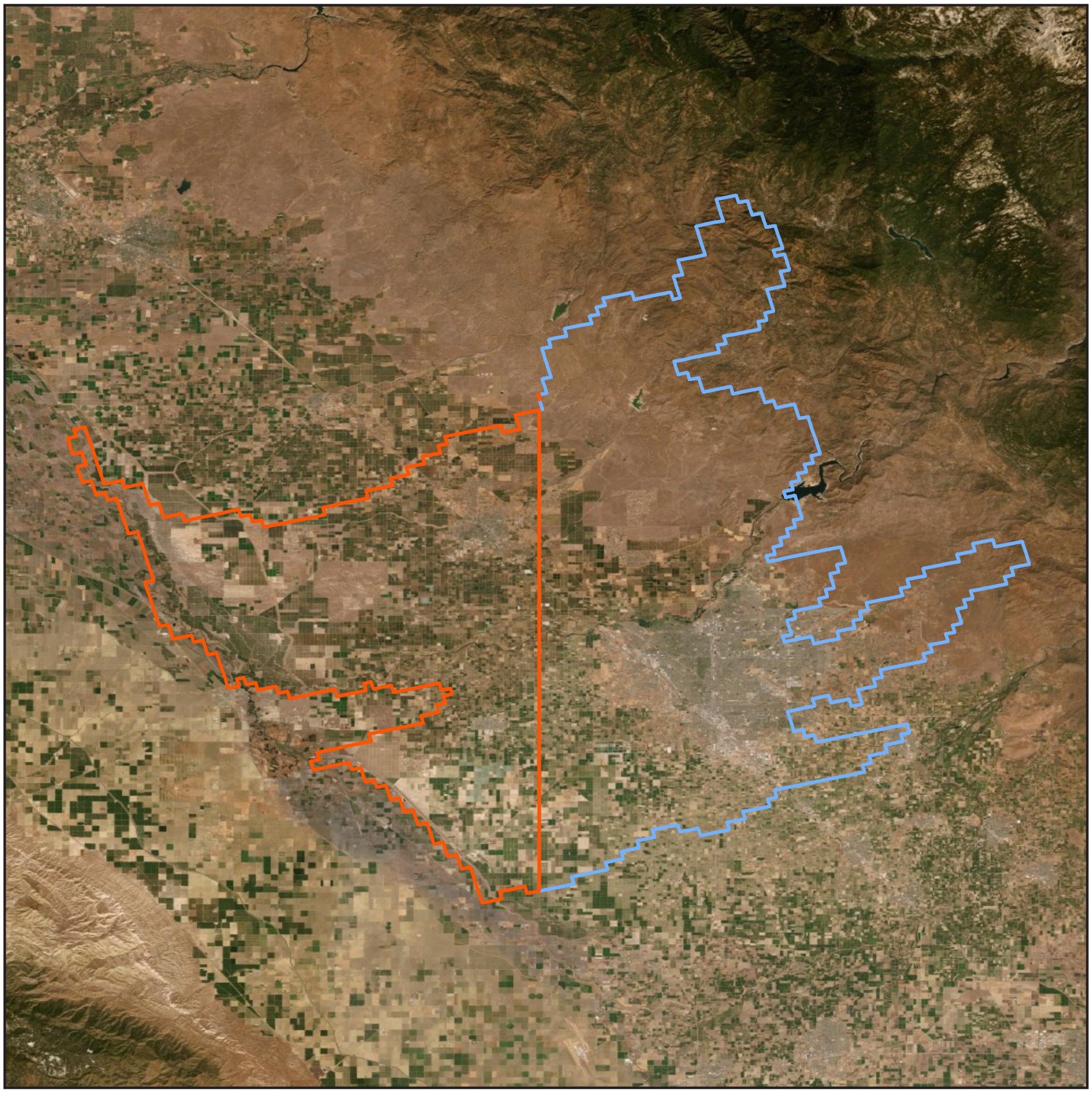
CA FEMA R9 Fresno 2019 D20

Airborne Lidar Report

June 2021



Contract #	G16PC00022
Task Order #	140G0220F0033
Project ID #	186770
Work Unit ID #	186767 (UTM10); 206240 (UTM11)

Contractor	Woolpert
Project #	80592

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1. Overview

About

This project contains a comprehensive outline of the 140G0220F0033 CA FEMA R9 Fresno 2019 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 data over one area of interest covering approximately 1,474 square miles in California around Fresno's watersheds.

Data partially covers the following counties:

- Fresno
- Madera
- Merced

Purpose

This project will support the 3DEP mission 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 2.1 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.

Table 1-1. Spatial Reference Systems

		UTM z10	UTM z11
Horizontal	**EPSG Code**	6339	6340
	Datum	NAD83 (2011)	NAD83 (2011)
	Projection	UTM Zone 10	UTM Zone 11
	Units	Meters	Meters
Vertical	**Datum**	NAVD88	NAVD88
	Geoid	GEOID12B	GEOID12B
	Units	Meters	Meters
	Height Type	Orthometric	Orthometric

