Survey Report
San Juan/Puerto Nuevo, Puerto Rico
Aerial Imagery

Prepared For:

Jacksonville District USACE
Geomatics Section

Prepared By:

Premier Geospatial, Inc.

SURVEY 13-034
REPORT DATE: APRIL 30, 2013

Survey Report

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Aerial Imagery

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1 Introduction and Specifications

Premier Geospatial, Inc. (PremierGeo) was tasked by the U.S. Army Corps of Engineers (CORPS) to obtain new digital aerial imagery covering the San Juan and Puerto Nuevo regions of the Commonwealth of Puerto Rico. The project area encompasses approximately 181 square kilometers of land and adjacent water bodies. The aerial imagery was collected utilizing a Leica Geosystems ADS40 – II sensor. The aircraft utilized during collection was a twin-piston Cessna 402C.

Imagery collection was coordinated to occur during periods in which environmental conditions would not obstruct the view of the Earth's surface. Survey missions occurred during a solar elevation window of 25 degrees to 55 degrees above the horizon. Survey lines were flown at a nominal height of 3200' AMT to collect imagery with a nominal 10cm GSD. Imagery collection was completed in four survey missions between the dates of March 13, 2013 through March 15, 2013.

Control for the aerial imagery exposure stations was provided by ABGPS/IMU data collected simultaneously with imagery and ground based GPS data used to differentially correct the airborne data. Photo-identifiable features surveyed using static and RTK surveys were observed during aero-triangulation to provide final adjustment to the project datum. Imagery was orthorectified to a hybrid surface gridded from existing LiDAR derived mass points and new auto-correlated mass points in select areas.

2 Spatial Reference System

The spatial reference of the imagery is as follows.

Horizontal Spatial Reference
- Projection: State Plane Puerto Rico Virgin Islands, units of Meters
- Datum: North American Datum of 1983 (2011)

Vertical Spatial Reference
- Orthometric Heights: Puerto Rico Vertical Datum of 2002 (GEOID12A)
- Ellipsoidal Heights: Geodetic Reference System 1980

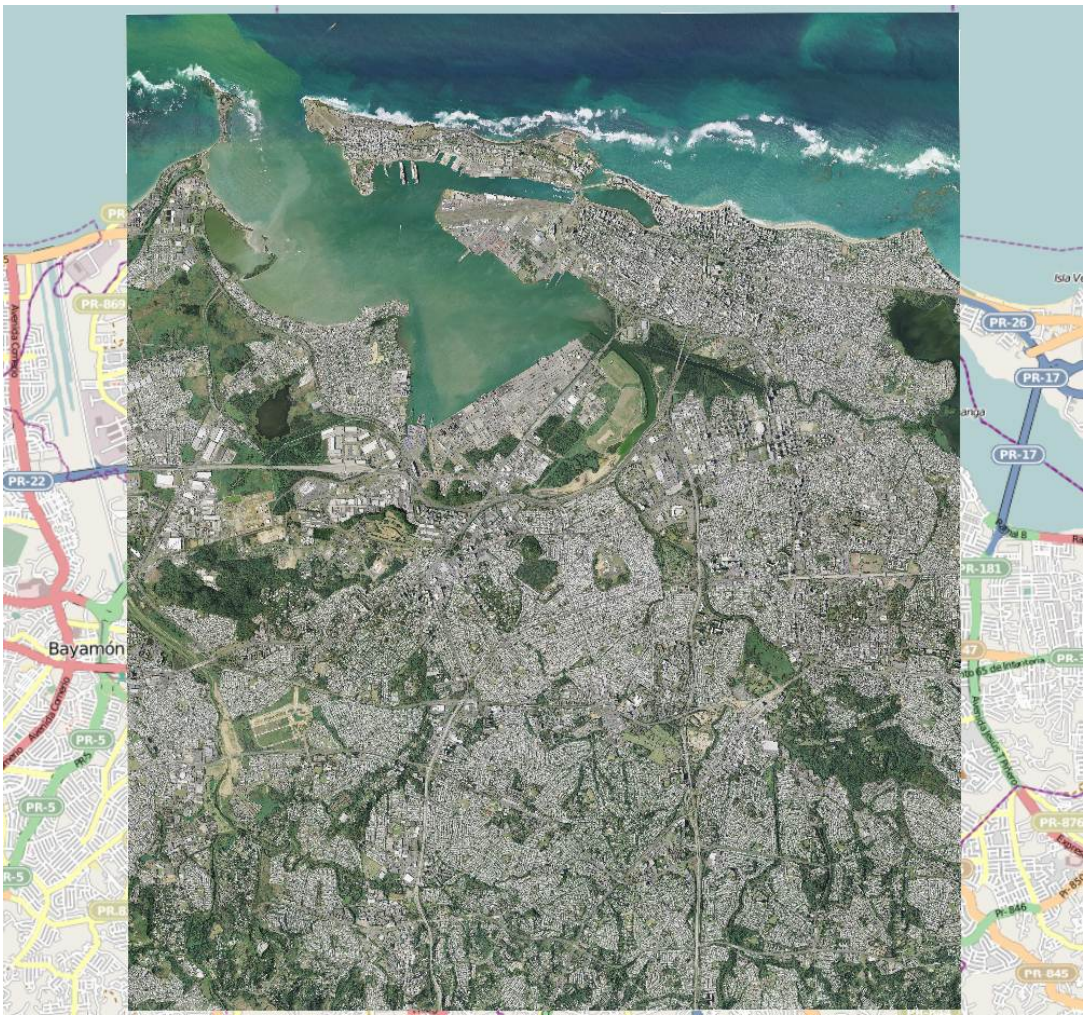
3 Abbreviations and Definitions

ABGPS – Airborne Global Positioning System
AMT – Above Mean Terrain
BRDF – Bi-directional Reflectance Distribution Function
DEM – Digital Elevation Model
EO – Exterior Orientation
GSD – Ground Sample Distance
GCP – Ground Control Point
QC – Quality Control
GPS – Global Positioning System
IMU – Inertial Measurement Unit
MMU – Mass Memory Unit
NAD83(2011) – North American Datum 1983, 2011 adjustment
NGS OPUS – Online Positioning User Service
PRVD02(GEOID99) – Puerto Rico Vertical Datum 2002, NGS GEOID99 realization
PRVD02(GEOID12A) – Puerto Rico Vertical Datum 2002, NGS GEOID12A realization
USGS NED – United States Geological Survey National Elevation Dataset

4 Aerial Imagery Survey

4.1 Survey Area

The survey area covers approximately 181 square kilometers of the San Juan and Puerto Nuevo regions of the Commonwealth of Puerto Rico. The survey provides new imagery depicting current conditions of various CORPS civil works projects along the Rio Puerto Nuevo and its associated drainages.



Puerto Rico Survey Area

4.2 Sensor Information

PremierGeo utilized the ADS40 – II pushbroom sensor to collect aerial imagery during the survey flights.

Leica Geosystems ADS40 SH51 – S/N 1326

GPS Antenna – AeroAntenna Technology (AAT) Model 512 Rev 2, survey grade dual frequency L1/L2
GPS Receiver – Novatel OEM4
IMU – Litton LN200 integrated with Applanix POS AV-ADC

The ADS40 – II is a "push broom" style sensor, collecting imagery with linear CCD lines in a continuous manner along a given flight line. The ADS sensor used simultaneously collected 7 CCD lines at a swath

width of 12,000 pixels each and cross track Field of View (FOV) angle of 64 degrees. The ADS40 – II CCDs have pixel dimensions of 6.5 microns x 6.5 microns, and the sensor's calibrated focal length is 62.7mm.

Image Channel	Look Angle	Wave Length
Panchromatic Forward	+27 degrees	465 – 680 nm
Panchromatic Nadir	+2 degrees	465 – 680 nm
Panchromatic Back	- 14 degrees	465 – 680 nm
Red Nadir	0 degrees	608 – 662 nm
Green Nadir	0 degrees	533 – 587 nm
Blue Nadir	0 degrees	428 – 492 nm
Near-infrared Nadir	0 degrees	833 – 837 nm

ADS40 – II Image Channels

The multi-spectral channels at nadir are 'optically' co-registered through the use of a tetrachroid beam splitter. The focal plane and optics of the ADS40 – II permit all image channels to be collected at the native GSD. No multi-spectral image channels are "pan-sharpened" to obtain final resolution multi-spectral images. The current sensor calibration report is attached in Appendix D, Sensor Calibration Report.

4.3 Survey Parameters

Survey parameters were selected in the context of the accuracy and GSD requirements for the project, and the hypsography of the survey area. The fixed focal length of the ADS40 – II places aircraft flying height AMT, speed over ground, and sensor integration time as the configurable variables in deriving a particular GSD. Side overlap is selected to provide sufficient areas for tie point matching during aero-triangulation and to allow exclusion of the most off-nadir areas from the orthomosaic. Speed over ground and sensor integration time control the GSD in the along-track direction of the sensor. Existing USGS NED data is used during planning to estimate the GSD and sidelap that will be achieved for each line in the survey plan.

Survey Parameter	Value
Flying Height AMT	3200 feet
Sidelap	35 %
Speed Over Ground	135 knots
Integration Time	1.25 milliseconds
Line Spacing	2500 feet
Total Length of Lines	276.26 km
GSD	10 cm

Survey Parameters – Flight Plan and Sensor Settings

4.4 Survey Dates

All mobilizations and survey missions occurred during March 2013. Imagery was collected during the four survey missions listed below, with multiple re-flights performed to mitigate cloud shadows frequently encountered during surveys in tropical regions. Imagery from the 3/14/2013 mission was not used in the final mosaic due to extensive cloud shadows present in the imagery.

Date	Sensor
03/13/2013	ADS40 SH51 – S/N 1326
03/14/2013	ADS40 SH51 – S/N 1326
03/15/2013 Lift A	ADS40 SH51 – S/N 1326
03/15/2013 Lift B	ADS40 SH51 – S/N 1326

Survey Mission Dates

5 Image Processing

5.1 Raw Data Extraction

Leica Geosystems GPro version 3.3.1.79 was used to download the raw flight data from the MMU. Raw data for the ADS sensor consists of the un-rectified strip images in TIFF format, commonly referred to as L0 images in ADS workflows, and the raw ABGPS/IMU observables.

5.2 ABGPS/IMU

ABGPS/IMU data was collected on the aircraft during the survey mission, providing sensor position and orientation information for geo-referencing the imagery data. ABGPS observations were collected at a frequency of 2Hz, and IMU observations were collected at a frequency of 200Hz. Precise lever arm measurements from the ABGPS/IMU measurement reference points to the principal point of the ADS focal plane are used in reducing the raw vehicle position/attitude observables to sensor exterior orientation. These lever arm measurements are measured during sensor installation in the survey aircraft.

Sensor	GPS Lever Arm (m)	IMU Lever Arm (m)
ADS40 SH51 – SN1326	x: 1.950, y: 0.000, z: -1.180	x: 0.000, y: 0.000, z: -0.330

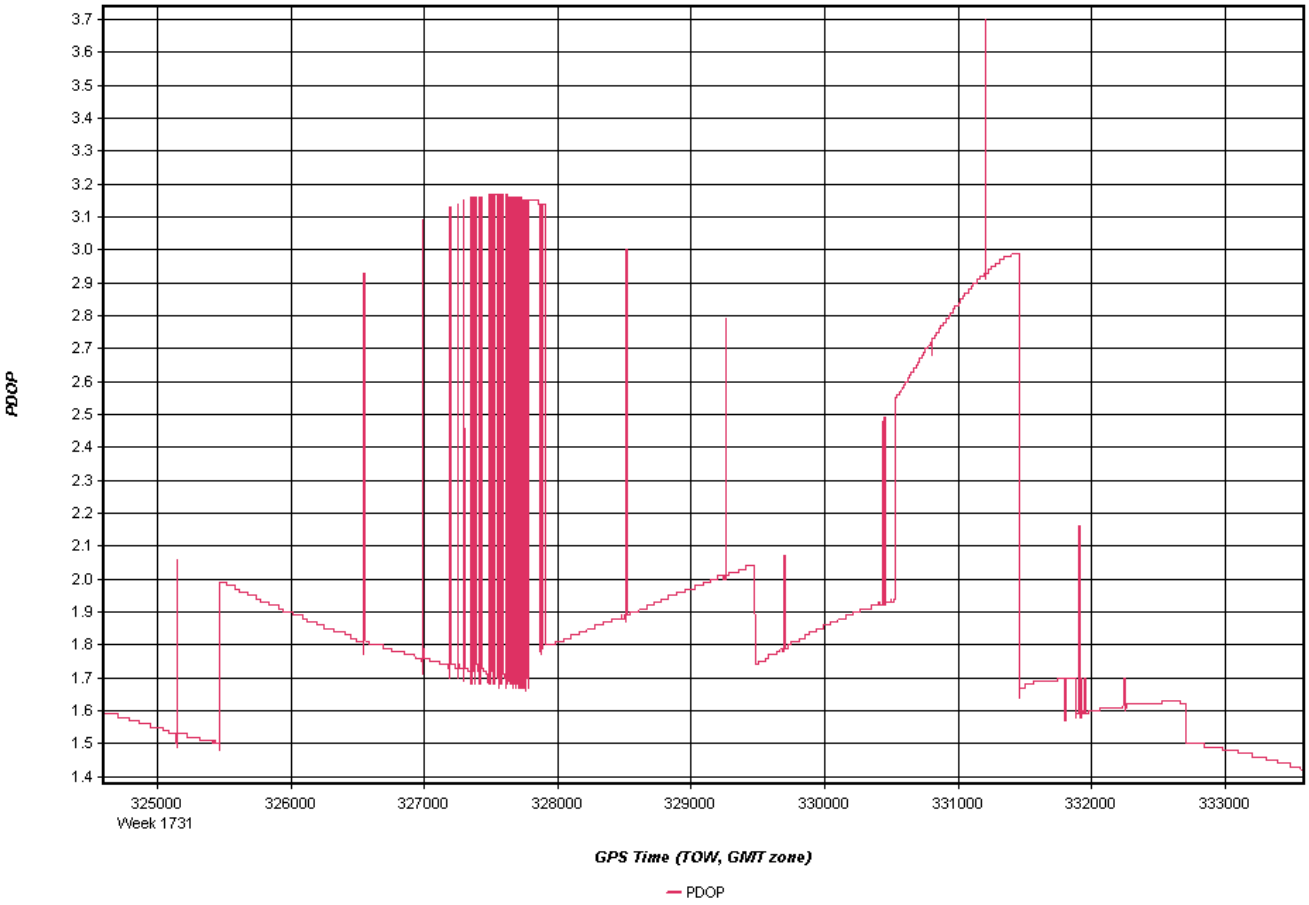
Navigation Sensor to ADS Lever Arms

GPS data was collected with a ground base station during the survey mission, providing corrections to support differential post-processing of the ABGPS. The ground GPS base station was setup on a temporary benchmark designated as PUR1, located at the Isla Grande Airport in San Juan, Puerto Rico. Ground GPS observations were collected at a frequency of 2Hz. Reference coordinates for the temporary benchmark were derived using NGS OPUS software, operated in the Static mode with a minimum of 4.5 hours of 2 hertz observations. The NGS OPUS datasheet for PUR1 is in Appendix B, Base Station Datasheet. Base station log sheets are in Appendix C, Base Station Logs.

