Data Collection and Processing Report for 2015 Mapping Project of the Walker Fault System in Nevada

PI: Steven G. Wesnousky

Steven G. Wesnousky Professor of Geology and Seismology Director Center for Neotectonic Studies 1664 North Virginia Street University of Nevada, Reno Reno, NV 89557 USA	Email: wesnousky@unr.edu Phone: 77578456067

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 Piper PA-31-350 Navajo Chieftain (Tail Number N154WW). The instrument nominal specifications are listed in Table 1.

Table 1 – Optech GEMINI specifications from Optech.

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)

See http://www.teledyneoptech.com/index.php/products/airborne-survey/ for more information from the manufacturer.

2. Areas of Interest.

The requested survey consists of a 1-km wide swath centered along 335 km of fault centerlines. There were a total of 44 fault segments for 12 fault lines, totaling a nominal 335 km² of map area. The faults are spread throughout an area of 15,600 km² of central western Nevada east of Lake Tahoe. The faults names and 4 letter identifiers used for the data products are: Antelope Valley (AntV), Benton (Bent), Benton North (BntN), Bridgeport (Brdg), Carson Linement (CarL), Little Valley (LitV), Mason (Masn), Petrified Springs (PetS), Smith Valley (SmtV), Wassuks (Wass), Wabuska (Wbsk), Olinghouse Opton (OlOp). Figure 1 (below) displays an image from Google Earth showing the location and extent of the mapped faults.

