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Texas Lavaca Wharton FEMA R6 Lidar

Report Produced for U.S. Geological Survey

USGS Contract: G16PC00020

Task Order: G17PD00014

Report Date: 10/23/2018

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Executive Summary

The primary purpose of this project was to develop a consistent and accurate surface elevation dataset derived from high-accuracy Light Detection and Ranging (lidar) technology for the Texas Lavaca Wharton FEMA R6 Project Area.

The lidar data were processed and classified according to project specifications. Detailed breaklines and bare-earth Digital Elevation Models (DEMs) were produced for the project area. Data was formatted according to tiles with each tile covering an area of 1500m by 1500m. A total of 3,501 tiles were produced for the project encompassing an area of approximately 2881 sq. miles.

THE PROJECT TEAM

Dewberry served as the prime contractor for the project. The LAS classification was sub-contracted to E-terra. In addition to project management, Dewberry was responsible for LAS classification QAQC, all lidar products, breakline production, Digital Elevation Model (DEM) production, and quality assurance.

Dewberry's Gary D. Simpson completed ground surveying for the project and delivered surveyed checkpoints. His task was to acquire surveyed checkpoints for the project to use in independent testing of the vertical accuracy of the lidar-derived surface model. He also verified the GPS base station coordinates used during lidar data acquisition to ensure that the base station coordinates were accurate. Please see Appendix A to view the separate Survey Report that was created for this portion of the project.

Digital Aerial Solutions, LLC completed lidar data acquisition and data calibration for the project area.

SURVEY AREA

The project area addressed by this report falls within the Texas counties of Colorado, DeWitt, Lavaca, and Wharton.

DATE OF SURVEY

The lidar aerial acquisition was conducted from January 5th, 2018 thru January 15, 2018.

COORDINATE REFERENCE SYSTEM

Data produced for the project were delivered in the following reference system.

Horizontal Datum: The horizontal datum for the project is North American Datum of 1983 with the 2011 Adjustment (NAD 83 (2011))
Vertical Datum: The Vertical datum for the project is North American Vertical Datum of 1988 (NAVD88)
Coordinate System: UTM Zone 14
Units: Horizontal units are in meters, Vertical units are in meters.
Geiod Model: Geoid12B (Geoid 12B was used to convert ellipsoid heights to orthometric heights).

LIDAR VERTICAL ACCURACY

For the Texas Lavaca Wharton FEMA R6 Lidar Project, the tested $RMSE_z$ of the classified lidar data for checkpoints in non-vegetated terrain equaled **7.6 cm** compared with the 10 cm specification; and the NVA of the classified lidar data computed using $RMSE_z$ x 1.9600 was equal to **15 cm**, compared with the 19.6 cm specification.

For the Texas Lavaca Wharton FEMA R6 Lidar Project, the tested VVA of the classified lidar data computed using the 95^{th} percentile was equal to **20.9 cm,** compared with the 29.4 cm specification.

Additional accuracy information and statistics for the classified lidar data, raw swath data, and bare earth DEM data are found in the following sections of this report.

PROJECT DELIVERABLES

The deliverables for the project are listed below.

1. Classified Point Cloud Data (Tiled)
2. Bare Earth Surface (Raster DEM – IMG Format)
3. Intensity Images (8-bit gray scale, tiled, GeoTIFF format)
4. Breakline Data (File GDB)
5. Independent Survey Checkpoint Data (Report, Photos, & Points)
6. Calibration Points
7. Metadata
8. Project Report (Acquisition, Processing, QC)
9. Project Extents, Including a shapefile derived from the lidar deliverable

PROJECT TILING FOOTPRINT

Three thousand five-hundred and one (3,501) tiles were delivered for the project. Each tile's extent is 1,500 meters by 1,500 meters (see Appendix C for a complete listing of delivered tiles).

Texas Lavaca Wharton FEMA R6 - Project Area

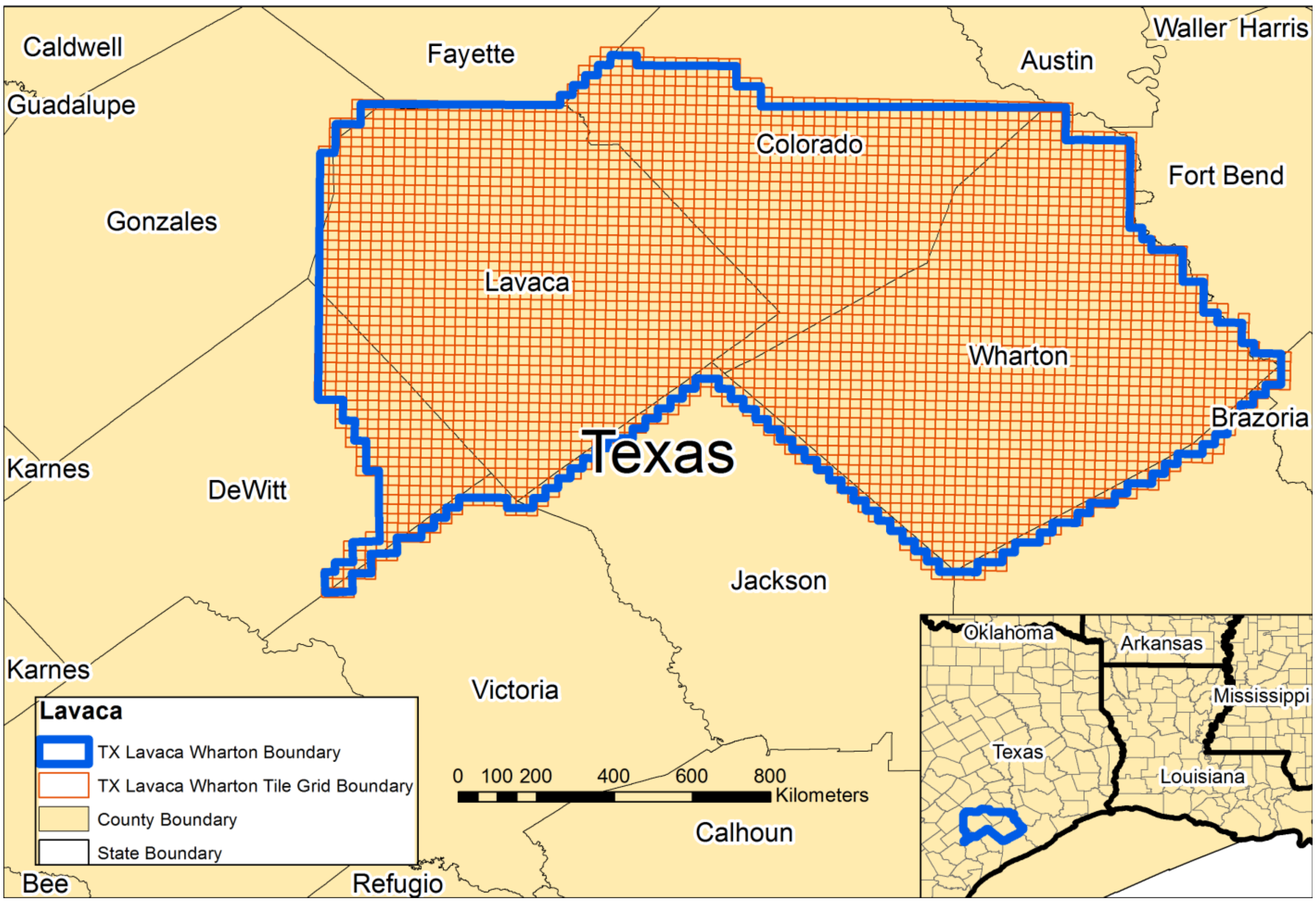


Figure 1 - Project Map

Lidar Acquisition Report

Dewberry elected to subcontract the lidar acquisition and calibration activities to Digital Aerial Solutions, LLC. Digital Aerial Solutions, LLC was responsible for providing lidar acquisition, calibration and delivery of lidar data files to Dewberry.

Dewberry received calibrated swath data from Digital Aerial Solutions, LLC on February 23, 2018.

LIDAR ACQUISITION DETAILS

Digital Aerial Solutions, LLC planned 152 passes for the project area as a series of parallel flight lines with cross flightlines for the purposes of quality control. The flight plan included zigzag flight line collection as a result of the inherent IMU drift associated with all IMU systems. In order to reduce any margin for error in the flight plan, Digital Aerial Solutions, LLC followed FEMA's Appendix A "guidelines" for flight planning and, at a minimum, includes the following criteria:

- A digital flight line layout using LEICA MISSION PRO flight design software for direct integration into the aircraft flight navigation system.
- Planned flight lines; flight line numbers; and coverage area.
- Lidar coverage extended by a predetermined margin beyond all project borders to ensure necessary over-edge coverage appropriate for specific task order deliverables.
- Local restrictions related to air space and any controlled areas have been investigated so that required permissions can be obtained in a timely manner with respect to schedule. Additionally, Digital Aerial Solutions, LLC will file our flight plans as required by local Air Traffic Control (ATC) prior to each mission.

Digital Aerial Solutions, LLC monitored weather and atmospheric conditions and conducted lidar missions only when no conditions exist below the sensor that will affect the collection of data. These conditions include leaf-off for hardwoods, no snow, rain, fog, smoke, mist and low clouds. Lidar systems are active sensors, not requiring light, thus missions may be conducted during night hours when weather restrictions do not prevent collection. Digital Aerial Solutions, LLC accesses reliable weather sites and indicators (webcams) to establish the highest probability for successful collection in order to position our sensor to maximize successful data acquisition.

Within 72-hours prior to the planned day(s) of acquisition, Digital Aerial Solutions, LLC closely monitored the weather, checking all sources for forecasts at least twice daily. As soon as weather conditions were conducive to acquisition, our aircraft mobilized to the project site to begin data collection. Once on site, the acquisition team took responsibility for weather analysis.

Digital Aerial Solutions, LLC lidar sensors are calibrated at a designated site located at the Plant City Airport, Florida and are periodically checked and adjusted to minimize corrections at project sites.

LIDAR SYSTEM PARAMETERS

Digital Aerial Solutions, LLC operated a Cessna 421 (Tail # N112MJ) outfitted with a LEICA ALS80-HP lidar system during the collection of the study area. Table 1 illustrates Digital Aerial Solutions, LLC system parameters for lidar acquisition on this project.

Item	Parameter
System	Leica ALS-80 HP
Altitude (AGL meters)	1701
Approx. Flight Speed (knots)	165
Scanner Pulse Rate (kHz)	314.6
Scan Frequency (hz)	48.8
Pulse Duration of the Scanner (nanoseconds)	0.003
Pulse Width of the Scanner (m)	0.43
Swath width (m)	1409.38
Central Wavelength of the Sensor Laser (nanometers)	1064
Did the Sensor Operate with Multiple Pulses in The Air? (yes/no)	Yes
Beam Divergence (milliradians)	0.15 – 0.25
Nominal Swath Width on the Ground (m)	1409.38
Swath Overlap (%)	11
Total Sensor Scan Angle (degree)	45.0
Computed Down Track spacing (m) per beam	0.87
Computed Cross Track Spacing (m) per beam	1.30
Nominal Pulse Spacing (single swath), (m)	0.62
Nominal Pulse Density (single swath) (ppsm), (m)	2.63
Aggregate NPS (m) (if ANPS was designed to be met through single coverage, ANPS and NPS will be equal)	0.62
Aggregate NPD (m) (if ANPD was designed to be met through single coverage, ANPD and NPD will be equal)	2.63
Maximum Number of Returns per Pulse	8

Table 1: Digital Aerial Solutions, LLC lidar system parameters

ACQUISITION STATUS REPORT AND FLIGHTLINES

Upon notification to proceed, the flight crew loaded the flight plans and validated the flight parameters. The Acquisition Manager contacted air traffic control and coordinated flight pattern requirements. Lidar acquisition began immediately upon notification that control base stations were in place. During flight operations, the flight crew monitored weather and atmospheric conditions. Lidar missions were flown only when no condition existed below the sensor that would affect the collection of data. The pilot constantly monitored the aircraft course, position, pitch, roll, and yaw of the aircraft. The sensor operator monitored the sensor, the status of PDOPs, and performed the first Q/C review during acquisition. The flight crew constantly reviewed weather and cloud locations. Any flight lines impacted by unfavorable conditions were marked as invalid and re-flown immediately or at an optimal time.

Figure 2 shows the combined trajectory of the flightlines.

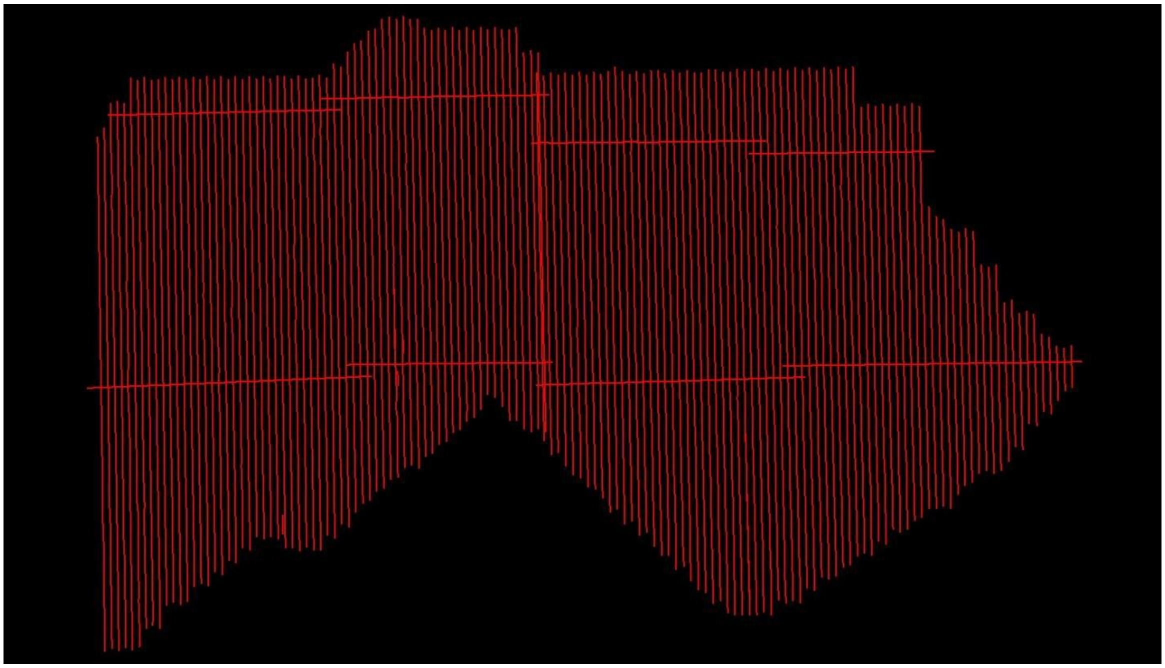


Figure 2: Trajectories as flown by Digital Aerial Solutions, LLC

LIDAR CONTROL

Three establish CORS Stations and two newly established base stations were used to control the lidar acquisition for the Texas Lavaca Wharton lidar project area. The coordinates of all used base stations are provided in the table below. All control and calibration points are also provided in shapefile format as part of the final deliverables.

Name	GCS NAD83(2011) UTM 14		Ellipsoid Ht (NAD83(2011), m)	Orthometric Ht (NAVD88 Geoid12B, m)
	Easting X (m)	Northing Y (m)		
KARM	364283.206	4013695.117	2.722	127.349
KARM2	322661.737	4041480.164	2.735	117.290
txcu	358138.885	3943017.011	54.046	148.680
TXHA	321799.245	4004728.178	63.834	95.100
TXWH	277085.155	4013099.338	8.597	85.464

Table 2 – Base stations used to control lidar acquisition

AIRBORN GPS KINEMATIC

Airborne GPS data was processed using the Inertial Explorer software suite. Flights were flown with a minimum of 6 satellites in view (10° above the horizon) and with a PDOP of better than 4. Distances from base station to aircraft were kept to a maximum of 55 km.

For all flights, the GPS data can be classified as excellent, with GPS residuals of 3 cm average or better but no larger than 10 cm being recorded.

GPS processing reports for each mission are included in Appendix D.

GENERATION AND CALIBRATION OF LASER POINTS (RAW DATA)

The initial step of calibration is to verify availability and status of all needed GPS and Laser data against field notes and compile any data if not complete.

Subsequently the mission points are output using Leica CloudPro, initially with default values from Cloudpro or the last mission calibrated for the system. The initial point generation for each mission calibration is verified within Microstation/Terrascan for calibration errors. If a calibration error greater than specification is observed within the mission, the roll, pitch and scanner scale corrections that need to be applied are calculated. The missions with the new calibration values are regenerated and validated internally once again to ensure quality.

Data collected by the lidar unit is reviewed for completeness, acceptable density and to make sure all data is captured without errors or corrupted values. In addition, all GPS, aircraft trajectory, mission information, and ground control files are reviewed and logged into a database.

On a project level, a supplementary coverage check is carried out to ensure no data voids unreported by Field Operations are present.

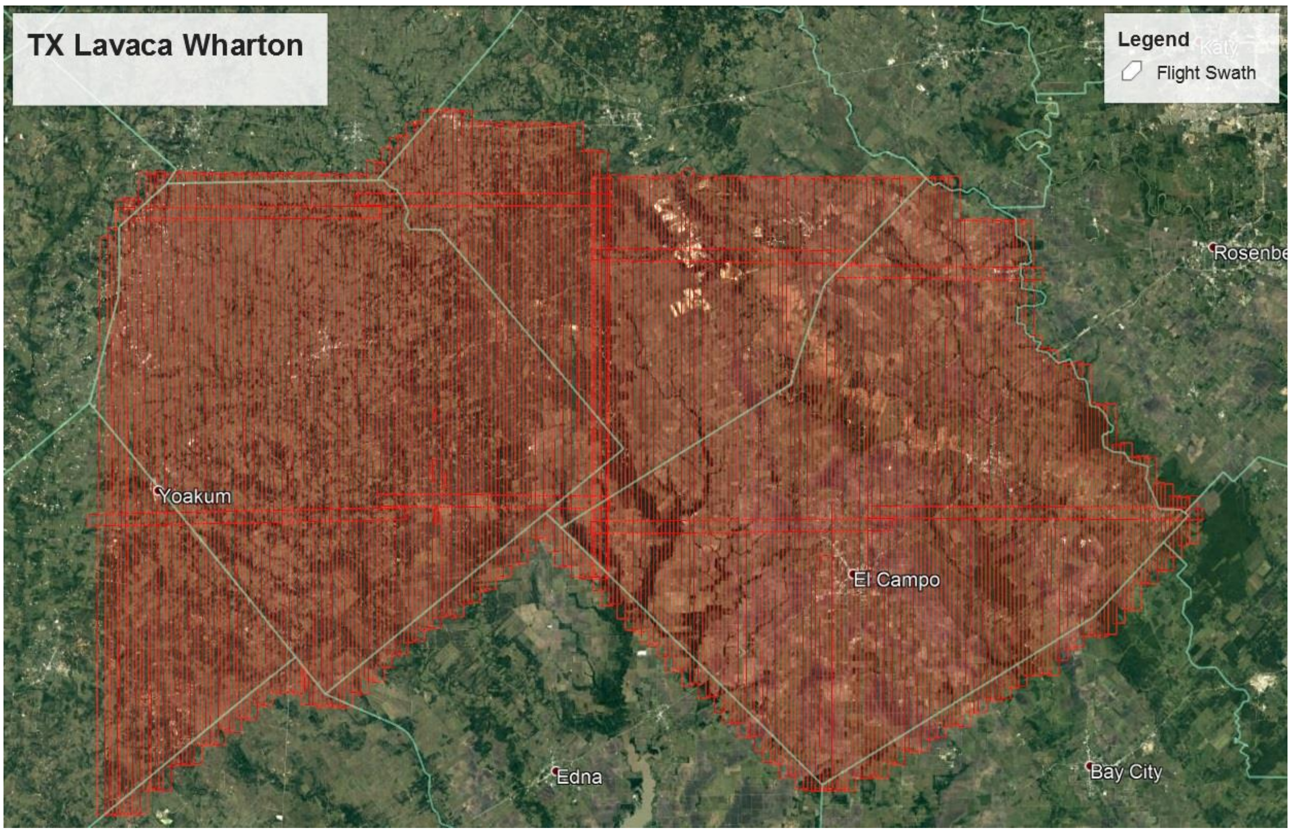


Figure 3 – Lidar swath output showing complete coverage.

BORESIGHT AND RELATIVE ACCURACY

The initial points for each mission calibration are inspected for flight line errors, flight line overlap, slivers or gaps in the data, point data minimums, or issues with the lidar unit or GPS. Roll, pitch and scanner scale are optimized during the calibration process until the relative accuracy is met.

Relative accuracy and internal quality are checked using at least 3 regularly spaced QC blocks in which points from all lines are loaded and inspected. Vertical differences between ground surfaces of each line are displayed. Color scale is adjusted so that errors greater than the specifications are flagged. Cross sections are visually inspected across each block to validate point to point, flight line to flight line and mission to mission agreement.

For this project the specifications used are as follow:
Relative accuracy <= 6 cm maximum difference within individual swaths and <=8 cm RMSDz between adjacent and overlapping swaths.

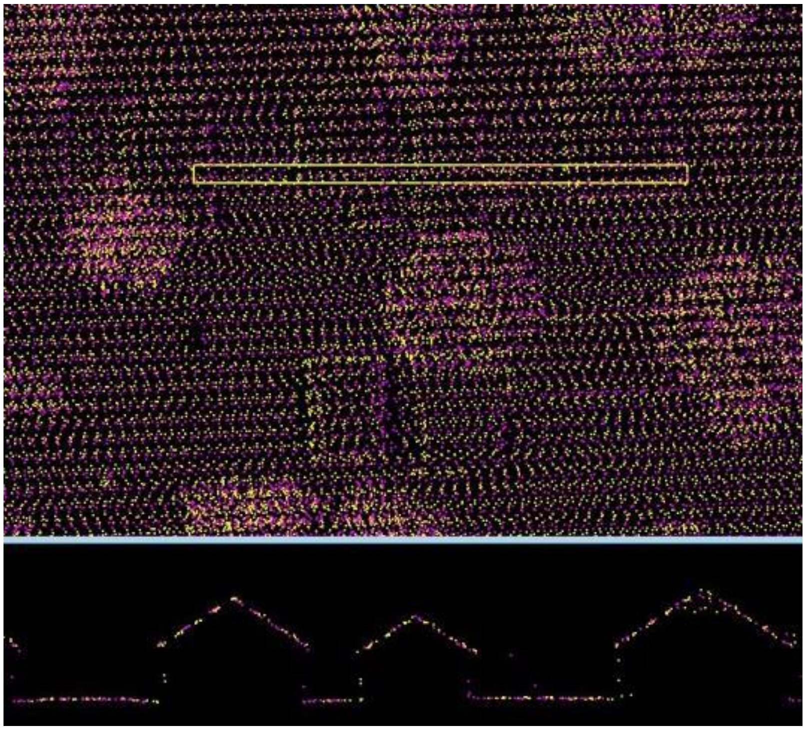


Figure 4 – Profile views showing correct roll and pitch adjustments.

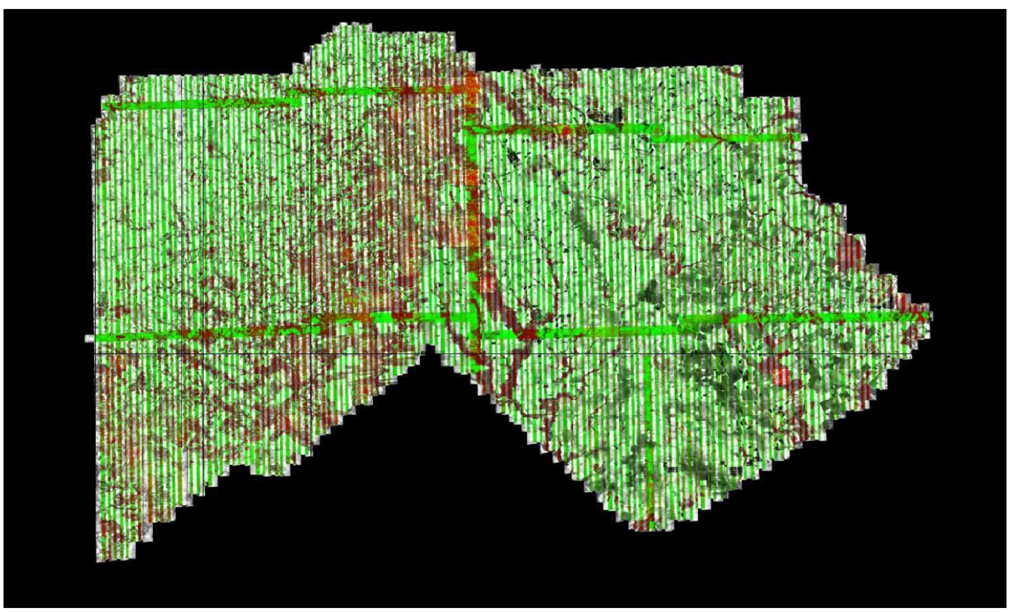


Figure 5 – QC block colored by distance to ensure accuracy at swath edges.

A different set of QC blocks are generated for final review after all transformations have been applied.

Lidar Processing & Qualitative Assessment

INITIAL PROCESSING

Once Dewberry receives the calibrated swath data from the acquisition provider, Dewberry performs several validations on the dataset prior to starting full-scale production on the project.

These validations include vertical accuracy of the swath data, inter-swath (between swath) relative accuracy validation, intra-swath (within a single swath) relative accuracy validation, verification of horizontal alignment between swaths, and confirmation of point density and spatial distribution. This initial assessment allows Dewberry to determine if the data are suitable for full-scale production. Addressing issues at this stage allows the data to be corrected while imposing the least disruption possible on the overall production workflow and overall schedule.

Final Swath Vertical Accuracy Assessment

Once Dewberry received the calibrated swath data from DAS, Dewberry tested the vertical accuracy of the non-vegetated terrain swath data prior to additional processing. Dewberry tested the vertical accuracy of the swath data using the fifty-one non-vegetated (open terrain and urban) independent survey check points. The vertical accuracy is tested by comparing survey checkpoints in non-vegetated terrain to a triangulated irregular network (TIN) that is created from the raw swath points. Only checkpoints in non-vegetated terrain can be tested against raw swath data because the data has not undergone classification techniques to remove vegetation, buildings, and other artifacts from the ground surface. Checkpoints are always compared to interpolated surfaces from the lidar point cloud because it is unlikely that a survey checkpoint will be located at the location of a discrete lidar point. Dewberry typically uses LP360 software to test the swath lidar vertical accuracy, Terrascan software to test the classified lidar vertical accuracy, and Esri ArcMap to test the DEM vertical accuracy so that three different software programs are used to validate the vertical accuracy for each project. Project specifications require a NVA of 19.6 cm based on the $RMSE_z$ (10 cm) x 1.96. The dataset for the Texas Lavaca Wharton satisfies this criteria. This raw lidar swath data set was tested to meet ASPRS Positional Accuracy Standards for Digital Geospatial Data (2014) for a 10 cm $RMSE_z$ Vertical Accuracy Class. Actual NVA accuracy was found to be $RMSE_z$ = 8.3 cm, equating to +/- 16.3 cm at 95% confidence level. The table below shows all calculated statistics for the raw swath data.

100 % of Totals	# of Points	$RMSE_z$ NVA Spec=0.10 m	NVA –Non-vegetated Vertical Accuracy ($RMSE_z$ x 1.9600) Spec=0.196 m	Mean (m)	Median (m)	Skew	Std Dev (m)	Min (m)	Max (m)
Non-Vegetated Terrain	48	0.083	0.163	0.005	0.001	1.170	0.084	-0.240	0.362

Table 3: NVA at 95% Confidence Level for Raw Swaths

Two checkpoints (NVA-19 & NVA-33) were removed from the raw swath vertical accuracy testing due to their location underneath a power line. Only non-vegetated terrain checkpoints are used to test the raw swath data because the raw swath data has not been classified to remove vegetation, structures, and other above ground features from the ground classification. While NVA-19 & NVA-33 are located in open terrain, the overhead power lines are modeled by the lidar point cloud. These high points caused erroneous high values during the swath vertical accuracy testing so these points were removed from the final calculations. Once the data underwent the classification process, the power lines were removed from the final ground classification and these points could be used in the final vertical accuracy testing for the fully classified lidar data. Table 4, below, provides the coordinates for these checkpoints and the vertical accuracy results from the raw swath data. Table 5, below, provides the usable vertical accuracy results of this checkpoint from the fully classified lidar. The differences in the tables show how above ground features can cause erroneous vertical accuracy results in the raw swath data. Figure 6, below, shows a 3D model of the lidar point cloud and the location of the checkpoint beneath a power line.

Point ID	NAD83(2011) UTM Zone 14N		NAVD88 (Geoid 12B)	Lidar Z (m)	Delta Z	AbsDeltaZ
	Easting X (m)	Northing Y (m)	Survey Z (m)			
NVA-19	689268.399	3272977.835	108.011	108.837	0.826	0.826
NVA-33	767784.107	3256114.212	40.189	46.137	5.948	5.948

Table 4: Checkpoints removed from raw swath vertical accuracy testing

Point ID	NAD83(2011) UTM Zone 14N		NAVD88 (Geoid 12B)	Lidar Z (m)	Delta Z	AbsDeltaZ
	Easting X (m)	Northing Y (m)	Survey Z (m)			
NVA-19	689268.399	3272977.835	108.011	107.960	-0.051	0.051
NVA-33	767784.107	3256114.212	40.189	40.210	0.021	0.021

Table 5: Final tested vertical accuracy for NVA-19 & NVA-33 post ground classification

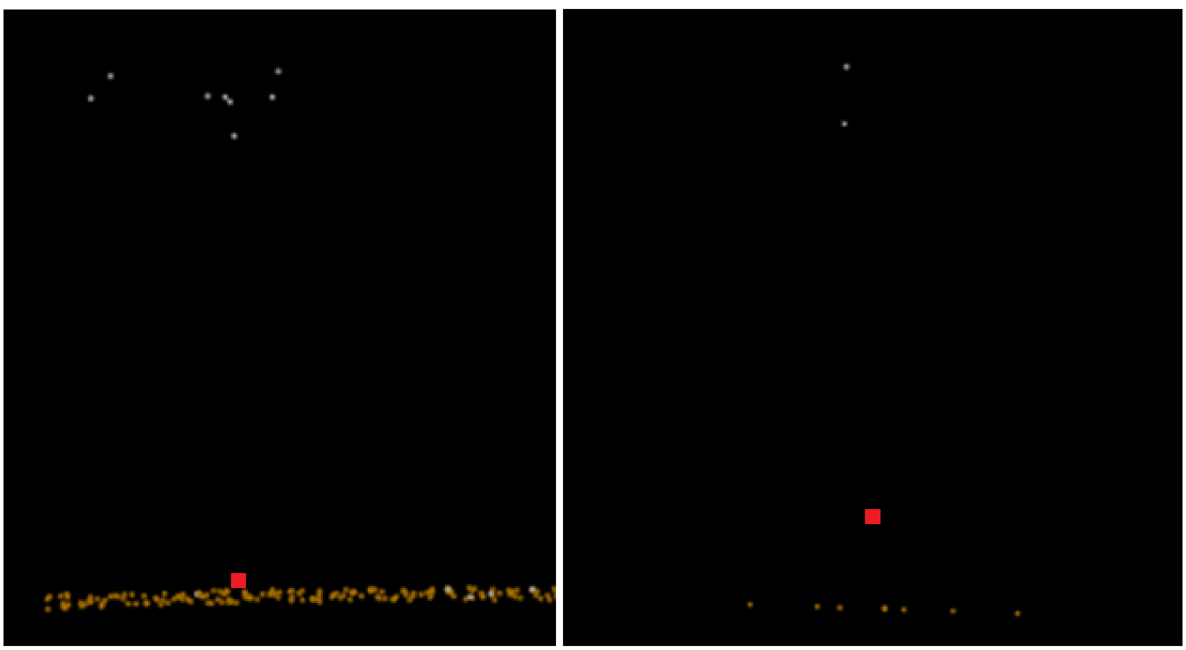


Figure 6 – Open Terrain checkpoints NVA-19 (left) & NVA-33 (right), approximate location shown as red points, are located underneath power line features. These points were removed from raw swath vertical accuracy testing because above ground features, including power lines (gray), have not been separated from the ground classification yet.

Inter-Swath (Between Swath) Relative Accuracy

Dewberry verified inter-swath or between swath relative accuracy of the dataset by creating Delta-Z (DZ) orthos. According to the SOW, USGS Lidar Base Specifications v1.2, and ASPRS Positional Accuracy Standards for Digital Geospatial Data, 10 cm Vertical Accuracy Class or QL2 data must meet inter-swath relative accuracy of 8 cm RMSDz or less with maximum differences less than 16 cm. These measurements are to be taken in non-vegetated and flat open terrain using single or only returns from all classes. Measurements are calculated in the DZ orthos on 1-meter pixels or cell sizes. Areas in the dataset where overlapping flight lines are within 8 cm of each other within each pixel are colored green, areas in the dataset where overlapping flight lines have elevation differences in each pixel between 8 cm to 16 cm are colored yellow, and areas in the dataset where overlapping flight lines have elevation differences in each pixel greater than 16 cm are colored red. Pixels that do not contain points from overlapping flight lines are colored according to their intensity values. Areas of vegetation and steep slopes (slopes with 16 cm or more of valid elevation change across 1 linear meter) are expected to appear yellow or red in the DZ orthos. If the project area is heavily vegetated, Dewberry may also create DZ Orthos from the initial ground classification only, while keeping all other parameters consistent. This allows Dewberry to review the ground classification relative accuracy beneath vegetation and to ensure flight line ridges or other issues do not exist in the final classified data.

Flat, open areas are expected to be green in the DZ orthos. Large or continuous sections of yellow or red pixels can indicate the data was not calibrated correctly or that there were issues during acquisition that could affect the usability of the data, especially when these yellow/red sections follow the flight lines and not the terrain or areas of vegetation. The DZ orthos for Texas Lavaca Wharton are shown in the figure below; this project meets inter-swath relative accuracy specifications.

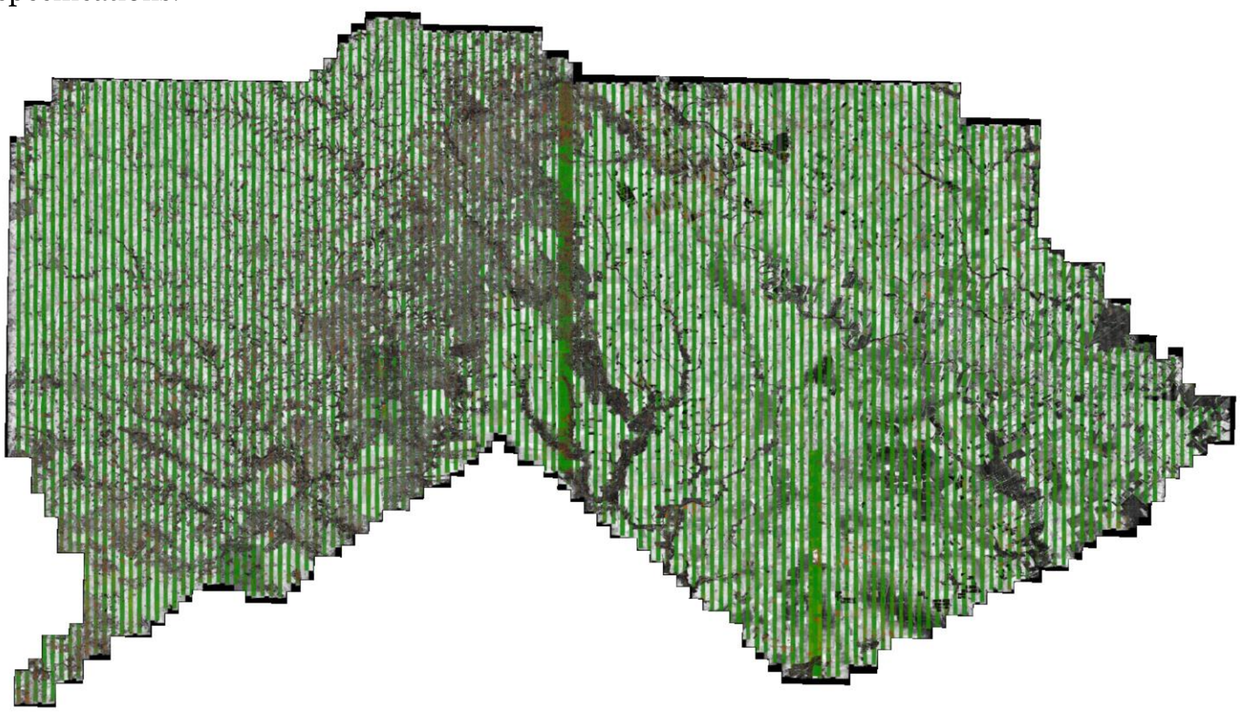


Figure 7– Single return DZ Orthos for the Texas Lava Wharton. Inter-swath relative accuracy passes specifications.

Intra-Swath (Within a Single Swath) Relative Accuracy

Dewberry verifies the intra-swath or within swath relative accuracy by using Quick Terrain Modeler (QTM) scripting and visual reviews. QTM scripting is used to calculate the maximum difference of all points within each 1-meter pixel/cell size of each swath. Dewberry analysts then identify planar surfaces acceptable for repeatability testing and analysts review the QTM results in those areas. According to the SOW, USGS Lidar Base Specifications v1.2, and ASPRS Positional Accuracy Standards for Digital Geospatial Data, 10 cm Vertical Accuracy Class or QL2 data must meet intra-swath relative accuracy of 6 cm maximum difference or less. The image below shows two examples of the intra-swath relative accuracy of Texas Lavaca Wharton; this project meets intra-swath relative accuracy specifications.

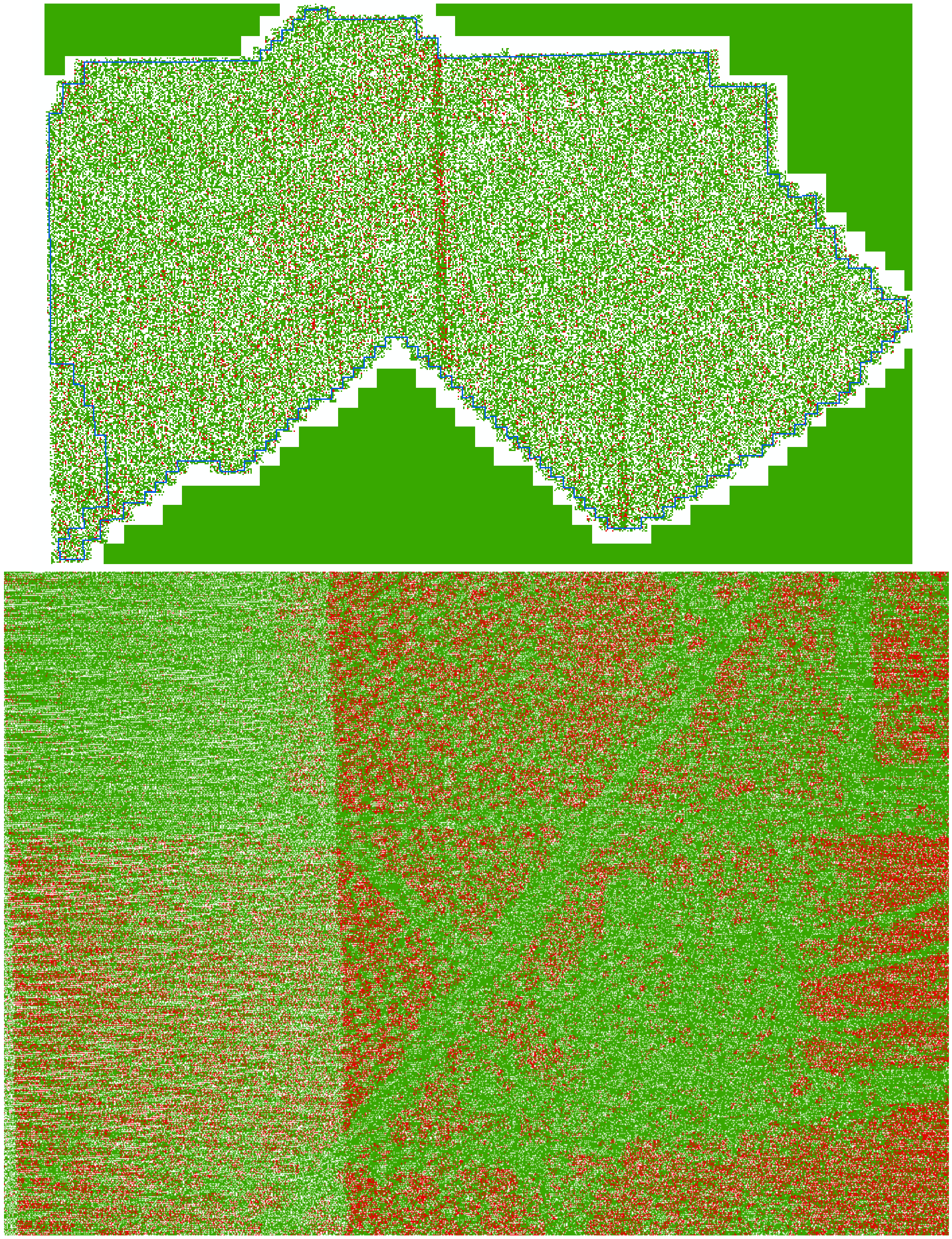


Figure 8–Intra-swath relative accuracy. The top image shows the full project area; areas where the maximum difference is ≤6 cm per pixel within each swath are colored green and areas exceeding 6 cm are colored red. The bottom image is a close-up of a flat area. With the exception of few trees (shown in red as the elevation/height difference in vegetated areas will exceed 6 cm) this open flat area is acceptable for repeatability testing. Intra-swath relative accuracy passes specifications.

Horizontal Alignment

To ensure horizontal alignment between adjacent or overlapping flight lines, Dewberry uses QTM scripting and visual reviews. QTM scripting is used to create files similar to DZ orthos for each swath but this process highlights planar surfaces, such as roof tops. In particular, horizontal shifts or misalignments between swaths on roof tops and other elevated planar surfaces are highlighted. Visual reviews of these features, including additional profile verifications, are used to confirm the results of this process. The image below shows an example of the horizontal alignment between swaths for Texas Lavaca Wharton; no horizontal alignment issues were identified.

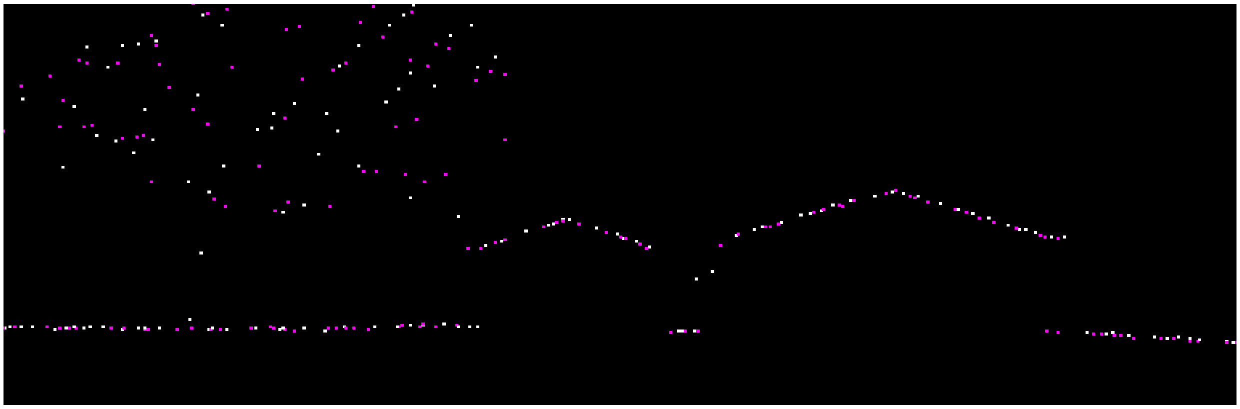


Figure 9– Horizontal Alignment. Two separate flight lines differentiated by color (Purple/White) are shown in this profile. There is no visible offset between these two flight lines. No horizontal alignment issues were identified.

Point Density and Spatial Distribution

The required Aggregate Nominal Point Spacing (ANPS) for this project is no greater than 0.70 meters, which equates to an Aggregate Nominal Point Density (ANPD) of 2 points per square meter or greater. Density calculations were performed using first return data only located in the geometrically usable center portion (typically ~90%) of each swath. By utilizing statistics, the project area was determined to have an ANPS of 0.6 meters or an ANPD of 2.81 points per square meter which satisfies the project requirements. A visual review of a 1-square meter density grid (figure below) shows that most 1-meter cells that do contain 2 points per square meter (green areas). Density passes with no issues.

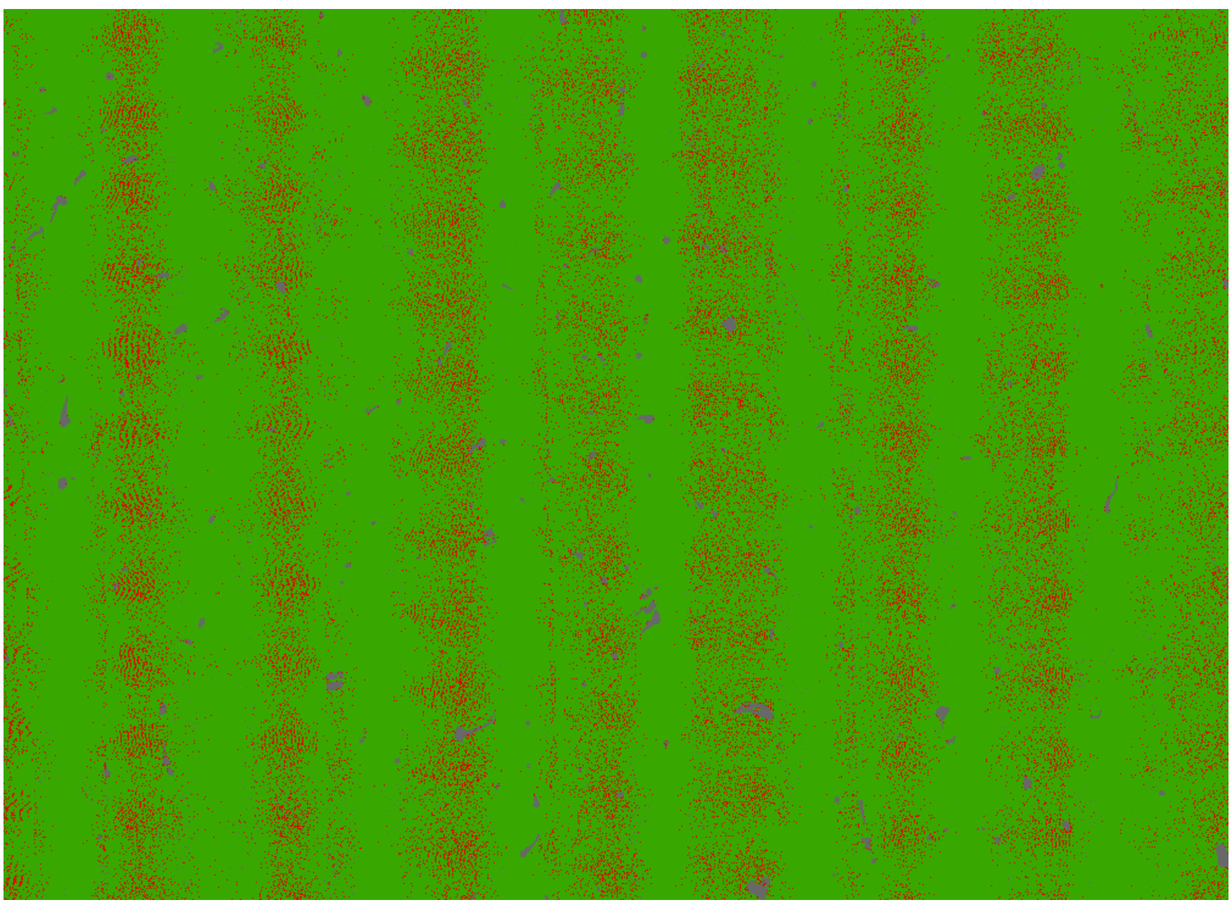


Figure 10– 1-square meter density grid. There are some 1-meter cells that do not contain 2 points per square meter (red areas) due to the irregular spacing of lidar point cloud data. Most 1-sqaure meter

cells contain at least 2 points per square meter (green areas) showing there are no systematic density issues.

The spatial distribution of points must be uniform and free of clustering. This specification is tested by creating a grid with cell sizes equal to the design NPS*2. ArcGIS tools are then used to calculate the number of first return points of each swath within each grid cell. At least 90% of the cells must contain 1 lidar point, excluding acceptable void areas such as water or low NIR reflectivity features, i.e. some asphalt and roof composition materials. This project passes spatial distribution requirements, as shown in the image below.

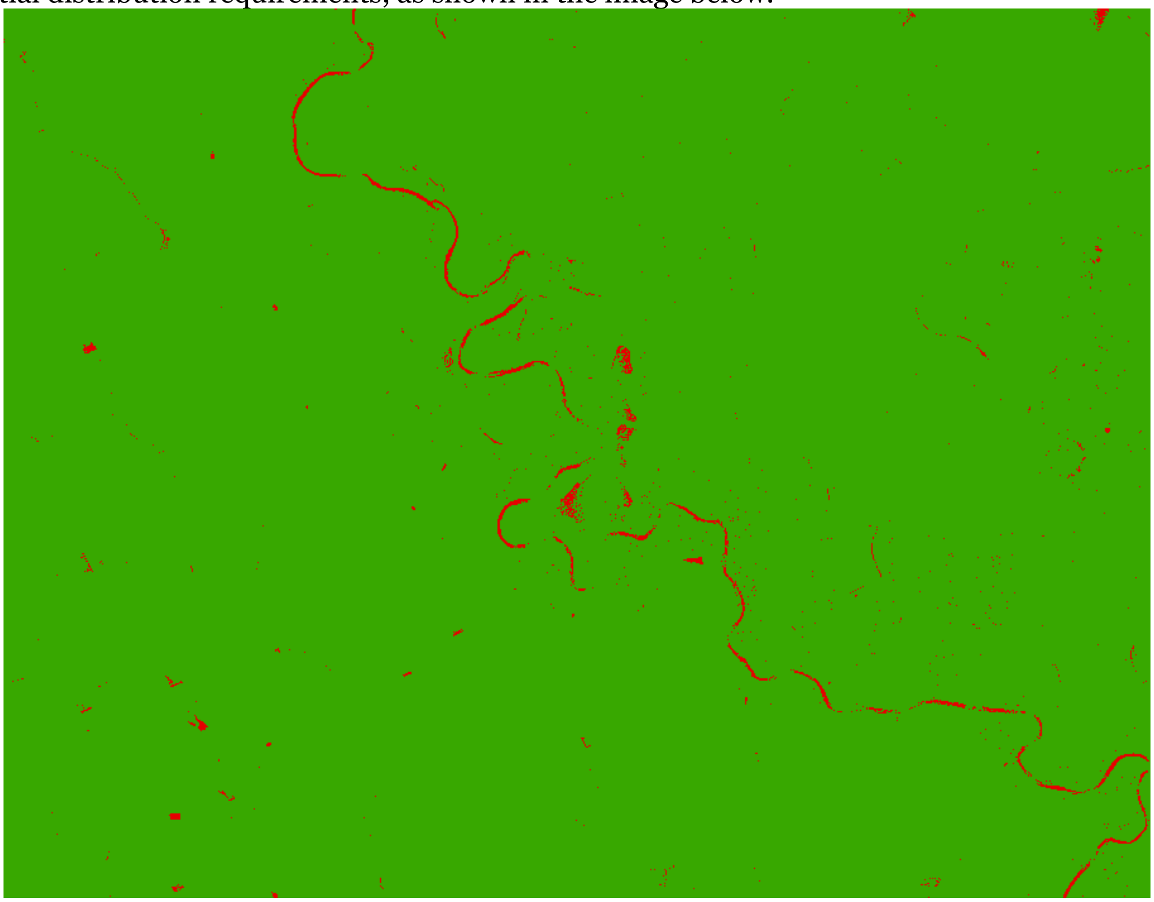


Figure 11– Spatial Distribution. All cells (2*NPS cellsize) containing at least one lidar point are colored green. Cells that do not contain a lidar point, including water bodies which are acceptable NoData areas, are colored red. Without removing acceptable NoData areas due to water, 99.4% of cells contain at least one lidar point.