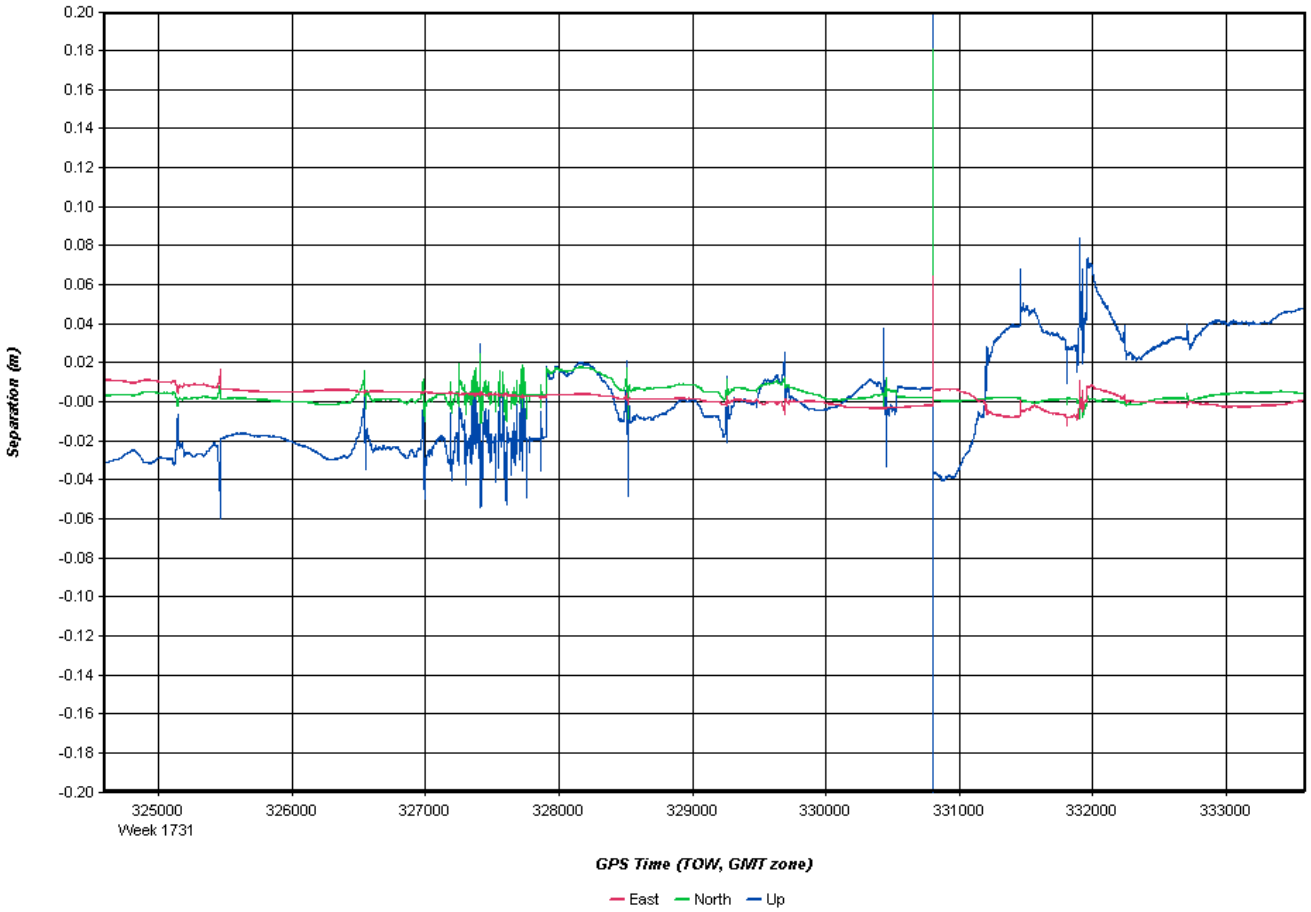
Date	Benchmark	Antenna Height
03/13/2013	Temporary BM (PUR1) at Isla Grande Airport	1.795 meters
03/14/2013	Temporary BM (PUR1) at Isla Grande Airport	1.826 meters
03/15/2013	Temporary BM (PUR1) at Isla Grande Airport	1.800 meters

Ground Base Station Antenna Heights

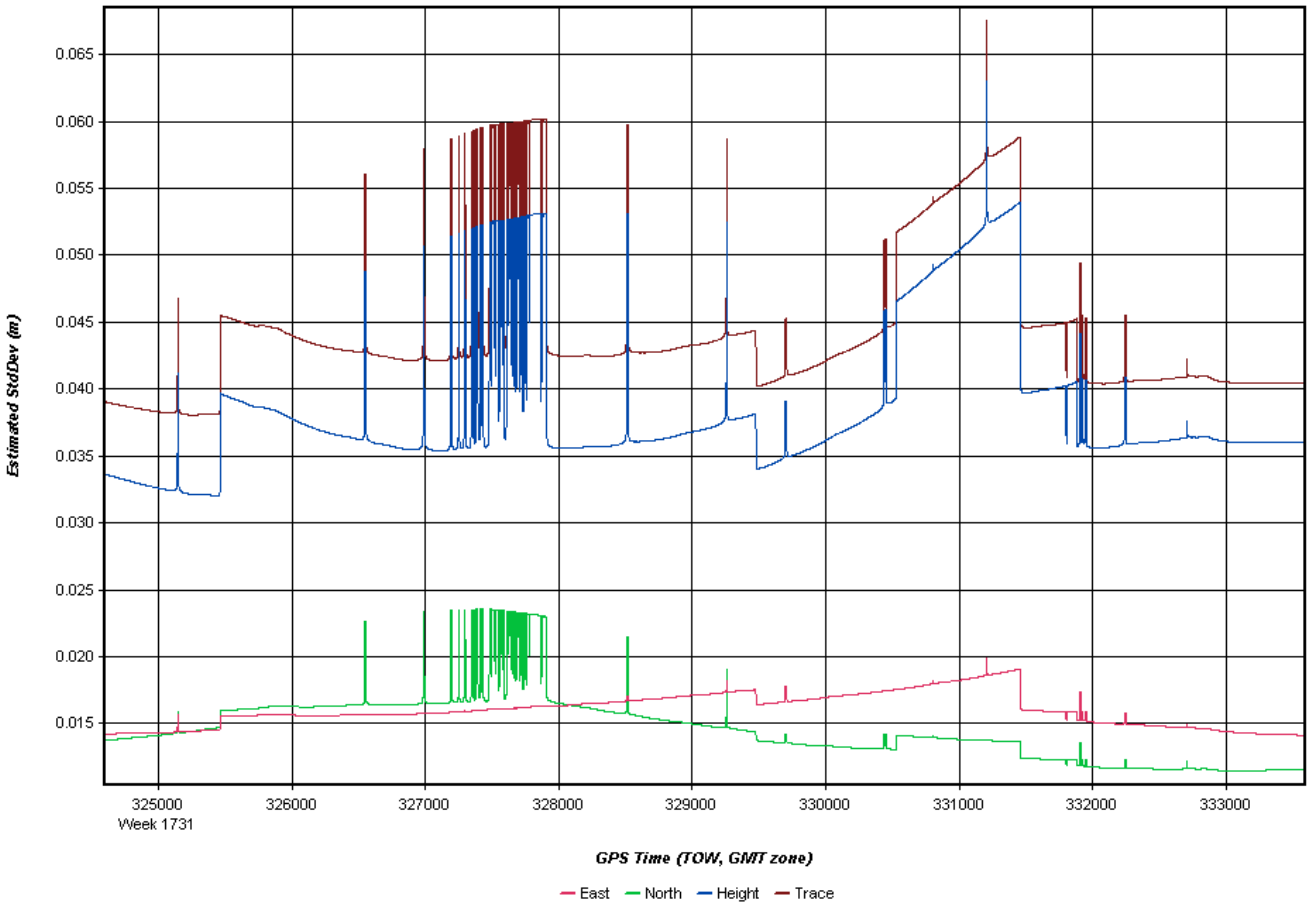
Differential correction of the ABGPS data using the ground base station data was performed in Waypoint GravNav software version 8.4. The NAD83(2011) geodetic coordinates developed through NGS OPUS for PUR1 were held as reference during differential correction. Corrected ABGPS data was exported from GrafNav for Applanix POSPac software version 4.3. POSPac was used to combine the ABGPS and IMU data through a Kalman filtering algorithm to arrive at a smoothed best estimate of the sensor's trajectory during the survey missions. This trajectory estimate along with precise exposure timing data provide initial EO estimates for the imagery in aero-triangulation. The graphs and map following below provide a summary of the trajectory quality and show the trajectory events from each survey mission.



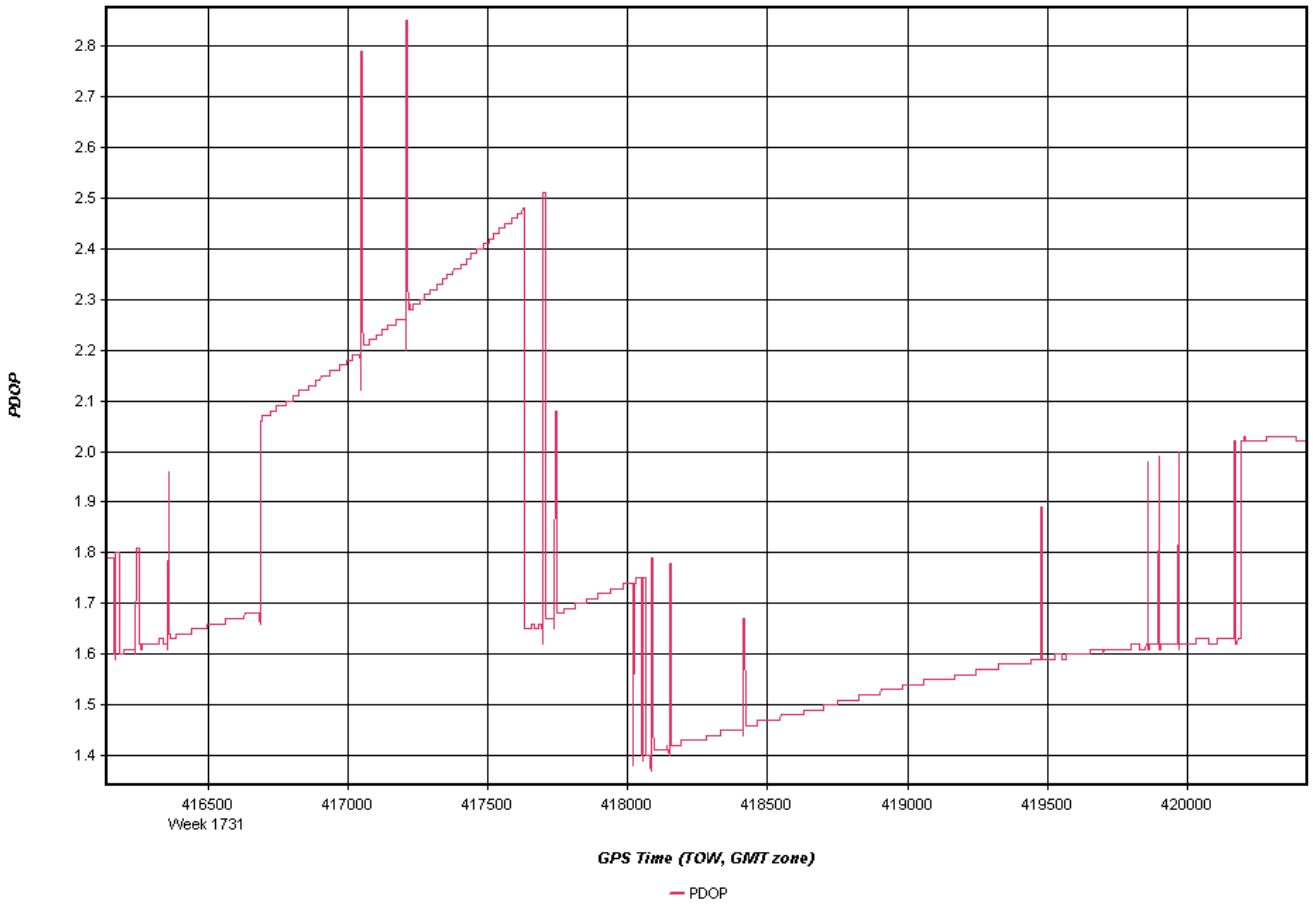
13032013 GPS PDOP Graph – Spikes generally correspond to turns.