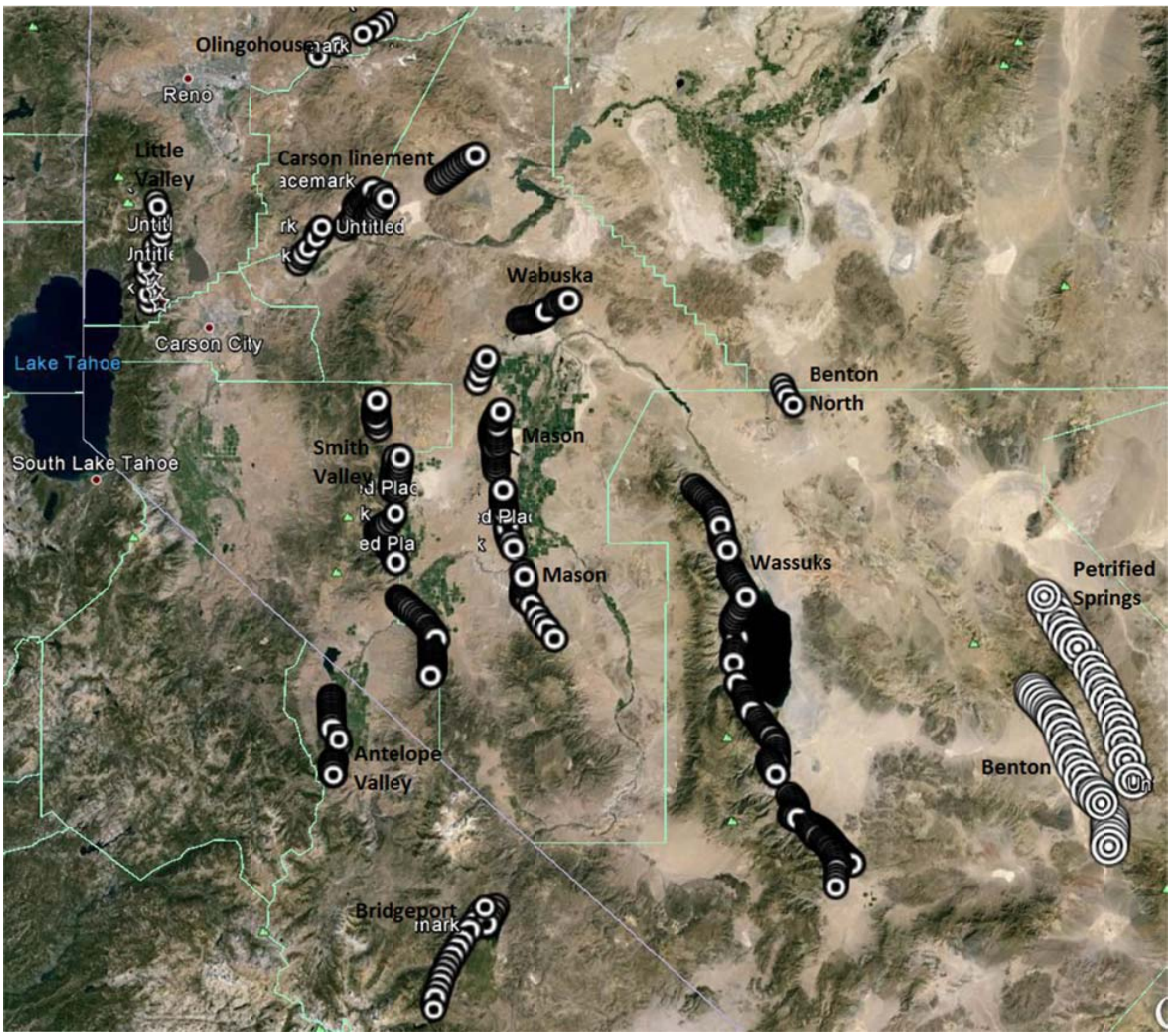

Figure 1 – Location and extent of faults segments that comprise the Walker Fault System and were mapped as part of this project.

3. Data Collection

a) Survey Dates: A total of 9 flights were required to collect data for the 12 faults, the flights took place between June 27th and July 1st, 2015 (DOYs: 178-182) and between July 13th and July 15th (DOYs: 194-196). Table 2 provides details about the flights.

Table 2 – Project flight information (ET: engine on time, FT: flight time, LOT: laser –on-time).

Flight	Date	DOY	ET [hr]	FT [hr]	LOT [hr]	Areas Mapped	# Strips	LAS Strip Numbers
1	27-Jun-15	178	4.6	4.2	2.4	Carson,Olinghouse	29	1001-1029
1						Little Valley	13	1030-1042
2	27-Jun-15	178	1.8	1.5	0.5	Carson	29	2001-2029
3	28-Jun-15	179	6	5.6	3.05	Wassuks	37	3001-3037
4	28-Jun-15	179	1.95	1.15	0.25	Benton North	11	4001-4011
5	30-Jun-15	181	5.5	5.15	2.7	Mason Wabuska	33	5001-5033
						Little Valley Polygon	15	5034-5048
6	1-Jul-15	182	1.78	1.51	0.47	Bridgeport Partial	8	6001-6008
7	13-Jul-15	194	5.55	5.25	1.85	Calibration Smith	31	7001-7031
						Bridgeport (L2-13), Antelope	30	7032-7061
						Smith	8	7062-7064
8	14-Jul-15	195	1.74	1.74	0.72	Smith	23	8001-8023
9	15-Jul-15	196	5.3	4.94	2.67	Petrified, Benton, Smith	35	9001-9034
		Totals	**34.2**	**31.0**	**14.61**			

Note on flight line numbering: The flight number assigned to each of the returns contained on the .LAS tiles has been encoded with four digits. Where the first digit corresponds to the flight number and the next three digits correspond to the sequential order of each flight strip for that particular flight.

b) Nominal Airborne Survey Parameters: Survey parameters are provided in Table 3 below.

Table 3 – Nominal flight parameters, equipment settings and survey totals; actual parameters vary with the terrain.

Nominal Flight Parameters		**Equipment Settings**		**Survey Totals**	
Flight Altitude	600 m	Laser PRF	125 kHz	Total Flight Time	34.2 hr.
Flight Speed	65 m/s	Beam Divergence	0.8 mrad	Total Laser Time	14.61 hr.
Swath Width	335 m	Scan Frequency	60 Hz	Total Swath Area	650 km^2
Swath Overlap	Min 50 %	Scan Angle	± 15°	Total AOI Area	335 km^2
Shot Density	12 s/m^2	Scan Cutoff	1.0°	Pass spacing	N/A

c) Ground GPS: A total of 14 GPS reference station locations were used throughout the project flights, not all of them were used to derive navigation solutions for a given flight. Perhaps, data from two to three stations were used for each flight. All stations belong to the UNAVCO

PBO network (see http://pbo.unavco.org/ for more information). All GPS reference observations were logged at 1 Hz. Table 4 (below) gives the coordinates of the stations and Figure 1 (above) shows the project area and the GPS reference station locations.

Table 4 – Coordinates of GPS reference stations in NAD83 (2011) Epoch 2010.0000.

