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Eastern Shore Virginia QL2 LiDAR BAA

Report Produced for U.S. Geological Survey

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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 USGS Eastern Shore, Virginia 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 were formatted according to tiles with each tile covering an area of 5,000 ft by 5,000 ft. A total of 1375 LAS tiles and 1310 DEMs were produced for the project encompassing an area of approximately 994 sq. miles. Sixty-five tiles are water tiles where no topographic ground is present. DEMs were not produced for all water tiles.

THE PROJECT TEAM

Dewberry served as the prime contractor for the project. In addition to project management, Dewberry was responsible for LAS classification, all LiDAR products, breakline production, Digital Elevation Model (DEM) production, and quality assurance.

Dewberry's Gary 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.

Leading Edge Geomatics completed LiDAR data acquisition and data calibration for the project area.

SURVEY AREA

The project area addressed by this report falls within the Virginia counties of Northampton and Accomack.

DATE OF SURVEY

The LiDAR aerial acquisition was conducted from April 11, 2015 to April 24, 2015.

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: Virginia State Plane South
Units: Horizontal units are in US Survey feet, Vertical units are in US Survey feet.
Geiod Model: Geoid12A (Geoid 12A was used to convert ellipsoid heights to orthometric heights).

LIDAR VERTICAL ACCURACY

For the Eastern Shore Virginia LiDAR Project, the tested $RMSE_z$ of the classified LiDAR data for checkpoints in non-vegetated terrain equaled **6.4 cm (0.21 ft)** compared with the 10 cm (0.33 ft) specification; and the NVA of the classified LiDAR data computed using $RMSE_z$ x 1.9600 was equal to **12.5 cm (0.41 ft)**, compared with the 19.6 cm (0.64 ft) specification.

For the Eastern Shore LiDAR Project, the tested VVA of the classified LiDAR data computed using the 95^{th} percentile was equal to **17.7 cm (0.58 ft),** compared with the 29.4 cm (0.96 ft) 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. Raw Point Cloud Data (Swaths)
2. Classified Point Cloud Data (Tiled)
3. Bare Earth Surface (Raster DEM – IMG Format)
4. Intensity Images (8-bit gray scale, tiled, GeoTIFF format)
5. Breakline Data (File GDB)
6. Independent Survey Checkpoint Data (Report, Photos, & Points)
7. Calibration Points
8. Metadata
9. Project Report (Acquisition, Processing, QC)
10. Project Extents, Including a shapefile derived from the LiDAR Deliverable
11. Other Ancillary Data (Areas identified as temporally changed)

PROJECT TILING FOOTPRINT

One thousand three hundred seventy-five (1375) LAS tiles and one thousand three hundred ten (1310) DEM tiles were delivered for the project. Sixty five (65) tiles contained all water and were removed from DEM processing as these tiles do not contain any topographic data. Dewberry extended the client provided boundary where tiles had ground to include thirty four (34) extra tiles. Each tile's extent is 5,000 feet by 5,000 feet (see Appendix B for a complete listing of delivered tiles and Appendix C for a list of water tiles that were not included in the DEM).

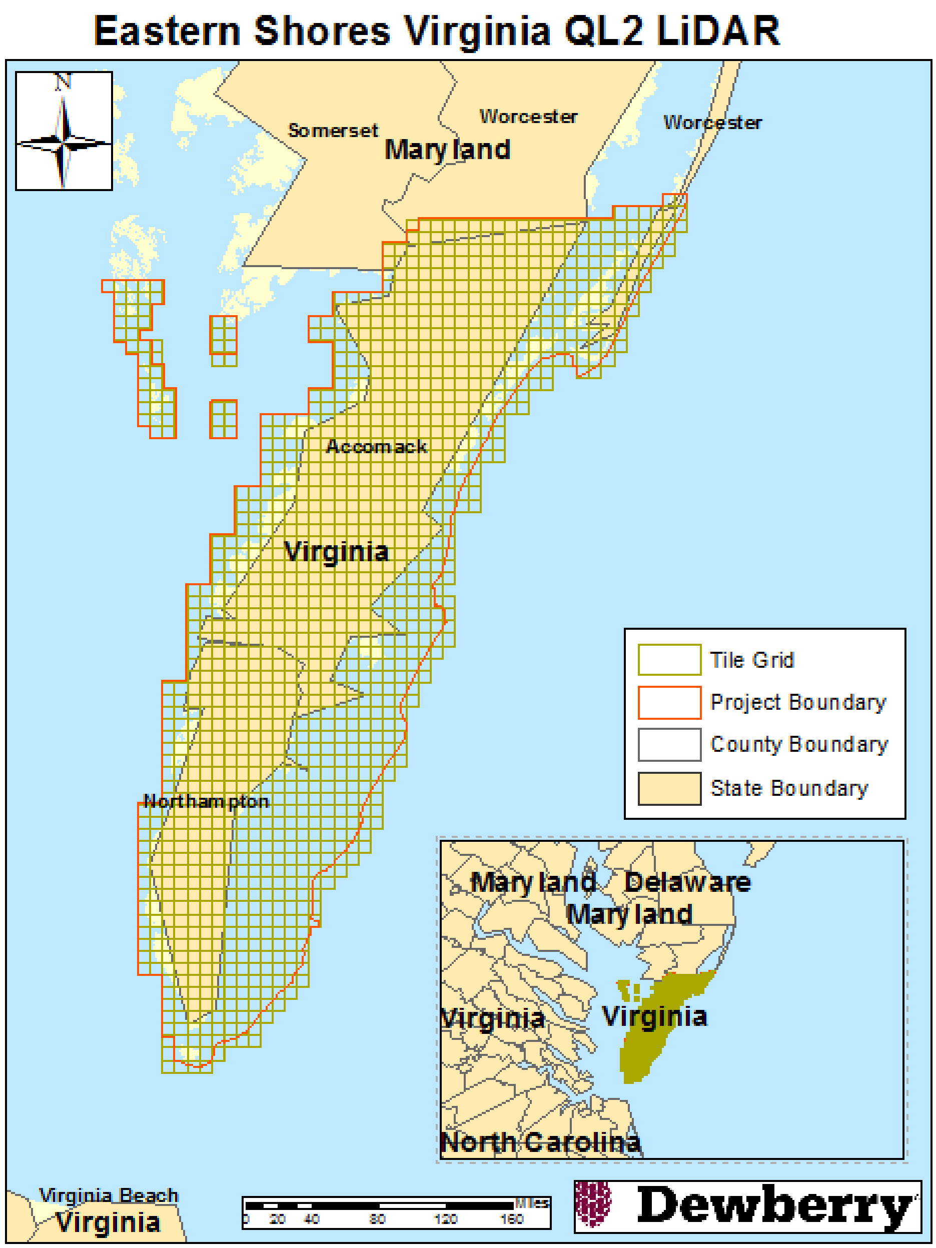


Figure 1 - Project Map

LiDAR Acquisition Report

Dewberry elected to subcontract the LiDAR Acquisition and Calibration activities to Leading Edge Geomatics (LEG). LEG was responsible for providing LiDAR acquisition, calibration and delivery of LiDAR data files to Dewberry.

Dewberry received calibrated swath data from LEG on August 31, 2015.

LIDAR ACQUISITION DETAILS

Leading Edge Geomatics planned 181 passes total for the entire project area and 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, Leading Edge Geomatics followed FEMA's Appendix A "guidelines" for flight planning and, at a minimum, includes the following criteria:

- A digital flight line layout using Track Air 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, LEG will file our flight plans as required by local Air Traffic Control (ATC) prior to each mission.

LEG 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. LEG 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, LEG 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.

Leading Edge Geomatics' LiDAR sensors are calibrated at a designated site located in downtown Fredericton, New Brunswick and are periodically checked and adjusted to minimize corrections at project sites. Both systems were calibrated before departing for the project area.

LIDAR SYSTEM PARAMETERS

Leading Edge Geomatics operated two Cessna 172 (Tail # C-FMNB and C-GUNB) each outfitted with a Riegl 680i LiDAR system during the collection of the entire project. Table 1 illustrates LEG's system parameters for LiDAR acquisition on this project.

Item	Parameter
System	Riegl 680i
Altitude (AGL meters)	1000
Approx. Flight Speed (knots)	100
Scanner Pulse Rate (kHz)	200
Scan Frequency (hz)	78
Pulse Duration of the Scanner (nanoseconds)	5
Pulse Width of the Scanner (m)	0.8994
Swath width (m)	1155
Central Wavelength of the Sensor Laser (nanometers)	1064
Did the Sensor Operate with Multiple Pulses in The Air? (yes/no)	No
Beam Divergence (milliradians)	5.0
Nominal Swath Width on the Ground (m)	1155
Swath Overlap (%)	50
Total Sensor Scan Angle (degree)	60
Computed Down Track spacing (m) per beam	0.66
Computed Cross Track Spacing (m) per beam	0.66
Nominal Pulse Spacing (single swath), (m)	0.66
Nominal Pulse Density (single swath) (ppsm), (m)	2.25
Aggregate NPS (m) (if ANPS was designed to be met through single coverage, ANPS and NPS will be equal)	0.53
Aggregate NPD (m) (if ANPD was designed to be met through single coverage, ANPD and NPD will be equal)	3.45
Maximum Number of Returns per Pulse	7

Table 1: LEG's 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.

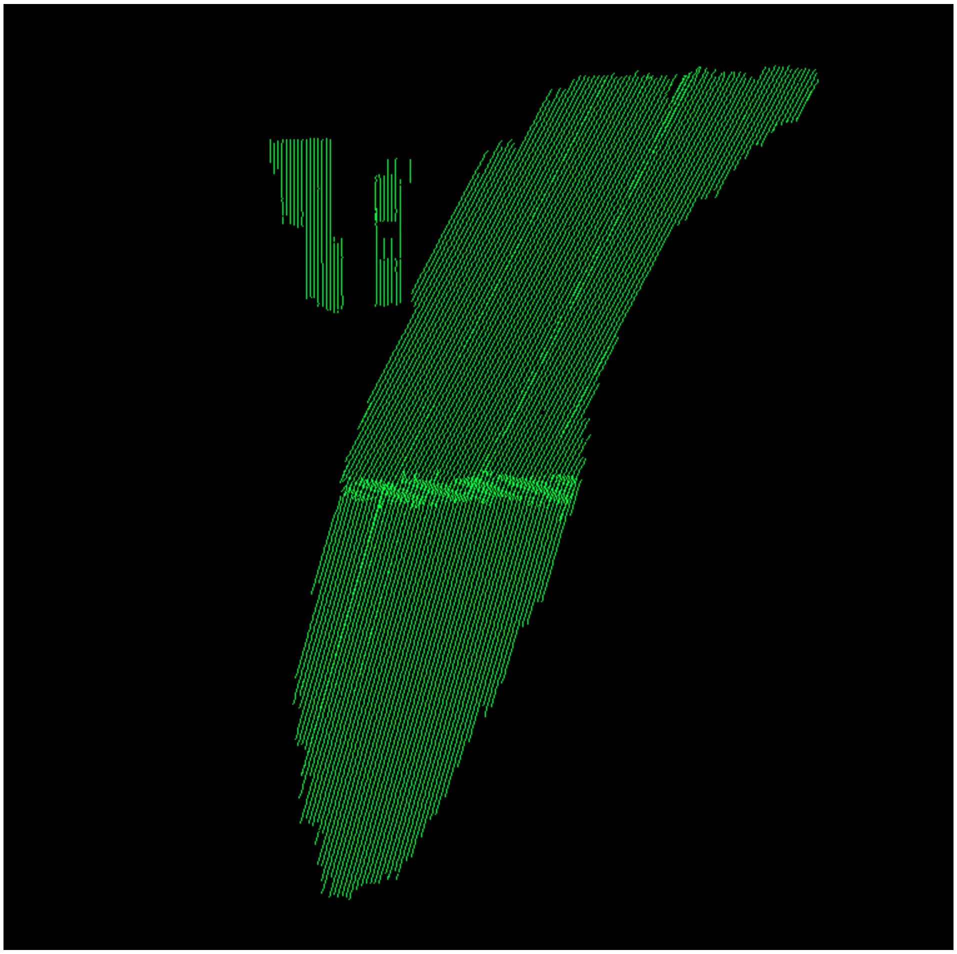


Figure 2: Trajectories as flown by LEG

LIDAR CONTROL

Seven active base stations from Leica Smartnet were employed as well as three existing NGS monuments and one newly established base station were used to control the LiDAR acquisition for the Eastern Shore VA 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	NAD83(2011) State Plane VA South		Ellipsoid Ht (meters)	Orthometric Ht (NAVD88, Geoid12A, ft)
	Easting X (ft)	Northing Y (ft)		
LOYG	12173127.9778	4179657.87	-21.772	91.9320
LOYM	12018715.5239	4006085.1738	6.099	117.2294
LOYW	12251869.1056	3726623.3987	-22.492	97.7099
LOYX	12007914.0974	3629210.1275	2.198	117.9719
LS03	12226769.4158	3456648.5533	-22.006	102.4152
LS09	12390532.8985	3982774.1816	-17.442	101.1909
VAHP	12094608.6656	3552986.7166	-22.683	97.0186

Accomac Reset	12300004.0789	3796950.0510	-23.118	96.8955
Jerry McCready	12245554.5854	3889314.6319	-35.442	83.0352
Nelson	12335638.4318	3901413.8731	-26.809	92.5438
REBAR1	12229779.9442	3642235.0442	-27.753	93.4894

Table 2 – Base Stations used to control LiDAR acquisition

AIRBORN GPS KINEMATIC

Airborne GPS data was processed using the PosPac kinematic On-The-Fly (OTF) software suite using Applanix Smartbase processing. Flights were flown with a minimum of 6 satellites in view (13° above the horizon) and with a PDOP of better than 4.

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

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 Riegl's RiProcess application. System calibration was conducted prior to the aircraft departing for the project and the initial calibration values are used to position the point cloud. If a calibration error greater than specification is observed within the mission, the roll, pitch and yaw 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.

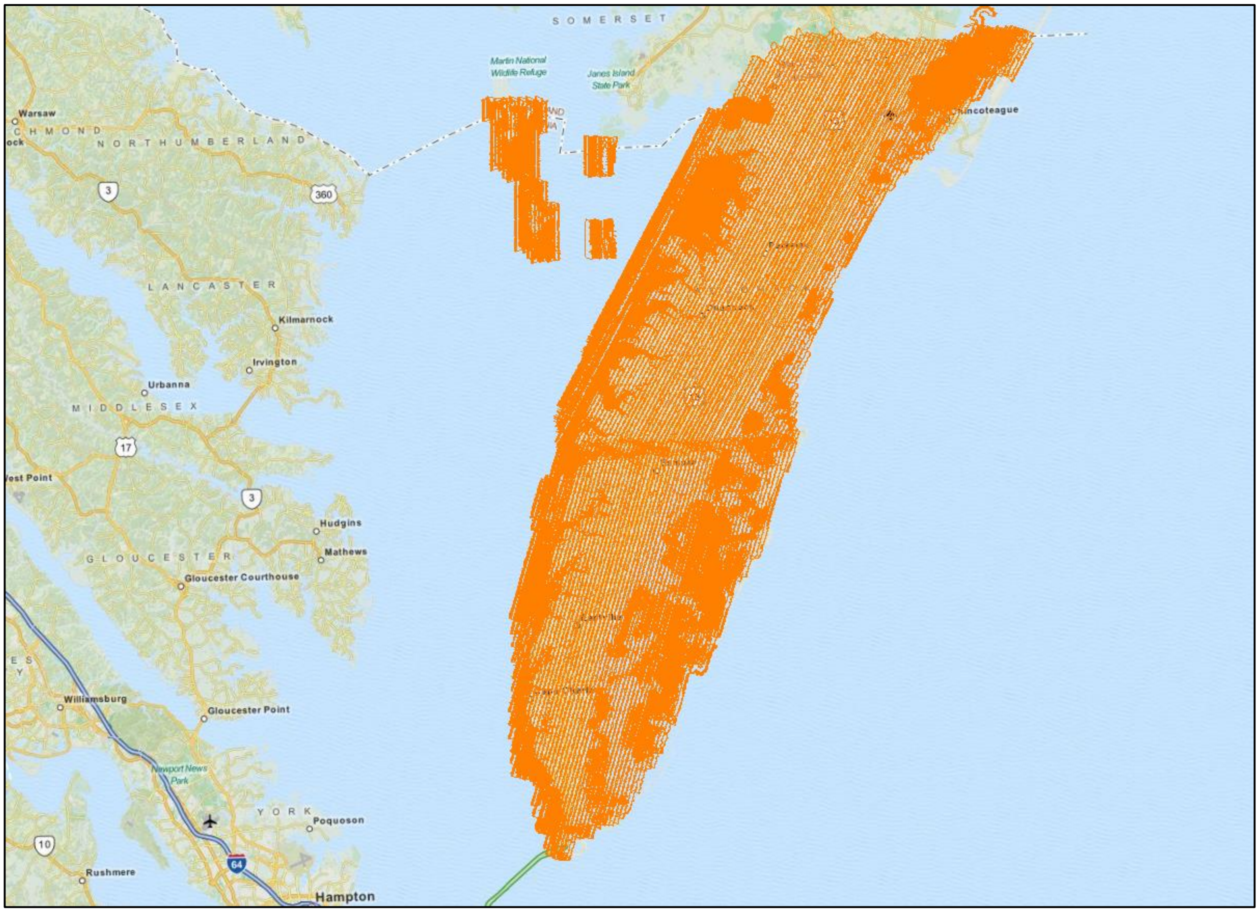


Figure 3 – LiDAR Swath output showing complete coverage.

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 yaw 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 within swath overlap (between adjacent swaths).

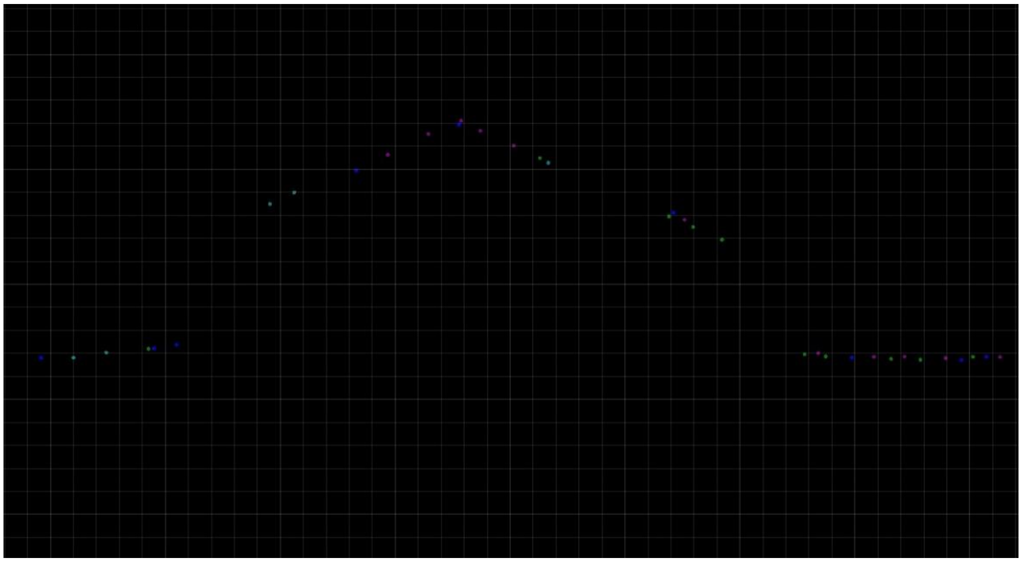


Figure 4 – Profile view colored by flightline showing correct roll and pitch adjustments.

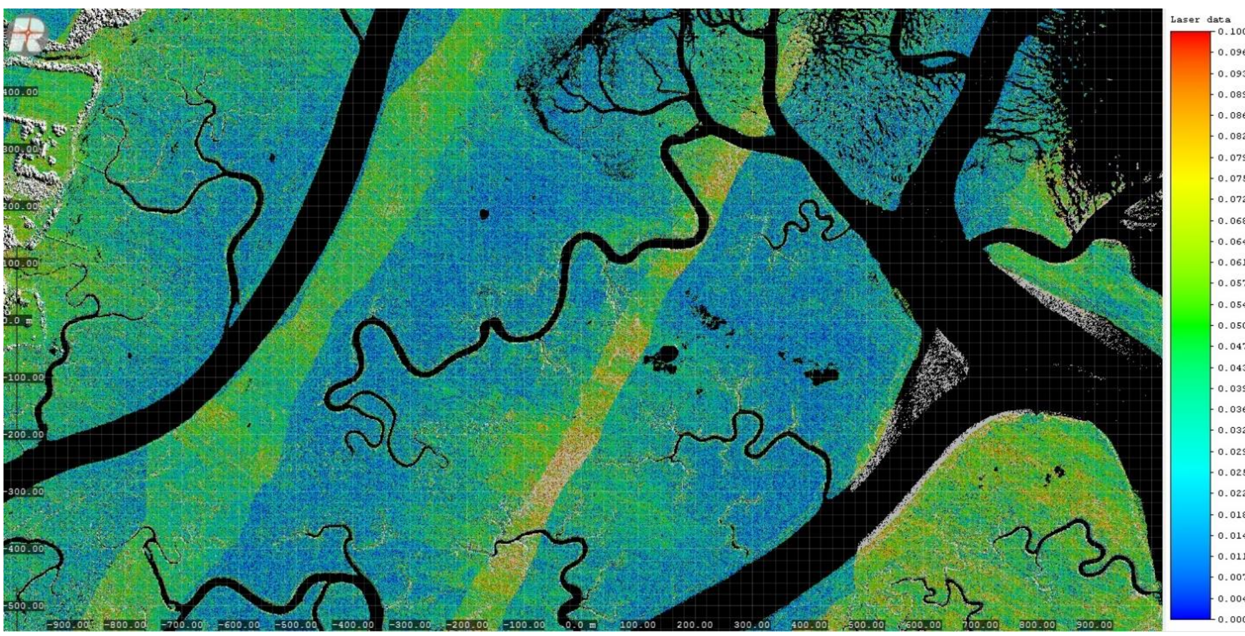


Figure 5 – QC block colored by elevation differences to ensure accuracy at swath edges.

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

PRELIMINARY VERTICAL ACCURACY ASSESSMENT

A preliminary $RMSE_z$ error check is performed by Leading Edge Geomatics at this stage of the project life cycle in the raw LiDAR dataset against GPS static and kinematic data and compared to $RMSE_z$ project specifications. The LiDAR data is examined in open, flat areas away from breaks. Ground control points are collected by RTK survey and compared against the LiDAR ground points and statistics are generated. 23% of the flight lines flown for the project were directly tested against independently collected RTK control.

Prior to delivery to Dewberry, the elevation data was verified internally to ensure it met fundamental accuracy requirements (vertical accuracy NSSDA $RMSE_z$ = 10 cm (NSSDA $Accuracy_z$ 95% = 19.6 cm) or better in open, non-vegetated terrain) when compared to static and kinematic GPS checkpoints. Below is a summary for the test:

The calibrated Virginia LiDAR dataset was tested to 0.133 m (0.438 ft) vertical accuracy at 95% confidence level based on consolidated $RMSE_z$ (0.068m x 1.9600) when compared to 287 RTK collected static check points.

The following are the final statistics for the GPS static checkpoints used by LEG to internally verify vertical accuracy.

Average dz	+0.055 m
Root mean square	0.068 m
Std deviation	0.0402 m

Overall the calibrated LiDAR data products collected by LEG meet or exceed the requirements set out in the Statement of Work. The quality control requirements of LEG quality management program were adhered to throughout the acquisition stage for this project to ensure product quality.

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 LEG, 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-nine (59) 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. Project specifications require a NVA of 19.6 cm (0.64 ft) based on the $RMSE_z$ (10 cm/0.33 ft) x 1.96. The dataset for the Eastern Shore VA LiDAR Project satisfies this criteria. This raw LiDAR swath data set was tested to meet ASPRS Positional Accuracy Standards for Digital Geospatial Data (2014) for a 0.33 ft (10 cm)

$RMSE_z$ Vertical Accuracy Class. Actual NVA accuracy was found to be $RMSE_z$ = 0.20 ft (6.1 cm), equating to +/- 0.39 ft (11.9 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=0.33 ft	NVA –Non-vegetated Vertical Accuracy ($RMSE_z$ x 1.9600) Spec=0.64 ft	Mean (ft)	Median (ft)	Skew	Std Dev (ft)	Min (ft)	Max (ft)	Kurtosis
Non-Vegetated Terrain	59	0.20	0.39	0.00	0.03	-0.22	0.20	-0.48	0.44	-0.20

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

One checkpoint (NVA-54) was removed from the raw swath vertical accuracy testing due to its 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-54 is located in urban 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 this point was removed from the raw swath accuracy calculations. Once the data underwent the classification process, the power lines were removed from the final ground classification and this point could be used in the final vertical accuracy testing for the fully classified LiDAR data. Table 4, below, provides the coordinates for this checkpoint. Table 5, below, provides the usable vertical accuracy results of this checkpoint from the fully classified LiDAR. 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) State Plane VA South		NAVD88 (Geoid 12A)
	Easting X (ft)	Northing Y (ft)	Survey Z (ft)
NVA-54	12226073.01	3628990.53	32.54

Table 4: Checkpoint removed from raw swath vertical accuracy testing.

Point ID	NAD83 (2011) VA State Plane South		NAVD88 (Geoid 12A)		DeltaZ	AbsDeltaZ
	Easting X (ft)	Northing Y (ft)	Z-Survey (ft)	Z-LiDAR (ft)		
NVA-54	12226073.01	3628990.53	32.54	32.26	-0.28	0.28

Table 5: Final tested vertical accuracy for NVA-54 after ground classification.

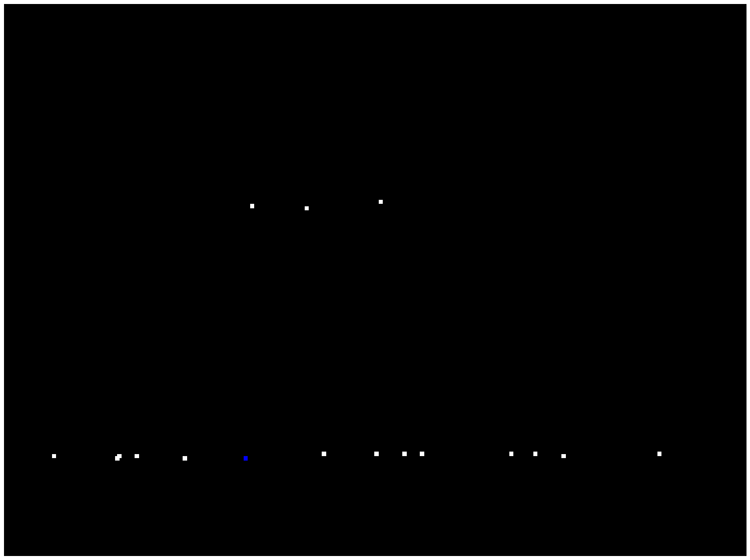


Figure 6 – Urban Terrain checkpoint NVA-54, shown as blue dot, is located underneath power line features. This point was removed from raw swath vertical accuracy testing because above ground features, including power lines, have not yet been classified separately from the ground.

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 -12 cm are colored yellow, and areas in the dataset where overlapping flight lines have elevation differences in each pixel greater than 12 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 12 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 Eastern Shore Virginia are shown in the figure below; this project meets inter-swath relative accuracy specifications.

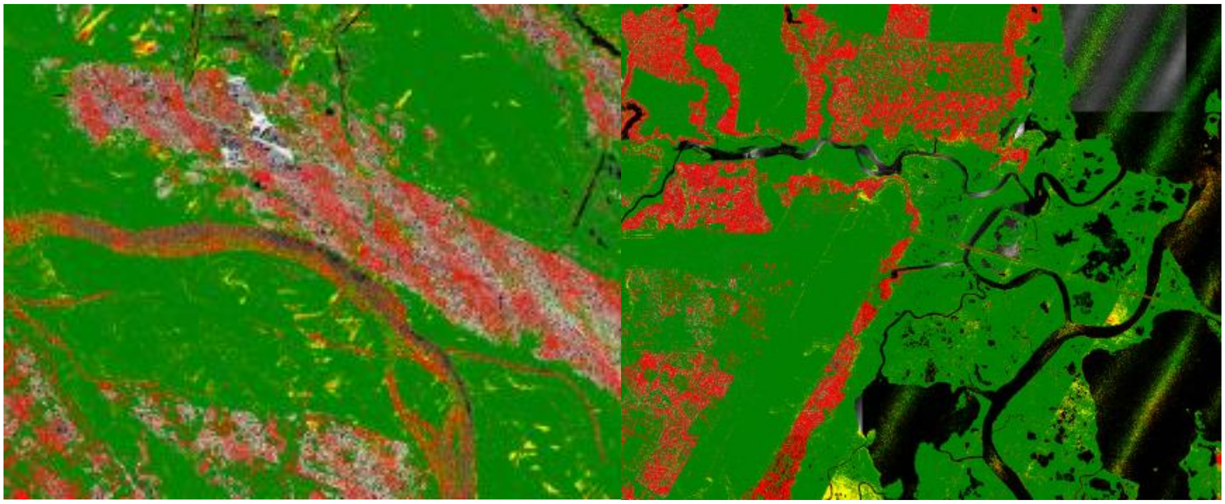


Figure 7– Single return DZ Orthos for the Eastern Shore Virginia Lidar Project. Inter-swath relative accuracy passes specifications.

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 $RMSD_z$ 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 RMSDz or less. The image below shows two examples of the intra-swath relative accuracy of Eastern Shore Virginia; this project meets intra-swath relative accuracy specifications.

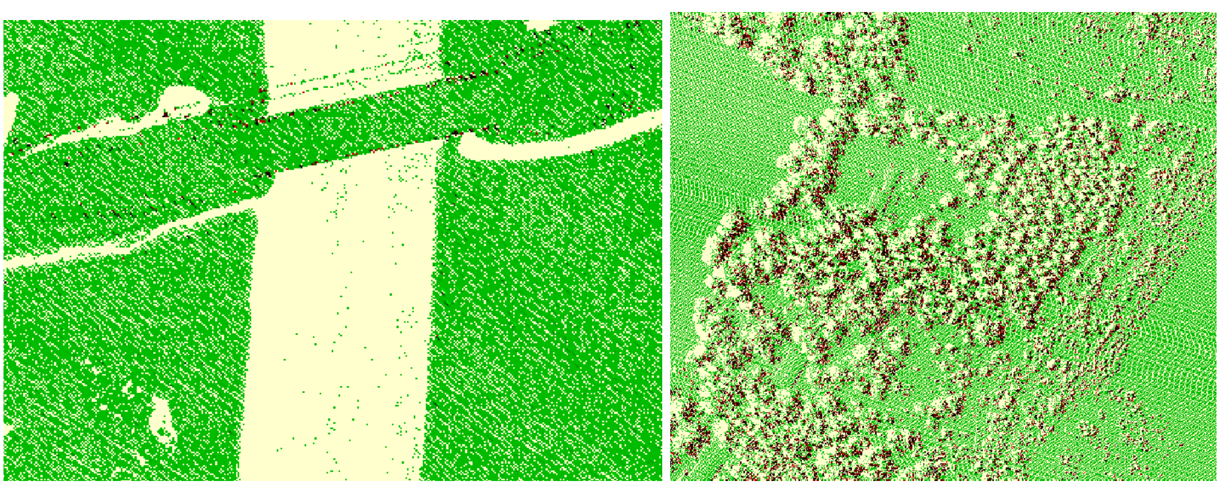


Figure 8–Intra-swath relative accuracy. The left image shows a portion of the dataset; flat, open areas are colored green as they are within 6 cm RMSDz whereas sloped terrain is colored red because it exceeds 6 cm RMSDz, as expected, due to actual slope/terrain change. The right image is a close-up of a flat area. With the exception of f trees (shown in red as the RMSDz 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 Eastern Shore Virginia; no horizontal alignment issues were identified.

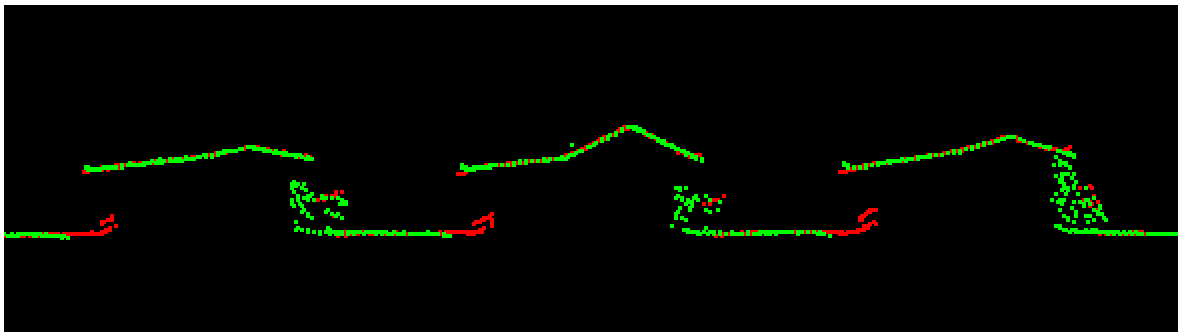


Figure 9– Horizontal Alignment. Two separate flight lines differentiated by color (Red/Green) are shown in this profile. There is no visible offset between these two flight lines. No horizontal alignment issues were identified.

Point Density and Spatial Distribution

The required Aggregate Nominal Point Spacing (ANPS) for this project is no greater than 0.71 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 0.53 meters or an ANPD of 3.45 points per square meter which satisfies the project requirements.

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. QTM scripting is 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.

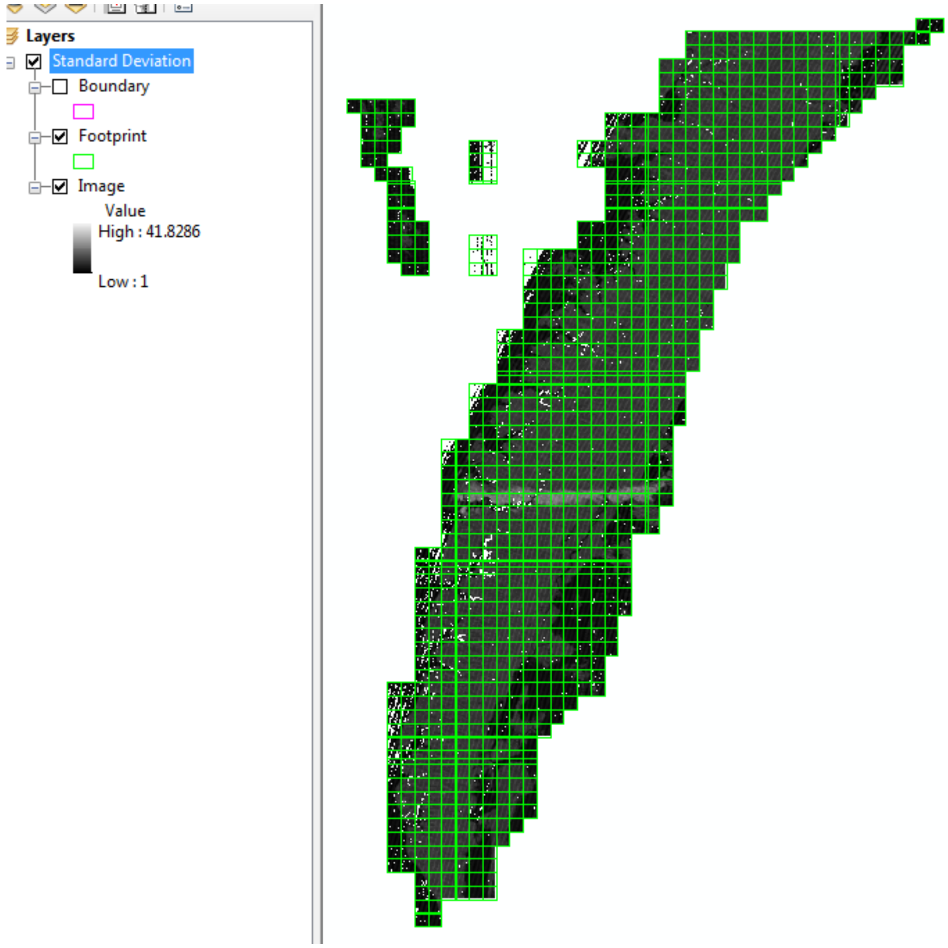


Figure 10– Spatial Distribution. The 2*NPS grid shows all tiles contain at least one LiDAR point. All no data pixels are within water bodies and are acceptable data voids.

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 (bare earth points identified as Model Key Points are flagged with the Model Key Point bit)
- 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, the LAS files were then converted from LAS v1.2 to LAS v1.4 using GeoCue software. At this time, 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

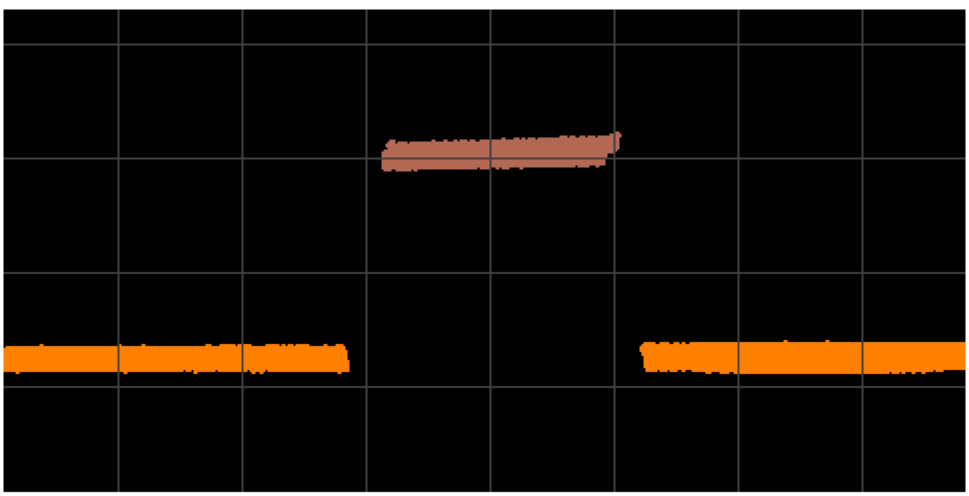
The following sections describe common types of issues identified in LiDAR data and the results of the visual review for Eastern Shore VA LiDAR project.

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 Eastern Shore Virginia LiDAR project.

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.



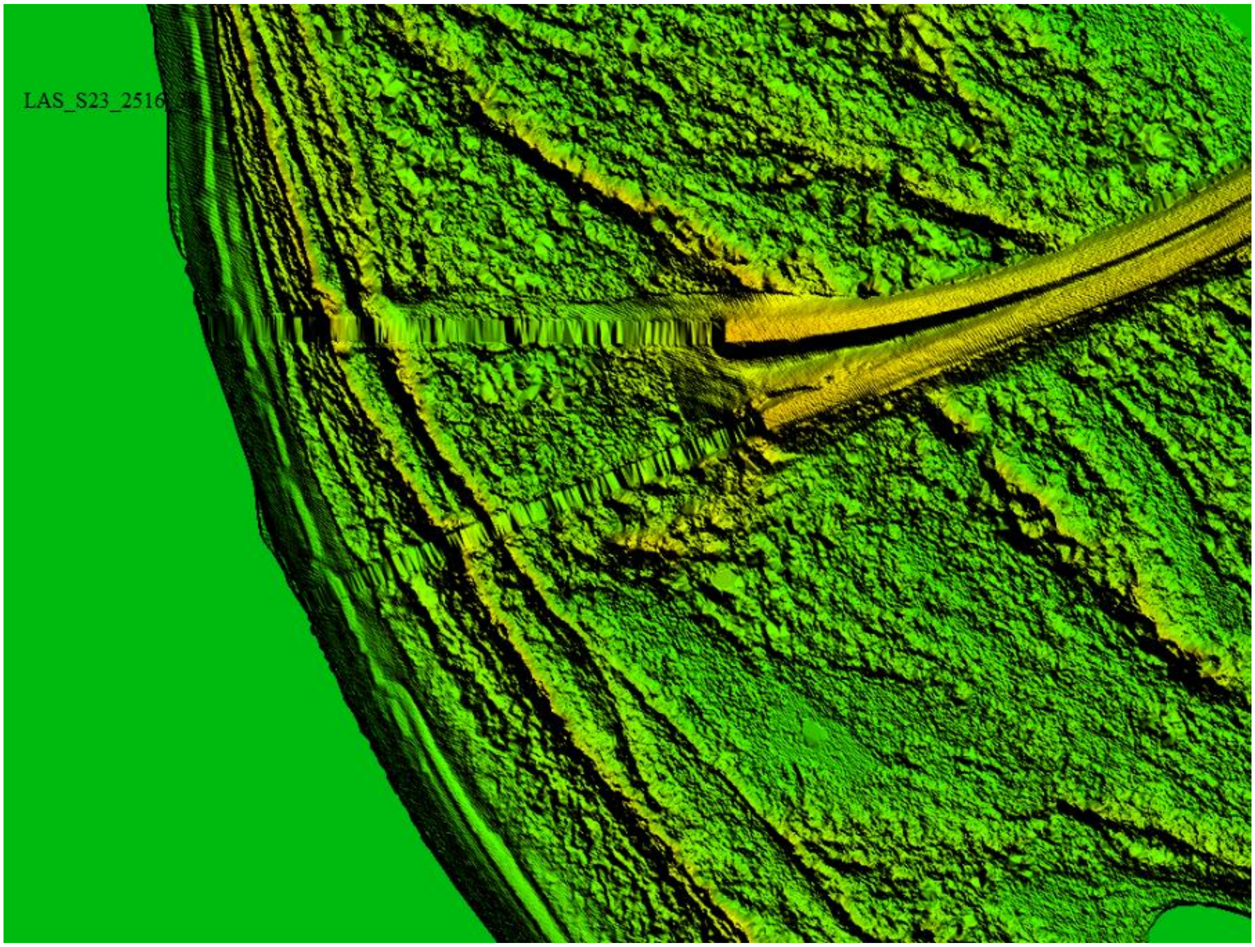


Figure 11 – Tile number DEM_S23_2516_30. The DEM in the bottom view shows an area where a bridge has been removed from ground. The surface model must make a continuous model and in order to do so, points are connected through interpolation. This results in less detail where the surface must be interpolated. 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 bridge deck (brown).

Culverts

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.

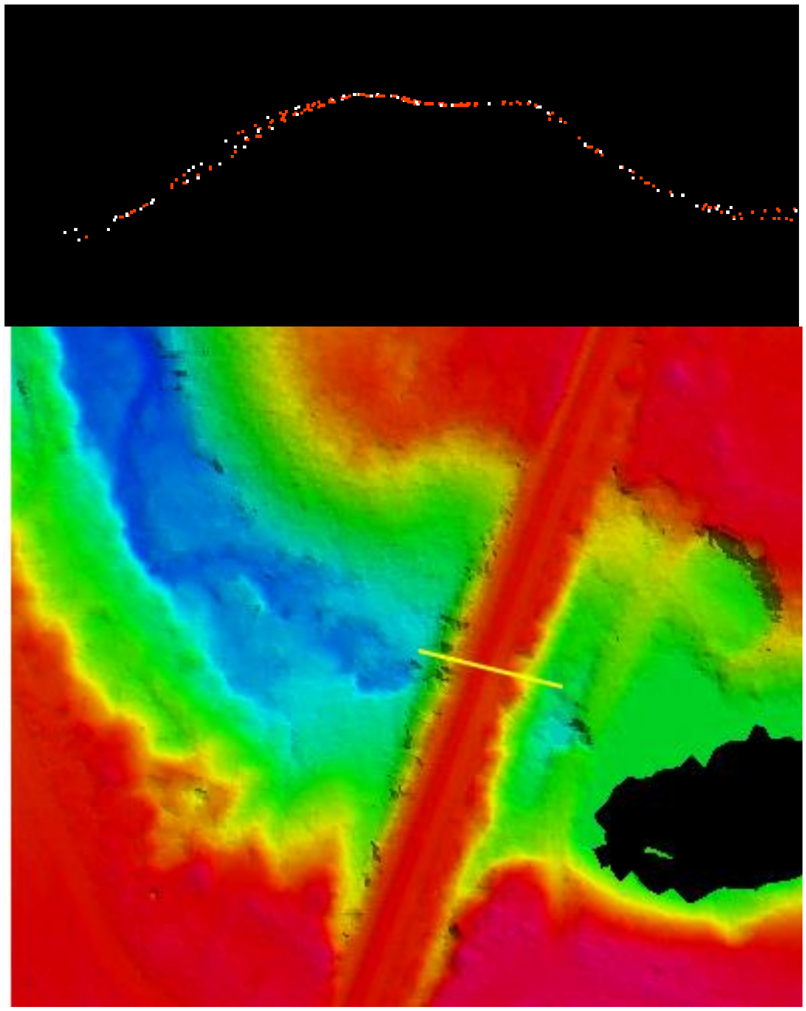


Figure 12– Tile number DEM_S23_2426_20. Profile with points colored by class (class 1=white, class 2=orange, model key point=red) is shown in the top view and the DEM is shown in the bottom view. This culvert remains in the bare earth surface. Bridges have been removed from the bare earth surface and classified to class 17.

Dirt Mounds

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

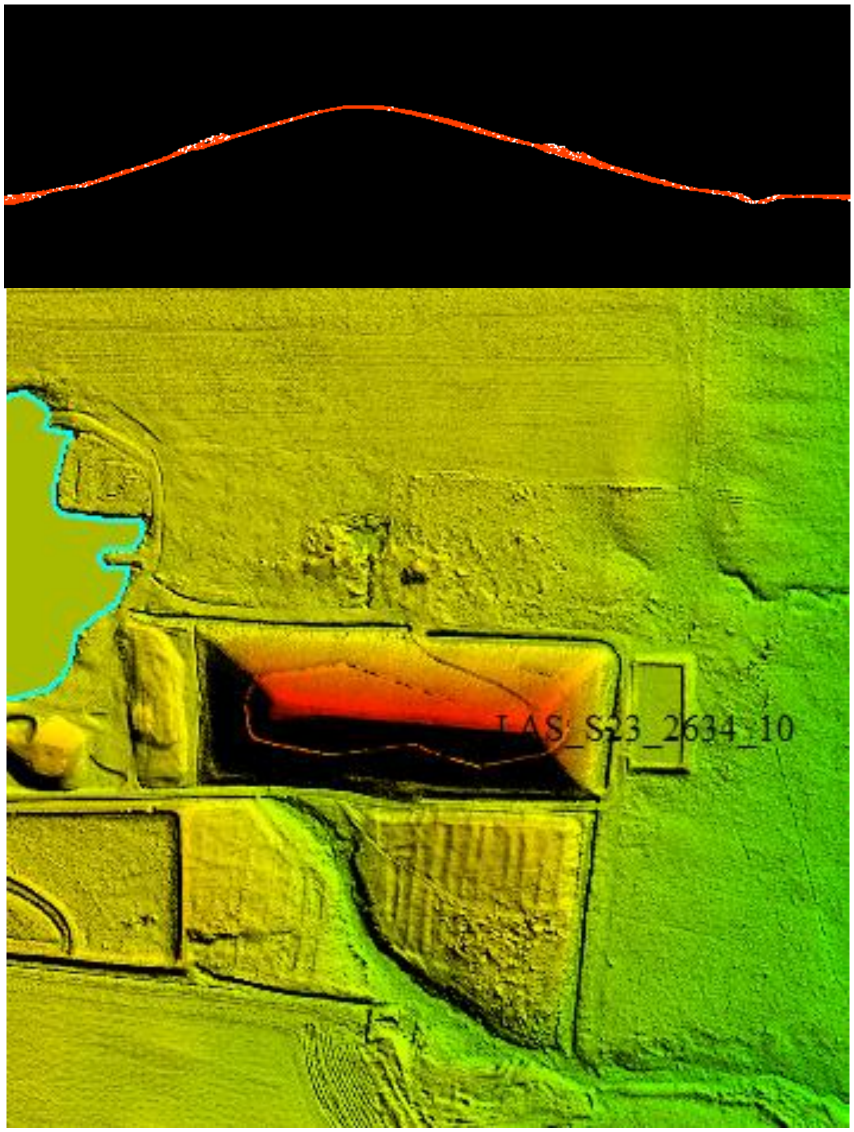


Figure 13 - Tile LAS_S23_2634_10. Profile with the points colored by class (unclassified points are white, ground points are orange) is shown in the top view and a DEM of the surface is shown in the bottom view. These features are correctly included in the ground classification.

Elevation Changes within Tidal Water Bodies

While water bodies are flattened in the final DEMs, tidal areas can have changes in elevation due to tidal fluctuations. Dewberry has reviewed the DEMs to ensure that these changes in elevation due to tidal fluctuations are shown from bank to bank. These changes are often shown as steps to reduce the presence of artifacts. An example is shown below.

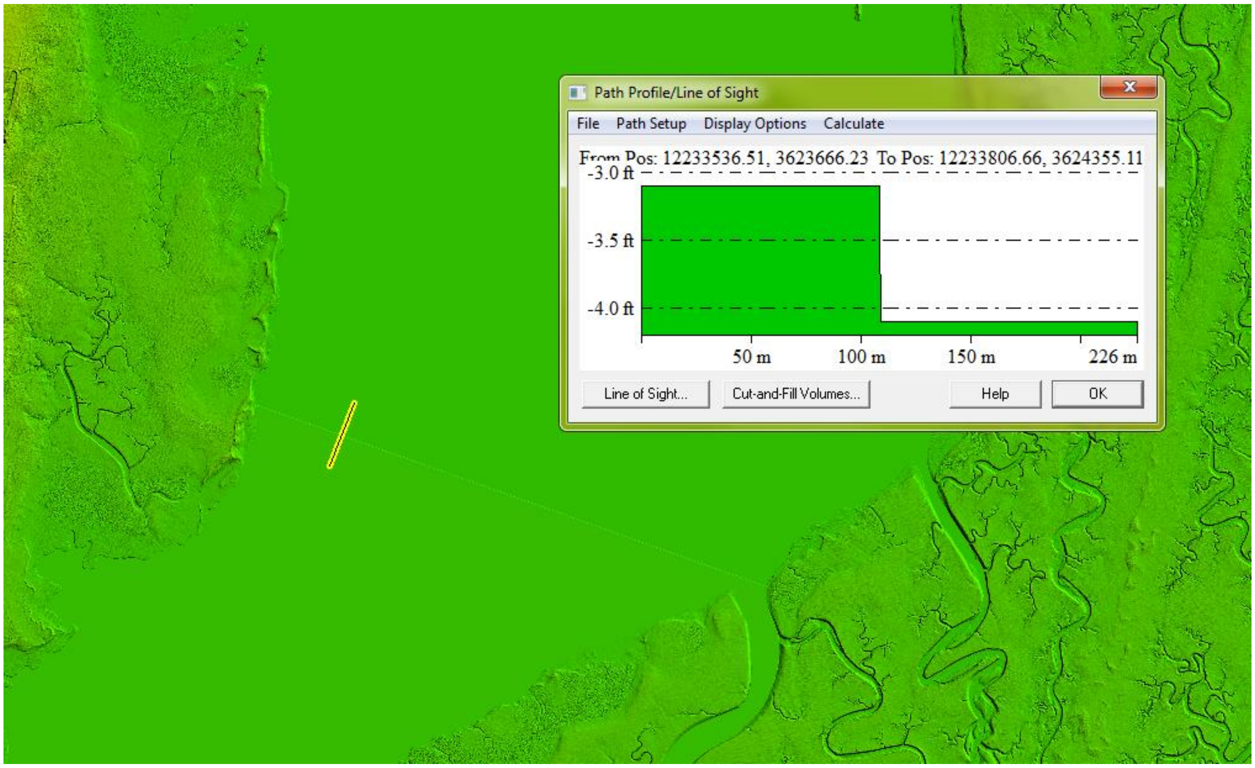


Figure 14 – Tiles DEM_S23_2632_10 and DEM_S23_2632_40. Elevation change in a tidal water body due to tidal fluctuations has been stair stepped. The steps are flat from bank to bank.

Flightline Ridges

Ridges occur when there is a difference between the elevations of adjoining flight lines or swaths. Some flightline ridges are visible in the final DEMs but they do not exceed the project specifications and the overall relative accuracy requirements for the project area have been met. An example of a visible ridge that is within tolerance is shown below.

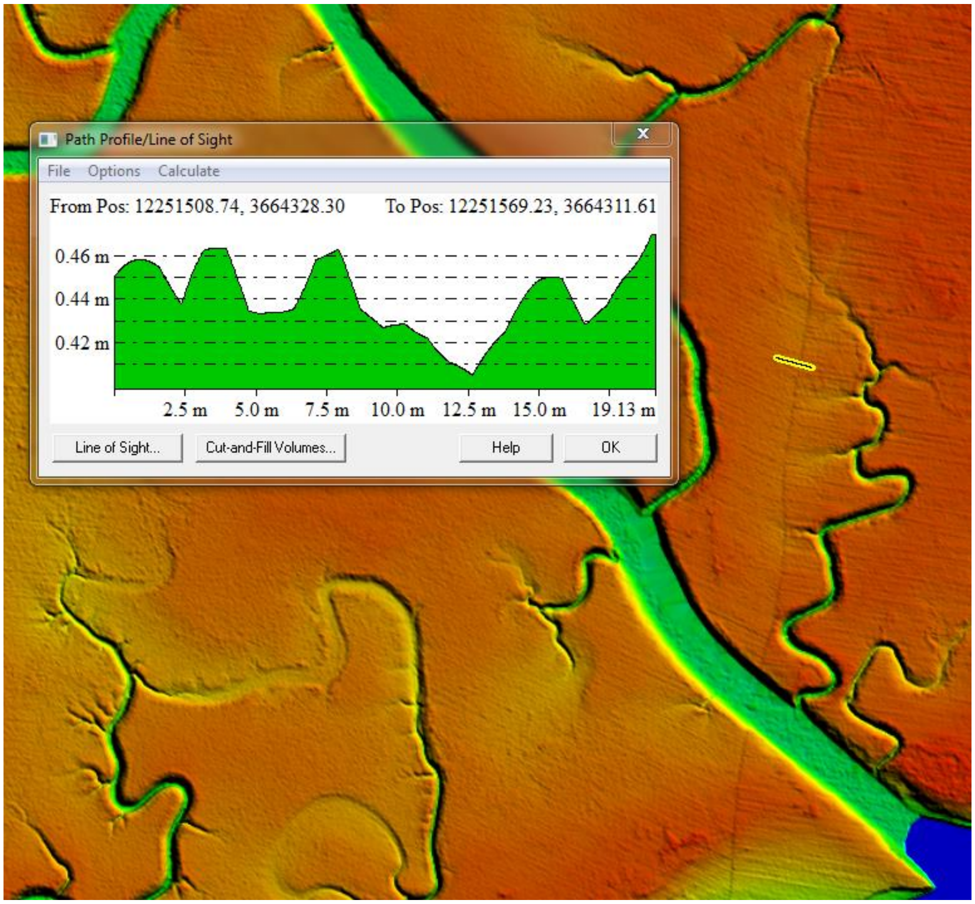


Figure 15– Tile number DEM_S23_2656_10. The flight line ridge is less than 8 cm. Overall, the Eastern Shore Virginia LiDAR data meets the project specifications for 8 cm RMSDz relative accuracy requirement.

Temporal Changes

Because the Eastern Shore Virginia LiDAR project includes data from the Sandy Topobathy project, there are some temporal differences between the areas collected at different times. The majority of temporal differences are found along water or hydrographic features, but some changes were noted on terrestrial features as well. The most common temporal changes observed were along hydrographic features, most notably along the eastern coastal side that included the Sandy data. In that area, adjoining flight lines were from different collection time windows and individual flight lines may have been flown at different tide stages.

The temporal differences between the Sandy data and the data collected by LEG also appear in many water bodies that were too small for the Eastern Shore hydro flattening requirements. . In these small water features, Sandy topobathy data that was classified as bathy bottom was reclassified to ground in order to match this project's classification schema (per USGS guidance). . Sandy was collected using a green sensor which can penetrate the water surface and reach the bottom of water bodies, where LEG used a NIR sensor which generally cannot penetrate the water surface. Overlapping bathy bottom (now ground) points from the Sandy data and points classified as ground along the water surface from LEG data give these areas a rough texture in the DEMs.

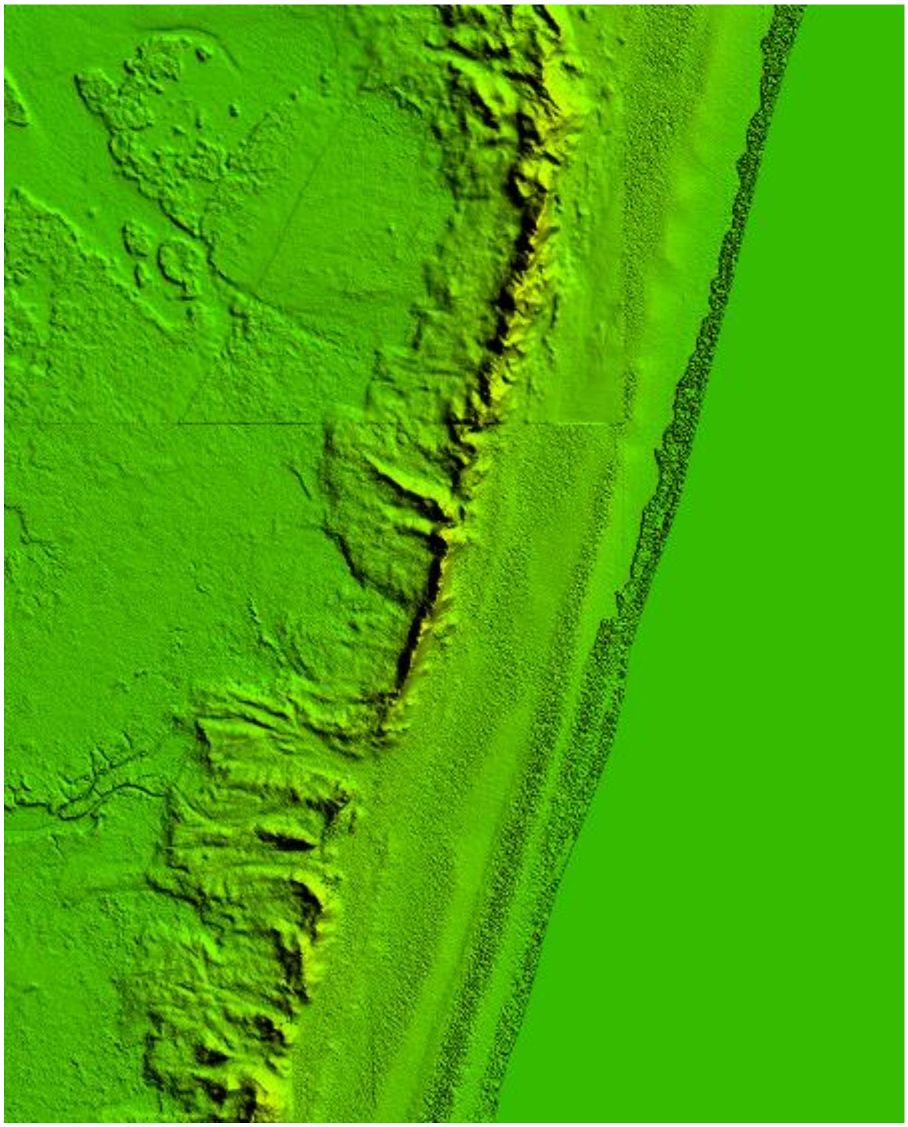


Figure 16- Tile number DEM_S23_3729_40 shows a temporal ridge due to temporal changes between the Sandy/LEG datasets and textured tidal areas due to different overlapping grounds in the Sandy/LEG datasets caused by LIDAR sensor differences.

Figure 17- This image is an example from DEM_S23_3728_10 showing textured ground in a river smaller than the minimum project requirements for hydro flattening. This textured ground is caused by overlapping bathy bottom (now ground due to reclassification of Sandy data to meet the Eastern Shore classification schema) points mixed in with the LEG NIR points that are along the water surface.

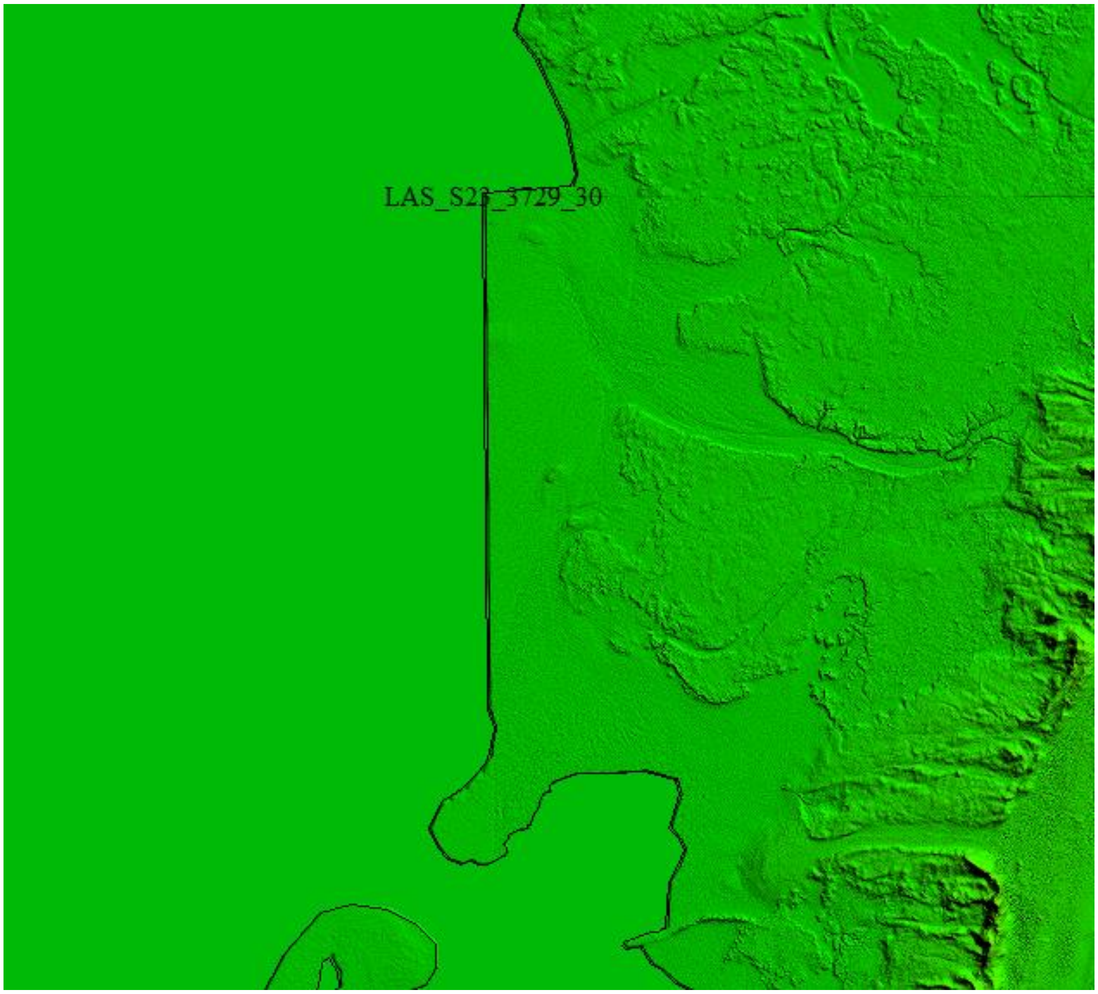


Figure 18- Tile DEM_S23_3729_30 shows a temporal difference where the Eastern Shore LEG data meets the Sandy data. The straight vertical line between the hydro flattened area and the terrestrial area is the dividing line between the Sandy topobathy data and the data collected by LEG. This area was submerged in the area collected by LEG and was not submerged in the Sandy data.

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		
Validation	**Requirement**	**Pass/Fail**
LAS Version	1.4	Pass

Point Data Format	Format 6	Pass
Coordinate Reference System	NAD83 (2011) State Plane Virginia South, US Survey feet and NAVD88 (Geoid 12A), US Survey feet	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 (includes model key point bit) 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 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, one hundred thirteen (113) check points were surveyed for the project and are located within bare earth/open terrain, grass/weeds/crops, brush/low trees, 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) State Plane VA South		NAVD88 (Geoid 12A)
	Easting X (ft)	Northing Y (ft)	Elevation (ft)
NVA-1	12196414.01	3884364.651	1.339
NVA-2	12207349.4	3834754.755	3.4
NVA-10	12307410.12	3856666.261	1.986
NVA-12	12336260.66	3830310.758	15.683
NVA-14	12277689.67	3814839.19	3.29
NVA-15	12311495.71	3817405.053	41.106
NVA-16	12320051.31	3795915.182	4.25
NVA-17	12302530.6	3809832.272	38.898
NVA-18	12277752.73	3794462.14	13.767
NVA-19	12268180.43	3799251.427	4.438
NVA-21	12306616.78	3786617.331	18.905
NVA-22	12304276.41	3770432.922	8.151
NVA-24	12265368.17	3782487.624	9.538
NVA-26	12242395.7	3770064.715	3.58
NVA-29	12280088.9	3742835.676	8.541
NVA-30	12266728.44	3742757.88	32.977
NVA-31	12246774.66	3747788.886	22.639
NVA-32	12229848.1	3739447.722	2.877
NVA-34	12258548.61	3715952.41	28.943
NVA-36	12230736.5	3730286.178	4.388

NVA-37	12243200.41	3723008.043	23.504
NVA-41	12228145.56	3712527.147	18.859
NVA-44	12241632.84	3676363.976	28.837
NVA-45	12216293.66	3688645.459	10.567
NVA-46	12221336.04	3678925.913	17.969
NVA-49	12224380.96	3659206.754	28.065
NVA-53	12210752.83	3615608.025	7.971
NVA-55	12216133.33	3603594.973	34.74
NVA-56	12223934.22	3601143.623	26.158
NVA-60	12281896.39	3870410.577	5.572
NVA-3	12334426.97	3906508.754	20.499
NVA-4	12369437.32	3906210.864	31.448
NVA-5	12373394.91	3878728.478	4.061
NVA-6	12353618.26	3876879.63	32.149
NVA-7	12314423.94	3882489.387	6.346
NVA-8	12345098.85	3862707.771	32.21
NVA-9	12346680.11	3852015.627	16.79
NVA-11	12331979.08	3853514.729	46.074
NVA-13	12315462.53	3841739.518	22.503
NVA-20	12290033.72	3791572.158	42.809
NVA-23	12283996.66	3777497.908	49.834
NVA-25	12255263.66	3774938.485	5.846
NVA-27	12275043.71	3759251.252	41.386
NVA-28	12296139.1	3754969.311	7.603
NVA-33	12258997.98	3728527.241	36.707
NVA-35	12243354.19	3734016.408	3.685
NVA-38	12247956.65	3707433.084	34.406
NVA-39	12250334.48	3698943.637	31.473
NVA-40	12238260.51	3703313.748	20.839
NVA-42	12228154.32	3697406.637	17.692
NVA-43	12240646.92	3689370.087	38.612
NVA-47	12231449.38	3659656.001	33.422
NVA-48	12208510.7	3652516.165	7.497
NVA-50	12223921.46	3645687.163	37.852
NVA-51	12221305.89	3638302.328	34.492
NVA-52	12205446.95	3629616.668	6.562
NVA-54	12226073.01	3628990.534	32.537
NVA-57	12214970.71	3594092.821	8.201
NVA-58	12226011.25	3580164.399	4.476
NVA-59	12220288.01	3567530.256	11.877
VVA-1	12210869.02	3837260.505	4.135
VVA-2	12236321.16	3824165.676	3.116
VVA-3	12233408.01	3859989.622	1.099
VVA-4	12338668.43	3894495.05	20.771
VVA-7	12377291.99	3879672.008	0.6
VVA-9	12312473.53	3903657.646	2.338
VVA-14	12297561.5	3843886.826	3.343
VVA-18	12305072.33	3830869.906	10.257
VVA-22	12321485.89	3808493.47	16.842
VVA-23	12291371.66	3803110.679	28.619
VVA-25	12269736.36	3805351.042	2.027
VVA-28	12292884.15	3782116.367	39.068
VVA-31	12241977.85	3766097.419	1.751

VVA-32	12274513.98	3770795.67	44.902
VVA-37	12236722.14	3740061.662	9.355
VVA-39	12259551.45	3719746.021	35.052
VVA-42	12222679.06	3708229.622	13.831
VVA-45	12220150.12	3669478.605	14.623
VVA-47	12218067.08	3633610.889	19.259
VVA-49	12221502.61	3593117.253	29.833
VVA-50	12220156.54	3567729.962	8.009
VVA-5	12322375.94	3880672.953	12.56
VVA-8	12358846.02	3900342.753	34.53
VVA-11	12318748.36	3870457.619	8.074
VVA-12	12335835.7	3866204.032	38.718
VVA-13	12313785.22	3856334.676	2.943
VVA-15	12343159.59	3854836.177	36.85
VVA-16	12327955.78	3830528.774	38.172
VVA-17	12319036.17	3842443.411	34.005
VVA-19	12288047.43	3818747.39	4.534
VVA-20	12303792.13	3820309.494	33.22
VVA-29	12266605.35	3791388.973	7.142
VVA-34	12280632.57	3753003.122	14.68
VVA-35	12262785.3	3755704.689	38.762
VVA-40	12247952.03	3729283.816	27.815
VVA-43	12250914.5	3700751.503	29.751
VVA-46	12226217.62	3651851.475	36.3
VVA-6	12301163.36	3873369.638	3.217
VVA-10	12284958.32	3874257.928	2.035
VVA-21	12319528.03	3819093.11	39.17
VVA-24	12274428.18	3812682.652	1.626
VVA-26	12315572.41	3791983.98	13.646
VVA-27	12304941.06	3774212.276	6.103
VVA-30	12257694.47	3784904.872	4.161
VVA-33	12294155.26	3758794.49	7.203
VVA-36	12239523.07	3749853.325	6.545
VVA-38	12273452.75	3731273.35	4.065
VVA-41	12226095.56	3721904.738	14.083
VVA-44	12231685.78	3692139.913	18.025
VVA-48	12225556.14	3616330.009	31.776
BLT34	12219946.44	3567822.742	3.471
TWC34	12220365.83	3567544.088	4.321
OT34	12220092.62	3567671.947	5.515

Table 6: Eastern Shore VA LiDAR surveyed accuracy checkpoints

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

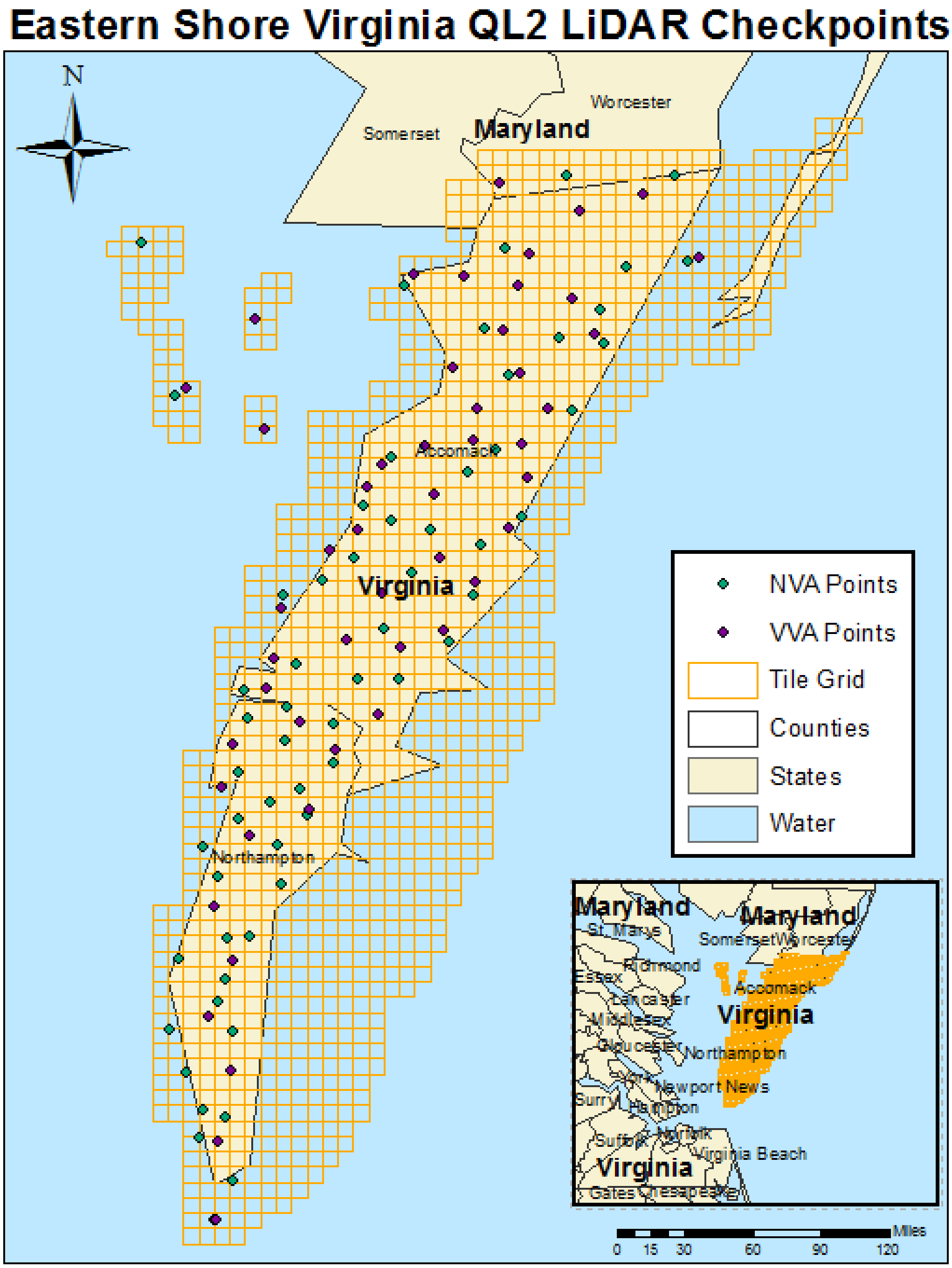


Figure 19 – Location of QA/QC Checkpoints

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 Eastern Shore LiDAR project, vertical accuracy must be 0.64 ft (19.6 cm) or less based on an $RMSE_z$ of 0.33 ft (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 95th percentile error for all checkpoints in all vegetated land cover categories combined. The Eastern Shore VA LiDAR Project VVA standard is 0.96 ft (29.4 cm) based on the 95th percentile. The VVA is accompanied by a listing of the 5% outliers that are larger than the 95th 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	0.64 ft (based on $RMSE_z$ (0.33 ft cm) * 1.9600)
Vegetated Vertical Accuracy (VVA) in all vegetated land cover categories combined at the 95% confidence level	0.96 ft (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=0.64 ft	VVA – Vegetated Vertical Accuracy (95th Percentile) Spec=0.96 ft
NVA	61.00	0.41	
VVA	52.00		0.58

Table 8 – Tested NVA and VVA

This LiDAR dataset was tested to meet ASPRS Positional Accuracy Standards for Digital Geospatial Data (2014) for a 0.33 ft (10 cm) RMSEz Vertical Accuracy Class. Actual NVA accuracy was found to be RMSE$_z$ =0.21 ft (6. 40 cm), equating to +/- 0.41 ft (12.5 cm) at 95% confidence level. Actual VVA accuracy was found to be +/- 0.58 ft (17.7 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 +/- 0.20 ft of the checkpoints elevations, but there were some outliers where LiDAR and checkpoint elevations differed by up to +88 cm.

