



Extending Predictions of Bonneville Cutthroat Trout Spawning Hotspots Using Multi-Scalar LiDAR: 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 06SEN195 mounted in a twin-engine Chieftain aircraft (Tail Number N931SA). 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 BD950 72-channel 10Hz GPS receiver
Laser Wavelength/Class	1047 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 survey area consisted of an irregular polygon located 26 km northeast of Logan, Utah. The polygon is approximately 36.0 square km and measured 5.5 km wide by 6.9 km long and is shown below (with approximate flight lines) in Figure 1.



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

3. Data Collection

a) **Survey Dates:** The survey took place on August 31, 2011 (DOY 243).

b) **Airborne Survey Parameters:** The 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	4.8 hrs
Flight Speed	60 m/s	Beam Divergence	0.25 mrad	Total Laser Time	1.1 hrs
Swath Width	460 m	Scan Frequency	45 Hz	Total Swath Area	40.6 km ²
Swath Overlap	50%	Scan Angle	± 21°	Total AOI Area	36.0 km ²
Point Density	3.5 p/m ²	Scan Cutoff	2°		

Table 2 – Survey Parameters and Totals.

c) **Ground GPS:** Three GPS reference station locations were used during the survey: 1LGN (set by NCALM), P101, and HWUT. Stations P101 and HWUT are part of the UNAVCO PBO network. All reference GPS observations were logged at 1 Hz. Table 3 gives the coordinates of the stations.

GPS station	1LGN	HWUT	P101
Operating agency	NCALM	UNAVCO	UNAVCO
Latitude	41.77922938	41.60724088	41.69227400
Longitude	-111.8560669	-111.5651155	-111.2360160
Ellipsoid Height (m)	1354.790	1715.073	2016.123

Table 3 – GPS Coordinates of ground reference stations

4. GPS/IMU Data Processing

Reference coordinates 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 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 3) shows a general overview of the NCALM LiDAR data processing workflow

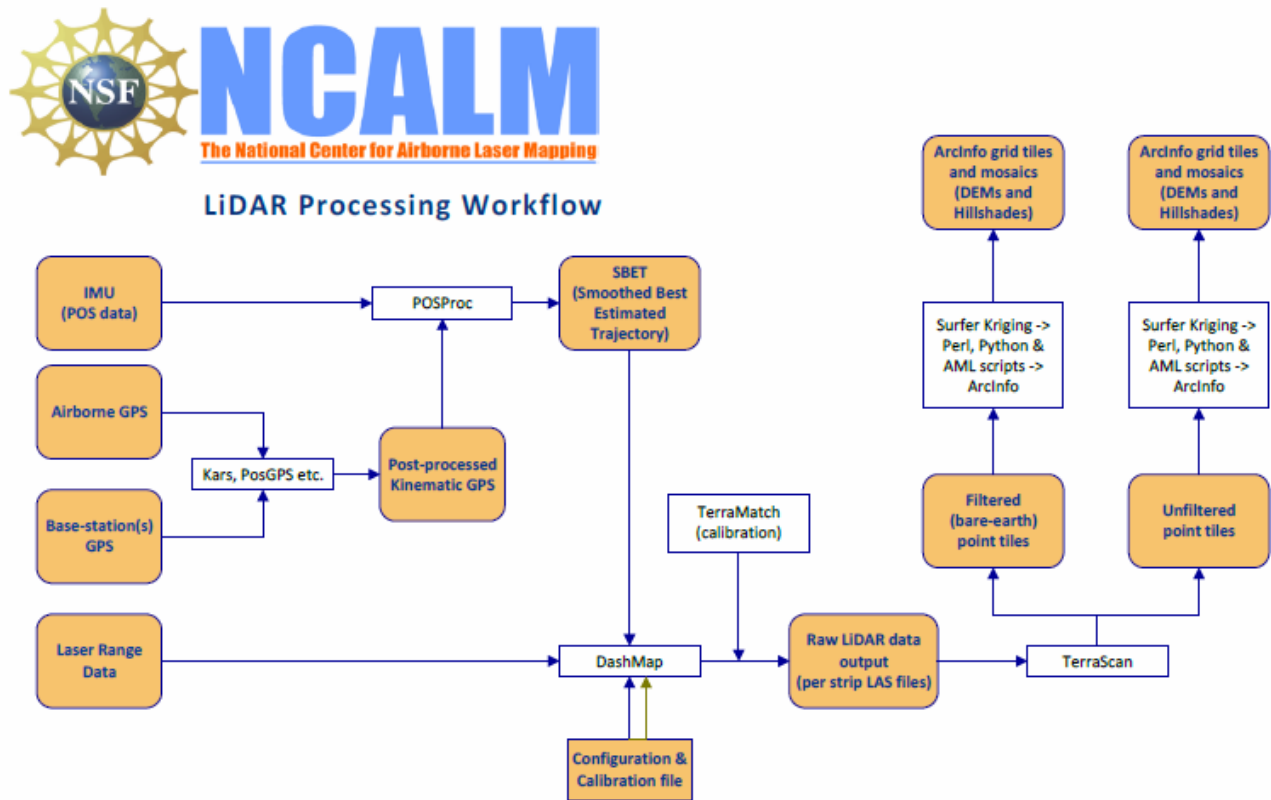


Figure 2 NCALM LiDAR Processing Workflow

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 12N
- 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 452000 through 453000, and northing equals 4627000 through 4628000 then the tile filename incorporates 452000_4627000. 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. 'fme452000'. The hillshade files have a prefix 'sh' after the name, for e.g. 'fme452000sh'.

7. Notes

- 1. Although half-meter spacing was requested for the elevation rasters, one-meter rasters were produced because the ground-class point density averaged only 2.5 points per square meter. It has been our experience that this low density of ground-class points tends to exaggerate artifacts in the DEM at half-meter spacing. NCALM will re-grid the ground-class point cloud at half-meter spacing if requested.
- 2. PTS format is a Leica point cloud format (I think) and NCALM uses an Optech ALTM. NCALM is unaware of converters from LAS to PTS.