WY Yellowstone NP 2020 D20

Lidar Mapping Report Work Unit WY Yellowstone NP 1 2020 - 196955 April 2021





 Contract #
 G16PC00022

 Task Order #
 140G0220F0199



ContractorWoolpertProject #81200

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1. Overview

About

This project contains a comprehensive outline of the 140G0220F0199 WY Yellowstone NP2020 D20 task order issued by the United States Geological Survey's National Geospatial Technical Operations Center (USGS-NGTOC). This task order called for the acquisition and processing of QL2 and QL1 data over two areas of interest covering approximately 6,549 square miles in Yellowstone National Park and Park County, Montana (Figure 1-1).

This report encompasses the Work Unit 196955 area of interest (Figure 1-2). This AOI totals approximately 2,632 square miles and includes the following counties in Montana:

- Gallatin
- Meagher
- Park

Purpose

This project will support the 3DEP mission, the Natural Resources Conservation Service (NRCS) high resolution elevation enterprise program and the Federal Emergency Management Agency (FEMA) Risk Mapping Assessment and Planning (MAP) program.

Specifications

Data for this task order was acquired and produced to meet USGS Lidar Base Specification 2020 revision A standards and the American Society of Photogrammetry and Remote Sensing (ASPRS) Positional Accuracy Standards for Digital Geospatial Data (Edition 1, Version 1.0).

Spatial Reference

Geospatial data products were produced using the following horizontal and vertical spatial data reference system information listed in Table 1-1.

Table 1-1.	Spatial	Reference	System
------------	---------	-----------	--------

Horizontal	EPSG Code	6341
	Datum	NAD83 (2011)
	Projection	UTM Zone 12
	Units	Meters
Vertical	Datum	NAVD88
	Geoid	GEOID18
	Units	Meters
	Height Type	Orthometric

Figure 1-1. Project Area



Figure 1-2. Project Area - Work Unit 196955



Task Order Deliverables

All data products produced as part of this task order are listed in Table 1-2. All tiled deliverables had a tile size of 1,000-meter x 1,000-meters. Tile names are derived from the US National Grid.

Example: 12TVQ960940

This delivery's tiled dataset contains a total of 7,208 tiles.

Table 1-2. Deliverables

Lidar Data			
Classified lidar point cloud data	Tiles in LAS v1.4 format Classes • 1 – Processed, not Classified • 2 – Ground • 7 – Noise • 9 – Water • 17 – Bridge Decks • 18 – High Noise • 20 – Ignored Ground		
Breaklines used for hydro- flattening	 Lake and River features as feature classes in an Esri file geodatabase Water bodies greater than 2 acres as polygon features Rivers 30.5 meters / 100 feet and greater in width as polyline features Bridges used in DEM generation as point features in Esri shapefile format 		
Hydro-flattened bare earth digital elevation model (DEM)	1-meter pixel size, 32-bit floating-point; no bridges or overpass structures GeoTIFF format		
Intensity imagery	1-meter pixel size, 8-bit gray-scale (linear rescaling from 16-bit intensity) GeoTIFF format		
Vertical Accuracy Data			
Ground control survey report	Survey report in PDF format		
Calibration control points	Esri shapefile format		
NVA and VVA checkpoints	Esri shapefile format		
Interswath and intraswath test results	Esri shapefile format		

Table 1-2: Deliverables (continued)

Spatial Metadata			
Data extent	Esri shapefile format		
Tile index	Esri shapefile format		
Swath polygons	Georeferenced, polygonal representation of the detailed extents of each lidar swath Polygon feature class in an Esri file geodatabase		
Swath separation images	2-meter pixel size, 8-bit, GeoTIFF format		
Maximum surface height rasters	1-meter pixel size, 32-bit floating point, GeoTIFF format		
Metadata and Reports			
XML metadata	Deliverable-level FGDC CSDGM/USGS MetaParser Compliant metadata in XML format		
Lidar mapping report	Project report with ancillary data in PDF format		

2. Acquisition

Flight Planning

Acquisition was planned based on the task order specifications listed in Table 2-1.

Table 2-1. Acquisition Requirements

Specification	Target
Resolution	 2 points per square meter 0.71-meter nominal point spacing
Overlap	At contractor's discretion, but enough to ensure there are no data gaps between usable portions of the swath and to ensure the aggregate nominal point density (ANPD) is achieved
Acquisition Window	During period of annual minimal water level and minimal snow in the fall 2020 leaf-off window running through November 15, 2020
Data Voids	 Not allowed except Where caused by water bodies Where caused by areas of low near infra-red (NIR) reflectivity (i.e. asphalt or composition roofing) Where caused by lidar shadowing from buildings or other features Where appropriately filled-in by another swath
Data Acquisition Conditions	 Atmospheric Cloud and fog-free between the aircraft and ground Ground Snow free No unusual flooding or inundation, except in cases where the goal of the collection is to map the inundation Vegetation Leaf-off is preferred Time of Day Time of day is not of concern

Flight plans were created using Leica MissionPro software.

Lidar Sensor Information

Aerial lidar data was acquired for this project using the following lidar sensor systems:

• Leica TerrainMapper - serial numbers 511, 515, 557

Table 2-2 depicts a summary of sensor information. See Appendix 1 for the sensor calibration reports.

Table 2-2. Leica Terrain Mapper Sensor Info

Sensor Specifications			
Operating Altitude (m AGL)	300 - 5,500 at 10% reflective target		
Maximum Measurement Rate (kHz)	2,000		
Scan Angle	20 - 40		
Scan Width	Up to 70% of flight altitude		
Scan Frequency	Programmable up to 125 Hz (7,500 RPM), 250 scan lines per second		
Number of Returns	15		
Number of intensity measurements	15		
Pulse Mode(s)	Up to 35 pulses in air		
Laser Specifications			
Laser Beam Divergence	0.25 mrad (1/e)		
Laser Classification	Class 4 laser product		
Accuracy			
Range Resolution	< 1 cm RMS		
Elevation Accuracy	< 5 cm 1 σ		
Horizontal Accuracy	< 13 cm 1 σ		
Physical Specifications			
Size (cm), Weight (kg) • Scanner • Control Electronics	• 37 W x 68 L x 26 H cm, 47 kg • 45 W x 47 D x 25 H cm, 33 kg		
Operating Temperature • Scanner • Control Electronics	 0 - 40°C cabin-side temperature 0 - 40°C 		
Flight Management	Leica FlightPro		
Power Consumption	922 W @ 22.0 – 30.3 VDC		

Source: Leica TerrainMapper Data Sheet

https://leica-geosystems.com/en-US/products/airborne-systems/topographic-lidar-sensors/leica-terrainmapper

Lidar Sensor Settings

Aerial lidar was acquired using the sensors and settings listed in the Table 2-3.

Table 2-3. Lidar Sensor Settings

Settings	Blocks 1- 3	Block 4
Max. Number of Returns	15	15
Nominal Point Spacing	0.71 m	0.71 m
Nominal Point Density	2 ppsm	2 ppsm
Flying Height Above Ground Level	3,450 m	3,250 m
Flight Speed	150 knots	150 knots
Scan Angle	40°	40°
Scan Rate Used	81 Hz	82 Hz
Pulse Rate Used	670 kHz	650 kHz
Multi-Pulse in Air	Enabled	Enabled
Swath Width	2,511 m	2,366 m
Swath Overlap	25%	25%

Timeline

Lidar data was collected rom September 13, 2020 through October 9, 2020. A total of 158 individual flight lines were collected. Figure 2-1 shows aerial lidar coverage by lift.

For more information, see the Flight Logs in Appendix 2.

GNSS and IMU Equipment

Prior to mobilizing to the project site, flight crews coordinated with the necessary air traffic control personnel to ensure airspace access. Crews were on-site, operating a Global Navigation Satellite System (GNSS) Base Station for the airborne GPS support.

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

Base stations were set by acquisition staff and was used to support the aerial data acquisition. Table 2-4 lists the Station ID and coordinates for all base stations operated during acquisition.

For more information, see the GPS/IMU graphics in Appendix 3.

Figure 2-1. Flight Coverage



Table 2-4. GNSS Base Stations

Station Name	Longitude (DMS)	Latitude (DMS)	Ellipsoid Height L1 Phase Center (Meters)
MTSU_CORS	45° 39' 40.37685"	111° 2' 42.00897"	1495.554

Acquisition Quality Assurance

An initial quality control process was immediately performed on to review the data coverage, airborne GPS data, and trajectory solution.

Woolpert developed a quality assurance and validation plan to ensure the acquired lidar data meets the USGS Base Specification requirements. For quality assurance purposes, the lidar data was processed immediately following acquisition to verify the coverage has appropriate density, distribution, and no unacceptable data voids. Accompanying GPS data was post processed using differential and Kalman filter algorithms to derive a best estimate of trajectory. The quality of the solution was verified to be consistent with the accuracy requirements of the task order. Any required re-flights were scheduled at the earliest opportunity.

The spatial distribution of the geometrically usable first return lidar points was reviewed for density requirements as well as regular and uniform point distribution - verifying the lidar data is spaced so that 90% of the cells in a 2*NPS grid placed over the data contain at least one lidar point. The NPS assessment is made against single swath, first return data located within the geometrically usable center portion (typically ~90%) of each swath. Additionally, the data was reviewed for unacceptable data voids – verifying no area greater than or equal to $(4 \times ANPS)^2$ exhibited data coverage gaps.

3. Processing

Processing Summary

Once the lidar data passed initial QC, the dataset was corrected for aircraft orientation and movement. This process used airborne inertial, orientation, and GPS data collected during acquisition along with ground-based GPS data. The data went through a geometric calibration that further corrected each laser point. This calibrated data set was used to create the LAS point cloud. The LAS point data was initially classified into "ground" and "non-ground", then further refined using the classes specified in this task order. Breaklines were drawn to denote hydrological features. After the hydro-flattening process, the final deliverables products were created.

GPS-IMU Trajectory Processing

Kinematic corrections for the aircraft position were resolved using aircraft GPS and static ground GPS (1-Hz) for each geodetic control (base station) for three subsystems: inertial measurement unit (IMU), sensor orientation information, and airborne GPS data.

Post-processing of the IMU system data and aircraft position with attitude data was completed to compute an optimally accurate, blended navigation solution based on Kalman filtering technology, or the smoothed best estimate of trajectory (SBET).

For more information, see the GPS/IMU graphics in Appendix 3.

Software: POSPac Software v. 5.3, IPAS Pro v.1.35., Novatel Inertial Explorer v8.60.6129

Trajectory Quality

The GNSS trajectory and high-quality IMU data are key factors in determining the overall positional accuracy of the final sensor data. Within the trajectory processing, there are many factors that affect the overall quality, but the most indicative are the combined separation, the estimated positional accuracy, and the positional dilution of precision (PDOP).

Combination Separation

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

The data for this task order was processed with a goal to maintain a combined separation difference of less than ten (10) centimeters.

Estimated Positional Accuracy

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

PDOP

The PDOP measures the precision of the GPS solution in regard to the geometry of the satellites acquired

and used for the solution.

The data for this task order was processed with a goal to maintain an average PDOP value below 3.0. Brief periods of PDOP over 3.0 are acceptable due to the calibration and control process if other metrics are within specification.

Geometric Calibration

After the initial phase was complete, a formal reduction process was performed on the data. Laser point position was calculated by associating the SBET position to each laser point return time, scan angle, intensity, etc. Raw laser point cloud data was created for the whole project area in LAS format. Automated line-to-line calibrations were then performed for system attitude parameters (pitch, roll, heading), mirror flex (scale) and GPS/IMU drift. Statistical reports were generated for comparison and used to make the necessary adjustments to remove any residual systematic error.

For more information, see the Sensor Calibration Report(s) in Appendix 1.

Software: Proprietary Software, TerraMatch v20, Leica CloudPro 1.2.4

Relative Accuracy: Interswath (Overlap) Consistency

Interswath or overlap consistency was assessed at multiple locations within overlap in non-vegetated areas containing only single returns and located in areas with slopes of less than 10 degrees. To the extent allowed by the data, test areas were chosen where the full width of the overlap was represented. These overlap areas include adjacent, overlapping parallel swaths within a project, cross-tie swaths and a sample of intersecting project swaths in both flight directions, and adjacent, overlapping lifts.

This project required the interswath accuracy to meet ≤ 8 cm RMSDz. Accuracy was assessed in accordance with the USGS Base Specification v2020 revision A.

The interswath consistency results were produced as polygon features in Esri shapefile format. Table 3-1 lists the interswath test results. Figure 3-1 depicts the location of the interswath test locations.

Table 3-1. Interswath Results

Minimum (m)	Maximum (m)	RMSDz (m)
-0.031	0.056	0.024
-0.035	0.097	0.038
-0.064	0.008	0.031
-0.051	0.050	0.019
-0.092	0.053	0.025
-0.083	0.058	0.025
-0.023	0.058	0.023
-0.061	0.060	0.021
-0.035	0.038	0.017
-0.072	0.047	0.029
-0.035	0.048	0.018
-0.067	0.020	0.026
-0.039	0.036	0.017
-0.089	0.115	0.028
-0.064	0.087	0.025



Figure 3-1. Interswath Testing Locations

Relative Accuracy: Intraswath Precision

Intraswath precision (or smooth surface precision) was performed on hard surfaces with areas consisting of approximately 100 pixels (ex.: parking lots, large rooftops) and containing only single return lidar points. Sample areas were selected where full width of the swath(s) (left, center, and right) were represented to the extent the data allowed.

This project required the intraswath accuracy to meet ≤ 6 cm RMSDz. Accuracy was assessed in accordance with the USGS Base Specification v2020 revision A.

The intraswath precision results were produced as polygon features in Esri shapefile format. Table 3-2 lists the intraswath test results. Figure 3-2 depicts the location of the intraswath test locations.