Task Order Deliverables

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

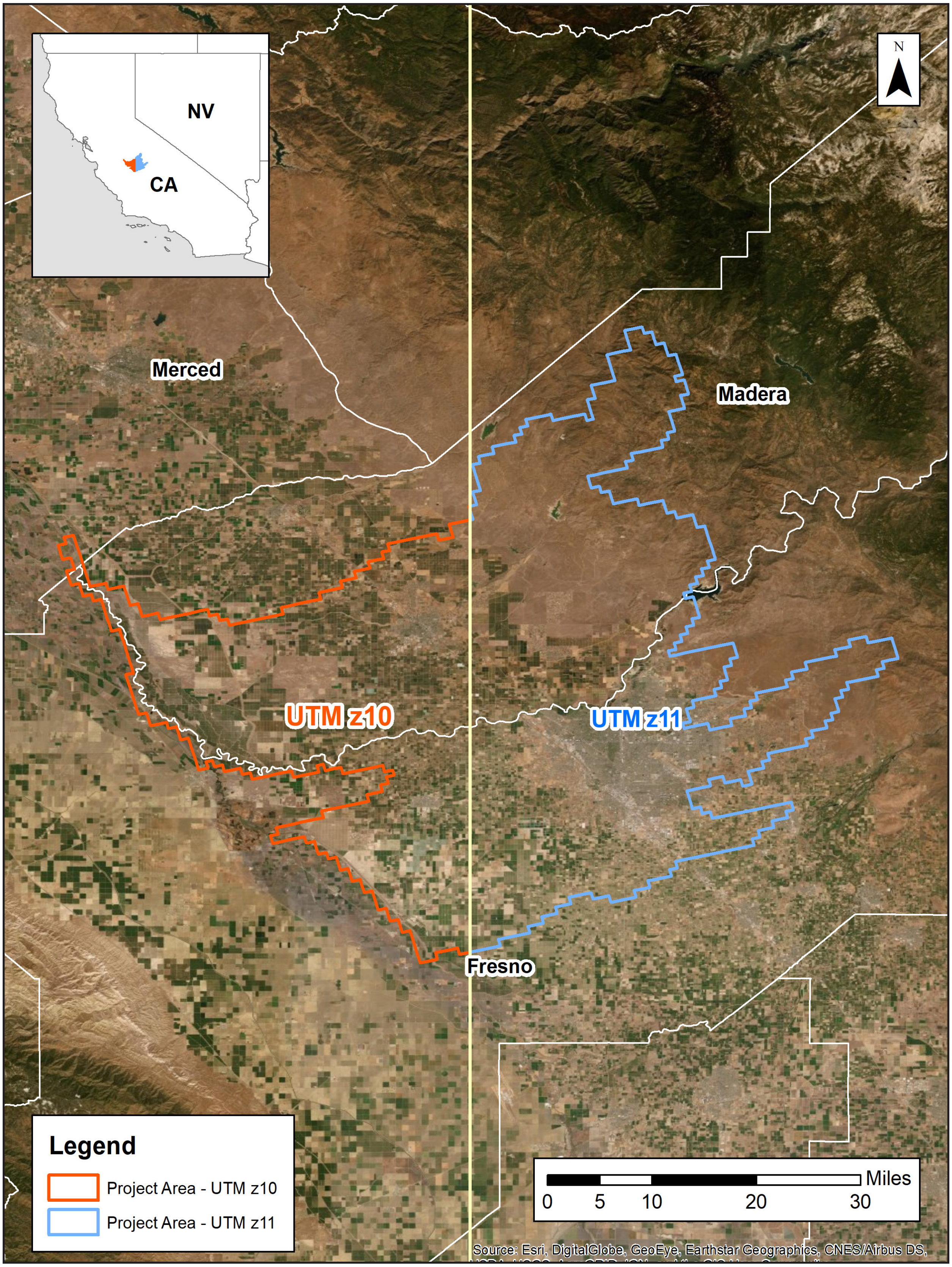
Table 1-2. Deliverables

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
Flight Line Index	Polygon feature class in an Esri file geodatabase
Control Data	
Lidar calibration points	Esri shapefile format
Lidar NVA checkpoints	Esri shapefile format
Lidar VVA checkpoints	Esri shapefile format
Other Data	
Tile Index	Esri shapefile format
Inter-Swath and Intra-Swath Test Results	Esri shapefile format
Swath Separation Image	3-meter pixel size, 8-bit, JPG2000 format
Metadata and Reports	
Metadata	Project-level FGDC CSDGM/USGS MetaParser Compliant metadata in .xml format
Lidar Project Report	Project report with flight logs in .pdf format
Survey Report	Survey report in .pdf format

Figure 1-1. Project Area



2. Acquisition

Flight Planning

Aerial lidar data for this project was collected using the specifications listed below.

Table 2-1. Acquisition Requirements

Specification	Target
Resolution	• 2 points per square meter • 0.71-meter nominal point spacing
Acquisition Window	Fall/Winter 2019/2020 leaf-off window (October 2019 – April 2020)
Overlap	At contractor's discretion, but enough to ensure there are no data gaps between usable portions of the swath and nominal point density is achieved
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
Acquisition Conditions	• Cloud and fog-free between the aircraft and ground • Ground is snow free • Ground has no unusual flooding or inundation, except in cases where the goal of the collection is to map the inundation • Preference of vegetation is leaf-off • Time of day is not of concern
Control	Airborne Global Positioning System (ABGPS) and Inertial Measurement Unit (IMU) data to be used along with differentially-corrected GPS ground control points

Lidar Sensor Information

Aerial lidar data was acquired for this project using the Optech Galaxy Prime lidar sensor system. A total of 123 flight lines were collected for this project.

Table 2-2. Optech Galaxy PRIME Sensor Info

Sensor Performance	
Performance envelope [1, 2, 3, 4]	150-6000 m AGL, nominal
Absolute horizontal accuracy [2, 3]	1/10,000 × altitude; 1 σ
Absolute elevation accuracy [2, 3]	< 0.03-0.25 m RMSE from 150-6000 m AGL
Laser Configuration	
Topographic laser	1064-nm near-infrared
Laser classification	Class IV (US FDA 21 CFR 1040.10 and 1040.11; IEC/EN 60825-1)
Pulse repetition frequency (effective)	Programmable, 50-1000 kHz
Beam divergence	0.25 mrad (1/e)
Laser range precision [5]	< 0.008 m, 1 σ
Minimum target separation distance	< 0.7 m (discrete)
Range capture	Up to 8 range measurements, including last
Intensity capture	Up to 8 intensity measurements, including last (12-bit)
Sensor Configuration	
Position and orientation system	POS AV™ AP60 (OEM); 220-channel dual frequency GNSS receiver; GNSS airborne antenna with Iridium filters; high-accuracy AIMU (Type 57); non-ITAR
Scan angle (FOV)	10-60°
Swath width	10-115% of altitude AGL
Scan frequency	0-120 Hz advertised (0-240 scan lines/sec)
Scan product	2000 maximum
Flight management system	Optech FMS (Airborne Mission Manager and Nav) with operator console
SwathTRAK™	Dynamic FOV for fixed-width data swaths in variable terrain
PulseTRAK™	Multipulse tracking algorithm with no density loss across PIA transition zones
Roll compensation	±5° minimum
Data storage	Removable SSD (primary); internal SSD (spare)
Power requirements	28 V; 400 W
Dimensions and weight	Sensor: 0.34 × 0.34 × 0.25 m, 27 kg PDU: 0.42 × 0.33 × 0.10 m, 6.5 kg
Operating temperature	0 to +35°C

1. Target reflectivity ≥20%; 99% detection probability
2. Dependent on selected operational parameters; assumes nominal FOV of up to 40° in standard atmospheric conditions (i.e. 23-km visibility) and use of Optech LMS Professional software suite
3. Angle of incidence ≤20°
4. Target size ≥ laser footprint
5. Under Teledyne Optech test conditions, 1 sigma

Source: Optech Galaxy PRIME Airborne Lidar Terrain Mapper Specification Sheet
http://info.teledyneoptech.com/acton/attachment/19958/f-0278/1/-/-/-/-/Galaxy%20PRIME%20Brochure.pdf

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.

