Testing the Distribution of Slip in the Central Mojave: 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 06SEN/CON195 mounted in a twin-engine Piper PA-31 Chieftain aircraft (Tail Number N31PR). 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 and Glonass) receiver
Laser Wavelength/Class	1054 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/gemini.htm).

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

2. Area of Interest.

The original Seed project requested survey area of 40 km² was defined by two irregular polygons located along the Harper Lake Fault in the areas adjacent Gravel and Waterman Hills. Additional funding was secured to add two additional areas also located along the faults and between the original two polygons. The combined area of all the four polygons totaled 75.875 km². The Harper lake fault is aligned between the towns of Barstow and Ridgecrest, California. The location and extent of the polygon are shown below in Figure 1.

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

3. Data Collection

In order to optimize the data collected by maximizing the collected area for a given flight time the survey was planned as a corridor, rather than polygons. With this plan the corridor was designed to be 61.7 km long X 3.5 km wide.

a) Survey Dates: Two flights were required to collect the data. Both flights took place on Sunday June 17, 2012 (DOY 169). It was collected on a Sunday because part of the survey area are underneath Restricted airspace controlled by the Edwards Air Force Base and access to it is preferably granted on Sundays. Also due to airspace restrictions the flying height above average ground was 900m rather than the preferred 600m. The plan consisted of 16 project lines running NW – SE along the fault center line as depicted on Figure 2. The Barstow-Daggett Airport (KDAG) was used as base for this mission.

Figure 2 – Shape and location of survey polygon (Google Earth).

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

Nominal Flight Parameters		Equipment Settings		Survey Totals	
Flight Altitude	900m AGL	Laser PRF	100 kHz	Total Flight Time	7.65 hrs
Flight Speed	65 m/s	Beam Divergence	0.25 mrad	Total Laser Time	5.86 hrs
Swath Width	448.8 m	Scan Frequency	60 Hz	Total Swath Area	75.875 km^2
Swath Overlap	50%	Scan Angle	± 15°	Total AOI Area	215.95 km^2
Point Density	6.4 p/m²	Scan Cutoff	1°		

Table2 – Survey Parameters and Totals.

c) Ground GPS: Three GPS reference station locations were used during the survey, the stations are part of the UNAVCO PBO GPS network, see http://pbo.unavco.org/data/gps. Observations were logged at 1 Hz. Table 3 gives the coordinates of the stations, and Figure 3 shows the location of the GPS stations with respect to the project area.

GPS station	BSRY	P590	P592
Operating agency	UNAVCO	UNAVCO	UNAVCO
Latitude	34.918612	35.11677695	35.23844
Longitude	-117.011993	-117.36475	-117.30366
Ellipsoid Height (m)	613.5034	678.5257	1048

