LIDAR Data Collection over Portions of Reynolds Creek, Owyhee County, ID

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1. Sensor Description and Specifications

This survey was performed with an Optech Titan multispectral airborne LiDAR sensor (serial number 14SEN340) mounted in a twin-engine Piper PA-31-350 Navajo Chieftain (Tail Number N154WW).

The instrument nominal specifications are listed below in Table 1.

Parameter	Specification
Operating altitude [1,2]	300 - 2500 m AGL, 1064 nm, nominal 300 - 2000 m AGL, 532 nm, nominal 300 - 2000 m AGL, 1550 nm, nominal
Horizontal accuracy [2]	1/5,500 x altitude; 1 σ
Elevation accuracy [2]	< 5-15cm; 1σ
Pulse repetition frequency	Programmable; 35 – 300 kHz (each wavelength)
Scan frequency	Programmable; 0 - 70 Hz
Scan angle (FOV)	Programmable; 0 - 60° maximum
Roll compensation	Programmable; ±5° at full FOV
Position and orientation system	POSAV AP50 (OEM) 220-channel dual frequency
Minimum target separation distance	<1.0 m
Range capture	Up to 4 range measurements for each pulse, including last
Beam divergence	0.5 mrad ($1/e^2$) 1064 nm 1.0 mrad ($1/e^2$) 532 nm 0.5 mrad ($1/e^2$) 1550 nm
Laser classification	Class IV (US FDA 21 CFR 1040.10 and 1040.11; IEC/EN 60825-1)
Intensity capture	Up to 4 range measurements for each pulse, including last 12-bit dynamic measurement and data range
Data storage hard drives	Removable solid state disk SSD (SATA II)

[1]10% reflective target
[2]Dependent on selected operational parameters using nominal 50° FOV in standard atmospheric conditions

Note: To meet its stated accuracy, the ALTM must receive GPS data of sufficient quality. GPS data quality shall be viable only when all of the following conditions are met:
- At least 4 satellites are in lock (tracked by the receiver) throughout the survey
- Elevation of the satellites is above 15°
- Geometry of the satellites is good (i.e., PDOP < 4)
- Aircraft stays within 30 km of the GPS base station

If one or more of these conditions is not met, or if any source of electromagnetic interference causes the GPS receivers to repeatedly lose lock, the specified accuracy of the ALTM shall be compromised.

Table 1 – Optech TITAN specifications http:/www.teledyneoptech.com/index.php/product/titan/)

2. Area of Interest.

The survey area consisted of a polygon represented by the intersection of the Soda fire burn scar and the Reynolds Creek CZO (green polygon). The total area surveyed was approximately **150 square km.** Figure 1 (below) is an image plotted in Google Earth showing the shape and location of the burn scar polygon (in red, 1146 square km), the CZO polygon (in green, 270 square km), and the LiDAR survey coverage (in yellow,150 square km). Yellow push-pin markers show the locations of the three GPS reference stations.

