NCALM Data Collection & Processing Summary

LIDAR and DIMAC High resolutions Imagery data collection at Antelope Valley

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1. Instrumentation

LiDAR System Titan Multi-spectra

Parameter	Specification
Laser Wavelength	Channel 1: 1550 nm – does not penetrate water Channel 2: 1064 nm – does not penetrate water Channel 3: 532 nm – penetrates water
Operating Altitude [1,2]	300–2000 m AGL (1550 nm) 300–2500 m AGL (1064 nm) 300–2000 m AGL (532 nm)
Horizontal Accuracy [2]	1/5500 × altitude (1σ)
Vertical Accuracy [2]	< 5–15 cm (1σ)
Minimum Target Separation	< 1.0 m
Pulse Repetition Frequency	50–300 kHz (each wavelength)
Scan Frequency	0–70 Hz
Scan Angle	0–60° maximum
Beam Divergence	0.5 mrad ($1/e^2$) (1550 nm) 0.5 mrad ($1/e^2$) (1064 nm) 1.0 mrad ($1/e^2$) (532 nm)
Range Capture	Up to 4 range measurements for each pulse, including last
Intensity Capture	12-bit dynamic measurement and data range
Image Capture	Integrated digital camera
Position and Orientation System	POSAV AP50 (OEM), 220-channel dual frequency
Laser Classification	Class IV
Power Requirements	28 V, 30 A, 800 W
Dimensions and Weight	Sensor head: 630 × 540 × 450 mm, 65 kg Control rack: 650 × 590 × 490 mm, 46 kg
Data Storage Hard Drives	Removable solid state disk SSD (SATA II)

Table 1: Optech Titan multispectral LiDAR system

[1]20% reflective target

[2]Dependent on selected operational parameters using nominal 50° FOV in standard atmospheric conditions and good GNSS data quality

DiMAC Ultralight (Optech D-8900)

Parameter	Specification
Sensor Type	60 MP full-frame CCD, RGB
Sensor Format (H × V)	8984 × 6732 pix
Pixel Size	6 × 6 µm
Frame Rate	1 frame/2 s
Lens Focal Length	70 mm
Filter	Color and near-infrared removable filters

Table 2: DiMAC ULTRALiGHT+ (i.e., Optech D-8900) aerial digital camera (from DiMAC datasheet)

Parameter	Specification
FMC	Electro-mechanical, driven by Piezo technology
Shutter	Electro-mechanical iris mechanism 1/125–1/500 s, f-stops: 4, 5.6, 8, 11, 16
Power Requirements	24–28 V, 8 A, 168 W
Dimensions and Weight	200 × 150 × 120 mm, ~4.5 kg
Data Storage Hard Drives	500 GB removable solid state drives

Table 3: DiMAC ULTRALiGHT+ aerial digital camera

Parameter	Specification
Position and Orientation System	POSAV AP50 (OEM), 220-channel dual frequency
Laser Classification	Class IV
Power Requirements	28 V, 30 A, 800 W
Dimensions and Weight	Sensor head: 630 × 540 × 450 mm, 65 kg Control rack: 650 × 590 × 490 mm, 46 kg
Data Storage Hard Drives	Removable solid state disk SSD (SATA II)

Table 3: Optech Titan multispectral lidar system

2 Processing

2.1 GNSS/IMU Data Processing

Reference coordinates for all stations are derived from observation sessions taken over the project duration and submitted to the NGS's on-line processor OPUS, which processes static differential baselines in relation to the international CORS network. For further information on OPUS see: www.ngs.noaa.gov/OPUS, and for more information on the CORS network see: www.ngs.noaa.gov/CORS.

Aircraft trajectories for surveys are processed using Kintools software, originally developed by Dr. Gerald L. Mader of the NGS Research Laboratory. Kintools 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 projects are blended solutions from at least two of the available reference stations. For more information on KARS, see: www.generalpositioning.com.

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 (currently Mobile Mapping Suite Version 7.1 SP2). 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).