In lieu of traditional base station occupations, Applanix PP-RTX technology was used. This solution provides high-accuracy GNSS positioning nationwide by combining real-time data from a global reference station infrastructure.

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.

Timeline

Lidar data was collected from December 12, 2019 through January 16, 2020. Acquisition specifications are listed in the table below. An initial quality control process was immediately performed on to review the data coverage, airborne GPS data, and trajectory solution.

For more information, see the Flight Logs in Appendix 1.

Table 2-3. Project Acquisition Specifications

Settings	Optech ALTM Galaxy
Max. Number of Returns	8
Nominal Point Spacing	0.71 m
Nominal Point Density	2.53 ppsm
Flying Height Above Ground Level	1,600 m
Flight Speed	170 knots
Scan Angle	40°
Scan Rate Used	69.5 Hz
Pulse Rate Used	300 kHz
Multi-Pulse in Air	Enabled
Swath Width	1,165 m
Swath Overlap	30%

Acquisition Quality Assurance

Woolpert developed a quality assurance and validation plan to ensure the acquired lidar data meets the USGS Base Specification Version 2.1. 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.

GNSS-IMU Trajectory Processing

Kinematic corrections for the aircraft position were resolved using aircraft GPS and the Applanix PP-RTX solution data 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).

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.

Software: Proprietary Software, TerraMatch v20, Leica CloudPro 1.2.4

Lidar Data Classification

LAS data was classified as ground and non-ground points with additional filters created to meet the task order classification specifications. Statistical absolute accuracy was assessed via direct comparisons of ground classified points to ground RTK survey data. Based on the statistical analysis, the lidar data was then adjusted to reduce the vertical bias when compared to the survey ground control of higher accuracy.

Calibrated LAS files were imported into the task order tiles and initially filtered to create a ground and non-ground class. Then additional classes were filtered as necessary to meet the following client-specified classes:

- Class 1 – Default / Processed, but not Classified
- Class 2 – Bare Earth Ground
- Class 7 – Low Noise
- Class 9 – Water
- Class 17 – Bridge Decks
- Class 18 – High Noise
- Class 20 – Ignored Ground

Classified LAS files were evaluated through a series of manual QA/QC steps as well as a peer-based review to eliminate remaining artifacts from the ground class. This included a review of the DEM surface to remove artifacts and ensure topographic quality.

Software: Proprietary Software, TerraScan v20

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, an 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, 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 format intensity imagery files. Files were clipped to the data extent.

Software: TerraScan v20, Esri ArcMap v10.7

Swath Separation Image

A swath separation image is generated to visualize the DZ between the overlapping areas of the flight lines. To generate this surface a point insertion method is used as the primary algorithm. All returns for all point classes except classes 7 and 18 are used in the calculation for each cell. GSD and color ramp values are dependent on the Quality Level and point spacing for the project. The GSD for the surface is no more then 4 times the NPS of the lidar data rounded to an appropriate whole number. The color ramp for the following QL levels are as follows:

QL1 + QL2

- Less than 8 cm – Green
- 8 cm to 16 cm – Yellow
- Greater than 16 cm – Red

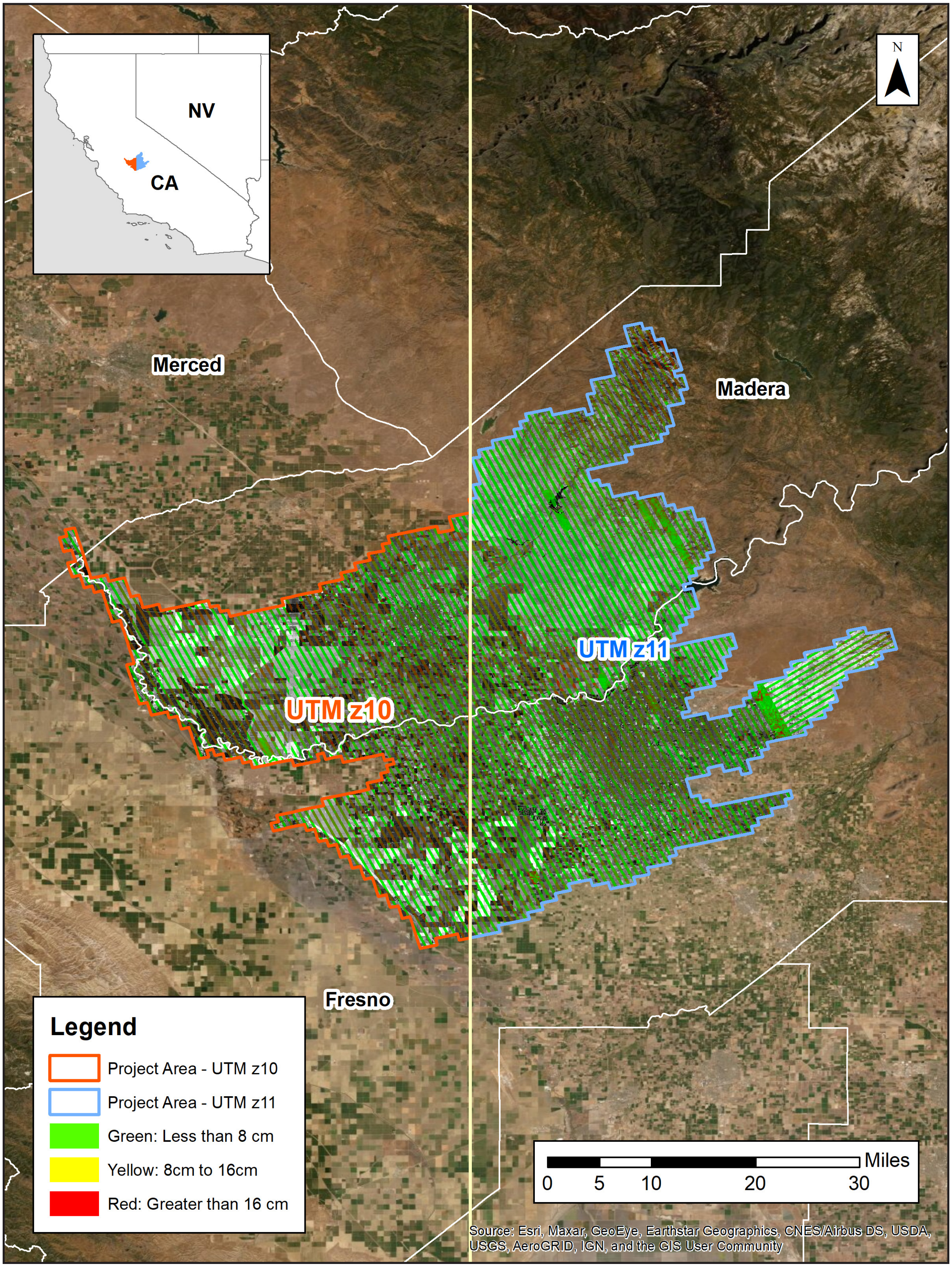
QL0

- Less than 4 cm – Green
- 4 cm to 8 cm – Yellow
- Greater than 8 cm – Red

Intensity values are modulated to 50% to ensure that there is no oversaturation of intensities values throughout the surface. After all calculations and surfaces have been made a JPEG2000 mosaic is produced for the DPA

Software: LP360 v2018.2.59.5

Figure 3-1. Swath Separation Image



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 and delivery 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.

4. Accuracy Assessment

Horizontal Accuracy

The data sets was produced to meet ASPRS “Positional Accuracy Standards for Digital Geospatial Data” (2014) for a 8.65 cm RMSEx / RMSEy Horizontal Accuracy Class which equates to Positional Horizontal Accuracy = +/- 21.2 cm at a 95% confidence level.

Raw Lidar Swath Testing

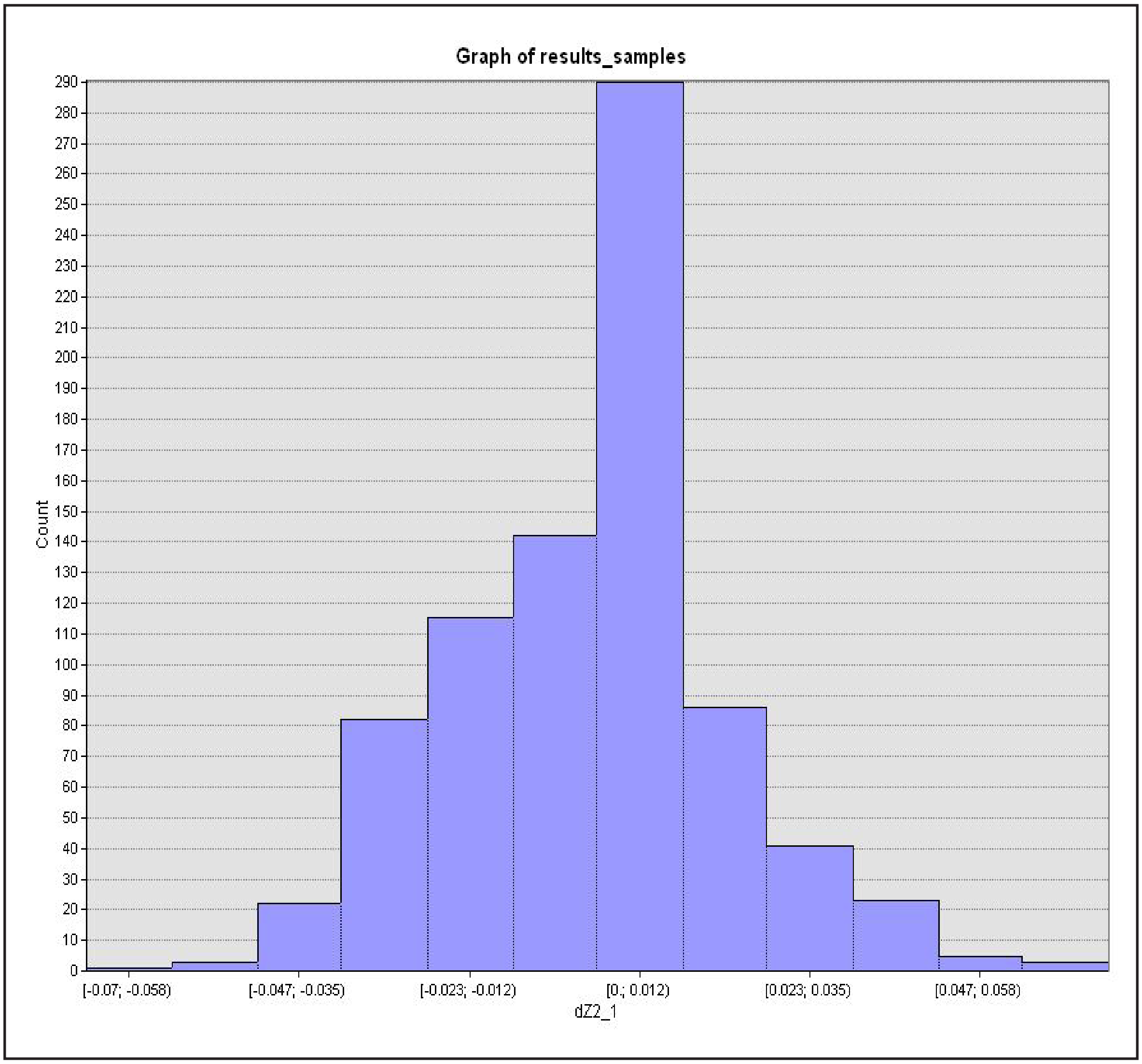
This project required the lidar point cloud swath to be produced to meet a Non-Vegetated Vertical Accuracy (NVA) value of 19.6 cm at a 95% confidence level using an RMSEz target value of 10 cm x 1.9600.

Digital Elevation Model Testing

This project required DEM data to be produced to meet a Non-Vegetated Vertical Accuracy (NVA) value of 19.6 cm at a 95% confidence level using an RMSEz target value of 10 cm x 1.9600 and a Vegetated Vertical Accuracy (VVA) value of 0.30 cm at the 95th percentile error.