DATA CLASSIFICATION AND EDITING

Once the calibration, absolute swath vertical accuracy, and relative accuracy of the data was confirmed, Dewberry utilized a variety of software suites for data processing. The data was processed using GeoCue and TerraScan software. The initial step is the setup of the GeoCue project, which is done by importing a project defined tile boundary index encompassing the entire project area. The acquired 3D laser point clouds, in LAS binary format, were imported into the GeoCue project and tiled according to the project tile grid. Once tiled, the laser points were classified using a proprietary routine in TerraScan. This routine classifies any obvious low outliers in the dataset to class 7 and high outliers in the dataset to class 18. Points along flight line edges that are geometrically unusable are identified as withheld and classified to a separate class so that they will not be used in the initial ground algorithm. After points that could negatively affect the ground are removed from class 1, the ground layer is extracted from this remaining point cloud. The ground extraction process encompassed in this routine takes place by building an iterative surface model.

This surface model is generated using three main parameters: building size, iteration angle and iteration distance. The initial model is based on low points being selected by a "roaming window" with the assumption that these are the ground points. The size of this roaming window is determined by the building size parameter. The low points are triangulated and the remaining points are evaluated and subsequently added to the model if they meet the iteration angle and distance constraints. This process is repeated until no additional points are added within iterations. A second critical parameter is the maximum terrain angle constraint, which determines the maximum terrain angle allowed within the classification model.

Each tile was then imported into Terrascan and a surface model was created to examine the ground classification. Dewberry analysts visually reviewed the ground surface model and corrected errors in the ground classification such as vegetation, buildings, and bridges that were present following the initial processing conducted by Dewberry. Dewberry analysts employ 3D visualization techniques to view the point cloud at multiple angles and in profile to ensure that non-ground points are removed from the ground classification. Bridge decks are classified to class 17 using bridge breaklines compiled by Dewberry. After the ground classification corrections were completed, the dataset was processed through a water classification routine that utilizes breaklines compiled by Dewberry to automatically classify hydro features. The water classification routine selects ground points within the breakline polygons and automatically classifies them as class 9, water. During this water classification routine, points that are within 1x NPS or less of the hydrographic features are moved to class 10, an ignored ground due to breakline proximity. Overage points are then identified in Terrascan and GeoCue is used to set the overlap bit for the overage points and the withheld bit is set on the withheld points previously identified in Terrascan before the ground classification routine was performed.

The lidar tiles were classified to the following classification schema:

- Class 1 = Unclassified, used for all other features that do not fit into the Classes 2, 7, 9, 10, 17, or 18, including vegetation, buildings, etc.
- Class 2 = Bare-Earth Ground
- Class 7 = Low Noise
- Class 9 = Water, points located within collected breaklines
- Class 10 = Ignored Ground due to breakline proximity
- Class 17 = Bridge Decks
- Class 18 = High Noise

After manual classification, the LAS tiles were peer reviewed and then underwent a final QA/QC. After the final QA/QC and corrections, all headers, appropriate point data records, and variable length records, including spatial reference information, are updated in GeoCue software and then verified using proprietary Dewberry tools.

Lidar Qualitative Assessment

Dewberry's qualitative assessment utilizes a combination of statistical analysis and interpretative methodology or visualization to assess the quality of the data for a bare-earth digital terrain model (DTM). This includes creating pseudo image products such as lidar orthos produced from the intensity returns, Triangular Irregular Network (TIN)'s, Digital Elevation Models (DEM) and 3-dimensional models as well as reviewing the actual point cloud data. This process looks for anomalies in the data, areas where man-made structures or vegetation points may not have been classified properly to produce a bare-earth model, and other classification errors. This report will present representative examples where the lidar and post processing had issues as well as examples of where the lidar performed well.

VISUAL REVIEW

The following sections describe common types of issues identified in lidar data and the results of the visual review for Texas Lavaca Wharton FEMA R6.

Data Voids

The LAS files are used to produce density grids using the commercial software package QT Modeler (QTM) which creates a 3-dimensional data model derived from Class 2 (ground) points in the LAS files. Grid spacing is based on the project density deliverable requirement for un-obscured areas. Acceptable voids (areas with no lidar returns in the LAS files) that are present in the majority of lidar projects include voids caused by bodies of water. No unacceptable voids are present in the Texas Lavaca Wharton FEMA R6 lidar project.

Artifacts

Artifacts are caused by the misclassification of ground points and usually represent vegetation and/or man-made structures. The artifacts identified are usually low lying structures, such as porches or low vegetation used as landscaping in neighborhoods and other developed areas. These low lying features are extremely difficult for the automated algorithms to detect as non-ground and must be removed manually. The vast majority of these features have been removed but a small number of these features are still in the ground classification. The limited numbers of features remaining in the ground are usually 0.3 meters or less above the actual ground surface, and should not negatively impact the usability of the dataset.

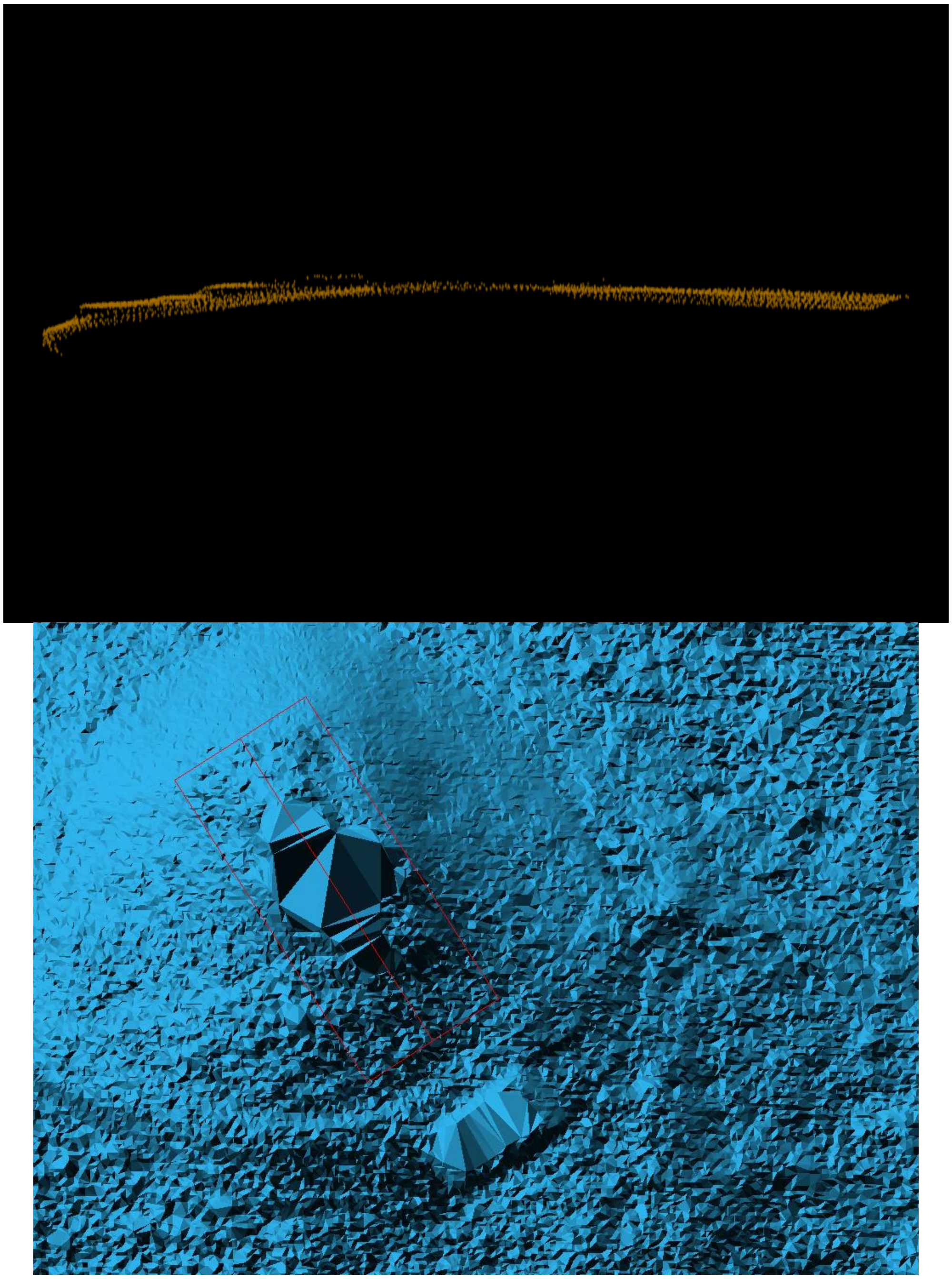


Figure 12 –14RQT2049. Profile with points colored by class (class 2=orange) is shown in the top view and a TIN of the surface is shown in the bottom view. The arrow identifies low vegetation points. A limited number of these small features are still classified as ground but do not impact the usability of the dataset.

Bridge Removal Artifacts

The DEM surface models are created from TINs or Terrains. TIN and Terrain models create continuous surfaces from the inputs. Because a continuous surface is being created, the TIN or Terrain will use interpolation to continue the surface beneath the bridge where no lidar data was acquired. Locations where bridges were removed will generally contain less detail in the bare-earth surface because these areas are interpolated.

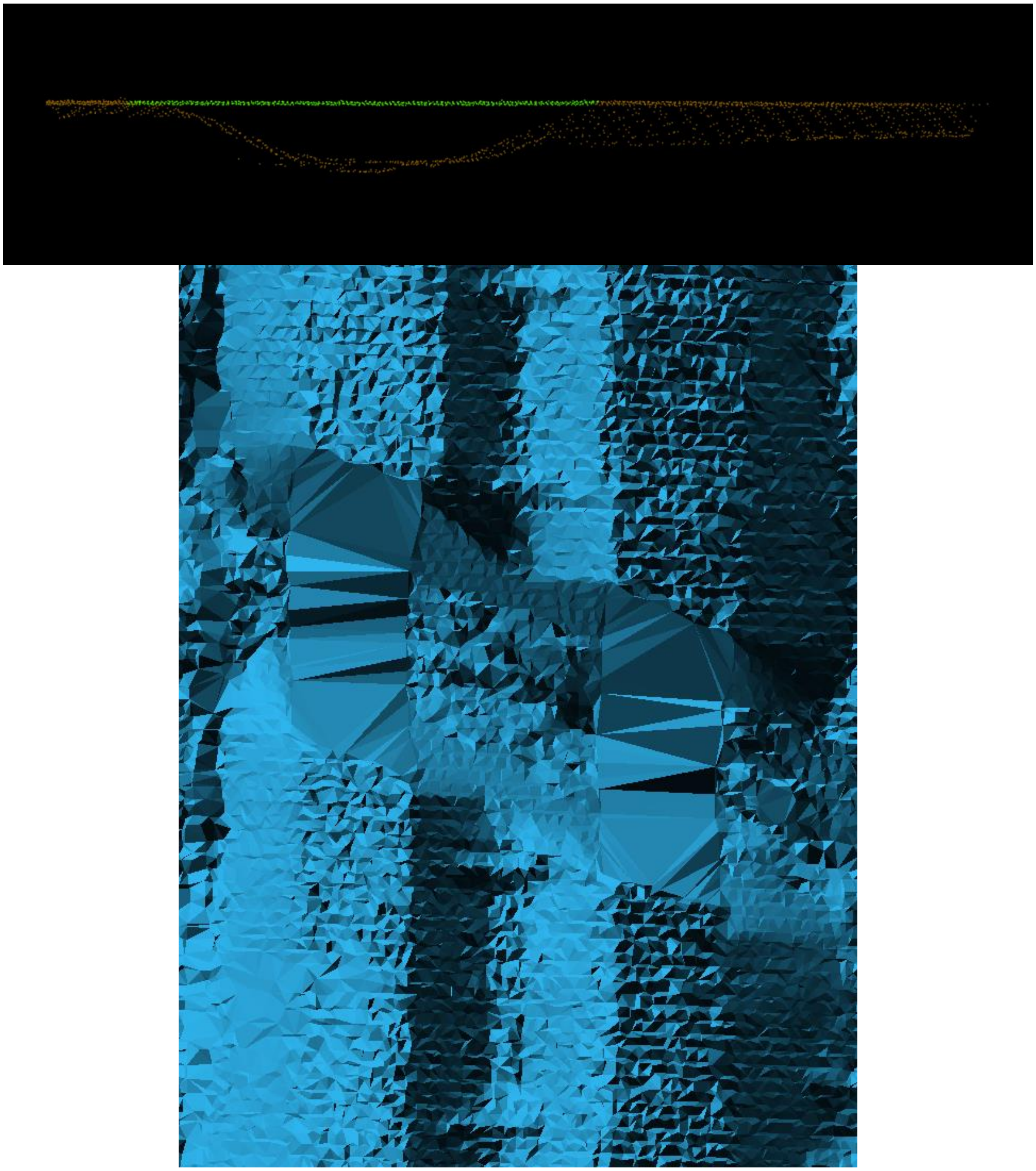


Figure 13 –14RPT9422. The DEM in the bottom view shows an area where a bridge has been removed from ground. The surface model must make a continuous model and in order to do so, points are connected through interpolation. This results in less detail where the surface must be interpolated. The profile in the top view shows the lidar points of this particular feature colored by class. All bridge points have been removed from ground (orange) and are classified as bridge deck (green).

Culverts and Bridges

Bridges have been removed from the bare earth surface while culverts remain in the bare earth surface. In instances where it is difficult to determine if the feature is a culvert or bridge, such as with some small bridges, Dewberry erred on assuming they would be culverts especially if they are on secondary or tertiary roads. Below is an example of a culvert that has been left in the ground surface.

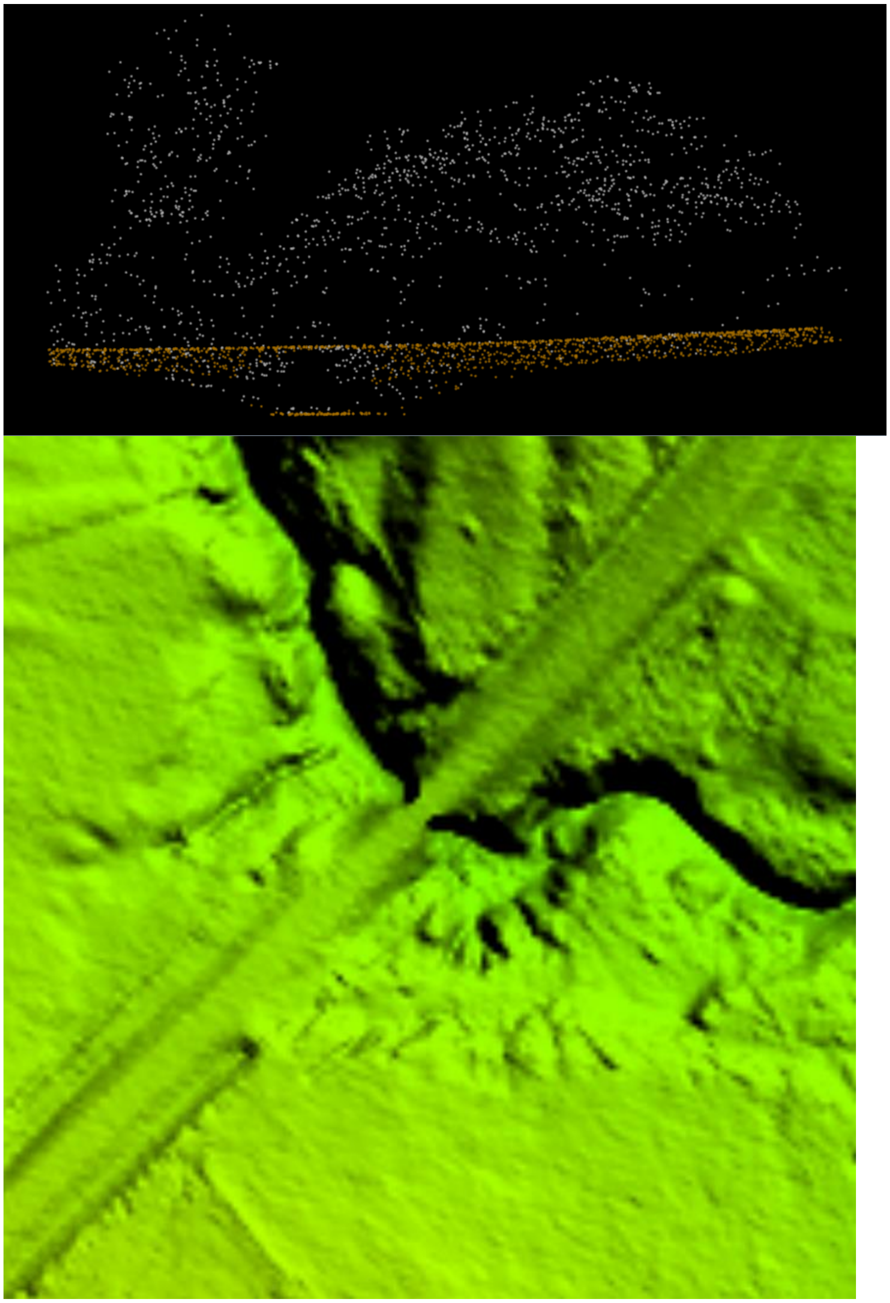
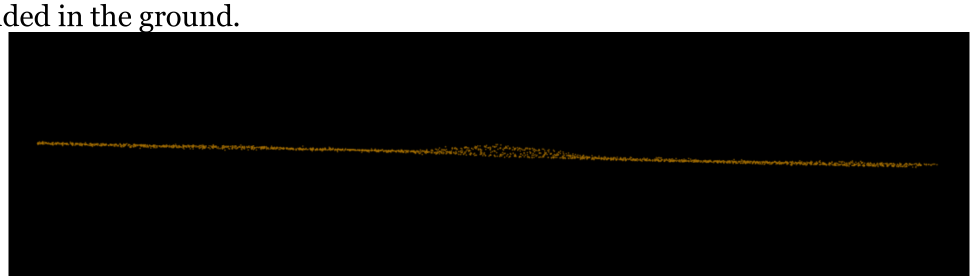


Figure 14–14RQT1177. Profile with points colored by class (class 1=gray, class 2=orange) is shown in the top view and the DEM is shown in the bottom view. This culvert remains in the bare earth surface. Bridges have been removed from the bare earth surface and classified to class 17.

Dirt Mounds

Irregularities in the natural ground exist and may be misinterpreted as artifacts that should be removed. Small hills and dirt mounds are present throughout the project area. These features are correctly included in the ground.



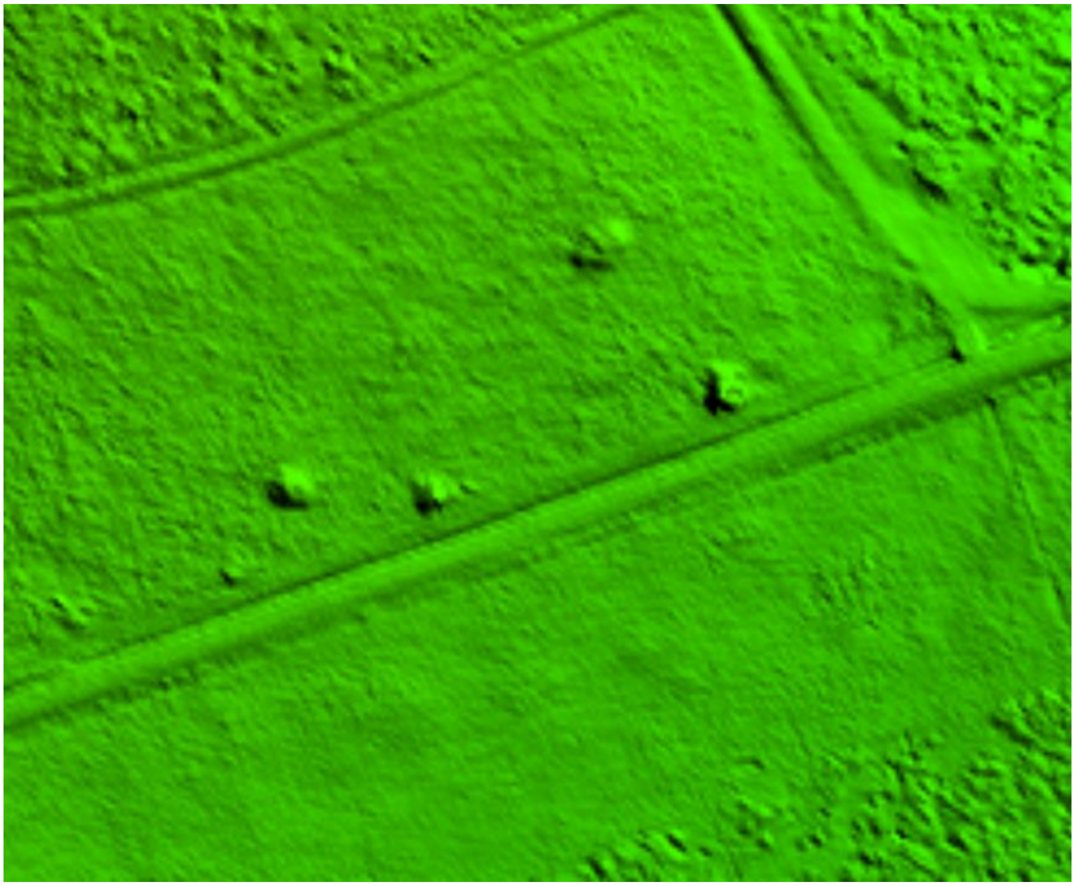


Figure 15 - 14RQT1449. Profile with the points colored by class (class 2=orange) is shown in the top view and a DEM of the surface is shown in the bottom view. These features are correctly included in the ground classification.

FORMATTING

After the final QA/QC is performed and all corrections have been applied to the dataset, all lidar files are updated to the final format requirements and the final formatting, header information, point data records, and variable length records are verified using Dewberry proprietary tools. The table below lists some of the main lidar header fields that are updated and verified.

Classified Lidar Formatting		
Parameter	**Requirement**	**Pass/Fail**
LAS Version	1.4	Pass
Point Data Format	Format 6	Pass
Coordinate Reference System	NAD83 (2011) UTM Zone 14, meters and NAVD88 (Geoid 12B), meters in WKT Format	Pass
Global Encoder Bit	Should be set to 17 for Adjusted GPS Time	Pass
Time Stamp	Adjusted GPS Time (unique timestamps)	Pass
System ID	Should be set to the processing system/software and is set to NIIRS10 for GeoCue software	Pass
Multiple Returns	The sensor shall be able to collect multiple returns per pulse and the return numbers are recorded	Pass
Intensity	16 bit intensity values are recorded for each pulse	Pass
Classification	Required Classes include: Class 1: Unclassified Class 2: Ground Class 7: Low Noise Class 9: Water Class 10: Ignored Ground Class 17: Bridge Decks Class 18: High Noise	Pass
Overlap and Withheld Points	Overlap (Overage) and Withheld points are set to the Overlap and Withheld bits	Pass
Scan Angle	Recorded for each pulse	Pass
XYZ Coordinates	Unique Easting, Northing, and Elevation coordinates are recorded for each pulse	Pass

Lidar Positional Accuracy

BACKGROUND

Dewberry quantitatively tested the dataset by testing the vertical accuracy of the lidar. The vertical accuracy is tested by comparing the discreet measurement of the survey checkpoints to that of the interpolated value within the three closest lidar points that constitute the vertices of a three-dimensional triangular face of the TIN. Therefore, the end result is that only a small sample of the lidar data is actually tested. However there is an increased level of confidence with lidar data due to the relative accuracy. This relative accuracy in turn is based on how well one lidar point "fits" in comparison to the next contiguous lidar measurement, and is verified as part of the initial processing. If the relative accuracy of a dataset is within specifications and the dataset passes vertical accuracy requirements at the location of survey checkpoints, the vertical accuracy results can be applied to the whole dataset with high confidence due to the passing relative accuracy. Dewberry typically uses LP360 software to test the swath lidar vertical accuracy, Terrascan software to test the classified lidar vertical accuracy, and Esri ArcMap to test the DEM vertical accuracy so that three different software programs are used to validate the vertical accuracy for each project.

Dewberry also tests the horizontal accuracy of lidar datasets when checkpoints are photo-identifiable in the intensity imagery. Photo-identifiable checkpoints in intensity imagery typically include checkpoints located at the ends of paint stripes on concrete or asphalt surfaces or checkpoints located at 90 degree corners of different reflectivity, e.g. a sidewalk corner adjoining a grass surface. The XY coordinates of checkpoints, as defined in the intensity imagery, are compared to surveyed XY coordinates for each photo-identifiable checkpoint. These differences are used to compute the tested horizontal accuracy of the lidar. As not all projects contain photo-identifiable checkpoints, the horizontal accuracy of the lidar cannot always be tested.

SURVEY VERTICAL ACCURACY CHECKPOINTS

For the vertical accuracy assessment, eighty five (85) check points were surveyed for the project and are located within bare earth/open terrain, grass/weeds/crops, and forested/fully grown land cover categories. Please see appendix A to view the survey report which details and validates how the survey was completed for this project.

Checkpoints were evenly distributed throughout the project area so as to cover as many flight lines as possible using the "dispersed method" of placement.

All checkpoints surveyed for vertical accuracy testing purposes are listed in the following table.

Point ID	NAD83(2011) UTM Zone 14		NAVD88 (Geoid 12B)
	Easting X (m)	Northing Y (m)	Elevation (m)
NVA-1	679508.526	3209019.230	49.031
NVA-2	684690.845	3217411.015	65.061
NVA-3	679904.384	3226193.947	88.032
NVA-4	695867.892	3222409.481	49.188
NVA-5	706440.247	3227343.898	35.839
NVA-6	696275.778	3235889.508	51.156
NVA-7	681998.274	3235615.213	79.382
NVA-8	679435.832	3240997.352	95.831
NVA-9	677819.999	3256740.045	112.580
NVA-10	690623.817	3245339.967	74.740
NVA-11	705930.952	3236863.476	58.160
NVA-12	714236.826	3236180.880	49.912
NVA-13	723477.567	3240276.702	43.581
NVA-14	710697.182	3246248.202	70.436
NVA-15	698757.092	3258390.930	72.706
NVA-16	688502.170	3259520.656	111.038
NVA-17	679869.190	3266018.738	129.935

NVA-18	679301.628	3273596.756	131.983
NVA-19	689268.399	3272977.835	108.011
NVA-20	708459.866	3267365.596	79.302
NVA-21	714777.740	3255710.275	55.003
NVA-22	731878.814	3245360.223	48.143
NVA-23	745386.411	3235979.289	34.079
NVA-24	752345.190	3223943.314	25.882
NVA-25	763143.572	3210702.820	16.708
NVA-26	771799.931	3217597.316	20.928
NVA-27	777215.583	3228436.316	24.986
NVA-28	788928.893	3235452.029	25.817
NVA-29	796928.500	3241205.727	24.915
NVA-30	779451.106	3247795.443	32.702
NVA-31	763349.261	3234970.039	34.754
NVA-32	757751.017	3244186.712	41.185
NVA-33	767784.107	3256114.212	40.189
NVA-34	779811.688	3262574.141	35.515
NVA-35	783765.159	3270609.075	38.328
NVA-36	769848.701	3272741.639	45.225
NVA-37	759112.145	3256246.564	39.492
NVA-38	743653.087	3251455.733	46.594
NVA-39	726534.891	3255315.997	64.847
NVA-40	725720.916	3264977.491	84.641
NVA-41	740147.189	3262439.123	58.026
NVA-42	760941.986	3265363.071	49.549
NVA-43	758433.112	3275896.602	51.377
NVA-44	748876.174	3274317.282	54.259
NVA-45	738891.665	3268508.392	66.647
NVA-46	732366.026	3278874.396	90.150
NVA-47	724555.459	3271314.670	97.805
NVA-48	710435.391	3276971.428	90.265
NVA-49	715066.459	3286980.232	125.536
NVA-50	702003.475	3271605.934	105.360
VVA-1	802847.235	3238498.104	20.199
VVA-2	787490.027	3233272.980	23.397
VVA-3	771472.355	3225526.490	26.139
VVA-4	755851.743	3221918.531	23.547
VVA-5	753298.004	3234572.731	31.143
VVA-6	771812.756	3242338.307	32.661
VVA-7	777784.221	3253679.701	30.288
VVA-8	775710.453	3267292.839	37.139
VVA-9	765449.556	3258867.016	42.665
VVA-10	752396.425	3247406.020	42.824
VVA-11	738288.500	3235783.389	34.896
VVA-12	737699.842	3251898.241	49.569
VVA-13	748945.402	3259741.715	49.177
VVA-14	759555.009	3268878.379	50.390
VVA-15	766934.649	3277921.802	49.097

VVA-16	743547.500	3279855.116	62.151
VVA-17	736657.473	3261965.472	60.150
VVA-18	731551.214	3279518.806	82.764
VVA-19	715688.489	3280409.673	110.025
VVA-20	717758.136	3267807.457	94.904
VVA-21	725748.923	3258597.231	68.752
VVA-22	723457.323	3245543.720	44.654
VVA-23	713075.952	3239613.097	54.971
VVA-24	711480.820	3259955.963	55.895
VVA-25	701698.999	3274936.867	84.199
VVA-26	688928.981	3277850.294	130.007
VVA-27	684829.564	3269242.058	92.050
VVA-28	694613.773	3261723.981	73.155
VVA-29	699987.856	3254094.625	83.882
VVA-30	701548.808	3228631.722	47.058
VVA-31	690899.175	3225002.014	57.632
VVA-32	683446.962	3232079.431	73.909
VVA-33	685686.044	3249514.052	92.821
VVA-34	673854.980	3249895.490	133.760
VVA-35	674585.338	3265368.255	153.401

Table 6: Texas Lavaca Wharton FEMA R6 surveyed accuracy checkpoints

The figure below shows the location of the QA/QC checkpoints used to test the positional accuracy of the dataset.

Texas Lavaca Wharton FEMA R6 - Accuracy Check Points

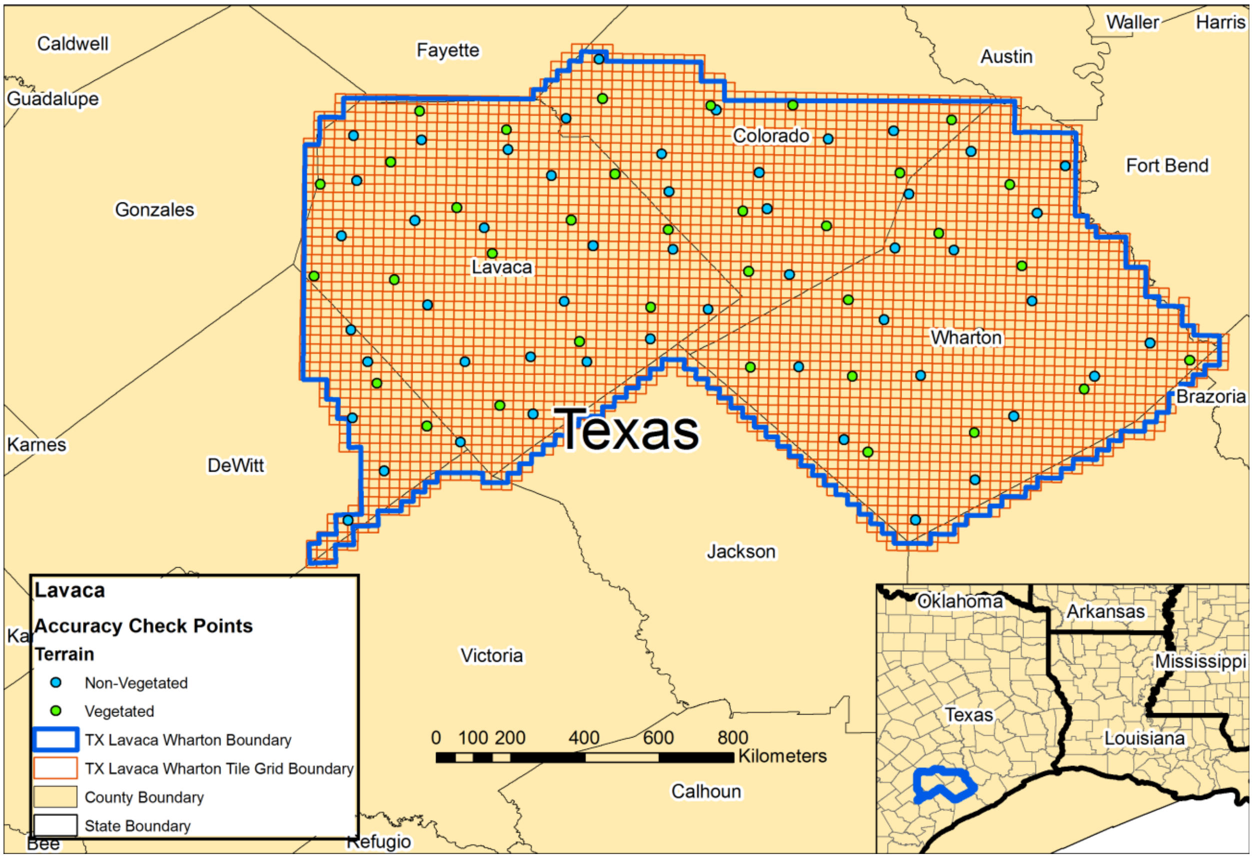


Figure 16 – Location of QA/QC Checkpoints

VERTICAL ACCURACY TEST PROCEDURES

NVA (Non-vegetated Vertical Accuracy) is determined with check points located only in non-vegetated terrain, including open terrain (grass, dirt, sand, and/or rocks) and urban areas, where there is a very high probability that the lidar sensor will have detected the bare-earth ground surface and where random errors are expected to follow a normal error distribution. The NVA determines how well the calibrated lidar sensor performed. With a normal error distribution, the vertical accuracy at the 95% confidence level is computed as the vertical root mean square error ($RMSE_z$) of the checkpoints x 1.9600. For the Texas Lavaca Wharton FEMA R6 lidar project, vertical accuracy must be 19.6 cm or less based on an $RMSE_z$ of 10 cm x 1.9600.

VVA (Vegetated Vertical Accuracy) is determined with all checkpoints in vegetated land cover categories, including tall grass, weeds, crops, brush and low trees, and fully forested areas, where there is a possibility that the lidar sensor and post-processing may yield elevation errors that do not follow a normal error distribution. VVA at the 95% confidence level equals the 95^{th} percentile error for all checkpoints in all vegetated land cover categories combined. The Texas Lavaca Wharton FEMA R6 Lidar Project VVA standard is 29.4 cm based on the 95^{th} percentile. The VVA is accompanied by a listing of the 5% outliers that are larger than the 95^{th} percentile used to compute the VVA; these are always the largest outliers that may depart from a normal error distribution. Here, $Accuracy_z$ differs from VVA because $Accuracy_z$ assumes elevation errors follow a normal error distribution where RMSE procedures are valid, whereas VVA assumes lidar errors may not follow a normal error distribution in vegetated categories, making the RMSE process invalid.

The relevant testing criteria are summarized in Table 7.

Quantitative Criteria	Measure of Acceptability
Non-Vegetated Vertical Accuracy (NVA) in open terrain and urban land cover categories using $RMSE_z$ *1.9600	19.6 cm (based on $RMSE_z$ (10 cm) * 1.9600)
Vegetated Vertical Accuracy (VVA) in all vegetated land cover categories combined at the 95% confidence level	29.4 cm (based on combined 95th percentile)

Table 7 — Acceptance Criteria

The primary QA/QC vertical accuracy testing steps used by Dewberry are summarized as follows:

1. Dewberry's team surveyed QA/QC vertical checkpoints in accordance with the project's specifications.
2. Next, Dewberry interpolated the bare-earth lidar DTM to provide the z-value for every checkpoint.
3. Dewberry then computed the associated z-value differences between the interpolated z-value from the lidar data and the ground truth survey checkpoints and computed NVA, VVA, and other statistics.
4. The data were analyzed by Dewberry to assess the accuracy of the data. The review process examined the various accuracy parameters as defined by the scope of work. The overall descriptive statistics of each dataset were computed to assess any trends or anomalies. This report provides tables, graphs and figures to summarize and illustrate data quality.

VERTICAL ACCURACY RESULTS

The table below summarizes the tested vertical accuracy resulting from a comparison of the surveyed checkpoints to the elevation values present within the fully classified lidar LAS files.

Land Cover Category	# of Points	NVA — Non-vegetated Vertical Accuracy ($RMSE_z$ x 1.9600) Spec=19.6 cm	VVA — Vegetated Vertical Accuracy (95th Percentile) Spec=29.4 cm
NVA	50	15.0	
VVA	35		20.9

Table 8 — Tested NVA and VVA

This lidar dataset was tested to meet ASPRS Positional Accuracy Standards for Digital Geospatial Data (2014) for a 10 cm RMSEz Vertical Accuracy Class. Actual NVA accuracy was found to be $RMSE_z$ = 7.6 cm, equating to +/- 15 cm at 95% confidence level. Actual VVA accuracy was found to be +/- 20.9 cm at the 95th percentile.

The figure below illustrates the magnitude of the differences between the QA/QC checkpoints and lidar data. This shows that the majority of lidar elevations were within +/- 25 cm of the checkpoints elevations, but there were one outlier where lidar and checkpoint elevations differed by 2.8 cm.

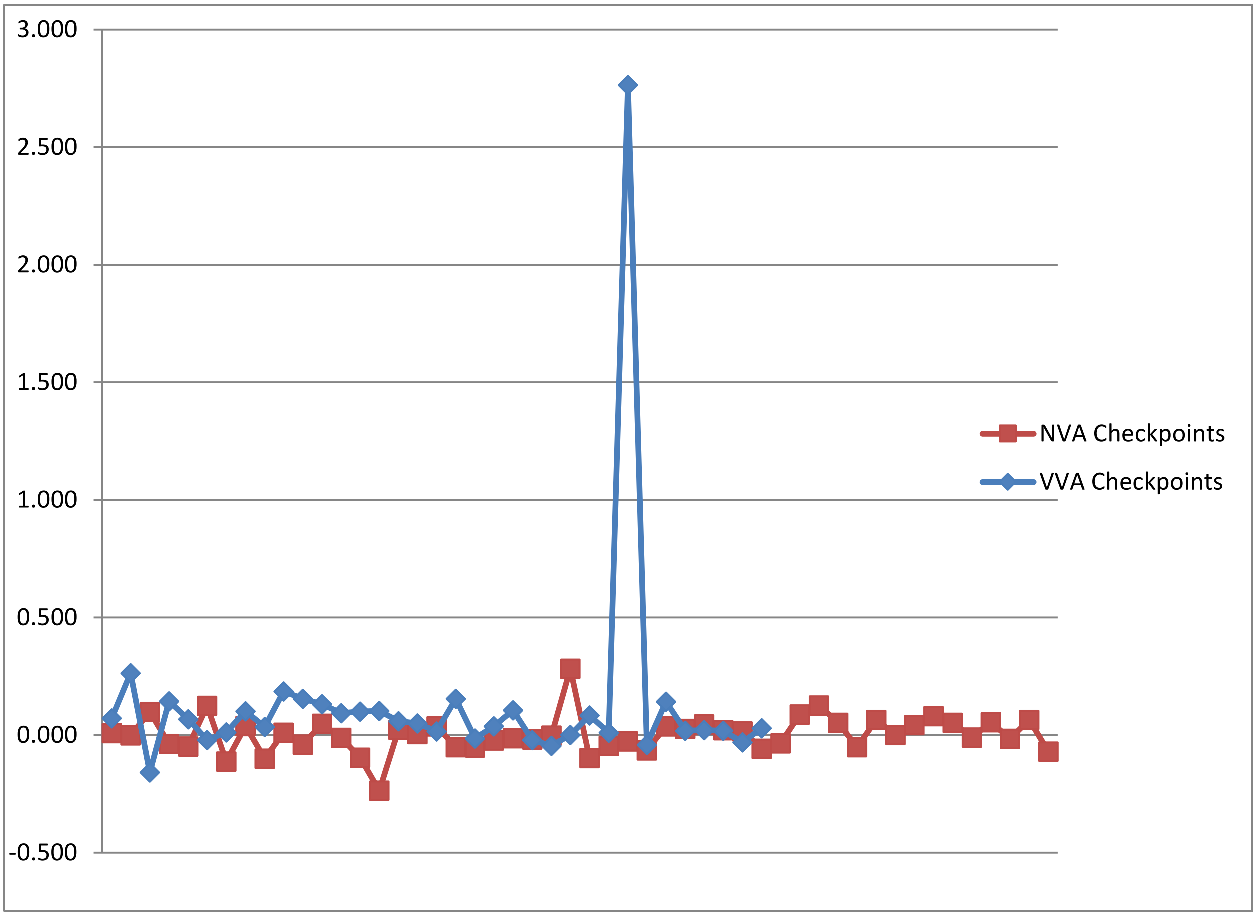


Figure 17 – Magnitude of elevation discrepancies per land cover category

Table 9 lists the 5% outliers that are larger than the VVA 95th percentile.

Point ID	NAD83(2011) UTM Zone 14		NAVD88 (Geoid 12B)	Lidar Z (m)	Delta Z	AbsDeltaZ
	Easting X (m)	Northing Y (m)	Survey Z (m)			
VVA-28	694613.773	3261723.981	73.155	75.920	2.765	2.765

Table 9 – 5% Outliers

Table 10 provides overall descriptive statistics.

100 % of Totals	# of Points	RMSEz (m) NVA Spec=0.1 m	Mean (m)	Median (m)	Skew	Std Dev (m)	Kurtosis	Min (m)	Max (m)
NVA	50	0.076	0.003	0.000	0.401	0.077	3.691	-0.236	0.282
VVA	35	N/A	0.133	0.050	-0.148	0.465	32.799	-0.159	2.765

Table 10 – Overall Descriptive Statistics

The figure below illustrates a histogram of the associated elevation discrepancies between the QA/QC checkpoints and elevations interpolated from the lidar triangulated irregular network (TIN). The frequency shows the number of discrepancies within each band of elevation differences. Although the discrepancies vary between a low of -0.236 meters and a high of +0.282 meters, the histogram shows that the majority of the discrepancies are skewed on the positive side. The vast majority of points are within the ranges of -0.12 meters to +0.12 meters.

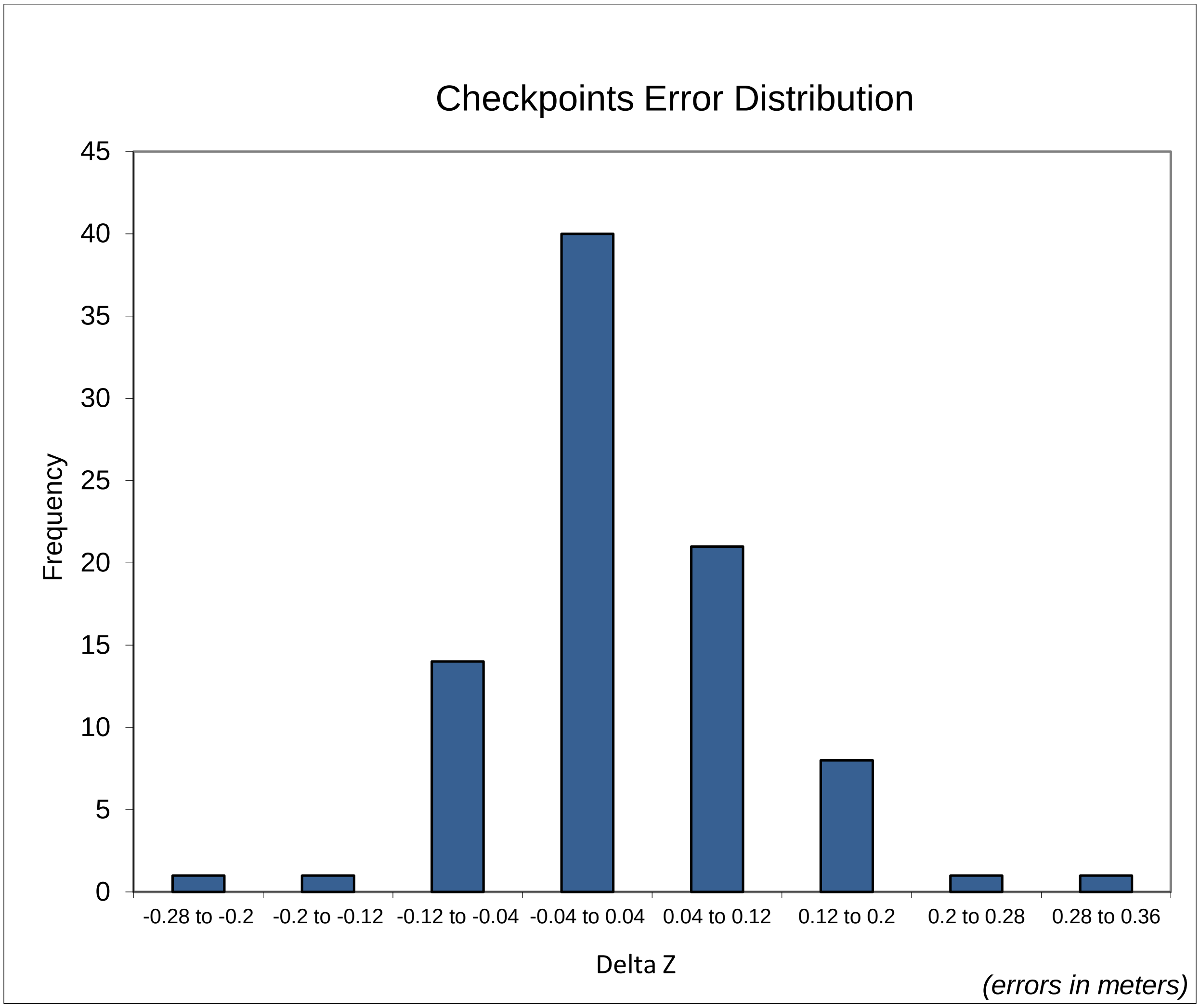


Figure 18 — Histogram of Elevation Discrepancies with errors in meters

Based on the vertical accuracy testing conducted by Dewberry, the lidar dataset for the USGS Texas Lavaca Wharton FEMA R6 Lidar Project satisfies the project's pre-defined vertical accuracy criteria.

HORIZONTAL ACCURACY TEST PROCEDURES

Horizontal accuracy testing requires well-defined checkpoints that can be identified in the dataset. Elevation datasets, including lidar datasets, do not always contain well-defined checkpoints suitable for horizontal accuracy assessment. However, the ASPRS Positional Accuracy Standards for Digital Geospatial Data (2014) recommends at least half of the NVA vertical check points should be located at the ends of paint stripes or other point features visible on the lidar intensity image, allowing them to double as horizontal check points.

Dewberry reviews all NVA checkpoints to determine which, if any, of these checkpoints are located on photo-identifiable features in the intensity imagery. This subset of checkpoints are then used for horizontal accuracy testing.

The primary QA/QC horizontal accuracy testing steps used by Dewberry are summarized as follows:

1. Dewberry's team surveyed QA/QC vertical checkpoints in accordance with the project's specifications and tried to locate half of the NVA checkpoints on features photo-identifiable in the intensity imagery.
2. Next, Dewberry identified the well-defined features in the intensity imagery.
3. Dewberry then computed the associated xy-value differences between the coordinates of the well-defined feature in the lidar intensity imagery and the ground truth survey checkpoints.
4. The data were analyzed by Dewberry to assess the accuracy of the data. Horizontal accuracy was assessed using NSSDA methodology where horizontal accuracy is calculated at the 95% confidence level. This report provides the results of the horizontal accuracy testing.

HORIZONTAL ACCURACY RESULTS

Thirteen checkpoints were determined to be photo-identifiable in the intensity imagery and were used to test the horizontal accuracy of the lidar dataset. As only thirteen (13) checkpoints were photo-identifiable, the results are not statistically significant enough to report as a final tested value, but the results of the testing are still shown in the Table below.

Using NSSDA methodology (endorsed by the ASPRS Positional Accuracy Standards for Digital Geospatial Data (2014)), horizontal accuracy at the 95% confidence level (called ACCURACYr) is computed by the formula RMSEr * 1.7308 or RMSExy * 2.448.

No horizontal accuracy requirements or thresholds were provided for this project. However, lidar datasets are generally calibrated by methods designed to ensure a horizontal accuracy of 1 meter or less at the 95% confidence level.

# of Points	$RMSE_x$ (Target=41 cm)	$RMSE_y$ (Target=41 cm)	$RMSE_r$ (Target=58 cm)	$ACCURACY_r$ ($RMSE_r$ x 1.7308) Target=100 cm
4	45.4	32.3	55.7	96.5

Table 11 - Tested horizontal accuracy at the 95% confidence level

This data set was produced to meet ASPRS Positional Accuracy Standards for Digital Geospatial Data (2014) for a 41 cm RMSEx/RMSEy Horizontal Accuracy Class which equates to Positional Horizontal Accuracy = +/- 1 meter at a 95% confidence level. Four (4) checkpoints were photo-identifiable but do not produce a statistically significant tested horizontal accuracy value. Using this small sample set of photo-identifiable checkpoints, positional accuracy of this dataset was found to be RMSEx = 45.4 cm and RMSEy = 32.3 cm which equates to +/- 96.5 cm at 95% confidence level. While not statistically significant, the results of the small sample set of checkpoints are within the produced to meet horizontal accuracy.

Breakline Production & Qualitative Assessment Report

BREAKLINE PRODUCTION METHODOLOGY

Dewberry used GeoCue software to develop lidar stereo models of the project area so the lidar derived data could be viewed in 3-D stereo using Socet Set softcopy photogrammetric software. Using lidargrammetry procedures with lidar intensity imagery, Dewberry used the stereo models to stereo-compile the two types of hydrographic breaklines in accordance with the project's Data Dictionary.

All drainage breaklines are monotonically enforced to show downhill flow. Water bodies are at a constant elevation where the lowest elevation of the water body has been applied to the entire water body.

BREAKLINE QUALITATIVE ASSESSMENT

Dewberry completed breakline qualitative assessments according to a defined workflow. The following workflow diagram represents the steps taken by Dewberry to provide a thorough qualitative assessment of the breakline data.

Completeness and horizontal placement is verified through visual reviews against lidar intensity imagery. Automated checks are applied on all breakline features to validate topology, including the 3D connectivity of features, enforced monotonicity on linear hydrographic breaklines, and flatness on water bodies.

The next step is to compare the elevation of the breakline vertices against the ground elevation extracted from the ESRI Terrain built from the lidar ground points, keeping in mind that a discrepancy is expected because of the hydro-enforcement applied to the breaklines and because of the interpolated imagery used to acquire the breaklines. A given tolerance is used to validate if the elevations differ too much from the lidar.

After all corrections and edits to the breakline features, the breaklines are imported into the final GDB and verified for correct formatting.