Minimum (m)	Maximum (m)	RMSDz (m)
1531.660	1531.880	0.036
1476.790	1477.470	0.026
1435.860	1436.020	0.027
1384.340	1384.830	0.035

Table 3-2. Intraswath Results





Lidar Data Classification

LAS data was initially classified as ground and non-ground points "first and only" as well as "last of many" lidar returns. Additional filters were created to meet the task order classification specifications. Statistical absolute accuracy was assessed via direct comparisons of ground classified points to ground RTK survey data. Based on the statistical analysis, the lidar data was then adjusted to reduce the vertical bias when compared to the survey ground control of higher accuracy.

The bare-earth (Class 2 - Ground) lidar points underwent a manual QA/QC step to verify the quality of the DEM as well as a peer-based QC review. This included a review of the DEM surface to remove artifacts and ensure topographic quality. After the bare-earth surface is finalized, it is then used to generate all hydro-breaklines through a semi-automated process.

All ground (Class 2) lidar data inside of the Lake Pond and Double Line Drain hydro flattening breaklines were then classified to water (Class 9) using TerraScan/LP360 macro functionality. A buffer of 0.7 meters was also used around each hydro-flattened feature to classify these ground (Class 2) points to Ignored Ground (Class 20). All Lake Pond Island and Double Line Drain Island features were checked to ensure that the ground (Class 2) points were reclassified to the correct classification after the automated classification was completed.

All overlap data was processed through automated functionality provided by TerraScan to classify the overlapping flight line data to approved classes by USGS. The overlap data was classified using standard LAS overlap bit. These classes were created through automated processes only and were not verified for classification accuracy. Due to software limitations within TerraScan, these classes were used to trip the withheld bit within various software packages. These processes were reviewed and accepted by USGS through numerous conference calls and pilot study areas.

All data was manually reviewed and any remaining artifacts removed using functionality provided by TerraScan and TerraModeler. Global Mapper was used as a final check of the bare earth dataset. GeoCue was then used to create the deliverable industry-standard LAS files. Woolpert proprietary software and LP360 was used to perform final statistical analysis of the classes in the LAS files, on a per tile level to verify final classification metrics and full LAS header information.

Table 3-3 lists the point classifications used.

Class Number	Class Name
Class 1	Processed, but unclassified
Class 2	Bare earth
Class 7	Low noise
Class 9	Water
Class 17	Bridge deck
Class 18	High noise
Class 20	Ignored ground

Table 3-3. Classified Point Breakdown

Hydrologic Flattening

The lidar task order required compilation of breaklines defining the following types of water body features:

Lakes, reservoirs, ponds	Minimum of 2-acres or greater Compiled as closed polygons, collected at a constant elevation
Rivers, streams	Nominal width of 30.5 meters / 100 feet Compiled in direction of flow, with both sides maintaining an equal elevation gradient
Bridge breaklines	Breaklines used to enforce a logical terrain surface below a bridge

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

- 1. The newly acquired lidar data was utilized to manually compile the hydrologic features in a 2D environment using the lidar intensity and bare earth surface. Open Source imagery was used as reference when necessary.
- 2. An integrated software approach was applied to combine the lidar data and 2D breaklines. This process "drapes" the 2D breaklines onto the 3D lidar surface model to assign an elevation. A monotonic process is performed to ensure the streams are consistently flowing in a gradient manner. A secondary step within the program verifies an equally matching elevation of both stream edges. The breaklines that characterize the closed water bodies are draped onto the 3D lidar surface and assigned a constant elevation at or just below ground elevation.
- 3. All classified ground points from inside the hydrologic feature polygons were reclassified to water, class nine (9).
- 4. All classified ground points were reclassified from within a buffer along the hydrologic feature breaklines to buffered ground, class twenty (20). The buffer distance was approximately the task order designed nominal pulse spacing distance.
- 5. Breaklines used for bridge removal during the hydrologic flattening were included with the hydrologic breakline geodatabase deliverable. The purpose of these breaklines is for a more aesthetically pleasing DEM appearance.
- 6. The lidar ground points and breaklines were used to generate a digital elevation model (DEM).
- 7. QA/QC for this task was performed by reviewing the hydrologically flattened DEM and hydrologic breakline features. Additionally, a combined approach utilizing commercial off the shelf software and proprietary methods were used to review the overall connectivity of the hydrologic breaklines.

TerraScan was used to add the hydrologic breakline vertices and export the lattice models.

Breaklines defining the water bodies greater than 2-acres were provided as polygon features. Rivers and streams with a nominal minimum width of 30.5 meters (100 feet) were provided as polyline features. All lake and river breaklines compiled as part of the flattening process were provided in an Esri file geodatabase.

Breaklines used for DEM generation were provided as point features in Esri shapefile format.

Software: TerraScan v20, TerraModeler v20, Esri ArcMap v10.7, LP360 v2019.1.30.4

Digital Elevation Model

TerraScan was used to add the hydrologic breakline vertices and export the lattice models. Class 2 (ground) lidar points in conjunction with the hydro breaklines and bridge breaklines were used to create 1-meter hydro-flattened bare-earth raster DEM files. Using automated scripting routines within ArcMap, a 32-bit floating point raster GeoTIFF file was created for each tile. Files were clipped to the data extent. Each surface is reviewed using Global Mapper to check for any surface anomalies or incorrect elevations found within the surface.

Software: TerraScan v20, GDAL 2.4.0, Esri ArcMap v10.7, Global Mapper v20.0

Intensity Imagery

Lidar intensity data derived from the acquired lidar data was linearly rescaled from 16-bit intensity and provided as 1-meter pixel, 8-bit, 256 gray scale GeoTIFF files. Files were clipped to the data extent.

Software: TerraScan v20, Esri ArcMap v10.7

Metadata

FGDC CSDGM/USGS MetaParser-compliant metadata was produced in XML format. The metadata includes a complete description of the task order client information, contractor information, project purpose, lidar acquisition and ground survey collection parameters, lidar acquisition and ground survey collection dates, spatial reference system information, data processing including acquisition quality assurance procedures, GPS and base station processing, geometric calibration, lidar classification, hydrologic flattening, intensity imagery development, and final product development.

Other metadata deliverables included Esri shapefiles of the ground control and QA/QC points, interswath and intraswath test results, data extent, and tile index. A georeferenced, polygonal representation of the detailed extents of each acquired lidar swath was produced as a polygon feature class in an Esri file geodatabase. Swath separation images were produced in GeoTIFF format. Maximum height separation rasters were produced in GeoTIFF format.

4. Accuracy Assessment

Horizontal Accuracy

The data set was produced to meet ASPRS "Positional Accuracy Standards for Digital Geospatial Data" (2014) for a 0.249 cm RMSEx / RMSEy Horizontal Accuracy Class which equates to Positional Horizontal Accuracy = +/- 0.609 cm at a 95% confidence level.

Classified Lidar Point Cloud Testing

This project required Non-Vegetated Vertical Accuracy (NVA) and Vegetated Vertical Accuracy (VVA) to be tested on the classified lidar point cloud data. The dataset was required to meet a target NVA value of 19.6 cm at a 95% confidence level using an RMSEz target value of 10 cm x 1.9600 and a target VVA value of 30 cm at the 95th percentile. Testing was assessed and reported using guidelines developed by the National Digital Elevation Program (NDEP) and the American Society for Photogrammetry and Remote Sensing (ASPRS).

The NVA and VVA values were calculated using independent checkpoints that were not used in the calibration or post processing of the lidar point cloud data. Checkpoints were distributed throughout the project area. NVA checkpoints were located in bare earth and urban (non-vegetated) land cover classes. VVA checkpoints were located in brush/tall grass/weeds (vegetated) land cover classes. These checkpoints were surveyed using GPS techniques. See the survey report for acquisition methodologies.

Testing was performed using TINs created from the final calibrated and controlled swath data. For each NVA checkpoint, an elevation value was derived from the TIN at the point's x,y location. This value was compared to the checkpoint's surveyed elevation value.

The classified lidar point cloud accuracy test results are listed below in Table 4-1.

	Result	Points Used
NVA	0.042 m RMSEz 0.082 m at 95% CL	125
VVA	0.217 at 95th Percentile	95

Table 4-1. Classified Point Cloud Vertical Accuracy

Digital Elevation Model Testing

This project required Non-Vegetated Accuracy (NVA) and Vegetated Vertical Accuracy (VVA) testing of the digital elevation model (DEM) dataset. The calculated NVA value was required to meet 19.6 cm at a 95% confidence level using an RMSEz target value of 10 cm x 1.9600. VVA was required to meet 0.30 cm at the 95th percentile error. Testing was assessed and reported using guidelines developed by the National Digital Elevation Program (NDEP) and the American Society for Photogrammetry and Remote Sensing (ASPRS).

Testing was performed using the bare earth DEM created as part of this task order. For each checkpoint, an elevation value was derived from the DEM at the point's x,y location. This value was compared to the checkpoint's surveyed elevation value.

The NVA and VVA values were calculated using independent checkpoints that were not used in the calibration or post processing of the lidar point cloud data. Checkpoints were distributed throughout the project area. NVA checkpoints were located in bare earth and urban (non-vegetated) land cover classes. VVA checkpoints were located in brush/tall grass/weeds (vegetated) land cover classes. These checkpoints were surveyed using GPS techniques. See the survey report for acquisition methodologies.

The classified lidar point cloud accuracy test results are listed below in Table 4-2.

Table 4-2. DEM Accuracy

	Result	Points Used
NVA	0.042 m RMSEz 0.082 m at 95% CL	113
VVA	0.205 at 95th Percentile	78

Appendix 1: Sensor Calibration Report

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Leica Geosystems Leica TerrainMapper-LN Calibration Certificate

Product	Leica TerrainMapper-LN
Serial Number	91511
Date	03 July 2019
Inspector	Mark O'Neal



Leica Geosystems AG Heinrich-Wild-Strasse CH-9435 Heerbrugg Schweiz www.leica-geosystems.com

1. System Components

Component	Туре	Serial Number
Pod	TerrainMapper Pod	91511
GNSS/IMU	Litef LCI-100C 500 Hz	1139
LiDAR Unit	Hyperion2 LiDAR Unit	5511
Camera Head Lens	CH82 NAT-D 2.8/80	82659 80254

2. Estimation Process

		Passed	Date	Inspector
Image Flight	completed	ok	10.05.2019	Philip Benz
Image Quality Check	checked	ok	16.05.2019	Philip Benz
Image Calibration	completed	ok	18.05.2019	Xu Wang
Image Misalignment Update	completed	ok	02.07.2019	Mark O'Neal
LiDAR Flight	completed	ok	10.17.2018	Deniz Arslan
LiDAR Quality Check	checked	ok	23.10.2018	Rene Heirli
LiDAR Calibration and Accuracy	completed	ok	24.10.2018	Robert Bosch
LiDAR Misalingment Update	completed			

3. Inspectors

Name Position	Bernhard Riedl Production Manager	15.11.2018	Rid Renhard
Name Position	Robert Bosch Support Engineer	23.05.2019	Xu Wang
Name Position	Michael Vetter Support Engineer	03.07.2019	4.35A

4. Remarks

5. LiDAR Calibration Results

The calibration results for the LiDAR Unit are only valid for:

• IMU and Pod as listed in the System Components section

5.1 LiDAR Geometric Calibration Results

IMU Misalignment		Value	Unit
	ω	-0.138877	degree
	Φ	0.130994	degree
	К	-0.006412	degree
Boresight		Value	Unit
	Θ	0.001052	degree
	Φ	-0.001885	degree
Receiver 1		Value	Unit
Range	∆ Offset	0.000000	meters
Wedge 0		Value	Unit
Wedge	∆ Alpha	0.001241	degree
Wedge Position	∆ Offset	-0.426898	degree
Position Correction	Х	-0.019523	degree
	Y	0.007883	degree
Mount	Roll	-0.020901	degree
	Pitch	0.107683	degree
Rotation Axis	Roll	0.103712	degree
	Pitch	0.124140	degree
Wedge 1		Value	Unit
Wedge	∆ Alpha	-0.009545	degree
Wedge Position	∆ Offset	0.412993	degree
Position Correction	Х	0.004000	degree
	Y	0.011085	degree
Mount	Roll	0.102859	degree
	Pitch	0.025756	degree
	Speed Pitch	1.50E-06	degree/rps ²
Rotation Axis	Roll	0.114811	degree
	Pitch	-0.080531	degree
LiDAR Geometric Calibration File			
HYPERION_GEOMETRY_LIDARUNIT-551	1-C-855570-DATETIME	E-20181023-153458.XM	ЛL
	Date	23.10.2018	
LiDAR Misalingment Flight	Date	-	
LiDAR Misalingment Update Completed	Date	-	

5.2 LiDAR Unit Accuracy Check

Accuracy checks:

- Deviation of two perpendicular lines to GCP's
- Difference of two perpendicular lines
- Difference of forward and backward scan of one line

5.2.1 Multi-line accuracy of two perpendicular lines to ground control points



Figure 1 Vertical distance to ground control points at 1000 m AGL.

5.2.2 Difference of forward and backward scan of one line

Color	Limits [m]	Number of patches	Proportion of total number of patches [%]
	<=0.04	293823	93.48
	0.04-0.07	20386	6.49
	0.07-0.1	89	0.03
	>0.1	16	0.01
	>0.1	16	0.01



5.2.3 Multi-line accuracy between two perpendicular lines

M003_1000C_111212_vs_M010_1000C_111736

39940 valid patches with size of 2 m found. Only patches with standard deviation < 0.05 m and minimum of 5 points are included.

Color	Limits [m]	Number of patches	Proportion of total number of patches [%]
	<=0.04	32066	80.29
	0.04-0.07	7841	19.63
	0.07-0.1	21	0.05
	>0.1	12	0.03



Figure 3 Vertical difference betweeen two perpendicular lines at 1000 m AGL.

6. Imaging Sensors Estimation Results

The estimation results for the camera head and lens combination are only valid for:

- IMU and Pod as listed in the System Components section.
- Camera Head, lens and specified position as listed in the Estimation Results sections.

