Trinity River LIDAR data collection

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1. LiDAR System Description and Specifications

This survey was performed with an Optech Titan multispectral airborne LiDAR sensor (serial number 14SEN340) mounted in a twin-engine Piper PA-31-350 Navajo Chieftain (Tail Number N544WW). The instrument nominal specifications are listed below in Table 1.

Parameter	Specification
Operating altitude [1,2]	300 - 2500 m AGL, 1064 nm, nominal 300 - 2000 m AGL, 532 nm, nominal 300 - 2000 m AGL, 1550 nm, nominal
Horizontal accuracy [2]	1/5,500 x altitude; 1 σ
Elevation accuracy [2]	< 5-15cm; 1σ
Pulse repetition frequency	Programmable; 35 – 300 kHz (each wavelength)
Scan frequency	Programmable; 0 - 70 Hz
Scan angle (FOV)	Programmable; 0 - 60° maximum
Roll compensation	Programmable; ±5° at full FOV
Position and orientation system	POSAV AP50 (OEM) 220-channel dual frequency
Minimum target separation distance	<1.0 m
Range capture	Up to 4 range measurements for each pulse, including last
Beam divergence	0.5 mrad ($1/e^2$) 1064 nm 1.0 mrad ($1/e^2$) 532 nm 0.5 mrad ($1/e^2$) 1550 nm
Laser classification	Class IV (US FDA 21 CFR 1040.10 and 1040.11; IEC/EN 60825-1)
Intensity capture	Up to 4 range measurements for each pulse, including last 12-bit dynamic measurement and data range
Data storage hard drives	Removable solid state disk SSD (SATA II)

[1]10% reflective target
[2]Dependent on selected operational parameters using nominal 50° FOV in standard atmospheric conditions

Note: To meet its stated accuracy, the ALTM must receive GPS data of sufficient quality. GPS data quality shall be viable only when all of the following conditions are met:

- At least 4 satellites are in lock (tracked by the receiver) throughout the survey
- Elevation of the satellites is above 15°
- Geometry of the satellites is good (i.e., PDOP < 4)
- Aircraft stays within 30 km of the GPS base station

If one or more of these conditions is not met, or if any source of electromagnetic interference causes the GPS receivers to repeatedly lose lock, the specified accuracy of the ALTM shall be compromised.

Table 1 – Optech TITAN specifications (http://www.optech.com/index.php/product/titan/).

See http://www.optech.com/ for more information from the manufacturer.

2. Areas of Interest.

The requested survey area consisted of three polygons located east of Houston, TX, about 52 Km east of George Bush Intercontinental Airport (IAH), over the Trinity River. The total area surveyed was approximately 385 Square Km. Figure 1 (below) is an image from Google Earth showing the shape and location of the survey.