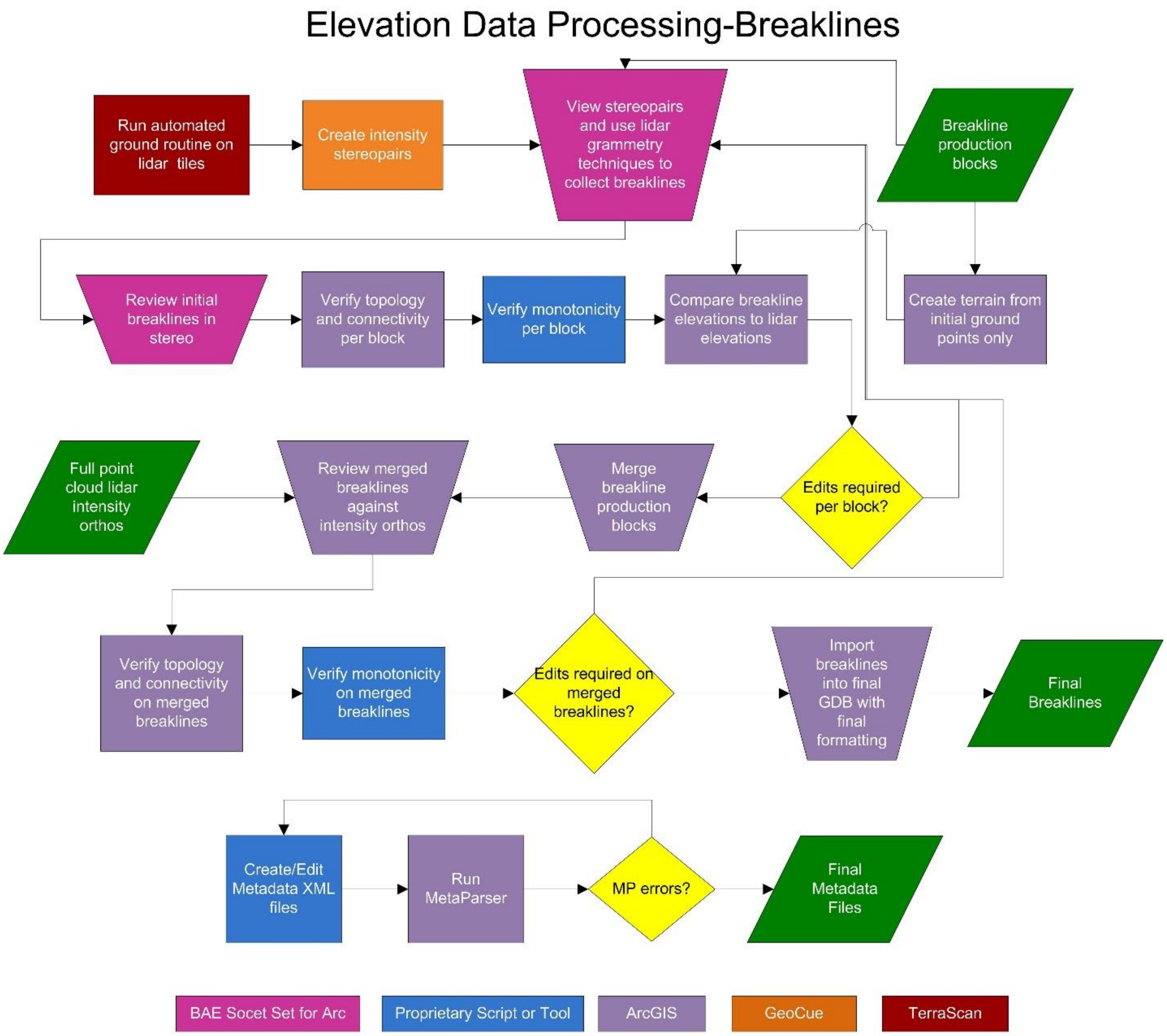


Figure 19-Breakline QA/QC workflow

BREAKLINE CHECKLIST

The following table represents a portion of the high-level steps in Dewberry's Production and QA/QC checklist that were performed for this project.

Pass/Fail	Validation Step
Pass	Use lidar-derived data, which may include intensity imagery, stereo pairs, bare earth ground models, density models, slope models, and terrains, to collect breaklines according to project specifications.
Pass	In areas of heavy vegetation or where the exact shoreline is hard to delineate, it is better to err on placing the breakline *slightly* inside or seaward of the shoreline (breakline can be inside shoreline by 1x-2x NPS).
Pass	After each producer finishes breakline collection for a block, each producer must perform a completeness check, breakline variance check, and all automated checks on their block before calling that block complete and ready for the final merge and QC
Pass	After breaklines are completed for production blocks, all production blocks should be merged together and completeness and automated checks should be performed on the final, merged GDB. Ensure correct snapping-horizontal (x,y) and vertical (z)-between all production blocks.

Pass	Check entire dataset for missing features that were not captured, but should be to meet baseline specifications or for consistency. Features should be collected consistently across tile bounds. Check that the horizontal placement of breaklines is correct. Breaklines should be compared to full point cloud intensity imagery and terrains
Pass	Breaklines are correctly edge-matched to adjoining datasets in completion, coding, and horizontal placement.
Pass	Using a terrain created from lidar ground (all ground including 2, 8, and 10) and water points (class 9), compare breakline Z values to interpolated lidar elevations.
Pass	Perform all Topology and Data Integrity Checks
Pass	Perform hydro-flattening and hydro-enforcement checks including monotonicity and flatness from bank to bank on linear hydrographic features and flatness of water bodies. Tidal waters should preserve as much ground as possible and can include variations or be non-monotonic.

Table 12-A subset of the high-level steps from Dewberry's Production and QA/QC checklist performed for this project.

DATA DICTIONARY

The following data dictionary was used for this project.

Horizontal and Vertical Datum

The horizontal datum shall be North American Datum of 1983(2011), Units in Meters. The vertical datum shall be referenced to the North American Vertical Datum of 1988 (NAVD 88), Units in Meters. Geoid12B shall be used to convert ellipsoidal heights to orthometric heights.

Coordinate System and Projection

All data shall be projected to UTM Zone 14, Horizontal Units in Meters and Vertical Units in Meters.

Inland Streams and Rivers

Feature Dataset: BREAKLINES
Feature Type: Polygon
Contains Z Values: Yes
XY Resolution: Accept Default Setting
XY Tolerance: 0.003

Feature Class: STREAMS_AND_RIVERS
Contains M Values: No
Annotation Subclass: None
Z Resolution: Accept Default Setting
Z Tolerance: 0.001

Description

This polygon feature class will depict linear hydrographic features with a width greater than 100 feet.

Table Definition

Field Name	Data Type	Allow Null Values	Default Value	Domain	Precision	Scale	Length	Responsibility
OBJECTID	Object ID							Assigned by Software
SHAPE	Geometry							Assigned by Software
SHAPE_LENGTH	Double	Yes			0	0		Calculated by Software
SHAPE_AREA	Double	Yes			0	0		Calculated by Software

Feature Definition

Description	Definition	Capture Rules
Streams and Rivers	Linear hydrographic features such as streams, rivers, canals, etc. with an average width greater than 100 feet. In the case	Capture features showing dual line (one on each side of the feature). Average width shall be greater than 100 feet to show as a double line. Each vertex placed should maintain vertical integrity. Generally both banks shall be collected to show

	of embankments, if the feature forms a natural dual line channel, then capture it consistent with the capture rules. Other natural or manmade embankments will not qualify for this project.	consistent downhill flow. There are exceptions to this rule where a small branch or offshoot of the stream or river is present. The banks of the stream must be captured at the same elevation to ensure flatness of the water feature. If the elevation of the banks appears to be different see the task manager or PM for further guidance. Breaklines must be captured at or just below the elevations of the immediately surrounding terrain. Under no circumstances should a feature be elevated above the surrounding lidar points. Acceptable variance in the negative direction will be defined for each project individually. These instructions are only for docks or piers that follow the coastline or water's edge, not for docks or piers that extend perpendicular from the land into the water. If it can be reasonably determined where the edge of water most probably falls, beneath the dock or pier, then the edge of water will be collected at the elevation of the water where it can be directly measured. If there is a clearly-indicated headwall or bulkhead adjacent to the dock or pier and it is evident that the waterline is most probably adjacent to the headwall or bulkhead, then the water line will follow the headwall or bulkhead at the elevation of the water where it can be directly measured. If there is no clear indication of the location of the water's edge beneath the dock or pier, then the edge of water will follow the outer edge of the dock or pier as it is adjacent to the water, at the measured elevation of the water. Every effort should be made to avoid breaking a stream or river into segments. Dual line features shall break at road crossings (culverts). In areas where a bridge is present the dual line feature shall continue through the bridge. Islands: The double line stream shall be captured around an island if the island is greater than 1 acre. In this case a segmented polygon shall be used around the island in order to allow for the island feature to remain as a "hole" in the feature.

Inland Ponds and Lakes

Feature Dataset: BREAKLINES
Feature Type: Polygon
Contains Z Values: Yes
XY Resolution: Accept Default Setting
XY Tolerance: 0.003
Feature Class: PONDS_AND_LAKES
Contains M Values: No
Annotation Subclass: None
Z Resolution: Accept Default Setting
Z Tolerance: 0.001

Description

This polygon feature class will depict closed water body features that are at a constant elevation.

Table Definition

Field Name	Data Type	Allow Null Values	Default Value	Domain	Precision	Scale	Length	Responsibility
OBJECTID	Object ID							Assigned by Software
SHAPE	Geometry							Assigned by Software
SHAPE_LENGTH	Double	Yes			0	0		Calculated by Software
SHAPE_AREA	Double	Yes			0	0		Calculated by Software

Feature Definition

Description	Definition	Capture Rules
Ponds and Lakes	Land/Water boundaries of constant elevation water bodies such as lakes, reservoirs, ponds, etc. Features shall be defined as closed polygons and contain an elevation value that reflects the best estimate of the water elevation at the time of data capture. Water body features will be captured for features 2 acres in size or greater. "Donuts" will exist where there are islands within a closed water body feature.	Water bodies shall be captured as closed polygons with the water feature to the right. The compiler shall take care to ensure that the z-value remains consistent for all vertices placed on the water body. Breaklines must be captured at or just below the elevations of the immediately surrounding terrain. Under no circumstances should a feature be elevated above the surrounding lidar points. Acceptable variance in the negative direction will be defined for each project individually. An Island within a Closed Water Body Feature that is 1 acre in size or greater will also have a "donut polygon" compiled. These instructions are only for docks or piers that follow the coastline or water's edge, not for docks or piers that extend perpendicular from the land into the water. If it can be reasonably determined where the edge of water most probably falls, beneath the dock or pier, then the edge of water will be collected at the elevation of the water where it can be directly measured. If there is a clearly-indicated headwall or bulkhead adjacent to the dock or pier and it is evident that the waterline is most probably adjacent to the headwall or bulkhead, then the water line will follow the headwall or bulkhead at the elevation of the water where it can be directly measured. If there is no clear indication of the location of the water's edge beneath the dock or pier, then the edge of water will follow the outer edge of the dock or pier as it is adjacent to the water, at the measured elevation of the water.

Beneath Bridge Breaklines

Feature Dataset: BREAKLINES
Feature Type: Polyline
Contains Z Values: Yes
XY Resolution: Accept Default Setting
XY Tolerance: 0.003

Feature Class: Bridge_Breaklines
Contains M Values: No
Annotation Subclass: None
Z Resolution: Accept Default Setting
Z Tolerance: 0.001

Description

This polyline feature class is used to enforce terrain beneath bridge decks where ground data may not have been acquired. Enforcing the terrain beneath bridge decks prevents bridge saddles.

Table Definition

Field Name	Data Type	Allow Null Values	Default Value	Domain	Precision	Scale	Length	Responsibility
OBJECTID	Object ID							Assigned by Software
SHAPE	Geometry							Assigned by Software
SHAPE_LENGTH	Double	Yes			0	0		Calculated by Software

Feature Definition

Description	Definition	Capture Rules
Bridge Breaklines	Bridge Breaklines should be used where necessary to enforce terrain beneath bridge decks and to prevent bridge saddles in the bare earth DEMs.	Bridge breaklines should be collected beneath bridges where bridge saddles exist or are likely to exist in the bare earth DEMs. Bridge breaklines should be collected perpendicular to the bridge deck so that the endpoints are on either side of the bridge deck. Typically two bridge breaklines are collected per bridge deck, one at either end of the bridge deck to enforce the terrain under the full bridge deck. The endpoints of the bridge breaklines will match the elevation of the ground at their xy position to enforce the ground/bare earth elevations beneath the bridge deck and prevent bridge saddles from forming.

DEM Production & Qualitative Assessment

DEM PRODUCTION METHODOLOGY

Dewberry utilized ESRI software and Global Mapper for the DEM production and QC process. ArcGIS software is used to generate the products and the QC is performed in both ArcGIS and Global Mapper. The figure below shows the entire process necessary for bare earth DEM production, starting from the lidar swath processing.

The final bare-earth lidar points are used to create a terrain. The final 3D breaklines collected for the project are also enforced in the terrain. The terrain is then converted to raster format using linear interpolation. For most projects, a single terrain/DEM can be created for the whole project. For very large projects, multiple terrains/DEMs may be created. The DEM(s) is reviewed for any issues requiring corrections, including remaining lidar mis-classifications, erroneous breakline elevations, poor hydro-flattening or hydro-enforcement, and processing artifacts. After corrections are applied, the DEM(s) is then split into individual tiles following the project tiling scheme. The tiles are verified for final formatting and then loaded into Global Mapper to ensure no missing or corrupt tiles and to ensure seamlessness across tile boundaries.

Figure 20-DEM Production Workflow

DEM QUALITATIVE ASSESSMENT

Dewberry performed a comprehensive qualitative assessment of the bare earth DEM deliverables to ensure that all tiled DEM products were delivered with the proper extents, were free of processing artifacts, and contained the proper referencing information. This process was performed in ArcGIS software with the use of a tool set Dewberry has developed to verify that the raster extents match those of the tile grid and contain the correct projection information. The DEM data was reviewed at a scale of 1:5000 to review for artifacts caused by the DEM generation process and to review the hydro-flattened features. To perform this review Dewberry creates HillShade models and overlays a partially transparent colorized elevation model to review for these issues. All corrections are completed using Dewberry's proprietary correction workflow. Upon completion of the corrections, the DEM data is loaded into Global Mapper for its second review and to verify corrections. Once the DEMs are tiled out, the final tiles are again loaded into Global Mapper to ensure coverage, extents, and that the final tiles are seamless.

The image below show an example of a bare earth DEM.

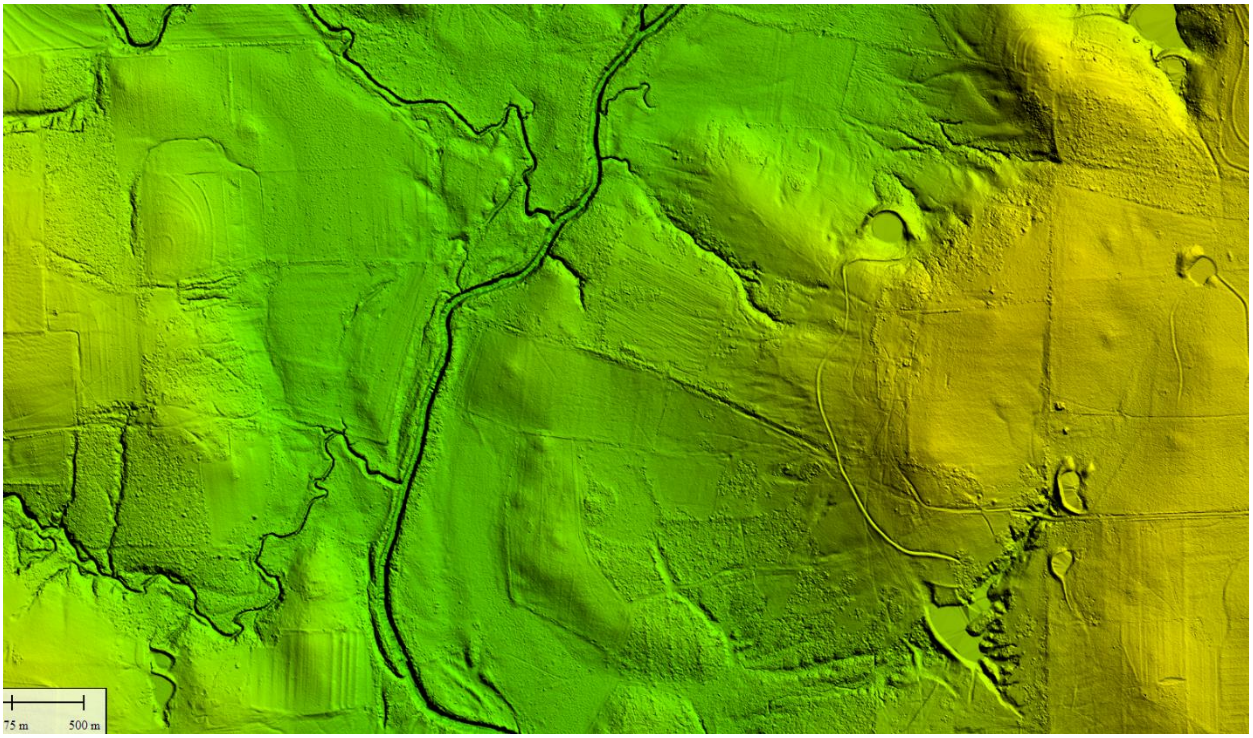


Figure 21-Tile 14RQT0580. Bare earth DEM.

DEM VERTICAL ACCURACY RESULTS

The same 85 checkpoints that were used to test the vertical accuracy of the lidar were used to validate the vertical accuracy of the final DEM products as well. Accuracy results may vary between the source lidar and final DEM deliverable. DEMs are created by averaging several lidar points within each pixel which may result in slightly different elevation values at each survey checkpoint when compared to the source LAS, which does not average several lidar points together but may interpolate (linearly) between two or three points to derive an elevation value. The vertical accuracy of the DEM is tested by extracting the elevation of the pixel that contains the x/y coordinates of the checkpoint and comparing these DEM elevations to the surveyed elevations. Dewberry typically uses LP360 software to test the swath lidar vertical accuracy, Terrascan software to test the classified lidar vertical accuracy, and Esri ArcMap to test the DEM vertical accuracy so that three different software programs are used to validate the vertical accuracy for each project.

Table 13 summarizes the tested vertical accuracy results from a comparison of the surveyed checkpoints to the elevation values present within the final DEM dataset.

Land Cover Category	# of Points	NVA – Non-vegetated Vertical Accuracy ($RMSE_z$ x 1.9600) Spec=19.6 cm	VVA – Vegetated Vertical Accuracy (95th Percentile) Spec=29.4 cm
NVA	50	14.7	
VVA	35		19.5

Table 13 – DEM tested NVA and VVA

This DEM dataset was tested to meet ASPRS Positional Accuracy Standards for Digital Geospatial Data (2014) for a 10 cm RMSEz Vertical Accuracy Class. Actual NVA accuracy was found to be $RMSE_z$ =5 cm, equating to +/- 10 cm at 95% confidence level. Actual VVA accuracy was found to be +/- 13 cm at the 95th percentile.

Table 14 lists the 5% outliers that are larger than the VVA 95th percentile.

Point ID	NAD83(2011) UTM Zone 14		NAVD88 (Geoid 12B)	DEM Z (m)	Delta Z	AbsDeltaZ
	Easting X (m)	Northing Y (m)	Survey Z (m)			
VVA-2	3233272.980	787490.027	23.397	23.615	0.218	0.218
VVA-28	3261723.981	694613.773	73.155	75.922	2.767	2.767

Table 14 – 5% Outliers

Table 15 provides overall descriptive statistics.

100 % of Totals	# of Points	RMSEz (m) NVA Spec=0.1 m	Mean (m)	Median (m)	Skew	Std Dev (m)	Kurtosis	Min (m)	Max (m)
NVA	50	0.075	0.002	0.002	0.738	0.076	4.737	-0.223	0.299
VVA	35	N/A	0.131	0.052	5.656	0.465	32.919	-0.176	2.767

Table 15 – Overall Descriptive Statistics

Based on the vertical accuracy testing conducted by Dewberry, the DEM dataset for the Texas Lavaca Wharton FEMA R6 Lidar Project satisfies the project's pre-defined vertical accuracy criteria.

DEM CHECKLIST

The following table represents a portion of the high-level steps in Dewberry's bare earth DEM Production and QA/QC checklist that were performed for this project.

Pass/Fail	Validation Step
Pass	Masspoints (LAS to multipoint) are created from ground points only (class 2 and class 8 if model key points created, but no class 10 ignored ground points or class 9 water points
Pass	Create a terrain for each production block using the final bare earth lidar points and final breaklines.
Pass	Convert terrains to rasters using project specifications for grid type, formatting, and cell size
Pass	Create hillshades for all DEMs
Pass	Manually review bare-earth DEMs in ArcMap with hillshades to check for issues
Pass	DEMs should be hydro-flattened or hydro-enforced as required by project specifications
Pass	DEMs should be seamless across tile boundaries

Pass	Water should be flowing downhill without excessive water artifacts present
Pass	Water features should NOT be floating above surrounding
Pass	Bridges should NOT be present in bare-earth DEMs.
Pass	Any remaining bridge saddles where below bridge breaklines were not used need to be fixed by adding below bridge breaklines and re-processing.
Pass	All qualitative issues present in the DEMs as a result of lidar processing and editing issues must be marked for corrections in the lidar These DEMs will need to be recreated after the lidar has been corrected.
Pass	Calculate DEM Vertical Accuracy including NVA, VVA, and other statistics
Pass	Split the DEMs into tiles according to the project tiling scheme
Pass	Verify all properties of the tiled DEMs, including coordinate reference system information, cell size, cell extents, and that compression has not been applied to the tiled DEMs
Pass	Load all tiled DEMs into Global Mapper to verify complete coverage to the (buffered) project boundary and that no tiles are corrupt.

Table 16-A subset of the high-level steps from Dewberry's bare earth DEM Production and QA/QC checklist performed for this project.

Appendix A: Checkpoint Survey Report

Check Point Survey Report

"Texas Lavaca-Wharton FEMA Region 6 LiDAR"
USGS Contract: G16PC00020 Task Order Number: G17PC00014

Prepared for:

United States Geological Survey (USGS)

Prepared By:

Dewberry Consultants LLC

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Lanham, Maryland, 20706
Phone (301)364-1855 Fax (301)731-0188

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6. Deliverables ....Sent via Electronic Transfer

Including: a) Point Documentation Report & Photos of Survey Points

b) Final Coordinate List in Excel Format

c) NGS Data Sheets for Project Controls

1. INTRODUCTION

1.1 *Project Summary*

Dewberry Consultants LLC is under contract to the United States Geological Survey to provide 85 Check Points in the State of Texas. Under the above referenced USGS Task Order, Dewberry is tasked to complete the quality assurance of LiDAR products. As part of this work Dewberry staff will complete Check Point surveys that will be used to evaluate vertical and horizontal accuracy. The ground survey was conducted January 8 thru January 11, 2017.

Existing NGS Control Points were located and surveyed to check the accuracy of the RTK/GPS survey equipment with the results shown in Section 2.4 of this Report.

As an internal QA/QC procedure and to verify that the Check Points meet the 95% confidence level approximately 50% of the points were re-observed and are shown in Section 5 of this report.

Final horizontal coordinates are referenced to UTM, Zone 14, NAD83 (2011) in meters. Final Vertical elevations are referenced to NAVD88 in meters using Geoid model 2012B (Geoid12B).

1.2 *Points of Contact*

Questions regarding the technical aspects of this report should be addressed to:

Dewberry Consultants LLC

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10003 Derekwood Lane
Suite 204
Lanham, Maryland 20706
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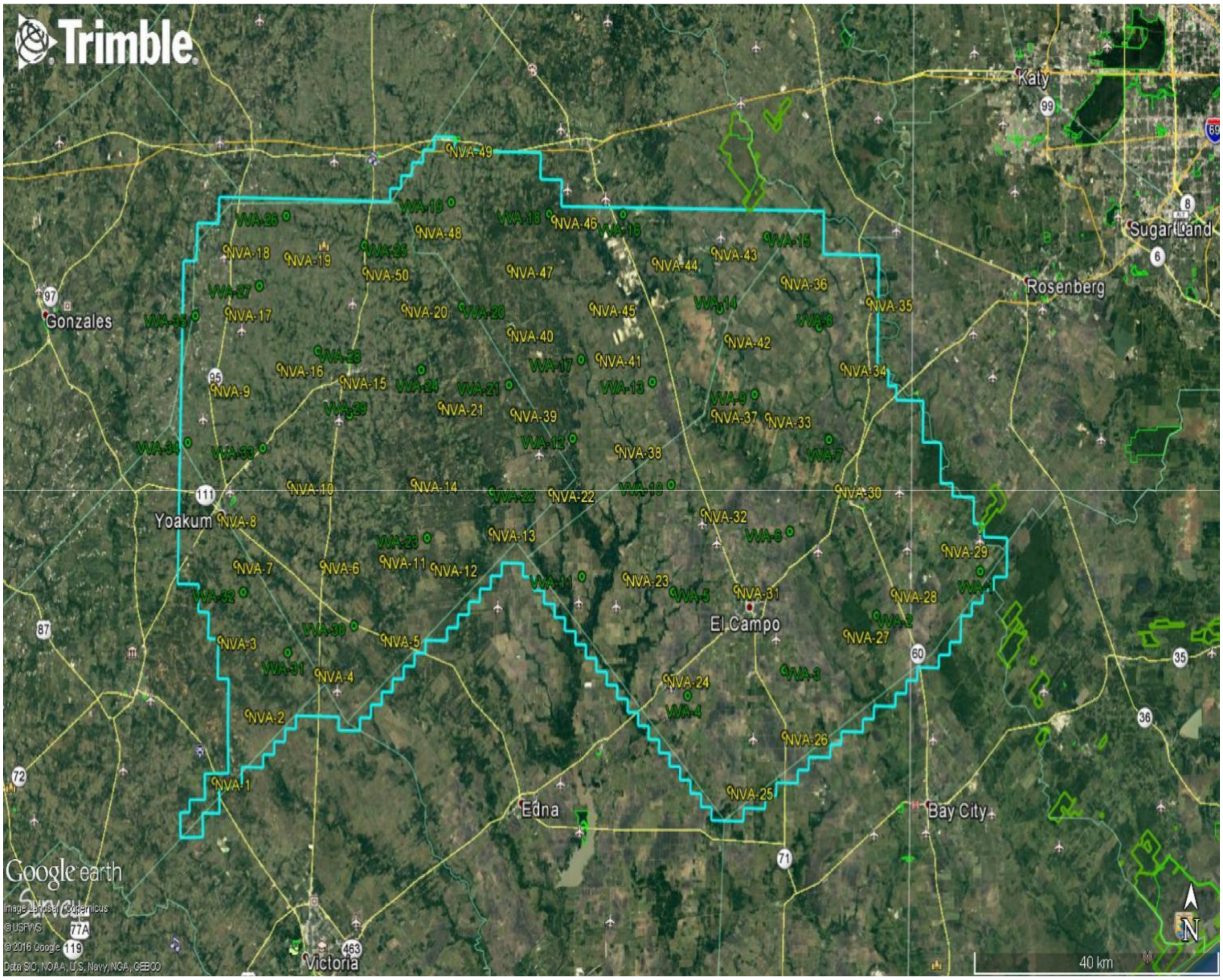
1.3 *Project Area*



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PROJECT DETAILS

2.1 *Survey Equipment*

In performing the GPS observations Trimble R-10 GNSS receiver/antenna attached to a two meter fixed height pole with a Trimble TSC3 Data Collector to collect GPS raw data were used to perform the field surveys.

2.2 *Survey Point Detail*

The 85 LiDAR Check Points were well distributed throughout the project area.

A sketch was made for each location and a nail was set at the point where possible or at an identifiable point. The Check Point locations are detailed on the "Check Point Documentation Report" sheets attached to this report.

2.3 *Network Design*

The GPS survey performed by Dewberry offices located in Lanham, Maryland and Charleston, West Virginia and was tied to a Real Time Network operated by the TXDOT RTN. The network is a series of "real-time" continuously operating, high precision GPS reference stations. All of the reference stations have been linked together using Trimble GPSNet software, creating a Virtual Reference Station System (VRS).

The Trimble NetR5 Reference Station is a multi-channel, multi-frequency GNSS (Global Navigation Satellite System) receiver designed for use as a stand-alone reference station or as part of a GNSS infrastructure solution. Trimble R-Track technology in the NetR5 receiver supports the modernized GPS L2C and L5 signals as well as GLONASS L1/L2 signals.

2.4 Field *Survey Procedures and Analysis*

Dewberry field surveyors used Trimble R-10 GNSS receivers, which is a geodetic quality dual frequency GPS receiver, to collect data at each surveyed location.

All locations were occupied once with approximately 50% of the locations being re-observed. All re-observations matched the initially derived station positions within the allowable tolerance of ± 5cm or within the 95% confidence level. Each occupation which utilized the VRS network was occupied for approximately three (3) minutes in duration and measured to 180 epochs.

Each occupation which utilized OPUS (if used) was occupied between 20 and 30 minutes.

Field GPS observations are detailed on the "Check Point Documentation Reports" submitted as part of this report.

Six (6) existing NGS monument listed in the NSRS database were located as an additional QA/QC method to check the horizontal and vertical accuracy of the VRS network as well as being the primary project control monuments designated as AX0131, AX2610, AX0107, CR1356, BZ1450 and BZ0061. The results are as follows:

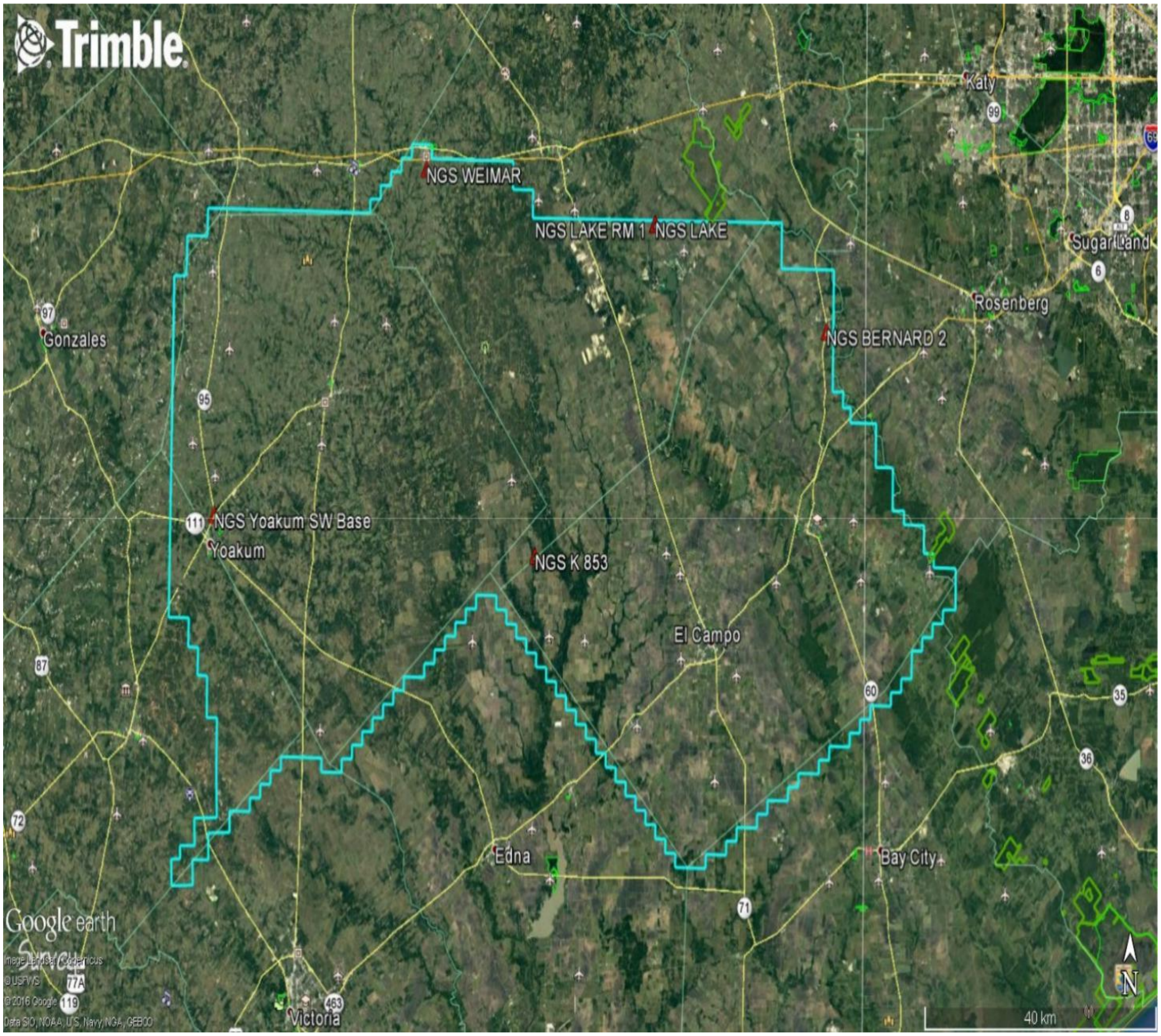
	Observed Values			Data Sheet Values					
PT. #	NORTHING	EASTING	ELEVS.	NORTHING	EASTING	ELEVS.	Δ X	Δ Y	Δ Z
CALPORT**	3378380.696	720142.292	118.154	3,378,380.678	720,142.269	118.360	0.018	0.023	N/A
MEXPORT**	3503174.163	735740.617	163.366	3,503,174.147	735,740.601	163.450	0.016	0.016	N/A
A 937*	3519055.737	744698.500	128.029	N/A	N/A	127.977	N/A	N/A	0.050
YOAKUM SW BASE**	3244673.301	680118.205	110.623	3,244,673.302	680,118.189	110.700	-0.001	0.016	N/A
LAKE	3280376.188	754359.115	62.738	3,280,376.190	754,359.223	62.750	-0.002	-0.008	-0.012
BERNARD 2*	3269041.251	784052.777	36.676	N/A	N/A	36.650	N/A	N/A	0.026

(*) Indicates a vertical NGS Mark (**)

Indicates a horizontal NGS Mark

The above results indicate that the VRS network is providing positional values within the 5cm parameters for this survey.

NGS Monuments



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2.5 *Adjustment*

The survey data was collected using Virtual Reference Stations (VRS) methodology within a Virtual Reference System (VRS).

The system is designed to provide a true Network RTK performance, the RTKNet software enables high-accuracy positioning in real time across a geographic region. The RTKNet software package uses real-time data streams from the TXDOT RTN system user and generates correction models for high-accuracy RTK GPS corrections throughout the network. Therefore, corrections were applied to the points as they were being collected, thus negating the need for a post process adjustment.

2.6 *Data Processing Procedures*

After field data is collected the information is downloaded from the data collectors into the office software. The Software program used is called TBC or Trimble Business Center.

Downloaded data is run through the TBC program to obtain the following reports; points report, point comparison report and a point detail report. The reports are reviewed for point accuracy and precision.

After review of the point data an “ASCII” or “txt” file which is the industry standard is created. Point files are loaded into our CADD program (Carlson Survey 2014) to make a visual check of the point data (Pt. #, Coordinates, Elev. and Description). The data can now be imported into the final product.

3. *FINAL COORDINATES*

	UTM Zone 14, NAD83 (2011), NAVD88		
POINT ID	NORTHING (m)	EASTING (m)	ELEV. (m)
	NVA		
NVA-1	3209019.230	679508.526	49.031
NVA-2	3217411.015	684690.845	65.061
NVA-3	3226193.947	679904.384	88.032
NVA-4	3222409.481	695867.892	49.188
NVA-5	3227343.898	706440.247	35.839
NVA-6	3235889.508	696275.778	51.156
NVA-7	3235615.213	681998.274	79.382
NVA-8	3240997.352	679435.832	95.831
NVA-9	3256740.045	677819.999	112.580
NVA-10	3245339.967	690623.817	74.740
NVA-11	3236863.476	705930.952	58.160
NVA-12	3236180.880	714236.826	49.912
NVA-13	3240276.702	723477.567	43.581
NVA-14	3246248.202	710697.182	70.436
NVA-15	3258390.930	698757.092	72.706
NVA-16	3259520.656	688502.170	111.038
NVA-17	3266018.738	679869.190	129.935
NVA-18	3273596.756	679301.628	131.983
NVA-19	3272977.835	689268.399	108.011
NVA-20	3267365.596	708459.866	79.302
NVA-21	3255710.275	714777.740	55.003

NVA-22	3245360.223	731878.814	48.143
NVA-23	3235979.289	745386.411	34.079
NVA-23	3235979.289	745386.411	34.079
NVA-24	3223943.314	752345.190	25.882
NVA-25	3210702.820	763143.572	16.708
NVA-26	3217597.316	771799.931	20.928
NVA-27	3228436.316	777215.583	24.986
NVA-28	3235452.029	788928.893	25.817
NVA-29	3241205.727	796928.500	24.915
NVA-30	3247795.443	779451.106	32.702
NVA-30	3247795.443	779451.106	32.702
NVA-31	3234970.039	763349.261	34.754
NVA-32	3244186.712	757751.017	41.185
NVA-32	3244186.712	757751.017	41.185
NVA-33	3256114.212	767784.107	40.189

NVA-34	3262574.141	779811.688	35.515
NVA-35	3270609.075	783765.159	38.328
NVA-36	3272741.639	769848.701	45.225
NVA-37	3256246.564	759112.145	39.492
NVA-38	3251455.733	743653.087	46.594
NVA-39	3255315.997	726534.891	64.847
NVA-40	3264977.491	725720.916	84.641
NVA-41	3262439.123	740147.189	58.026
NVA-42	3265363.071	760941.986	49.549
NVA-43	3275896.602	758433.112	51.377
NVA-44	3274317.282	748876.174	54.259
NVA-45	3268508.392	738891.665	66.647
NVA-46	3278874.396	732366.026	90.150
NVA-47	3271314.670	724555.459	97.805
NVA-48	3276971.428	710435.391	90.265
NVA-49	3286980.232	715066.459	125.536
NVA-50	3271605.934	702003.475	105.360
	VVA		
VVA-1	3238498.104	802847.235	20.199
VVA-2	3233272.980	787490.027	23.397
VVA-3	3225526.490	771472.355	26.139
VVA-4	3221918.531	755851.743	23.547
VVA-5	3234572.731	753298.004	31.143
VVA-6	3242338.307	771812.756	32.661
VVA-7	3253679.701	777784.221	30.288
VVA-8	3267292.839	775710.453	37.139
VVA-9	3258867.016	765449.556	42.665
VVA-10	3247406.020	752396.425	42.824
VVA-11	3235783.389	738288.500	34.896
VVA-12	3251898.241	737699.842	49.569
VVA-13	3259741.715	748945.402	49.177
VVA-14	3268878.379	759555.009	50.390
VVA-15	3277921.802	766934.649	49.097
VVA-16	3279855.116	743547.500	62.151
VVA-17	3261965.472	736657.473	60.150
VVA-18	3279518.806	731551.214	82.764
VVA-19	3280409.673	715688.489	110.025
VVA-20	3267807.457	717758.136	94.904
VVA-21	3258597.231	725748.923	68.752
VVA-22	3245543.720	723457.323	44.654
VVA-23	3239613.097	713075.952	54.971
VVA-24	3259955.963	711480.820	55.895

VVA-25	3274936.867	701698.999	84.199
VVA-26	3277850.294	688928.981	130.007
VVA-27	3269242.058	684829.564	92.050
VVA-28	3261723.981	694613.773	73.155
VVA-29	3254094.625	699987.856	83.882
VVA-30	3228631.722	701548.808	47.058
VVA-31	3225002.014	690899.175	57.632
VVA-32	3232079.431	683446.962	73.909
VVA-33	3249514.052	685686.044	92.821
VVA-34	3249895.490	673854.980	133.760
VVA-35	3265368.255	674585.338	153.401

4. *GPS OBSERVATIONS*

POINT ID	OBSERV. DATE	JULIAN DATE	TIME OF DAY	RE-OBSERV. DATE	RE-OBSERV. TIME
NVA's					
NVA-1	1/9/2017	9	17:25	N/A	N/A
NVA-2	1/9/2017	9	16:45	N/A	N/A
NVA-3	1/10/2017	10	11:25	N/A	N/A
NVA-4	1/9/2017	9	16:15	N/A	N/A
NVA-5	1/9/2017	9	15:05	1/11/2017	14:55
NVA-6	1/10/2017	10	13:01	1/11/2017	14:24
NVA-7	1/10/2017	10	12:09	N/A	N/A
NVA-8	1/10/2017	10	13:10	1/11/2017	15:30
NVA-9	1/10/2017	10	14:34	1/11/2017	17:09
NVA-10	1/10/2017	10	10:31	N/A	N/A
NVA-11	1/10/2017	10	13:43	N/A	N/A
NVA-12	1/9/2017	9	14:25	N/A	N/A
NVA-13	1/9/2017	9	13:39	1/11/2017	10:46
NVA-14	1/10/2017	10	14:55	N/A	N/A
NVA-15	1/10/2017	10	11:19	1/11/2017	9:11
NVA-16	1/10/2017	10	9:10	N/A	N/A
NVA-17	1/10/2017	10	15:31	1/11/2017	17:39
NVA-18	1/10/2017	10	17:30	1/11/2017	18:05
NVA-19	1/10/2017	10	16:25	N/A	N/A
NVA-20	1/10/2017	10	10:13	N/A	N/A
NVA-21	1/10/2017	10	15:48	1/11/2017	12:53
NVA-22	1/9/2017	9	13:58	N/A	N/A
NVA-23	1/9/2017	9	11:38	1/11/2017	11:21
NVA-24	1/9/2017	9	10:31	1/9/2017	10:34
NVA-25	1/9/2017	9	8:49	1/9/2017	8:52
NVA-26	1/8/2017	8	17:15	N/A	N/A
NVA-27	1/9/2017	9	7:42	N/A	N/A
NVA-28	1/8/2017	8	15:00	N/A	N/A
NVA-29	1/8/2017	8	13:05	N/A	N/A
NVA-30	1/8/2017	8	10:55	1/11/2017	13:11
NVA-31	1/8/2017	8	8:48	N/A	N/A
NVA-32	1/8/2017	8	9:45	1/11/2017	18:09
NVA-33	1/9/2017	9	8:16	1/11/2017	17:37
NVA-34	1/8/2017	8	17:34	1/11/2017	13:48

NVA-35	1/8/2017	8	16:33	1/11/2017	14:25
NVA-36	1/8/2017	8	14:47	1/11/2017	15:04
NVA-37	1/9/2017	9	8:47	N/A	N/A
NVA-38	1/9/2017	9	16:09	N/A	N/A
NVA-39	1/9/2017	9	12:34	1/11/2017	10:03
NVA-40	1/9/2017	9	11:46	1/11/2017	9:44
NVA-41	1/11/2017	11	18:56	N/A	N/A
NVA-42	1/9/2017	9	9:04	1/11/2017	17:15
NVA-43	1/8/2017	8	13:40	1/11/2017	16:37
NVA-44	1/8/2017	8	11:53	1/11/2017	16:15
NVA-45	1/11/2017	11	19:34	N/A	N/A
NVA-46	1/9/2017	9	10:25	N/A	N/A
NVA-47	1/9/2017	9	11:30	1/11/2017	9:28
NVA-48	1/10/2017	10	20:08	1/11/2017	11:29
NVA-49	1/10/2017	10	19:23	1/11/2017	10:58
NVA-50	1/10/2017	10	9:48	1/11/2017	9:52
			VVA's		
VVA-1	1/8/2017	8	13:37	N/A	N/A
VVA-2	1/8/2017	8	15:43	N/A	N/A
VVA-3	1/9/2017	9	7:14	N/A	N/A
VVA-4	1/9/2017	9	10:08	N/A	N/A
VVA-5	1/9/2017	9	11:18	1/11/2017	11:35
VVA-6	1/8/2017	8	10:12	1/11/2017	12:24
VVA-7	1/9/2017	9	7:32	N/A	N/A
VVA-8	1/8/2017	8	15:36	N/A	N/A
VVA-9	1/9/2017	9	8:28	1/11/2017	17:28
VVA-10	1/8/2017	8	10:03	N/A	N/A
VVA-11	1/9/2017	9	12:13	1/11/2017	11:04
VVA-12	1/9/2017	9	16:39	N/A	N/A
VVA-13	1/8/2017	8	10:54	N/A	N/A
VVA-14	1/9/2017	9	9:20	1/11/2017	17:01
VVA-15	1/8/2017	8	14:06	1/11/2017	15:23
VVA-16	1/8/2017	8	11:33	1/11/2017	16:35
VVA-17	1/11/2017	11	19:11	N/A	N/A
VVA-18	1/9/2017	9	10:37	N/A	N/A
VVA-19	1/10/2017	10	19:48	1/11/2017	11:10
VVA-20	1/10/2017	10	16:53	1/11/2017	12:11
VVA-21	1/9/2017	9	12:19	N/A	N/A

VVA-22	1/9/2017	9	13:11	1/11/2017	10:29
VVA-23	1/9/2017	9	14:05	N/A	N/A
VVA-24	1/10/2017	10	16:23	1/11/2017	13:08
VVA-25	1/10/2017	10	9:23	N/A	N/A
VVA-26	1/10/2017	10	16:39	1/11/2017	10:03
VVA-27	1/10/2017	10	16:07	N/A	N/A
VVA-28	1/10/2017	10	8:20	N/A	N/A
VVA-29	1/10/2017	10	11:41	1/11/2017	13:37
VVA-30	1/9/2017	9	15:32	1/11/2017	14:38
VVA-31	1/10/2017	10	11:07	N/A	N/A
VVA-32	1/10/2017	10	11:56	N/A	N/A
VVA-33	1/10/2017	10	10:15	1/11/2017	16:45
VVA-34	1/10/2017	10	14:10	N/A	N/A
VVA-35	1/10/2017	10	15:13	N/A	N/A

5. POINT COMPARISON

Point ID	Point CK	Delta North (m)	Delta East (m)	Vertical Difference (m)
NVA-5	NVA-5CK	0.008	0.009	-0.010
NVA-6	NVA-6CK	-0.016	-0.012	0.021
NVA-8	NVA-8CK	-0.010	0.022	-0.014
NVA-9	NVA-9CK	0.010	-0.004	0.047
NVA-13	NVA-13CK	-0.005	0.000	-0.028
NVA-15	NVA-15CK	-0.012	-0.007	0.031
NVA-17	NVA-17CK	0.012	0.010	0.028
NVA-18	NVA-18CK	0.006	-0.017	-0.006
NVA-21	NVA-21CK	-0.002	-0.001	0.002
NVA-23	NVA-23CK	-0.023	0.006	0.016
NVA-24	NVA-24CK	-0.005	-0.002	0.001
NVA-25	NVA-25CK	-0.003	0.003	0.002
NVA-30	NVA-30CK	-0.002	0.000	0.009
NVA-32	NVA-32CK	0.007	0.010	0.013
NVA-33	NVA-33CK	0.010	-0.003	0.013
NVA-34	NVA-34CK	0.007	-0.002	-0.010
NVA-35	NVA-35CK	0.002	-0.015	-0.002
NVA-36	NVA-36CK	-0.006	-0.006	0.023
NVA-39	NVA-39CK	0.002	-0.009	-0.030
NVA-40	NVA-40CK	0.003	0.015	0.020
NVA-42	NVA-42CK	-0.004	-0.007	0.017
NVA-43	NVA-43CK	-0.007	-0.001	-0.016
NVA-44	NVA-44CK	-0.008	-0.009	0.004
NVA-47	NVA-47CK	-0.012	0.004	-0.005
NVA-48	NVA-48CK	0.016	-0.005	-0.010
NVA-49	NVA-49CK	-0.033	-0.037	-0.032
NVA-50	NVA-50CK	0.014	0.022	0.007
VVA-5	VVA-5CK	0.013	0.031	-0.044
VVA-6	VVA-6CK	-0.007	-0.004	-0.020
VVA-9	VVA-9CK	-0.020	-0.017	0.020
VVA-11	VVA-11CK	0.010	0.005	0.008
VVA-14	VVA-14CK	-0.011	0.001	-0.019
VVA-15	VVA-15CK	-0.015	0.004	-0.018
VVA-16	VVA-16CK	0.007	0.006	-0.021
VVA-19	VVA-19CK	-0.004	-0.004	0.013
VVA-20	VVA-20CK	0.000	0.000	-0.021
VVA-22	VVA-22CK	0.006	0.009	-0.004
VVA-24	VVA-24CK	-0.008	0.008	-0.020

VVA-26	**VVA-26CK**	**0.002**	**0.000**	**-0.020**
VVA-29	**VVA-29CK**	**-0.004**	**0.014**	**0.009**
VVA-30	**VVA-30CK**	**0.008**	**-0.030**	**-0.041**
VVA-33	**VVA-33CK**	**0.015**	**0.002**	**0.008**

Appendix B: Ground Control Point Survey Report

Ground Control Point Survey Report

"Texas Lavaca-Wharton FEMA Region 6 LiDAR"
USGS Contract: G16PC00020 Task Order Number: G17PC00014

Prepared for:
United States Geological Survey (USGS)

Prepared By:
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10003 Derekwood Lane, Suite 204
Lanham, Maryland, 20706
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5. Point Comparison Report 13

7. Deliverables .... Sent via Electronic Transfer
Including: a) Point Documentation Report & Photos of Survey Points
b) Final Coordinate List in Excel Format
c) NGS Data Sheets for Project Controls

2. INTRODUCTION

1.1 *Project Summary*

Dewberry Consultants LLC is under contract to the United States Geological Survey to provide 60 Ground Control Points in the State of Texas. Under the above referenced USGS Task Order, Dewberry is tasked to complete the quality assurance of LiDAR products. As part of this work Dewberry staff will complete Ground Control Point surveys that will be used to evaluate vertical and horizontal accuracy. The ground survey was conducted January 8 thru January 11, 2017.

Existing NGS Control Points were located and surveyed to check the accuracy of the RTK/GPS survey equipment with the results shown in Section 2.4 of this Report.

As an internal QA/QC procedure and to verify that the Ground Control Points meet the 95% confidence level approximately 50% of the points were re-observed and are shown in Section 5 of this report.

Final horizontal coordinates are referenced to UTM, Zone 14, NAD83 (2011) in meters. Final Vertical elevations are referenced to NAVD88 in meters using Geoid model 2012B (Geoid12B).

1.2 *Points of Contact*

Questions regarding the technical aspects of this report should be addressed to:

Dewberry Consultants LLC

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Senior Associate
10003 Derekwood Lane
Suite 204
Lanham, Maryland 20706
(302)364-1855 direct
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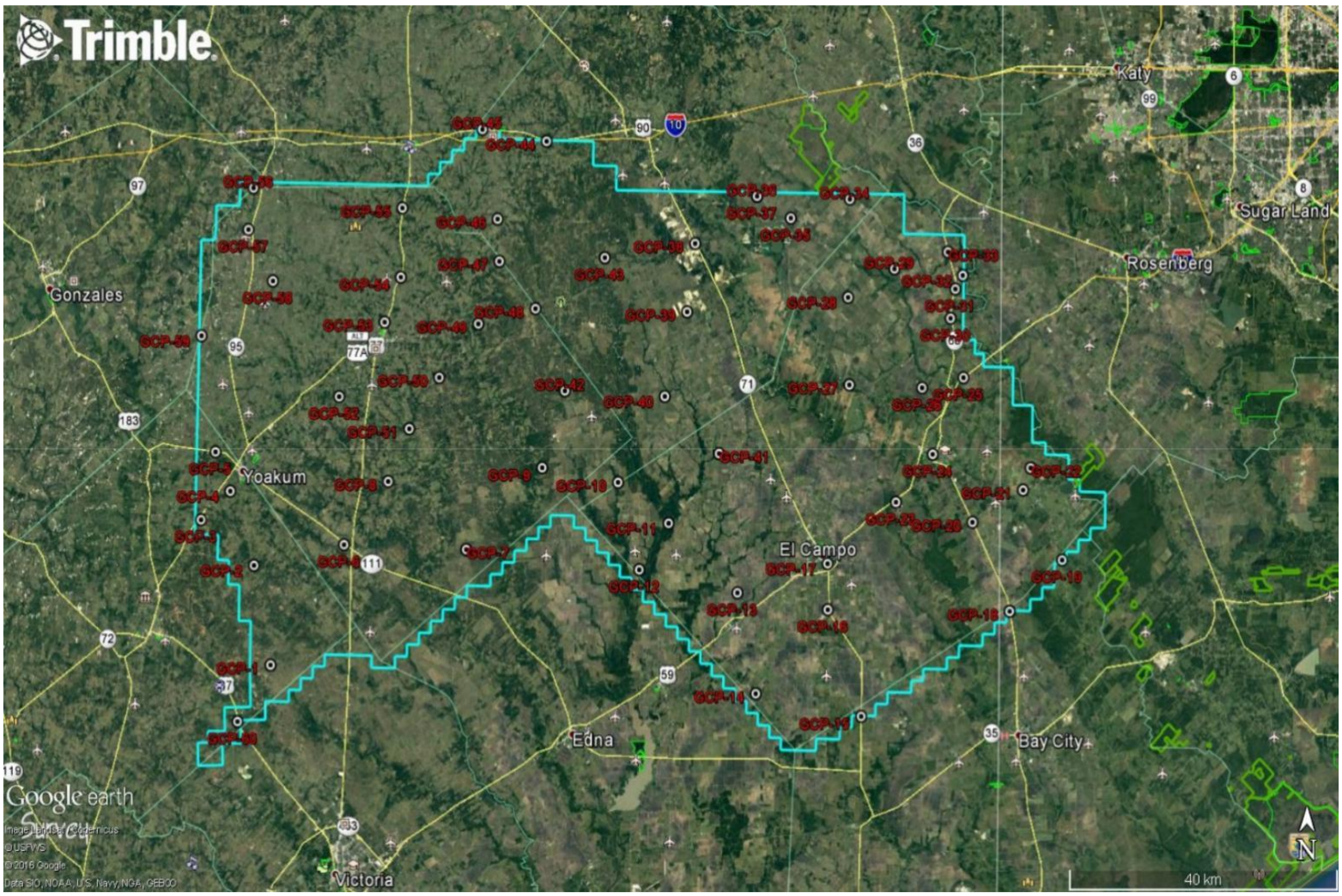
1.3 *Project Area*



PROJECT DETAILS

2.1 *Survey Equipment*

In performing the GPS observations Trimble R-10 GNSS receiver/antenna attached to a two meter fixed height pole with a Trimble TSC3 Data Collector to collect GPS raw data were used to perform the field surveys.