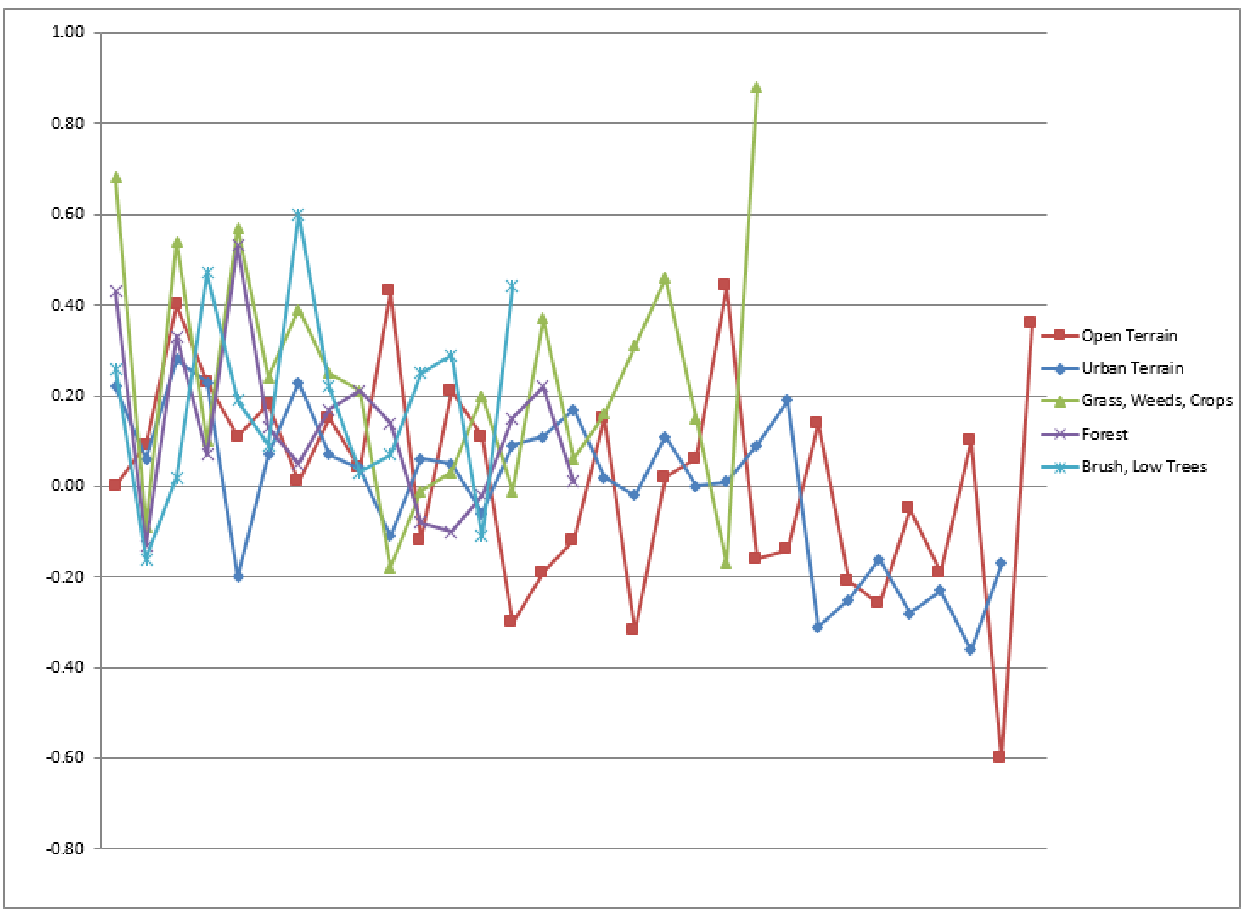


Figure 20 – Magnitude of elevation discrepancies per land cover category

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

Point ID	NAD83 (2011) VA State Plane South		NAVD88 (Geoid 12A)		DeltaZ	AbsDeltaZ
	Easting X (ft)	Northing Y (ft)	Z-Survey (ft)	Z-LiDAR (ft)		
VVA-1	12210869.02	3837260.51	4.14	4.82	0.69	0.69
VVA-30	12257694.47	3784904.87	4.16	4.76	0.60	0.60
TWC34	12220365.83	3567544.09	4.32	5.20	0.88	0.88

Table 9 — 5% Outliers

Table 10 provides overall descriptive statistics.

100 % of Totals	# of Points	RMSEz (ft) NVA Spec=0.33 ft	Mean (ft)	Median (ft)	Skew	Std Dev (ft)	Kurtosis	Min (ft)	Max (ft)
Open Terrain	31	0.24	0.02	0.04	-0.27	0.24	0.23	-0.60	0.44
Urban	30	0.17	0.00	0.04	-0.45	0.18	-0.70	-0.36	0.28
NVA	**61**	**0.21**	**0.01**	**0.04**	**-0.28**	**0.21**	**0.19**	**-0.60**	**0.44**
Tall Weeds and Crops	22	N/A	0.23	0.21	0.58	0.27	0.04	-0.18	0.88
Brush Lands and Trees	14	N/A	0.19	0.21	0.23	0.22	-0.43	-0.16	0.60
Forested and Fully Grown	16	N/A	0.13	0.13	0.62	0.19	0.06	-0.13	0.53
VVA	**52**	**N/A**	**0.19**	**0.17**	**0.66**	**0.24**	**0.28**	**-0.18**	**0.88**

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 -0.60 feet and a high of +0.88 feet, 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 -0.25 feet to +0.25 feet.

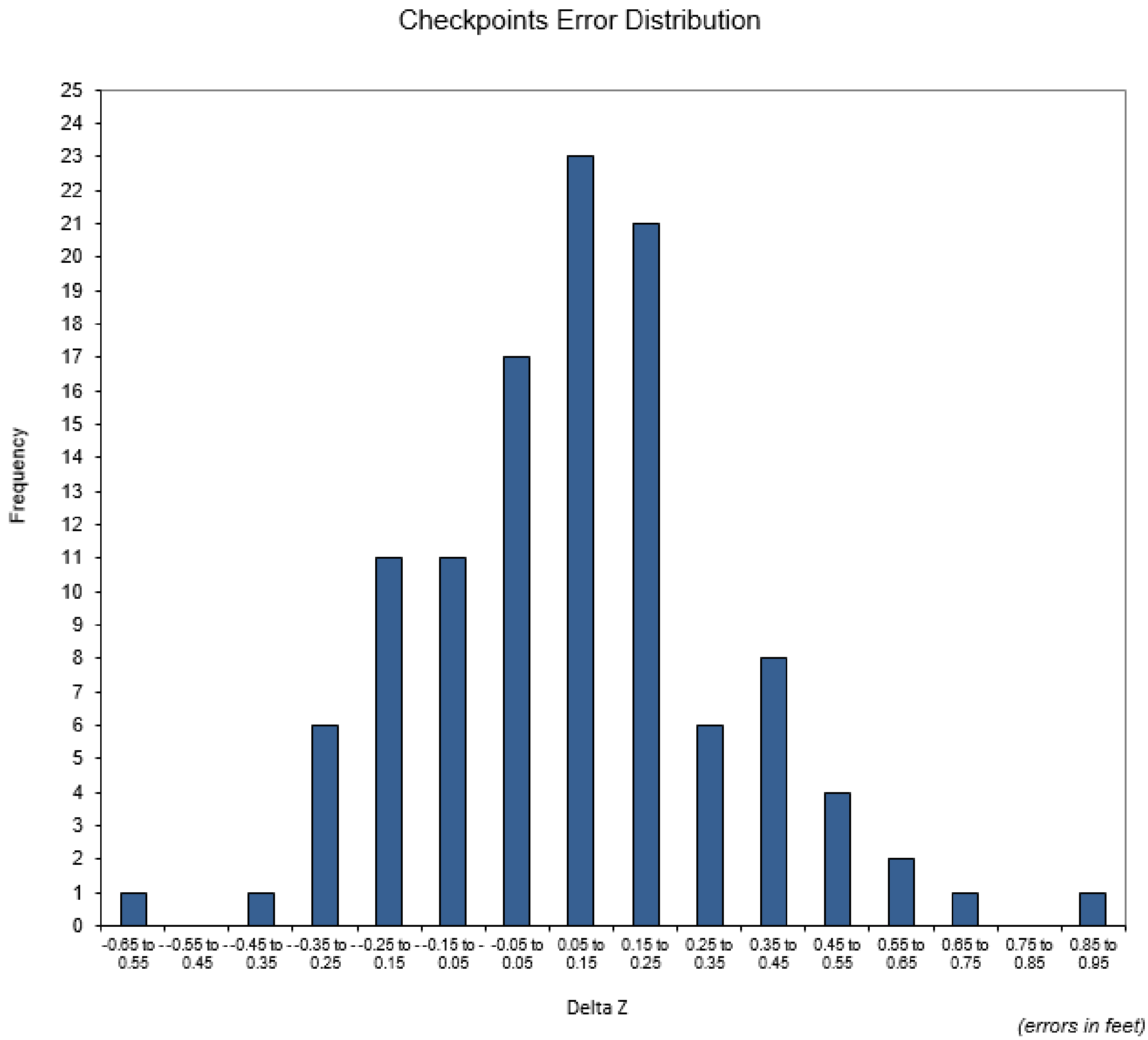


Figure 21 — Histogram of Elevation Discrepancies with errors in feet

Based on the vertical accuracy testing conducted by Dewberry, the LiDAR dataset for the Eastern Shore VA 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

Seventeen 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 seventeen (17) 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.

# of Points	$RMSE_x$ (Spec=1.34 ft)	$RMSE_y$ (Spec=1.34 ft)	$RMSE_r$ (Spec=1.9 ft)	$ACCURACY_r$ ($RMSE_r$ x 1.7308) Spec=3.28 ft
17	0.83	0.91	1.23	2.13

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

Actual positional accuracy of this dataset was found to be RMSEx = 0.83 ft (25.3 cm) and RMSEy = 0.91 ft (27.7 cm) which equates to +/- 2.13 ft (64.9 cm) at 95% confidence level.

Breakline Production & Qualitative Assessment Report

BREAKLINE PRODUCTION METHODOLOGY

Dewberry used GeoCue software to develop LiDAR stereo models of the Eastern Shore VA LiDAR 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 developed by Dewberry to stereo-compile the two types of hard breaklines in accordance with the project's Data Dictionary.

Water bodies are reviewed in stereo and the lowest elevation is applied to the entire water body. Tidal breaklines may show tidal fluctuations but as much ground as possible is modeled in the dataset.

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.

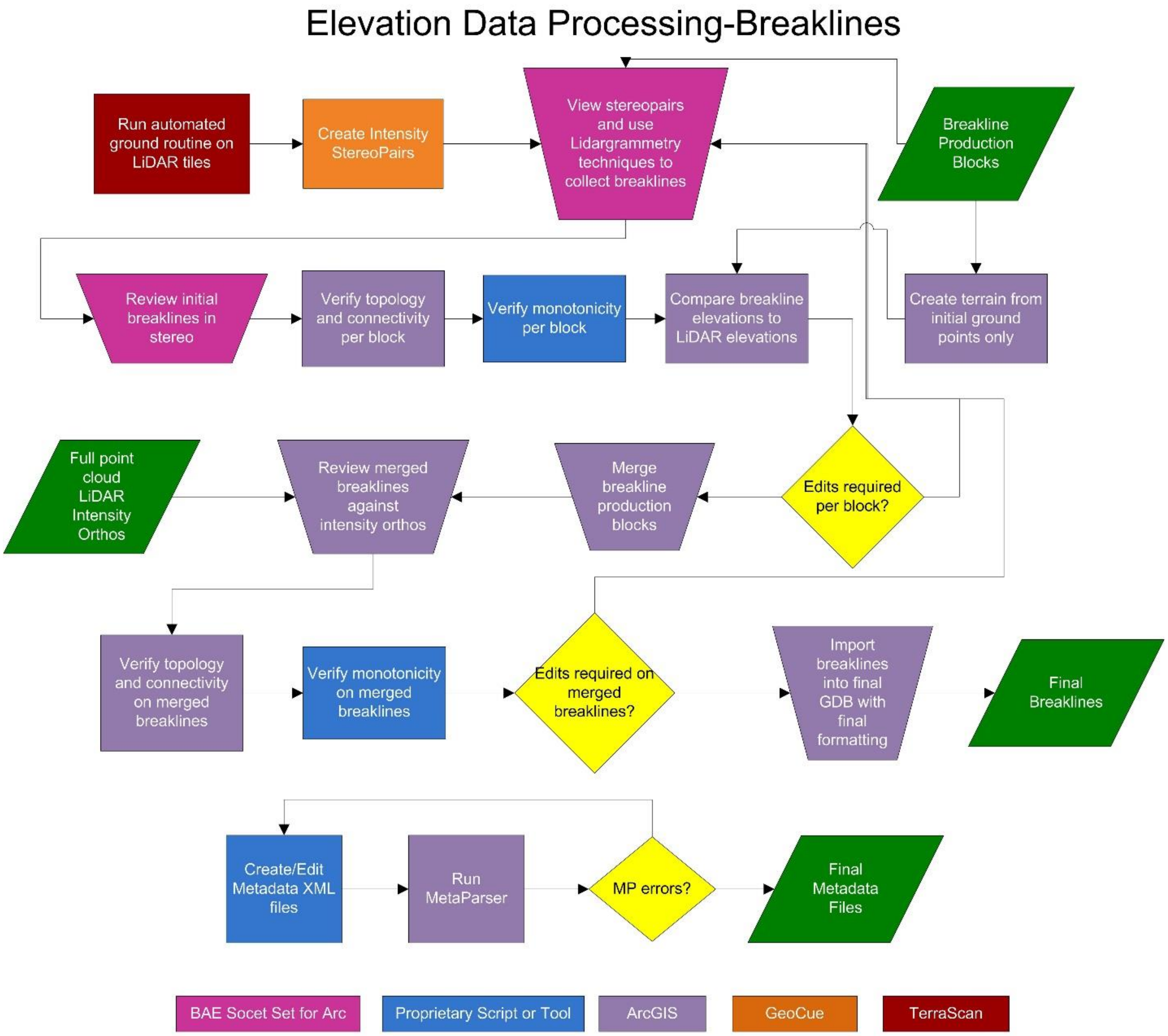


Figure 22- Breakline QA/QC workflow

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 intensity imagery, stereo pairs, 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 all checks-completeness, breakline variance, 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 US Survey feet. The vertical datum shall be referenced to the North American Vertical Datum of 1988 (NAVD 88), Units in US Survey feet Geoid12a shall be used to convert ellipsoidal heights to orthometric heights.

Coordinate System and Projection

All data shall be projected to State Plane Virginia South, Horizontal Units in US Survey feet and Vertical Units in US Survey feet.

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.

Tidal Waters

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

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

Description

This polygon feature class will outline the land / water interface at the time of LiDAR acquisition.

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
TIDAL_WATERS	The coastal breakline will delineate the land water interface using LiDAR data as reference. In flight line boundary areas with tidal variation the coastal shoreline may show stair stepping as no feathering is allowed. Stair stepping is allowed to show as much ground as the collected data permits.	The feature shall be extracted at the apparent land/water interface, as determined by the LiDAR intensity data, to the extent of the tile boundaries. Differences caused by tidal variation are acceptable and breaklines delineated should reflect that change with no feathering. 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. 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. Breaklines shall snap and merge seamlessly with linear hydrographic features.

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 23-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.

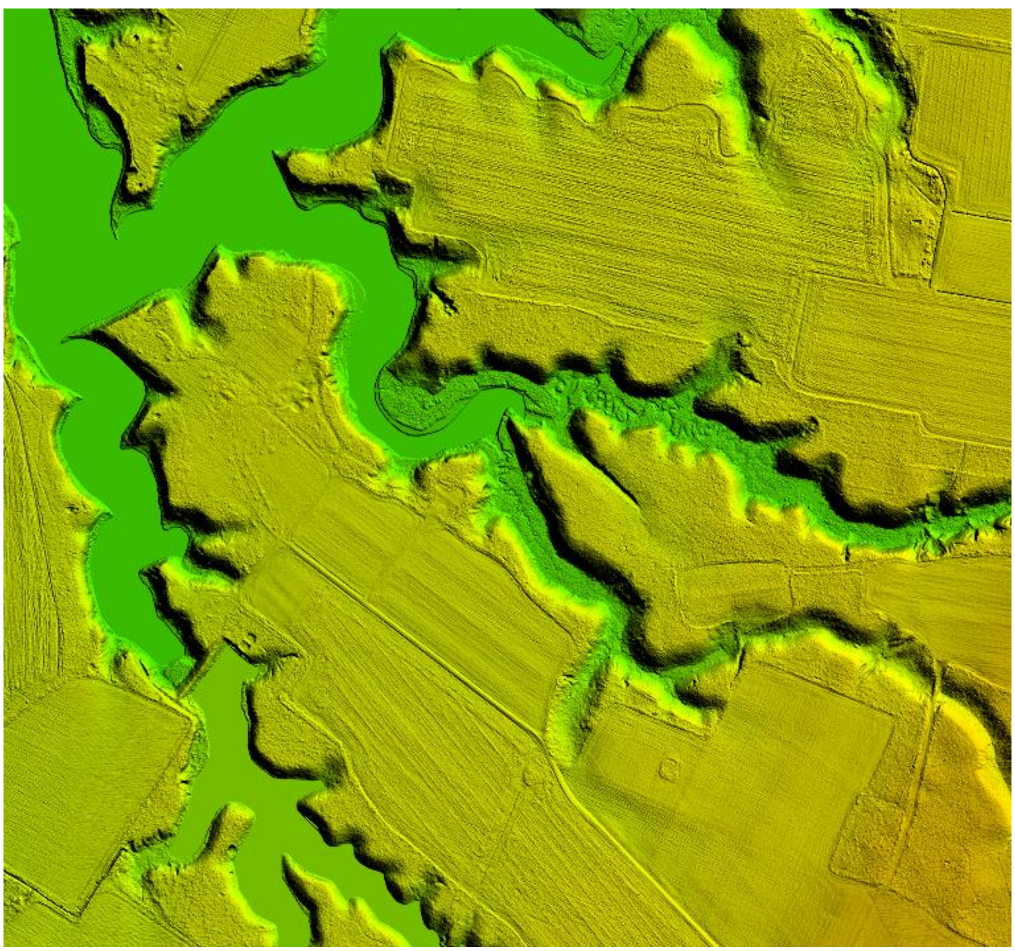


Figure 24-Tile DEM_S23_2627_40. The bare earth DEM

DEM VERTICAL ACCURACY RESULTS

The same 113 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.

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=0.64 ft	VVA – Vegetated Vertical Accuracy (95th Percentile) Spec=0.96 ft
NVA	61.00	0.40	
VVA	52.00		0.60

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 0.33 ft (10 cm) RMSEz Vertical Accuracy Class. Actual NVA accuracy was found to be $RMSE_z$ =0.20 ft (6.10 cm), equating to +/- 0.40 ft (12.19 cm) at 95% confidence level. Actual VVA accuracy was found to be +/- 0.60 ft (18.28 cm) at the 95th percentile.

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

Point ID	NAD83 (2011) VA State Plane South		NAVD88 (Geoid 12A)		DeltaZ	AbsDeltaZ
	Easting X (ft)	Northing Y (ft)	Z-Survey (ft)	Z-LiDAR (ft)		
VVA-1	12210869.02	3837260.51	4.14	4.83	0.700	0.700
VVA-7	12377291.990	3879672.010	0.600	1.220	0.620	0.620
TWC34	12220365.83	3567544.09	4.32	5.19	0.870	0.870

Table 14 – 5% Outliers

Table 15 provides overall descriptive statistics.

100 % of Totals	# of Points	RMSEz (ft) NVA Spec=0.33 ft	Mean (ft)	Median (ft)	Skew	Std Dev (ft)	Kurtosis	Min (ft)	Max (ft)
Open Terrain	31	0.23	0.01	0.03	-0.33	0.23	0.14	-0.58	0.41
Urban	30	0.17	-0.01	0.04	-0.55	0.18	-0.58	-0.38	0.28
NVA	61	0.20	0.00	0.045	-0.35	0.20	0.06	-0.58	0.41
Tall Weeds/Crops	22	N/A	0.24	0.22	0.36	0.29	-0.11	-0.29	0.87
Brush Lands and Trees	14	N/A	0.18	0.20	0.03	0.21	-0.70	-0.15	0.53

Forested and Fully Grown	16	N/A	0.13	0.12	0.59	0.19	0.43	-0.16	0.56
VVA	**52**	**N/A**	**0.19**	**0.18**	**0.52**	**0.24**	**0.24**	**-0.29**	**0.87**

Table 15 — Overall Descriptive Statistics

Based on the vertical accuracy testing conducted by Dewberry, the DEM dataset for the Eastern Shore VA 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: Survey Report

1. INTRODUCTION

1.1 *Project Summary*

Dewberry Consultants LLC is under contract to the United States Geological Survey to provide 110 Check Points in the State of Virginia. 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 May 11 to May 15, 2015.

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 18, NAD83 in feet. Final Vertical elevations are referenced to NAVD88 in feet using Geoid model 2012A (Geoid12A).

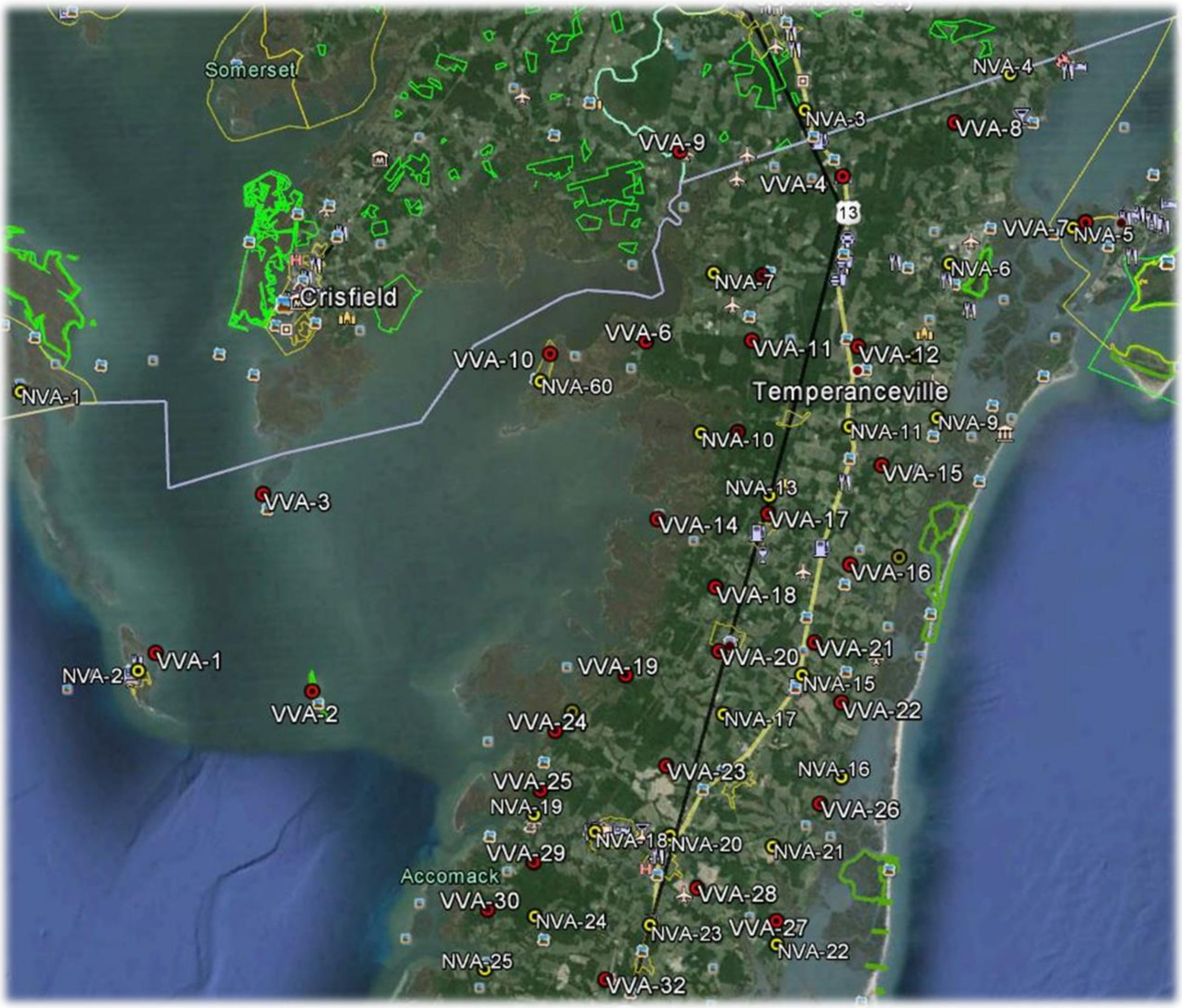
1.2 *Points of Contact*

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

Dewberry Consultants LLC

Gary D. Simpson, L.S.
Senior Associate
10003 Derekwood Lane
Suite 204
Lanham, Maryland 20706
(301) 364-1855 direct
(301) 731-0188 fax

1.3 *Project Area*


Somerset
NVA-4
NVA-3
VVA-8
VVA-9
VVA-4
13
VVA-7
NVA-5
Crisfield
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NVA-7
VVA-6
VVA-10
VVA-11
VVA-12
NVA-60
NVA-1
Temperanceville
NVA-10
NVA-11
NVA-9
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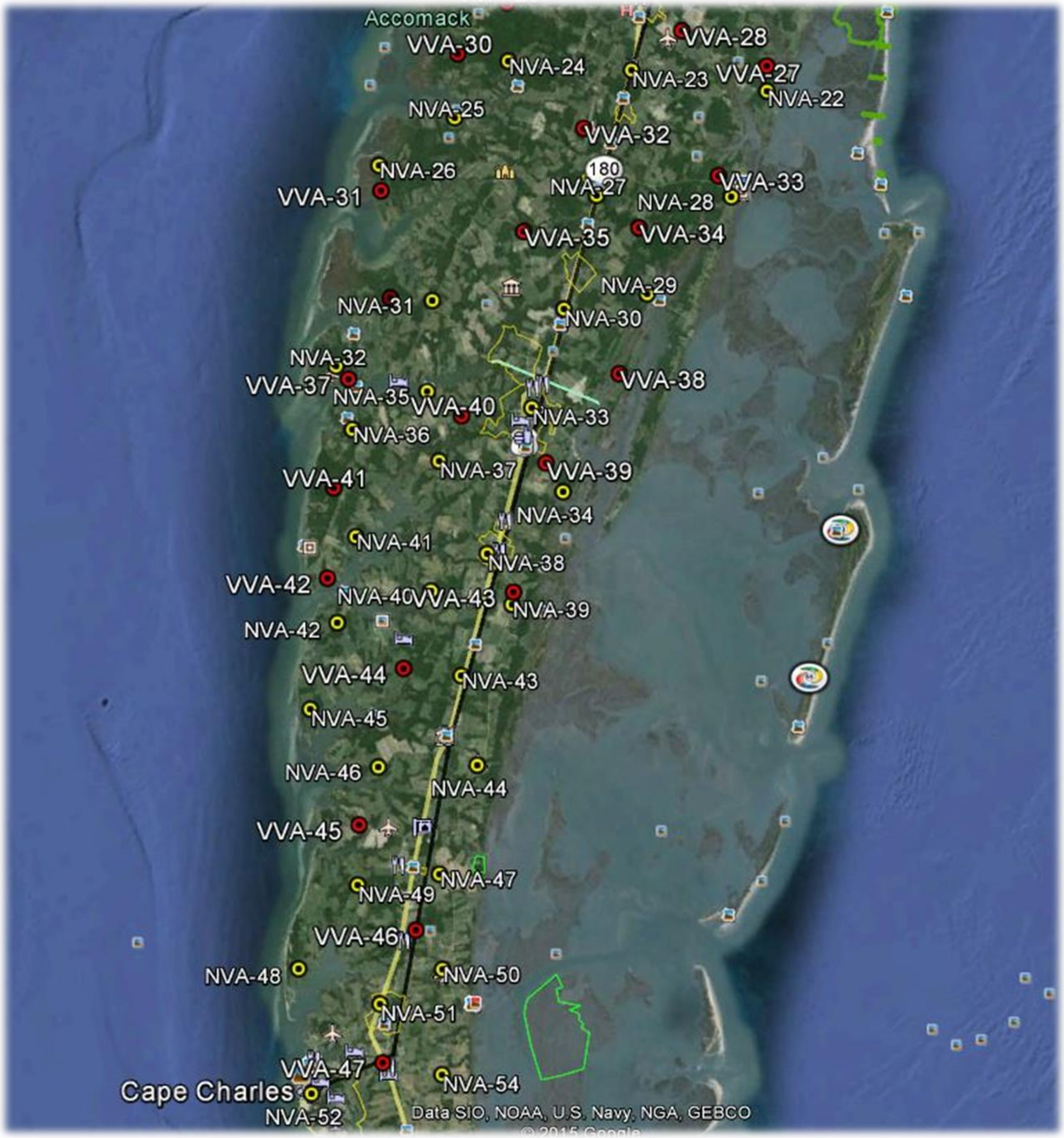
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NVA-47
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VVA-46
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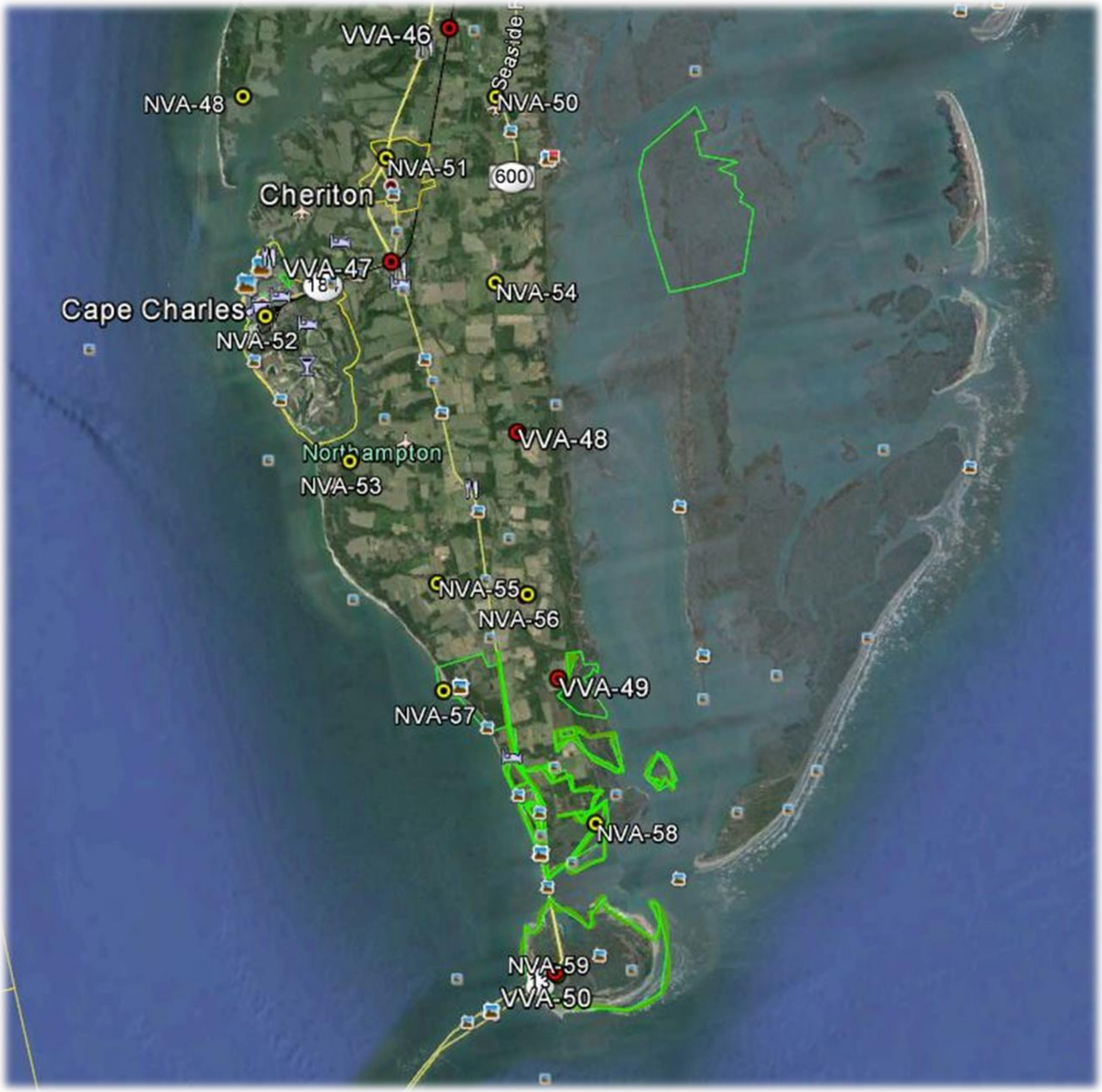
NVA-51
VVA-47
NVA-54
Cape Charles
NVA-52
Data SIO, NOAA, U.S. Navy, NGA, GEBCO



2. 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 110 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 "Control Point Documentation Report" sheets attached to this report.

2.3 *Network Design*

The GPS survey performed by Dewberry Consultants LLC office located in Lanham, MD was tied to a Real Time Network (RTN) managed by KEYNET GPS, Inc. 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 18 and 20 minutes.

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

There (3) existing NGS monuments listed in the NSRS database and one (1) aerial acquisition firm control point were located as an additional QA/QC method to check the accuracy of the VRS network as well as being the primary project control monuments designated as W 420, NELSON, ACCOMAC RESET and REBAR 1. The results are as follows:

	As Surveyed (ft)			Published (ft)			Differences (ft)		
NGS PT. ID	Northing(ft)	Easting(ft)	Elev.(ft)	Northing(ft)	Easting(ft)	Elev.(ft)	Δ N	Δ E	Δ Elev.
W420	N/A	N/A	3.08	N/A	N/A	3.13	N/A	N/A	0.05
NELSON	13799401.38	1484775.42	31.28	13799401.40	1484775.50	31.27	0.02	0.07	0.01
ACCOMAC RESET	13696368.85	1445299.97	N/A	13696368.85	1445299.92	44.25	0.01	0.05	N/A
REBAR 1	13544408.85	1369407.22	30.46	13544408.79	1369407.28	N/A	0.06	0.06	N/A

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

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 KEYNET 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

POINT #	NORTHING (ft)	EASTING (ft)	ELEV. (ft)
NVA CHECK POINTS			
NVA-1	13787544.72	1345061.37	1.34
NVA-2	13737576.97	1354141.25	3.40
NVA-3	13804535.78	1483754.54	20.50
NVA-4	13802938.37	1518716.14	31.45
NVA-5	13775338.62	1521649.52	4.06
NVA-6	13774225.72	1501825.31	32.15
NVA-7	13781284.79	1462880.68	6.35
NVA-8	13760385.06	1492788.87	32.21
NVA-9	13749645.45	1493971.62	16.79
NVA-10	13755749.08	1454915.20	1.99
NVA-11	13751688.65	1479341.61	46.07
NVA-12	13728349.88	1482757.49	15.68
NVA-13	13740538.80	1462405.07	22.50

NVA-14	**13715068.25**	**1423672.01**	**3.29**
NVA-15	**13716376.57**	**1457539.03**	**41.11**
NVA-16	**13694591.10**	**1465288.41**	**4.25**
NVA-17	**13709144.25**	**1448301.98**	**38.90**
NVA-18	**13694709.28**	**1422978.56**	**13.77**
NVA-19	**13699849.12**	**1413593.59**	**4.44**
NVA-20	**13691366.38**	**1435139.99**	**42.81**
NVA-21	**13685801.16**	**1451522.49**	**18.91**
NVA-22	**13669719.87**	**1448584.00**	**8.15**
NVA-23	**13677530.24**	**1428586.66**	**49.83**
NVA-24	**13683206.34**	**1410161.85**	**9.54**
NVA-25	**13676039.67**	**1399787.10**	**5.85**
NVA-26	**13671648.26**	**1386750.83**	**3.58**
NVA-27	**13659633.88**	**1418965.56**	**41.39**
NVA-28	**13654573.59**	**1439881.17**	**7.60**
NVA-29	**13643047.34**	**1423396.80**	**8.54**
NVA-30	**13643465.21**	**1410046.59**	**32.98**
NVA-31	**13649231.57**	**1390298.90**	**22.64**
NVA-32	**13641526.45**	**1373079.19**	**2.88**
NVA-33	**13629535.20**	**1401795.83**	**36.71**
NVA-34	**13616989.25**	**1400880.55**	**28.94**
NVA-35	**13635649.31**	**1386370.80**	**3.69**
NVA-36	**13632340.72**	**1373626.86**	**4.39**
NVA-37	**13624607.26**	**1385808.85**	**23.50**
NVA-38	**13608870.92**	**1389982.92**	**34.41**
NVA-39	**13600301.49**	**1392043.70**	**31.47**
NVA-40	**13605115.06**	**1380143.36**	**20.84**
NVA-41	**13614694.74**	**1370379.71**	**18.86**
NVA-42	**13599588.29**	**1369827.79**	**17.69**
NVA-43	**13591096.27**	**1382010.54**	**38.61**
NVA-44	**13578066.06**	**1382513.43**	**28.84**
NVA-45	**13591275.12**	**1357653.54**	**10.57**
NVA-46	**13581277.83**	**1362330.87**	**17.97**
NVA-47	**13561751.38**	**1371720.52**	**33.42**
NVA-48	**13555468.16**	**1348538.92**	**7.50**
NVA-49	**13561564.46**	**1364642.16**	**28.07**
NVA-50	**13548074.67**	**1363682.22**	**37.85**
NVA-51	**13540793.69**	**1360795.58**	**34.49**

NVA-52	**13532703.53**	**1344629.83**	**6.56**
NVA-53	**13518511.52**	**1349412.03**	**7.97**
NVA-54	**13531314.14**	**1365213.32**	**32.54**
NVA-55	**13506310.57**	**1354342.76**	**34.74**
NVA-56	**13503572.78**	**1362045.54**	**26.16**
NVA-57	**13496860.40**	**1352829.53**	**8.20**
NVA-58	**13482536.60**	**1363344.19**	**4.48**
NVA-59	**13470126.21**	**1357158.95**	**11.88**
NVA-60	**13770426.82**	**1429938.34**	**5.57**
VVA CHECK POINTS			
VVA-1	**13739949.46**	**1357750.56**	**4.14**
VVA-2	**13725921.77**	**1382691.12**	**3.12**
VVA-3	**13761818.33**	**1381112.05**	**1.10**
VVA-4	**13792377.41**	**1487545.35**	**20.77**
VVA-5	**13779174.95**	**1470756.86**	**12.56**
VVA-6	**13772667.10**	**1449295.26**	**3.22**
VVA-7	**13776136.53**	**1525577.46**	**0.60**
VVA-8	**13797469.73**	**1507918.44**	**34.53**
VVA-9	**13802503.13**	**1461718.62**	**2.34**
VVA-10	**13774156.44**	**1433140.04**	**2.04**
VVA-11	**13769105.05**	**1466753.75**	**8.07**
VVA-12	**13764221.50**	**1483665.24**	**38.72**
VVA-13	**13755181.12**	**1461271.37**	**2.94**
VVA-14	**13743348.53**	**1444602.19**	**3.34**
VVA-15	**13752593.71**	**1490559.47**	**36.85**
VVA-16	**13728875.89**	**1474469.29**	**38.17**
VVA-17	**13741109.30**	**1466001.15**	**34.01**
VVA-18	**13730066.09**	**1451622.03**	**10.26**
VVA-19	**13718587.96**	**1434164.42**	**4.53**
VVA-20	**13719563.99**	**1449951.12**	**33.22**
VVA-21	**13717764.78**	**1465625.79**	**39.17**
VVA-22	**13707103.33**	**1467188.27**	**16.84**
VVA-23	**13702843.64**	**1436904.84**	**28.62**
VVA-24	**13713034.97**	**1420333.73**	**1.63**
VVA-25	**13705884.89**	**1415374.41**	**2.03**
VVA-26	**13690830.08**	**1460668.19**	**13.65**
VVA-27	**13673470.77**	**1449388.20**	**6.10**
VVA-28	**13681814.29**	**1437636.66**	**39.07**

VVA-29	13692053.05	1411728.08	7.14
VVA-30	13685906.03	1402585.45	4.16
VVA-31	13667700.33	1386186.14	1.75
VVA-32	13671186.54	1418864.70	44.90
VVA-33	13658468.55	1438041.21	7.20
VVA-34	13653184.58	1424317.10	14.68
VVA-35	13656545.62	1406587.62	38.76
VVA-36	13651563.07	1383130.93	6.55
VVA-37	13641884.77	1379969.41	9.36
VVA-38	13631742.52	1416338.33	4.07
VVA-39	13620741.99	1402023.09	35.05
VVA-40	13630700.74	1390788.65	27.82
VVA-41	13624139.43	1368679.46	14.08
VVA-42	13610604.02	1364759.03	13.83
VVA-43	13602086.11	1392690.19	29.75
VVA-44	13594195.65	1373160.63	18.03
VVA-45	13571983.39	1360795.94	14.62
VVA-46	13554148.09	1366204.57	36.30
VVA-47	13536226.63	1357386.05	19.26
VVA-48	13518684.74	1364228.13	31.78
VVA-49	13495644.01	1359319.15	29.83
VVA-50	13470330.59	1357035.00	8.01

4. GPS OBSERVATIONS

VIRGINIA EASTERN SHORE LiDAR QA					
POINT ID	OBSERV. DATE	JULIAN DATE	TIME OF DAY (PST)	RE-OBSERV. DATE	RE-OBSERV. TIME
NVA-1	5/12/2015	132	17:12	N/A	N/A
NVA-2	5/12/2015	132	10:10	N/A	N/A
NVA-3	5/11/2015	131	6:40	5/11/2015	17:29
NVA-4	5/11/2015	131	16:20	N/A	N/A
NVA-5	5/13/2015	133	12:27	N/A	N/A
NVA-6	5/13/2015	133	12:46	N/A	N/A
NVA-7	5/11/2015	131	7:35	N/A	N/A
NVA-8	5/13/2015	133	14:34	N/A	N/A
NVA-9	5/13/2015	133	15:13	N/A	N/A
NVA-10	5/11/2015	131	8:35	5/11/2015	19:26

NVA-11	5/11/2015	131	9:15	5/11/2015	20:51
NVA-12	5/13/2015	133	17:12	5/14/2015	7:09
NVA-13	5/11/2015	131	10:45	5/14/2015	20:19
NVA-14	5/14/2015	134	10:39	N/A	N/A
NVA-15	5/11/2015	131	10:15	N/A	N/A
NVA-16	5/13/2015	133	18:31	5/14/2015	19:56
NVA-17	5/11/2015	131	12:20	5/14/2015	5:08
NVA-18	5/14/2015	134	12:03	N/A	N/A
NVA-19	5/14/2015	134	11:41	N/A	N/A
NVA-20	5/13/2015	133	20:06	5/14/2015	18:58
NVA-21	5/13/2015	133	19:10	5/14/2015	19:16
NVA-22	5/13/2015	133	19:40	N/A	N/A
NVA-23	5/14/2015	134	16:06	5/14/2015	18:10
NVA-24	5/14/2015	134	13:12	5/14/2015	18:33
NVA-25	5/14/2015	134	13:38	N/A	N/A
NVA-26	5/14/2015	134	14:19	5/15/2015	6:12
NVA-27	5/14/2015	134	15:29	5/15/2015	6:49
NVA-28	5/14/2015	134	17:01	N/A	N/A
NVA-29	5/14/2015	134	15:12	5/15/2015	7:51
NVA-30	5/14/2015	134	14:44	5/15/2015	7:19
NVA-31	5/13/2015	133	12:25	5/13/2015	20:29
NVA-32	5/13/2015	133	13:09	5/13/2015	20:51
NVA-33	5/13/2015	133	16:30	N/A	N/A
NVA-34	5/13/2015	133	17:25	5/14/2015	5:21
NVA-35	5/13/2015	133	14:22	5/13/2015	21:09
NVA-36	5/13/2015	133	14:55	5/13/2015	21:23
NVA-37	5/13/2015	133	14:39	N/A	N/A
NVA-38	5/13/2015	133	17:44	5/14/2015	5:41
NVA-39	5/13/2015	133	19:42	5/14/2015	6:28
NVA-40	5/13/2015	133	18:28	N/A	N/A
NVA-41	5/13/2015	133	15:43	5/13/2015	22:10
NVA-42	5/13/2015	133	18:45	5/14/2015	7:01
NVA-43	5/13/2015	133	19:28	5/14/2015	22:15
NVA-44	5/14/2015	134	7:45	N/A	N/A
NVA-45	5/13/2015	133	19:00	N/A	N/A
NVA-46	5/14/2015	134	8:18	5/14/2015	21:59
NVA-47	5/14/2015	134	9:24	5/14/2015	20:49
NVA-48	5/14/2015	134	10:25	N/A	N/A

NVA-49	**5/14/2015**	**134**	**9:52**	**5/14/2015**	**21:10**
NVA-50	**5/14/2015**	**134**	**11:26**	**5/14/2015**	**20:07**
NVA-51	**5/14/2015**	**134**	**12:19**	**5/14/2015**	**19:49**
NVA-52	**5/14/2015**	**134**	**12:50**	**5/14/2015**	**19:33**
NVA-53	**5/14/2015**	**134**	**15:12**	**N/A**	**N/A**
NVA-54	**5/14/2015**	**134**	**14:05**	**5/14/2015**	**18:51**
NVA-55	**5/14/2015**	**134**	**15:40**	**N/A**	**N/A**
NVA-56	**5/14/2015**	**134**	**16:05**	**N/A**	**N/A**
NVA-57	**5/14/2015**	**134**	**16:36**	**N/A**	**N/A**
NVA-58	**5/14/2015**	**134**	**17:30**	**N/A**	**N/A**
NVA-59	**5/14/2015**	**134**	**18:23**	**N/A**	**N/A**
NVA-60	**5/11/2015**	**131**	**13:45**	**5/11/2015**	**18:51**
VVA-1	**5/12/2015**	**132**	**9:50**	**N/A**	**N/A**
VVA-2	**5/12/2015**	**132**	**11:35**	**N/A**	**N/A**
VVA-3	**5/12/2015**	**132**	**14:10**	**N/A**	**N/A**
VVA-4	**5/11/2015**	**131**	**6:56**	**5/11/2015**	**17:11**
VVA-5	**5/11/2015**	**131**	**7:22**	**N/A**	**N/A**
VVA-6	**5/11/2015**	**131**	**7:50**	**5/11/2015**	**18:15**
VVA-7	**5/13/2015**	**133**	**12:13**	**N/A**	**N/A**
VVA-8	**5/11/2015**	**131**	**16:45**	**N/A**	**N/A**
VVA-9	**5/11/2015**	**131**	**14:20**	**5/11/2015**	**17:43**
VVA-10	**5/11/2015**	**131**	**13:30**	**5/11/2015**	**18:39**
VVA-11	**5/11/2015**	**131**	**13:10**	**N/A**	**N/A**
VVA-12	**5/13/2015**	**133**	**14:19**	**5/14/2015**	**7:59**
VVA-13	**5/11/2015**	**131**	**12:55**	**N/A**	**N/A**
VVA-14	**5/14/2015**	**134**	**8:49**	**N/A**	**N/A**
VVA-15	**5/13/2015**	**133**	**15:27**	**5/14/2015**	**7:29**
VVA-16	**5/13/2015**	**133**	**15:54**	**5/14/2015**	**6:42**
VVA-17	**5/11/2015**	**131**	**12:45**	**5/11/2015**	**20:10**
VVA-18	**5/14/2015**	**134**	**9:37**	**N/A**	**N/A**
VVA-19	**5/14/2015**	**134**	**10:00**	**N/A**	**N/A**
VVA-20	**5/13/2015**	**133**	**17:02**	**5/14/2015**	**5:33**
VVA-21	**5/13/2015**	**133**	**16:37**	**5/14/2015**	**5:49**
VVA-22	**5/13/2015**	**133**	**17:25**	**5/14/2015**	**6:09**
VVA-23	**5/13/2015**	**133**	**17:46**	**N/A**	**N/A**
VVA-24	**5/14/2015**	**134**	**11:00**	**N/A**	**N/A**
VVA-25	**5/14/2015**	**134**	**11:24**	**N/A**	**N/A**
VVA-26	**5/13/2015**	**133**	**18:51**	**5/14/2015**	**19:31**

VVA-27	5/13/2015	133	19:27	N/A	N/A
VVA-28	5/13/2015	133	16:31	5/14/2015	18:59
VVA-29	5/14/2015	134	12:26	N/A	N/A
VVA-30	5/14/2015	134	12:54	N/A	N/A
VVA-31	5/14/2015	134	13:58	5/15/2015	6:31
VVA-32	5/14/2015	134	15:49	5/14/2015	17:46
VVA-33	5/13/2015	133	10:48	N/A	N/A
VVA-34	5/13/2015	133	11:13	N/A	N/A
VVA-35	5/13/2015	133	11:50	N/A	N/A
VVA-36	5/13/2015	133	12:52	5/13/2015	20:10
VVA-37	5/13/2015	133	13:20	N/A	N/A
VVA-38	5/13/2015	133	16:56	N/A	N/A
VVA-39	5/13/2015	133	17:14	N/A	N/A
VVA-40	5/13/2015	133	13:54	N/A	N/A
VVA-41	5/13/2015	133	15:24	5/13/2015	21:46
VVA-42	5/13/2015	133	16:03	5/14/2015	6:10
VVA-43	5/13/2015	133	18:10	N/A	N/A
VVA-44	5/13/2015	133	19:16	N/A	N/A
VVA-45	5/14/2015	134	8:52	5/14/2015	21:29
VVA-46	5/14/2015	134	10:57	5/14/2015	20:31
VVA-47	5/14/2015	134	13:36	5/14/2015	19:13
VVA-48	5/14/2015	134	14:32	N/A	N/A
VVA-49	5/14/2015	134	17:01	N/A	N/A
VVA-50	5/14/2015	134	17:59	N/A	N/A

5. POINT COMPARISON

LiDAR QA				
POINT ID	POINT CK	DELTA NORTH (ft)	DELTA EAST (ft)	VERT. DIFF (ft)
NVA-3	NVA-3CK	0.00	0.01	0.00
NVA-10	NVA-10CK	0.02	0.03	0.10
NVA-11	NVA-11CK	0.02	0.00	0.03
NVA-12	NVA-12CK	0.01	0.01	0.04
NVA-13	NVA-13CK	0.01	0.01	0.01
NVA-16	NVA-16CK	0.03	0.01	0.01
NVA-17	NVA-17CK	0.01	0.03	0.04
NVA-20	NVA-20CK	0.02	0.00	0.00
NVA-21	NVA-21CK	0.01	0.00	0.05
NVA-23	NVA-23CK	0.02	0.02	0.04

NVA-24	**NVA-24CK**	**0.01**	**0.01**	**0.01**
NVA-26	**NVA-26CK**	**0.01**	**0.01**	**0.03**
NVA-27	**NVA-27CK**	**0.02**	**0.04**	**0.02**
NVA-29	**NVA-29CK**	**0.01**	**0.00**	**0.03**
NVA-30	**NVA-30CK**	**0.01**	**0.03**	**0.01**
NVA-31	**NVA-31CK**	**0.01**	**0.01**	**0.03**
NVA-32	**NVA-32CK**	**0.02**	**0.00**	**0.01**
NVA-34	**NVA-34CK**	**0.01**	**0.01**	**0.03**
NVA-35	**NVA-35CK**	**0.00**	**0.00**	**0.00**
NVA-36	**NVA-36CK**	**0.03**	**0.03**	**0.01**
NVA-38	**NVA-38CK**	**0.02**	**0.02**	**0.04**
NVA-39	**NVA-39CK**	**0.01**	**0.00**	**0.05**
NVA-41	**NVA-41CK**	**0.00**	**0.00**	**0.03**
NVA-42	**NVA-42CK**	**0.01**	**0.03**	**0.00**
NVA-43	**NVA-43CK**	**0.00**	**0.02**	**0.01**
NVA-46	**NVA-46CK**	**0.03**	**0.04**	**0.04**
NVA-47	**NVA-47CK**	**0.01**	**0.03**	**0.03**
NVA-49	**NVA-49CK**	**0.04**	**0.04**	**0.05**
NVA-50	**NVA-50CK**	**0.07**	**0.06**	**0.04**
NVA-51	**NVA-51CK**	**0.04**	**0.05**	**0.05**
NVA-52	**NVA-52CK**	**0.06**	**0.04**	**0.07**
NVA-54	**NVA-54CK**	**0.07**	**0.07**	**0.04**
NVA-60	**NVA-60CK**	**0.01**	**0.00**	**0.01**
VVA-4	**VVA-4CK**	**0.00**	**0.01**	**0.01**
VVA-6	**VVA-6CK**	**0.01**	**0.01**	**0.02**
VVA-9	**VVA-9CK**	**0.00**	**0.02**	**0.05**
VVA-10	**VVA-10CK**	**0.01**	**0.00**	**0.03**
VVA-12	**VVA-12CK**	**0.00**	**0.00**	**0.00**
VVA-15	**VVA-15CK**	**0.01**	**0.02**	**0.01**
VVA-16	**VVA-16CK**	**0.02**	**0.03**	**0.01**
VVA-17	**VVA-17CK**	**0.03**	**0.03**	**0.01**
VVA-20	**VVA-20CK**	**0.04**	**0.01**	**0.04**
VVA-21	**VVA-21CK**	**0.01**	**0.01**	**0.04**
VVA-22	**VVA-22CK**	**0.00**	**0.01**	**0.02**
VVA-26	**VVA-26CK**	**0.01**	**0.01**	**0.04**
VVA-28	**VVA-28CK**	**0.00**	**0.01**	**0.03**
VVA-31	**VVA-31CK**	**0.00**	**0.03**	**0.03**
VVA-32	**VVA-32CK**	**0.02**	**0.02**	**0.02**

VVA-36	VVA-36CK	0.02	0.02	0.05
VVA-41	VVA-41CK	0.01	0.04	0.06
VVA-42	VVA-42CK	0.02	0.03	0.04
VVA-45	VVA-45CK	0.03	0.05	0.06
VVA-46	VVA-46CK	0.09	0.08	0.09
VVA-47	VVA-47CK	0.05	0.09	0.05

Appendix B: Complete List of Delivered Tiles

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Appendix C: List of Water Tiles

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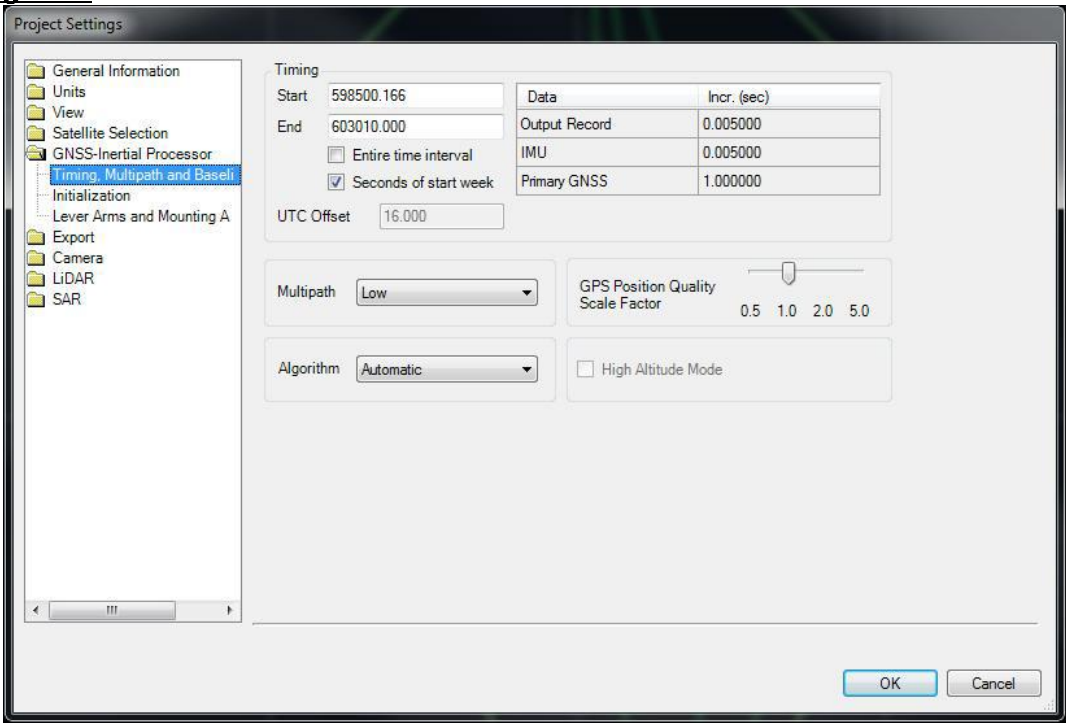
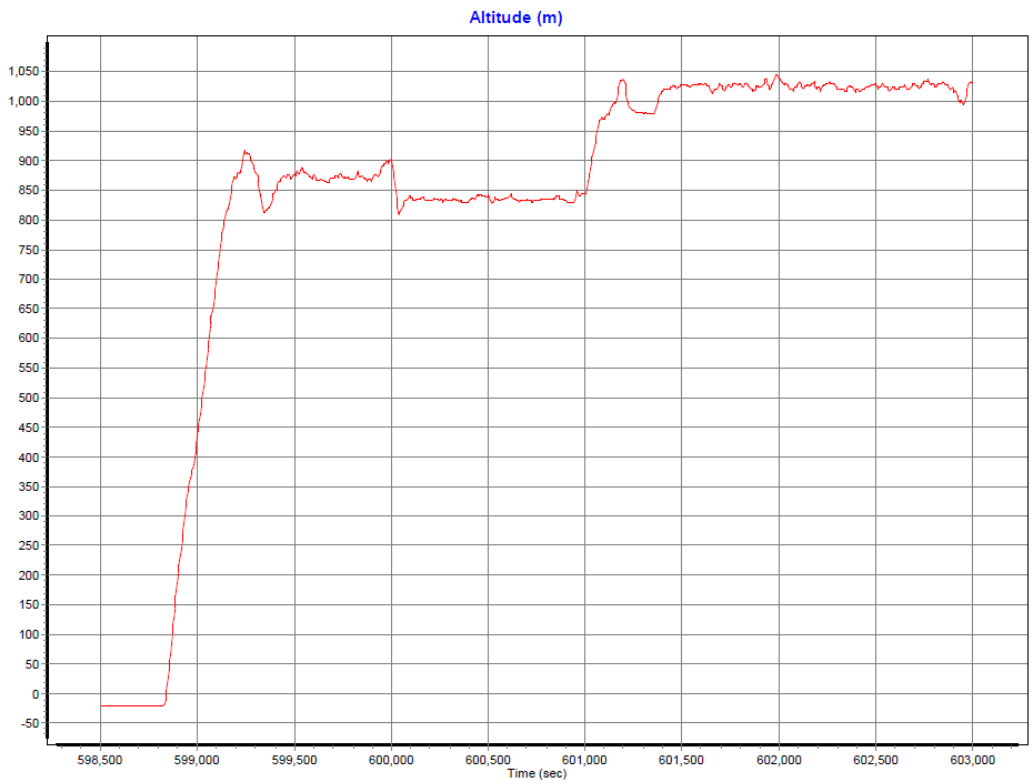
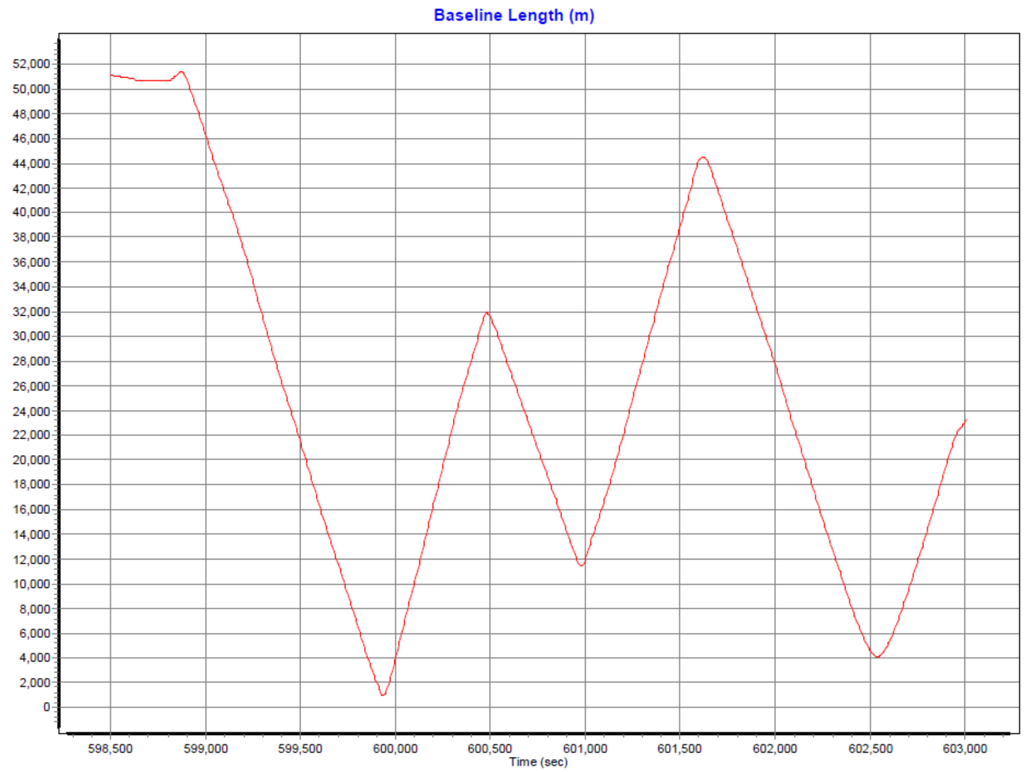
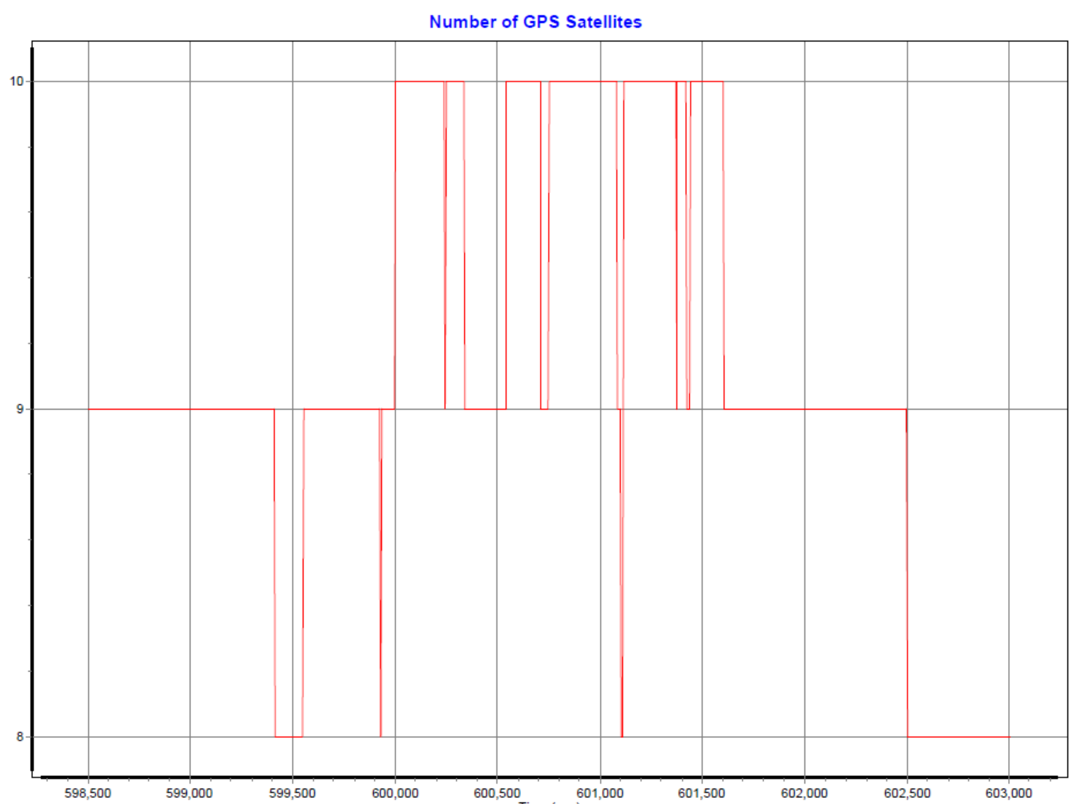
Appendix D: GPS Processing

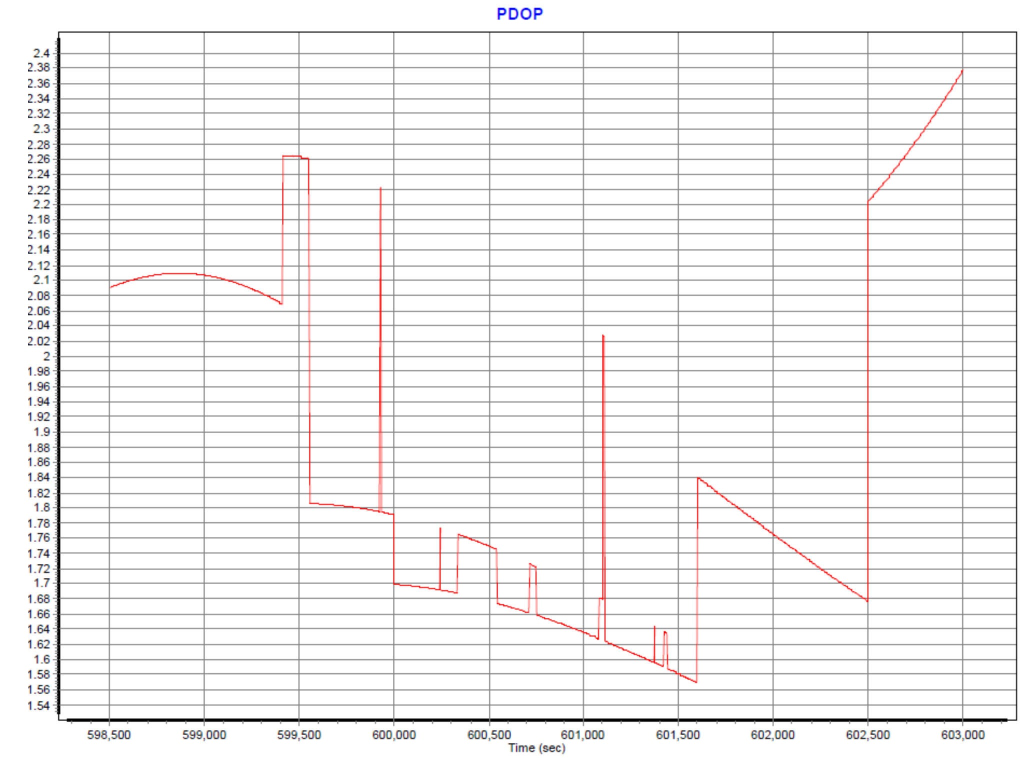
MNB15101A

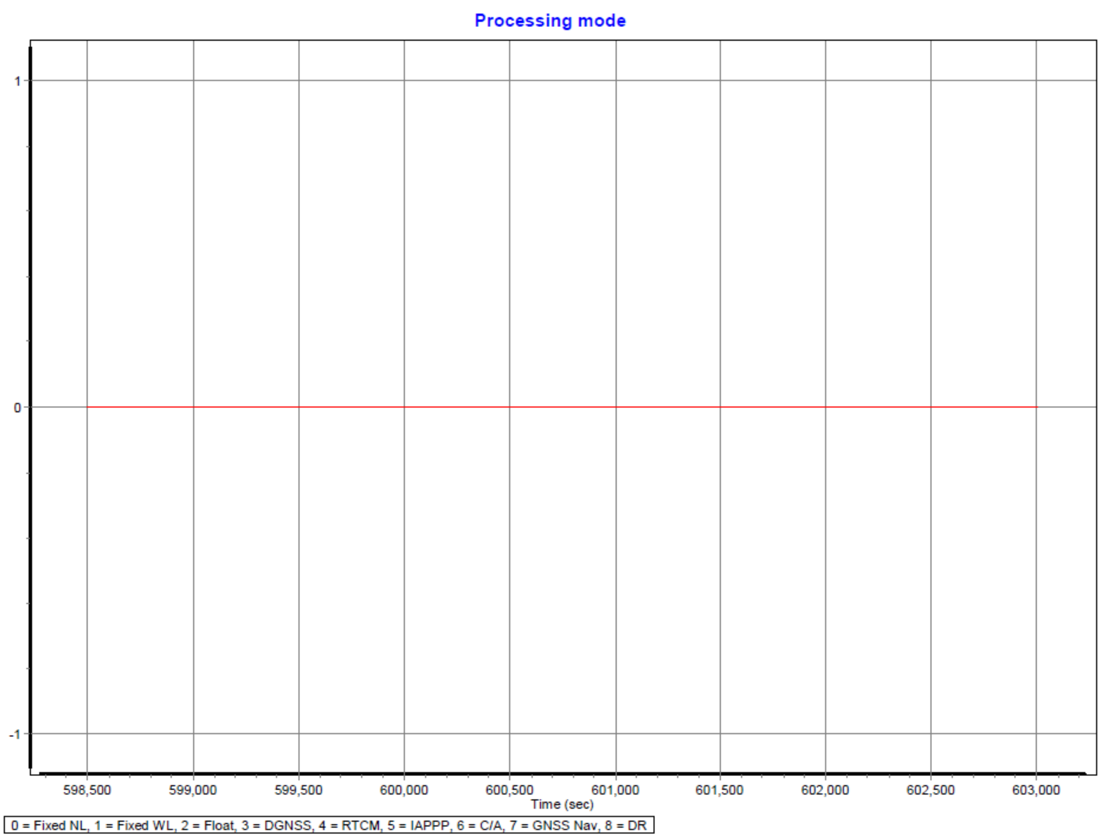


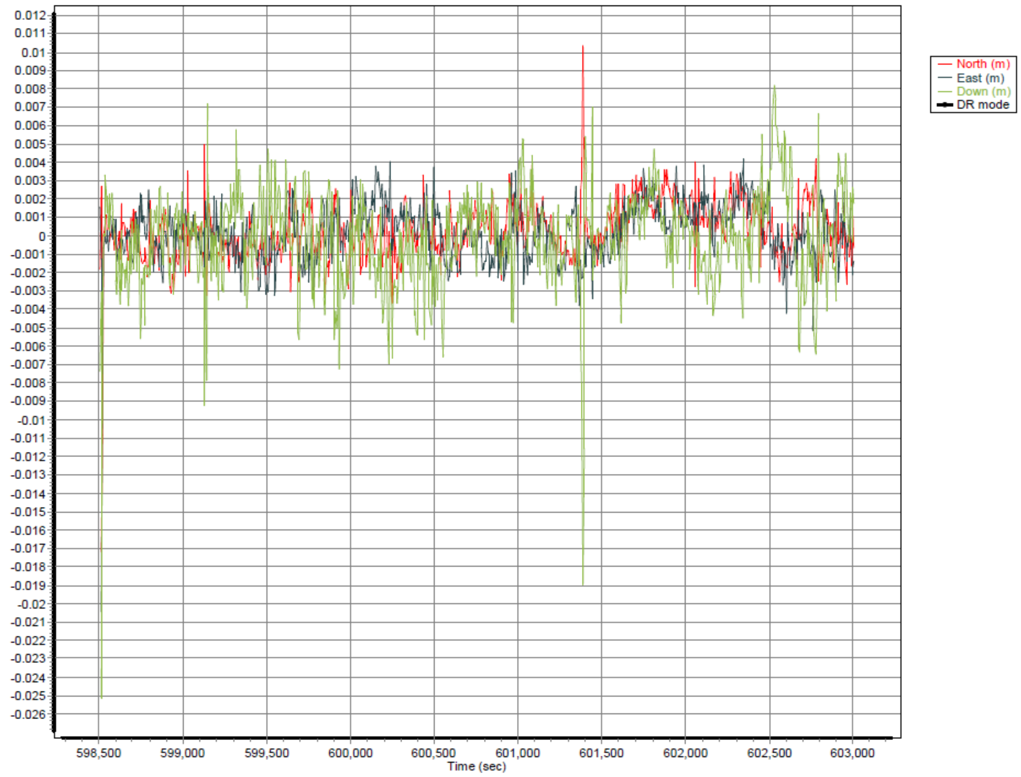


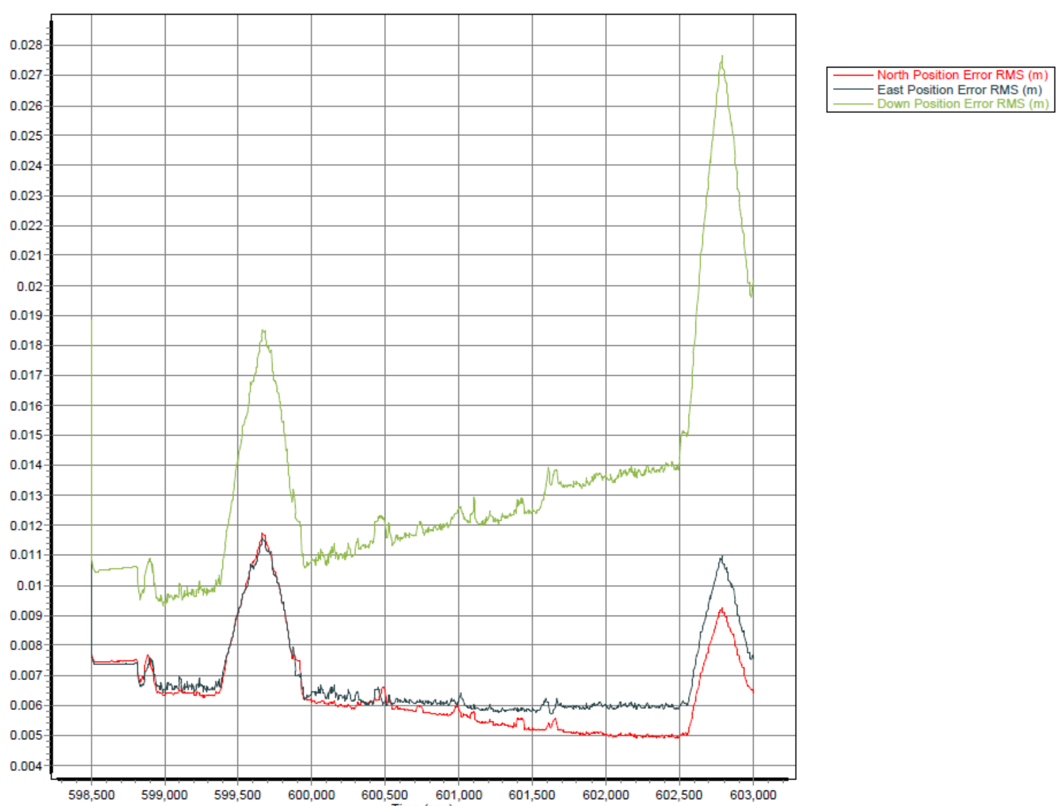

Baseline Length (m)
52,000
50,000
48,000
46,000
44,000
42,000
40,000
38,000
36,000
34,000
32,000
30,000
28,000
26,000
24,000
22,000
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
598,500
599,000
599,500
600,000
600,500
601,000
601,500
602,000
602,500
603,000
Time (sec)

