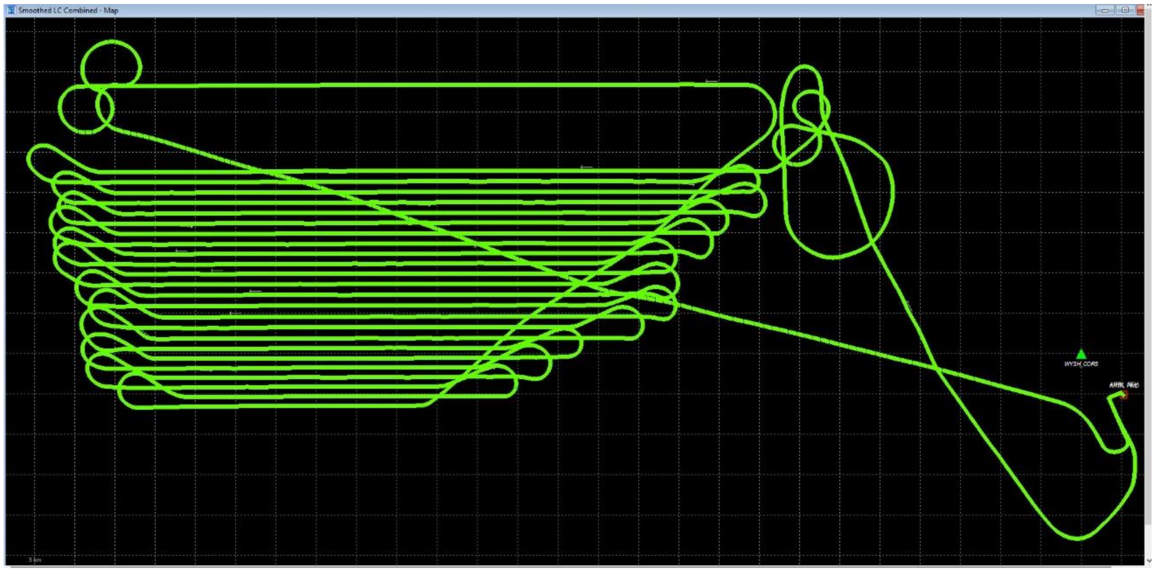
Line #	Direction	Start Time (UTC)	End Time (UTC)	Time On-Line	Satellite	PDOP	Line Notes/Comments
13	W	13:34:00	13:43:00		21	1.2	
14	E	13:46:00	13:55:00		19	1.2	
15	W	13:58:00	14:08:00	00:10:00	20	1.1	
16	E	14:10:00	14:19:00	00:09:00	21	1	
17	W	14:22:00	14:31:00	00:09:00	23	0.9	
18	E	14:34:00	14:42:00	00:08:00	23	1	
19	W	14:46:00	14:54:00	00:08:00	21	1.3	
20	E	14:57:00	15:05:00	00:08:00	20	1.4	Mount Roll 14:59
21	W	15:08:00	15:16:00	00:08:00	20	1.4	
22	E	15:19:00	15:26:00	00:07:00	21	1.5	
23	W	15:29:00	15:36:00	00:07:00	21	1.4	
24	E	15:40:00	15:47:00	00:07:00	20	1.5	
25	W	15:50:00	15:57:00	00:07:00	23	1.3	
26	E	16:00:00	16:07:00	00:07:00	21	1.3	
27	W	16:10:00	16:16:00	00:06:00	2	1.3	
28	E	16:19:00	16:26:00	00:07:00	22	1.1	
29	W	16:29:00	16:35:00	00:06:00	19	1.5	
30	E	16:38:00	16:43:00	00:05:00	20	1.3	
31	W	16:46:00	16:51:00	00:05:00	21	1.3	
32	E	16:54:00	16:59:00	00:05:00	22	1.1	
33	W	17:02:00	17:07:00	00:05:00	21	1.2	
34	E	17:10:00	17:14:00	00:04:00	21	1.2	
35	W	17:17:00	17:21:00	00:04:00	21	1.3	
36	E	17:24:00	17:27:00	00:03:00	20	1.3	
5	W	17:35:00	17:45:00	00:10:00	23	1.1	ReFlight

Page 1 **Verify S-Turns After Mission** Yes

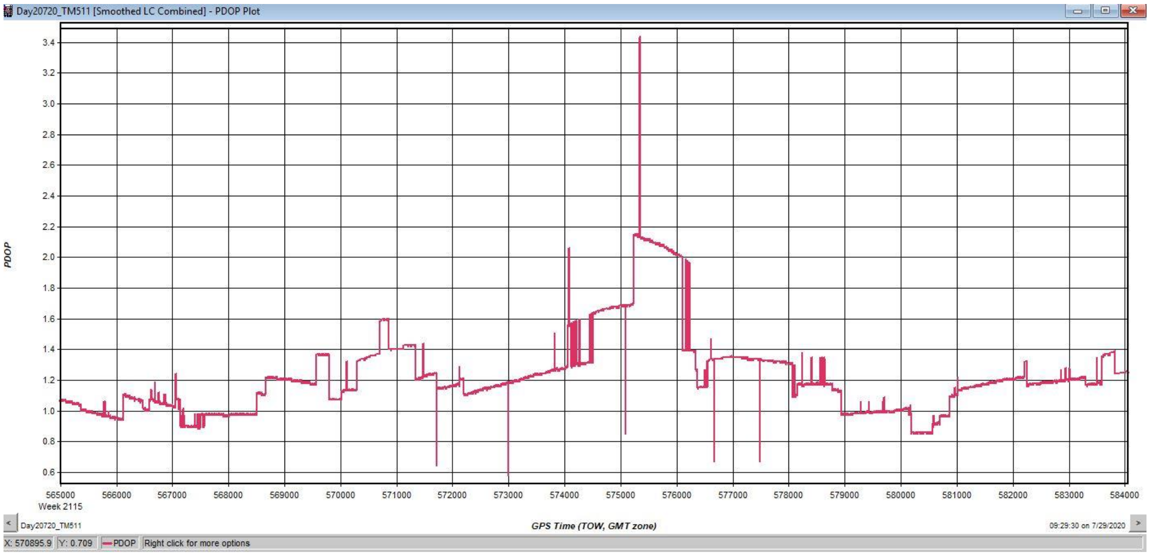
Additional Comments

Sheridan County QL2 Block 1

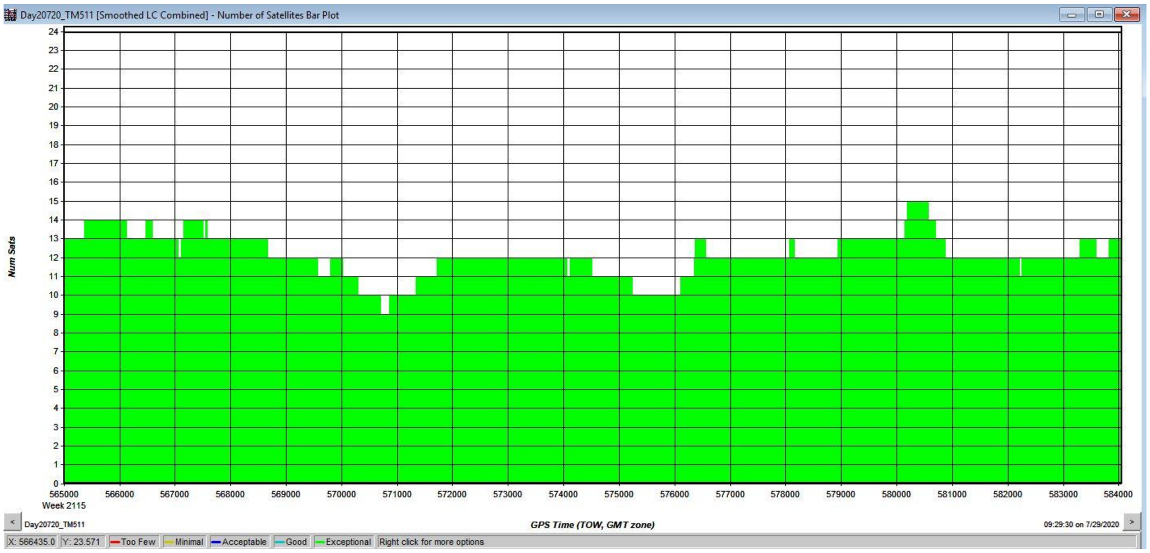
Mission Trajectory



PDOP

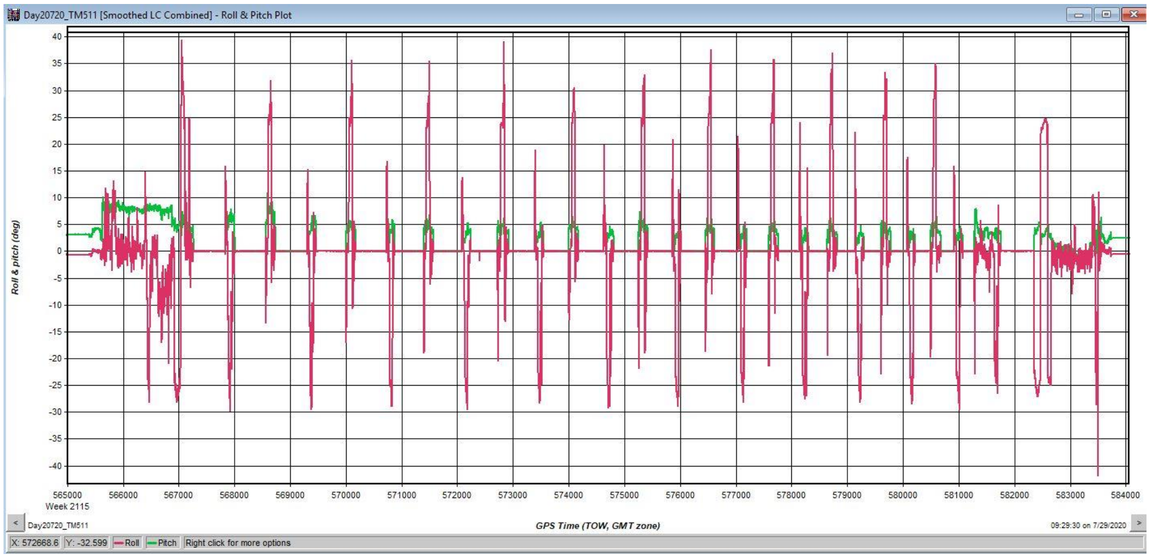


Satellites



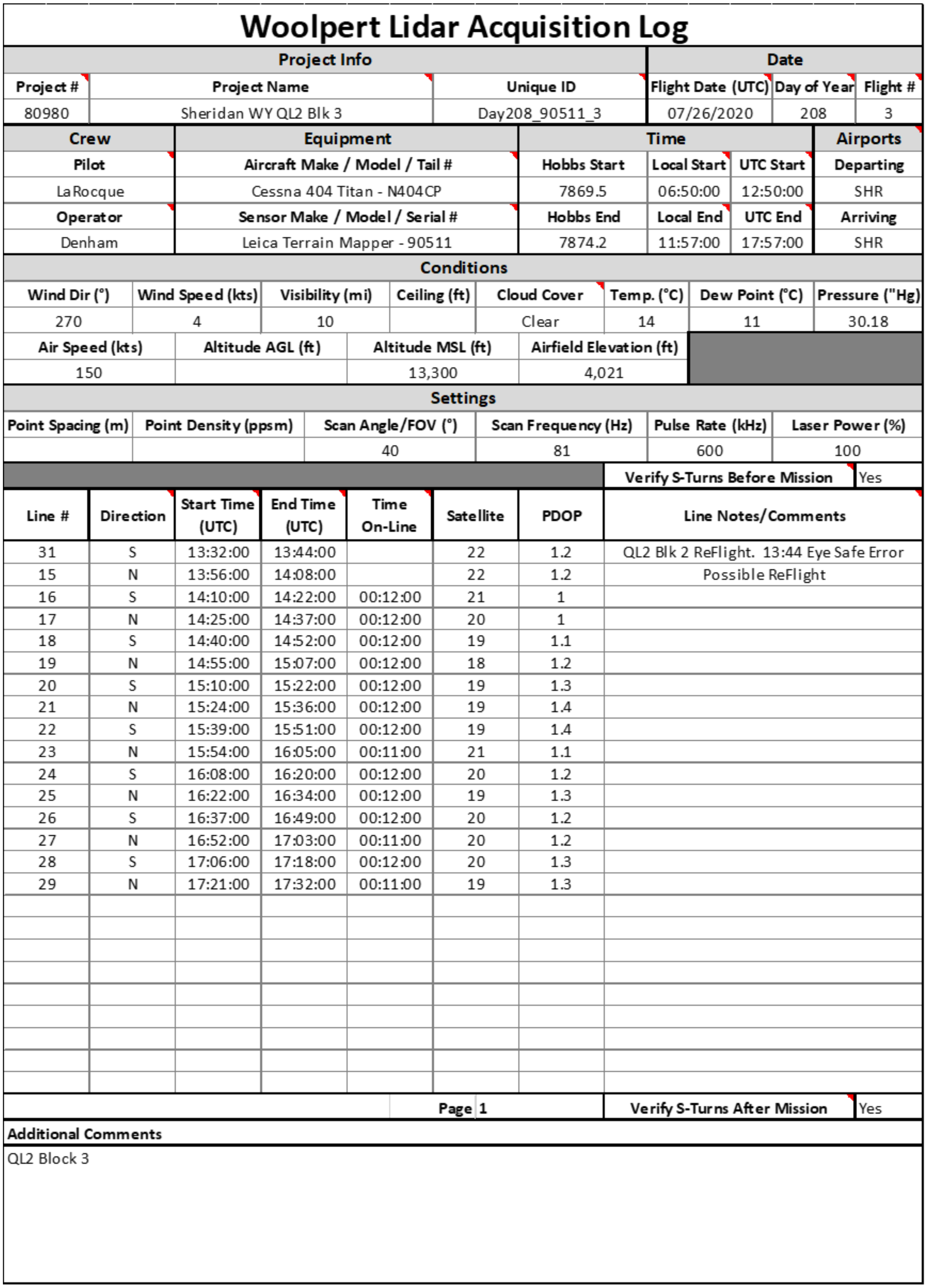
RMS (m)

RPH (deg)


Day20720_TM511 [Smoothed LC Combined] - Roll & Pitch Plot
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
Roll & pitch (deg)
565000
Week 2115
566000
567000
568000
569000
570000
571000
572000
573000
574000
575000
576000
577000
578000
579000
580000
581000
582000
583000
584000
Day20720_TM511
GPS Time (TOW, GMT zone)
09:29:30 on 7/29/2020
X: 572668.6
Y: -32.599
Roll
Pitch
Right click for more options

Mission 7 (20200726)

Flight Log



Woolpert Lidar Acquisition Log

Project Info			Date		
Project #	**Project Name**	**Unique ID**	**Flight Date (UTC)**	**Day of Year**	**Flight #**
80980	Sheridan WY QL2 Blk 3	Day208_90511_3	07/26/2020	208	3

Crew	Equipment	Time			Airports
Pilot	**Aircraft Make / Model / Tail #**	**Hobbs Start**	**Local Start**	**UTC Start**	**Departing**
LaRocque	Cessna 404 Titan - N404CP	7869.5	06:50:00	12:50:00	SHR
Operator	**Sensor Make / Model / Serial #**	**Hobbs End**	**Local End**	**UTC End**	**Arriving**
Denham	Leica Terrain Mapper - 90511	7874.2	11:57:00	17:57:00	SHR

Conditions

Wind Dir (°)	Wind Speed (kts)	Visibility (mi)	Ceiling (ft)	Cloud Cover	Temp. (°C)	Dew Point (°C)	Pressure ("Hg)
270	4	10		Clear	14	11	30.18

Air Speed (kts)	Altitude AGL (ft)	Altitude MSL (ft)	Airfield Elevation (ft)
150		13,300	4,021

Settings

Point Spacing (m)	Point Density (ppsm)	Scan Angle/FOV (°)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power (%)
		40	81	600	100

Verify S-Turns Before Mission Yes

Line #	Direction	Start Time (UTC)	End Time (UTC)	Time On-Line	Satellite	PDOP	Line Notes/Comments
31	S	13:32:00	13:44:00		22	1.2	QL2 Blk 2 ReFlight. 13:44 Eye Safe Error
15	N	13:56:00	14:08:00		22	1.2	Possible ReFlight
16	S	14:10:00	14:22:00	00:12:00	21	1	
17	N	14:25:00	14:37:00	00:12:00	20	1	
18	S	14:40:00	14:52:00	00:12:00	19	1.1	
19	N	14:55:00	15:07:00	00:12:00	18	1.2	
20	S	15:10:00	15:22:00	00:12:00	19	1.3	
21	N	15:24:00	15:36:00	00:12:00	19	1.4	
22	S	15:39:00	15:51:00	00:12:00	19	1.4	
23	N	15:54:00	16:05:00	00:11:00	21	1.1	
24	S	16:08:00	16:20:00	00:12:00	20	1.2	
25	N	16:22:00	16:34:00	00:12:00	19	1.3	
26	S	16:37:00	16:49:00	00:12:00	20	1.2	
27	N	16:52:00	17:03:00	00:11:00	20	1.2	
28	S	17:06:00	17:18:00	00:12:00	20	1.3	
29	N	17:21:00	17:32:00	00:11:00	19	1.3	

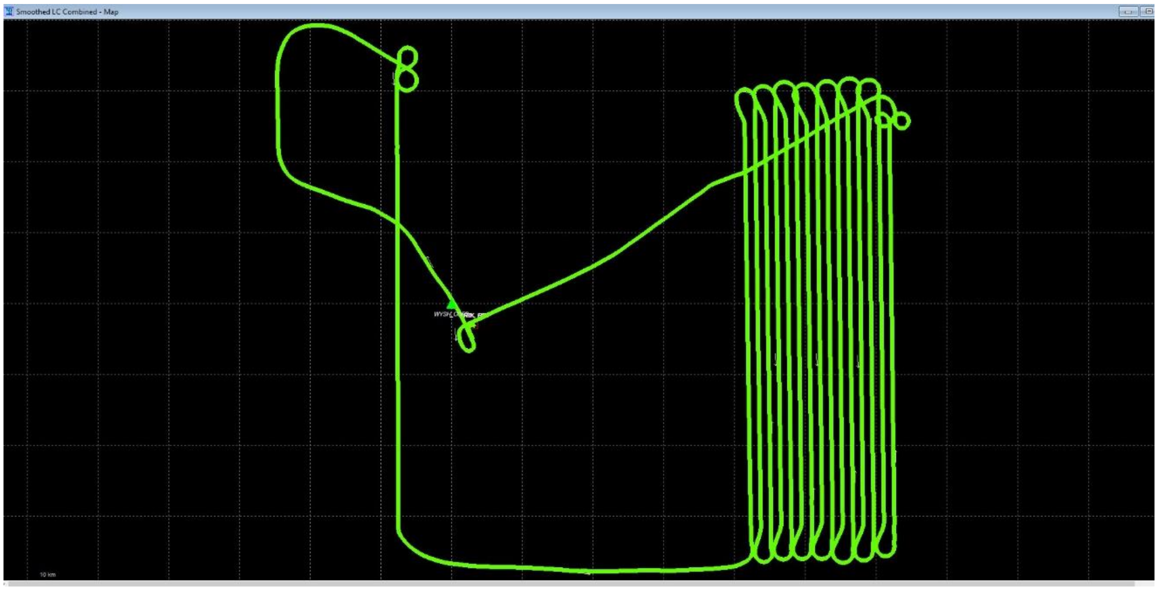
Page 1

Verify S-Turns After Mission Yes

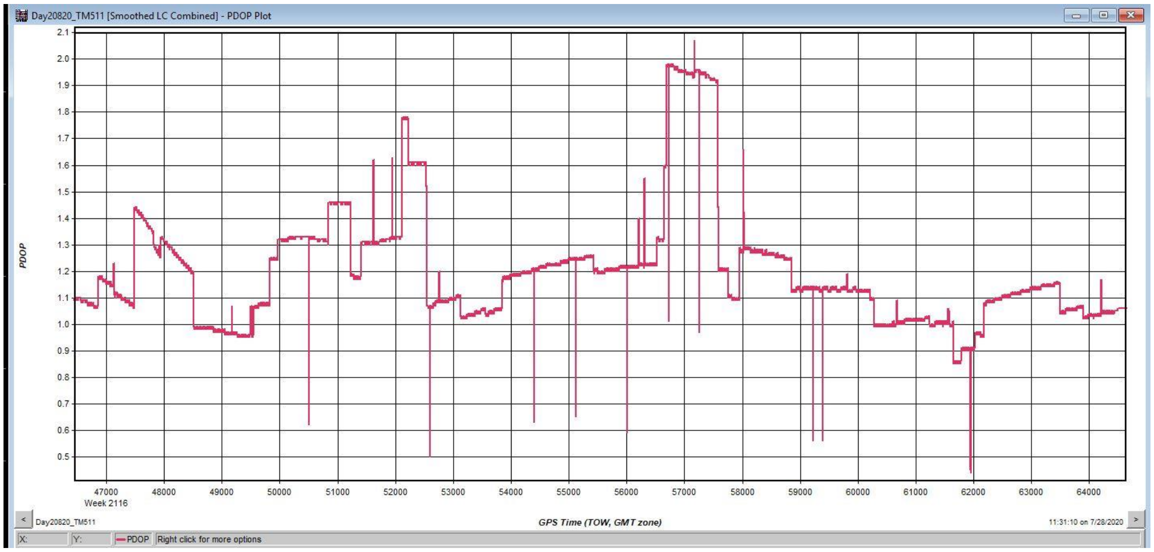
Additional Comments

QL2 Block 3

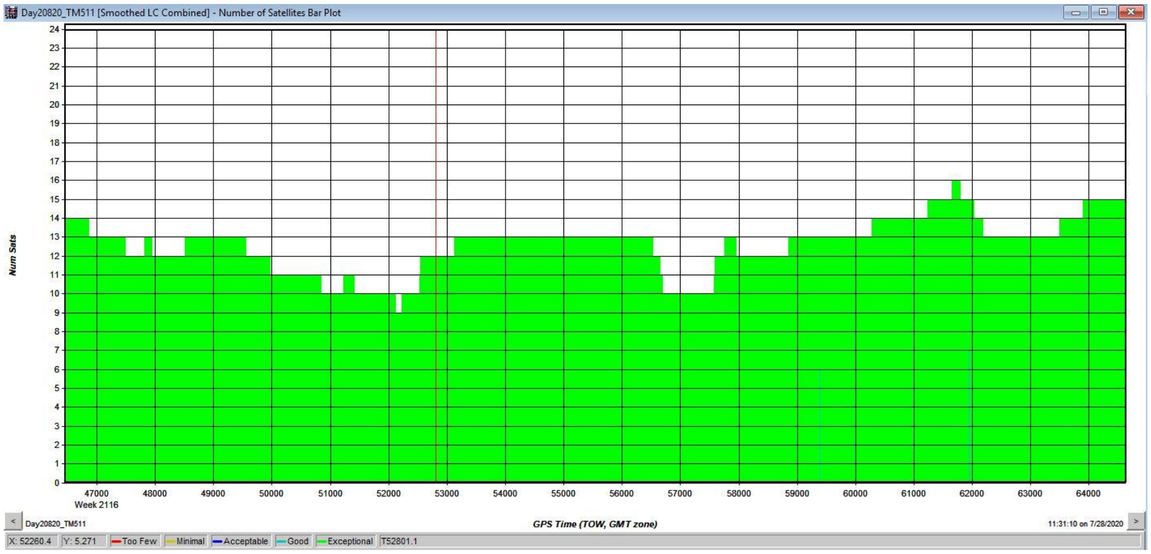
Mission Trajectory


Smoothed LC Combined - Map
10 km

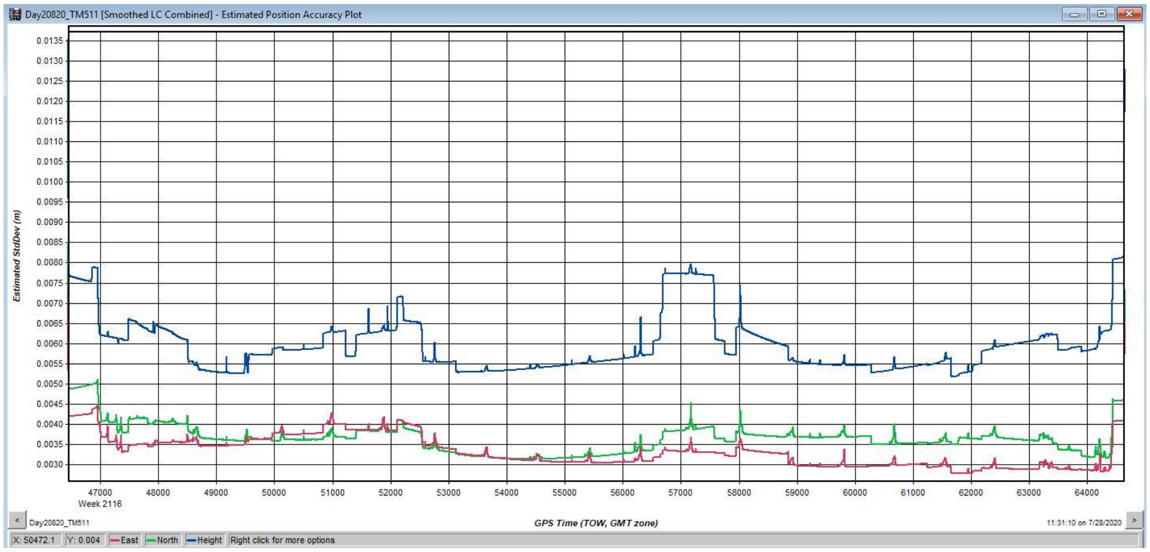
PDOP


Day20820_TM511 [Smoothed LC Combined] - PDOP Plot
2.1
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
PDOP
47000
Week 2116
48000
49000
50000
51000
52000
53000
54000
55000
56000
57000
58000
59000
60000
61000
62000
63000
64000
GPS Time (TOW, GMT zone)
Day20820_TM511
11:31:10 on 7/28/2020
X:
Y:
PDOP
Right click for more options

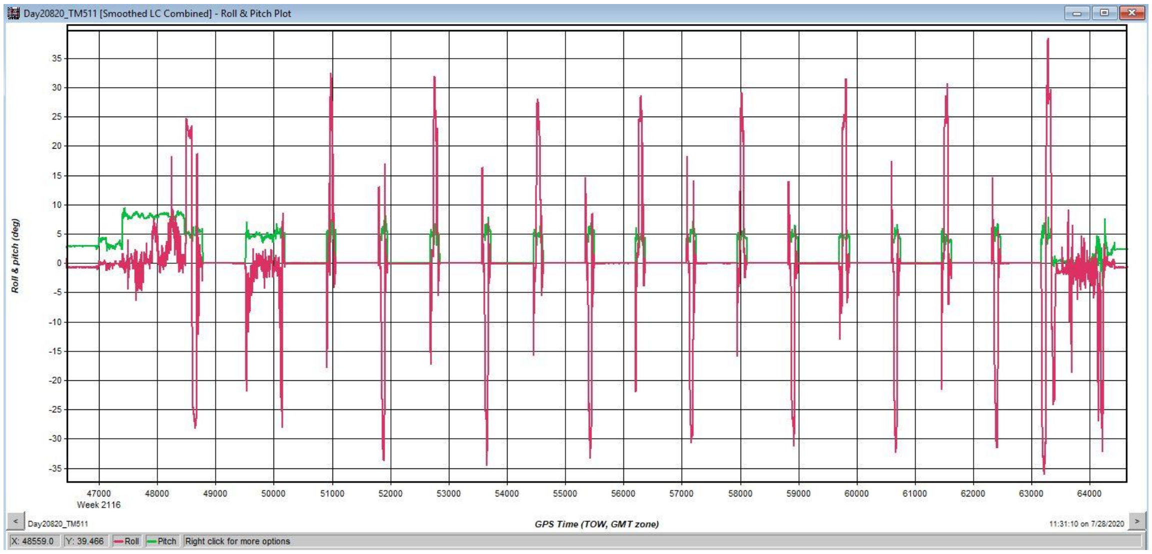
Satellites



RMS (m)



RPH (deg)