6.1 Camera Model of distortion free images

All factory calibration results contain fixed nominal focal lengths and zero principal point offsets. Leica HxMap applies the grid to create distortion-free images of nominal focal length and pixel size.

6.1.1 CH8x Model

			Component
Camera Head Lens			CH82 NAT-D 2.8/80
Camera Model			
Focal Length			Distance [mm]
	С		83.00
Radial Symmetric Distorsion			Distance [mm]
	ko k1 k2		0.0000 0.0000 0.0000
Decentering Distortion	р ₁ р2		Distance [mm] 0.0000 0.0000
Non-Orthogonality Distortion			Distance [mm]
Pixel Size (Height and Width)	b ₁ b ₂		0.0000 0.0000 Distance [mm]
	RGB NIR		0.0052 0.0120
Rows and Columns		Rows	Columns
	Active RGB Raw RGB Active NIR Raw NIR	7752 7788 3654 3366	10320 10336 4478 4500

6.2 Results of Geometric Calibration

6.2.1 Calibration method for Green Reference Band

Estimation of additional parameters (focal length, principal point, radial symmetric distortion, correction grid) and IMU misalignment in simultaneous bundle adjustment

Reference band (green)	Distance [mm]

Resulting sigma naught of bundle adjustment:

Final bundle adjustment results after elimination of tie point blunders:



6.2.2 Calibration method for Other Spectral Bands

Estimation of additional parameters (correction grid), based on the result for green in simultaneous bundle adjustment

Other Spectral Bands

```
Distance [mm]
```

0.002

0.0007

Co-registration to green better than:

Leica HxMap applies the grid to create distortion-free images of nominal focal length and fixed pixel size of 0.0052 mm.

6.3 Estimation Results for Nadir Camera Head and Lens

		Component	Serial Number
Camera Head Lens View Direction in Pod Position		CH82 NAT-D 2.8/80 Nadir	82659 80254
IMU Misalignment		Angle [degree]	
	ω Φ κ	-0.00815 0.00028 -0.26654	
Principal Point		Distance [mm]	
	x y	0.0000 0.0000	
Focal Length		Distance [mm]	
	С	83.00	
Geometric Calibration File			

RCD30_Geometry_CameraHead-82659-E-798528_LensSystem-80254-B-785423_DateTime-20190518-214751.xml

Date	18.05.2019
Date	05.02.2019
Date	23.06.2019
Date	02.07.2019
	Date Date Date Date

Remaining image space residuals after applying the calibration results



Radius of circles is 0.0007 mm



- when it has to be **right**

Leica Geosystems Leica TerrainMapper-L Calibration Certificate

Product	Leica TerrainMapper-L
Serial Number	90515
Date	12 December 2018
Inspector	Robert Bosch



Leica Geosystems AG Heinrich-Wild-Strasse CH-9435 Heerbrugg Schweiz www.leica-geosystems.com

1. System Components

Component	Туре	Serial Number
Pod	Terrainmapper Pod	90515
GNSS/IMU	Litef LCI-100C 500 Hz	1226
LiDAR Unit	Hyperion2 LiDAR Unit	5516

2. Estimation Process

		Passed	Date	Inspector
LiDAR Flight	completed	ok	29.11.2018	Philip Benz
LiDAR Quality Check	checked	ok	06.12.2018	Rene Heierli
LiDAR Calibration and Accuracy	completed	ok	12.12.2018	Robert Bosch
LiDAR Misalignment Update	completed			

3. Inspectors

Name Position	Bernhard Riedl Production Manager	12.12.2018	Rid Runhard
Name Position	Robert Bosch Support Engineer	12.12.2018	4.Bod

4. Remarks

5. LiDAR Calibration Results

The calibration results for the LiDAR Unit are only valid for:

• IMU and Pod as listed in the System Components section

5.1 LiDAR Geometric Calibration Results

IMU Misalignment		Value	Unit
	ω Φ	-0.022555 0.056357	degree dearee
	ĸ	0.000504	degree
Boresight		Value	Unit
	Θ	0.015419	degree
	Φ	-0.001923	degree
Receiver 1		Value	Unit
Range	∆ Offset	0.000000	meters
Wedge 0		Value	Unit
Wedge	Δ Alpha	-0.043014	degree
Wedge Position	∆ Offset	0.442789	degree
Position Correction	Х	-0.012826	degree
	Y	0.000012	degree
Mount	Roll	0.045379	degree
	Pitch	0.210132	degree
Rotation Axis	Roll	0.031087	degree
	Pitch	0.076675	degree
Wedge 1		Value	Unit
Wedge	∆ Alpha	-0.005517	degree
Wedge Position	∆ Offset	0.559649	degree
Position Correction	Х	0.030760	degree
	Y	-0.001169	degree
Mount	Roll	0.012366	degree
	Pitch	0.054254	degree
	Speed Pitch	1.50E-06	degree/rps ²
Rotation Axis	Roll	0.032485	degree
	Pitch	-0.029191	degree
LiDAR Geometric Calibration File			
HYPERION_GEOMETRY_LIDARUN	IT-5516-C-855570-DATETIME	-20181204-161828.XN	/IL
	Date	04.12.2018	

LiDAR Misalignment Flight	Date	-
LiDAR Misalignment Update Completed	Date	-
5.2 LiDAR Unit Accuracy Check

Accuracy checks:

- Deviation of two perpendicular lines to GCP's
- Difference of two perpendicular lines
- Difference of forward and backward scan of one line

5.2.1 Multi-line accuracy of two perpendicular lines to ground control points



Figure 1 Vertical distance to ground control points at 1000 m AGL.

5.2.2 Difference of forward and backward scan of one line

Color	Limits (m)	Number of patches	Proportion of total number of patches [%]
	<=0.04	302593	99.75
	0.04-0.07	716	0.24
	0.07-0.1	17	0.01
	>0.1	29	0.01



5.2.3 Multi-line accuracy between two perpendicular lines

Color	Limits (m)	Number of patches	Proportion of total number o patches [%]	
	<=0.04	29546	99.86	
	0.04-0.07	38	0.13	
	0.07-0.1	1	0.00	
	>0.1	3	0.01	

M003_1000C_091330_vs_M010_1000C_091927

29588 valid patches with size of 2 m found. Only patches with standard deviation < 0.05 m and minimum of 5 points are included.



Figure 3 Vertical difference betweeen two perpendicular lines at 1000 m AGL.

- when it has to be **right**



Leica Geosystems Leica TerrainMapper-LN Calibration Certificate

Product	Leica TerrainMapper-LN
Serial Number	91557
Date	01 July 2020
Inspector	Ivan Belchev



Leica Geosystems AG Heinrich-Wild-Strasse CH-9435 Heerbrugg Schweiz www.leica-geosystems.com

1. System Components

Component	Туре	Serial Number
Pod	TerrainMapper Pod	91557
GNSS/IMU	Litef LCI-100C 500 Hz	1346
LiDAR Unit	Hyperion2 LiDAR Unit	5561
Camera Head Lens	CH82 NAT-D 2.8/80	82673 80264

2. Estimation Process

		Passed	Date	Inspector
Image Flight	completed	ok	23.06.2020	Deniz Arslan
Image Quality Check	checked	ok	29.06.2020	Bernhard Riedl
Image Calibration	completed	ok	29.06.2020	Zoltan Poth
Image Misalingment Update	completed			
LiDAR Flight	completed	ok	23.06.2020	Deniz Arslan
LiDAR Quality Check	checked	ok	26.06.2020	Rene Heierli
LiDAR Calibration and Accuracy	completed	ok	25.06.2020	Michael Vetter
LiDAR Misalingment Update	completed			

3. Inspectors

Name Position	Bernhard Riedl Production Manager	01.07.2020	Rud Runhard
Name Position	Ivan Belchev Workflow Specialist	01.07.2020	Utres
Name Position	Michael Vetter Support Engineer	01.07.2020	Vate Scilard

4. Remarks

5. LiDAR Calibration Results

The calibration results for the LiDAR Unit are only valid for:

• IMU and Pod as listed in the System Components section

5.1 LiDAR Geometric Calibration Results

IMU Misalignment		Value	Unit
	ω Φ κ	-0.063987 -0.049738 -0.005305	degree degree degree
Boresight	, c	Value	Unit
C C	Θ	-0.001796	degree
	Φ	-0.003034	degree
Receiver 1		Value	Unit
Range	∆ Offset	0.000000	meters
Wedge 0		Value	Unit
Wedge	Δ Alpha	-0.045434	degree
Wedge Position	∆ Offset	0.352942	degree
Position Correction	Х	-0.014623	degree
	Y	0.020330	degree
Mount	Roll	0.210896	degree
	Pitch	0.426854	degree
Rotation Axis	Roll	0.232742	degree
	Pitch	0.169968	degree
Wedge 1		Value	Unit
Wedge	Δ Alpha	0.003457	degree
Wedge Position	Δ Offset	0.393122	degree
Position Correction	Х	0.019198	degree
	Y	-0.002307	degree
Mount	Roll	0.020583	degree
	Pitch	0.038667	degree
	Speed Pitch	1.50E-06	degree/rps ²
Rotation Axis	Roll	0.061823	degree
	Pitch	0.034555	degree
LiDAR Geometric Calibration File			
HYPERION_GEOMETRY_LIDARUNIT-556	1-D-855570-DATETIME	E-20200625-085747.XN	ЛL
	Date	25.06.2020	
LiDAR Misalingment Flight	Date	-	
LiDAR Misalingment Undate Completed	Date	-	
epidate epidete			

5.2 LiDAR Unit Accuracy Check

Accuracy checks:

- Deviation of two perpendicular lines to GCP's
- Difference of two perpendicular lines
- Difference of forward and backward scan of one line

5.2.1 Multi-line accuracy of two perpendicular lines to ground control points



TM-LN-91557_200623_OutputControlReport_200625

Figure 1 Vertical distance to ground control points at 1000 m AGL.

5.2.2 Difference of forward and backward scan of one line

M003_1000C_090208

377750 valid patches with size of 2 m found. Only patches with standard deviation < 0.05 m and minimum of 5 points are included.

Color	Limits [m]	Number of patches	Proportion of total number of patches [%]
	<=0.04	372019	98.48
	0.04-0.07	5529	1.46
	0.07-0.1	169	0.04
	>0.1	33	0.01



Figure 2 Vertical difference betweeen forward and backward scan at 1000 m AGL.

5.2.3 Multi-line accuracy between two perpendicular lines

$M003_1000C_090208_vs_M010_1000C_084836$

50693 valid patches with size of 2 m found. Only patches with standard deviation < 0.05 m and minimum of 5 points are included.

Color	Limits [m]	Number of patches	Proportion of total number of patches [%]
	<=0.04	50354	99.33
	0.04-0.07	327	0.65
	0.07-0.1	6	0.01
	>0.1	6	0.01



Figure 3 Vertical difference betweeen two perpendicular lines at 1000 m AGL.

6. Imaging Sensors Estimation Results

The estimation results for the camera head and lens combination are only valid for:

- IMU and Pod as listed in the System Components section.
- Camera Head, lens and specified position as listed in the Estimation Results sections.

6.1 Camera Model of distortion free images

All factory calibration results contain fixed nominal focal lengths and zero principal point offsets. Leica HxMap applies the grid to create distortion-free images of nominal focal length and pixel size.

6.1.1 CH8x Model

			Component
Camera Head Lens			CH82 NAT-D 2.8/80
Camera Model			
Focal Length			Distance [mm]
	С		83.00
Radial Symmetric Distorsion			Distance [mm]
	ko k1 k2		0.0000 0.0000 0.0000
Decentering Distortion	Р1 Р2		Distance [mm] 0.0000 0.0000
Non-Orthogonality Distortion			Distance [mm]
Pixel Size (Height and Width)	b ₁ b ₂		0.0000 0.0000 Distance [mm]
	RGB NIR		0.0052 0.0120
Rows and Columns		Rows	Columns
	Active RGB Raw RGB Active NIR Raw NIR	7752 7788 3654 3366	10320 10336 4478 4500

6.2 Results of Geometric Calibration

6.2.1 Calibration method for Green Reference Band

Estimation of additional parameters (focal length, principal point, radial symmetric distortion, correction grid) and IMU misalignment in simultaneous bundle adjustment

Reference band (green)	Distance [mm]
Resulting sigma naught of bundle adjustment:	0.0010

Final bundle adjustment results after elimination of tie point blunders:



6.2.2 Calibration method for Other Spectral Bands

Estimation of additional parameters (correction grid), based on the result for green in simultaneous bundle adjustment

Other Spectral Bands

Distance [mm]

0.002

Co-registration to green better than:

Leica HxMap applies the grid to create distortion-free images of nominal focal length and fixed pixel size of 0.0052 mm.