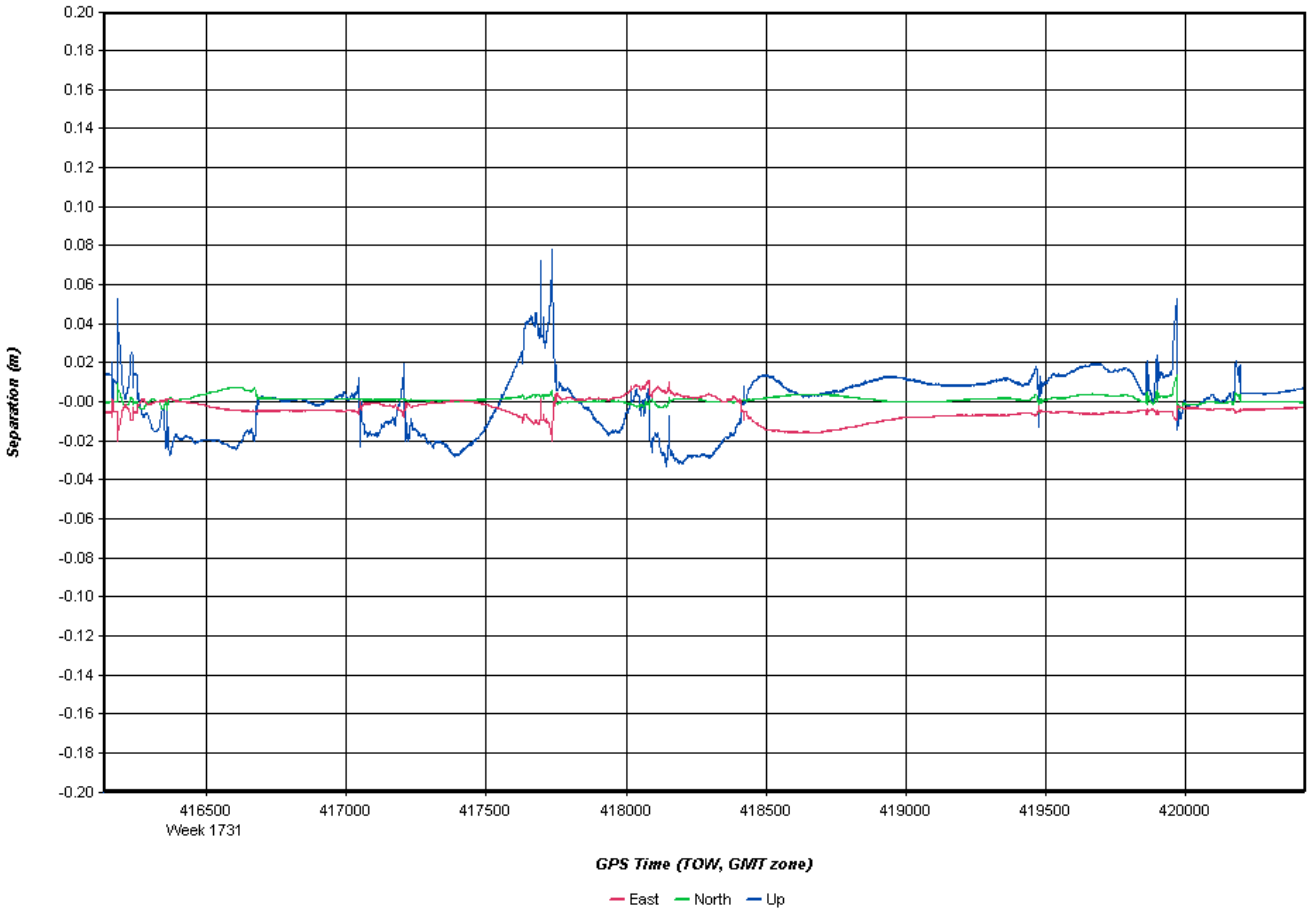
13032013 GPS Combined Separation Graph – Shows difference between forward and reverse differential GPS solution. Spike near time 331000 occurs in a turn.



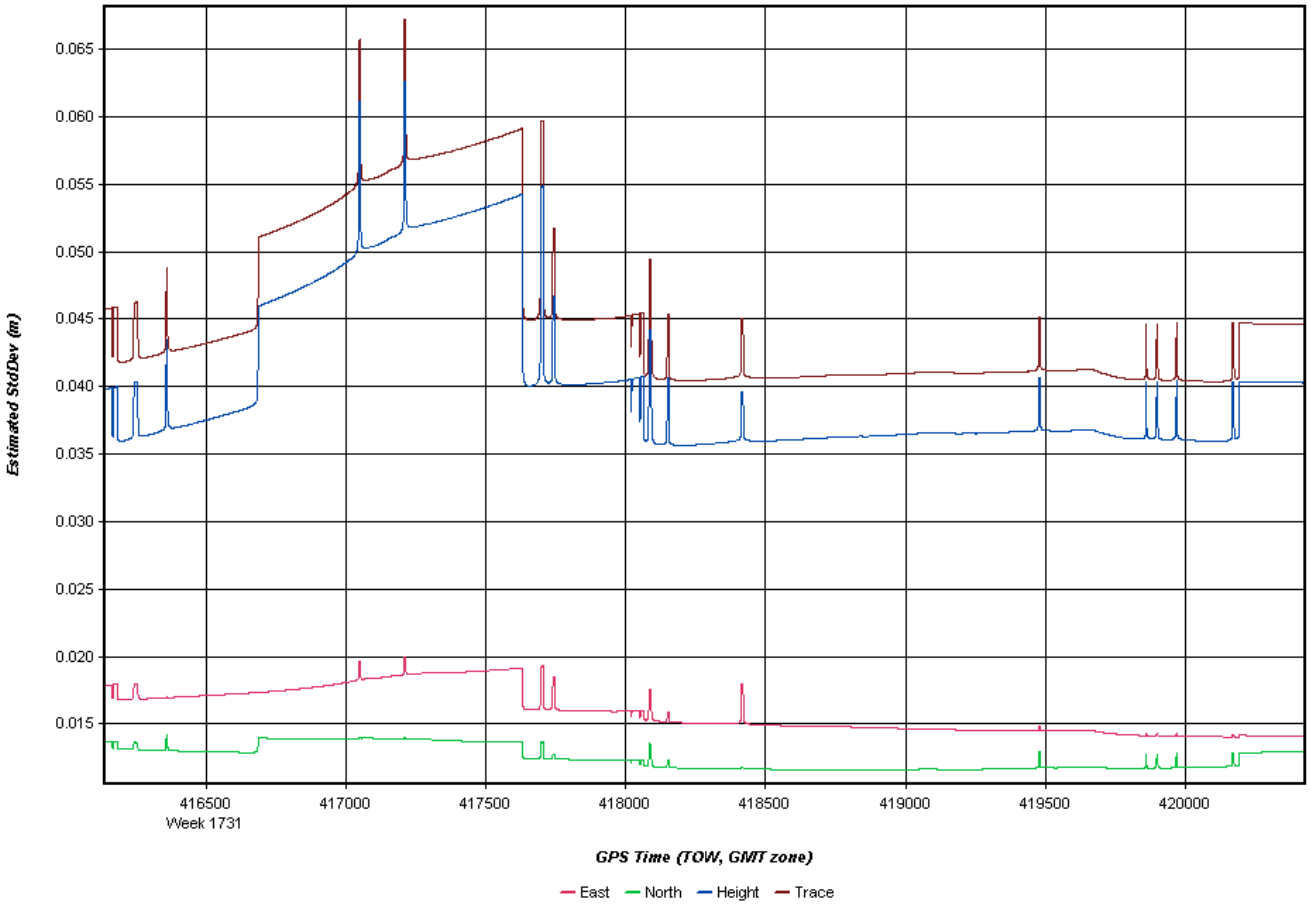
13032013 GPS Standard Deviation Graph – Shows estimated standard deviation of position solution. Spikes generally occur in turns.



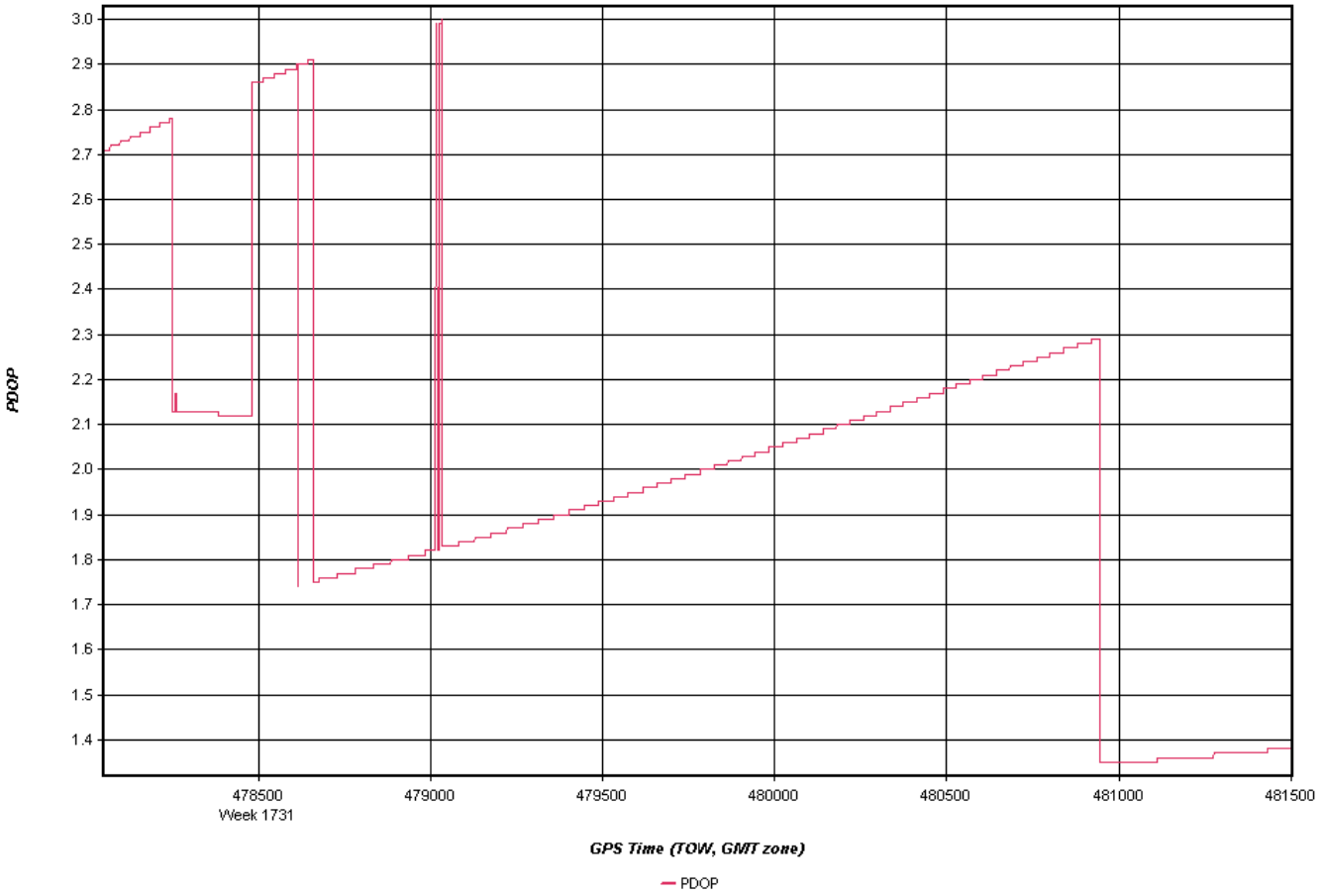
14032013 GPS PDOP Graph – Spikes generally correspond to turns.