Day20820_TM511 [Smoothed LC Combined] - Roll & Pitch Plot
Roll & pitch (deg)
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
47000
Week 2116
48000
49000
50000
51000
52000
53000
54000
55000
56000
57000
58000
59000
60000
61000
62000
63000
64000
Day20820_TM511
GPS Time (TOW, GMT zone)
11:31:10 on 7/28/2020
X: 48559.0
Y: 39.466
Roll
Pitch
Right click for more options

Mission 8 (20200727)

Flight Log

Woolpert Lidar Acquisition Log

Project Info			Date		
Project #	**Project Name**	**Unique ID**	**Flight Date (UTC)**	**Day of Year**	**Flight #**
80980	Sheridan County WY QL2 Block 3	Day209_90511_4	07/27/2020	209	4

Crew	Equipment	Time			Airports
Pilot	**Aircraft Make / Model / Tail #**	**Hobbs Start**	**Local Start**	**UTC Start**	**Departing**
Diepenbrek	Cessna 404 Titan - N404CP	7874.2	07:11:00	13:11:00	SHR
Operator	**Sensor Make / Model / Serial #**	**Hobbs End**	**Local End**	**UTC End**	**Arriving**
Denham	Leica Terrain Mapper - 90511	7878.3	11:49:00	17:49:00	SHR

Conditions

Wind Dir (°)	Wind Speed (kts)	Visibility (mi)	Ceiling (ft)	Cloud Cover	Temp. (°C)	Dew Point (°C)	Pressure ("Hg)
190	3	10		Clear	17	11	30.2

Air Speed (kts)	Altitude AGL (ft)	Altitude MSL (ft)	Airfield Elevation (ft)
150		13,300	4,021

Settings

Point Spacing (m)	Point Density (ppsm)	Scan Angle/FOV (°)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power (%)
		40	81	600	100

Verify S-Turns Before Mission Yes

Line #	Direction	Start Time (UTC)	End Time (UTC)	Time On-Line	Satellite	PDOP	Line Notes/Comments
30	S	14:02:00	14:14:00		22	0.9	
31	N	14:17:00	14:29:00		20	1.1	Mount Roll 14:23,14:26
32	S	14:32:00	14:45:00	00:13:00	18	1.1	Mount Pitch 14:35 Mount Roll 14:43
33	N	14:47:00	15:00:00	00:13:00	18	1.3	
34	S	15:06:00	15:18:00	00:12:00	19	1.3	
35	N	15:21:00	15:33:00	00:12:00	19	1.4	Mount Roll 15:22,15:28
36	S	15:36:00	15:48:00	00:12:00	20	1.4	
37	N	15:51:00	16:03:00	00:12:00	20	1.4	
38	S	16:06:00	16:18:00	00:12:00	22	1.1	Mount Roll 16:12
39	N	16:20:00	16:32:00	00:12:00	21	1.2	
40	S	16:35:00	16:47:00	00:12:00	22	1.2	
41	N	16:49:00	17:01:00	00:12:00	23	1.1	

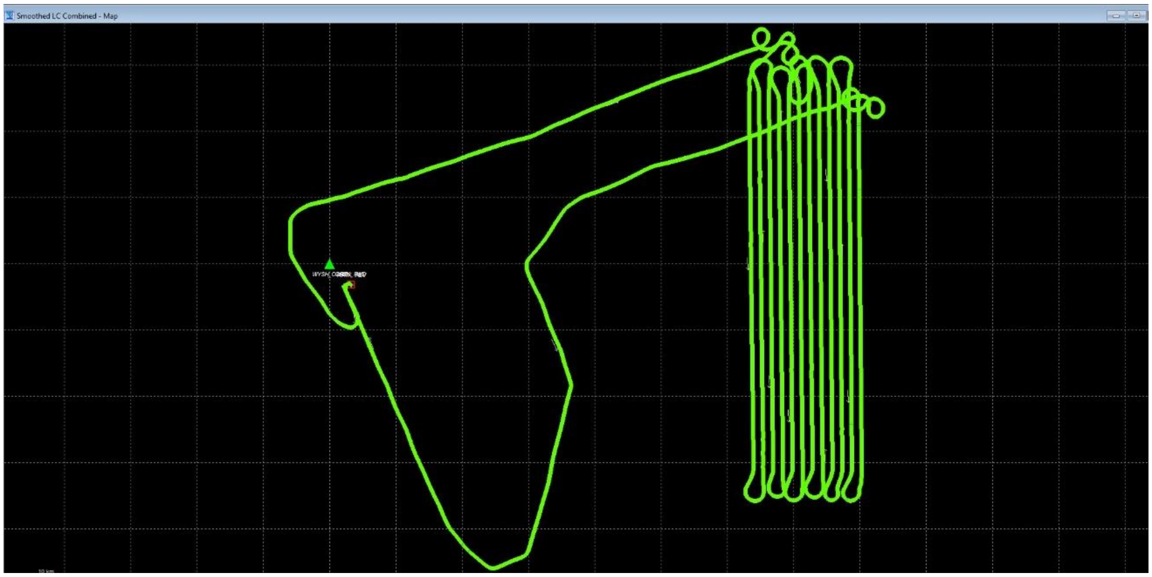
Page 1

Verify S-Turns After Mission Yes

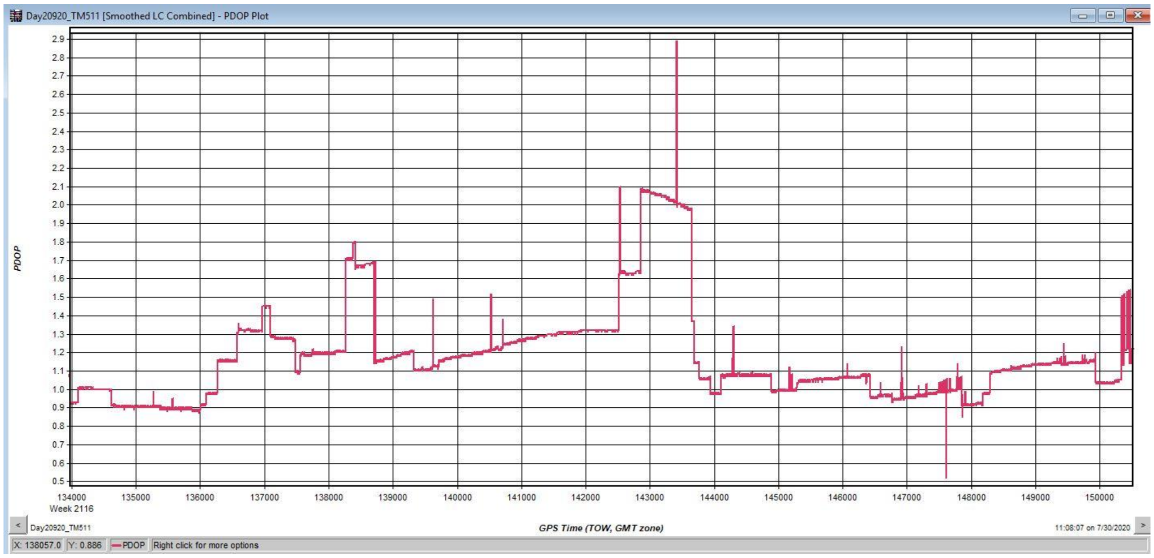
Additional Comments

New Pilot. Ray Larocque Right Seat. QL2 Block 3.

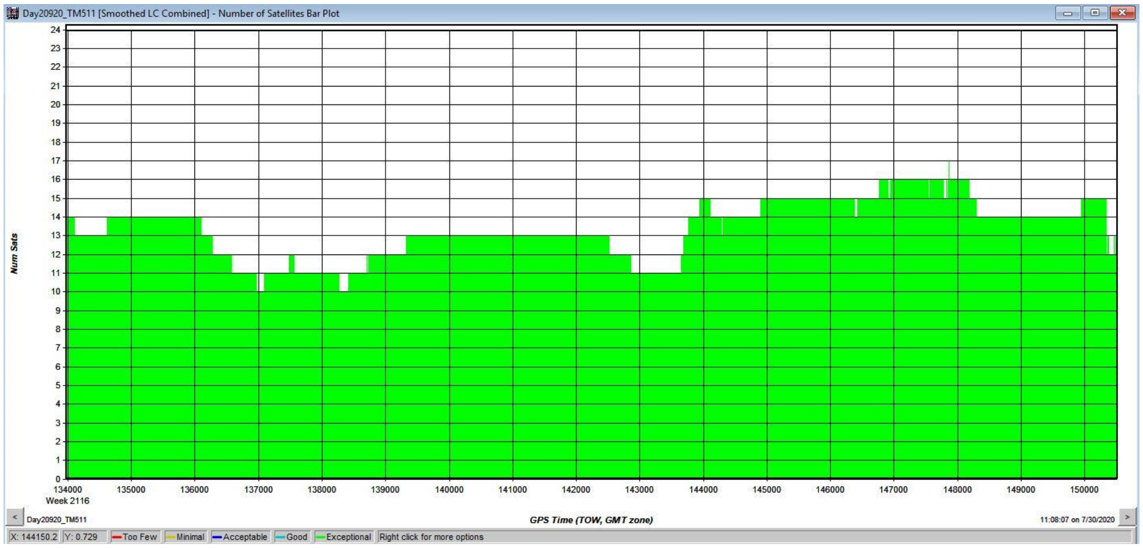
Mission Trajectory



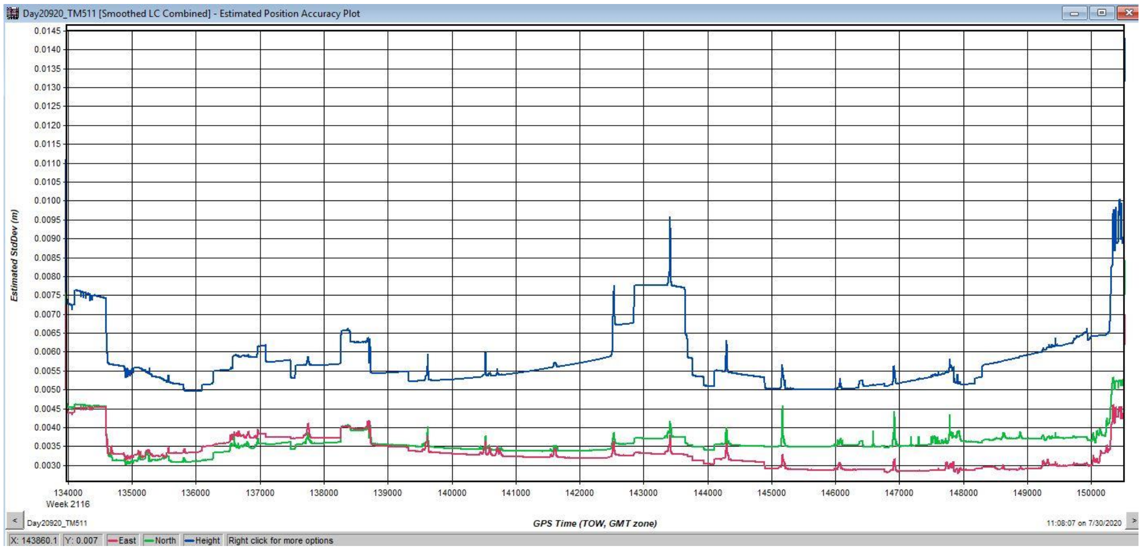
PDOP



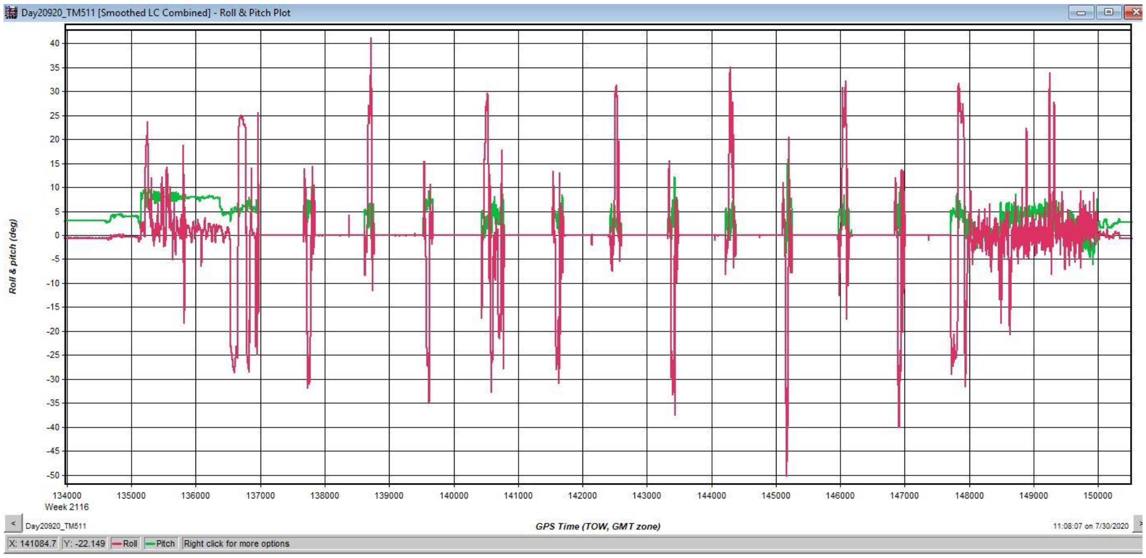
Satellites



RMS (m)



RPH (deg)


Day20920_TM511 [Smoothed LC Combined] - Roll & Pitch Plot
Roll & pitch (deg)
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
134000
Week 2116
135000
136000
137000
138000
139000
140000
141000
142000
143000
144000
145000
146000
147000
148000
149000
150000
Day20920_TM511
GPS Time (TOW, GMT zone)
11:08:07 on 7/30/2020
X: 141084.7
Y: -22.149
Roll
Pitch
Right click for more options

Mission 9 (20200731)

Flight Log

Woolpert Lidar Acquisition Log

Project Info			Date		
Project #	**Project Name**	**Unique ID**	**Flight Date (UTC)**	**Day of Year**	**Flight #**
80980	Sheridan Co WY QL1	Day213_90557_1	07/31/2020	213	1

Crew	Equipment	Time			Airports
Pilot	**Aircraft Make / Model / Tail #**	**Hobbs Start**	**Local Start**	**UTC Start**	**Departing**
Costanzo	Reims 406 - N406SD	335.5	08:36:00	14:36:00	SHR
Operator	**Sensor Make / Model / Serial #**	**Hobbs End**	**Local End**	**UTC End**	**Arriving**
Kennedy	Leica Terrain Mapper - 90557	338.9	11:37:00	17:37:00	SHR

Conditions

Wind Dir (°)	Wind Speed (kts)	Visibility (mi)	Ceiling (ft)	Cloud Cover	Temp. (°C)	Dew Point (°C)	Pressure ("Hg)
	0	10		Clear	18	11	30.21

Air Speed (kts)	Altitude AGL (ft)	Altitude MSL (ft)	Airfield Elevation (ft)
150	4,757		4,021

Settings

Point Spacing (m)	Point Density (ppsm)	Scan Angle/FOV (°)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power (%)
0.35		34	150	1600	100

Verify S-Turns Before Mission Yes

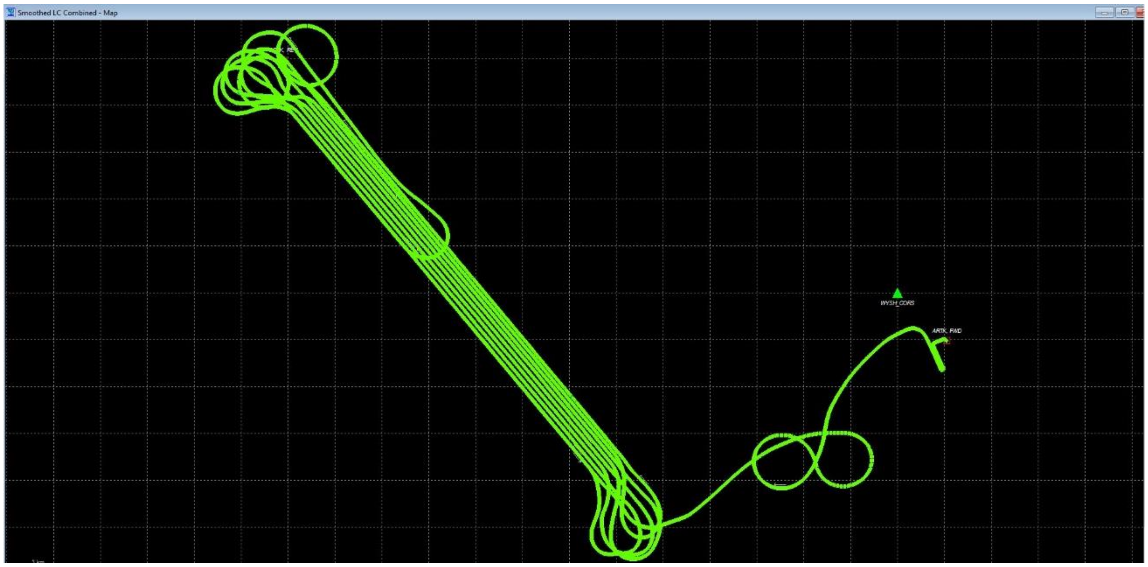
Line #	Direction	Start Time (UTC)	End Time (UTC)	Time On-Line	Satellite	PDOP	Line Notes/Comments
1	NW	14:49:00					Out of vertical range
1	SE						Reflight of line 1, out of vertical range
1	SE	15:07:00	15:13:00	00:06:00	21	1.3	Reflight of line 1
2	NW	15:17:00	15:24:00	00:07:00	21	1.3	
3	SE	15:27:00	15:33:00	00:06:00	23	1.1	
4	NW	15:37:00	15:43:00	00:06:00	23	1	
5	SE	15:46:00	15:53:00	00:07:00	22	1.1	
6	NW	15:57:00	16:04:00	00:07:00	22	1.1	
7	SE	16:07:00	16:14:00	00:07:00	20	1.2	
8	NW	16:18:00	16:25:00	00:07:00	19	1.3	Internal PAV error, locked on line. Reboot
9	SE	16:56:00	17:03:00	00:07:00	19	1.3	Internal PAV error, locked on line. Reboot
10	NW	17:17:00	17:23:00	00:06:00	19	1.1	
11	SE	17:27:00			18	1.6	ternal PAV error, locked on line. Mission end
							mx hobbs 5305.6

Page 1

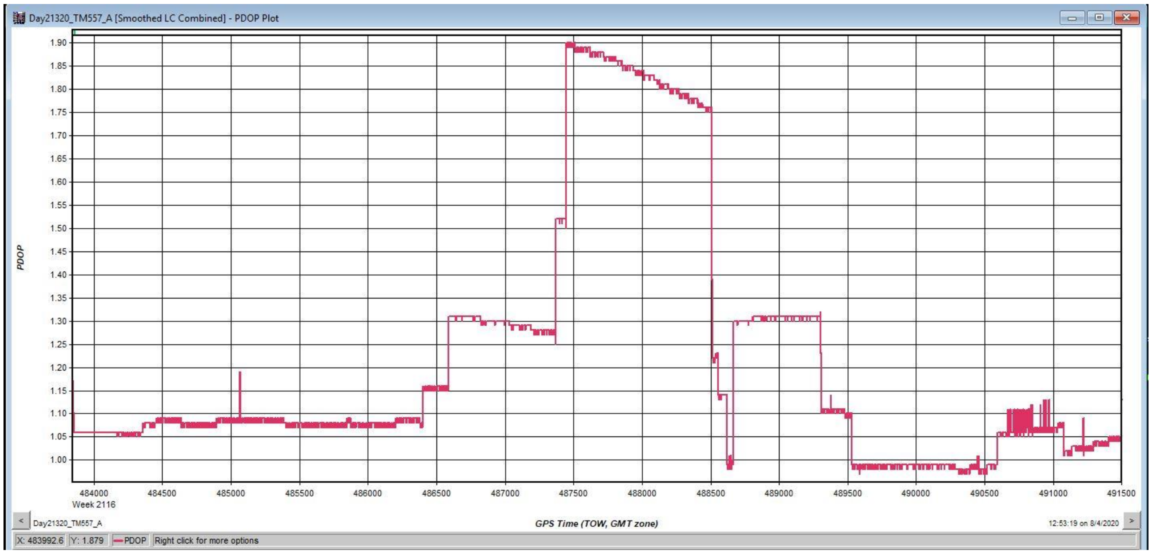
Verify S-Turns After Mission Yes

Additional Comments

Mission Trajectory

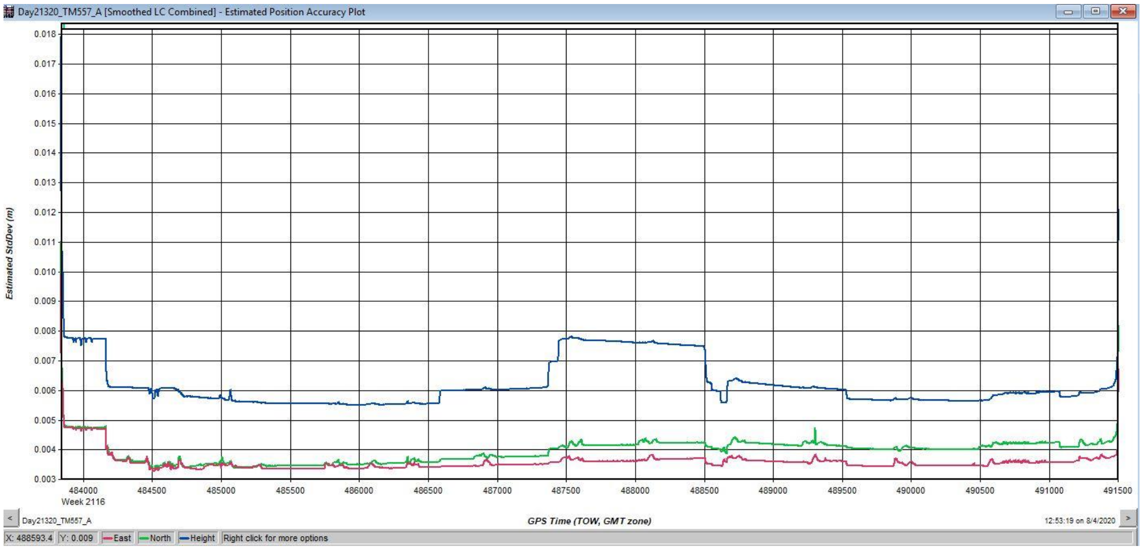


PDOP

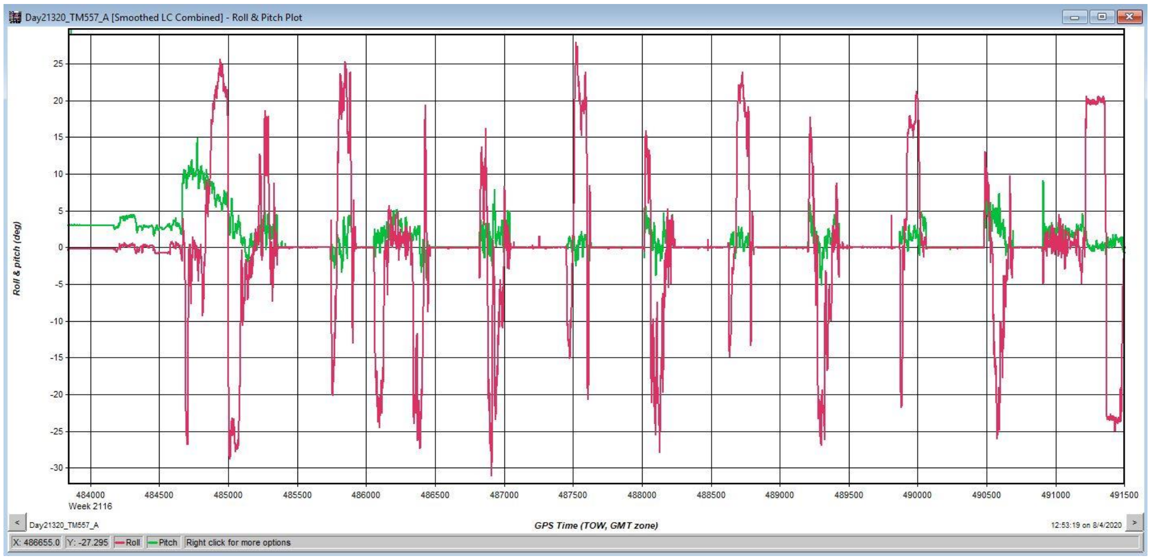


Satellites

RMS (m)

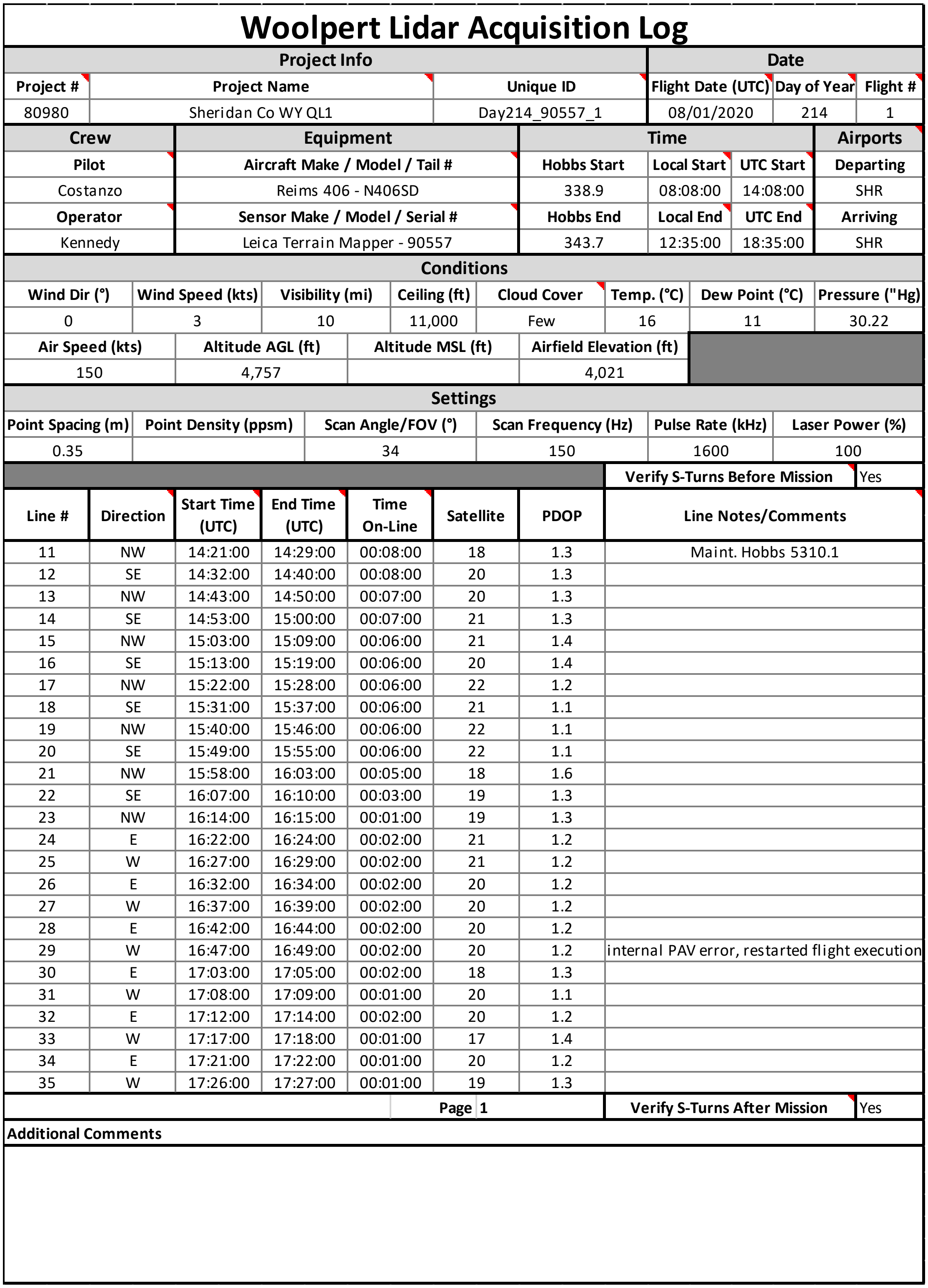


RPH (deg)