6.3 Estimation Results for Nadir Camera Head and Lens

		Component	Serial Number
Camera Head Lens View Direction in Pod Position		CH82 NAT-D 2.8/80 Nadir	82673 80264
IMU Misalignment		Angle [degree]	
μ 4 κ)	0.03017 -0.01221 -0.25213	
Principal Point		Distance [mm]	
x y		0.0000 0.0000	
Focal Length		Distance [mm]	
с		83.00	
Geometric Calibration File			
DCD20 Cosmotry Comprehend 0207		ana Swatam 20264 F	705400 DotoTi

RCD30_Geometry_CameraHead-82673---798528_LensSystem-80264-B-785423_DateTime-20200629-142416.xml

Geometric Calibration Date	Date	29.06.2020
Radiometric Calibration Date	Date	30.01.2020
Misalingment Flight	Date	-
Misalingment Update Completed	Date	-

Remaining image space residuals after applying the calibration results

RMS-X: 0.13 RMS-Y: 0.11



Radius of circles is 0.0010 mm

Appendix 2: Flight Logs

			Woolp	ert Li	idar /	Acq	uisitio	n Log					
			Project	Info						D	ate		
Project #		Project	t Name			U	nique ID	Flig	,ht Date	(UTC)	Day o	f Year	Flight #
81200	Pa	ark Co. Montai	na Blks 2,3 ar	nd 4		Day2	57_91557_A	()9/13/20)20	25	57	Α
Cr	ew		Equi	pment				Tim	е			Ai	rports
Pi	lot	Ai	rcraft Make	/ Model /	Tail #		Hobbs St	art Loc	al Start		start	De	parting
Cor	mer		Cessna 404 II	itan - N532	.NM		461.4		:37:00	1/:3/	7:00	<u> </u>	KBZN
Oper By		<u> </u>	nsor wake /	Manner - 9	2riai #						Ena	A	
				Mapper - 9.	Condit	ions	404.4		.50.00	10.50	5:00	<u> </u>	KBZIN
Wind Dir	r (°) Win	d Speed (kts)	Visibility	(mi) Ce	eiling (ft)	Cle	oud Cover	Temp. (°C	:) Dev	v Point	(°C)	Pres	sure ("Hg)
0		0	10	(,			Clear	17	1	4			3019
Air Spe	ed (kts)	Altitude	e AGL (ft)	Altitu	.de MSL (ft)	Airfield Ele	vation (ft)					
1'	50	10,	663		17,415		4,4	473					
					Settir	ngs							
Point Spacir	ng (m) Poi	int Density (pr	osm) Sc	an Angle/F	:OV (°)	Sca	n Frequency	(Hz) Pu	lse Rate	(kHz)	Las	er Po	wer (%)
0.7		2		40			81		670			10	0
								Verify	δ-Turns I	Before	Missic	วท	Yes
Line #	pacing (m) Point Density (ppsm) Scan Angle/FOV (°) Scan Frequency (Hz) Pulse Rate (kHz) Laser Power (hz) 0.7 2 40 81 670 10 Verify S-Turns Before Mission # Direction Start Time (UTC) End Time (UTC) Time On-Line Satellite PDOP Line Notes/Comments # 17:37:00 17:46:00 00:09:00 17 1.4 BLOCK 4/ 17,415 MSL W 17:49:00 17:58:00 00:09:00 17 1.4 some smoke and snow W V V V V V V V V												
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Additional C	omments												

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			Project	Info								D	ate		
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81200		Park Co N	ЛТ Block 1				Day2	65_90515	_1	09	/21/20	20	26	65	1
Cre	ew		Equi	pment						Time				Ai	rports
Pil	lot	Ai	ircraft Make	/ Mode	el / Tai	l #		Hobbs	s Start	Loca	l Start	UTC S	tart	De	parting
Gibi	ilaro		Cessna 404	Гitan - N	17079F	:		292	<u>'</u> 1.1	11:5	54:00	17:54	:00		LAR
Oper	rator	Se	nsor Make /	Model	/ Seria	al #		Hobb	s End	Loca	I End	UTC F	End	A	rriving
Kenr	nedy	L	eica Terrain I	Mapper	- 9051	15		292	25.9	16:3	39:00	22:41	:00		BZN
					C	ondit	ions								
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Air Spe	ed (kts)	Altitude	: AGL (ft)	A	ltitude	MSL (ft)	Airfield	Elevatio	on (ft)					
15	50	11,	319		15,	512			4,473						
						Settin	ngs			-					
Point Spacin	ıg (m) Poi	int Density (pr	osm) Sc	an Angl	le/FOV	/ (°)	Scar	n Frequen	icy (Hz)	Pulse	e Rate	(kHz)	Las	er Pov	wer (%)
0.7				4	.0			81			670			10	0
										erify S-	Turns B	Before N	Vissio	on	Yes
Line #	Direction	Start Time (UTC)	End Time (UTC)	Tin On-l	ne Line	Sate	ellite	PDOP			Line N	otes/Co	omme	ents	
35	S	20:45:00	21:01:00	00:1	6:00	2	<u>!1</u>	1.2	\square						
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Pi	lot	Ai	ircraft Make	/ Model / Ta	uil #		Hobbs St	art Loc	al Start	UTCS	Start	De	parting	
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Ope	rator	Se	nsor Make /	Model / Seri	ial #	-	Hobbs E	nd Lo	cal End		Fnd		rriving	
			eica Terrain I	Manner - 915	57	-	470 7	12	2.26.00	19.2	<u>6.00</u>	<u> </u>	KR7N	
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			JSM) SCA	an Angle/ FU	V() 3	scar	A Frequency	(HZ) Pui	Se kale	(KHZ)	Las	ier Pov	Ner (%)	
U./		2	<u> </u>	670		2.612.01	100)						
					_			verity :	s-Turns i	Before	MISSIC	วท	Yes	
Line #	Int Spacing (m) Point Density (ppsm) Scan Angle/FOV (*) Scan Frequency (Hz) Pulse Rate (kHz) Laser Point Density (ppsm) 0.7 2 40 81 670 10 Understand Start Time (UTC) End Time (UTC) Time On-Line Satellite PDOP Line Notes/Comments 1 N 14:26:00 14:30:00 00:07:00 20 1.2													
		(UIC)	2 40 81 670 100 Verify S-Turns Before Mission Ye Start Time (UTC) Time (UTC) Satellite PDOP Line Notes/Comments Ye 14:26:00 14:30:00 00:04:00 21 1.2 <td< td=""></td<>											
⊥ 2	c IN	14:20:00	14:30:00	00:04:00	21		1.2	<u> </u>						
2	N N	14.55.00	14.42.00	00.07.00	20		1.2	<u> </u>						
J	S IN	14.40.00	15.03.00	00.07.00	19		13							
	N	15:06:00	15:14:00	00:08:00	18		1.4							
6	S	15:23:00	15:37:00	00:14:00	20	-	1.3	S	m cloud	8 mi fro	om so	uth en	d	
7	N	15:40:00	15:54:00	00:14:00	20	-	1.2	S	m cloud	8 mi frc	om so	uth en	d	
8	S	15:58:00	16:12:00	00:14:00	22		1.1	S	m cloud	8 mi fro	om so	uth en	d	
9	N	16:16:00	16:31:00	00:15:00	19		1.4							
10	S	16:33:00	16:48:00	00:15:00	20		1.2							
11	N	16:53:00	17:08:00	00:15:00	20		1.2	<u> </u>						
12	S	17:11:00	17:25:00	00:14:00	18		1.4	<u> </u>						
13	N C	17:29:00	17:43:00	00:14:00	18		1.3	 						
14		17:40:00	18:00:00	00:14:00	19		1.2	<u> </u>						
16	S IN	18.03.00	18.34.00	00.14.00	17		1 2							
17	N	18:38:00	18:53:00	00:15:00	19		1.1							
18	S	18:56:00	19:10:00	00:14:00	18	-	1.2							
19	N	19:12:00	19:26:00	00:14:00	20	-	1							
	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>			<u> </u>						
				<u> </u>	Ţ			<u> </u>						
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	<u> </u>		<u> </u>			_	<u> </u>	Vorifi	C. Turne	Attor	discie			
t -l -liti a nol C					Раде I		J	verny	S-Turns	Aftern	/115510	n	Yes	
Additional C	omments													
1														

		۲	Woolp	ert l	idar	Acq	uisiti	on L	og					
			Project I	nfo							D	ate		
Project #		Project	t Name			U	nique ID		Flight	t Date ((UTC)	Day o	f Year	Flight #
81200	Pa	ark Co. Monta	ana Blocks 3 {	& 1		Day2	65_91557	_B	09	/21/20	20	26	5 5	В
Cro	ew		Equir	oment					Time				Ai	rports
Pi	lot	Ai	ircraft Make	/ Model	/ Tail #		Hobb	s Start	Local	Start	UTC S	start	De	parting
Cor	mer		Reims 40	6 - N406S	Ď		47	0.7	15:0	03:00	21:03	3:00	,	KBZN
Ope	rator	Se	nsor Make /	Model /	Serial #		Hobb	s End	Loca	l End	UTC	End	A	rriving
Ry	/an	L	eica Terrain I	Mapper -	91557		47	5.1	18:2	2:00	00:22	2:00	,	KBZN
				·	Cond	itions								
Wind Dir	(°) Winc	Speed (kts)	Visibility	(mi) (Ceiling (ft) Cla	oud Cover	Tem	ıp. (°C)	Dew	/ Point	(°C)	Press	ure ("Hg)
0		0	10		20,000	S	cattered		22		0		í í	3009
Air Spe	ed (kts)	Altitude	AGL (ft)	Alti	tude MSI	(ft)	Airfield	l Elevatic	on (ft)					
1!	50	11,	,319		16,509			4,473						
				-	Sett	ings								
Point Spacir	ng (m) Poir	nt Density (pr	osm) Sc	an Angle,	/FOV (°)	Sca	n Frequer	ncy (Hz)	Pulse	a Rate /	(kHz)	Las	er Pov	wer (%)
0.7		2		40		+	81		+	670	· · · · · · · · · · · · · · · · · · ·		10	0
								V	erify S-	Turns E	3efore	Missie	on	Yes
Line #	Direction	Start Time (UTC)	End Time (UTC)	Time On-Li	e Sa	tellite	PDOP			Line N	otes/C	omme	ents	
20	S	21:03:00	21:17:00	00:14:	00	20	1.3	-+		BLC	DCK 3	16,50	9	
21	N	21:20:00	21:33:00	00:13:	00	23	1							
22	S	21:36:00	21:49:00	00:13:	00	22	1.1							
23	N	21:52:00	22:05:00	00:13:	00	24	1.1							
24	S	22:08:00	22:21:00	00:13:	00	25	1.1							
25	N	22:24:00	22:38:00	00:14:	00	24	1.1							
26	S N	22:42:00	22:53:00	00:11:	00	26	16	_						
27 28	S IN	22:57:00	23:09:00	00.12		22	1.0	<u> </u>						
20	N	23:27:00	23:38:00	00:11:	00	23	1.4							
				<u> </u>				1		BLOCK	K 1 15	,512 N	٨SL	
52	Ν	23:43:00	23:50:00	00:07:	00	25	1.1							
51	S	23:54:00	00:01:00	00:07:	00	26	1.1							
50	N	00:04:00	00:11:00	00:07:	00	26	1							
49	S	00:15:00	00:22:00	00:07:	00	23	1.2	_						
		<u> </u> '			-+		<u> </u>	-						
					<u> </u>									
							<u> </u>							
				<u> </u>	_		1							
			<u> </u>	†										
	<u> </u>	<u> </u>	<u> </u>	<u> </u>			<u> </u>							
			<u> </u>					<u> </u>		_				
					Рад	,e 1		`	/erity S-	Turns	After IV	/lissio	n	Yes
Additional C	omments													

			Woolp	ert Lid	ar Ac	qı	uisitior	<u>ו Lo</u>	g_					
			Project	Info							٢	Date		
Project #		Projec	t Name		T	U	nique ID		Flight	Date	(UTC)	Day o	of Year	Flight #
81200		Park Co/Y	ellowstone		Da	av2f	66 90511 A		09	/22/20	20	2	66	A
Cr	ew		Eaui	nment		<u> </u>			Time	,			Ai	rports
Pi	lot	A	ircraft Make	/ Model / Ta			Hobbs St	art	Local	Start		Start	De	narting
Diene	nhroek		Corra 101	$\frac{1}{\text{Titan} - N/0/10}$	<u>п</u>	\neg	8040 (00.2	0.00	15.2	0.00		
Ορο			Cessila 404 i	Madal / Sor	۲ 	\neg) 	105.2	LEDU		5.00 End		
Cher			NSUI IVIANE /		ai #	-			42.E		10.5	Enu		
Slai	iton		elca Terrain i	Mapper - 905			8044.0	5	13:5	1:00	19:5.	1:00		BZIN
	101 14/1	· · · · · · · · · · · · · · · · · · ·			Conditions	-	1.2	-	(0.0)	-		(2.0)		(11.1.)
Wind Dir	(°) Win	d Speed (kts)	Visibility	(mi) Celli	ng (ft)	Clo	ud Cover	Temp). (°C)	Dew	/ Point	(°C)	Press	ure ("Hg)
0		0	7	40	,000		Clear	9)		4		3	30.07
Air Spe	ed (kts)	Altitude	AGL (ft)	Altitude	e MSL (ft)		Airfield Ele	evation	(ft)					
15	50	11,	319	15	,879		4,4	173						
					Settings									
Point Spacir	ng (m) Po	int Density (pr	usm) Sc	an Angle/FO	v (°) _ s	Scar	n Frequency	(Hz)	Pulse	Rate	(kHz)	Las	ser Pov	wer (%)
0.7		2		40			81			670			10	0
								Ver	rify S-T	iurns E	3efore	Missi	on	Yes
Line #	Direction	Start Time (UTC)	End Time (UTC)	Time On-Line	Satellite	e	PDOP			Line N	otes/C	omm	ents	
40	N	16:04:00	16:08:00	00:04:00	22	-	1.2		Park C	to Bloc	:k 2 ha:	zey fro	om sm	oke
39	S	16:12:00	16:16:00	00:04:00	22	\neg	1.2		90%	6 R1, la	ower v	alues	at rive	r
38	N	16:19:00	16:24:00	00:05:00	20		1.3							
37	S	16:27:00	16:34:00	40 81 670 100 40 81 670 100 Verify S-Turns Before Mission Yes ime C) Time On-Line Satellite PDOP Line Notes/Comments 8:00 00:04:00 22 1.2 Park Co Block 2 hazey from smoke 6:00 00:04:00 22 1.2 90% R1, lower values at river 4:00 00:05:00 20 1.3										
36	N	16:37:00	16:45:00	00:08:00	21		1.2							
35	S	16:48:00	17:01:00	00:13:00	21		1.1							
34	N	17:04:00	17:16:00	00:12:00	20		1.2							
33	S	17:20:00	17:34:00	00:14:00	20		1.3	<u> </u>						
32	N	17:37:00	17:57:00	00:20:00	21		1.2	Ļ		Som	e spee	d issu	es	
31	S	17:56:00	18:10:00	00:14:00	21		1	<u> </u>				· · ·		
30	N S	18:12:00	18:27:00	00:15:00	18	\rightarrow	1.4	──		Som	e spee	d issu	es	
29		18:31.00	10.45.00	00:14:00	19	\rightarrow	1.2							
20	ς Γ	19:05:00	19:02:00	00.14:00	23	\rightarrow	1			Som	e snee	d issu	<u></u>	
<i>L1</i>		15.05.00	13.13.00	00.17.00	25	\rightarrow	-				<u> </u>	u 1556		
		+		+	+	\neg	'							
		+		+	+	-								
i	<u> </u>	1	<u> </u>	<u> </u>	<u> </u>									
		'												
	<u> </u>	'	Ļ	<u> </u>	<u> </u>		'	<u> </u>						
	<u> </u>	'		<u> </u>	<u> </u>			Ļ						
	<u> </u>	'		<u> </u>	<u> </u>	\square	ļ'	<u> </u>						
	<u> </u>	'				\rightarrow	'							
	<u> </u>				Page 1			Ve	rify S	Turns	After [Missic		Voc
A dditional C					Page 1			ve	:liiy 3-	Turns	Anterin	VIISSIC	<u>, m</u>	res
	omments					—								