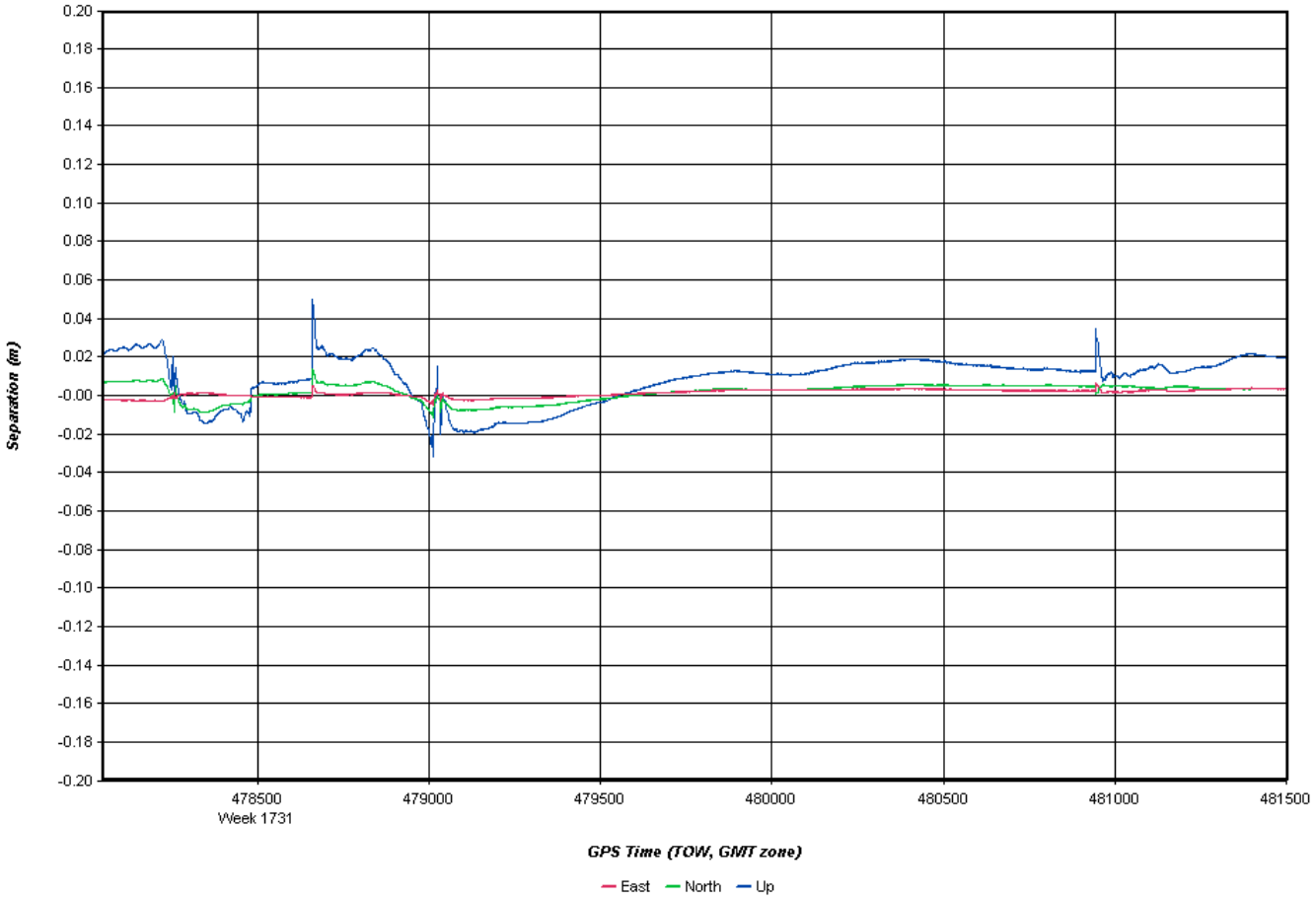
14032013 GPS Combined Separation Graph – Shows difference between forward and reverse differential GPS solution.



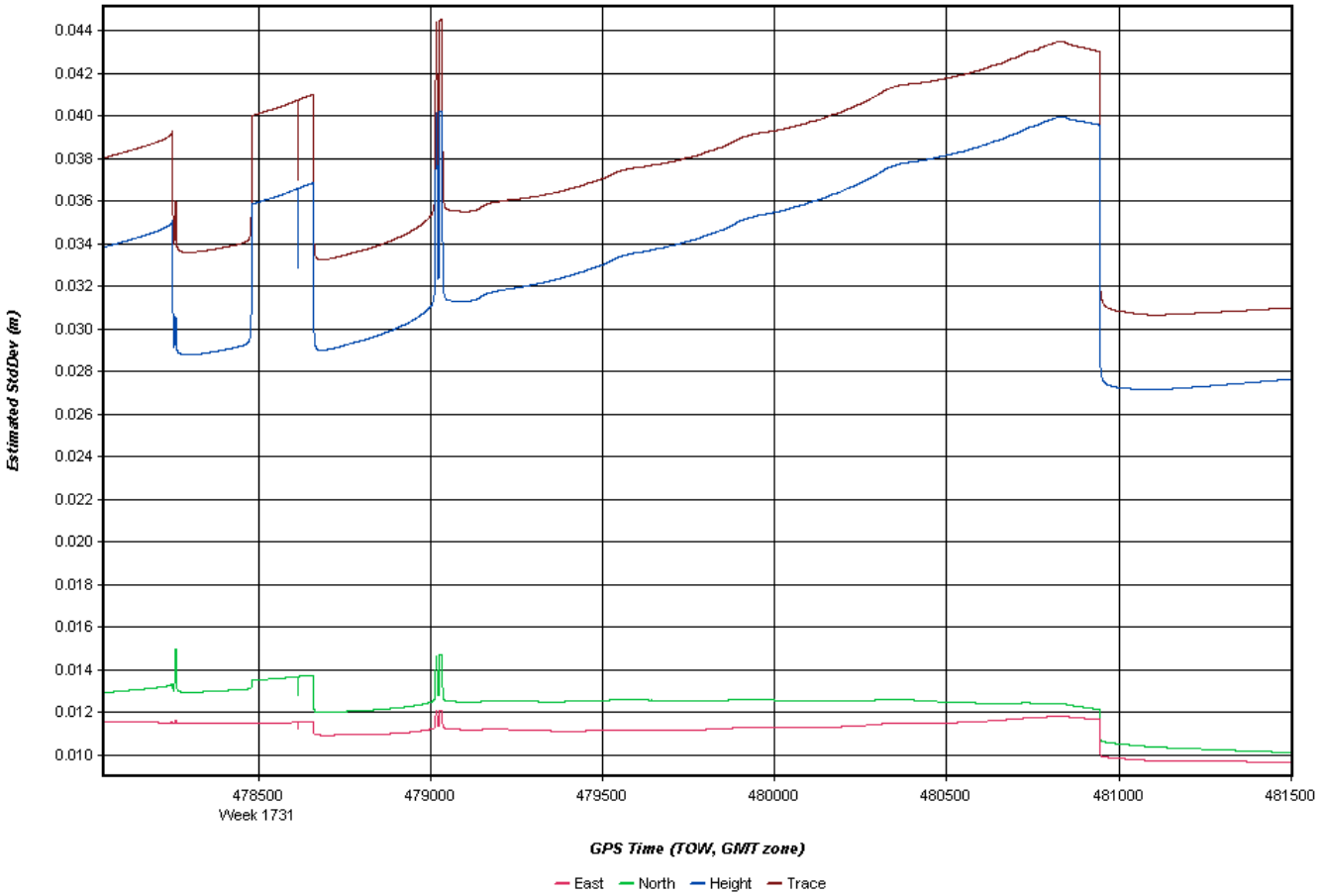
14032013 GPS Standard Deviation Graph – Shows estimated standard deviation of position solution. Spikes generally occur in turns.



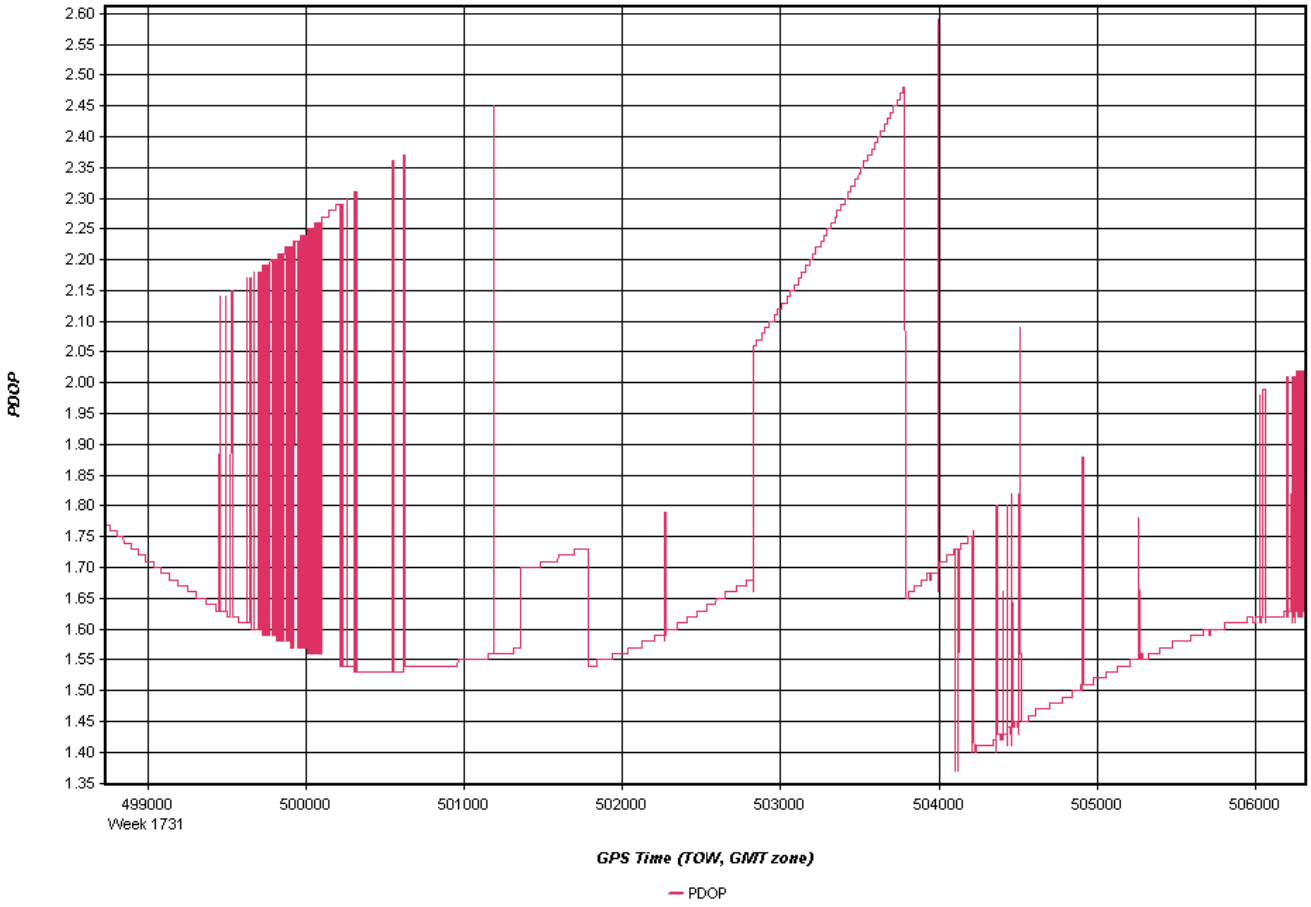
15032013a GPS PDOP Graph – Spikes generally correspond to turns.



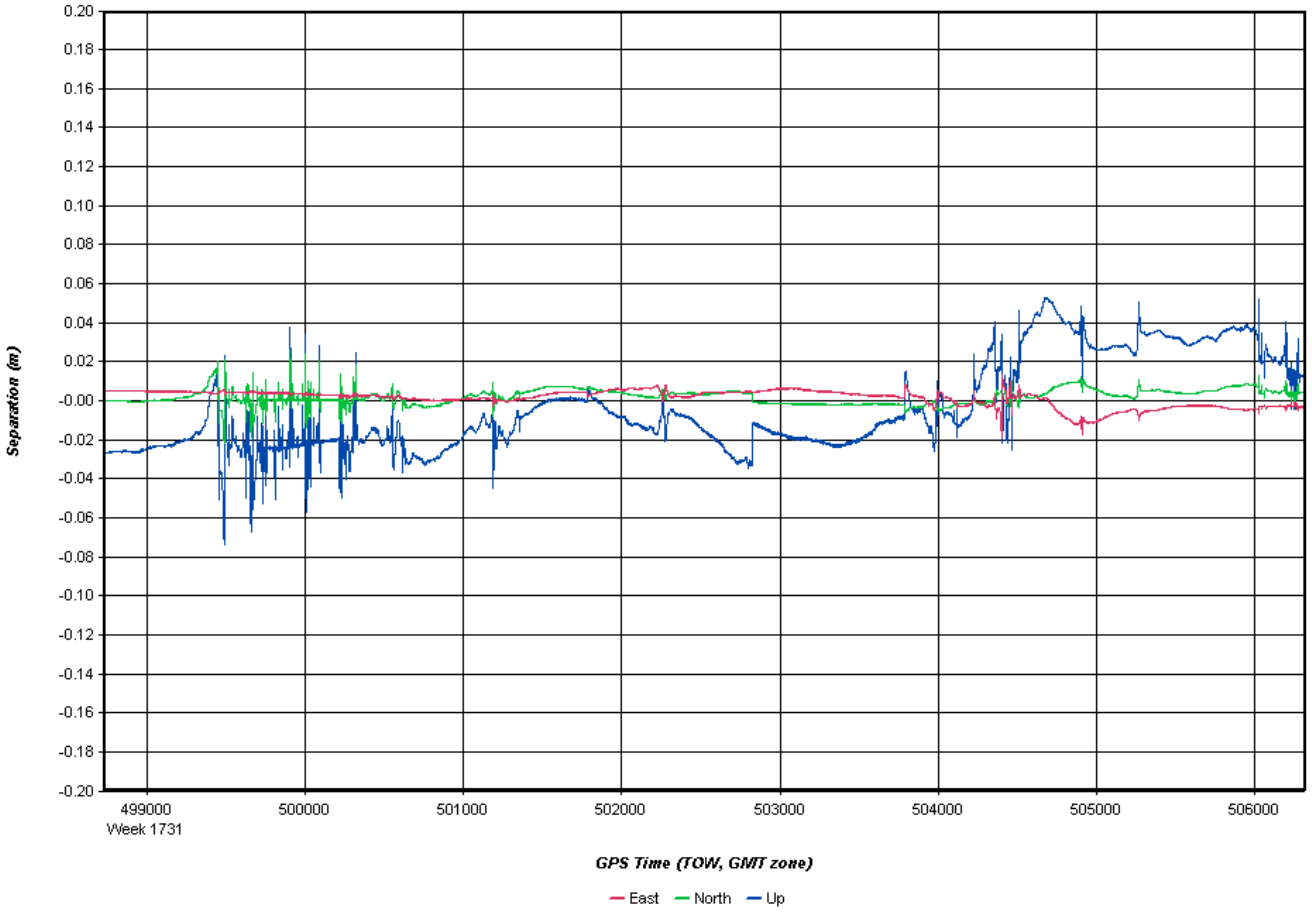
15032013a GPS Combined Separation Graph – Shows difference between forward and reverse differential GPS solution.



