Data Collection and Processing Report for CZO South Carolina

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1. Sensor Descriptions and Specifications

The LiDAR portion of the 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 LiDAR 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) 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.

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

The Hyperspectral imaging portion of the survey was performed with a CASI-1500 - a push broom type hyperspectral imaging sensor sold by ITRES. It is mounted on a vibration isolated mount together with the LIDAR sensor. The instrument nominal specifications are listed below in Table 2.

Sensor type	VNIR Pushbroom sensor (Compact Airborne Spectrographic Imager)
Spectral Range	380-1050 nm
No. of Spectral Channels	288
No. of Across Track pixels	1500
Total Field of View	40 degrees
Instant Field of View	0.49 mRad
Spectral Width Sampling/Row	2.4 nm
Spectral Resolution	< 3.5 nm
Pixel Size	20 µm X 20 µm
Dynamic Range	14 bits

Table 2– CASI-1500 Hyperspectral sensor specifications (For more info see manufacturer's website: http://www.itres.com/casi-1500/)

2. Area of Interest.

The requested survey area consisted of a rectangle enclosing approximately 150 square kilometers located 40 km SE of Spartanburg, South Carolina and is shown below in Figure 1 (Google Earth). The yellow push pins (BAS1, SCUN) represent the locations of the GPS reference stations.

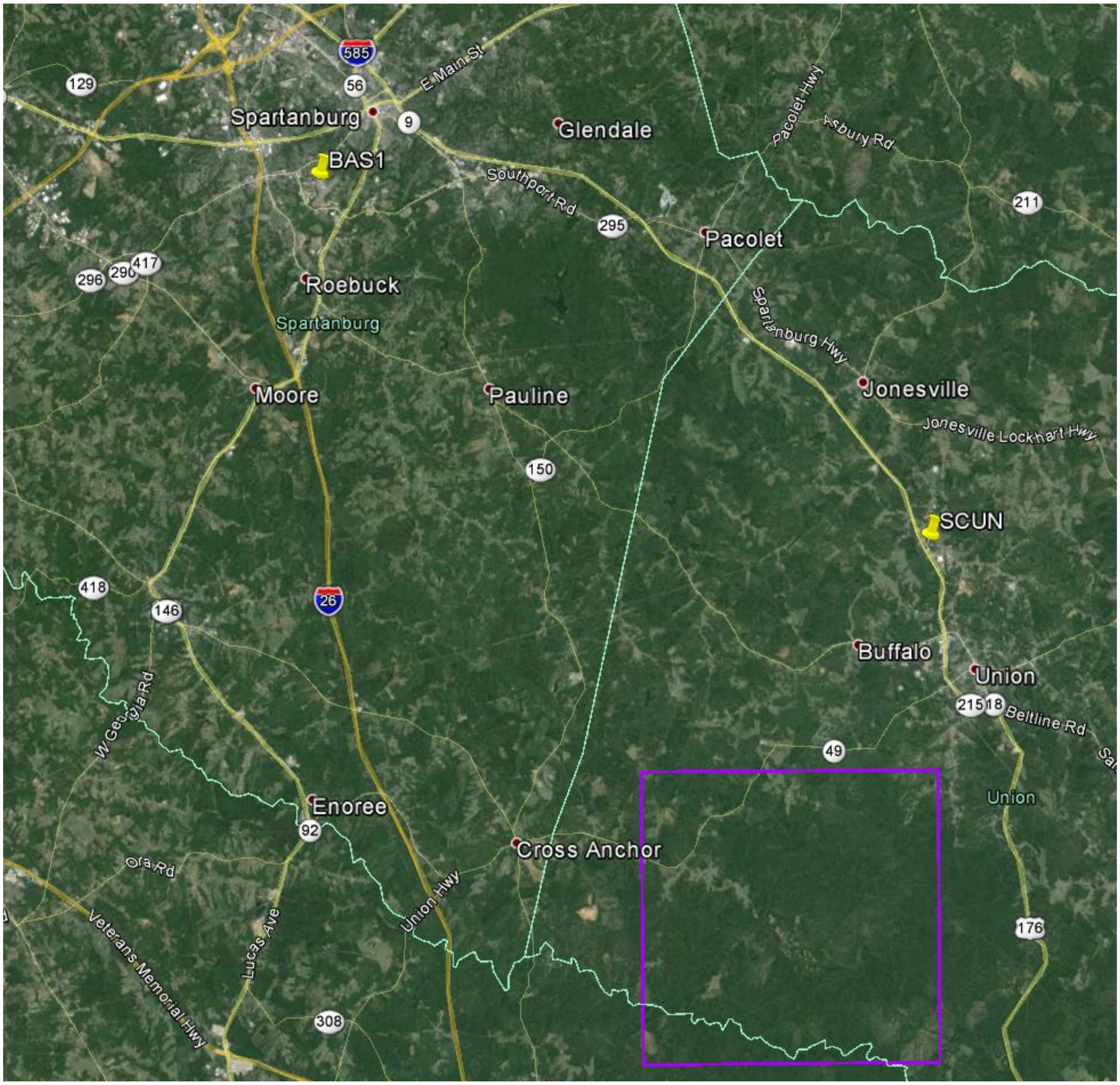

Figure 1 – Shape and location of the survey rectangle is shown in purple, yellow push pins represent GPS reference station locations. (Google Earth).