			Woolp	ert L	idar /	4cq	uisitio	n Log					
			Project I	nfo						D	ate		
Project #		Projec	t Name			U	nique ID	Fligh	nt Date	(UTC) I	Day o	f Year	Flight #
81200		Park Co N	AT Block 1			Day2		0'	9/22/20	020	26	66	1
Cr	ew		Equir	oment				Time	<u>ر بر ا</u>			Ai	irports
Pi	lot	A	ircraft Make	/ Model /	Tail #		Hobbs St	art Loca	al Start	UTC S	tart	De	narting
Gib	ilaro		Cossna 404 T	(itan - N7(170F		2925 (<u>المال المال مال </u>	04.00	14.04	1.00		R7N
One	rator		mor Make /		Sorial #		Hobbs F				00 End		riving
Kon			aico Torrain I	Mannar (2021 /	11u Loca	20.00	10.20	2:00		
Kenn	neuy			Napper - 5	Condit		2951.4	· 15.	38:00	19.50	.00		BZIN
tational Dis	(0) \A/:-		• et - the tiltage of	(1) (1.0	(%)	Dev	Delint	(0.0)	2	("11-)
			VISIDIIITY		eiling (tt)			1emp. (°C)	Dew	V Point (<u>(°C)</u>	Press	sure ("Hg)
U		0	10	<u>_</u>			Clear	3		0		<u> </u>	30.07
Air Spe	ed (kts)	Altitude	AGL (ft)	Altite	ude MSL (1	ft)	Airfield Ele	evation (tt)					
1:	50	11,	319		15,512		4,4	¥73					
					Settin	igs							
Point Spacin	າg (m) Po	int Density (pr	osm) Sca	an Angle/I	FOV (°)	Sca	n Frequency	(Hz) Puls	e Rate	(kHz)	Las	er Pov	wer (%)
0.7				40			81		670			10	0
								Verify S	-Turns l	Before I	Missic	วท	Yes
line #	Direction	Start Time	End Time	Time	Sate	allita	рлор		line N	lates/Cr	omm	onts	
	Direction	(UTC)	(UTC)	On-Lin	e	me	r boi	<u> </u>			<u> </u>	ints	
30	N	14:30:00	14:48:00	00:18:0)0 2	2	1.2						
29	S	14:51:00	15:09:00	00:18:0	<u> </u>	1	1.3	Ļ					
28	N	15:12:00	15:29:00	00:17:0)0 2	!1	1.3	Ļ					
27	S	15:33:00	15:51:00	00:18:0)0 2	0	1.3	<u> </u>					
26	N	15:54:00	16:11:00	00:17:0	10 2	:3	1.2	<u> </u>					
25		16:14:00	16:30:00	00:16:0		.9	1.4	<u> </u>					
24	IN C	16:34:00	16:50:00	00:16:0		.1	1.2						
23		17.12.00	17:09:00	00:10.0		.1	1.1						
22	S	17:32:00	17:48:00	00.10.0	$\frac{10}{10}$ $\frac{2}{7}$.0 M	1.5						
21	N	17:50:00	18:06:00	00.10.0		20	11						
1	S	18:20:00	18:24:00	00:04:0		9	1.3						
2	N	18:27:00	18:32:00	00:05:0	0 1	.9	1.3						
3	S	18:36:00	18:41:00	00:05:0	0 1	9	1.2						
4	N	18:44:00	18:50:00	00:06:0	0 2	0	1.1	<u> </u>					
5	S	18:54:00	18:59:00	00:05:0	JO 2	21	1.1						
6	N	19:02:00	19:08:00	00:06:0	JO 2	2	1						
7	S	19:12:00	19:19:00	00:07:0	<u> </u>	2	1	<u> </u>					
				<u> </u>			ļ	Ļ					
		'	<u> </u>					<u> </u>					
					<u> </u>								
	<u></u>		<u> </u>		Page	1	<u> </u>	Verify ?	S-Turns	After N	/issio	n	Yes
Additional C	omments					_		,					1.00
1													

			Wool	pert	Lid	ar /	٩cq	uisitic	on L	og					
			Project	t Info								C	Date		
Project #		Projec	t Name				U	nique ID		Flight	t Date	(UTC)	Day o	f Year	Flight #
81200		Park Co. Bl	ock 1 and 4			<u> </u>	Dav2	66 91557 /	Δ	09	/22/20	20	26	 66	A
Cr	ew		Εαν	vinment			,			Time	/==,			Ai	rnorts
Pi	lot	Ai	ircraft Mak	o / Mode	ol / Tai	il #		Hobbs	Start		Start	UTCS	Start	De	narting
Cor	mor		Reims 4	06 - N40		<u> </u>		475	1	08.2	2000	14.2	2.00		
One	rator	50	mor Make		/ Seri:			Hobbs	<u>-</u> 5nd		- End		5.00 5nd		riving
			aica Terrair	Manner	- 0150	11 # 		//70	0	12.0		12.0	7.00		
i y	dii			Ναμμει	- 9155)/ `ondit	ions	475.	9	12.0	17.00	10.07	7.00	<u> </u>	
Wind Dir	. /º) W/in	d Smood (kts)	Vicibilit	(mi)	Coilir	-~ (f+)		Cover	Tom	- (°C)	Dow	Doint	(°C)	Brock	····ro ("Ha)
120				<u>y (iiii)</u>	Cenn	18 (11)				p. (c)	Dew	1		Pless	
100		3				- ACL ((1)			6		1	_		3006
			AGL (IT)				rt)		levatio	n (π)					
1.	50	11,	319		15,:	512		4	.,4/3						
D. Let Connell		· · · · · · · · · · · · · · · · · · ·			. (50)	Settin	igs		(11-)	Distas	Dete	(1.1.)		Der	(0/)
Point Spacin	1g (m) POI	nt Density (pp	sm) s	can Angi	le/FUV	/(*)	Sca	n Frequency	y (Hz)	Puise	e Rate	(kHz)	Las	er Pov	ver (%)
0.7		2		4	,0			81		<u> </u>	670		· ·	10)
	-									erity S-	Turns E	Setore	Missio	วท	Yes
Line #	Direction	Start Time (UTC)	Ime End Time Time Satellite PDOP Line Notes/Comments ::00 14:29:00 00:01:00 22 1.2 Block 4 / N.G. Aborted line due to high												
1	E	14:28:00	14:29:00	00:0	1:00	2	2	1.2	Bloc	:k 4 / N	I.G. Ab	orted	line dı	ue to h	igh wind
		'	<u> </u>	<u> </u>				ļ	<u> </u>				- 1 2 4		
40	<u> </u>	4.4:27:00	445400	00.1	7:00	<u> </u>		1.2			BLOCK	(1 15	,512 N	ЛSL	
48	C N	14:37:00	End Time (UTC) Time On-Line Satellite PDOP Line Notes/Comments 14:29:00 00:01:00 22 1.2 Block 4 / N.G. Aborted line due to high 14:29:00 00:01:00 22 1.2 Block 4 / N.G. Aborted line due to high 14:54:00 00:17:00 21 1.3 11												
47	N N	14:57:00	15:15:00	00.1	.8:00 ACM		.3 91	1.1							
45	S	15:39:00	15:56:00	00:1	7.00		. <u> </u>	1.3							
44	N	16:01:00	16:17:00	00:1	6:00	2	22	1.2	+						
43	S	16:22:00	16:39:00	00:1	7:00	2	2	1.2	1						
42	<u>N</u>	16:43:00	16:59:00	00:1	6:00	2	1	1.1							
41	S	17:03:00	17:19:00	00:1	.6:00	2	20	1.2							
40	N	17:23:00	17:39:00	00:1	6:00	2	0	1.3							
39	S	17:42:00	17:58:00	00:1	.6:00		:1	1.1							
38	N	18:02:00	18:07:00	00:0	15:00	<u> </u>	.1	1.2			N.G.	. abort	ed line	5	
		+'		+		├───									
		+		+		<u> </u>			+						
	<u> </u>	<u> </u>	<u> </u>	<u> </u>		Ĺ		<u> </u>	<u> </u>						
	 	'	<u> </u>	<u> </u>											
	 	'	 		!	──									
·						Page	1			/orify S	-Turns	After N	Aissio	n	Ves
	omments					1 - 8-	<u> </u>			C, -		/1100	1100.2		103
Additional C	Uninents														

			1	Woo	Ipe	rt Lic	lar /	1cdi	uisitio	n Lo	g					
				Proje	ect Inf	0							D	ate		
Project #			Project	t Name				U	nique ID		Flight	Date	(UTC) [Day o	f Year	Flight #
81200			Park Co/Ye	ellowstor	1e		1	Day2	67_9 <u>0511_</u> A		09,	/23/20	20	26	<u>57</u>	A
Cr	ew			E	quipm	ient					Time				Ai	rports
Pi	lot		Ai	rcraft M	ake / M	Vodel / Ta	ail #		Hobbs S	itart	Local	Start	UTC S	tart	De	parting
Dieper	nbroek			Cessna 4	04 Tita	in - N4040	СР		8044.	.8	08:0	2:00	14:02	2:00		BZN
Ope	rator		Ser	nsor Ma	ke / M	odel / Ser	ial #		Hobbs I	End	Loca	l End	UTC I	End	Ar	rriving
Star	nton		Le	eica Terr	ain Ma	pper - 905	511		8048.	.8	12:1	.8:00	18:18	3:00		BZN
							Conditi	ons								
Wind Dir	· (°) V	Nind	Speed (kts)	Visibi	ility (m	i) Ceil	ing (ft)	Clc	oud Cover	Temp). (°C)	Dew	Point	(°C)	Press	ure ("Hg)
160			4		10	40),000		Clear	1	0		3		3	30.15
Air Spe	ed (kts)		Altitude	AGL (ft)		Altitud	e MSL (ft)	Airfield El	levation	(ft)					
1!	50		11,3	319		15	5,879		4,	,473						
							Settin	gs								
Point Spacin	ng (m)	Poin	t Density (pp	/sm)	Scan	Angle/FO	√V (°)	Scar	n Frequency	/ (Hz)	Pulse	e Rate	(kHz)	Las	er Pov	<i>w</i> er (%)
0.7			2	<u> </u>		40			81			670			100	0
										Ver	rify S-T	furns E	sefore I	Missi	on	Yes
Line #	Directi	on	Start Time (UTC)	End Tir (UTC	ne :)	Time On-Line	Sate	ellite	PDOP			Line N	otes/Co	omme	ents	
26	S		14:44:00	14:58:	00	00:14:00	2	21	1.1		Park C	Co Bloc	k 2 haz	ey fro	om sm	oke
25	N C	-+	15:01:00	15:15:	00	00:14:00	2	21	1.3		90%	% R1, lo	ower va	alues	at rive	r
24		-+	15:17:00	15:31:	00	00:14:00		<u>יין 1</u>	1.3	+						
23	S	-+	15:54:00	16:05:		00.10.00		2	1.2	+						
21	N	\neg	16:08:00	16:23:	.00	00:15:00	+	24	1.2	+						
20	S		16:25:00	16:39:	00	00:14:00	12	22	1.2	†						
19	N		16:41:00	16:56:	00	00:15:00	2	23	1.2							
18	S	$ \rightarrow $	16:59:00	17:12:	00	00:13:00	2	20	1.2	<u> </u>						
17		-+	17:15:00	17:30:		00:15:00		20	1.2							
10	<u> </u>	-+	17:52.00	17.40.		00:14.00		0	1.2	+						
		\neg			-		+			+						
							\square			\square						
	<u> </u>	$ \rightarrow $			\rightarrow		<u> </u>		ļ							
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		\neg			+		+			+						
							<u>+</u>			<u>† </u>						
	ļ						<u> </u>		<u> </u>]						
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		-+		i	-+		+			+						
							Page	1		Ve	erifv S-	Turns	After N	۸issio	n	Yes
Additional C	omment	s									,					1.00
	<u> </u>															

