Data Collection and Processing Report for CZO Sangamon River IL

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1. Sensor Descriptions and Specifications

This survey was performed with 3 airborne remote sensing mapping systems. Two of these systems are LiDAR systems: 1) Optech Gemini Airborne Laser Terrain Mapper (ALTM) (serial # 06SEN195) which is an infrared laser mapping sensor and 2) Optech Aquarius ALTM (serial # 11SEN279) which is a hybrid laser mapping system as it collects simultaneous land and shallow water-depth measurements. It operates in the green spectrum, thus enabling it to penetrate water.

These two LiDAR mapping systems along with an Optech 12-bit full waveform digitizer were mounted consecutively in a twin-engine Piper PA-31-350 Navajo Chieftain (Tail Number N154WW). The Gemini nominal specifications are listed in Table 1, followed by the Aquarius nominal specifications in Table 2 and the Digitizer specifications in Table 3.

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)

Table 1 – Optech GEMINI specifications.

Operating Altitude	300-600m AGL, nominal
Range Capture	Up to 4 range measurements, including 1st, 2^{nd} ,3^{rd} and last
Intensity Capture	12-bit dynamic measurement range
Scan FOV	0-25 degrees
Scan Frequency	0-70 Hz
Pulse Rate Frequency	33,50,70 kHz
Laser Footprint on water surface	30 – 60 cm
Position Orientation System	Applanix POS/AV 510 OEM includes embedded BD960 72-channel 10Hz (GPS and Glonass) receiver
Laser Wavelength/Class	532 nm
Operating temperature	0-35 degree Celsius
Full waveform capture	12 bit IWD-2 Intelligent Waveform Digitizer

Table 2 – Optech Aquarius specifications.

Parameter	**Specification**
Sample Interval	1 ns
Maximum Acquisition and recording rate	Variable, up to 100 kHz At higher laser PRF automatically sub-samples 1:2, 1:3, as required
Record Length: T0 Return	 40 ns 440 ns (Total)
Full-Scale Input Range	0-1 V
Data Storage	Removable SSD
Operating temperature	0-35 degree C
Power	<200 W
Relative Humidity	0-98% non-condensing

Table 3 – Optech 12-bit Digitizer specifications.

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

The third airborne sensor was for Hyperspectral imaging. This 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 Gemini LIDAR sensor. The instrument nominal specifications are listed below in Table 4.

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 4– 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 two connected rectangles enclosing approximately 198 square kilometers along with their associated watercourse corridors. The project rectangles are located 20 km west of Champaign. IL. Both rectangles are shown below in Figure 1 (Google Earth). The entire enclosed area of these 2 rectangles was surveyed with the Gemini; the enclosed watercourse corridors illustrate where Aquarius data was also collected. The yellow push pins (BAS1, BAS2) represent the locations of the GPS reference stations located at the operational airport in Champaign.

