NCALM National Center for Airborne Laser Mapping — University of Houston • University of California, Berkeley

Data Collection & Processing Report

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Data Collection & Geospatial Reference Summary:

Collection Dates and Flights:	Single flight conducted on February 16, 2017, day of year 047. Between 16:31 and 18:18 GMT (10:31 to 12:18 local time). Aircraft was a Piper PA-31-350 Navajo Chieftain (N640WA).
Horizontal / Vertical Datum:	North American Datum of 1983 (NAD83) / NAD83 Ellipsoidal Elevations (No Geoid)
Projection / Units:	UTM Zone 15N / meters

Sensor Suite Position and Orientation Data Collection, Processing and Products

Integrated Navigation System (INS):	• Applanix POSAV AP50 • Litton L200 Inertial Measurement Unit (IMU)
GPS base stations	3 base stations: 2 continuously operated stations located at the University of Houston Energy Research Park (UHEP) and the Earth and Atmospheric Science building (UH01) and one temporary station located at the Baytown airport (KHPY). Stations are equipped with Trimble NetR9 receivers and Trimble Zephyr Geodetic 2 GPS Antennas
Reference, Positioning and Navigation Processing	1. Determination of reference station (base station) coordinates. 2. Determination of differential 3D trajectories of the airplane/sensor with respect to reference stations. (KARS, Applanix POSPAC). 3. Blending of 3D trajectory with the IMU data into a smoothed best estimate trajectory (SBET) through a Kalman filter algorithm (Applanix POSPAC).
SBET Data Product	One (1) comma delimited text file with 7 columns data corresponding to the INS 1) GPS time, 2) Northing, 3) Easting, 4) Ellipsoidal Elevation 5)Roll in radians, 6) Pitch in radians and 7) Heading in radians.

Multispectral Lidar Data Collection, Processing and Products

Lidar Sensor	• Optech Titan MW (14SEN/CON340) with an integrated digital camera. • The Titan MW operates three channels with different laser wavelengths and look angles. Channel 2 resembles a traditional single channel lidar system and it is based on a 1064 nm laser (near-infrared) scanned with an oscillating mirror on an arc of ± 30° from nadir. Channel 1 is based on a 1550 nm laser (near-infrared) and it is scanned through the same mirror and scan angle of channel 2 but it is pointed 3.5° forward of nadir. Channel 3 operates a 532 nm laser scanned with the same mirror and angle but oriented 7° forward of nadir. Each channel can operate at pulse repetition frequencies (PRF) of 50 to 300 kHz for a total combined (and synchronized) PRF of 150 to 900 kHz. • More details on this particular sensor can be found on: Capability Assessment and Performance Metrics for the Titan Multispectral Mapping Lidar. Remote Sens. 2016, 8, 936. http://www.mdpi.com/2072-4292/8/11/936
Flight Plan Parameters:	Flying height: 500 m AGL, Swath width: 445 m, Overlap: 50%, Line spacing: 225 m
Equipment Parameters:	PRF: 175 kHz per channel (525 kHz total), Scan Frequency: 25 Hz, Scan Angle: ± 26°, ±2° cut-off at processing. Nominal Laser Shot Density 32 shots/m².