				Wo	olp	ert	Lid	ar A	١cq	uisit	tior	n Lo	og					
				Pro	oject l	nfo									C	Date		
Project #			Project	: Name	3				U	nique IC	D		Flight	: Date (UTC)	Day o	f Year	Flight #
81200			Park Co MT	Block	1 & 2				Day2	67 9051	15_1		09,	/23/20	20	26	57	1
Cr	ew				Equir	oment				_	_		Time				Ai	rports
Pi	lot		Ai	rcraft	Make	/ Mode	اد / Tai	1 #		Hot	bs Sta	art	Local	Start	UTC	Start	De	parting
Gib	ilaro			Cessna	- 404 T	itan - N	17079F	:		2	931.4		08:2	5.00	14:2	5.00		R7N
Ope	rator		Sei	nsor N	lake /	Model	/ Seria			Но	hhs Fr	hr	Loca	Fnd		Fnd	Δ	rriving
Ken	nady	—			rrain M	Aanner	0051	11 m 1 C		2	022 1	lu	15.0		21.0		~.	D7NI
Ken	leuy			fica re		Ларрсі	<u> </u>	`onditi	205	-	.930.1		15.0	5.00	21.0.	5.00		DZIN
Wind Dir	- (%) \A	lind	Speed (kts)	Vic	:hility	(mi)	Coilir	.011u1ti		and Cov	~~	Tomr	(°C)	Dow	Doint	(°C)	Dross	
160	() **	////		V 131	10	(IIII)	Cenii	18 (14)		Cloar	er	1). (C) ^	Dew	2	()	FIESS	
100			4		10							⊥ سماند	0 (61)		3	_		30.15
		\dashv	Altitude		t)				t)	Airtie		vation) (ft)					
1:	50		11,3	319			15,	512			4,4	/3						
					6.	A	(50)	Settin	gs	-			2 1				2	(0()
Point Spacing (m)Point Density (ppsm)Scan Angle/FOV (°)Scan Frequency (Hz)Pulse Rate (kHz)0.74081670Verify S-Turns Before Mi													Las	er Pov	<i>w</i> er (%)			
0.7 40 81 670 Verify S-Turns Befo															100) 		
O.7 40 81 670 100 Understand 0.7 40 81 670 100 Understand Start Time (UTC) End Time (UTC) Time On-Line Satellite PDOP Line Notes/Comments													Yes					
0.7 40 81 670 100 Understand Start Time (UTC) End Time (UTC) Time On-Line Satellite PDOP Line Notes/Comments 36 N 14:55:00 15:11:00 00:16:00 1.1 1.3 37 S 15:11:00 00:16:00 21 1.3																		
36	N		14:55:00	15:1	1:00	00:1	6:00	1.	.1	1.3	3							
37	S	$ \rightarrow$	15:14:00	15:3	0:00	00:1	6:00	2	1	1.3	3							
38	N C	\dashv	15:39:00	15:5	5:00	00:1	6:00	2	2	1.2	2			cloud	s on n	orth e	nd	
8	S N	$ \rightarrow$	16:05:00	16:1	2:00	00:0	7:00	2	4	1.2	2							
9 10		-+	16:15:00	16:2	3:00	00:00	8:00	2	2	1.2	2							
10		\dashv	16:20:00	16.3	9.00	00.1	0:00	2	3 2	1.1	L 7							
12	S S	\neg	16:53:00	17:0	0.00 9.00	00:1	9.00 6.00	2	5 7	1.1	<u>-</u> 1							
13	N	\neg	17:12:00	17:2	8:00	00:1	6:00	2	0	1.2	2							
14	S		17:32:00	17:4	9:00	00:1	7:00	2	0	1.2	2							
15	N		17:52:00	18:0	9:00	00:1	7:00	2	0	1.3	3							
16	S		18:13:00	18:3	0:00	00:1	7:00	1	6	1.3	3							
17	N		18:33:00	18:5	0:00	00:1	7:00	1	7	1.1	1							
18	S		18:53:00	19:0	9:00	00:1	6:00	1	9	1.1	1							
19	N	$ \rightarrow$	19:15:00	19:3	1:00	00:1	6:00	2	0	1								
1		-+	10.52.00	20.0	0.00	00.0	7.00	<u> </u>	7	1.5				Black	<u>າ ລ 1</u> ເ	070 1	401	
2		\dashv	19:53:00	20:0	1.00	00.0	7:00	1 2	/	1.3	5			BIOCK	2@13	18/9 IV	/ISL	
2		-+	20:04:00	20.1	2.00	00.0	7:00	2	1	1.3	5 7							
4		-+	20:15:00	20:2	2.00	00:0	7.00 8.00	2	1	1.2	<u>,</u>							
5	S	\neg	20:36:00	20:4	3:00	00:0	7:00	2	1	1.2	2							
					<u></u>						-							
				<u> </u>									-					
								Page	1			V	erify S-	Turns	After N	vissio	n	Yes
Additional C	omments	;																

			Woolp	ert L	idar /	٩cq	uisitio	n Log						
			Project I	nfo						Dat	e			
Project #		Project	t Name			U	Inique ID	Flig	ht Date	(UTC) Da	y of Ye	ar Flight #		
81200	Yello	owstone Park	Co Blocks 4	and 2		Day2	67 91557 A	C	9/23/20)20	267	A		
Cr	ew		Equir	oment		,		Tim	2			Airports		
Pi	lot	Ai	rcraft Make	/ Model /	Tail #		Hobbs St	art Loc	al Start	UTC Sta	rt	Departing		
Cor	mer		Reims 400	5 - N406SF)		479.9	09	01.00	15.01.0	0	KB7N		
One	rator	50	nsor Make /		orial #		Hobbs F	nd Loc	al End		<u>ч</u>	Arriving		
Оре		Je	nico Torrain N	Annor 0			195.0	14	01.00	20.01.0	0			
Ку	dli	<u> </u>		Napper - 9	Condit	ione	465.9	14	.01.00	20.01.0	0	NDZIN		
	(0)		N // 11 1111	()) (ions		- (%)		D : : /84		/////		
Wind Dir	(°) Wind	Speed (Kts)	Visibility	(mi) C	eiling (ft)		oud Cover	Temp. (°C) Dew	Point (°C	.) Pro	essure ("Hg)		
160		4	10		18,000	S	cattered	10		3		3015		
Air Spe	ed (kts)	Altitude	AGL (ft)	Altit	ude MSL (ft)	Airfield Ele	evation (ft)	_					
1	50	10,	663		17,415		4,4	173						
					Setti	ngs								
Point Spacir	ng (m) 🛛 Poii	nt Density (pp	osm) Sca	an Angle/	FOV (°)	Sca	n Frequency	(Hz) Pul	se Rate	(kHz)	Laser F	ower (%)		
0.7		2		40			82		650			100		
Line # Direction Start Time (UTC) End Time (UTC) Time On-Line Satellite PDOP Line Notes/Comments 1 E 15:01:00 15:09:00 00:08:00 21 1.5 BLOCK 4 17,415 MSL														
Point Spacing (m) Point Density (pp m) Sca - Angle/FOV (r) Sca - Frequency (Hz) Pulse Rate (kHz) Laser Power (Hz) 0.7 2 40 82 650 10 Unite of the tensity (pp m) Tensity (pp m) Tensity (pp m) Laser Power (Hz) Discrete (Hz) Laser Power (Hz) 0.7 2 40 82 82 650 10 7 Line # Direction Start Time (UTC) Image: (UTC) Time (UTC) Start Time (UTC) On-Line Phoop Line Notes/colspan="4">Line Notes/colspan="4">Line Notes/colspan="4">Line Notes/colspan="4">Line Notes/colspan="4">Unite Notes/colspan="4">Line Notes/colspan="4">Line Notes/colspan="4">Unite Notes/colspan="4" 1 1 1 1 0 0 1 1 1 1 1 <t< td=""></t<>														
0.7 2 40 82 650 100 Verify S-Turns Before Mission Yes Line # Direction Start Time (UTC) End Time (UTC) Time On-Line Satellite PDOP Line Notes/Comments 1 E 15:01:00 15:09:00 00:08:00 21 1.5 BLOCK 4 17,415 MSL 3 W 15:13:00 15:22:00 00:09:00 21 1.3 4 E 15:25:00 15:33:00 00:08:00 21 1.2 1.2														
1	t Spacing (m)Point Density (ppsm)Scan Angle/FOV (°)Scan Frequency (Hz)Pulse Rate (kHz)Laser Power 0.7 24082650100Verify S-Turns Before MissionYesne #DirectionStart Time (UTC)End Time (UTC)Time On-LineSatellitePDOPLine Notes/Comments1E15:01:0015:09:0000:08:00211.5BLOCK 417,415 MSL3W15:13:0015:22:0000:09:00211.31.24E15:25:0015:33:0000:06:00221.2N. G. stopped line due to clouds3E15:48:0015:52:0000:04:00241.2N. G. stopped line due to clouds18W16:02:0016:06:0000:04:00241.2sm cloud beginning of east end													
3	cing (m)Point Density (ppsm)Scan Angle/FOV (°)Scan Frequency (Hz)Pulse Rate (kHz)Laser Power224082650100Verify S-Turns Before MissionYesDirectionStart Time (UTC)End Time (UTC)Time (UTC)SatellitePDOPLine Notes/Comments E 15:01:0015:09:0000:08:00211.5BLOCK 417,415 MSL W 15:13:0015:22:0000:09:00211.3 1.2 $V = 15:37:00$ $15:43:00$ W 15:37:0015:43:0000:06:00221.2N. G. stopped line due to clouds $U = 0$ W 16:02:0016:6:0000:04:00241.2Sm cloud beginning of east end													
4	E	Start Time (UTC) End Time (UTC) Time On-Line Satellite PDOP Line Notes/Comments Yes E 15:01:00 15:09:00 00:08:00 21 1.5 BLOCK 4 17,415 MSL W 15:13:00 15:22:00 00:09:00 21 1.3 E 15:25:00 15:33:00 00:08:00 21 1.2 W 15:37:00 15:43:00 00:06:00 22 1.2 N. G. stopped line due to clouds F 15:48:00 15:52:00 00:09:00 24 1.2 N. G. stopped line due to clouds												
5	W	Start Time (UTC) End Time (UTC) Time On-Line Satellite PDOP Line Notes/Comments 15:01:00 15:09:00 00:08:00 21 1.5 BLOCK 4 17,415 MSL 15:13:00 15:22:00 00:09:00 21 1.3 1.2 15:37:00 15:43:00 00:06:00 22 1.2 N. G. stopped line due to clouds 15:48:00 15:52:00 00:04:00 24 1.2 N. G. stopped line due to clouds												
3	E	15:48:00	t Time (UTC) End Time On-Line Time On-Line Satellite PDOP Line Notes/Comments 01:00 15:09:00 00:08:00 21 1.5 BLOCK 4 17,415 MSL 13:00 15:22:00 00:09:00 21 1.3 25:00 15:33:00 00:08:00 21 1.2 37:00 15:43:00 00:06:00 22 1.2 48:00 15:52:00 00:04:00 24 1.2											
18	W	16:02:00	End Time (UTC) Time On-Line Satellite PDOP Line Notes/Comments 15:09:00 00:08:00 21 1.5 BLOCK 4 17,415 MSL 15:22:00 00:09:00 21 1.3 15:33:00 00:08:00 21 1.2 15:43:00 00:06:00 22 1.2 N. G. stopped line due to clouds 15:52:00 00:04:00 24 1.2 Sm cloud beginning of east end 16:14:00 00:04:00 24 1.2 Sm cloud beginning of east end											
17	E	16:10:00	16:14:00	00:04:0	0 2	24	1.2							
16	W	16:18:00	16:22:00	00:04:0	0 2	21	1.2							
15	E	16:30:00	16:39:00	00:09:0	0 2	23	1.3							
14	W	16:44:00	16:52:00	00:08:0		22	1.2			4 ·1 C				
13	E	16:56:00	17:05:00	00:09:0		19	1.2	sr	n cloud :	1 mile from	m east	end		
12	VV	17:09:00	17:17:00	00:08:0	0 2	20	1.2	Sr	n cioua .	1 mile fro	m east	end		
15	с С	17.26.00	17.50.00	00.14.0	0 7	20	11		BLOC	K 2 15 87				
14	N	17:54:00	18:06:00	00.14.0		20	1.1		BLOCI	KZ 13,87	9 IVI3L			
13	S	18:10:00	18:22:00	00:12:0	0 7		1.5							
12	N	18:27:00	18:40:00	00:13:0	0	- L5	1.4							
11	S	18:43:00	18:56:00	00:13:0	0 1	L7	1.2							
10	N	19:02:00	19:14:00	00:12:0	0 1	19	1.1	sn	nall clou	d north ei	nd last	mile		
6	S	19:20:00	19:27:00	00:07:0	0 2	20	1							
7	N	19:31:00	19:39:00	00:08:0	0 1	18	1.3							
8	S	19:42:00	19:49:00	00:07:0	00 2	18	1.2							
9	N	19:53:00	20:01:00	00:08:0	0 1	L7	1.3							
					Page	1		Verify	S-Turns	After Mis	sion	Yes		
Additional C	omments													

