



High Point Density LiDAR Survey of Mayapan, MX

PI: Timothy S. Hare, Ph.D.

Timothy S. Hare, Ph.D. Associate Professor of Anthropology Institute for Regional Analysis and Public Policy Morehead State University 414 C Bert Combs Building Morehead, KY 40351-1689	Office: (606) 783-9436 Fax: (606) 783-5092 E-Mail: t.hare@morehead-st.edu
---	---

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 Cessna Skymaster (Tail Number N337P). The instrument nominal specifications are listed below 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+GLONASS) 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 (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 a rectangular polygon shown with red outline below in Figure 1. The polygon is located approximately 40 km southeast of Merida, MX on the Yucatan Peninsula and encloses approximately 55 km².



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

3. Data Collection

a) **Survey Dates:** The survey took place over 3 flights beginning on June 07, 2013 (DOY 158), continuing with a flight on June 09 (DOY 160), and the final flight taking place on June 11, 2013 (DOY 162).

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	125 kHz	Total Flight Time	10.4 hrs.
Flight Speed	60 m/s	Beam Divergence	0.25 mrad	Total Laser Time	6.3 hrs.
Swath Width	344 m	Scan Frequency	45 Hz	Total Swath Area	58.5 km ²
Swath Overlap	400%	Scan Angle	± 17°	Total AOI Area	55 km ²
Point Density	>40 p/m ²	Scan Cutoff	1.0°		

Table 2 – Nominal survey parameters and totals, some actual parameters will vary with the wind and terrain.

c) **The flight plan** called for 133 lines flown in both north-south and east-west directions in order to maximize the canopy penetration.

d) **Ground GPS:** Two GPS reference station locations were used during the survey: MMD1 and 3429. MMD1 is part of the Continuously Operating Reference Station network (CORS) (see <http://www.ngs.noaa.gov/CORS/> for more information) and 3429 was established by NCALM on the roof of a laboratory building on the survey site. Both stations logged observations at 1 Hz. Table 3 (below) gives the coordinates of the stations in NAD83 (2011/CORS96/2007)(Epoch 2013.44) and Figure 2 shows the project area and the reference GPS station locations.

GPS station	MMD1	3429
Agency	CORS	NCALM
Latitude	20 55 54.86155 N	20 38 37.79394 N
Longitude	89 39 46.20185 W	89 27 49.32030 W
Height	30.285 m (ellipsoid)	8.458 m (ellipsoid)

Table 3 – GPS Coordinates of ground reference stations given in NAD83 (2011/CORS96/2007)(Epoch 2013.44)

Reference coordinates for 3429 were 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/>