2.2 *Survey Point Detail*

The 60 Ground Control Points were well distributed throughout the project area.

A sketch was made for each location and a nail was set at the point where possible or at an identifiable point. The Ground Control Point locations are detailed on the "Check Point Documentation Report" sheets attached to this report.

2.3 *Network Design*

The GPS field survey performed by Dewberry offices located in Lanham, Maryland and Charleston, West Virginia and was tied to a Real Time Network operated by the TXDOT RTN. The network is a series of "real-time" continuously operating, high precision GPS reference stations. All of the reference stations have been linked together using Trimble GPSNet software, creating a Virtual Reference Station System (VRS).

The Trimble NetR5 Reference Station is a multi-channel, multi-frequency GNSS (Global Navigation Satellite System) receiver designed for use as a stand-alone reference station or as part of a GNSS infrastructure solution. Trimble R-Track technology in the NetR5 receiver supports the modernized GPS L2C and L5 signals as well as GLONASS L1/L2 signals.

2.4 *Field Survey Procedures and Analysis*

Dewberry field surveyors used Trimble R-10 GNSS receivers, which is a geodetic quality dual frequency GPS receiver, to collect data at each surveyed location.

All locations were occupied once with approximately 50% of the locations being re-observed. All re-observations matched the initially derived station positions within the allowable tolerance of ± 5cm or within the 95% confidence level. Each occupation which utilized the VRS network was occupied for approximately three (3) minutes in duration and measured to 180 epochs.

Each occupation which utilized OPUS (if used) was occupied between 20 and 30 minutes.

Field GPS observations are detailed on the "Control Point Documentation Reports" submitted as part of this report.

Six (6) existing NGS monument listed in the NSRS database were located as an additional QA/QC method to check the horizontal and vertical accuracy of the VRS network as well as being the primary project control monuments designated as AX0131, AX2610, AX0107, CR1356, BZ1450 and BZ0061. The results are as follows:

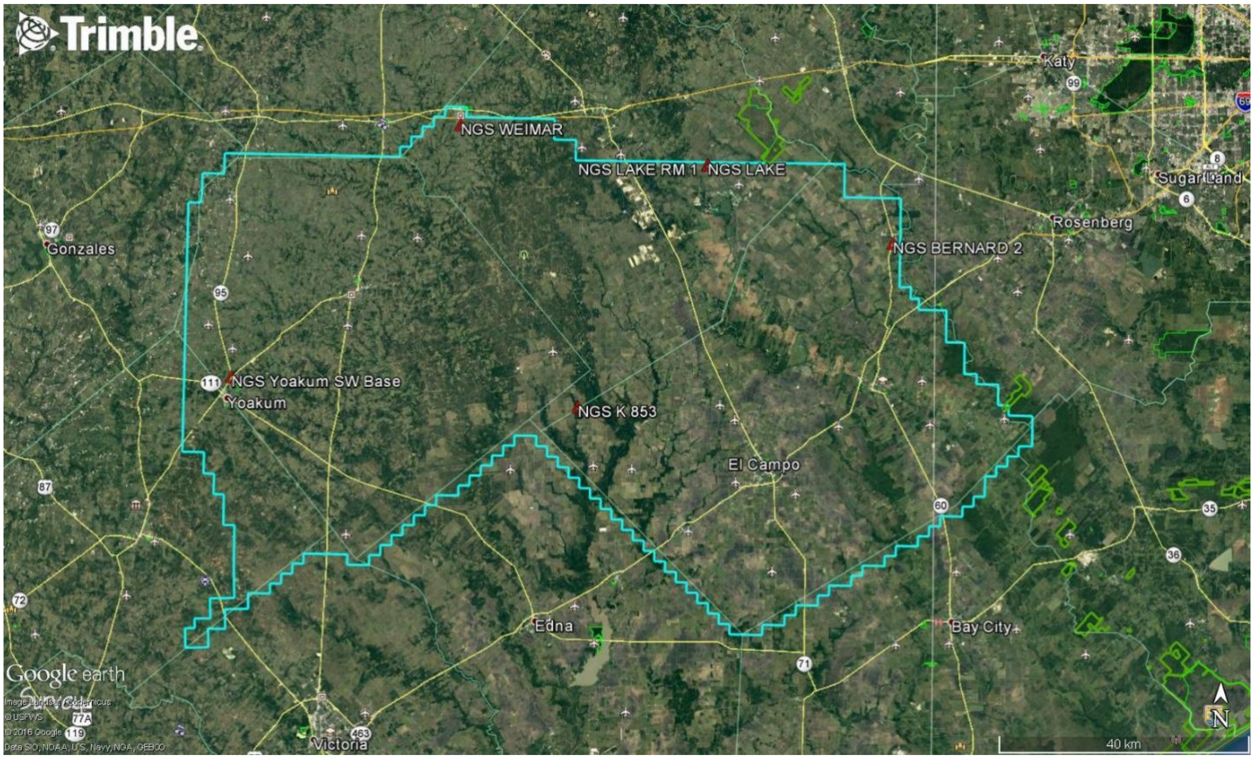
	Observed Values			Data Sheet Values					
PT. #	NORTHING	EASTING	ELEVS.	NORTHING	EASTING	ELEVS.	Δ X	Δ Y	Δ Z
CALPORT**	3378380.696	720142.292	118.154	3,378,380.678	720,142.269	118.360	0.018	0.023	N/A
MEXPORT**	3503174.163	735740.617	163.366	3,503,174.147	735,740.601	163.450	0.016	0.016	N/A
A 937*	3519055.737	744698.500	128.029	N/A	N/A	127.977	N/A	N/A	0.050
YOAKUM SW BASE**	3244673.301	680118.205	110.623	3,244,673.302	680,118.189	110.700	-0.001	0.016	N/A
LAKE	3280376.188	754359.115	62.738	3,280,376.190	754,359.223	62.750	-0.002	-0.008	-0.012
BERNARD 2*	3269041.251	784052.777	36.676	N/A	N/A	36.650	N/A	N/A	0.026

(*) Indicates a vertical NGS Mark (**)

Indicates a horizontal NGS Mark

The above results indicate that the VRS network is providing positional values within the 5cm parameters for this survey.

NGS Monuments



2.5 *Adjustment*

The survey data was collected using Virtual Reference Stations (VRS) methodology within a Virtual Reference System (VRS).

The system is designed to provide a true Network RTK performance, the RTKNet software enables high-accuracy positioning in real time across a geographic region. The RTKNet software package uses real-time data streams from the TXDOT RTN system user and generates correction models for high-accuracy RTK GPS corrections throughout the network. Therefore, corrections were applied to the points as they were being collected, thus negating the need for a post process adjustment.

2.6 *Data Processing Procedures*

After field data is collected the information is downloaded from the data collectors into the office software. The Software program used is called Trimble Business Center.

Downloaded data is run through the TBC program to obtain the following reports; points report, point comparison report and a point detail report. The reports are reviewed for point accuracy and precision.

After review of the point data an “ASCII” or “txt” file which is the industry standard is created. Point files are loaded into our CADD program (Carlson Survey 2014) to make a visual check of the point data (Pt. #, Coordinates, Elev. and Description). The data can now be imported into the final product.

4. *FINAL COORDINATES/ELEVATIONS*

UTM Zone 14, NAD83 (2011), NAVD88			
Point ID	**Northing (m)**	**Easting (m)**	**Elevation (m)**
GCP-001	3215746.852	684517.582	70.752
GCP-002	3228716.522	681742.030	72.560
GCP-003	3234745.561	673661.938	98.899
GCP-004	3238587.119	677780.951	90.674
GCP-005	3243827.251	675496.127	92.534
GCP-006	3232109.678	694889.828	64.072
GCP-007	3232083.089	710036.121	43.538
GCP-008	3240732.156	701124.400	67.971
GCP-009	3243299.452	723833.244	47.317
GCP-010	3241727.877	735095.236	40.909
GCP-011	3236528.046	742726.260	34.720
GCP-012	3230211.228	738603.192	30.504
GCP-013	3227622.989	753188.596	27.479
GCP-014	3214298.284	756323.781	20.788
GCP-015	3211775.986	772002.917	18.305
GCP-016	3225801.645	766609.021	27.446
GCP-017	3231923.038	766379.782	29.740
GCP-018	3226361.140	793522.750	22.048
GCP-019	3233490.857	801030.980	19.146
GCP-020	3238124.328	787598.292	27.041
GCP-021	3242656.617	794945.179	25.658
GCP-022	3245644.601	795971.157	22.937
GCP-023	3240424.592	776196.130	30.355
GCP-024	3246974.556	781418.737	31.571
GCP-025	3257301.321	785634.944	31.226
GCP-026	3255755.476	779617.271	34.045
GCP-027	3255773.020	768781.445	39.298
GCP-028	3267392.309	768235.127	45.254
GCP-029	3271415.845	774938.458	40.710
GCP-030	3265125.036	783472.592	35.602
GCP-031	3269041.248	784052.776	36.666
GCP-032	3270878.626	785093.451	36.795
GCP-033	3273921.737	782809.723	37.791
GCP-034	3280436.714	768065.127	47.651
GCP-035	3277640.822	759446.570	55.165

GCP-036	3280376.170	754359.109	62.765
GCP-037	3276160.719	753515.577	53.667
GCP-038	3273784.890	745423.323	61.762
GCP-039	3264682.805	744546.073	57.593
GCP-040	3253366.184	741611.978	47.900
GCP-041	3246032.335	749866.172	40.395
GCP-042	3253616.938	726847.834	65.757
GCP-043	3271487.129	732162.658	83.838
GCP-044	3286661.062	723042.599	104.234
GCP-045	3287937.072	713544.220	123.534
GCP-046	3276083.787	716144.291	104.246
GCP-047	3270482.205	716621.560	89.553
GCP-048	3264271.547	722303.765	73.423
GCP-049	3262062.736	713786.800	60.381
GCP-050	3254774.730	708247.721	86.608
GCP-051	3247829.131	704089.132	54.342
GCP-052	3251796.041	693555.238	68.609
GCP-053	3261859.423	699945.326	91.325
GCP-054	3267904.956	702128.559	101.314
GCP-055	3277111.424	702051.258	97.870
GCP-056	3279088.136	679934.972	134.296
GCP-057	3273520.575	679386.824	129.364
GCP-058	3266817.585	683231.690	141.770
GCP-059	3259192.022	672887.276	125.955
GCP-060	3208040.719	679872.089	45.280

5. *GPS OBSERVATIONS*

POINT ID	OBSERV. DATE	JULIAN DATE	TIME OF DAY	RE-OBSERV. DATE	RE-OBSERV. TIME
GCP-1	1/9/2017	9	17:00	N/A	N/A
GCP-2	1/10/2017	10	11:40	N/A	N/A
GCP-3	1/10/2017	10	12:51	1/11/2017	15:54
GCP-4	1/10/2017	10	12:26	1/11/2017	15:41
GCP-5	1/10/2017	10	13:53	N/A	N/A
GCP-6	1/9/2017	9	15:54	1/11/2017	15:08
GCP-7	1/9/2017	9	14:45	N/A	N/A
GCP-8	1/10/2017	10	13:22	1/11/2017	14:02
GCP-9	1/9/2017	9	13:24	1/11/2017	10:36
GCP-10	1/9/2017	9	13:08	N/A	N/A
GCP-11	1/9/2017	9	11:54	1/11/2017	11:11
GCP-12	1/9/2017	9	12:39	N/A	N/A
GCP-13	1/9/2017	9	10:49	N/A	N/A
GCP-14	1/9/2017	9	9:12	N/A	N/A
GCP-15	1/9/2017	9	8:23	N/A	N/A
GCP-16	1/8/2017	8	17:36	N/A	N/A
GCP-17	1/8/2017	8	9:06	1/11/2017	11:55
GCP-18	1/8/2017	8	16:14	N/A	N/A
GCP-19	1/8/2017	8	14:02	N/A	N/A
GCP-20	1/8/2017	8	15:18	N/A	N/A
GCP-21	1/8/2017	8	12:20	N/A	N/A
GCP-22	1/8/2017	8	12:42	N/A	N/A
GCP-23	1/8/2017	8	9:44	1/11/2017	12:08
GCP-24	1/8/2017	8	11:20	1/11/2017	12:42
GCP-25	1/8/2017	8	11:44	1/11/2017	13:35
GCP-26	1/9/2017	9	7:46	1/11/2017	13:24
GCP-27	1/9/2017	9	8:05	1/11/2017	17:43
GCP-28	1/8/2017	8	15:09	1/11/2017	16:24
GCP-29	1/8/2017	8	15:53	1/11/2017	14:50
GCP-30	1/8/2017	8	17:21	1/11/2017	14:00
GCP-31	1/8/2017	8	17:03	1/11/2017	14:08
GCP-32	1/8/2017	8	16:50	1/11/2017	14:17
GCP-33	1/8/2017	8	16:15	1/11/2017	14:31
GCP-34	1/8/2017	8	14:23	N/A	N/A
GCP-35	1/8/2017	8	13:24	1/11/2017	15:46

GCP-36	1/8/2017	8	12:23	1/11/2017	16:00
GCP-37	1/9/2017	9	9:36	N/A	N/A
GCP-38	1/8/2017	8	11:17	N/A	N/A
GCP-39	1/11/2017	11	18:38	N/A	N/A
GCP-40	1/9/2017	9	17:03	N/A	N/A
GCP-41	1/8/2017	8	10:22	N/A	N/A
GCP-42	1/9/2017	9	12:45	1/11/2017	10:11
GCP-43	1/9/2017	9	11:01	N/A	N/A
GCP-44	1/10/2017	10	18:43	N/A	N/A
GCP-45	1/10/2017	10	19:05	1/11/2017	10:42
GCP-46	1/10/2017	10	17:31	N/A	N/A
GCP-47	1/10/2017	10	17:14	1/11/2017	11:57
GCP-48	1/9/2017	9	12:00	1/11/2017	11:43
GCP-49	1/10/2017	10	16:04	1/11/2017	12:41
GCP-50	1/10/2017	10	15:25	N/A	N/A
GCP-51	1/10/2017	10	12:17	N/A	N/A
GCP-52	1/10/2017	10	9:40	N/A	N/A
GCP-53	1/10/2017	10	10:52	1/11/2017	9:27
GCP-54	1/10/2017	10	10:35	1/11/2017	9:44
GCP-55	1/10/2017	10	8:47	N/A	N/A
GCP-56	1/10/2017	10	17:08	1/11/2017	18:35
GCP-57	1/10/2017	10	17:46	1/11/2017	18:15
GCP-58	1/10/2017	10	15:44	1/11/2017	17:47
GCP-59	1/10/2017	10	14:52	1/11/2017	17:23
GCP-60	1/9/2017	9	17:35	N/A	N/A

6. *POINT COMPARISON*

Point ID	Point CK	Delta North (M)	Delta East (M)	Vertical Difference (M)
GCP-003	GCP-003CK	-0.020	0.002	0.028
GCP-004	GCP-004CK	0.017	-0.012	-0.005
GCP-006	GCP-006CK	-0.019	-0.006	-0.017
GCP-008	GCP-008CK	0.011	0.014	0.022
GCP-009	GCP-009CK	-0.007	-0.008	0.012
GCP-011	GCP-011CK	0.000	0.022	0.000
GCP-017	GCP-017CK	0.000	0.008	0.013
GCP-023	GCP-023CK	0.013	0.000	-0.018
GCP-024	GCP-024CK	0.000	-0.002	-0.010
GCP-025	GCP-025CK	-0.004	0.028	0.015
GCP-026	GCP-026CK	-0.003	-0.001	0.016
GCP-027	GCP-027CK	0.003	0.009	-0.008
GCP-028	GCP-028CK	0.005	-0.001	-0.002
GCP-029	GCP-029CK	-0.005	0.000	-0.019
GCP-030	GCP-030CK	0.002	0.001	-0.009
GCP-031	GCP-031CK	-0.001	0.017	-0.013
GCP-032	GCP-032CK	0.002	0.002	-0.004
GCP-033	GCP-033CK	0.017	0.004	0.007
GCP-035	GCP-035CK	0.001	-0.001	0.038
GCP-036	GCP-038CK	0.001	0.000	0.003
GCP-042	GCP-042CK	0.002	-0.002	-0.034
GCP-045	GCP-045CK	0.008	0.008	-0.022
GCP-047	GCP-047CK	-0.037	0.000	-0.001
GCP-048	GCP-048CK	0.015	0.004	0.005
GCP-049	GCP-049CK	-0.006	-0.006	-0.011
GCP-053	GCP-053CK	-0.012	0.006	0.010
GCP-054	GCP-054CK	0.021	0.016	-0.007
GCP-056	GCP-056CK	0.018	-0.010	0.049
GCP-057	GCP-057CK	0.005	0.021	0.012
GCP-058	GCP-058CK	-0.003	-0.015	-0.009
GCP-059	GCP-059CK	0.002	0.020	0.025

Appendix C: Complete List of Delivered Tiles

14RPT7301	14RPT7501	14RPT7601	14RPT7302
14RPT7502	14RPT7602	14RPT7304	14RPT7504
14RPT7604	14RPT7804	14RPT7904	14RPT7505
14RPT7605	14RPT7805	14RPT7905	14RQT5905
14RQT6005	14RQT6205	14RQT6305	14RQT6505
14RPT7607	14RPT7807	14RPT7907	14RPT8107
14RPT8207	14RQT5707	14RQT5907	14RQT6007
14RQT6207	14RQT6307	14RQT6507	14RQT6607
14RQT6807	14RPT7608	14RPT7808	14RPT7908
14RPT8108	14RPT8208	14RQT5608	14RQT5708
14RQT5908	14RQT6008	14RQT6208	14RQT6308
14RQT6508	14RQT6608	14RQT6808	14RPT7910
14RPT8110	14RPT8210	14RPT8410	14RPT8510
14RPT8710	14RQT5410	14RQT5610	14RQT5710
14RQT5910	14RQT6010	14RQT6210	14RQT6310
14RQT6510	14RQT6610	14RQT6810	14RQT6910
14RPT8111	14RPT8211	14RPT8411	14RPT8511
14RPT8711	14RPT8811	14RQT5411	14RQT5611
14RQT5711	14RQT5911	14RQT6011	14RQT6211
14RQT6311	14RQT6511	14RQT6611	14RQT6811
14RQT6911	14RQT7111	14RQT7211	14RQT7411
14RPT8113	14RPT8213	14RPT8413	14RPT8513
14RPT8713	14RPT8813	14RPT9013	14RQT5313
14RQT5413	14RQT5613	14RQT5713	14RQT5913
14RQT6013	14RQT6213	14RQT6313	14RQT6513
14RQT6613	14RQT6813	14RQT6913	14RQT7113
14RQT7213	14RQT7413	14RQT7513	14RPT8114
14RPT8214	14RPT8414	14RPT8514	14RPT8714
14RPT8814	14RPT9014	14RPT9114	14RPT9914
14RQT0014	14RQT0214	14RQT5014	14RQT5114
14RQT5314	14RQT5414	14RQT5614	14RQT5714
14RQT5914	14RQT6014	14RQT6214	14RQT6314
14RQT6514	14RQT6614	14RQT6814	14RQT6914
14RQT7114	14RQT7214	14RQT7414	14RQT7514
14RQT7714	14RQT7814	14RPT8116	14RPT8216
14RPT8416	14RPT8516	14RPT8716	14RPT8816
14RPT9016	14RPT9116	14RPT9316	14RPT9416
14RPT9616	14RPT9716	14RPT9916	14RQT0016
14RQT0216	14RQT0316	14RQT4816	14RQT5016
14RQT5116	14RQT5316	14RQT5416	14RQT5616
14RQT5716	14RQT5916	14RQT6016	14RQT6216
14RQT6316	14RQT6516	14RQT6616	14RQT6816
14RQT6916	14RQT7116	14RQT7216	14RQT7416
14RQT7516	14RQT7716	14RQT7816	14RQT8016
14RPT8117	14RPT8217	14RPT8417	14RPT8517
14RPT8717	14RPT8817	14RPT9017	14RPT9117
14RPT9317	14RPT9417	14RPT9617	14RPT9717
14RPT9917	14RQT0017	14RQT0217	14RQT0317
14RQT0517	14RQT4717	14RQT4817	14RQT5017
14RQT5117	14RQT5317	14RQT5417	14RQT5617
14RQT5717	14RQT5917	14RQT6017	14RQT6217
14RQT6317	14RQT6517	14RQT6617	14RQT6817

14RQT6917	14RQT7117	14RQT7217	14RQT7417
14RQT7517	14RQT7717	14RQT7817	14RQT8017
14RQT8117	14RQT8317	14RPT8119	14RPT8219
14RPT8419	14RPT8519	14RPT8719	14RPT8819
14RPT9019	14RPT9119	14RPT9319	14RPT9419
14RPT9619	14RPT9719	14RPT9919	14RQT0019
14RQT0219	14RQT0319	14RQT0519	14RQT4519
14RQT4719	14RQT4819	14RQT5019	14RQT5119
14RQT5319	14RQT5419	14RQT5619	14RQT5719
14RQT5919	14RQT6019	14RQT6219	14RQT6319
14RQT6519	14RQT6619	14RQT6819	14RQT6919
14RQT7119	14RQT7219	14RQT7419	14RQT7519
14RQT7719	14RQT7819	14RQT8019	14RQT8119
14RQT8319	14RQT8419	14RQT8619	14RPT7820
14RPT7920	14RPT8120	14RPT8220	14RPT8420
14RPT8520	14RPT8720	14RPT8820	14RPT9020
14RPT9120	14RPT9320	14RPT9420	14RPT9620
14RPT9720	14RPT9920	14RQT0020	14RQT0220
14RQT0320	14RQT0520	14RQT0620	14RQT0820
14RQT4420	14RQT4520	14RQT4720	14RQT4820
14RQT5020	14RQT5120	14RQT5320	14RQT5420
14RQT5620	14RQT5720	14RQT5920	14RQT6020
14RQT6220	14RQT6320	14RQT6520	14RQT6620
14RQT6820	14RQT6920	14RQT7120	14RQT7220
14RQT7420	14RQT7520	14RQT7720	14RQT7820
14RQT8020	14RQT8120	14RQT8320	14RQT8420
14RQT8620	14RQT8720	14RQT8920	14RPT7822
14RPT7922	14RPT8122	14RPT8222	14RPT8422
14RPT8522	14RPT8722	14RPT8822	14RPT9022
14RPT9122	14RPT9322	14RPT9422	14RPT9622
14RPT9722	14RPT9922	14RQT0022	14RQT0222
14RQT0322	14RQT0522	14RQT0622	14RQT0822
14RQT0922	14RQT4222	14RQT4422	14RQT4522
14RQT4722	14RQT4822	14RQT5022	14RQT5122
14RQT5322	14RQT5422	14RQT5622	14RQT5722
14RQT5922	14RQT6022	14RQT6222	14RQT6322
14RQT6522	14RQT6622	14RQT6822	14RQT6922
14RQT7122	14RQT7222	14RQT7422	14RQT7522
14RQT7722	14RQT7822	14RQT8022	14RQT8122
14RQT8322	14RQT8422	14RQT8622	14RQT8722
14RQT8922	14RQT9022	14RPT7823	14RPT7923
14RPT8123	14RPT8223	14RPT8423	14RPT8523
14RPT8723	14RPT8823	14RPT9023	14RPT9123
14RPT9323	14RPT9423	14RPT9623	14RPT9723
14RPT9923	14RQT0023	14RQT0223	14RQT0323
14RQT0523	14RQT0623	14RQT0823	14RQT0923
14RQT1123	14RQT3923	14RQT4123	14RQT4223
14RQT4423	14RQT4523	14RQT4723	14RQT4823
14RQT5023	14RQT5123	14RQT5323	14RQT5423
14RQT5623	14RQT5723	14RQT5923	14RQT6023
14RQT6223	14RQT6323	14RQT6523	14RQT6623
14RQT6823	14RQT6923	14RQT7123	14RQT7223
14RQT7423	14RQT7523	14RQT7723	14RQT7823
14RQT8023	14RQT8123	14RQT8323	14RQT8423
14RQT8623	14RQT8723	14RQT8923	14RQT9023

15RQT9223	14RPT7625	14RPT7825	14RPT7925
14RPT8125	14RPT8225	14RPT8425	14RPT8525
14RPT8725	14RPT8825	14RPT9025	14RPT9125
14RPT9325	14RPT9425	14RPT9625	14RPT9725
14RPT9925	14RQT0025	14RQT0225	14RQT0325
14RQT0525	14RQT0625	14RQT0825	14RQT0925
14RQT1125	14RQT1225	14RQT3825	14RQT3925
14RQT4125	14RQT4225	14RQT4425	14RQT4525
14RQT4725	14RQT4825	14RQT5025	14RQT5125
14RQT5325	14RQT5425	14RQT5625	14RQT5725
14RQT5925	14RQT6025	14RQT6225	14RQT6325
14RQT6525	14RQT6625	14RQT6825	14RQT6925
14RQT7125	14RQT7225	14RQT7425	14RQT7525
14RQT7725	14RQT7825	14RQT8025	14RQT8125
14RQT8325	14RQT8425	14RQT8625	14RQT8725
14RQT8925	14RQT9025	15RQT9225	15RQT9325
15RQT9525	15RQT9625	14RPT7626	14RPT7826
14RPT7926	14RPT8126	14RPT8226	14RPT8426
14RPT8526	14RPT8726	14RPT8826	14RPT9026
14RPT9126	14RPT9326	14RPT9426	14RPT9626
14RPT9726	14RPT9926	14RQT0026	14RQT0226
14RQT0326	14RQT0526	14RQT0626	14RQT0826
14RQT0926	14RQT1126	14RQT1226	14RQT1426
14RQT1526	14RQT3626	14RQT3826	14RQT3926
14RQT4126	14RQT4226	14RQT4426	14RQT4526
14RQT4726	14RQT4826	14RQT5026	14RQT5126
14RQT5326	14RQT5426	14RQT5626	14RQT5726
14RQT5926	14RQT6026	14RQT6226	14RQT6326
14RQT6526	14RQT6626	14RQT6826	14RQT6926
14RQT7126	14RQT7226	14RQT7426	14RQT7526
14RQT7726	14RQT7826	14RQT8026	14RQT8126
14RQT8326	14RQT8426	14RQT8626	14RQT8726
14RQT8926	14RQT9026	15RQT9226	15RQT9326
15RQT9526	15RQT9626	15RQT9826	14RPT7528
14RPT7628	14RPT7828	14RPT7928	14RPT8128
14RPT8228	14RPT8428	14RPT8528	14RPT8728
14RPT8828	14RPT9028	14RPT9128	14RPT9328
14RPT9428	14RPT9628	14RPT9728	14RPT9928
14RQT0028	14RQT0228	14RQT0328	14RQT0528
14RQT0628	14RQT0828	14RQT0928	14RQT1128
14RQT1228	14RQT1428	14RQT1528	14RQT1728
14RQT3528	14RQT3628	14RQT3828	14RQT3928
14RQT4128	14RQT4228	14RQT4428	14RQT4528
14RQT4728	14RQT4828	14RQT5028	14RQT5128
14RQT5328	14RQT5428	14RQT5628	14RQT5728
14RQT5928	14RQT6028	14RQT6228	14RQT6328
14RQT6528	14RQT6628	14RQT6828	14RQT6928
14RQT7128	14RQT7228	14RQT7428	14RQT7528
14RQT7728	14RQT7828	14RQT8028	14RQT8128
14RQT8328	14RQT8428	14RQT8628	14RQT8728
14RQT8928	14RQT9028	15RQT9228	15RQT9328
15RQT9528	15RQT9628	15RQT9828	14RPT7529
14RPT7629	14RPT7829	14RPT7929	14RPT8129
14RPT8229	14RPT8429	14RPT8529	14RPT8729
14RPT8829	14RPT9029	14RPT9129	14RPT9329

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14RQT1229	14RQT1429	14RQT1529	14RQT1729
14RQT1829	14RQT2029	14RQT3329	14RQT3529
14RQT3629	14RQT3829	14RQT3929	14RQT4129
14RQT4229	14RQT4429	14RQT4529	14RQT4729
14RQT4829	14RQT5029	14RQT5129	14RQT5329
14RQT5429	14RQT5629	14RQT5729	14RQT5929
14RQT6029	14RQT6229	14RQT6329	14RQT6529
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14RQT7229	14RQT7429	14RQT7529	14RQT7729
14RQT7829	14RQT8029	14RQT8129	14RQT8329
14RQT8429	14RQT8629	14RQT8729	14RQT8929
14RQT9029	15RQT9229	15RQT9329	15RQT9529
15RQT9629	15RQT9829	15RQT9929	14RPT7531
14RPT7631	14RPT7831	14RPT7931	14RPT8131
14RPT8231	14RPT8431	14RPT8531	14RPT8731
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14RPT9431	14RPT9631	14RPT9731	14RPT9931
14RQT0031	14RQT0231	14RQT0331	14RQT0531
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14RQT1831	14RQT2031	14RQT2131	14RQT3231
14RQT3331	14RQT3531	14RQT3631	14RQT3831
14RQT3931	14RQT4131	14RQT4231	14RQT4431
14RQT4531	14RQT4731	14RQT4831	14RQT5031
14RQT5131	14RQT5331	14RQT5431	14RQT5631
14RQT5731	14RQT5931	14RQT6031	14RQT6231
14RQT6331	14RQT6531	14RQT6631	14RQT6831
14RQT6931	14RQT7131	14RQT7231	14RQT7431
14RQT7531	14RQT7731	14RQT7831	14RQT8031
14RQT8131	14RQT8331	14RQT8431	14RQT8631
14RQT8731	14RQT8931	14RQT9031	15RQT9231
15RQT9331	15RQT9531	15RQT9631	15RQT9831
15RQT9931	14RPT7232	14RPT7332	14RPT7532
14RPT7632	14RPT7832	14RPT7932	14RPT8132
14RPT8232	14RPT8432	14RPT8532	14RPT8732
14RPT8832	14RPT9032	14RPT9132	14RPT9332
14RPT9432	14RPT9632	14RPT9732	14RPT9932
14RQT0032	14RQT0232	14RQT0332	14RQT0532
14RQT0632	14RQT0832	14RQT0932	14RQT1132
14RQT1232	14RQT1432	14RQT1532	14RQT1732
14RQT1832	14RQT2032	14RQT2132	14RQT2332
14RQT2932	14RQT3032	14RQT3232	14RQT3332
14RQT3532	14RQT3632	14RQT3832	14RQT3932
14RQT4132	14RQT4232	14RQT4432	14RQT4532
14RQT4732	14RQT4832	14RQT5032	14RQT5132
14RQT5332	14RQT5432	14RQT5632	14RQT5732
14RQT5932	14RQT6032	14RQT6232	14RQT6332
14RQT6532	14RQT6632	14RQT6832	14RQT6932
14RQT7132	14RQT7232	14RQT7432	14RQT7532
14RQT7732	14RQT7832	14RQT8032	14RQT8132
14RQT8332	14RQT8432	14RQT8632	14RQT8732
14RQT8932	14RQT9032	15RQT9232	15RQT9332

15RQT9532	15RQT9632	15RQT9832	15RQT9932
15RQT0132	14RPT7234	14RPT7334	14RPT7534
14RPT7634	14RPT7834	14RPT7934	14RPT8134
14RPT8234	14RPT8434	14RPT8534	14RPT8734
14RPT8834	14RPT9034	14RPT9134	14RPT9334
14RPT9434	14RPT9634	14RPT9734	14RPT9934
14RQT0034	14RQT0234	14RQT0334	14RQT0534
14RQT0634	14RQT0834	14RQT0934	14RQT1134
14RQT1234	14RQT1434	14RQT1534	14RQT1734
14RQT1834	14RQT2034	14RQT2134	14RQT2334
14RQT2434	14RQT2734	14RQT2934	14RQT3034
14RQT3234	14RQT3334	14RQT3534	14RQT3634
14RQT3834	14RQT3934	14RQT4134	14RQT4234
14RQT4434	14RQT4534	14RQT4734	14RQT4834
14RQT5034	14RQT5134	14RQT5334	14RQT5434
14RQT5634	14RQT5734	14RQT5934	14RQT6034
14RQT6234	14RQT6334	14RQT6534	14RQT6634
14RQT6834	14RQT6934	14RQT7134	14RQT7234
14RQT7434	14RQT7534	14RQT7734	14RQT7834
14RQT8034	14RQT8134	14RQT8334	14RQT8434
14RQT8634	14RQT8734	14RQT8934	14RQT9034
15RQT9234	15RQT9334	15RQT9534	15RQT9634
15RQT9834	15RQT9934	15RQT0134	15RQT0234
14RPT7235	14RPT7335	14RPT7535	14RPT7635
14RPT7835	14RPT7935	14RPT8135	14RPT8235
14RPT8435	14RPT8535	14RPT8735	14RPT8835
14RPT9035	14RPT9135	14RPT9335	14RPT9435
14RPT9635	14RPT9735	14RPT9935	14RQT0035
14RQT0235	14RQT0335	14RQT0535	14RQT0635
14RQT0835	14RQT0935	14RQT1135	14RQT1235
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14RQT2959	14RQT3059	14RQT3259	14RQT3359
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14RQT2661	14RQT2761	14RQT2961	14RQT3061
14RQT3261	14RQT3361	14RQT3561	14RQT3661
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14RQT4461	14RQT4561	14RQT4761	14RQT4861
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14RQT5661	14RQT5761	14RQT5961	14RQT6061
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14RPT8262	14RPT8462	14RPT8562	14RPT8762
14RPT8862	14RPT9062	14RPT9162	14RPT9362
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14RQT4262	14RQT4462	14RQT4562	14RQT4762
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14RPT7665	14RPT7865	14RPT7965	14RPT8165
14RPT8265	14RPT8465	14RPT8565	14RPT8765
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14RQT6665	14RQT6865	14RQT6965	14RQT7165
14RQT7265	14RQT7465	14RQT7565	14RQT7765
14RQT7865	14RQT8065	14RQT8165	14RQT8365
14RQT8465	14RPT7267	14RPT7367	14RPT7567
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14RPT8867	14RPT9067	14RPT9167	14RPT9367
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14RQT1267	14RQT1467	14RQT1567	14RQT1767
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14RQT3067	14RQT3267	14RQT3367	14RQT3567
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14RQT3068	14RQT3268	14RQT3368	14RQT3568
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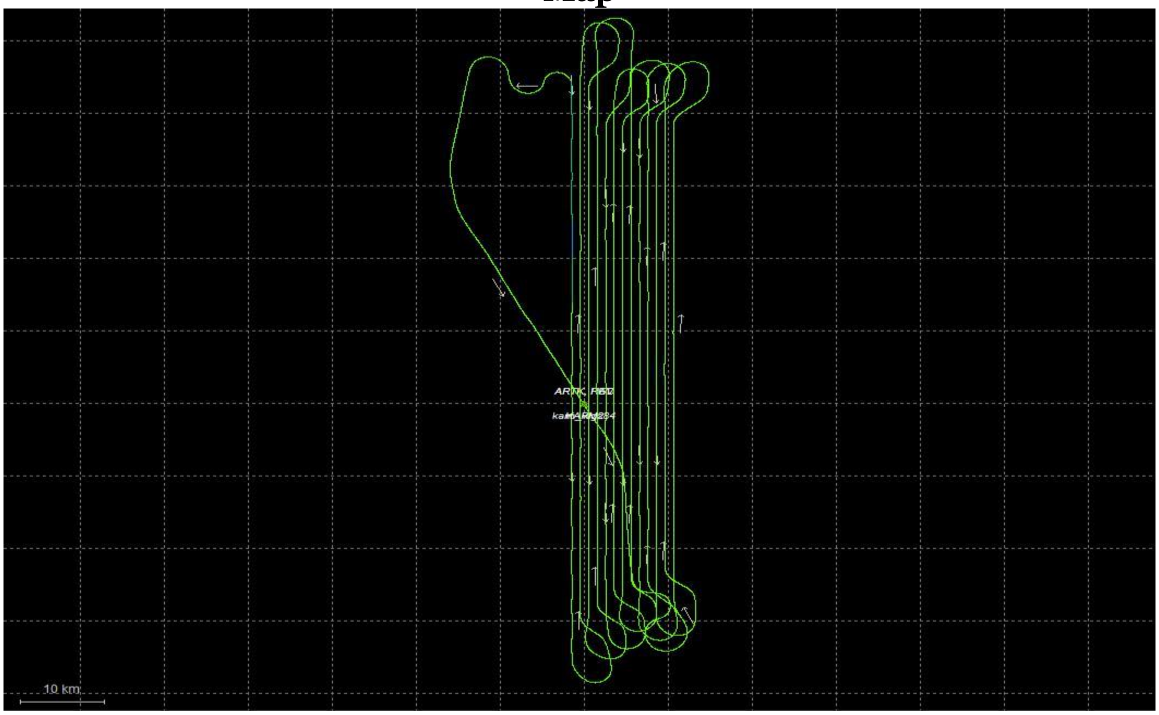
14RQT1588

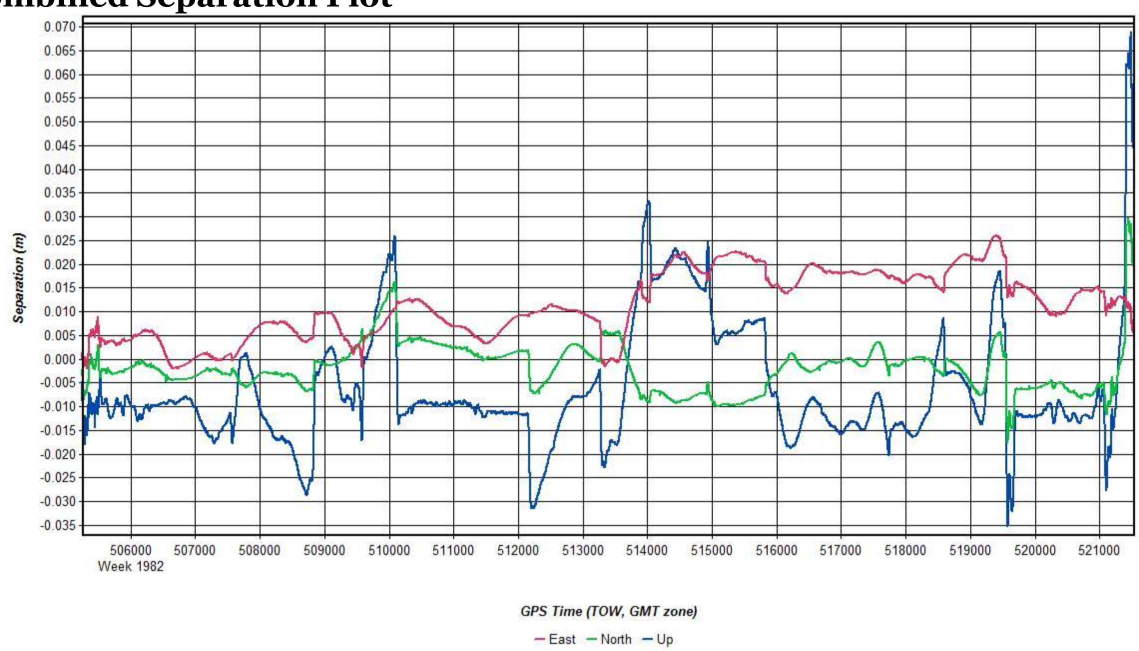
Appendix D: GPS Processing

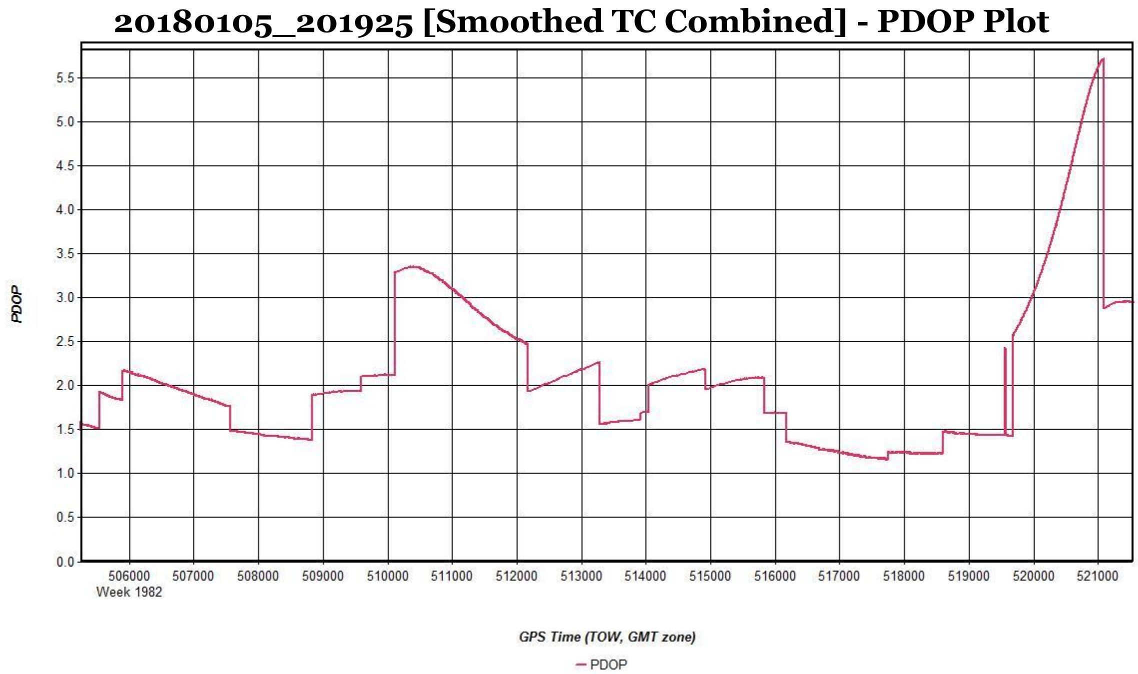
Mission 01/05/2018 A

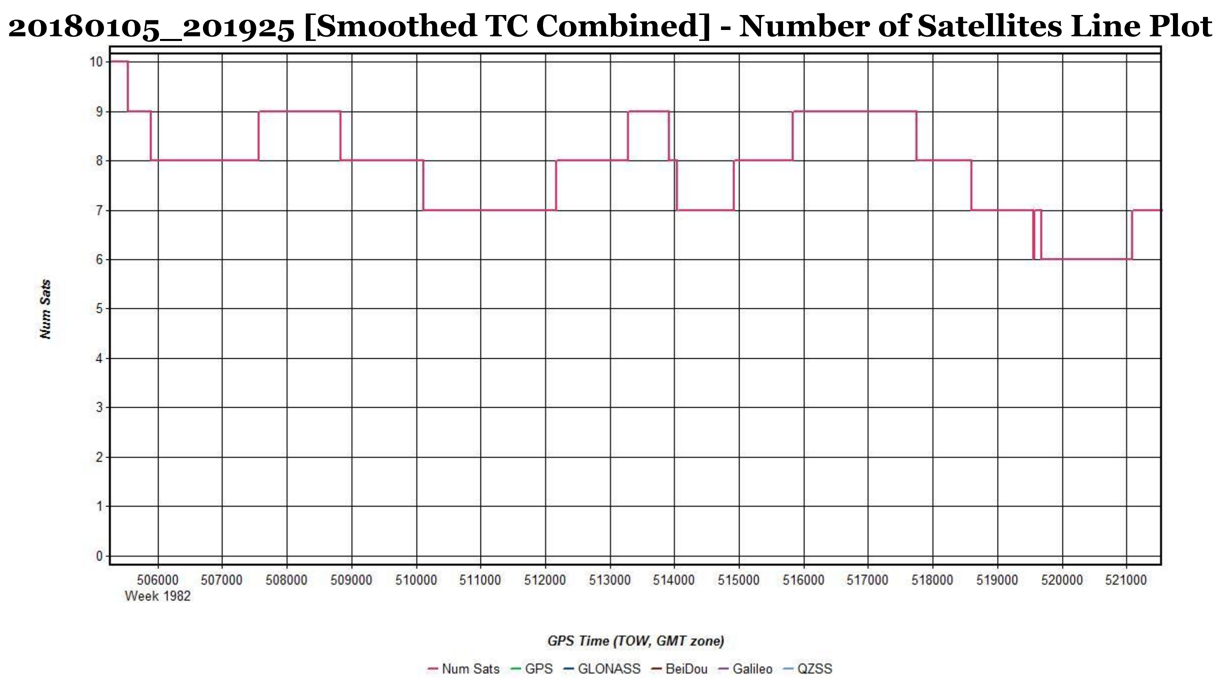
20180105_201925 [Smoothed TC Combined] - Smoothed TC Combined – Map



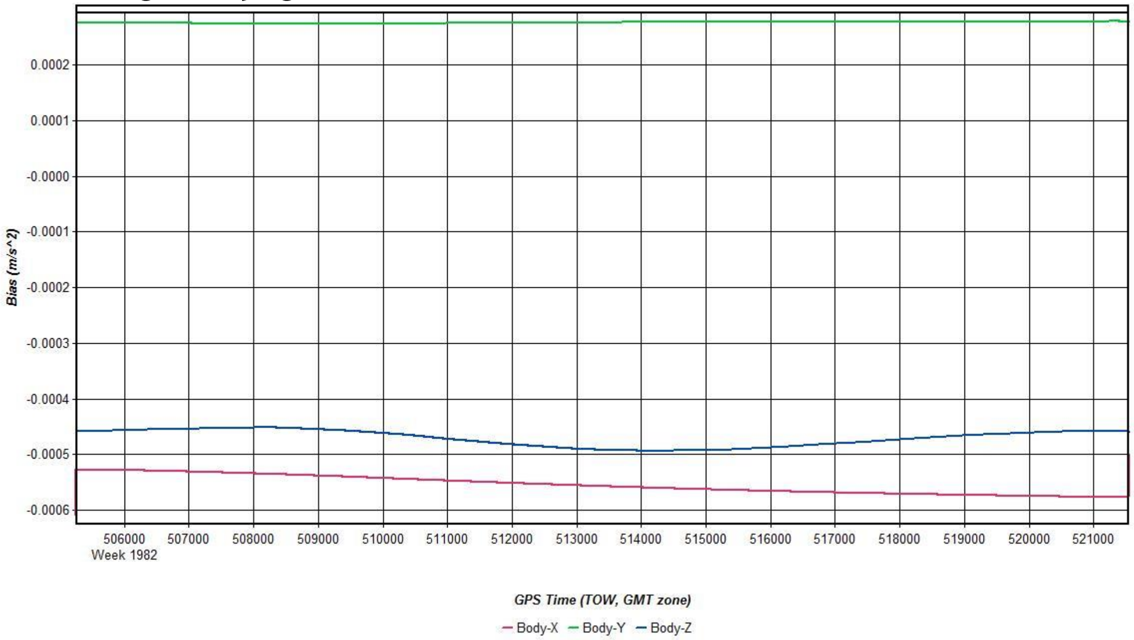
20180105_201925 [Smoothed TC Combined] - Forward/Reverse or Combined Separation Plot



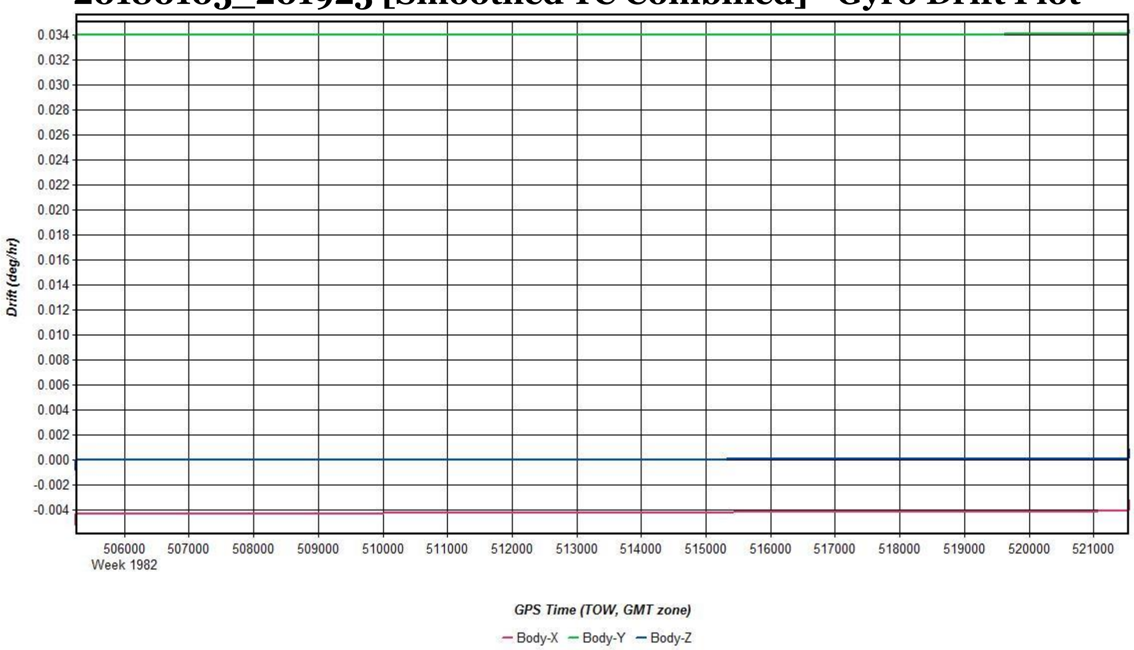

20180105_201925 [Smoothed TC Combined] - PDOP Plot
PDOP
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
506000 507000 508000 509000 510000 511000 512000 513000 514000 515000 516000 517000 518000 519000 520000 521000
Week 1982
GPS Time (TOW, GMT zone)
PDOP


20180105_201925 [Smoothed TC Combined] - Number of Satellites Line Plot
Num Sats
10
9
8
7
6
5
4
3
2
1
0
506000 507000 508000 509000 510000 511000 512000 513000 514000 515000 516000 517000 518000 519000 520000 521000
Week 1982
GPS Time (TOW, GMT zone)
Num Sats GPS GLONASS BeiDou Galileo QZSS

20180105_201925 [Smoothed TC Combined] - Accelerometer Bias Plot



20180105_201925 [Smoothed TC Combined] - Gyro Drift Plot



Processing Summery Information

Project:
N:\Production\LiDAR_Projects\18001_TX_FL16_Addon\Flight_Raw\20180105_201925\GnssImu\201801 05_201925.cfg

Solution Type: Combined

Number of Epochs:

Total in GPB file:	32745
No processed position:	134
Missing Fwd or Rev:	2
With bad C/A code:	0
With bad L1 Phase:	0

Measurement RMS Values:

L1 Phase:	0.0144	(m)
C/A Code:	0.42	(m)
L1 Doppler:	0.027	(m/s)

Fwd/Rev Separation RMS Values:

East:	0.013	(m)
North:	0.005	(m)
Height:	0.014	(m)

Fwd/Rev Sep. RMS for dual FWD/REV fixes (32609 occurrences):

East:	0.013	(m)
North:	0.005	(m)
Height:	0.014	(m)

Quality Number Percentages:

Q 1:	97.6 %
Q 2:	2.0 %
Q 3:	0.3 %
Q 4:	0.0 %
Q 5:	0.0 %
Q 6:	0.0 %

Position Standard Deviation Percentages:

0.00 - 0.10 m:	100.0 %
0.10 - 0.30 m:	0.0 %
0.30 - 1.00 m:	0.0 %
1.00 - 5.00 m:	0.0 %
5.00 m + over:	0.0 %

Percentages of epochs with DD_DOP over 10.00:

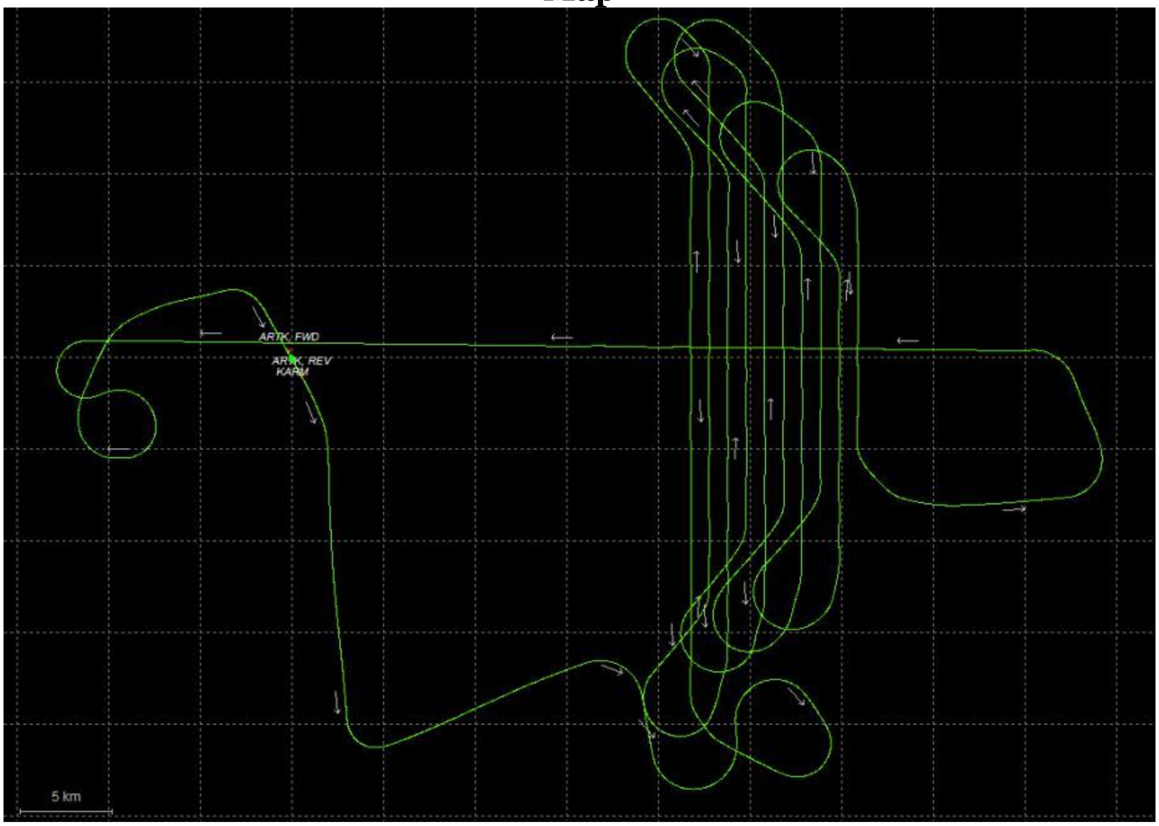
DOP over Tol: 4.0 %

Baseline Distances:

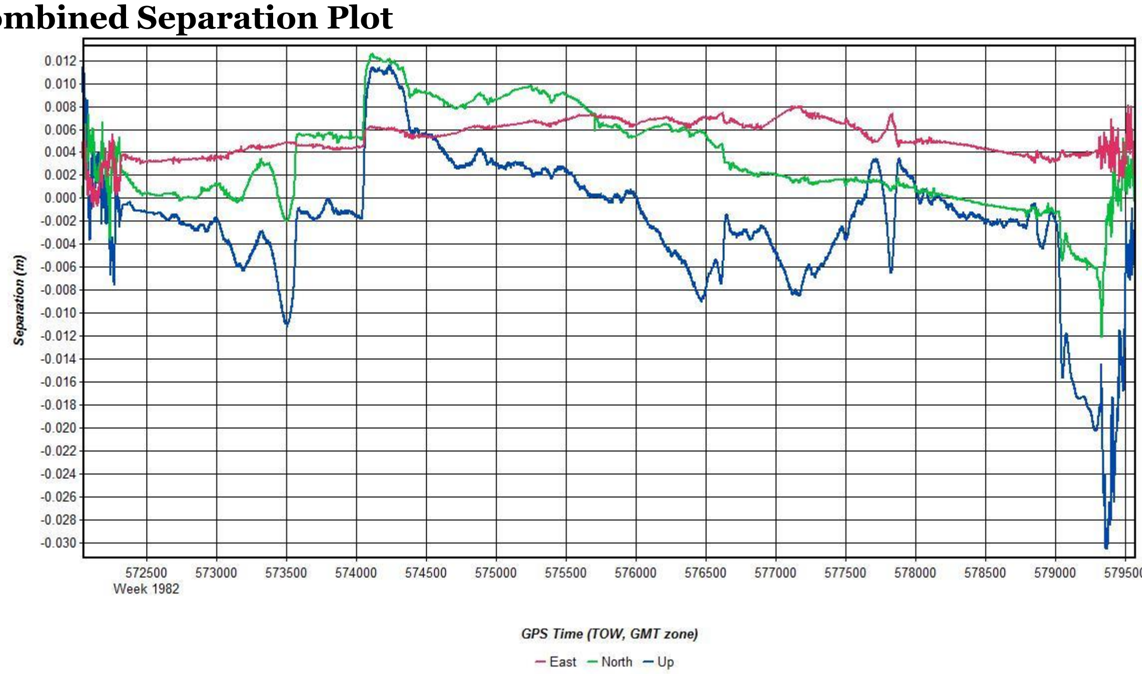
Maximum:	52.815	(km)
Minimum:	0.016	(km)
Average:	22.005	(km)
First Epoch:	0.022	(km)
Last Epoch:	0.029	(km)

Mission 01/05/2018 B

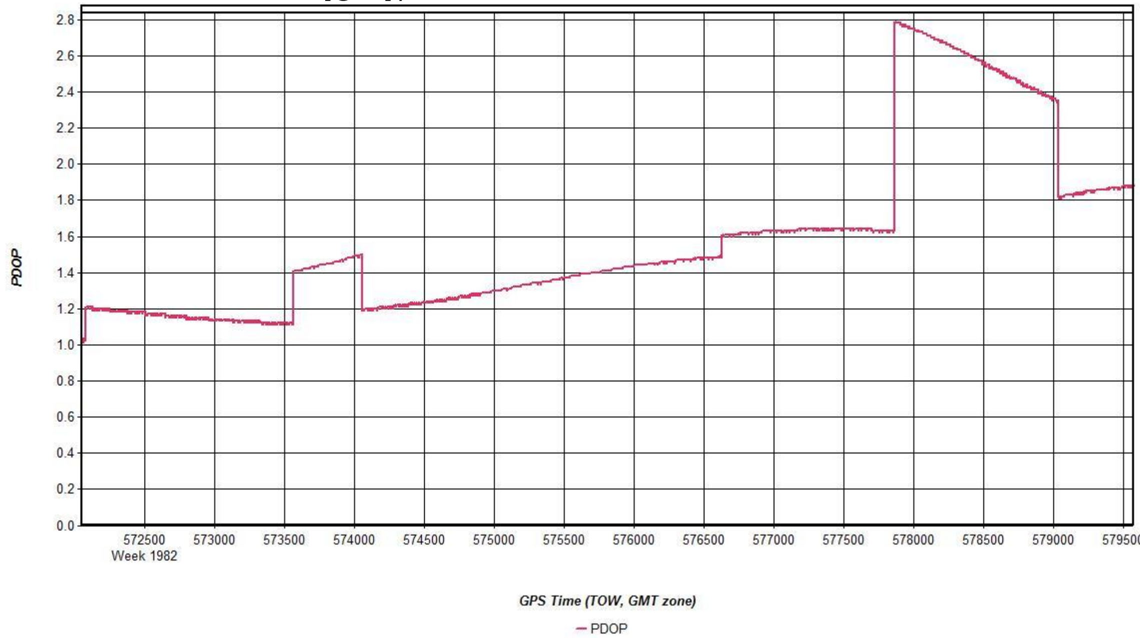
20180106_145247 [Smoothed TC Combined] - Smoothed TC Combined – Map



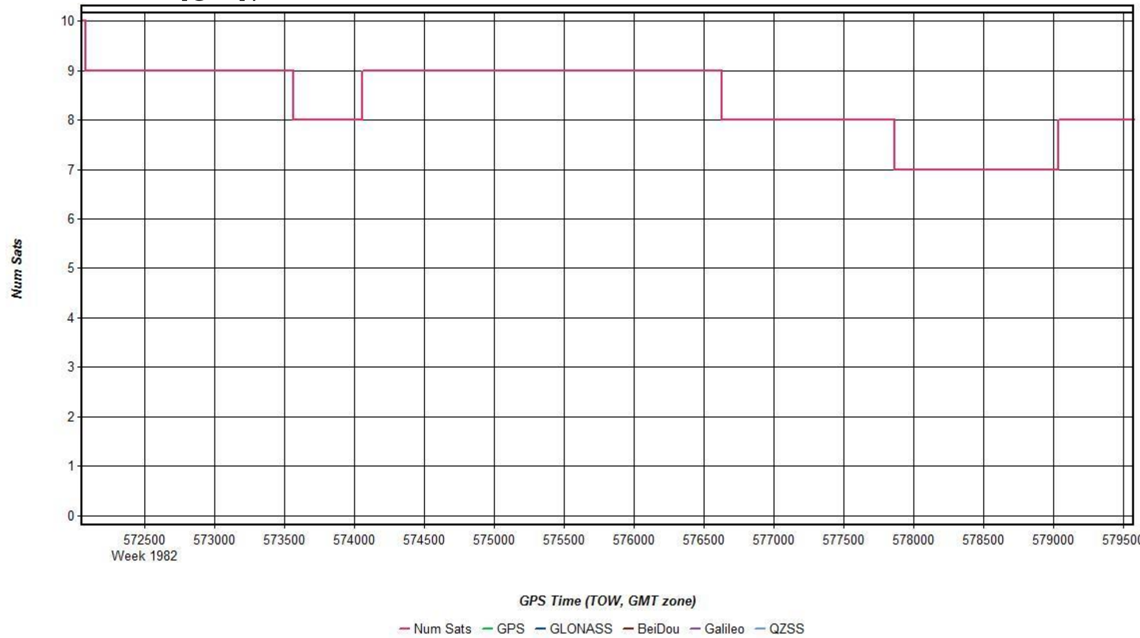
20180106_145247 [Smoothed TC Combined] - Forward/Reverse or Combined Separation Plot



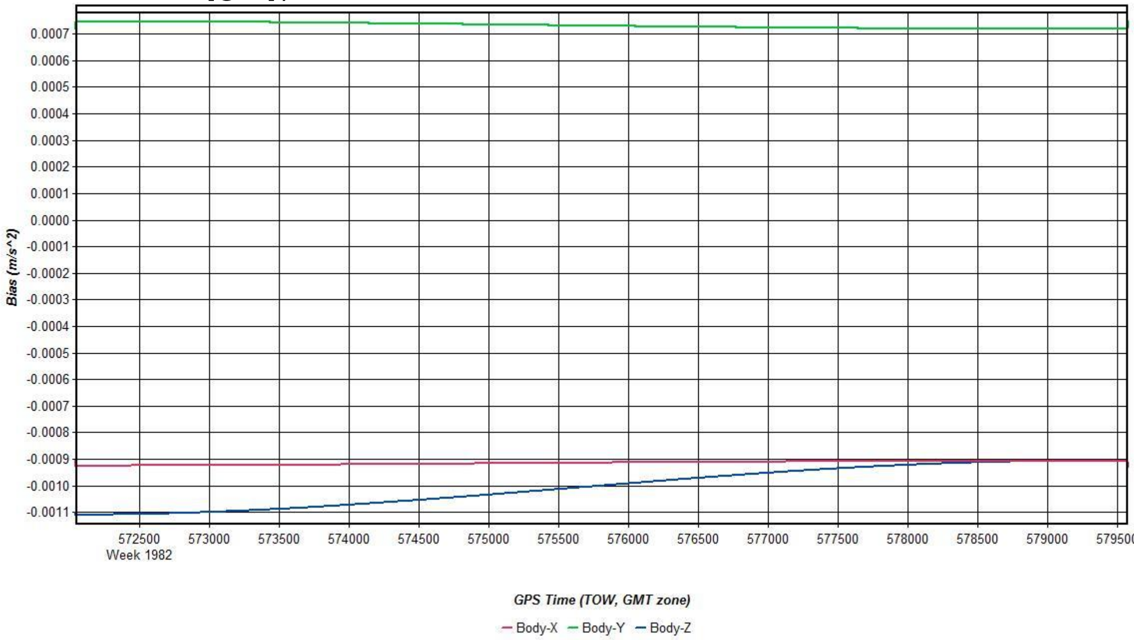
20180106_145247 [Smoothed TC Combined] - PDOP Plot



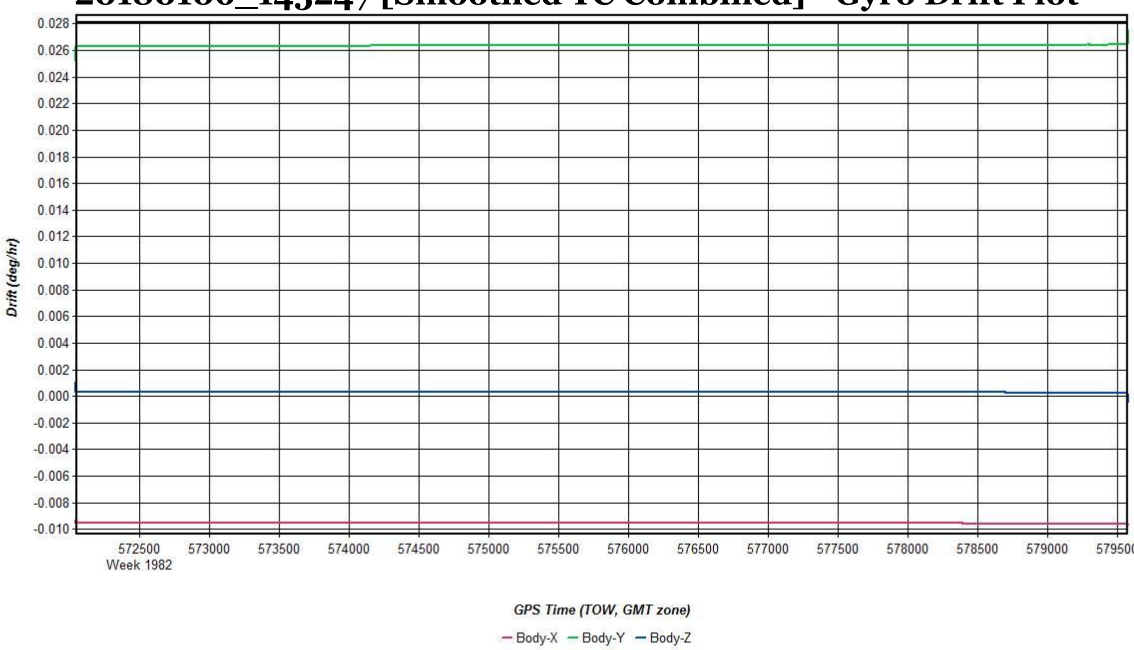
20180106_145247 [Smoothed TC Combined] - Number of Satellites Line Plot



20180106_145247 [Smoothed TC Combined] - Accelerometer Bias Plot



20180106_145247 [Smoothed TC Combined] - Gyro Drift Plot



Processing Summery Information

Project:

N:\Production\LiDAR_Projects\18001_TX_FL16_Addon\Flight_Raw\20180106_145247\GnssImu\201801 06_145247.cfg

Solution Type: Combined

Number of Epochs:

Total in GPB file:	15073
No processed position:	2
Missing Fwd or Rev:	2
With bad C/A code:	0
With bad L1 Phase:	0

Measurement RMS Values:

L1 Phase:	0.0136	(m)
C/A Code:	0.37	(m)
L1 Doppler:	0.026	(m/s)

Fwd/Rev Separation RMS Values:

East:	0.005	(m)
North:	0.005	(m)
Height:	0.006	(m)

Fwd/Rev Sep. RMS for dual FWD/REV fixes (15069 occurances):

East:	0.005	(m)
North:	0.005	(m)
Height:	0.006	(m)

Quality Number Percentages:

Q 1:	100.0 %
Q 2:	0.0 %
Q 3:	0.0 %
Q 4:	0.0 %
Q 5:	0.0 %
Q 6:	0.0 %

Position Standard Deviation Percentages:

0.00 - 0.10 m:	100.0 %
0.10 - 0.30 m:	0.0 %
0.30 - 1.00 m:	0.0 %
1.00 - 5.00 m:	0.0 %
5.00 m + over:	0.0 %

Percentages of epochs with DD_DOP over 10.00:

DOP over Tol: 0.0 %

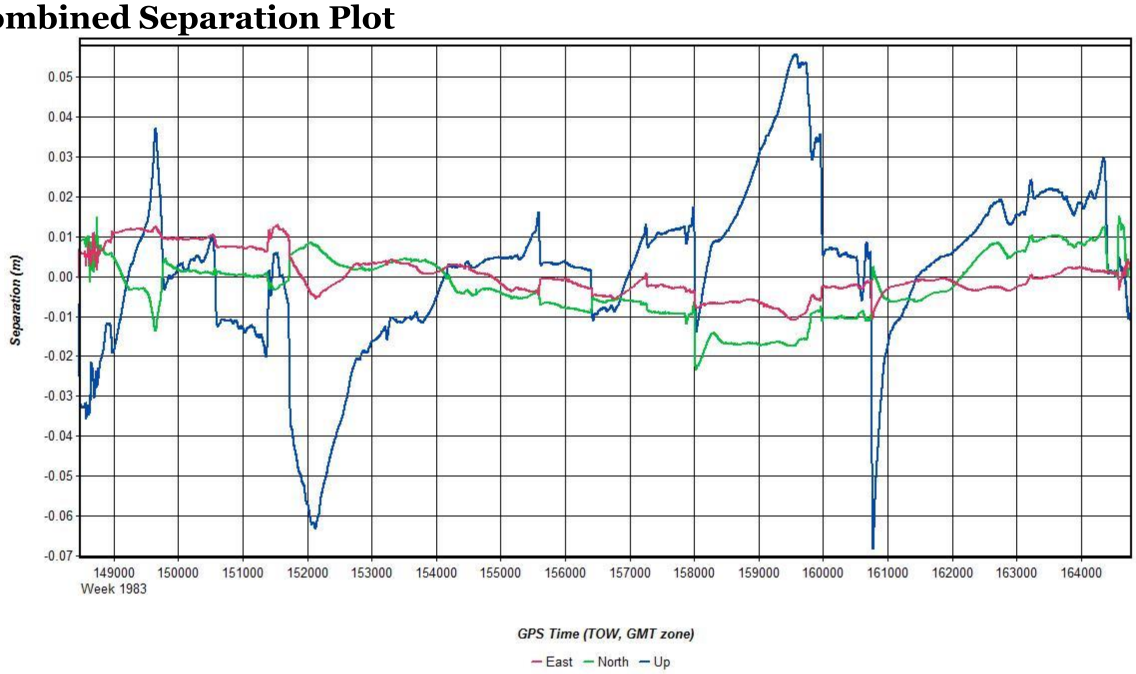
Baseline Distances:

Maximum:	44.539	(km)
Minimum:	0.086	(km)
Average:	22.617	(km)
First Epoch:	0.354	(km)
Last Epoch:	1.122	(km)

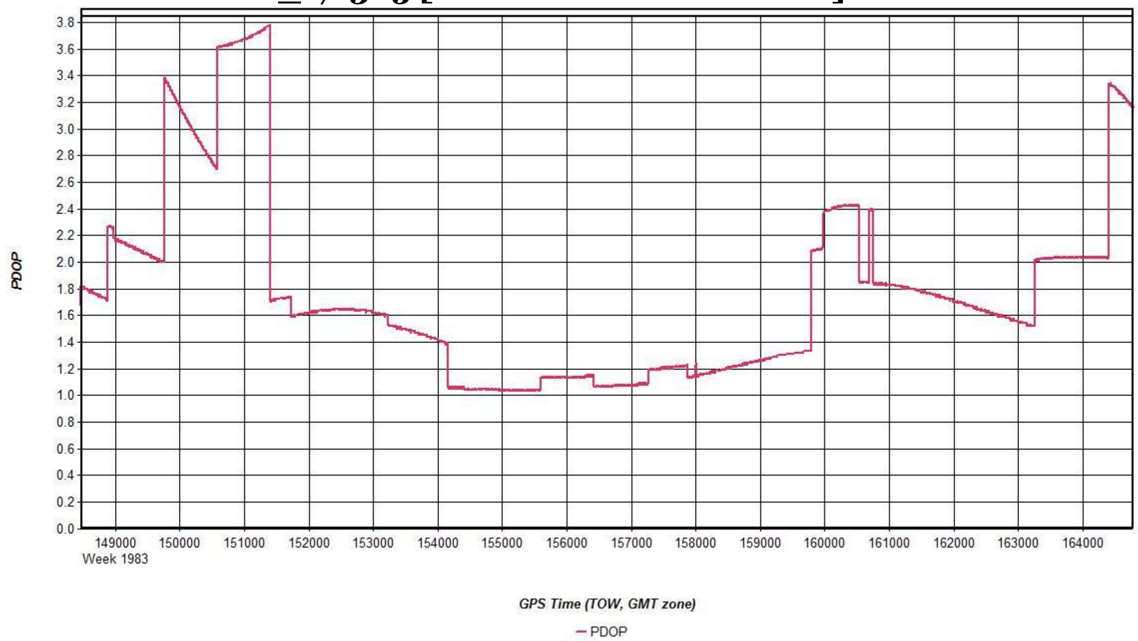
Mission 01/06/2018 A

20180108_171305 [Smoothed TC Combined] - Smoothed TC Combined – Map

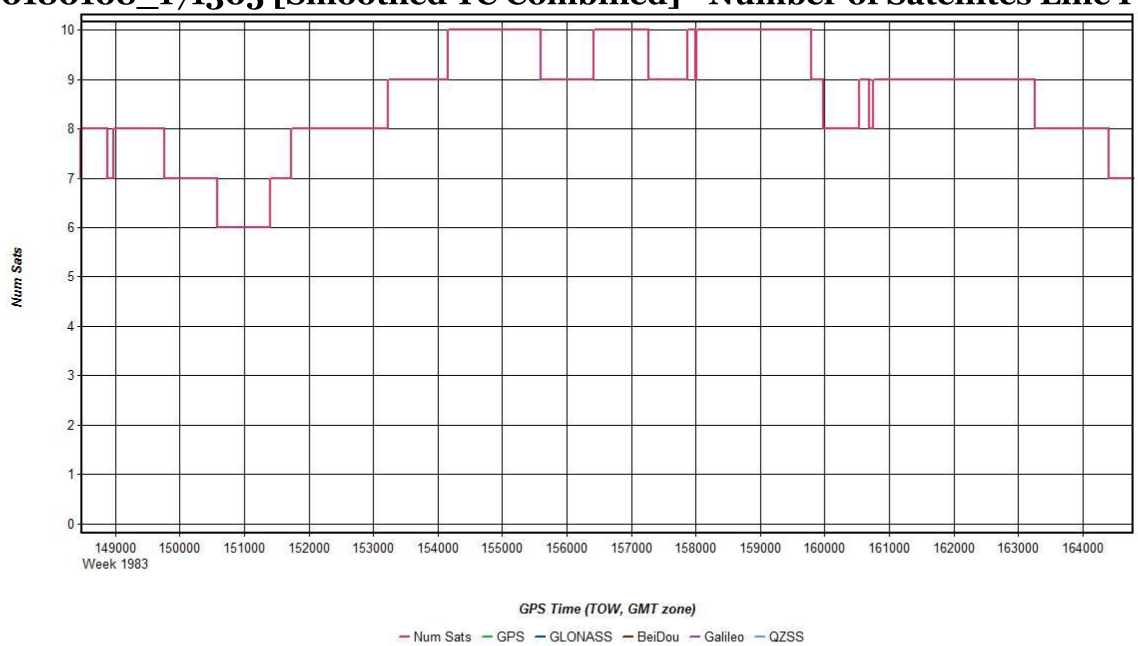
20180108_171305 [Smoothed TC Combined] - Forward/Reverse or Combined Separation Plot



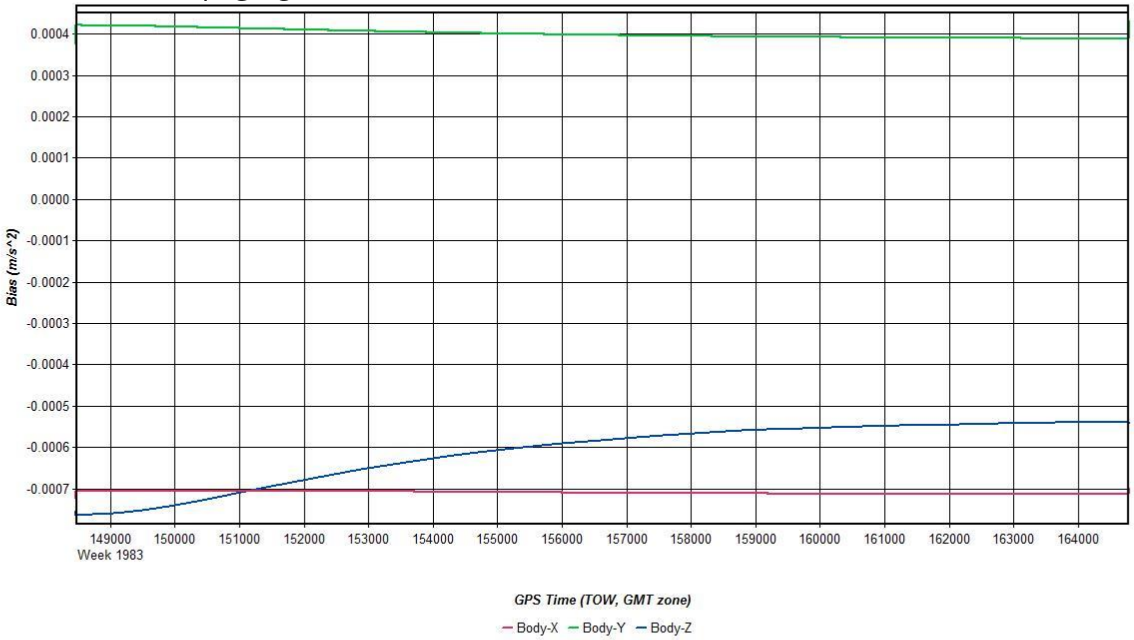
20180108_171305 [Smoothed TC Combined] - PDOP Plot



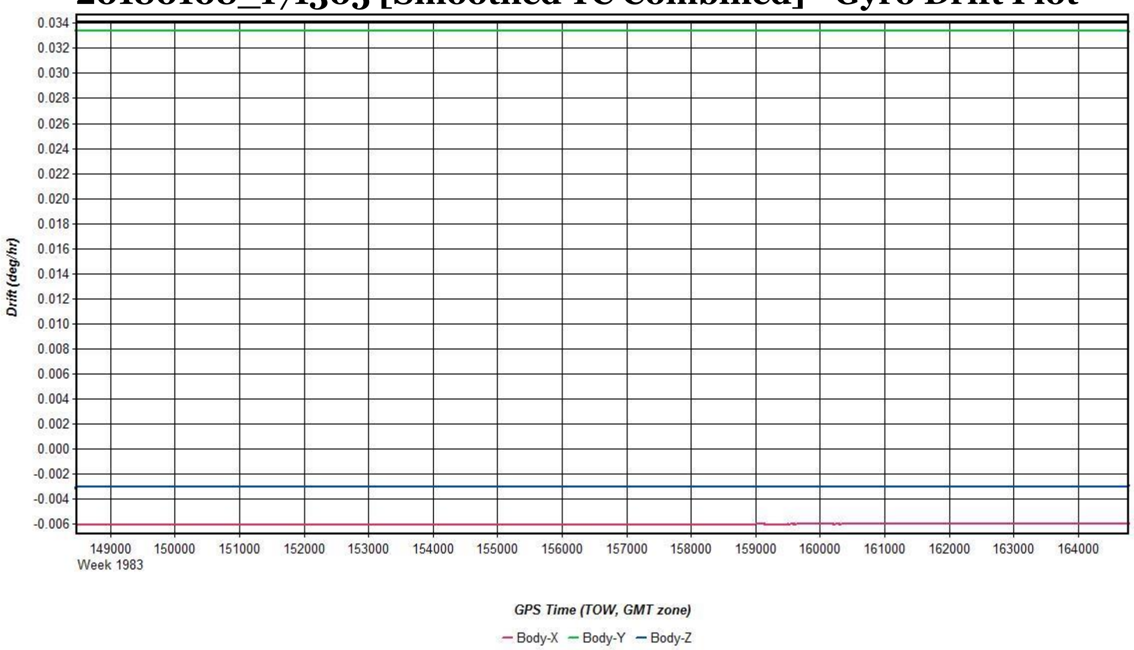
20180108_171305 [Smoothed TC Combined] - Number of Satellites Line Plot



20180108_171305 [Smoothed TC Combined] - Accelerometer Bias Plot



20180108_171305 [Smoothed TC Combined] - Gyro Drift Plot



Processing Summery Information

Project:

N:\Production\LiDAR_Projects\18001_TX_FL16_Addon\Flight_Raw\20180108_171305\GnssImu\201801 08_171305.cfg

Solution Type: Combined

Number of Epochs:

Total in GPB file:	32664
No processed position:	3
Missing Fwd or Rev:	2
With bad C/A code:	0
With bad L1 Phase:	0

Measurement RMS Values:

L1 Phase:	0.0167	(m)
C/A Code:	0.37	(m)
L1 Doppler:	0.029	(m/s)

Fwd/Rev Separation RMS Values:

East:	0.005	(m)
North:	0.008	(m)
Height:	0.020	(m)

Fwd/Rev Sep. RMS for dual FWD/REV fixes (32658 occurances):

East:	0.005	(m)
North:	0.008	(m)
Height:	0.020	(m)

Quality Number Percentages:

Q 1:	100.0 %
Q 2:	0.0 %
Q 3:	0.0 %
Q 4:	0.0 %
Q 5:	0.0 %
Q 6:	0.0 %

Position Standard Deviation Percentages:

0.00 - 0.10 m:	100.0 %
0.10 - 0.30 m:	0.0 %
0.30 - 1.00 m:	0.0 %
1.00 - 5.00 m:	0.0 %
5.00 m + over:	0.0 %

Percentages of epochs with DD_DOP over 10.00:

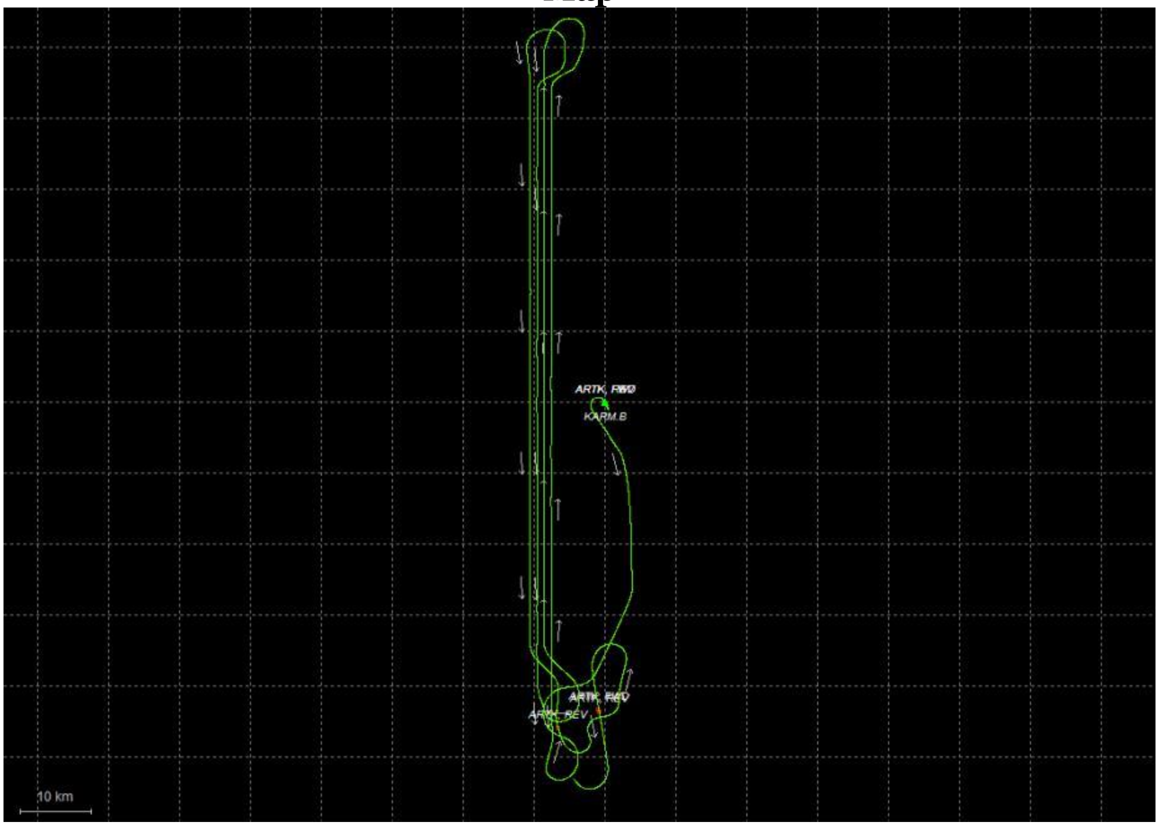
DOP over Tol: 0.0 %

Baseline Distances:

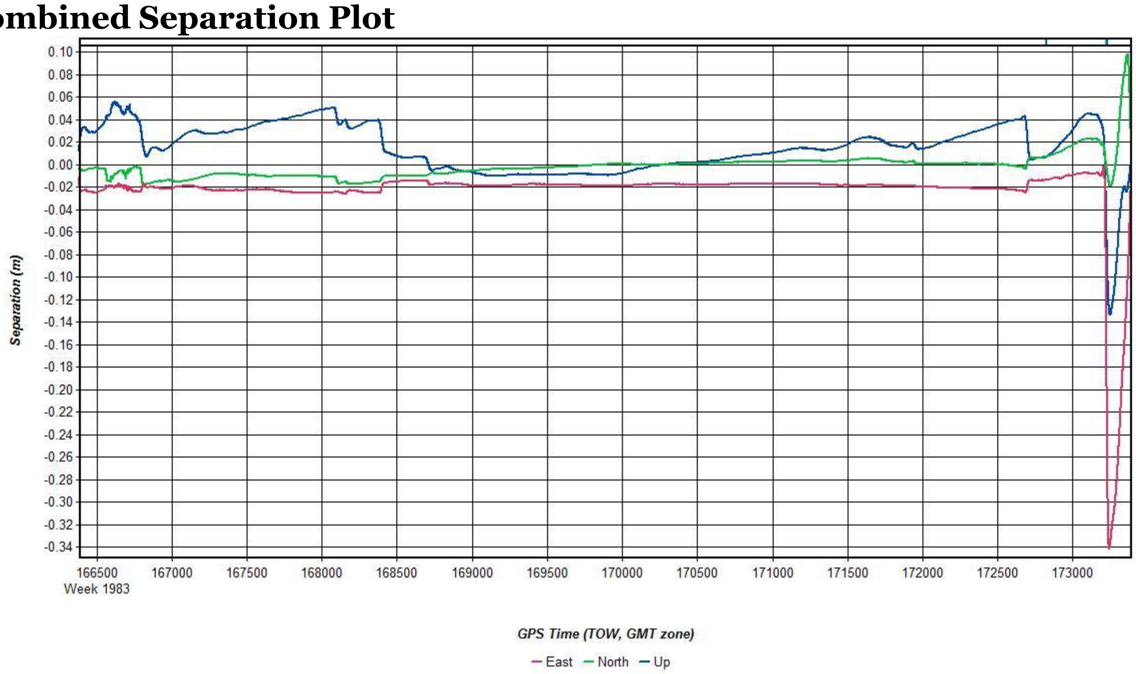
Maximum:	52.962	(km)
Minimum:	0.053	(km)
Average:	23.070	(km)
First Epoch:	0.333	(km)
Last Epoch:	0.053	(km)

Mission 01/08/2018 A

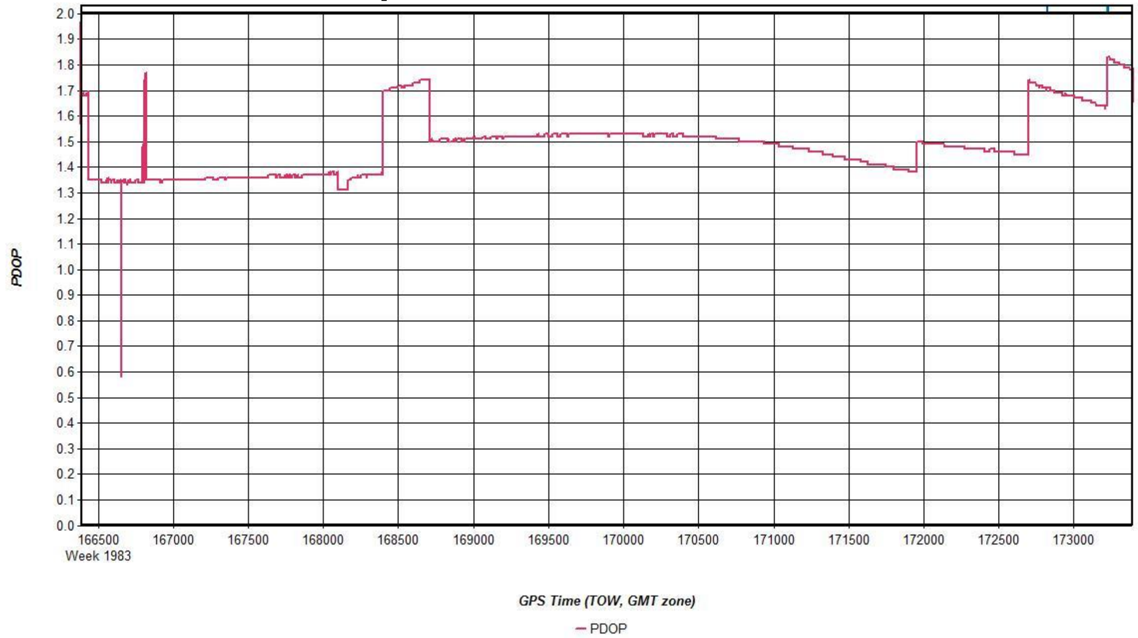
20180108_221148 [Smoothed TC Combined] - Smoothed TC Combined – Map



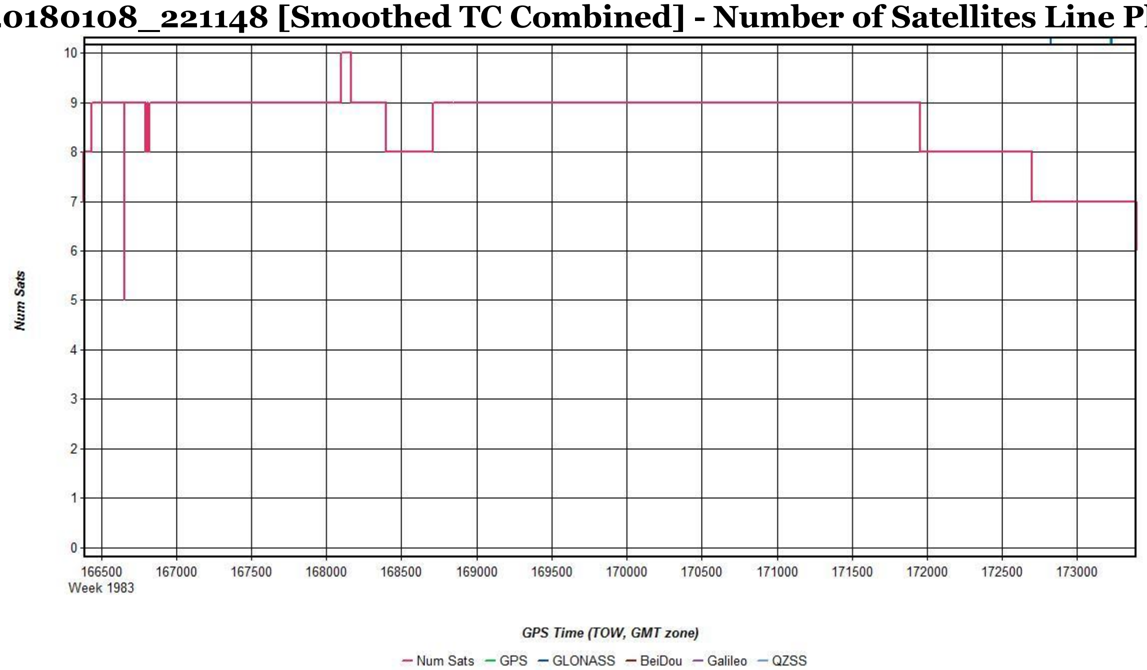
20180108_221148 [Smoothed TC Combined] - Forward/Reverse or Combined Separation Plot



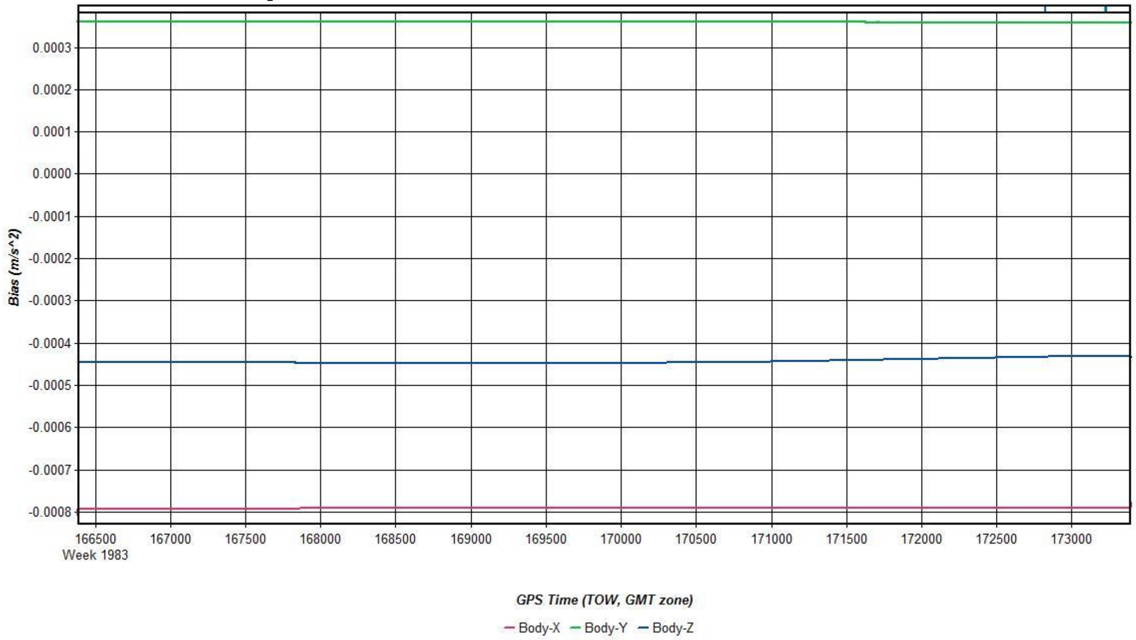
20180108_221148 [Smoothed TC Combined] - PDOP Plot



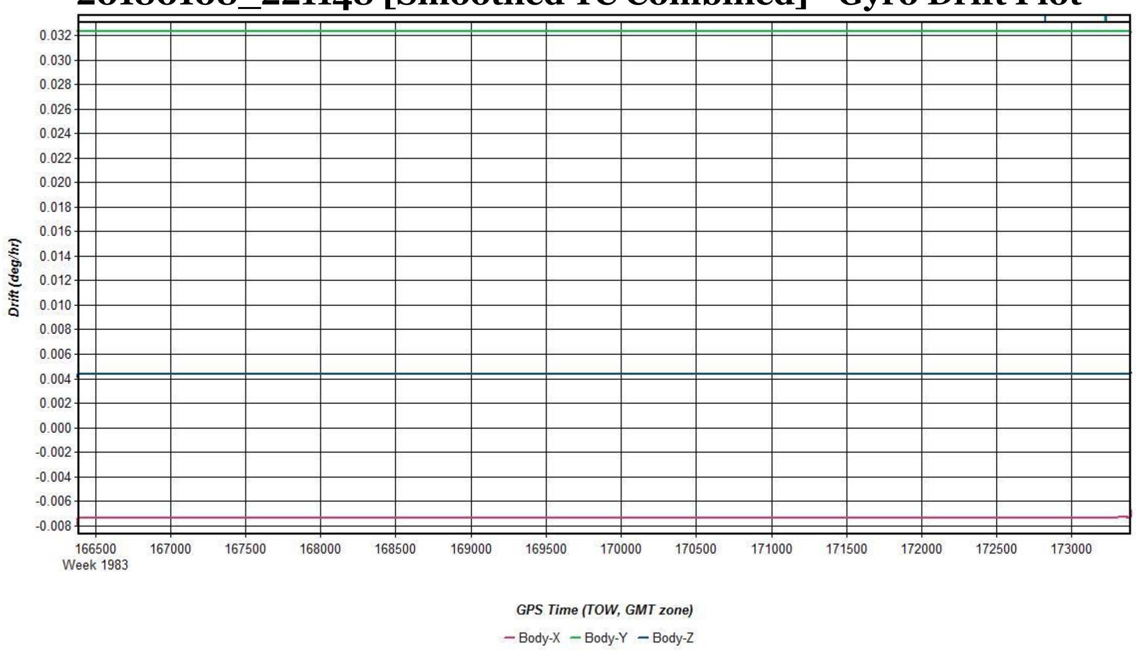
20180108_221148 [Smoothed TC Combined] - Number of Satellites Line Plot



20180108_221148 [Smoothed TC Combined] - Accelerometer Bias Plot



20180108_221148 [Smoothed TC Combined] - Gyro Drift Plot



Processing Summery Information

Project:

N:\Production\LiDAR_Projects\18001_TX_FL16_Addon\Flight_Raw\20180108_221148\GnssImu\201801 08_221148.cfg

Solution Type: Combined

Number of Epochs:

Total in GPB file:	14029
No processed position:	2
Missing Fwd or Rev:	19
With bad C/A code:	0
With bad L1 Phase:	0

Measurement RMS Values:

L1 Phase:	0.0178	(m)
C/A Code:	0.33	(m)
L1 Doppler:	0.029	(m/s)

Fwd/Rev Separation RMS Values:

East:	0.042	(m)
North:	0.011	(m)
Height:	0.027	(m)

Fwd/Rev Sep. RMS for dual FWD/REV fixes
(13687 occurances):

East:	0.020	(m)
North:	0.008	(m)
Height:	0.025	(m)

Quality Number Percentages:

Q 1:	100.0 %
Q 2:	0.0 %
Q 3:	0.0 %
Q 4:	0.0 %
Q 5:	0.0 %
Q 6:	0.0 %

Position Standard Deviation Percentages:

0.00 - 0.10 m:	100.0 %
0.10 - 0.30 m:	0.0 %
0.30 - 1.00 m:	0.0 %
1.00 - 5.00 m:	0.0 %
5.00 m + over:	0.0 %

Percentages of epochs with DD_DOP over 10.00:

DOP over Tol: 0.0 %

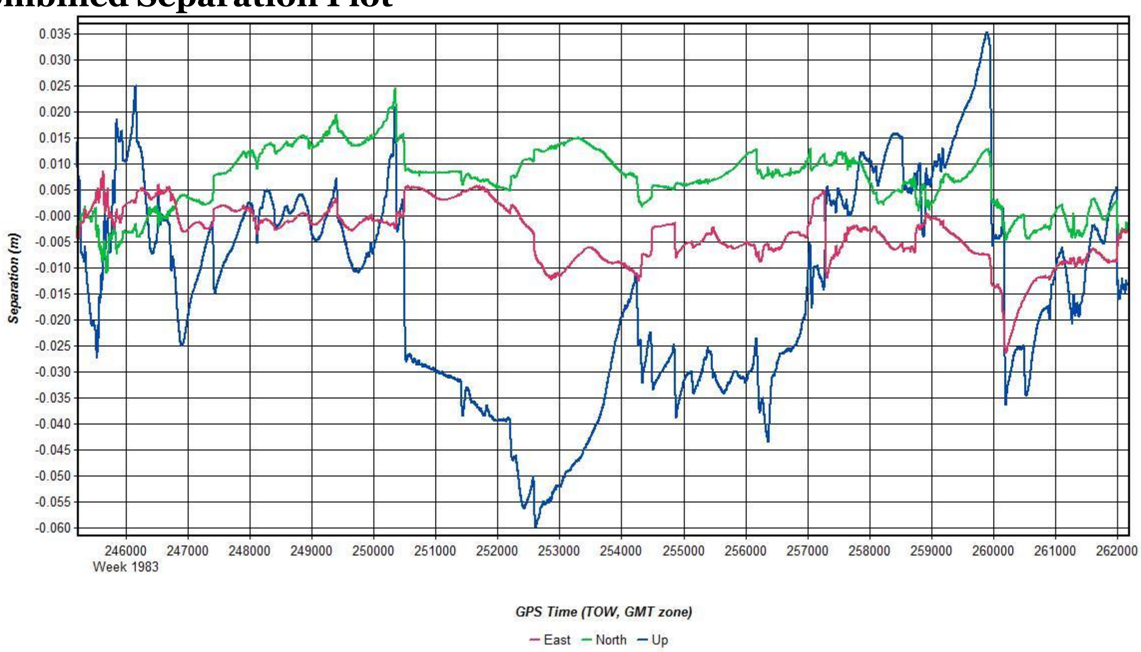
Baseline Distances:

Maximum:	53.892	(km)
Minimum:	0.089	(km)
Average:	27.467	(km)
First Epoch:	0.133	(km)
Last Epoch:	52.574	(km)

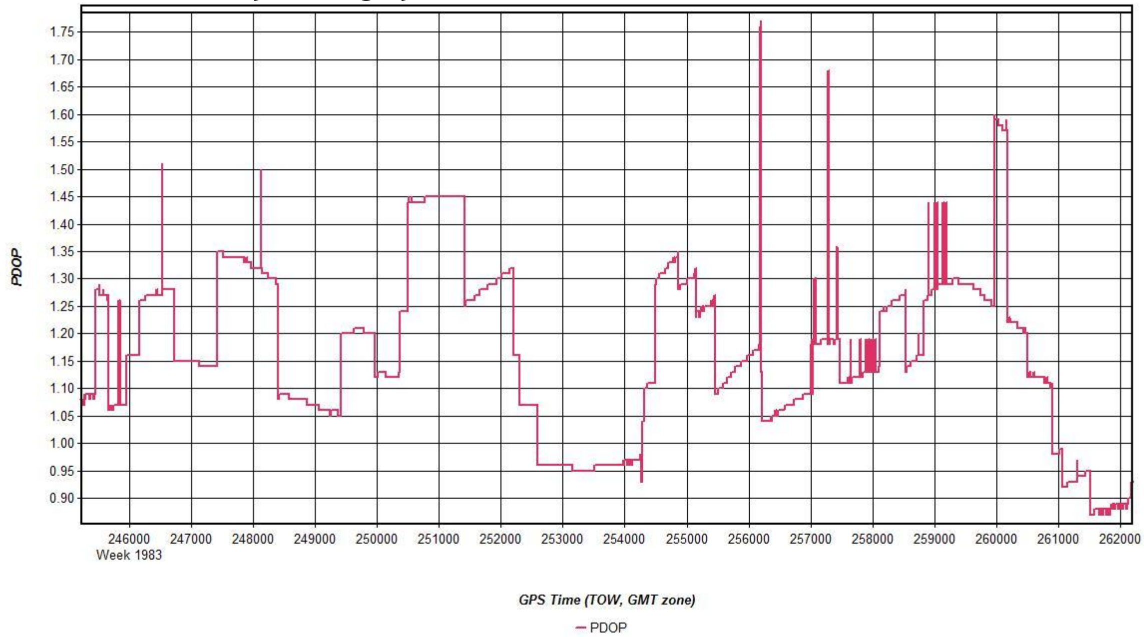
Mission 01/09/2018 A

20180109_200529 [Smoothed TC Combined] - Smoothed TC Combined – Map

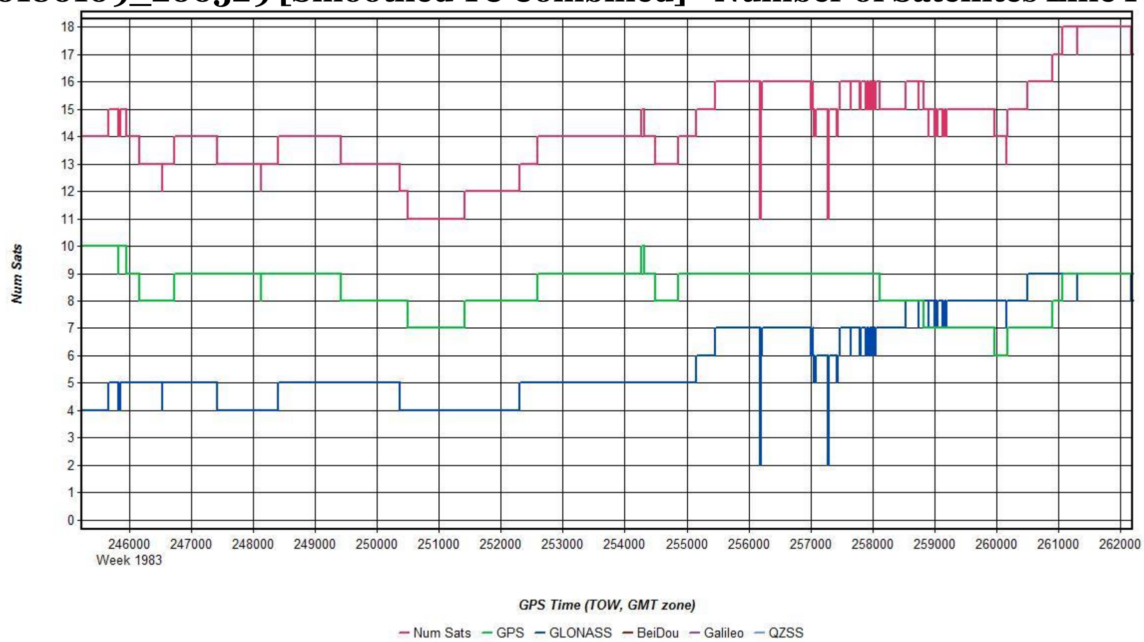
20180109_200529 [Smoothed TC Combined] - Forward/Reverse or Combined Separation Plot