			١	Wo	olp	ert	Lid	ar /	4cq	ui	isitio	n Lo)g					
				Pro	oject li	nfo									C	ate		
Project #			Project	: Name	2				U	Iniq	ue ID		Flight	: Date (UTC)	Day o	f Year	Flight #
81200	<u> </u>		Park Co	Refligh	ıts			<u> </u>	Day2	76	_90515_1		10	/02/20	20	27	76	1
Cr	ew				Equip	ment							Time				Ai	rports
Pi	lot		Ai	rcraft	Make /	/ Mode	el / Tai	#		L	Hobbs Sta	art	Local	Start	UTCS	start	De	parting
Gibi	ilaro			Cessna	3 404 Ti	itan - N	17079F			┡	2955.1		09:1	0:00	15:10):00	<u> </u>	BZN
Ope	rator		Ser	isor M	lake / I	Model	/ Seria	al #		┡	Hobbs Er	nd	Loca	I End	UTC	End	A	rriving
Keni	nedy		LE	elca re	rrain iv	/lapper	- 9051	.5 `andit	lone	L			10:2	9:00	16:2:	9:00		BZN
Wind Dir	r (°) M	/ind	Speed (kts)	Vis	ibility ((mi)		onun		huo	Cover	Temr	- (°C)	Dew	Point	(°C)	Drest	ure ("Hø)
0	()			V 13.	10			15 (14)		Cle	ear	1011p	λ. (C, 2	500	0		FIESS	30 27
Air Spe	ed (kts)		Altitude	AGL (ft)		ltitude	MSL (ft)		Airfield Ele	vatior	, , (ft)		Ť			50.27
1	.50	\neg	11,	349			15,	512		┢	4,4	73						
								Settir	ngs									
Point Spacir	ng (m) 🛛 ſ	Poin	it Density (pp	osm)	Sca	an Ang	le/FOV	/ (°)	Sca	n F	requency	(Hz)	Pulse	e Rate ((kHz)	Las	ser Pov	wer (%)
0.35						4	10				81			670			10	0
												Ve	rify S-1	Гurns В	efore	Missic	on	Yes
Line #	Directio	'n	Start Time (UTC)	End (U	Time TC)	Tir On-	ne Line	Sate	ellite		PDOP			Line No	otes/C	omme	ents	
27	S		15:32:00	15:4	-0:00	00:0	00:80	2	<u>'1</u>		1.3	Mar	nual ac	tivatio	n on s	ome p	artial	reflights
26	S	-+	16:03:00	16:1	.1:00	00:0	18:00	2	4	\vdash	1.2	E۶	xtreme	PAV vi	bratio	ns. Mi	ssion (ended
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								Page	1			Ve	erity S-	Turns	After N	Aissio	n	Yes
Additional C	omments																	

		1	Woolp	bert '	Lida	ar Ac	. q	uisitio	n Lc	פר g_						
			Project	Info								۵	Date			
Project #		Projec	t Name				U	nique ID		Flight	t Date /	(UTC)	Day o	of Year Flight #		
81200		Park Co	Reflights			D	77_90515_1		10/03/2020				277			
Cr	ew		Equi	pment						Time				Ai	rports	
Pi	lot	Ai	ircraft Make	/ Mode	Model / Tail #			Hobbs St	tart	Local	Start	UTC	Start	De	parting	
Geb	bhart	_	Cessna 404	Titan - N	7079F			2956.4	4	10:1	2:00	16:12	2:00		BZN	
Оре	rator	Se	nsor Make /	/ Model /	/ Serial	#		Hobbs E	nd	Loca	l End	UTC	End	Α	rriving	
Ken	nedy	L	eica Terrain	Mapper	- 9051!	5		2959.4	4	13:1	1:00	19:1	1:00		BZN	
					Co	ondition	s									
Wind Dir	r (°) Wir	nd Speed (kts)	Visibility	(mi)	Ceilin	g (ft)	Clc	oud Cover	Temp	э. (°С)	Dew	/ Point	(°C)	Press	sure ("Hg)	
120		3	10					Clear	7	,		2	• •		30.29	
Air Spe	ed (kts)	Altitude	AGL (ft)	Alt	titude l	MSL (ft)		Airfield El	evation	ı (ft)						
1	50	11,	,349	+	15,5	512	-	4,4	473	<u> </u>						
					Ş	Settings										
Point Spaci	ng (m) Pc	oint Density (pr	osm) Sc	an Angle	e/FOV	(°)	Sca	n Frequency	(Hz)	Pulse	Rate	(kHz)	Las	Laser Power (%)		
0.35	0.35			4(ວ <u>ີ</u>			81	· ·		670	<u> </u>		10	0	
									Ve	rify S-	Turns F	Before	Missi	on	Yes	
Line #	Direction	Start Time	End Time	Tim	ne	Satellite PDOP				Line Notes/Comments						
	<u> </u>		(UIC)	00.0(ine	10		1.2	 							
25		16:28:00	16:49:00	00:05	3:00 2:00	<u>10</u>		1.3								
24	S S	16:53:00	16:56:00	00:02	3.00	20		1.2								
		10.00.00	10.00.00		+	20				Manı	ual tes	t fires k	betwe	en blo	cks	
3	S	17:08:00	17:14:00	00:06	5:00	22		1	<u> </u>		Block	2@15	5879 N	N SL		
4	N	17:17:00	17:21:00	00:04	4:00	20		1.1 F		quent	smoke	, possil	ole sn	ow, all	block 2	
5	S	17:24:00	17:27:00	00:03	3:00	19		1.3								
11	N	17:33:00	17:47:00	00:14	1:00	18		1.2	<u> </u>							
12	S NI	17:50:00	18:03:00	00:13	3:00	18		1.2	<u> </u>							
13 27		18:00:00	18:19:00	00:13	3:00 = · ∩ ∩			1.2								
28	N N	18:42:00	18:56:00	00:14	4:00	21	—	1								
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						Page 1			Ve	erity S-	Turns	After N	√lissio	n	Yes	
Additional C	omments															

		,	Woolp	oert L	.idar	Acq	uisitic	n La	Jg						
			Project	Info							D	ate			
Project #		Project	t Name			U	nique ID		Flight	t Date ((UTC)	Day o	f Year	Flight #	
81200		Park Co	Reflights			Day2	78_90515_1	L	10	10/04/2020		278		1	
Cr	ew		Equi	pment									Ai	rports	
Pi	lot	Ai	ircraft Make	/ Model /	/ Tail #		Hobbs S	Start	Local Start		UTC Start		De	parting	
Geb	hart		Cessna 404	Γitan - N7(079F		2959	.4	10:4	3:00	16:43	16:43:00		BZN	
Оре	rator	Se	nsor Make /	Model / S	Serial #		Hobbs	End	Loca	l End	UTC	End	A	rriving	
Kenr	nedy	L(eica Terrain I	Mapper - 9	90515		2961	.7	13:0	2:00	19:02	2:00		BZN	
Min d Dia	(0))) ()	10		1 1) (Cona	tions	10	1 T 2 1001	(%c)	Davi	D = lask	(90)	2:00	("11-)	
			VISIDIIITY	(mi) C	Ceiling (TC		Sud Cover	Temp	<u>). (°C)</u>	Dew		(°C)	Press	ure ("Hg)	
1U Air Spo					do MSI				.2 (f+)		5			30.12	
	Air Speed (kts) Aititude AGL (ft) Aititude AGL (ft) 150 11 349					(11)		10Valion	1 (11)						
	50	<u> </u>	545		Sett	ings	·	,475							
Point Spacir	ng (m) Po	int Density (pr	osm) Sc	an Angle/	/FOV (°)	Sca	n Frequenc	v (Hz)	Pulse	e Rate	(kHz)	Las	Laser Power (%)		
0.35			,	40		+	81	/ ,		670	···· /		10	0	
								Ve	erify S-	Turns I	3efore	Missi	on	Yes	
Line #	Direction	Start Time (UTC)	End Time (UTC)	Time On-Lir	e Sa	tellite	PDOP	\square		Line N	otes/C	omme	ents		
29	S	17:06:00	17:10:00	00:04:	00	21	1	+							
30	N	17:13:00	17:22:00	00:09:	00	22	22 0.9								
31	S	17:24:00	17:30:00	00:06:0	00	19	1.1	<u> </u>							
32	S N	17:32:00	17:38:00	00:06:0	00	18	1.3	+							
33	N	17:48:00	17:52:00	00:04:	00	18	1.5	+							
35	S	17:55:00	18:01:00	00:06:	00	17	1.2	<u>+</u>							
5	N S	18:09:00	18:12:00	00:03:0	00	17	1.2	'	Line re	startec	d once,	altitu	de too	low	
б 7	N N	18:10:00	18:19:00	00:03.	00	20		+							
, 14	N	18:29:00	18:37:00	00:08:	00	20	1	+							
	<u> </u>		<u> </u>	Ţ											
			<u> </u>				<u> </u>								
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	 						<u> </u>								
				+	-+-			+-							
		+		+				+							
				1											
					Pag	e 1		V	erify S-	-Turns	After N	Aissio	n	Yes	
Additional C	omments														

			,	Wo	olp	ert l	_id	ar A	\cq	uisitio	n Lo	og						
Project # Project Name Unique ID														D	ate			
Project #			Project	t Name	5				U	nique ID		Flight	: Date	(UTC)	Day o	f Year	Flight #	
81200		Park	CO MT B4 / Y	ellows	tone N	IP B2			Day2	82_91557_1		10/08/2020 282					1	
Cr	ew				Equip	ment			-			Time				Ai	rports	
Pi	lot		Ai	rcraft	 Make	/ Model	/ Tai	#		Hobbs S	tart	Local	cal Start UTC :		start	De	parting	
Dar	Perl			Reir	ns F40	6 - N406	SD			519		09:2	1:00	15:21	1:00		(B7N	
One	rator		Se	nsor N	lake /	Model /	Seria	al #		Hobbs F	nd	Loca	l Fnd		End	Δ	riving	
Eanning Loice Terrain Manner 01										524.2		12.0	6.00	10.04	5.00			
Tan	mig			`onditi	000	524.2		15.0	0.00	19.00	0.00	· · ·						
Wind Dir	(°)	Wind	Speed (kts)	Vic	ibility ((mi)	Coilir	onunu va (ft)		aud Cover	Tom	<u>ارم ا</u>	Dow	Doint	(°C)	Dross	ure ("Ha)	
190	()	vviitu		V15		,	10				rem	J. (C)	Dew	2	()	Fless		
180	/	,	4		0		18,					+		-2		4	<u>19.94</u>	
Air Spe	ed (kts)	Altitude	AGL (1	t)	Alt	itude	IVISL (1	t)	Airfield El	evatior	n (ft)						
1	50		10,	663			17,	415		4,	471							
							-	Settin	gs									
Point Spacin	ıg (m)	Poir	nt Density (pp	osm)	Sca	an Angle	/FOV	/ (°)	Sca	n Frequency	(Hz)	Pulse	e Rate	(kHz)	Las	Laser Power (%)		
0.7			2			40				82			650			10)	
											Ve	rify S-1	Turns E	Before	Missio	on	Yes	
line #	Dire	tion	Start Time	End	Time	Tim	e	Sate	llita		P Line Notes					onte		
Line #	Direc		(UTC)	(U	TC)	On-Li	ne	Jac	inte	rbor			LINEIN	oles/C		ents		
2	E	E	15:21:00	15:2	9:00	00:08	:00	2	5	1.1		PITCH	5°-6° C	ON WES	ST SID	E OF L	INE.	
4	V	V	15:32:00	15:4	0:00	00:08	:00	24		1.2	L					RMAF	ROST	
5	E		15:44:00	15:5	2:00	00:08	:00	2	5	1.1		(P	F) ON I	EAST SI	DE OF	LINE.		
6	V	V	15:56:00	16:0	4:00	00:08	:00	2	4	1.1		L5: 16	55Kts+	@ WES	ST SID	E OF L	NE	
/	t t	-	16:08:00	16:1	6:00 8:00	00:08	:00	22		1.3		15.1	L5-L8:					
0 0	V F	v -	16.20.00	16.2	0.00 0.00	00.08	.00	2	۷ ۲	1.2		10	.0. LIGF					
10	V	- V	16:43:00	16.5	1.00	00:08	·00	2	2	1.2				VIALL	LARES			
11	E		16:56:00	17:0	4:00	00:08	:00	2	2	1.2		5°-6	5° PITCI	H WEST	SIDE	OF LN	E	
13	V	V	17:08:00	17:1	6:00	00:08	:00	2	1	1.3								
15	E	2	17:20:00	17:2	8:00	00:08	:00	2	1	1.2								
17	V	V	17:31:00	17:3	5:00	00:04	:00	2	1	1.1		B4	1 PARK	CO MT	COM	IPLETE		
81	9	5	17:44:00	17:5	6:00	00:12	:00	1	9	1.2		BE	GIN YE	LLOWS	TONE	NP B2	<u>'</u>	
82	1	<u>ا</u>	18:00:00	18:1	1:00	00:11	:00	2	2	1	M		VARIES	S, POIN		ISITY=	3PPSM	
83 01)	18:14:00	18:2	4:00	00:10	:00	2	0 T	1 1 2	SCA	IN FREC	λ = 150	JHZ, PU	LSE R	AIE =	LS&UKHZ	
04 Q5	r c	N :	18.20.00	10.5	2.00	00.07	.00	1	9	1.2			MO		- CHO	D		
85	-	7	18:56:00	19.0	6.00	00.09	.00 ·00	1	8	1.2		IGHT S	FASON				ΓΟΝ	
		•	10.00.00	15.0	0.00	00.10		-	0				NOR	THERN	SLOPI	ES.		
																-		
Page 1 Verify S-Turns After Mission Yes																		
Additional C	omme	nts																
4346 GB 🛛 W	/U: 08:	55MST	WD: 13:4	3MST	NOT	E: EXIST	ENCE	OF GL	ACIATE	D TERRAIN A	ND PE	RMAFR		I PARK	CO BL	OCK 4		
PARTICULAR	LY IN L	INES 4	-8 & 13 & 15.	A LIGH	IT SEAS	SONAL S	NOW	ALSO	EXISTS	IN SMALL AI	NOUNT	S ON I	MOST (OF THE	NORT	THERLY	SLOPES.	
THE UPPERS	WERE	BLOW	ING 38Kts+ FF	ROM T	HE WE	ST, GS O	N WE	EST SID	E OF L	INES WAS 16	5Kts+ A		ES (L2,5	5,7,9,1	L,15),	PITCH	4°-6°.	

MAINT HOBBS: 5465.1.