Day21320_TM557_A [Smoothed LC Combined] - Roll & Pitch Plot
Roll & pitch (deg)
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
484000
Week 2116
484500
485000
485500
486000
486500
487000
487500
488000
488500
489000
489500
490000
490500
491000
491500
<
Day21320_TM557_A
GPS Time (TOW, GMT zone)
12:53:19 on 8/4/2020
>
X: 486655.0
Y: -27.295
Roll
Pitch
Right click for more options

Mission 10 (20200801)

Flight Log



Woolpert Lidar Acquisition Log

Project Info			Date		
Project #	Project Name	Unique ID	Flight Date (UTC)	Day of Year	Flight #
80980	Sheridan Co WY QL1	Day214_90557_1	08/01/2020	214	1

Crew	Equipment	Time			Airports
Pilot	Aircraft Make / Model / Tail #	Hobbs Start	Local Start	UTC Start	Departing
Costanzo	Reims 406 - N406SD	338.9	08:08:00	14:08:00	SHR
Operator	Sensor Make / Model / Serial #	Hobbs End	Local End	UTC End	Arriving
Kennedy	Leica Terrain Mapper - 90557	343.7	12:35:00	18:35:00	SHR

Conditions							
Wind Dir (°)	Wind Speed (kts)	Visibility (mi)	Ceiling (ft)	Cloud Cover	Temp. (°C)	Dew Point (°C)	Pressure ("Hg)
0	3	10	11,000	Few	16	11	30.22
Air Speed (kts)	Altitude AGL (ft)	Altitude MSL (ft)	Airfield Elevation (ft)				
150	4,757		4,021				

Settings					
Point Spacing (m)	Point Density (ppsm)	Scan Angle/FOV (°)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power (%)
0.35		34	150	1600	100

Verify S-Turns Before Mission: Yes

Line #	Direction	Start Time (UTC)	End Time (UTC)	Time On-Line	Satellite	PDOP	Line Notes/Comments
11	NW	14:21:00	14:29:00	00:08:00	18	1.3	Maint. Hobbs 5310.1
12	SE	14:32:00	14:40:00	00:08:00	20	1.3	
13	NW	14:43:00	14:50:00	00:07:00	20	1.3	
14	SE	14:53:00	15:00:00	00:07:00	21	1.3	
15	NW	15:03:00	15:09:00	00:06:00	21	1.4	
16	SE	15:13:00	15:19:00	00:06:00	20	1.4	
17	NW	15:22:00	15:28:00	00:06:00	22	1.2	
18	SE	15:31:00	15:37:00	00:06:00	21	1.1	
19	NW	15:40:00	15:46:00	00:06:00	22	1.1	
20	SE	15:49:00	15:55:00	00:06:00	22	1.1	
21	NW	15:58:00	16:03:00	00:05:00	18	1.6	
22	SE	16:07:00	16:10:00	00:03:00	19	1.3	
23	NW	16:14:00	16:15:00	00:01:00	19	1.3	
24	E	16:22:00	16:24:00	00:02:00	21	1.2	
25	W	16:27:00	16:29:00	00:02:00	21	1.2	
26	E	16:32:00	16:34:00	00:02:00	20	1.2	
27	W	16:37:00	16:39:00	00:02:00	20	1.2	
28	E	16:42:00	16:44:00	00:02:00	20	1.2	
29	W	16:47:00	16:49:00	00:02:00	20	1.2	internal PAV error, restarted flight execution
30	E	17:03:00	17:05:00	00:02:00	18	1.3	
31	W	17:08:00	17:09:00	00:01:00	20	1.1	
32	E	17:12:00	17:14:00	00:02:00	20	1.2	
33	W	17:17:00	17:18:00	00:01:00	17	1.4	
34	E	17:21:00	17:22:00	00:01:00	20	1.2	
35	W	17:26:00	17:27:00	00:01:00	19	1.3	

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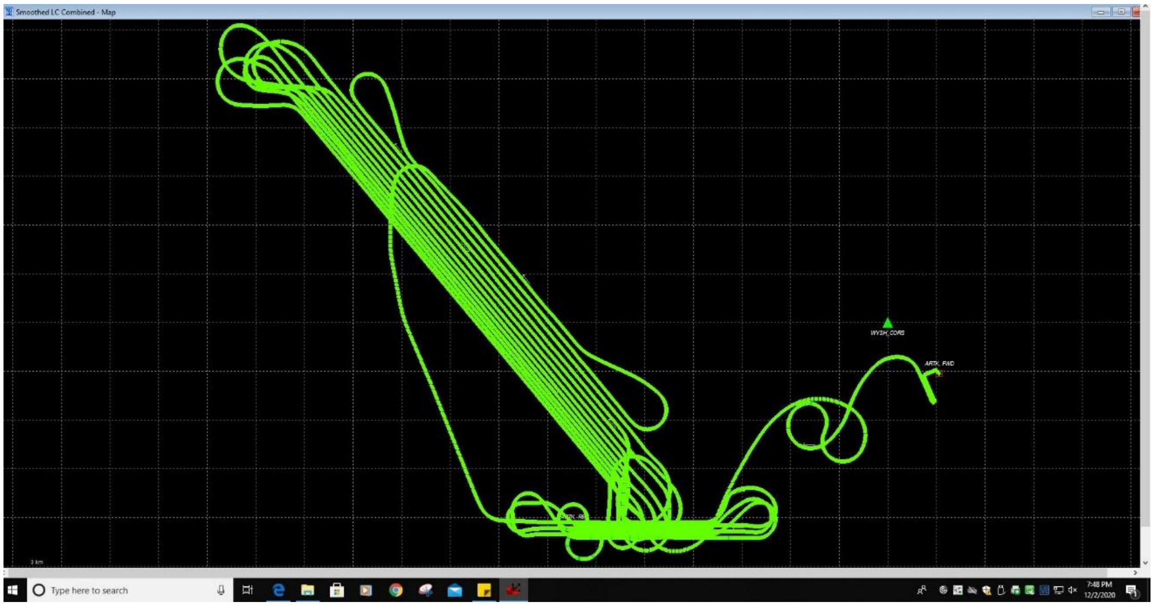
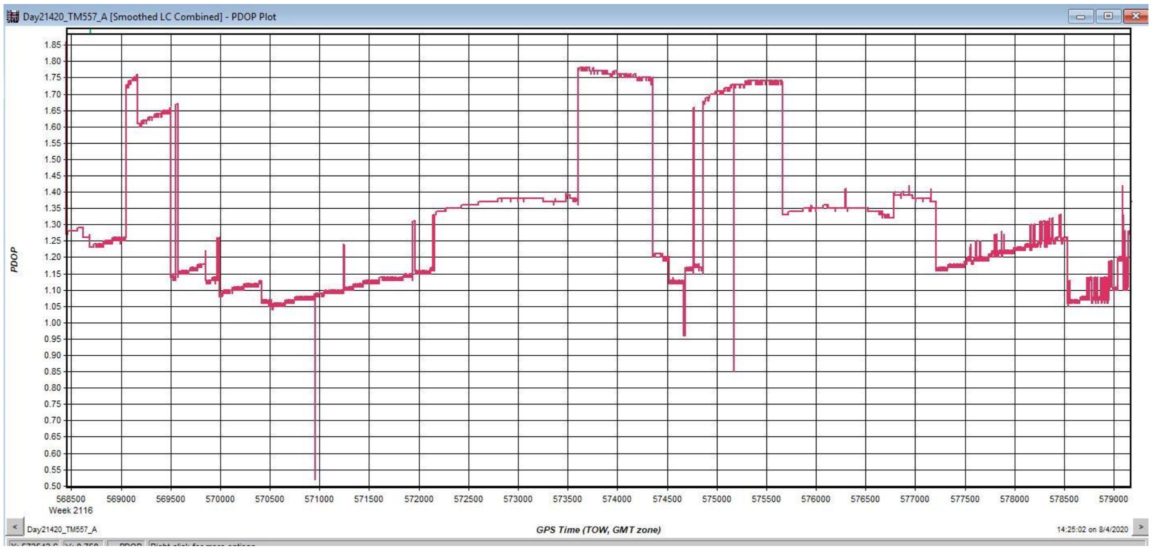
Verify S-Turns After Mission: Yes

Additional Comments

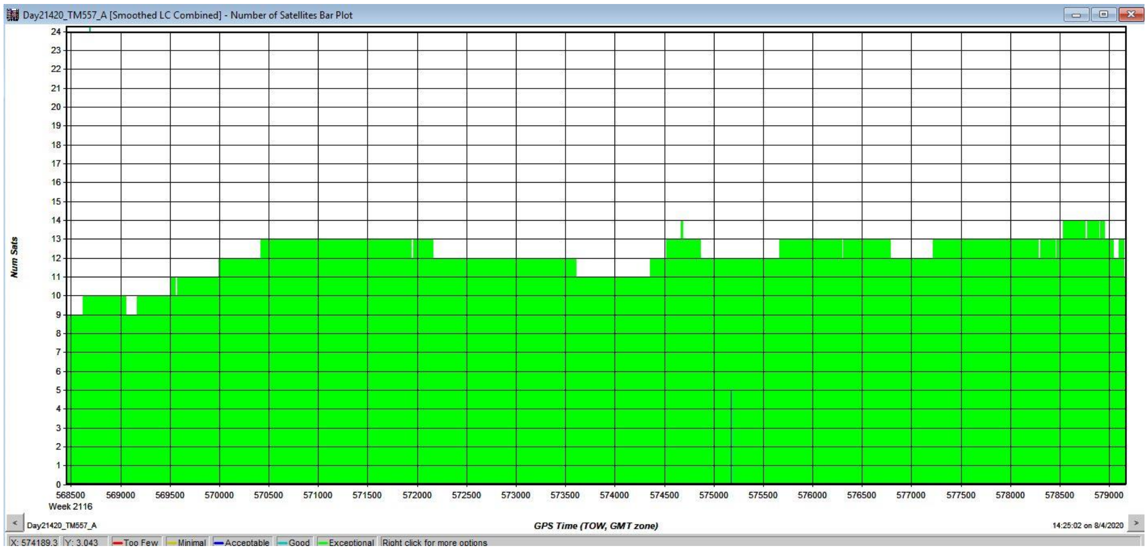
Mission Trajectory



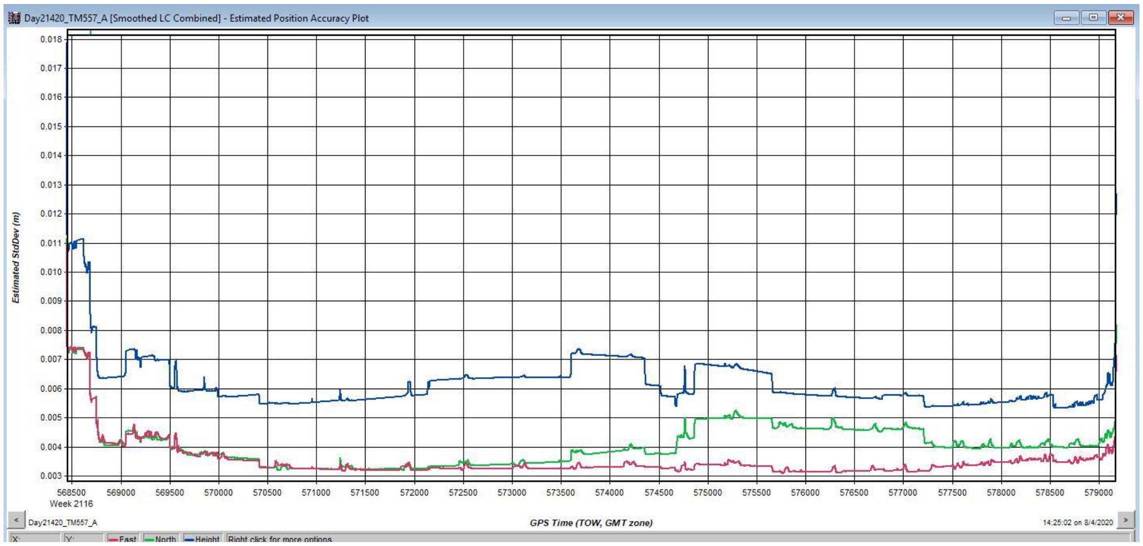
PDOP



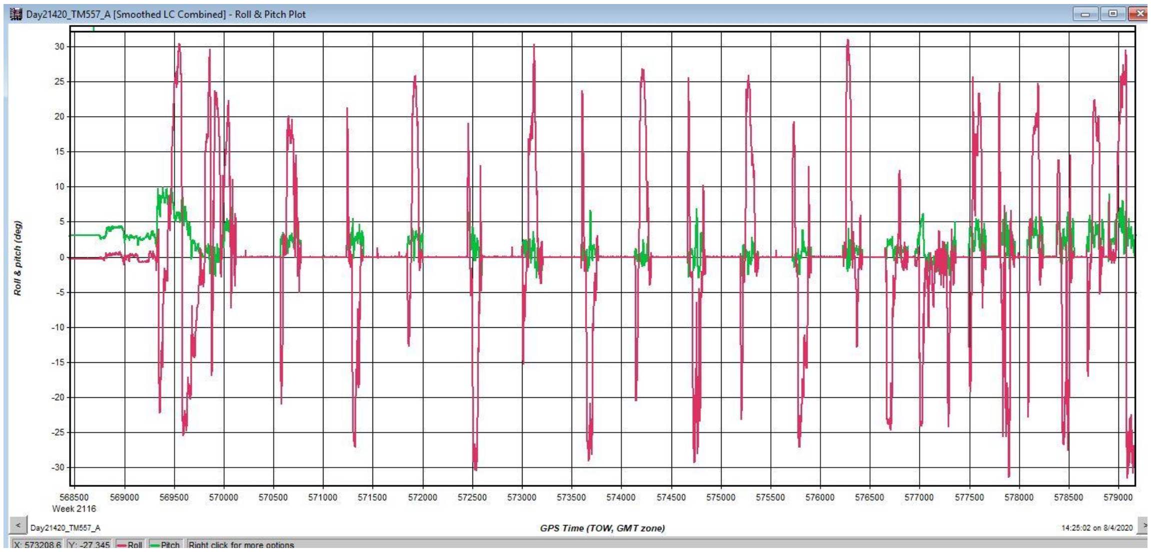
Satellites



RMS (m)



RPH (deg)


Day21420_TM557_A [Smoothed LC Combined] - Roll & Pitch Plot
Roll & pitch (deg)
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
568500
Week 2116
569000
569500
570000
570500
571000
571500
572000
572500
573000
573500
574000
574500
575000
575500
576000
576500
577000
577500
578000
578500
579000
Day21420_TM557_A
GPS Time (TOW, GMT zone)
14:25:02 on 8/4/2020
X: 573208.6
Y: -27.345
Roll
Pitch
Right click for more options

Mission 11 (20200801)

Flight Log

Woolpert Lidar Acquisition Log

Project Info			Date		
Project #	**Project Name**	**Unique ID**	**Flight Date (UTC)**	**Day of Year**	**Flight #**
80980	Sheridan Co WY QL1	Day214_90557_1	08/01/2020	214	1

Crew	Equipment	Time			Airports
Pilot	**Aircraft Make / Model / Tail #**	**Hobbs Start**	**Local Start**	**UTC Start**	**Departing**
Costanzo	Reims 406 - N406SD	465.7			SHR
Operator	**Sensor Make / Model / Serial #**	**Hobbs End**	**Local End**	**UTC End**	**Arriving**
Kennedy	Leica Terrain Mapper - 90557				SHR

Conditions

Wind Dir (°)	Wind Speed (kts)	Visibility (mi)	Ceiling (ft)	Cloud Cover	Temp. (°C)	Dew Point (°C)	Pressure ("Hg)
0	3	0,010	11,000	Few	16	11	30.22

Air Speed (kts)	Altitude AGL (ft)	Altitude MSL (ft)	Airfield Elevation (ft)
150	4,757		4,021

Settings

Point Spacing (m)	Point Density (ppsm)	Scan Angle/FOV (°)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power (%)
0.35		34	150	1600	100

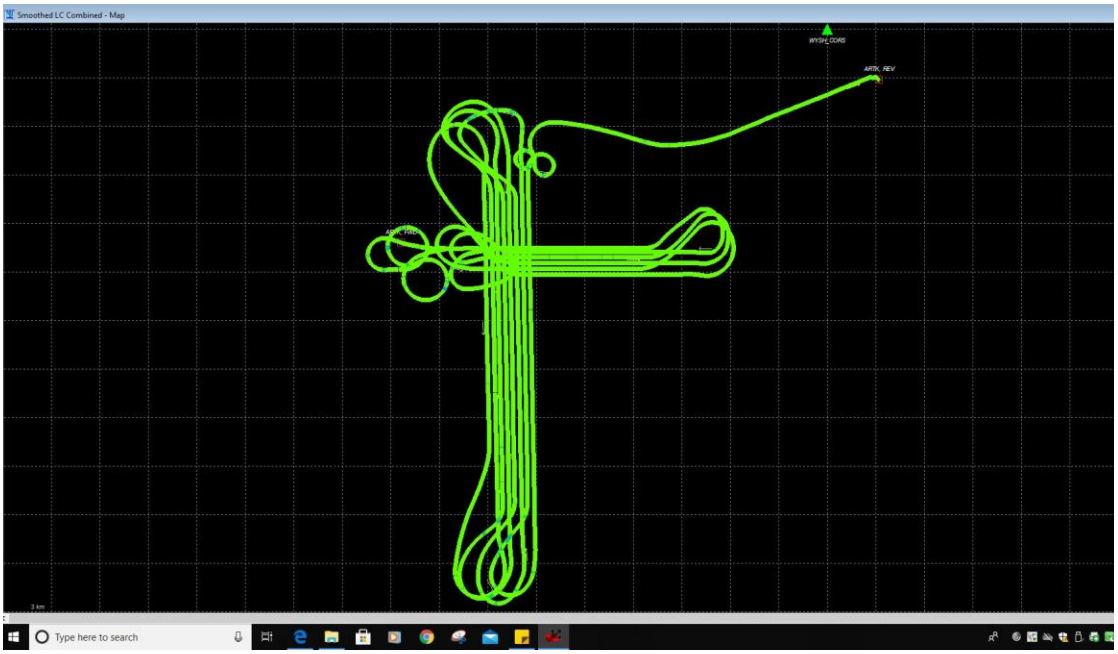
Verify S-Turns Before Mission	Yes

Line #	Direction	Start Time (UTC)	End Time (UTC)	Time On-Line	Satellite	PDOP	Line Notes/Comments
36	S	17:32:00	17:35:00	00:03:00	20	1.2	
37	N	17:39:00	17:43:00	00:04:00	20	1.2	
38	S	17:46:00	17:50:00	00:04:00	20	1.3	
39	N	17:53:00	17:57:00	00:04:00	20	1.2	
40	S	18:01:00	18:05:00	00:04:00	19	1.3	
41	N	18:08:00	18:12:00	00:04:00	20	1.3	
42	S	18:15:00	18:19:00	00:04:00	20	1.2	
43	N	18:22:00	18:26:00	00:04:00	19	1.2	

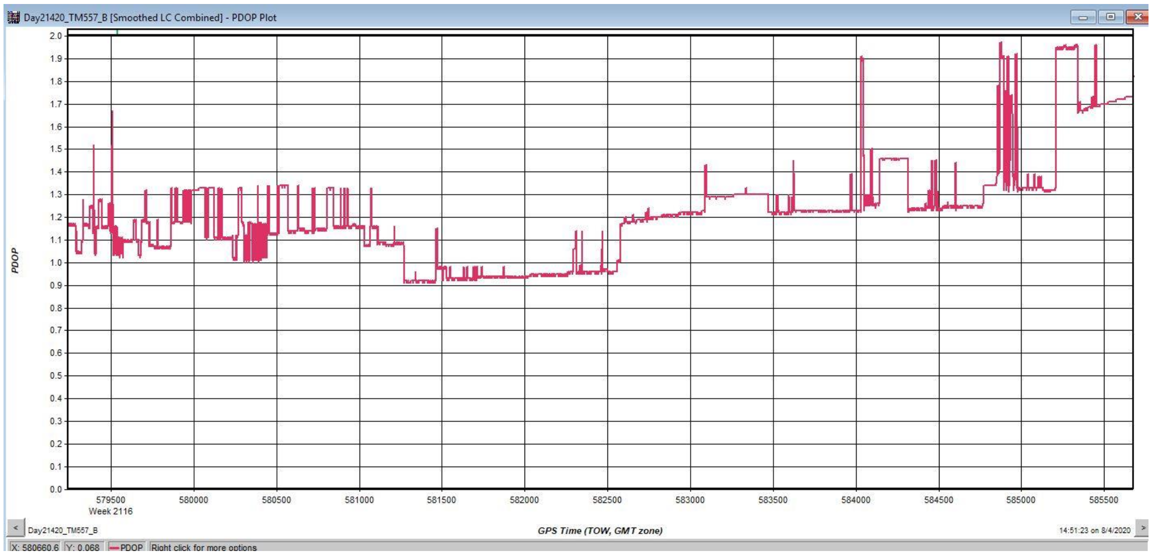
Page 2	**Verify S-Turns After Mission**	

Additional Comments

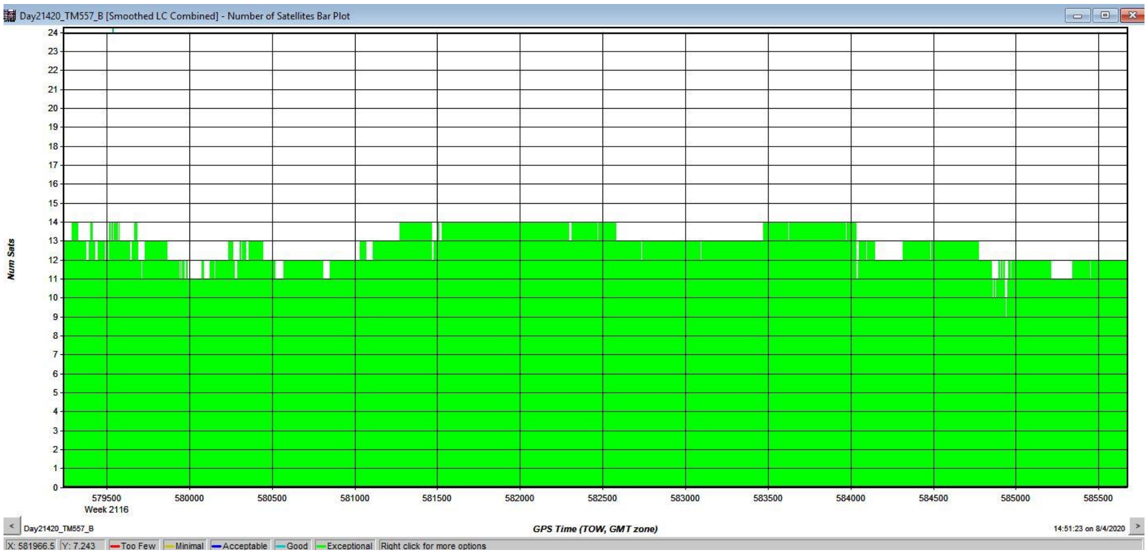
Mission Trajectory



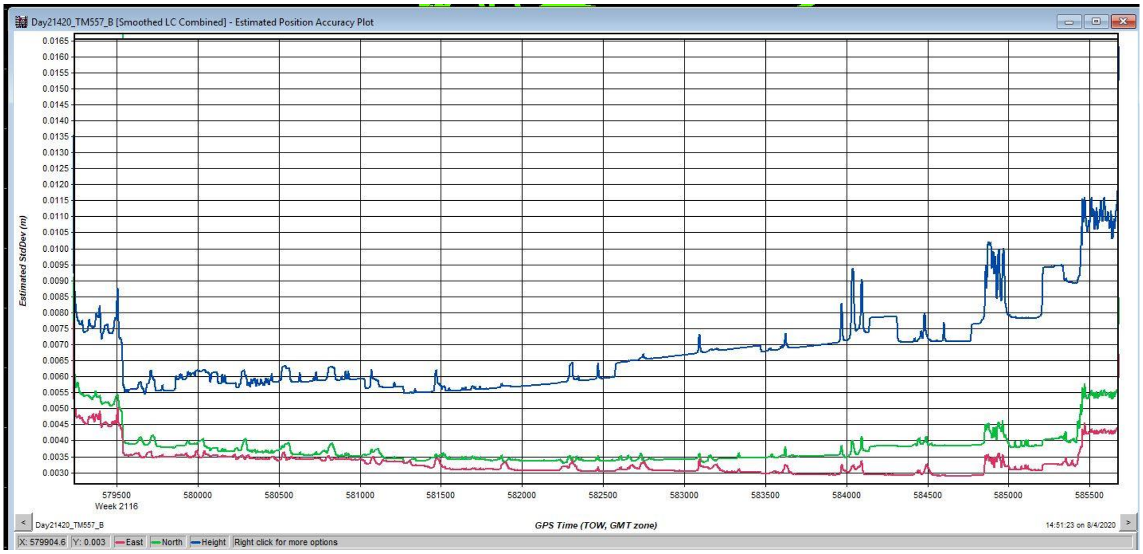
PDOP



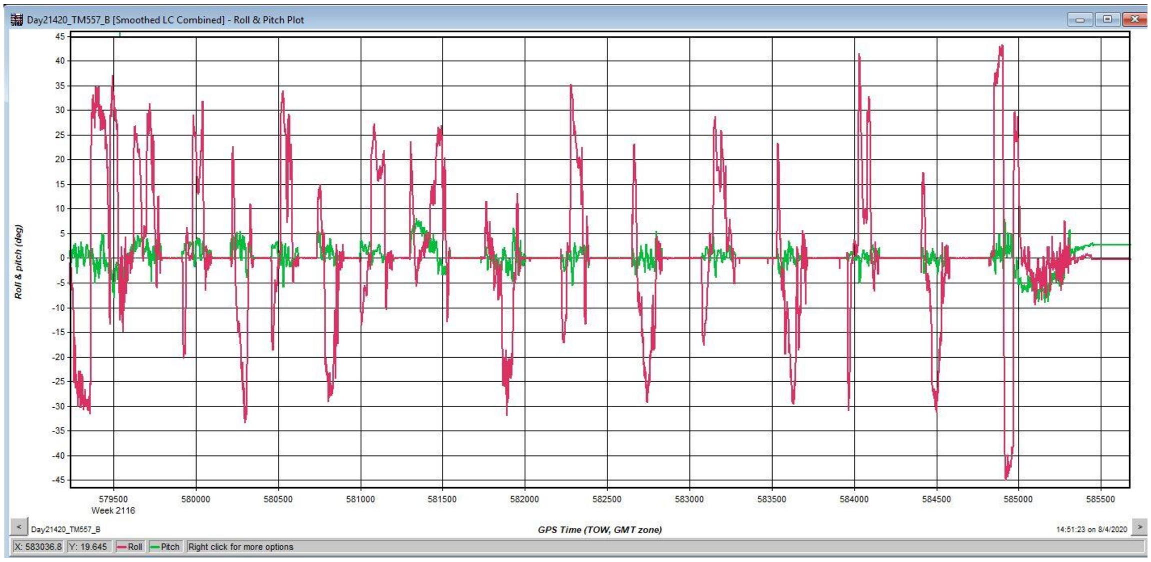
Satellites



RMS (m)



RPH (deg)



Day21420_TM557_B [Smoothed LC Combined] - Roll & Pitch Plot
Roll & pitch (deg)
45
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
579500
Week 2116
580000
580500
581000
581500
582000
582500
583000
583500
584000
584500
585000
585500
<
Day21420_TM557_B
GPS Time (TOW, GMT zone)
14:51:23 on 8/4/2020
>
X: 583036.8
Y: 19.645
Roll
Pitch
Right click for more options

Mission 12 (20200802)

Flight Log

Woolpert Lidar Acquisition Log

Project Info			Date		
Project #	**Project Name**	**Unique ID**	**Flight Date (UTC)**	**Day of Year**	**Flight #**
80980	Sheridan Co WY QL1	Day215_90557_1	08/02/2020	215	1

Crew	Equipment	Time			Airports
Pilot	**Aircraft Make / Model / Tail #**	**Hobbs Start**	**Local Start**	**UTC Start**	**Departing**
Costanzo	Reims 406 - N406SD	343.7	08:51:00	13:51:00	SHR
Operator	**Sensor Make / Model / Serial #**	**Hobbs End**	**Local End**	**UTC End**	**Arriving**
Kennedy	Leica Terrain Mapper - 90557	349.4	13:03:00	19:03:00	SHR