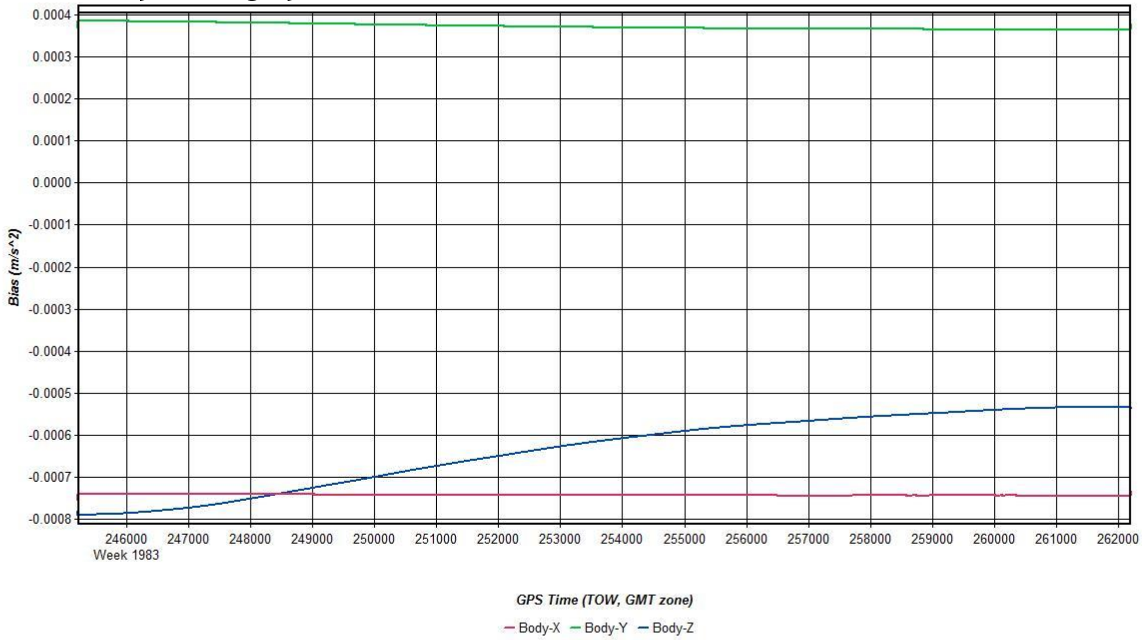
20180109_200529 [Smoothed TC Combined] - PDOP Plot



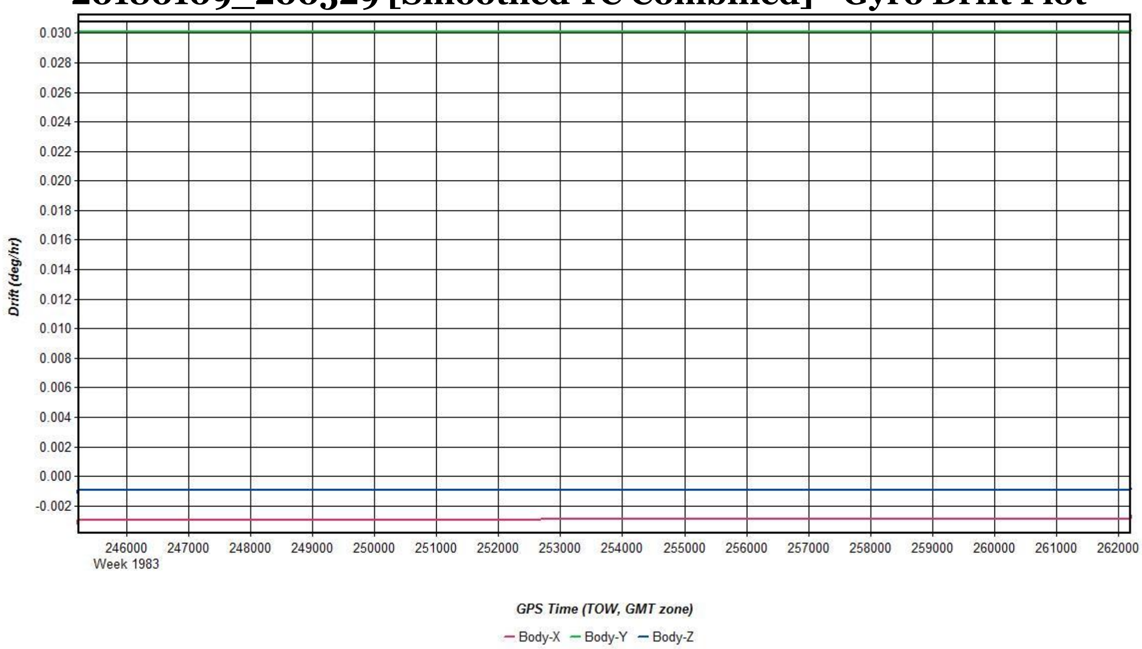
20180109_200529 [Smoothed TC Combined] - Number of Satellites Line Plot



20180109_200529 [Smoothed TC Combined] - Accelerometer Bias Plot



20180109_200529 [Smoothed TC Combined] - Gyro Drift Plot



Processing Summary Information

Project:

N:\Production\LiDAR_Projects\18001_TX_FL16_Addon\Flight_Raw\20180109_200529\GnssImu\201801 09_200529.cfg

Solution Type: Combined

Number of Epochs:

Total in GPB file:	34008
No processed position:	3
Missing Fwd or Rev:	2
With bad C/A code:	0
With bad L1 Phase:	0

Measurement RMS Values:

L1 Phase:	0.017 0	(m)
C/A Code:	0.39	(m)
L1 Doppler:	0.030	(m/s)

Fwd/Rev Separation RMS Values:

East:	0.006	(m)
North:	0.009	(m)
Height:	0.024	(m)

Fwd/Rev Sep. RMS for dual FWD/REV fixes (34003 occurances):

East:	0.006	(m)
North:	0.009	(m)
Height:	0.024	(m)

Quality Number Percentages:

Q 1:	100.0 %
Q 2:	0.0 %
Q 3:	0.0 %
Q 4:	0.0 %
Q 5:	0.0 %
Q 6:	0.0 %

Position Standard Deviation Percentages:

0.00 - 0.10 m:	100.0 %
0.10 - 0.30 m:	0.0 %
0.30 - 1.00 m:	0.0 %
1.00 - 5.00 m:	0.0 %
5.00 m + over:	0.0 %

Percentages of epochs with DD_DOP over 10.00:

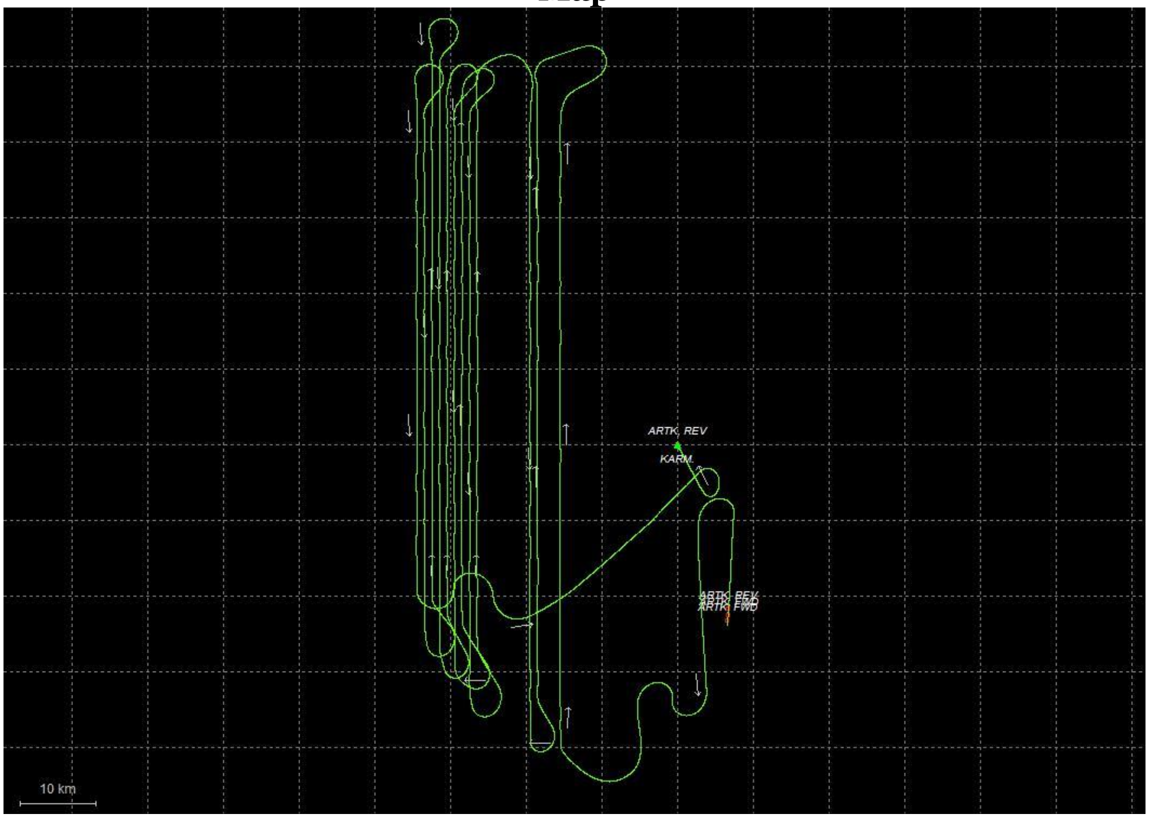
DOP over Tol: 0.0 %

Baseline Distances:

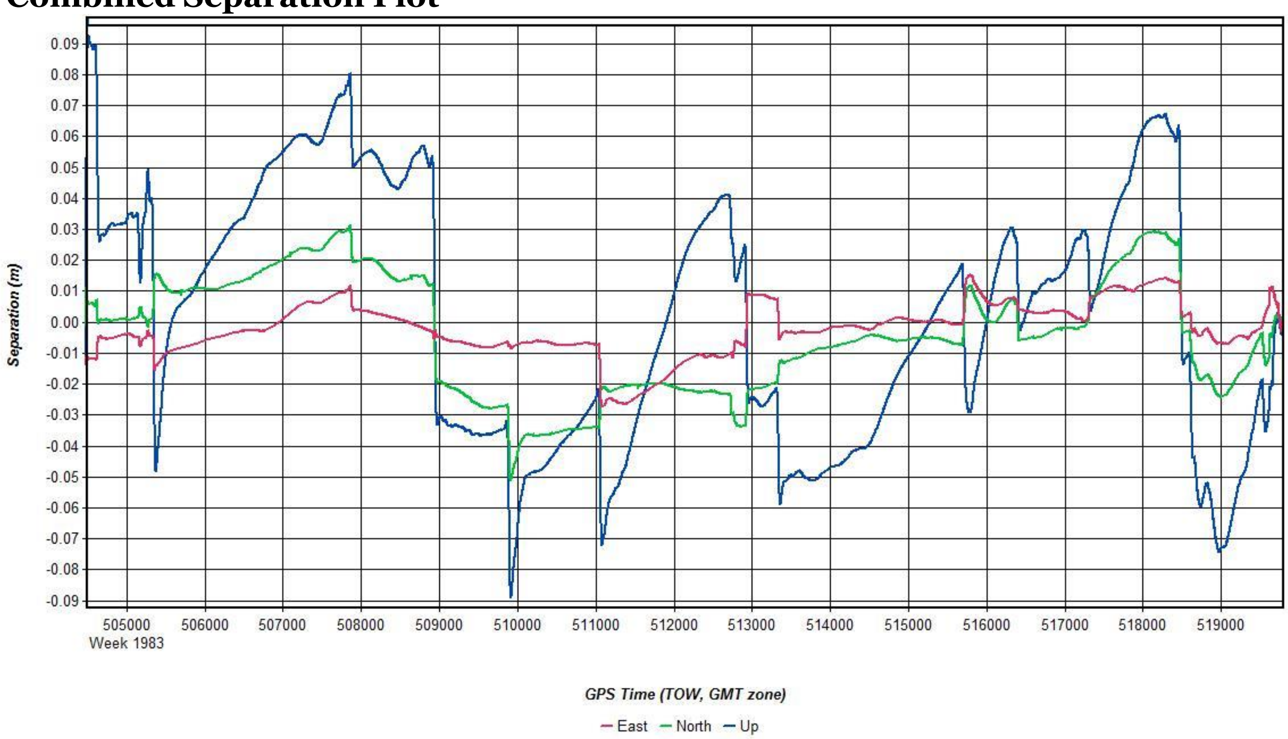
Maximum:	56.280	(km)
Minimum:	0.015	(km)
Average:	29.864	(km)
First Epoch:	0.018	(km)
Last Epoch:	0.350	(km)

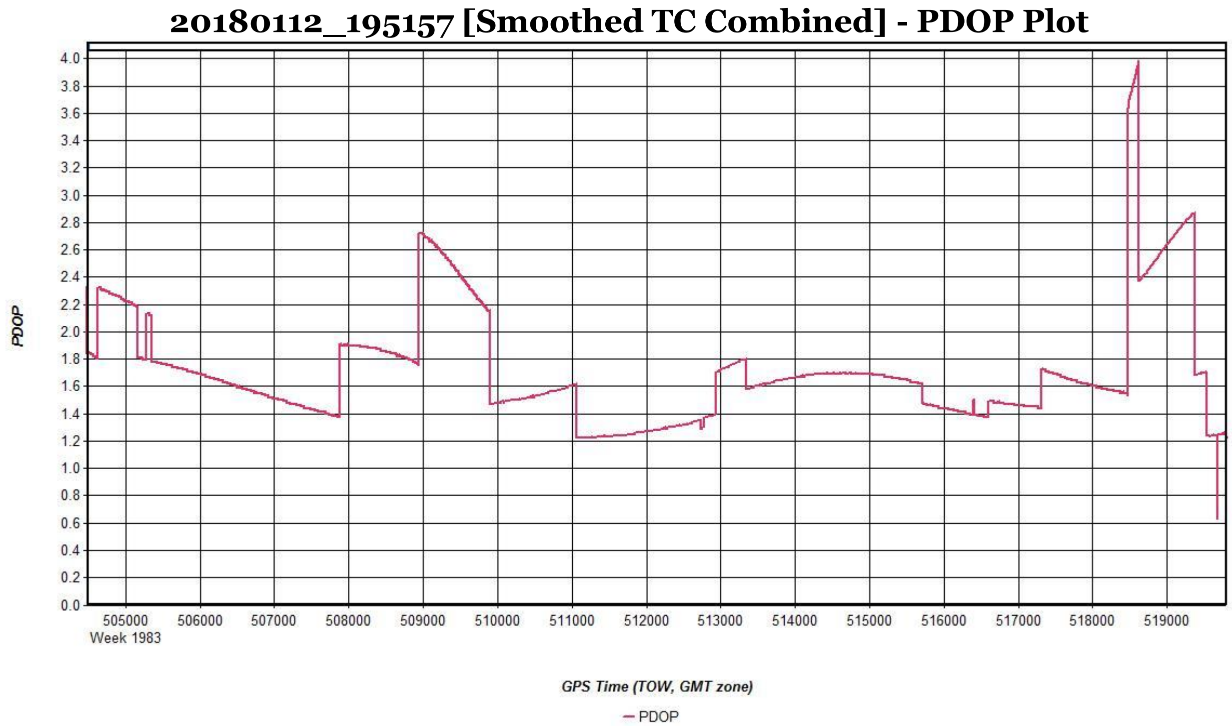
Mission 01/12/2018 A

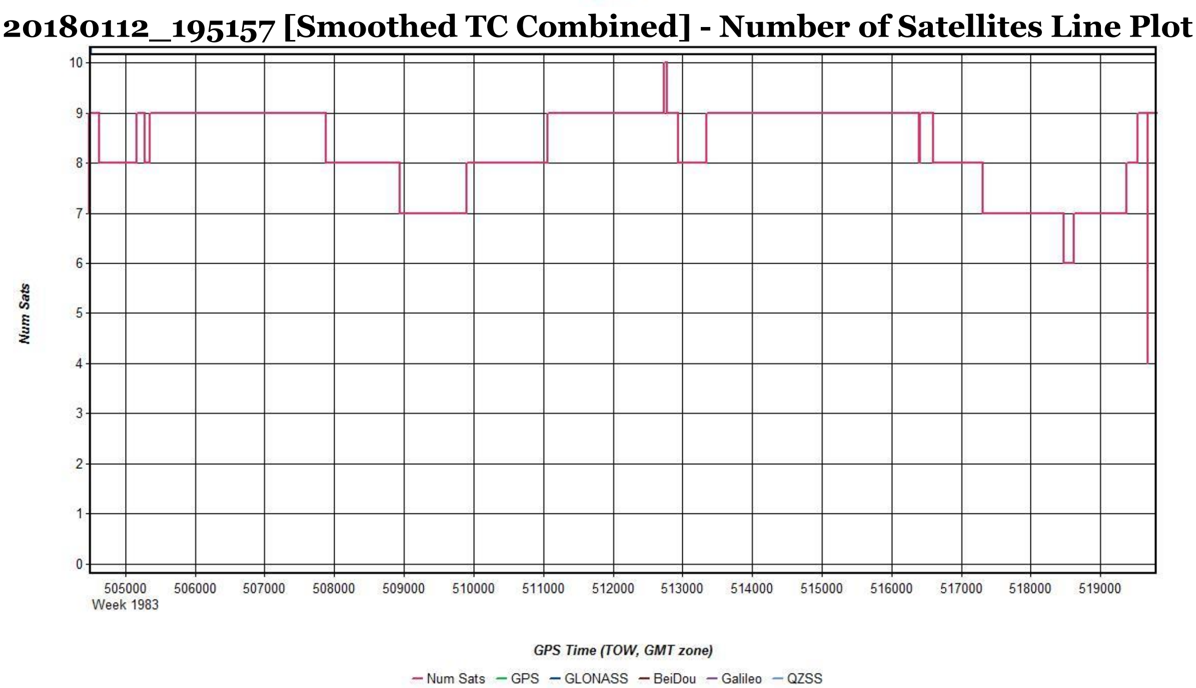
20180112_195157 [Smoothed TC Combined] - Smoothed TC Combined – Map



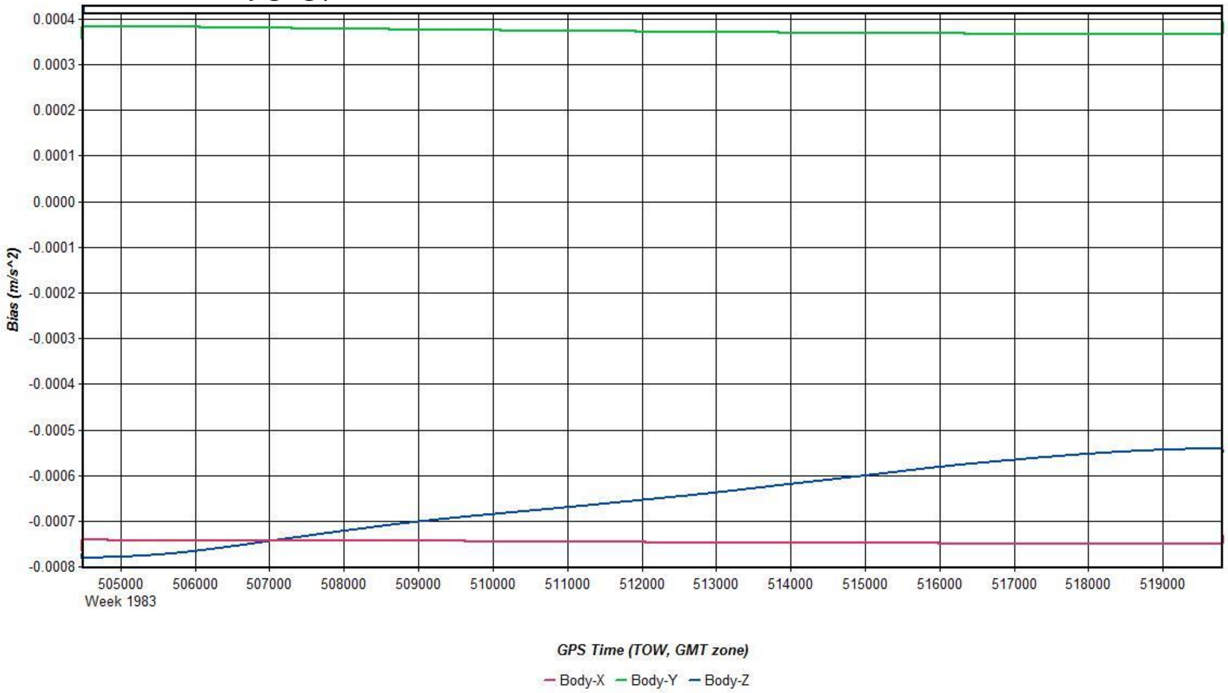
20180112_195157 [Smoothed TC Combined] - Forward/Reverse or Combined Separation Plot



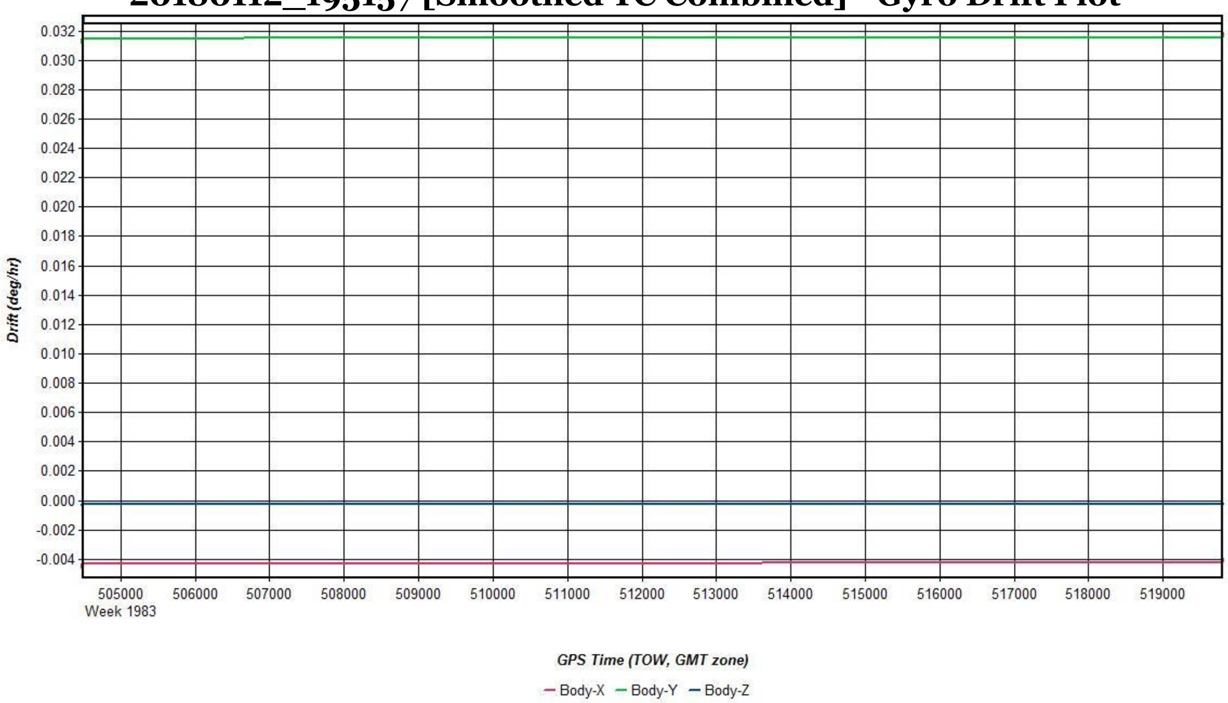

20180112_195157 [Smoothed TC Combined] - PDOP Plot
PDOP
4.0
3.8
3.6
3.4
3.2
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
505000
506000
507000
508000
509000
510000
511000
512000
513000
514000
515000
516000
517000
518000
519000
Week 1983
GPS Time (TOW, GMT zone)
PDOP


20180112_195157 [Smoothed TC Combined] - Number of Satellites Line Plot
Num Sats
10
9
8
7
6
5
4
3
2
1
0
505000
506000
507000
508000
509000
510000
511000
512000
513000
514000
515000
516000
517000
518000
519000
Week 1983
GPS Time (TOW, GMT zone)
Num Sats
GPS
GLONASS
BeiDou
Galileo
QZSS

20180112_195157 [Smoothed TC Combined] - Accelerometer Bias Plot



20180112_195157 [Smoothed TC Combined] - Gyro Drift Plot



Processing Summery Information

Project:

N:\Production\LiDAR_Projects\18001_TX_FL16_Addon\Flight_Raw\20180112_195157\Gnss Imu\201801 12_195157.cfg

Solution Type: Combined

Number of Epochs:

Total in GPB file:	30660
No processed position:	3
Missing Fwd or Rev:	2
With bad C/A code:	0
With bad L1 Phase:	0

Measurement RMS Values:

L1 Phase:	0.0213	(m)
C/A Code:	0.39	(m)
L1 Doppler:	0.029	(m/s)

Fwd/Rev Separation RMS Values:

East:	0.009	(m)
North:	0.019	(m)
Height:	0.041	(m)

Fwd/Rev Sep. RMS for dual FWD/REV fixes (30640 occurances):

East:	0.009	(m)
North:	0.019	(m)
Height:	0.041	(m)

Quality Number Percentages:

Q 1:	100.0 %
Q 2:	0.0 %
Q 3:	0.0 %
Q 4:	0.0 %
Q 5:	0.0 %
Q 6:	0.0 %

Position Standard Deviation Percentages:

0.00 - 0.10 m:	100.0 %
0.10 - 0.30 m:	0.0 %
0.30 - 1.00 m:	0.0 %
1.00 - 5.00 m:	0.0 %
5.00 m + over:	0.0 %

Percentages of epochs with DD_DOP over 10.00:

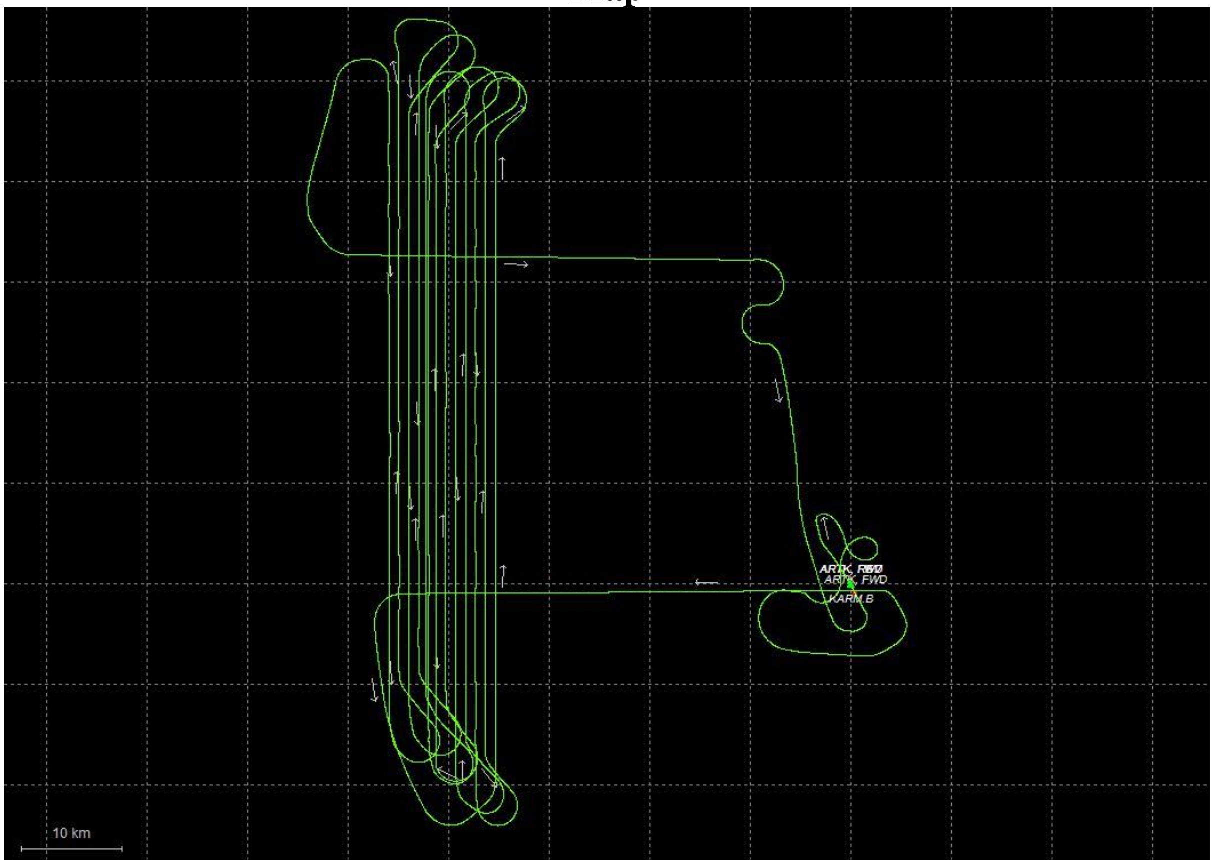
DOP over Tol: 0.0 %

Baseline Distances:

Maximum:	64.088 (km)
Minimum:	0.054 (km)
Average:	35.007 (km)
First Epoch:	24.598 (km)
Last Epoch:	0.054 (km)

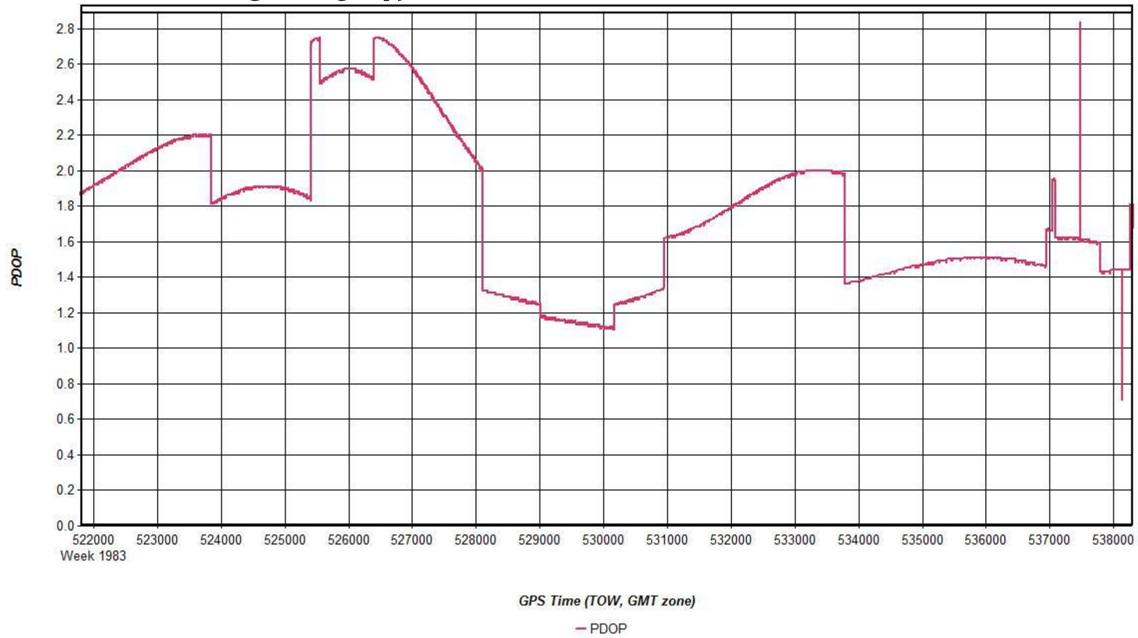
Mission 01/13/2018 A

20180113_005249 [Smoothed TC Combined] - Smoothed TC Combined – Map



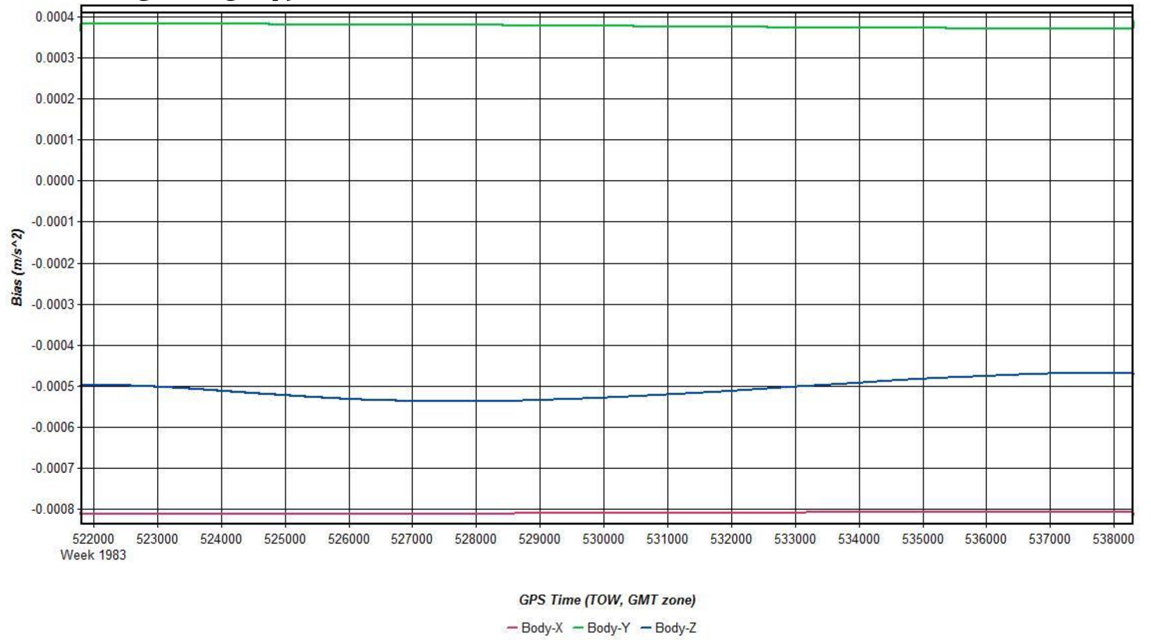
20180113_005249 [Smoothed TC Combined] - Forward/Reverse or Combined Separation Plot

20180113_005249 [Smoothed TC Combined] - PDOP Plot

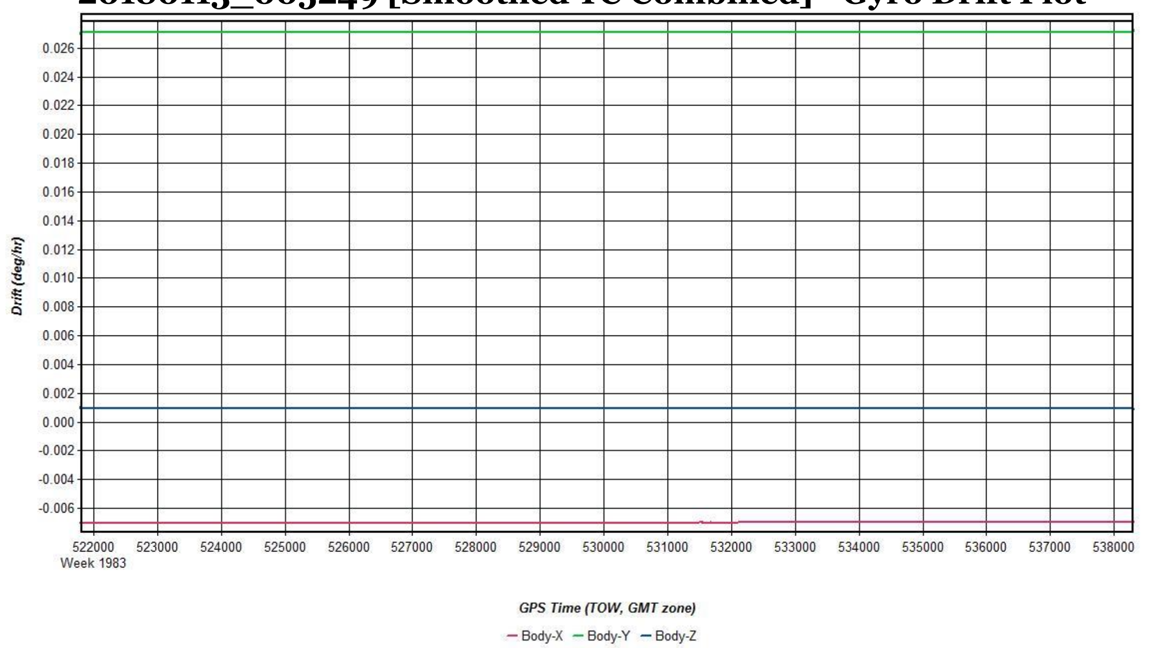


20180113_005249 [Smoothed TC Combined] - Number of Satellites Line Plot

20180113_005249 [Smoothed TC Combined] - Accelerometer Bias Plot



20180113_005249 [Smoothed TC Combined] - Gyro Drift Plot



Processing Summery Information

Project:

N:\Production\LiDAR_Projects\18001_TX_FL16_Addon\Flight_Raw\20180113_005249\GnssImu\201801 13_005249.cfg

Solution Type: Combined

Number of Epochs:

Total in GPB file:	33035
No processed position:	2
Missing Fwd or Rev:	2
With bad C/A code:	0
With bad L1 Phase:	0

Measurement RMS Values:

L1 Phase:	0.0180	(m)
C/A Code:	0.38	(m)
L1 Doppler:	0.029	(m/s)

Fwd/Rev Separation RMS Values:

East:	0.010	(m)
North:	0.008	(m)
Height:	0.026	(m)

Fwd/Rev Sep. RMS for dual FWD/REV fixes (33030 occurances):

East:	0.010	(m)
North:	0.008	(m)
Height:	0.026	(m)

Quality Number Percentages:

Q 1:	100.0 %
Q 2:	0.0 %
Q 3:	0.0 %
Q 4:	0.0 %
Q 5:	0.0 %
Q 6:	0.0 %

Position Standard Deviation Percentages:

0.00 - 0.10 m:	100.0 %
0.10 - 0.30 m:	0.0 %
0.30 - 1.00 m:	0.0 %
1.00 - 5.00 m:	0.0 %
5.00 m + over:	0.0 %

Percentages of epochs with DD_DOP over 10.00:

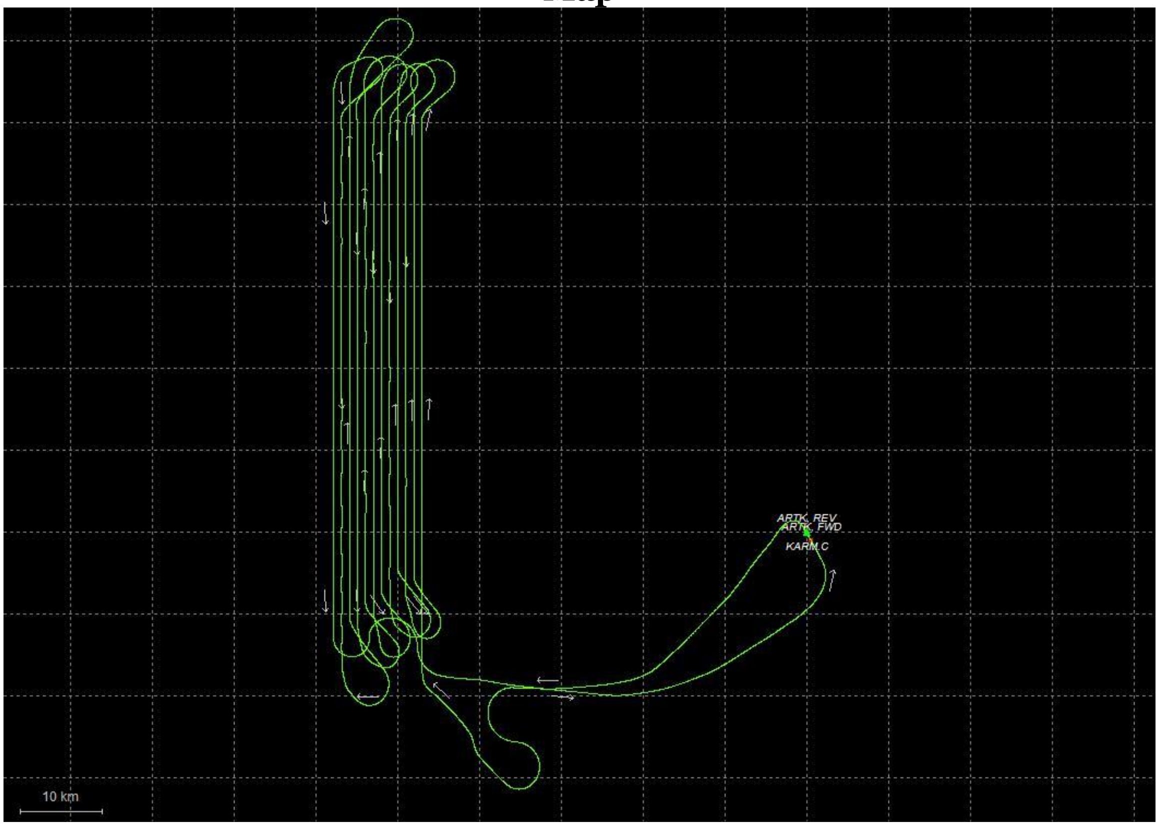
DOP over Tol: 0.0 %

Baseline Distances:

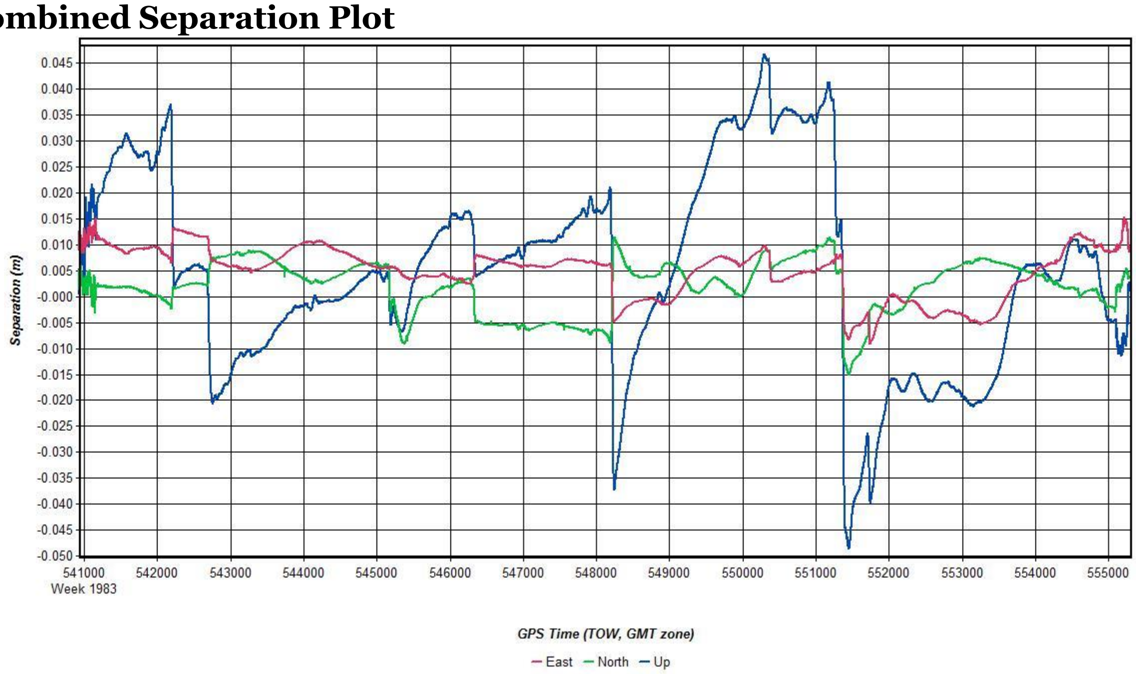
Maximum:	71.858	(km)
Minimum:	0.037	(km)
Average:	41.904	(km)
First Epoch:	1.142	(km)
Last Epoch:	0.037	(km)

Mission 01/13/2018 B

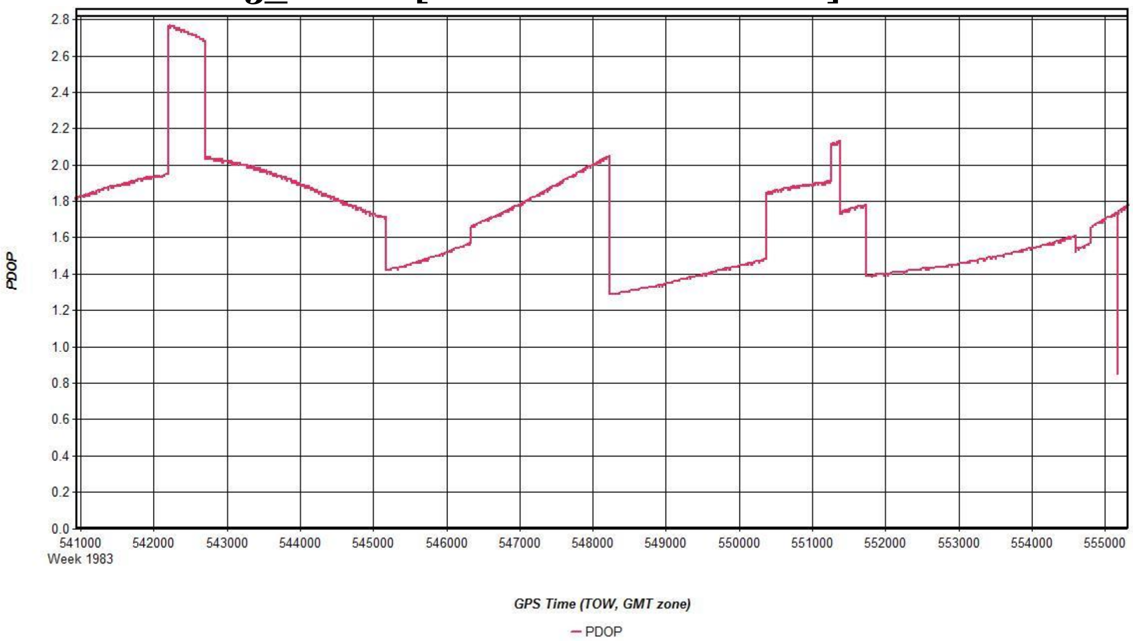
20180113_061100 [Smoothed TC Combined] - Smoothed TC Combined – Map



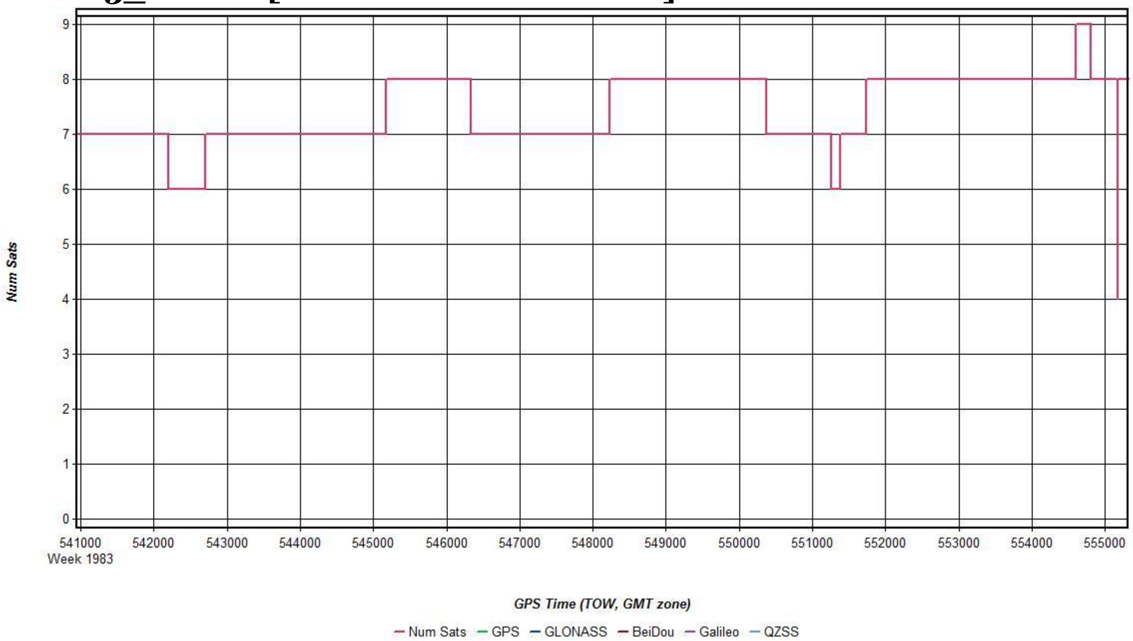
20180113_061100 [Smoothed TC Combined] - Forward/Reverse or Combined Separation Plot



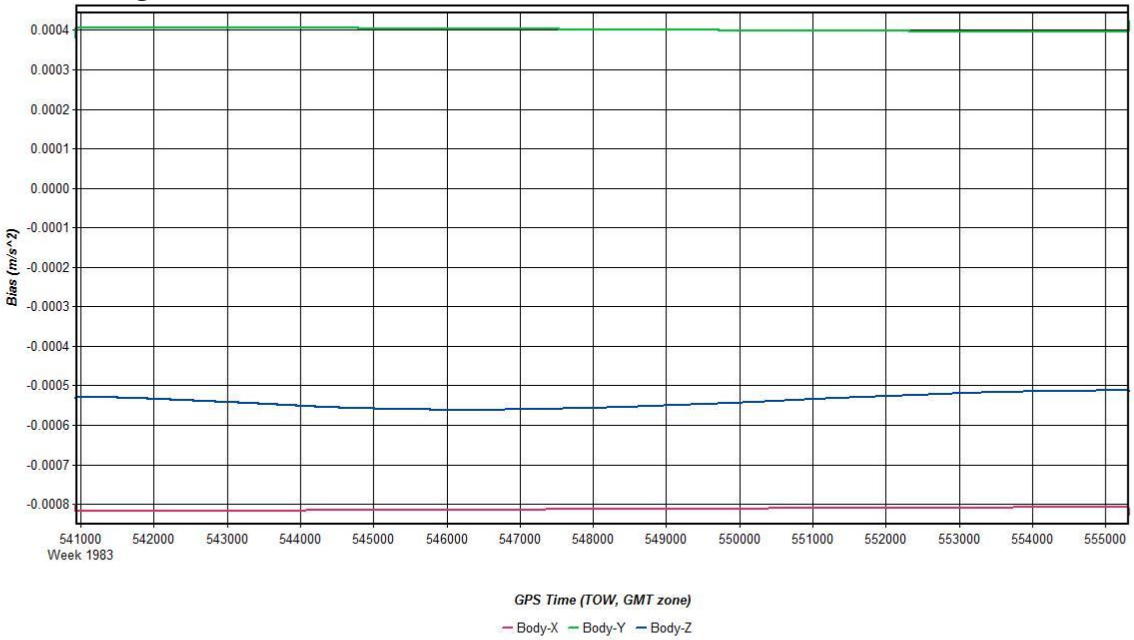
20180113_061100 [Smoothed TC Combined] - PDOP Plot