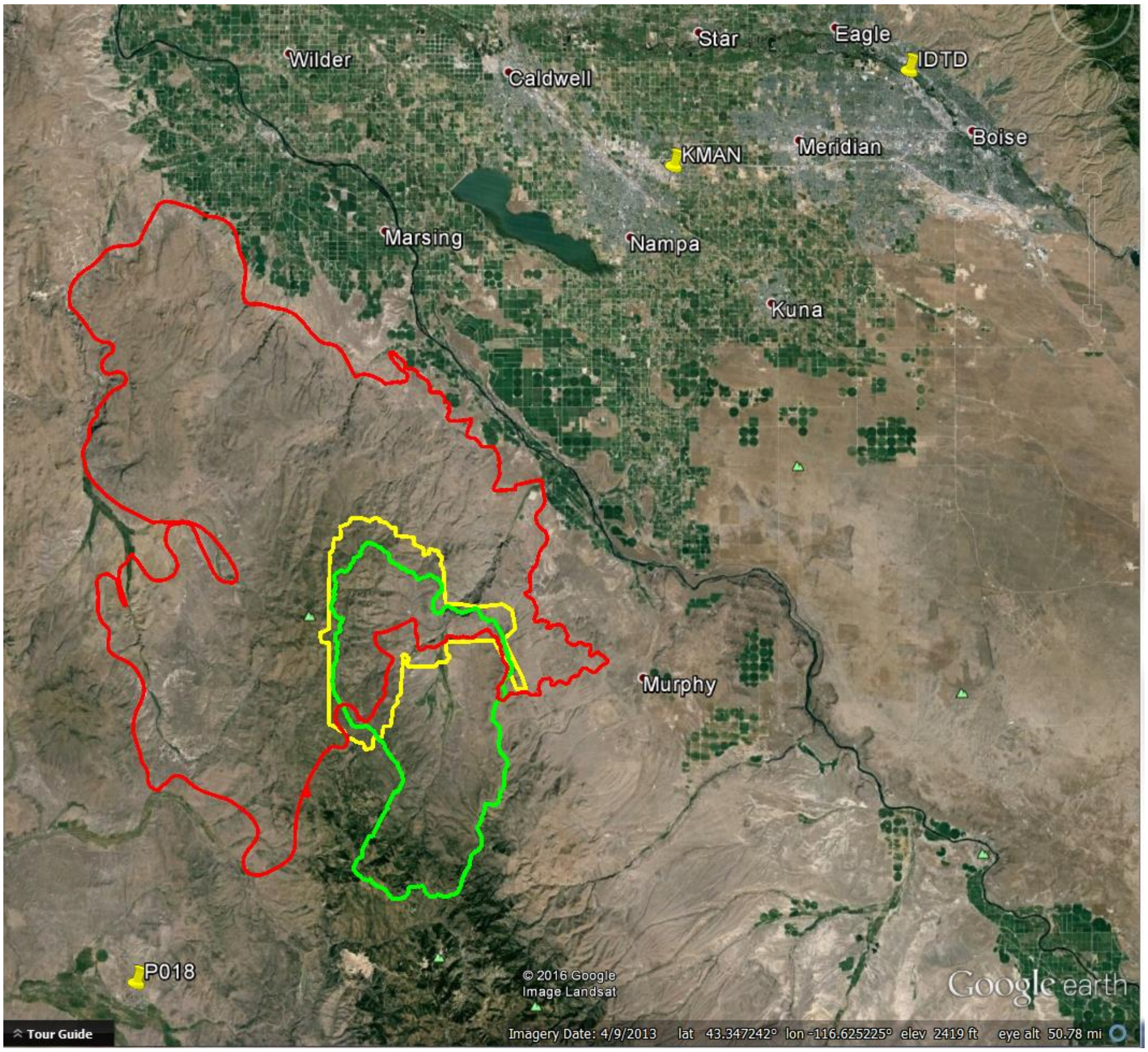

Figure 1 – Shape and location of survey LiDAR coverage polygon shown in yellow, Soda fire scar shown in red, Reynolds Creek CZO shown in green. Yellow push-pin markers show GPS reference locations IDTD, P018, and KMAN. (Google Earth).

3. Data Collection.

3.1 Survey Dates

The survey took place in two flights, the first flight on October 16, 2015 and the second on October 21, 2015 (DOY 289 and 294).

3.2 Airborne Survey Parameters

Survey parameters are provided below in Table 2.

Nominal Flight Parameters		Equipment Settings		Survey Totals	
Flight Altitude	700 m	Laser PRF	375 kHz	Total Flight Time	6.9 hrs.
Flight Speed	66 m/s	Scan Frequency	25 Hz	Total Laser Time	2.6 hrs.
Swath Width	744 m	Scan Angle	± 30°	Total Swath Area	150 km^2
Swath Overlap	Min 50 %	Scan Cutoff	2.0°	Pass spacing	380 m
Point Density	10-35 p/m^2				

Table 2 – Nominal flight parameters, equipment settings and survey totals for LIDAR collection; actual parameters vary with the terrain.