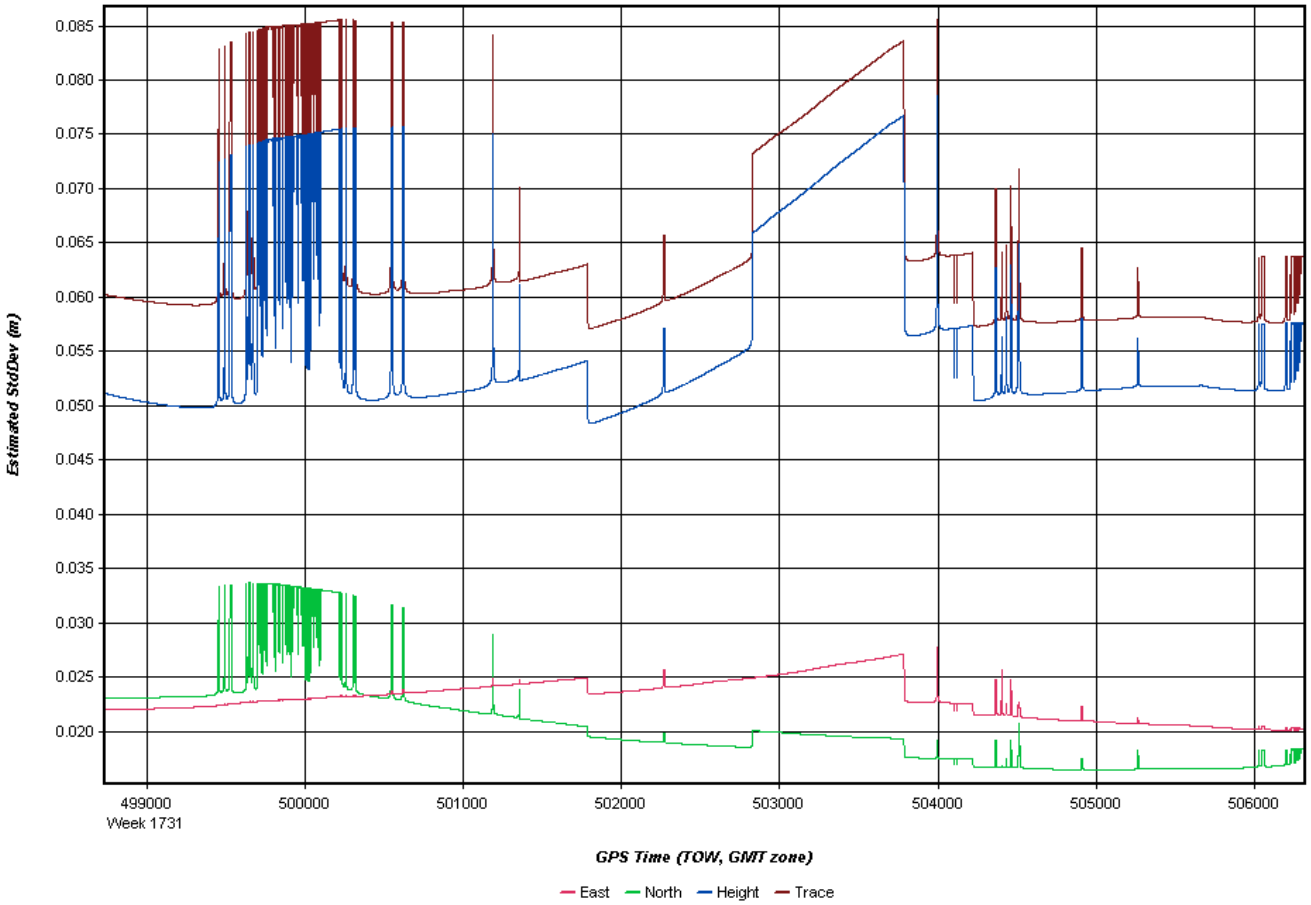
15032013a GPS Standard Deviation Graph – Shows estimated standard deviation of position solution. Spikes generally occur in turns.



15032013b GPS PDOP Graph – Spikes generally correspond to turns.



15032013b GPS Combined Separation Graph – Shows difference between forward and reverse differential GPS solution.



15032013b GPS Standard Deviation Graph – Shows estimated standard deviation of position solution. Spikes generally occur in turns.

Survey 13-034

San Juan/Puerto Nuevo AOI

- GPS/IMU Events 13032013
- GPS/IMU Events 14032013
- GPS/IMU Events 15032013a
- GPS/IMU Events 15032013b

Survey 13-034 San Juan/Puerto Nuevo, Puerto Rico
Airborne GPS/IMU Events

Prepared For: Jacksonville District USACE
Prepared By: Premier Geospatial, Inc.

Survey Date: 3/13/2013 - 3/15/2013

Aerial Sensor: ADS40 - II
Ground Sample Distance: 10cm

Horizontal Datum: NAD83(2011)
Vertical Datum: PRVD02(GEOID12A)

Survey Area

5.3 Aero-triangulation

Aero-triangulation was performed using StellaCore PictoVera software version 1.3.15. PictoVera's automatic point matching algorithm was used to match image tie points in the side overlap between adjacent image strips. The tie point observations were used in a least squares bundle adjustment to solve for systematic errors in the smoothed best estimate of trajectory, including GPS drift and timing offsets. The bundle adjustment also identifies and eliminates measurement blunders in the tie points. All survey flight lines were processed in a single aero-triangulation block.

After solving for systematic navigation errors and removing measurement blunders, ground control points were manually measured in the imagery. Ground control points coordinates used had horizontal reference of Puerto Rico State Plane, NAD83(2011), meters; and vertical reference of GRS80 ellipsoid heights, meters. AT for the ADS sensor is performed in the ellipsoid vertical reference to avoid systematic errors that geoid undulations cause in the pushbroom sensor model. The ground control point observations are used to solve for any remaining datum transformation required to determine EO in the project datum. Ground control points for this project consisted of photo-identifiable features. Ground control data collection and processing was performed by Gustin, Cothern & Tucker, Inc. of Niceville, FL.

Ground control points were assigned statistical weight, equivalent to their estimated accuracy, in the final least squares adjustment to solve for the control datum transformation. In order to validate the datum transformation solution, selected ground control points in the interior of the aero-triangulation block were permitted to statistically float (making them true check points). The least-squares adjustment RMSE values of these points when configured as check were compared to the RMSE values obtained when the same points were weighted as control to validate the solution. Points ACK_1, ACK_2-B, ACK_3, and PGEO_PR1 were selected as the candidate check points for this validation. The tables below summarize the RMSE for all observations of each point; both control and check, under different weighting scenarios.

RMSE of **check points** with **check points** allowed to **float**:

PID	RMSE x (m)	RMSE y (m)	RMSE z (m)	Magnitude (m)
ACK_1	-0.080	-0.027	-0.066	0.107
ACK_2-B	0.059	-0.027	-0.182	0.194
ACK_3	-0.017	-0.016	-0.019	0.030
PGEO_PR1	0.090	0.117	-0.024	0.149

RMSE of **check points** with **checkpoints weighted** as control:

PID	RMSE x (m)	RMSE y (m)	RMSE z (m)	Magnitude (m)
ACK_1	-0.073	-0.036	-0.023	0.085
ACK_2-B	0.067	-0.023	-0.115	0.135
ACK_3	-0.022	-0.017	0.009	0.030
PGEO_PR1	0.077	0.112	-0.021	0.137

RMSE of **control points** with **check points** allowed to **float**:

PID	RMSE x (m)	RMSE y (m)	RMSE z (m)	Magnitude (m)
ACL_1	-0.045	-0.017	-0.011	0.049
ACL_2	-0.079	-0.110	0.054	0.146
ACL_3	-0.065	-0.062	-0.080	0.120
ACL_4	0.055	-0.007	0.014	0.058
ACL_5	0.059	0.010	-0.044	0.074
ACL_6	0.004	0.012	0.032	0.034
PGEO_PR2	0.051	0.053	-0.021	0.076
PGEO_PR3	0.025	0.139	-0.007	0.141

RMSE of **control points** with **checkpoints weighted** as control:

PID	RMSE x (m)	RMSE y (m)	RMSE z (m)	Magnitude (m)
ACL_1	-0.052	-0.033	-0.012	0.062
ACL_2	-0.086	-0.104	0.091	0.162
ACL_3	-0.077	-0.065	-0.069	0.122
ACL_4	0.067	-0.023	0.057	0.091
ACL_5	0.070	0.020	0.041	0.083
ACL_6	0.007	0.010	0.077	0.078
PGEO_PR2	0.037	0.047	-0.021	0.063
PGEO_PR3	0.009	0.133	-0.010	0.134

The RMSE values for measurements at control and check points are consistent at the sub-pixel level when the check points are allowed to float in the final least squares adjustment and when they are held fixed as control. This consistency validates the aero-triangulation solution, and provides a high degree of confidence that there are no remaining systematic errors or blunders distorting the solution.

5.4 Surface Model

PremierGeo used two sources of elevation data to develop a DEM for orthorectification of the collected imagery. A bare-earth LiDAR mass point dataset, originally collected in 2004 at a nominal point spacing of 2 meters, was provided by the Government. This dataset was loaded into TerraSolid TerraScan software, reviewed for non-ground artifacts, and edited where necessary. A DEM was gridded from the edited LiDAR mass points at 1.524 meter post spacing.

Available metadata for the existing LiDAR data was somewhat ambiguous regarding the vertical datum reference, but appeared to indicate a vertical datum of PRVD02(GEOID99). Initially, delta-z's were calculated at aero-triangulation control points between the surveyed z values (orthometric heights referenced to PRVD02(GEOID12A)) and surface z values (orthometric heights referenced to PRVD02(GEOID99)). The calculated delta-z values showed a substantial discrepancy between the ground control and the surface, with surface heights an average of 1.76 meters **higher** than the control point heights.

GCP	LiDAR z (m)	GCP z (m)	Difference (m)
PGEO1	5.165	3.360	1.805
PGEO2	4.284	2.479	1.805
PGEO3	4.846	3.170	1.676
ACL1	5.958	4.002	1.956
ACL2	2.903	1.638	1.265
ACL3	8.759	6.921	1.838
ACL4	45.453	43.558	1.895
ACL5	94.921	92.989	1.932
ACL6	20.449	18.360	2.089
ACK1	45.189	43.335	1.854
ACK2-T	36.837	35.241	1.596
ACK2-B	36.863	35.441	1.422
ACK3	4.508	2.775	1.733
		Average dZ (m) =	**1.759**

Orthometric Height Surface to Control Comparison

The next step taken in examining the LiDAR data was to convert its vertical reference to ellipsoid heights and recalculate the control point delta-z's against the control point ellipsoid heights. The LiDAR data was converted to ellipsoid heights using the published NGS GEOID99 geoid height grids. The ellipsoid heights calculated from post processing of the survey data were used for the aero-triangulation control points. The calculated delta-z values in ellipsoid heights showed a better fit, with the surface heights an average of 0.54 meters lower than the control point heights.

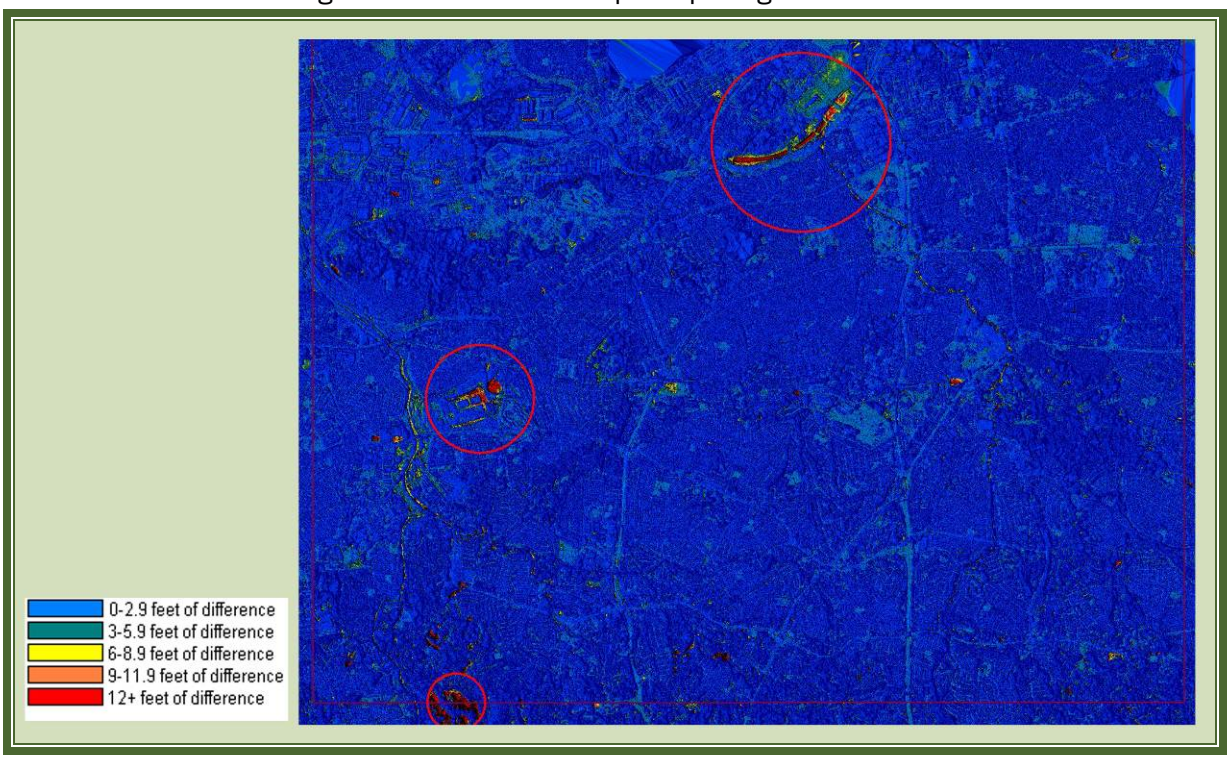
GCP	LiDAR z (m)	GCP z (m)	Difference (m)
PGEO1	-40.023	-39.523	-0.500
PGEO2	-40.901	-40.413	-0.488
PGEO3	-40.521	-39.895	-0.626
ACL1	-38.692	-38.365	-0.327
ACL2	-41.693	-40.693	-1.000
ACL3	-36.283	-35.829	-0.454
ACL4	2.240	2.661	-0.421
ACL5	51.594	52.007	-0.413
ACL6	-23.414	-23.220	-0.194
ACK1	1.576	2.038	-0.462
ACK2-T	-6.683	-5.980	-0.703
ACK2-B	-6.662	-5.783	-0.879
ACK3	-39.956	-39.416	-0.540
		Average dZ (m) =	**-0.539**

Ellipsoid Height Surface to Control Comparison

These comparisons indicate that there is potentially a difference between the GEOID99 height models and the GEOID12A height models, as the surface fits the control better when both are reduced to ellipsoid. An additional z-shift of + 0.54 meters was applied to the ellipsoid LiDAR data to bring into reasonable agreement with the aero-triangulation control.