Conditions

Wind Dir (°)	Wind Speed (kts)	Visibility (mi)	Ceiling (ft)	Cloud Cover	Temp. (°C)	Dew Point (°C)	Pressure ("Hg)
200	3	10		Clear	14	10	30.15

Air Speed (kts)	Altitude AGL (ft)	Altitude MSL (ft)	Airfield Elevation (ft)
150	4,757		4,021

Settings

Point Spacing (m)	Point Density (ppsm)	Scan Angle/FOV (°)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power (%)
0.35		34	150	1600	100

Verify S-Turns Before Mission Yes

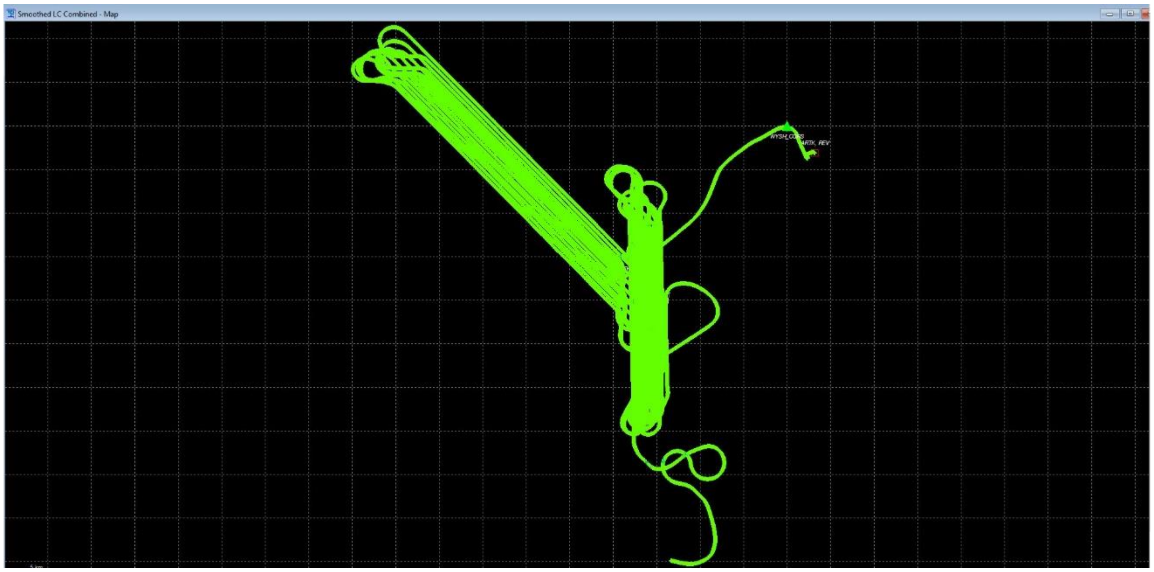
Line #	Direction	Start Time (UTC)	End Time (UTC)	Time On-Line	Satellite	PDOP	Line Notes/Comments
44	N	14:29:00	14:33:00	00:04:00	17	1.4	mx hobbs 5315.3
45	S	14:36:00	14:40:00	00:04:00	17	1.4	
46	N	14:43:00	14:48:00	00:05:00	17	1.4	
47	S	14:51:00	14:55:00	00:04:00	17	1.4	
48	N	14:58:00	15:02:00	00:04:00	17	1.4	
49	S	15:06:00	15:10:00	00:04:00	17	1.4	
50	N	15:12:00	15:16:00	00:04:00	16	1.5	
51	S	15:20:00	15:23:00	00:03:00	17	1.4	
52	N	15:26:00	15:30:00	00:04:00	16	1.4	
53	S	15:33:00	15:37:00	00:04:00	17	1.4	
54	N	15:40:00	15:45:00	00:05:00	17	1.3	
55	S	15:47:00	15:51:00	00:04:00	18	1.1	
56	N	15:54:00	15:58:00	00:04:00	17	1.2	
57	S	16:02:00	16:06:00	00:04:00	17	1.2	
58	N	16:10:00	16:14:00	00:04:00	17	1.3	
59	S	16:17:00	16:20:00	00:03:00	18	1.2	
60	N	16:24:00	16:25:00	00:01:00	19	1.1	
61	NW	16:31:00	16:39:00	00:08:00	19	1.1	
62	SE	16:42:00	16:50:00	00:08:00	18	1.3	
63	NW	16:53:00	17:00:00	00:07:00	18	1.3	
64	SE	17:04:00	17:11:00	00:07:00	19	1.1	
65	NW	17:15:00	17:22:00	00:07:00	18	1.5	
66	SE	17:25:00	17:32:00	00:07:00	19	1.3	
67	NW	17:35:00	17:42:00	00:07:00	20	1.2	
68	SE	17:45:00	17:52:00	00:07:00	20	1.2	

Page 1

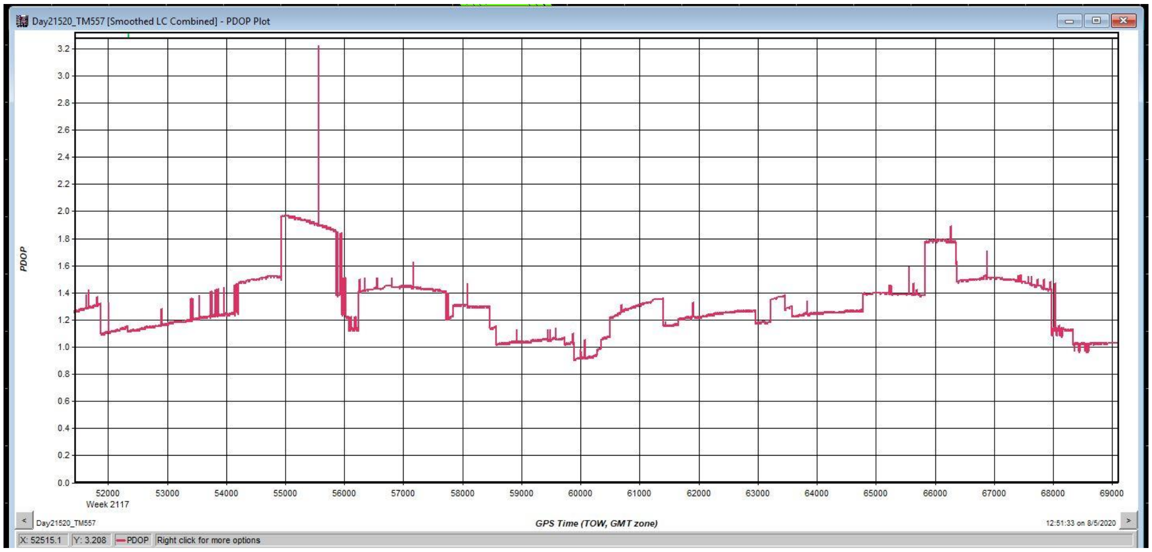
Verify S-Turns After Mission Yes

Additional Comments

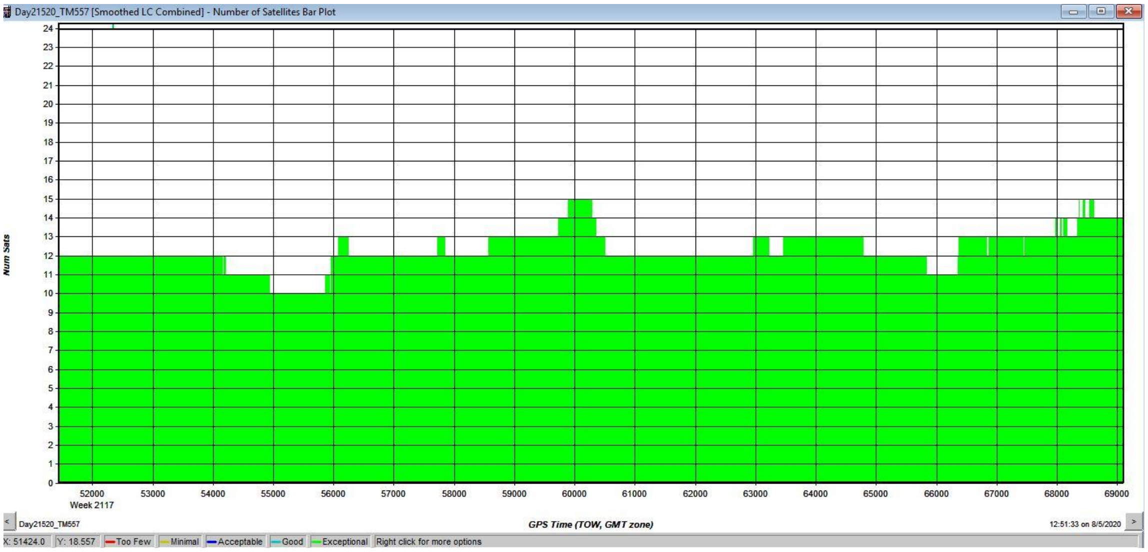
Mission Trajectory



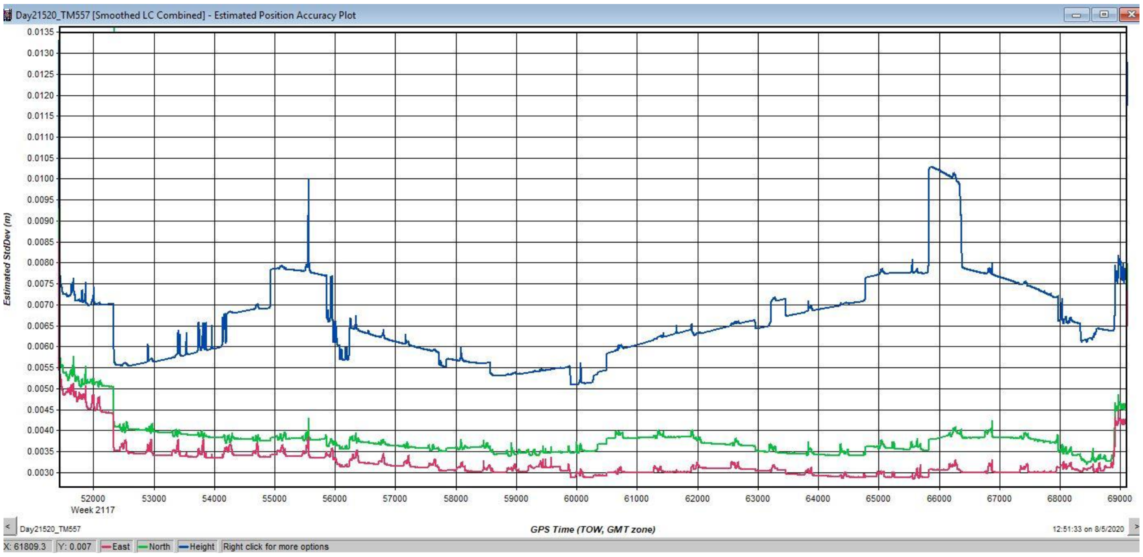
PDOP



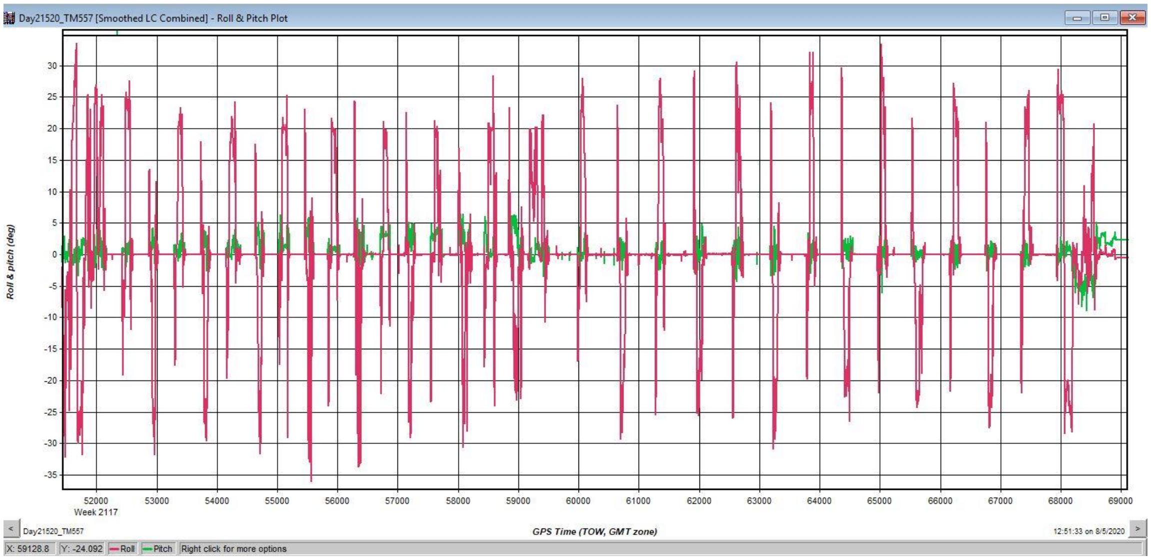
Satellites



RMS (m)



RPH (deg)


Day21520_TM557 [Smoothed LC Combined] - Roll & Pitch Plot
Roll & pitch (deg)
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
52000
Week 2117
53000
54000
55000
56000
57000
58000
59000
60000
61000
62000
63000
64000
65000
66000
67000
68000
69000
<
Day21520_TM557
GPS Time (TOW, GMT zone)
12:51:33 on 8/5/2020
>
X: 59128.8
Y: -24.092
Roll
Pitch
Right click for more options

Mission 13 (20200803)

Flight Log

Woolpert Lidar Acquisition Log

Project Info			Date		
Project #	**Project Name**	**Unique ID**	**Flight Date (UTC)**	**Day of Year**	**Flight #**
80980	Sheridan Co WY QL1	Day216_90557_1	08/03/2020	216	1

Crew	Equipment	Time			Airports
Pilot	**Aircraft Make / Model / Tail #**	**Hobbs Start**	**Local Start**	**UTC Start**	**Departing**
Costanzo	Reims 406 - N406SD	349.4	07:43:00	13:43:00	SHR
Operator	**Sensor Make / Model / Serial #**	**Hobbs End**	**Local End**	**UTC End**	**Arriving**
Kennedy	Leica Terrain Mapper - 90557	352.1	10:00:00	16:00:00	SHR

Conditions

Wind Dir (°)	Wind Speed (kts)	Visibility (mi)	Ceiling (ft)	Cloud Cover	Temp. (°C)	Dew Point (°C)	Pressure ("Hg)
0	0	10		Clear	16	11	30.05

Air Speed (kts)	Altitude AGL (ft)	Altitude MSL (ft)	Airfield Elevation (ft)
150	4,757		4,021

Settings

Point Spacing (m)	Point Density (ppsm)	Scan Angle/FOV (°)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power (%)
0.35		34	150	1600	100

Verify S-Turns Before Mission Yes

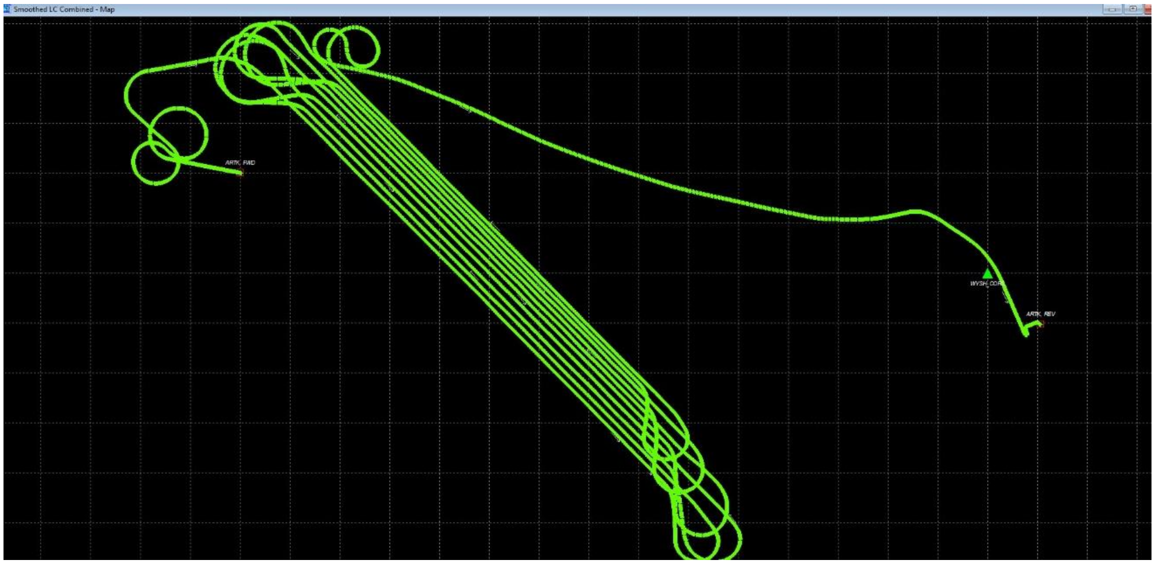
Line #	Direction	Start Time (UTC)	End Time (UTC)	Time On-Line	Satellite	PDOP	Line Notes/Comments
75	NW	13:56:00	14:02:00	00:06:00	21	1	
76	SE	14:18:00	14:24:00	00:06:00	17	1.1	AV error on start of line, rebooted and reflow
77	NW	14:27:00	14:33:00	00:06:00	18	1.2	
78	SE	14:37:00	14:43:00	00:06:00	18	1.3	
79	NW	14:47:00	14:53:00	00:06:00	17	1.4	
80	SE	14:57:00	15:02:00	00:05:00	18	1.4	
81	NW	15:06:00	15:11:00	00:05:00	17	1.5	
82	SE	15:16:00	15:21:00	00:05:00	21	1.1	
83	NW	15:25:00	15:30:00	00:05:00	22	1.1	
84	SE	15:33:00	15:38:00	00:05:00	20	1.2	
85	NW	15:42:00	15:47:00	00:05:00	20	1.2	Mx 5317.5

Page 1

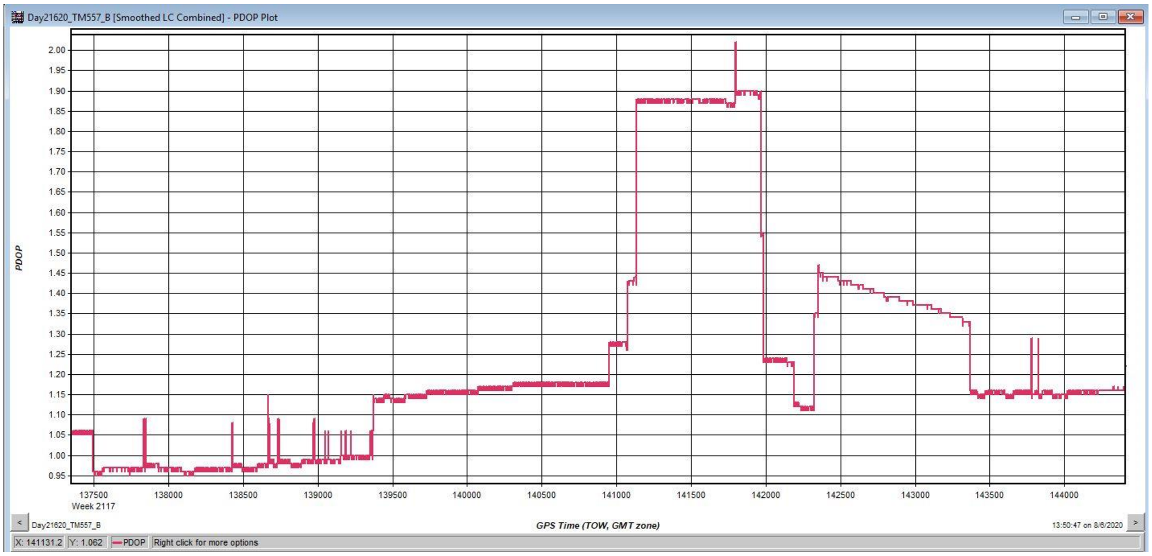
Verify S-Turns After Mission Yes

Additional Comments

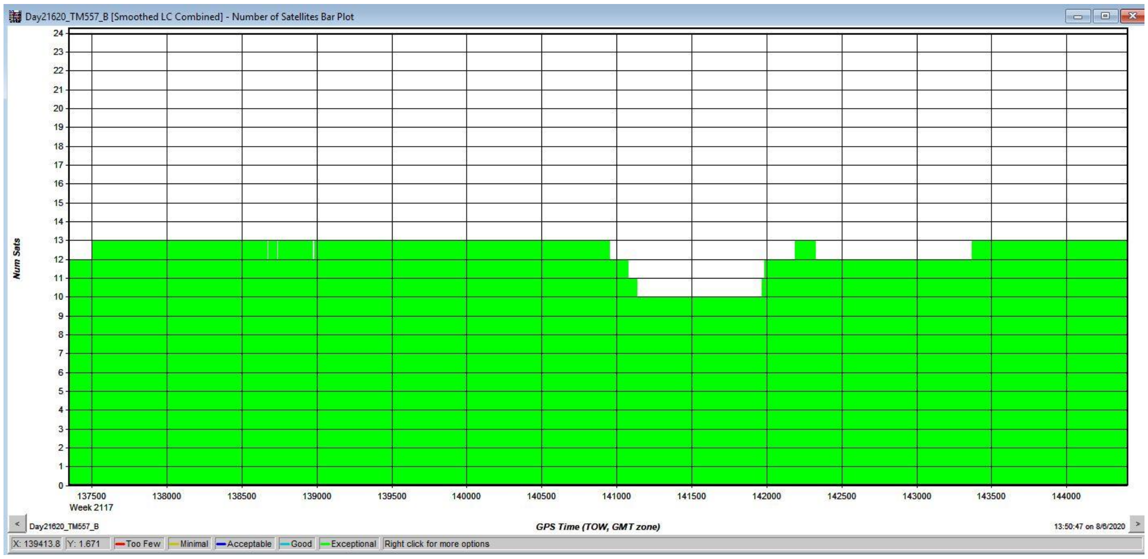
Mission Trajectory



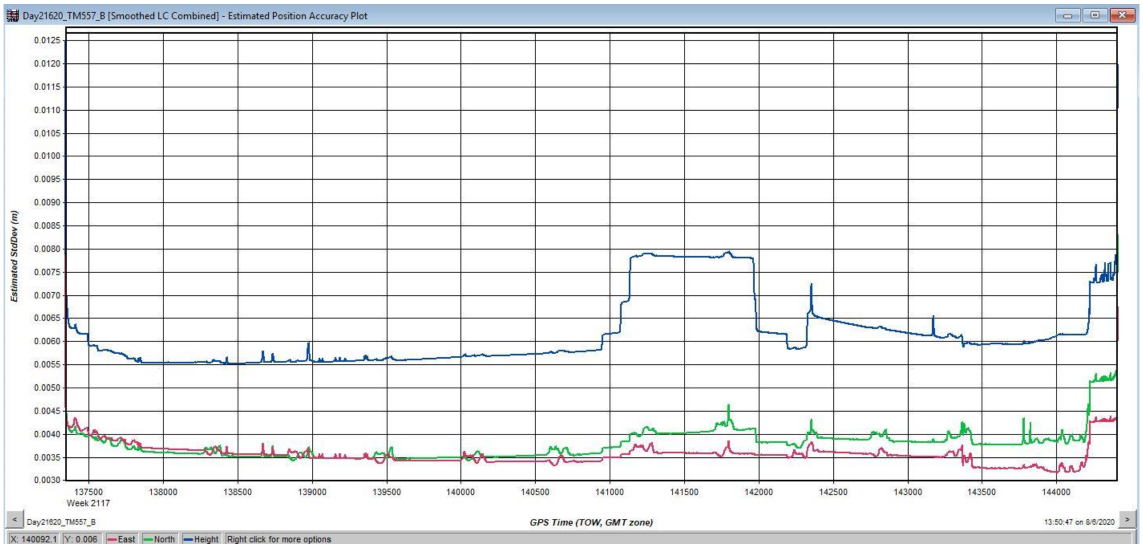
PDOP



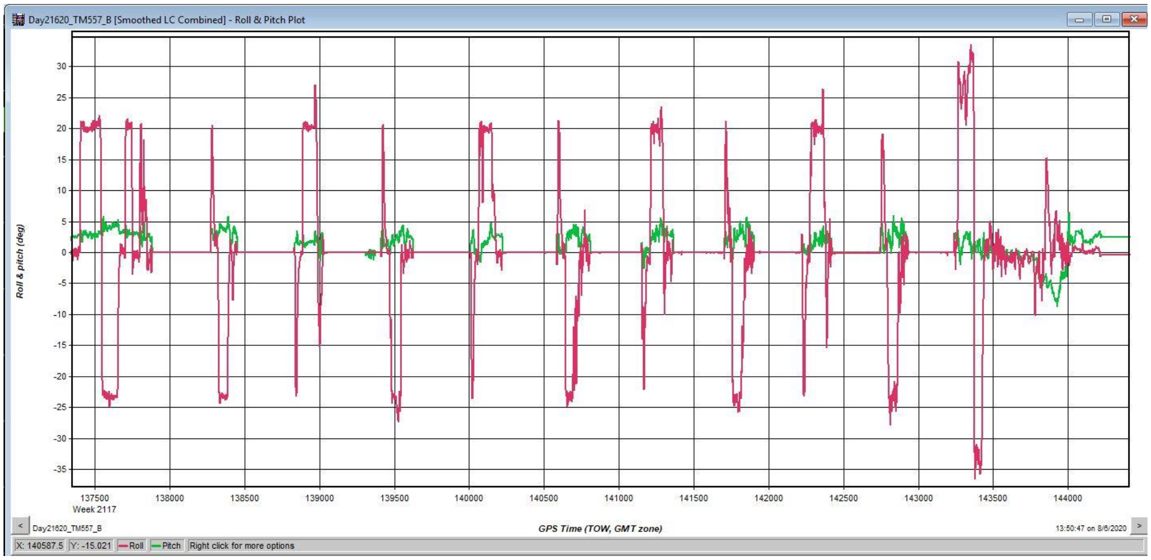
Satellites



RMS (m)



RPH (deg)


Day21620_TM557_B [Smoothed LC Combined] - Roll & Pitch Plot
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
Roll & pitch (deg)
137500
Week 2117
138000
138500
139000
139500
140000
140500
141000
141500
142000
142500
143000
143500
144000
GPS Time (TOW, GMT zone)
Day21620_TM557_B
13:50:47 on 8/6/2020
X: 140587.5
Y: -15.021
Roll
Pitch
Right click for more options

Mission 14 (20200803)

Flight Log

Woolpert Lidar Acquisition Log

Project Info			Date		
Project #	**Project Name**	**Unique ID**	**Flight Date (UTC)**	**Day of Year**	**Flight #**
80980	Sheridan Co WY QL1	Day216_90557_2	08/03/2020	216	2

Crew	Equipment	Time			Airports
Pilot	**Aircraft Make / Model / Tail #**	**Hobbs Start**	**Local Start**	**UTC Start**	**Departing**
Costanzo	Reims 406 - N406SD	352.1	10:49:00	16:49:00	SHR
Operator	**Sensor Make / Model / Serial #**	**Hobbs End**	**Local End**	**UTC End**	**Arriving**
Kennedy	Leica Terrain Mapper - 90557	354.2	12:27:00	18:27:00	SHR

Conditions							
Wind Dir (°)	**Wind Speed (kts)**	**Visibility (mi)**	**Ceiling (ft)**	**Cloud Cover**	**Temp. (°C)**	**Dew Point (°C)**	**Pressure ("Hg)**
0	0	10		Clear	25	11	30.05
Air Speed (kts)	**Altitude AGL (ft)**	**Altitude MSL (ft)**	**Airfield Elevation (ft)**				
150	4,757		4,021				

Settings					
Point Spacing (m)	**Point Density (ppsm)**	**Scan Angle/FOV (°)**	**Scan Frequency (Hz)**	**Pulse Rate (kHz)**	**Laser Power (%)**
0.35		34	150	1600	100