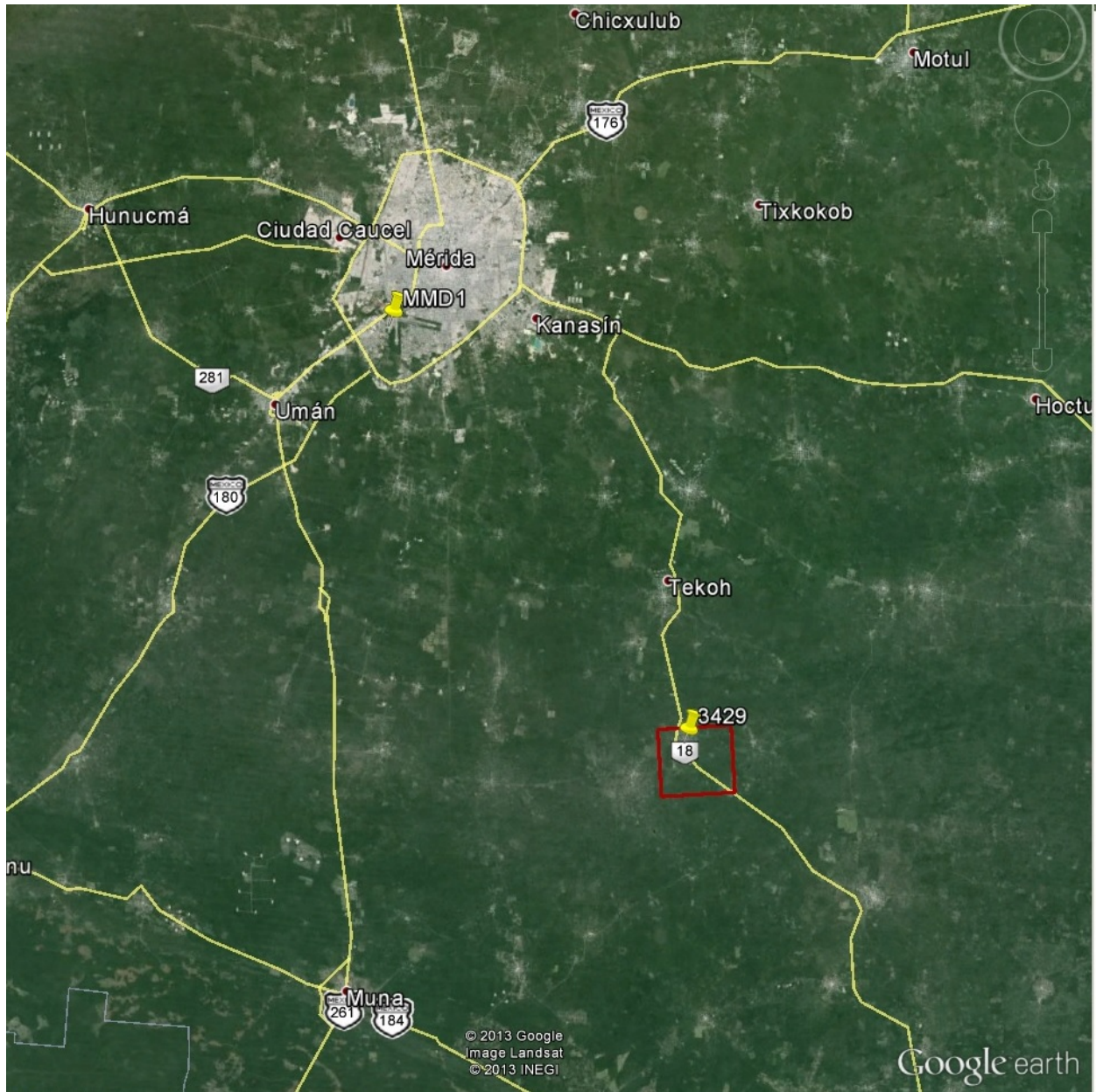


Figure 2 - Project area and GPS reference locations MMD1 and 3429

4. GPS/IMU Data Processing

- a) 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.
- b) 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).
- c) An SBET together with laser ranges and mirror angles from the range file are finally combined in Optech's DashMap software (Version 5.201) to generate a flight-strip point cloud in LAS 1.2 format.

5. LiDAR Data Processing Overview

The following diagram (Figure 2) shows a general overview of the NCALM LiDAR data processing workflow