Table 3 – GPS Coordinates of ground reference stations

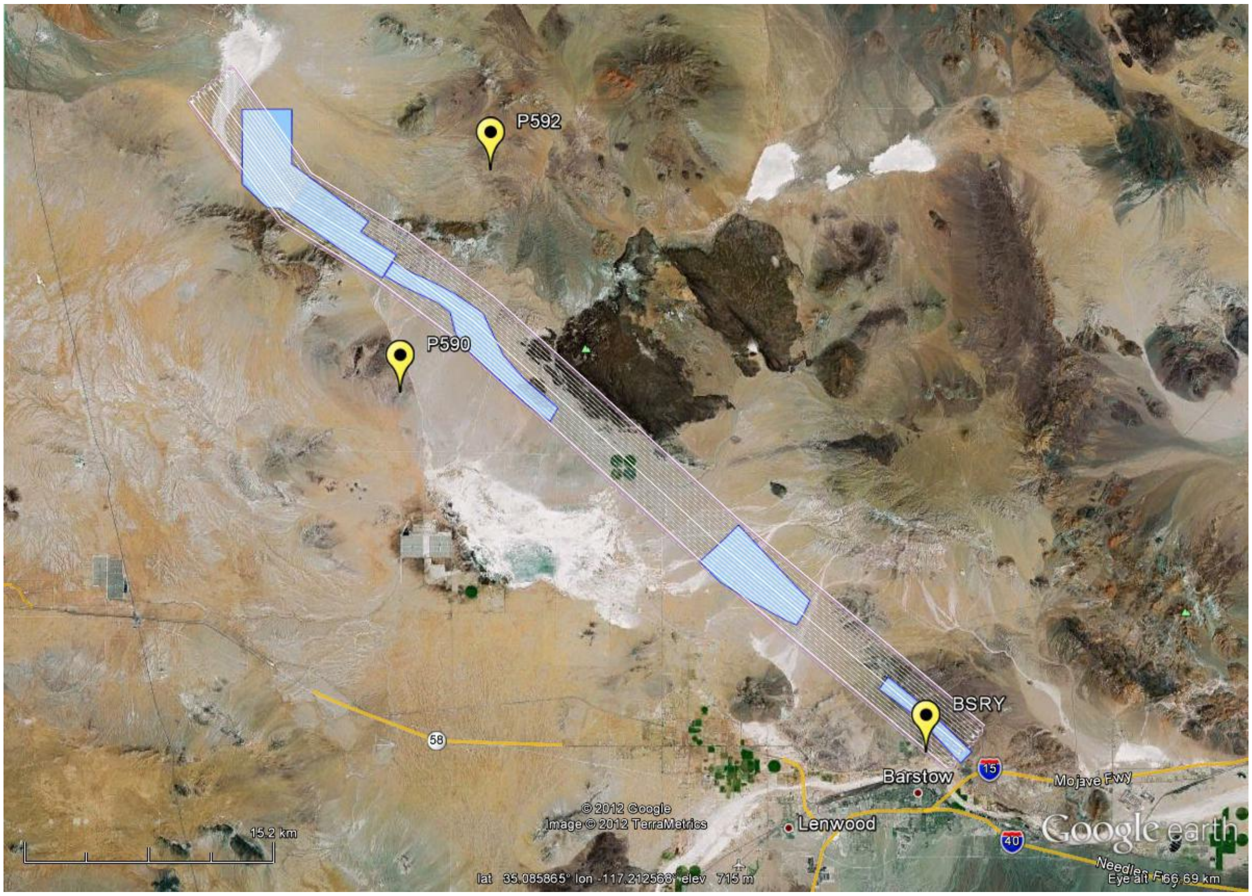

Figure 3 – Location of the GPS Stations used in the survey (Google Earth).

4. GPS/IMU Data Processing

Reference coordinates for all NCALM 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 4) shows a general overview of the NCALM LiDAR data processing workflow

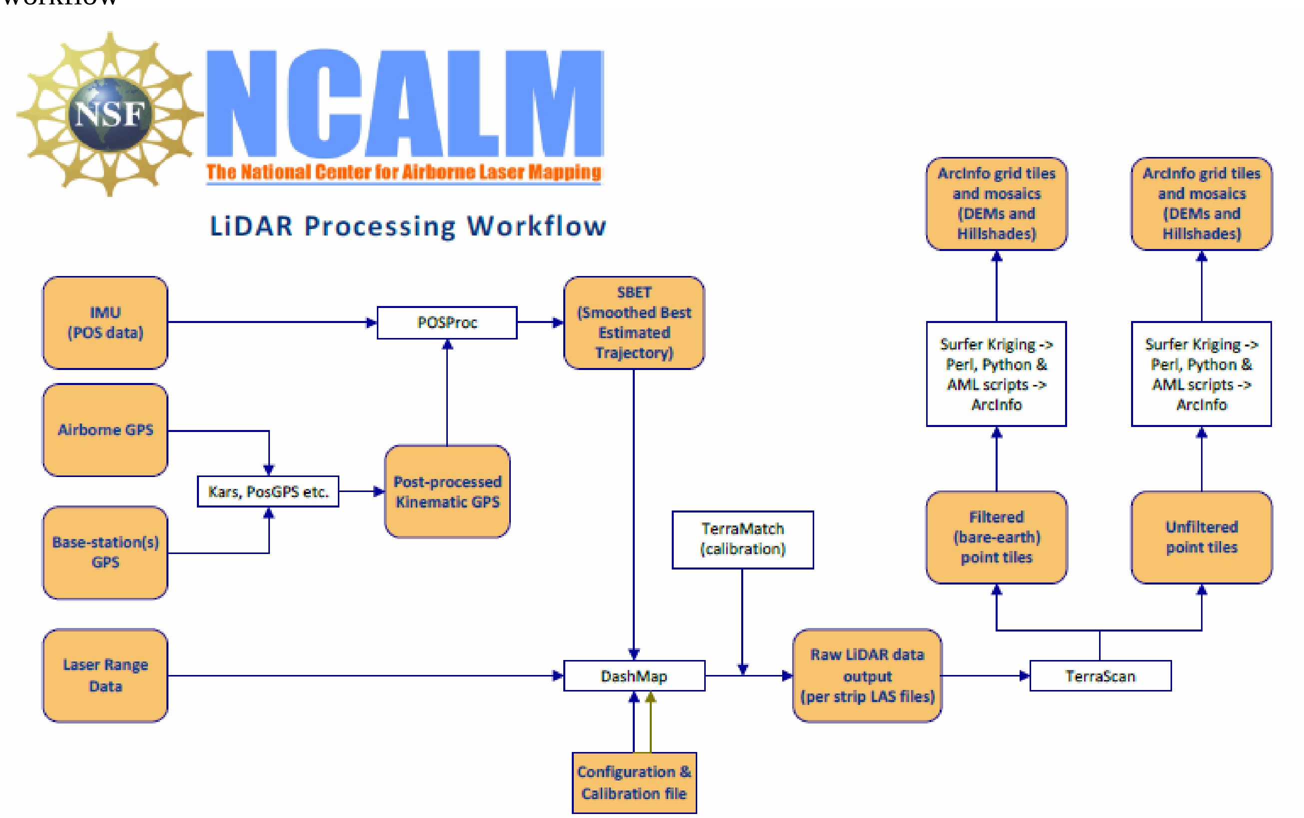

Figure 4 NCALM LiDAR Processing Workflow

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 453000 through 454000, and northing equals 3903000 through 3904000 then the tile filename incorporates 453000_3903000. 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. 'fme453000'. The hillshade files have a prefix 'sh' after the name, for e.g. 'fme453000sh'.