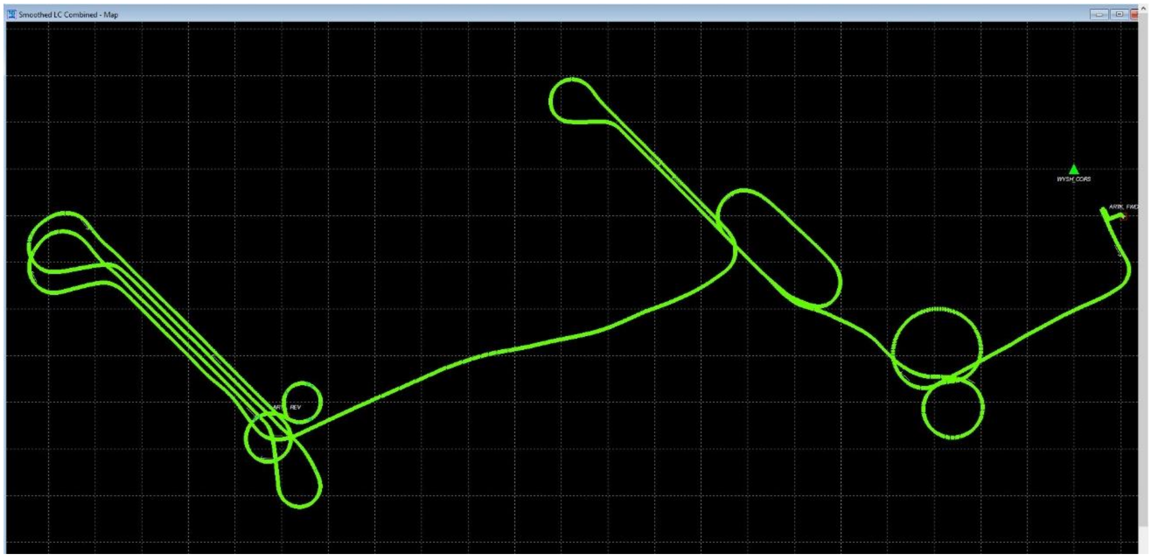
Verify S-Turns Before Mission Yes

Line #	Direction	Start Time (UTC)	End Time (UTC)	Time On-Line	Satellite	PDOP	Line Notes/Comments
86	NW	17:07:00	17:09:00	00:02:00	20	1.2	
87	SE	17:12:00	17:13:00	00:01:00	21	1.1	
88	NW	17:23:00	17:24:00	00:01:00	21	1.2	
89	SE	17:28:00	17:30:00	00:02:00	23	1.1	
90	NW	17:34:00	17:36:00	00:02:00	23	1.1	
91	SE	17:40:00	17:42:00	00:02:00	23	1.1	PAV error, reboot
92	NW	18:01:00	18:04:00	00:03:00	23	1.1	
93	SE	18:08:00	18:11:00	00:03:00	23	1.1	PAV eror, mission ended
							mx hobbs 5319.2

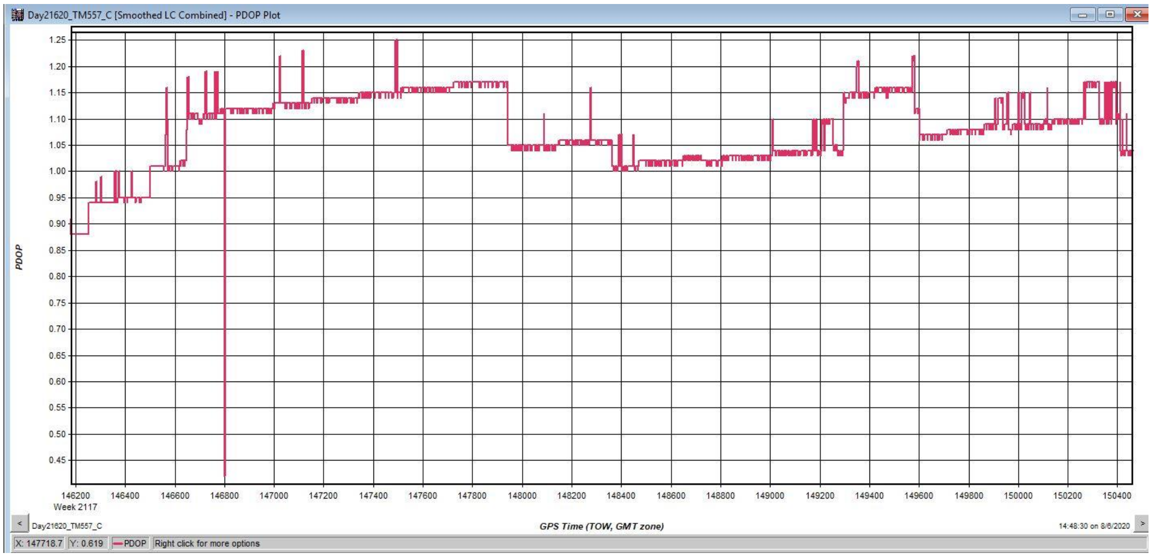
Page 1 **Verify S-Turns After Mission** Yes

Additional Comments

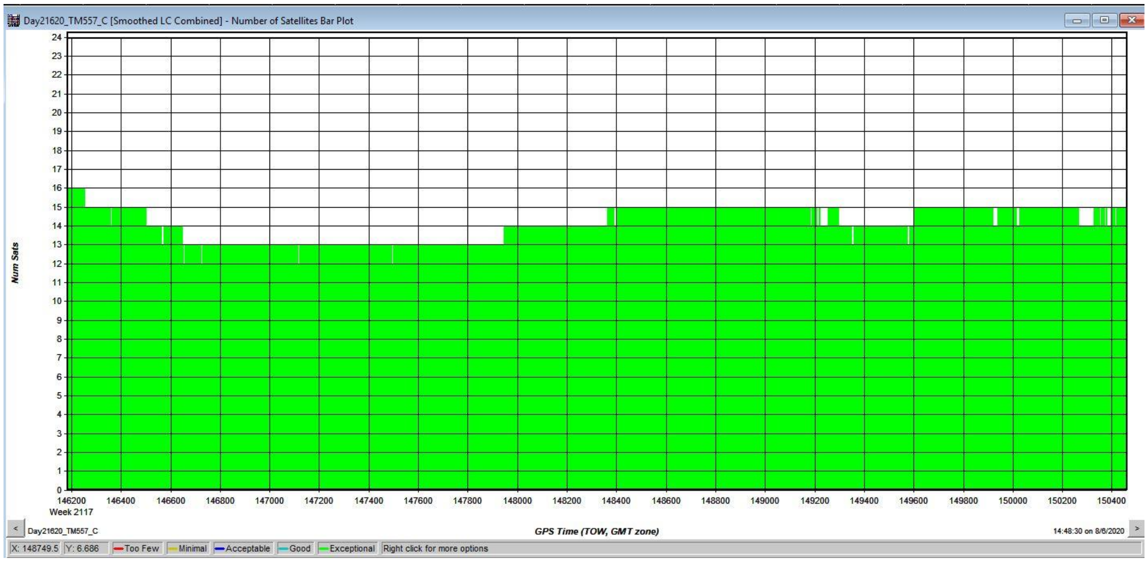
Mission Trajectory



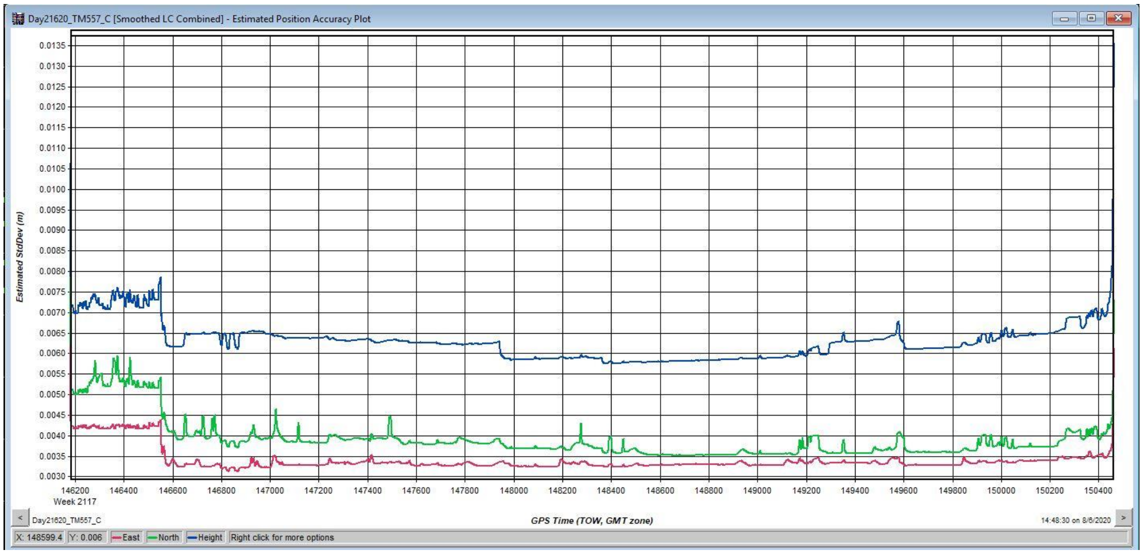
PDOP



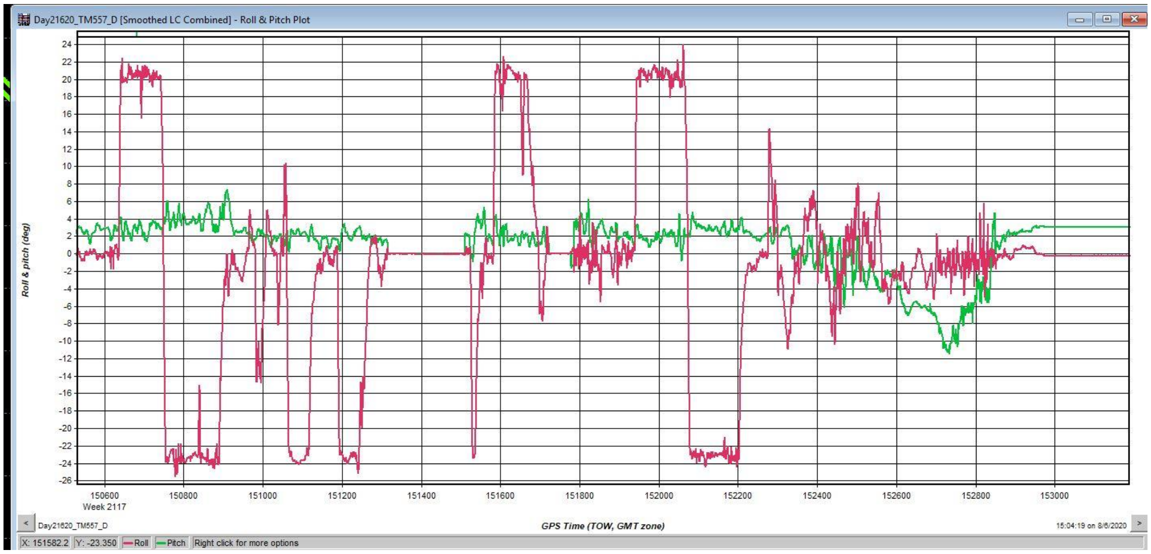
Satellites



RMS (m)

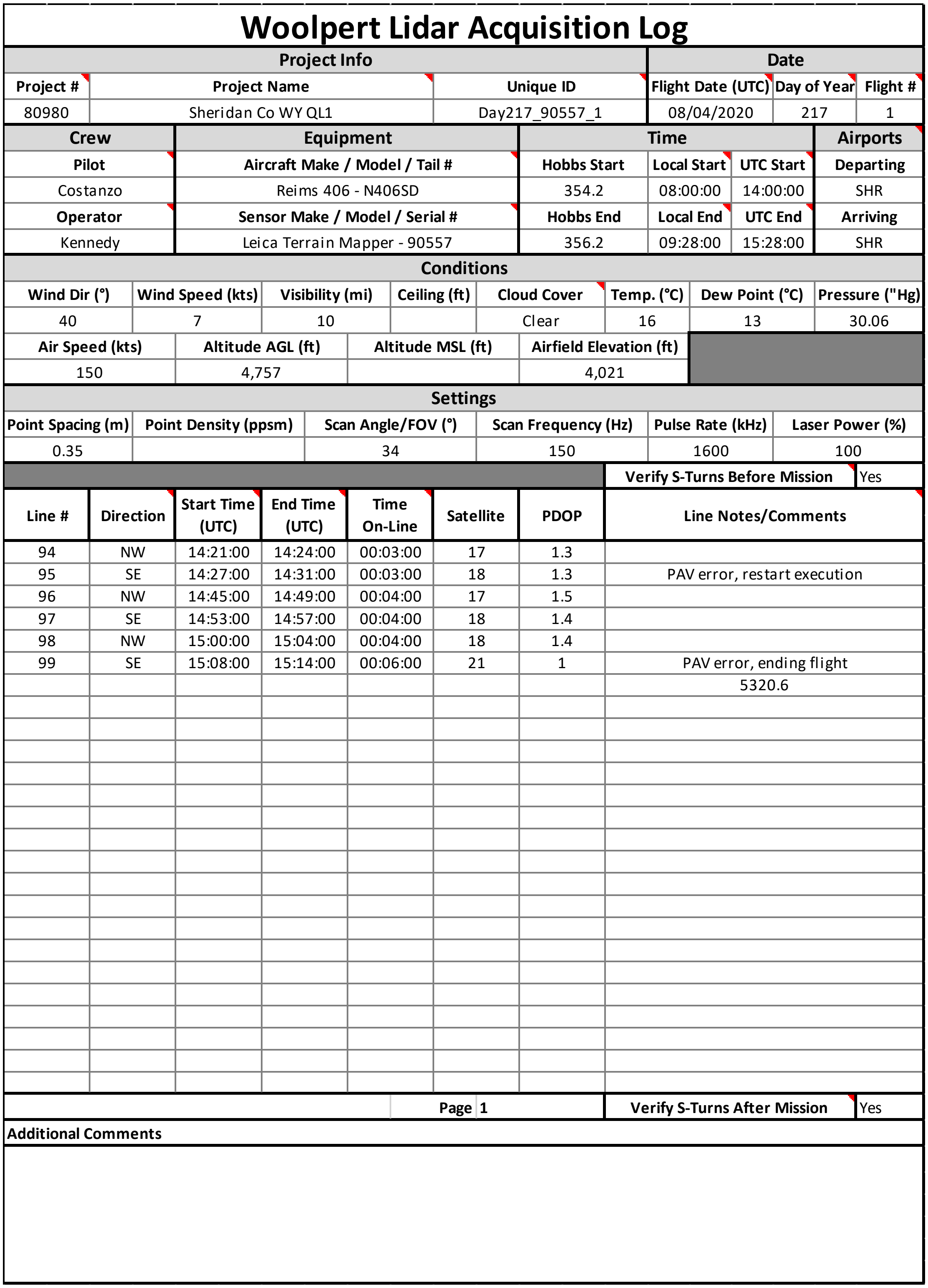


RPH (deg)


Day21620_TM557_D [Smoothed LC Combined] - Roll & Pitch Plot
Roll & pitch (deg)
24
22
20
18
16
14
12
10
8
6
4
2
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
150600
Week 2117
150800
151000
151200
151400
151600
151800
152000
152200
152400
152600
152800
153000
Day21620_TM557_D
GPS Time (TOW, GMT zone)
15:04:19 on 8/6/2020
X: 151582.2
Y: -23.350
Roll
Pitch
Right click for more options

Mission 15 (20200804)

Flight Log



Woolpert Lidar Acquisition Log

Project Info			Date		
Project #	**Project Name**	**Unique ID**	**Flight Date (UTC)**	**Day of Year**	**Flight #**
80980	Sheridan Co WY QL1	Day217_90557_1	08/04/2020	217	1

Crew	Equipment	Time			Airports
Pilot	**Aircraft Make / Model / Tail #**	**Hobbs Start**	**Local Start**	**UTC Start**	**Departing**
Costanzo	Reims 406 - N406SD	354.2	08:00:00	14:00:00	SHR
Operator	**Sensor Make / Model / Serial #**	**Hobbs End**	**Local End**	**UTC End**	**Arriving**
Kennedy	Leica Terrain Mapper - 90557	356.2	09:28:00	15:28:00	SHR

Conditions

Wind Dir (°)	Wind Speed (kts)	Visibility (mi)	Ceiling (ft)	Cloud Cover	Temp. (°C)	Dew Point (°C)	Pressure ("Hg)
40	7	10		Clear	16	13	30.06

Air Speed (kts)	Altitude AGL (ft)	Altitude MSL (ft)	Airfield Elevation (ft)
150	4,757		4,021

Settings

Point Spacing (m)	Point Density (ppsm)	Scan Angle/FOV (°)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power (%)
0.35		34	150	1600	100

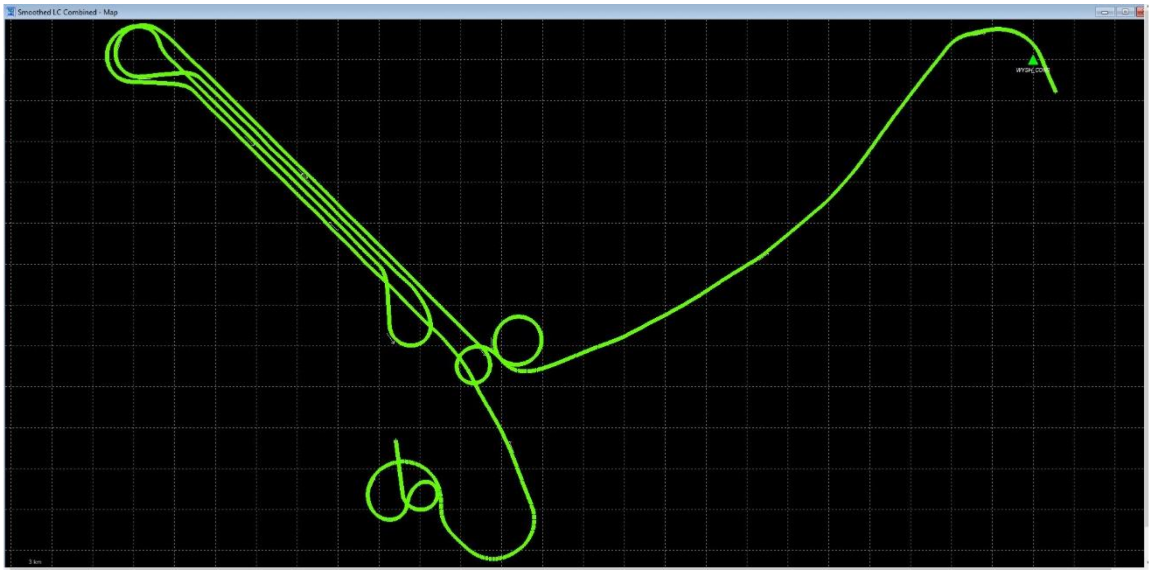
Verify S-Turns Before Mission Yes

Line #	Direction	Start Time (UTC)	End Time (UTC)	Time On-Line	Satellite	PDOP	Line Notes/Comments
94	NW	14:21:00	14:24:00	00:03:00	17	1.3	
95	SE	14:27:00	14:31:00	00:03:00	18	1.3	PAV error, restart execution
96	NW	14:45:00	14:49:00	00:04:00	17	1.5	
97	SE	14:53:00	14:57:00	00:04:00	18	1.4	
98	NW	15:00:00	15:04:00	00:04:00	18	1.4	
99	SE	15:08:00	15:14:00	00:06:00	21	1	PAV error, ending flight
							5320.6

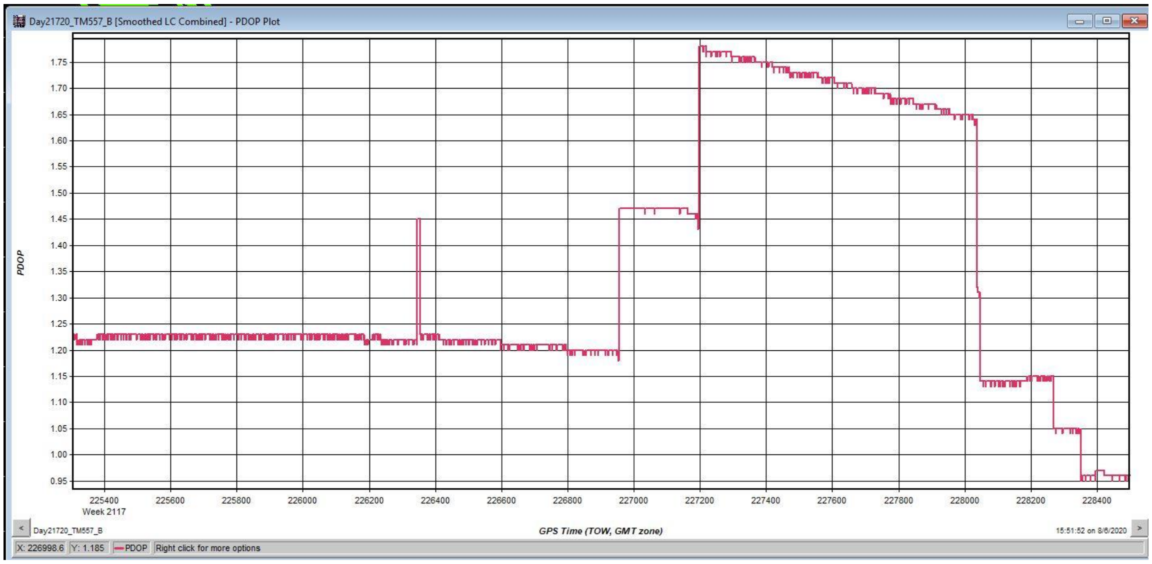
Page 1 **Verify S-Turns After Mission** Yes

Additional Comments

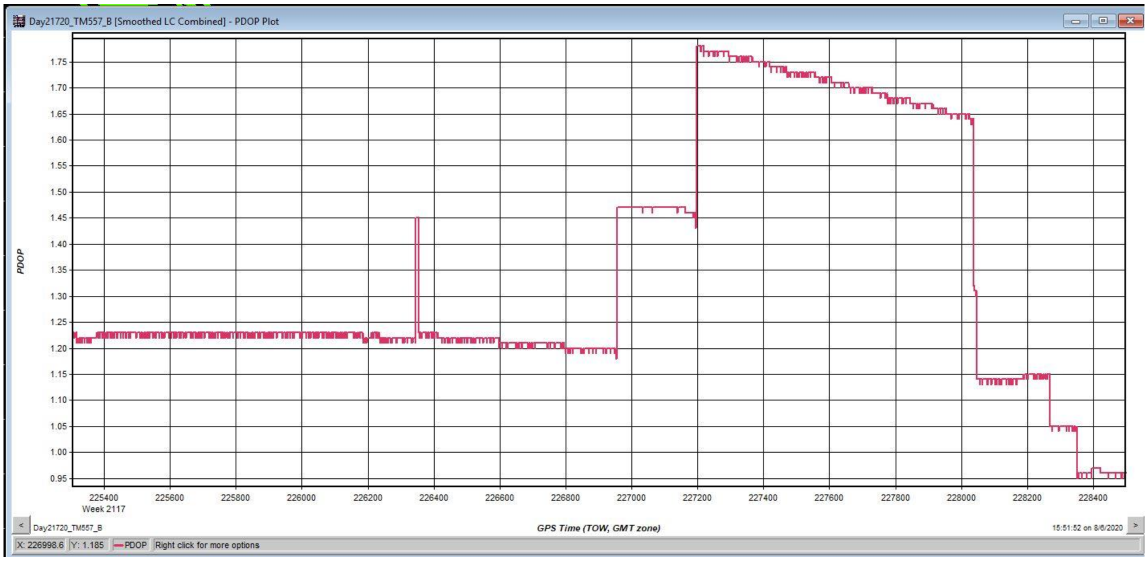
Mission Trajectory



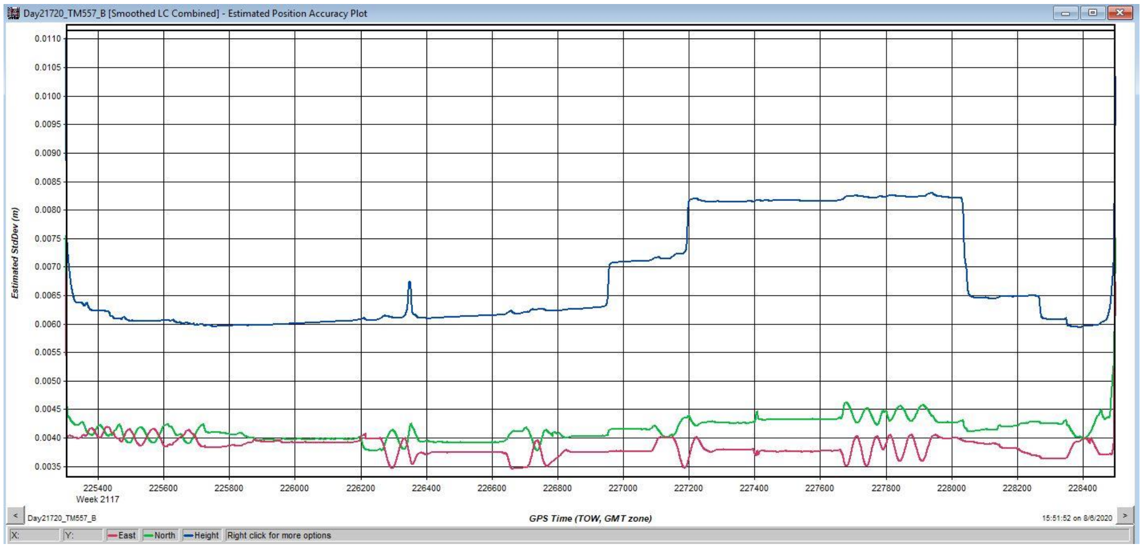
PDOP



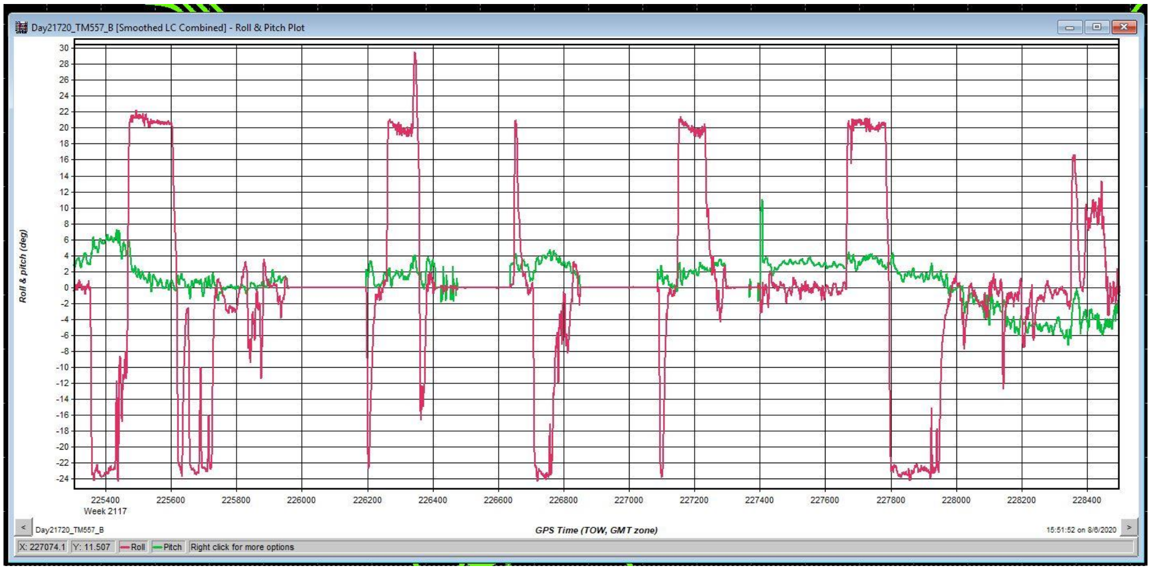
Satellites



RMS (m)