2.2 Lidar Data Processing

The following diagram (Figure 1) shows a general overview of the NCALM lidar data processing workflow:

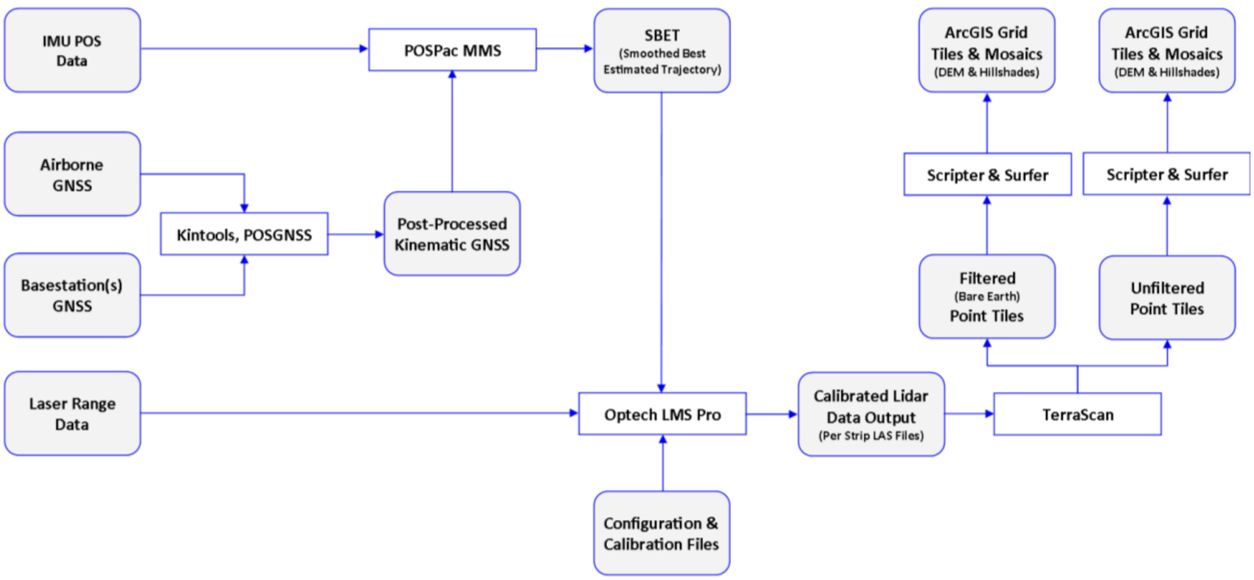

Figure 1: NCALM's typical lidar processing workflow

2.3 Classification

Classification is done by automated means, using TerraSolid software (currently TerraScan Version 16.031): 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), errors in bathymetry determination, and data gaps. A detailed discussion on the causes of data artifacts, and how to recognize them, can be found here: 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:
ncalm.berkeley.edu/reports/NCALM_WhitePaper_v1.2.pdf.

Additionally, when surveying near or over urban areas, the difficulty of classification often increases, causing “urban artifacts.” This is usually evident when viewing raster files (i.e., hillshades). The user will notice “pits” in the ground model where the laser penetrated skylights in buildings or storm drains on the sides of roads. Swimming pools, which can look like holes when bathymetry processing is completed, will also be observed.

NCALM cannot devote the required time to remove all artifacts from datasets, especially urban artifacts, when the study area is not over a city or town, or involving infrastructure specifically, but will attempt to provide the most aesthetically pleasing hillshades, etc. If researchers find areas with artifacts that influence their applications, they should contact NCALM (ncalm@egr.uh.edu), 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.

The point cloud delivered is classed as follows: Class 1 = default (unclassified); Class 2 = ground (used for creating bare-earth raster; Class 6 = overlap point (not used in DEM creation); Class 7 = outlier or isolated point.

2.4 Digital Imagery Processing

Digital imagery processing can be simplified in three steps: radiometric correction, calibration, and orthorectification. An overview of the processing steps is shown in the flowchart in Figure 2:

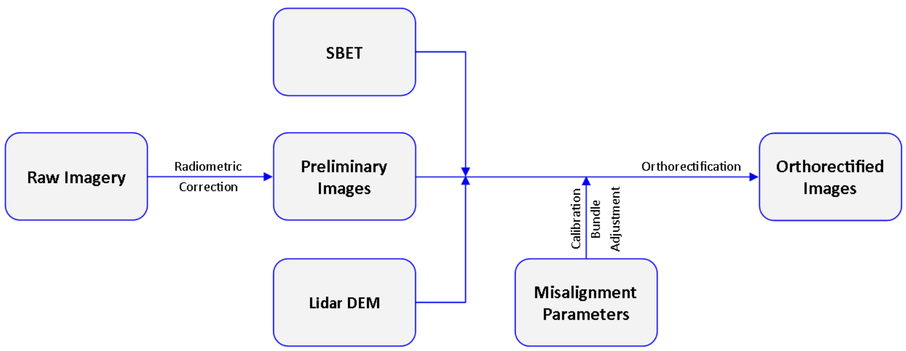

Figure 2: Imagery processing workflow

Radiometric correction for DiMAC images involves fine-tuning the white balance and exposure correction. This procedure is done using Capture One image processing software (www.phaseone.com/capture-one). The next two steps of calibration through bundle adjustment and orthorectification are completed using TerraPhoto (currently Version 16.005), part of the TerraSolid software suite.

Calibration is typically done on a set of images taken over a calibration site with perpendicular and opposing headings. Calibration involves using a bundle adjustment to solve for linear and angular misalignments with tie points and ground control points. For this purpose, the calibration site is located over an area with distinct road markings, such as parking lots or an airport. For this project, the site chosen was Yuba City Airport. Finally, the calculated misalignment values are fed back into the process to produce the orthorectified images.

3. Calibration and Accuracy Assessment of Lidar Data

3.1 Calibration

System calibration of the sensor's three boresight angles (roll, pitch, and heading) and scanner mirror scale factor are done by automated means using Optech LMS Pro software (currently Version

4.0.0.18178) as well as checking them for internal consistency in Terramatch. Project lines or non-project lines over a calibration area are flown with opposite headings and combined with perpendicular cross lines. These are used as input for solving for the calibration values. These are checked and optimized on a flight-by-flight basis.

3.2 Accuracy

3.2.1 Relative and Absolute Accuracy

After the calibration values are optimized, project flight lines are output, tiled into blocks and classified into ground and non-ground classes. Surfaces are developed for each flight strip from the ground class points, then these individual flight strip surfaces are differenced, and a value for the average magnitude of the height mismatch (unsigned vertical differences between flight strips) over the entire project area is calculated.

Note that any lidar-derived DEM accuracy will usually degrade on steep terrain and under canopy.

Absolute accuracy aree checked with checkpoints collected by alternate survey methods. 1600 checkpoints were collected at the Yuba City airport with a separate kinematic survey and used to remove any biases in the Lidar Data.

4. Data Deliverables

4.1 Typical File Formats

1. Point cloud in LAS format (Version 1.2), classified with ground, bathymetry , and non-ground returns, in 1000-m × 1000-m rectangular tiles
2. ESRI FLT format 1-m DEM from classified ground and bathymetry points
3. ESRI-created Hillshade raster from the grid listed above
4. ESRI FLT format 1-m DEM from first-return points (canopy and buildings included)
5. ESRI-created Hillshade raster from the grid listed above
6. Point cloud density image map
7. Geotiff format, RGB orthorectified images, 5 cm pixel size, 500mx500m tiles

4.2 File Naming Convention

4.2.1 LAS Files

The 1000-m × 1000-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 are the coordinate values from Easting 550000 through 551000, and Northing 4330000 through 4331000, then the tile file-name incorporates *550000_4330000*.

4.2.2 ESRI Files

Due to the limited number of characters that can be used for some ArcGIS data products, the convention is less standardized. CH03 indicates the raster was assembled from only CH03 data (may contain bathymetry) or CH0102 means the raster was assembled from only NIR data. If the raster is a

Hillshade (not a DEM) its name will include "hs". "BE" indicates "Bare-Earth", "First" indicate "first surface" buildings, vegetation, power lines etc. included.

4.2.3 RGB Files

Tiles are 500m x 500m and follow a naming convention similar to the LAS tiles. The file uses the lower-left coordinate (minimum X, Y) as the seed for the file name as follows: *XXXXXX_YYYYYYY*. For e.g. 553500_4330500.tif

4.3 LAS File Information

Each of the returns contained on the LAS tiles are encoded with a laser channel value. As previously noted, the Optech Titan has three channels: 1550, 1064, and 532 nm. The values used are *1* (1550 nm), *2* (1064 nm), and *3* (532 nm), and are stored in the User Data record of the Point Data records in the LAS file. Additionally, the Classification Values of the points follow the ASPRS Standard: www.asprs.org/Committee-General/LASer-LAS-File-Format-Exchange-Activities.html.

NCALM also includes the datum/projection information in the LAS file in the Variable Length Records.