Inter-Swath Testing

Inter-swath accuracy was tested against well-distributed flight line overlap locations. The relative accuracy for the lidar measured at 0.020 meters RMSE.



Values are in meters.

Approved By	Name	Signature	Date
Associate Member, Lidar Specialist Certified Photogrammetrist #1381	Qian Xiao		October 2020

Intra-Swath Testing

Intra-swath accuracy, also known as “within swath” accuracy, was tested against single swath first return data located in flat open areas. The intra-swath accuracy for the lidar measured at 0.014 meters RMSDz.

Appendix 1: Flight Logs

Woolpert Lidar Acquisition Log

Project Info			Date		
Project #	**Project Name**	**Unique ID**	**Flight Date (UTC)**	**Day of Year**	**Flight #**
80592	CA FEMA R9 Fresno	Day346_SH5060430_AB	12/12/2019	346	AB

Crew	Equipment		Time			Airports
Pilot	**Aircraft Make/Model**	**Aircraft Tail #**	**Hobbs Start**	**Local Start**	**UTC Start**	**Departing**
Shupe	Cessna/T310R	N310WJ	1561.8	09:09:00	17:09:00	KFAT
Operator	**Sensor Make/Model**	**Sensor Serial #**	**Hobbs End**	**Local End**	**UTC End**	**Arriving**
Muncer	Optech Galaxy Prime	5060430	1569.8	18:12:00	02:12:00	KFAT

Conditions

Wind Dir (°)	Wind Speed (kts)	Visibility (mi)	Ceiling (ft)	Cloud Cover	Temp. (°C)	Dew Point (°C)	Pressure ("Hg)
0	0	10	25,000	Few	9	8	30.31

Air Speed (kts)	Altitude AGL (ft)	Altitude MSL (ft)	Airfield Elevation (ft)
170	5,200	5,600	336

Settings

Point Spacing (m)	Point Density (ppsm)	Scan Angle/FOV (°)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power (%)
0.63	2	40	69	300	100

Verify S-Turns Before Mission

Line #	Direction	Start Time (UTC)	End Time (UTC)	Time On-Line	Satellite	PDOP	Line Notes/Comments
30	W	17:39:00	17:43:00	00:04:00		1.07	Crossflight
1	s	17:45:00	17:47:00	00:02:00		0.92	
2	n	17:49:00	17:54:00	00:05:00		0.9	
3	s	17:56:00	17:59:00	00:03:00		0.79	
4	n	18:03:00	18:07:00	00:04:00		0.8	
5	s	18:09:00	18:14:00	00:05:00		0.8	
6	n	18:16:00	18:21:00	00:05:00		0.8	
7	s	18:23:00	18:29:00	00:06:00		0.81	
8	n	18:32:00	18:37:00	00:05:00		0.84	
9	s	18:39:00	18:42:00	00:03:00		0.89	
10	n	18:46:00	19:05:00	00:19:00		0.9	
11	s	19:07:00	19:16:00	00:09:00		0.97	
12	n	19:19:00	19:30:00	00:11:00		0.98	
13	s	19:32:00	19:42:00	00:10:00		0.99	
14	n	19:43:00	19:49:00	00:06:00		1.01	
15	s	19:50:00	19:55:00	00:05:00		0.92	
16	n	19:58:00	20:28:00	00:30:00		0.99	Break mid line over lake area
17	s	20:30:00	20:43:00	00:13:00		0.91	Break mid line over lake area
18	n	20:46:00	21:03:00	00:17:00		0.9	Break mid line over lake area
29	w	21:11:00	21:29:00	00:18:00		0.81	Crossflight / End lift 1
19	s	23:46:00	00:00:00	00:14:00		0.87	Break mid line over lake area
20	n	00:03:00	00:19:00	00:16:00		0.84	
21	s	00:21:00	00:34:00	00:13:00		0.83	
22	n	00:37:00	00:52:00	00:15:00		0.9	
23	s	01:01:00	01:17:00	00:16:00		1.02	

Verify S-Turns After Mission Yes

Additional Comments

Drive #

Woolpert Lidar Acquisition Log

Project Info			Date		
Project #	Project Name	Unique ID	Flight Date (UTC)	Day of Year	Flight #
80592	CA FEMA R9 Fresno	Day346_SH5060430_AB	12/12/2019	346	AB

Crew	Equipment		Time			Airports
Pilot	Aircraft Make/Model	Aircraft Tail #	Hobbs Start	Local Start	UTC Start	Departing
Shupe	Cessna/T310R	N310WJ	1561.8	09:09:00	17:09:00	KFAT
Operator	Sensor Make/Model	Sensor Serial #	Hobbs End	Local End	UTC End	Arriving
Muncer	Optech Galaxy Prime	5060430	1569.8	18:12:00	02:12:00	KFAT

Conditions

Wind Dir (°)	Wind Speed (kts)	Visibility (mi)	Ceiling (ft)	Cloud Cover	Temp. (°C)	Dew Point (°C)	Pressure ("Hg)
0	0	10	25,000	Few	9	8	30.31

Air Speed (kts)	Altitude AGL (ft)	Altitude MSL (ft)	Airfield Elevation (ft)
170	5,200	5,600	336

Settings

Point Spacing (m)	Point Density (ppsm)	Scan Angle/FOV (°)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power (%)
0.63	2	40	69	300	100

Verify S-Turns Before Mission

Line #	Direction	Start Time (UTC)	End Time (UTC)	Time On-Line	Satellite	PDOP	Line Notes/Comments
24	n	01:20:00	01:35:00	00:15:00		0.93	
25	s	01:37:00	01:52:00	00:15:00		0.98	

Verify S-Turns After Mission

Additional Comments	Drive #	

Woolpert Lidar Acquisition Log

Project Info			Date		
Project #	Project Name	Unique ID	Flight Date (UTC)	Day of Year	Flight #
80592	CA FEMA R9 Fresno	Day353_SH5060430_AB	12/19/2019	353	AB

Crew	Equipment		Time			Airports
Pilot	Aircraft Make/Model	Aircraft Tail #	Hobbs Start	Local Start	UTC Start	Departing
Shupe	Cessna/T310R	N310WJ	1590.4	07:45:00	15:45:00	KFAT
Operator	Sensor Make/Model	Sensor Serial #	Hobbs End	Local End	UTC End	Arriving
Muncer	Optech Galaxy Prime	5060430	1599	17:30:00	01:30:00	KFAT