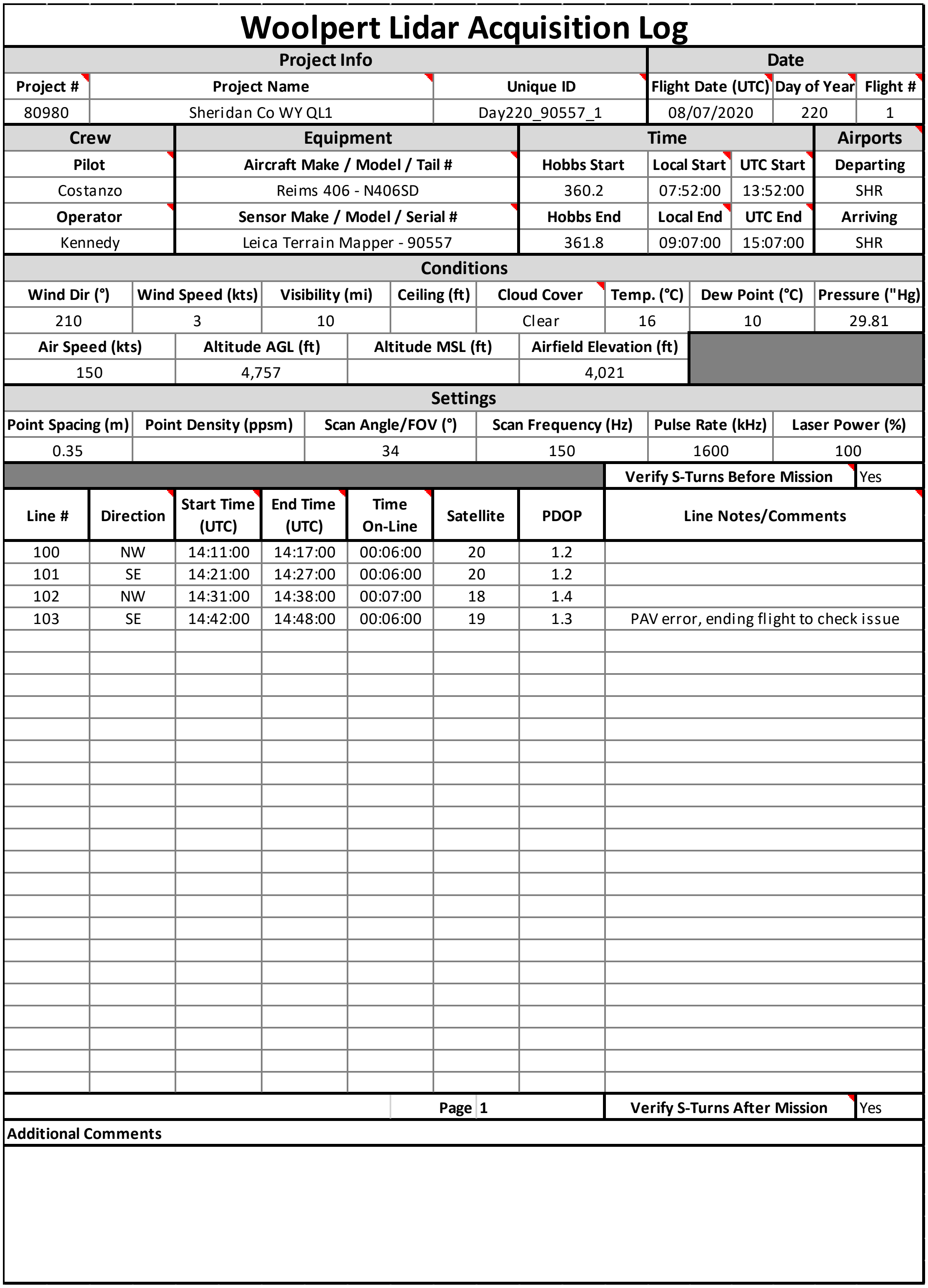


RPH (deg)


Day21720_TM557_B [Smoothed LC Combined] - Roll & Pitch Plot
Roll & pitch (deg)
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
225400
Week 2117
225600
225800
226000
226200
226400
226600
226800
227000
227200
227400
227600
227800
228000
228200
228400
Day21720_TM557_B
GPS Time (TOW, GMT zone)
15:51:52 on 8/6/2020
X: 227074.1
Y: 11.507
Roll
Pitch
Right click for more options

Mission 16 (20200807)

Flight Log



Woolpert Lidar Acquisition Log

Project Info			Date		
Project #	**Project Name**	**Unique ID**	**Flight Date (UTC)**	**Day of Year**	**Flight #**
80980	Sheridan Co WY QL1	Day220_90557_1	08/07/2020	220	1

Crew	Equipment	Time			Airports
Pilot	**Aircraft Make / Model / Tail #**	**Hobbs Start**	**Local Start**	**UTC Start**	**Departing**
Costanzo	Reims 406 - N406SD	360.2	07:52:00	13:52:00	SHR
Operator	**Sensor Make / Model / Serial #**	**Hobbs End**	**Local End**	**UTC End**	**Arriving**
Kennedy	Leica Terrain Mapper - 90557	361.8	09:07:00	15:07:00	SHR

Conditions

Wind Dir (°)	Wind Speed (kts)	Visibility (mi)	Ceiling (ft)	Cloud Cover	Temp. (°C)	Dew Point (°C)	Pressure ("Hg)
210	3	10		Clear	16	10	29.81

Air Speed (kts)	Altitude AGL (ft)	Altitude MSL (ft)	Airfield Elevation (ft)
150	4,757		4,021

Settings

Point Spacing (m)	Point Density (ppsm)	Scan Angle/FOV (°)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power (%)
0.35		34	150	1600	100

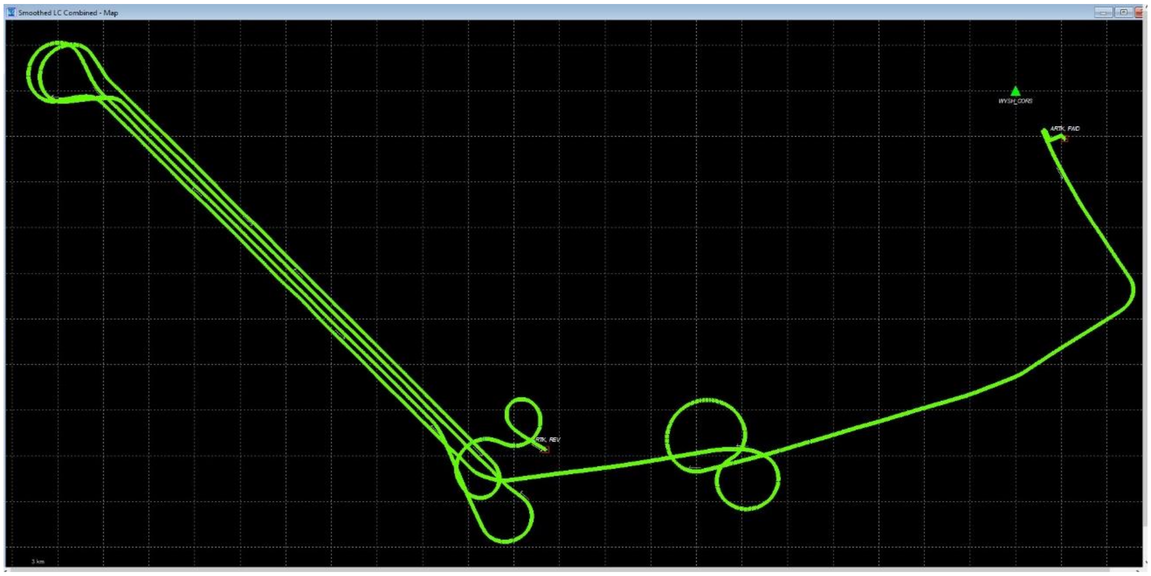
Verify S-Turns Before Mission Yes

Line #	Direction	Start Time (UTC)	End Time (UTC)	Time On-Line	Satellite	PDOP	Line Notes/Comments
100	NW	14:11:00	14:17:00	00:06:00	20	1.2	
101	SE	14:21:00	14:27:00	00:06:00	20	1.2	
102	NW	14:31:00	14:38:00	00:07:00	18	1.4	
103	SE	14:42:00	14:48:00	00:06:00	19	1.3	PAV error, ending flight to check issue

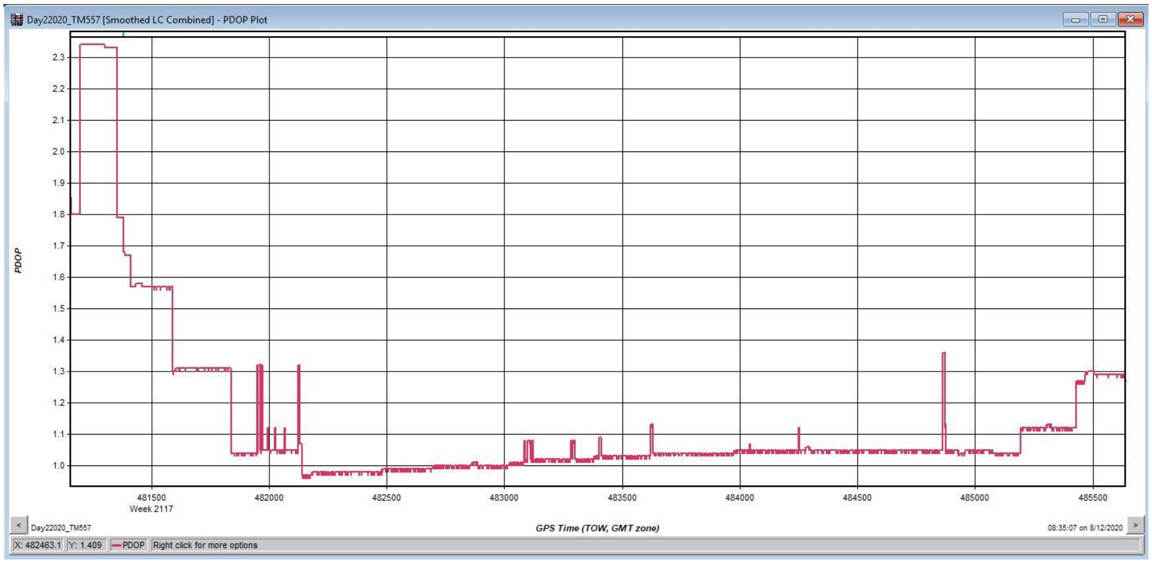
Page 1 **Verify S-Turns After Mission** Yes

Additional Comments

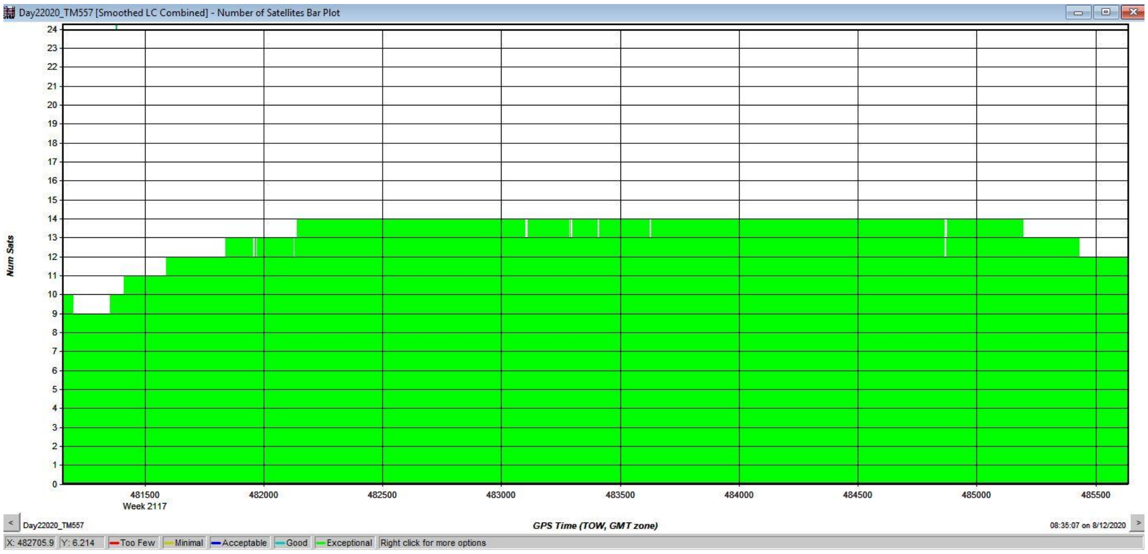
Mission Trajectory



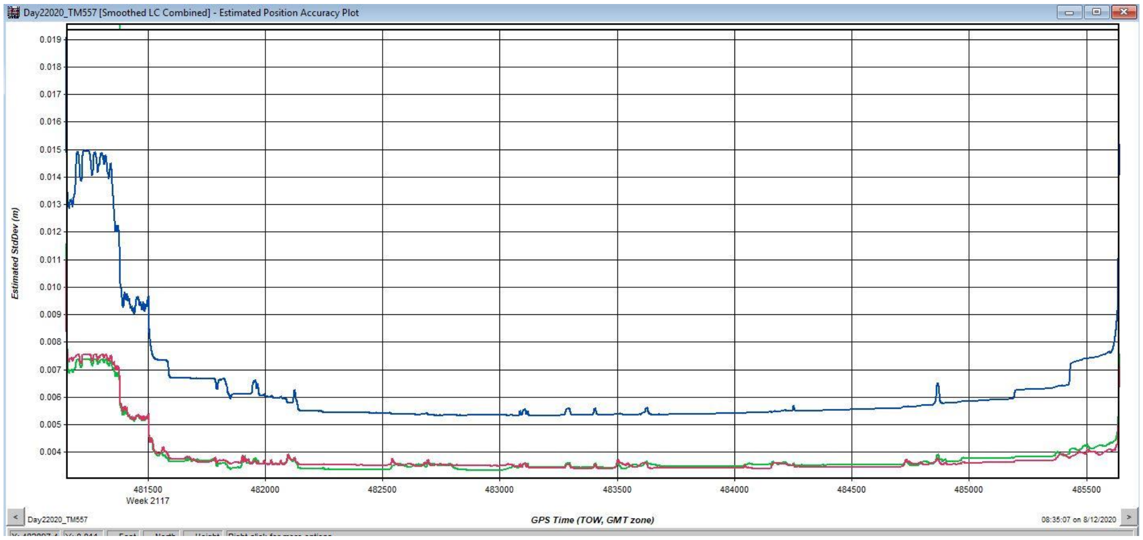
PDOP



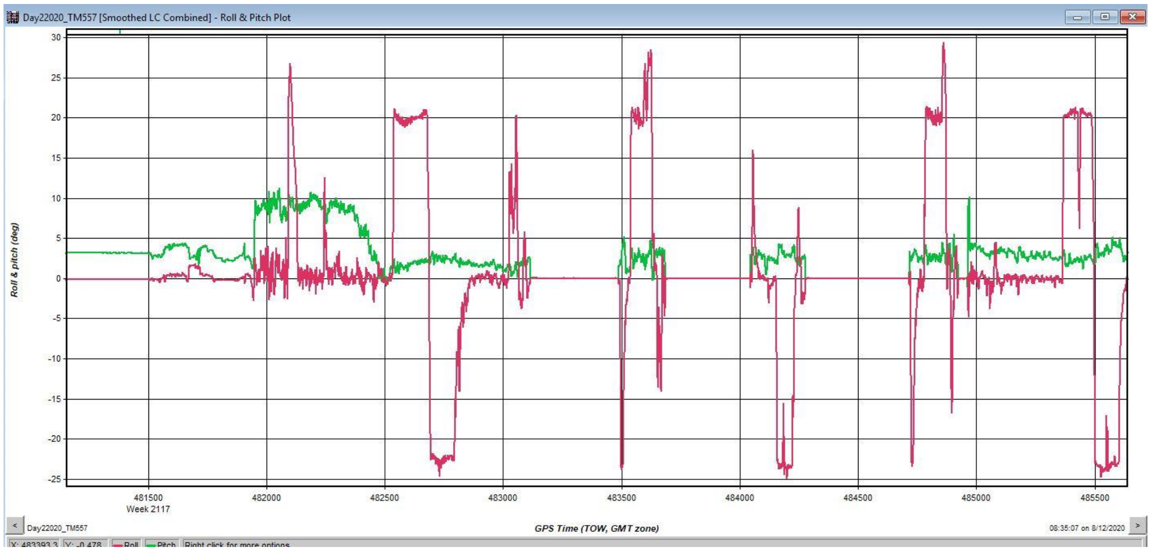
Satellites



RMS (m)



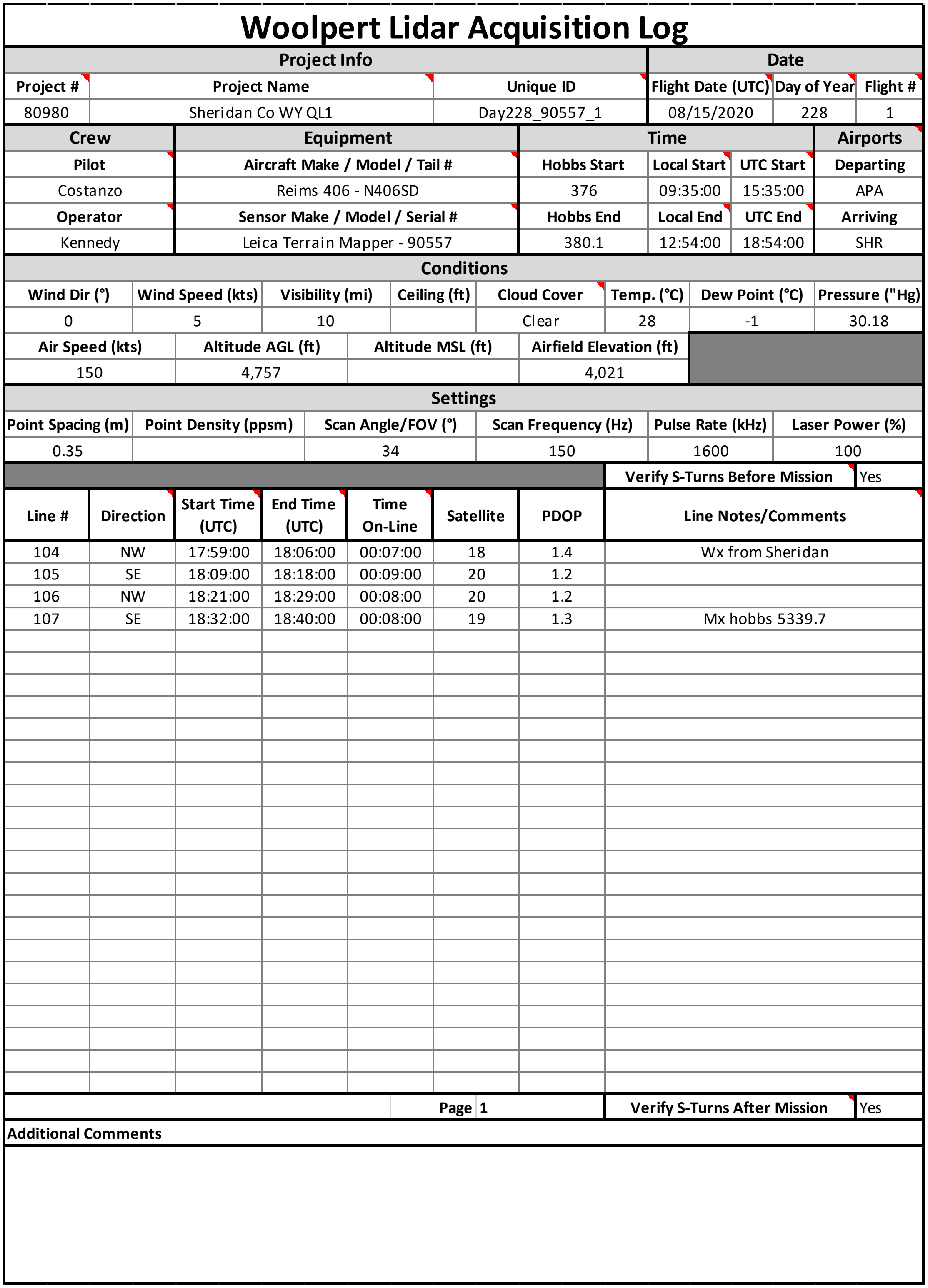
RPH (deg)



Day22020_TM557 [Smoothed LC Combined] - Roll & Pitch Plot
Roll & pitch (deg)
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
481500
Week 2117
482000
482500
483000
483500
484000
484500
485000
485500
Day22020_TM557
GPS Time (TOW, GMT zone)
08:35:07 on 8/12/2020
X: 483393.3
Y: -0.478
Roll
Pitch
Right click for more options

Mission 17 (20200815)

Flight Log



Woolpert Lidar Acquisition Log

Project Info			Date		
Project #	**Project Name**	**Unique ID**	**Flight Date (UTC)**	**Day of Year**	**Flight #**
80980	Sheridan Co WY QL1	Day228_90557_1	08/15/2020	228	1

Crew	Equipment	Time			Airports
Pilot	**Aircraft Make / Model / Tail #**	**Hobbs Start**	**Local Start**	**UTC Start**	**Departing**
Costanzo	Reims 406 - N406SD	376	09:35:00	15:35:00	APA
Operator	**Sensor Make / Model / Serial #**	**Hobbs End**	**Local End**	**UTC End**	**Arriving**
Kennedy	Leica Terrain Mapper - 90557	380.1	12:54:00	18:54:00	SHR

Conditions

Wind Dir (°)	Wind Speed (kts)	Visibility (mi)	Ceiling (ft)	Cloud Cover	Temp. (°C)	Dew Point (°C)	Pressure ("Hg)
0	5	10		Clear	28	-1	30.18

Air Speed (kts)	Altitude AGL (ft)	Altitude MSL (ft)	Airfield Elevation (ft)
150	4,757		4,021

Settings

Point Spacing (m)	Point Density (ppsm)	Scan Angle/FOV (°)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power (%)
0.35		34	150	1600	100

Verify S-Turns Before Mission Yes

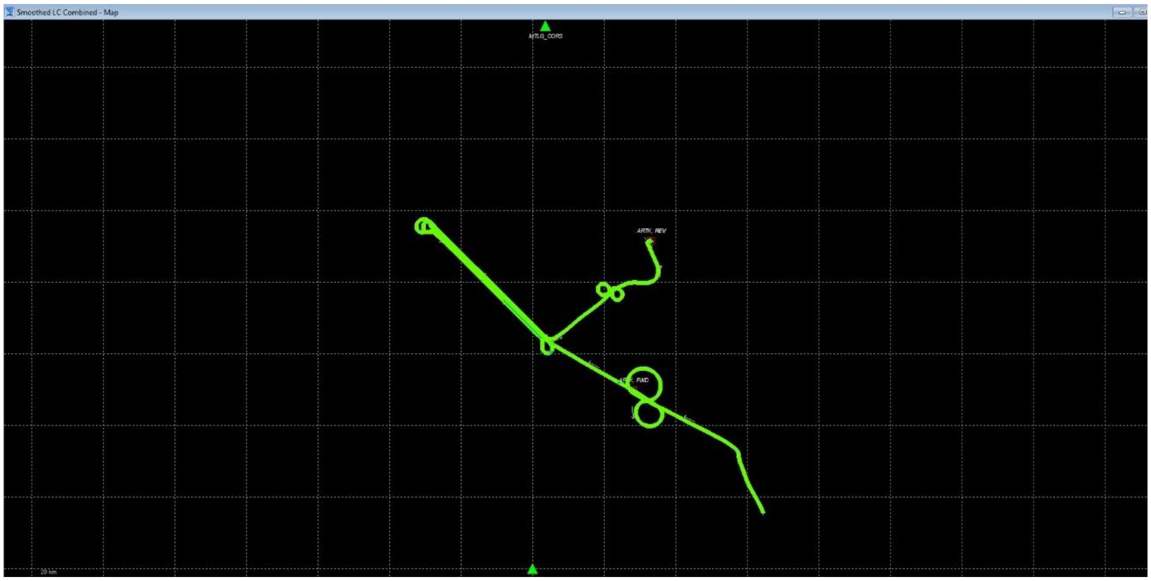
Line #	Direction	Start Time (UTC)	End Time (UTC)	Time On-Line	Satellite	PDOP	Line Notes/Comments
104	NW	17:59:00	18:06:00	00:07:00	18	1.4	Wx from Sheridan
105	SE	18:09:00	18:18:00	00:09:00	20	1.2	
106	NW	18:21:00	18:29:00	00:08:00	20	1.2	
107	SE	18:32:00	18:40:00	00:08:00	19	1.3	Mx hobbs 5339.7

Page 1

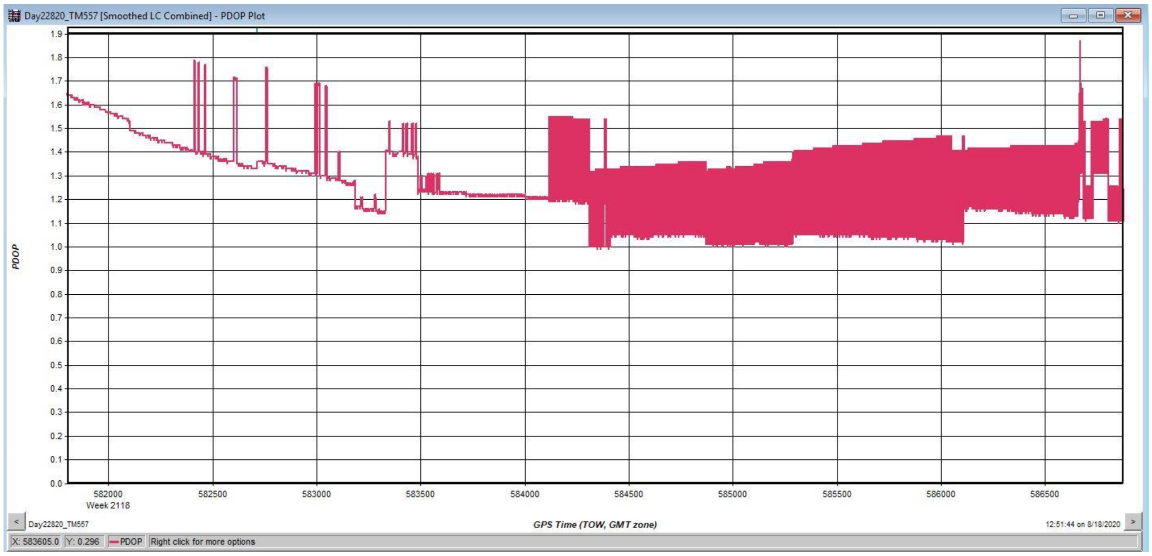
Verify S-Turns After Mission Yes

Additional Comments

Mission Trajectory

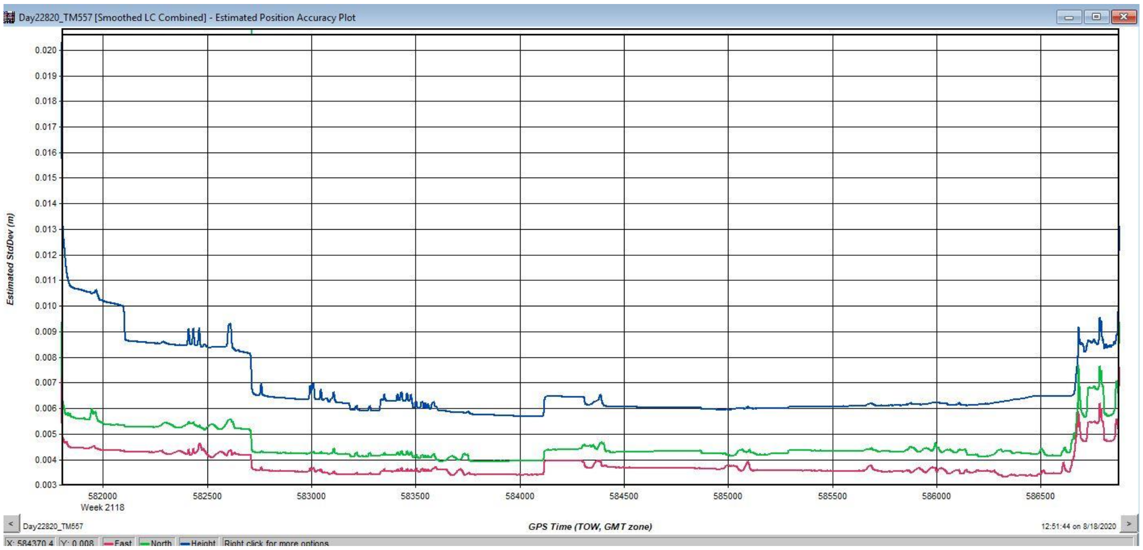


PDOP

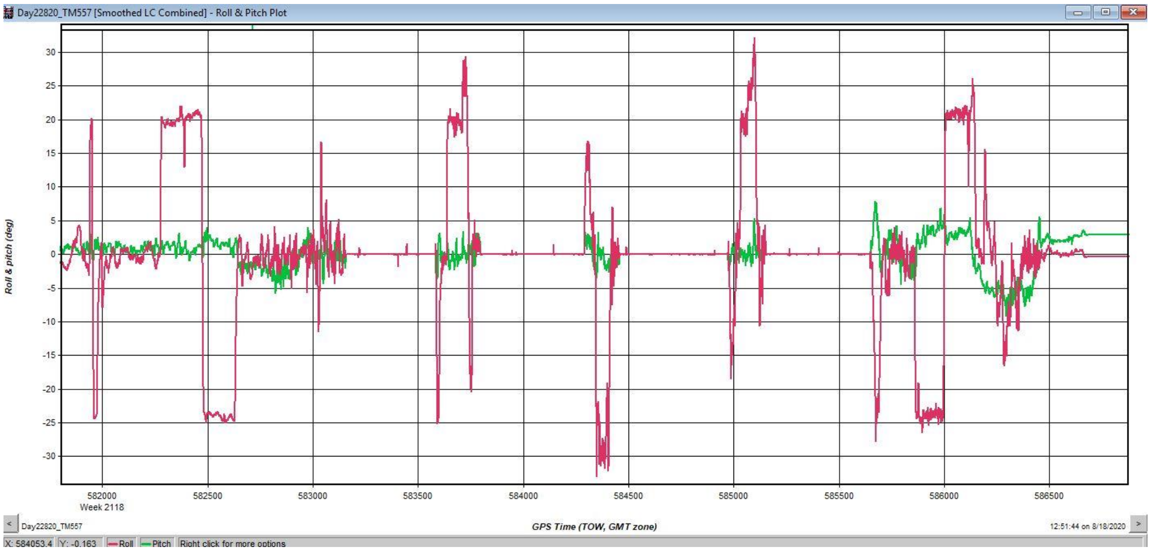


Satellites

RMS (m)



