Data Collection and Processing Report for 2013 SEED Project:

Searching for Earthquake Induced Landslides in the Oregon Coast Range

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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 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) 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 consisted of two separate polygons located 38 km west of Eugene Oregon in the Oregon Coast Range. Together the polygons enclose approximately 40 square km. Figure 1 (below) is an image from Google Earth showing the shape and location of the survey.

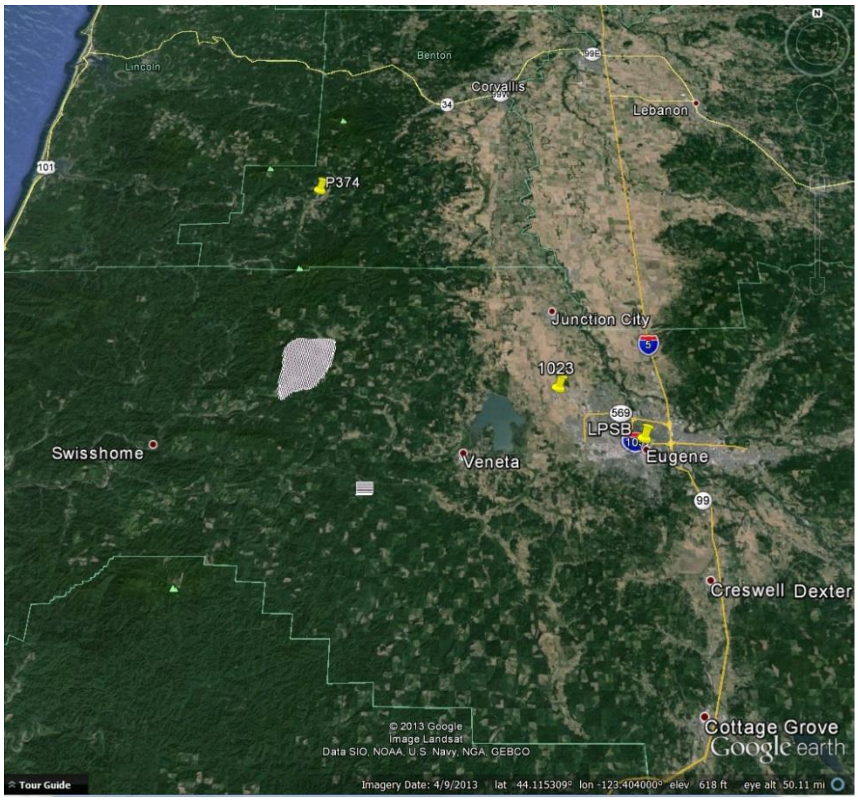

Figure 1 – Shape and location of survey polygons with planned flight lines in white. GPS reference station locations are shown as yellow push pins. (Google Earth).

3. Data Collection

3.1 Survey Dates.

The survey took place on August 02, 2013 (DOY 214).

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	4.5 hrs.
Flight Speed	+/- 60 m/s	Beam Divergence	0.25 mrad	Total Laser Time	1.1 hrs.
Swath Width	437 m	Scan Frequency	45 Hz	Total Swath Area	45.4 km^2
Swath Overlap	Min 50 %	Scan Angle	± 22°	Total AOI Area	40.0 km^2
Point Density	6.9 p/m^2	Scan Cutoff	2.0°	Pass spacing	218 m

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

3.3 GPS Reference Stations

Ground GPS: Three GPS reference station locations were used during the survey: one belongs to the national CORS network (see http://www.ngs.noaa.gov/CORS/), one belongs to UNAVCO's PBO network (see http://pbo.unavco.org/network/gps) and the remaining one was established by NCALM at the operational airport in Eugene. All GPS reference observations were logged at 1 Hz. Table 3 (below) gives the coordinates of the stations and Figure 1 (above) shows the project area and the GPS reference station locations.

GPS station	1023	P374	LPSB
Agency	NCALM	UNAVCO	NOAA/NGS
Latitude	44.11439	44.3819°	44.05123
W Longitude	123.21199	-123.5906°	123.09007
GRS80 Height	90.486	73.220	118.103