Conditions

Wind Dir (°)	Wind Speed (kts)	Visibility (mi)	Ceiling (ft)	Cloud Cover	Temp. (°C)	Dew Point (°C)	Pressure ("Hg)
0	0	10	25,000	Scattered	4	-1	30.21

Air Speed (kts)	Altitude AGL (ft)	Altitude MSL (ft)	Airfield Elevation (ft)
170	5,200	5,600	336

Settings

Point Spacing (m)	Point Density (ppsm)	Scan Angle/FOV (°)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power (%)
0.63	2	40	69	300	100

Verify S-Turns Before Mission

Line #	Direction	Start Time (UTC)	End Time (UTC)	Time On-Line	Satellite	PDOP	Line Notes/Comments
26	n	16:00:00	16:16:00	00:16:00		1.08	
27	s	16:16:00	16:34:00	00:18:00		0.93	
28	n	16:37:00	16:52:00	00:15:00		0.86	
29	s	16:55:00	17:10:00	00:15:00		0.86	
30	n	17:13:00	17:34:00	00:21:00		0.95	gap over a lake 6 miles from the north end
31	s	17:37:00	17:52:00	00:15:00		0.96	
32	n	17:55:00	18:16:00	00:21:00		0.98	gap over a lake 20.7 miles from north end
33	s	18:19:00	18:31:00	00:12:00		0.99	
34	n	18:34:00	18:50:00	00:16:00		0.91	
35	s	18:53:00	19:06:00	00:13:00		0.85	
36	n	19:09:00	19:24:00	00:15:00		0.85	
37	s	19:27:00	19:44:00	00:17:00		0.91	gap over a pond 13 miles from south end
38	n	19:47:00	20:02:00	00:15:00		0.83	End lift 1
39	s	22:45:00	22:58:00	00:13:00		0.91	gap over a pond 8 miles from the north end
40	n	23:01:00	23:16:00	00:15:00		1.02	
41	s	23:19:00	23:30:00	00:11:00		1.15	
42	n	23:33:00	23:46:00	00:13:00		1.12	
43	s	23:49:00	00:01:00	00:12:00		0.91	
44	n	00:04:00	00:16:00	00:12:00		0.95	large gap over the lake 18.6 from north end
45	s	00:19:00	00:31:00	00:12:00		0.94	
46	n	00:33:00	00:48:00	00:15:00		0.94	
47	s	00:51:00	01:02:00	00:11:00		0.98	
48	n	01:03:00	01:15:00	00:12:00		0.94	End Lift 2

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Verify S-Turns After Mission: Yes

Additional Comments

Drive #

Woolpert Lidar Acquisition Log

Project Info			Date		
Project #	Project Name	Unique ID	Flight Date (UTC)	Day of Year	Flight #
80590/80592	CA FEMA R9 Fresno	Day354_SH5060430_AB	12/20/2019	354	AB

Crew	Equipment		Time			Airports
Pilot	Aircraft Make/Model	Aircraft Tail #	Hobbs Start	Local Start	UTC Start	Departing
Shupe	Cessna/T310R	N310WJ	1599	08:15:00	16:15:00	KFAT
Operator	Sensor Make/Model	Sensor Serial #	Hobbs End	Local End	UTC End	Arriving
Muncer	Optech Galaxy Prime	5060430	1608.2	17:55:00	01:55:00	KFAT

Conditions

Wind Dir (°)	Wind Speed (kts)	Visibility (mi)	Ceiling (ft)	Cloud Cover	Temp. (°C)	Dew Point (°C)	Pressure ("Hg)
0	0	10	20,000	Broken	6	2	30.29

Air Speed (kts)	Altitude AGL (ft)	Altitude MSL (ft)	Airfield Elevation (ft)
170	5,200	5,600	336

Settings

Point Spacing (m)	Point Density (ppsm)	Scan Angle/FOV (°)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power (%)
0.63	2	40	69	300	100

Verify S-Turns Before Mission

Line #	Direction	Start Time (UTC)	End Time (UTC)	Time On-Line	Satellite	PDOP	Line Notes/Comments
352	s	16:45:00	17:11:00	00:26:00		0.83	Fresno
353	n	17:14:00	17:26:00	00:12:00		0.96	
354	s	17:29:00	17:42:00	00:13:00		1.08	
355	n	17:45:00	17:57:00	00:12:00		1.09	
356	s	18:00:00	18:12:00	00:12:00		0.97	
357	n	18:15:00	18:27:00	00:12:00		1.01	
358	s	18:29:00	18:41:00	00:12:00		1.05	
359	n	18:44:00	18:54:00	00:10:00		1.02	
360	s	18:57:00	19:08:00	00:11:00		0.88	
361	n	19:11:00	19:21:00	00:10:00		0.91	
362	s	19:24:00	19:36:00	00:12:00		0.97	End lift 1
49	s	21:25:00	21:53:00	00:28:00		1.09	Estrella
50	n	21:56:00	22:11:00	00:15:00		0.81	
51	s	22:14:00	22:32:00	00:18:00		1.05	
52	n	22:35:00	23:05:00	00:30:00		1.07	
53	s	23:10:00	23:42:00	00:32:00		1.07	
54	n	23:45:00	00:00:00	00:15:00		0.92	
55	s	00:03:00	00:15:00	00:12:00		0.92	
56	n	00:18:00	00:31:00	00:13:00		1.02	
57	s	00:34:00	00:49:00	00:15:00		0.92	
58	n	00:51:00	01:04:00	00:13:00		0.91	Gap over pond 10.5 miles from south end
59	s	01:07:00	01:21:00	00:14:00		0.93	
60	n	01:24:00	01:34:00	00:10:00		0.94	End lift 2

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Verify S-Turns After Mission: Yes

Additional Comments

Drive #

Woolpert Lidar Acquisition Log

Project Info			Date		
Project #	Project Name	Unique ID	Flight Date (UTC)	Day of Year	Flight #
80592	CA FEMA R9 Fresno	Day355_SH5060430_A	12/21/2019	355	A

Crew	Equipment		Time			Airports
Pilot	Aircraft Make/Model	Aircraft Tail #	Hobbs Start	Local Start	UTC Start	Departing
Shupe	Cessna/T310R	N310WJ	1608.2	07:50:00	15:50:00	KFAT
Operator	Sensor Make/Model	Sensor Serial #	Hobbs End	Local End	UTC End	Arriving
Muncer	Optech Galaxy Prime	5060430	1614	10:58:00	18:58:00	KFAT