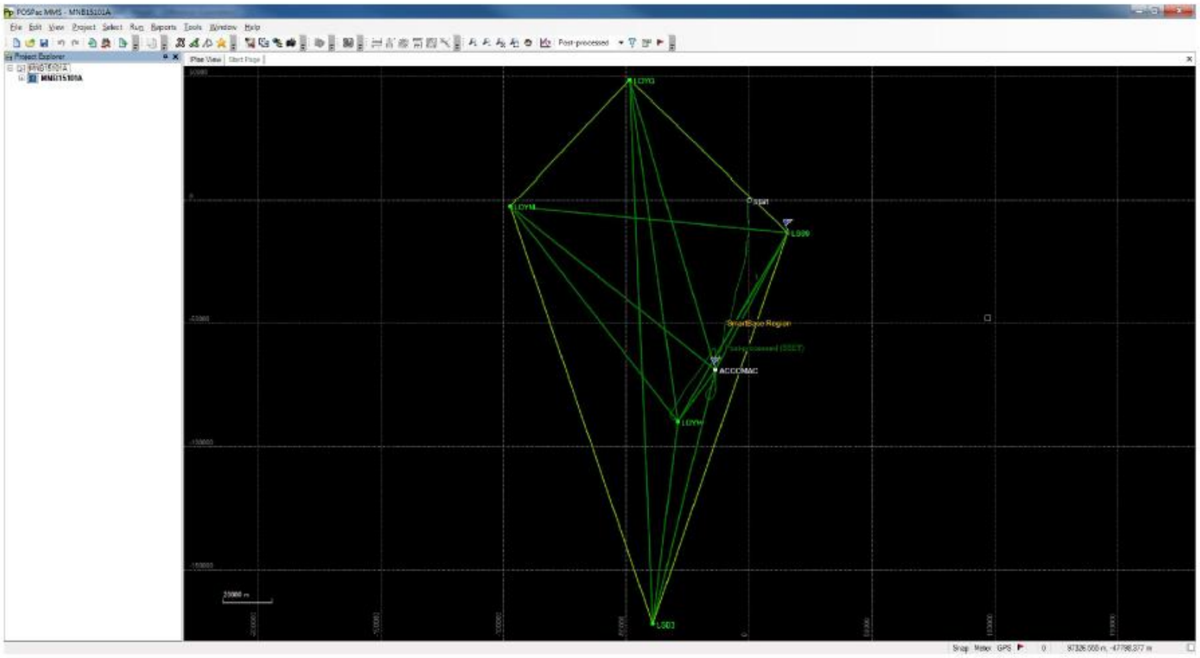

Number of GPS Satellites
10
9
8
598,500
599,000
599,500
600,000
600,500
601,000
601,500
602,000
602,500
603,000
Time (sec)


PDOP
Time (sec)


Processing mode
Time (sec)
0 = Fixed NL, 1 = Fixed WL, 2 = Float, 3 = DGNSS, 4 = RTCM, 5 = IAPPP, 6 = C/A, 7 = GNSS Nav, 8 = DR


North (m)
East (m)
Down (m)
DR mode
Time (sec)


North Position Error RMS (m)
East Position Error RMS (m)
Down Position Error RMS (m)
Time (sec)



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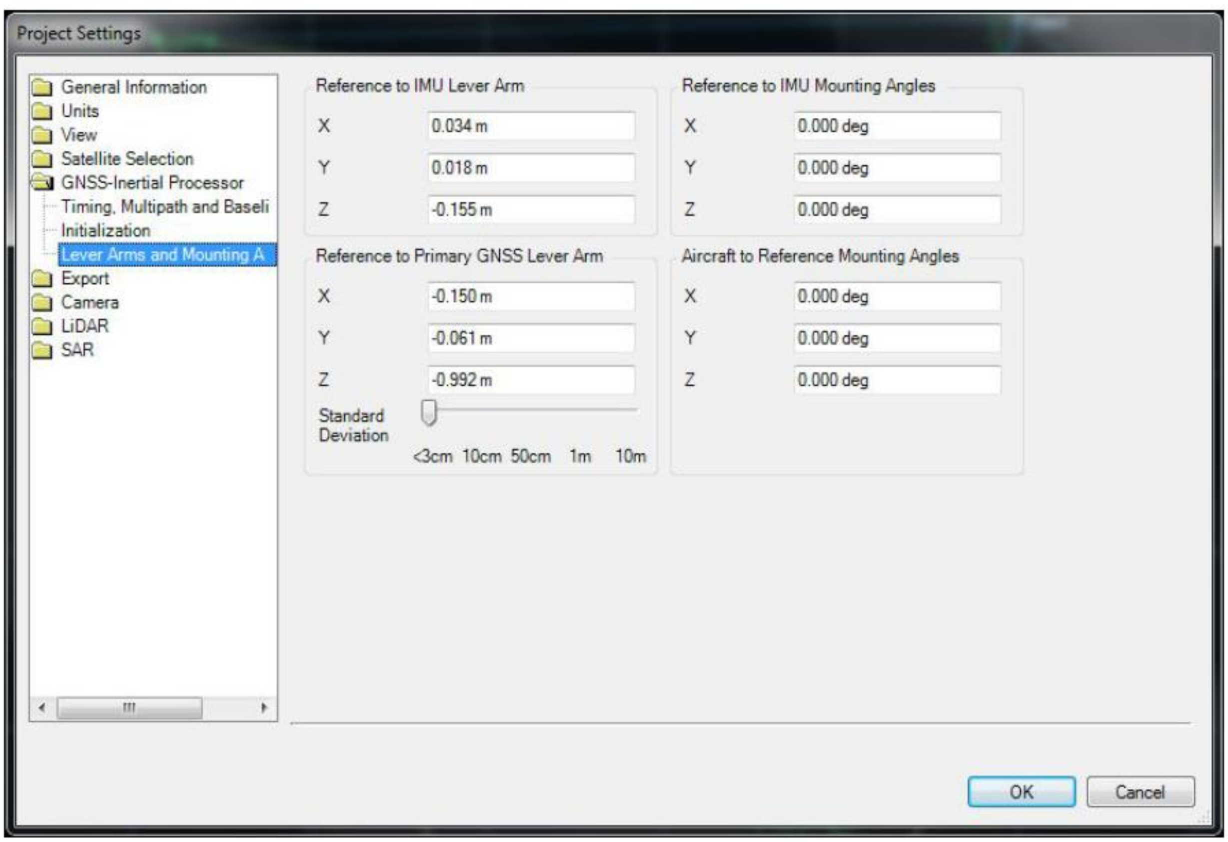
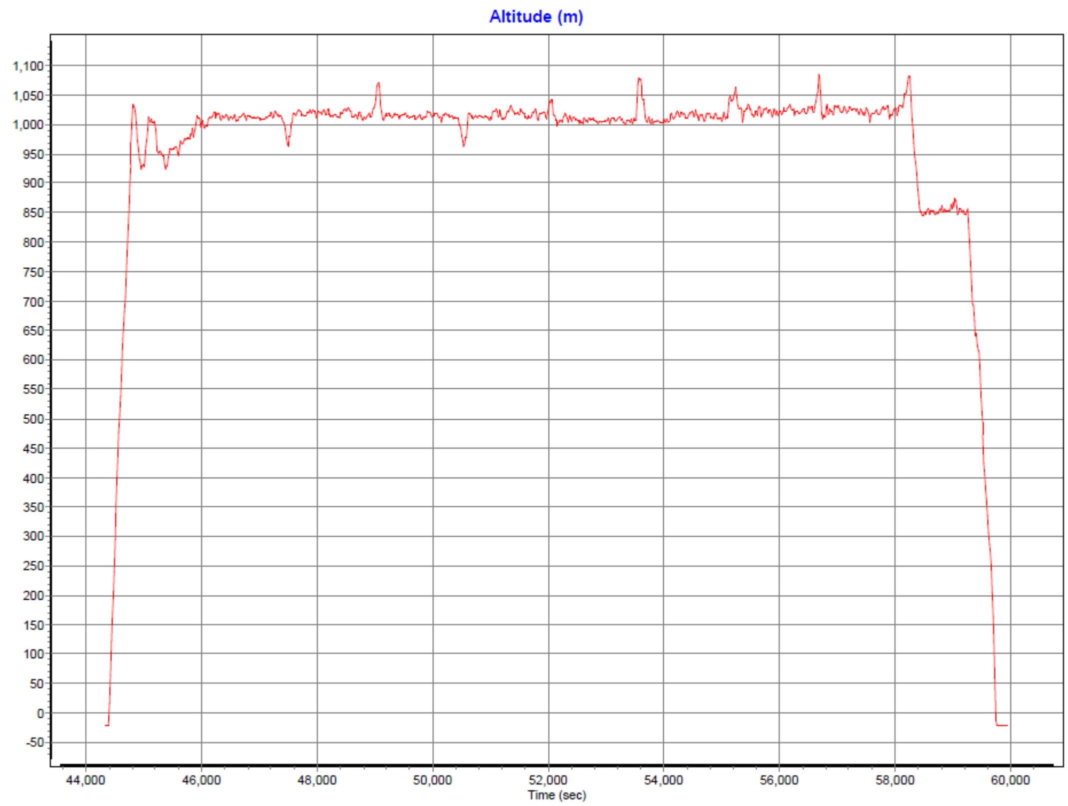
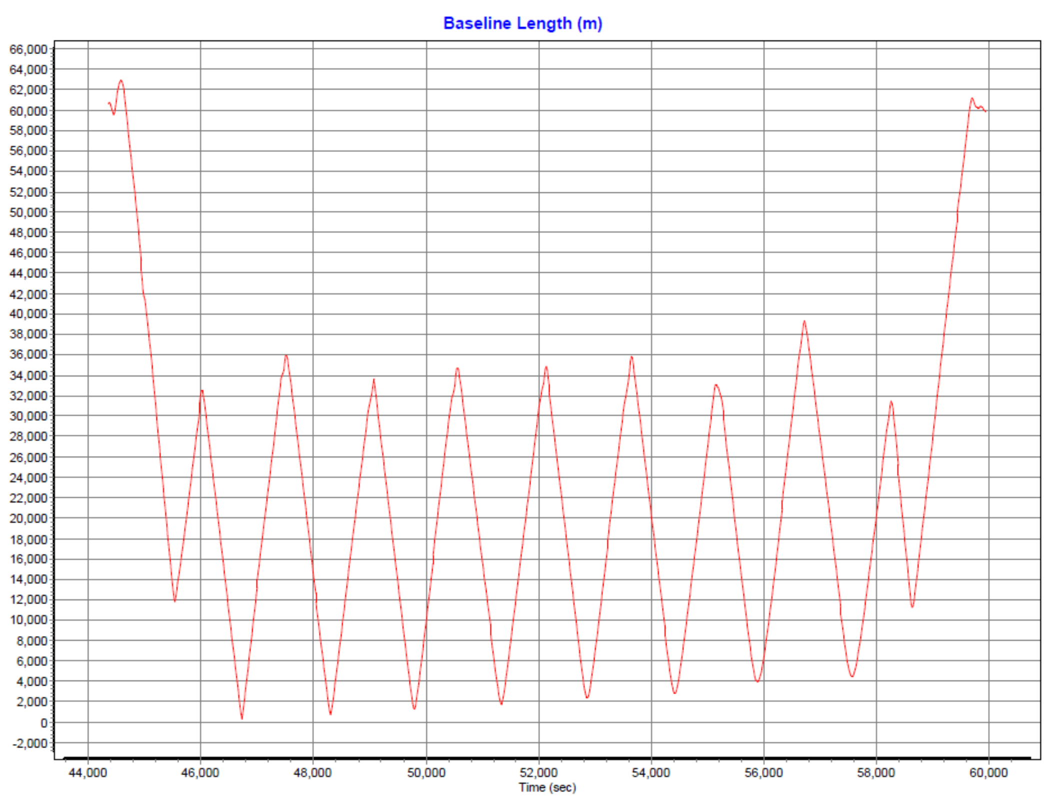
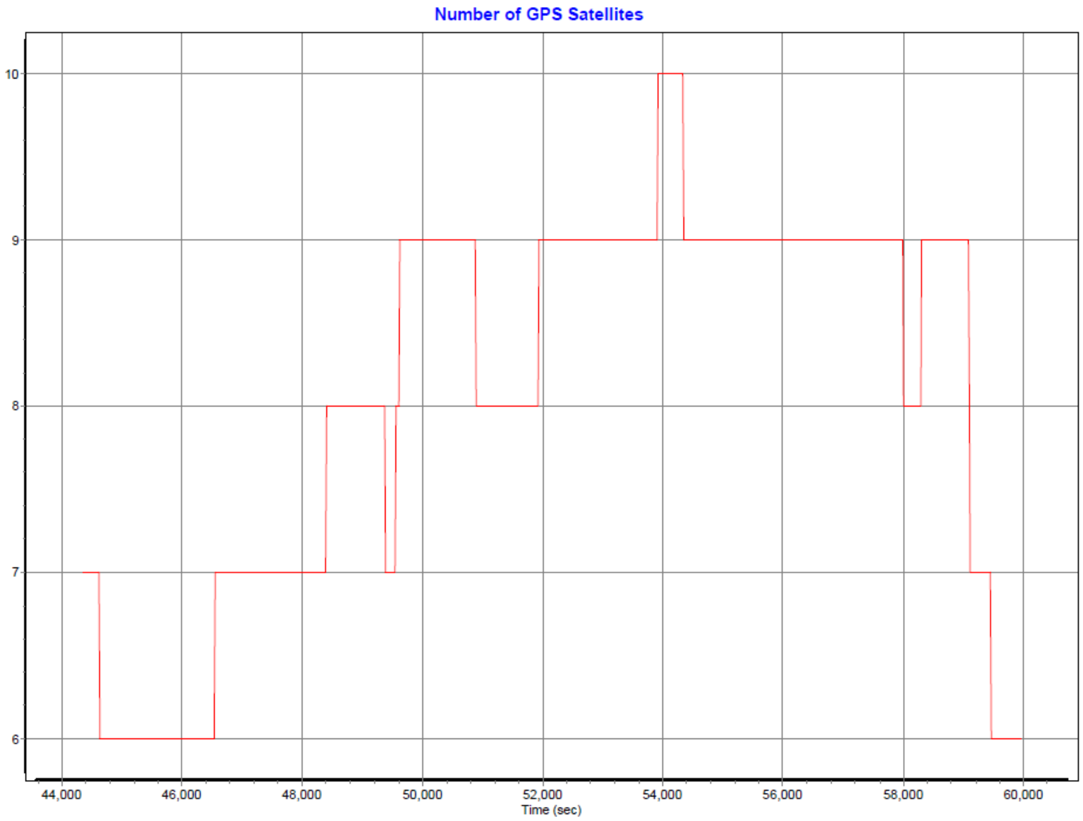
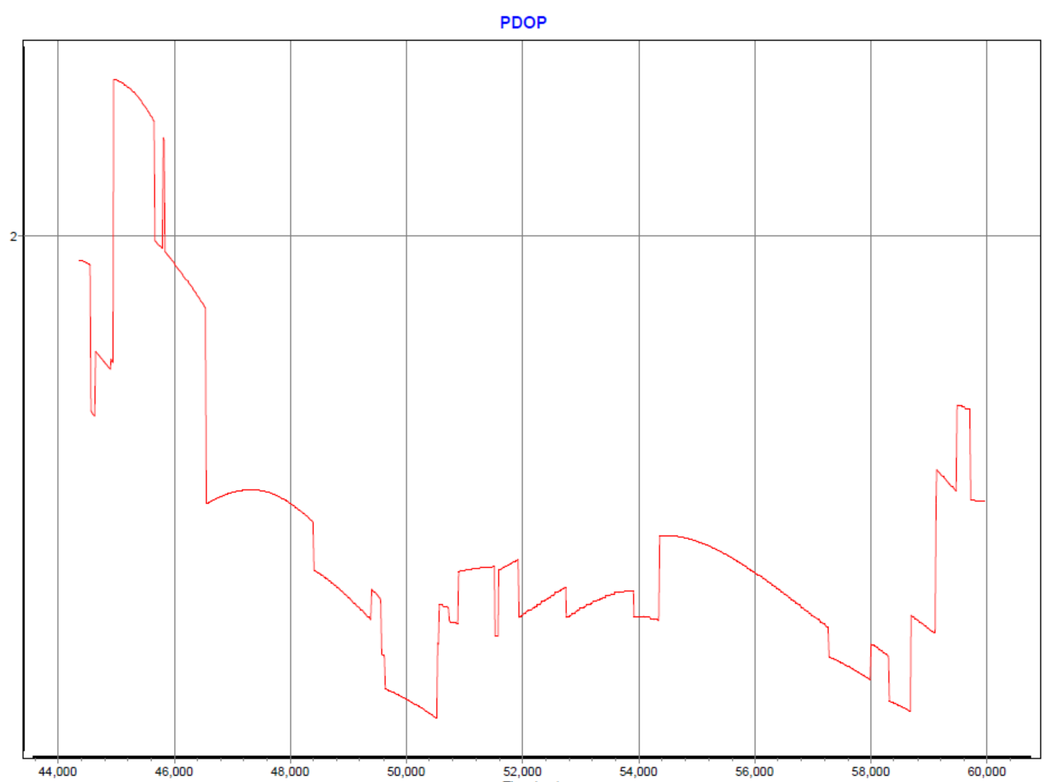
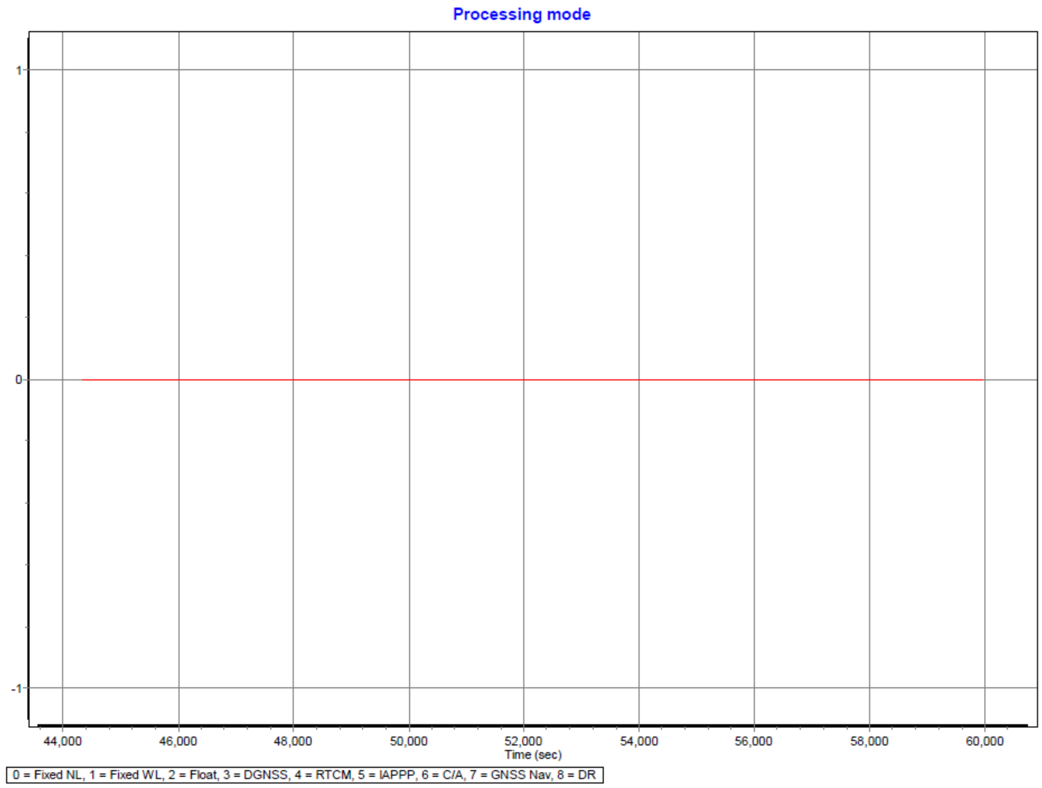

Project Settings
General Information
Units
View
Satellite Selection
GNSS-Inertial Processor
Timing, Multipath and Baseli
Initialization
Lever Arms and Mounting A
Export
Camera
LiDAR
SAR
Reference to IMU Lever Arm
X 0.034 m
Y 0.018 m
Z -0.155 m
Reference to IMU Mounting Angles
X 0.000 deg
Y 0.000 deg
Z 0.000 deg
Reference to Primary GNSS Lever Arm
X -0.150 m
Y -0.061 m
Z -0.992 m
Standard Deviation
<3cm 10cm 50cm 1m 10m
Aircraft to Reference Mounting Angles
X 0.000 deg
Y 0.000 deg
Z 0.000 deg
OK
Cancel

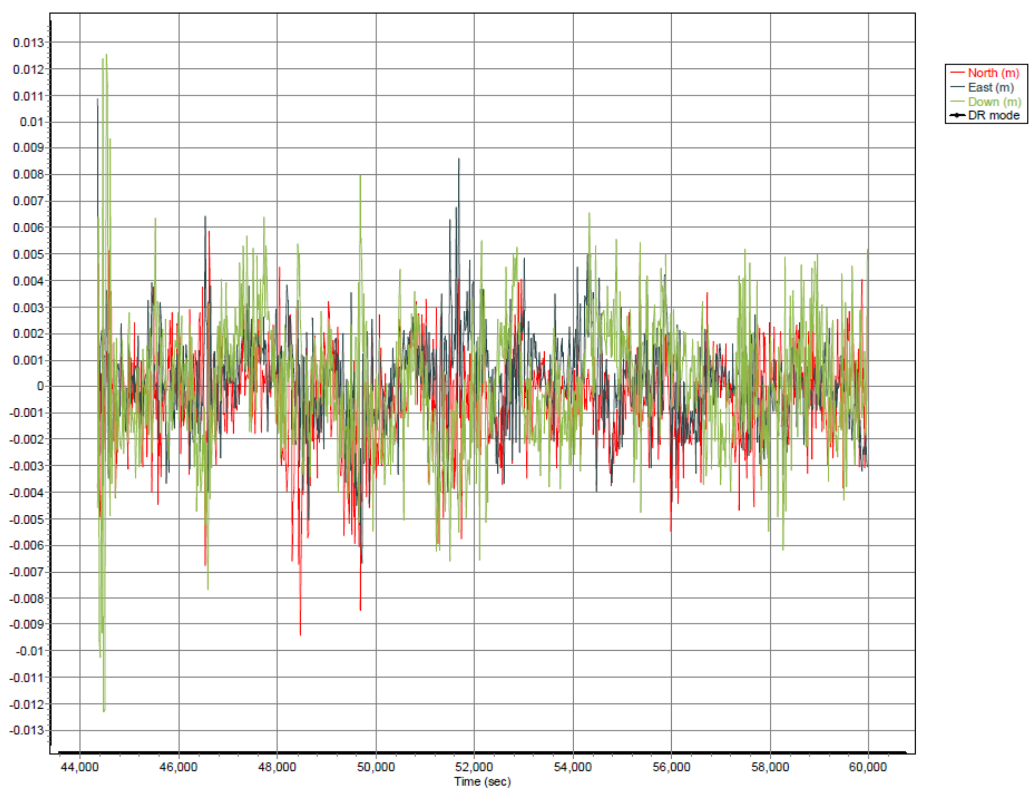

Altitude (m)
1,100
1,050
1,000
950
900
850
800
750
700
650
600
550
500
450
400
350
300
250
200
150
100
50
0
-50
44,000
46,000
48,000
50,000
52,000
54,000
56,000
58,000
60,000
Time (sec)

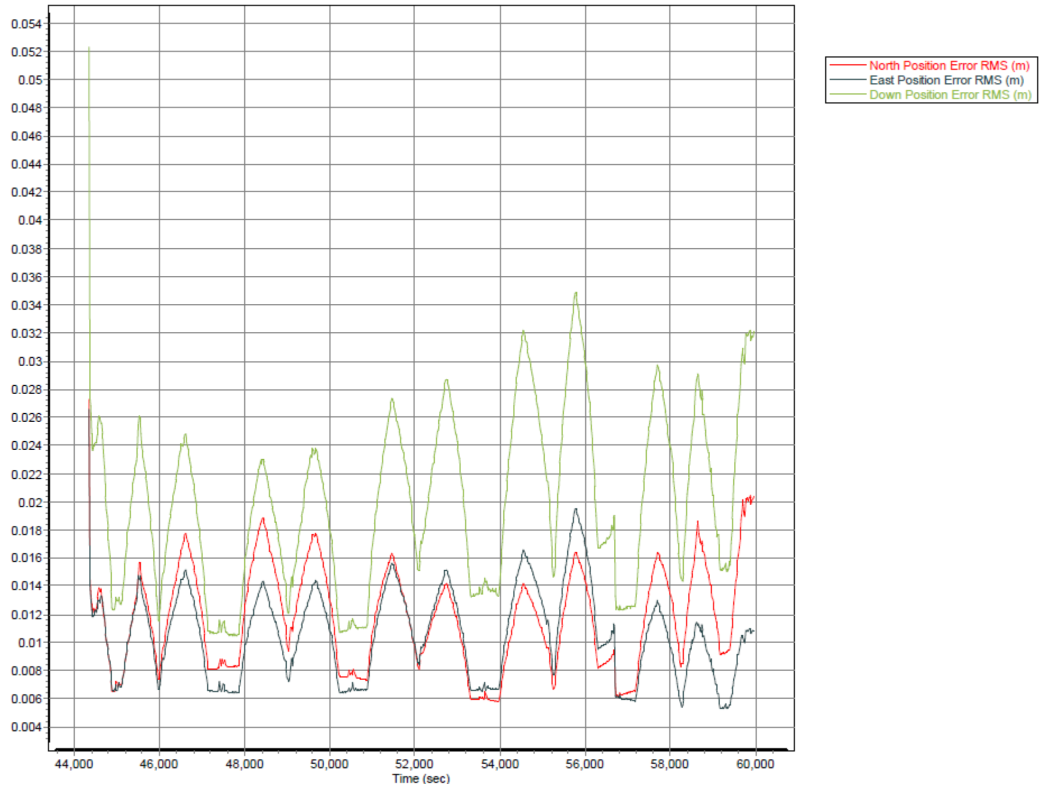

Baseline Length (m)
66,000
64,000
62,000
60,000
58,000
56,000
54,000
52,000
50,000
48,000
46,000
44,000
42,000
40,000
38,000
36,000
34,000
32,000
30,000
28,000
26,000
24,000
22,000
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
-2,000
44,000
46,000
48,000
50,000
52,000
54,000
56,000
58,000
60,000
Time (sec)

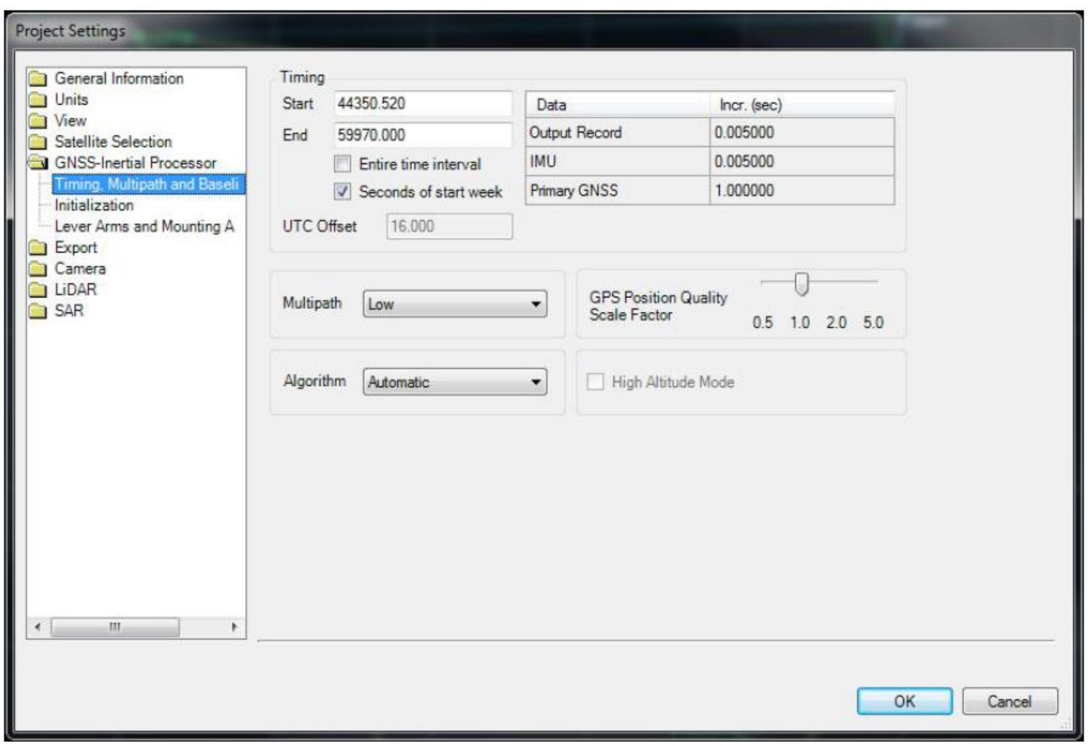

Number of GPS Satellites
10
9
8
7
6
44,000
46,000
48,000
50,000
52,000
54,000
56,000
58,000
60,000
Time (sec)

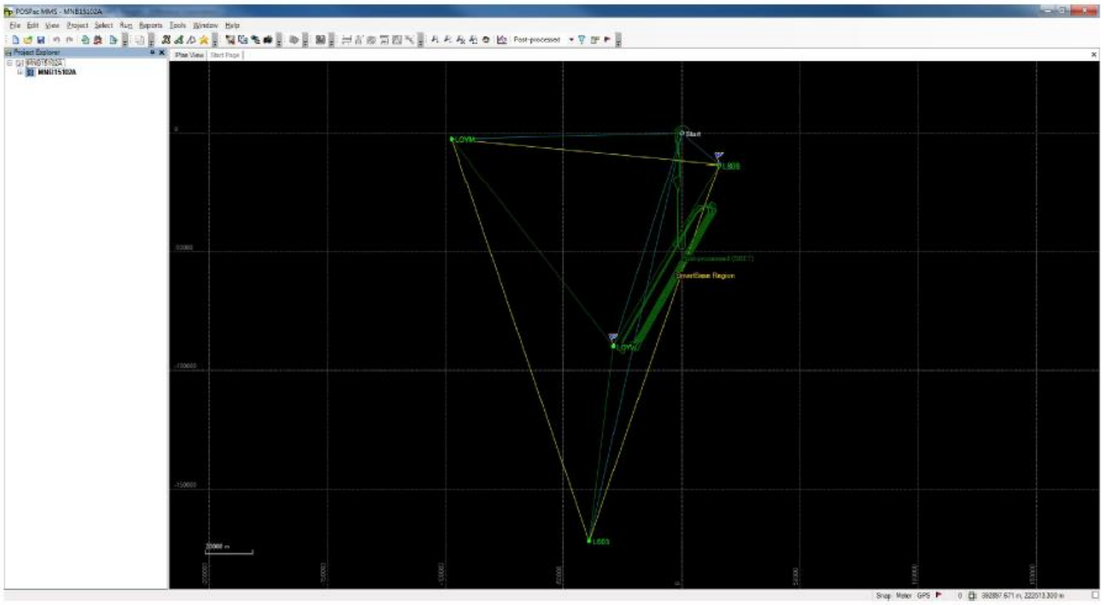

PDOP
2
44,000
46,000
48,000
50,000
52,000
54,000
56,000
58,000
60,000
Time (sec)


Processing mode
1
0
-1
44,000
46,000
48,000
50,000
52,000
54,000
56,000
58,000
60,000
Time (sec)
0 = Fixed NL, 1 = Fixed WL, 2 = Float, 3 = DGNSS, 4 = RTCM, 5 = IAPPP, 6 = C/A, 7 = GNSS Nav, 8 = DR


North (m)
East (m)
Down (m)
DR mode
0.013
0.012
0.011
0.01
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
-0.001
-0.002
-0.003
-0.004
-0.005
-0.006
-0.007
-0.008
-0.009
-0.01
-0.011
-0.012
-0.013
44,000
46,000
48,000
50,000
52,000
54,000
56,000
58,000
60,000
Time (sec)


North Position Error RMS (m)
East Position Error RMS (m)
Down Position Error RMS (m)
Time (sec)


Project Settings
General Information
Units
View
Satellite Selection
GNSS-Inertial Processor
Timing, Multipath and Baseli
Initialization
Lever Arms and Mounting A
Export
Camera
LiDAR
SAR
Timing
Start 44350.520
End 59970.000
Entire time interval
Seconds of start week
UTC Offset 16.000
Data
Incr. (sec)
Output Record 0.005000
IMU 0.005000
Primary GNSS 1.000000
Multipath Low
GPS Position Quality Scale Factor
0.5 1.0 2.0 5.0
Algorithm Automatic
High Altitude Mode
OK
Cancel



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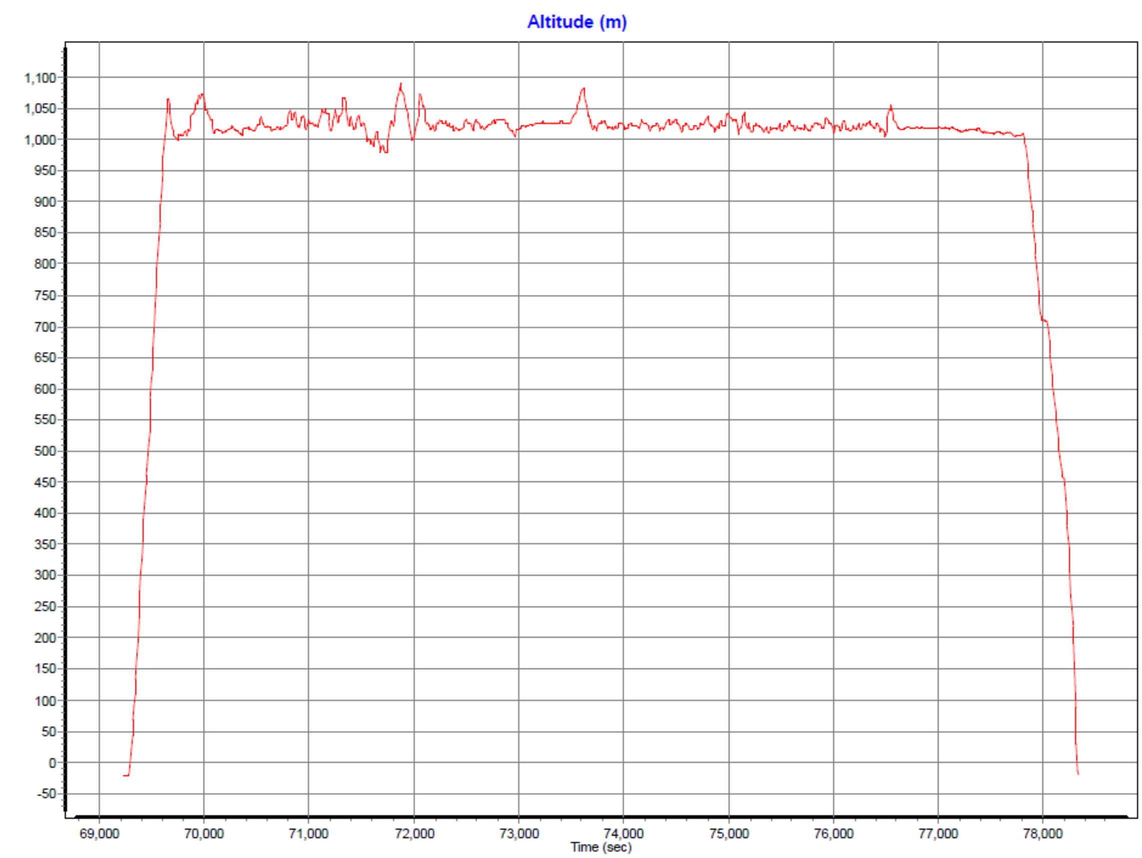
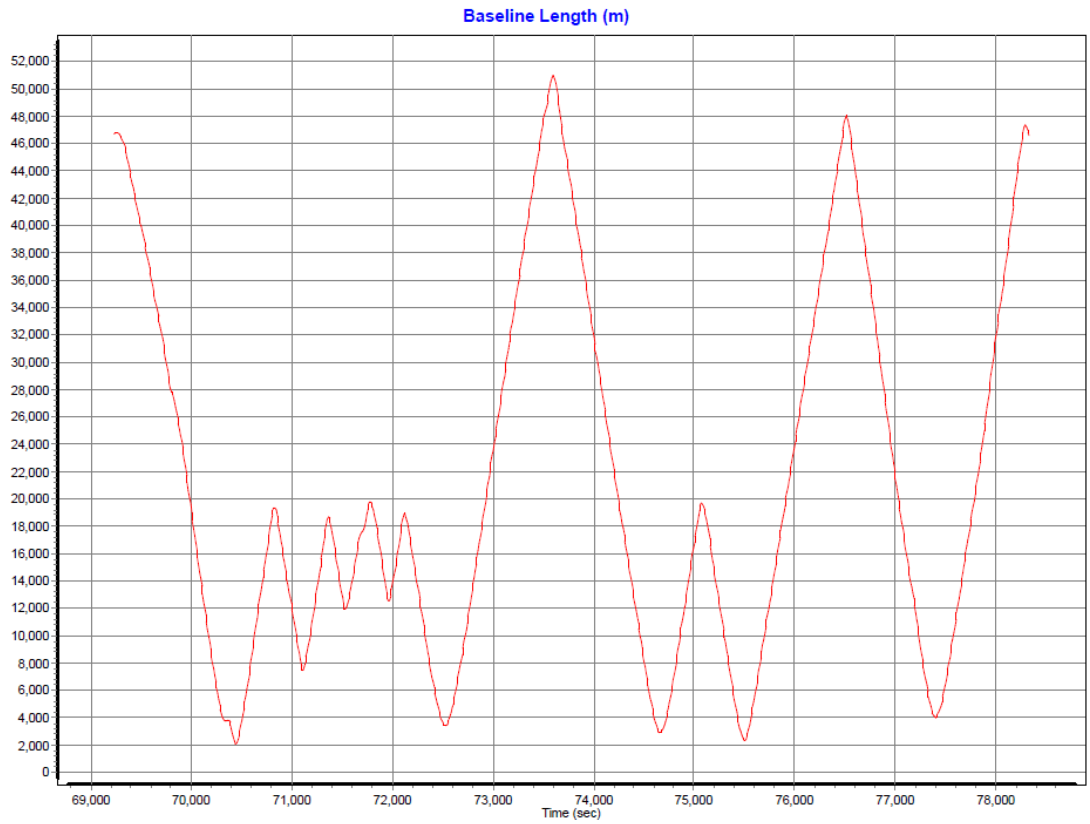
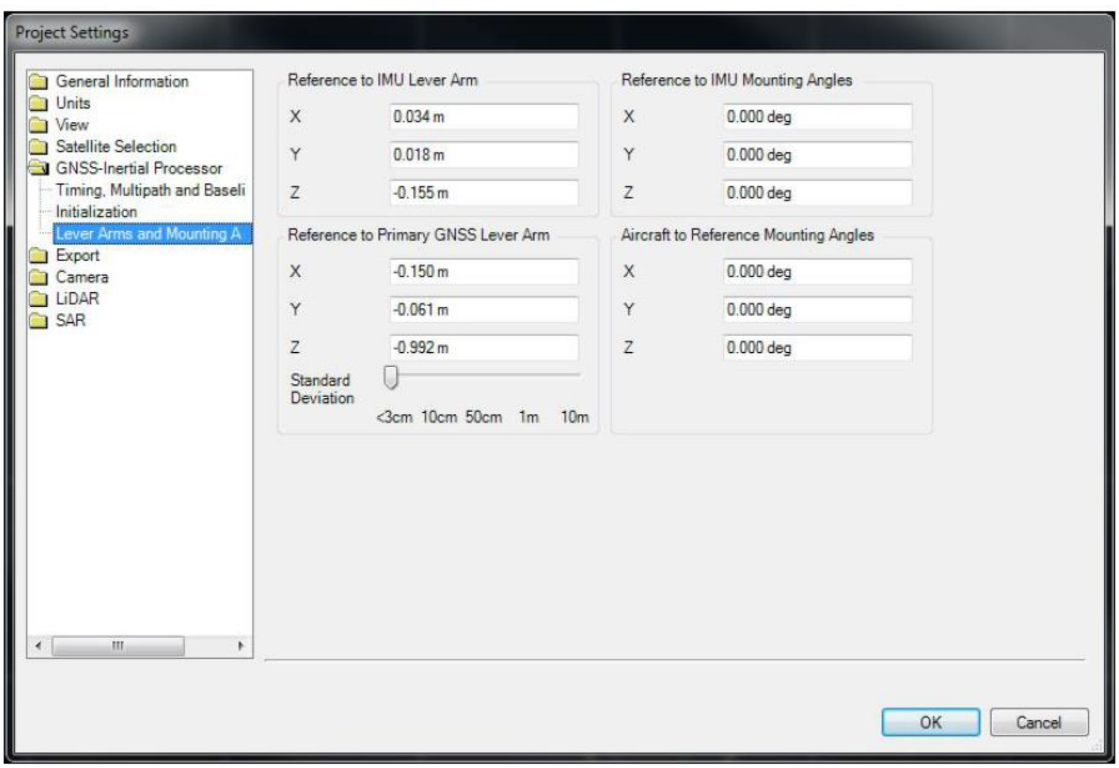
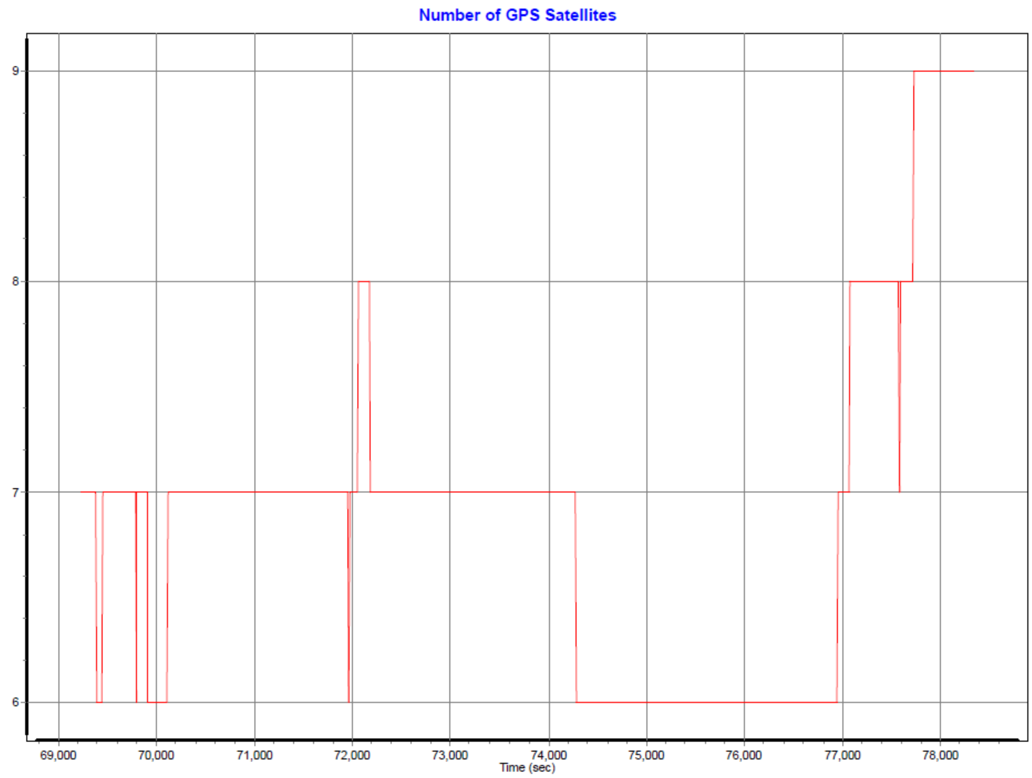
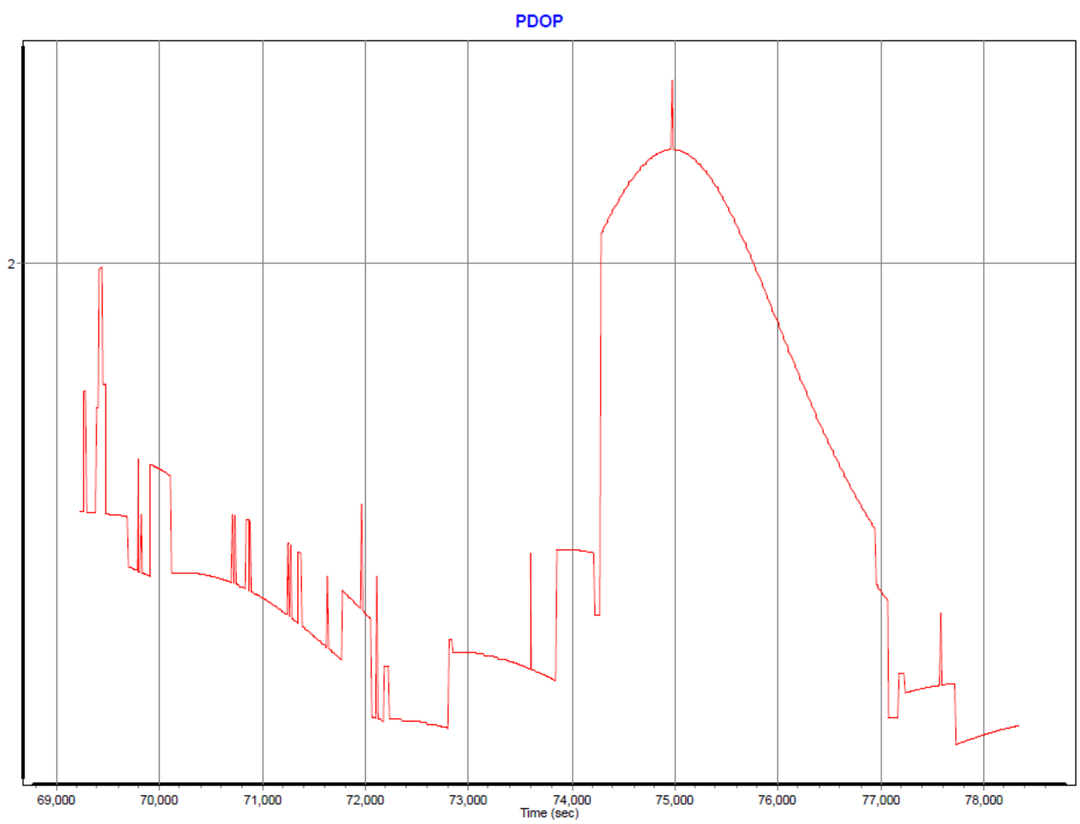
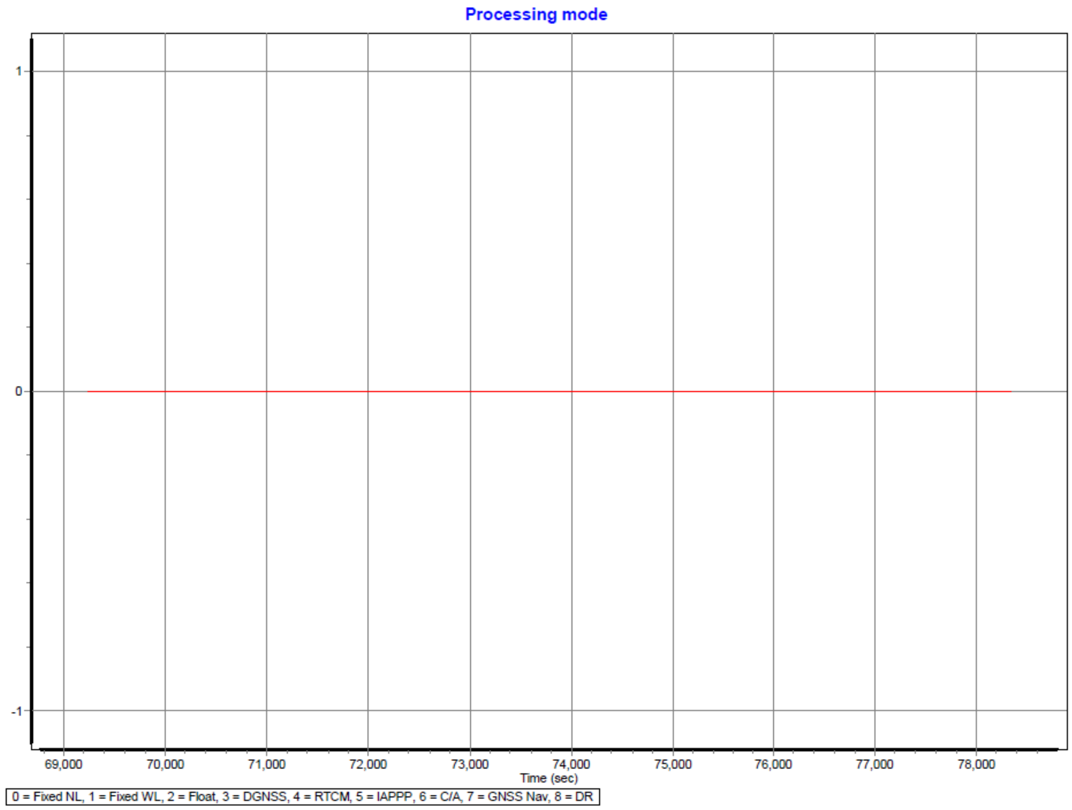

Altitude (m)
1,100
1,050
1,000
950
900
850
800
750
700
650
600
550
500
450
400
350
300
250
200
150
100
50
0
-50
69,000
70,000
71,000
72,000
73,000
74,000
75,000
76,000
77,000
78,000
Time (sec)

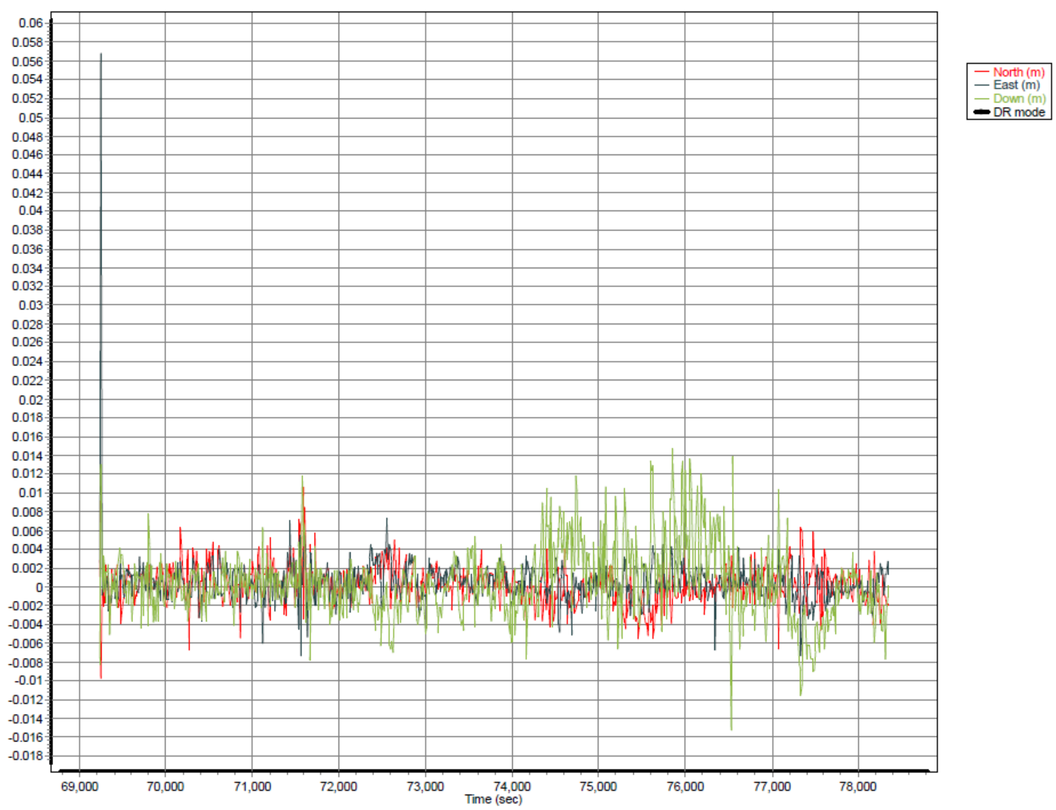

Baseline Length (m)
52,000
50,000
48,000
46,000
44,000
42,000
40,000
38,000
36,000
34,000
32,000
30,000
28,000
26,000
24,000
22,000
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
69,000
70,000
71,000
72,000
73,000
74,000
75,000
76,000
77,000
78,000
Time (sec)

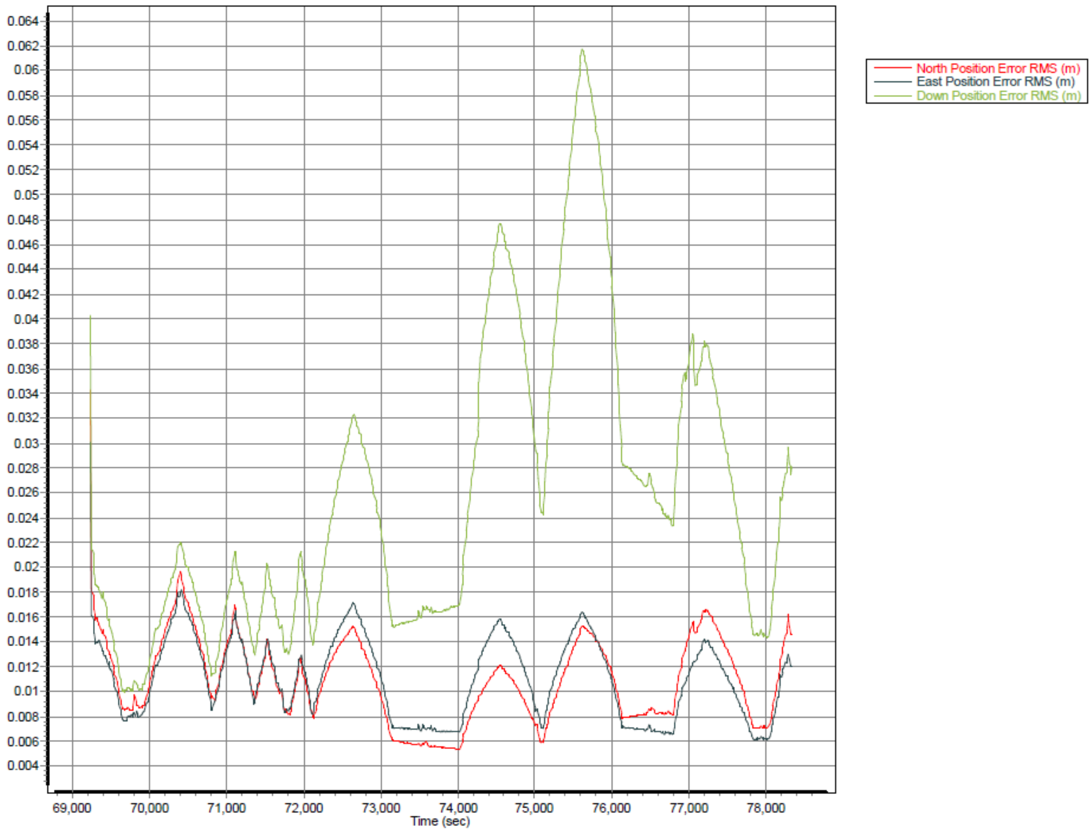

Project Settings
General Information
Units
View
Satellite Selection
GNSS-Inertial Processor
Timing, Multipath and Baseli
Initialization
Lever Arms and Mounting A
Export
Camera
LiDAR
SAR
Reference to IMU Lever Arm
X 0.034 m
Y 0.018 m
Z -0.155 m
Reference to IMU Mounting Angles
X 0.000 deg
Y 0.000 deg
Z 0.000 deg
Reference to Primary GNSS Lever Arm
X -0.150 m
Y -0.061 m
Z -0.992 m
Standard Deviation
<3cm 10cm 50cm 1m 10m
Aircraft to Reference Mounting Angles
X 0.000 deg
Y 0.000 deg
Z 0.000 deg
OK
Cancel

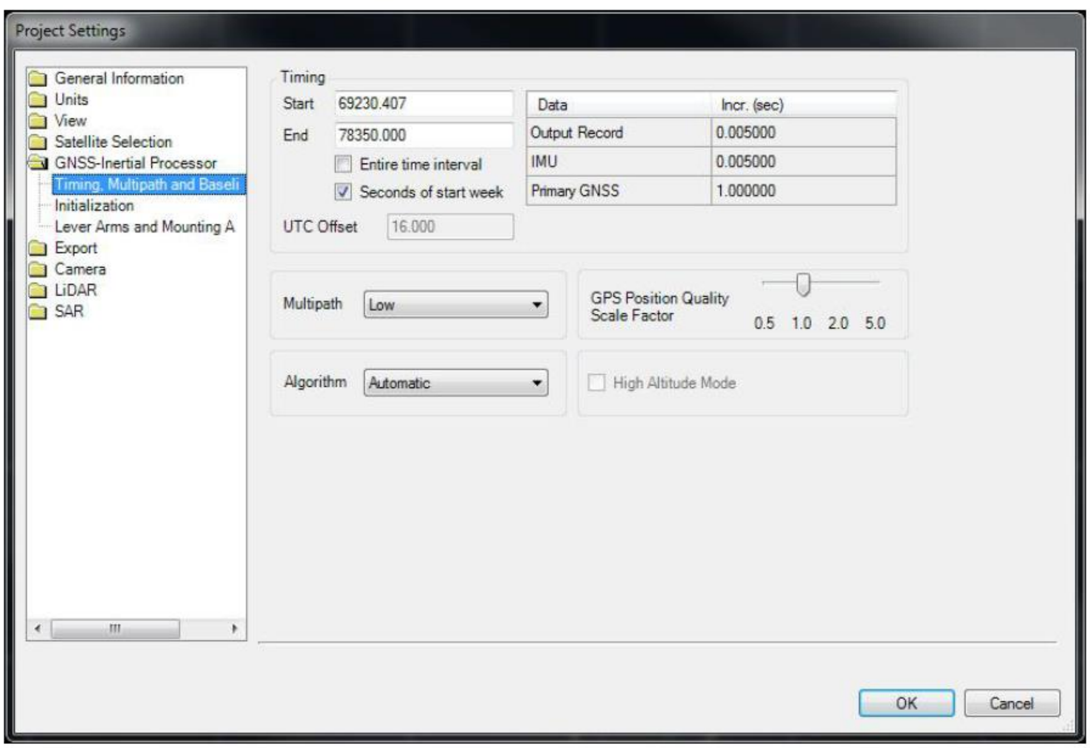

Number of GPS Satellites
9
8
7
6
69,000
70,000
71,000
72,000
73,000
74,000
75,000
76,000
77,000
78,000
Time (sec)

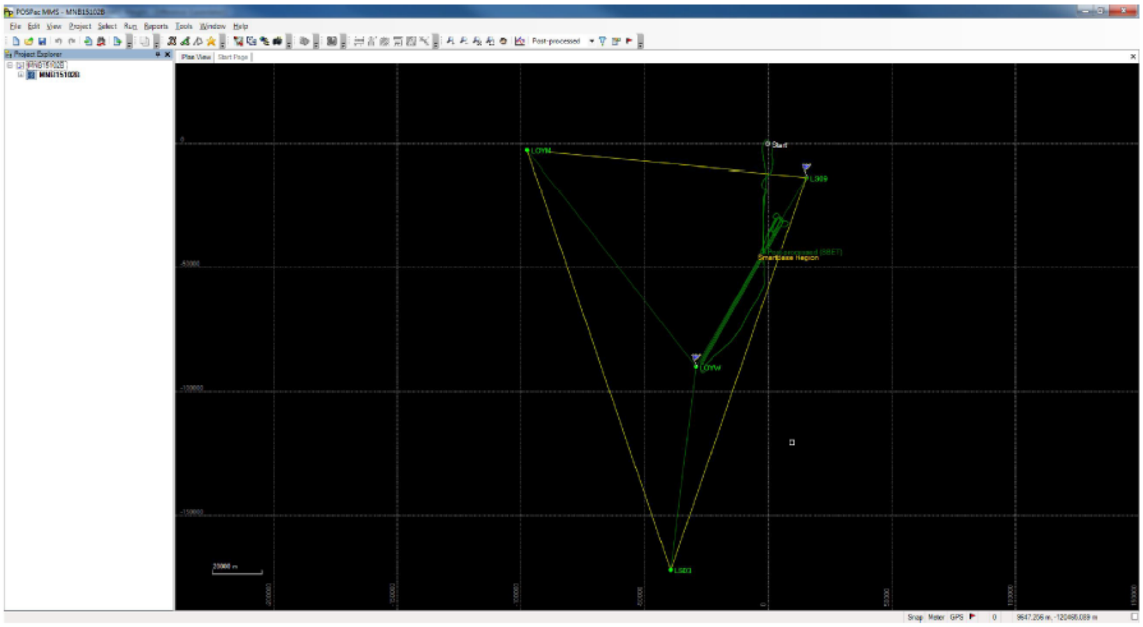

PDOP
2
69,000
70,000
71,000
72,000
73,000
74,000
75,000
76,000
77,000
78,000
Time (sec)


Processing mode
1
0
-1
69,000
70,000
71,000
72,000
73,000
74,000
75,000
76,000
77,000
78,000
Time (sec)
0 = Fixed NL, 1 = Fixed WL, 2 = Float, 3 = DGNSS, 4 = RTCM, 5 = IAPPP, 6 = C/A, 7 = GNSS Nav, 8 = DR


North (m)
East (m)
Down (m)
DR mode
Time (sec)


North Position Error RMS (m)
East Position Error RMS (m)
Down Position Error RMS (m)
Time (sec)
69,000
70,000
71,000
72,000
73,000
74,000
75,000
76,000
77,000
78,000


Project Settings
General Information
Units
View
Satellite Selection
GNSS-Inertial Processor
Timing, Multipath and Baseli
Initialization
Lever Arms and Mounting A
Export
Camera
LiDAR
SAR
Timing
Start 69230.407
End 78350.000
Entire time interval
Seconds of start week
UTC Offset 16.000
Data | Incr. (sec)
Output Record | 0.005000
IMU | 0.005000
Primary GNSS | 1.000000
Multipath Low
GPS Position Quality Scale Factor
0.5 1.0 2.0 5.0
Algorithm Automatic
High Altitude Mode
OK
Cancel



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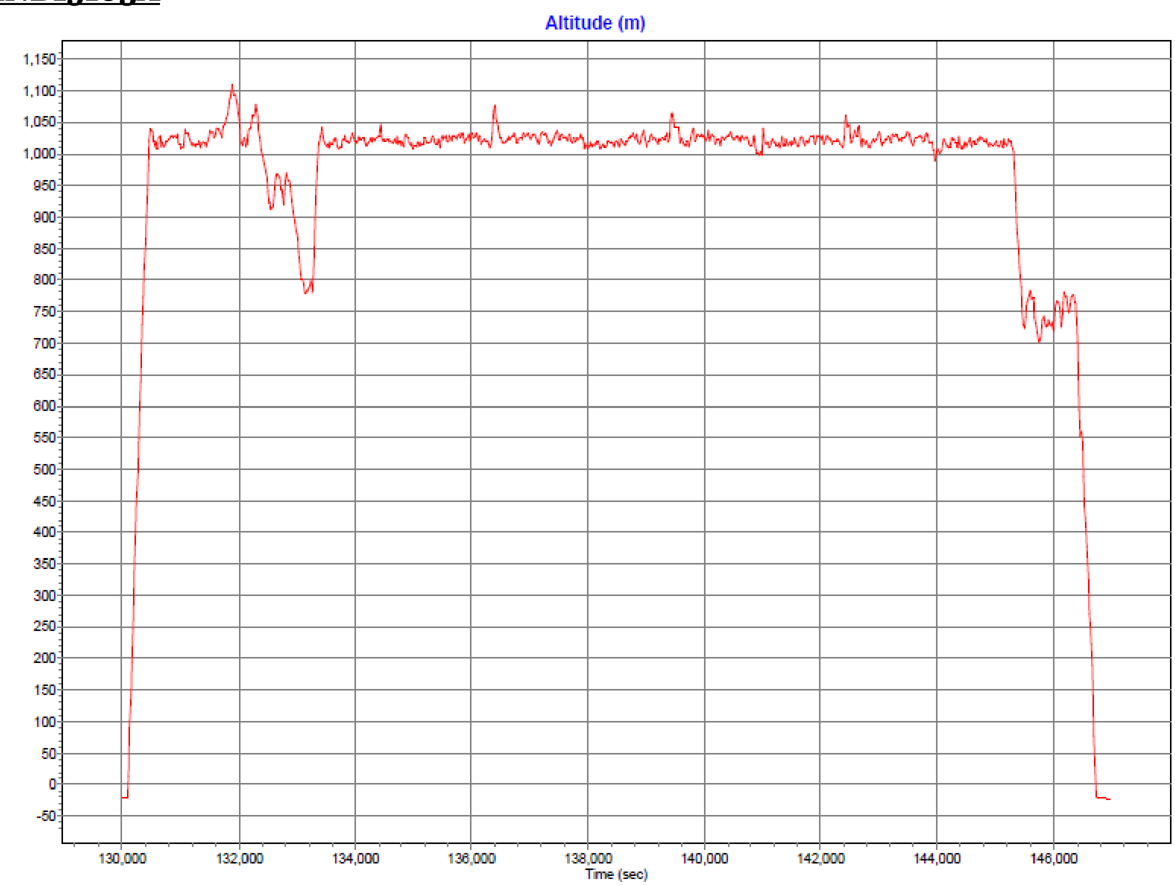
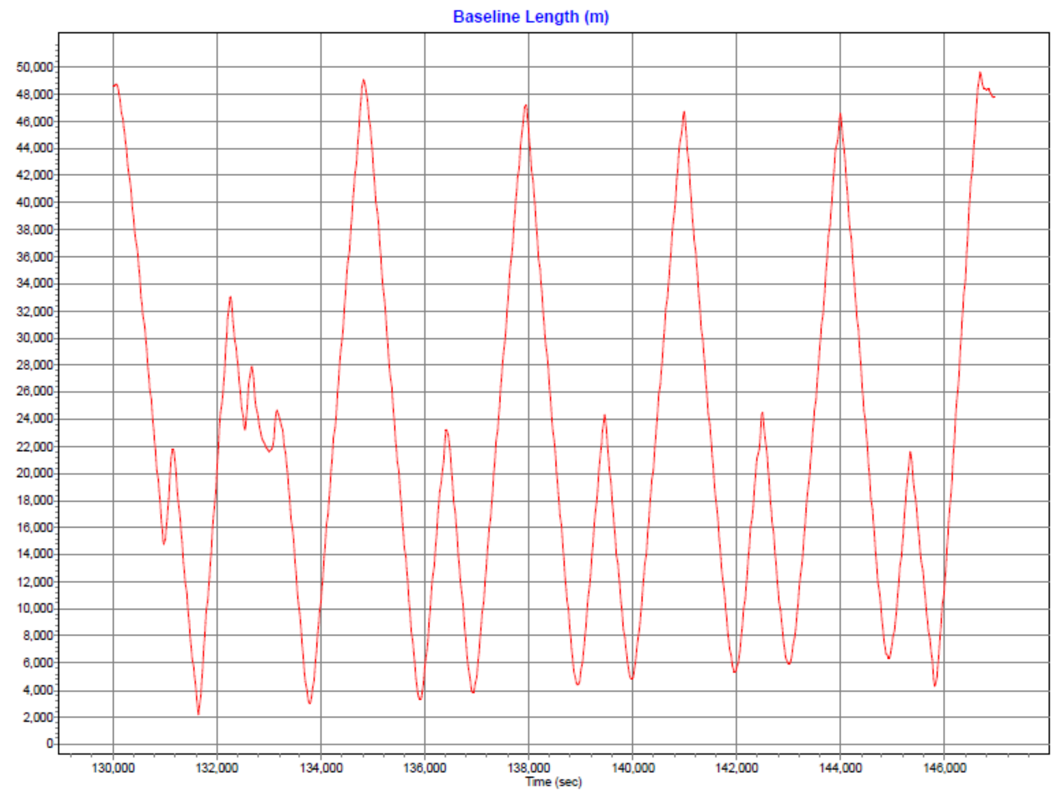
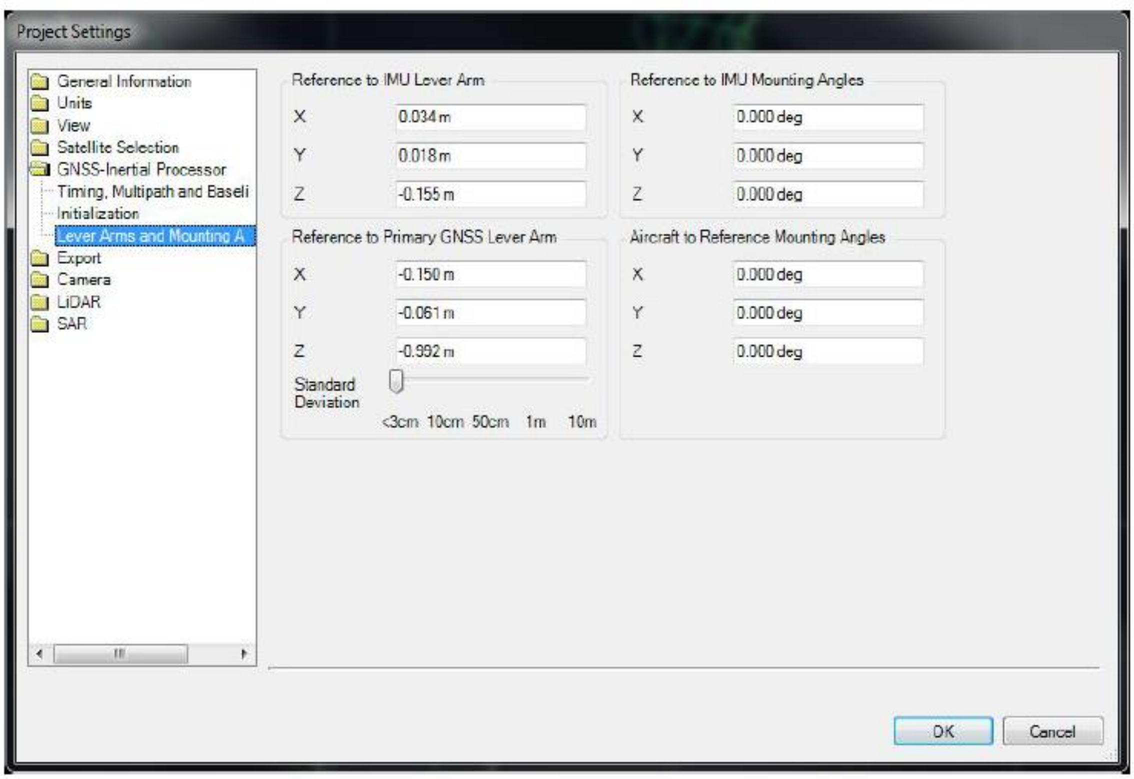
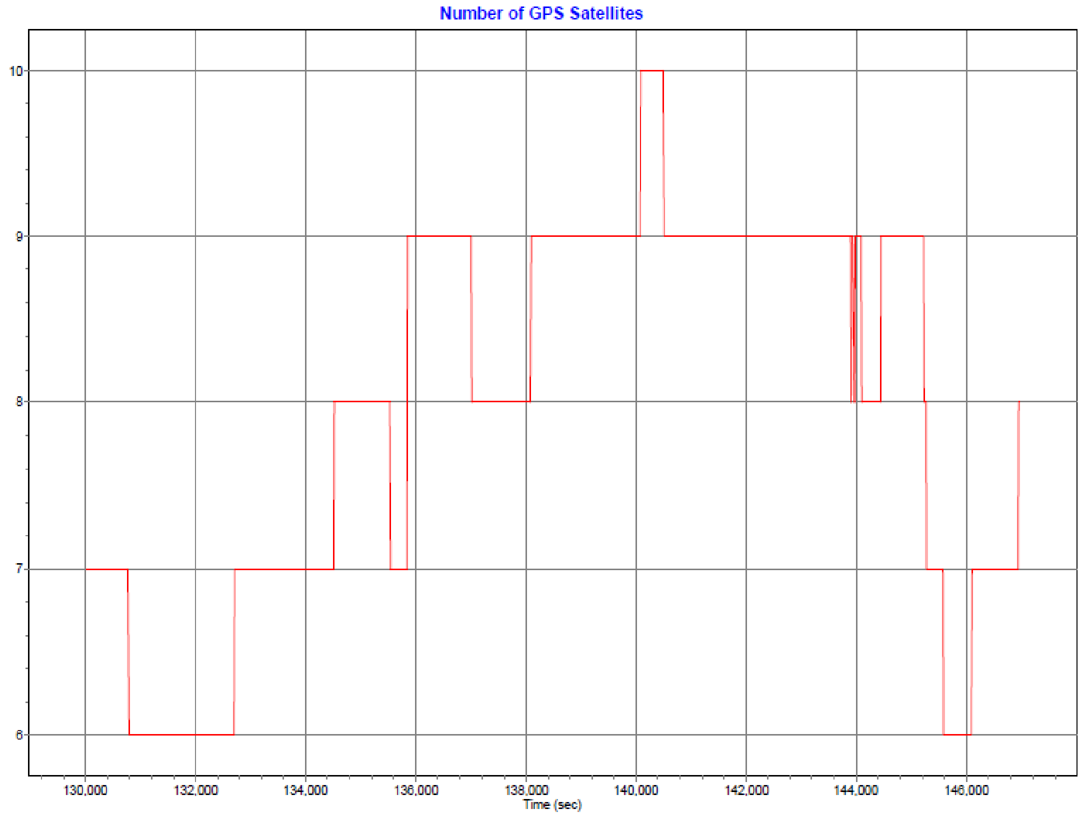
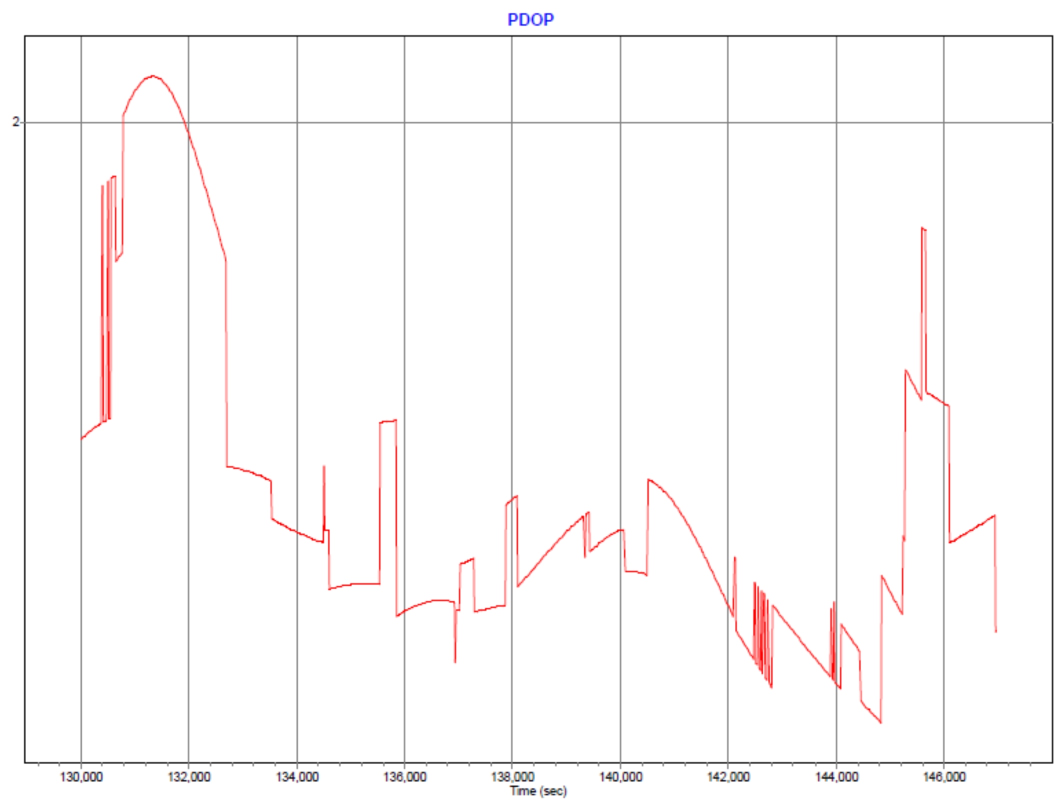
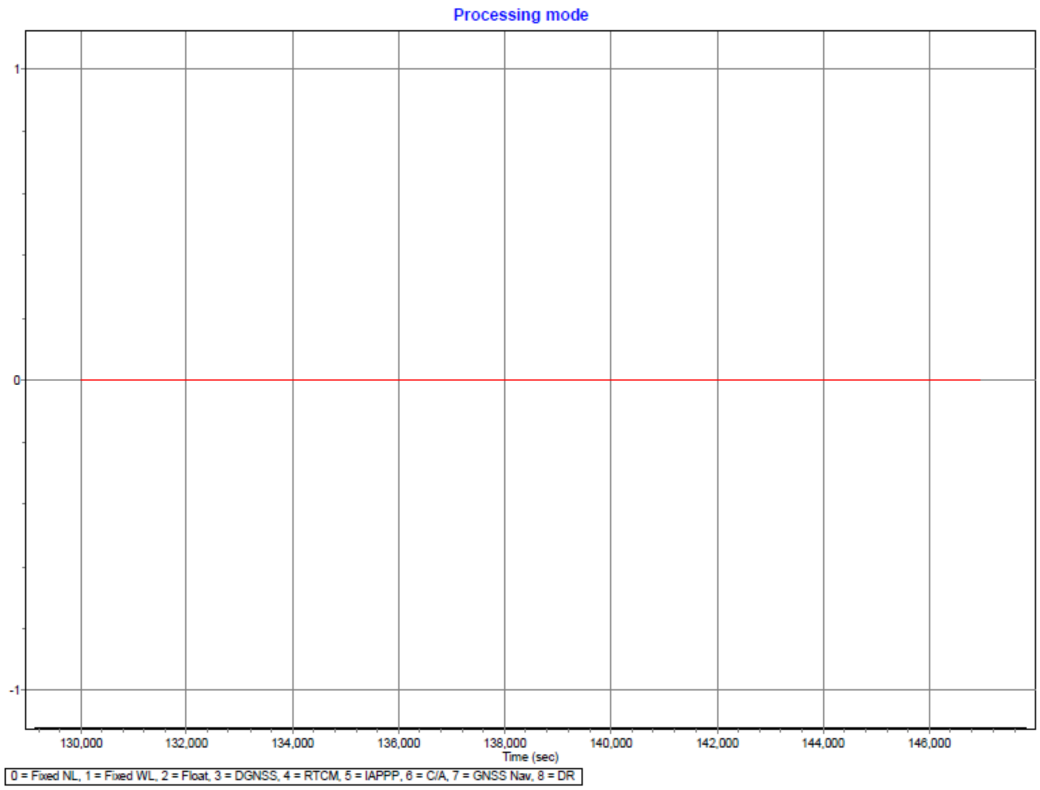