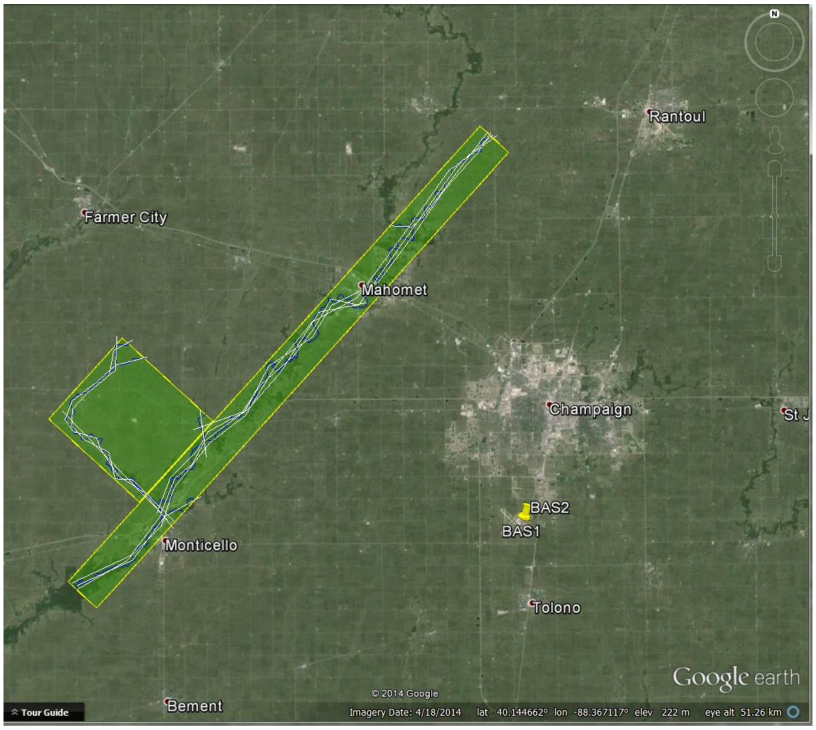

Figure 1 – Shape and location of the survey rectangles is shown in green and the yellow push pins represent GPS reference station locations. The enclosed corridors show where Aquarius data were collected. (Google Earth).

3. Data Collection

a) **Survey Dates**: The Aquarius LiDAR survey and the CASI hyperspectral survey took place over two flights - both of which occurred on August 4, 2014 (DOY 216). The Gemini LiDAR survey also took place on two flights - both of which occurred the following day August 5, 2014 (DOY 217).

b) **Aquarius Survey Parameters:** Survey parameters for the Aquarius LiDAR portion are provided in Table 5 below.

Nominal Flight Parameters		Equipment Settings		Survey Totals	
Flight Altitude	400 m	Laser PRF	33 kHz	Total Flight Time	3.5 Hrs.
Flight Speed	+/- 65 m/s	Beam Divergence	0.80 mrad (Wide)	Total Laser Time	2.5 Hrs.
Swath Width	291 m	Scan Frequency	40 Hz	Total Swath Area	55 km^2
Swath Overlap	n/a	Scan Angle	± 21°	Total AOI Area	43 km^2
Point Density	1.3-7 p/m^2	Scan Cutoff	1.0°	Pass spacing	n/a

Table 5 – Aquarius nominal flight parameters, equipment settings and survey totals; actual parameters vary with the terrain.

c) **Gemini Survey parameters:** Survey parameters for the Gemini LiDAR portion are provided in Table 6 below.

Nominal Flight Parameters		Equipment Settings		Survey Totals	
Flight Altitude	600 m	Laser PRF	100 kHz	Total Flight Time	12.1Hrs.
Flight Speed	+/- 65 m/s	Beam Divergence	0.80 mrad (Wide)	Total Laser Time	6.1 Hrs.
Swath Width	367 m	Scan Frequency	50 Hz	Total Swath Area	199 km^2
Swath Overlap	Min 50%	Scan Angle	± 18°	Total AOI Area	199 km^2
Point Density	7.8 p/m^2	Scan Cutoff	1.0°	Pass spacing	185 m

Table 6 – Gemini 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: BAS1 and BAS2. Both were established by NCALM near the operational airport. GPS reference observations from both of these stations were logged at 1 Hz. Table 7 (below) gives the coordinates of the stations and Figure 1 (above) shows the project area and the GPS reference station locations.

GPS station	BAS1	BAS2
Agency	NCALM	NCALM
Latitude	40.036819°	40.036812°
W Longitude	-88.268211°	-88.268241°
GRS80 Height	196.314	195.185