Station	**SLID**	**P142**	**P143**	**P136**	**P135**	**P134**	**P130**
Latitude:	39.314	39.124	38.760	38.761	38.705	38.981	39.268
Longitude:	-119.884	-119.811	-119.765	-119.459	-119.015	-118.930	-118.938
Elevation:	2902.526	1782.358	1734.138	1773.270	1692.140	1886.571	1380.067
Station	**P127**	**P128**	**P133**	**P308**	**P654**	**P649**	**P627**
Latitude:	39.499	39.486	38.725	37.901	38.058	37.903	37.973
Longitude:	-119.600	-119.069	-118.460	-119.840	-119.150	-118.736	-118.379
Elevation:	1523.935	1320.581	1782.415	1502.000	2054.062	2154.551	2342.761

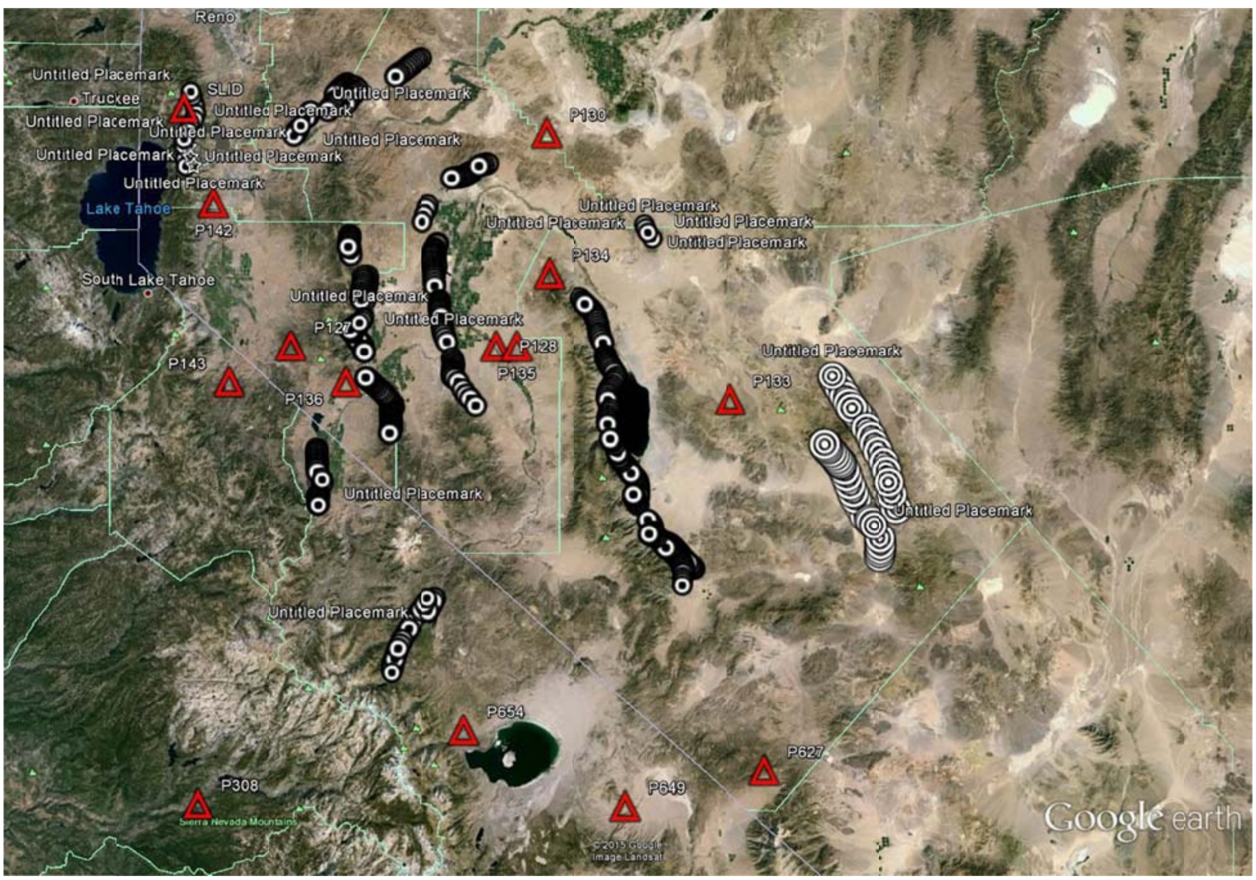

Figure 2 – Location of GPS stations in relation to the mapped faults.

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 14 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 using the APPLANIX software POSPac MMS (Mobile Mapping Suite Version 7.1). 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 2) shows a general overview of the NCALM LiDAR data processing workflow