Altitude (m)
1,150
1,100
1,050
1,000
950
900
850
800
750
700
650
600
550
500
450
400
350
300
250
200
150
100
50
0
-50
130,000
132,000
134,000
136,000
138,000
140,000
142,000
144,000
146,000
Time (sec)

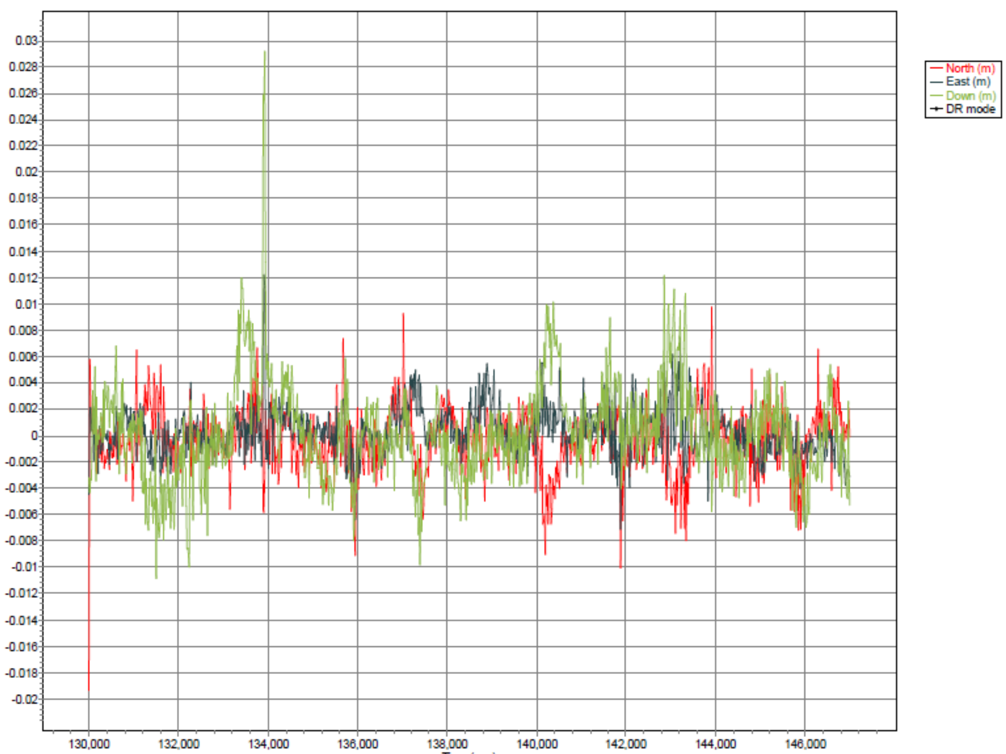

Baseline Length (m)
50,000
48,000
46,000
44,000
42,000
40,000
38,000
36,000
34,000
32,000
30,000
28,000
26,000
24,000
22,000
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
130,000
132,000
134,000
136,000
138,000
140,000
142,000
144,000
146,000
Time (sec)

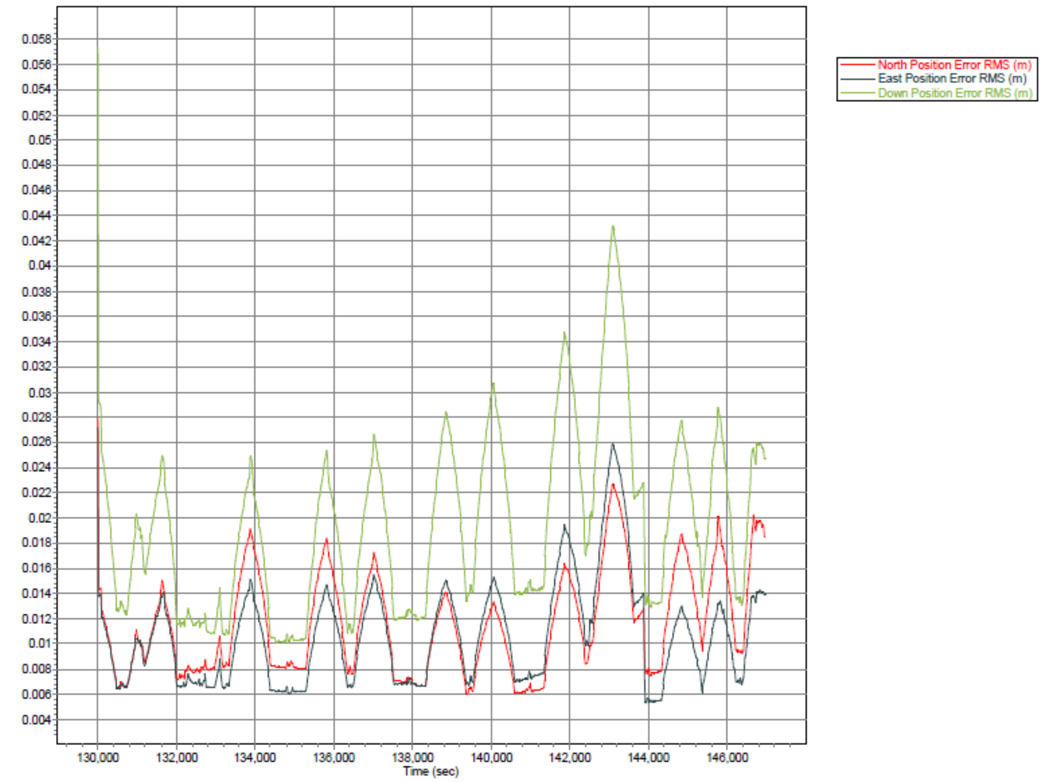

Project Settings
General Information
Units
View
Satellite Selection
GNSS-Inertial Processor
Timing, Multipath and Baseli
Initialization
Lever Arms and Mounting A
Export
Camera
LiDAR
SAR
Reference to IMU Lever Arm
X 0.034 m
Y 0.018 m
Z -0.155 m
Reference to IMU Mounting Angles
X 0.000 deg
Y 0.000 deg
Z 0.000 deg
Reference to Primary GNSS Lever Arm
X -0.150 m
Y -0.061 m
Z -0.992 m
Standard Deviation
<3cm 10cm 50cm 1m 10m
Aircraft to Reference Mounting Angles
X 0.000 deg
Y 0.000 deg
Z 0.000 deg
OK
Cancel

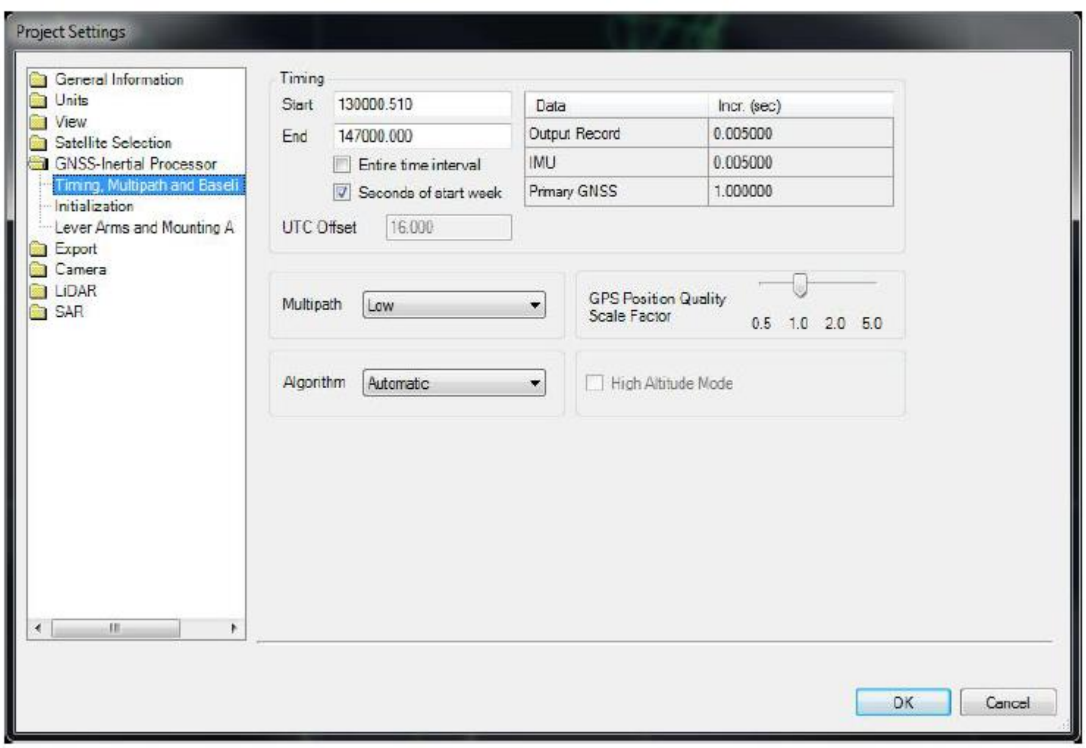

Number of GPS Satellites
10
9
8
7
6
130,000
132,000
134,000
136,000
138,000
140,000
142,000
144,000
146,000
Time (sec)

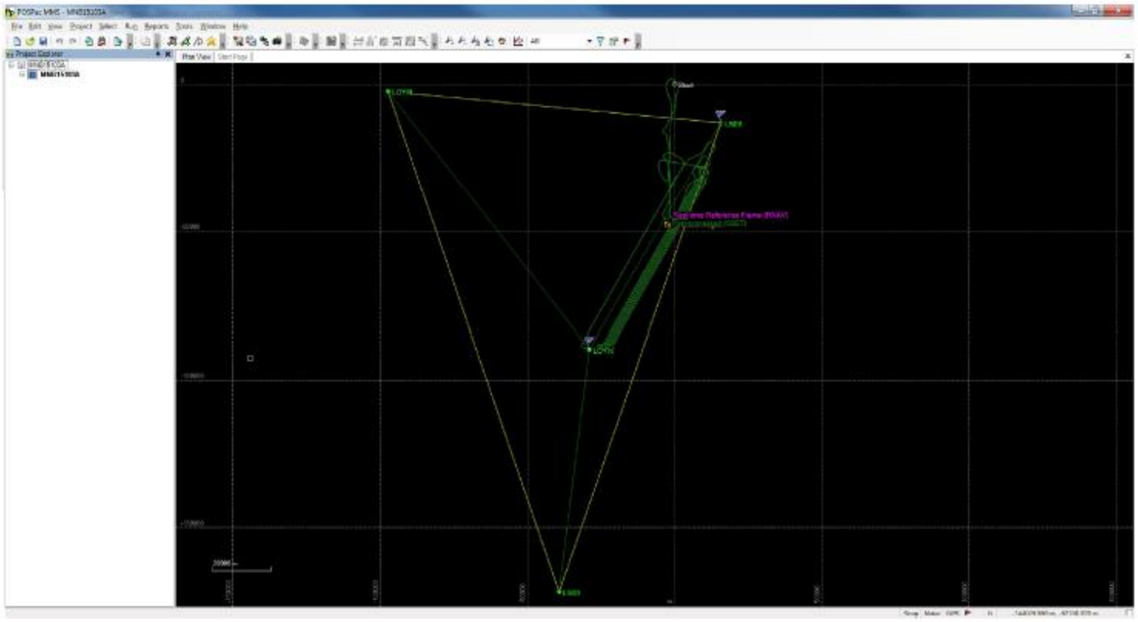

PDOP
2
130,000
132,000
134,000
136,000
138,000
140,000
142,000
144,000
146,000
Time (sec)


Processing mode
1
0
-1
130,000
132,000
134,000
136,000
138,000
140,000
142,000
144,000
146,000
Time (sec)
0 = Fixed NL, 1 = Fixed WL, 2 = Float, 3 = DGNSS, 4 = RTCM, 5 = IAPPP, 6 = C/A, 7 = GNSS Nav, 8 = DR


North (m)
East (m)
Down (m)
DR mode
Time (sec)


North Position Error RMS (m)
East Position Error RMS (m)
Down Position Error RMS (m)
0.058
0.056
0.054
0.052
0.05
0.048
0.046
0.044
0.042
0.04
0.038
0.036
0.034
0.032
0.03
0.028
0.026
0.024
0.022
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
130,000
132,000
134,000
136,000
138,000
140,000
142,000
144,000
146,000
Time (sec)


Project Settings
General Information
Units
View
Satellite Selection
GNSS-Inertial Processor
Timing, Multipath and Baseli
Initialization
Lever Arms and Mounting A
Export
Camera
LiDAR
SAR
Timing
Start 130000.510
End 147000.000
Entire time interval
Seconds of start week
UTC Offset 16.000
Data
Incr. (sec)
Output Record 0.005000
IMU 0.005000
Primary GNSS 1.000000
Multipath Low
GPS Position Quality Scale Factor
0.5 1.0 2.0 5.0
Algorithm Automatic
High Altitude Mode
OK
Cancel



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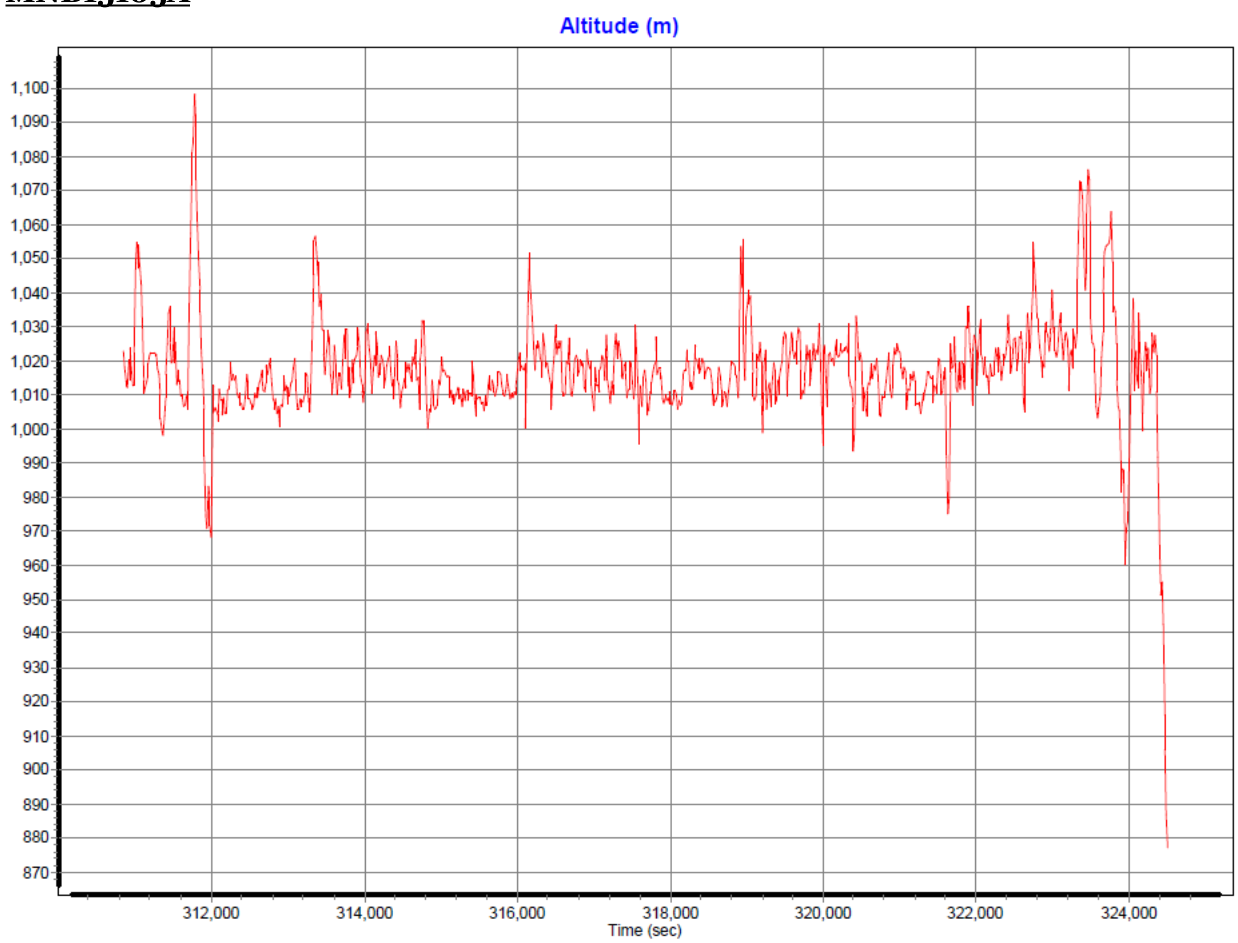
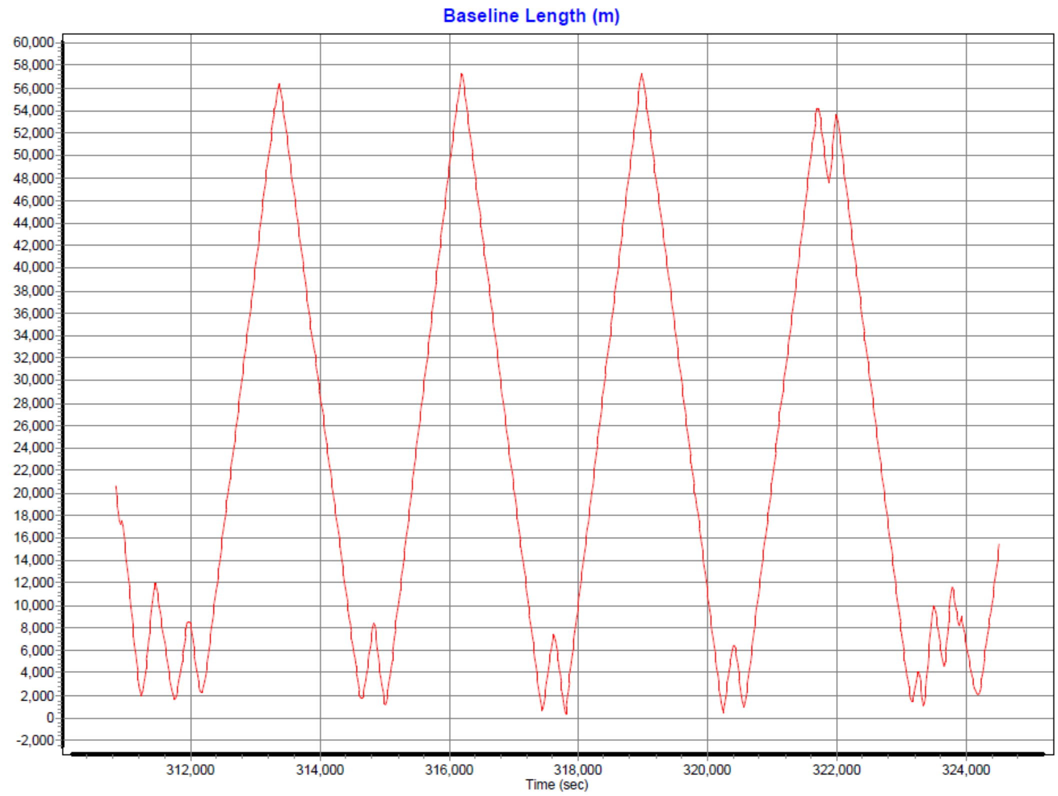
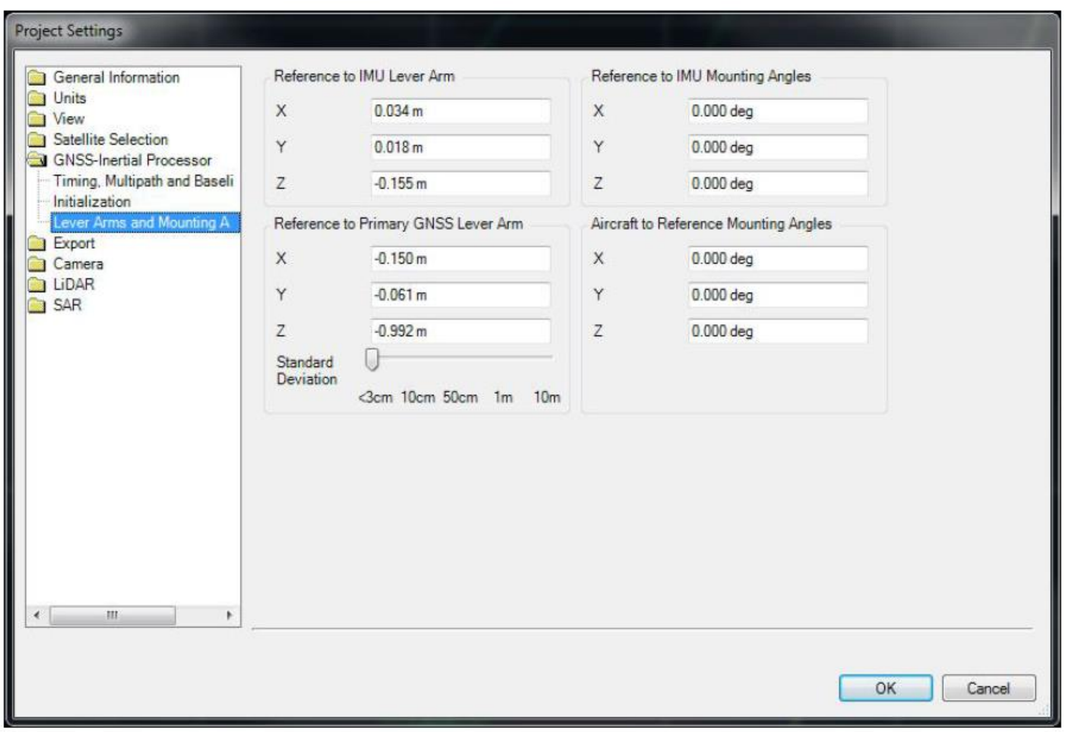
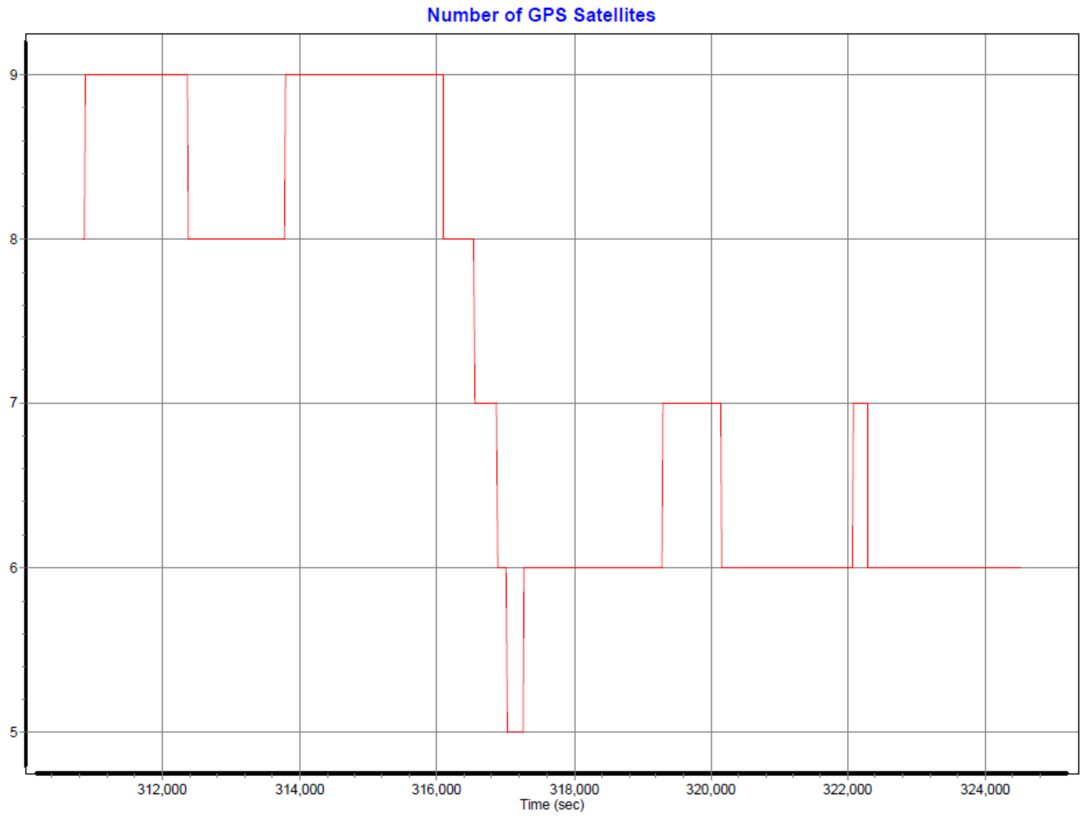
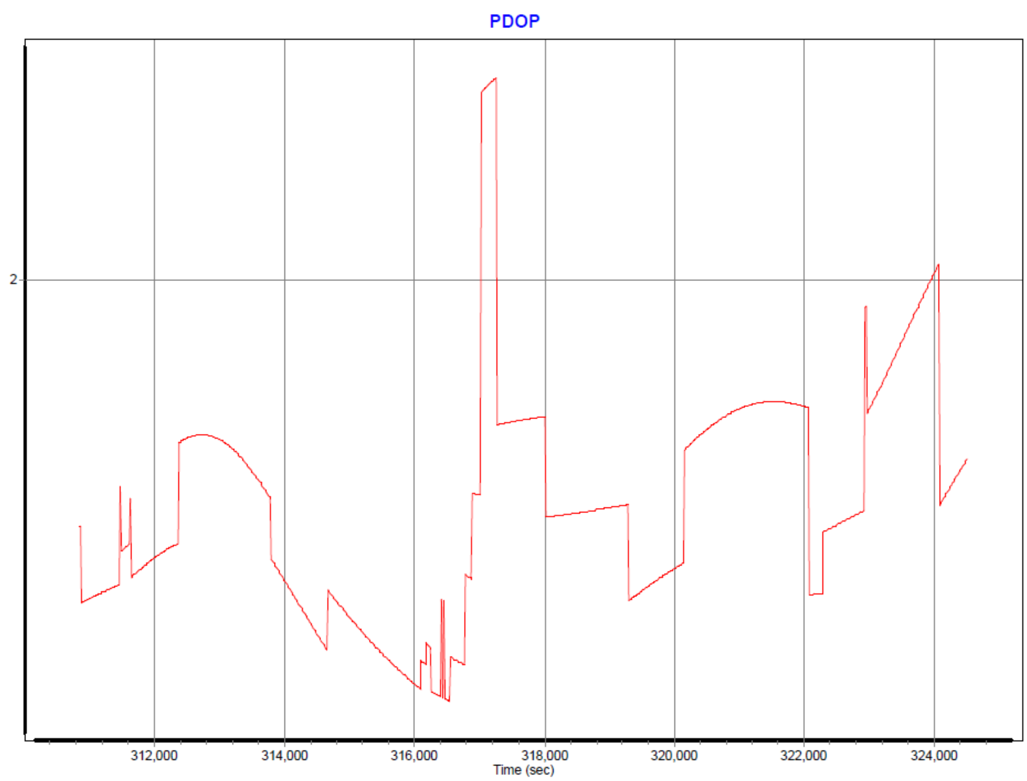
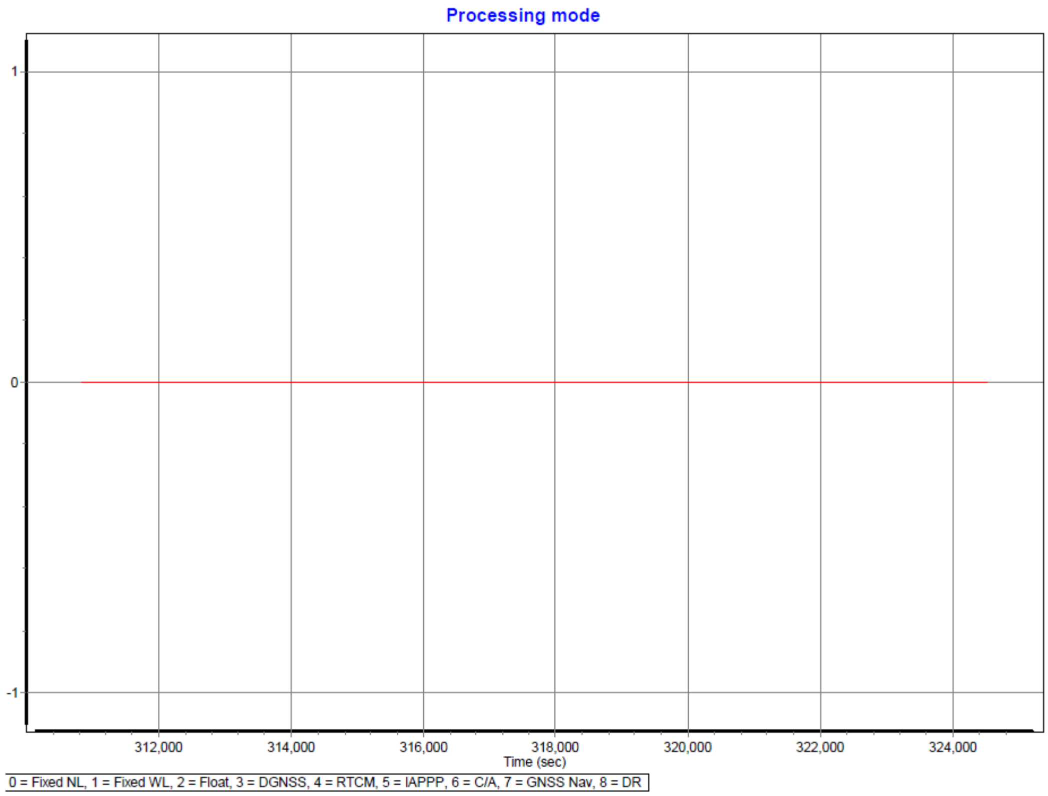

Altitude (m)
1,100
1,090
1,080
1,070
1,060
1,050
1,040
1,030
1,020
1,010
1,000
990
980
970
960
950
940
930
920
910
900
890
880
870
312,000
314,000
316,000
318,000
320,000
322,000
324,000
Time (sec)

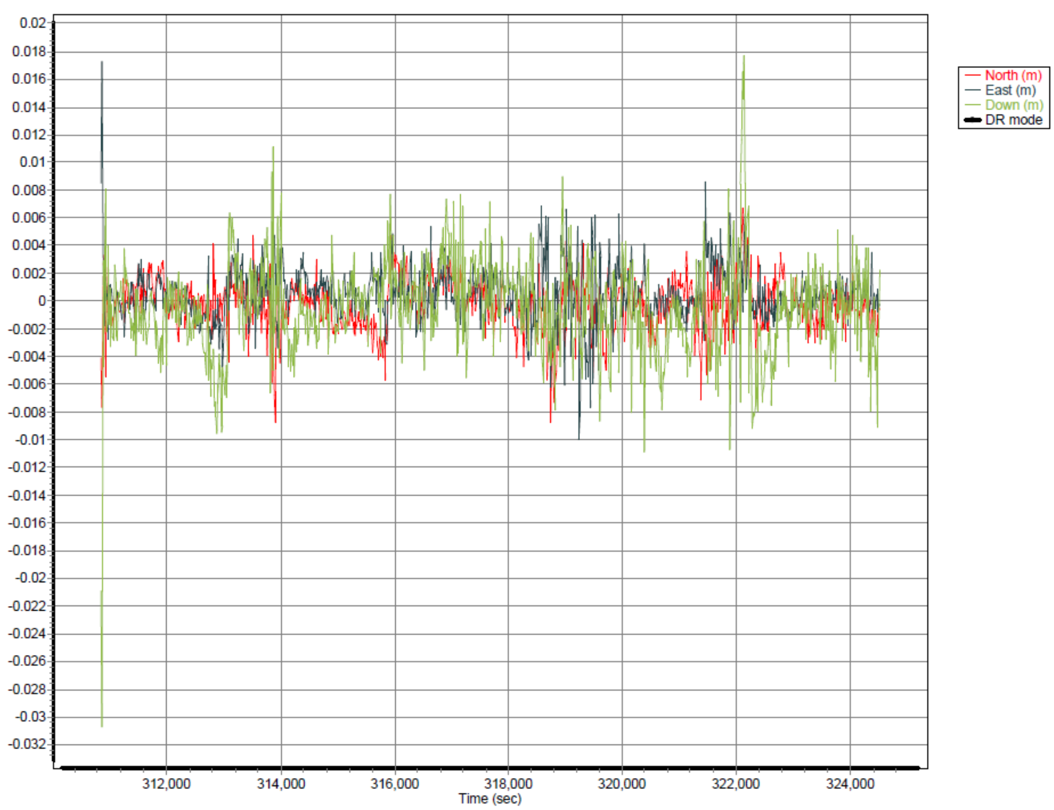

Baseline Length (m)
60,000
58,000
56,000
54,000
52,000
50,000
48,000
46,000
44,000
42,000
40,000
38,000
36,000
34,000
32,000
30,000
28,000
26,000
24,000
22,000
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
-2,000
312,000
314,000
316,000
318,000
320,000
322,000
324,000
Time (sec)

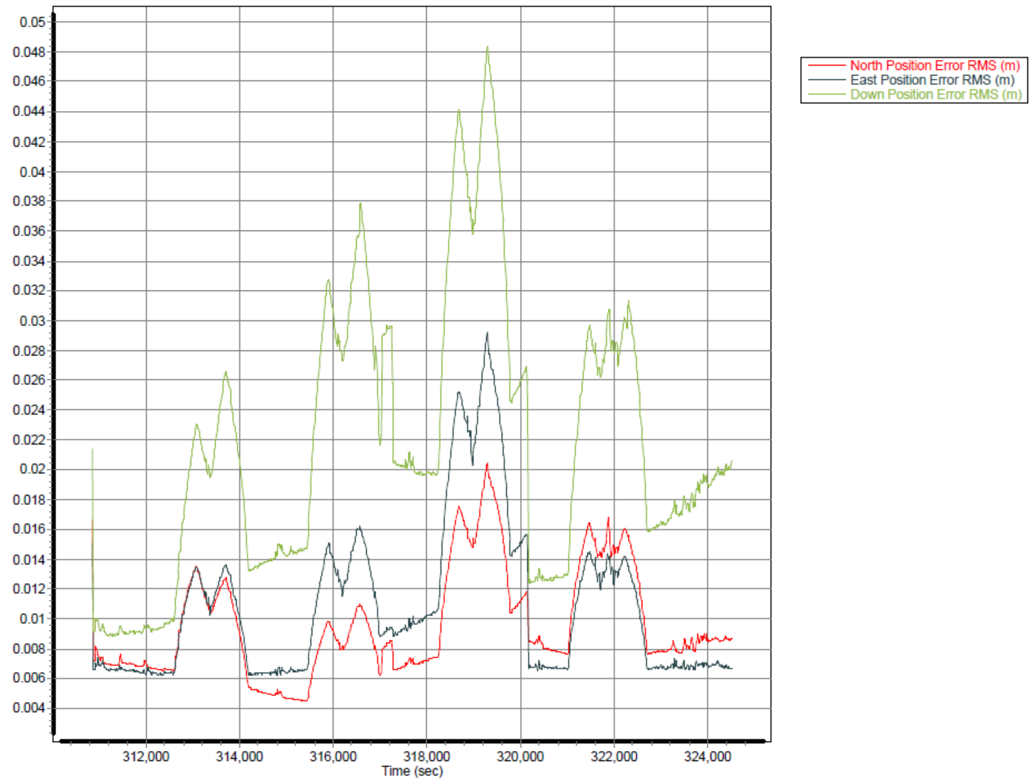

Project Settings
General Information
Units
View
Satellite Selection
GNSS-Inertial Processor
Timing, Multipath and Baseli
Initialization
Lever Arms and Mounting A
Export
Camera
LiDAR
SAR
Reference to IMU Lever Arm
X 0.034 m
Y 0.018 m
Z -0.155 m
Reference to IMU Mounting Angles
X 0.000 deg
Y 0.000 deg
Z 0.000 deg
Reference to Primary GNSS Lever Arm
X -0.150 m
Y -0.061 m
Z -0.992 m
Standard Deviation
<3cm 10cm 50cm 1m 10m
Aircraft to Reference Mounting Angles
X 0.000 deg
Y 0.000 deg
Z 0.000 deg
OK
Cancel

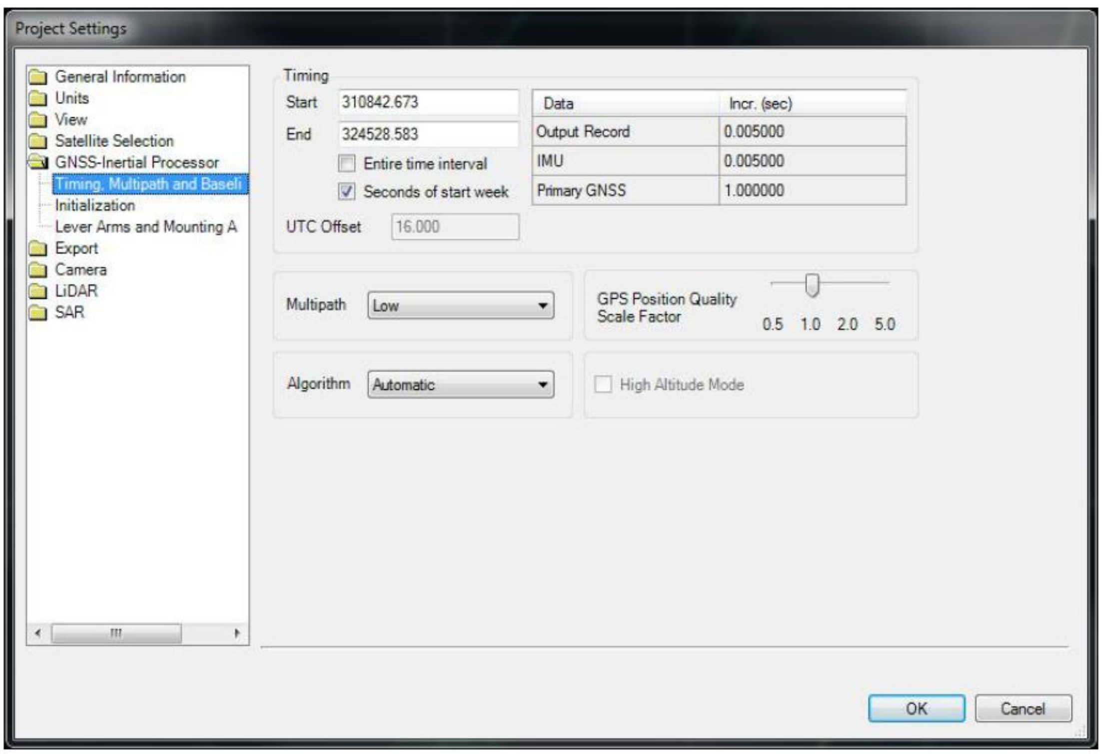

Number of GPS Satellites
9
8
7
6
5
312,000
314,000
316,000
318,000
320,000
322,000
324,000
Time (sec)

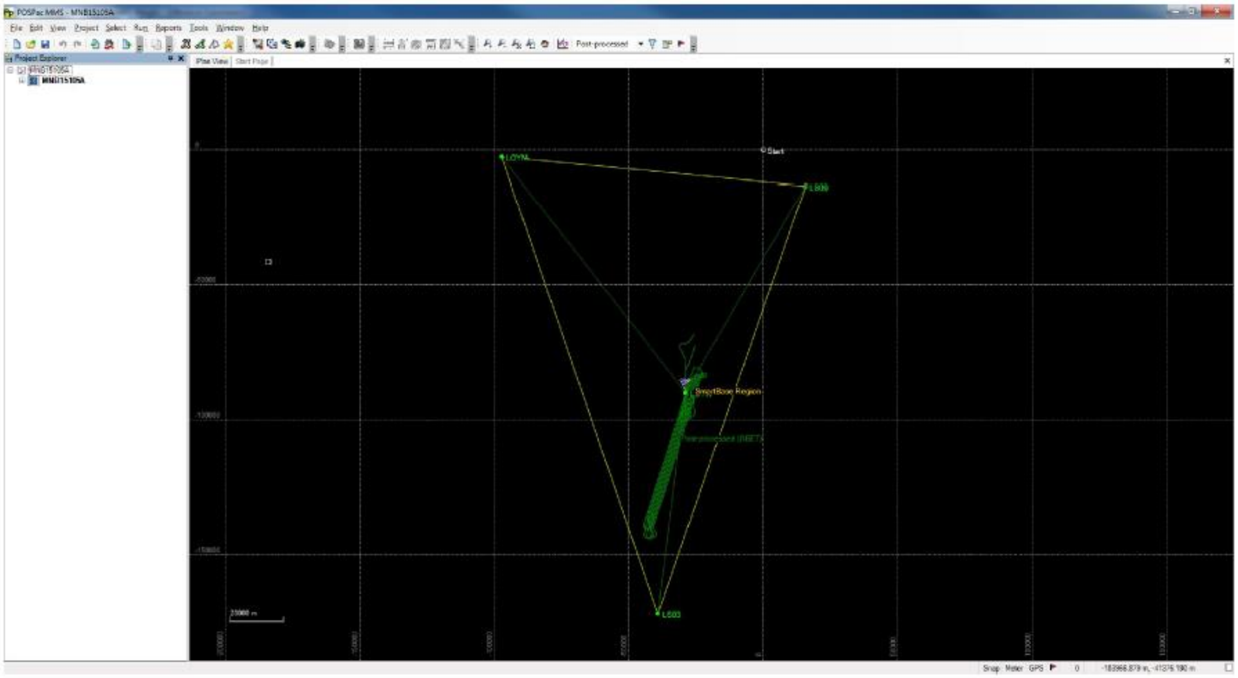

PDOP
2
312,000
314,000
316,000
318,000
320,000
322,000
324,000
Time (sec)


Processing mode
1
0
-1
312,000
314,000
316,000
318,000
320,000
322,000
324,000
Time (sec)
0 = Fixed NL, 1 = Fixed WL, 2 = Float, 3 = DGNSS, 4 = RTCM, 5 = IAPPP, 6 = C/A, 7 = GNSS Nav, 8 = DR


North (m)
East (m)
Down (m)
DR mode
0.02
0
-0.032
312,000
314,000
316,000
318,000
320,000
322,000
324,000
Time (sec)


North Position Error RMS (m)
East Position Error RMS (m)
Down Position Error RMS (m)
Time (sec)


Project Settings
General Information
Units
View
Satellite Selection
GNSS-Inertial Processor
Timing, Multipath and Baseli
Initialization
Lever Arms and Mounting A
Export
Camera
LiDAR
SAR
Timing
Start 310842.673
End 324528.583
Entire time interval
Seconds of start week
UTC Offset 16.000
Data
Incr. (sec)
Output Record 0.005000
IMU 0.005000
Primary GNSS 1.000000
Multipath Low
GPS Position Quality Scale Factor
0.5 1.0 2.0 5.0
Algorithm Automatic
High Altitude Mode
OK
Cancel



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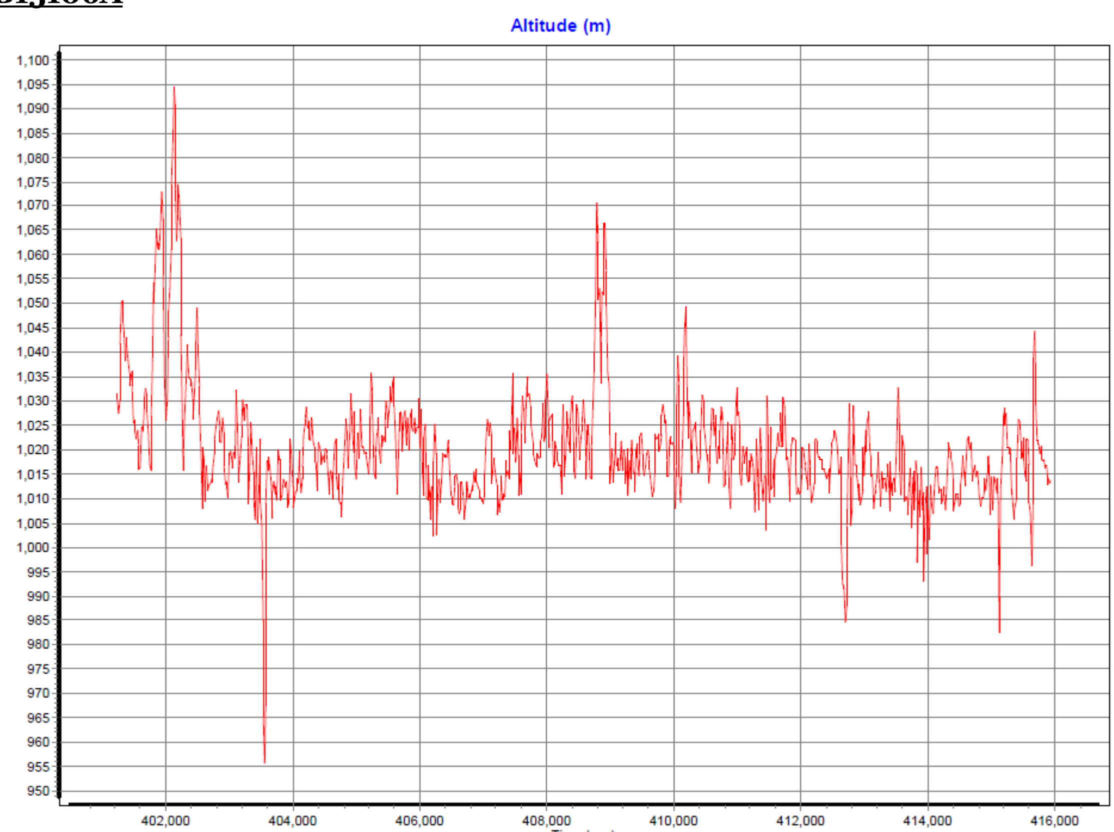
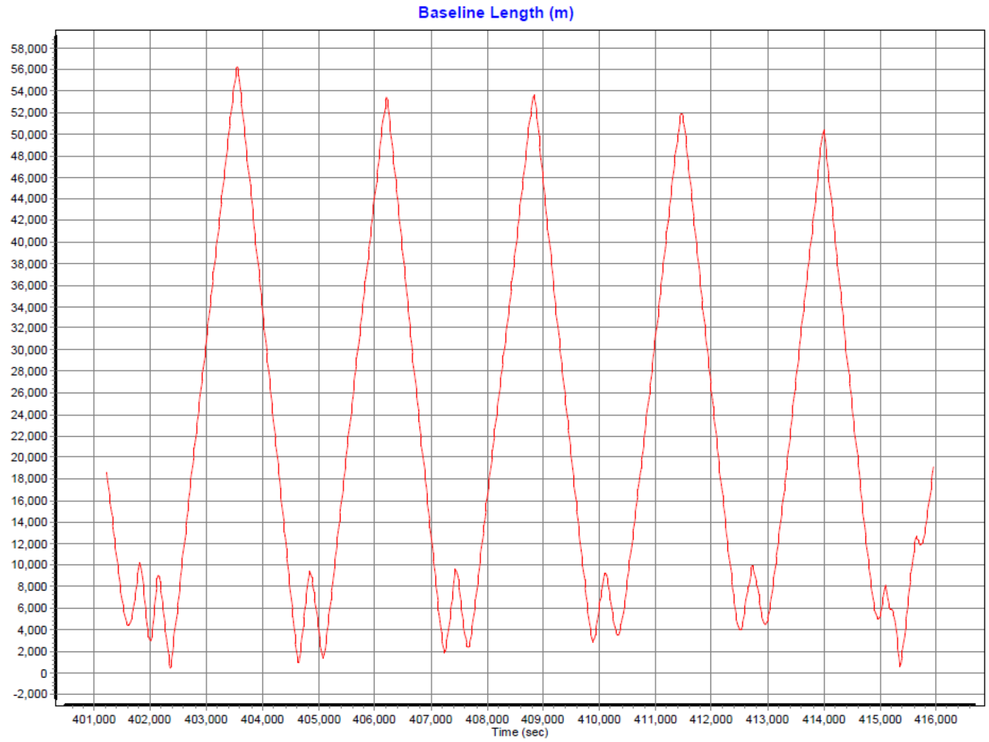
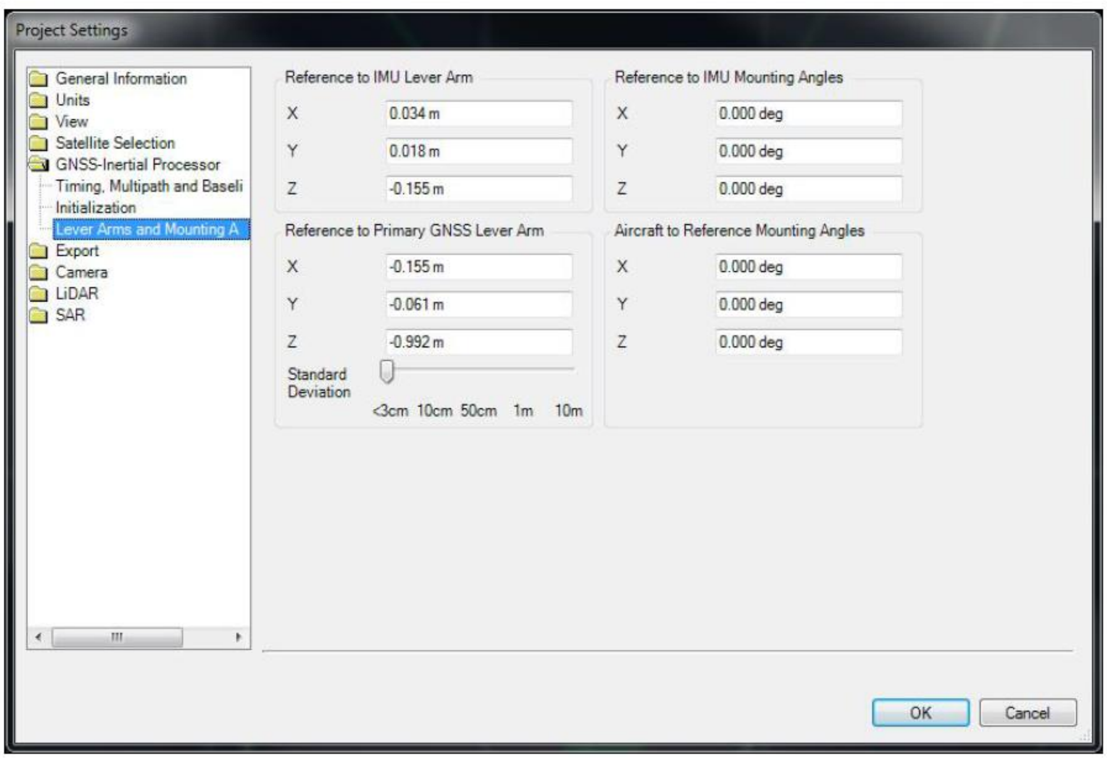
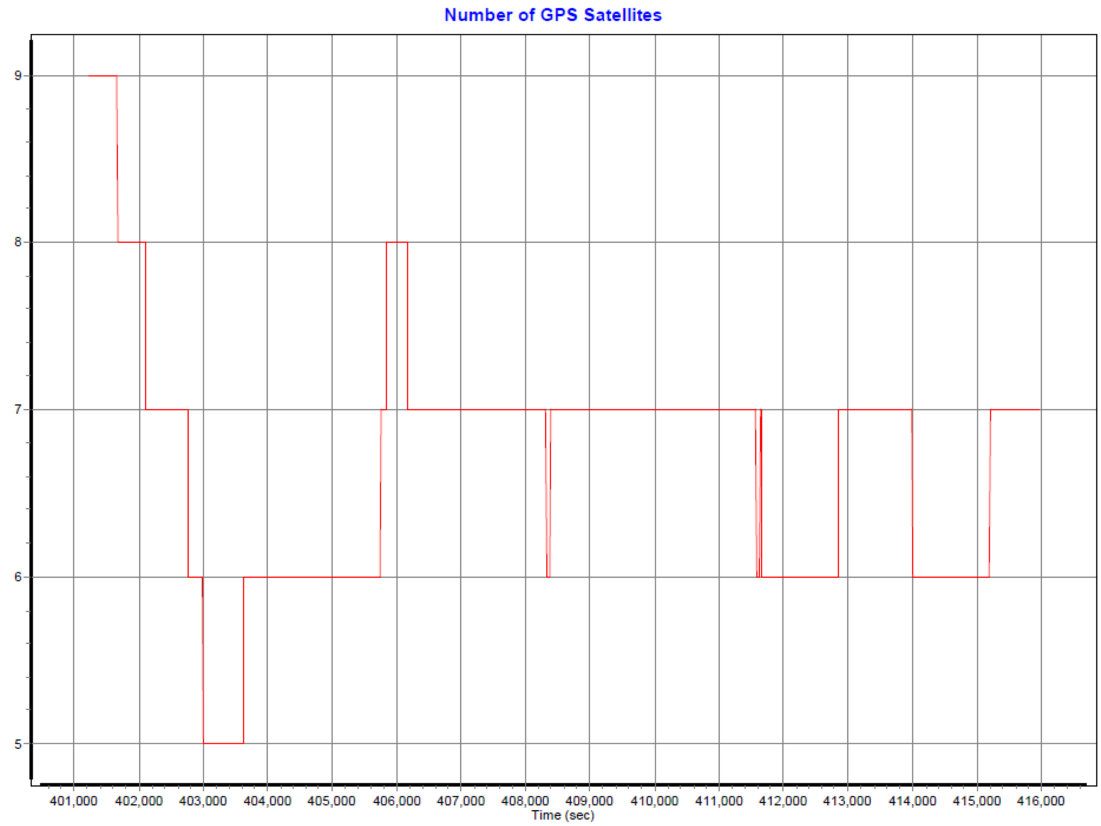
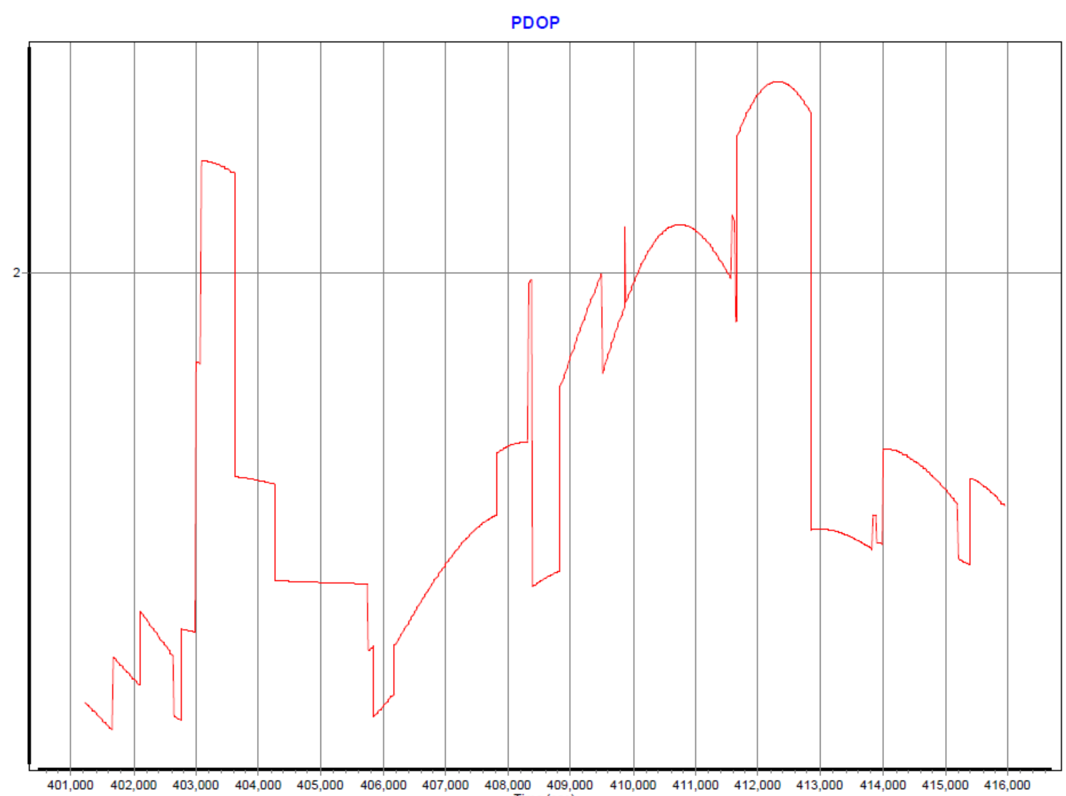
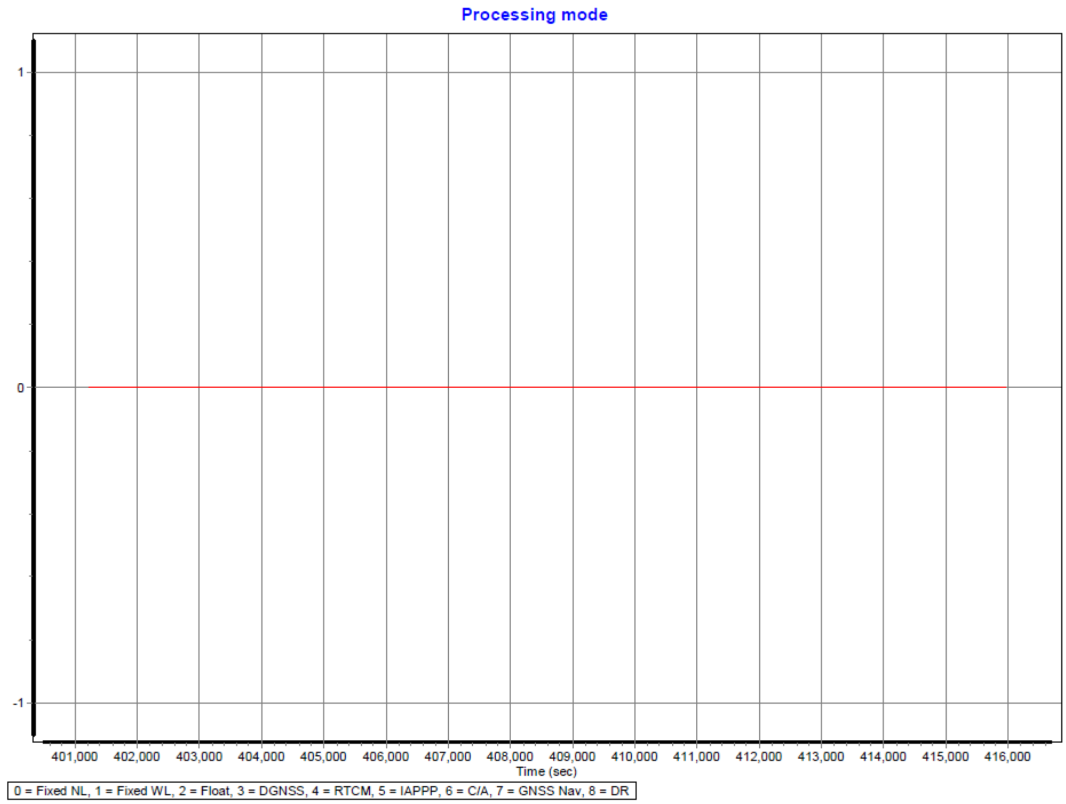

Altitude (m)
1,100
1,095
1,090
1,085
1,080
1,075
1,070
1,065
1,060
1,055
1,050
1,045
1,040
1,035
1,030
1,025
1,020
1,015
1,010
1,005
1,000
995
990
985
980
975
970
965
960
955
950
402,000
404,000
406,000
408,000
410,000
412,000
414,000
416,000
Time (sec)

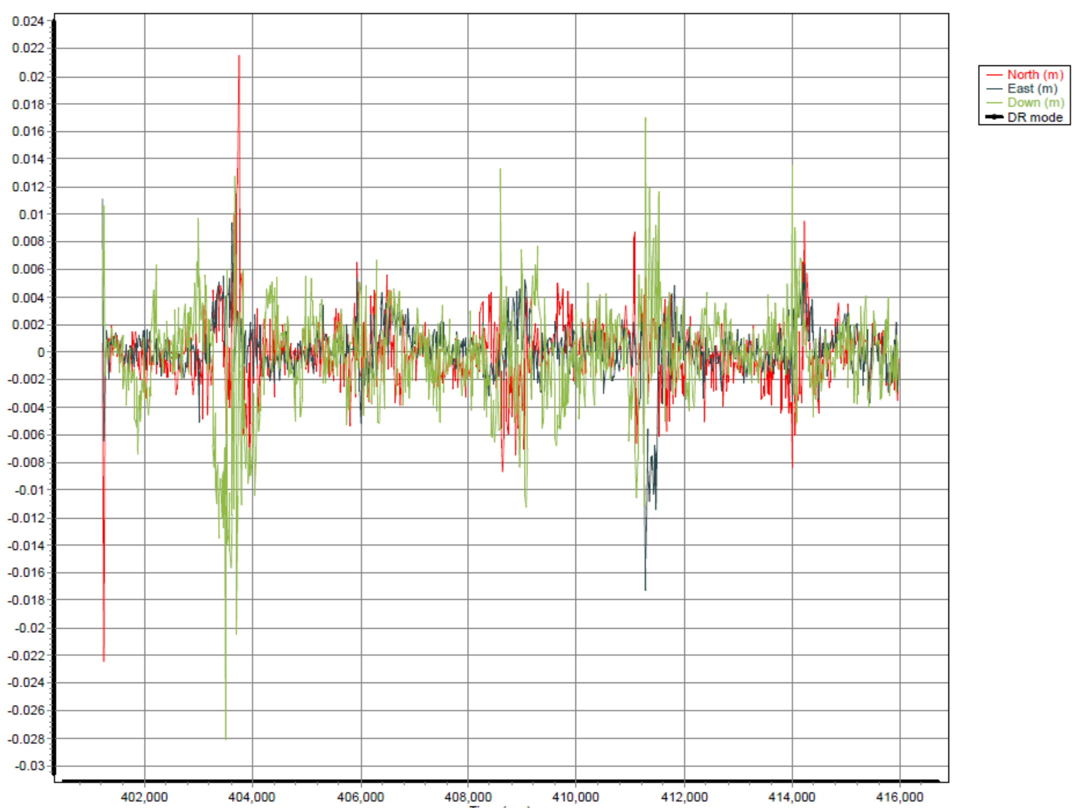

Baseline Length (m)
58,000
56,000
54,000
52,000
50,000
48,000
46,000
44,000
42,000
40,000
38,000
36,000
34,000
32,000
30,000
28,000
26,000
24,000
22,000
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
-2,000
401,000 402,000 403,000 404,000 405,000 406,000 407,000 408,000 409,000 410,000 411,000 412,000 413,000 414,000 415,000 416,000
Time (sec)

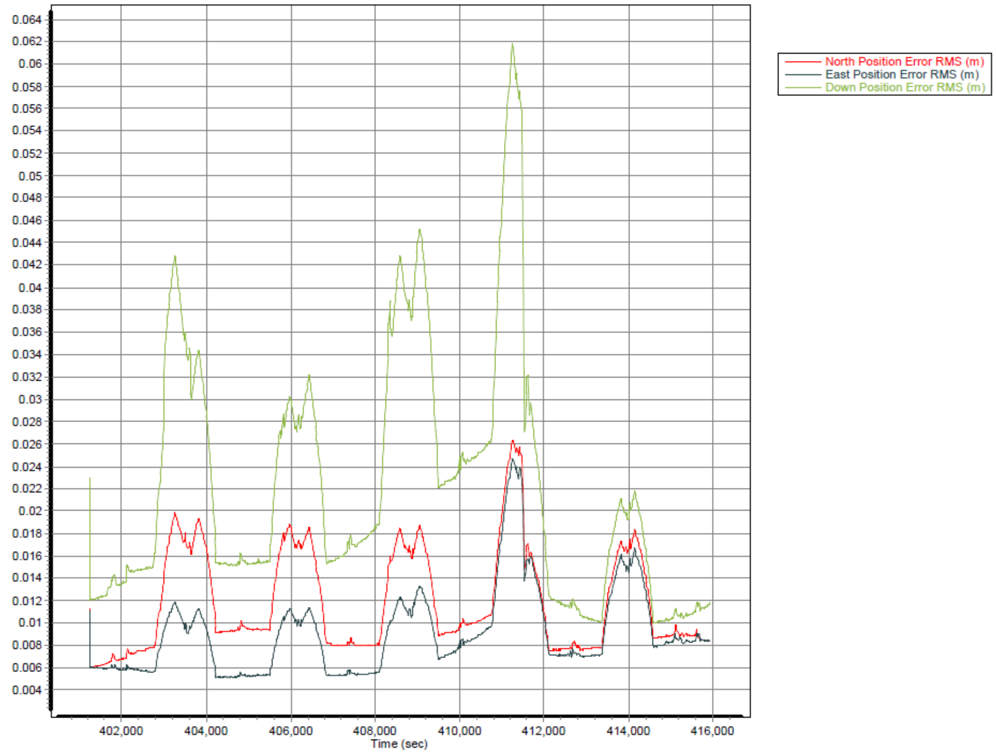

Project Settings
General Information
Units
View
Satellite Selection
GNSS-Inertial Processor
Timing, Multipath and Baseli
Initialization
Lever Arms and Mounting A
Export
Camera
LiDAR
SAR
Reference to IMU Lever Arm
X 0.034 m
Y 0.018 m
Z -0.155 m
Reference to IMU Mounting Angles
X 0.000 deg
Y 0.000 deg
Z 0.000 deg
Reference to Primary GNSS Lever Arm
X -0.155 m
Y -0.061 m
Z -0.992 m
Standard Deviation
<3cm 10cm 50cm 1m 10m
Aircraft to Reference Mounting Angles
X 0.000 deg
Y 0.000 deg
Z 0.000 deg
OK
Cancel

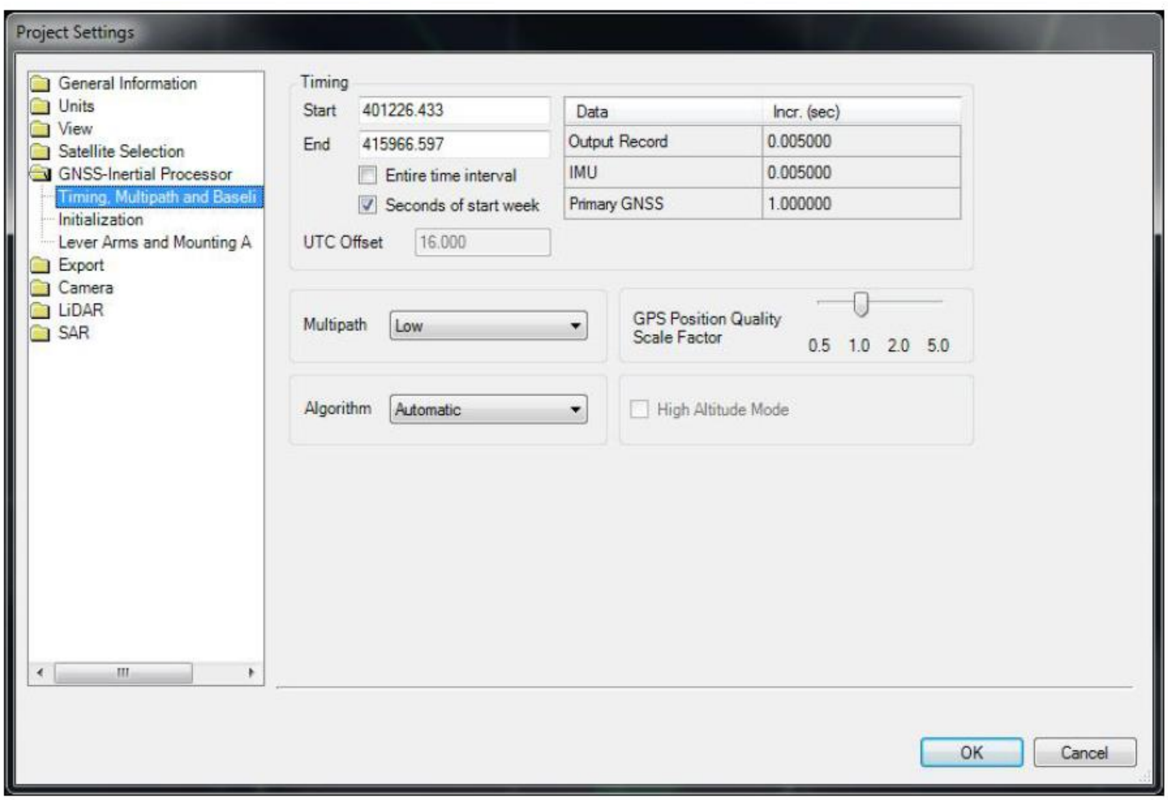

Number of GPS Satellites
9
8
7
6
5
401,000
402,000
403,000
404,000
405,000
406,000
407,000
408,000
409,000
410,000
411,000
412,000
413,000
414,000
415,000
416,000
Time (sec)

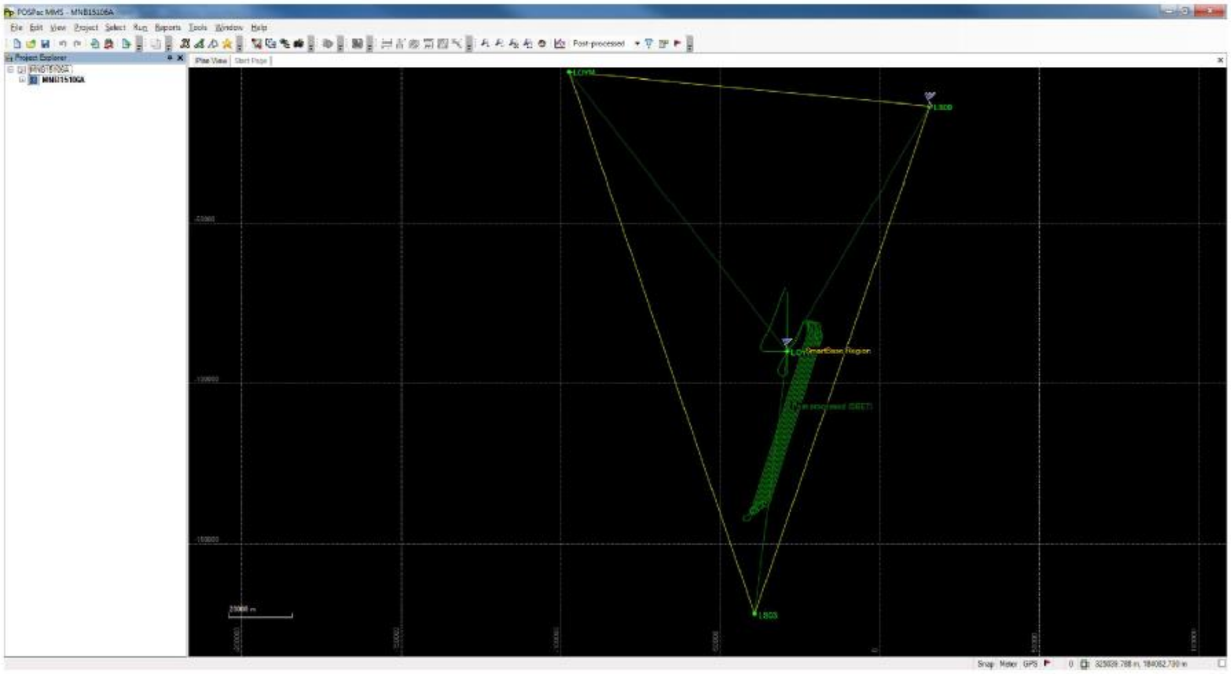

PDOP
2
401,000
402,000
403,000
404,000
405,000
406,000
407,000
408,000
409,000
410,000
411,000
412,000
413,000
414,000
415,000
416,000
Time (sec)


