



Data Collection and Processing Report for 2013 SEED Project:
ASLM Survey of Exposed Subsurface Volcanic Features in San Rafael, Utah

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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 ±1 degree
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. Area of Interest.

The requested survey area is a rectangular polygon located 85 km southwest of Green River, Utah in the San Rafael region of the state. The polygon is approximately 4.5 km wide by 8.3 km long and encloses 40.5 square km. Figure 1 (below) is an image from Google Earth showing the shape and location of the survey.

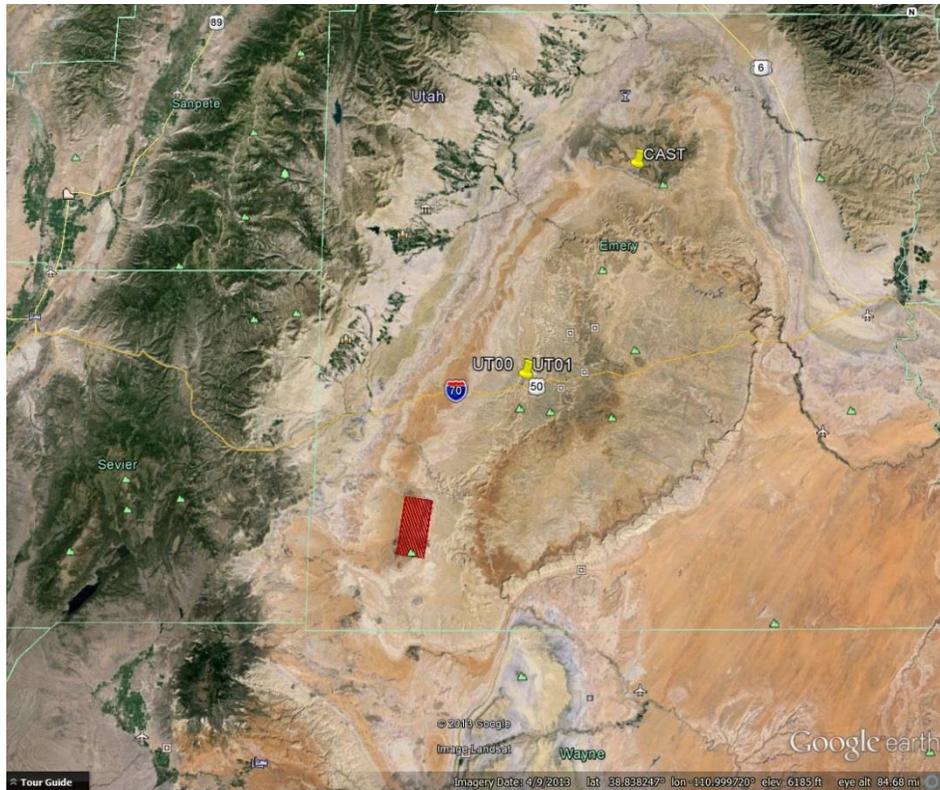


Figure 1 – Shape and location of survey polygon in red. GPS reference station locations are shown as yellow push pins. (Google Earth).

3. Data Collection

3.1 Survey Dates.

The survey took place on August 14, 2013 (DOY 226).

3.2 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	3.7 hrs.
Flight Speed	+/- 60 m/s	Beam Divergence	0.25 mrad	Total Laser Time	0.9 hrs.
Swath Width	460.6 m	Scan Frequency	40 Hz	Total Swath Area	40.5 km ²
Swath Overlap	Min 50 %	Scan Angle	± 24°	Total AOI Area	40.5 km ²
Point Density	6.25 p/m ²	Scan Cutoff	1.0°	Pass spacing	230 m

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

3.3 GPS Reference Stations

Three GPS reference station locations were used during the survey: one of them (CAST) belongs to UNAVCO's PBO network (see <http://pbo.unavco.org/> for more information from UNAVCO) and the remaining two (UT00 and UT01) were established by NCALM at a highway rest stop on I-70 westbound. All GPS reference observations were logged at 1 Hz.

Table 3 (below) gives the coordinates of the stations; refer above to Figure 1 for the relationship of the project area to the GPS reference station locations.

GPS station	UT00	UT01	CAST
Agency	NCALM	NCALM	UNAVCO
Latitude	38 51 22.21131	38 51 18.21035	39 11 27.66113
W Longitude	110 54 30.46094	110 54 26.68586	110 40 38.28101
GRS80 Height	2155.219	2162.374	2245.908

Table 3 – Coordinates of GPS reference stations in NAD83 (2011) Epoch 2010.0000 - ellipsoid height in meters.