3.3 Reference GPS

Three GPS reference stations were used. One was set by NCALM at the Nampa Airport (**KMAN**), another was part of the CORS permanent GPS network (**IDTD**) (see http://www.ngs.noaa.gov/CORS/) located northwest of Boise, ID and the third (**P018**) belongs to UNAVCO's PBO network (http://www.unavco.org/instrumentation/networks/status/pbo) and is 35 km southwest of the project area. Table 3 (below) gives the coordinates of the GPS reference station locations.

GPS station	KMAN	IDTD	P018
Agency	NCALM	CORS	UNAVCO
Latitude	43.58282	43.65294	42.98170
Longitude	-116.523890°	-116.28339	-117.06456

Table 3 – Coordinates of GPS reference stations in NAD83 (2011) Epoch 2010.0000

4. GPS/IMU Data Processing

Reference coordinates (NAD83 (2011) Epoch 2010.0000) for all the stations are derived from observation sessions taken over the project duration and submitted to the NGS on-line processor OPUS which processes static differential baselines tied to the international CORS network. For further information on OPUS see http://www.ngs.noaa.gov/OPUS/ and for more information on the CORS network see http://www.ngs.noaa.gov/CORS/

Airplane trajectories for this survey were processed using KARS (Kinematic and Rapid Static) software written by Dr. Gerald Mader (retired) of the NGS Research Laboratory. KARS kinematic GPS processing uses the dual-frequency phase history files of the reference and airborne receivers to determine a high-accuracy fixed integer ionosphere-free differential solution at 1 Hz. All final aircraft trajectories for this project are blended solutions from at least two stations.

After GPS processing, the 1 Hz trajectory solution and the 200 Hz raw inertial measurement unit (IMU) data collected during the flights are combined in APPLANIX software POSPac MMS (Mobile Mapping Suite Version 7). POSPac MMS implements a Kalman Filter algorithm to produce a final, smoothed, and complete navigation solution including both aircraft position and orientation at 200 Hz. This final navigation solution is known as an SBET (Smoothed Best Estimated Trajectory).

4. Data Processing Overview

4.1 LiDAR.

The following diagram (Figure 2) shows a general overview of the NCALM LiDAR data processing workflow