RPH (deg)


Day22820_TM557 [Smoothed LC Combined] - Roll & Pitch Plot
Roll & pitch (deg)
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
582000
Week 2118
582500
583000
583500
584000
584500
585000
585500
586000
586500
Day22820_TM557
GPS Time (TOW, GMT zone)
12:51:44 on 8/18/2020
X: 584053.4
Y: -0.163
Roll
Pitch
Right click for more options

Mission 18 (20200816)

Flight Log

Woolpert Lidar Acquisition Log

Project Info			**Date**		
Project #	**Project Name**	**Unique ID**	**Flight Date (UTC)**	**Day of Year**	**Flight #**
80980	Sheridan Co WY QL1, QL2 Reflights	Day229_90557_1	08/16/2020	229	1

Crew	**Equipment**	**Time**			**Airports**
Pilot	**Aircraft Make / Model / Tail #**	**Hobbs Start**	**Local Start**	**UTC Start**	**Departing**
Costanzo	Reims 406 - N406SD	380.1	08:43:00	14:43:00	SHR
Operator	**Sensor Make / Model / Serial #**	**Hobbs End**	**Local End**	**UTC End**	**Arriving**
Kennedy	Leica Terrain Mapper - 90557	384.2	12:21:00	18:21:00	SHR

Conditions

Wind Dir (°)	**Wind Speed (kts)**	**Visibility (mi)**	**Ceiling (ft)**	**Cloud Cover**	**Temp. (°C)**	**Dew Point (°C)**	**Pressure ("Hg)**
160	5	10		Clear	17	4	30.25

Air Speed (kts)	**Altitude AGL (ft)**	**Altitude MSL (ft)**	**Airfield Elevation (ft)**
150	4,757		4,021

Settings

Point Spacing (m)	**Point Density (ppsm)**	**Scan Angle/FOV (°)**	**Scan Frequency (Hz)**	**Pulse Rate (kHz)**	**Laser Power (%)**
0.35		34	150	1600	100

Verify S-Turns Before Mission Yes

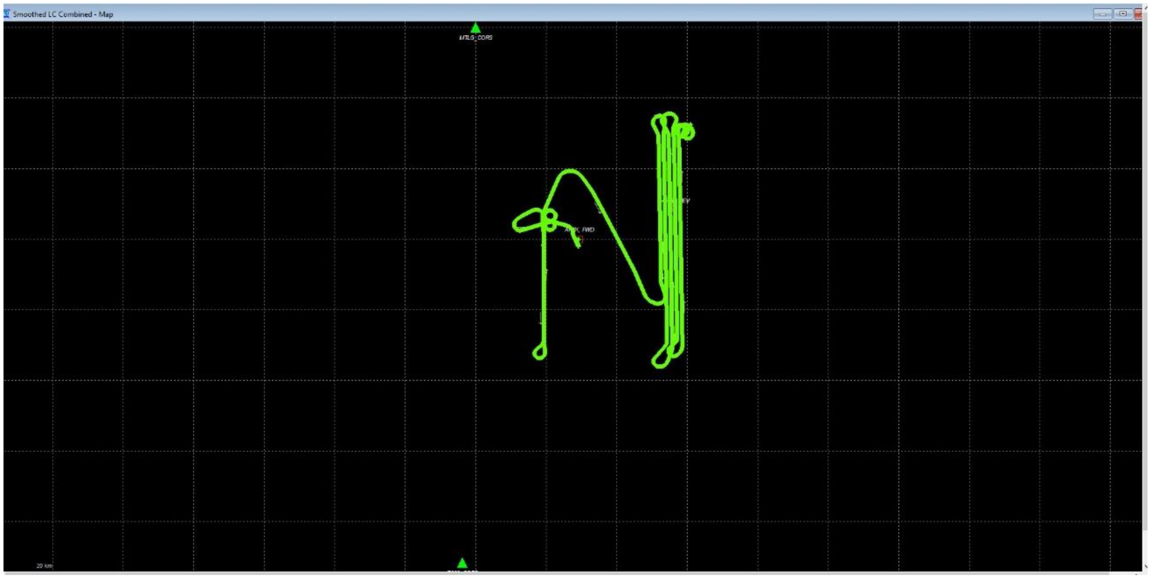
Line #	**Direction**	**Start Time (UTC)**	**End Time (UTC)**	**Time On-Line**	**Satellite**	**PDOP**	**Line Notes/Comments**
32	N	15:06:00	15:12:00	00:06:00	19	1.2	QL2 Blk 2 @ 9842 AGL, 13278 MSL
							40deg, 82Hz, 600kHz
4	N	15:26:00	15:33:00	00:07:00	21	1.1	QL2 Blk 3 @ 9842 AGL, 13297 MSL
5	S	15:36:00	15:48:00	00:12:00	21	1.1	
6	N	15:53:00	16:05:00	00:12:00	21	1.3	
7	S	16:08:00	16:21:00	00:13:00	22	1	
8	N	16:24:00	16:37:00	00:13:00	19	1.6	estarted flight execution to check mount statu
108	SE	17:11:00	17:19:00	00:08:00	20	1.4	QL1 @ 4757 AGL, variable MSL
109	NW	17:23:00	17:31:00	00:08:00	18	1.4	34deg, 150 Hz, 1600kHz
110	SE	17:34:00	17:43:00	00:09:00	18	1.1	
111	NW	17:46:00	17:55:00	00:09:00	17	1.3	
112	SE	17:58:00	18:07:00	00:09:00	19	1.2	mx hobbs 5343.3

Page 1

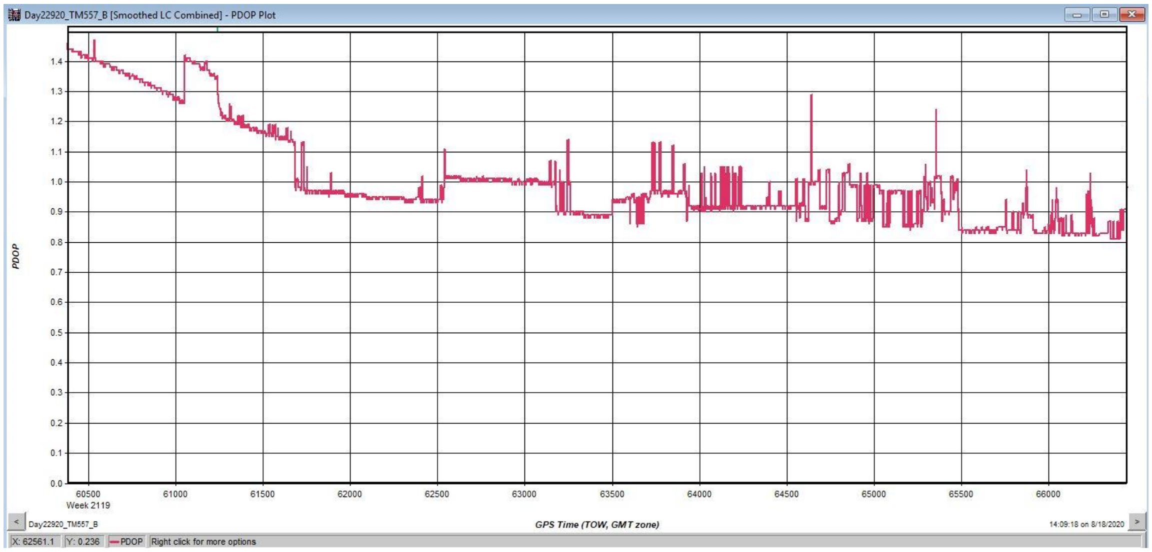
Verify S-Turns After Mission Yes

Additional Comments

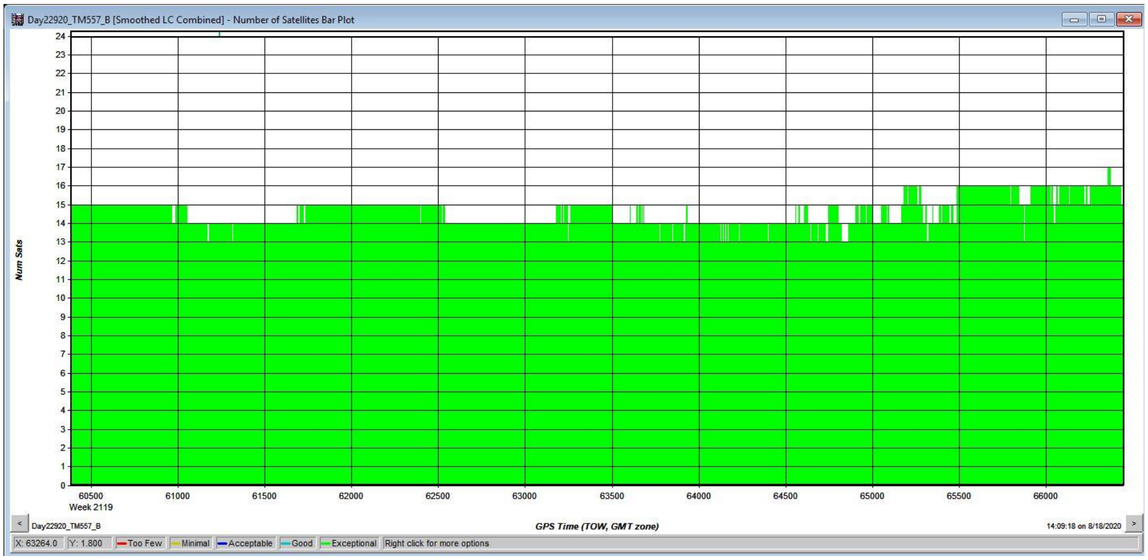
Mission Trajectory



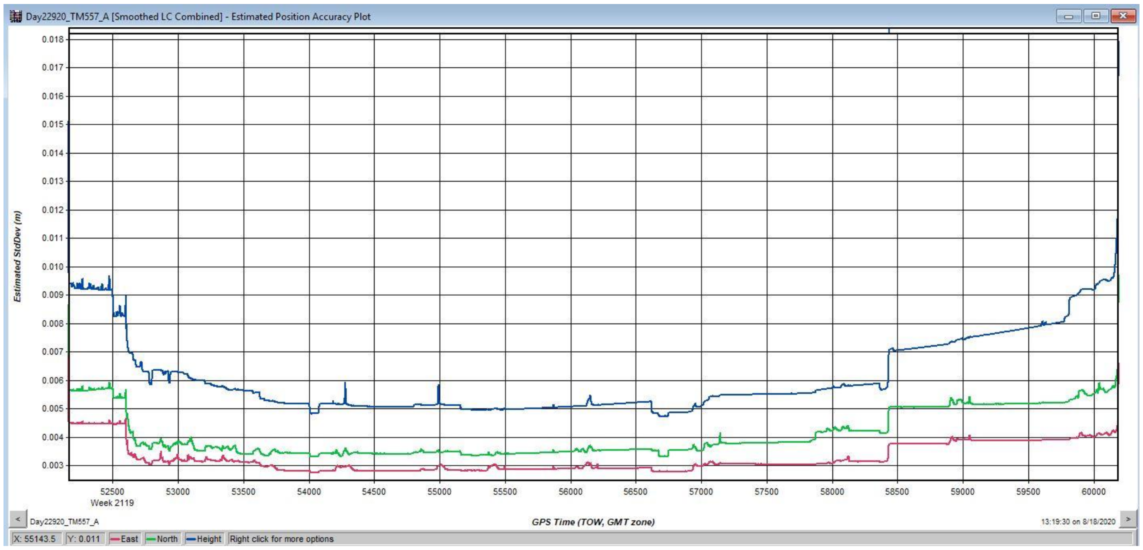
PDOP



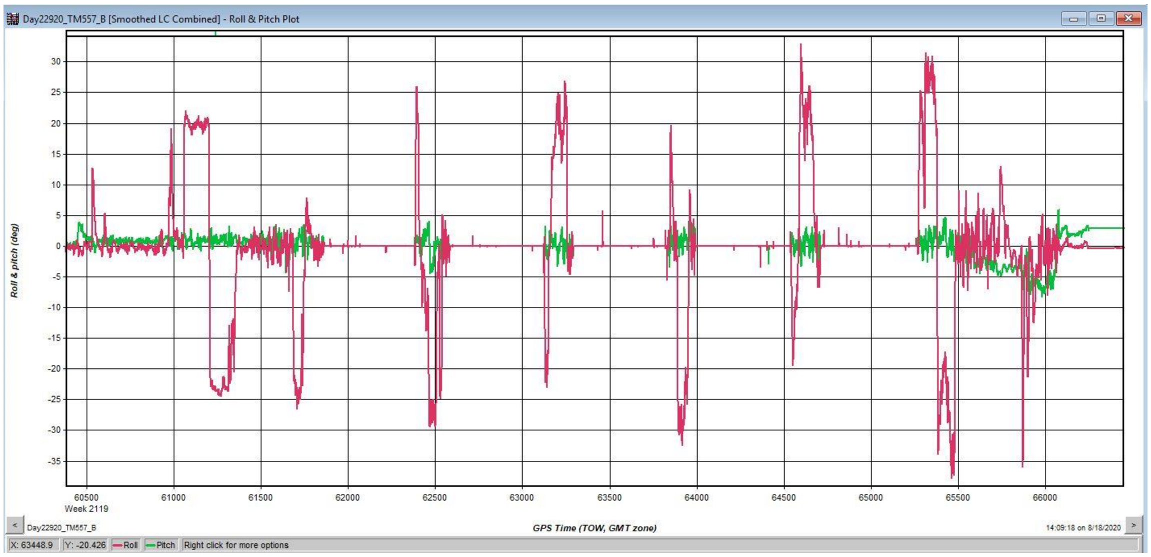
Satellites



RMS (m)



RPH (deg)


Day22920_TM557_B [Smoothed LC Combined] - Roll & Pitch Plot
Roll & pitch (deg)
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
60500
Week 2119
61000
61500
62000
62500
63000
63500
64000
64500
65000
65500
66000
GPS Time (TOW, GMT zone)
Day22920_TM557_B
14:09:18 on 8/18/2020
X: 63448.9
Y: -20.426
Roll
Pitch
Right click for more options

Mission 19 (20200817)

Flight Log

Woolpert Lidar Acquisition Log

Project Info			Date		
Project #	**Project Name**	**Unique ID**	**Flight Date (UTC)**	**Day of Year**	**Flight #**
80980	Sheridan Co WY QL1	Day230_90557_1	08/17/2020	230	1

Crew	Equipment	Time			Airports
Pilot	**Aircraft Make / Model / Tail #**	**Hobbs Start**	**Local Start**	**UTC Start**	**Departing**
Costanzo	Reims 406 - N406SD	384.2	07:55:00	13:55:00	SHR
Operator	**Sensor Make / Model / Serial #**	**Hobbs End**	**Local End**	**UTC End**	**Arriving**
Kennedy	Leica Terrain Mapper - 90557	388.8	12:09:00	18:09:00	SHR

Conditions

Wind Dir (°)	Wind Speed (kts)	Visibility (mi)	Ceiling (ft)	Cloud Cover	Temp. (°C)	Dew Point (°C)	Pressure ("Hg)
0	0	10		Clear	14	6	30.23

Air Speed (kts)	Altitude AGL (ft)	Altitude MSL (ft)	Airfield Elevation (ft)
150	4,757		4,021

Settings

Point Spacing (m)	Point Density (ppsm)	Scan Angle/FOV (°)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power (%)
0.35		34	150	1600	100

Verify S-Turns Before Mission Yes

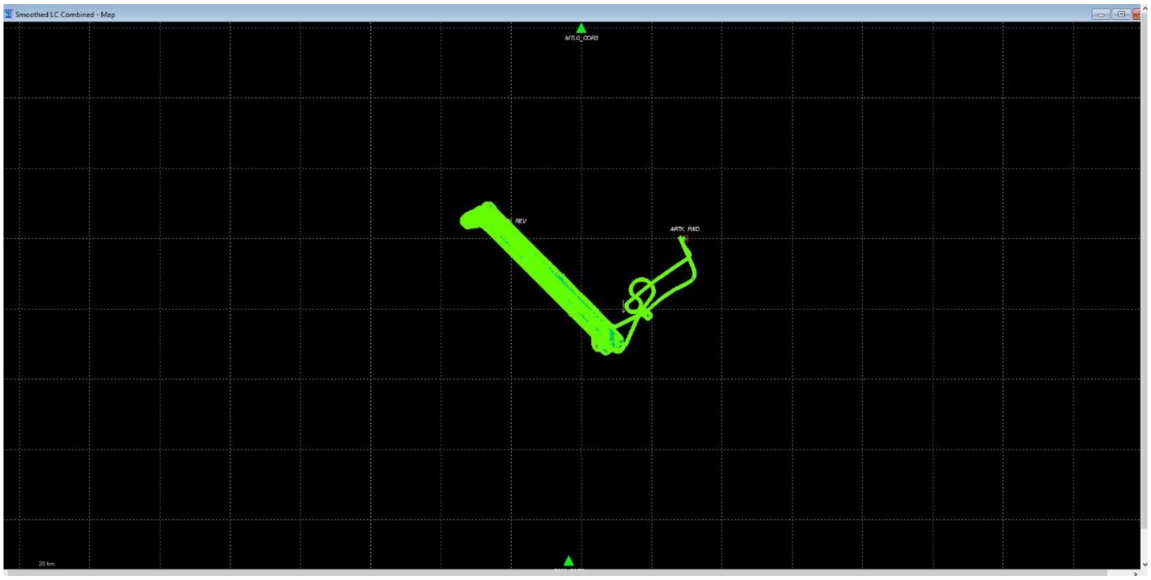
Line #	Direction	Start Time (UTC)	End Time (UTC)	Time On-Line	Satellite	PDOP	Line Notes/Comments
113	NW	14:17:00	14:26:00	00:09:00	22	1.2	
114	SE	14:30:00	14:39:00	00:09:00	24	1.1	
115	NW	14:42:00	14:51:00	00:09:00	23	1.1	
116	SE	14:54:00	15:04:00	00:10:00	20	1.6	
117	NW	15:07:00	15:16:00	00:09:00	21	1.3	
118	SE	15:19:00	15:28:00	00:09:00	23	1.2	
119	NW	15:32:00	15:41:00	00:09:00	24	1.2	
120	SE	15:44:00	15:53:00	00:09:00	23	1.3	
121	NW	15:57:00	16:06:00	00:09:00	23	1.3	
122	SE	16:09:00	16:18:00	00:09:00	21	1.3	
123	NW	16:21:00	16:30:00	00:09:00	21	1.3	
124	SE	16:34:00	16:43:00	00:09:00	22	1.2	
125	NW	18:46:00	16:55:00	22:09:00	23	1.3	
126	SE	16:58:00	17:07:00	00:09:00	22	1.3	
127	NW	17:10:00	17:19:00	00:09:00	23	1.2	
128	SE	17:23:00	17:32:00	00:09:00	20	1.4	
129	NW	17:35:00	17:45:00	00:10:00	22	1.3	
130	SE	17:48:00	17:57:00	00:09:00	20	1.3	mx hobbs 5347.5

Page 1

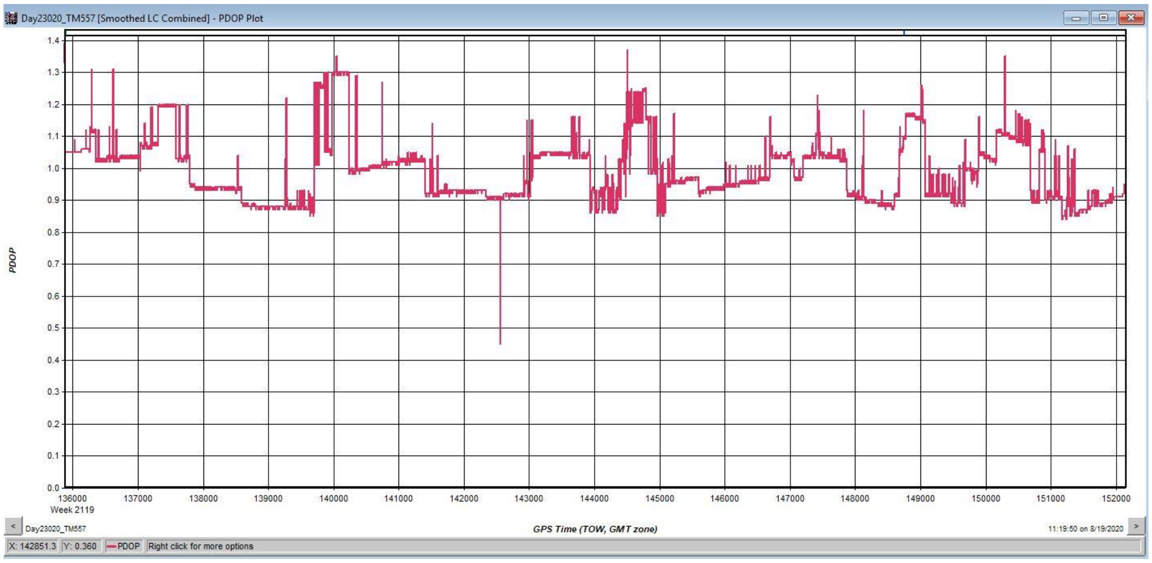
Verify S-Turns After Mission Yes

Additional Comments

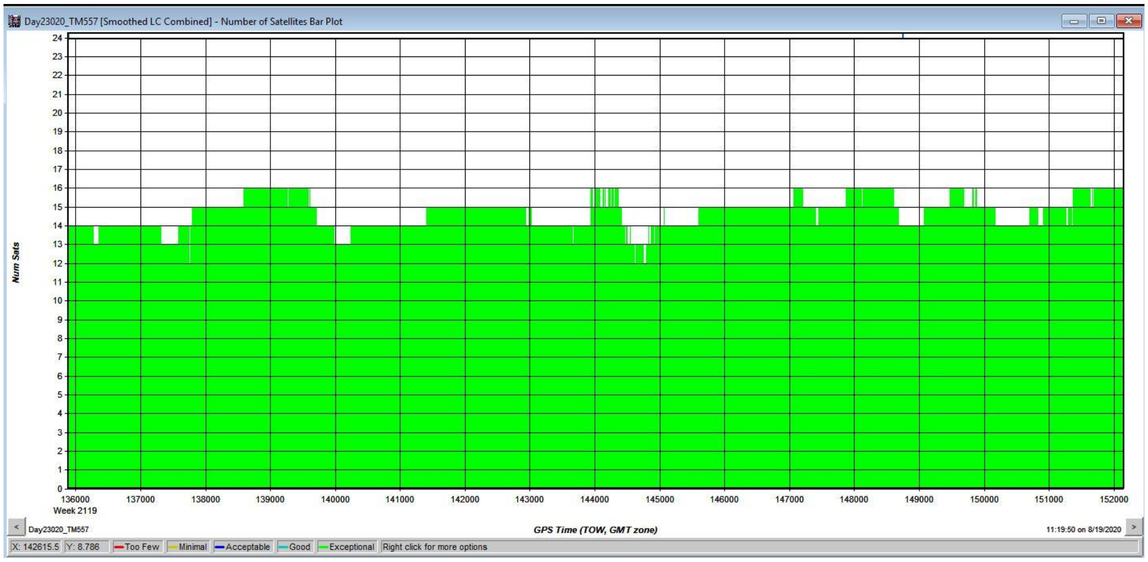
Mission Trajectory



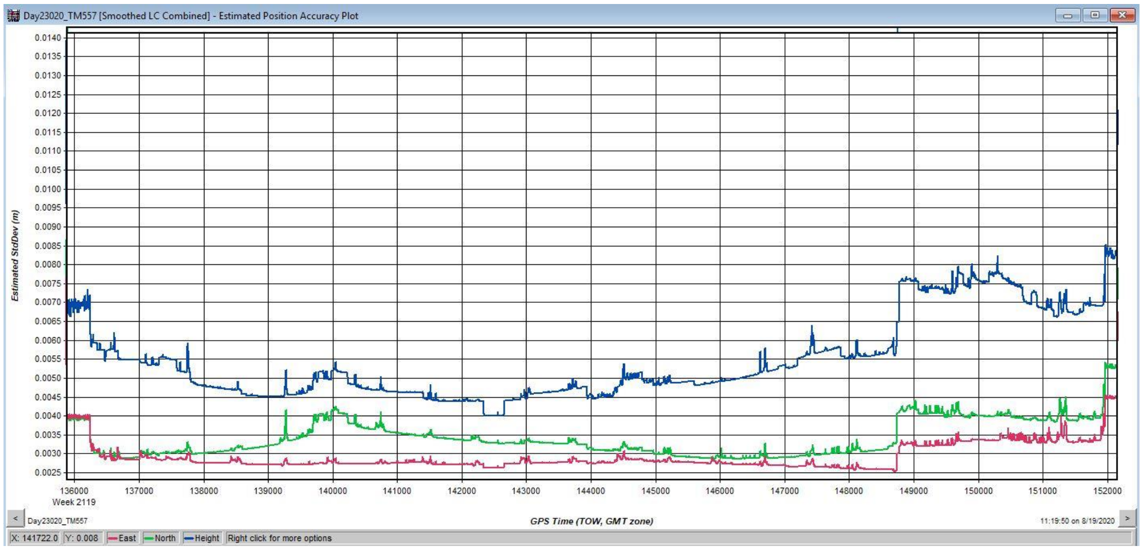
PDOP



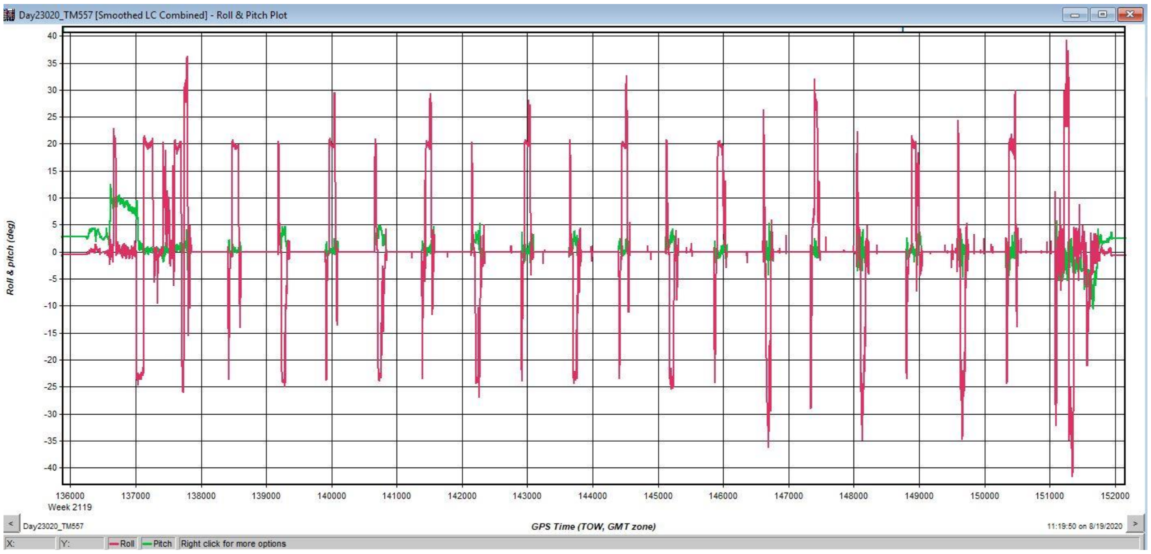
Satellites



RMS (m)