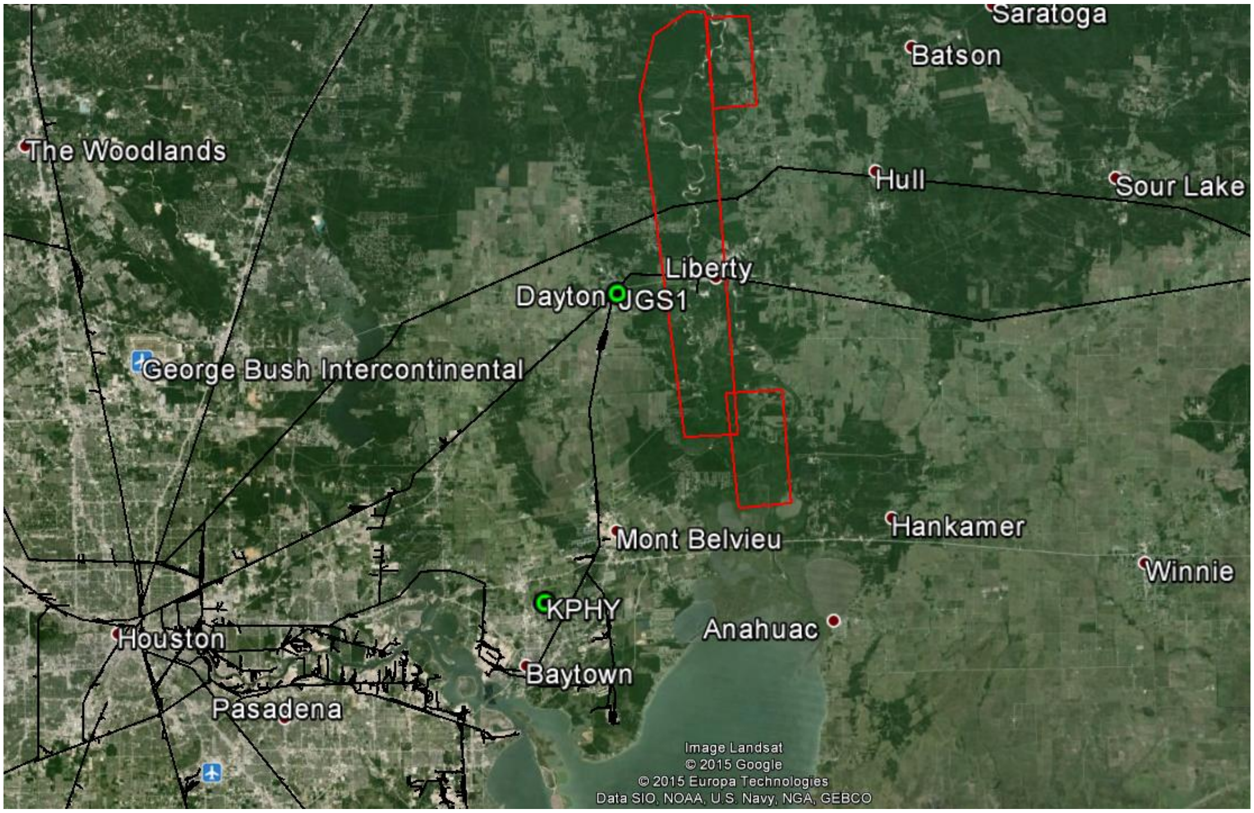

Figure 1 – Shape and location of survey polygon (red) and locations of GPS reference stations (Green). (Google Earth).

3. Data Collection

a) Survey Dates: The survey took place on 3 days, a flight each day, on August 7, 8 and 10, 2015 (DOY 219, 220 and 222).

b) Airborne Survey Parameters: Survey parameters are provided in Table 2 below.

Nominal Flight Parameters		Equipment Settings		Survey Totals	
Flight Altitude	700 m	Laser PRF	450 kHz	Total Flight Time	10 hrs.
Flight Speed	66 m/s	Scan Frequency	20 Hz	Total Laser Time	4.9 hrs.
Swath Width	800 m	Scan Angle	± 30°	Total Swath Area	385km^2
Swath Overlap	Min 50 %	Scan Cutoff	2.0°	Pass spacing	388 m
Point Density	~20 p/m^2				

Table 2 – Nominal flight parameters, equipment settings and survey totals; actual parameters vary with the terrain.

c) **Ground GPS:** Two GPS reference stations were used. One was setup by NCALM at the Baytown Airport (KPHY) and the other was part of the CORS permanent GPS network (JGS2) located in Dayton, TX, just west of the survey polygons. For both of them, GPS reference observations were logged at 1 Hz. Table 3 (below) gives the coordinates of the stations and Figure 1 (above) shows the project area and the GPS reference station locations.

GPS station	KPHY	JGS2
Agency	NCALM	CORS
Latitude	29.789167	30.04537
W Longitude	94.957888	94.89052

Table 3 – Coordinates of GPS reference stations in NAD83 (2011) Epoch 2010.0000

4. GPS/IMU Data Processing

Reference coordinates (NAD83 (2011) Epoch 2010.0000) for both the 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 two 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 7). 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