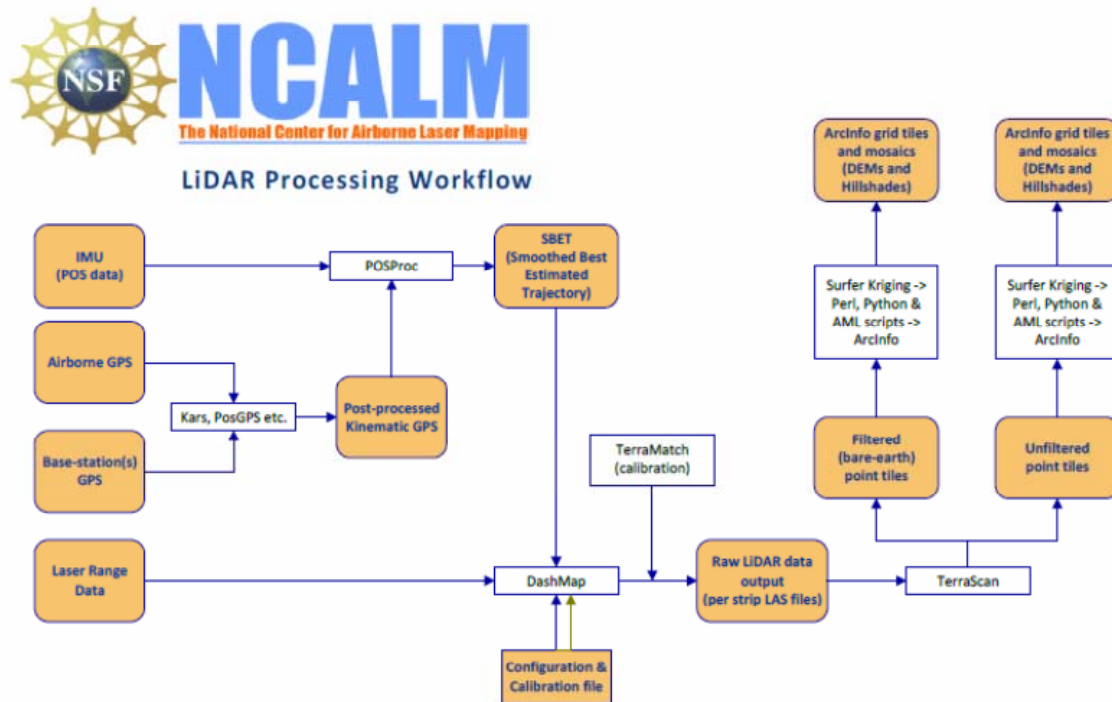


Figure 3 - NCALM LiDAR Processing Workflow

a) **Relative Calibration procedure** was performed as follows:

1. Planning and flying swaths with >50% side lap.
2. Surveying crossing flight-lines over calibration areas (buildings with sloped roofs work best) and over the natural terrain in the project polygon.
3. Optimize four calibration parameters (three bore sight alignment angles -roll, pitch, yaw and the scanner mirror-angle scale factor) by analyzing overlap areas of adjacent flight swaths and cross-lines in TerraMatch software. TerraMatch employs a least-squares approach to minimize the height differences between computed laser surfaces from individual crossing and/or overlapping flight lines and calculates best-fit values for these four parameters.
4. Output the final calibrated flight swaths.
5. Perform a global “Z-Shift” wherein each flight swath’s surface height is adjusted such that the average difference of all individual flight swath surface heights is fixed at zero.

See <http://www.terrasolid.com/products/terramatchpage.html> for more information about TerraMatch software.

At the conclusion of the relative calibration procedures, the RMS value for height differences between individual flight lines over the entire project was **0.063 meters**. No check points were collected for this project.

b) **Tiling.** The adjusted calibrated flight strip point cloud files were combined and tiled into 1/4 kilometer (500 m square) blocks.

c) **Classification A.K.A. Filtering.** Classification done by automated means using TerraSolid Software.
<http://www.terrasolid.com/home.php>

Ground Classification. This routine classifies ground points by iteratively building a triangulated surface model. The algorithm starts by selecting some local low points assumed as sure hits on the ground, within a specified windows size. This makes the algorithm particularly sensitive to low outliers in the initial dataset, hence the requirement of removing as many erroneous low points as possible in the first step.

The routine builds an initial model from selected low points. Triangles in this initial model are mostly below the ground with only the vertices touching ground. The routine then starts molding the model upwards by iteratively adding new laser points to it. Each added point makes the model follow ground surface more closely. Iteration parameters determine how close a point must be to a triangle plane so that the point can be accepted to the model. Iteration angle is the maximum angle between point, its projection on triangle plane and closest triangle vertex. The smaller the iteration angle, the less eager the routine is to follow changes in the point cloud. Iteration distance parameter makes sure that the iteration does not make big jumps upwards when triangles are large. This helps to keep low buildings out of the model. The routine can also help avoid adding

unnecessary points to the ground model by reducing the eagerness to add new points to ground inside a triangle with all edges shorter than a specified length.

Ground classification parameters used:

Max Building Size (window size): 3.0 m - classifies buildings as ground (unusual).

Max Terrain Angle: 89.9

Iteration Angle: 16.0

Iteration Distance: 1.4 m

Ground point density after classification was approximately 12 pts/meter in canopy and much higher in the cleared areas.

6. Data Deliverables

- a) **Horizontal Datum:** NAD83 (2011)
- b) **Vertical Datum:** NAVD88 (GGM06)
- c) **Projection:** UTM Zone 16N
- d) **File Formats:**
 1. Point Cloud in LAS 1.2 format, classified as ground or non-ground, in 500 m square tiles.
 2. ESRI format 0.25-m DEM from ground classified points.
 3. ESRI format 0.25-m Hillshade raster from ground classified points
 4. ESRI format 0.25-m DEM from all points (canopy included).
 5. ESRI format 0.25-m Hillshade raster from all points (canopy included).
- e) **File naming convention:** 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 243000 through 243500, and northing equals 2282500 through 2283000 then the tile filename incorporates 243000_2282500. These tile footprints are available as an AutoCAD DXF or ESRI shapefile. The ESRI DEMs are single mosaic files created by combining together the 500 m tiles.

7. Notes

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.