Processing mode
1
0
-1
401,000
402,000
403,000
404,000
405,000
406,000
407,000
408,000
409,000
410,000
411,000
412,000
413,000
414,000
415,000
416,000
Time (sec)
0 = Fixed NL, 1 = Fixed WL, 2 = Float, 3 = DGNSS, 4 = RTCM, 5 = IAPPP, 6 = C/A, 7 = GNSS Nav, 8 = DR


North (m)
East (m)
Down (m)
DR mode
Time (sec)


North Position Error RMS (m)
East Position Error RMS (m)
Down Position Error RMS (m)
0.064
0.062
0.06
0.058
0.056
0.054
0.052
0.05
0.048
0.046
0.044
0.042
0.04
0.038
0.036
0.034
0.032
0.03
0.028
0.026
0.024
0.022
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
402,000
404,000
406,000
408,000
410,000
412,000
414,000
416,000
Time (sec)


Project Settings
General Information
Units
View
Satellite Selection
GNSS-Inertial Processor
Timing, Multipath and Baseli
Initialization
Lever Arms and Mounting A
Export
Camera
LiDAR
SAR
Timing
Start
401226.433
End
415966.597
Entire time interval
Seconds of start week
UTC Offset
16.000
Data
Incr. (sec)
Output Record
0.005000
IMU
0.005000
Primary GNSS
1.000000
Multipath
Low
GPS Position Quality
Scale Factor
0.5
1.0
2.0
5.0
Algorithm
Automatic
High Altitude Mode
OK
Cancel



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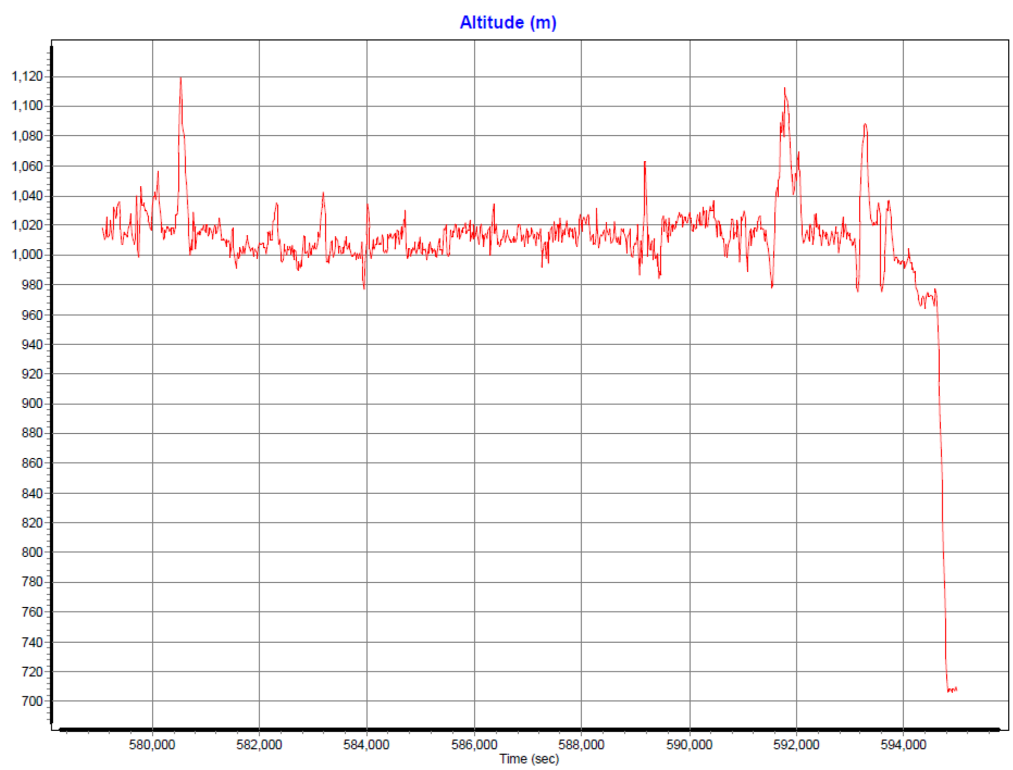
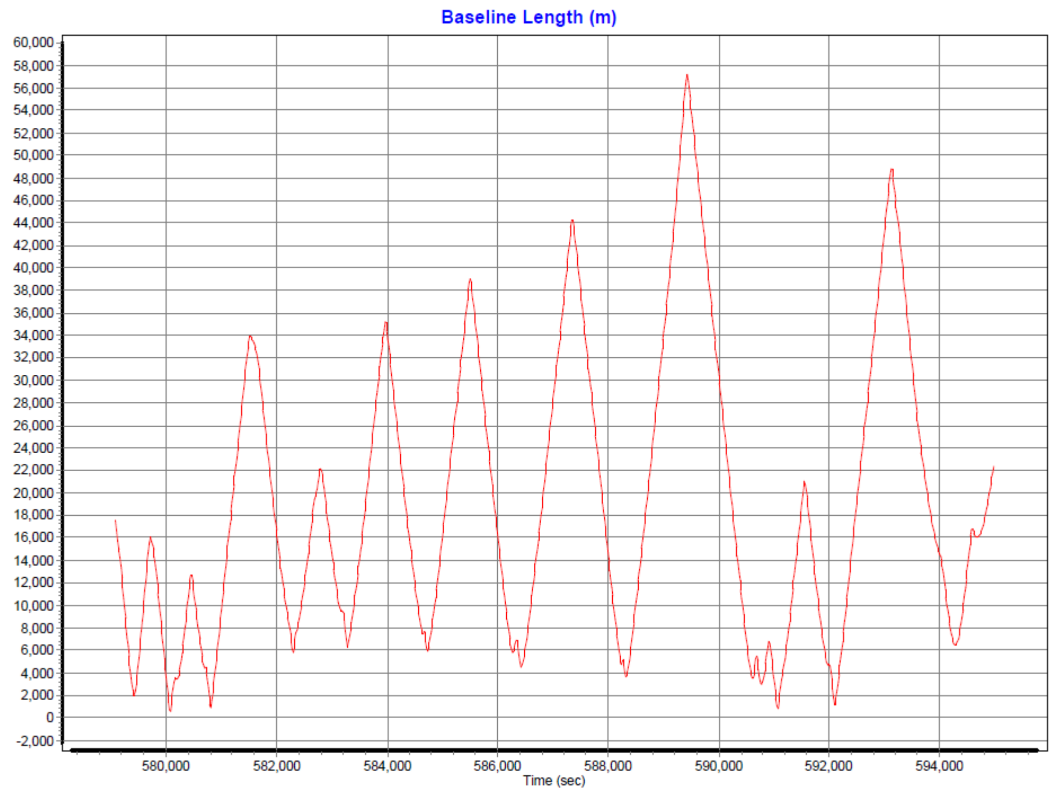
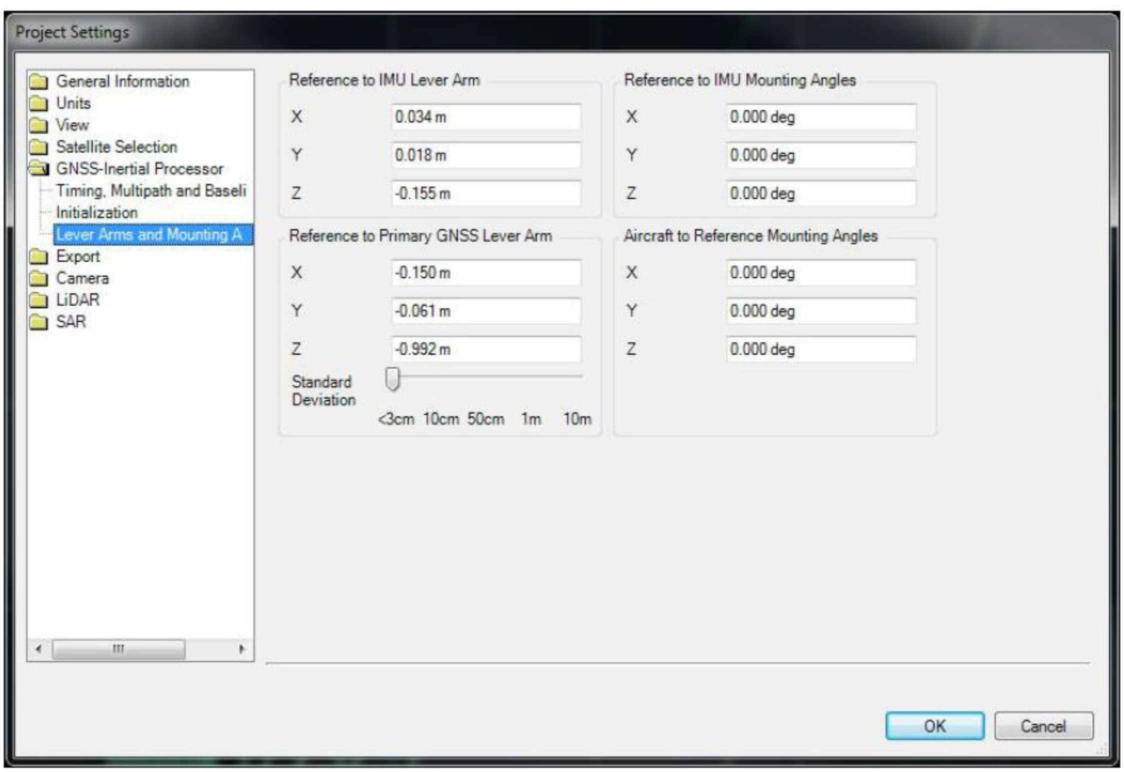
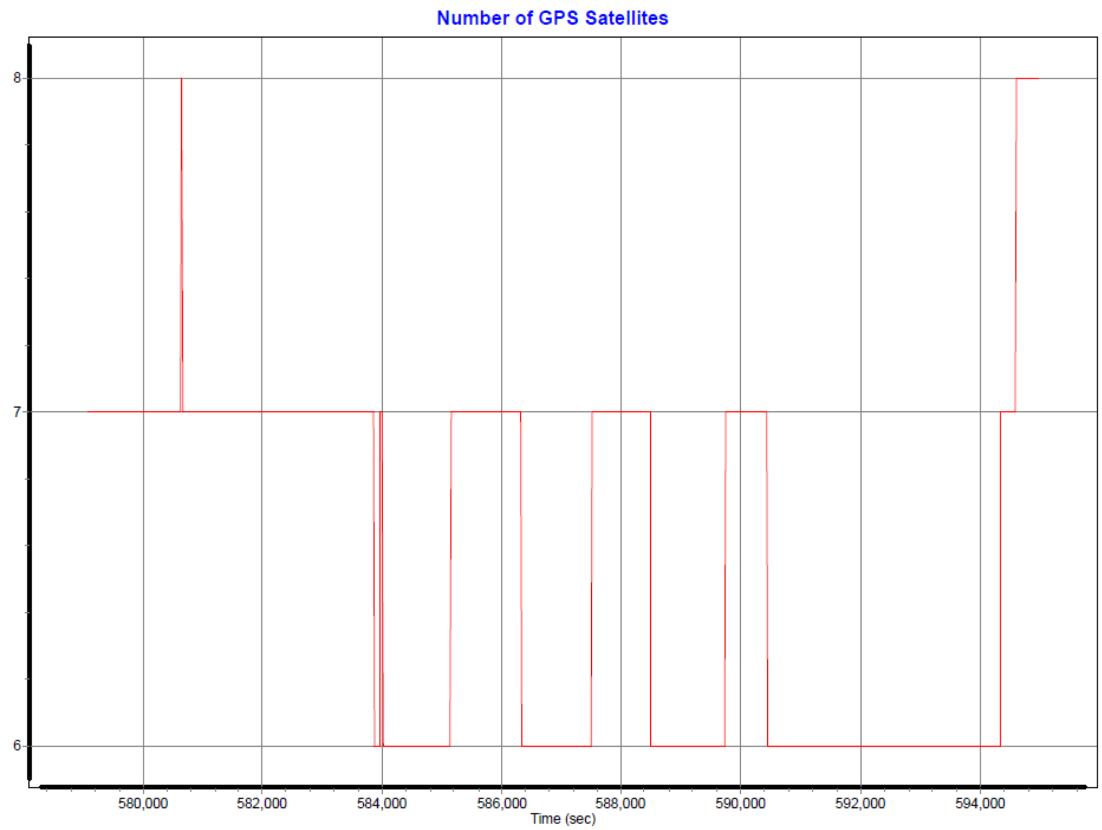
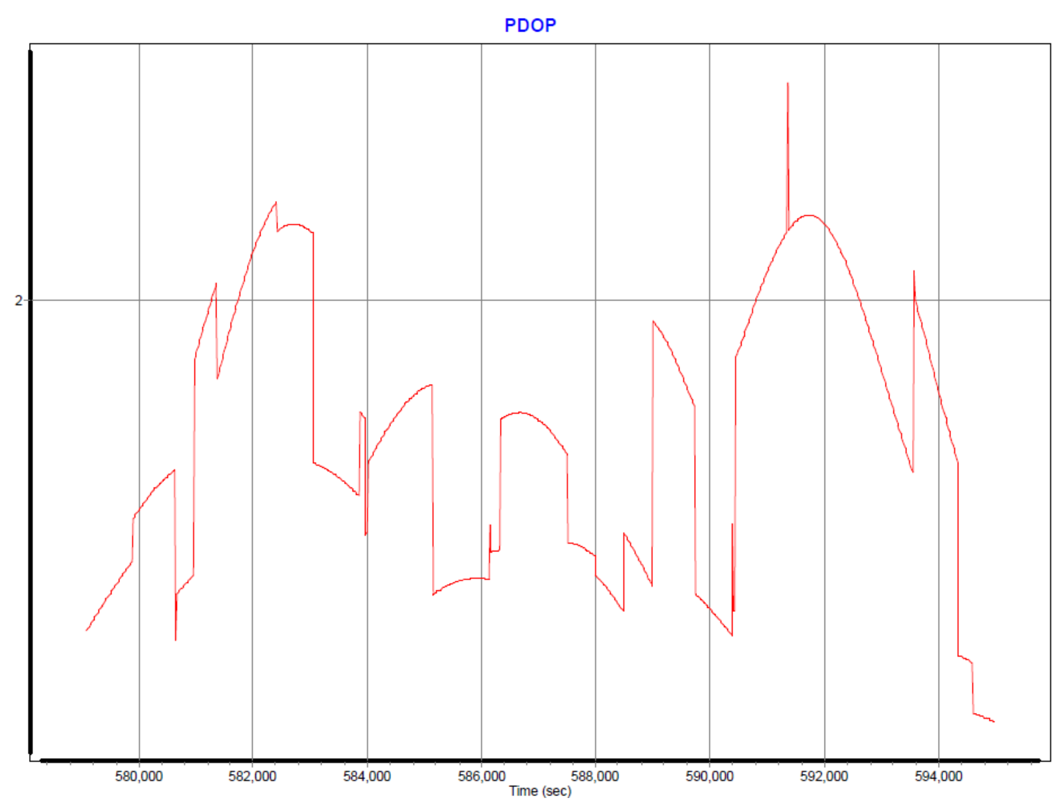
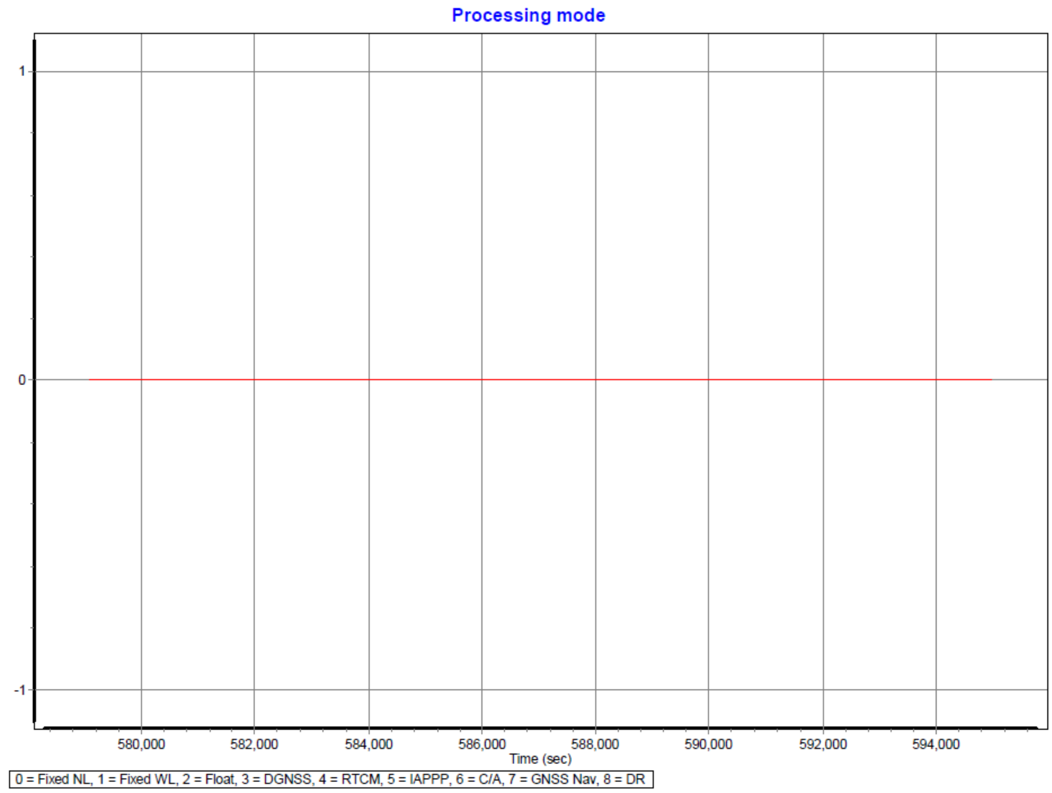

Altitude (m)
1,120
1,100
1,080
1,060
1,040
1,020
1,000
980
960
940
920
900
880
860
840
820
800
780
760
740
720
700
580,000
582,000
584,000
586,000
588,000
590,000
592,000
594,000
Time (sec)

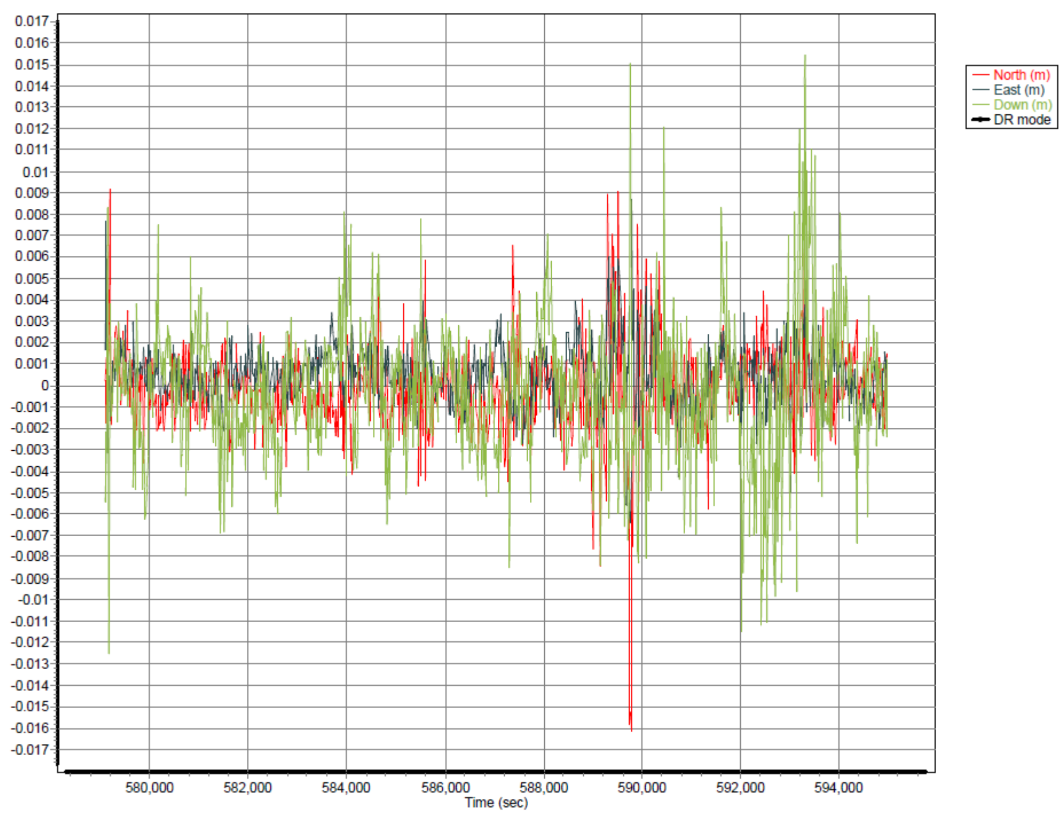

Baseline Length (m)
60,000
58,000
56,000
54,000
52,000
50,000
48,000
46,000
44,000
42,000
40,000
38,000
36,000
34,000
32,000
30,000
28,000
26,000
24,000
22,000
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
-2,000
580,000
582,000
584,000
586,000
588,000
590,000
592,000
594,000
Time (sec)

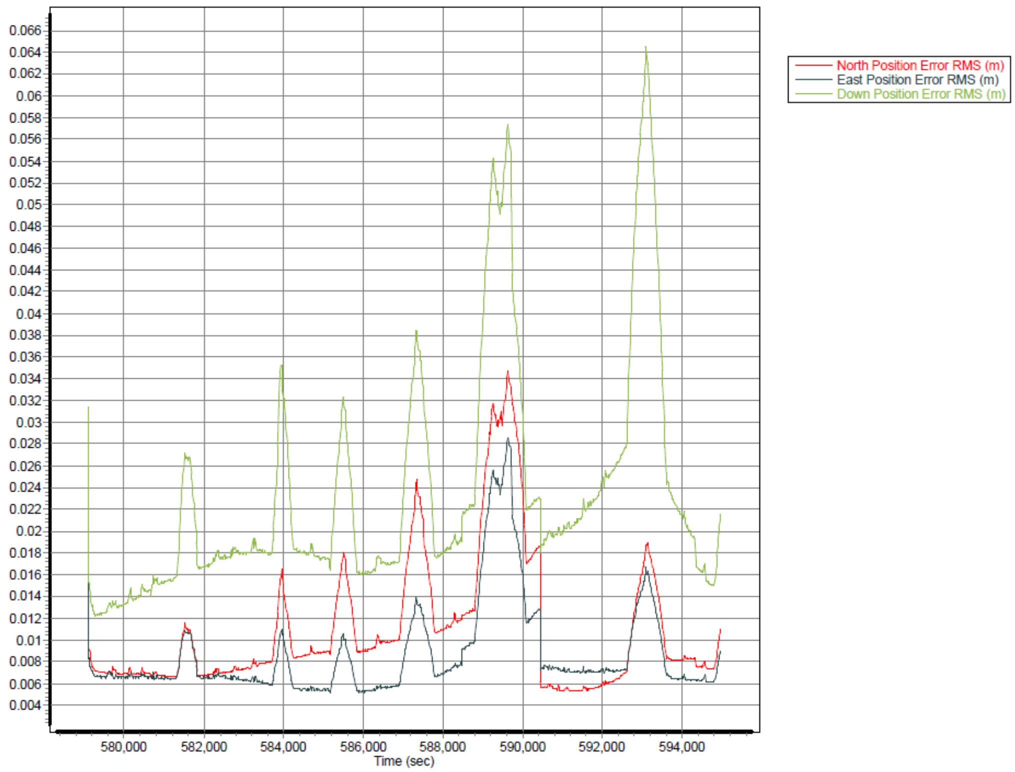

Project Settings
General Information
Units
View
Satellite Selection
GNSS-Inertial Processor
Timing, Multipath and Baseli
Initialization
Lever Arms and Mounting A
Export
Camera
LiDAR
SAR
Reference to IMU Lever Arm
X 0.034 m
Y 0.018 m
Z -0.155 m
Reference to IMU Mounting Angles
X 0.000 deg
Y 0.000 deg
Z 0.000 deg
Reference to Primary GNSS Lever Arm
X -0.150 m
Y -0.061 m
Z -0.992 m
Standard Deviation
<3cm 10cm 50cm 1m 10m
Aircraft to Reference Mounting Angles
X 0.000 deg
Y 0.000 deg
Z 0.000 deg
OK
Cancel

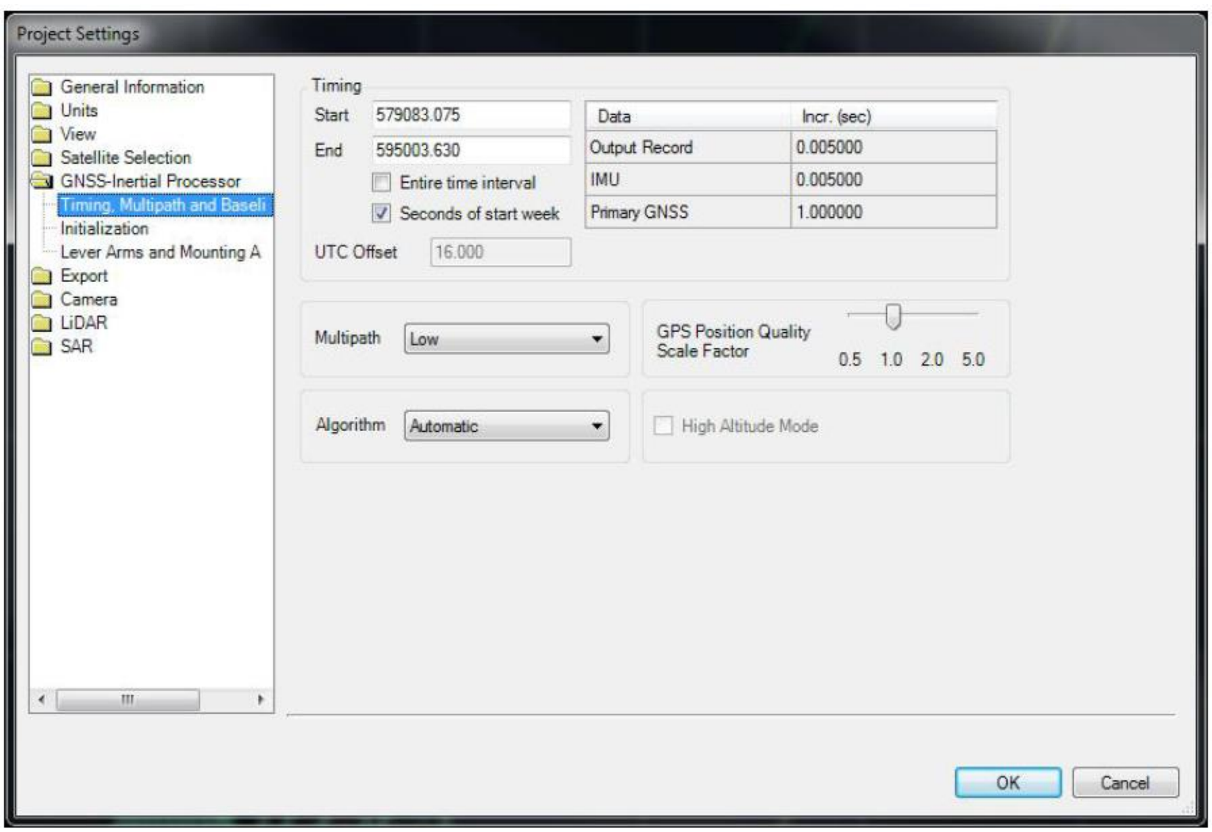

Number of GPS Satellites
8
7
6
580,000
582,000
584,000
586,000
588,000
590,000
592,000
594,000
Time (sec)

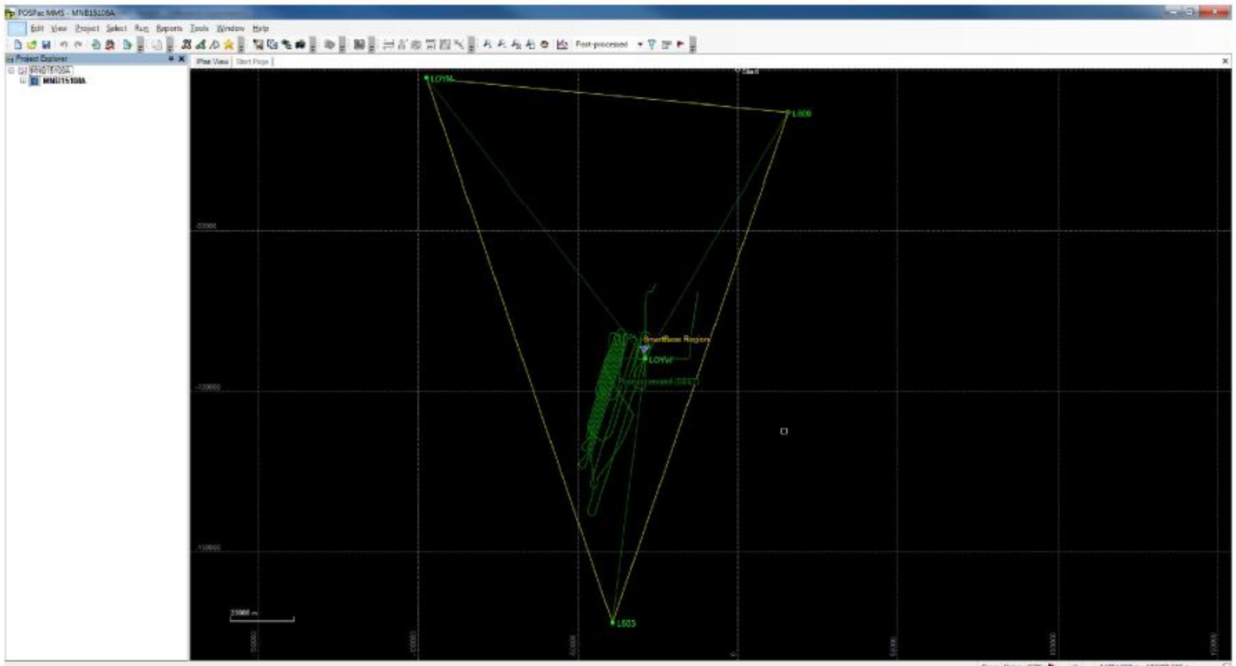

PDOP
2
580,000
582,000
584,000
586,000
588,000
590,000
592,000
594,000
Time (sec)


Processing mode
1
0
-1
580,000
582,000
584,000
586,000
588,000
590,000
592,000
594,000
Time (sec)
0 = Fixed NL, 1 = Fixed WL, 2 = Float, 3 = DGNSS, 4 = RTCM, 5 = IAPPP, 6 = C/A, 7 = GNSS Nav, 8 = DR


North (m)
East (m)
Down (m)
DR mode
580,000
582,000
584,000
586,000
588,000
590,000
592,000
594,000
Time (sec)


North Position Error RMS (m)
East Position Error RMS (m)
Down Position Error RMS (m)
0.066
0.064
0.062
0.06
0.058
0.056
0.054
0.052
0.05
0.048
0.046
0.044
0.042
0.04
0.038
0.036
0.034
0.032
0.03
0.028
0.026
0.024
0.022
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
580,000
582,000
584,000
586,000
588,000
590,000
592,000
594,000
Time (sec)


Project Settings
General Information
Units
View
Satellite Selection
GNSS-Inertial Processor
Timing, Multipath and Baseli
Initialization
Lever Arms and Mounting A
Export
Camera
LiDAR
SAR
Timing
Start 579083.075
End 595003.630
Entire time interval
Seconds of start week
UTC Offset 16.000
Data
Incr. (sec)
Output Record 0.005000
IMU 0.005000
Primary GNSS 1.000000
Multipath Low
GPS Position Quality Scale Factor
0.5 1.0 2.0 5.0
Algorithm Automatic
High Altitude Mode
OK
Cancel



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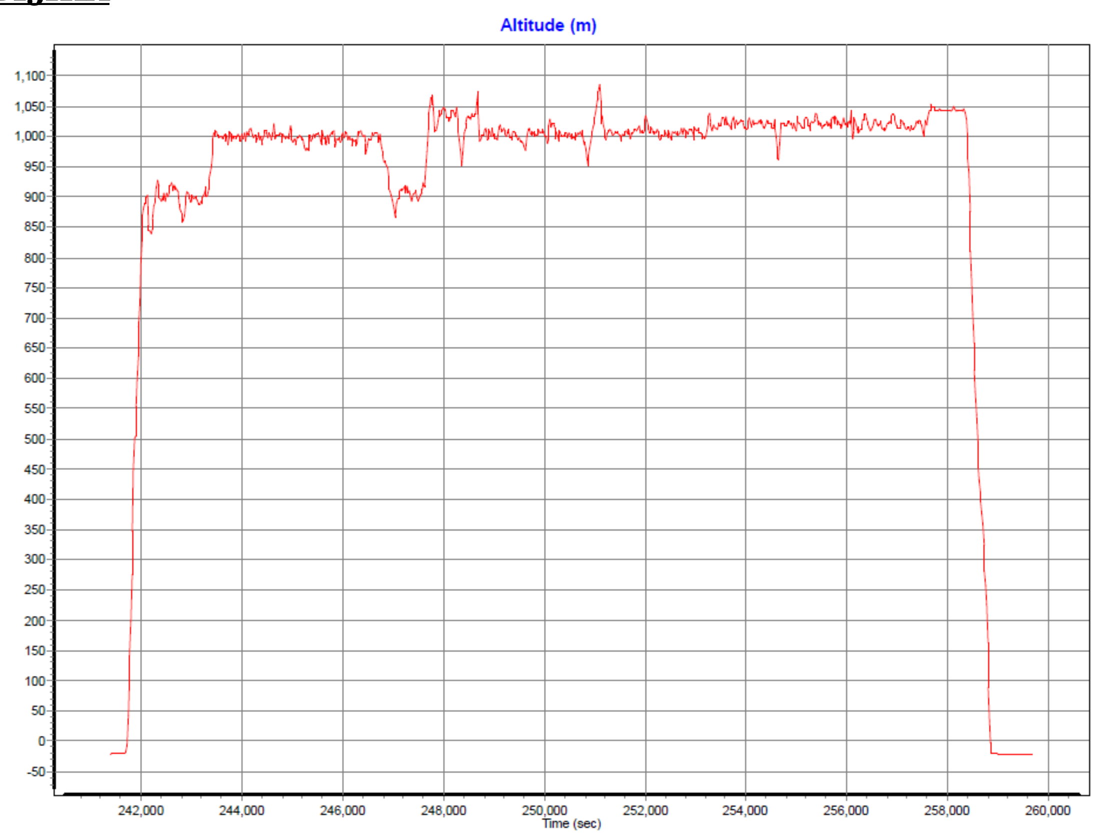
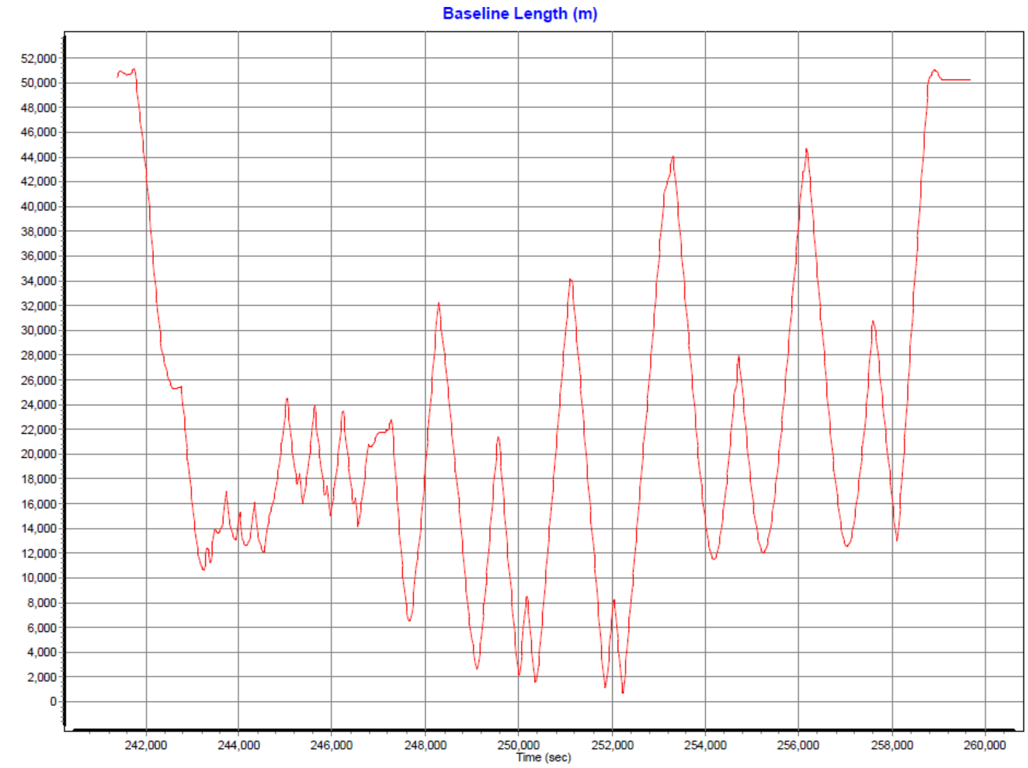
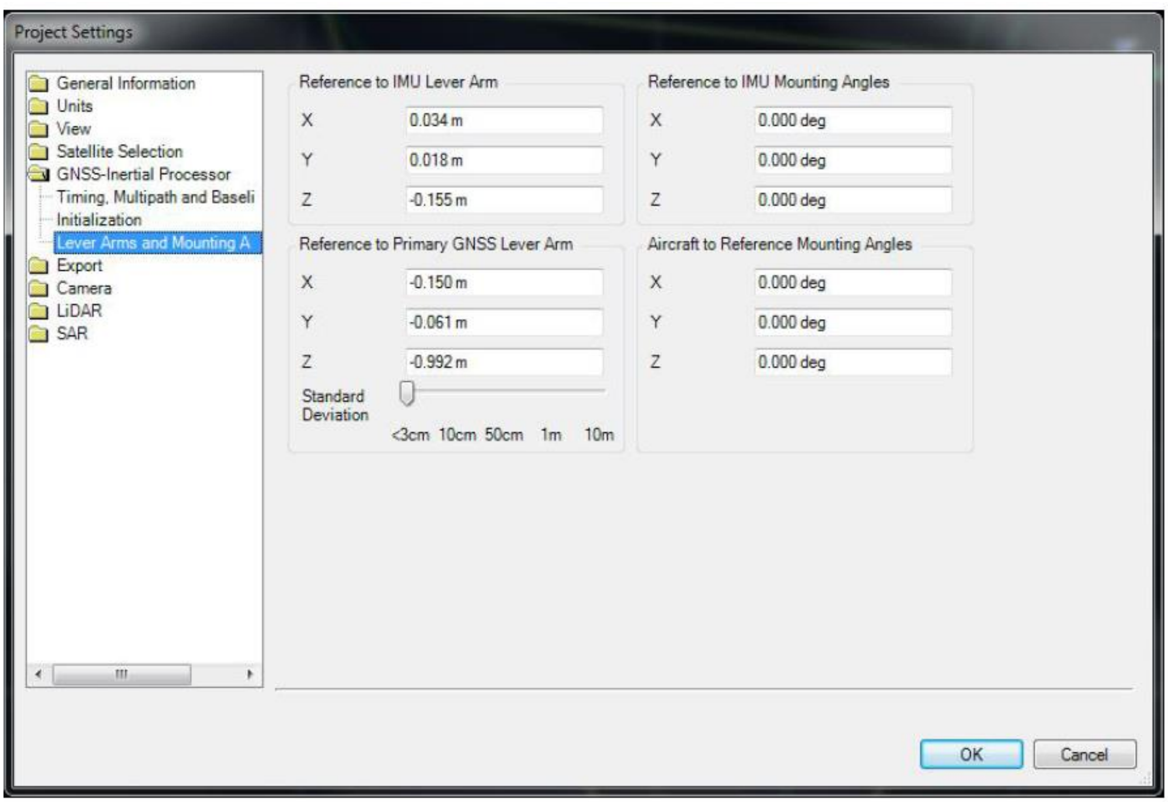
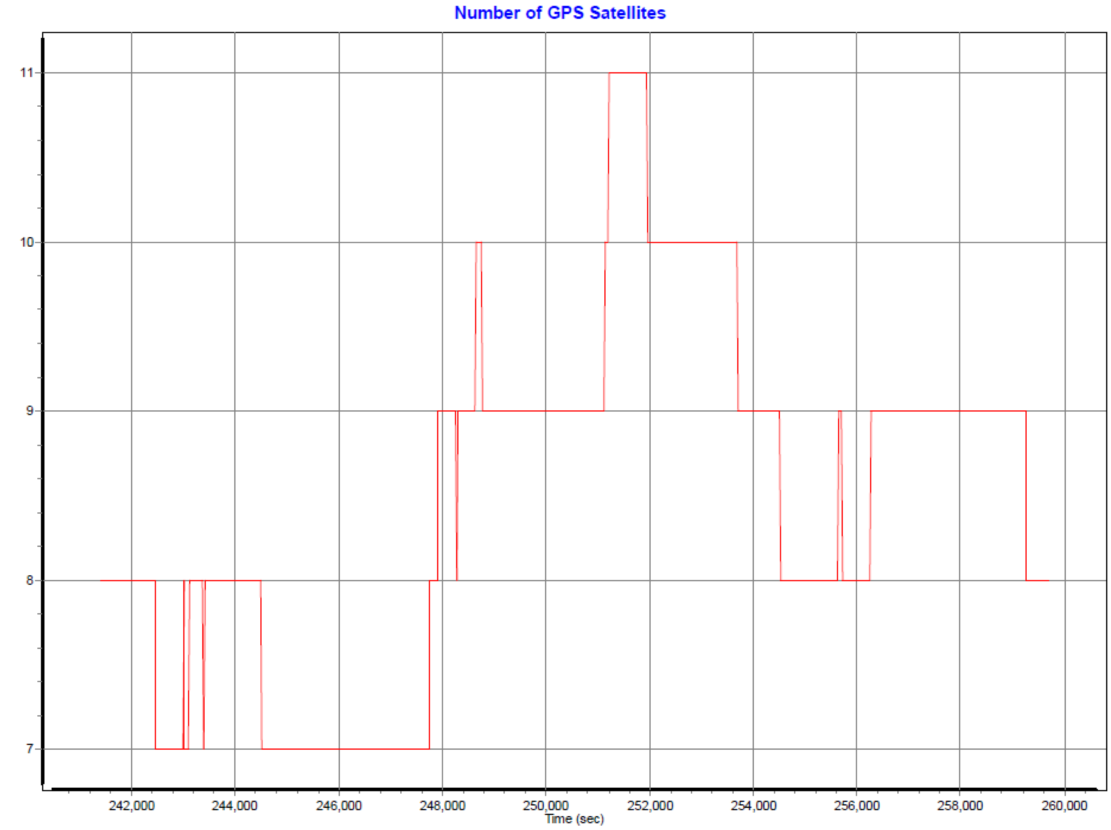
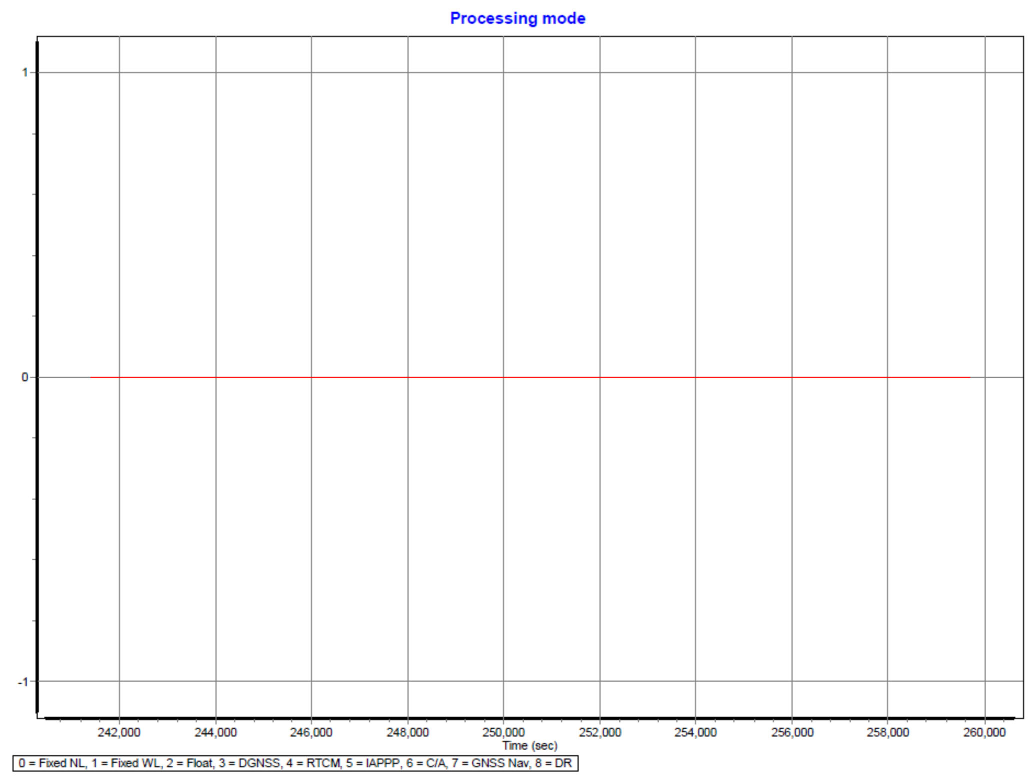

Altitude (m)
1,100
1,050
1,000
950
900
850
800
750
700
650
600
550
500
450
400
350
300
250
200
150
100
50
0
-50
242,000
244,000
246,000
248,000
250,000
252,000
254,000
256,000
258,000
260,000
Time (sec)

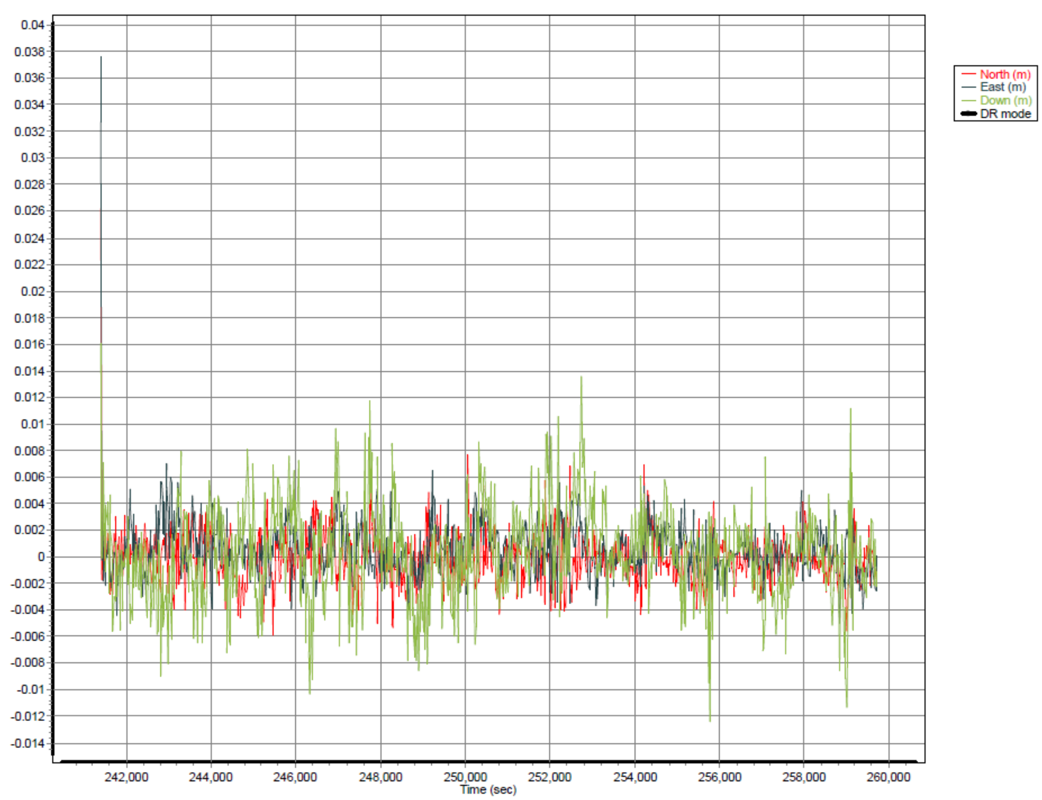

Baseline Length (m)
52,000
50,000
48,000
46,000
44,000
42,000
40,000
38,000
36,000
34,000
32,000
30,000
28,000
26,000
24,000
22,000
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
242,000
244,000
246,000
248,000
250,000
252,000
254,000
256,000
258,000
260,000
Time (sec)

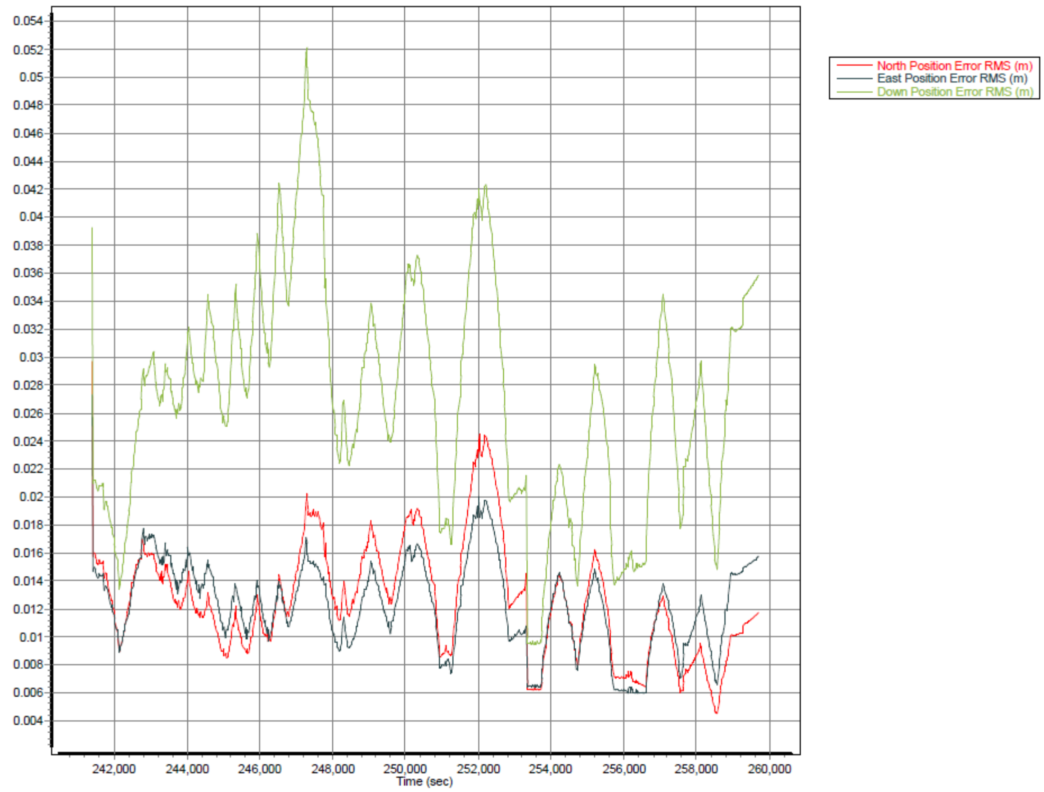

Project Settings
General Information
Units
View
Satellite Selection
GNSS-Inertial Processor
Timing, Multipath and Baseli
Initialization
Lever Arms and Mounting A
Export
Camera
LiDAR
SAR
Reference to IMU Lever Arm
X 0.034 m
Y 0.018 m
Z -0.155 m
Reference to IMU Mounting Angles
X 0.000 deg
Y 0.000 deg
Z 0.000 deg
Reference to Primary GNSS Lever Arm
X -0.150 m
Y -0.061 m
Z -0.992 m
Standard Deviation
<3cm 10cm 50cm 1m 10m
Aircraft to Reference Mounting Angles
X 0.000 deg
Y 0.000 deg
Z 0.000 deg
OK
Cancel

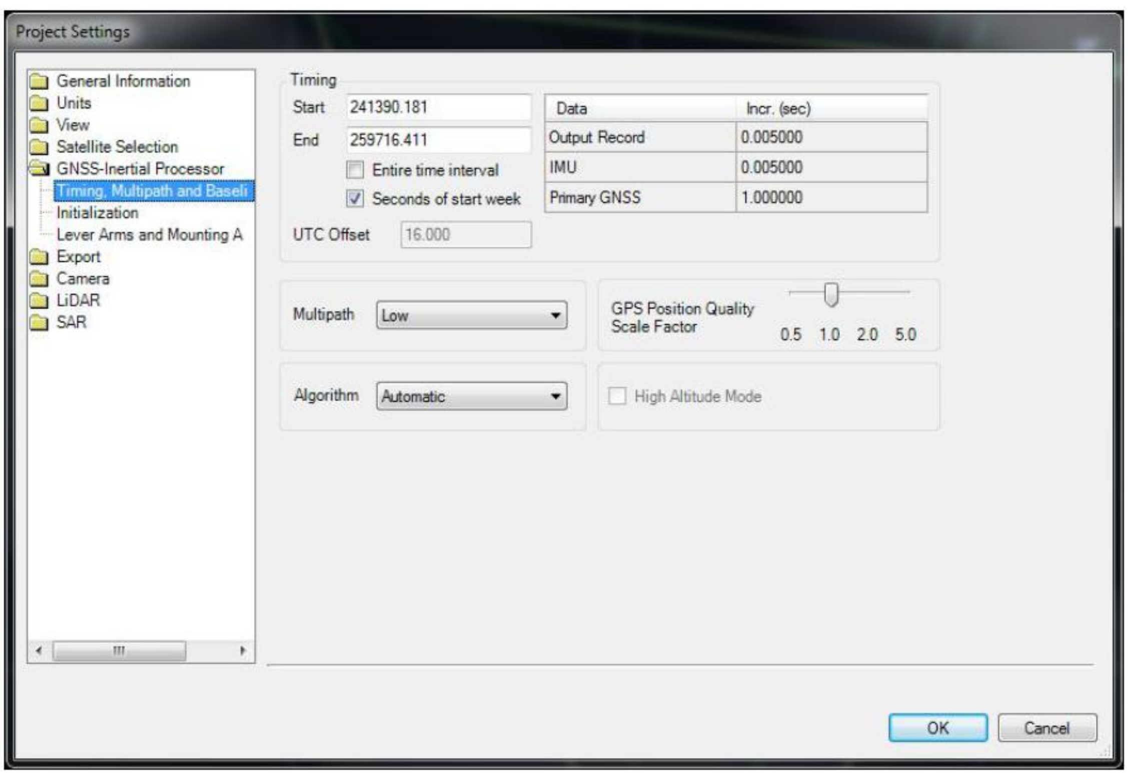

Number of GPS Satellites
11
10
9
8
7
242,000
244,000
246,000
248,000
250,000
252,000
254,000
256,000
258,000
260,000
Time (sec)


PDOP
2.02
2
1.98
1.96
1.94
1.92
1.9
1.88
1.86
1.84
1.82
1.8
1.78
1.76
1.74
1.72
1.7
1.68
1.66
1.64
1.62
1.6
1.58
1.56
1.54
1.52
1.5
1.48
1.46
1.44
1.42
1.4
1.38
1.36
1.34
1.32
1.3
1.28
1.26
1.24
1.22
1.2
1.18
1.16
1.14
1.12
242,000
244,000
246,000
248,000
250,000
252,000
254,000
256,000
258,000
260,000
Time (sec)

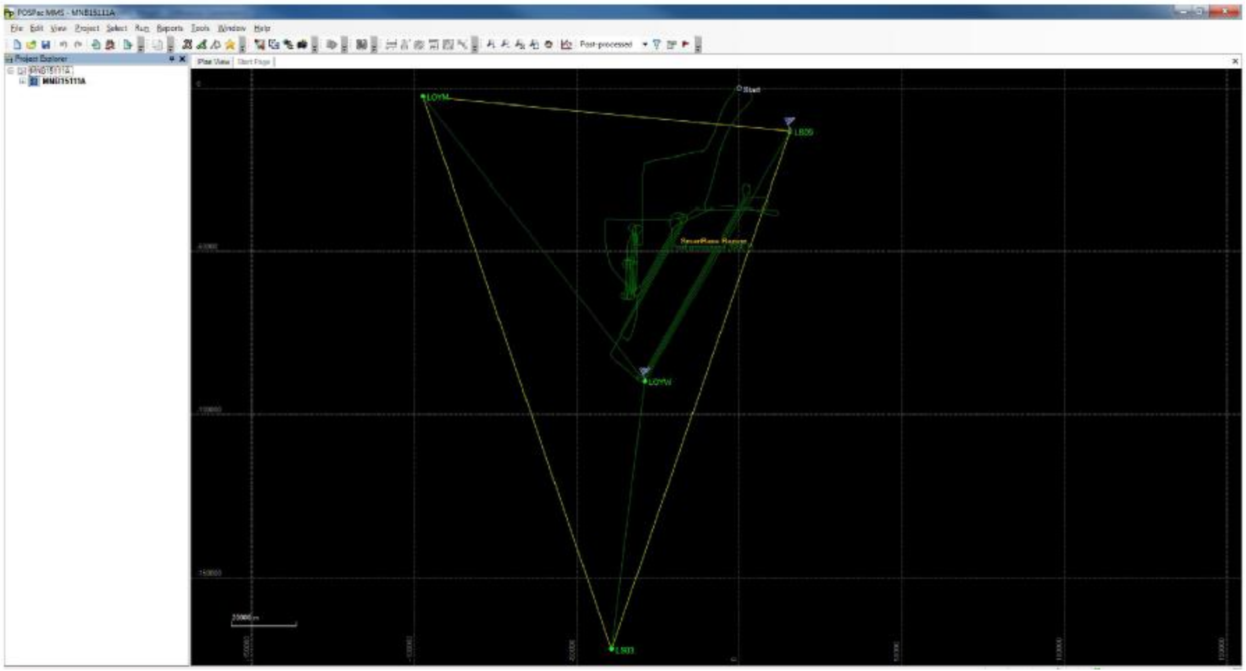

Processing mode
1
0
-1
242,000
244,000
246,000
248,000
250,000
252,000
254,000
256,000
258,000
260,000
Time (sec)
0 = Fixed NL, 1 = Fixed WL, 2 = Float, 3 = DGNSS, 4 = RTCM, 5 = IAPPP, 6 = C/A, 7 = GNSS Nav, 8 = DR

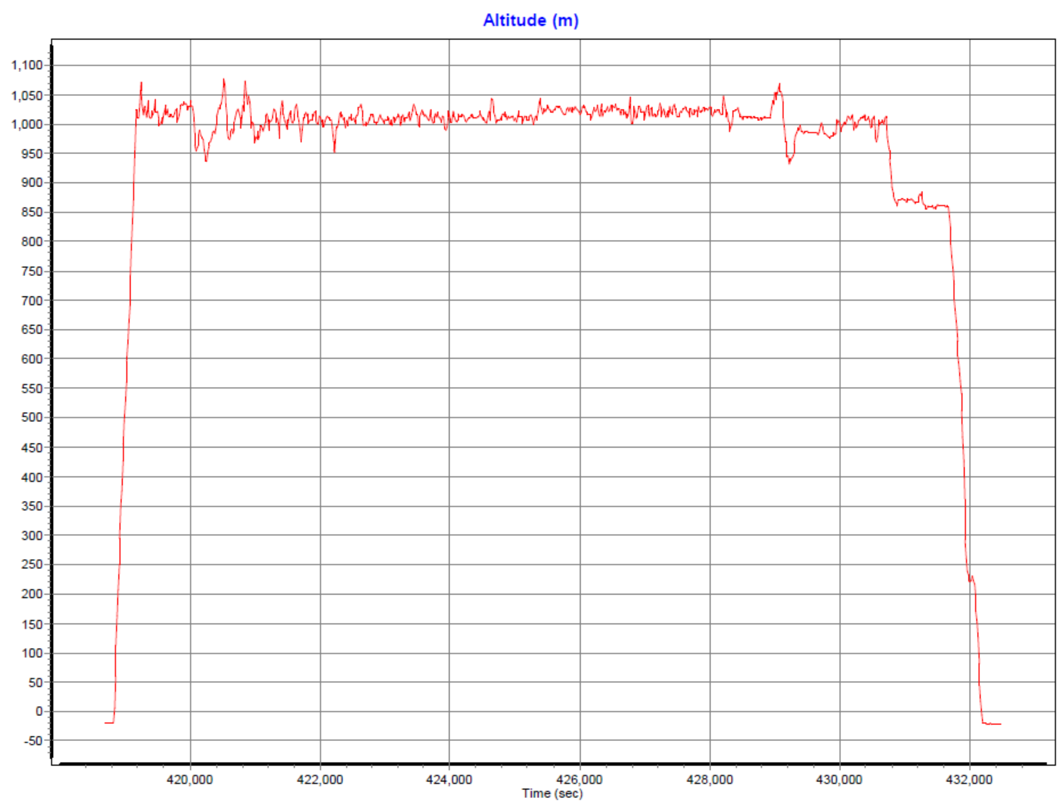

0.04
0.038
0.036
0.034
0.032
0.03
0.028
0.026
0.024
0.022
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
-0.002
-0.004
-0.006
-0.008
-0.01
-0.012
-0.014
242,000
244,000
246,000
248,000
250,000
252,000
254,000
256,000
258,000
260,000
Time (sec)
North (m)
East (m)
Down (m)
DR mode

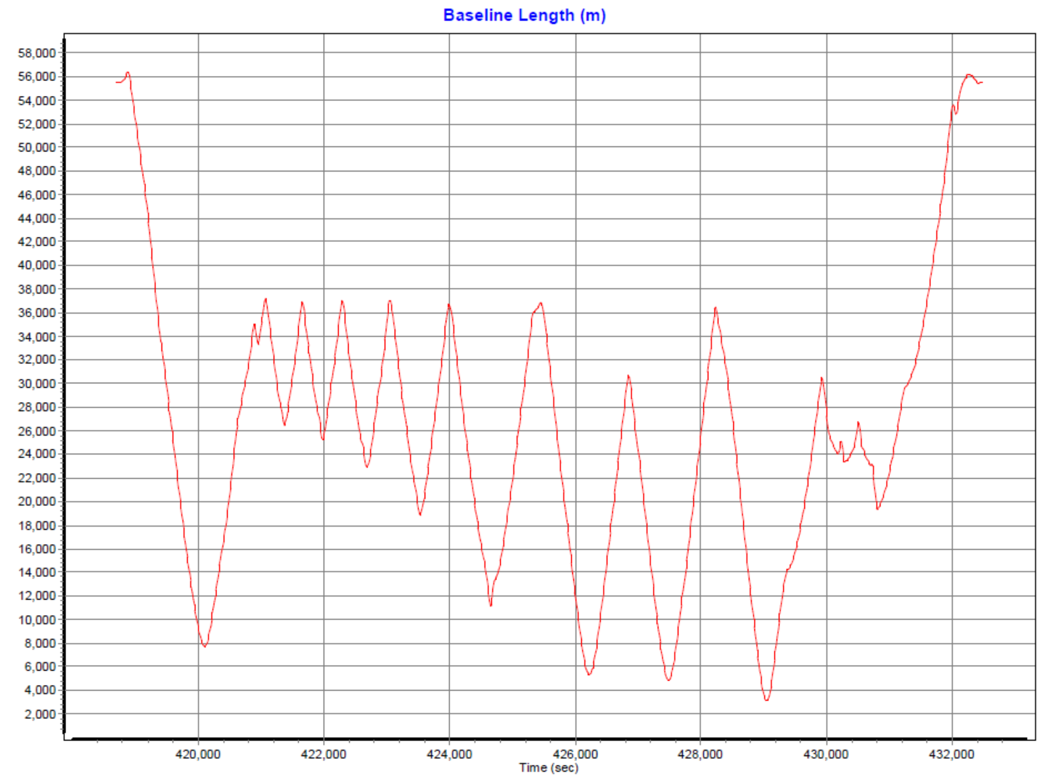

North Position Error RMS (m)
East Position Error RMS (m)
Down Position Error RMS (m)
Time (sec)

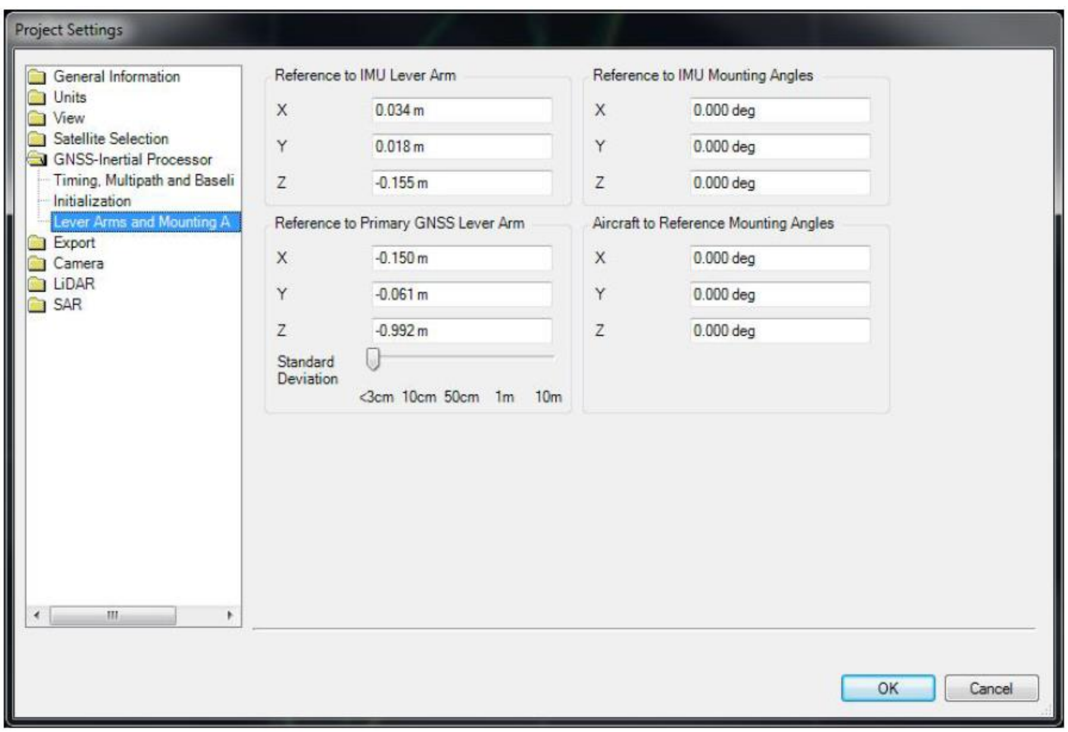

Project Settings
General Information
Units
View
Satellite Selection
GNSS-Inertial Processor
Timing, Multipath and Baseli
Initialization
Lever Arms and Mounting A
Export
Camera
LiDAR
SAR
Timing
Start 241390.181
End 259716.411
Entire time interval
Seconds of start week
UTC Offset 16.000
Data Incr. (sec)
Output Record 0.005000
IMU 0.005000
Primary GNSS 1.000000
Multipath Low
GPS Position Quality Scale Factor
0.5 1.0 2.0 5.0
Algorithm Automatic
High Altitude Mode
OK
Cancel

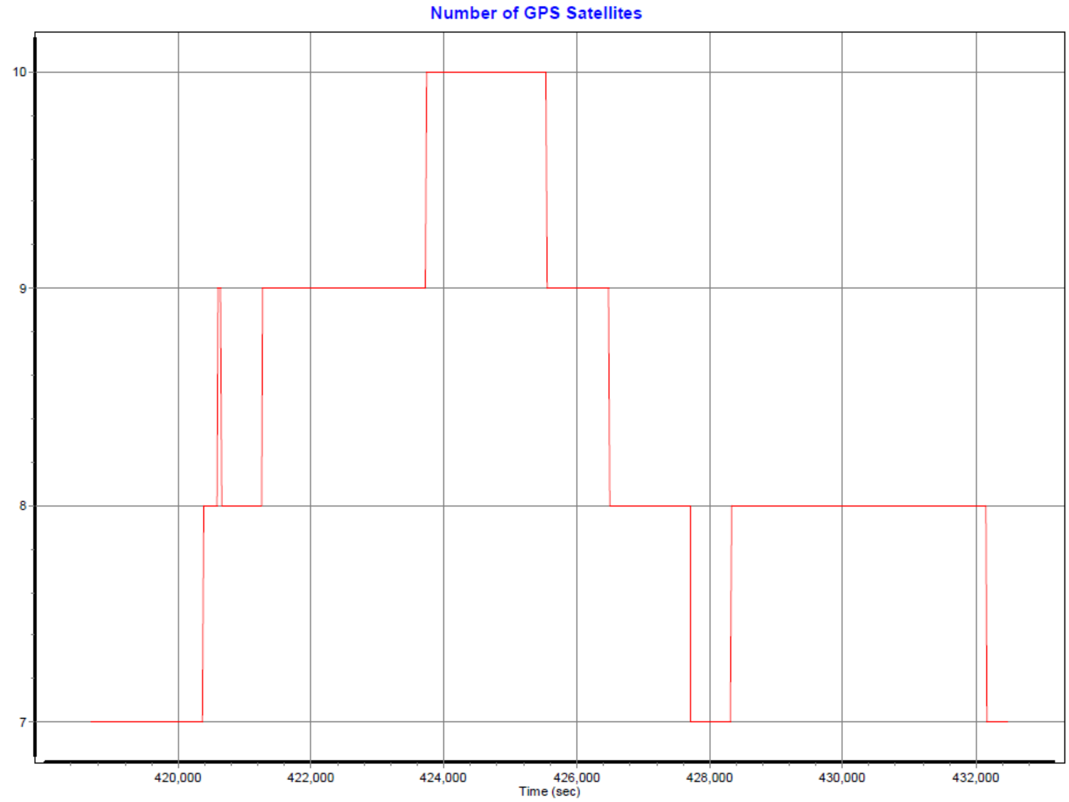
MNB15113A

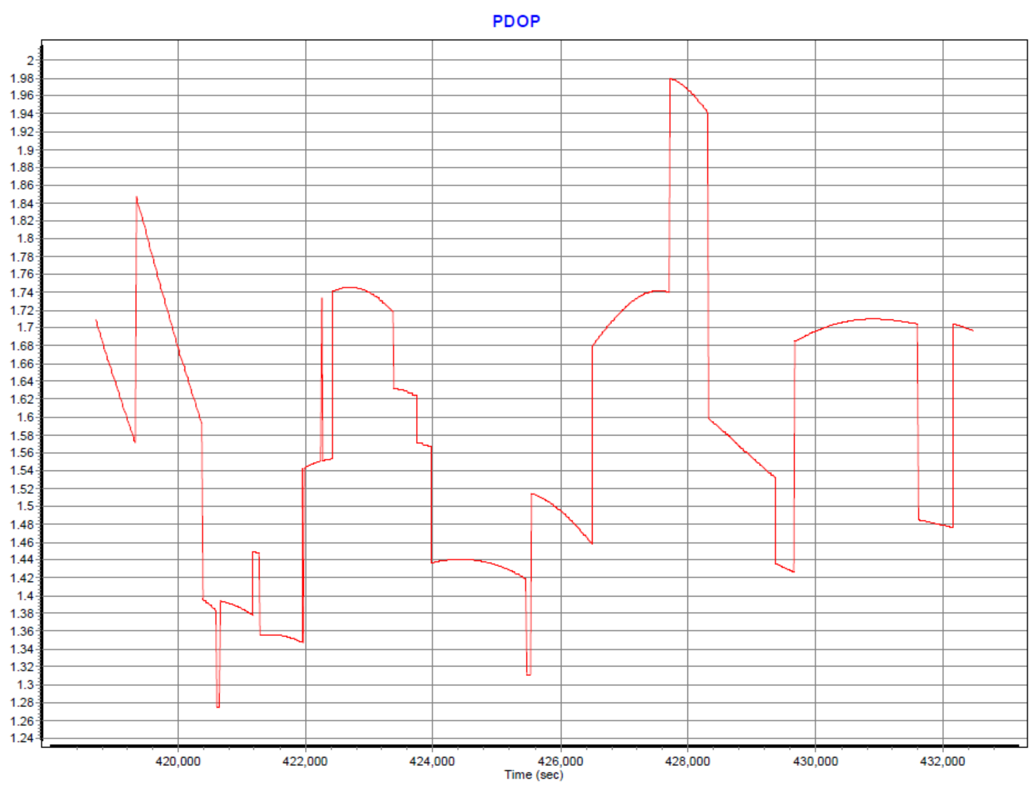


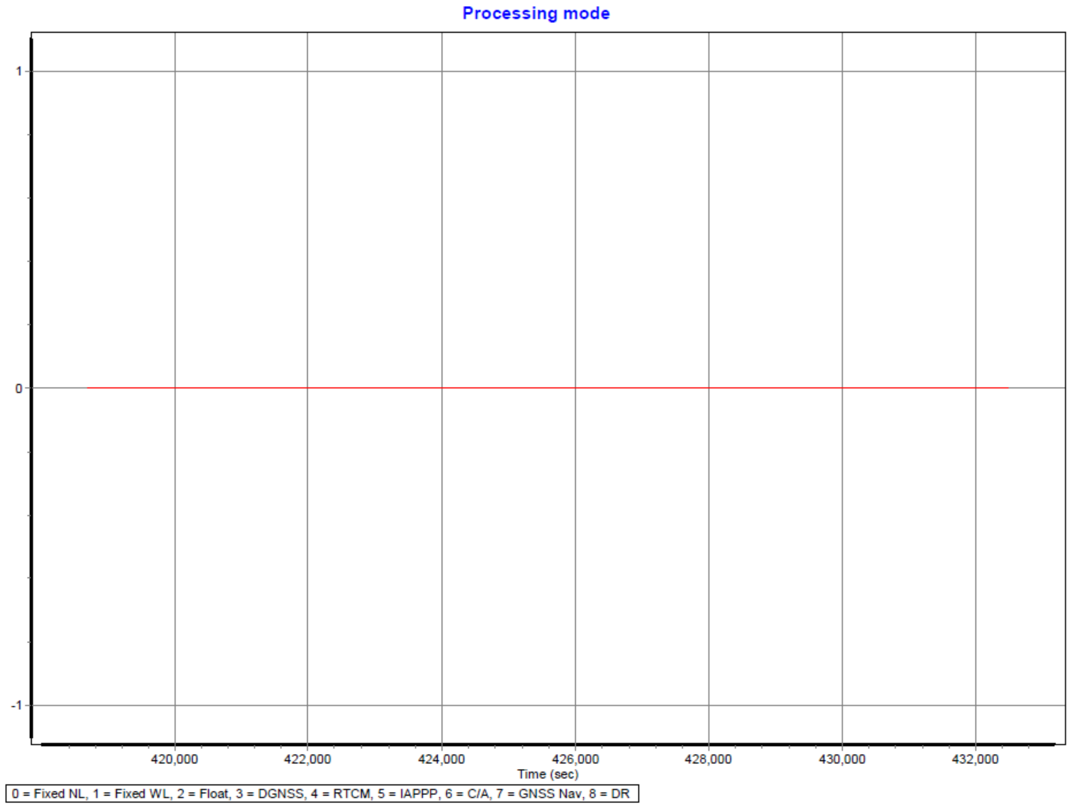

Altitude (m)
1,100
1,050
1,000
950
900
850
800
750
700
650
600
550
500
450
400
350
300
250
200
150
100
50
0
-50
420,000
422,000
424,000
426,000
428,000
430,000
432,000
Time (sec)