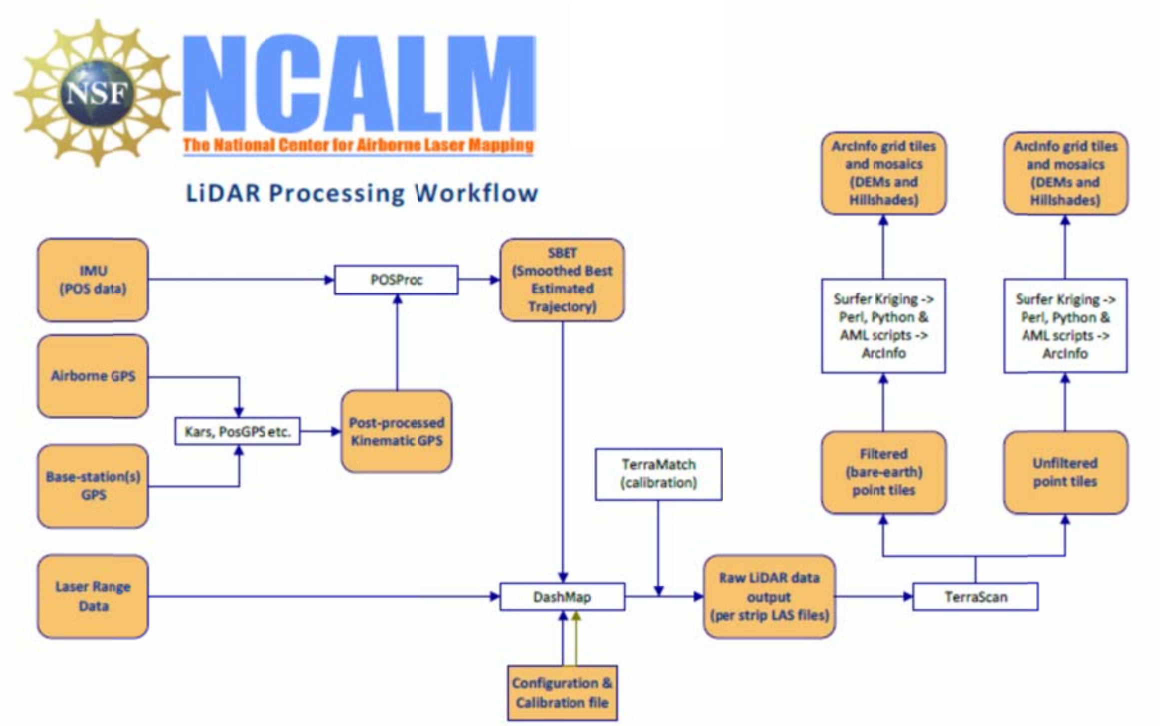

Figure 3 - NCALM LiDAR Processing Workflow

Classification done by automated means using TerraSolid software (TerraScan Version 14.017).
http://www.terrasolid.com/products/terrascanpage.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. 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 15.009). These calibration values are checked on a flight-flight basis.

After calibration values are optimized, project flight lines are output and then classified into ground and non-ground classes. Surfaces are developed for each flight strip from the ground class points, and then these individual flight strip surfaces are differenced and a value for the magnitude of the height mismatch over the entire project area is calculated.

For the surveyed area the average magnitude for vertical mismatch of ground surfaces (unsigned vertical differences between flight strips) in overlap zones is 0.047 m.

b) Absolute accuracy

No ground check points were collected for this project so a small (<0.15 m) 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 11N
d) **Units: meters.**
e) **File Formats:**

1. LiDAR returns in LAS format (Version 1.2), classified as ground or non-ground, in 500 m x 500 m square tiles.
2. ESRI format 0.5-m DEM from ground classified points.
3. ESRI format 0.5-m Hillshade raster from ground classified points
4. ESRI format 0.5-m DSM from first return (canopy included).
5. ESRI format 0.5-m Hillshade raster from first return (canopy included).

f) **LAS tile file naming convention:** The 500 m 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 556000 through 557000, and northing equals 3769000 through 3770000 then the tile filename incorporates 556000_3769000. The ESRI DEMs are mosaic files created by combining together the 1 km tiles.
g) **ArcGIS rasters naming conventions:** Due to the limited number of characters that can be used for ArcGIS data products the following format was followed: **NNNN-S-TWR##**. Where “NNNN” correspond to the 4 letter identifier of the fault as described in section 2 of this report; S can be either a number or a letter (1-4 , or N,S,E,W) that is an identifier for the raster section; the eight caracter of “T” represent the type of raster and it can be an “G” for a grid or “H” for a hillshade; the ninth character “W” represent what kind of data was used to create the raster and it can be an “E” for elevation or an “I” for intensity; the tenth character or “R” represents the type of return that was used for creating the raster and could be a “F” for First return or “G” for ground return, the last two characters “##” represent the raster resolution in decimeters. For example the raster “Wass_3_GEG05.flt” corresponds to the **Wass**uks fault, from the **3**rd section, it is a **G**rid, based on **E**levation data, obtained from the **G**round returns, with a resolution of **05** decimeters or 50 cm.