Conditions

Wind Dir (°)	Wind Speed (kts)	Visibility (mi)	Ceiling (ft)	Cloud Cover	Temp. (°C)	Dew Point (°C)	Pressure ("Hg)
80	5	10	15,000	Scattered	10	2	30.07

Air Speed (kts)	Altitude AGL (ft)	Altitude MSL (ft)	Airfield Elevation (ft)
170	5,200	5,600	336

Settings

Point Spacing (m)	Point Density (ppsm)	Scan Angle/FOV (°)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power (%)
0.63	2	40	69	300	100

Verify S-Turns Before Mission

Line #	Direction	Start Time (UTC)	End Time (UTC)	Time On-Line	Satellite	PDOP	Line Notes/Comments
61	s	16:20:00	16:37:00	00:17:00		0.94	
62	n	16:40:00	16:55:00	00:15:00		0.92	
63	s	16:58:00	17:13:00	00:15:00		0.92	
64	n	17:16:00	17:26:00	00:10:00		0.99	
65	s	17:28:00	17:43:00	00:15:00		0.99	
66	n	17:46:00	17:57:00	00:11:00		0.92	
67	s	18:00:00	18:16:00	00:16:00		0.94	
68	n	18:19:00	18:38:00	00:19:00		0.94	

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Verify S-Turns After Mission: Yes

Additional Comments

Drive #

Woolpert Lidar Acquisition Log

Project Info			Date		
Project #	Project Name	Unique ID	Flight Date (UTC)	Day of Year	Flight #
80592	CA FEMA R9 Fresno	Day11_SH5060410_A	01/11/2020	11	A

Crew	Equipment		Time			Airports
Pilot	Aircraft Make/Model	Aircraft Tail #	Hobbs Start	Local Start	UTC Start	Departing
Pendleton	Cessna/T310R	N7269T	1168	10:00:00	18:00:00	KFAT
Operator	Sensor Make/Model	Sensor Serial #	Hobbs End	Local End	UTC End	Arriving
Campbell	Optech Galaxy Prime	5060410	1169.4	10:35:00	18:35:00	KFAT

Conditions

Wind Dir (°)	Wind Speed (kts)	Visibility (mi)	Ceiling (ft)	Cloud Cover	Temp. (°C)	Dew Point (°C)	Pressure ("Hg)
0	0	10	25,000	Clear	6	3	30.28

Air Speed (kts)	Altitude AGL (ft)	Altitude MSL (ft)	Airfield Elevation (ft)
120	5,200	5,600	336

Settings

Point Spacing (m)	Point Density (ppsm)	Scan Angle/FOV (°)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power (%)
0.63	2	40	49	200	100

Verify S-Turns Before Mission: Yes

Line #	Direction	Start Time (UTC)	End Time (UTC)	Time On-Line	Satellite	PDOP	Line Notes/Comments
106	NE	18:00:00	18:02:00	00:02:00		1.04	
107	SE	18:05:00	18:08:00	00:03:00		1.03	
108	NE	18:11:00	18:14:00	00:03:00		1.01	
109	SE	18:19:00	18:24:00	00:05:00		0.92	
119	NE	18:30:00	18:35:00	00:05:00		0.85	

Verify S-Turns After Mission: Yes

Additional Comments

Drive #: PRIME 1

Woolpert Lidar Acquisition Log

Project Info			Date		
Project #	Project Name	Unique ID	Flight Date (UTC)	Day of Year	Flight #
80592	CA FEMA R9 Fresno	Day12_SH5060410_A	01/12/2020	12	A

Crew	Equipment		Time			Airports
Pilot	Aircraft Make/Model	Aircraft Tail #	Hobbs Start	Local Start	UTC Start	Departing
Pendleton	Cessna/T310R	N7269T	1169.4	15:49:00	23:49:00	KFAT
Operator	Sensor Make/Model	Sensor Serial #	Hobbs End	Local End	UTC End	Arriving
Muncer	Optech Galaxy Prime	5060410	1171.8	17:17:00	01:17:00	KFAT

Conditions

Wind Dir (°)	Wind Speed (kts)	Visibility (mi)	Ceiling (ft)	Cloud Cover	Temp. (°C)	Dew Point (°C)	Pressure ("Hg)
0	0	10	25,000	Clear	11	8	30.11

Air Speed (kts)	Altitude AGL (ft)	Altitude MSL (ft)	Airfield Elevation (ft)
120	5,200	5,600	336

Settings

Point Spacing (m)	Point Density (ppsm)	Scan Angle/FOV (°)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power (%)
0.63	2	40	49	200	100

Verify S-Turns Before Mission: Yes

Line #	Direction	Start Time (UTC)	End Time (UTC)	Time On-Line	Satellite	PDOP	Line Notes/Comments
69	S	23:49:00	00:05:00	24:05:00		0.96	
70	N	00:08:00	00:23:00	00:15:00		0.86	
71	S	00:26:00	00:41:00	00:15:00		0.9	
72	N	00:44:00	01:00:00	00:16:00		1.06	
73	S	01:03:00	01:17:00	00:14:00		1	

Verify S-Turns After Mission: Yes

Additional Comments

Drive #: PRIME 1

Woolpert Lidar Acquisition Log

Project Info			Date		
Project #	Project Name	Unique ID	Flight Date (UTC)	Day of Year	Flight #
80592	CA FEMA R9 Fresno	Day15_SH5060410_AB	01/15/2020	15	AB

Crew	Equipment		Time			Airports
Pilot	Aircraft Make/Model	Aircraft Tail #	Hobbs Start	Local Start	UTC Start	Departing
Pendleton	Cessna/T310R	N7269T	1172.6	08:37:00	16:37:00	KFAT
Operator	Sensor Make/Model	Sensor Serial #	Hobbs End	Local End	UTC End	Arriving
Muncer	Optech Galaxy Prime	5060410	1182.3	18:55:00	02:55:00	KFAT

Conditions

Wind Dir (°)	Wind Speed (kts)	Visibility (mi)	Ceiling (ft)	Cloud Cover	Temp. (°C)	Dew Point (°C)	Pressure ("Hg)
0	0	10	25,000	Clear	4	3	30.12