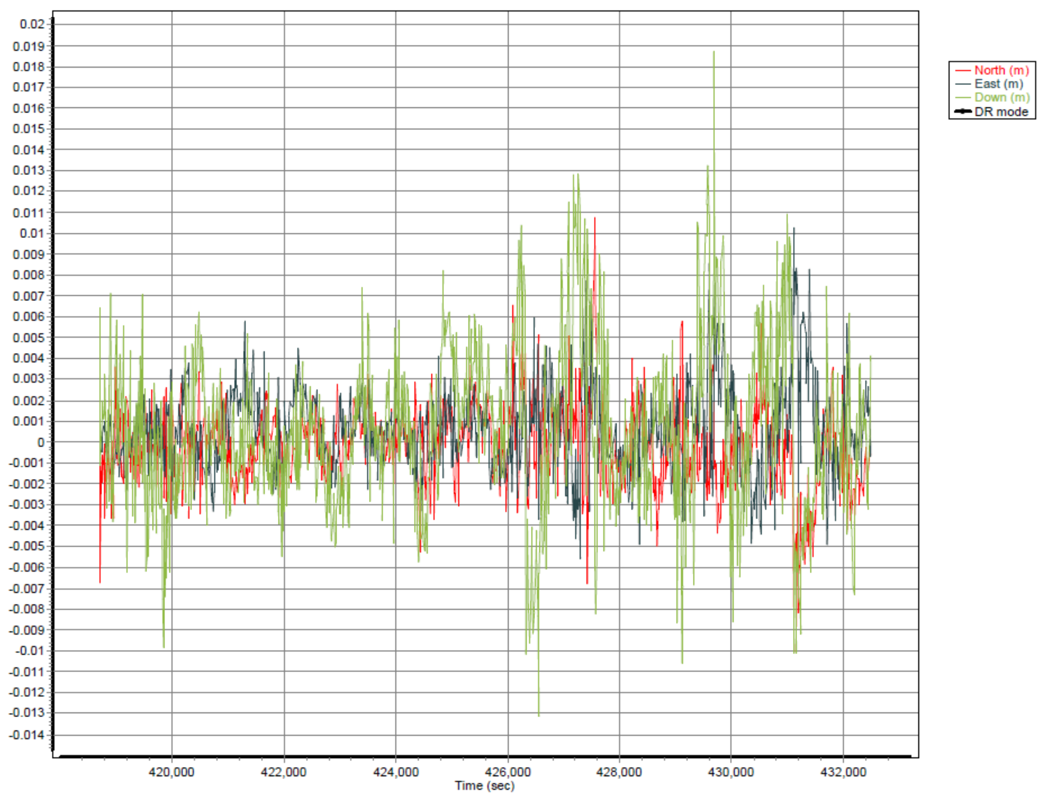

Baseline Length (m)
58,000
56,000
54,000
52,000
50,000
48,000
46,000
44,000
42,000
40,000
38,000
36,000
34,000
32,000
30,000
28,000
26,000
24,000
22,000
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
420,000
422,000
424,000
426,000
428,000
430,000
432,000
Time (sec)

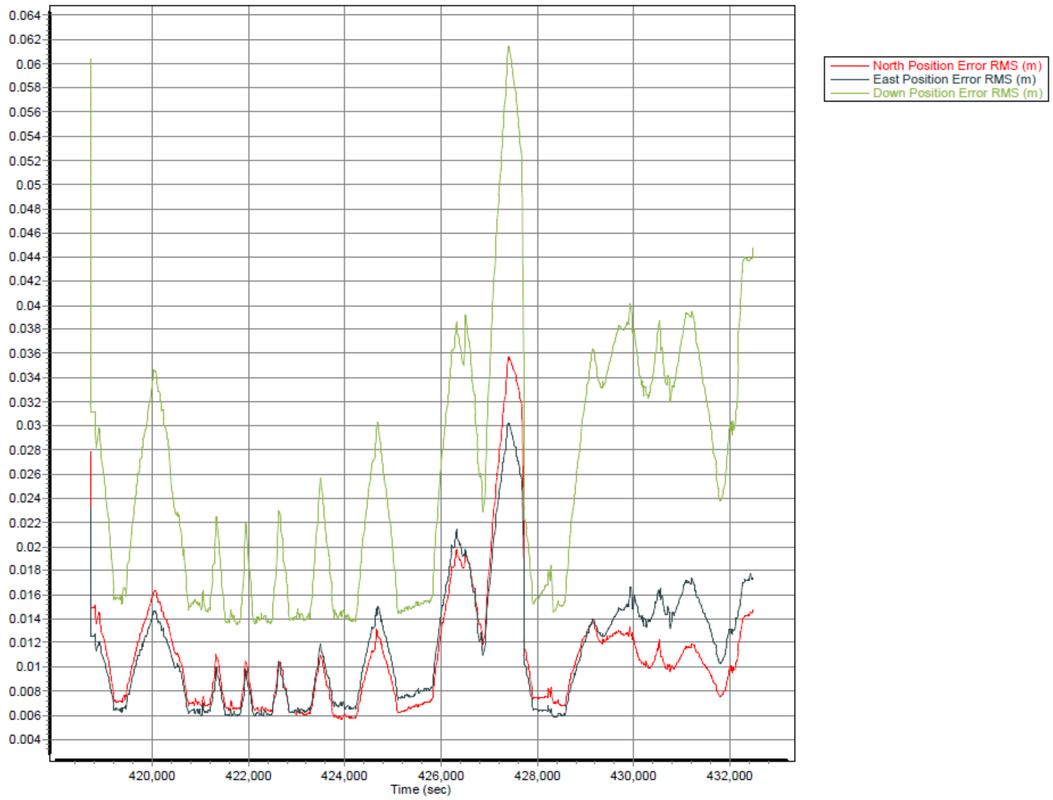

Project Settings
General Information
Units
View
Satellite Selection
GNSS-Inertial Processor
Timing, Multipath and Baseli
Initialization
Lever Arms and Mounting A
Export
Camera
LiDAR
SAR
Reference to IMU Lever Arm
X 0.034 m
Y 0.018 m
Z -0.155 m
Reference to IMU Mounting Angles
X 0.000 deg
Y 0.000 deg
Z 0.000 deg
Reference to Primary GNSS Lever Arm
X -0.150 m
Y -0.061 m
Z -0.992 m
Standard Deviation
<3cm 10cm 50cm 1m 10m
Aircraft to Reference Mounting Angles
X 0.000 deg
Y 0.000 deg
Z 0.000 deg
OK
Cancel

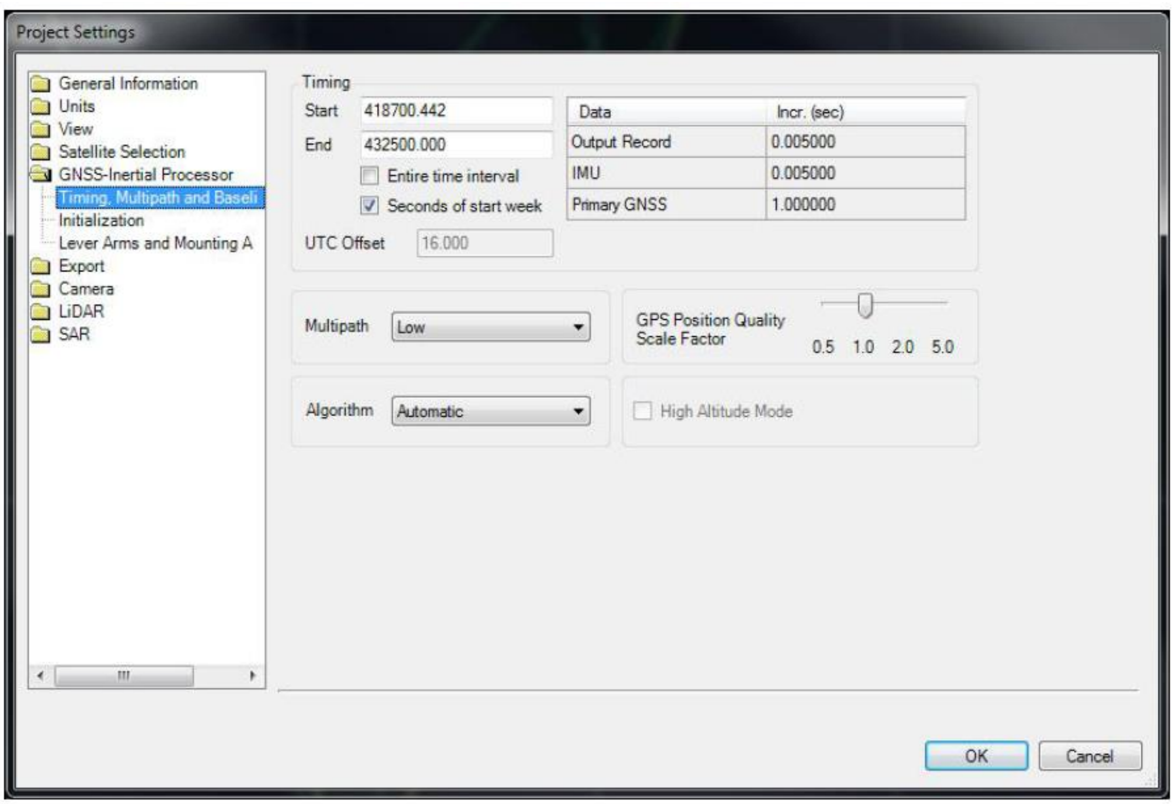

Number of GPS Satellites
10
9
8
7
420,000
422,000
424,000
426,000
428,000
430,000
432,000
Time (sec)

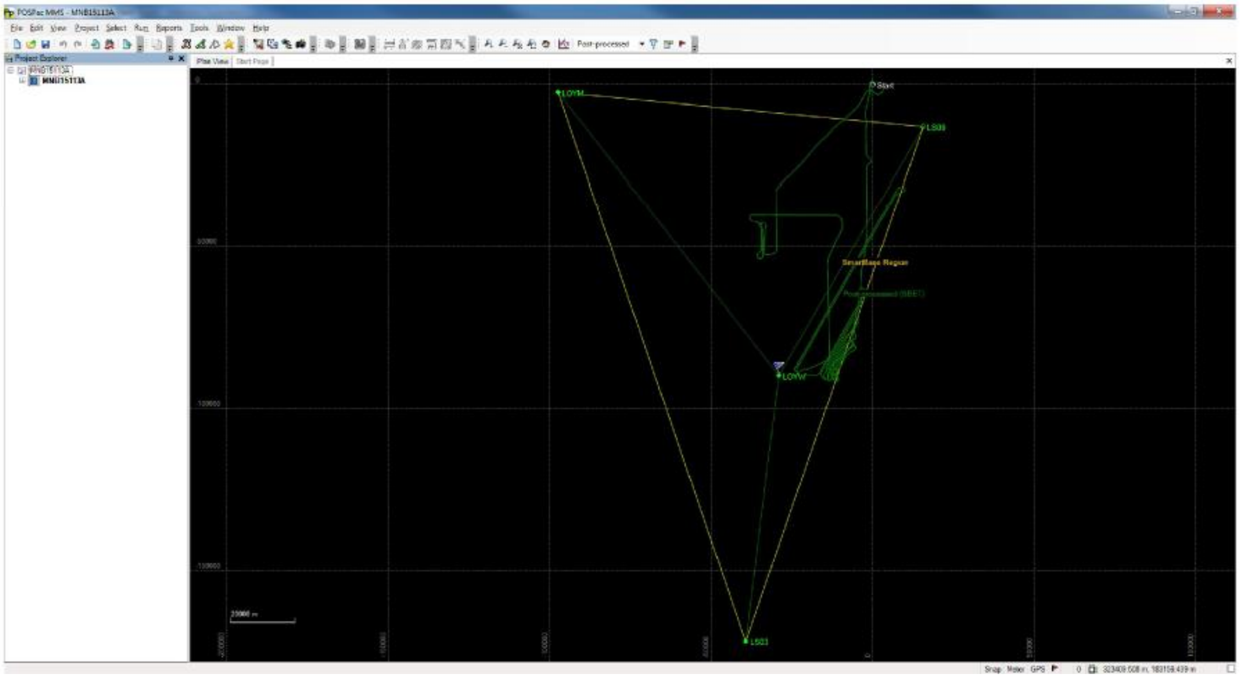

PDOP
2
1.98
1.96
1.94
1.92
1.9
1.88
1.86
1.84
1.82
1.8
1.78
1.76
1.74
1.72
1.7
1.68
1.66
1.64
1.62
1.6
1.58
1.56
1.54
1.52
1.5
1.48
1.46
1.44
1.42
1.4
1.38
1.36
1.34
1.32
1.3
1.28
1.26
1.24
420,000
422,000
424,000
426,000
428,000
430,000
432,000
Time (sec)


Processing mode
1
0
-1
420,000
422,000
424,000
426,000
428,000
430,000
432,000
Time (sec)
0 = Fixed NL, 1 = Fixed WL, 2 = Float, 3 = DGNSS, 4 = RTCM, 5 = IAPPP, 6 = C/A, 7 = GNSS Nav, 8 = DR

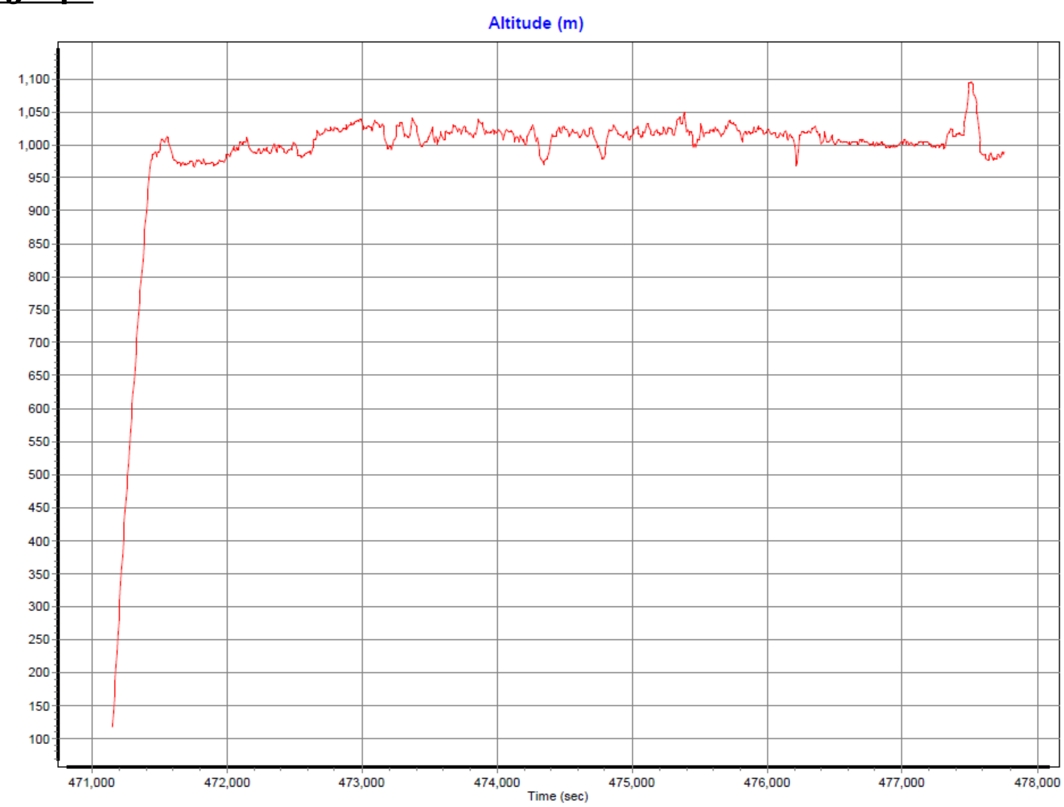

North (m)
East (m)
Down (m)
DR mode
0.02
0.019
0.018
0.017
0.016
0.015
0.014
0.013
0.012
0.011
0.01
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
-0.001
-0.002
-0.003
-0.004
-0.005
-0.006
-0.007
-0.008
-0.009
-0.01
-0.011
-0.012
-0.013
-0.014
420,000
422,000
424,000
426,000
428,000
430,000
432,000
Time (sec)

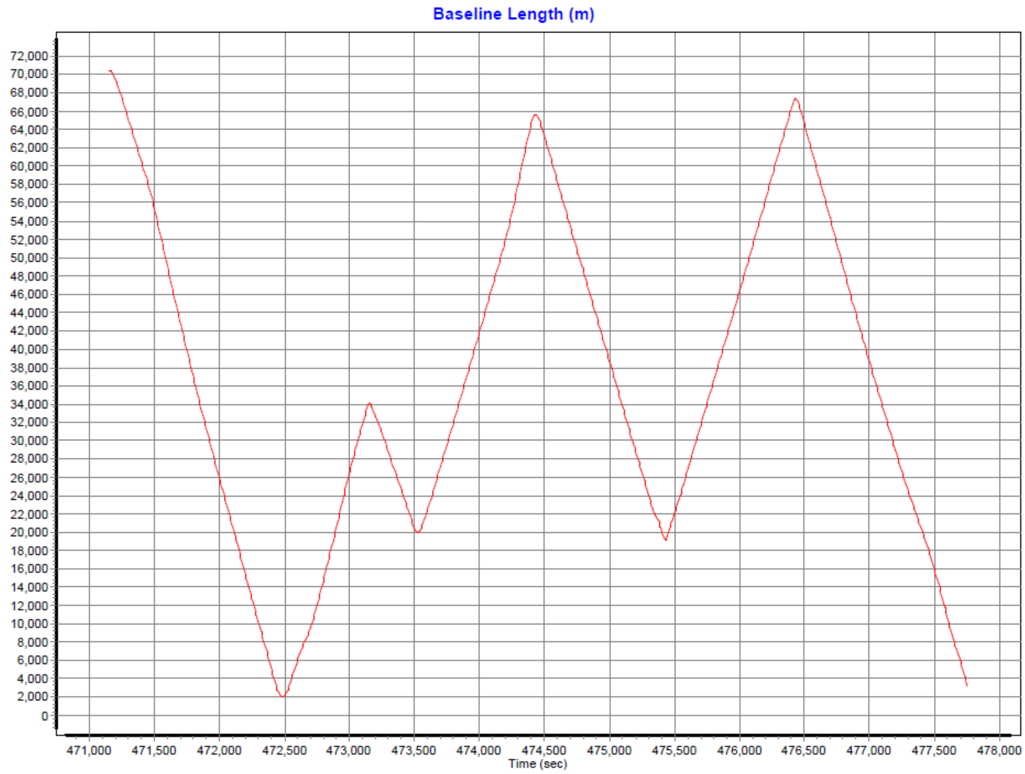

North Position Error RMS (m)
East Position Error RMS (m)
Down Position Error RMS (m)
0.064
0.062
0.06
0.058
0.056
0.054
0.052
0.05
0.048
0.046
0.044
0.042
0.04
0.038
0.036
0.034
0.032
0.03
0.028
0.026
0.024
0.022
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
420,000
422,000
424,000
426,000
428,000
430,000
432,000
Time (sec)

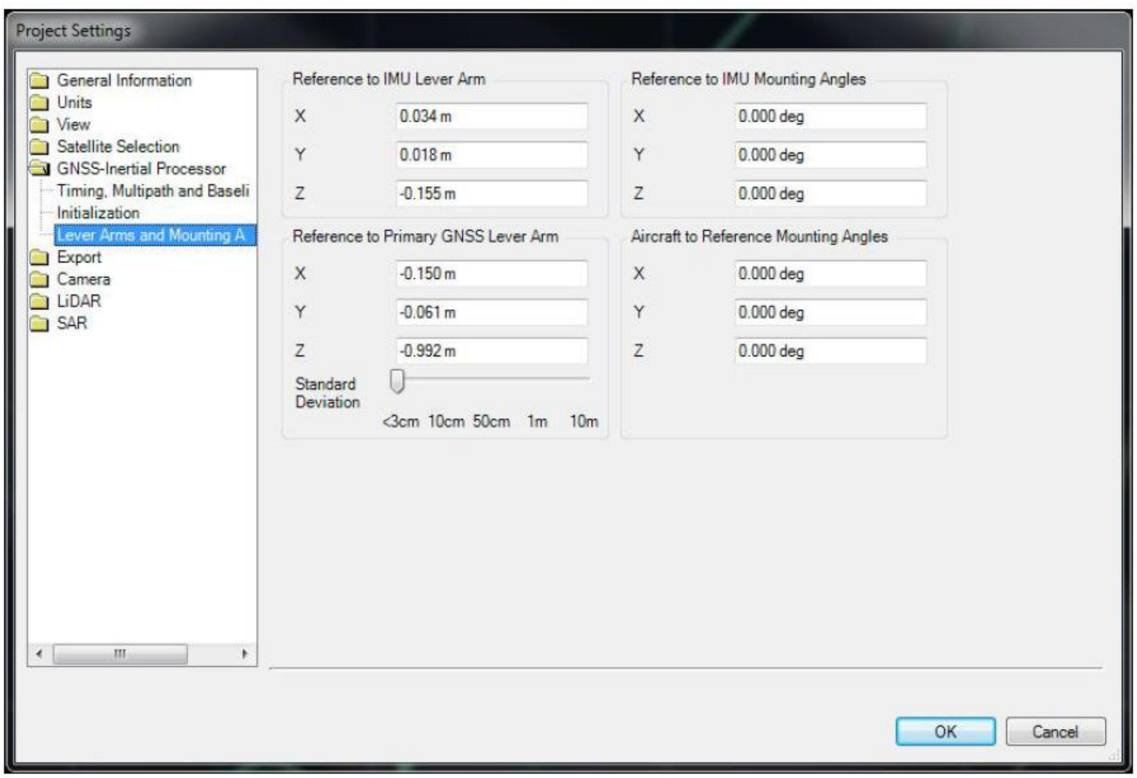

Project Settings
General Information
Units
View
Satellite Selection
GNSS-Inertial Processor
Timing, Multipath and Baseli
Initialization
Lever Arms and Mounting A
Export
Camera
LiDAR
SAR
Timing
Start 418700.442
End 432500.000
Entire time interval
Seconds of start week
UTC Offset 16.000
Data
Incr. (sec)
Output Record 0.005000
IMU 0.005000
Primary GNSS 1.000000
Multipath Low
GPS Position Quality Scale Factor
0.5 1.0 2.0 5.0
Algorithm Automatic
High Altitude Mode
OK
Cancel

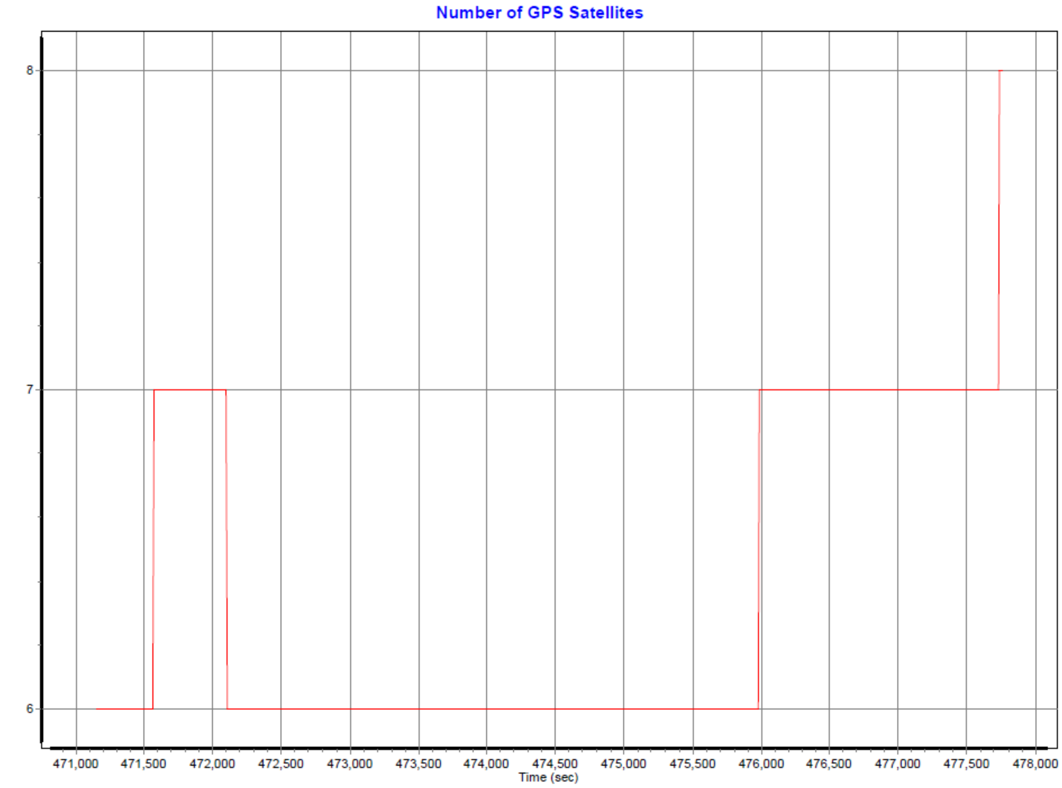


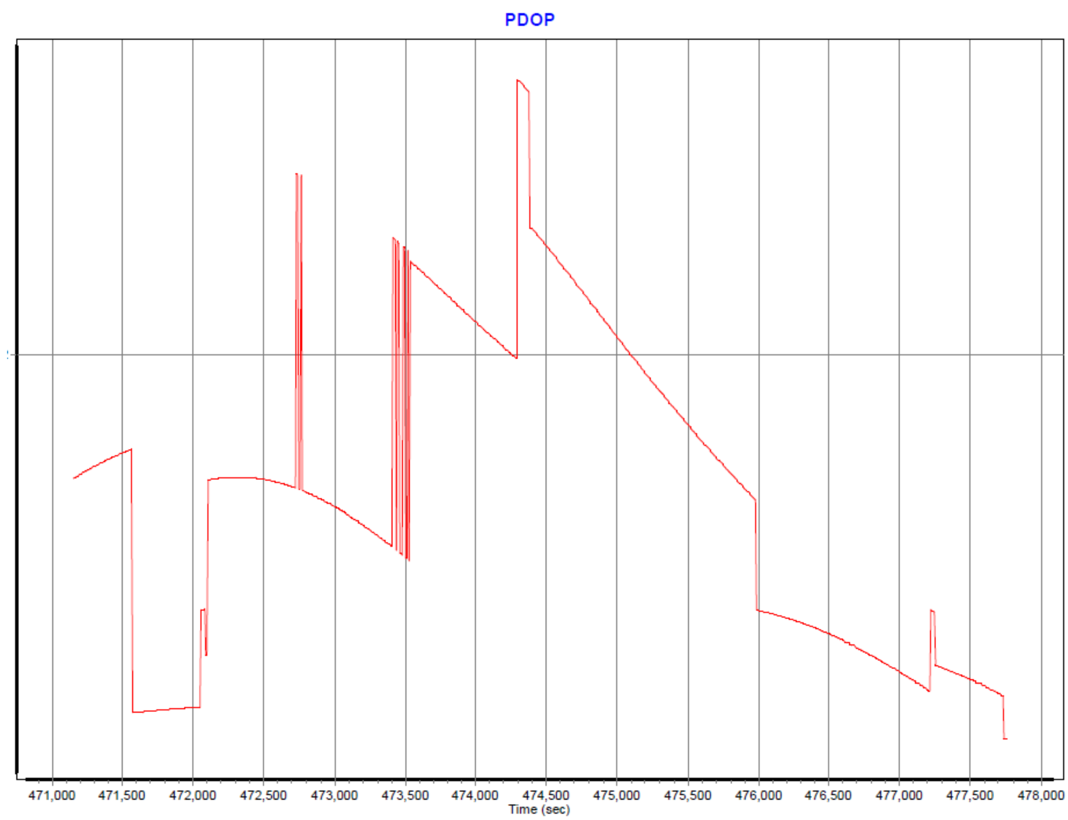
MNB15114A

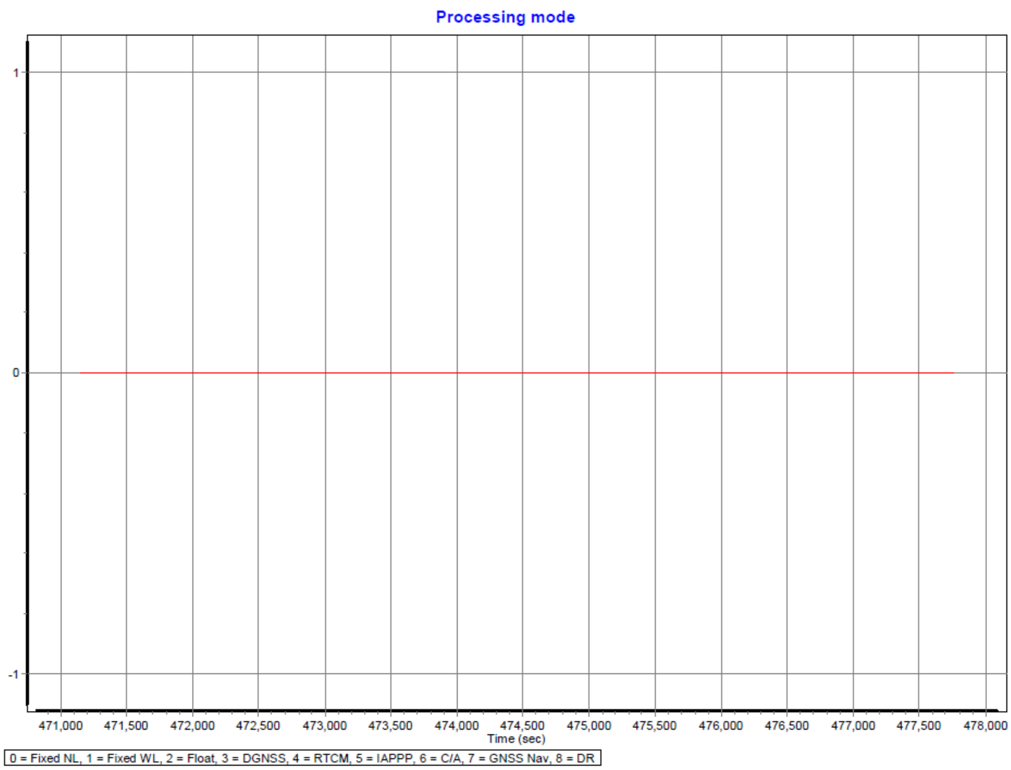

Altitude (m)
1,100
1,050
1,000
950
900
850
800
750
700
650
600
550
500
450
400
350
300
250
200
150
100
471,000
472,000
473,000
474,000
475,000
476,000
477,000
478,000
Time (sec)

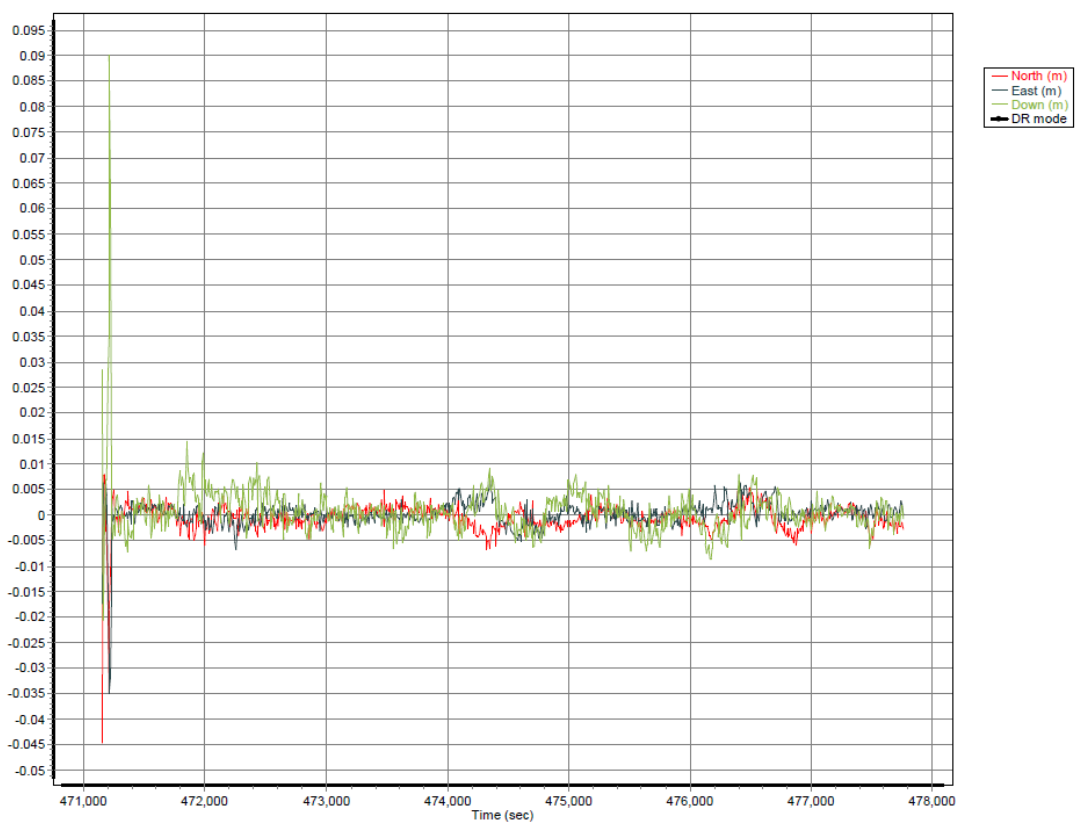

Baseline Length (m)
72,000
70,000
68,000
66,000
64,000
62,000
60,000
58,000
56,000
54,000
52,000
50,000
48,000
46,000
44,000
42,000
40,000
38,000
36,000
34,000
32,000
30,000
28,000
26,000
24,000
22,000
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
471,000
471,500
472,000
472,500
473,000
473,500
474,000
474,500
475,000
475,500
476,000
476,500
477,000
477,500
478,000
Time (sec)


Project Settings
General Information
Units
View
Satellite Selection
GNSS-Inertial Processor
Timing, Multipath and Baseli
Initialization
Lever Arms and Mounting A
Export
Camera
LiDAR
SAR
Reference to IMU Lever Arm
X 0.034 m
Y 0.018 m
Z -0.155 m
Reference to IMU Mounting Angles
X 0.000 deg
Y 0.000 deg
Z 0.000 deg
Reference to Primary GNSS Lever Arm
X -0.150 m
Y -0.061 m
Z -0.992 m
Standard Deviation
<3cm 10cm 50cm 1m 10m
Aircraft to Reference Mounting Angles
X 0.000 deg
Y 0.000 deg
Z 0.000 deg
OK
Cancel

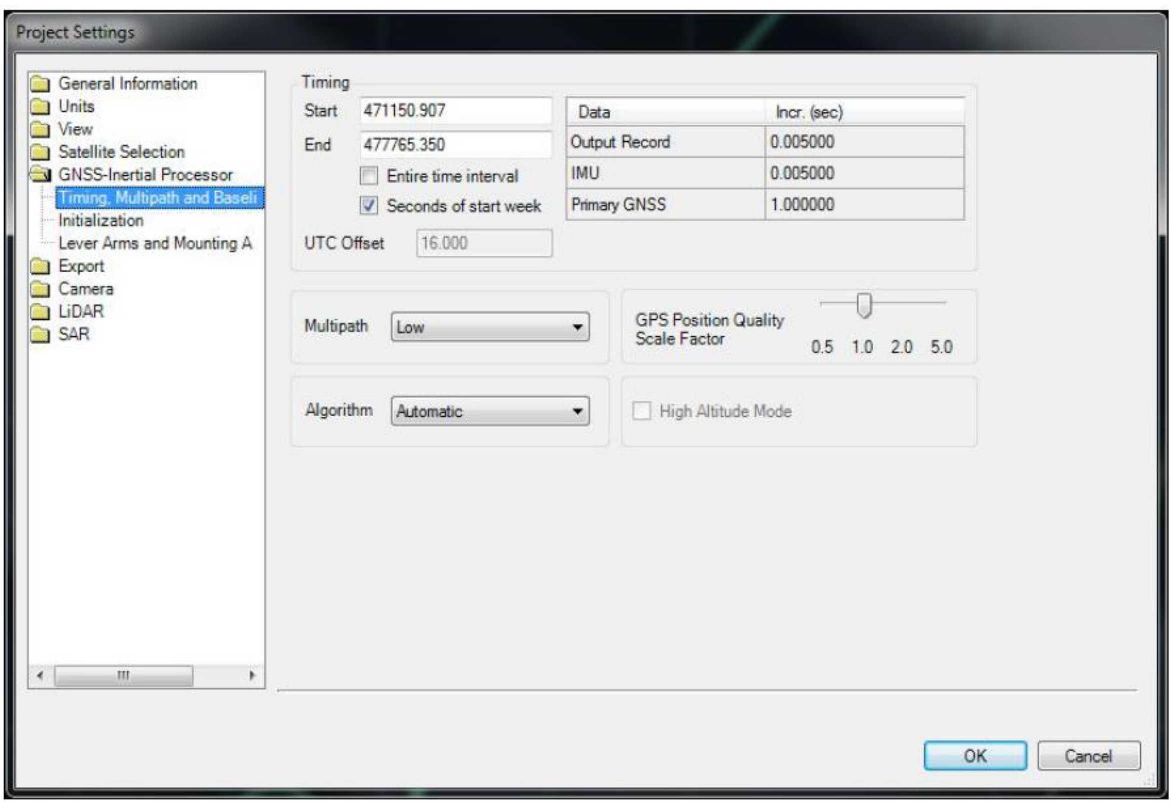

Number of GPS Satellites
8
7
6
471,000
471,500
472,000
472,500
473,000
473,500
474,000
474,500
475,000
475,500
476,000
476,500
477,000
477,500
478,000
Time (sec)

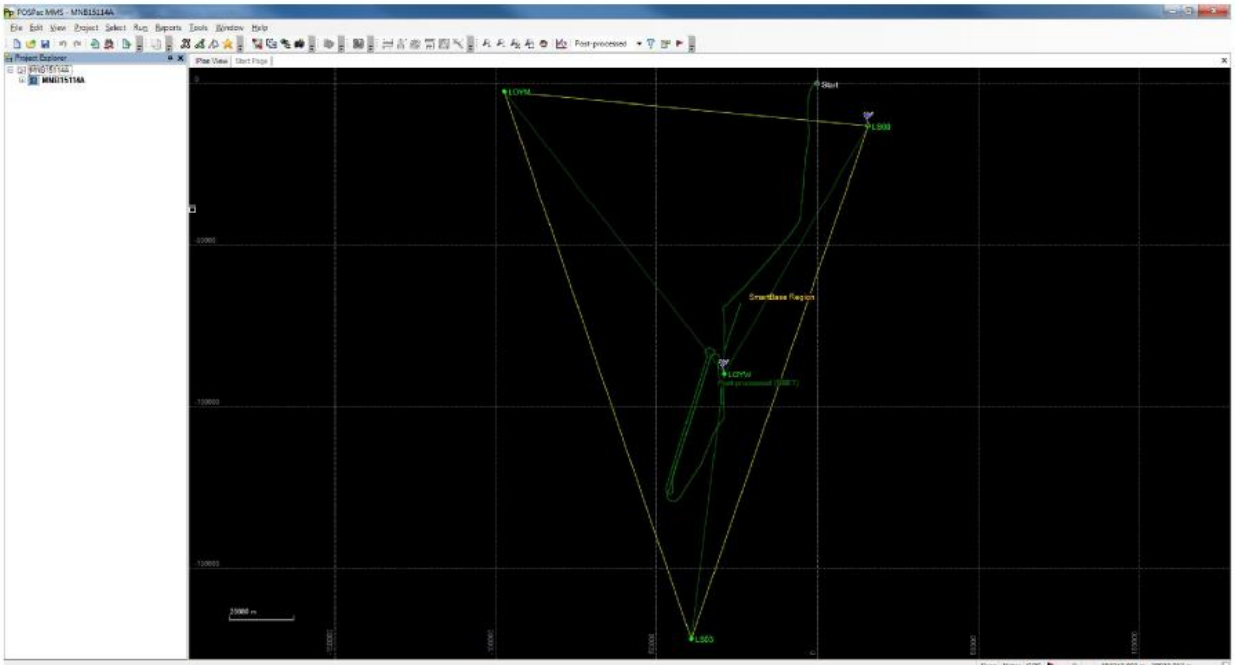

PDOP
471,000
471,500
472,000
472,500
473,000
473,500
474,000
474,500
475,000
475,500
476,000
476,500
477,000
477,500
478,000
Time (sec)


Processing mode
1
0
-1
471,000
471,500
472,000
472,500
473,000
473,500
474,000
474,500
475,000
475,500
476,000
476,500
477,000
477,500
478,000
Time (sec)
0 = Fixed NL, 1 = Fixed WL, 2 = Float, 3 = DGNSS, 4 = RTCM, 5 = IAPPP, 6 = C/A, 7 = GNSS Nav, 8 = DR

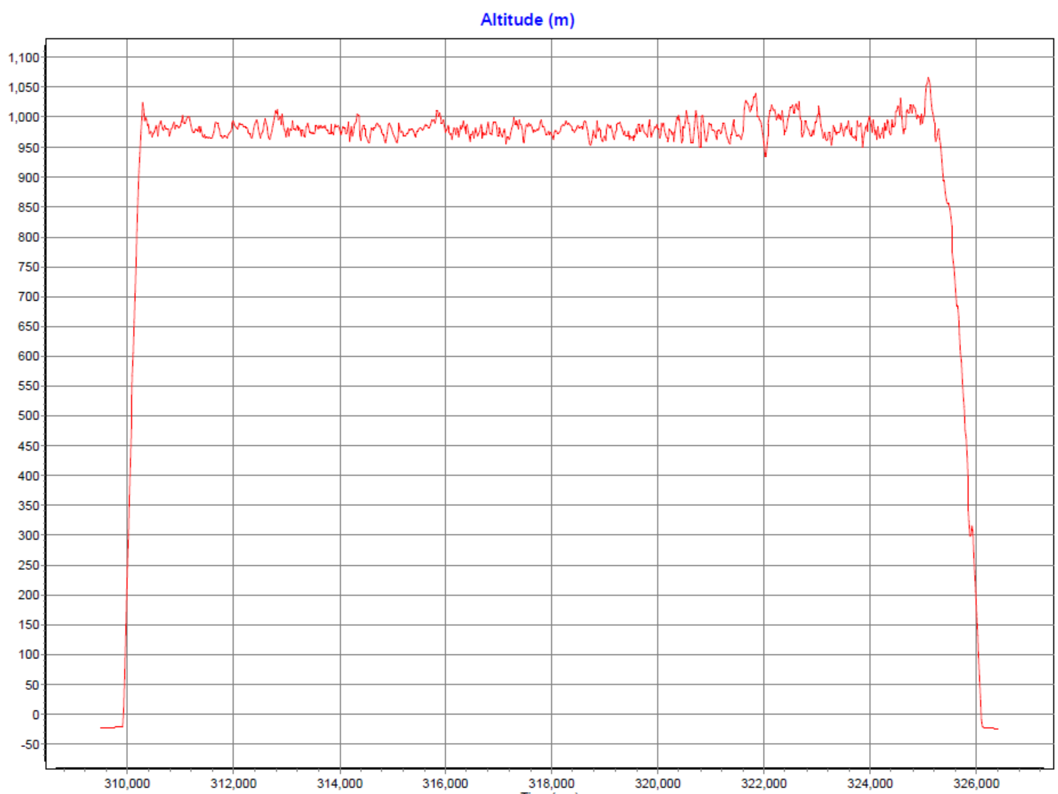

North (m)
East (m)
Down (m)
DR mode
0.095
0.09
0.085
0.08
0.075
0.07
0.065
0.06
0.055
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
-0.005
-0.01
-0.015
-0.02
-0.025
-0.03
-0.035
-0.04
-0.045
-0.05
471,000
472,000
473,000
474,000
475,000
476,000
477,000
478,000
Time (sec)

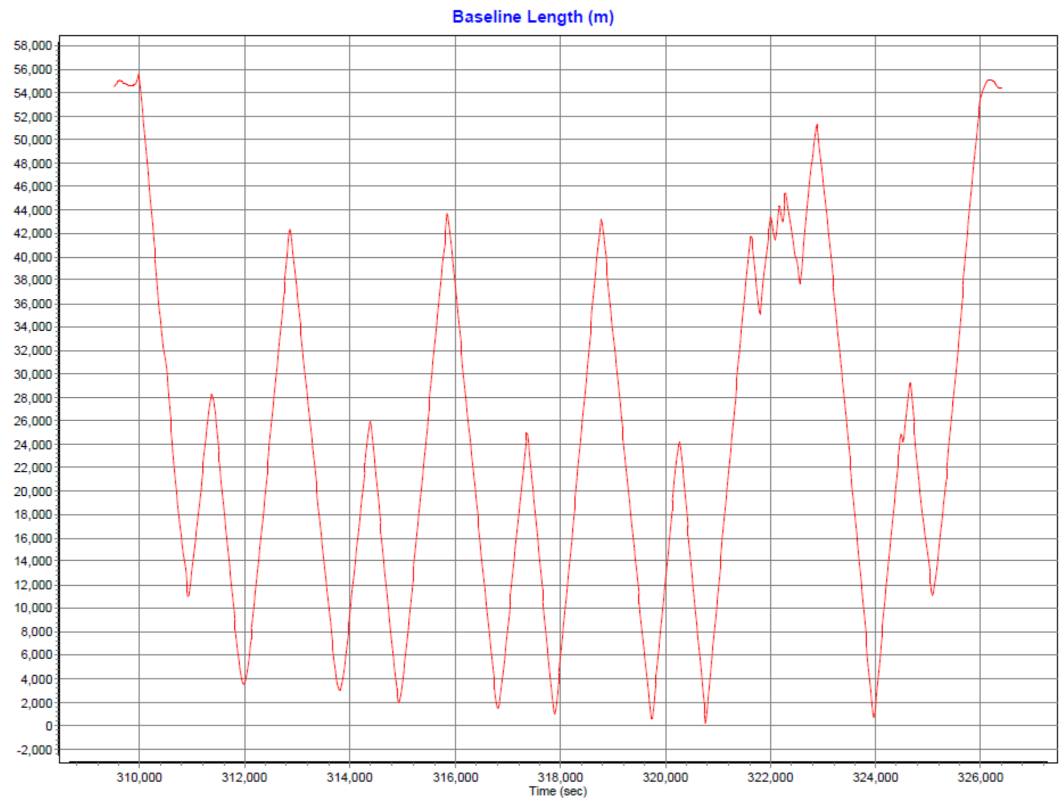

North Position Error RMS (m)
East Position Error RMS (m)
Down Position Error RMS (m)
0.066
0.064
0.062
0.06
0.058
0.056
0.054
0.052
0.05
0.048
0.046
0.044
0.042
0.04
0.038
0.036
0.034
0.032
0.03
0.028
0.026
0.024
0.022
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
471,000
472,000
473,000
474,000
475,000
476,000
477,000
478,000
Time (sec)

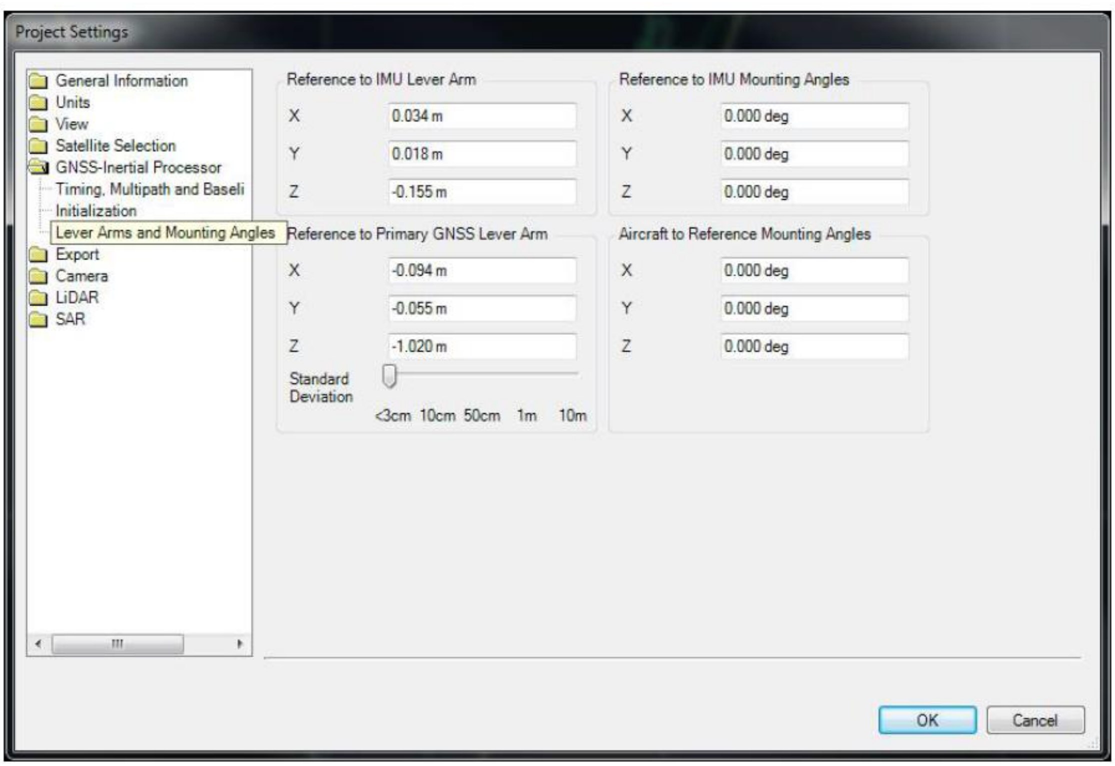

Project Settings
General Information
Units
View
Satellite Selection
GNSS-Inertial Processor
Timing, Multipath and Baseli
Initialization
Lever Arms and Mounting A
Export
Camera
LiDAR
SAR
Timing
Start 471150.907
End 477765.350
Entire time interval
Seconds of start week
UTC Offset 16.000
Data
Incr. (sec)
Output Record 0.005000
IMU 0.005000
Primary GNSS 1.000000
Multipath Low
GPS Position Quality Scale Factor
0.5 1.0 2.0 5.0
Algorithm Automatic
High Altitude Mode
OK
Cancel

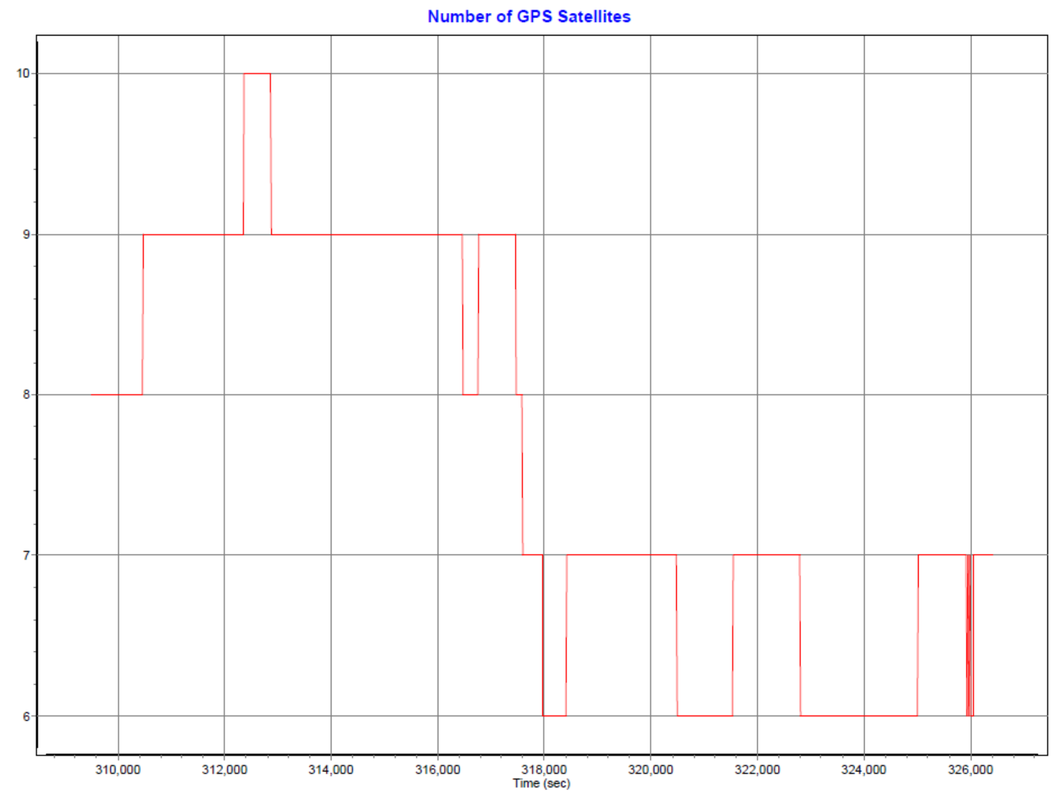


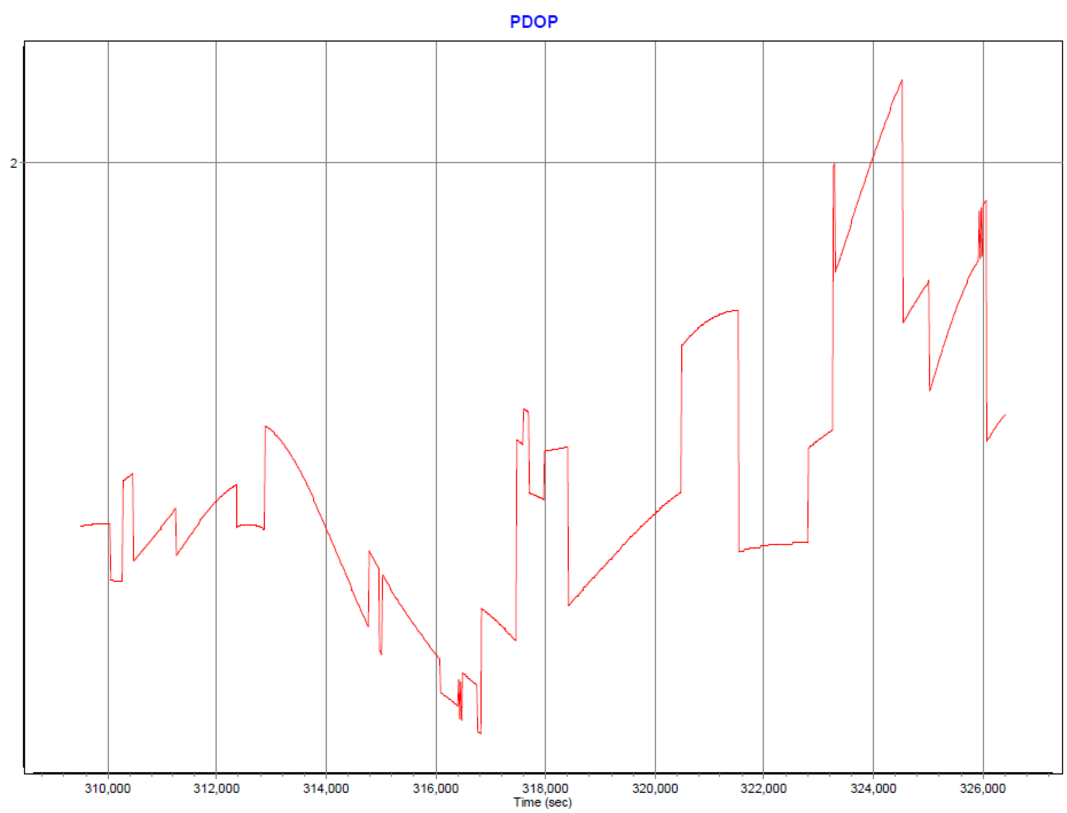
UNB15105A

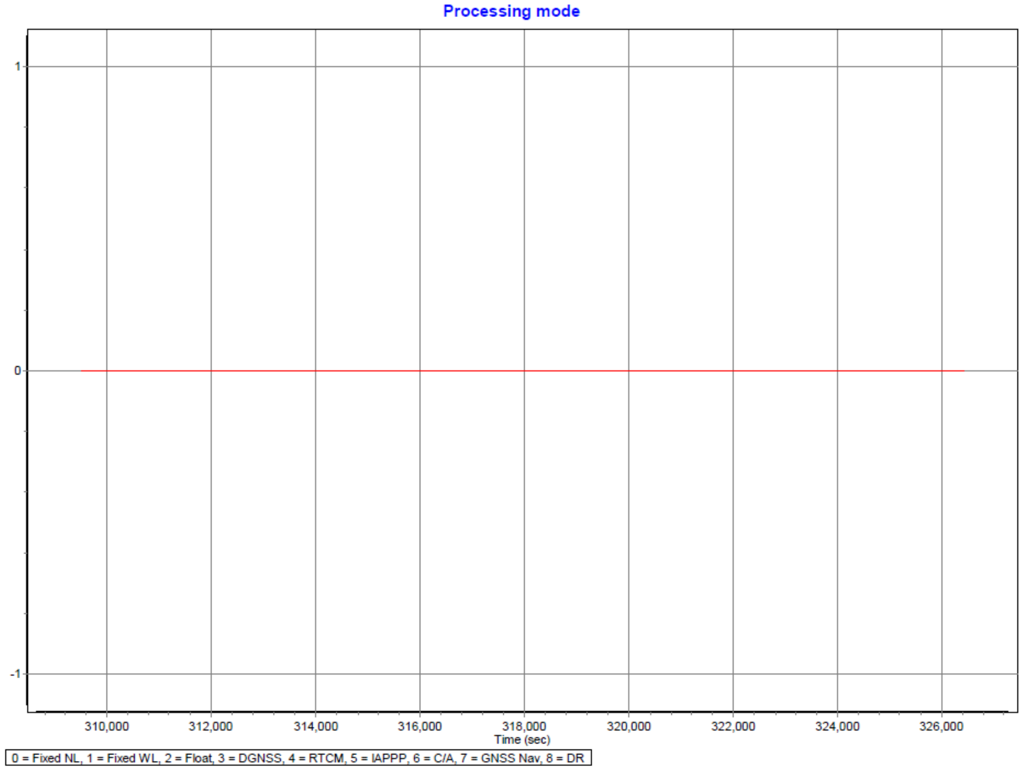

Altitude (m)
1,100
1,050
1,000
950
900
850
800
750
700
650
600
550
500
450
400
350
300
250
200
150
100
50
0
-50
310,000
312,000
314,000
316,000
318,000
320,000
322,000
324,000
326,000

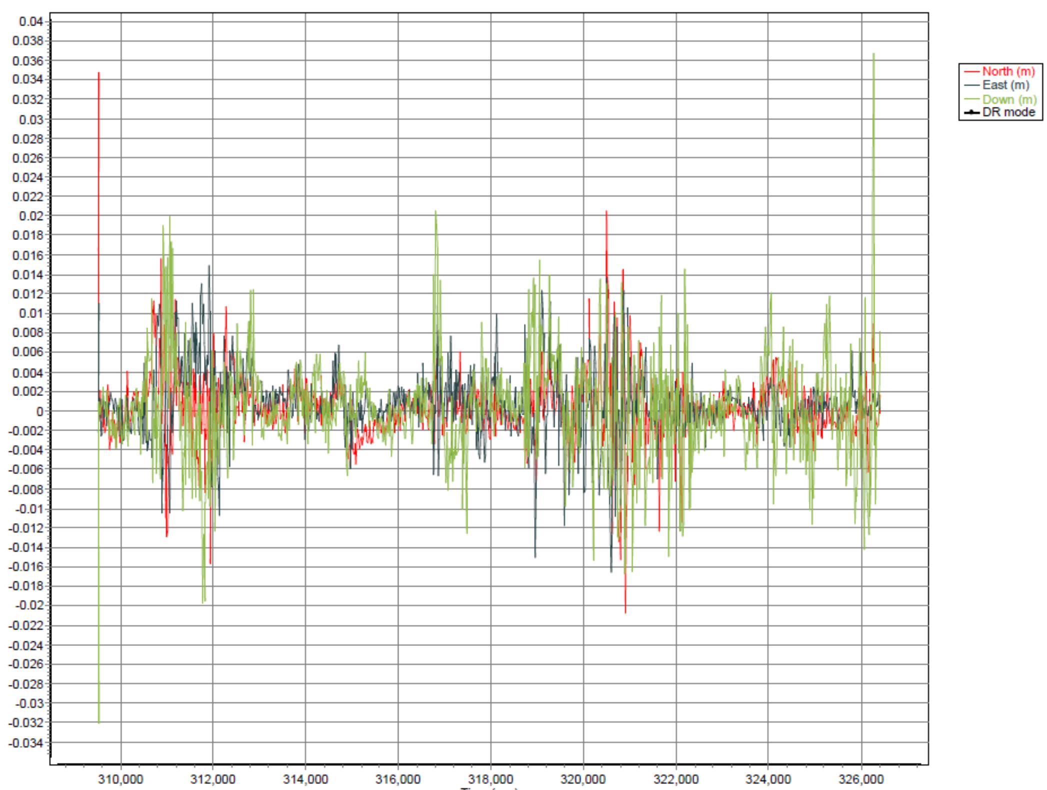

Baseline Length (m)
58,000
56,000
54,000
52,000
50,000
48,000
46,000
44,000
42,000
40,000
38,000
36,000
34,000
32,000
30,000
28,000
26,000
24,000
22,000
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
-2,000
310,000
312,000
314,000
316,000
318,000
320,000
322,000
324,000
326,000
Time (sec)

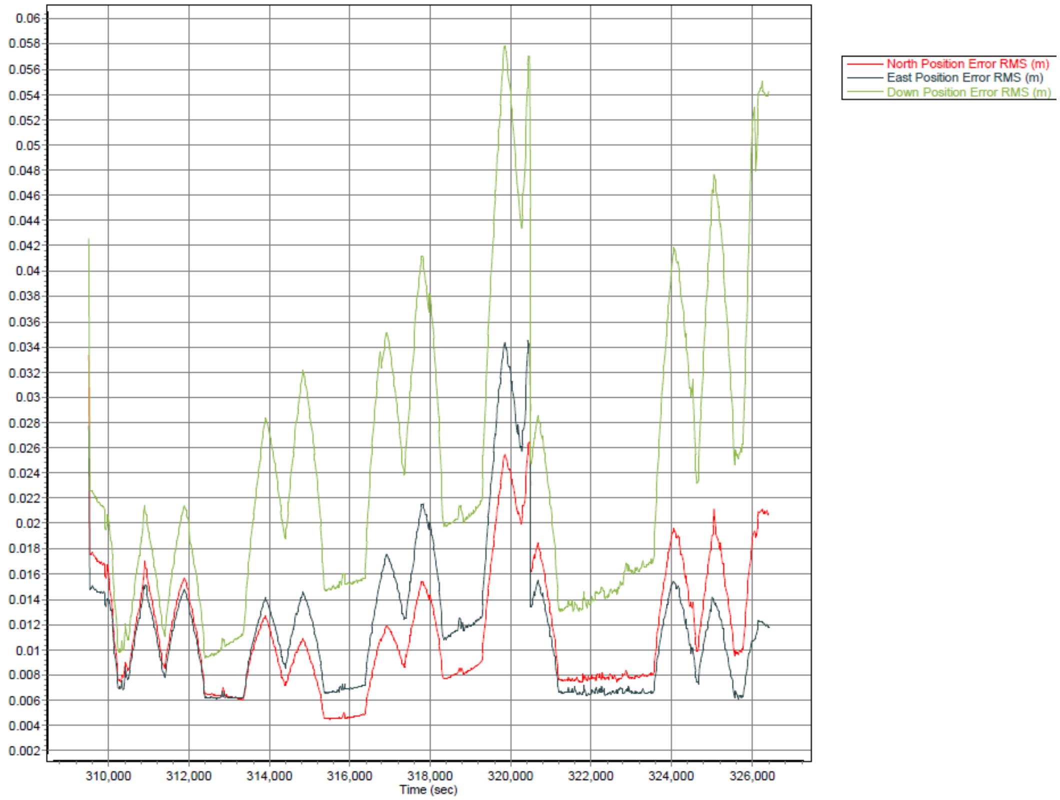

Project Settings
General Information
Units
View
Satellite Selection
GNSS-Inertial Processor
Timing, Multipath and Baseli
Initialization
Lever Arms and Mounting Angles
Export
Camera
LiDAR
SAR
Reference to IMU Lever Arm
X 0.034 m
Y 0.018 m
Z -0.155 m
Reference to IMU Mounting Angles
X 0.000 deg
Y 0.000 deg
Z 0.000 deg
Reference to Primary GNSS Lever Arm
X -0.094 m
Y -0.055 m
Z -1.020 m
Standard Deviation
<3cm 10cm 50cm 1m 10m
Aircraft to Reference Mounting Angles
X 0.000 deg
Y 0.000 deg
Z 0.000 deg
OK
Cancel

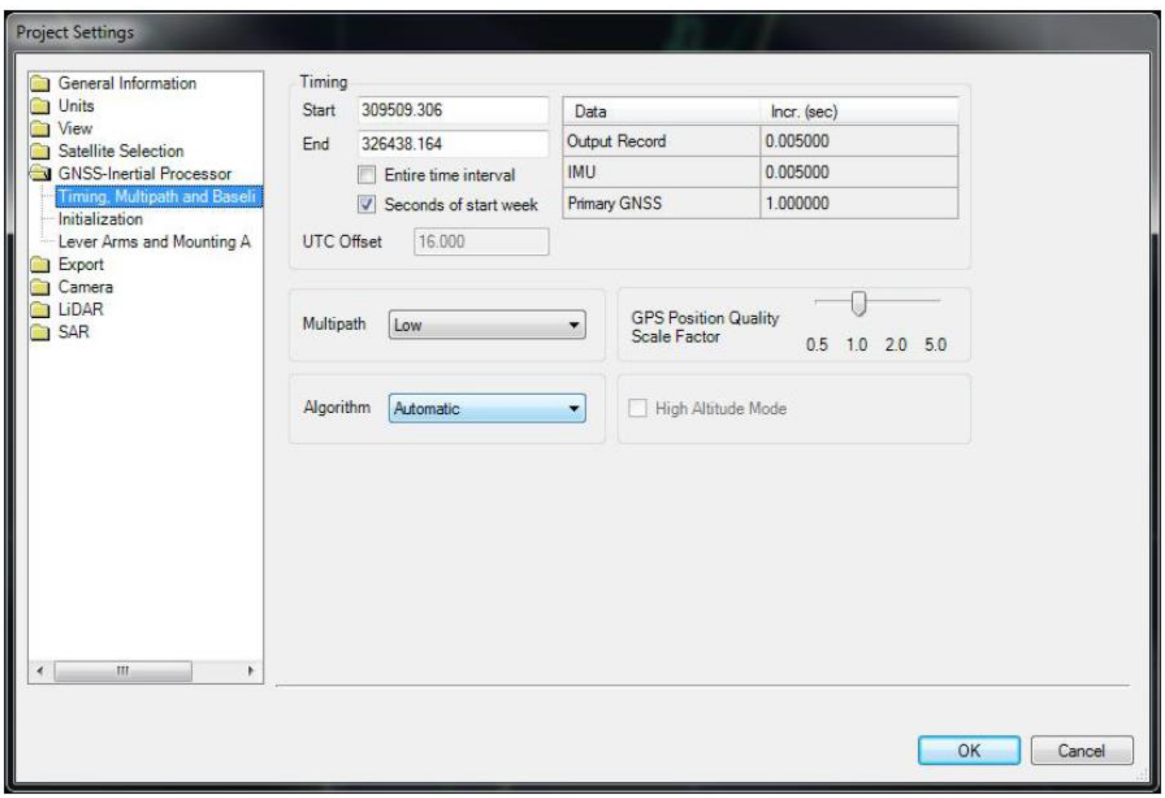

Number of GPS Satellites
10
9
8
7
6
310,000
312,000
314,000
316,000
318,000
320,000
322,000
324,000
326,000
Time (sec)

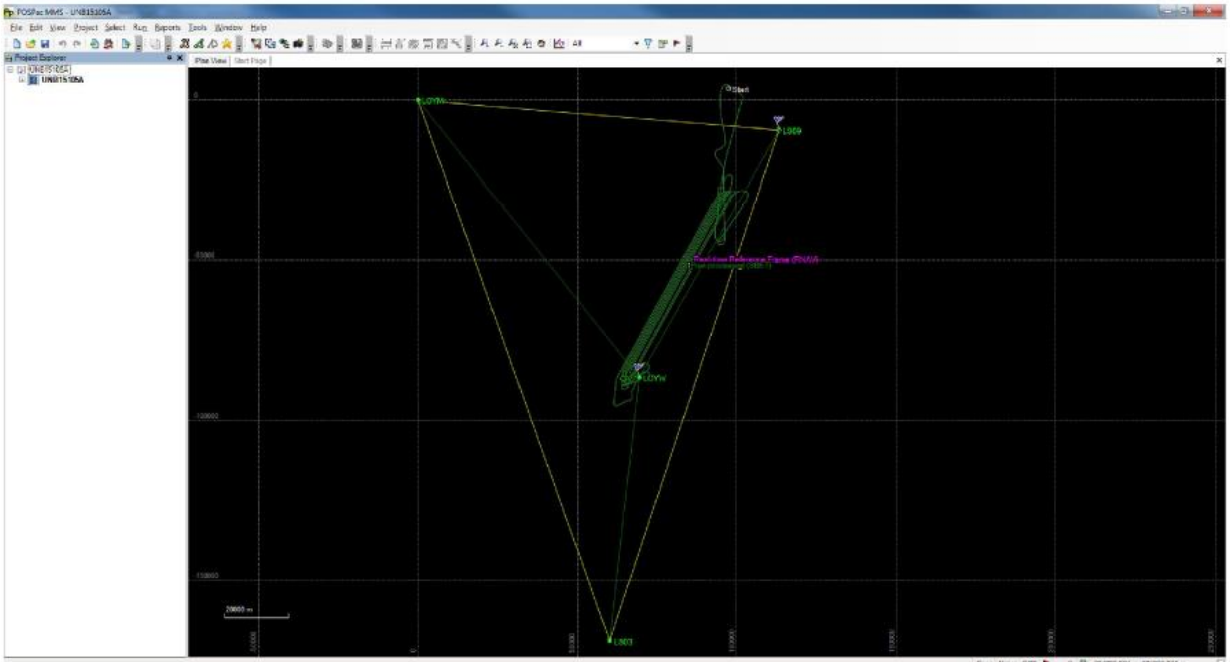

PDOP
2
310,000
312,000
314,000
316,000
318,000
320,000
322,000
324,000
326,000
Time (sec)


Processing mode
1
0
-1
310,000
312,000
314,000
316,000
318,000
320,000
322,000
324,000
326,000
Time (sec)
0 = Fixed NL, 1 = Fixed WL, 2 = Float, 3 = DGNSS, 4 = RTCM, 5 = IAPPP, 6 = C/A, 7 = GNSS Nav, 8 = DR


North (m)
East (m)
Down (m)
DR mode
Time (sec)


North Position Error RMS (m)
East Position Error RMS (m)
Down Position Error RMS (m)
0.06
0.058
0.056
0.054
0.052
0.05
0.048
0.046
0.044
0.042
0.04
0.038
0.036
0.034
0.032
0.03
0.028
0.026
0.024
0.022
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
310,000
312,000
314,000
316,000
318,000
320,000
322,000
324,000
326,000
Time (sec)


Project Settings
General Information
Units
View
Satellite Selection
GNSS-Inertial Processor
Timing, Multipath and Baseli
Initialization
Lever Arms and Mounting A
Export
Camera
LiDAR
SAR
Timing
Start
309509.306
End
326438.164
Entire time interval
Seconds of start week
UTC Offset
16.000
Data
Incr. (sec)
Output Record
0.005000
IMU
0.005000
Primary GNSS
1.000000
Multipath
Low
GPS Position Quality Scale Factor
0.5
1.0
2.0
5.0
Algorithm
Automatic
High Altitude Mode
OK
Cancel