3. Data Collection

a) Survey Dates: The hyperspectral survey took place on July 30, 2014 (DOY 211). The LiDAR survey took place over 2 days – started on August 5, 2014 and completed on August 6, 2014 (DOY 218 and 219).

b) Hyperspectral Survey parameters: The hyperspectral imaging mission required 3.6 hours of flying time, and 1.5 hours of sensor-on time. The CASI 1500 was flown at an altitude of 2150m above ground level.

c) Airborne LiDAR Survey Parameters: Survey parameters for the LiDAR portion are provided in Table 3 below.

Nominal Flight Parameters		Equipment Settings		Survey Totals	
Flight Altitude	500 m	Laser PRF	100 kHz	Total Flight Time	9.9 hrs.
Flight Speed	+/- 65 m/s	Beam Divergence	0.80 mrad (Wide)	Total Laser Time	5.0 hrs.
Swath Width	268 m	Scan Frequency	60 Hz	Total Swath Area	153.5 km^2
Swath Overlap	Min 50 %	Scan Angle	± 16°	Total AOI Area	150 km^2
Point Density	10.7 p/m^2	Scan Cutoff	1.0°	Pass spacing	134 m

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

d) Ground GPS: Two GPS reference station locations were used during the survey: SCUN belongs to the national CORS network and the remaining one (BAS1) was established by NCALM near the operational airport. GPS reference observations from both of these stations 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.

GPS station	BAS1	SCUN
Agency	NCALM	NOAA/NGS
Latitude	34.91776247	34.76627932
W Longitude	278.03851238	278.35119466
GRS80 Height	216.790	169.730

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

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 five 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 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

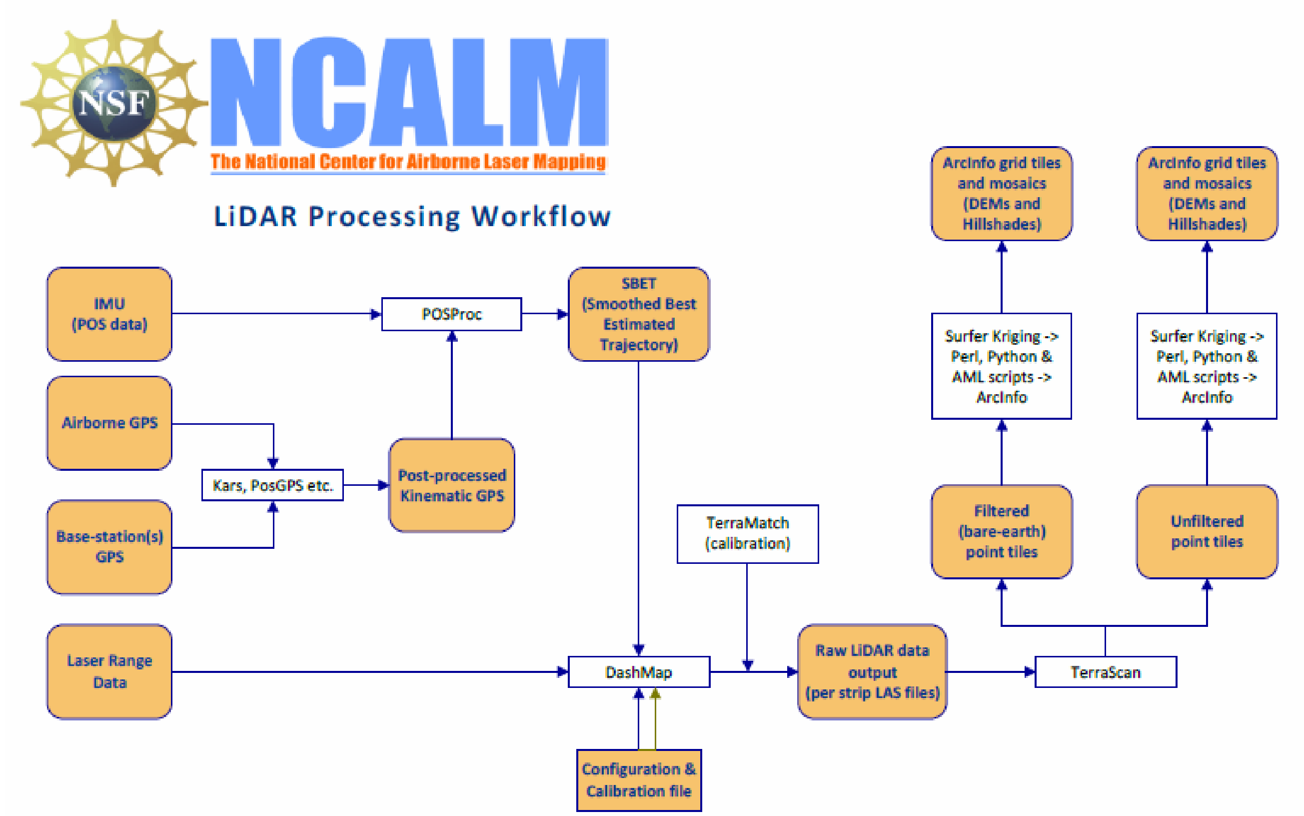

Figure 3 - NCALM LiDAR Processing Workflow

Classification done by automated means using TerraSolid Software (TerraScan Version 14.013). http://www.terrasolid.fi/en/products/4

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 13.006). 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 this project the average magnitude for vertical mismatch of ground surfaces (unsigned vertical differences between flight strips) in overlap zones is 0.067m.

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 17N – units in meters.
d) **File Formats:**

1. Point Cloud in LAS format (Version 1.2), 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 428000 through 429000, and northing equals 3822000 through 3823000 then the tile filename incorporates 428000_3822000. These tile footprints are available as an AutoCAD DXF or ESRI shapefile.