With the z reference ambiguities resolved, focus was shifted to potential areas of ground change within the project area. The second source of elevation data used for the project was an auto-correlated surface covering the survey area, generated by PremierGeo from the new imagery, using the auto-correlation module in the PictoVera software. The module correlates a dense elevation network of mass points from the stereo-viewable imagery of each flight line, with an approximate density of one point per 2 meters. The auto-correlated mass points represent ground and above ground features and must be filtered to bare-earth for use in orthorectification. This dataset was also gridded at 1.524 meter post spacing, consistent with the LiDAR derived DEM.

The strategy chosen to develop the final orthorectification surface was to supplement the LiDAR surface in areas of significant ground change with the autocorrelated surface. Editing an autorcorrelated surface for the entire project area to the level required for orthorectification was beyond the scope of the project. The two surfaces were compared to identify areas where edits should be focused. A difference surface was calculated between the two datasets (depicted on the next page) to identify these areas. Areas inspected were those falling in the range of 6 – 12+ feet of difference. Difference values below this threshold were generally found to be low vegetation noise in the autocorrelated points. The comparison identified three areas (encompassed in the circular polygons in the graphic on the next page) within the southern half of the project boundary that had significant ground change between 2004 and 2013. Other areas with change above the threshold were either buildings or high vegetation in the autocorrelated points. The LiDAR derived DEM was replaced with the autocorrelated DEM in these three areas, and any above ground artifacts removed in TerraScan. The final orthorectification DEM was gridded at 1.524 meter post spacing.



LiDAR to Autocorrelated Difference Surface

5.5 Orthorectification

Orthorectification of imagery was accomplished with the PictoVera software version 1.3.15 rectification module, which provided a seamless workflow for block bundle adjustment and generation of orthoimages. The PictoVera rectification module used the block bundle adjustment solution developed in the bundle adjustment module and the L0 images as inputs.

Radiometric correction of the imagery included applying the manufacturer's calibration and a proprietary process to account for atmospheric and lighting effects. Two principal effects were considered in the proprietary correction; atmospheric haze and bi-directional reflectance. Atmospheric haze describes the effect of sunlight reflecting off of aerosols dispersed in the atmosphere, especially in the blue wavelength of the visible light spectrum. Bi-directional reflectance describes the non-uniform brightness of the ground scene in an aerial image caused by varied viewing and illumination angles. Due to the ADS sensor's consistent nadir geometry in the along-track flight direction of the image strip, haze and reflectance only affect the ADS sensor in the across track direction of the image strip. The algorithm works by sampling the pixel values throughout the image strip and calculating an average pixel value for each column of pixels across the sensor track. A polynomial function is used to normalize the samples to remove any anomalies, such as specular reflection on water, from the column averages. Mean brightness of the column averages are calculated, and a correction value determined to adjust the average pixel value of each column in the strip to the mean. The corrections were calculated and applied in the raw 12-bit dynamic range of the ADS sensor, permitting a more accurate correction than one applied after the imagery has been histogram stretched for 8-bit storage and viewing. Correction values were stored in separate files for each multi-spectral image and were applied by the orthorectification module during orthoimage output. The manufacturer's factory calibrated radiometric gain parameters were also applied during orthorectification, modeling the variable sensitivity of each CCD in the ADS sensor to the wavelength of light it is assigned to collect.

The assembled DEM and atmospheric correction files were added to the PictoVera block definition. The rectification module was used to generate a 4-band orthorectified image strip, commonly referred to as L2 images in ADS workflows. The band order of the L2 was Red in Band 1, Green in Band 2, Blue in Band 3, and Near-Infrared in Band 4. The L2 was stored in 16-bit GeoTIFF file format, and had the atmospheric corrected 12-bit dynamic range of the ADS sensor. The L2 images were validated for relative and absolute horizontal accuracy by visual inspection using the inpho OrthoVista software. Photogrammetric technicians manually measured common features in the sidelap region of adjacent images and photo-identifiable ground control points to validate relative and absolute accuracy of the L2s. The results of the horizontal accuracy assessment are outlined in the table below. With horizontal accuracy requirements validated, the imagery was moved into the mosaic phase.

POINT ID	CONTROL (m)		IMAGE (m)		DELTA (m)		
	EASTING	NORTHING	EASTING	NORTHING	EASTING	NORTHING	HORIZ
PGEO_3	235323.99	269790.49	235323.97	269790.49	0.021	-0.004	0.022
PGEO_2	235196.57	268909.96	235196.51	268909.93	0.066	0.031	0.073
PGEO_1	235877.35	268879.36	235877.27	268879.36	0.077	-0.001	0.077
ACK_1	234031.29	259982.71	234031.30	259982.70	-0.009	0.005	0.010
ACK_2 - B	239630.16	259438.05	239630.18	259438.07	-0.019	-0.029	0.034
ACK_3	237309.23	265093.07	237309.29	265093.07	-0.060	0.002	0.060
ACL_1	230740.40	266006.10	230740.43	266006.14	-0.030	-0.040	0.050
ACL_2	240677.43	265872.65	240677.53	265872.58	-0.098	0.075	0.124
ACL_3	237037.60	268174.61	237037.57	268174.62	0.025	-0.001	0.025
ACL_4	230657.24	257679.74	230657.16	257679.77	0.082	-0.031	0.088
ACL_5	241998.44	257850.14	241998.37	257850.08	0.069	0.057	0.090
ACL_6	236971.48	261614.34	236971.46	261614.38	0.016	-0.044	0.046
RMSEeasting		0.06	Meters				
RMSEnorthing		0.04	Meters				
RMSEr		0.07	Meters				
Accuracyr		0.11	Meters				
FGDC-STD-007.3-1998							
RMSEnorthing = √ [∑ (CONTROLnorthing - MEASUREDnorthing)^2/n]							
RMSEeasting = √ [∑ (CONTROLeasting - MEASUREDeasting)^2/n]							
RMSEr = √ [RMSEeasting^2 + RMSEnorthing^2]							
Accuracyr = 1.7308 * RMSEr							
Coordinates in NAD1983(2011) State Plane Puerto Rico Virgin Islands FIPS 5200 Meters							

Orthoimagery Accuracy Calculations

5.6 Mosaic

The mosaicing of the L2 images was accomplished in the inpho OrthoVista Seam Editor (OrthoVista SE) software. Photogrammetric technicians manually placed seamlines using heads-up digitization techniques in OrthoVista SE. Use of OrthoVista SE allowed the technicians to see the resulting mosaic in real-time during editing, minimizing the number edits for seam placement required once tiles are clipped from the mosaic. Technicians placed the seams so as to utilize the most nadir portion of each orthoimage, while avoiding clipping of above ground features wherever possible. The manually placed seams were stored in seam definition files and applied during the tile clipping process in OrthoVista.

Color adjustment of the atmospherically corrected, 12-bit dynamic range L2 ADS strips, for storage and viewing as 8-bits per channel GeoTIFF images, was applied in the final processing step before individual orthoimages were clipped from the mosaic. The L2 strips generated from the PictoVera processing block were loaded into OrthoVista to perform the color adjustment, which allowed visual as well as numerical inspection of calculated color corrections in real-time, before the corrections were actually applied to the images. Color adjustments were calculated using the Radiometrix module in the OrthoVista software. The Radiometrix module was used to define a non-linear, splined curve histogram stretch to transform the 12-bit dynamic range of the L2 strip to the full dynamic range of the 16-bit GeoTIFF. The histogram stretch generally reflects a natural logarithm function; this is necessary to accommodate the way in which the human eye perceives light.

OrthoVista software was used to apply the seamlines and histogram stretch to generate the final 8-bit 4-band mosaic. The areas outside of the project area boundary were set to display as white pixels (255, 255, 255, 255). The tiling scheme for the mosaic was a 10,000 pixel x 10,000 pixel grid. The origin of the tiling scheme was based off of the nearest 1000 meter State Plane Grid Interval, starting at origin x:229,000.000 and origin y:257,000.000.

5.7 Stereo Imagery

Stereo viewable imagery, commonly referred to as L1 images in ADS workflows, was generated for each of the 7 image channels collected during the survey missions using the PictoVera stereo rectification module. L1 images are rectified from the L0 images to remove the effects of sensor and platform motion during flight. The L1 images have the manufacturer's radiometric correction and 8-bit color adjustments applied, but do not have corrections for atmosphere or haze applied, as these corrections can cause parallax error in the stereo rectified imagery. The three panchromatic images are stored in separate single band images for each channel. The four multi-spectral images at nadir are combined into a single four-band image for natural color and/or false color-infrared viewing.

There are several considerations for utilization of the stereo imagery in the DAT/EM Summit Evolution software. The stereo rectification module writes the final adjusted EO values to the .ODF files (orientation data files), so the .ODF.ADJ files produced in some ADS workflows are not needed for accurate stereo mensuration. The Leica definition for the .ODF file assumes elevations referenced to the ellipsoid, so the stereo plotter software must be configured to apply a geoid height model to perform stereo mensuration with an orthometric height reference. The Summit Evolution project should be configured using the "ADS 40/80 Using Leica Kit" option in the New Project dialog. Summit Evolution requires overviews for ADS L1 images in its proprietary .PYR file format; these should be created during project setup. The "Combine Split Imagery Blocks" option should be selected during Summit Evolution project setup to ensure proper stereo display of the full ADS L1 image strip.

Appendix A: Flight Logs

FLIGHT LOG - ADS IMAGE ACQUISITION

Company	Operator	Pilot	Date (mm/dd/yyyy)	Day of Year	Project
Premier Geospatial	JACOBUS	MCDONALD	3/13/2013	72	Puerto Rico

Aircraft	Hobbs Start	Hobbs End	Hobbs Total hr	Sensor Serial and Model	Local Start	Local Stop	UTC Start	UTC Stop	FPD/FDA File
N246MP	3733.7	3735.9	2.2	Serial: 1326 Model: SH51	14:10:00	16:38:33	18:10:00	20:38:33	PUERTORICO

CORS	GPS Base Station
Yes ☐ No ☒ Site ID: Site ID:	PID: PUR1 Rx: GX1220 Ant: AX1202 Ant Hgt: 1.795 Obs. File:PUR1.20130313

Departure Airport	Arrival Airport	Visibility	Ceiling	Cloud Cover	Grnd Temp	Grnd Pres	Alt Temp	Alt Pres	MM #	MM GB Start	MM GB End	Total GB
TJIG	TJIG	10mi	CLR	0%	29C	30.01in			1	777	665	112

GSD	Target Grnd Speed	AGL	Avg. Ground Elev.	MSL	Sensor Config SH52/82 ONLY
4"	155kts	2975ft	325ft	3300ft	PANF27 ☐ PANF02A ☐ REDN00 ☐ GRN00 ☐ REDB16 ☐ GRNB16 ☐ PANB14 ☐ PANF02B ☐ BLUN00 ☐ NIRN00 ☐ BLUB16 ☐ NIRB16 ☐

ASCOT #	FPES #	Dir	Start UTC	Stop UTC	IT	GS	# Sat's	PDOP	Alt	Notes Fixed IT 1.25 / Raw Application Class
	PR01	E	18:35:11	18:39:01	1.25	112	7	1.1	3189	Clear. Raw Application Class. Fixed IT 1.25ms
	PR02	W	18:41:39	18:41:41	x	x	x	x	x	**Clear. Image Data Gap after line start - Aborted and restarted line.**
	PR02	W	18:45:43	18:49:20	1.25	128	7	2.1	3256	Clear
	PR03	E	18:52:05	18:56:08	1.25	111	8	1.9	3284	Clear. IT warning
	PR04	W	18:59:02	19:02:26	1.25	141	8	1.9	3270	Clear. Switched to Standard Application Class.
	PR05	E	19:04:59	19:08:41	1.25	115	8	1.9	3276	Clear. IT warning 2mi from east end
	PR06	W	19:11:02	19:14:40	1.25	128	9	1.7	3242	Clear. IT warning 2mi from east end
	PR07	E	19:17:21	19:21:02	1.25	120	8	1.8	3243	Clear. IT warning 2mi from east end
	PR08	W	19:23:33	19:27:09	1.25	129	8	1.9	3234	Clear
	PR09	E	19:29:26	19:33:08	1.25	119	8	1.9	3248	Clear
	PR10	W	19:35:41	19:39:14	1.25	130	8	2	3242	Clouds
	PR11	E	19:42:14	19:45:55	1.25	120	8	2	3312	Clouds. Shadows 1-2mi from east end
	PR12	W	19:48:27	19:52:04	1.25	122	8	2.1	3317	Clouds
	PR13	E	19:54:32	19:58:20	1.25	118	8	2.2	3319	Clouds. Shadows 2mi from east end
	PR14	W	20:00:49	20:04:17	1.25	139	9	1.6	3308	Clouds. Shadows 2mi from east end
	PR15	E	20:07:03	20:10:44	1.25	121	9	1.7	3329	Clouds. Shadows 1-4mi from east end
	PR16	W	20:13:30	20:16:47	1.25	135	9	1.8	3332	Clouds. 1, 3, 5mi from east end
	PR17	E	20:19:43	20:23:40	1.25	120	9	1.8	3304	Clouds. 2, 3, 4-6mi from west end
										Ended for Sun Angle