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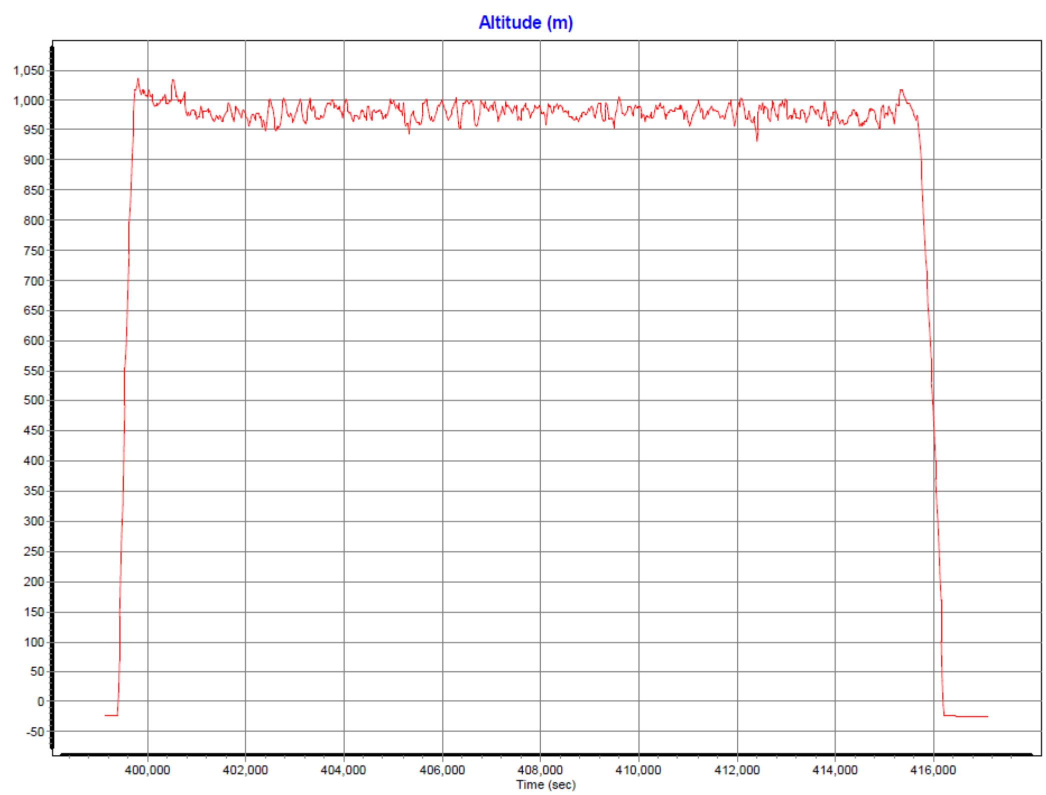
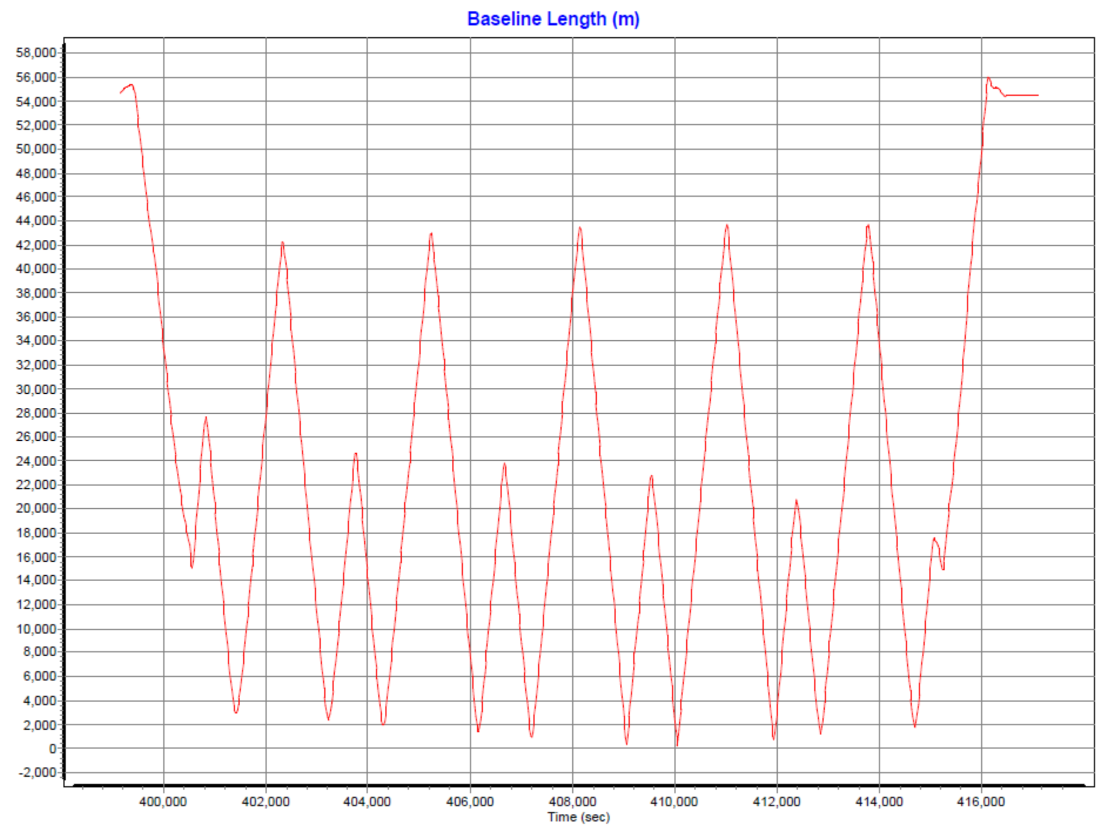
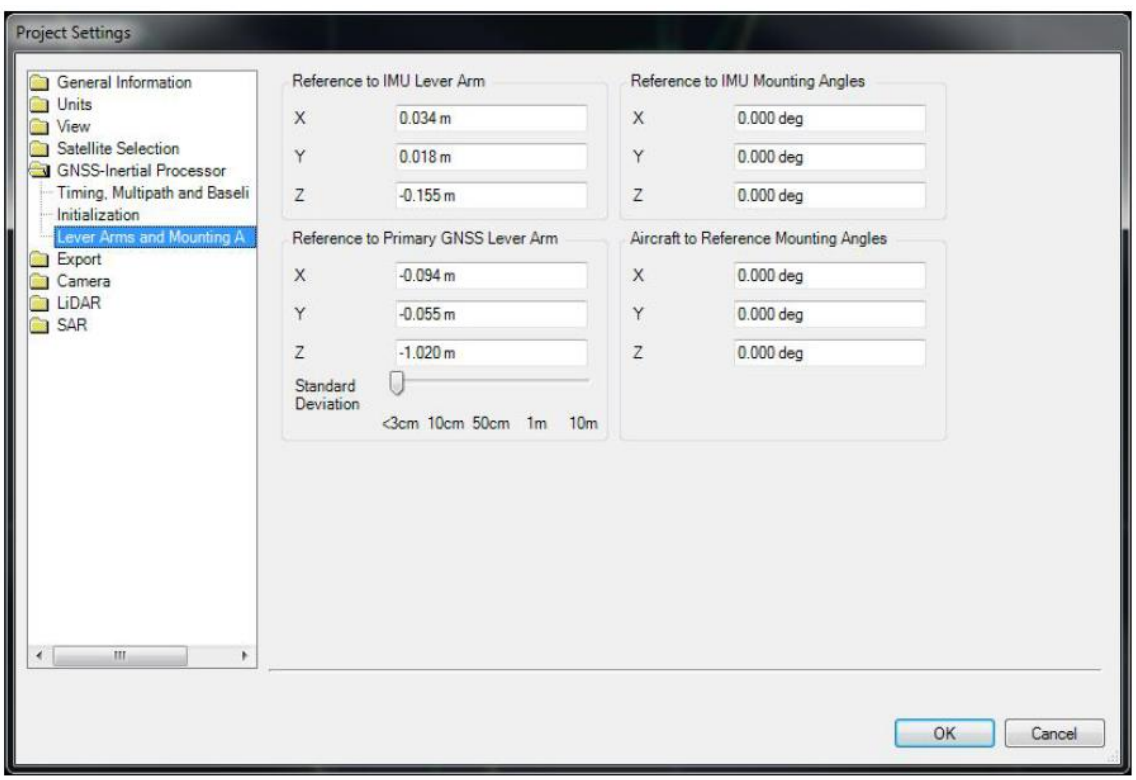
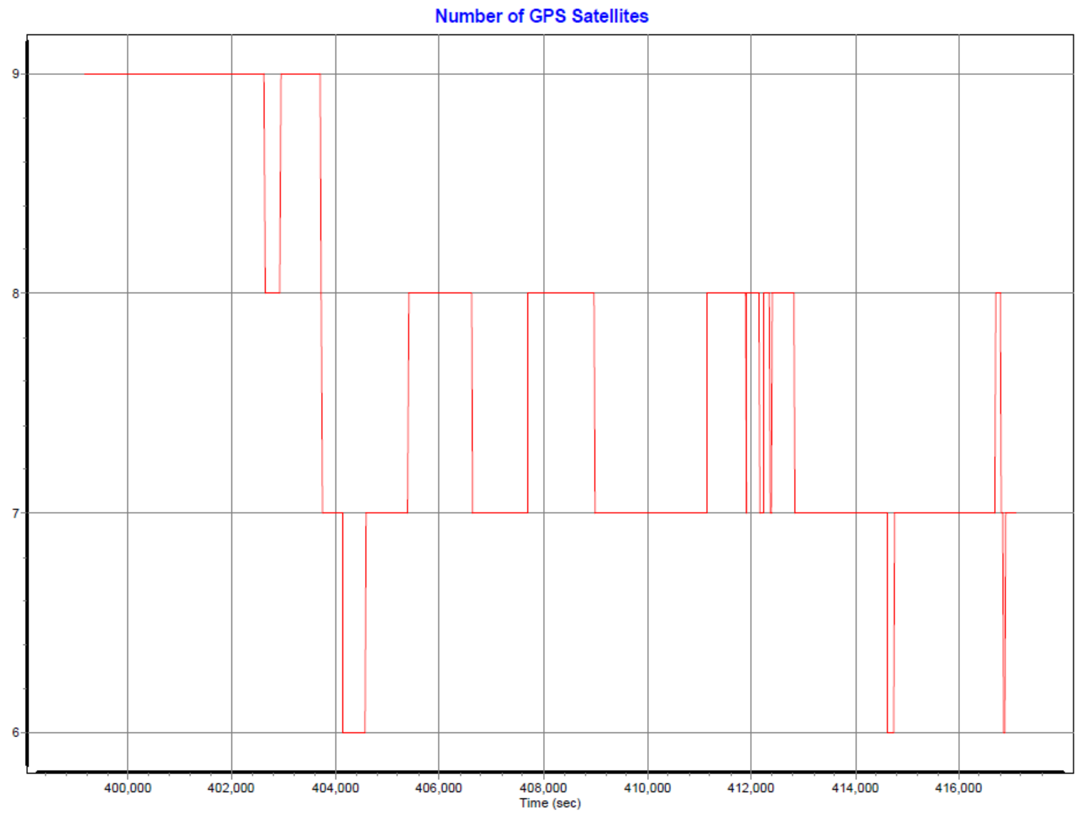
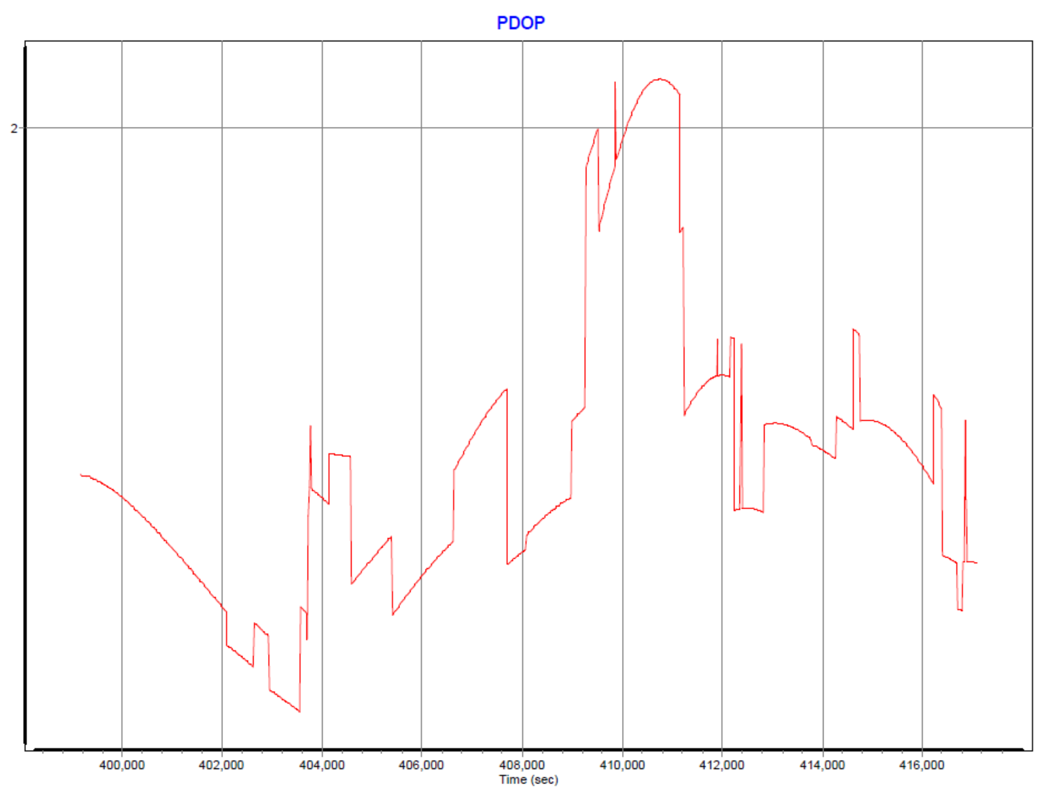
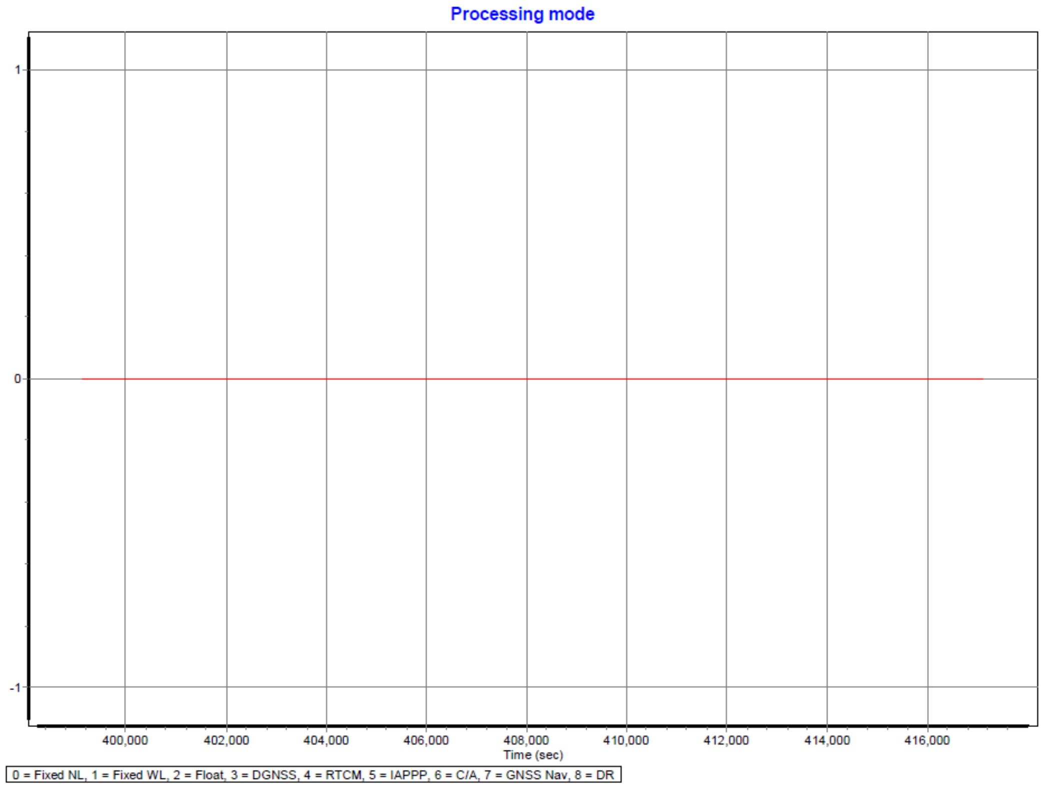

Altitude (m)
1,050
1,000
950
900
850
800
750
700
650
600
550
500
450
400
350
300
250
200
150
100
50
0
-50
400,000
402,000
404,000
406,000
408,000
410,000
412,000
414,000
416,000
Time (sec)

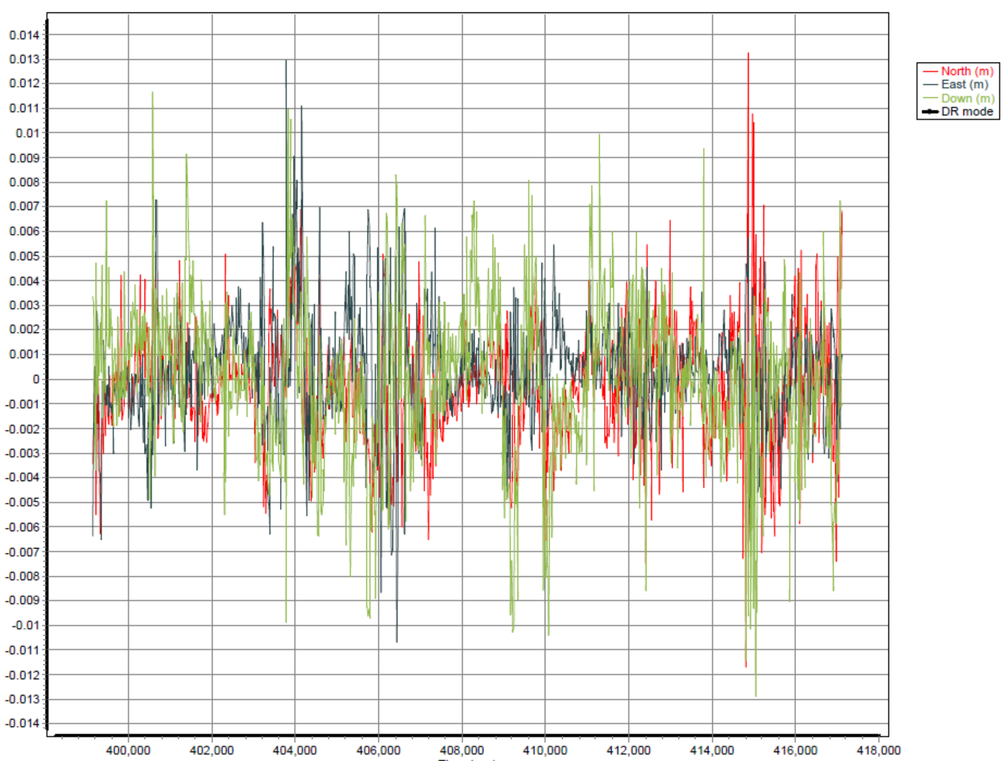

Baseline Length (m)
58,000
56,000
54,000
52,000
50,000
48,000
46,000
44,000
42,000
40,000
38,000
36,000
34,000
32,000
30,000
28,000
26,000
24,000
22,000
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
-2,000
400,000
402,000
404,000
406,000
408,000
410,000
412,000
414,000
416,000
Time (sec)

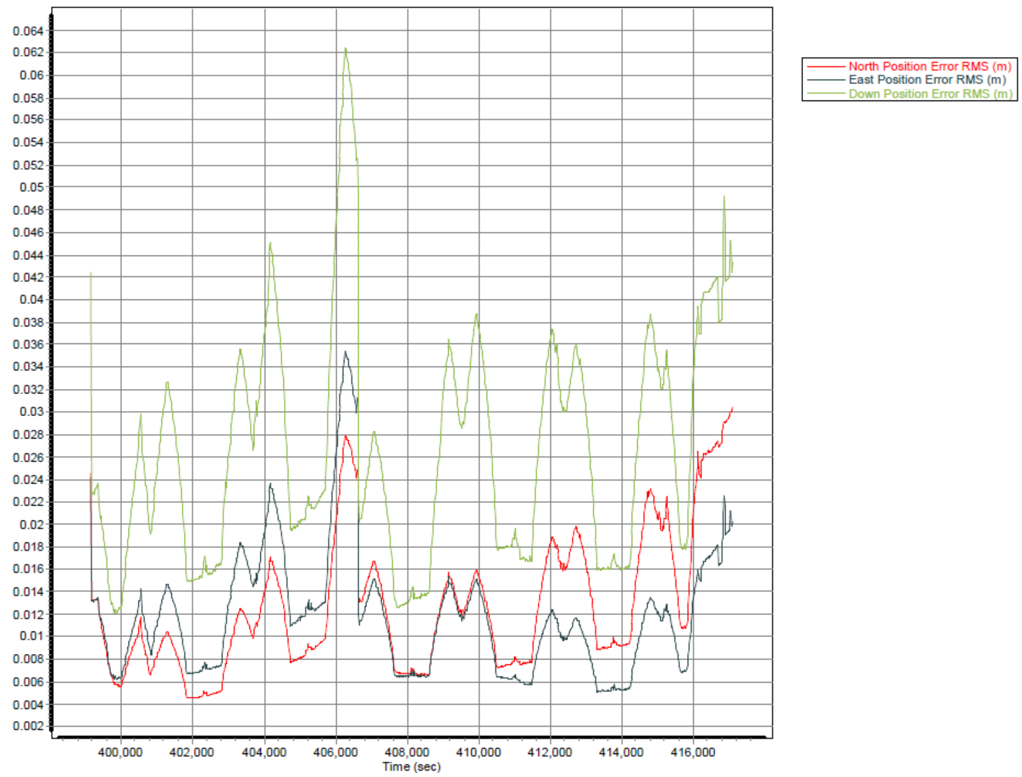

Project Settings
General Information
Units
View
Satellite Selection
GNSS-Inertial Processor
Timing, Multipath and Baseli
Initialization
Lever Arms and Mounting A
Export
Camera
LiDAR
SAR
Reference to IMU Lever Arm
X 0.034 m
Y 0.018 m
Z -0.155 m
Reference to IMU Mounting Angles
X 0.000 deg
Y 0.000 deg
Z 0.000 deg
Reference to Primary GNSS Lever Arm
X -0.094 m
Y -0.055 m
Z -1.020 m
Standard Deviation
<3cm 10cm 50cm 1m 10m
Aircraft to Reference Mounting Angles
X 0.000 deg
Y 0.000 deg
Z 0.000 deg
OK
Cancel

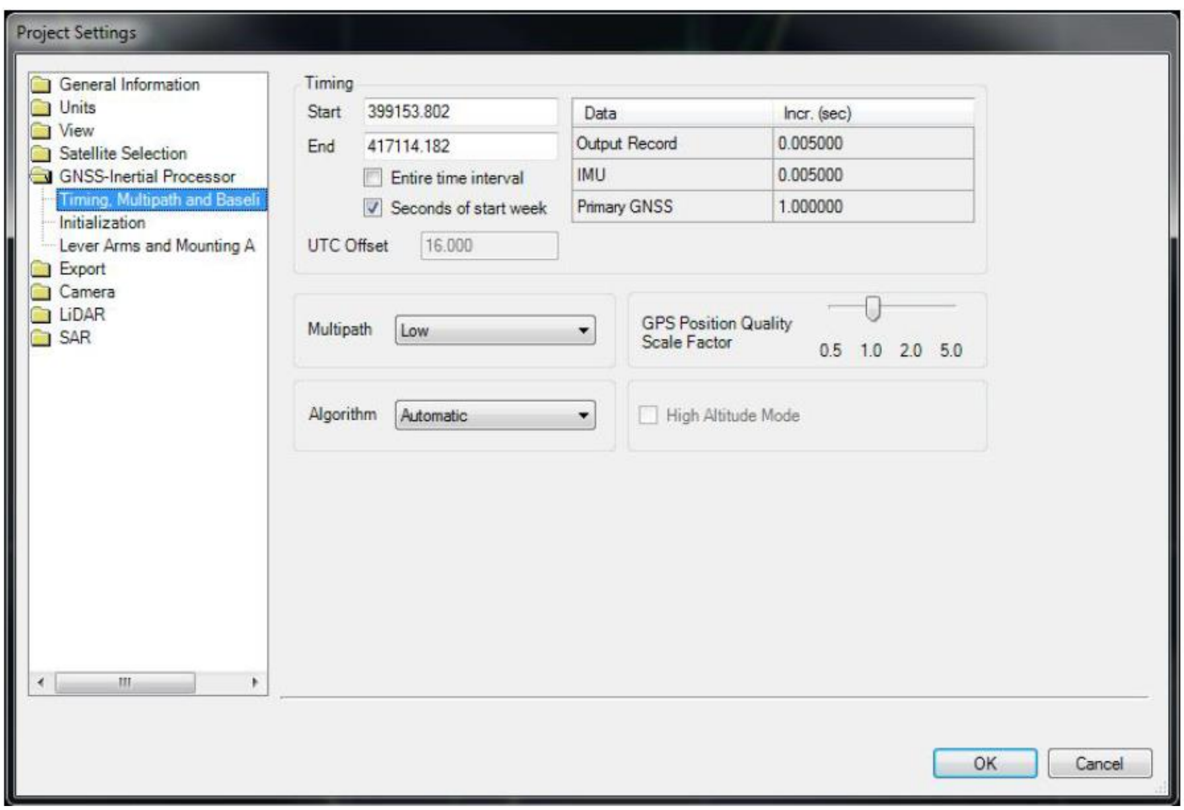

Number of GPS Satellites
9
8
7
6
400,000
402,000
404,000
406,000
408,000
410,000
412,000
414,000
416,000
Time (sec)

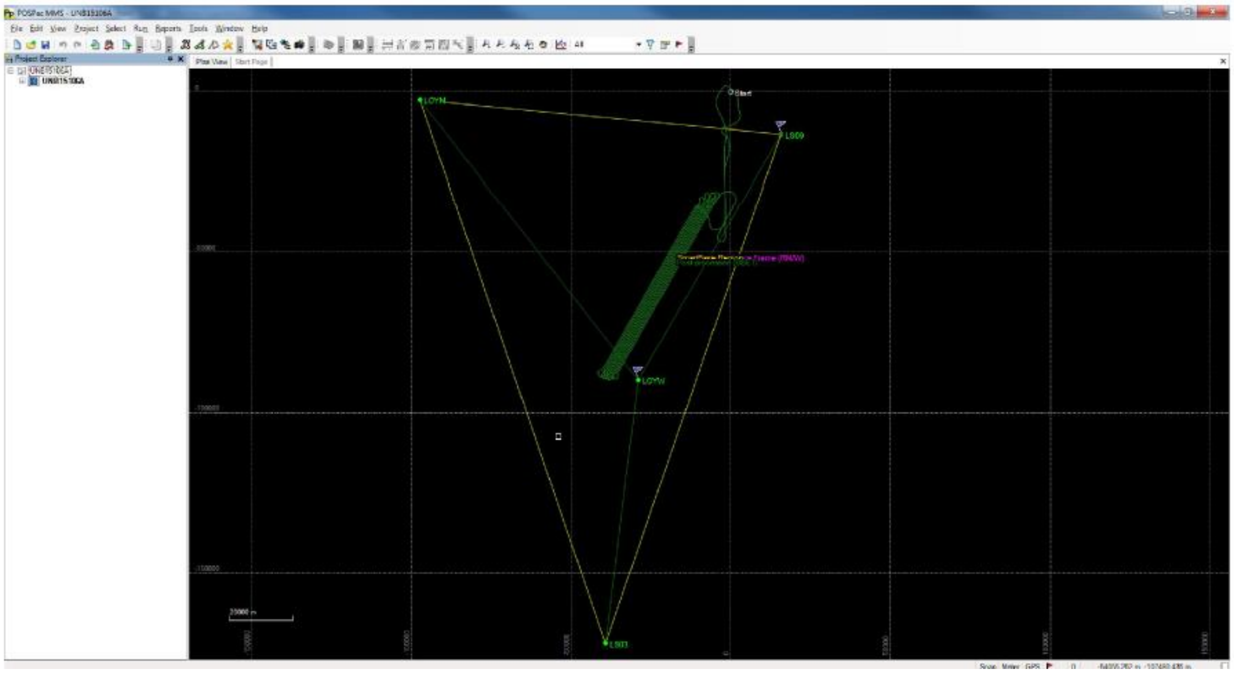

PDOP
2
400,000
402,000
404,000
406,000
408,000
410,000
412,000
414,000
416,000
Time (sec)


Processing mode
1
0
-1
400,000
402,000
404,000
406,000
408,000
410,000
412,000
414,000
416,000
Time (sec)
0 = Fixed NL, 1 = Fixed WL, 2 = Float, 3 = DGNSS, 4 = RTCM, 5 = IAPPP, 6 = C/A, 7 = GNSS Nav, 8 = DR


0.014
0.013
0.012
0.011
0.01
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
-0.001
-0.002
-0.003
-0.004
-0.005
-0.006
-0.007
-0.008
-0.009
-0.01
-0.011
-0.012
-0.013
-0.014
400,000
402,000
404,000
406,000
408,000
410,000
412,000
414,000
416,000
418,000
Time (sec)
North (m)
East (m)
Down (m)
DR mode


North Position Error RMS (m)
East Position Error RMS (m)
Down Position Error RMS (m)
0.064
0.062
0.06
0.058
0.056
0.054
0.052
0.05
0.048
0.046
0.044
0.042
0.04
0.038
0.036
0.034
0.032
0.03
0.028
0.026
0.024
0.022
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
400,000
402,000
404,000
406,000
408,000
410,000
412,000
414,000
416,000
Time (sec)


Project Settings
General Information
Units
View
Satellite Selection
GNSS-Inertial Processor
Timing, Multipath and Baseli
Initialization
Lever Arms and Mounting A
Export
Camera
LiDAR
SAR
Timing
Start
399153.802
End
417114.182
Entire time interval
Seconds of start week
UTC Offset
16.000
Data
Incr. (sec)
Output Record
0.005000
IMU
0.005000
Primary GNSS
1.000000
Multipath
Low
GPS Position Quality Scale Factor
0.5
1.0
2.0
5.0
Algorithm
Automatic
High Altitude Mode
OK
Cancel



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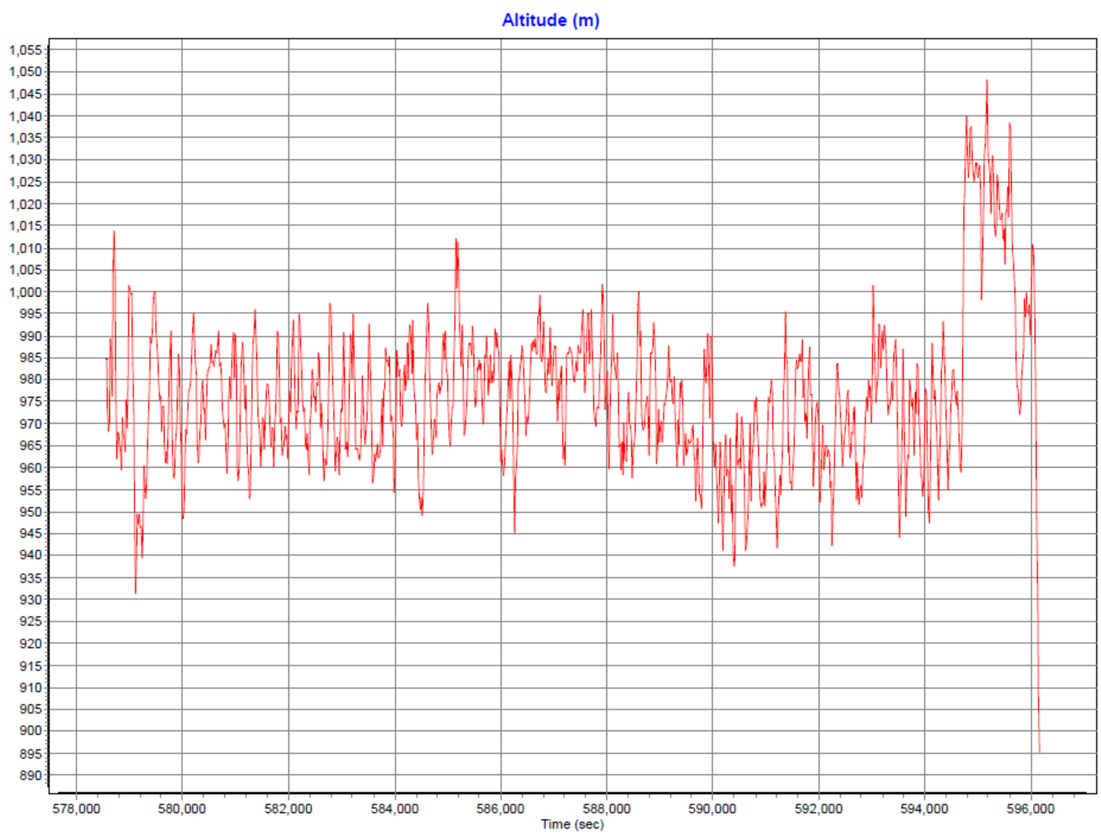
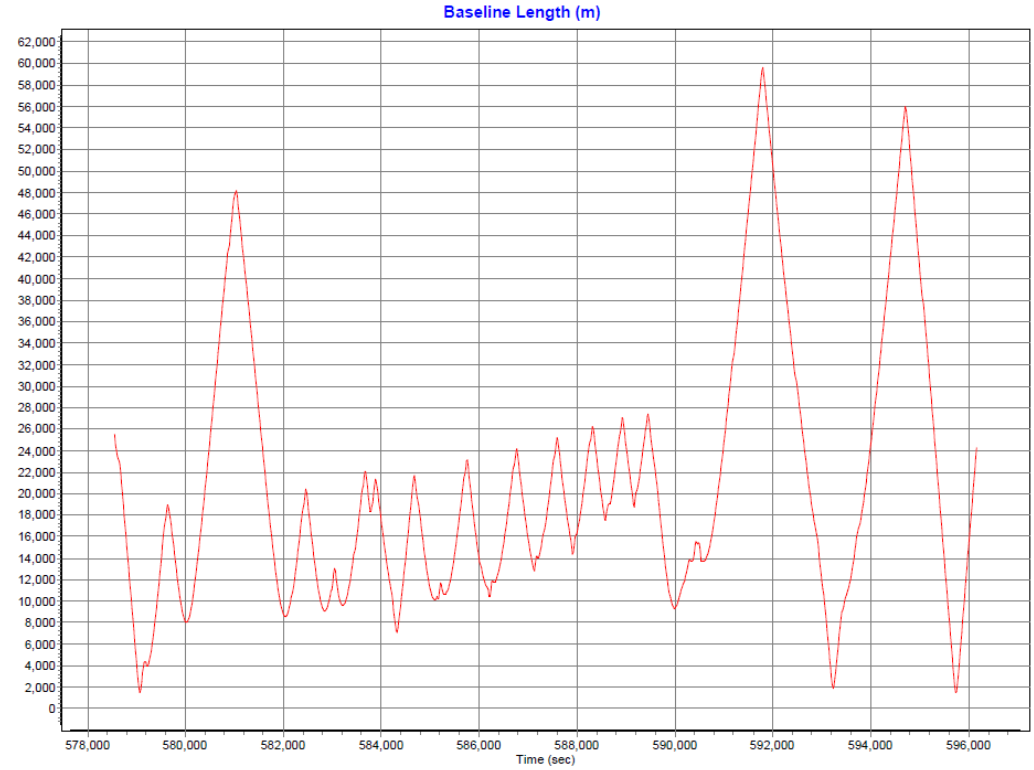
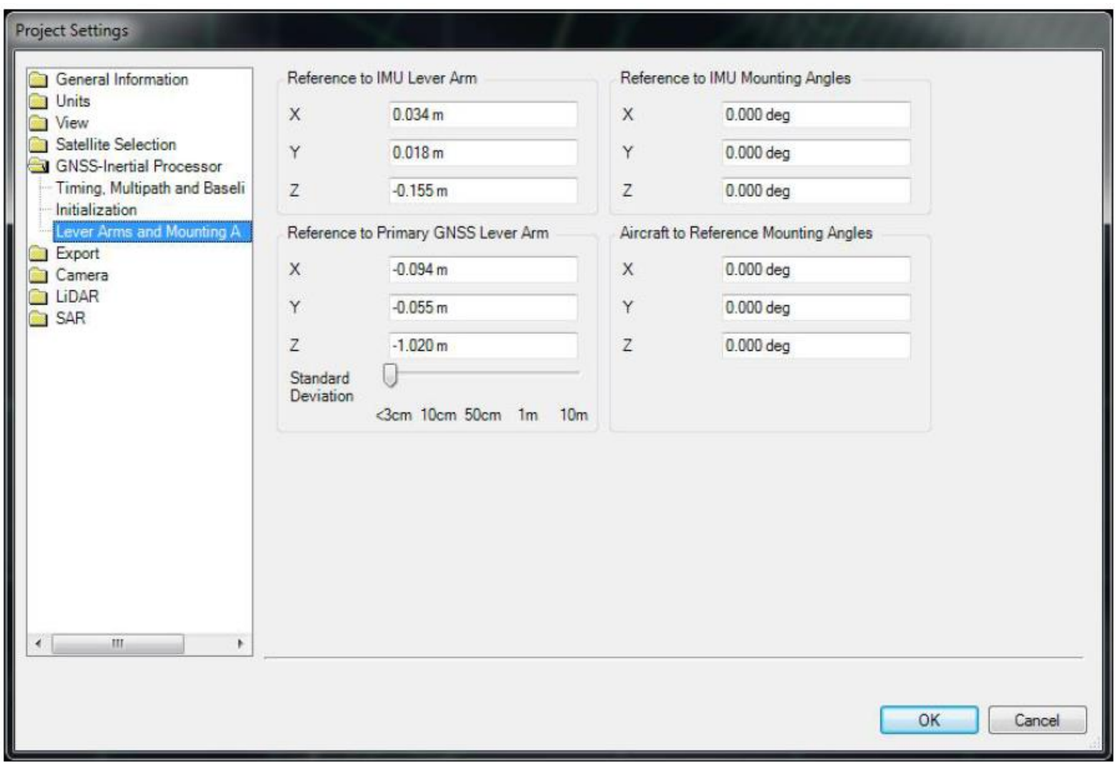
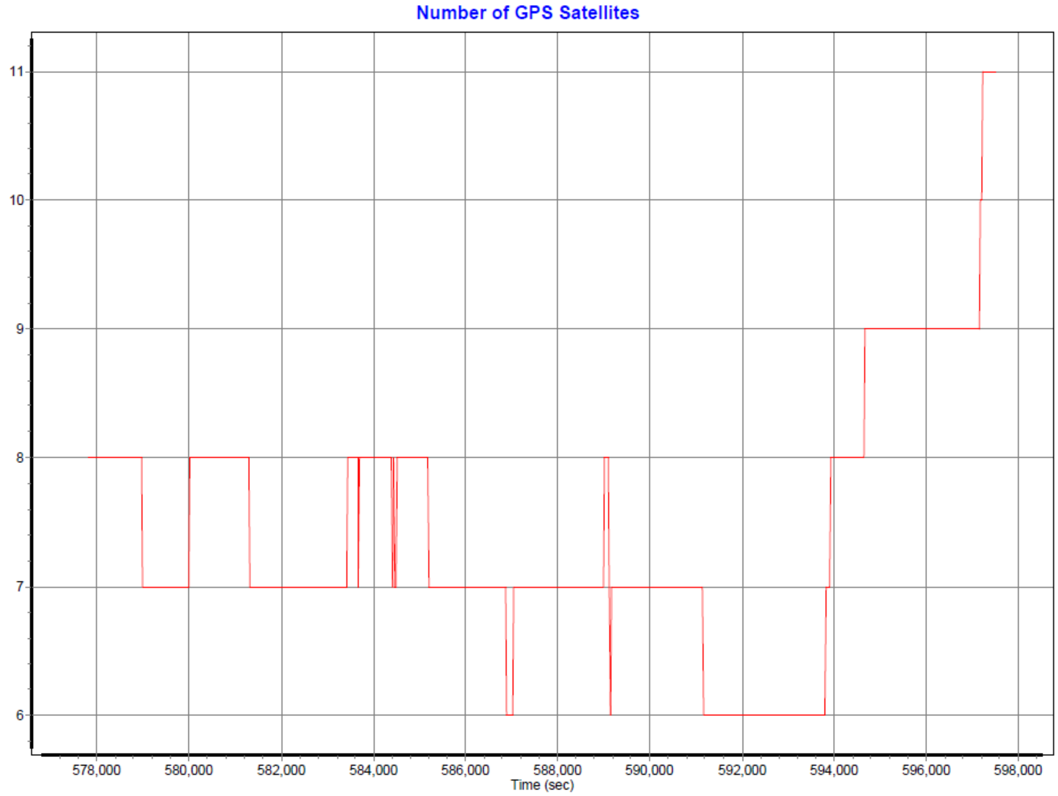
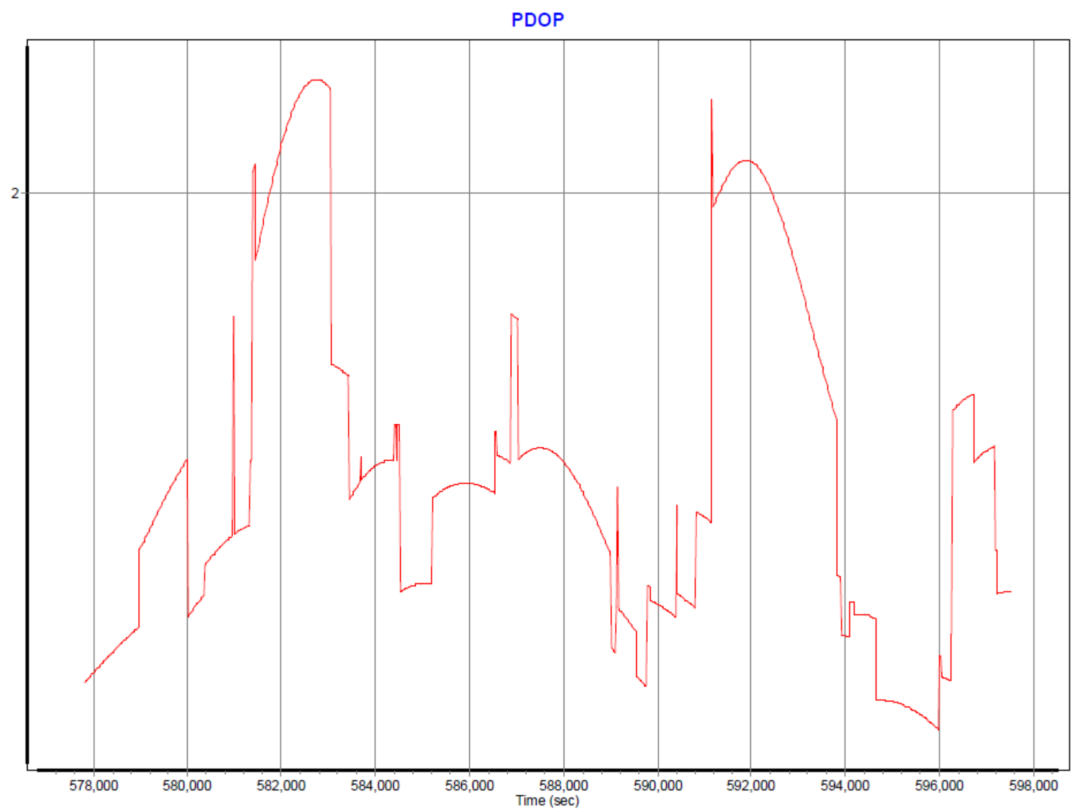
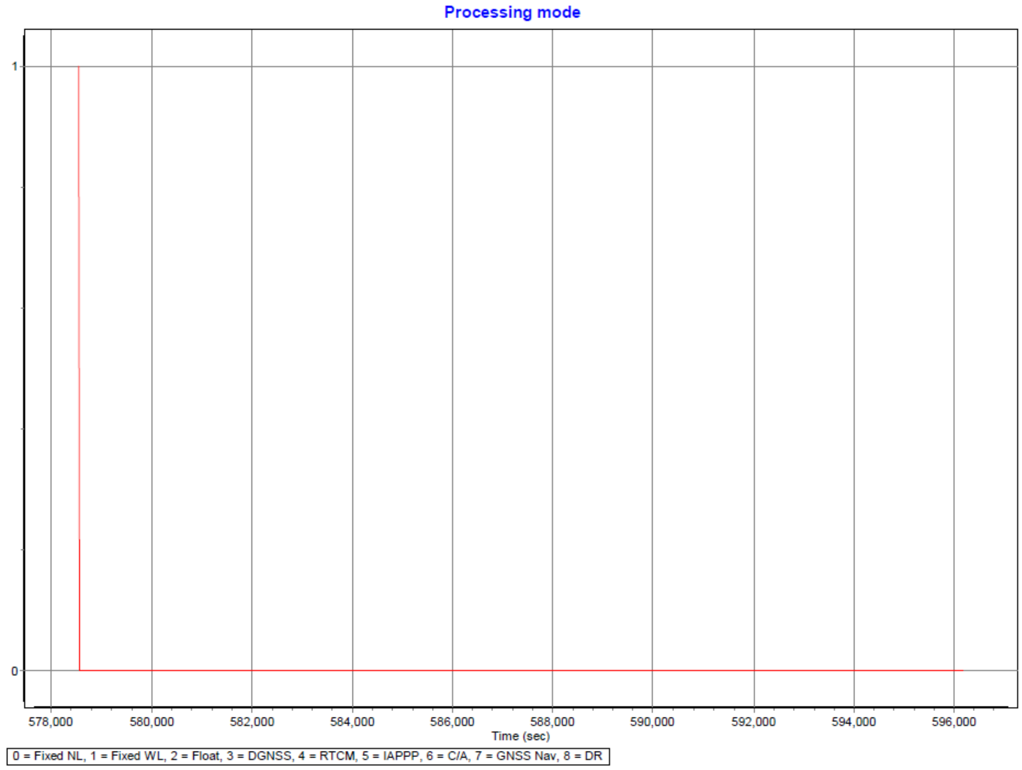

Altitude (m)
1,055
1,050
1,045
1,040
1,035
1,030
1,025
1,020
1,015
1,010
1,005
1,000
995
990
985
980
975
970
965
960
955
950
945
940
935
930
925
920
915
910
905
900
895
890
578,000
580,000
582,000
584,000
586,000
588,000
590,000
592,000
594,000
596,000
Time (sec)

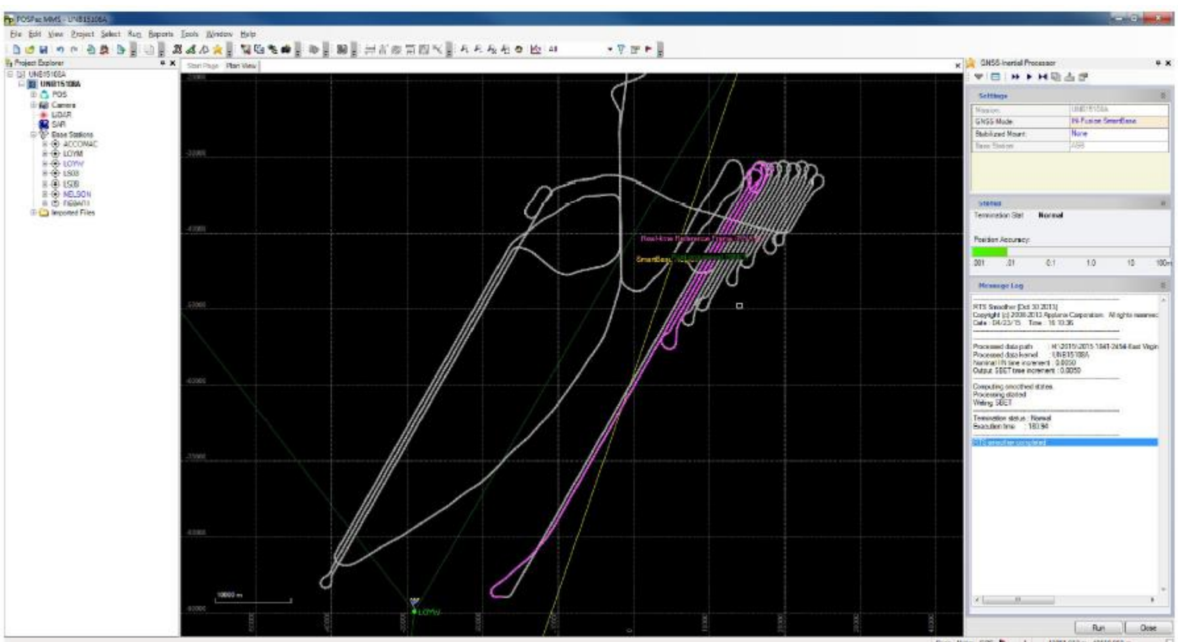

Baseline Length (m)
Time (sec)

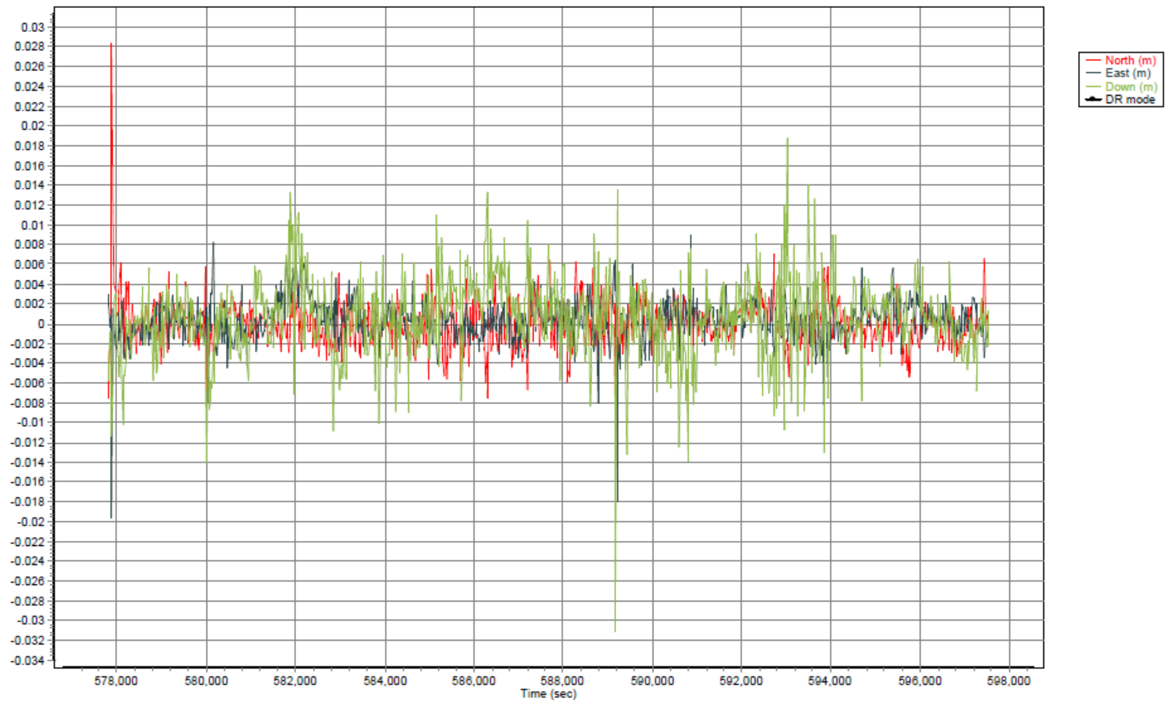

Project Settings
General Information
Units
View
Satellite Selection
GNSS-Inertial Processor
Timing, Multipath and Baseli
Initialization
Lever Arms and Mounting A
Export
Camera
LiDAR
SAR
Reference to IMU Lever Arm
X 0.034 m
Y 0.018 m
Z -0.155 m
Reference to IMU Mounting Angles
X 0.000 deg
Y 0.000 deg
Z 0.000 deg
Reference to Primary GNSS Lever Arm
X -0.094 m
Y -0.055 m
Z -1.020 m
Standard Deviation
<3cm 10cm 50cm 1m 10m
Aircraft to Reference Mounting Angles
X 0.000 deg
Y 0.000 deg
Z 0.000 deg
OK
Cancel

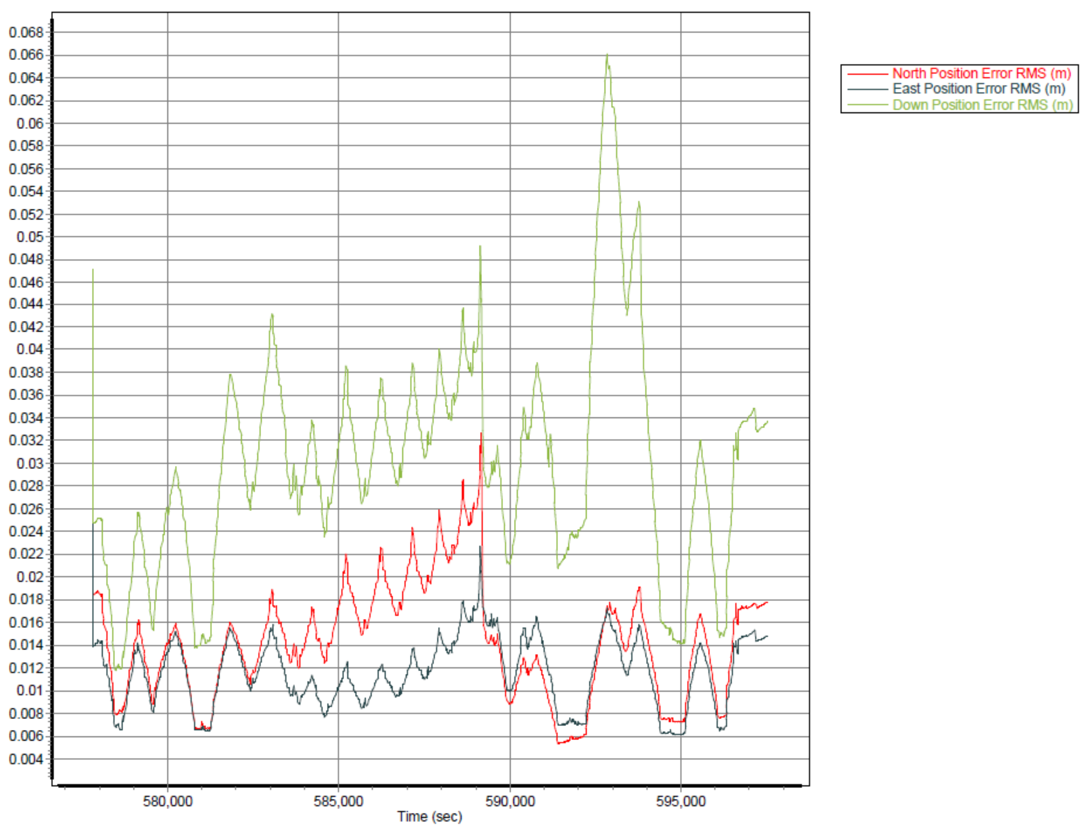

Number of GPS Satellites
11
10
9
8
7
6
578,000
580,000
582,000
584,000
586,000
588,000
590,000
592,000
594,000
596,000
598,000
Time (sec)

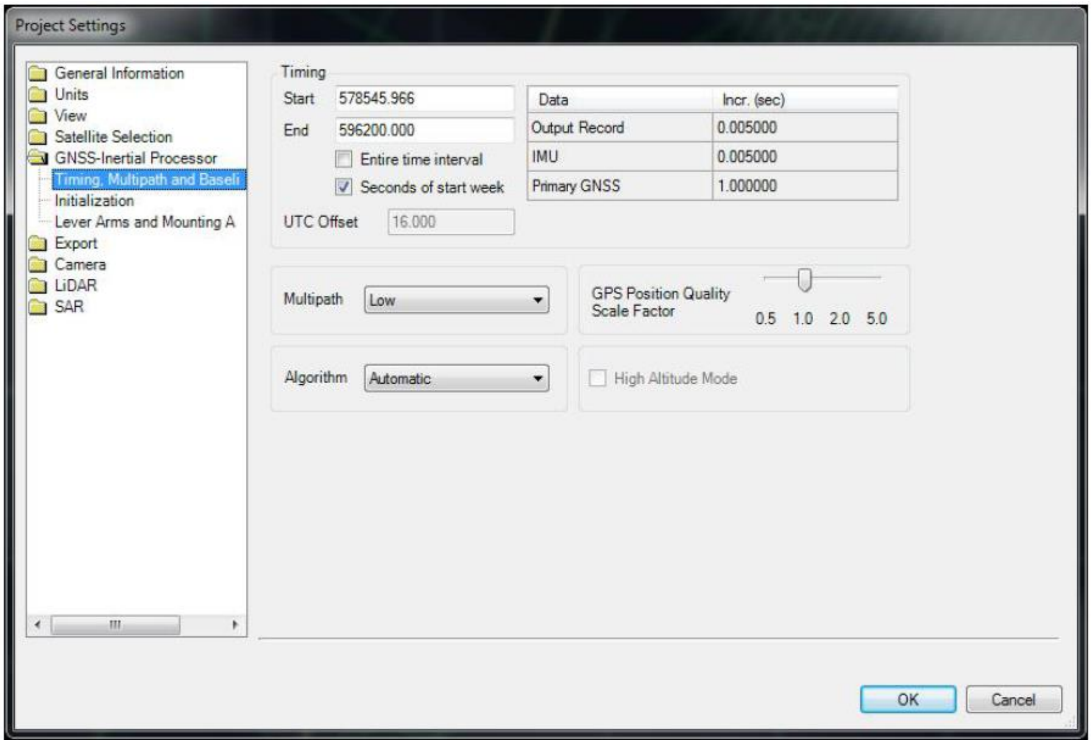

PDOP
2
578,000
580,000
582,000
584,000
586,000
588,000
590,000
592,000
594,000
596,000
598,000
Time (sec)

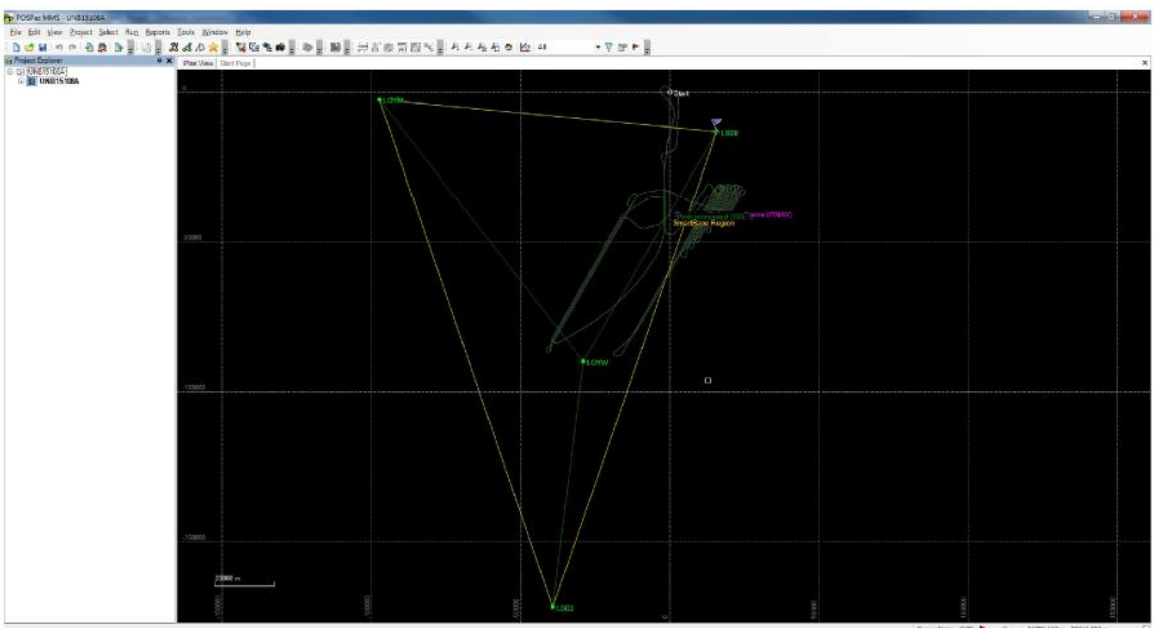

Processing mode
1
0
578,000
580,000
582,000
584,000
586,000
588,000
590,000
592,000
594,000
596,000
Time (sec)
0 = Fixed NL, 1 = Fixed WL, 2 = Float, 3 = DGNSS, 4 = RTCM, 5 = IAPPP, 6 = C/A, 7 = GNSS Nav, 8 = DR




North (m)
East (m)
Down (m)
DR mode
Time (sec)


North Position Error RMS (m)
East Position Error RMS (m)
Down Position Error RMS (m)
Time (sec)


Project Settings
General Information
Units
View
Satellite Selection
GNSS-Inertial Processor
Timing, Multipath and Baseli
Initialization
Lever Arms and Mounting A
Export
Camera
LiDAR
SAR
Timing
Start 578545.966
End 596200.000
Entire time interval
Seconds of start week
UTC Offset 16.000
Data
Incr. (sec)
Output Record 0.005000
IMU 0.005000
Primary GNSS 1.000000
Multipath Low
GPS Position Quality Scale Factor
0.5 1.0 2.0 5.0
Algorithm Automatic
High Altitude Mode
OK
Cancel


Start
SmartBase Region

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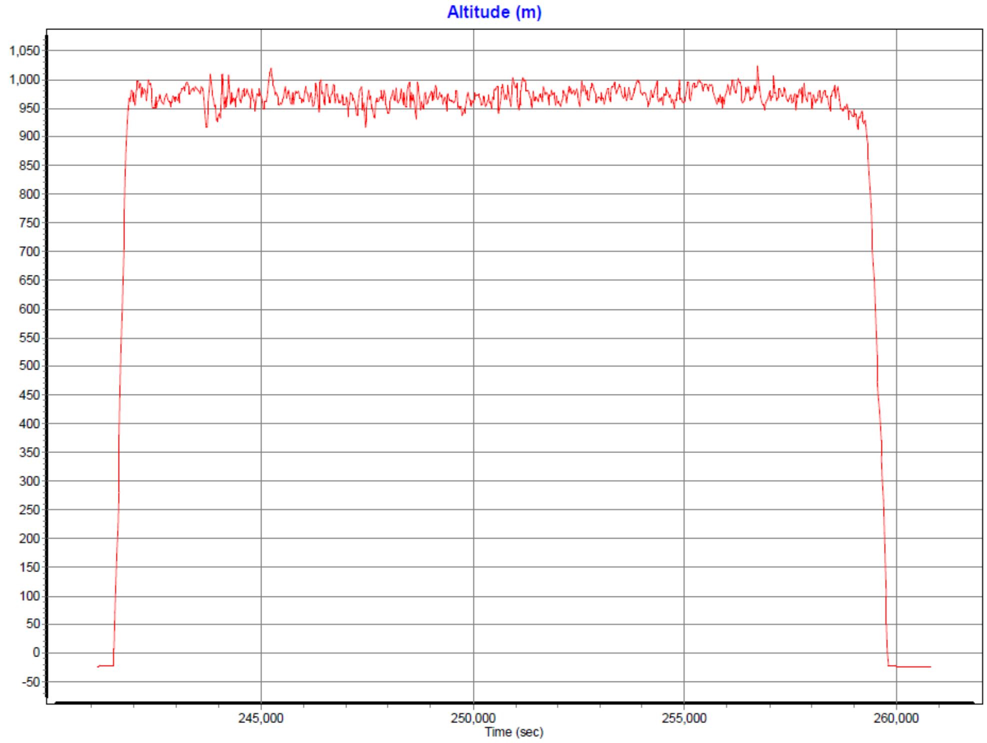
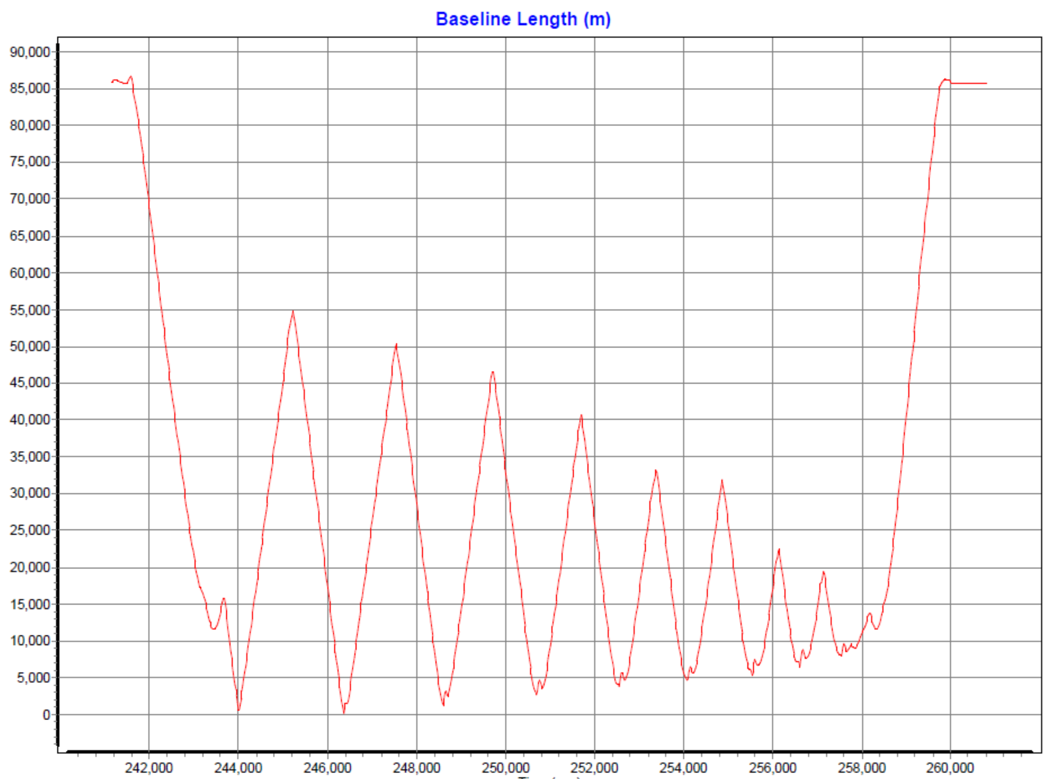
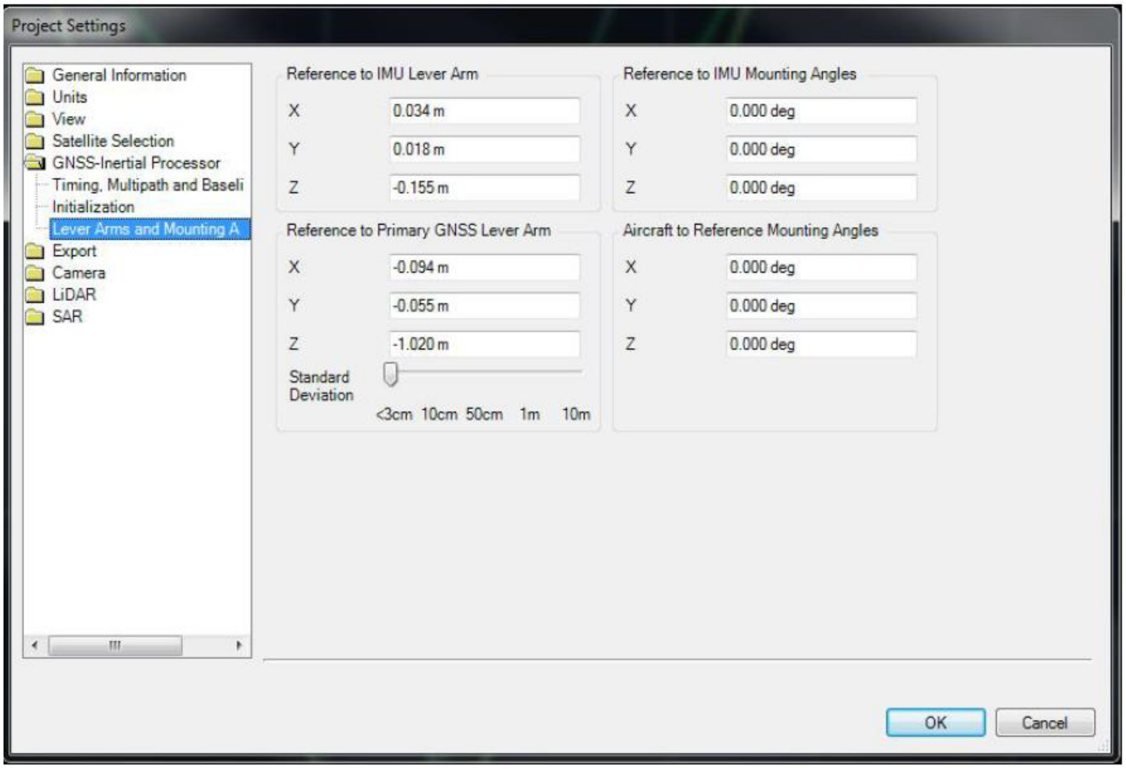
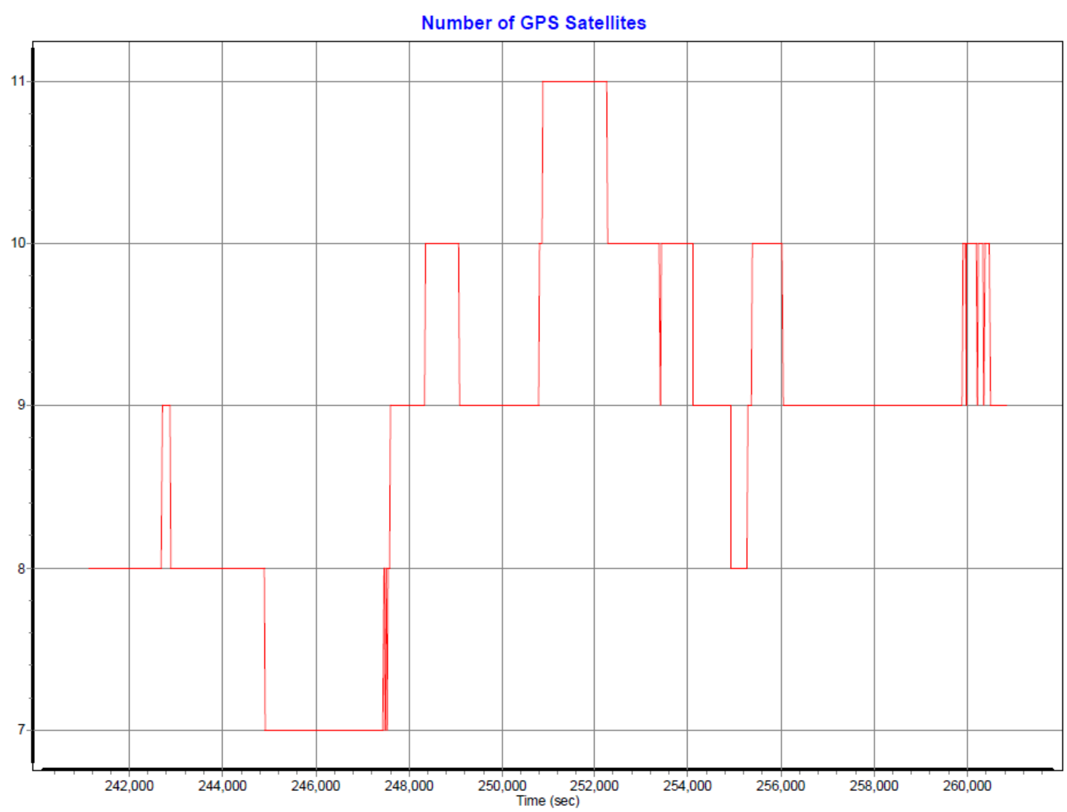
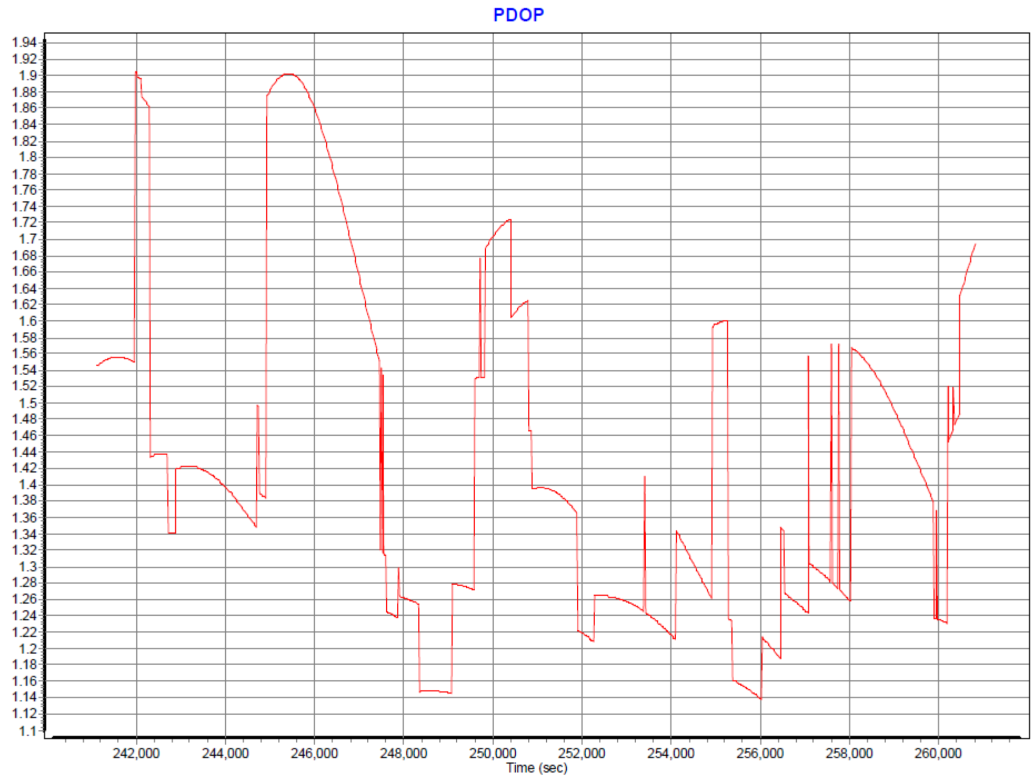
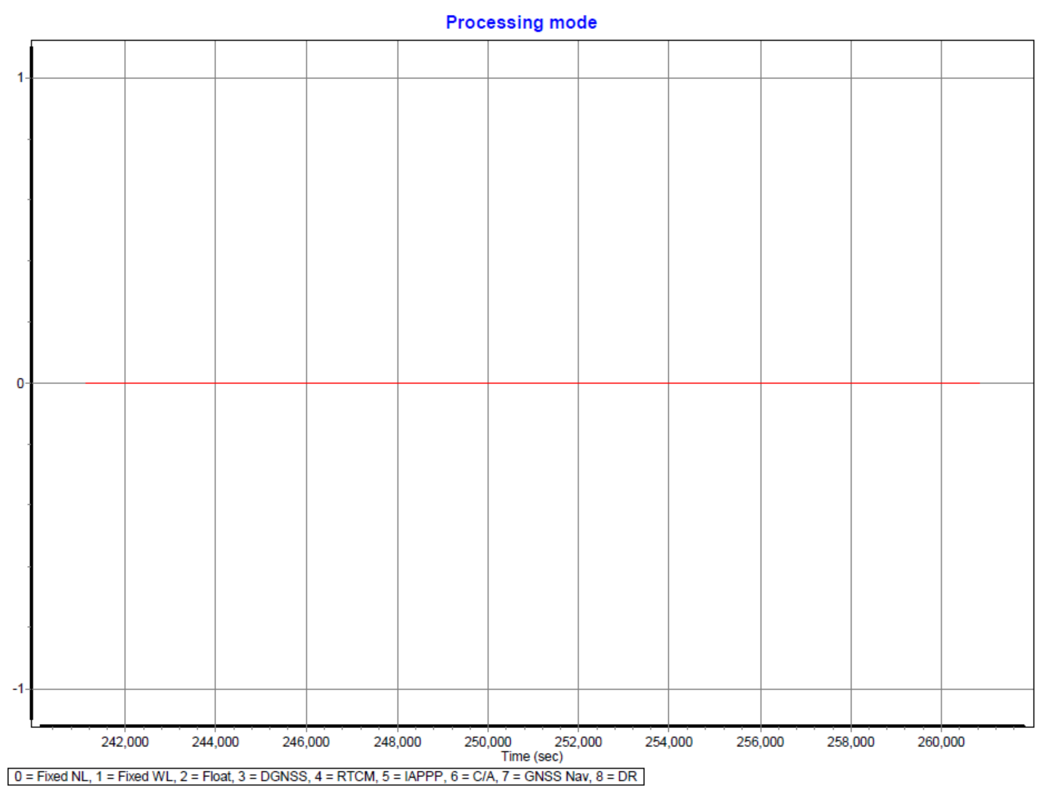

Altitude (m)
1,050
1,000
950
900
850
800
750
700
650
600
550
500
450
400
350
300
250
200
150
100
50
0
-50
245,000
250,000
255,000
260,000
Time (sec)

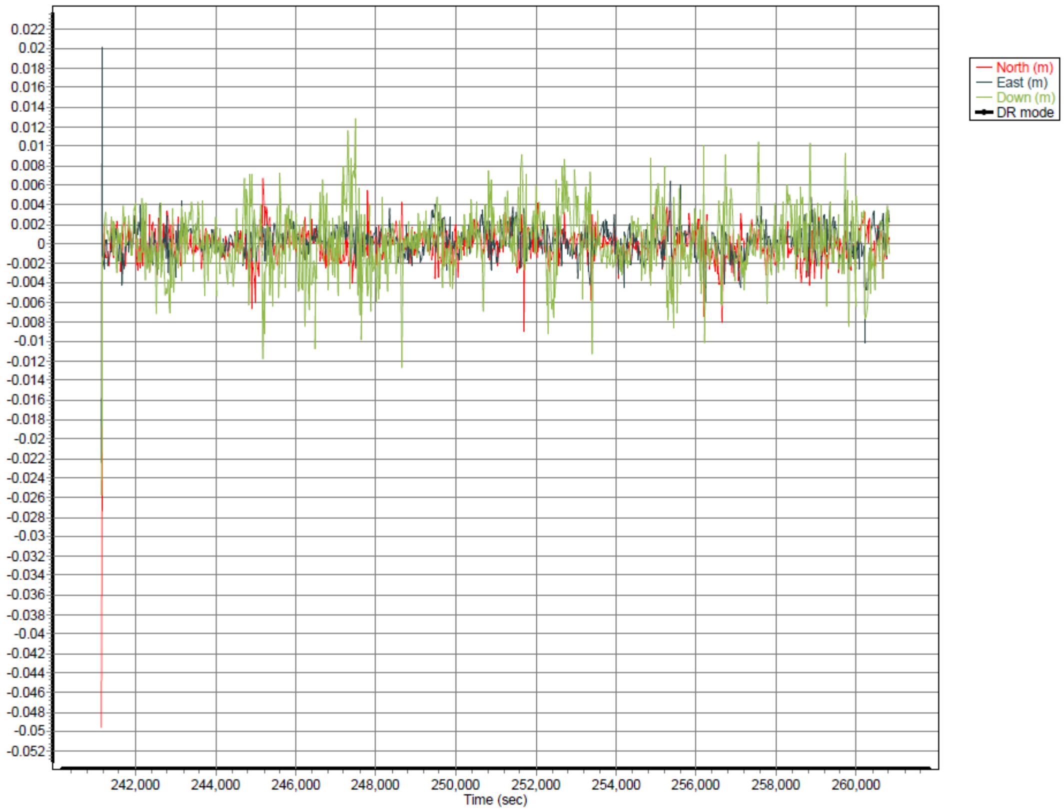

Baseline Length (m)
90,000
85,000
80,000
75,000
70,000
65,000
60,000
55,000
50,000
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
242,000
244,000
246,000
248,000
250,000
252,000
254,000
256,000
258,000
260,000
Time (sec)