4. GPS/IMU Data Processing

Control coordinates (NAD83 (2011) Epoch 2010.0000) for all GPS reference 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 all three reference 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

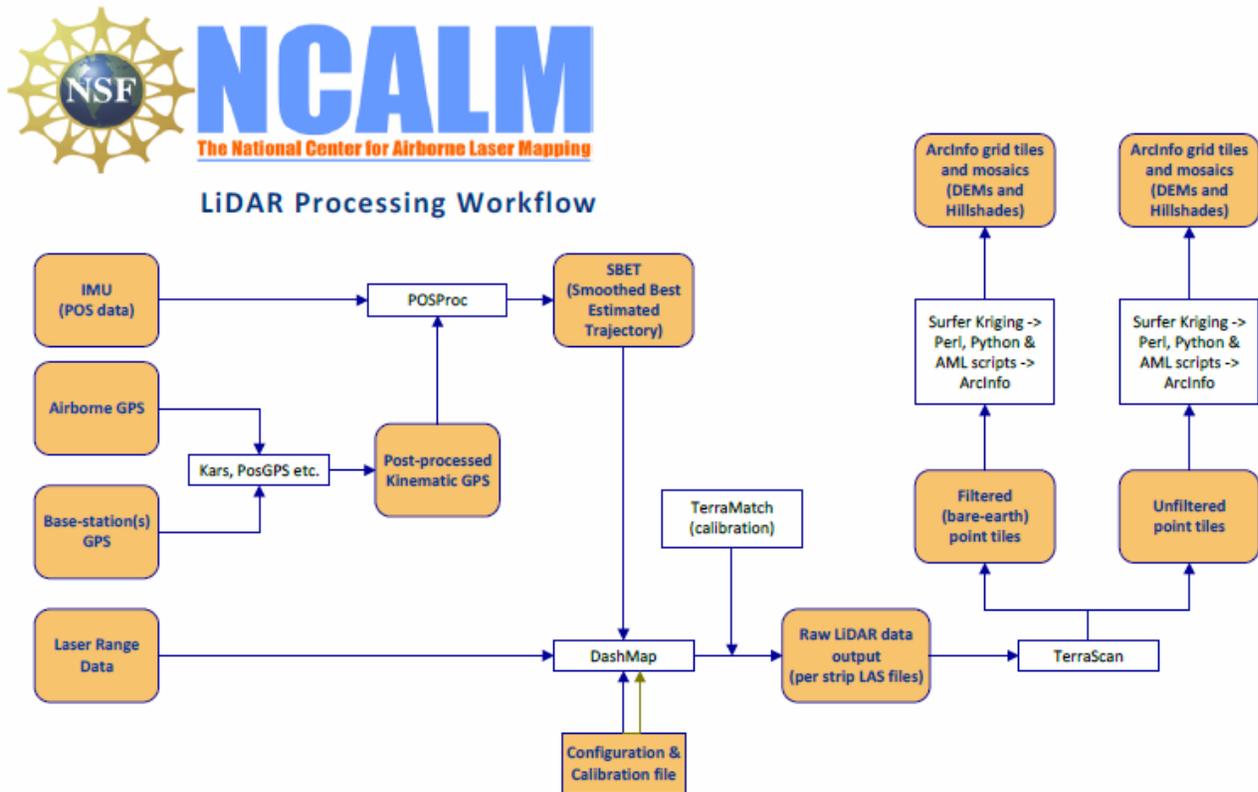


Figure 3 - NCALM LiDAR Processing Workflow

Classification of the ground points used to produce the bare-earth DEM was done by automated means using TerraSolid Software (TerraScan Version 13.015).

<http://www.terrasolid.com/home.php>

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. Calibration and Accuracy Assessment

6.1 Calibration

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.

6.2 Relative accuracy

To assess the relative accuracy of individual flight lines, surfaces are created from the ground-class points on a line by line basis and then the elevation mismatch between flight line surfaces in overlap areas is calculated over the entire project area. For this project the average elevation mismatch between individual flight lines is 0.050 meters.

Flightline	Points	Magnitude	Dz
17	22395691	0.0532	-0.0018
19	22255480	0.0485	0.0032
21	10905592	0.0494	0.0016
12	21627309	0.0484	-0.0031
14	23703576	0.0525	0.0029
11	19274844	0.0496	-0.003
7	16576428	0.0501	-0.0029
9	17918521	0.0504	-0.0018
3	21945857	0.048	0.0006
5	18382971	0.0488	0.0003
10	24794197	0.0493	0.0004
6	19124681	0.0554	0.0029
8	20378370	0.0488	-0.0003
16	25007638	0.0545	-0.0034
18	25345587	0.0507	0.0028
20	22221982	0.0471	0.0025
2	12524981	0.0504	-0.0001
4	20310247	0.0523	-0.0008
13	20084956	0.0507	0.0017
22	10747017	0.0497	-0.0045

Table 3 – Flight line elevation mismatch by flight line. Dz refers to the average of the signed differences between flight line surface elevations; Magnitude is the average of the unsigned differences.

6.3 Absolute Accuracy

No ground check points were collected for this project so it is possible that 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

7.1 Horizontal Datum: NAD83 (2011)

7.2 Vertical Datum: NAVD88 (GEOID 12a)

7.3 Projection: UTM Zone 12N – meters.

7.4 File Formats:

7.4.1 Point Cloud in LAS format (Version 1.2), classified as ground or non-ground, in 1 km square tiles.

7.4.2 ESRI format 1-m DEM from ground classified points.

7.4.3 ESRI format 1-m Hill shade raster from ground classified points.

7.4.4 ESRI format 1-m DEM from all points (canopy included).

7.4.5 ESRI format 1-m Hill shade raster from all points (canopy included).

7.5 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 491000 through 492000, and northing values are 4276000 through 4277000 then the tile filename incorporates 491000_4276000.

These tile footprints are available as an AutoCAD DXF or ESRI shapefile. The ESRI DEMs are single mosaic files created by combining together the 1 km tiles.