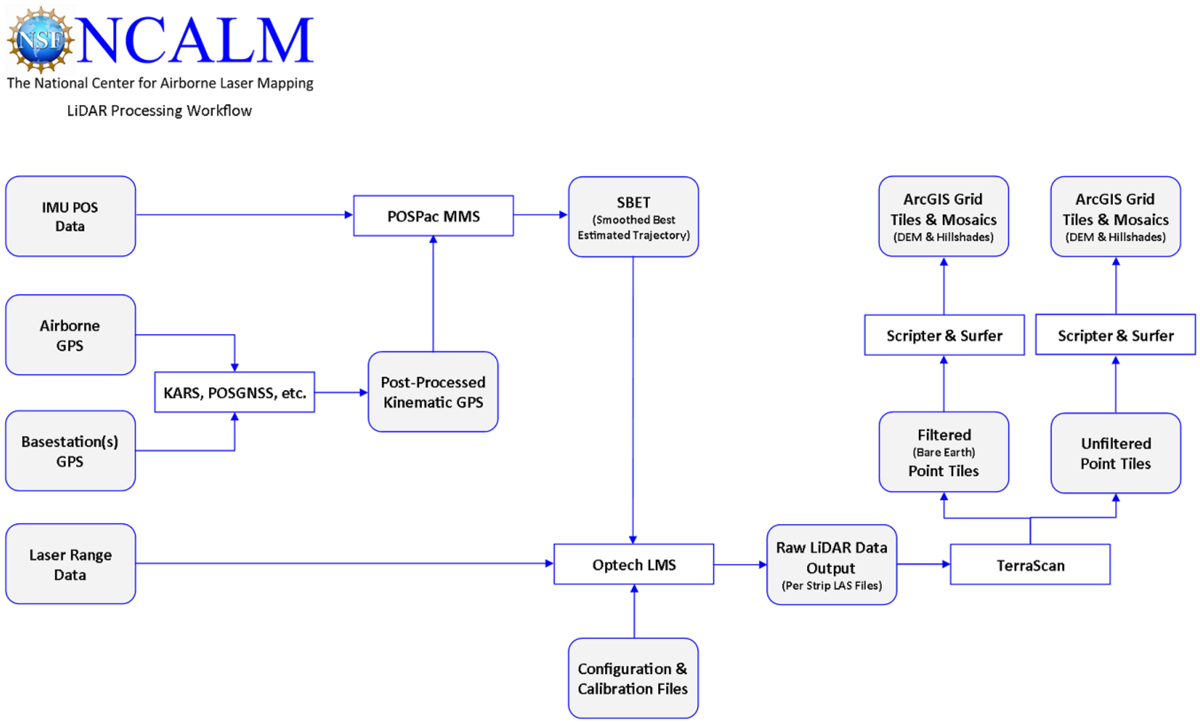

Figure 2 - NCALM LiDAR Processing Workflow

Classification done by automated means using TerraSolid software (TerraScan Version 14.017). http://www.terrasolid.com/products/terrascanpage.php

System calibration of the 3 sensor bore sight angles (roll, pitch, and yaw) and scanner mirror scale factor is done by automated means using LMSPro software provided by Optech. Overlapping parallel project lines along with perpendicular cross lines and lines over developed neighborhoods with many sloping roof lines are used as input into automated optimization and calibration routines. It uses least-squares algorithms to compute and apply optimal bore sight offsets and scale values that minimize height mismatches in overlapping flight lines. These routines are run and calibration values are updated for each flight.

There were 454 ground check points collected at the Nampa airfield using a vehicle-mounted GPS system to check for systematic vertical bias in the LIDAR data. No bias was observed; the RMS for the elevation differences was 0.03 m. Note that any LiDAR-derived DEM accuracy will usually degrade on steep terrain and under canopy.

NCALM makes every effort to produce the highest quality LiDAR data possible but every LiDAR point cloud and derived DEM will have visible artifacts if it is examined at a sufficiently fine level. Examples of such artifacts include visible swath edges, corduroy (visible scan lines), and data gaps. A detailed discussion on the causes of data artifacts and how to recognize them can be found here:
http://ncalm.berkeley.edu/reports/GEM_Rep_2005_01_002.pdf .
A discussion of the procedures NCALM uses to ensure data quality can be found here:
http://ncalm.berkeley.edu/reports/NCALM_WhitePaper_v1.2.pdf

NCALM cannot devote the required time to remove all artifacts from data sets, but if researchers find areas with artifacts that impact their applications they should contact NCALM and we will assist them in removing the artifacts to the extent possible – but this may well involve the PIs devoting additional time and resources to this process.

5. Data Deliverables

a) **Horizontal Datum**: NAD83 (2011)
b) **Vertical Datum:** NAVD88 (GEOID 12a)
c) **Projection:** UTM Zone 11N
d) **Units: meters**
e) **File Formats:**
    1. Point Cloud in LAS format (version 1.2), classified as ground or non-ground, in 1 km square tiles.
    2. ESRI float format 1.0-m DEM from ground classified points.
    3. ESRI raster format 1.0-m Hillshade raster from ground classified points
    4. ESRI float format 1.0-m DEM from first return points.
    5. ESRI raster format 1.0-m Hillshade raster first return points.
    6. ESRI raster format 1.0-m DEM of canopy heights created by subtracting the bare earth DEM from the HighZ raster (created by extracting the highest Z value in the point cloud for each 1 m pixel).

f) **File naming convention for LIDAR point clouds:** 1 km tiles follow a naming convention using the lower left coordinate (minimum X, Y) as the seed for the file name as follows: XXXXXX_YYYYYYY. For example if the tile bounds coordinate values from easting equals 535000 through 536000, and northing equals 4820000 through

4821000 then the tile filename incorporates 535000_4820000. The ESRI DEMs are mosaic files created by combining together the 1 km tiles to get a single mosaic file for each: bare earth and first return surface models.