Air Speed (kts)	Altitude AGL (ft)	Altitude MSL (ft)	Airfield Elevation (ft)
120	5,200	5,600	336

Settings

Point Spacing (m)	Point Density (ppsm)	Scan Angle/FOV (°)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power (%)
0.63	2	40	49	200	100

Verify S-Turns Before Mission: Yes

Line #	Direction	Start Time (UTC)	End Time (UTC)	Time On-Line	Satellite	PDOP	Line Notes/Comments
74	N	16:37:00	16:54:00	00:17:00		0.87	
75	S	16:57:00	17:15:00	00:18:00		0.97	
76	N	17:18:00	17:31:00	00:13:00		0.88	
77	S	17:34:00	17:50:00	00:16:00		0.96	
78	N	17:53:00	18:09:00	00:16:00		0.79	
79	S	18:12:00	18:29:00	00:17:00		0.82	
80	N	18:31:00	18:45:00	00:14:00		0.89	
81	S	18:48:00	19:08:00	00:20:00		0.88	
82	N	19:12:00	19:26:00	00:14:00		0.98	
83	S	19:29:00	19:46:00	00:17:00		0.92	
84	N	19:49:00	20:05:00	00:16:00		0.9	
85	S	20:08:00	20:23:00	00:15:00		0.87	
86	N	20:26:00	20:40:00	00:14:00		1	
87	S	20:42:00	20:55:00	00:13:00		0.99	
88	N	20:58:00	21:08:00	00:10:00		0.9	
89	S	21:12:00	21:33:00	00:21:00		0.9	
90	N	21:36:00	21:55:00	00:19:00		0.9	end lift 1
91	S	00:12:00	00:21:00	00:09:00		0.85	begin lift 2
92	N	00:24:00	00:37:00	00:13:00		0.9	
93	S	00:40:00	00:52:00	00:12:00		0.9	
94	N	00:55:00	01:05:00	00:10:00		0.98	
95	S	01:08:00	01:18:00	00:10:00		0.93	
96	N	01:20:00	01:29:00	00:09:00		0.85	
97	S	01:31:00	01:43:00	00:12:00		0.84	
98	N	01:45:00	01:54:00	00:09:00		0.96	See next page

Verify S-Turns After Mission: Yes

Additional Comments

Drive #: PRIME 1

Woolpert Lidar Acquisition Log

Project Info			Date		
Project #	Project Name	Unique ID	Flight Date (UTC)	Day of Year	Flight #
80592	CA FEMA R9 Fresno	Day15_SH5060410_AB	01/15/2020	15	AB

Crew	Equipment		Time			Airports
Pilot	Aircraft Make/Model	Aircraft Tail #	Hobbs Start	Local Start	UTC Start	Departing
Pendleton	Cessna/T310R	N7269T	1172.6	08:37:00	16:37:00	KFAT
Operator	Sensor Make/Model	Sensor Serial #	Hobbs End	Local End	UTC End	Arriving
Muncer	Optech Galaxy Prime	5060410	1182.3	18:55:00	02:55:00	KFAT

Conditions

Wind Dir (°)	Wind Speed (kts)	Visibility (mi)	Ceiling (ft)	Cloud Cover	Temp. (°C)	Dew Point (°C)	Pressure ("Hg)
0	0	10	25,000	Clear	4	3	30.12

Air Speed (kts)	Altitude AGL (ft)	Altitude MSL (ft)	Airfield Elevation (ft)
120	5,200	5,600	336

Settings

Point Spacing (m)	Point Density (ppsm)	Scan Angle/FOV (°)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power (%)
0.63	2	40	49	200	100

Verify S-Turns Before Mission

Line #	Direction	Start Time (UTC)	End Time (UTC)	Time On-Line	Satellite	PDOP	Line Notes/Comments
99	S	01:56:00	02:09:00	00:13:00		0.97	
100	N	02:11:00	02:21:00	00:10:00		0.91	
101	S	02:24:00	02:33:00	00:09:00		1	
102	N	02:35:00	02:45:00	00:10:00		1.06	
103	S	02:52:00	02:55:00	00:03:00		1	end lift 2

Verify S-Turns After Mission

Additional Comments	Drive #	

Woolpert Lidar Acquisition Log

Project Info			Date		
Project #	Project Name	Unique ID	Flight Date (UTC)	Day of Year	Flight #
80592	CA FEMA R9 Fresno	Day16_SH5060410_A	01/16/2020	16	A

Crew	Equipment		Time			Airports
Pilot	Aircraft Make/Model	Aircraft Tail #	Hobbs Start	Local Start	UTC Start	Departing
Pendleton	Cessna/T310R	N7269T	1182.3	09:00:00	17:00:00	KFAT
Operator	Sensor Make/Model	Sensor Serial #	Hobbs End	Local End	UTC End	Arriving
Muncer	Optech Galaxy Prime	5060410	1184.9	10:18:00	18:18:00	KFAT

Conditions

Wind Dir (°)	Wind Speed (kts)	Visibility (mi)	Ceiling (ft)	Cloud Cover	Temp. (°C)	Dew Point (°C)	Pressure ("Hg)
110	12	10	25,000	Few	8	3	29.95

Air Speed (kts)	Altitude AGL (ft)	Altitude MSL (ft)	Airfield Elevation (ft)
120	5,200	5,600	336

Settings

Point Spacing (m)	Point Density (ppsm)	Scan Angle/FOV (°)	Scan Frequency (Hz)	Pulse Rate (kHz)	Laser Power (%)
0.63	2	40	49	200	100

Verify S-Turns Before Mission: Yes

Line #	Direction	Start Time (UTC)	End Time (UTC)	Time On-Line	Satellite	PDOP	Line Notes/Comments
110	E	17:00:00	17:05:00	00:05:00		0.86	
111	W	17:08:00	17:14:00	00:06:00		0.8	
112	E	17:17:00	17:22:00	00:05:00		0.88	
113	W	17:25:00	17:32:00	00:07:00		0.86	
114	E	17:35:00	17:40:00	00:05:00		0.87	
115	W	17:43:00	17:49:00	00:06:00		0.84	
116	E	17:53:00	17:58:00	00:05:00		0.82	
117	W	18:02:00	18:08:00	00:06:00		0.88	
118	E	18:11:00	18:18:00	00:07:00		0.84	

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Verify S-Turns After Mission: Yes

Additional Comments

Drive #: PRIME 1