# Data Collection and Processing Report for 2013 SEED Project:
**A Deeper Insight into the Largest Reported Quaternary Debris Avalanche on Earth: The Case of Mount Shasta Volcano, Northern California**

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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 Cessna 337 Skymaster (Tail Number N337P). 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 $1^{st}$, $2^{nd}$, $3^{rd}$, 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) receiver |
| Laser Wavelength/Class | 1064 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. Areas of Interest.

The requested survey area consisted of a polygon located 115 Km North of Redding, California. The polygon encloses approximately 40 square km. Figure 1 (below) is an image from Google Earth showing the shape and location of the survey.



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

## 3. Data Collection

a) **Survey Dates**: The survey took place on August 05, 2013 (DOY 217).

b) **Airborne Survey Parameters:** 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 | 2.2 hrs |
| Flight Speed | +/- 60 m/s | Beam Divergence | 0.25 mrad | Total Laser Time | 1.2 hrs |
| Swath Width | 321.5 m | Scan Frequency | 50 Hz | Total Swath Area | 48.57 km$^2$ |
| Swath Overlap | Min 50 % | Scan Angle | ± 16° | Total AOI Area | 40 km$^2$ |
| Point Density | 9.71 p/m$^2$ | Scan Cutoff | 1.0$^o$ | Pass spacing | 183.4 m |

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

**c) Ground GPS:** Five GPS reference station locations were used during the survey: four of them belong to UNAVCO's PBO network (see http://pbo.unavco.org/ for more information from UNAVCO) and the remaining one was established by the NCALM field crew at the Siskiyou County airport in Montague, CA. All GPS reference observations were logged using dual-frequency geodetic-grade receivers and antennas at 1 Hz. Table 3 (below) gives the coordinates of the stations and Figure 2 shows the project area and the GPS reference station locations.

| GPS station | KSIY | P657 | P658 | P661 | P663 |
|---|---|---|---|---|---|
| **Agency** | NCALM | UNAVCO | UNAVCO | UNAVCO | UNAVCO |
| **Latitude** | 41.7816 | 41.3812 | 41.4792 | 41.4636 | 41.5319 |
| **W Longitude** | 122.4703 | 122.2938 | 122.1909 | 122.3127 | 122.1529 |
| **GRS80 Height** | 781.886 | 1684.901 | 1915.656 | 1324.659 | 2238.470 |

