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 Chieftain aircraft (Tail Number N400JM). 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	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 survey area is defined by an irregular polygon located 12 kilometers west of Los Alamos, NM. The polygon dimensions are approximately 21 x 8 km, with an enclosed area of 162 km². The location and extent of the polygon are shown below in Figure 1.
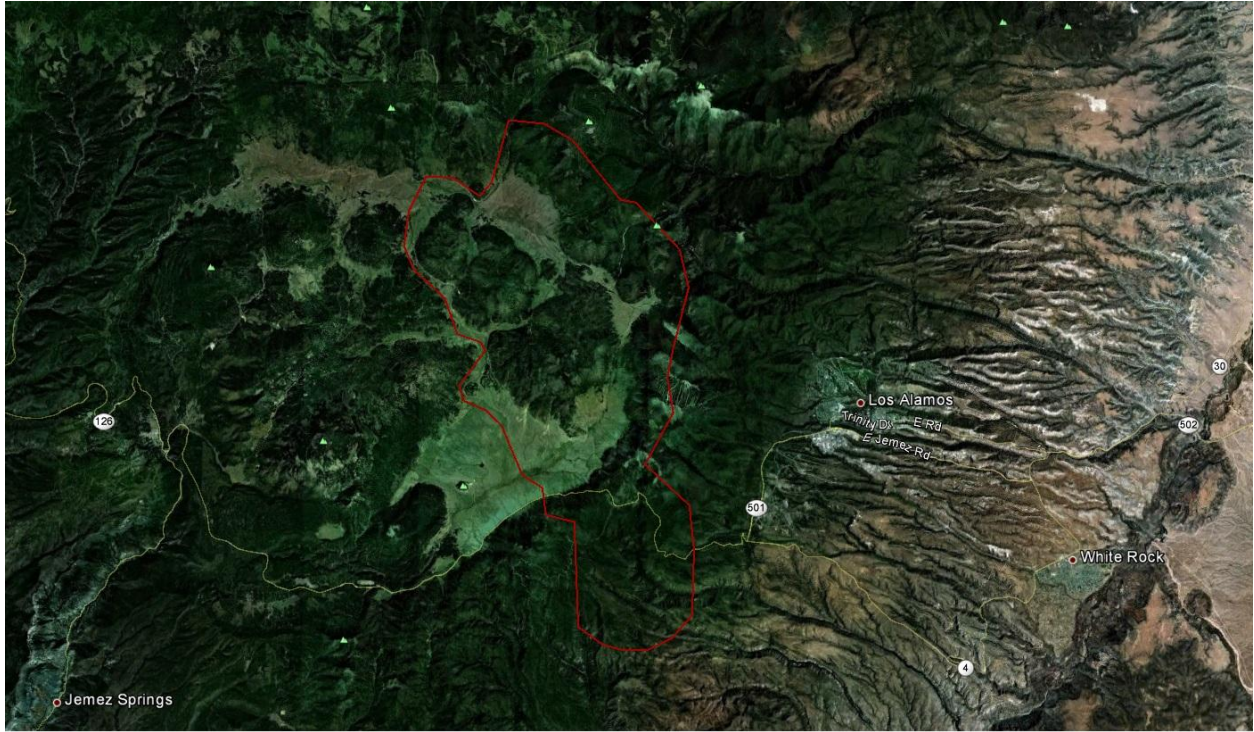

Figure 1 – Shape and location of survey polygon (Google Earth).

3. Data Collection

a) **Survey Dates**: The survey took place on May 25-28, 2012 (DOY 146-149) following plan file: Pelletier_NM_VallesCaldera_V2m.pln. The plan consisted of 92 project lines running north to south as well as cross lines flown for calibration purposes. The Santa Fe Airport (KSAF) was used as base for this mission.

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

Nominal Flight Parameters		Equipment Settings		Survey Totals	
Flight Altitude	600m AGL	Laser PRF	125 kHz	Total Flight Time	14.5 hrs
Flight Speed	65 m/s	Beam Divergence	0.25 mrad	Total Laser Time	5.7 hrs
Swath Width	360 m	Scan Frequency	60 Hz	Total Swath Area	174 km²
Swath Overlap	50%	Scan Angle	± 15°	Total AOI Area	162 km²
Point Density	12 p/m²	Scan Cutoff	1°		

Table2 – Survey Parameters and Totals.

c) **Ground GPS:** Three GPS reference station locations were used during the survey; two of these were run by NCALM: one at the airport at Santa Fe (SAF_) and one at the airport in Los Alamos (LAM_). The third reference station was the CORS station in Santa Fe, NMSF. See http://geodesy.noaa.gov/CORS/ for more information on the CORS network. Observations from the NCALM stations logged at 1 Hz, while NMSF logged at a 5-second rate that was interpolated to 1 Hz for processing. 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	SAF_	LAM_	NMSF
Operating agency	NCALM	NCALM	CORS
Latitude	35.61530	35.88130	35.67378
Longitude	-106.08085	-106.27903	-105.95859
Ellipsoid Height (m)	1902.840	2169.559	2097.239