FLIGHT LOG - ADS IMAGE ACQUISITION

Company	Operator	Pilot	Date (mm/dd/yyyy)	Day of Year	Project
Premier Geospatial	JACOBUS	MCDONALD	3/14/2013	73	Puerto Rico

Aircraft	Hobbs Start	Hobbs End	Hobbs Total hr	Sensor Serial and Model	Local Start	Local Stop	UTC Start	UTC Stop	FPD/FDA File
N246MP	3735.9	3736.9	1.0	Serial: 1326 Model: SH51	15:35:20	16:46:28	19:35:28	20:46:28	PUERTORICO

CORS	GPS Base Station
Yes ☐ No ☒ Site ID: Site ID:	PID: PUR1 Rx: GX1220 Ant: AX1202 Ant Hgt: 1.826 Obs. File:PUR1.20130314

Departure Airport	Arrival Airport	Visibility	Ceiling	Cloud Cover	Grnd Temp	Grnd Pres	Alt Temp	Alt Pres	MM #	MM GB Start	MM GB End	Total GB
TJIG	TJIG	20mi	SCT5K	30%	29C	29.93in			1	665	636	29

GSD	Target Grnd Speed	AGL	Avg. Ground Elev.	MSL	Sensor Config	SH52/82 ONLY
4"	155kts	3075ft	325ft	3400ft	PANF27 ☐ PANF02A ☐ REDN00 ☐ GRN00 ☐ REDB16 ☐ GRNB16 ☐	PANB14 ☐ PANF02B ☐ BLUN00 ☐ NIRN00 ☐ BLUB16 ☐ NIRB16 ☐

ASCOT #	FPES #	Dir	Start UTC	Stop UTC	IT	GS	# Sat's	PDOP	Alt	Notes Fixed IT 1.25 / STD Application Class
	PR19	E	19:57:29	20:00:38	1.25	156	9	1.6	3330	Clouds. Cloud Shadows 3.5, 4.5, 6.3, 7, 8mi from west end.
	PR20	W	20:03:04	20:06:15	1.25	152	9	1.7	3307	Clouds. Cloud shadows 1.5-2mi from east end
	PR18	E	20:08:46	20:12:08	1.25	156	9	1.8	3316	Clouds. Cloud shadows 1.5, 3-8mi from west end
	PR16	W	20:14:21	20:17:30	1.25	143	9	1.8	3380	Clouds. Cloud shadows 1, 5-6, 8.5mi from east end
	PR17	E	20:20:07	20:23:16	1.25	142	9	1.9	3378	Clouds. Cloud shadows 1.4, 3-7mi from west end
	PR14	W	20:25:39	20:28:38	1.25	156	9	1.9	3376	Clouds. No shadows seen.
										Ended for Sun Angle

FLIGHT LOG - ADS IMAGE ACQUISITION

Company	Operator	Pilot	Date (mm/dd/yyyy)	Day of Year	Project
Premier Geospatial	JACOBUS	MCDONALD	3/15/2013	74	Puerto Rico

Aircraft	Hobbs Start	Hobbs End	Hobbs Total hr	Sensor Serial and Model	Local Start	Local Stop	UTC Start	UTC Stop	FPD/FDA File
N246MP	3736.9	3737.6	0.7	Serial: 1326 Model: SH51	8:47:20	9:44:24	12:47:20	13:44:24	PUERTORICO4inch

CORS	GPS Base Station
Yes ☐ No ☒ Site ID: Site ID:	PID: PUR1 Rx: GX1220 Ant: AX1202 Ant Hgt: 1.800 Obs. File:PUR1.20130315

Departure Airport	Arrival Airport	Visibility	Ceiling	Cloud Cover	Grnd Temp	Grnd Pres	Alt Temp	Alt Pres	MM #	MM GB Start	MM GB End	Total GB
TJIG	TJIG	20mi	SCT5K	40%	25C	30.01in			1	636	617	19

GSD	Target Grnd Speed	AGL	Avg. Ground Elev.	MSL	Sensor Config SH52/82 ONLY
4"	150kts	3123ft	377ft	3500ft	PANF27 ☐ PANF02A ☐ REDN00 ☐ GRN00 ☐ REDB16 ☐ GRNB16 ☐ PANB14 ☐ PANF02B ☐ BLUN00 ☐ NIRN00 ☐ BLUB16 ☐ NIRB16 ☐

ASCOT #	FPES #	Dir	Start UTC	Stop UTC	IT	GS	# Sat's	PDOP	Alt	Notes Fixed IT 1.25 / STD Application Class
	PR20	E	13:08:02	13:11:11	1.25	145	7	2.6	3400	Clear
	PR19	W	13:14:01	13:17:03	1.25	151	7	2.7	3418	Clear
	PR18	E	13:20:15	13:23:25	1.25	137	7	2.9	3401	Clouds. Cloud shadows 2, 4-5mi from west end
	PR17	W	13:28:02	13:31:03	1.25	149	8	1.9	3421	Clouds. Cloud shadows 4, 5, 7, 8mi from west end
										Ended for clouds entire project

FLIGHT LOG - ADS IMAGE ACQUISITION

Company	Operator	Pilot	Date (mm/dd/yyyy)	Day of Year	Project
Premier Geospatial	JACOBUS	MCDONALD	3/15/2013	74	Puerto Rico

Aircraft	Hobbs Start	Hobbs End	Hobbs Total hr	Sensor Serial and Model	Local Start	Local Stop	UTC Start	UTC Stop	FPD/FDA File
N246MP	3737.6	3739.5	1.9	Serial: 1326 Model: SH51	14:31:53	16:37:23	18:31:53	20:37:23	PUERTORICO4inch

CORS	GPS Base Station
Yes ☐ No ☒ Site ID: Site ID:	PID: PUR1 Rx: GX1220 Ant: AX1202 Ant Hgt: 1.800 Obs. File:PUR1.20130315

Departure Airport	Arrival Airport	Visibility	Ceiling	Cloud Cover	Grnd Temp	Grnd Pres	Alt Temp	Alt Pres	MM #	MM GB Start	MM GB End	Total GB
TJIG	TJIG	10mi	Few 5K	15%	30C	29.97in			1	617	542	75

GSD	Target Grnd Speed	AGL	Avg. Ground Elev.	MSL	Sensor Config	SH52/82 ONLY
4"	155kts	3123ft	69ft	3500ft	PANF27 ☐ PANF02A ☐ REDN00 ☐ GRN00 ☐ REDB16 ☐ GRNB16 ☐	
					PANB14 ☐ PANF02B ☐ BLUN00 ☐ NIRN00 ☐ BLUB16 ☐ NIRB16 ☐	

ASCOT #	FPES #	Dir	Start UTC	Stop UTC	IT	GS	# Sat's	PDOP	Alt	Notes Fixed IT 1.25 / STD Application Class
Lift 2	PR10R	E	18:52:37	18:55:37	1.25	155	8	1.9	3355	Clear. IT warning 1.5mi from west end
	PR11R	W	18:58:51	19:01:49	1.25	147	8	1.9	3363	Clear. IT warning 3, 4.3mi from east end
	PR12R	E	19:04:23	19:07:23	1.25	153	9	1.7	3354	Clear. IT warning 5mi from west end
	PR13R	W	19:09:36	19:12:34	1.25	147	8	1.8	3339	Clear. IT warning 4mi from west end
	PR14R	E	19:14:59	19:18:01	1.25	151	8	1.9	3355	Clear
	PR15R	W	19:20:12	19:23:15	1.25	153	8	1.9	3313	Cloud shadow 3mi from west end
	PR16R	E	19:25:45	19:29:08	1.25	132	8	2.0	3354	Cloud shadow 5, 6mi from east end
	PR17R	W	19:31:46	19:34:48	1.25	145	8	2.0	3316	Cloud shadow 5mi from west end
	PR18R	E	19:37:29	19:40:37	1.25	143	8	2.1	3342	Cloud shadow 2-3mi from west end
	PR15R	W	19:44:11	19:47:14	1.25	146	8	2.1	3342	Clear
	PR16R	E	19:50:01	19:53:15	1.25	135	9	1.7	3369	Clear
	PR17R	W	19:55:31	19:58:35	1.25	151	9	1.6	3328	Clear
	PR18R	E	20:01:04	20:04:17	1.25	139	9	1.7	3390	Cloud shadow 0-0.3mi from west end
	PR02R	W	20:11:35	20:14:29	1.25	152	9	1.8	3347	Clear. Flew in raw mode on previous flight
	PR03R	E	20:17:03	20:19:58	1.25	151	9	1.9	3357	Clear. Flew in raw mode on previous flight
	PR01R	W	20:22:05	20:25:04	1.25	151	9	1.9	3369	Clear. IT warning underexposure. Flew in raw mode on previous flight
										Ended for sun angle

Appendix B: Base Station Datasheet

FILE: PUR1.20130313_PIX1_0313_105221.13o 0P1363365721888

NGS OPUS SOLUTION REPORT
==========

All computed coordinate accuracies are listed as peak-to-peak values.
For additional information: http://www.ngs.noaa.gov/OPUS/about.jsp#accuracy

USER: mark.oneal@premiergeospatial.com DATE: March 15, 2013
RINEX FILE: pur1072r.13o TIME: 16:45:38 UTC

SOFTWARE: page5 1209.04 master73.pl 082112 START: 2013/03/13 17:53:00
EPHEMERIS: igr17313.eph [rapid] STOP: 2013/03/13 22:41:00
NAV FILE: brdc0720.13n OBS USED: 11010 / 11318 : 97%
ANT NAME: LEIAX1202 NONE # FIXED AMB: 62 / 64 : 97%
ARP HEIGHT: 1.795 OVERALL RMS: 0.012(m)

REF FRAME: NAD_83(2011)(EPOCH:2010.0000) IGS08 (EPOCH:2013.1968)

X:	2451909.097(m)	0.019(m)	2451908.406(m)	0.019(m)
Y:	-5533164.238(m)	0.017(m)	-5533162.431(m)	0.017(m)
Z:	2006295.418(m)	0.018(m)	2006295.286(m)	0.018(m)

LAT:	18 27 21.09093	0.024(m)	18 27 21.10675	0.024(m)
E LON:	293 53 58.38625	0.015(m)	293 53 58.38967	0.015(m)
W LON:	66 6 1.61375	0.015(m)	66 6 1.61033	0.015(m)
EL HGT:	-40.564(m)	0.014(m)	-42.438(m)	0.014(m)
ORTHO HGT:	2.333(m)	0.024(m) [H = h-N (N = GEOID12A HGT)]		

UTM COORDINATES	STATE PLANE COORDINATES
UTM (Zone 19)	SPC (5200 PRVI)
Northing (Y) [meters]	2043075.916 268934.336
Easting (X) [meters]	806261.009 235162.524
Convergence [degrees]	0.91864115 0.10415581
Point Scale	1.00075973 1.00000144
Combined Factor	1.00076611 1.00000782

US NATIONAL GRID DESIGNATOR: 19QHA0626143075(NAD 83)

BASE STATIONS USED

PID	DESIGNATION	LATITUDE	LONGITUDE	DISTANCE(m)
DL7810	PRHL BAYAMON CORS ARP	N182248.091	W0660912.812	10096.5
DL6657	PRN4 4N INC CORS ARP	N180442.915	W0662208.704	50504.4
DL9080	PRLP LAS PIEDRAS CORS ARP	N181141.627	W0655205.750	37904.1

NEAREST NGS PUBLISHED CONTROL POINT

TV0985	GRANDE 1966	N182714.843	W0660608.678	283.3

Appendix C: Base Station Logsheets

GPS SURVEY LOGSHEET

Project Information

Project Code:	
State/County:	Puerto Rico
GPS Operator:	Jacobus

Receiver Information

Serial Number:	465697
Receiver Model:	Leica GX1220

Antenna Information

Serial Number:	7050107
Antenna Model:	Leica AX1202

Antenna Height (Slant)		Antenna Height (Vertical)	
Measured	Fixed	Measured	Fixed
(Meters/Feet)	(Meters/Feet)	(Meters/Feet)	(Meters/Feet)
		1.435 m	1.795m

Approximate Positioning

Latitude:	18 27 21.27243 N
Longitude:	066 06 01.62827 W
Ellipsoidal Height:	-39.298m
Flush	☒

Above Ground:		Meters/Feet
Below Ground:		Meters/Feet

Date:	3/13/13
Start Time:	1353hrs
End Time:	1841hrs
Control Point:	PUR1

☐	Aerial Target	☐	Photo I.D.
☐	Published Benchmark	☒	New Control
☐	Published Control	☐	LiDAR
☒	Base Station	☐	Other

Sketch

Description of Control Point:

Temporary Benchmark, flush with ground, at TJIG airport, south of runway, near taxiway

PremierGeo
An IHS Company

15000 W. 64th Ave. - Arvada Colorado 80007 303-302-8600

3/13/2013 – Page 2

Photo 1	Photo 2
	

GPS SURVEY LOGSHEET

Project Information

Project Code:	
State/County:	Puerto Rico
GPS Operator:	Jacobus

Receiver Information

Serial Number:	465697
Receiver Model:	Leica GX1220

Antenna Information

Serial Number:	7050107
Antenna Model:	Leica AX1202

Antenna Height (Slant)		Antenna Height (Vertical)	
Measured	Fixed	Measured	Fixed
(Meters/Feet)	(Meters/Feet)	(Meters/Feet)	(Meters/Feet)
		1.466 m	1.826m