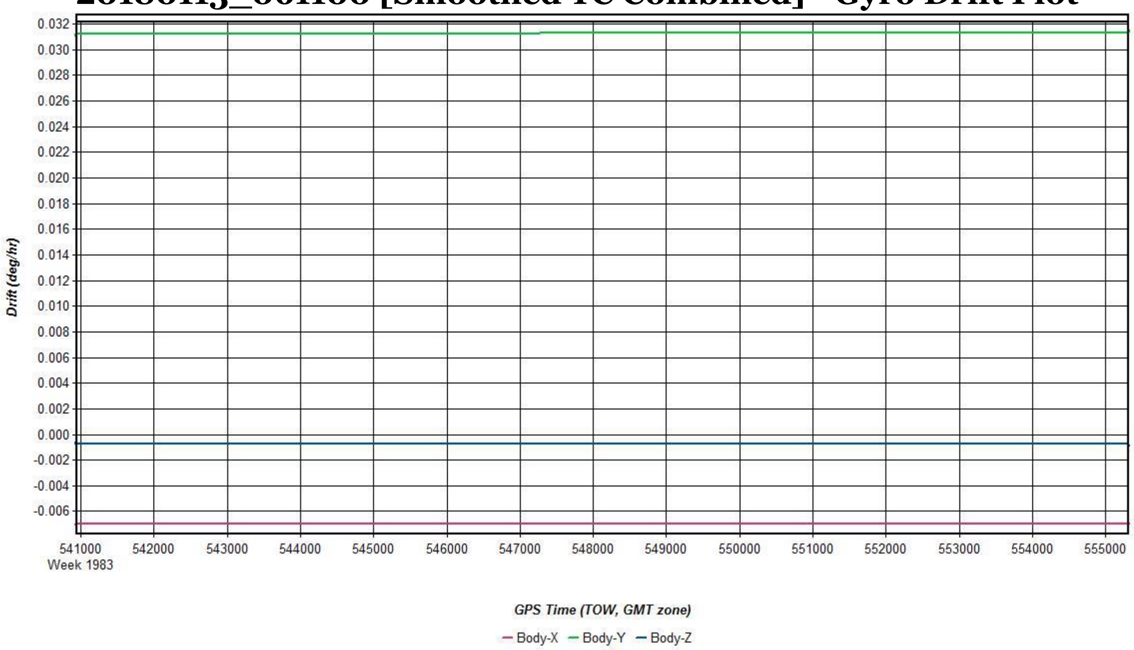
20180113_061100 [Smoothed TC Combined] - Number of Satellites Line Plot



20180113_061100 [Smoothed TC Combined] - Accelerometer Bias Plot



20180113_061100 [Smoothed TC Combined] - Gyro Drift Plot



Processing Summery Information

Project:

N:\Production\LiDAR_Projects\18001_TX_FL16_Addon\Flight_Raw\20180113_061100\GnssImu\201801 13_061100.cfg

Solution Type: Combined

Number of Epochs:

Total in GPB file:	28788
No processed position:	3
Missing Fwd or Rev:	2
With bad C/A code:	0
With bad L1 Phase:	0

Measurement RMS Values:

L1 Phase:	0.0161	(m)
C/A Code:	0.41	(m)
L1 Doppler:	0.029	(m/s)

Fwd/Rev Separation RMS Values:

East:	0.007	(m)
North:	0.005	(m)
Height:	0.019	(m)

Fwd/Rev Sep. RMS for dual FWD/REV fixes (28783 occurances):

East:	0.007	(m)
North:	0.005	(m)
Height:	0.019	(m)

Quality Number Percentages:

Q 1:	100.0 %
Q 2:	0.0 %
Q 3:	0.0 %
Q 4:	0.0 %
Q 5:	0.0 %
Q 6:	0.0 %

Position Standard Deviation Percentages:

0.00 - 0.10 m:	100.0 %
0.10 - 0.30 m:	0.0 %
0.30 - 1.00 m:	0.0 %
1.00 - 5.00 m:	0.0 %
5.00 m + over:	0.0 %

Percentages of epochs with DD_DOP over 10.00:

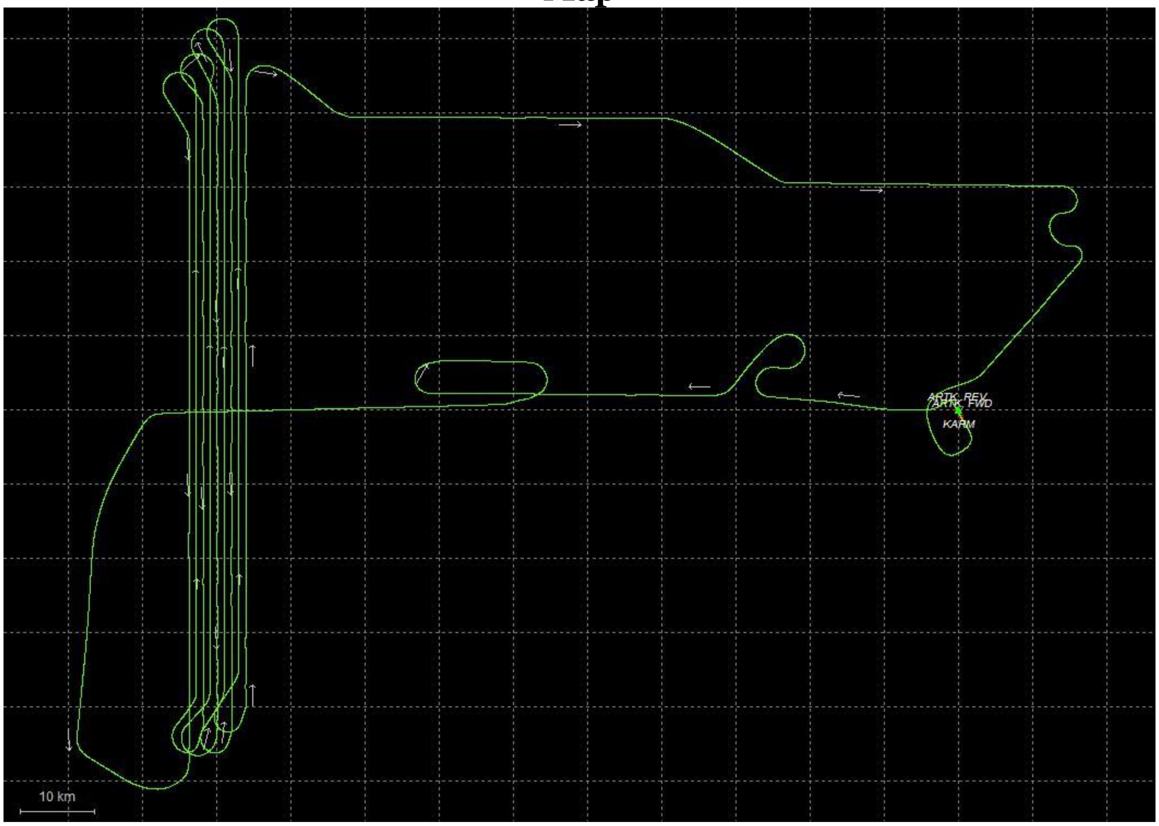
DOP over Tol: 0.0 %

Baseline Distances:

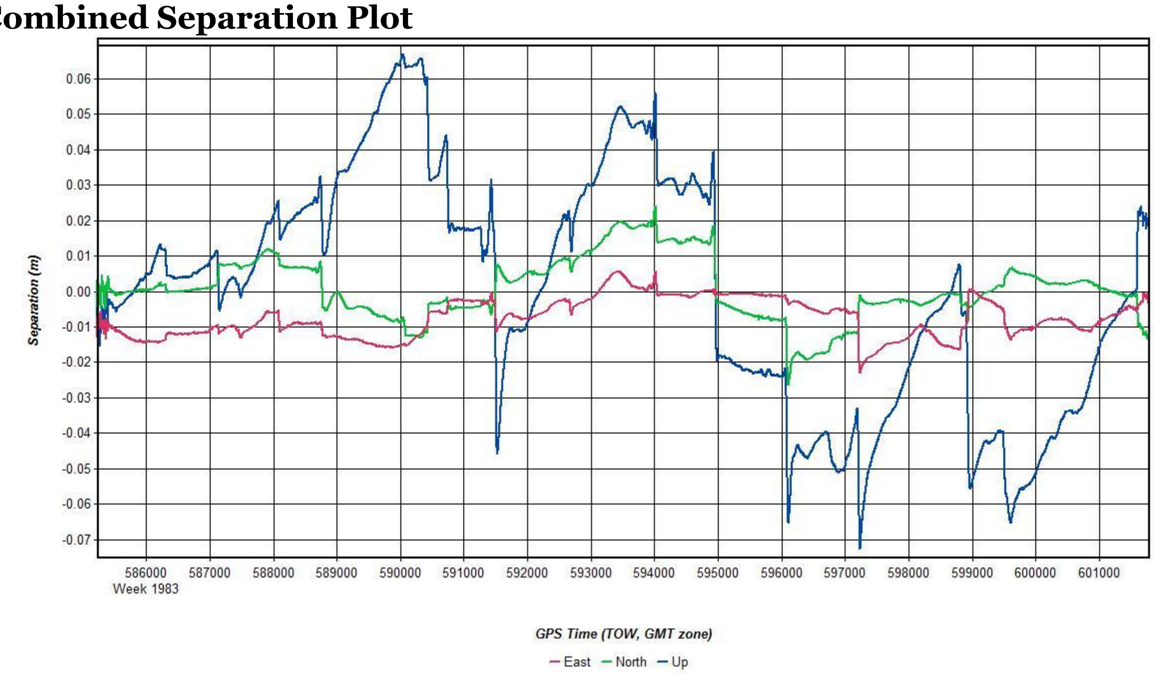
Maximum:	80.534	(km)
Minimum:	0.052	(km)
Average:	53.666	(km)
First Epoch:	1.142	(km)
Last Epoch:	0.052	(km)

Mission 01/13/2018 C

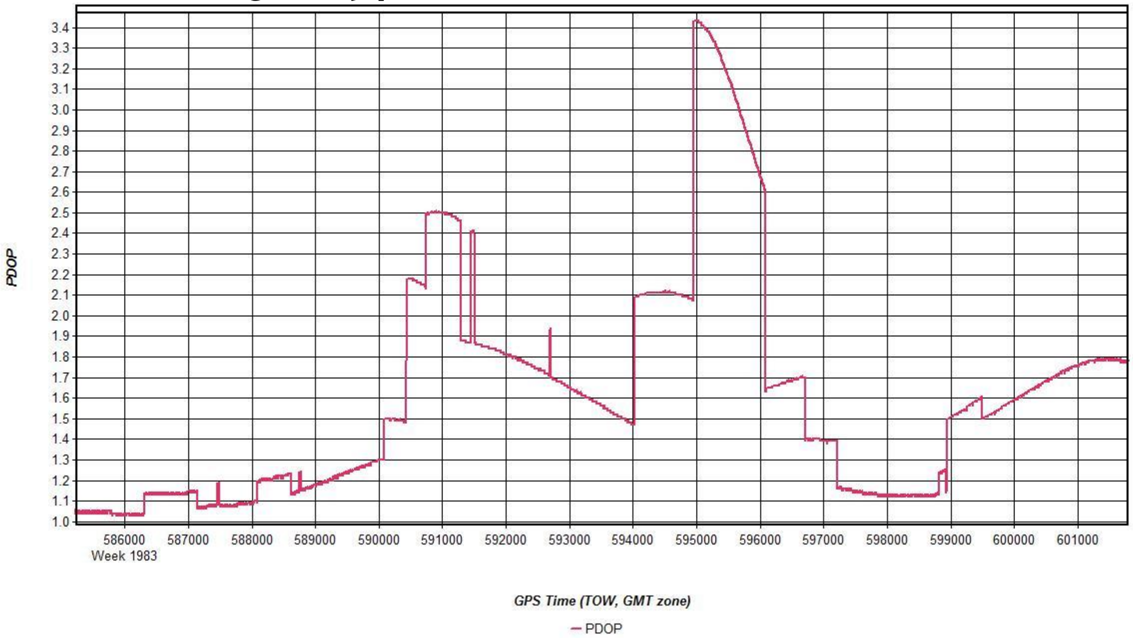
20180113_182941 [Smoothed TC Combined] - Smoothed TC Combined – Map



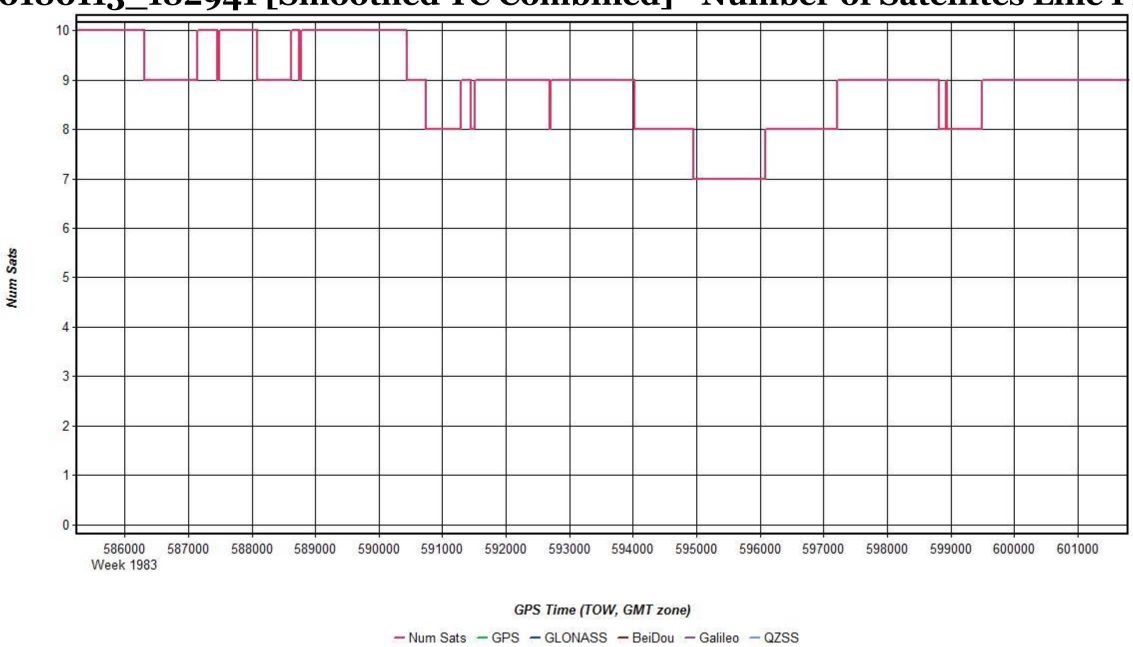
20180113_182941 [Smoothed TC Combined] - Forward/Reverse or Combined Separation Plot



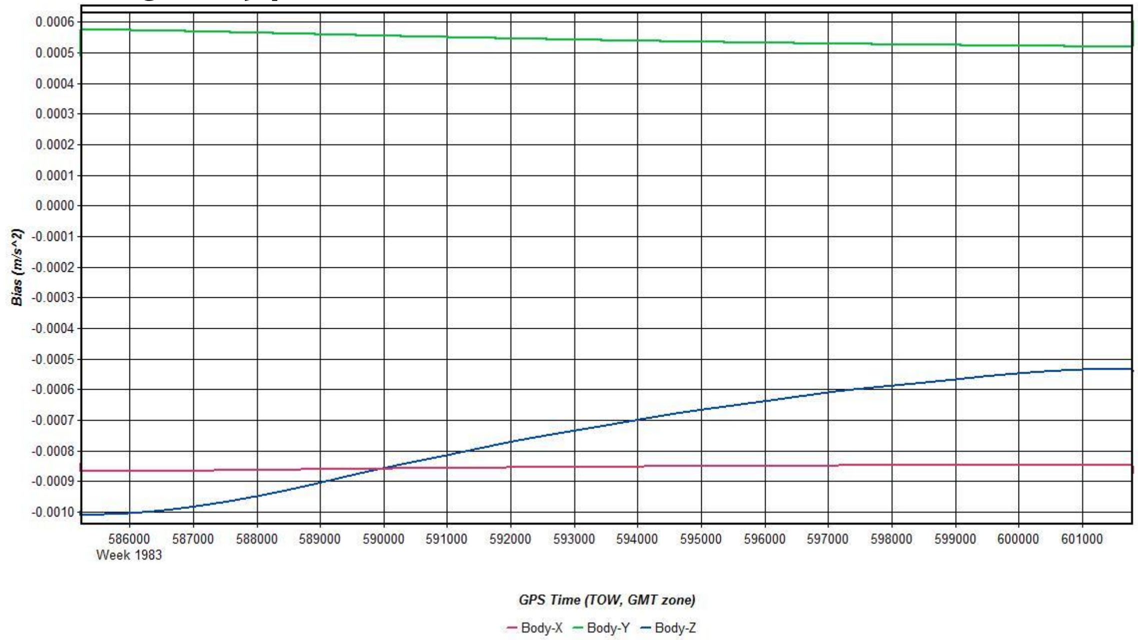
20180113_182941 [Smoothed TC Combined] - PDOP Plot



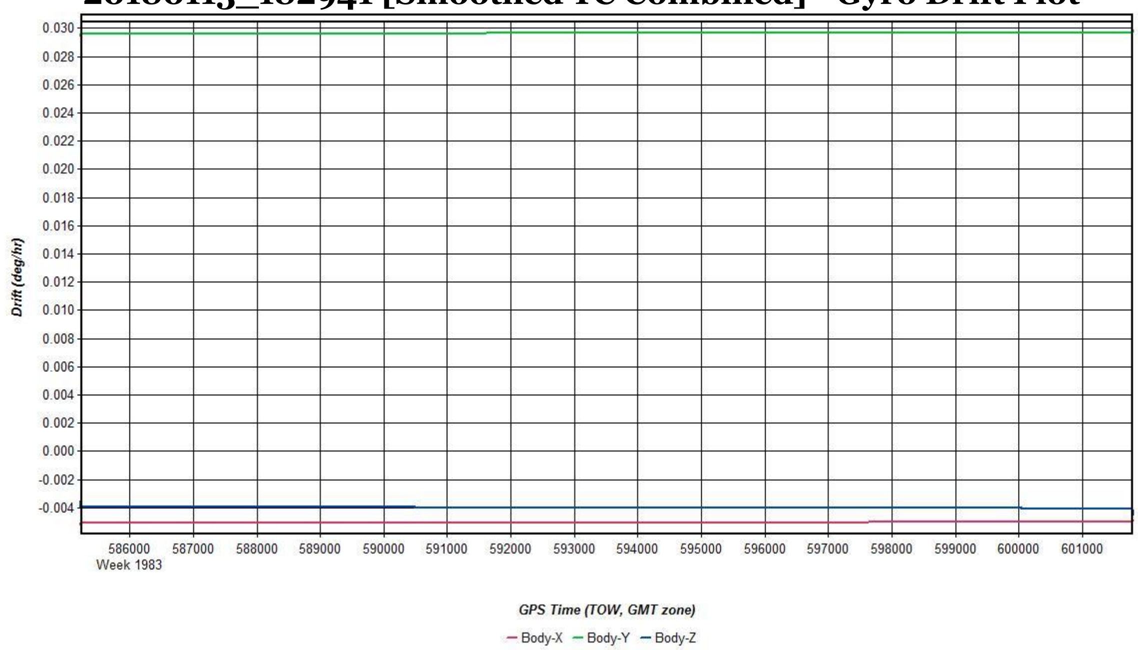
20180113_182941 [Smoothed TC Combined] - Number of Satellites Line Plot



20180113_182941 [Smoothed TC Combined] - Accelerometer Bias Plot



20180113_182941 [Smoothed TC Combined] - Gyro Drift Plot



Processing Summery Information

Project:

N:\Production\LiDAR_Projects\18001_TX_FL16_Addon\Flight_Raw\20180113_182941\Gnss Imu\201801 13_182941.cfg

Solution Type: Combined

Number of Epochs:

Total in GPB file:	33161
No processed position:	4
Missing Fwd or Rev:	2
With bad C/A code:	0
With bad L1 Phase:	0

Measurement RMS Values:

L1 Phase:	0.0174	(m)
C/A Code:	0.36	(m)
L1 Doppler:	0.021	(m/s)

Fwd/Rev Separation RMS Values:

East:	0.009	(m)
North:	0.009	(m)
Height:	0.032	(m)

Fwd/Rev Sep. RMS for dual FWD/REV fixes (33155 occurances):

East:	0.009	(m)
North:	0.009	(m)
Height:	0.032	(m)

Quality Number Percentages:

Q 1:	100.0 %
Q 2:	0.0 %
Q 3:	0.0 %
Q 4:	0.0 %
Q 5:	0.0 %
Q 6:	0.0 %

Position Standard Deviation Percentages:

0.00 - 0.10 m:	100.0 %
0.10 - 0.30 m:	0.0 %
0.30 - 1.00 m:	0.0 %
1.00 - 5.00 m:	0.0 %
5.00 m + over:	0.0 %

Percentages of epochs with DD_DOP over 10.00:

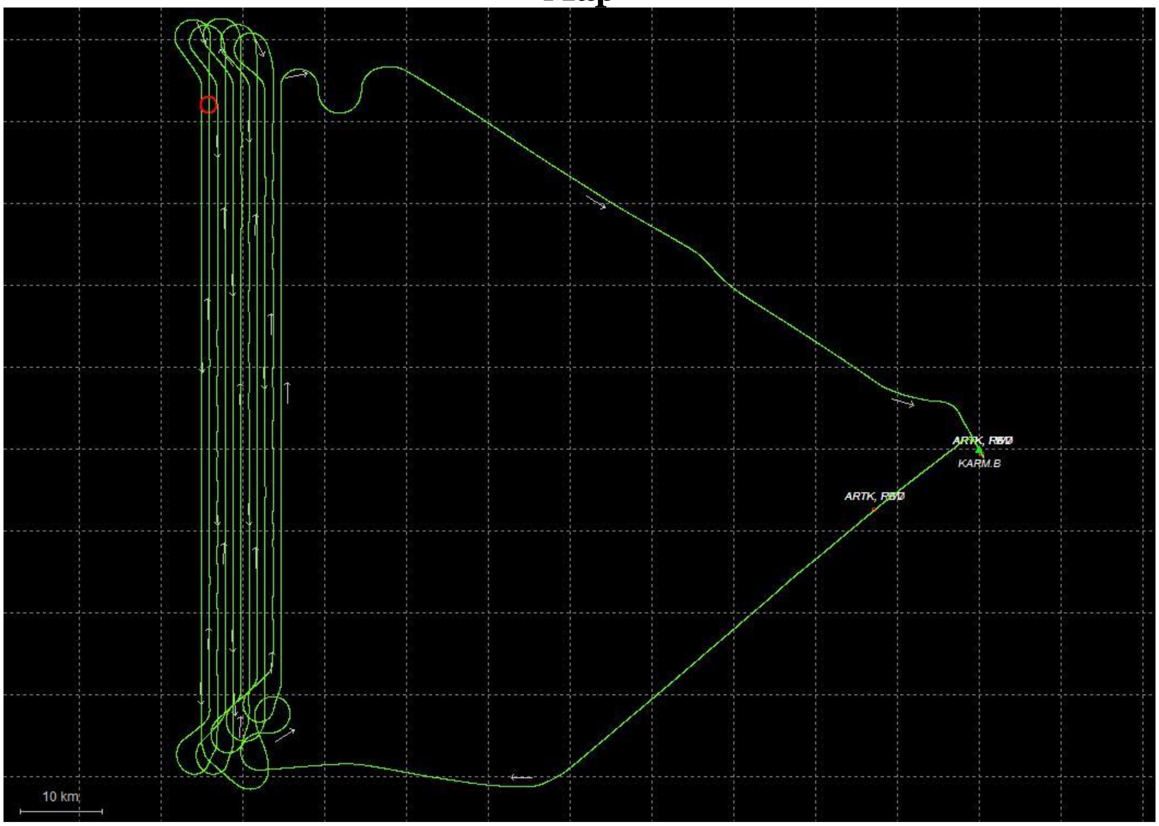
DOP over Tol: 0.0 %

Baseline Distances:

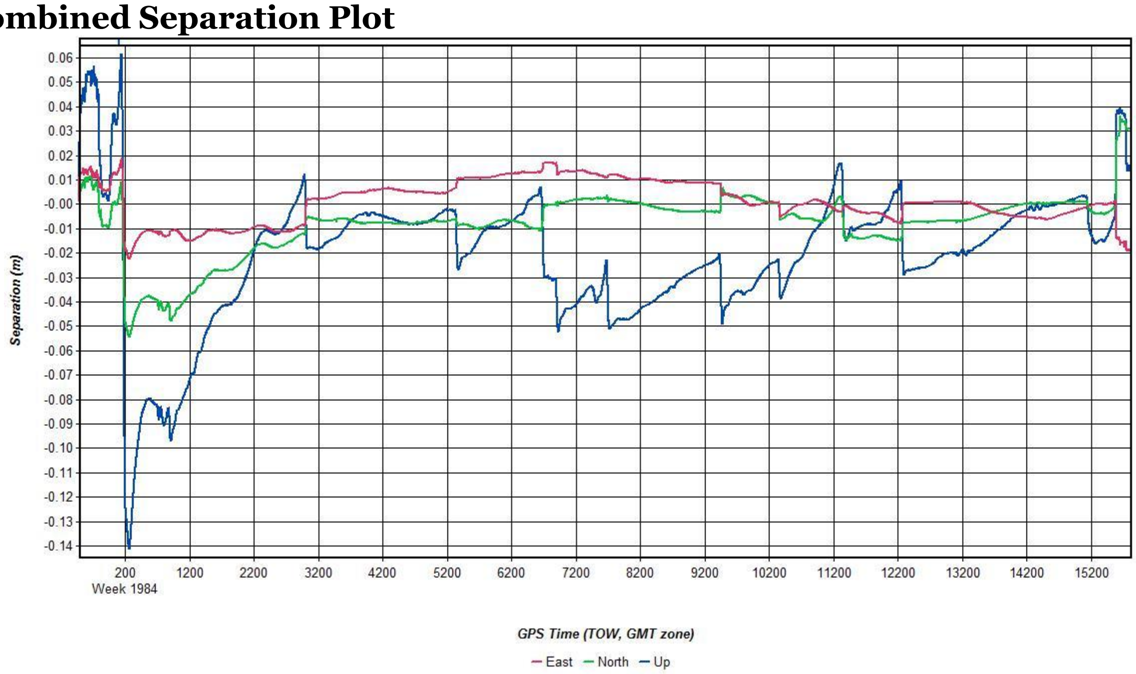
Maximum:	126.852	(km)
Minimum:	0.055	(km)
Average:	86.703	(km)
First Epoch:	1.142	(km)
Last Epoch:	0.055	(km)

Mission 01/13/2018 D

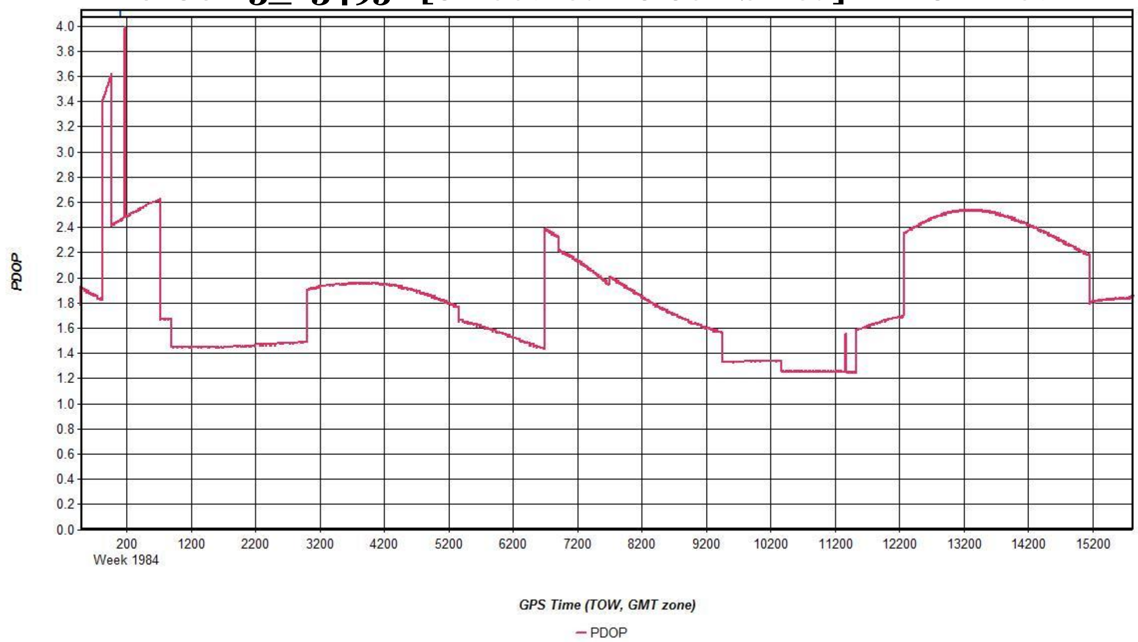
20180113_234952 [Smoothed TC Combined] - Smoothed TC Combined – Map



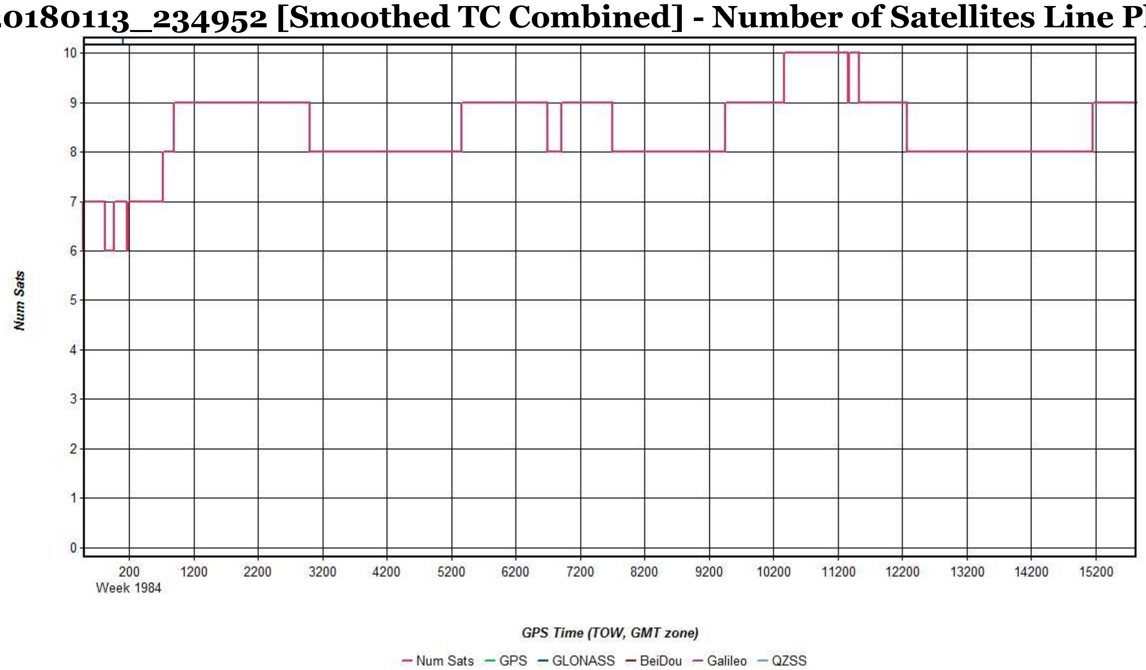
20180113_234952 [Smoothed TC Combined] - Forward/Reverse or Combined Separation Plot



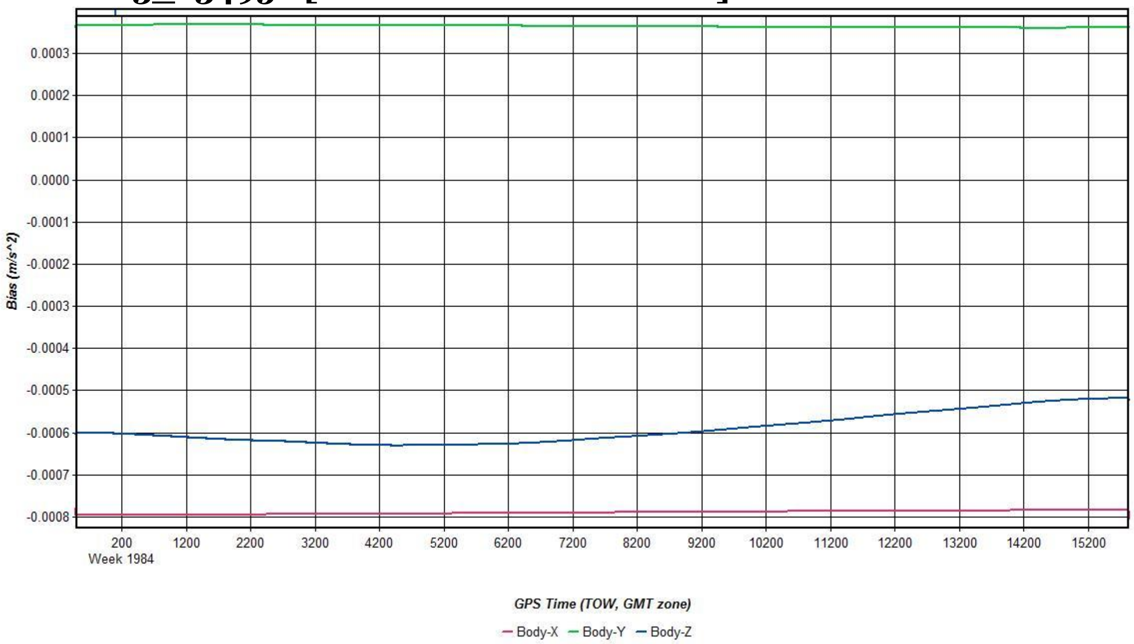
20180113_234952 [Smoothed TC Combined] - PDOP Plot



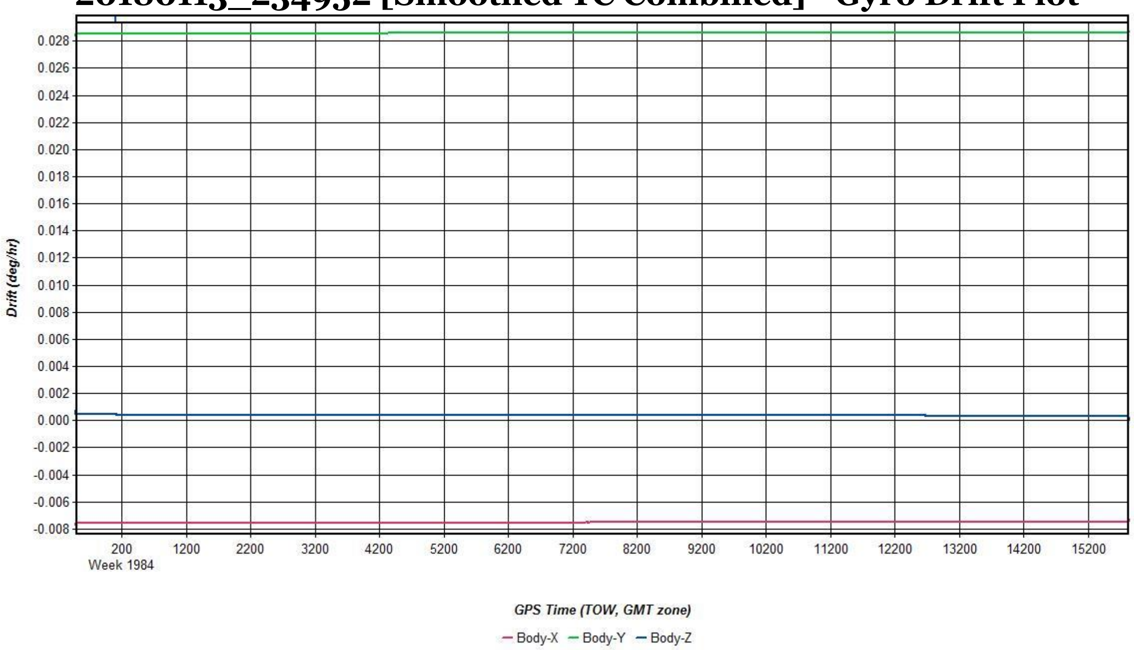
20180113_234952 [Smoothed TC Combined] - Number of Satellites Line Plot



20180113_234952 [Smoothed TC Combined] - Accelerometer Bias Plot



20180113_234952 [Smoothed TC Combined] - Gyro Drift Plot



Processing Summery Information

Project:

N:\Production\LiDAR_Projects\18001_TX_FL16_Addon\Flight_Raw\20180113_234952\GnssImu\201801 13_234952.cfg

Solution Type: Combined

Number of Epochs:

Total in GPB file:	32705
No processed position:	1414
Missing Fwd or Rev:	2
With bad C/A code:	0
With bad L1 Phase:	0

Measurement RMS Values:

L1 Phase:	0.0168	(m)
C/A Code:	0.40	(m)
L1 Doppler:	0.026	(m/s)

Fwd/Rev Separation RMS Values:

East:	0.006	(m)
North:	0.010	(m)
Height:	0.023	(m)

Fwd/Rev Sep. RMS for dual FWD/REV fixes (31270 occurances):

East:	0.006	(m)
North:	0.010	(m)
Height:	0.023	(m)

Quality Number Percentages:

Q 1:	100.0 %
Q 2:	0.0 %
Q 3:	0.0 %
Q 4:	0.0 %
Q 5:	0.0 %
Q 6:	0.0 %

Position Standard Deviation Percentages:

0.00 - 0.10 m:	100.0 %
0.10 - 0.30 m:	0.0 %
0.30 - 1.00 m:	0.0 %
1.00 - 5.00 m:	0.0 %
5.00 m + over:	0.0 %

Percentages of epochs with DD_DOP over 10.00:

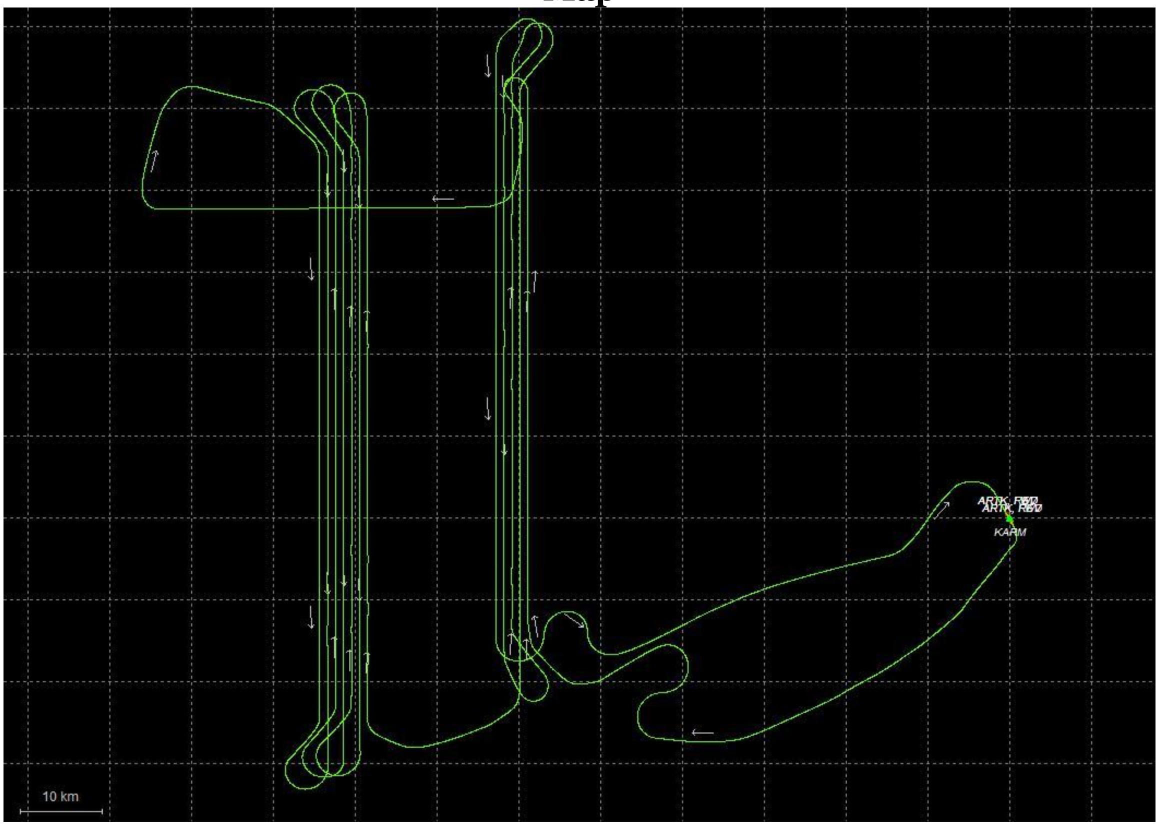
DOP over Tol: 0.0 %

Baseline Distances:

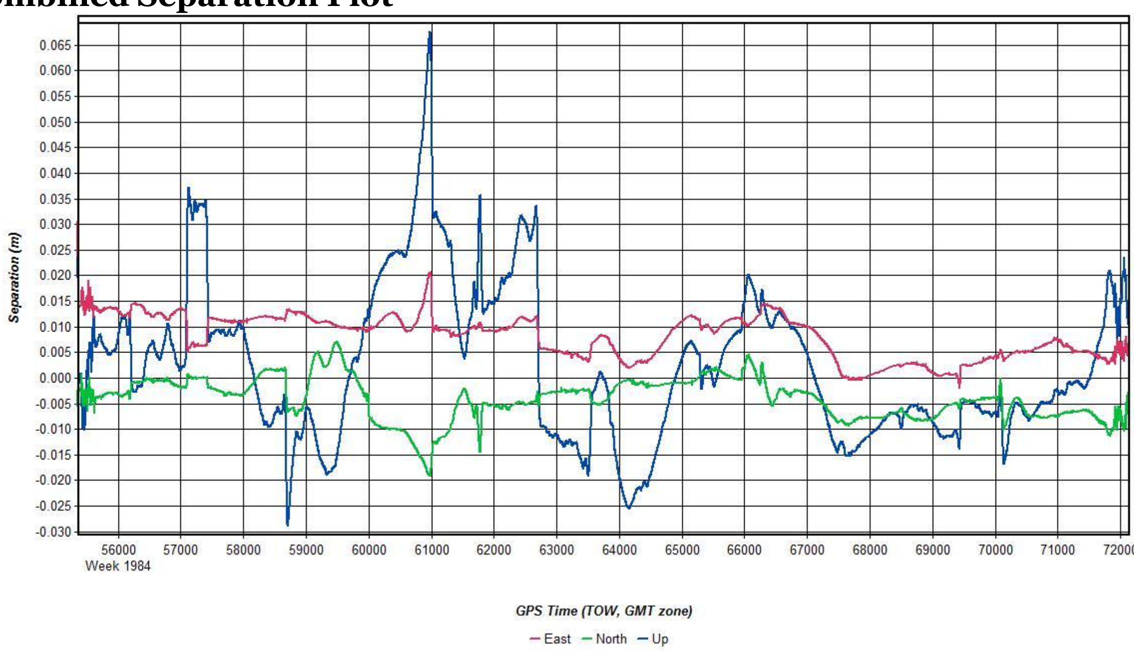
Maximum:	110.161	(km)
Minimum:	0.087	(km)
Average:	86.565	(km)
First Epoch:	20.649	(km)
Last Epoch:	0.762	(km)

Mission 01/14/2018 A

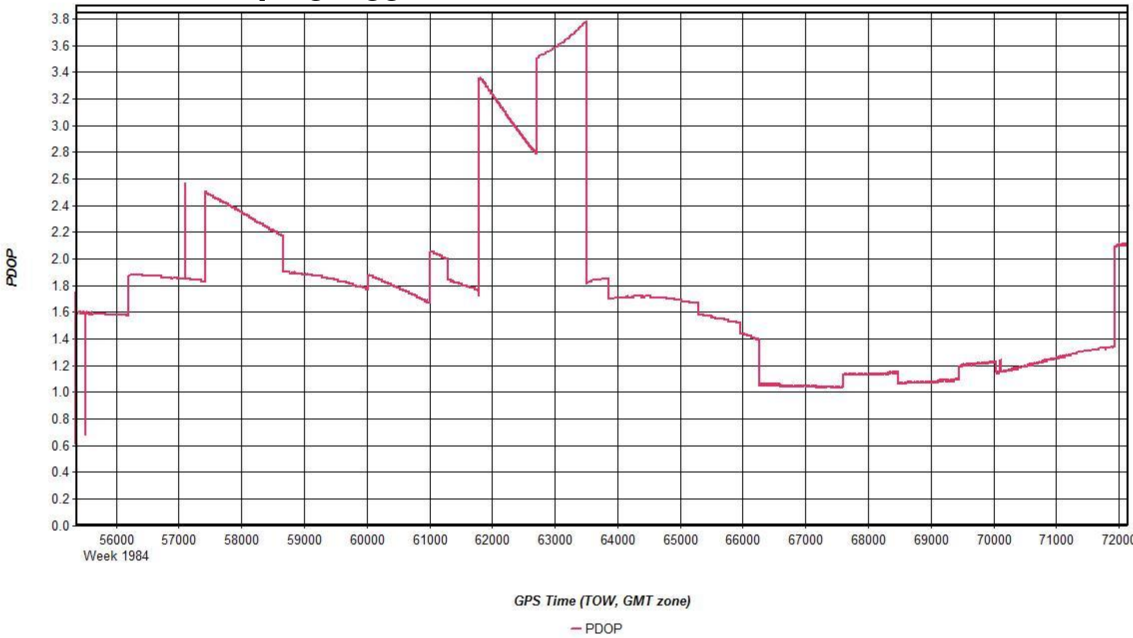
20180114_151855 [Smoothed TC Combined] - Smoothed TC Combined – Map



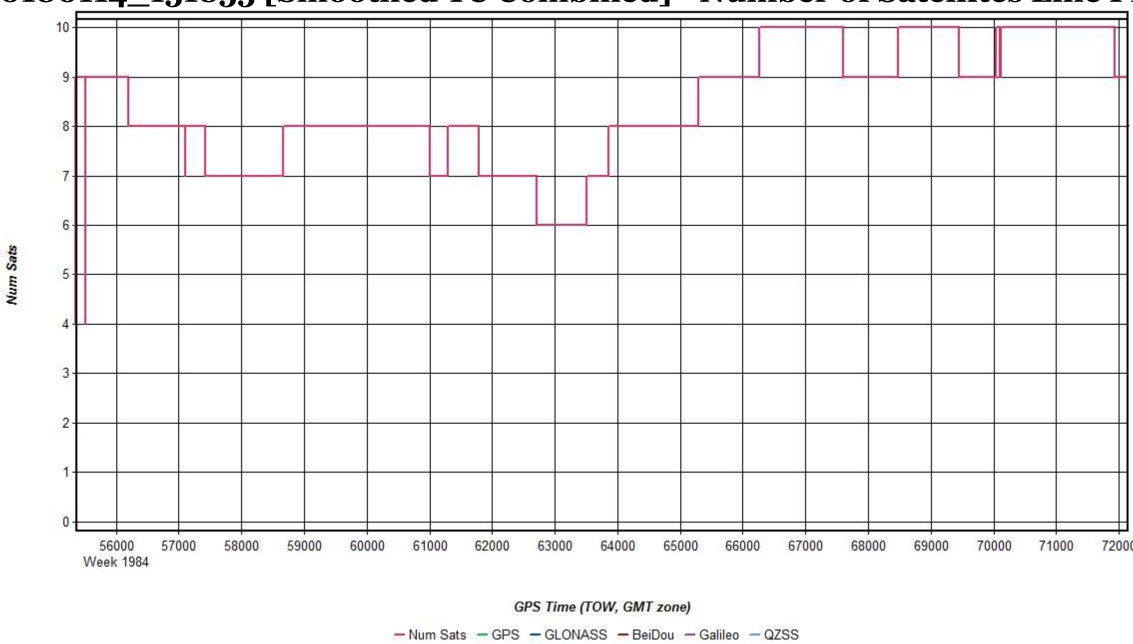
20180114_151855 [Smoothed TC Combined] - Forward/Reverse or Combined Separation Plot



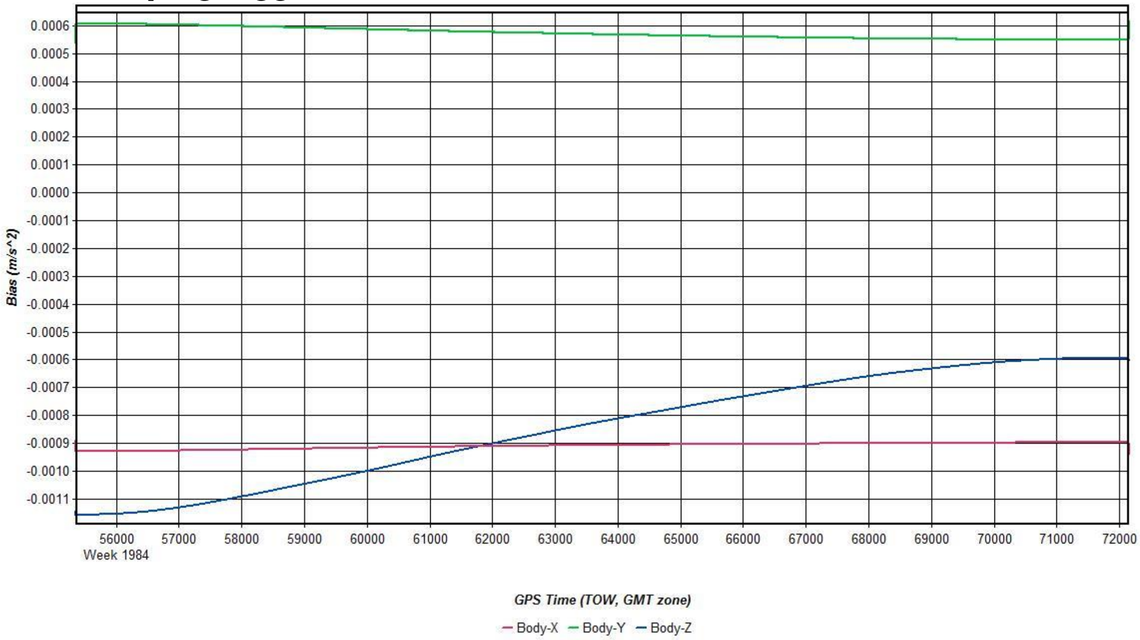
20180114_151855 [Smoothed TC Combined] - PDOP Plot



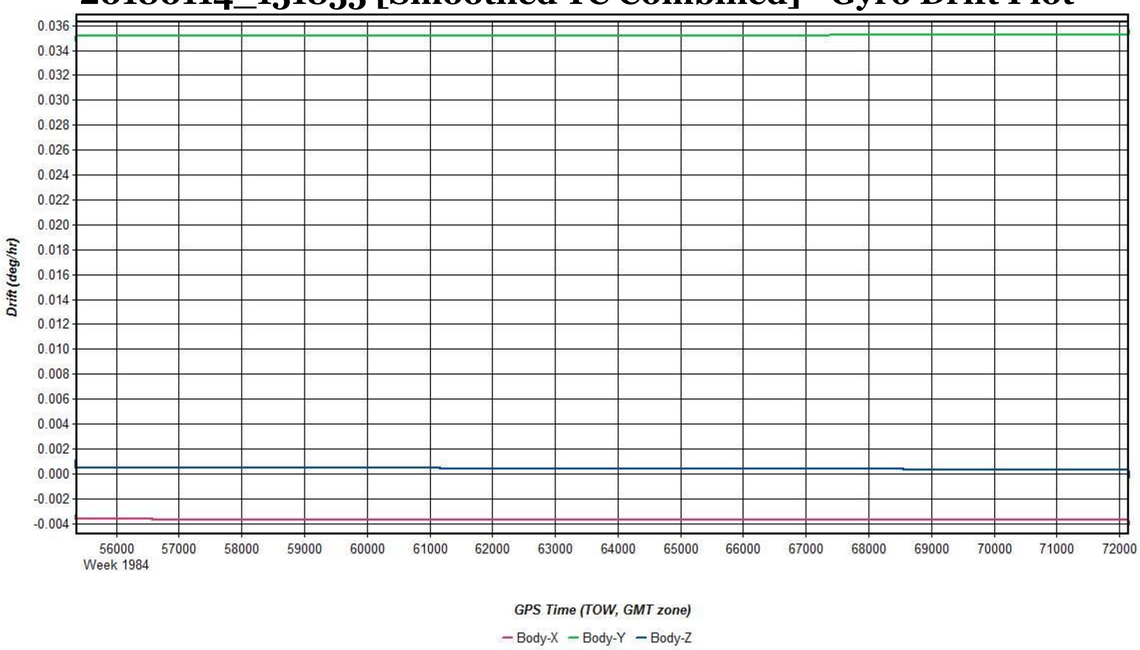
20180114_151855 [Smoothed TC Combined] - Number of Satellites Line Plot



