Avalanche Forecasting and Acoustic Detection Using Airborne Laser Swath Mapping Data:
SEED Project

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1. LiDAR System Description and Specifications

This survey was performed with an Optech Gemini Airborne Laser Terrain Mapper (ALTM) serial number 06SEN195 mounted in a twin-engine Chieftain aircraft (Tail Number N931SA). The instrument nominal specifications are listed in table 1.

Operating Altitude	150-4000 m, Nominal
Horizontal Accuracy	1/5,500 x altitude (m AGL); 1 sigma
Elevation Accuracy	5 - 35 cm; 1 sigma
Range Capture	Up to 4 range measurements, including 1st, 2nd, 3rd, last returns
Intensity Capture	12-bit dynamic range for all recorded returns, including last returns
Scan FOV	0 - 50 degrees; Programmable in increments of ±1degree
Scan Frequency	0 – 70 Hz
Scanner Product	Up to Scan angle x Scan frequency = 1000
Roll Compensation	±5 degrees at full FOV – more under reduced FOV
Pulse Rate Frequency	33 - 167 kHz
Position Orientation System	Applanix POS/AV 510 OEM includes embedded BD960 72-channel 10Hz (GPS and Glonass) receiver
Laser Wavelength/Class	1047 nanometers / Class IV (FDA 21 CFR)
Beam Divergence nominal (full angle)	Dual Divergence 0.25 mrad (1/e) or 0.80 mrad (1/e)

Table 1 – Optech GEMINI specifications (http://www.optech.ca/pdf/Gemini_SpecSheet_100908_Web.pdf).

See http://www.optech.ca for more information from the manufacturer.

2. Area of Interest.

The survey area consisted of a rectangular polygon located 24 Km west of Stanley, Idaho. The polygon is approximately 38.25 square Km and measured 4.5 Km wide by 8.5 Km long and is shown below in Figure1 (red outline).

Figure 1 – Shape and location of survey polygon (Google Earth).

3. Data Collection

a) **Survey Dates**: The survey took place on August 30, 2011 (DOY 242).
    Figure 2 shows the available coverage.

b) **Airborne Survey Parameters:** The survey parameters are provided in Table 2 below

Nominal Flight Parameters		Equipment Settings		Survey Totals	
Flight Altitude	600 m	Laser PRF	100 kHz	Total Flight Time	2.7 hrs
Flight Speed	60 m/s	Beam Divergence	0.25 mrad	Total Laser Time	1.0 hrs
Swath Width	460 m	Scan Frequency	45 Hz	Total Swath Area	43.6 km^2
Swath Overlap	50%	Scan Angle	± 21°	Total AOI Area	40.2 km^2
Point Density	5.2 p/m²	Scan Cutoff	2°		

Table2 – Survey Parameters and Totals.

c) **Ground GPS:** Three GPS reference station locations were used during the survey: KSTN
    and ROCK were set up by NCALM. Station P351 is part of the UNAVCO PBO network. All
    reference GPS observations were logged at 1 Hz. Table 3 gives the coordinates of the
    stations.

GPS station	KSTN	ROCK	P351
Operating agency	NCALM	NCALM	UNAVCO
Latitude	44.213615	44.213468	43.874410
Longitude	-114.933797	-114.933778	-114.719160
Ellipsoid Height (m)	1932.918	1932.854	2692.608

Table 3 – GPS Coordinates of ground reference stations

4. GPS/IMU Data Processing

Reference coordinates for all 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 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 the three stations.

After GPS processing, the trajectory solution and the raw inertial measurement unit (IMU) data
collected during the flights are combined in APPLANIX software POSPac MMS (Mobile
Mapping Suite Version 5.2). 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).