RPH (deg)


Day23020_TM557 [Smoothed LC Combined] - Roll & Pitch Plot
Roll & pitch (deg)
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
136000
Week 2119
137000
138000
139000
140000
141000
142000
143000
144000
145000
146000
147000
148000
149000
150000
151000
152000
Day23020_TM557
GPS Time (TOW, GMT zone)
11:19:50 on 8/19/2020
X:
Y:
Roll
Pitch
Right click for more options

Mission 20 (20200818)

Flight Log

Woolpert Lidar Acquisition Log

Project Info			Date		
Project #	**Project Name**	**Unique ID**	**Flight Date (UTC)**	**Day of Year**	**Flight #**
80980	Sheridan Co WY QL1	Day231_90557_1	08/18/2020	231	1

Crew	Equipment	Time			Airports
Pilot	**Aircraft Make / Model / Tail #**	**Hobbs Start**	**Local Start**	**UTC Start**	**Departing**
Costanzo	Reims 406 - N406SD	388.8	08:00:00	14:00:00	SHR
Operator	**Sensor Make / Model / Serial #**	**Hobbs End**	**Local End**	**UTC End**	**Arriving**
Kennedy	Leica Terrain Mapper - 90557	391.9	10:40:00	16:40:00	SHR

Conditions

Wind Dir (°)	Wind Speed (kts)	Visibility (mi)	Ceiling (ft)	Cloud Cover	Temp. (°C)	Dew Point (°C)	Pressure ("Hg)
200	3	10		Clear	25	8	30.18

Air Speed (kts)	Altitude AGL (ft)	Altitude MSL (ft)	Airfield Elevation (ft)
150	4,757		4,021

Settings

Point Spacing (m)	Point Density (ppsm)	Scan Angle/FOV (°)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power (%)
0.35		34	150	1600	100

Verify S-Turns Before Mission Yes

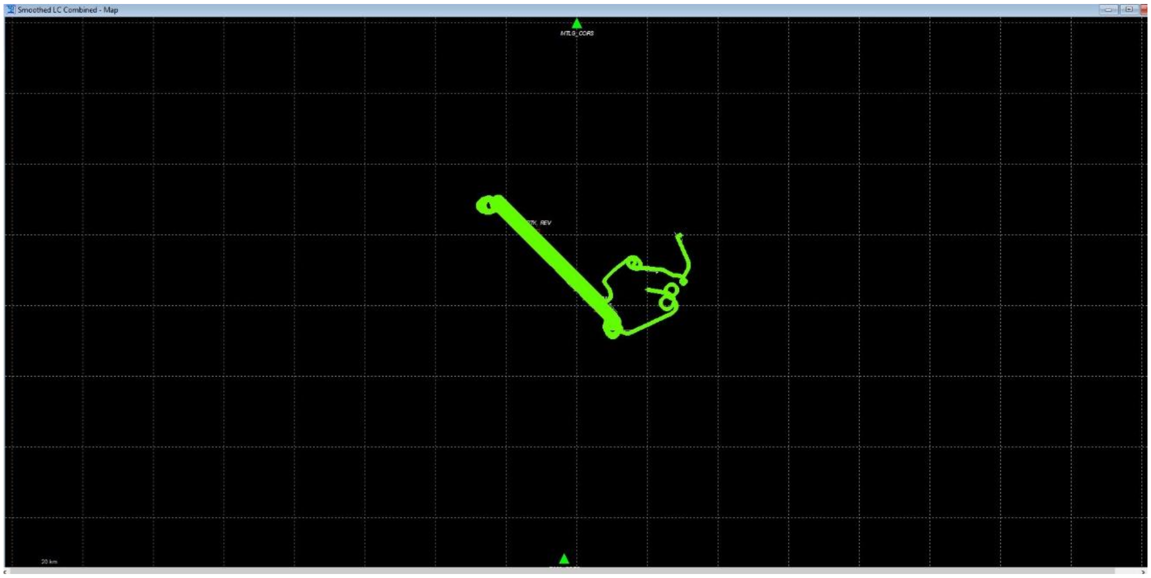
Line #	Direction	Start Time (UTC)	End Time (UTC)	Time On-Line	Satellite	PDOP	Line Notes/Comments
131	NW	14:32:00	14:41:00	00:09:00	15	1.3	Error before first line, restart execution
132	SE	14:45:00	14:53:00	00:08:00	16	1.1	
133	NW	14:56:00	15:05:00	00:09:00	17	1.3	
134	SE	15:08:00	15:16:00	00:08:00	17	1.3	
135	NW	15:20:00	15:29:00	00:09:00	20	1.1	
136	SE	15:32:00	15:40:00	00:08:00	19	1.3	
137	NW	15:44:00	15:52:00	00:08:00	19	1.3	
138	SE	15:55:00	16:03:00	00:08:00	21	1.1	
139	NW	16:07:00	16:15:00	00:08:00	20	1.5	
140	SE	16:18:00	16:25:00	00:07:00	21	1.2	Mx hobbs 5350.2

Page 1

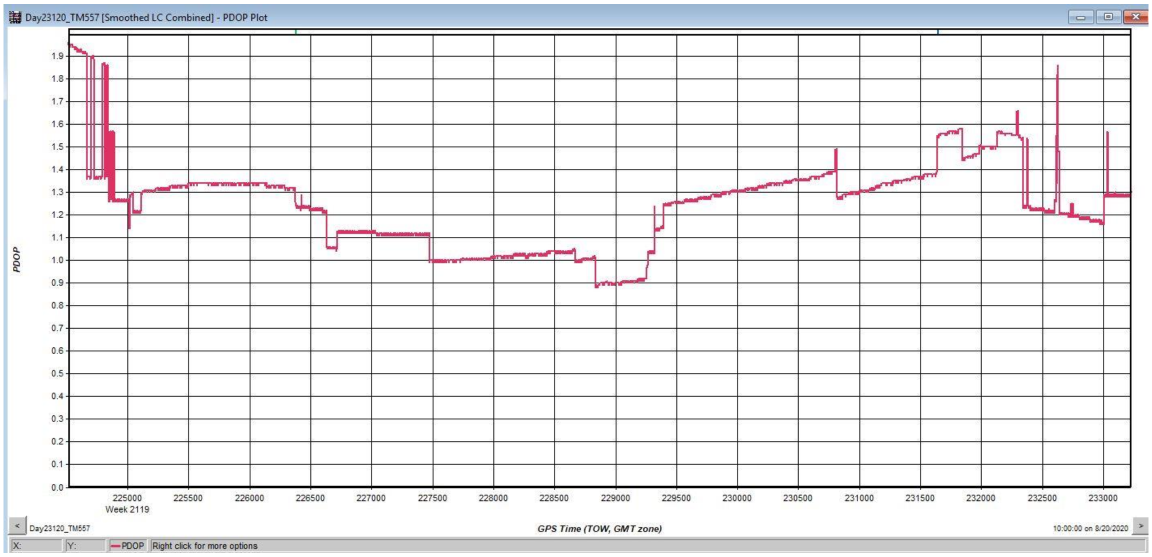
Verify S-Turns After Mission Yes

Additional Comments

Mission Trajectory

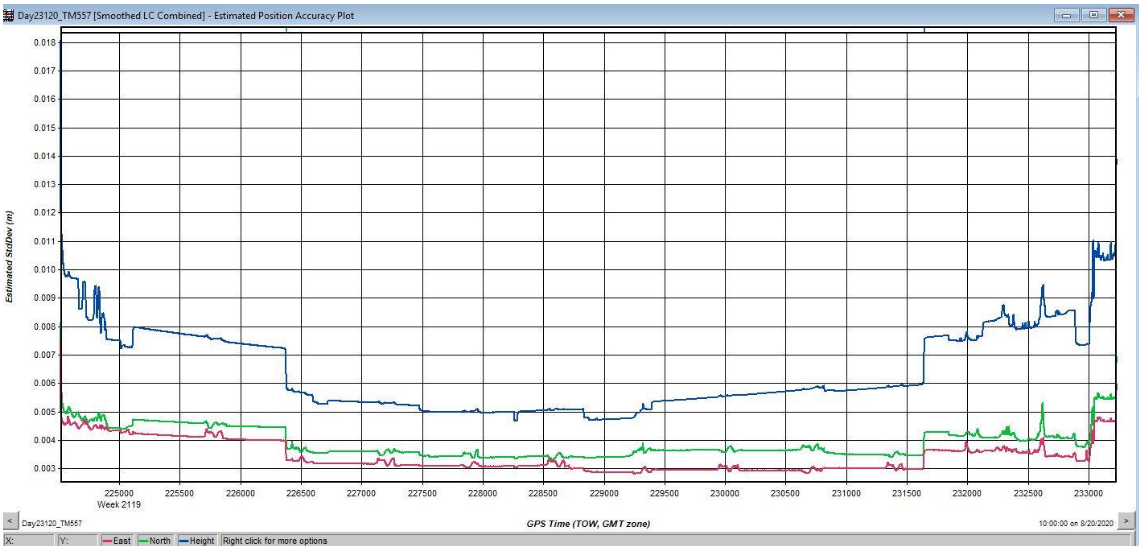


PDOP

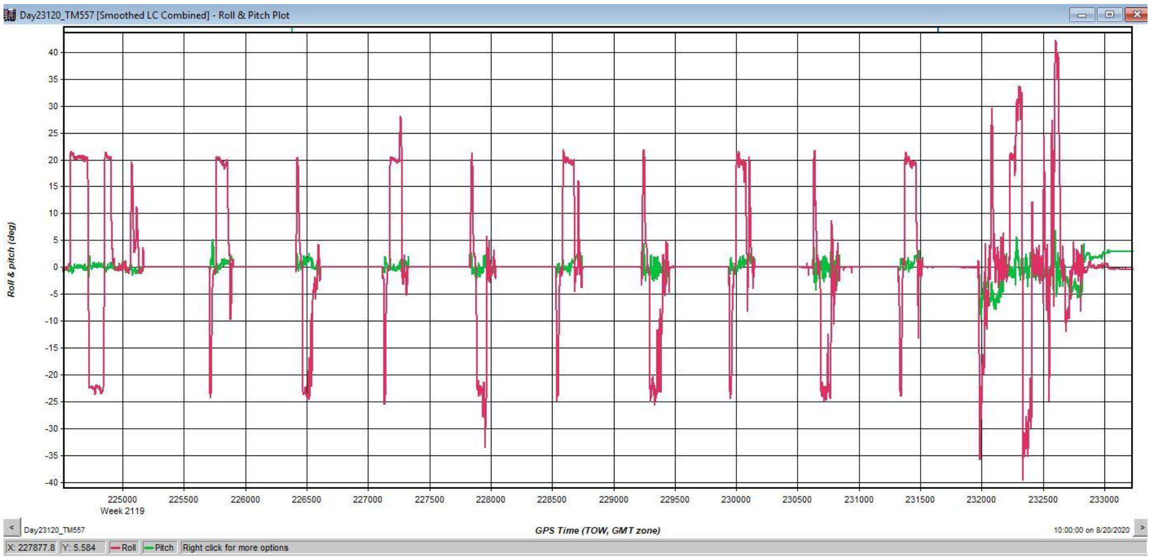


Satellites

RMS (m)

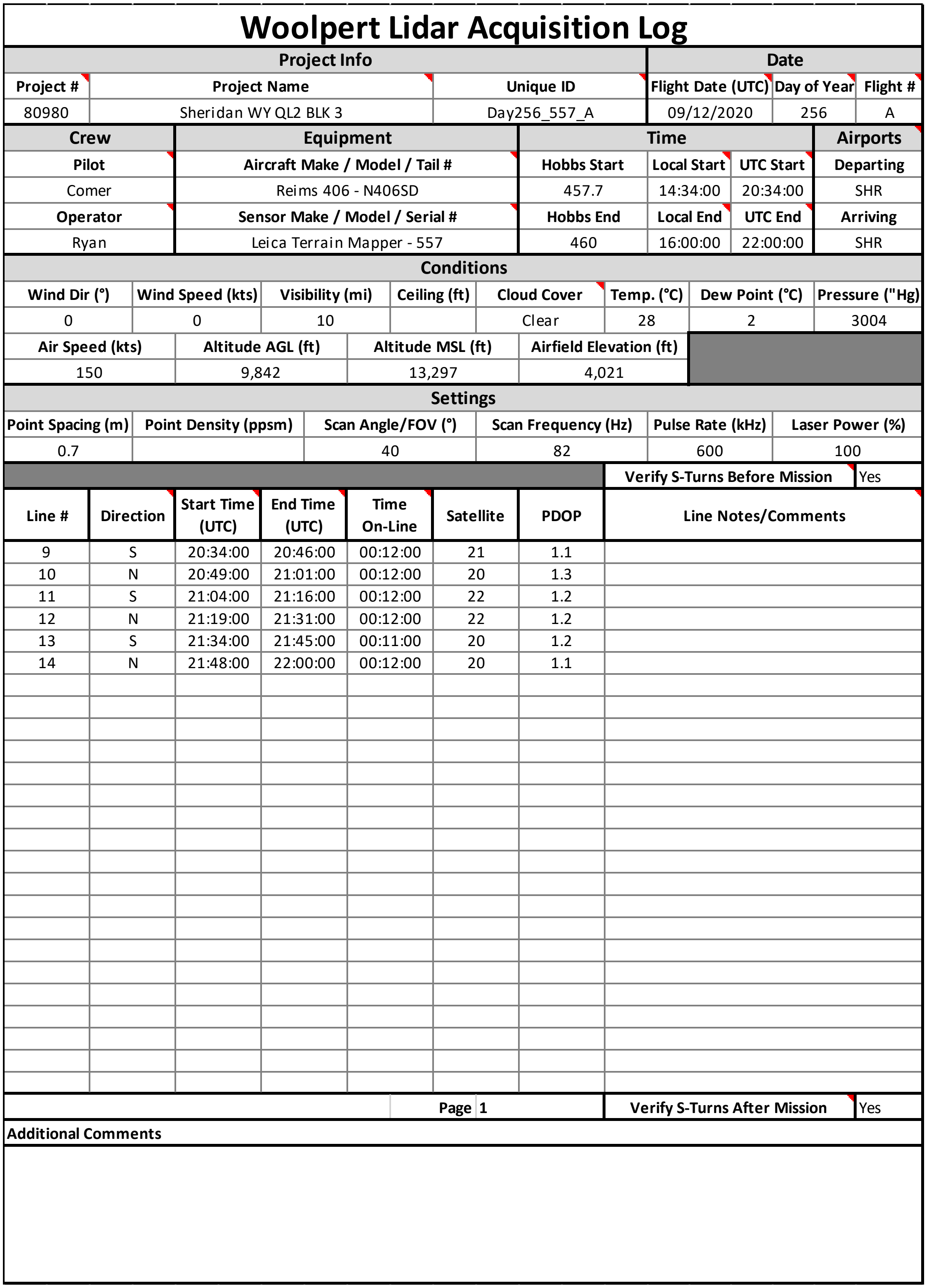


RPH (deg)


Day23120_TM557 [Smoothed LC Combined] - Roll & Pitch Plot
Roll & pitch (deg)
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
225000
Week 2119
225500
226000
226500
227000
227500
228000
228500
229000
229500
230000
230500
231000
231500
232000
232500
233000
Day23120_TM557
GPS Time (TOW, GMT zone)
10:00:00 on 8/20/2020
X: 227877.8
Y: 5.584
Roll
Pitch
Right click for more options

Mission 21 (20200912)

Flight Log



Woolpert Lidar Acquisition Log

Project Info			Date		
Project #	**Project Name**	**Unique ID**	**Flight Date (UTC)**	**Day of Year**	**Flight #**
80980	Sheridan WY QL2 BLK 3	Day256_557_A	09/12/2020	256	A

Crew	Equipment	Time			Airports
Pilot	**Aircraft Make / Model / Tail #**	**Hobbs Start**	**Local Start**	**UTC Start**	**Departing**
Comer	Reims 406 - N406SD	457.7	14:34:00	20:34:00	SHR
Operator	**Sensor Make / Model / Serial #**	**Hobbs End**	**Local End**	**UTC End**	**Arriving**
Ryan	Leica Terrain Mapper - 557	460	16:00:00	22:00:00	SHR

Conditions

Wind Dir (°)	Wind Speed (kts)	Visibility (mi)	Ceiling (ft)	Cloud Cover	Temp. (°C)	Dew Point (°C)	Pressure ("Hg)
0	0	10		Clear	28	2	3004

Air Speed (kts)	Altitude AGL (ft)	Altitude MSL (ft)	Airfield Elevation (ft)
150	9,842	13,297	4,021

Settings

Point Spacing (m)	Point Density (ppsm)	Scan Angle/FOV (°)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power (%)
0.7		40	82	600	100

Verify S-Turns Before Mission Yes

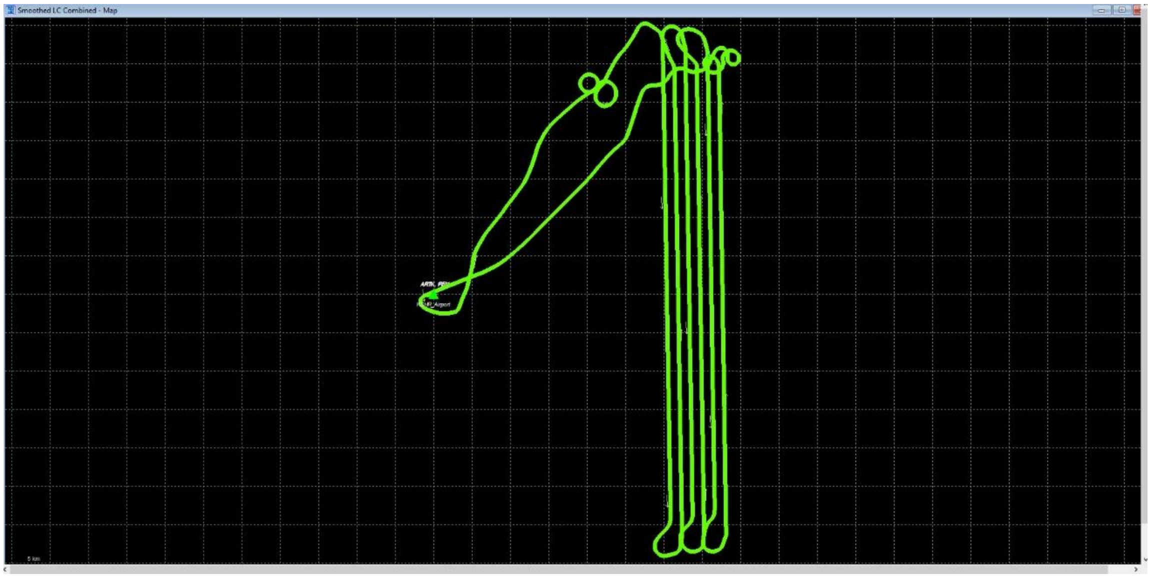
Line #	Direction	Start Time (UTC)	End Time (UTC)	Time On-Line	Satellite	PDOP	Line Notes/Comments
9	S	20:34:00	20:46:00	00:12:00	21	1.1	
10	N	20:49:00	21:01:00	00:12:00	20	1.3	
11	S	21:04:00	21:16:00	00:12:00	22	1.2	
12	N	21:19:00	21:31:00	00:12:00	22	1.2	
13	S	21:34:00	21:45:00	00:11:00	20	1.2	
14	N	21:48:00	22:00:00	00:12:00	20	1.1	

Page 1

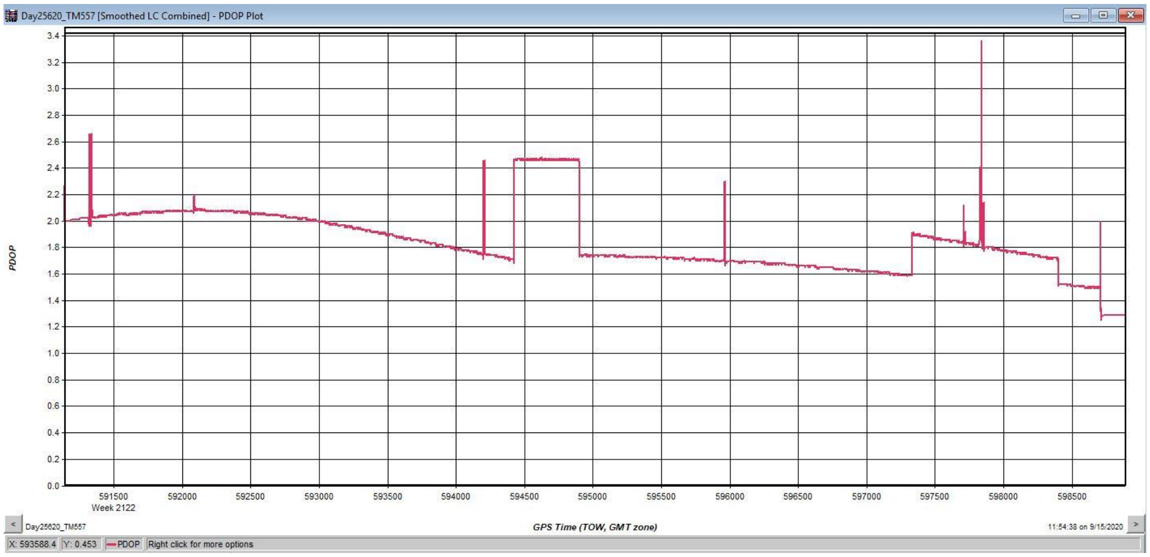
Verify S-Turns After Mission Yes

Additional Comments

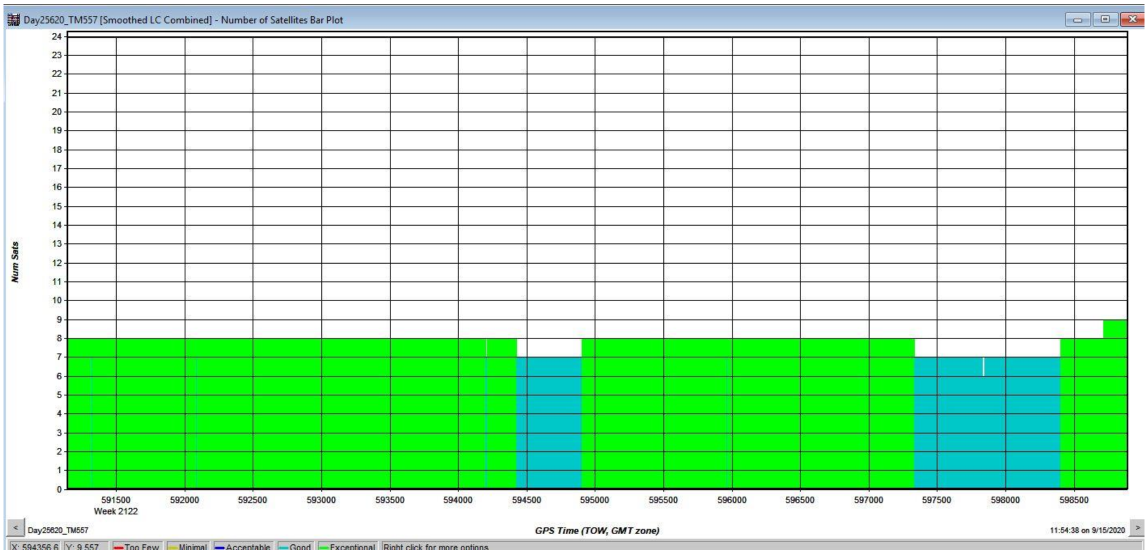
Mission Trajectory



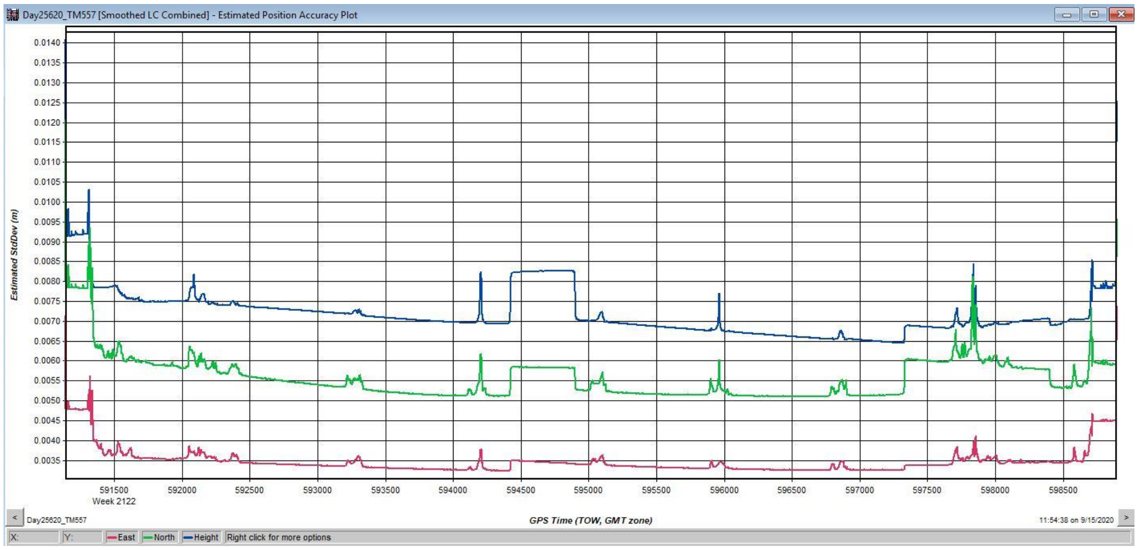
PDOP



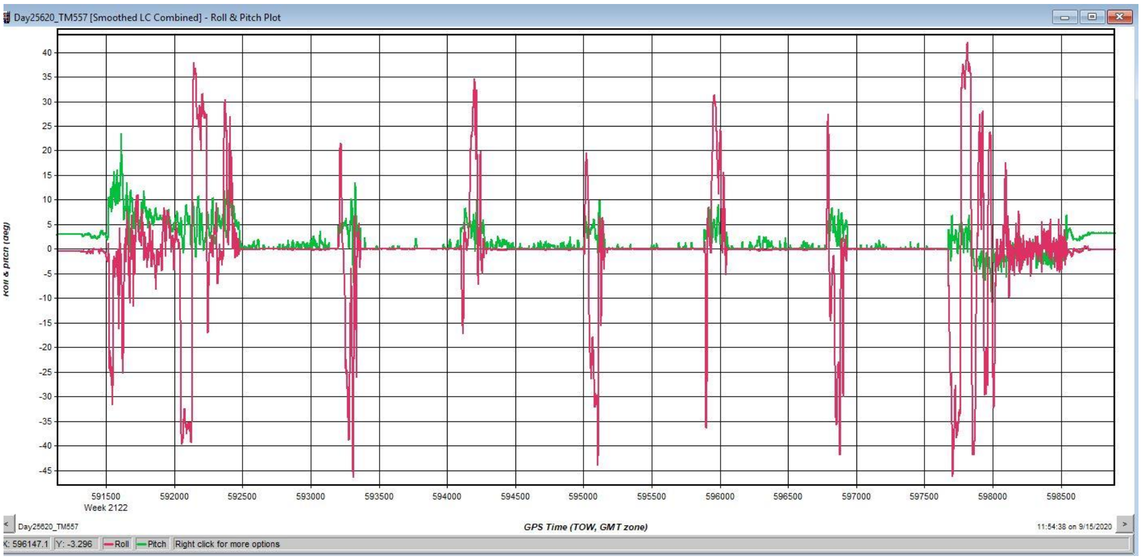
Satellites



RMS (m)



RPH (deg)



Day25620_TM557 [Smoothed LC Combined] - Roll & Pitch Plot
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
Roll & pitch (deg)
591500
Week 2122
592000
592500
593000
593500
594000
594500
595000
595500
596000
596500
597000
597500
598000
598500
Day25620_TM557
GPS Time (TOW, GMT zone)
11:54:38 on 9/15/2020
X: 596147.1
Y: -3.296
Roll
Pitch
Right click for more options