20180114_151855 [Smoothed TC Combined] - Accelerometer Bias Plot



20180114_151855 [Smoothed TC Combined] - Gyro Drift Plot



Processing Summery Information

Project:

N:\Production\LiDAR_Projects\18001_TX_FL16_Addon\Flight_Raw\20180114_151855\Gnss Imu\201801 14_151855.cfg

Solution Type: Combined

Number of Epochs:

Total in GPB file:	33616
No processed position:	5
Missing Fwd or Rev:	2
With bad C/A code:	0
With bad L1 Phase:	0

Measurement RMS Values:

L1 Phase:	0.0170	(m)
C/A Code:	0.37	(m)
L1 Doppler:	0.030	(m/s)

Fwd/Rev Separation RMS Values:

East:	0.009	(m)
North:	0.006	(m)
Height:	0.015	(m)

Fwd/Rev Sep. RMS for dual FWD/REV fixes (33589 occurances):

East:	0.009	(m)
North:	0.006	(m)
Height:	0.015	(m)

Quality Number Percentages:

Q 1:	99.9 %
Q 2:	0.1 %
Q 3:	0.0 %
Q 4:	0.0 %
Q 5:	0.0 %
Q 6:	0.0 %

Position Standard Deviation Percentages:

0.00 - 0.10 m:	100.0 %
0.10 - 0.30 m:	0.0 %
0.30 - 1.00 m:	0.0 %
1.00 - 5.00 m:	0.0 %
5.00 m + over:	0.0 %

Percentages of epochs with DD_DOP over 10.00:

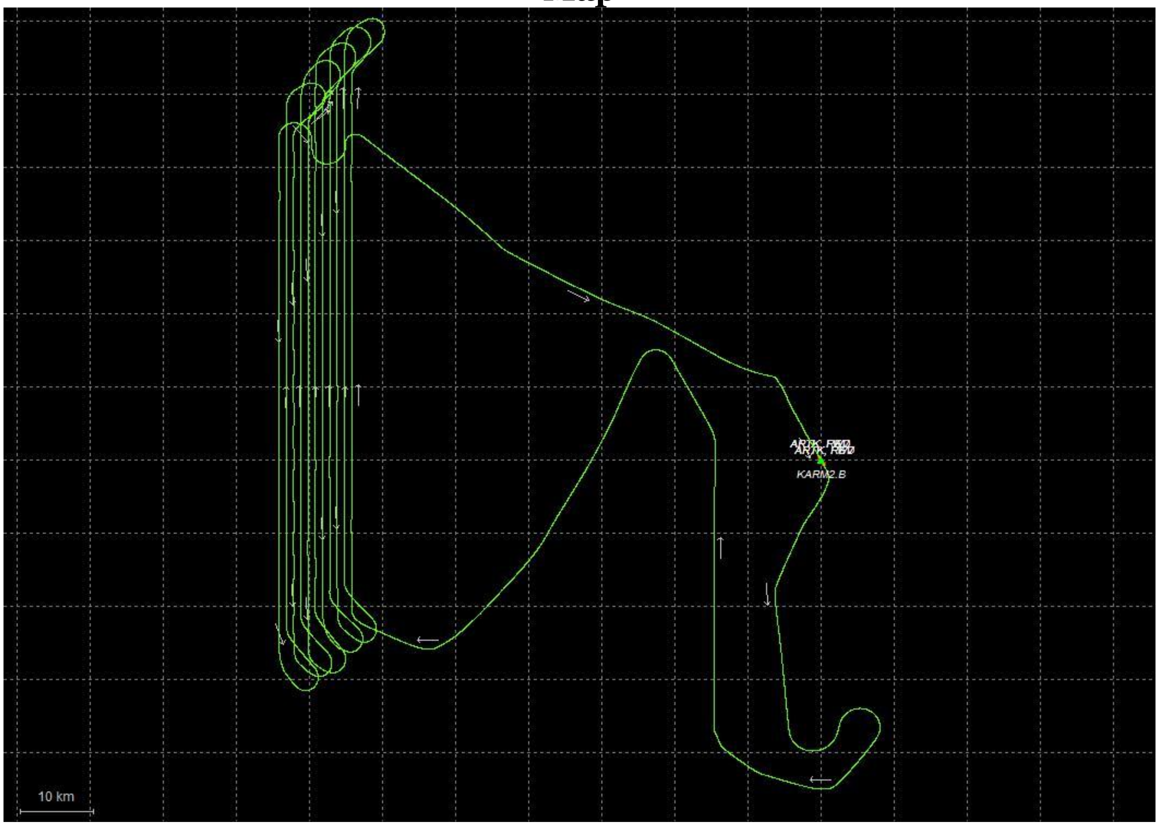
DOP over Tol: 0.0 %

Baseline Distances:

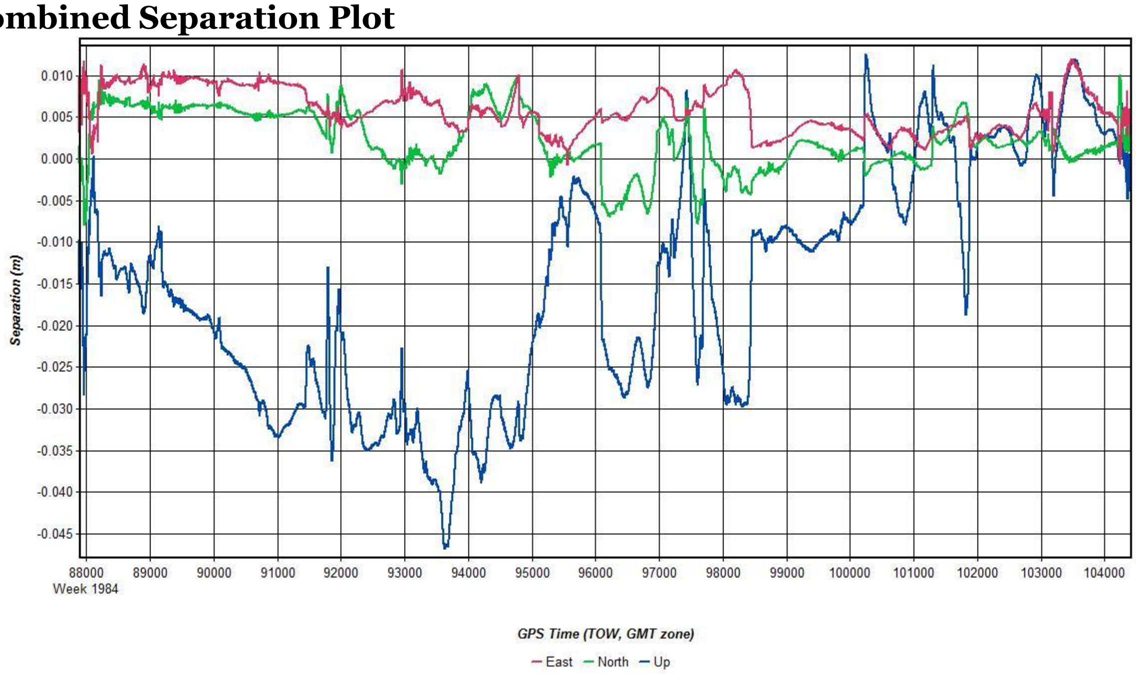
Maximum:	114.461	(km)
Minimum:	0.086	(km)
Average:	70.808	(km)
First Epoch:	0.355	(km)
Last Epoch:	0.677	(km)

Mission 01/15/2018 A

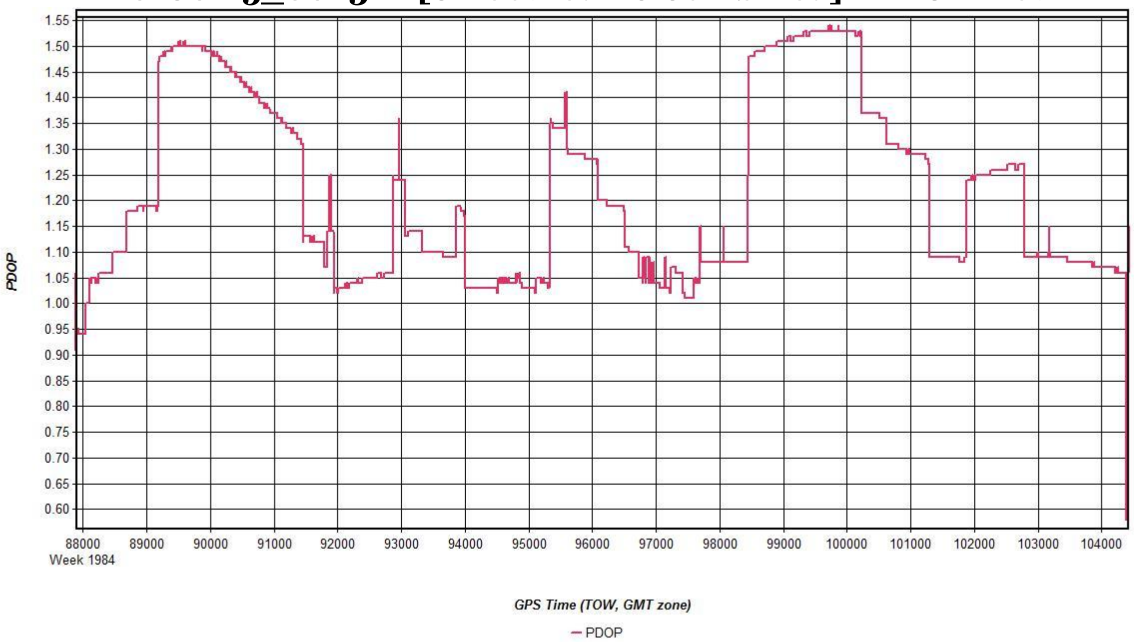
20180115_002322 [Smoothed TC Combined] - Smoothed TC Combined – Map



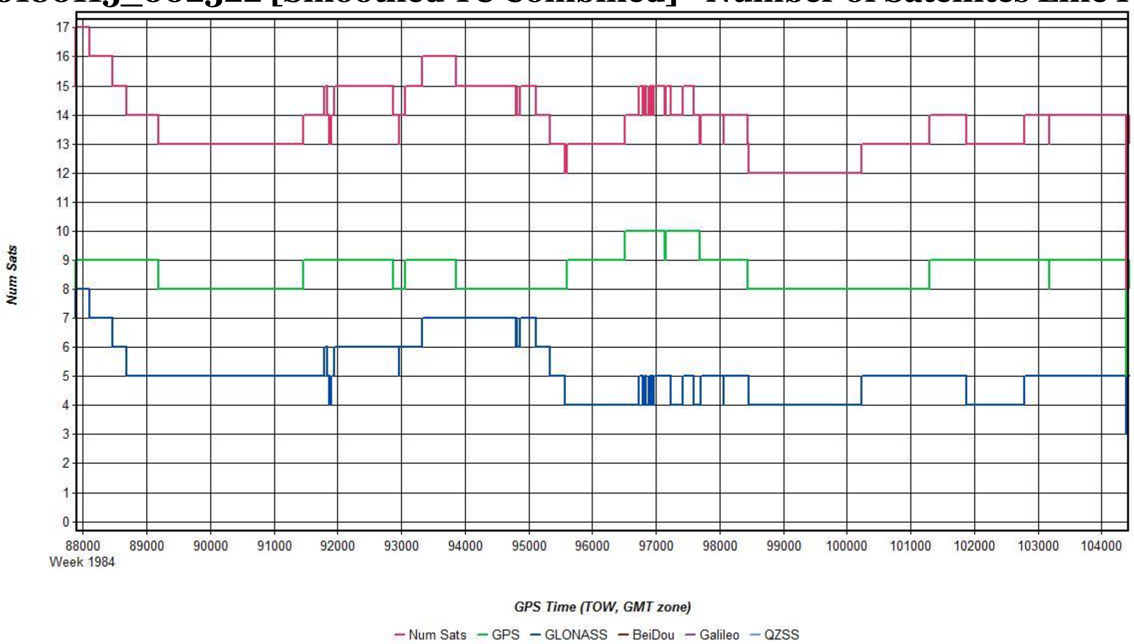
20180115_002322 [Smoothed TC Combined] - Forward/Reverse or Combined Separation Plot



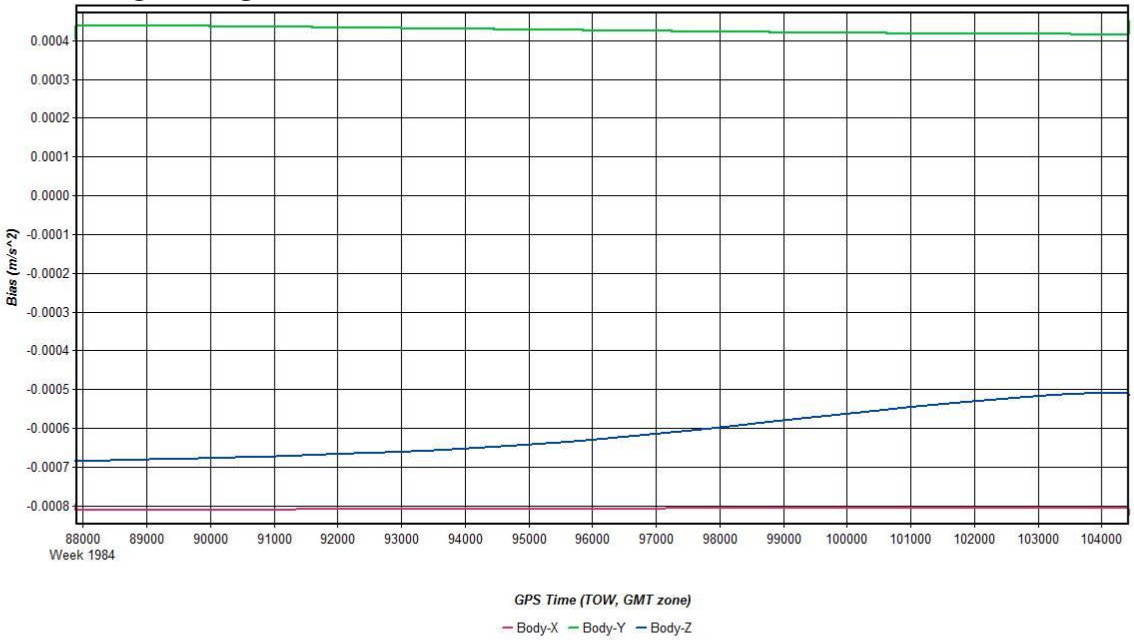
20180115_002322 [Smoothed TC Combined] - PDOP Plot



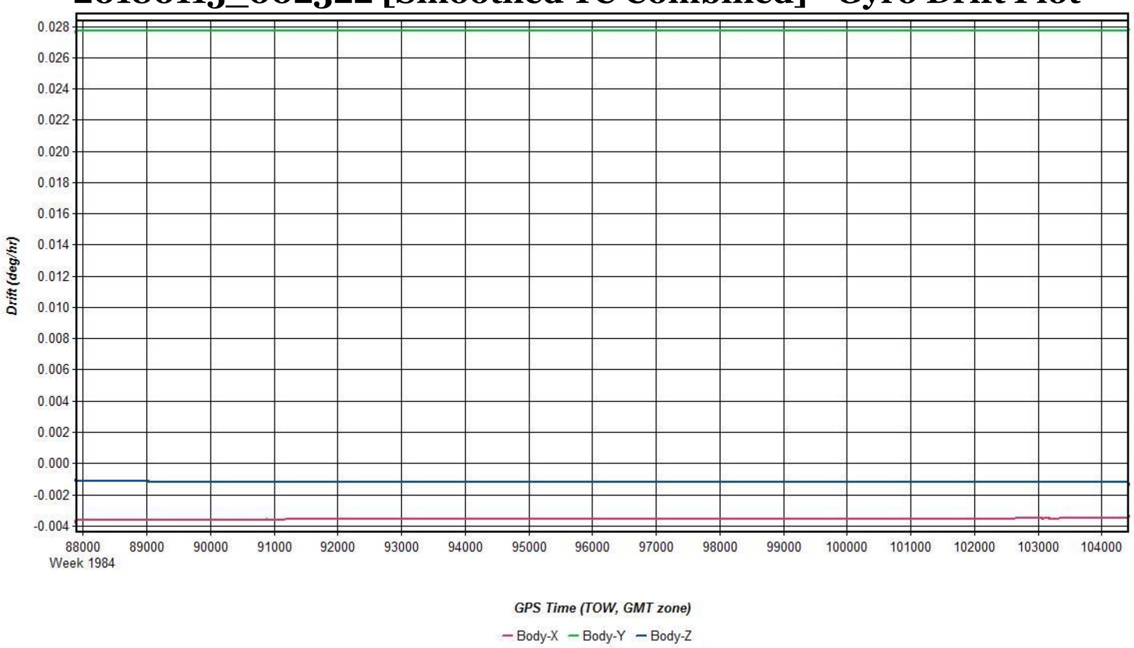
20180115_002322 [Smoothed TC Combined] - Number of Satellites Line Plot



20180115_002322 [Smoothed TC Combined] - Accelerometer Bias Plot



20180115_002322 [Smoothed TC Combined] - Gyro Drift Plot



Processing Summery Information

Project:

N:\Production\LiDAR_Projects\18001_TX_FL16_Addon\Flight_Raw\20180115_002322\GnssImu\201801 15_002322.cfg

Solution Type: Combined

Number of Epochs:

Total in GPB file:	33101
No processed position:	2
Missing Fwd or Rev:	2
With bad C/A code:	0
With bad L1 Phase:	0

Measurement RMS Values:

L1 Phase:	0.0153	(m)
C/A Code:	0.36	(m)
L1 Doppler:	0.028	(m/s)

Fwd/Rev Separation RMS Values:

East:	0.006	(m)
North:	0.004	(m)
Height:	0.020	(m)

Fwd/Rev Sep. RMS for dual FWD/REV fixes (33095 occurances):

East:	0.006	(m)
North:	0.004	(m)
Height:	0.020	(m)

Quality Number Percentages:

Q 1:	100.0 %
Q 2:	0.0 %
Q 3:	0.0 %
Q 4:	0.0 %
Q 5:	0.0 %
Q 6:	0.0 %

Position Standard Deviation Percentages:

0.00 - 0.10 m:	100.0 %
0.10 - 0.30 m:	0.0 %
0.30 - 1.00 m:	0.0 %
1.00 - 5.00 m:	0.0 %
5.00 m + over:	0.0 %

Percentages of epochs with DD_DOP over 10.00:

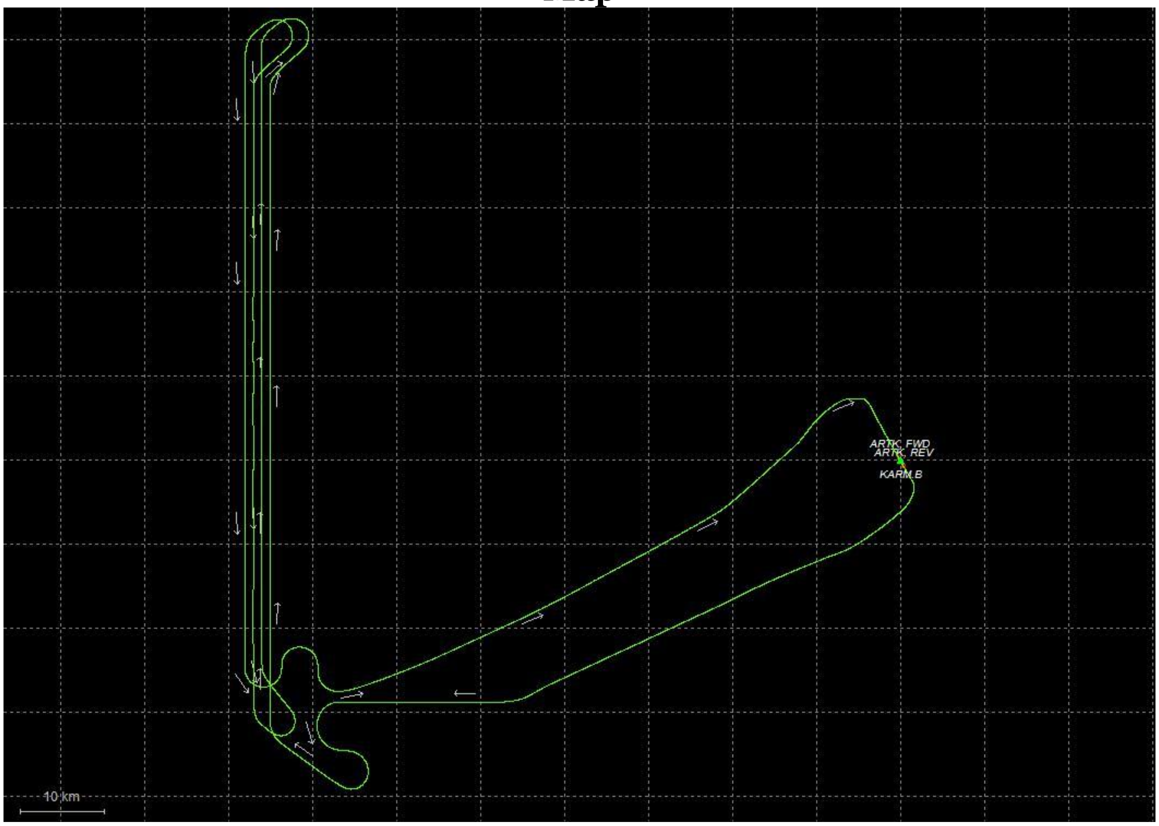
DOP over Tol: 0.0 %

Baseline Distances:

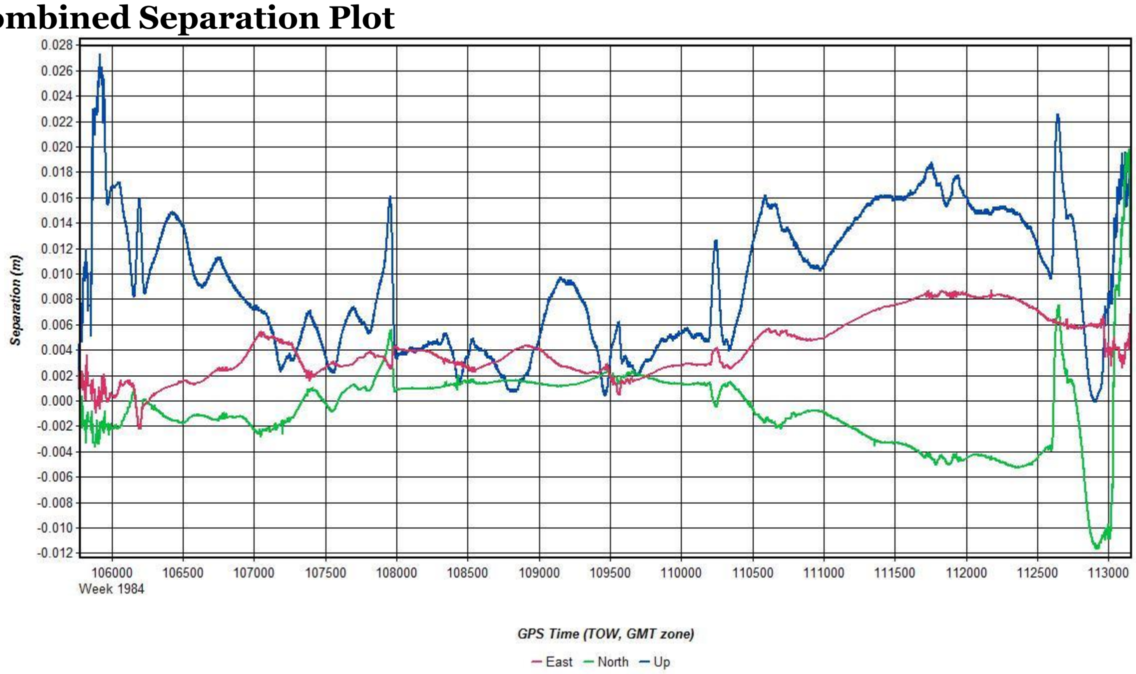
Maximum:	87.010	(km)
Minimum:	0.087	(km)
Average:	61.739	(km)
First Epoch:	0.217	(km)
Last Epoch:	0.764	(km)

Mission 01/15/2018 B

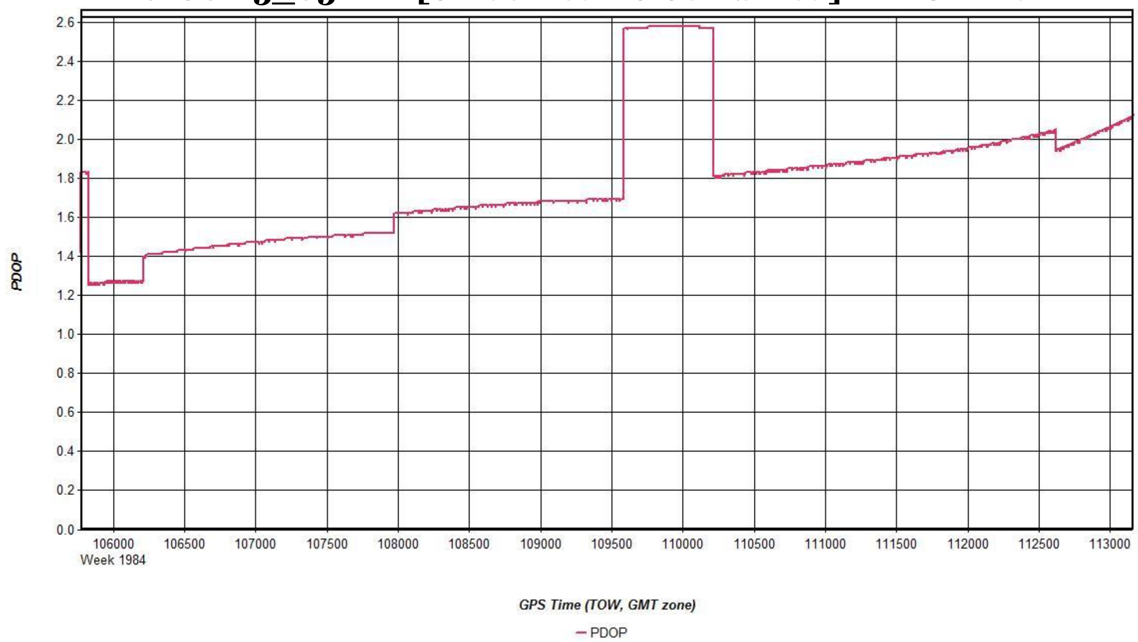
20180115_052112 [Smoothed TC Combined] - Smoothed TC Combined – Map



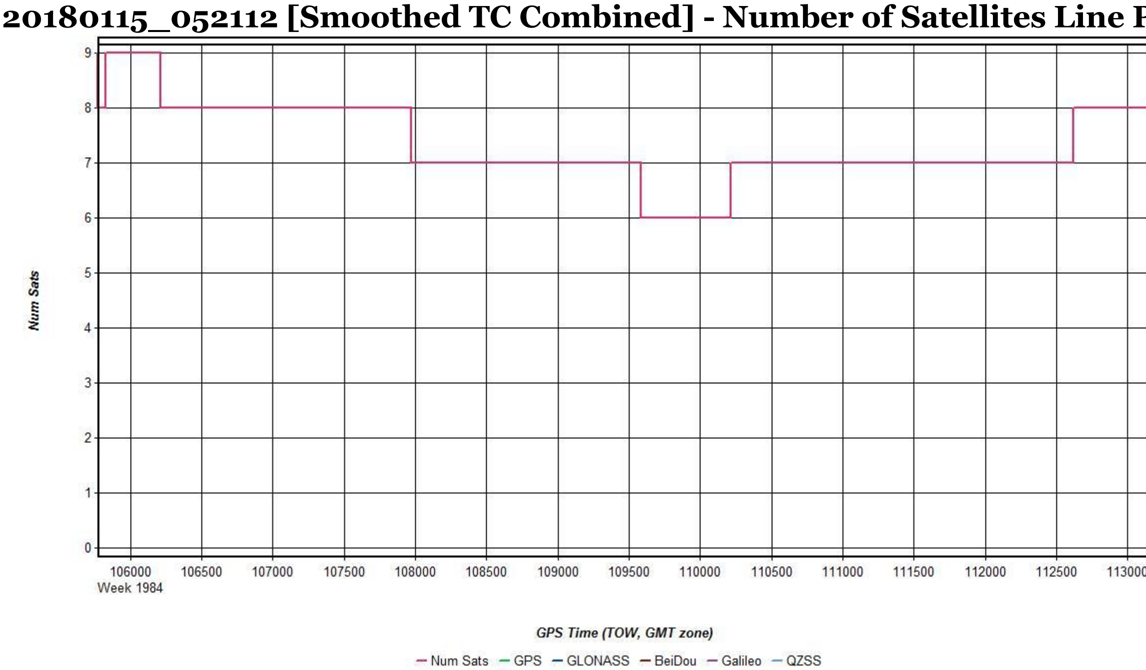
20180115_052112 [Smoothed TC Combined] - Forward/Reverse or Combined Separation Plot



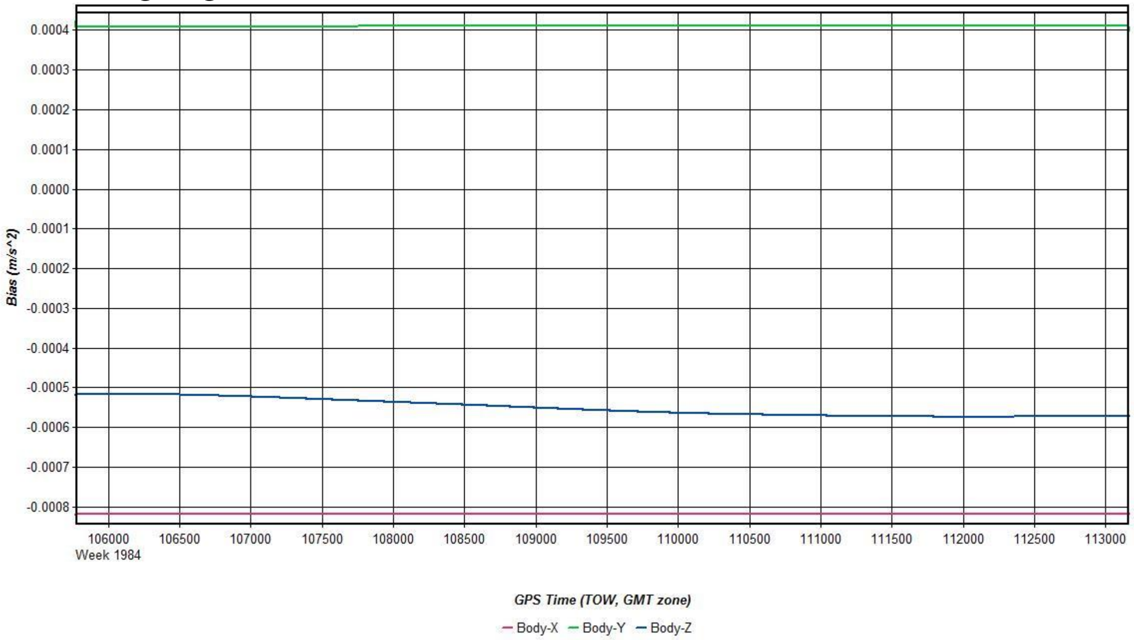
20180115_052112 [Smoothed TC Combined] - PDOP Plot



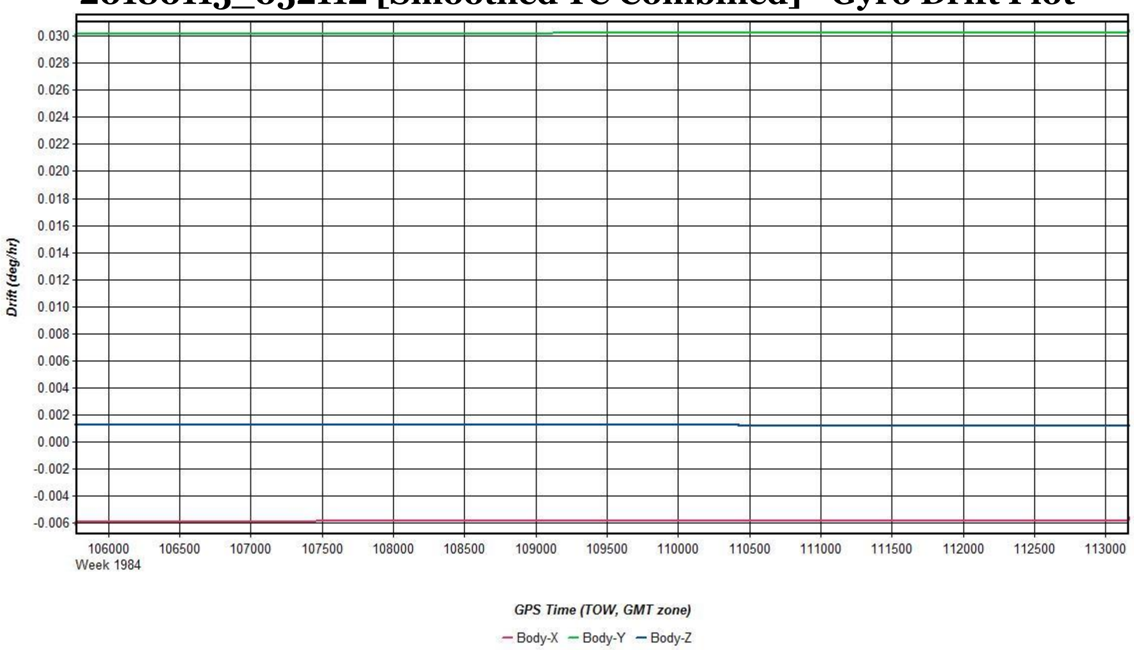
20180115_052112 [Smoothed TC Combined] - Number of Satellites Line Plot



20180115_052112 [Smoothed TC Combined] - Accelerometer Bias Plot



20180115_052112 [Smoothed TC Combined] - Gyro Drift Plot



Processing Summery Information

Project:

N:\Production\LiDAR_Projects\18001_TX_FL16_Addon\Flight_Raw\20180115_052112\Gnss Imu\201801 15_052112.cfg

Solution Type: Combined

Number of Epochs:

Total in GPB file:	14799
No processed position:	4
Missing Fwd or Rev:	2
With bad C/A code:	0
With bad L1 Phase:	0

Measurement RMS Values:

L1 Phase:	0.0147	(m)
C/A Code:	0.35	(m)
L1 Doppler:	0.030	(m/s)

Fwd/Rev Separation RMS Values:

East:	0.005	(m)
North:	0.003	(m)
Height:	0.011	(m)

Fwd/Rev Sep. RMS for dual FWD/REV fixes (14793 occurances):

East:	0.005	(m)
North:	0.003	(m)
Height:	0.011	(m)

Quality Number Percentages:

Q 1:	100.0 %
Q 2:	0.0 %
Q 3:	0.0 %
Q 4:	0.0 %
Q 5:	0.0 %
Q 6:	0.0 %

Position Standard Deviation Percentages:

0.00 - 0.10 m:	100.0 %
0.10 - 0.30 m:	0.0 %
0.30 - 1.00 m:	0.0 %
1.00 - 5.00 m:	0.0 %
5.00 m + over:	0.0 %

Percentages of epochs with DD_DOP over 10.00:

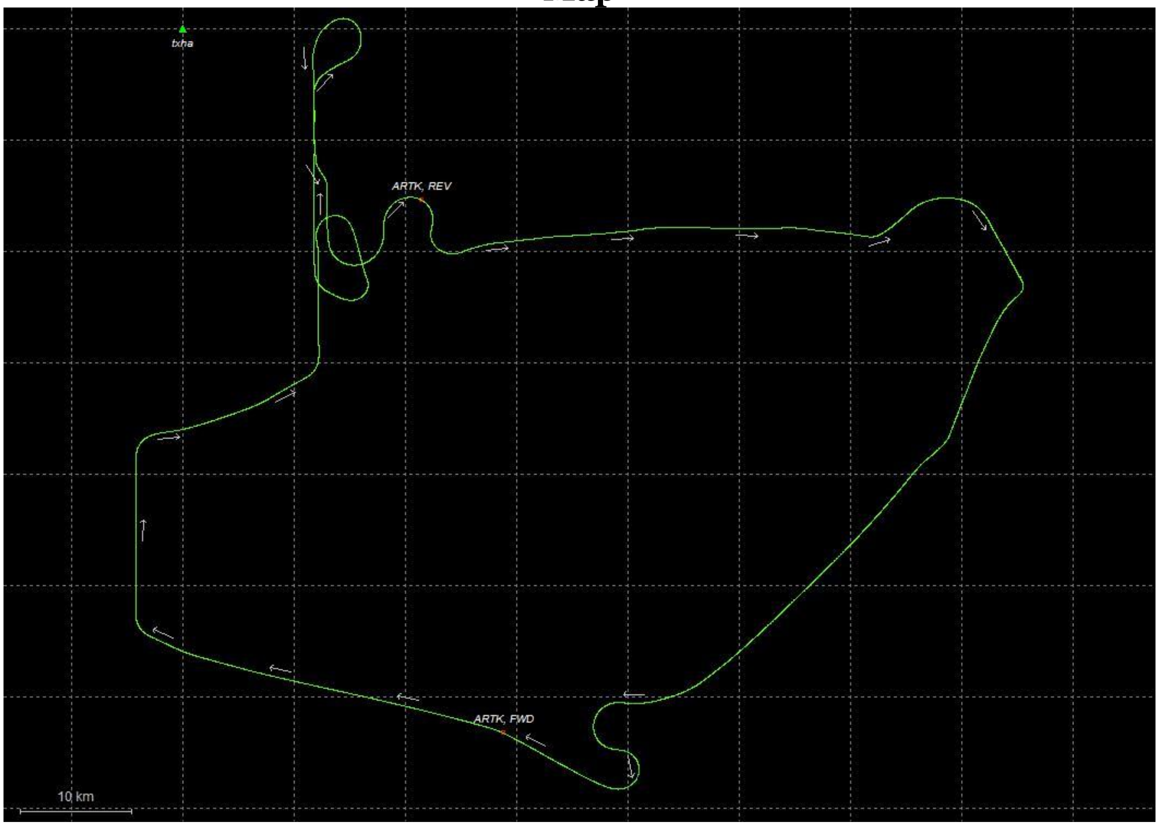
DOP over Tol: 0.0 %

Baseline Distances:

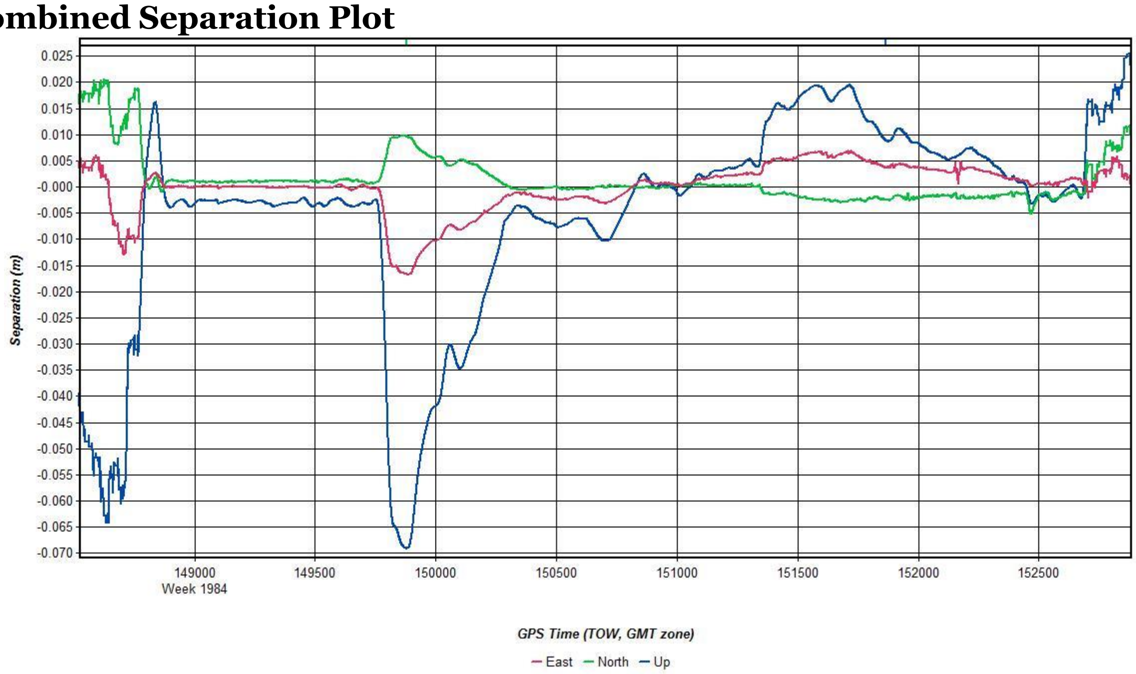
Maximum:	91.273	(km)
Minimum:	0.085	(km)
Average:	61.238	(km)
First Epoch:	0.364	(km)
Last Epoch:	0.754	(km)

Mission 01/15/2018 C

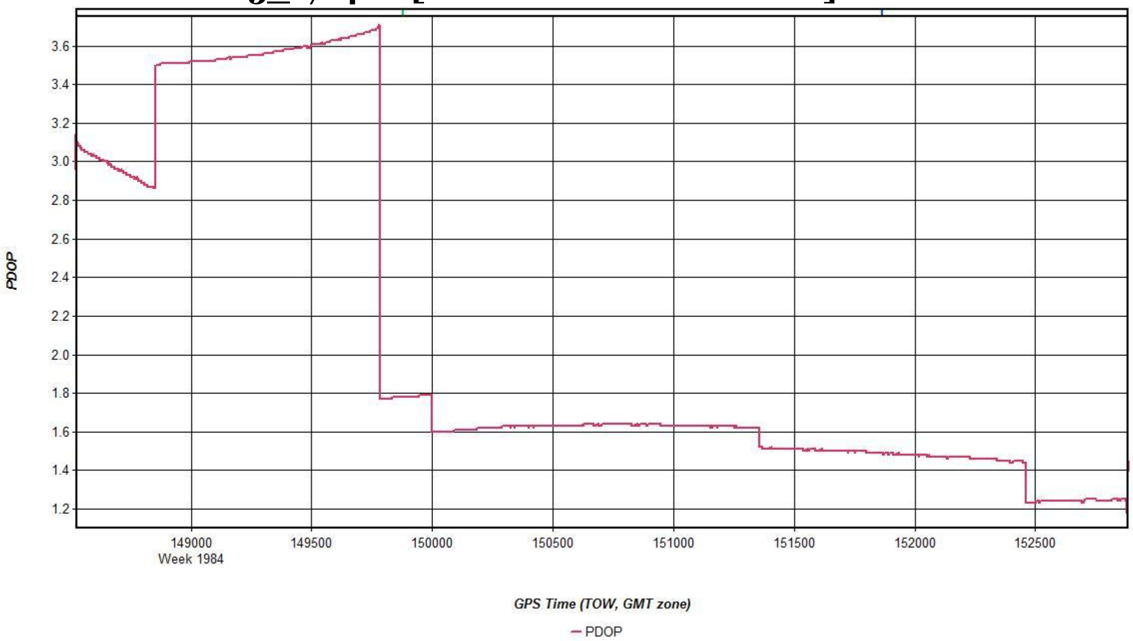
20180115_171406 [Smoothed TC Combined] - Smoothed TC Combined – Map



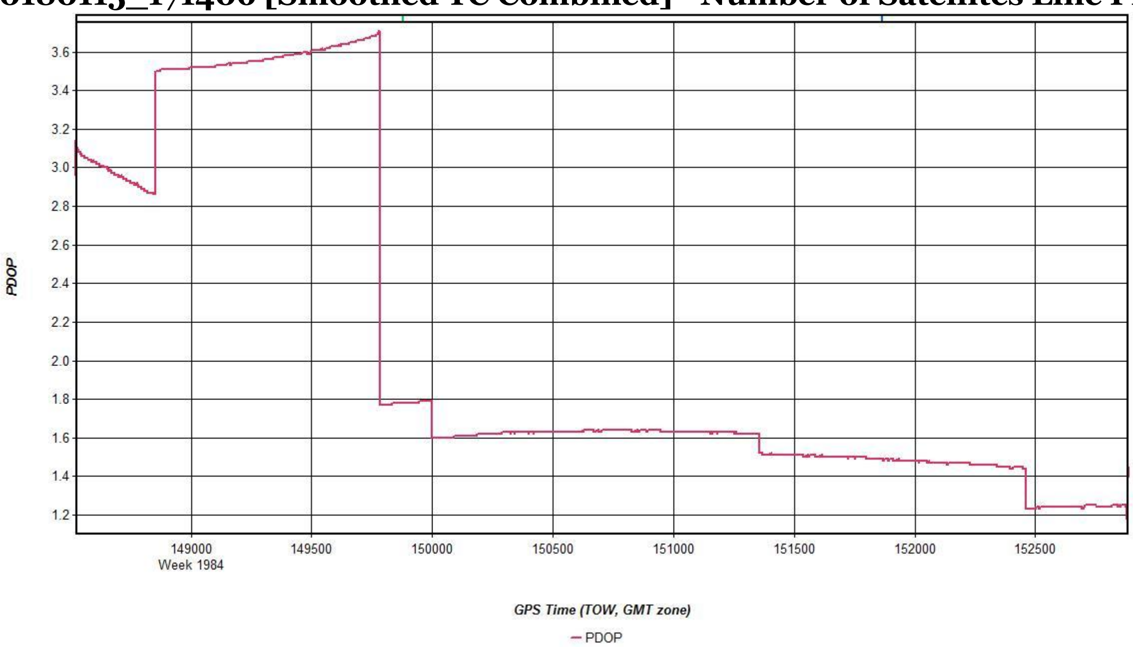
20180115_171406 [Smoothed TC Combined] - Forward/Reverse or Combined Separation Plot



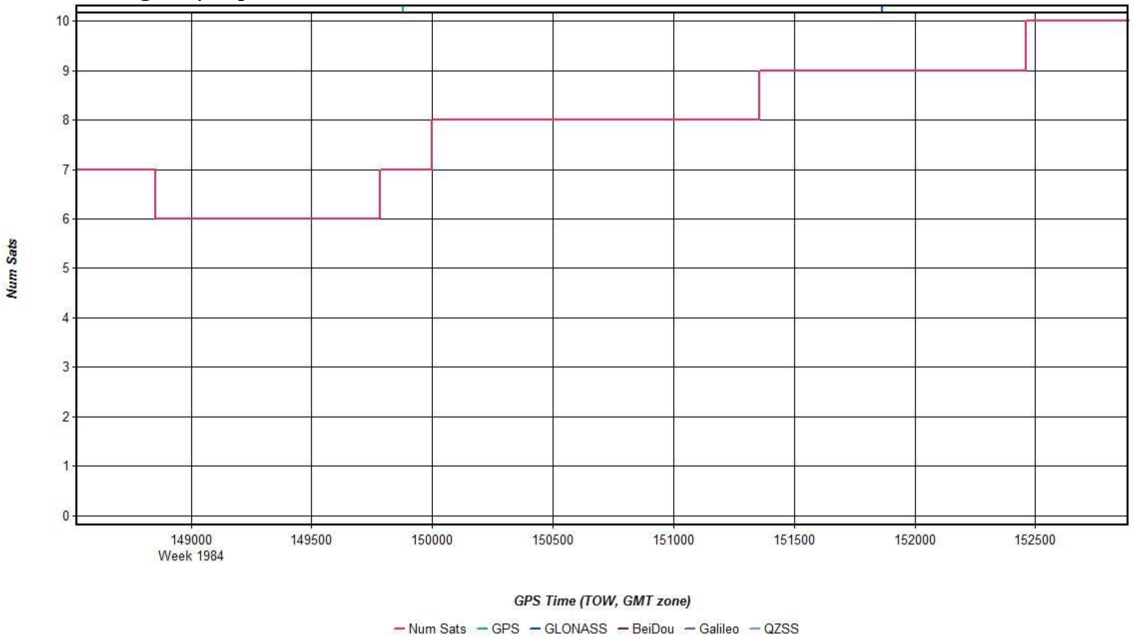
20180115_171406 [Smoothed TC Combined] - PDOP Plot



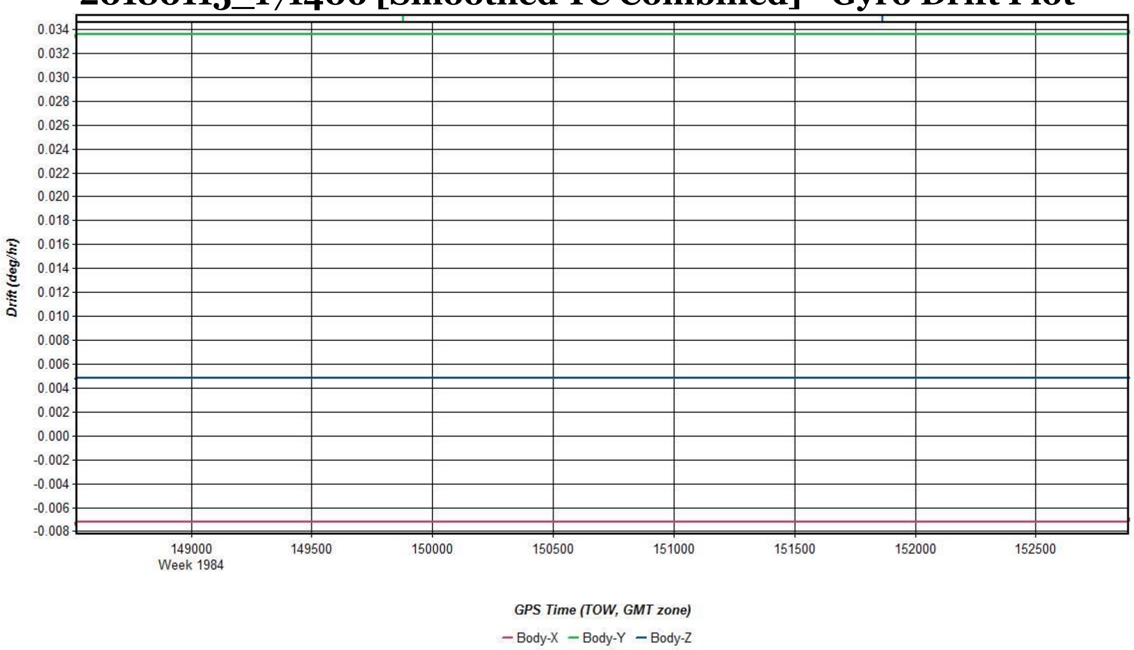
20180115_171406 [Smoothed TC Combined] - Number of Satellites Line Plot



20180115_171406 [Smoothed TC Combined] - Accelerometer Bias Plot



20180115_171406 [Smoothed TC Combined] - Gyro Drift Plot



Processing Summery Information

Project:

N:\Production\LiDAR_Projects\18001_TX_FL16_Addon\Flight_Raw\20180115_171406\Gnss Imu\201801 15_171406.cfg

Solution Type: Combined

Number of Epochs:

Total in GPB file:	8734
No processed position:	3
Missing Fwd or Rev:	2
With bad C/A code:	0
With bad L1 Phase:	0

Measurement RMS Values:

L1 Phase:	0.0183	(m)
C/A Code:	0.71	(m)
L1 Doppler:	0.023	(m/s)

Fwd/Rev Separation RMS Values:

East:	0.005	(m)
North:	0.005	(m)
Height:	0.021	(m)

Fwd/Rev Sep. RMS for dual FWD/REV fixes (8729 occurances):

East:	0.005	(m)
North:	0.005	(m)
Height:	0.021	(m)

Quality Number Percentages:

Q 1:	94.5 %
Q 2:	5.3 %
Q 3:	0.1 %
Q 4:	0.0 %
Q 5:	0.0 %
Q 6:	0.0 %

Position Standard Deviation Percentages:

0.00 - 0.10 m:	100.0 %
0.10 - 0.30 m:	0.0 %
0.30 - 1.00 m:	0.0 %
1.00 - 5.00 m:	0.0 %
5.00 m + over:	0.0 %

Percentages of epochs with DD_DOP over 10.00:

DOP over Tol: 0.0 %

Baseline Distances:

Maximum:	78.494 (km)
Minimum:	11.818 (km)
Average:	52.342 (km)
First Epoch:	77.176 (km)
Last Epoch:	77.963 (km)