**Table 3 – Coordinates of GPS reference stations in NAD83 (2011) Epoch 2010.0000 - Ellipsoid Height in meters.**



**Figure 2 - Project area (with the planned flight lines shown in white) and GPS reference locations.**

# 4. GPS/IMU Data Processing

Reference coordinates (NAD83 (2011) Epoch 2010.0000) 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 at least three of the five available 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 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
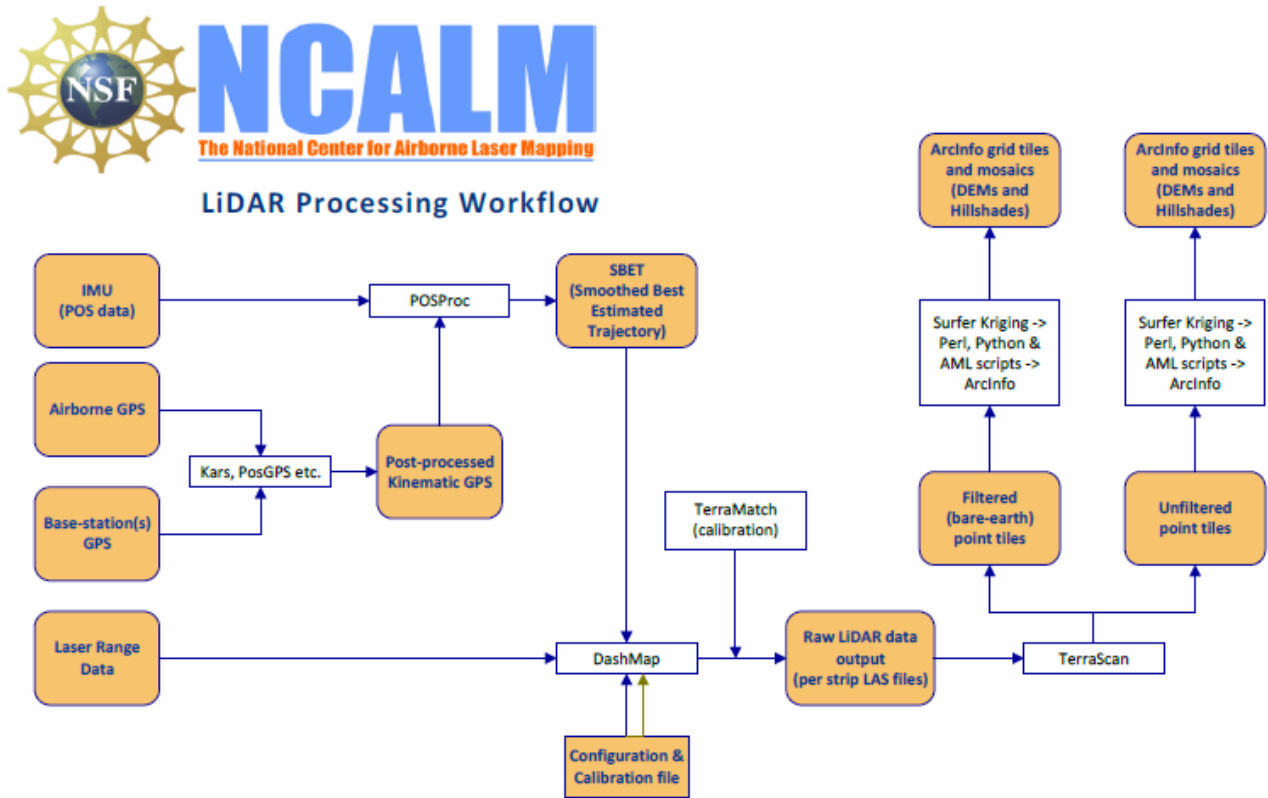


**Figure 3 - NCALM LiDAR Processing Workflow**

Classification done by automated means using TerraSolid Software (TerraScan Version 13.015).
http://www.terrasolid.fi/en/products/4

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.

# 6. Accuracy assessment

### a) Relative accuracy

System calibration of the 3 sensor bore sight angles (roll, pitch, and yaw) and scanner mirror scale factor is done by automated means using TerraSolid Software (TerraMatch). Project lines and off-project lines flown with opposite headings combined with perpendicular cross lines are used as input to TerraMatch (Version 13.006). The calibration values are checked on a flight-flight basis. After calibration values are determined project flight lines are checked for average mismatch. For this project the average delta Z for project flight lines is approximately 0.053 meters with a standard deviation of 0.032 meters.

### b) Absolute accuracy

No ground check points were collected for this project so a small (<0.15m) vertical bias in the elevations of the final point cloud and DEM may exist with respect to NAVD88. Note that any LiDAR-derived DEM accuracy will usually degrade on steep terrain and under canopy.

# 7. Data Deliverables

a) **Horizontal Datum**: NAD83 (2011)
b) **Vertical Datum:** NAVD88 (GEOID 12a)
c) **Projection:** UTM Zone 10N – meters.
d) **File Formats:**

1. Point Cloud in LAS format (Version 1.2), 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_YYYYYY. For example if the tile bounds coordinate values from easting equals 539000 through 540000, and northing equals 4617000 through 4618000 then the tile filename incorporates 539000_4617000. 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 'ume' and the lowest Easting coordinate rounded to the nearest 1000, for e.g. 'ume539000'. The hillshade files have a prefix 'sh' after the name, for e.g. 'ume539000sh'.