5. LiDAR Data Processing Overview

The following diagram (Figure 3) shows a general overview of the NCALM LiDAR data processing workflow
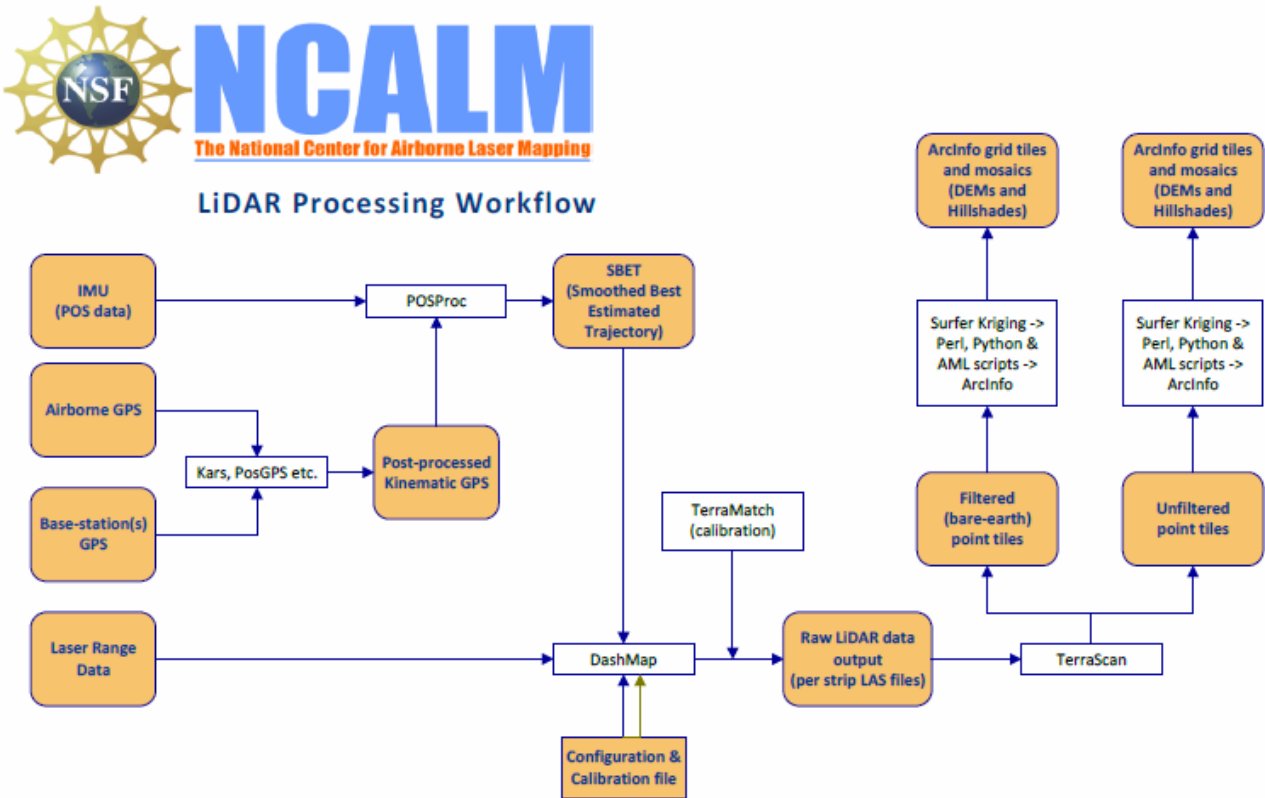

Figure 2 NCALM LiDAR Processing Workflow

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.

Classification done by automated means using TerraSolid Software
http://www.terrasolid.fi/en/products/4

6. Data Deliverables

a) **Horizontal Datum**: NAD83(2011)
b) **Vertical Datum:** GEOID 09
c) **Projection:** UTM Zone 11N
d) **File Formats:**

    1. Point Cloud in LAS format, classified as ground or non-ground, in 1 km square tiles.
    2. ESRI format 1-m DEM from ground classified points.
    3. ESRI format 1-m Hillshade raster from ground classified points
    4. ESRI format 1-m DEM from all points (canopy included).
    5. ESRI format 1-m Hillshade raster from all points (canopy included).

e) **File naming convention:** 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 639000 through 640000, and northing equals 4890000 through 4891000 then the tile filename incorporates 639000_4890000. These tile footprints are available as an AutoCAD DXF or ESRI shapefile. The ESRI DEMs are single mosaic files created by combining together the 1KM tiles. Their name consists of prefix 'fme' or 'ume' (depending whether the DEM is made using ground points or all points) and the lowest Easting coordinate rounded to the nearest 1000, for e.g. 'fme639000'. The hillshade files have a prefix 'sh' after the name, for e.g. 'fme639000sh'.

7. Notes

1. As requested in the seed proposal, vegetation has been classed by height from ground as follows:
    a) Low vegetation (<1 m) is class 3
    b) Medium vegetation (between 1 and 3 meters) is class 4.
    c) High vegetation (>3 m) is class 5.
2. Due to the mountainous terrain, high PRF of 100 KHz, and perhaps some ground fog, the bottom of the canyon in the southeast corner of the project has a very low point density. Hopefully this will have no impact on the scientific objectives of the project.