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 and for more information on the CORS network see

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

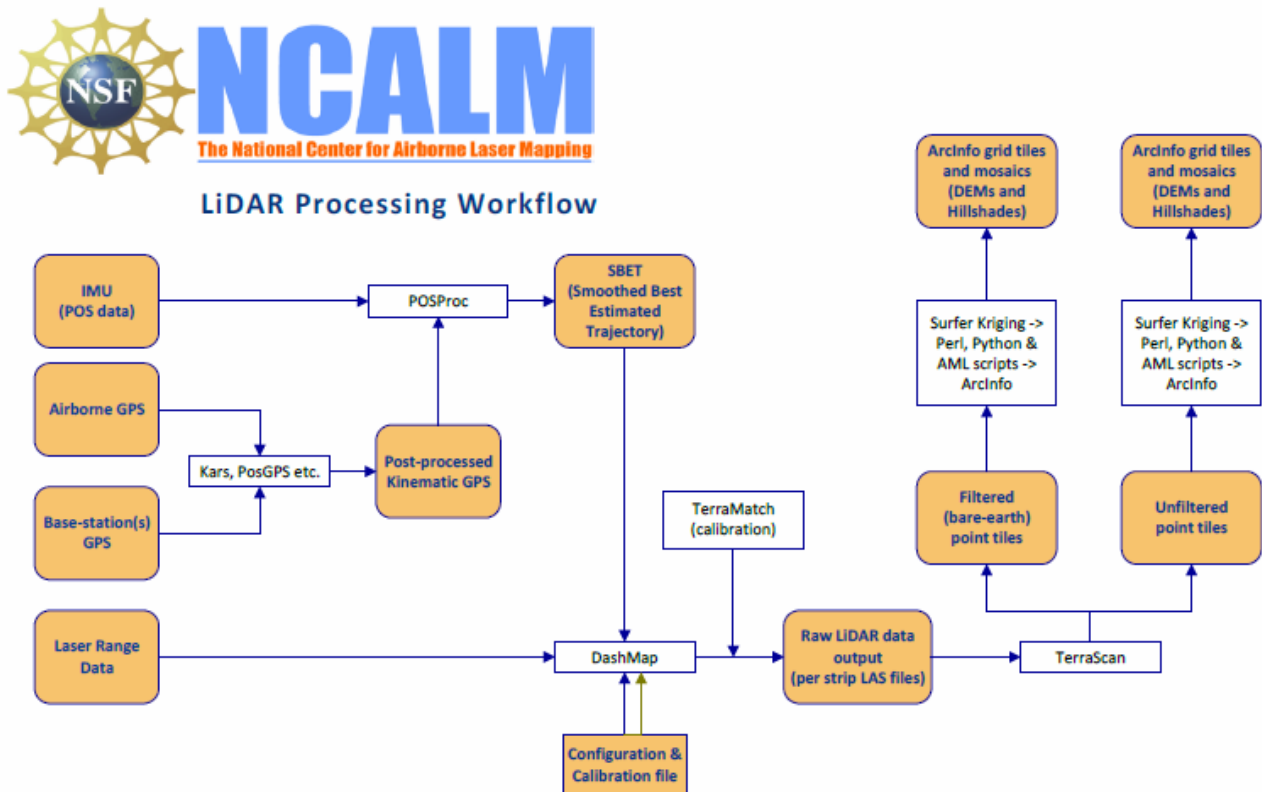The following diagram (Figure 4) shows a general overview of the NCALM LiDAR data processing workflow

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 – removal of outliers only.

http://www.terrasolid.fi/en/products/4

6. Data Deliverables

a) **Horizontal Datum**: NAD83(2011)
b) **Vertical Datum:** GEOID 09
c) **Projection:** UTM Zone 13N
d) **File Formats:**

1. Point Cloud in LAS 1.2 format, classified as ground or non-ground in 1 km square tiles.
2. ESRI format 1-m DEM from default-class points.
3. ESRI format 1-m Hillshade raster from default-class points
4. ESRI format 1-m DEM from ground-class points.
5. ESRI format 1-m Hillshade raster from ground-class points

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 370000 through 371000, and northing equals 3975000 through 3976000 then the tile filename incorporates 370000_3975000. These tile footprints are available as an AutoCAD DXF or ESRI shapefile. The ESRI DEMs are a single mosaic file. Their name consists of prefix 'ume' ('u' indicating that the DEM is made using default-class points, 'f' indicating ground-class points) and the lowest Easting coordinate rounded to the nearest 1000, for e.g. 'ume362000'. The hillshade files have a prefix 'sh' after the name, for e.g. 'ume362000sh'.

7. Notes

Accuracy assessments on these data were performed by comparing bare-earth surfaces created from individual flight lines in the zones where these surfaces overlapped both in the project area and over a separate calibration site in Los Alamos. The average height difference between the surfaces of adjacent flight lines was less than 0.05 m.