Table 7 – 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

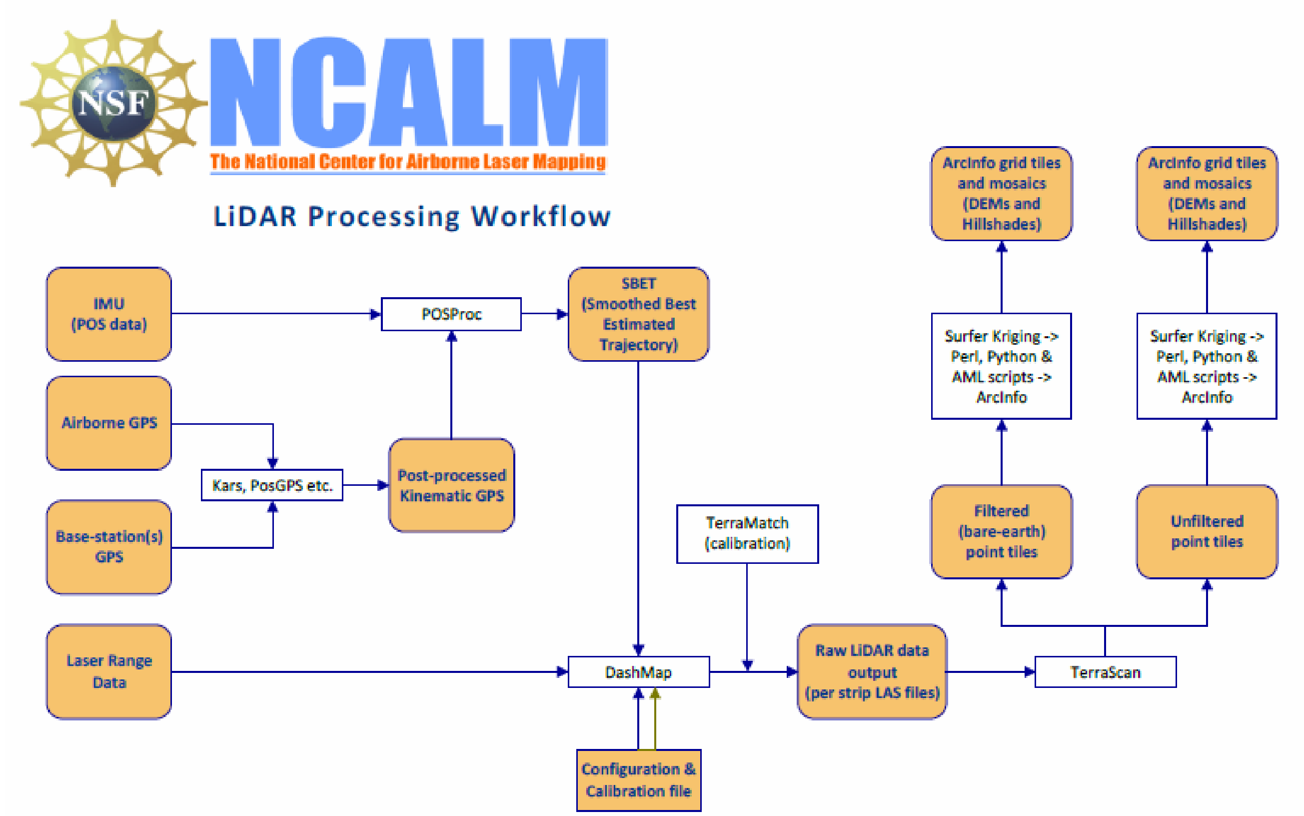

Figure 3 - NCALM LiDAR Processing Workflow

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 **0.044 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 16N – units in meters.
d) **File Formats:**

1. Gemini Point Cloud in LAS format (Version 1.2), classified as ground or non-ground, in 1 km square tiles.
2. Waveform files in DF2 and CSD formats
3. ESRI format 1-m DEM from Gemini ground classified points.
4. ESRI format 1-m DEM from all first return Gemini points (canopy included).
5. 1m Difference Raster from the subtraction of the bare-earth Gemini DEM from the Bare-earth Aquarius DEM. This raster contains uncorrected depths in meters and is only valid over water surfaces. To obtain a corrected depth multiply the difference value by 0.75 (water refraction coefficient).

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 431000 through 432000, and northing equals 4862000 through 4863000 then the tile filename incorporates 431000_4862000. These tile footprints are available as an AutoCAD DXF or ESRI shapefile.