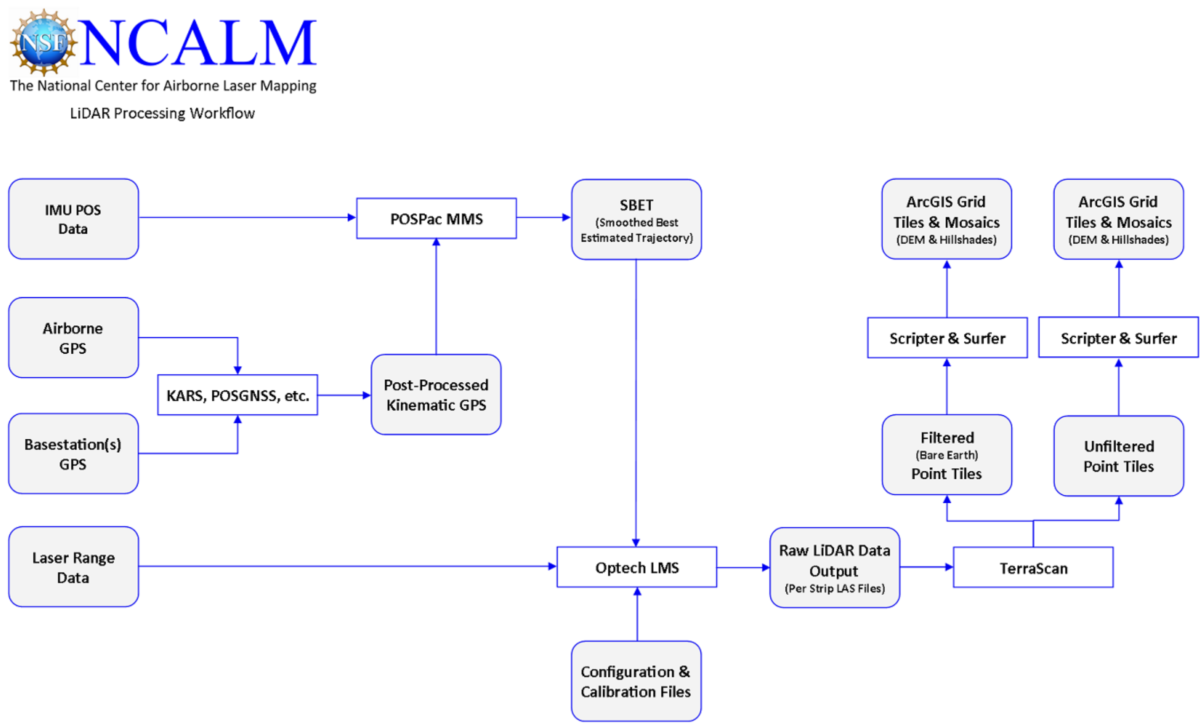

Figure 2 - NCALM LiDAR Processing Workflow

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. Calibration Procedure

System calibration of the 3 sensor bore sight angles (roll, pitch, and yaw) and scanner mirror scale factor is done by automated means using LMSPro software provided by Optech. Overlapping parallel project lines along with perpendicular cross lines and lines over developed neighborhoods with many sloping roof lines are used as input into automated optimization and calibration routines. It uses least-squares algorithms to compute and apply optimal bore sight offsets and scale values that minimize height mismatches in overlapping flight lines. These routines are run and calibration values are updated for each flight.

1719 ground check points were collected near the Ellington airfield to calculate for systematic bias in the LIDAR data. After the removal of the bias, the RMS for the elevation differences was 0.03 m. 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 15N
d) **Units: meters**
e) **File Formats:**
    1. Point Cloud in LAS format (version 1.2), classified as ground or non-ground, in 1 km square tiles.
    2. ESRI float format 1.0-m DEM from ground classified points.
    3. ESRI raster format 1.0-m Hillshade raster from ground classified points
    4. ESRI float format 1.0-m DEM from first return points.
    5. ESRI raster format 1.0-m Hillshade raster first return points.

f) **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: CXXXXXX_YYYYYYY. For example if the tile bounds coordinate values from easting equals 382000 through 383000, and northing equals 4130000 through 4131000 then the tile filename incorporates C382000_4130000. The ESRI DEMs are mosaic files created by combining together the 1 km tiles to get a single mosaic file for each: bare earth and first return surface models.