Approximate Positioning

Latitude:	18 27 21.18675 N
Longitude:	066 06 01.60422 W
Ellipsoidal Height:	-42.57294m
Flush	☒

Above Ground:		Meters/Feet
Below Ground:		Meters/Feet

Date:	3/14/13
Start Time:	0925hrs
End Time:	1649hrs
Control Point:	PUR1

☐	Aerial Target	☐	Photo I.D.
☐	Published Benchmark	☒	New Control
☐	Published Control	☐	LiDAR
☒	Base Station	☐	Other

Sketch

Description of Control Point:

Temporary Benchmark, flush with ground, at TJIG airport, south of runway, near taxiway

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3/14/2013 – Page 2

Photo 1	Photo 2
	

PremierGeo An IHS Company

15000 W. 64th Ave. - Arvada Colorado 80007 303-302-8600

GPS SURVEY LOGSHEET

Project Information

Project Code:	
State/County:	Puerto Rico
GPS Operator:	Jacobus

Receiver Information

Serial Number:	465697
Receiver Model:	Leica GX1220

Antenna Information

Serial Number:	7050107
Antenna Model:	Leica AX1202

Antenna Height (Slant)		Antenna Height (Vertical)	
Measured	Fixed	Measured	Fixed
(Meters/Feet)	(Meters/Feet)	(Meters/Feet)	(Meters/Feet)
		1.440m	1.800m

Approximate Positioning

Latitude:	18 27 21.24965 N
Longitude:	066 06 01.59898 W
Ellipsoidal Height:	-39.576m
Flush	☒

Above Ground:		Meters/Feet
Below Ground:		Meters/Feet

Date:	3/15/13
Start Time:	0833hrs
End Time:	1656hrs
Control Point:	PUR1

☐	Aerial Target	☐	Photo I.D.
☐	Published Benchmark	☒	New Control
☐	Published Control	☐	LiDAR
☒	Base Station	☐	Other

Sketch

Description of Control Point:

Temporary Benchmark, flush with ground, at TJIG airport, south of runway, near taxiway

PremierGeo An IHS Company

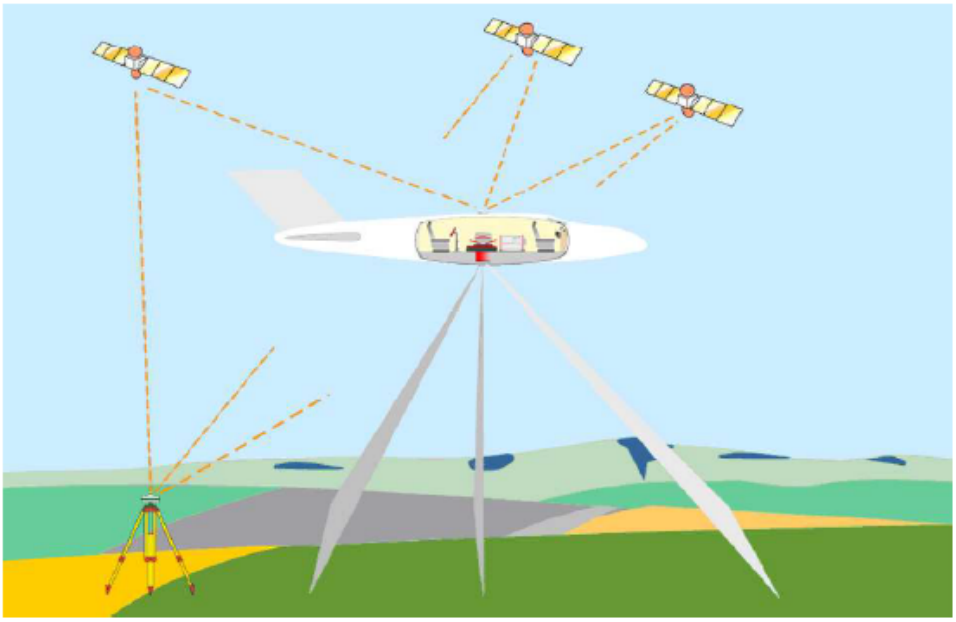
15000 W. 64th Ave. - Arvada Colorado 80007 303-302-8600

3/15/2013 – Page 2

Photo 1	Photo 2
	 Photo 2

Appendix D: Sensor Calibration Report

LEICA ADS40 Calibration Certificate



This certificate is valid for	Sensor Head	Serial Number	Control Unit	Serial Number
	SH51	***1326***	***CU40***	***1141***
	IMU	Serial Number		
	CUS6	***56025781***		
			Inspector	
Calibration certificate issued on	***09 August 2010***			
by			**Muzaffer Adigüzel**	
Certificate and calibration data ID	***870107_1326_100809-1***		Document code 870107	

ADS40

Leica Geosystems AG
Heinrich-Wild-Strasse
9435 Heerbrugg
Switzerland

Leica Geosystems

Components

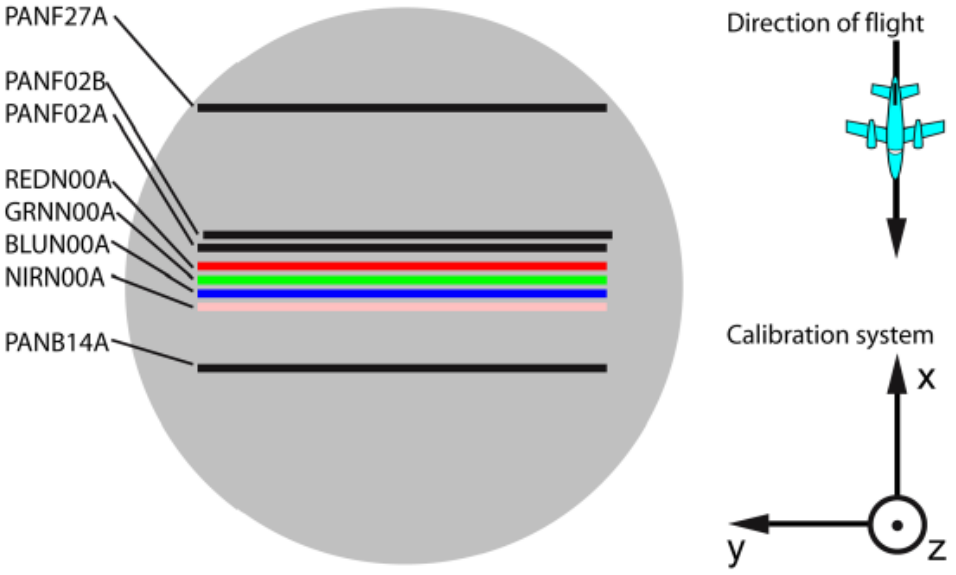
Component	Device	Type	Serial Number
SH51 # 1326	Lens system	DO64-810000	21955 / 0018
	Focal Plate Module cover	FCO	63
	Focal Plate Module (FPM)	FPM-A	63
	Inertial Measurement Unit	µIRS	56025781
CU40 # 1141	Positioning system incl.GPS/GLONASS	IPAS	1373

Nominal FPM layout of tested system

End pixel coordinates are center of pixel coordinates.
Middle coordinates are between pixels 6000 and 6001.
All values in [mm]

Line Name	X	Y, Pixel 1	Y, Center	Y, Pixel 12000
PANF27A	32.18400	-38.99675	0.00000	38.99675
PANF02B	02.21000	-38.99345	0.00330	39.00005
PANF02A	02.18400	-38.99675	0.00000	38.99675
REDN00A	00.01300	-38.99345	0.00330	39.00005
GRNN00A	-00.01300	-38.99675	0.00000	38.99675
BLUN00A	00.00000	-38.99345	0.00330	39.00005
NIRN00A	00.00000	-38.99675	0.00000	38.99675
PANB14A	-15.81600	-38.99675	0.00000	38.99675

View from top of Sensor Head



Calibration process

Adjustment of optical systems in optical laboratory

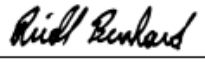
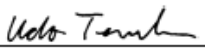
	Passed	Date	Inspector
DSNU (Dark Signal Non Uniformity)	ok	09.08.2010	Bernhard Riedl
PRNU (Photo Response Non Uniformity)	ok	09.08.2010	Bernhard Riedl
MTF	ok	09.08.2010	Bernhard Riedl
Best image plane	ok	09.08.2010	Bernhard Riedl

Flight and data processing

	Passed	Date	Inspector
Test flight	ok	25.06.2010	Deniz Arslan
GNSS and IMU data processing	ok	06.07.2010	Fernando Schapira
IMU accelerometer biases	ok	09.08.2010	Muzaffer Adigüzel
IMU latency	ok	09.08.2010	Muzaffer Adigüzel
Image data processing	ok	02.08.2010	Muzaffer Adigüzel
Geometrical calibration	ok	09.08.2010	Muzaffer Adigüzel

Inspection

Inspectors

Name	Bernhard Riedl	09.08.2010	
Position	ADS Production Manager		
Name	Gert Ferrano	09.08.2010	
Position	ADS System Engineer		
Name	Udo Tempelmann	09.08.2010	
Position	ADS Software Manager		

LEICA ADS40 calibration process specification

	Document code
Inspection plan	862100
Leica ADS40 system calibration process	870106

Maintenance

Last date of service	
Recommendations	

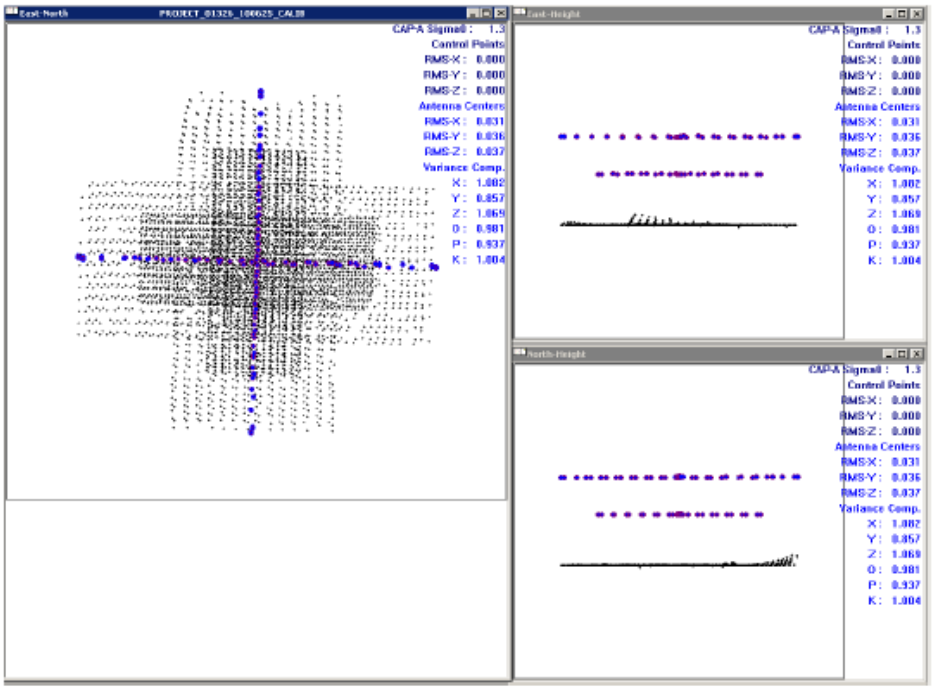
Results of geometrical calibration

Calibrated apparent pixel coordinates for all sensor lines are contained on the calibration file attached to this certificate. File: ***1326-100809-1***.zip

Stereo lines

A-lines	PANF27A PANF02A PANB14A
Calibration method	Estimation of additional parameters in simultaneous bundle adjustment
Sigma naught of bundle adjustment	1.3 micron
Mean local redundancy	> 0.5
Accuracy of calibrated apparent pixel coordinates	±1.0 micron

Final bundle adjustment result after elimination of tie point blunders and before introduction of ground control:



IMU misalignment

Misalignment results in [rad]:	ω =	-0.0003843056	±0.0000042033
	ϕ =	-0.0000086484	± 0.0000036393
	κ =	0.0017626053	± 0.0000083993

Color lines

Included lines	BLUN00A REDN00A GRNN00 NIRN00A
Calibration method	Optimal robust polynomial fit of tie point residuals from bundle adjustment
Mean accuracy of estimated fit for:	
Blue, Green, Red	± 1.3 micron
NIR	± 1.0 micron
Accuracy of apparent pixel-coordinates	± 1 micron

Llines of staggered panchromatic line pair

B-lines	PANF02B
Calibration method	Transfer of A-lines results, using the known offset of the staggered lines
Accuracy of apparent pixel coordinates	Same as for A-lines
Relative accuracy between the lines of a staggered pair	± 0.5 micron

Appendix E: Survey Map

PR01
PR02
PR03
PR04
PR05
PR06
PR07
PR08
PR09
PR10
PR11
PR12
PR13
PR14
PR15
PR16
PR17
PR18
PR19
PR20

PGEO_PR3
PUR1
PGEO_PR1
PGEO_PR2
ACL_3
ACL_1
ACL_2
ACK_3
ACL_6
ACK_1
ACK_2-B
ACL_4
ACL_5

Bahía De San Juan

N

0 0.75 1.5 3
Kilometers

PremierGeo
An IHS Company

Survey 13-034

- ABGPS Base Station
- Aerial Check Points
- Aerial Control Points
- Survey Lines
- San Juan/Puerto Nuevo AOI

Survey 13-034 San Juan/Puerto Nuevo, Puerto Rico
Aerial Imagery Survey Map

Prepared For: Jacksonville District USACE
Prepared By: Premier Geospatial, Inc.

Survey Date: 3/13/2013 - 3/15/2013

Aerial Sensor: ADS40 - II
Ground Sample Distance: 10cm
Horizontal Datum: NAD83(2011)
Vertical Datum: PRVD02(GEOID12A)

Survey Area