Lidar Data Processing Steps:	1. Determination of reference station (base station) coordinates. 2. Determination of differential trajectories of the airplane/sensor with respect to reference stations. (KARS, Applanix POSPAC) 3. Lidar/ INS boresight calibration (relative calibration) & lidar height calibration (absolute calibration). (Optech LMS PRO, Terrasolid Terra Match) 4. Lidar return computation and output of lidar point clouds per flight line and channel. Precise (calibrated) return geolocations and range corrected intensities. (LMS PRO) 5. Binning of flight strip point clouds into tiles. (Terrasolid Terrascan) 6. Flight strip elevation adjustment and point cloud classification on a tile per tile basis. (Terrasolid Terramatch andTerrascan) 7. Interpolation of lidar returns into elevation and intensity rasters. Elevation rasters include first surface model (DSM), bare-earth digital elevation model (DEM) with and without void filling, bare-earth and building model. (Golden Software Surfer, ESRI ArcGIS) While these steps have been listed sequentially, processing is an iterative process where the quality of the data products resultant of each step is assessed and if issues are found corrective action is taken in a previous step and repeated from there to all or a spatial subsection of the data.
Point Cloud Tiles:	• Three (3) sets of tiles (C1, C2, C3), each set with 4 tiles of dimensions (X × Y) 596 m × 601 m in LAS format (Version 1.2). The C1, C2 and C3 sets contain returns for respective titan channels 1, 2, and 3.. • The tile naming follows the convention of using the lower left coordinate (minimum X, Y) as the file name as follows: XXXXXX_YYYYYYY.las. • Returns were roughly classified using automated algorithms with some manual editing and coded using the LAS standard classes: 2 for ground, 6 for building (some building returns are also classified into class 17), 7 for outlier returns (multipath, atmospheric, or sensor spurious returns, and class 1 for returns that do not belong to any of the above classes (vegetation, power lines, power poles, etc. The classification of returns has not been optimized, some classification errors are expected. • The flight number assigned to each of the returns contained on the .LAS tiles has been encoded with four digits #### (i.e. 1012). Where the first digit corresponds to the Titan Channel (1: 1550, 2: 1064, 3: 532 nm) and the next three digits correspond to the sequential order of each flight strip ranging from 001 to 011. • Intensities in the lidar point cloud have been normalized by range, to a range of 600 meters. Titan channel information has been encoded for each return in the LAS "user data" field. NCALM has encoded this field with a "1" for the returns obtained from channel 1 (1550 nm), "2" for the returns from channel 2 (1064 nm) and "3" for the returns coming from channel 3 (532 nm).
Lidar Derived Rasters	• Seven (7) lidar derived raster in the geotiff format were produced. The values in the geotiff rasters have not been scaled, they represented actual interpolated values of elevations or range normalized intensities. • All rasters were generated by outputting LAS or text "source" files tiles of 520m x 520m meters with lidar returns specific to each raster type. The data from the source files were then interpolated using Golden Software Surfer into 504 x 504m grids, mosaicked, cropped and converted into ArcGIS rasters using Surfer. A final conversion into geotiffs was made with ESRI ArcGIS. • DSM_C12 is a first surface model (DSM) generated from first returns detected on Titan channels 2 and 1. The elevations of the first returns were interpolated to a 50 cm grid using Kriging with a search radius of 5 meters. • DEM_C123_3msr is a bare-earth digital elevation model (DEM) generated from returns

	classified as ground from all three Titan. The elevations of the first returns were interpolated to a 50 cm grid using Kriging with a search radius of 3 meters. This model represents terrain with data voids within the footprints of buildings and other manmade structures. • DEM_C123_TLI is a bare-earth digital elevation model (DEM) generated from returns classified as ground from all three Titan. The elevations of the first returns were interpolated to a 50 cm grid using a triangulation with linear interpolation algorithm. This model represents terrain where the voids of footprints of buildings and other manmade structures have been filled by the algorithm. • DEM+B_C123 is a hybrid digital elevation model that combines returns that where classified as coming from building and the ground detected in all three Titan channels. The elevations of the returns were interpolated to a 50 cm grid using Kriging with a search radius of 5 meters. • Intensity_C1, Intensity_C2 and Intensity_C3 are intensity rasters generated from Titan channels 1 (1550nm), 2 (1064 nm) and 3(532 nm) respectively. The intensity values of first returns were interpolated to a 50 cm grid using inverse distance weighting to a power (2) with a search radius of 3 meters.
Known Issues of Data Products:	• The main objective of channel 3 is the detection of bathymetric (underwater) returns. Thus it is tuned for the detection of weak signals and in some case when the detector is subjected to strong signals it will saturate. This saturation will produce spurious return (only for channel 2) that will spread through the entire channel range gate. This will be evident in the point cloud with returns in some areas that extend from 500 meters above the ground to about 100 meters below the ground. Besides the point cloud, this effect will be evident on the intensity raster of channel 2 as some dark/bright streaks.