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

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/

4. GPS/IMU Data Processing

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

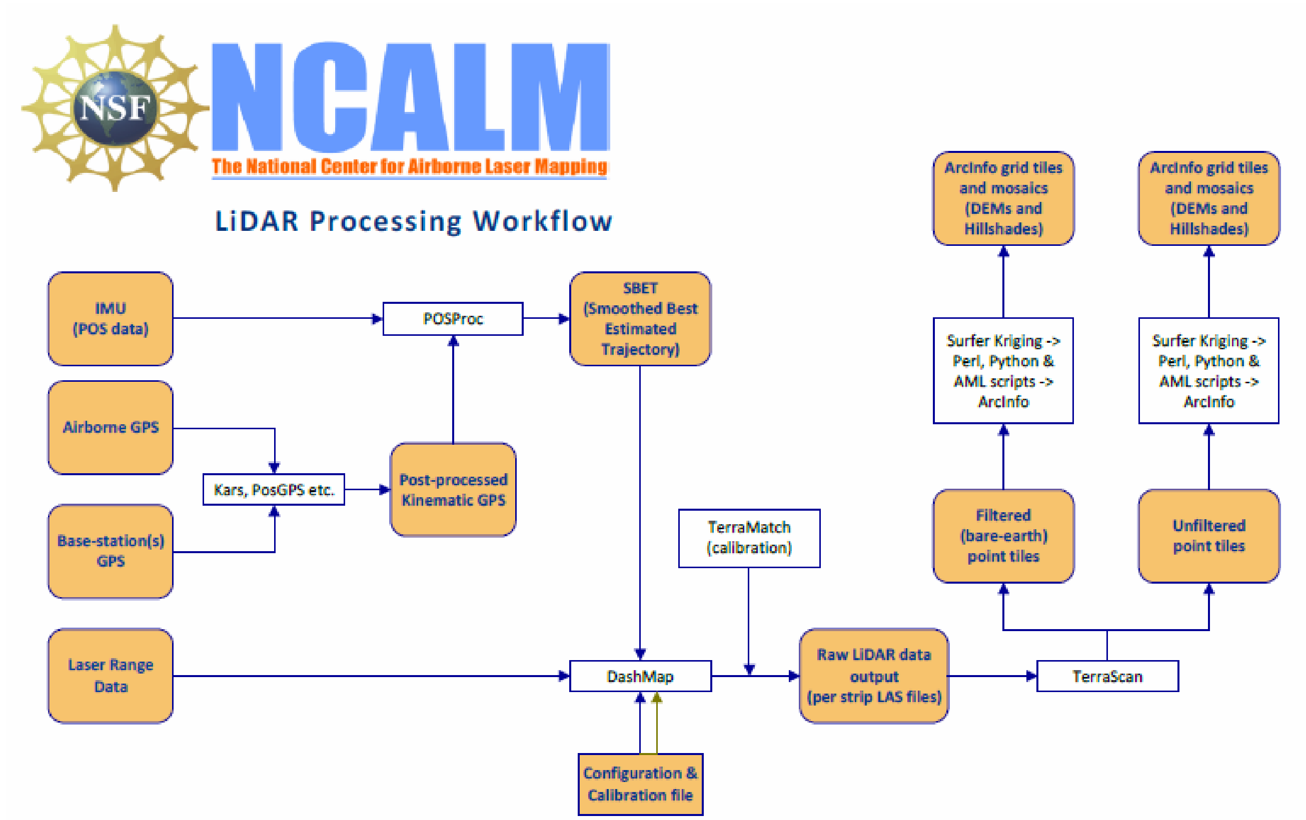

Figure 3 - NCALM LiDAR Processing Workflow

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 0.089 meters.

Line	Points	Magnitude	Dz	Line	Points	Magnitude	Dz
26	5763053	0.080	0.000	103	1002556	0.096	0.005
28	5363857	0.081	0.002	109	933680	0.094	-0.001
4	4697686	0.088	0.001	105	355669	0.123	-0.012
9	5376477	0.090	0.007	107	599583	0.116	-0.005
22	1821759	0.133	-0.006	108	1215236	0.100	0.001
6	6582683	0.081	0.005	109	1159745	0.098	0.002
11	6330918	0.080	0.004	102	171888	0.125	0.007
13	5651316	0.079	0.000	106	432623	0.124	-0.003
24	5546744	0.084	-0.002	14	6938451	0.066	0.003
15	4836185	0.086	-0.001	23	7812119	0.070	0.001
17	4385353	0.088	0.004	25	7206762	0.066	-0.003
31	4810034	0.087	-0.002	27	7272391	0.068	-0.004
33	4680097	0.091	-0.005	16	7255087	0.067	0.005
3	6583236	0.083	0.004	18	6708944	0.073	0.001
5	8549787	0.068	0.002	30	7018624	0.070	-0.005
8	6976882	0.086	0.001	32	5536214	0.076	-0.002
10	8666929	0.070	-0.007	20	4058277	0.078	0.002
19	4816961	0.092	0.002	1	941997	0.126	0.000
21	6677475	0.081	-0.004	2	1219953	0.131	0.003
12	7030930	0.067	-0.002	35	2480891	0.081	-0.006
				7	3355962	0.107	0.002

Table 4 – 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 10N – 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 451000 through 452000, and northing values are 4887000 through 4888000 then the tile filename incorporates 451000_4887000.

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.