			Woo	lpert	Lid	ar /	4cq	uisi	tior	ר Lc)g						
						D	ate										
Project #		Project	t Name				U	nique l	D		Flight	: Date ((UTC) I	Day o	f Year	Flight #	
81200	Pi	ark Co reflight	s Blk 1 / P	AGE 1			Day2	83_905	33_90511_A		10/09/2020		20	.0 283		A	
Cro	ew		Eq	uipment	:						Time					rports	
Pi	lot	Ai	ircraft Ma	ke / Mod	el / Tai	#		Hobbs Start		art	Local Start		UTC Start		De	parting	
Cor	mer		Cessna 40)4 Titan - M	N404CP	,		5	3101.4		08:3	8:00	14:38	3:00		KBZN	
Oper	rator	Se	nsor Mak	e / Model	l / Seria	al #		Но	bbs Er	nd	Local	l End	UTC	End	A	rriving	
Ry	/an	L	eica Terra	in Mappe	r - 9051	11		5	3106.9		12:5	7:00	18:57	/:00		KBZN	
						onditi	ions										
Wind Dir	Wind Dir (°) Wind Speed (kts) Visibility (mi) Cei					ng (ft)	Clc	oud Cov	/er	Temp). (°C)	Dew	Point ((°C)	Press	sure ("Hg)	
140		7	1	.0	18,0	000		Few		1	L		-5			3000	
Air Spe	Air Speed (kts) Altitude AGL (ft) Altitud					MSL (ft)	Airfi	eld Ele	vation	(ft)						
15	50	11,	319		15,	512			4,4	73							
						Settir	ngs										
Point Spacir	ıg (m) Poi	nt Density (pr	osm)	Scan Ang	le/FOV	/ (°)	Sca	an Frequency (Hz)			Pulse	Rate	(kHz)	Laser Power (%)			
0.7	0.7 2 40				10			81	1			670			100		
										Ve	rify S-T	Гurns В	3efore I	Missic	วท	Yes	
Line #	Direction	Start Time (UTC)	End Tim (UTC)	ie Tii On-	me -Line	Sate	Satellite PDOP										
38	S	14:38:00	14:44:0	0 00:0)6:00	2	1	1.	2			n	orth 20) mi			
39	S	14:54:00	15:10:0	0 00:1	16:00	2	22		2								
40	N C	15:13:00	15:31:0	0 00:1	18:00		23		$\frac{1}{2}$								
41	S NI	15:36:00	15:52:0		00:16:00		24		2								
42	S	16:16:00	16:32:0	0 00.1	00:16:00 21		. <u> </u>	1.	4 7								
44	N	16:36:00	16:55:0	0 00:1	19:00	2	25	- 1.	1								
45	S	16:57:00	17:14:0	0 00:1	17:00	2	25	1.	1								
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										N			1 ft or 1	21-010	<u> </u>	.,	
t -l-litional C						Page	1			Ve	erity S-	Turns	After iv	lissio	n	Yes	
	omments																
PAGE I																	

	Woolpert Lidar Acquisition Log													
			Project I	nfo					Date					
Project #		Project	t Name			U	nique ID	1	Flight	Date ((UTC) I	Day o	f Year	Flight #
81200		Yellowstone B	lock 2 / PAGE	2		Day2	83_90511_A	_90511_A			10/09/2020			А
Cr	ew		Equip	oment				Т	Time				Ai	rports
Pi	lot	Ai	ircraft Make	/ Model	/ Tail #		Hobbs St	art	Local	Start UTC S		tart	De	parting
Cor	mer		Cessna 404 T	ïtan - N4	04CP		8101.4	1	08:3	8:00	14:38	3:00	I	 BZN
Ope	rator	Se	nsor Make /	Model /	Serial #		Hobbs E	nd	Local	End	UTC	End	A	riving
Ry	van 🛛	L	eica Terrain N	Aapper -	90511		8106.9)	12:5	7:00	18:57	/:00		<bzn< td=""></bzn<>
					Con	ditions								
Wind Dir	·(°) Wi	nd Speed (kts)	Visibility	(mi) (Ceiling (ft) Clo	oud Cover	Temp.	(°C)	Dew	Point	(°C)	Press	ure ("Hg)
140		7	0,010		18,000)	Few	1			-5		:	3000
Air Spe	ed (kts)	Altitude	AGL (ft)	Alti	tude M	SL (ft)	Airfield Ele	evation	(ft)					
1	50	6,9) 98				4,4	473						
					Se	ttings								
Point Spacin	ng (m) P	oint Density (pr	osm) Sca	an Angle	/FOV (°)	Sca	n Frequency	(Hz)	Pulse	Rate ((kHz)	Las	er Pov	ver (%)
0.35		8		40			150			1580			10	<u>כ</u>
								Veri	ify S-T	Turns B	Before I	e Mission Yes		
Line #	Direction	Start Time (UTC)	End Time (UTC)	Time On-Lie	e g	Satellite	PDOP		Line Notes,		otes/Co	omme		
69	S	17:24:00	17:37:00) 00:13:00		22	1.1		Altitu	ude vai	ries bet	ween	all lin	es
70	N	17:40:00	17:53:00	00:13:	.00	20	1.2							
71	S	17:56:00	18:09:00	00:13:	00	24	1							
/2	N c	18:13:00	18:25:00	00:12:	00	23	1							
75	N N	18:44:00	18:41.00	00.13	00	22	1.1							
, , ,		10.11100	10.07.00	00.13			1.2							
					-+									
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					-+									
					\rightarrow									
										T.	۸ <i>4</i> + ۴	1:	_	Vec
Additional C	ommonto				Pa	age z		ve	rity 5-	Turns	Alterin	lissio	n	res
	omments													

		,	Woolp	ert Lic	lar A	١cq	uisitio	n Log						
			Project I	nfo			Date							
Project #		Project	t Name			U	nique ID	Flig	nt Date	(UTC) D	Day of	f Year	Flight #	
81200	Park Co,	MT B1&B3 Y	ellowstone N	IP B1&B4		Day2	83_91557_1	1	10/09/2020 283					
Cr	ew		Equip	oment	-			Tim	9	· · ·			rports	
Pi	lot	Ai	ircraft Make	/ Model / Ta	il #		Hobbs St	art Loc	Local Start		UTC Start		parting	
Dar	Perl		Reims F40	6 - N406SD			524.2	08	42:00	14:42	42:00		 BZN	
Ope	rator	Se	nsor Make /	Model / Ser	ial #		Hobbs E	nd Loc	al End	UTC E	nd	A	riving	
Fan	ning	L	eica Terrain N	/lapper - 915	57		529.1	11	40:00	17:40	:00	I	 BZN	
					Conditi	ons		•						
Wind Dir	(°) Wind	d Speed (kts)	Visibility	(mi) Ceili	ng (ft)	Clo	oud Cover	Temp. (°C	Dev	v Point (°C)	Press	ure ("Hg)	
140		7	10	21	,000		Few	1		-5			30	
Air Spe	ed (kts)	ed (kts) Altitude AGL (ft) Altitude				t)	Airfield Ele	evation (ft)						
1	50	11,	319	15	,512		4,4	171						
					Settin	gs								
Point Spacir	ng (m) Poi	nt Density (pp	osm) Sca	an Angle/FO	V (°)	Sca	n Frequency	(Hz) Pul	se Rate	(kHz)	Las	er Pov	ver (%)	
0.7		2		40			81		670			10	כ	
	i i i i i i i i i i i i i i i i i i i							Verify S	-Turns l	Before N	/lissic	n	Yes	
Line #	Direction	Start Time	End Time	Time	Sate	llite	PDOP		Line Notes/Comments					
40	N	(UIC)	(UIC)	On-Line	2	<u>,</u>	1 1							
49 50	S N	14:42:00	14:49:00	00:07:00	22	2 3	1.1		PARK	СОВІ	2885	VI)		
51	N	15:04:00	15:11:00	00:07:00	22	2	1.2							
52	S	15:15:00	15:22:00	00:07:00	23	3	1.1							
14	S	15:31:00	15:45:00	00:14:00	24	4	1.2	BEGIN PARK CO B3 (2PPSM)						
									1	l6,509' N	ЛSL			
		15.50.00	10.11.00	00.12.00	2	<u> </u>	1.2			ACTONE				
58	5	15:58:00	10:11:00	00:13:00	24	2	1.2	BEGIN	I YELLOV	S-150Hz			23IVI) D.	
								158	OkHz Pl	JLSE RAT	F: 69	98' A		
									0.35m	POINTS	SPACI	NG;		
									EY	E SAFE (OFF¤			
61	S	16:25:00	16:36:00	00:11:00	2:	1	1.2	В	EGIN YE	LLOWST	ONE	NP B4	ļ	
62	N	16:40:00	16:50:00	00:10:00	25	C ۱	1.4		(8PPS	M); MSL	VAR	IES		
62 62	5 N	17:08:00	17:04:00	00:10:00	24	+ 2	1.2	MO		/HEV///	DEDN			
69	S	17:17:00	17:23.00	00:06:00	2	<u>-</u> 1	13					RESEN		
70	N	17:26:00	17:32:00	00:06:00	22	2	1.1	ALL B4	LINES	61-71; LI	GHT	SEASC	NAL.	
71	S	17:34:00	17:40:00	00:06:00	20	C	1.2	YEL	OWSTO	ONE NP E	34 CO	MPLE	TE!	
					Page	1		Verify	S-Turns	After M	issio	n	Yes	
Additional C	omments							. ,	-				<u> </u>	
3976GB WI	J: 08:21MST	WD: 12:35N	IST MAINT	HOBBS: 546	9.3									
		-		-										

Appendix 3: GPS / IMU Graphics

Day25720_TM557 Trajectory



Day25720_TM557

Forward/Reverse or Combined Separation Plot



Day25720_TM557

Estimated Position Accuracy



Day25720_TM557 PDOP Plot



Day26520_TM515 Trajectory

● Day26520_TM515 - Inertial Explorer 8.70 File View Process Settings Output Tools Window Help	- D X
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🕱 Smoothed LC Combined - Map	
10 64	

Day26520_TM515

Forward/Reverse or Combined Separation Plot



Day26520_TM515

Estimated Position Accuracy


United States Geological Survey

PDOP Plot



140G0220F0199 - WY Yellowstone NP 2020 D20

Day26520_TM557_A Trajectory

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Smoothed LC Combined - Map	
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Day26520_TM557_A



Day26520_TM557_A Estimated Position Accuracy



Day26520_TM557_A PDOP Plot



Day26520_TM557_B

Trajectory



Day26520_TM557_B



Day26520_TM557_B Estimated Position Accuracy



Day26520_TM557_B PDOP Plot



Day26620_TM511 Trajectory



Day26620_TM511



Day26620_TM511 Estimated Position Accuracy



Day26620_TM511 PDOP Plot



Day26620_TM515 Trajectory

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Day26620_TM515



Day26620_TM515 Estimated Position Accuracy



Lidar Mapping Report - Appx. 3 GPS / IMU Graphics



Day26620_TM515 PDOP Plot



Day26620_TM557 Trajectory

M Day26620_TM557 - Inertial Explorer 8.70 File View Process Settings Output Tools Window Help	-	۵	×
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Day26620_TM557



Day26620_TM557

Estimated Position Accuracy



Day26620_TM557 PDOP Plot



Day26720_TM511 Trajectory

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Day26720_TM511



Day26720_TM511 Estimated Position Accuracy



Day26720_TM511 PDOP Plot



Day26720_TM515 Trajectory

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10 km	

Day26720_TM515



Day26720_TM515

Estimated Position Accuracy



Day26720_TM515 PDOP Plot



Day26720_TM557 Trajectory



Day26720_TM557



Day26720_TM557

Estimated Position Accuracy



Day26720_TM557 PDOP Plot



Day27620_TM515_A Trajectory



Day27620_TM515_A



Day27620_TM515_A Estimated Position Accuracy


Day27620_TM515_A PDOP Plot



Day27620_TM515_B Trajectory



Day27620_TM515_B



Day27620_TM515_B Estimated Position Accuracy

Day27620_TM515_B [Smoothed LC Combined] - Estimated Position Accuracy Plot 0.0140 0.0135 0.0130 0.0125 0.0120 0.0115 0.0110 0.0105 0.0100 (m) 0.0095 ated StdDev 0.0090 0.0085 Mm 0.0080 Estin 0.0075 0.0070 0.0065 Sall 0.0060 2 0.0055 0.0050 nn 0.0045 rrm 0.0040 5 0.0035 0.0030 489000 Week 2125 489200 489400 489600 489800 490000 490200 490400 490600 490800 491000 491200 491400 491600 491800 < Day27620_TM515_B 14:40:38 on 10/6/2020 > GPS Time (TOW, GMT zone) X: 489952.6 Y: 0.004 -East North Height Right click for more options



Day27620_TM515_B

PDOP Plot



Day27720_TM515 Trajectory

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10 km	

Day27720_TM515



Day27720_TM515 Estimated Position Accuracy

Day27720_TM515 [Smoothed LC Combined] - Estimated Position Accuracy Plot 0.0120 0.0115 0.0110 0.0105 0.0100 0.0095 0.0090 0.0085 ated StdDev (m) 0.0080 0.0075 0.0070 Estil 0.0065 manul 0.0060 11 0.0055 th. 0.0050 0.0045 0.0040 h 0.0035 Mas AN - 11 LK . A AL 0.0030 L.M 587000 577000 578000 579000 580000 581000 582000 583000 584000 585000 586000 Week 2125 < Day27720_TM515 14:02:21 on 10/7/2020 > GPS Time (TOW, GMT zone) Y: -East -North -Height Right click for more options X:

Day27720_TM515 PDOP Plot



Day27820_TM515 Trajectory

✓ Day27820_TMS15 - Inertial Explorer 8.70 File View Process Settings Output Tools Window Help	- 0 ×
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🕱 Smoothed LC Combined - Map	

Day27820_TM515



Day27820_TM515

Estimated Position Accuracy



Day27820_TM515 PDOP Plot



Day28220_TM557 Trajectory

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Day28220_TM557



Day28220_TM557

Estimated Position Accuracy



Day28220_TM557 PDOP Plot



United States Geological Survey

Day28320_TM511 Trajectory

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Smoothed LC Combined - Map	

Day28320_TM511



Day28320_TM511 Estimated Position Accuracy



Day28320_TM511 PDOP Plot



Day28320_TM557 Trajectory



Day28320_TM557



Day28320_TM557

Estimated Position Accuracy



Day28320_TM557 PDOP Plot