Very-High Resolution RGB Imagery data collection, processing and products

High Resolution RGB Camera :	• DiMAC ULTRALiGHT+ (Optech D-8900) with a 70 mm focal length lens • 8984 × 6732 pixels, (6 × 6 μm pitch) =
Flight Plan Parameters:	Flying height: 500 m AGL, image frame footprint (385 m x 288.5 m), raw ground sample distance (GSD) 4.3 cm, Nominal endlap 19%.
Equipment Parameters:	Trigger time between image captures: 3.5 seconds
High Resolution RGB Data Processing Steps:	1. Optimization of white balance for all raw images. (Phase One, Capture One) 2. Image conversion from raw to tiff format. (Phase One, Capture One) 3. Refinement of camera / INS boresight calibration taking the SBET and image time stamp data as inputs. (Terrasolid, Terraphoto) 4. Output of geolocated and orthorectified RGB image mosaics tiles in the geotif format at 5 cm pixel resolution. (Terrasolid, Terraphoto). While these steps have been listed sequentially, processing is an iterative process where the quality of the data products resultant of each step is assessed and if issues are found corrective action is taken in a previous step and repeated from there to all or a spatial subsection of the data.
Image Mosaic Tiles:	• Four (4) image tiles of dimensions (X × Y) 596 m × 601 m at 5 cm pixel resolution in geotif format. • File naming follows the convention of using the lower left coordinate (minimum X, Y) as a suffix to the string "UH_NAD83_" (e.g. UH_NAD83_XXXXXX_YYYYYYY.tif).
Known Issues of Data Products:	Geolocation and mosaicking of the individual 60 MP frame images into a larger and continuous raster is accomplished using the precise knowledge of the camera orientation parameters derived from INS and the manual selection of tie point between images. The accuracy of this process should be within a couple of pixels. However, the creation of a

	“seamless” image is extremely difficult given the large parallax differences between image capture positions from a platform flying relatively fast and at low altitudes and the complexity of the imaged surfaces. To reduce seamline and orthorectification artifacts NCALM forced the assignment of mosaic pixels from within large building footprints to come from a single 60 MP image frame. While this was possible for most buildings, certain areas around large structures such as the UH main stadium were not filled producing “black” data voids in the high resolution image.

Hyperspectral data collection, processing and products

Hyperspectral Sensor	• ITRES CASI 1500 (S/N 2525) hyperspectral camera. • Pushbroom sensor with 1500 across track pixels, spectral range 380–1050 nm.
Flight Plan Parameters:	Flying height: 2100 m AGL, swath width 1500 meters, pixel resolution 1 meter. Nominal ground speed: 65 m/s.
Equipment Parameters:	• Recording of 48 spectral bands. • Nominal integration time: 16 ms.
Hyperspectral Data Processing Steps:	1. Radiometric calibration/correction that coverts the raw digital numbers into units of spectral radiance using manufacturer determined calibration tables and their RCXSAV software 2. Refinement of camera / INS boresight calibration taking the SBET and raw image coordinates of control and tie points. (ITRES, PBSbund) 3. Output of geolocated and orthorectified hyperspectral image strips in the PIX format at 1 meter pixel resolution. (ITRES, Geocor). While these steps have been listed sequentially, processing is an iterative process where the quality of the data products resultant of each step is assessed and if issues are found corrective action is taken in a previous step and repeated from there to all or a spatial subsection of the data.
Hyperspectral Data:	• One (1) hyperspectral image cube of dimensions (X × Y) 2384 m × 601 m and 48 spectral bands at 1 meter pixel resolution. The file is named 2018_IEEE_GRSS_DFC_HSI_TR. • This hyperspectral data cube has been orthorectified and radiometrically calibrated to units of spectral radiance. The digital number in the PIX image corresponds to mili-SRU (spectral radiance units). One SRU is equivalent to 1 microwatt per square per centimeter per steradian per nanometer. A digital number of a 1000 in a PIX image will correspond to a 1 SRU.
Known Issues of Data Products:	There may be small misalignments between the hyperspectral data and the lidar or high resolution RGB imagery. This is due to small errors in the determination of the camera /INS boresight parameters, image parallax, image distortion and errors in the determination of the sensor trajectory.