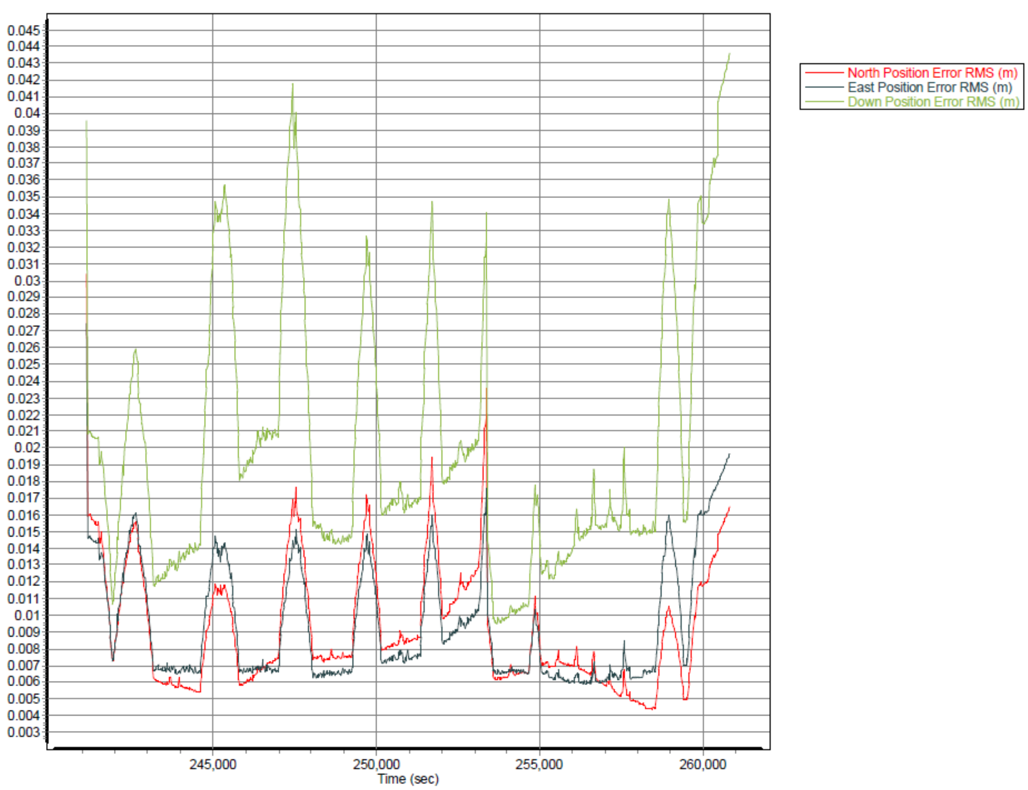

Project Settings
General Information
Units
View
Satellite Selection
GNSS-Inertial Processor
Timing, Multipath and Baseli
Initialization
Lever Arms and Mounting A
Export
Camera
LiDAR
SAR
Reference to IMU Lever Arm
X 0.034 m
Y 0.018 m
Z -0.155 m
Reference to IMU Mounting Angles
X 0.000 deg
Y 0.000 deg
Z 0.000 deg
Reference to Primary GNSS Lever Arm
X -0.094 m
Y -0.055 m
Z -1.020 m
Standard Deviation
<3cm 10cm 50cm 1m 10m
Aircraft to Reference Mounting Angles
X 0.000 deg
Y 0.000 deg
Z 0.000 deg
OK
Cancel

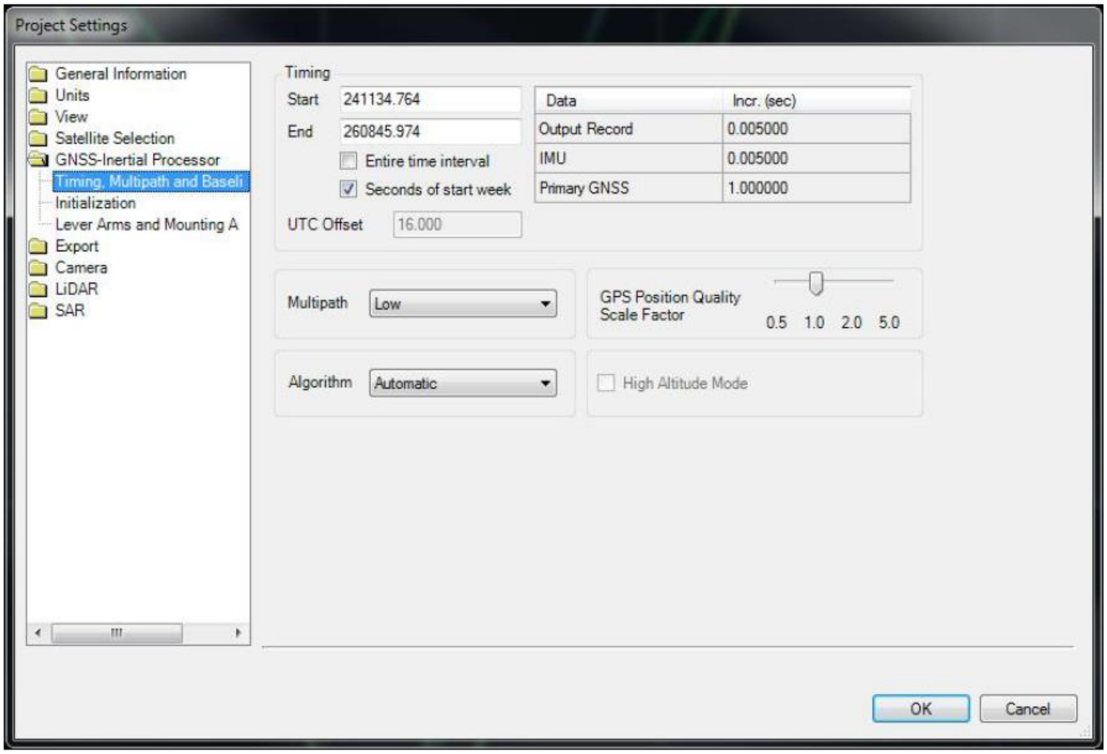

Number of GPS Satellites
11
10
9
8
7
242,000
244,000
246,000
248,000
250,000
252,000
254,000
256,000
258,000
260,000
Time (sec)

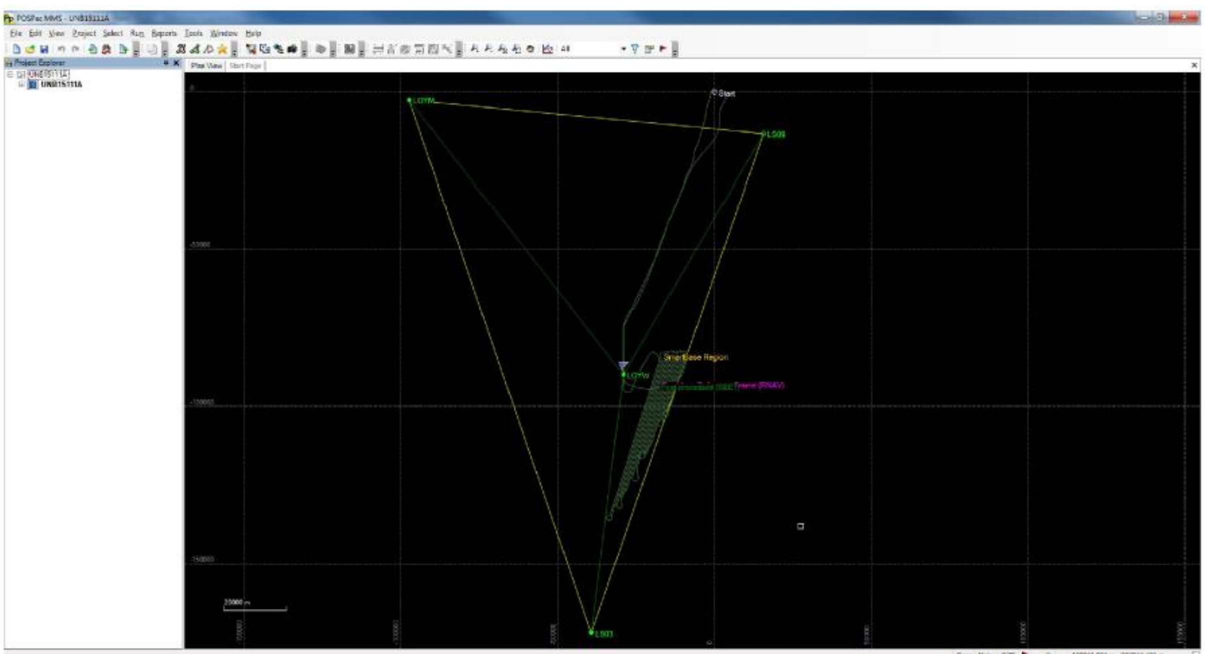

PDOP
Time (sec)


Processing mode
Time (sec)
0 = Fixed NL, 1 = Fixed WL, 2 = Float, 3 = DGNSS, 4 = RTCM, 5 = IAPPP, 6 = C/A, 7 = GNSS Nav, 8 = DR


North (m)
East (m)
Down (m)
DR mode
Time (sec)


North Position Error RMS (m)
East Position Error RMS (m)
Down Position Error RMS (m)
Time (sec)


Project Settings
General Information
Units
View
Satellite Selection
GNSS-Inertial Processor
Timing, Multipath and Baseli
Initialization
Lever Arms and Mounting A
Export
Camera
LiDAR
SAR
Timing
Start
241134.764
End
260845.974
Entire time interval
Seconds of start week
UTC Offset
16.000
Data
Incr. (sec)
Output Record
0.005000
IMU
0.005000
Primary GNSS
1.000000
Multipath
Low
GPS Position Quality Scale Factor
0.5 1.0 2.0 5.0
Algorithm
Automatic
High Altitude Mode
OK
Cancel



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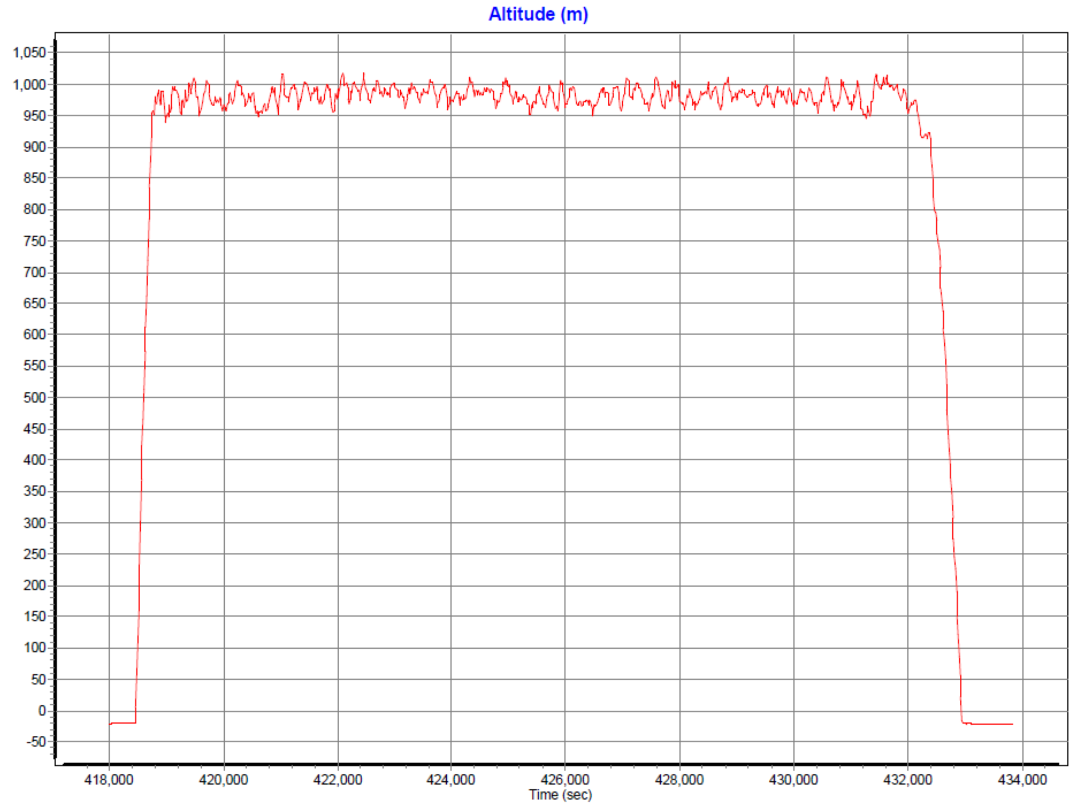
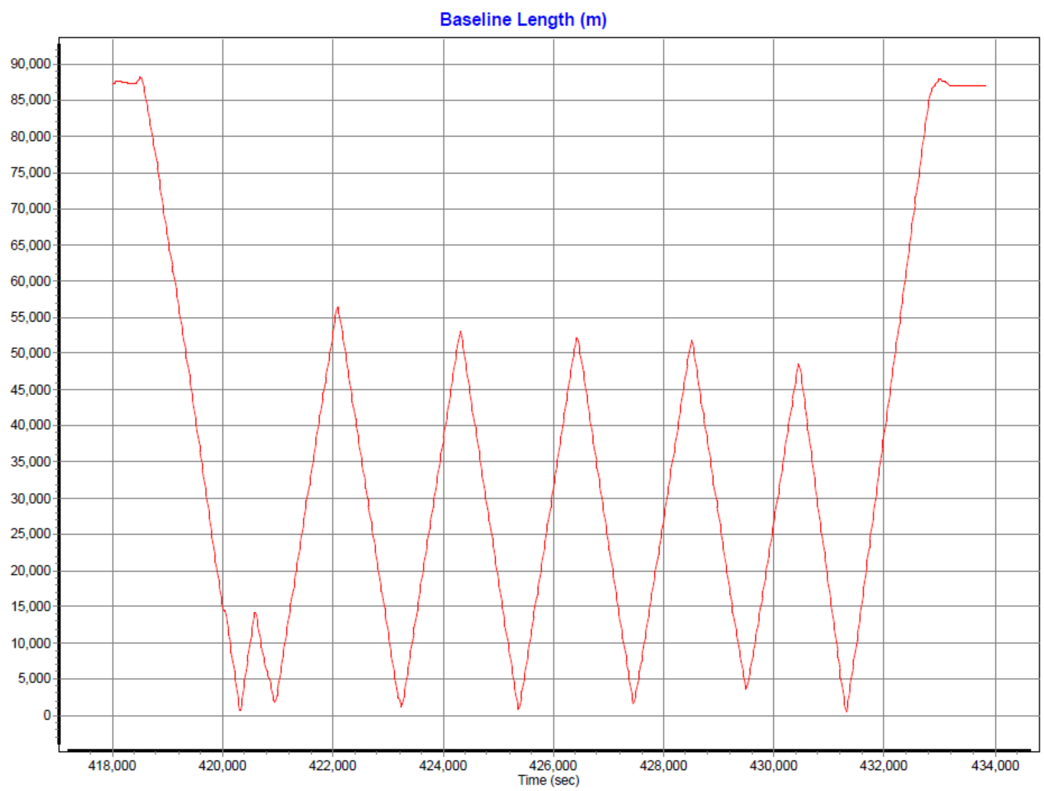
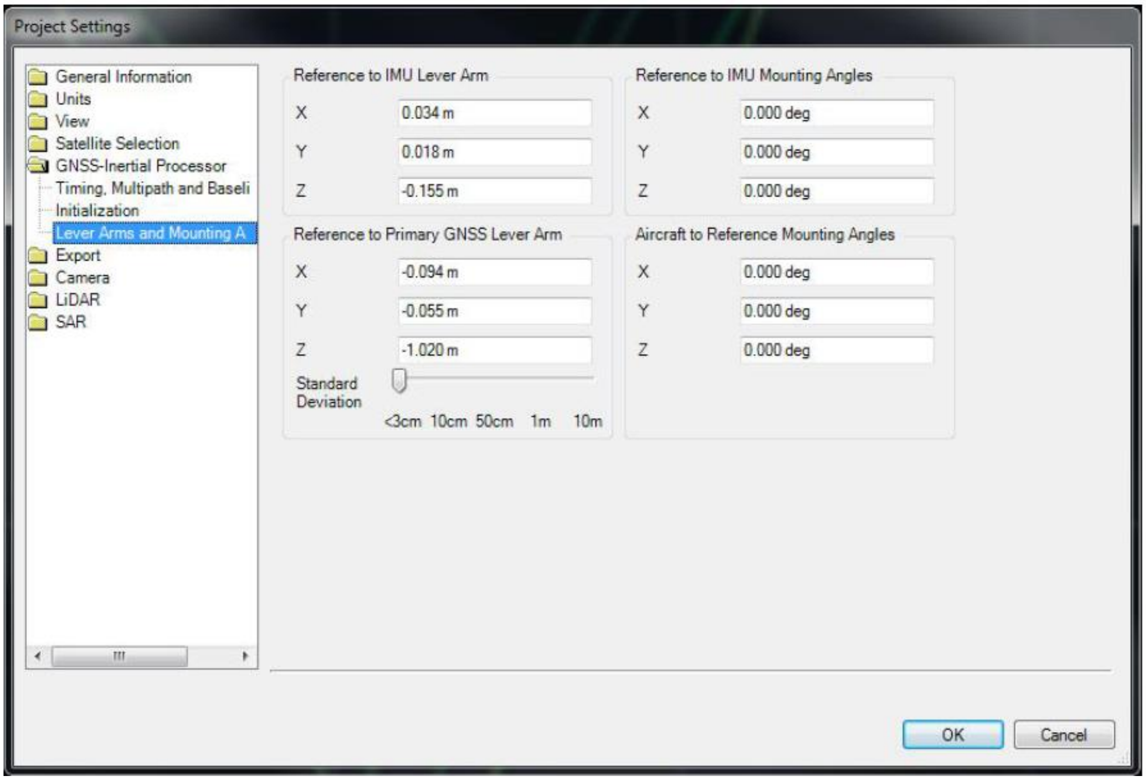
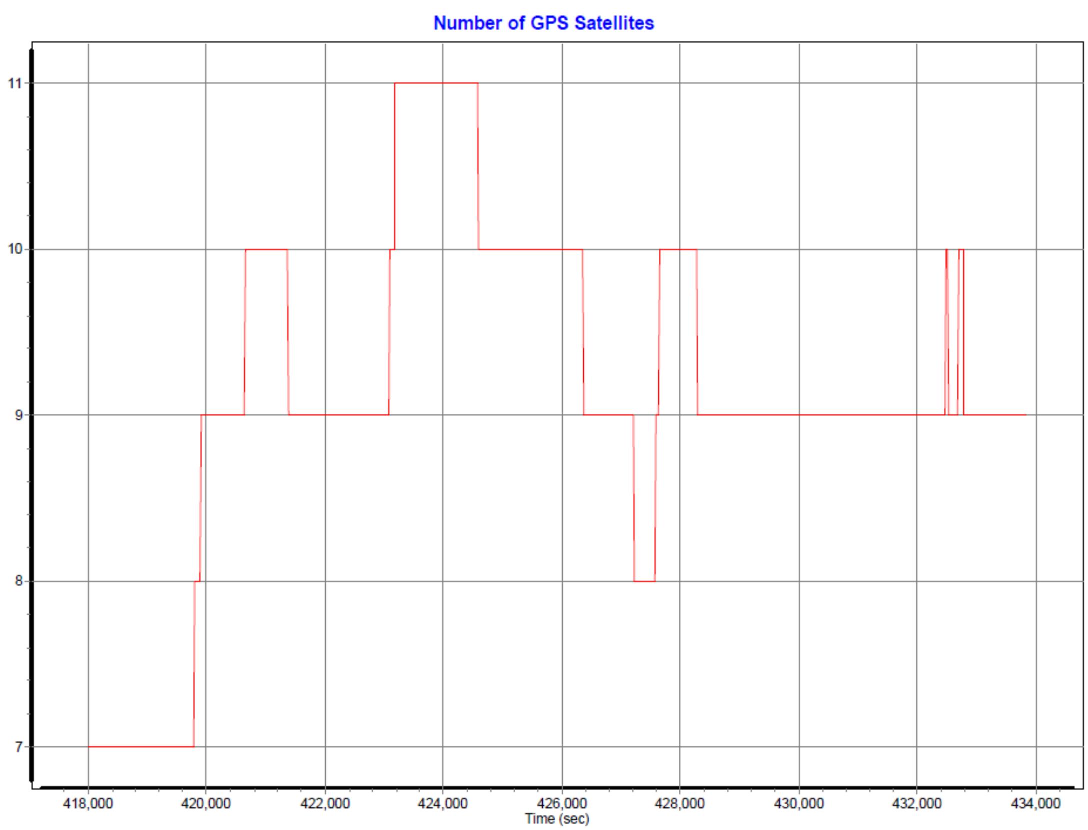
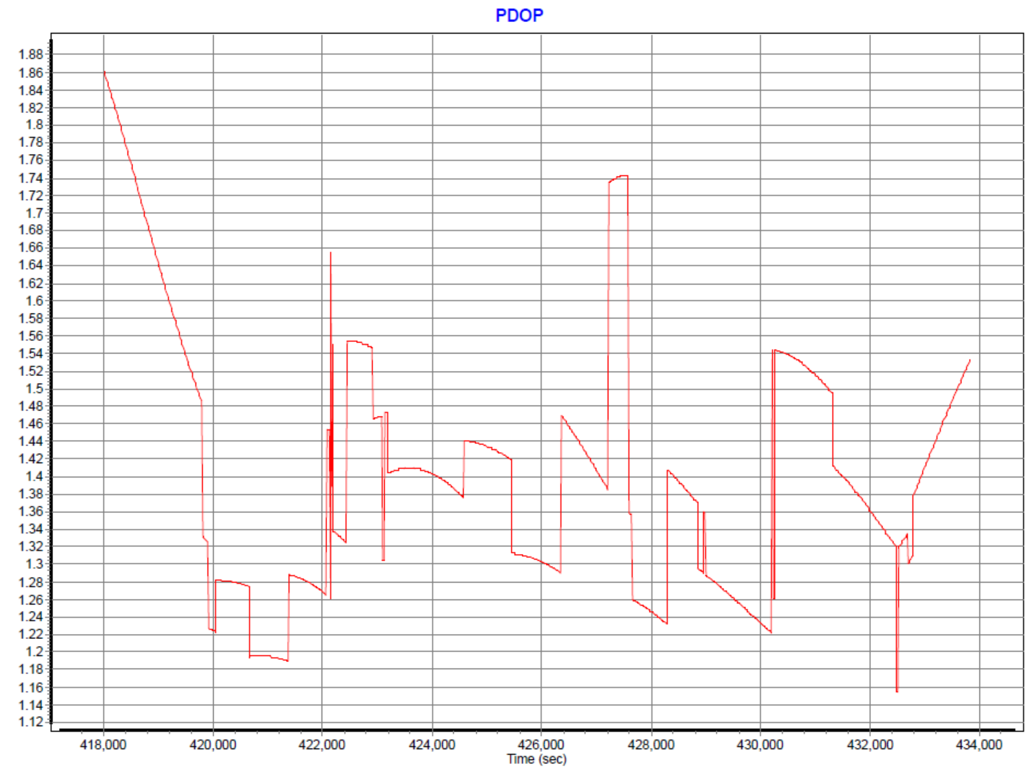
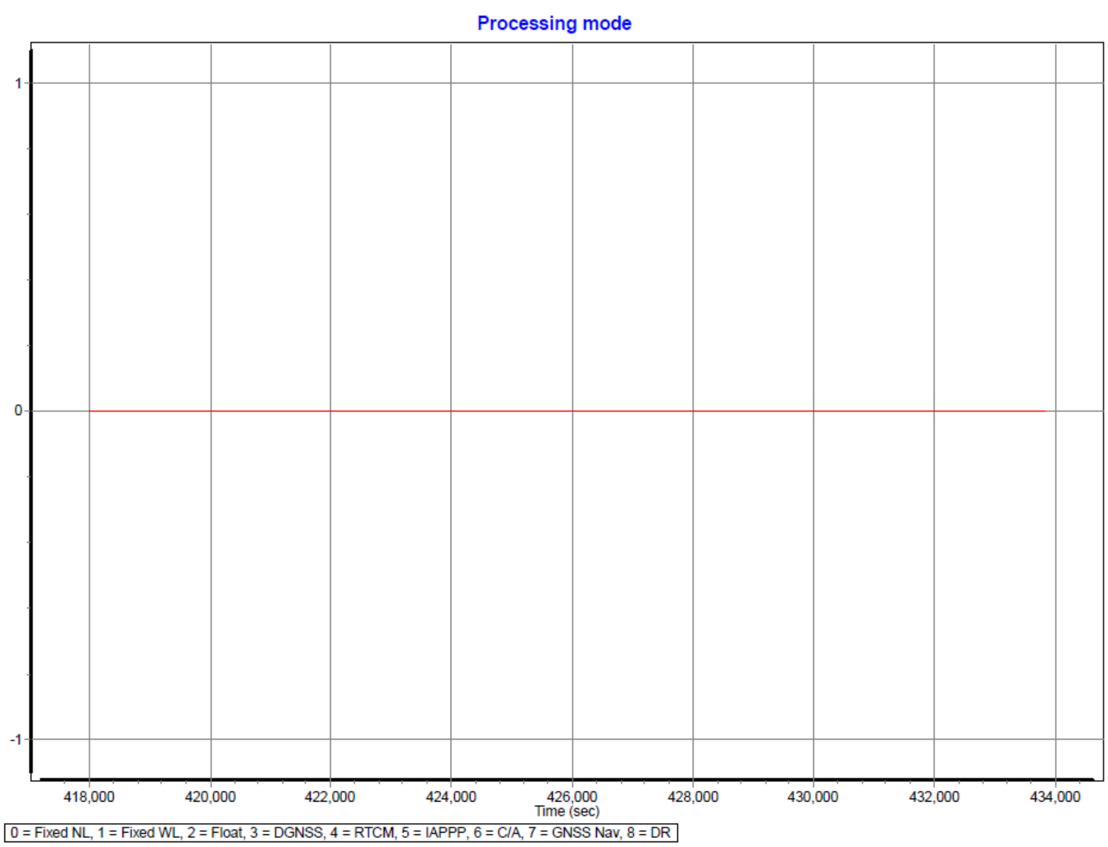

Altitude (m)
1,050
1,000
950
900
850
800
750
700
650
600
550
500
450
400
350
300
250
200
150
100
50
0
-50
418,000
420,000
422,000
424,000
426,000
428,000
430,000
432,000
434,000
Time (sec)

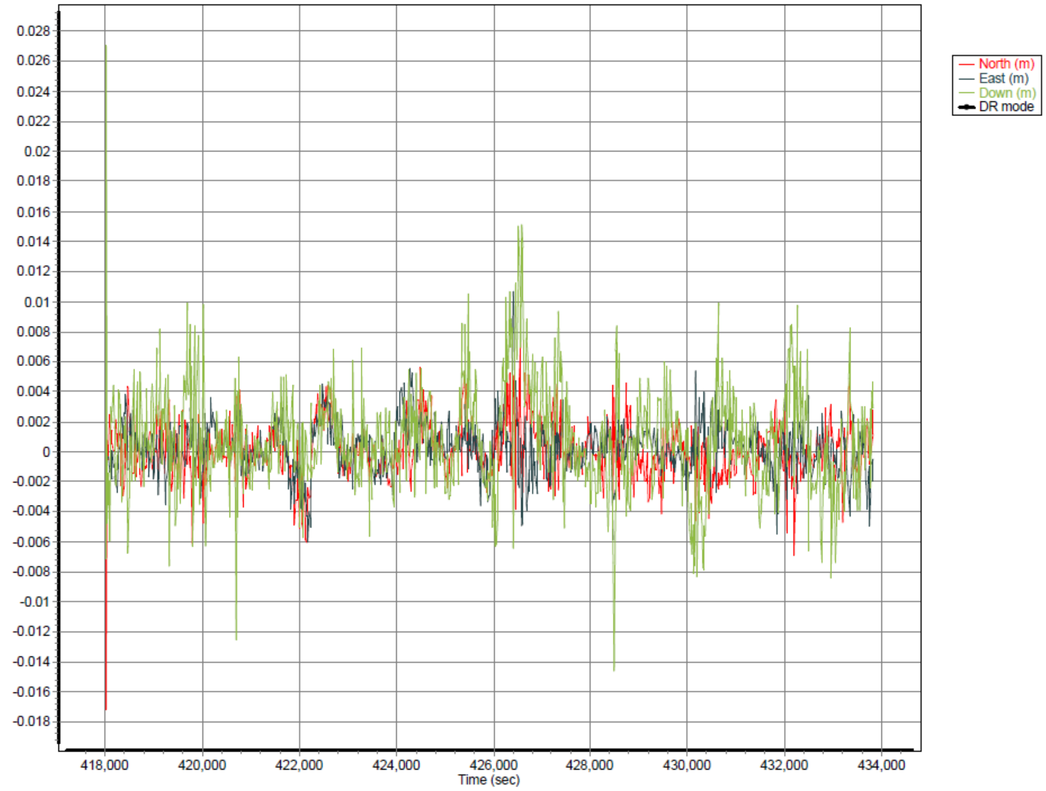

Baseline Length (m)
90,000
85,000
80,000
75,000
70,000
65,000
60,000
55,000
50,000
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
418,000
420,000
422,000
424,000
426,000
428,000
430,000
432,000
434,000
Time (sec)

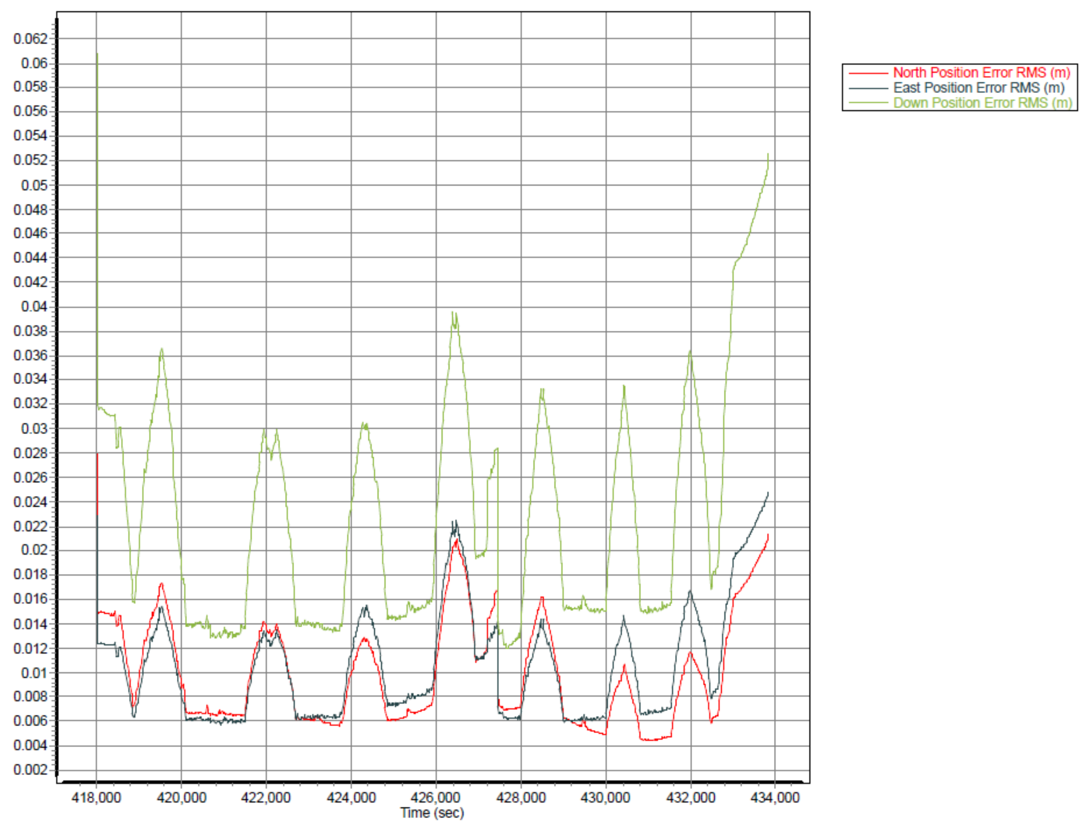

Project Settings
General Information
Units
View
Satellite Selection
GNSS-Inertial Processor
Timing, Multipath and Baseli
Initialization
Lever Arms and Mounting A
Export
Camera
LiDAR
SAR
Reference to IMU Lever Arm
X 0.034 m
Y 0.018 m
Z -0.155 m
Reference to IMU Mounting Angles
X 0.000 deg
Y 0.000 deg
Z 0.000 deg
Reference to Primary GNSS Lever Arm
X -0.094 m
Y -0.055 m
Z -1.020 m
Standard Deviation
<3cm 10cm 50cm 1m 10m
Aircraft to Reference Mounting Angles
X 0.000 deg
Y 0.000 deg
Z 0.000 deg
OK
Cancel

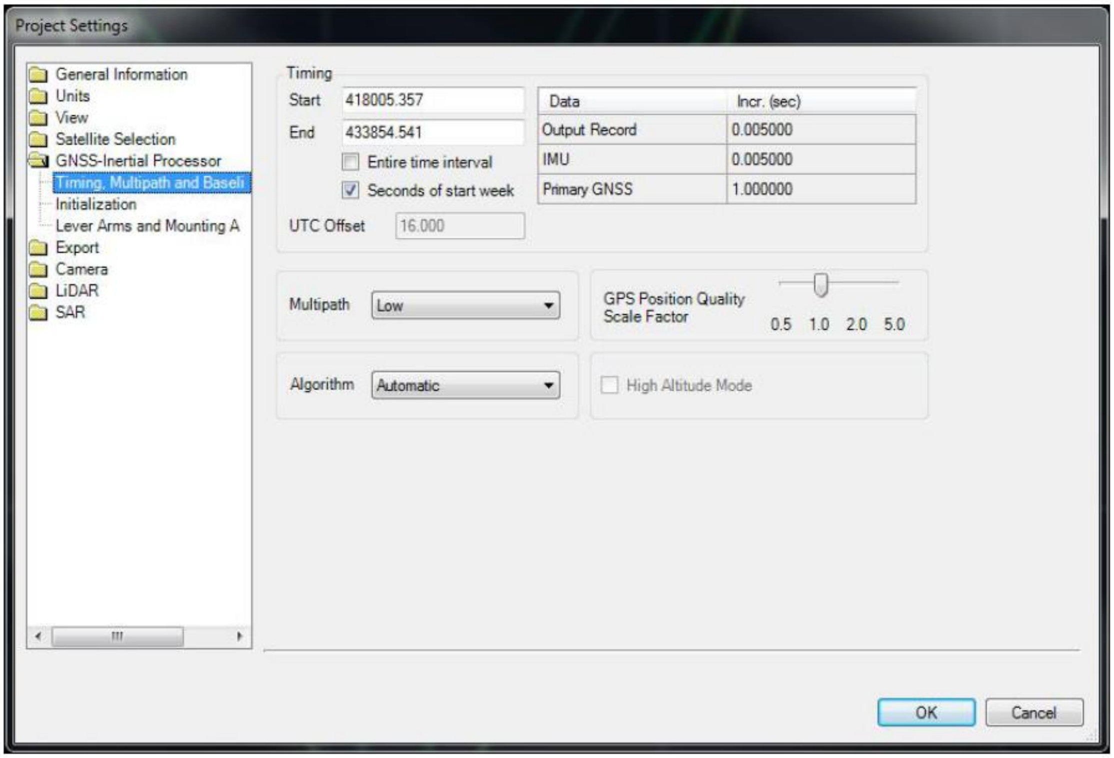

Number of GPS Satellites
11
10
9
8
7
418,000
420,000
422,000
424,000
426,000
428,000
430,000
432,000
434,000
Time (sec)

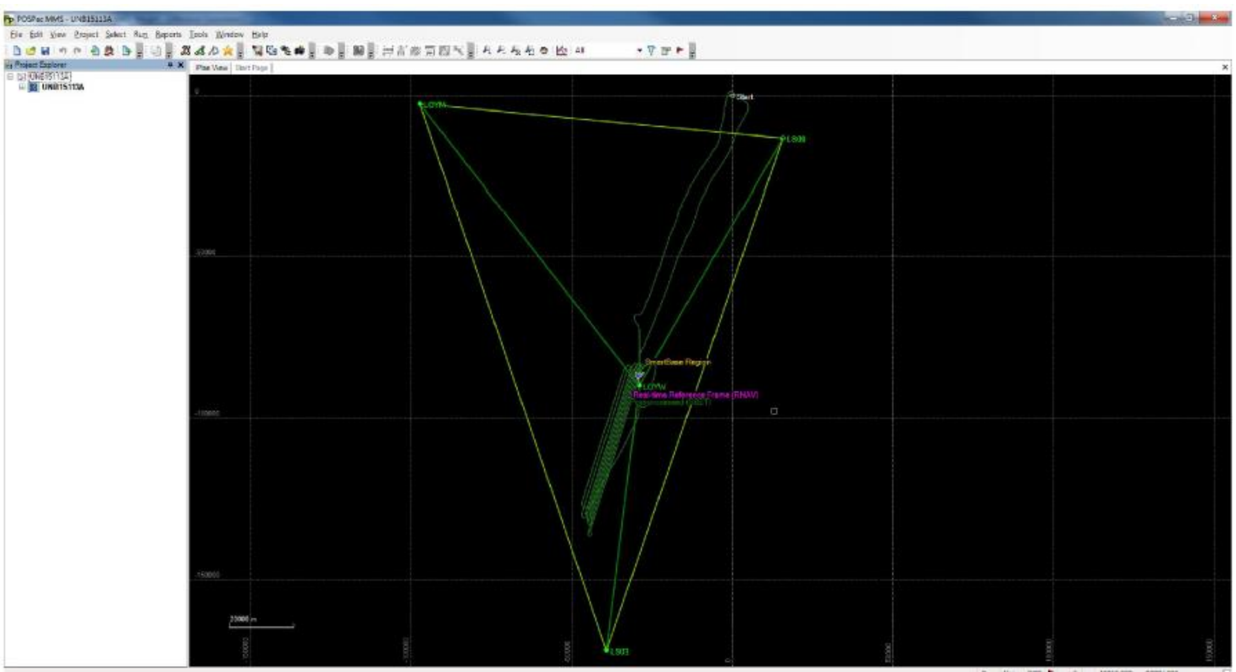

PDOP
1.88
1.86
1.84
1.82
1.8
1.78
1.76
1.74
1.72
1.7
1.68
1.66
1.64
1.62
1.6
1.58
1.56
1.54
1.52
1.5
1.48
1.46
1.44
1.42
1.4
1.38
1.36
1.34
1.32
1.3
1.28
1.26
1.24
1.22
1.2
1.18
1.16
1.14
1.12
418,000
420,000
422,000
424,000
426,000
428,000
430,000
432,000
434,000
Time (sec)


Processing mode
1
0
-1
418,000
420,000
422,000
424,000
426,000
428,000
430,000
432,000
434,000
Time (sec)
0 = Fixed NL, 1 = Fixed WL, 2 = Float, 3 = DGNSS, 4 = RTCM, 5 = IAPPP, 6 = C/A, 7 = GNSS Nav, 8 = DR

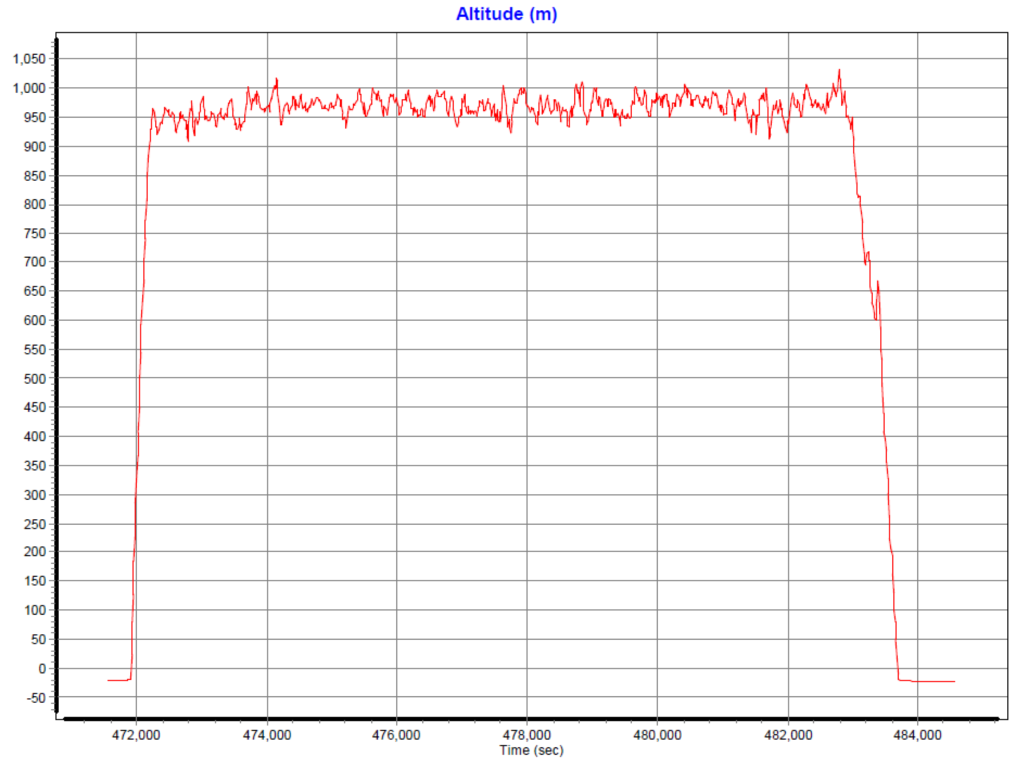

North (m)
East (m)
Down (m)
DR mode
Time (sec)

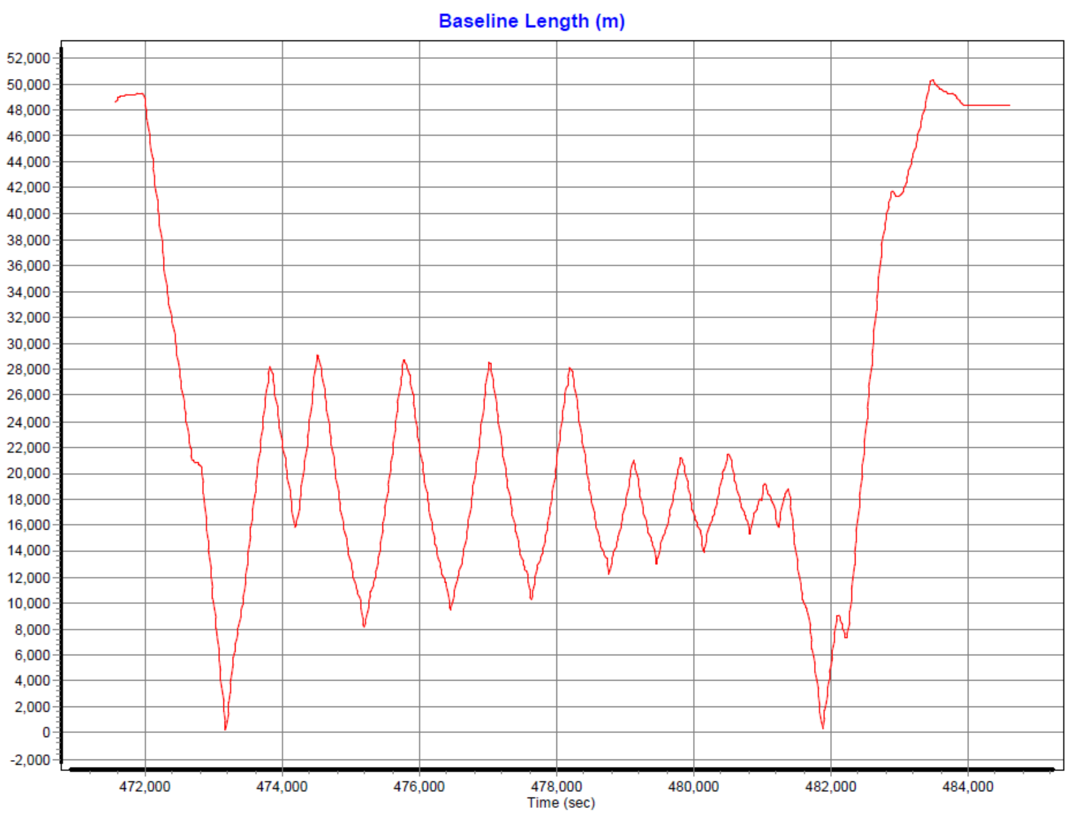

North Position Error RMS (m)
East Position Error RMS (m)
Down Position Error RMS (m)
Time (sec)

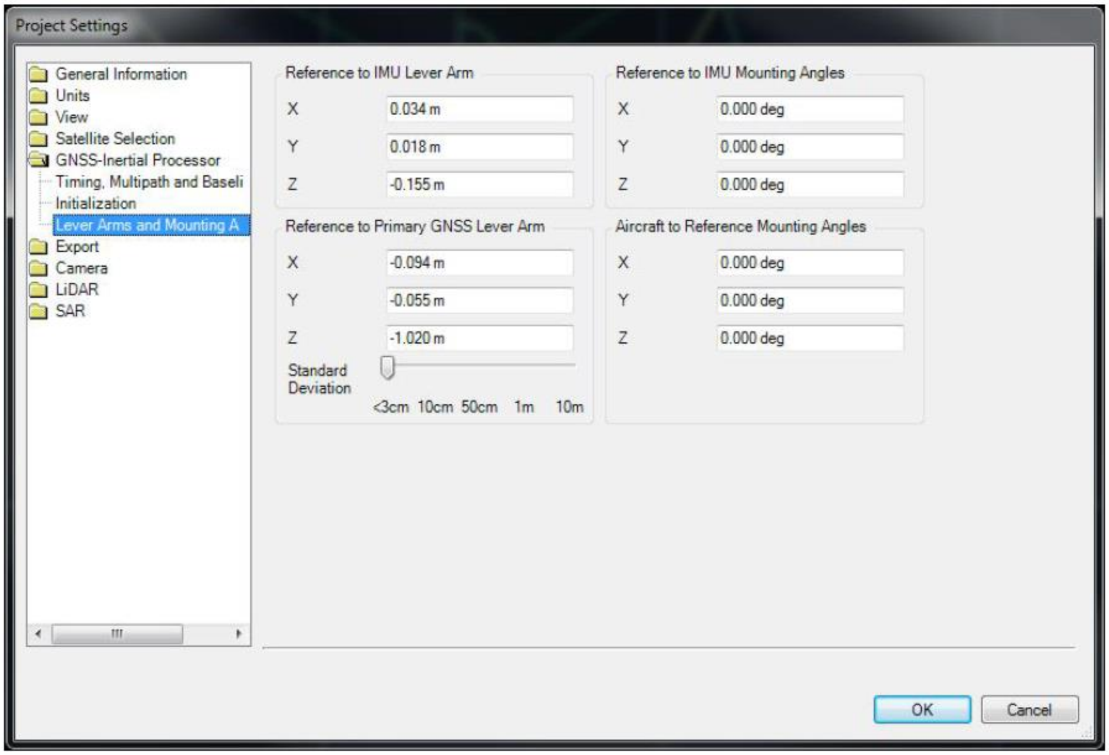

Project Settings
General Information
Units
View
Satellite Selection
GNSS-Inertial Processor
Timing, Multipath and Baseli
Initialization
Lever Arms and Mounting A
Export
Camera
LiDAR
SAR
Timing
Start
418005.357
End
433854.541
Entire time interval
Seconds of start week
UTC Offset
16.000
Data
Incr. (sec)
Output Record
0.005000
IMU
0.005000
Primary GNSS
1.000000
Multipath
Low
GPS Position Quality Scale Factor
0.5 1.0 2.0 5.0
Algorithm
Automatic
High Altitude Mode
OK
Cancel

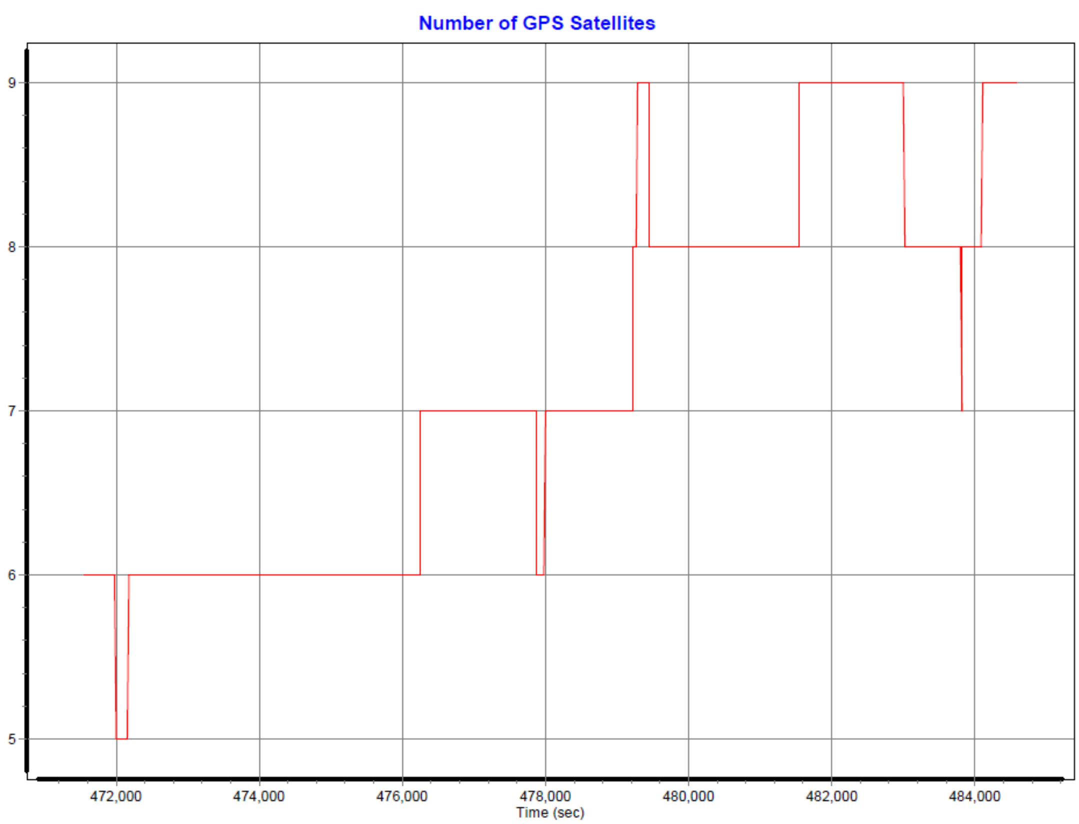


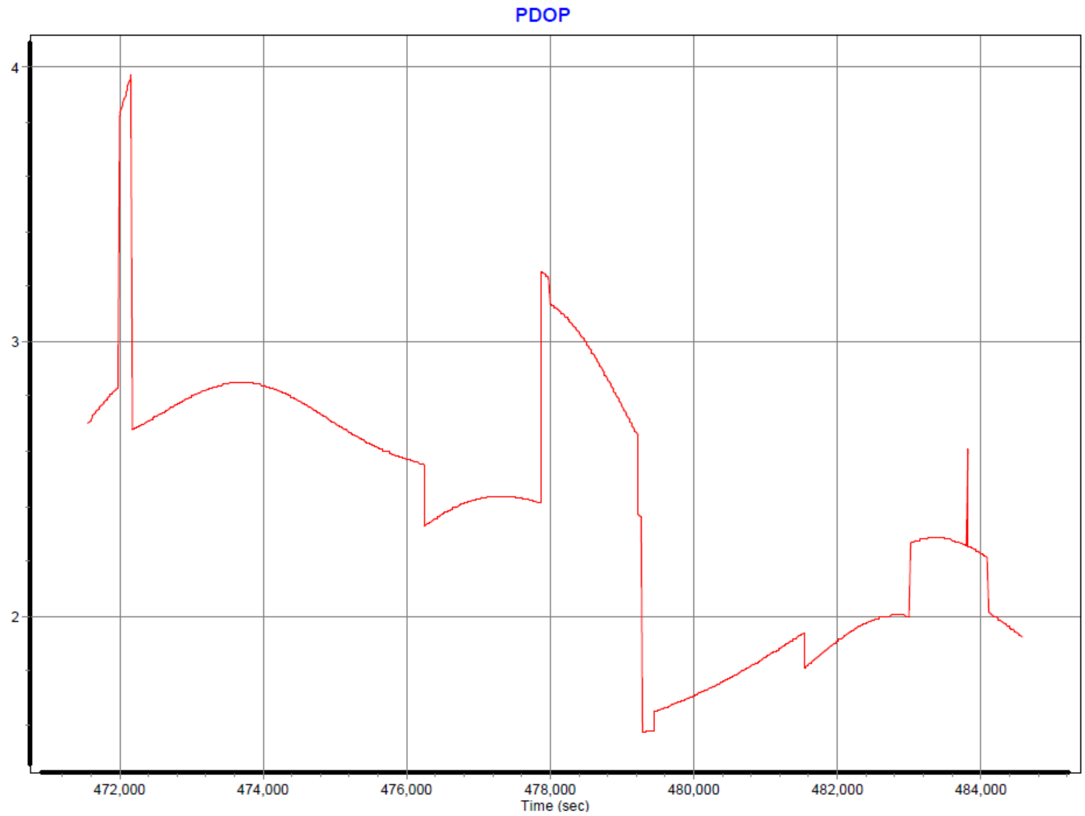
UNB15114A

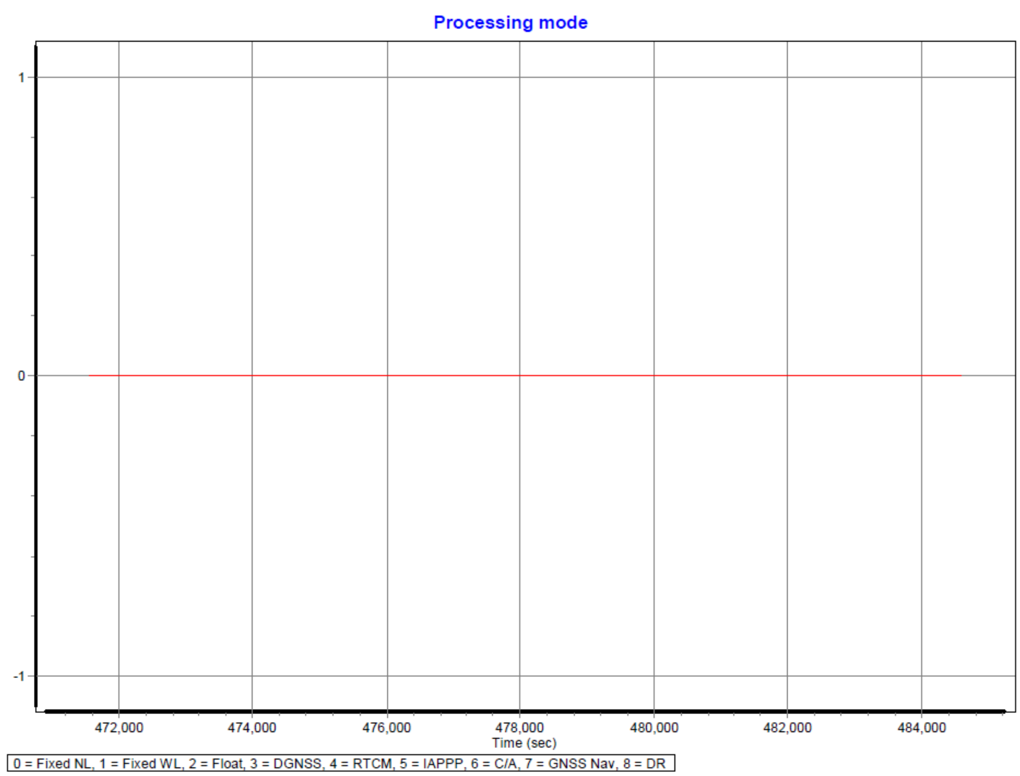

Altitude (m)
1,050
1,000
950
900
850
800
750
700
650
600
550
500
450
400
350
300
250
200
150
100
50
0
-50
472,000
474,000
476,000
478,000
480,000
482,000
484,000
Time (sec)


Baseline Length (m)
52,000
50,000
48,000
46,000
44,000
42,000
40,000
38,000
36,000
34,000
32,000
30,000
28,000
26,000
24,000
22,000
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
-2,000
472,000
474,000
476,000
478,000
480,000
482,000
484,000
Time (sec)

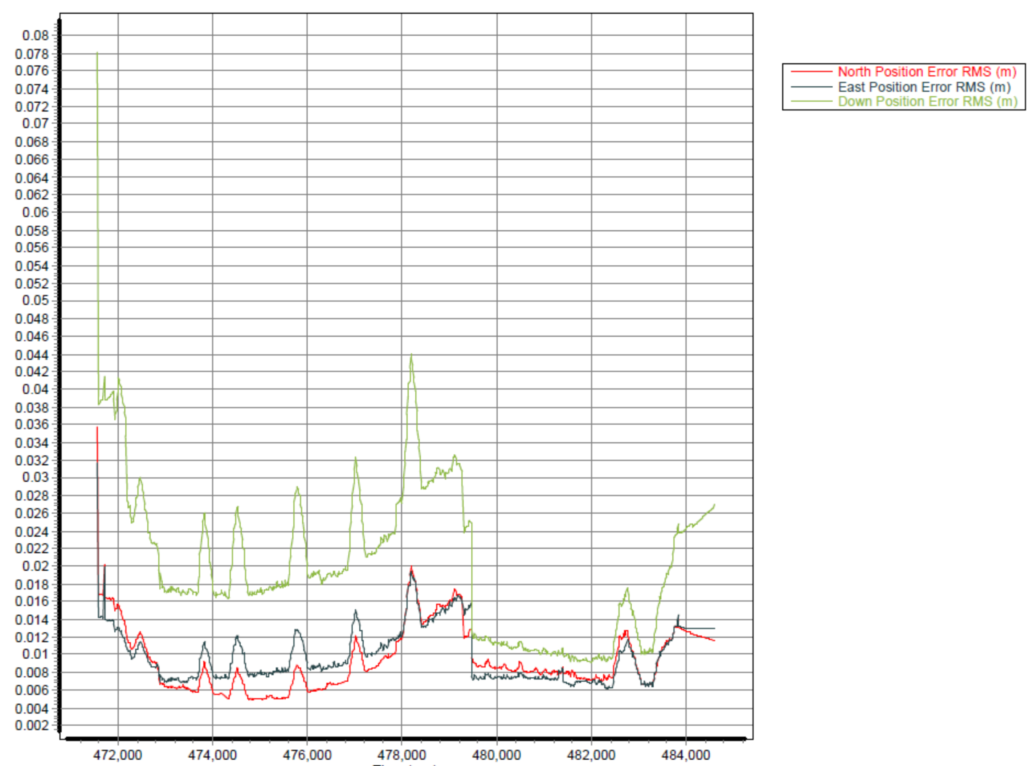

Project Settings
General Information
Units
View
Satellite Selection
GNSS-Inertial Processor
Timing, Multipath and Baseli
Initialization
Lever Arms and Mounting A
Export
Camera
LiDAR
SAR
Reference to IMU Lever Arm
X 0.034 m
Y 0.018 m
Z -0.155 m
Reference to IMU Mounting Angles
X 0.000 deg
Y 0.000 deg
Z 0.000 deg
Reference to Primary GNSS Lever Arm
X -0.094 m
Y -0.055 m
Z -1.020 m
Standard Deviation
<3cm 10cm 50cm 1m 10m
Aircraft to Reference Mounting Angles
X 0.000 deg
Y 0.000 deg
Z 0.000 deg
OK
Cancel

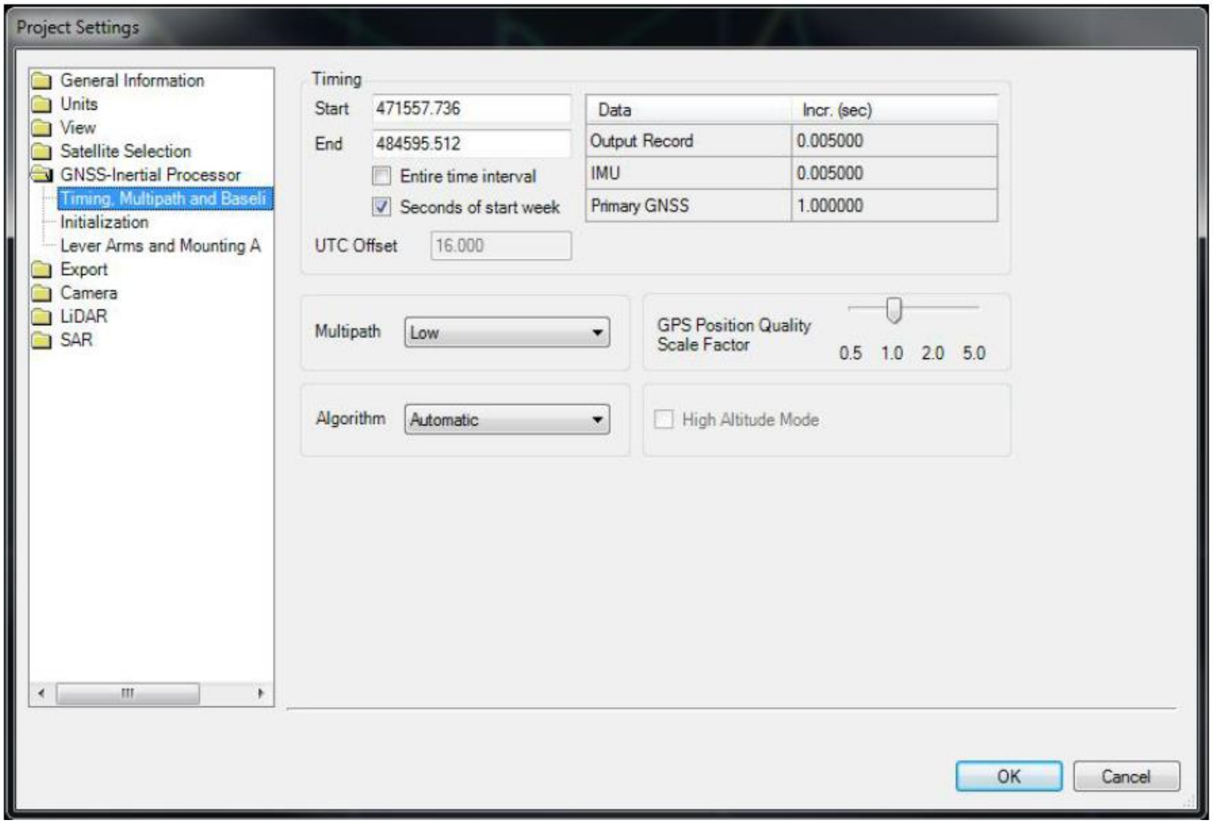

Number of GPS Satellites
9
8
7
6
5
472,000
474,000
476,000
478,000
480,000
482,000
484,000
Time (sec)

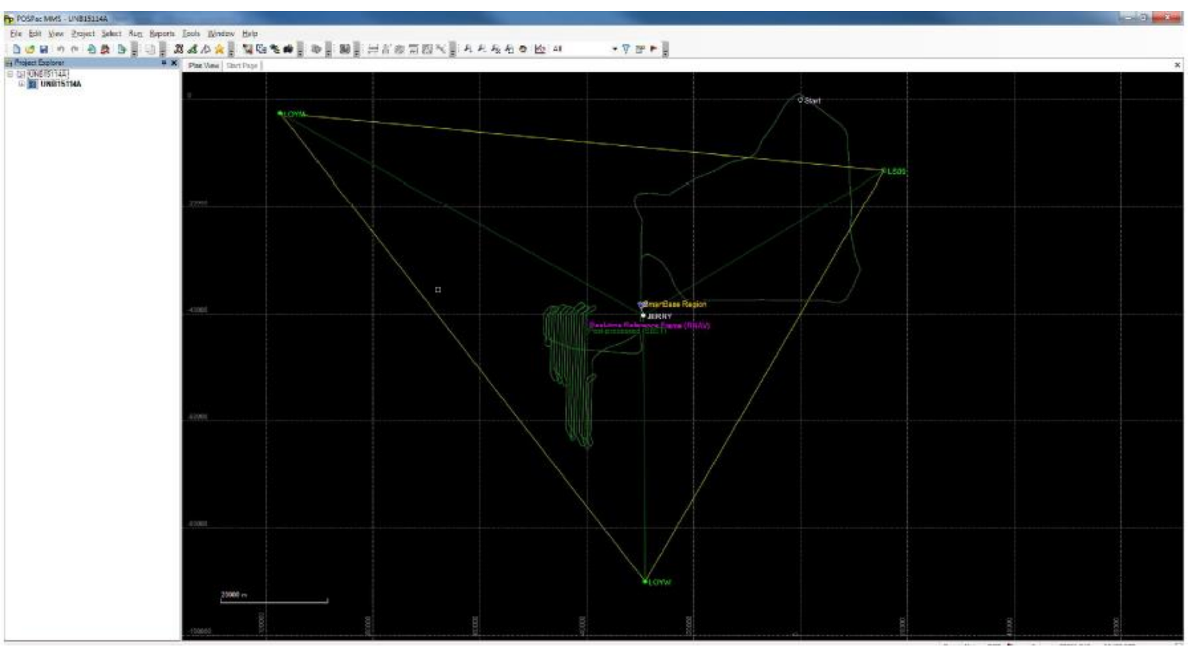

PDOP
4
3
2
472,000
474,000
476,000
478,000
480,000
482,000
484,000
Time (sec)


Processing mode
1
0
-1
472,000
474,000
476,000
478,000
480,000
482,000
484,000
Time (sec)
0 = Fixed NL, 1 = Fixed WL, 2 = Float, 3 = DGNSS, 4 = RTCM, 5 = IAPPP, 6 = C/A, 7 = GNSS Nav, 8 = DR

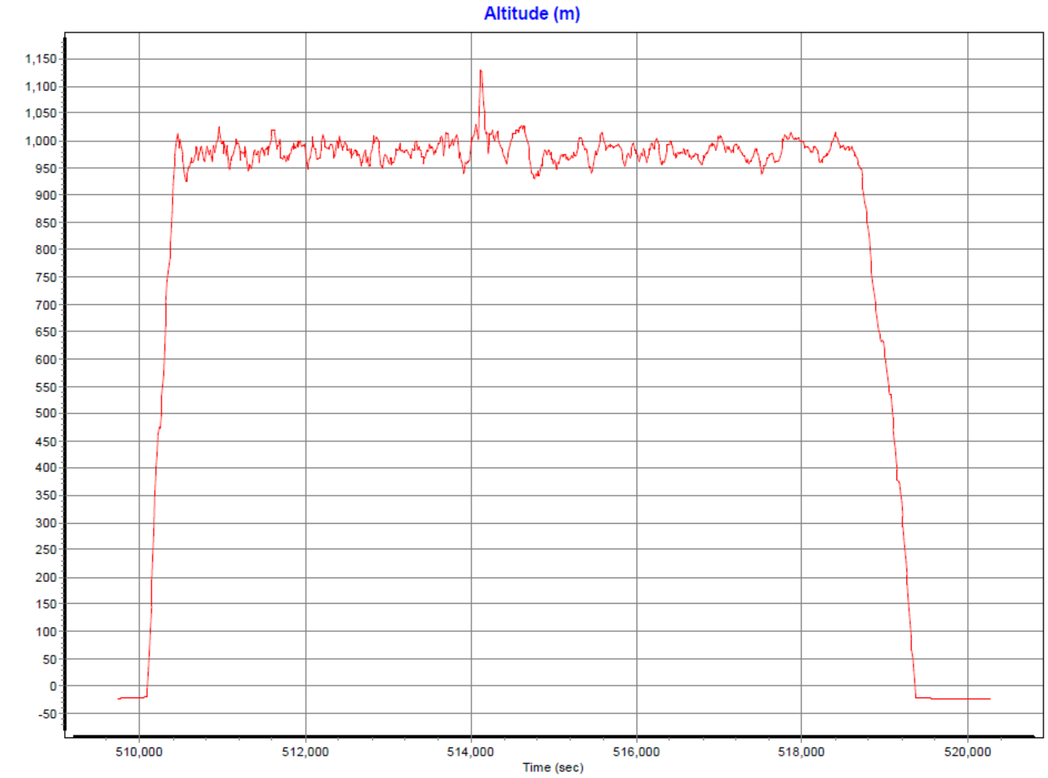

North (m)
East (m)
Down (m)
DR mode
Time (sec)

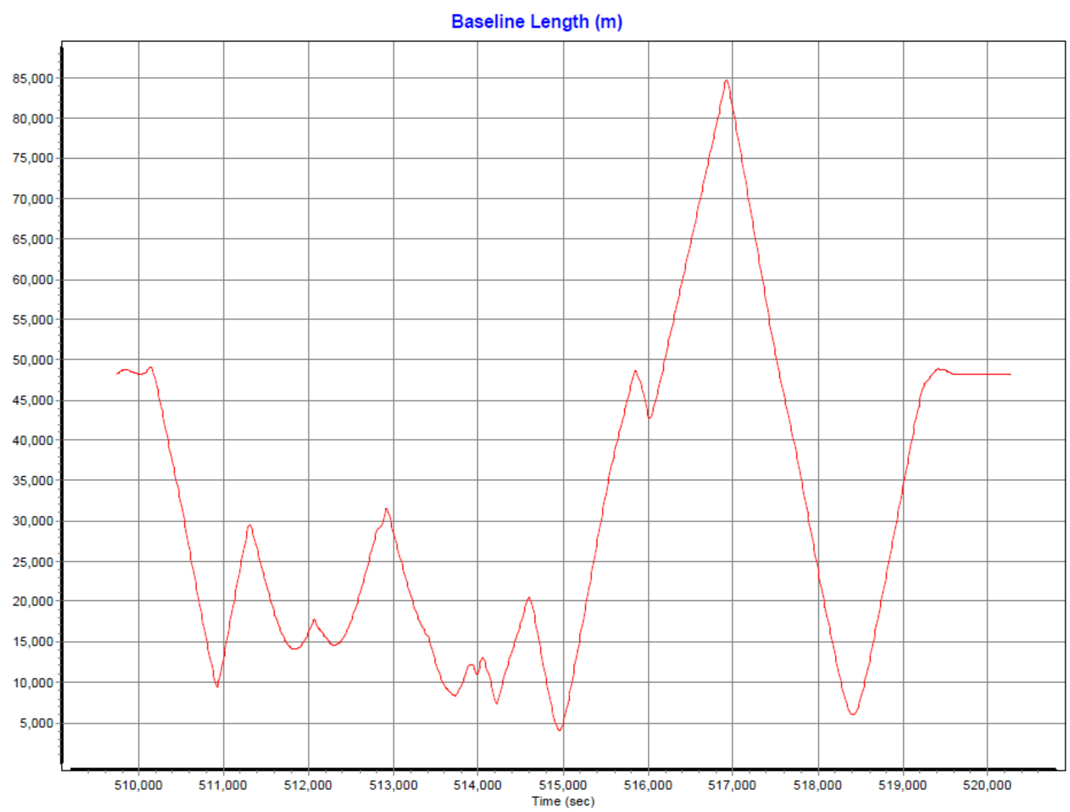

North Position Error RMS (m)
East Position Error RMS (m)
Down Position Error RMS (m)
Time (sec)

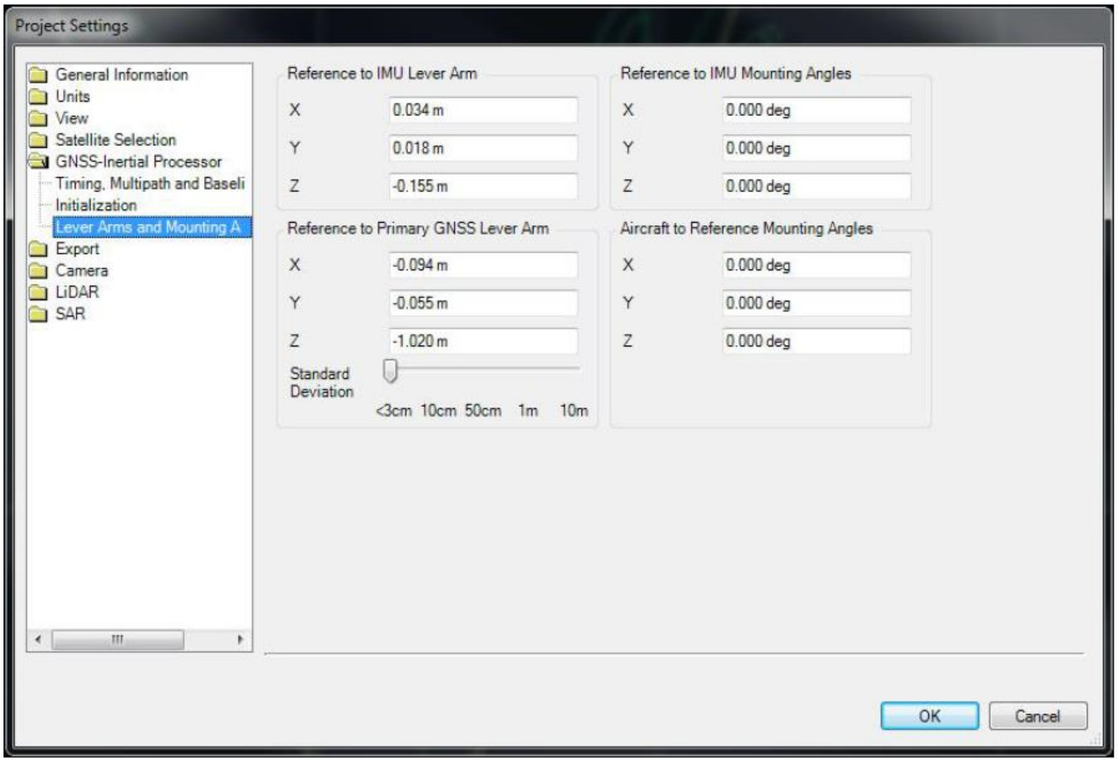

Project Settings
General Information
Units
View
Satellite Selection
GNSS-Inertial Processor
Timing, Multipath and Baseli
Initialization
Lever Arms and Mounting A
Export
Camera
LiDAR
SAR
Timing
Start 471557.736
End 484595.512
Entire time interval
Seconds of start week
UTC Offset 16.000
Data | Incr. (sec)
Output Record | 0.005000
IMU | 0.005000
Primary GNSS | 1.000000
Multipath Low
GPS Position Quality Scale Factor
0.5 1.0 2.0 5.0
Algorithm Automatic
High Altitude Mode
OK
Cancel

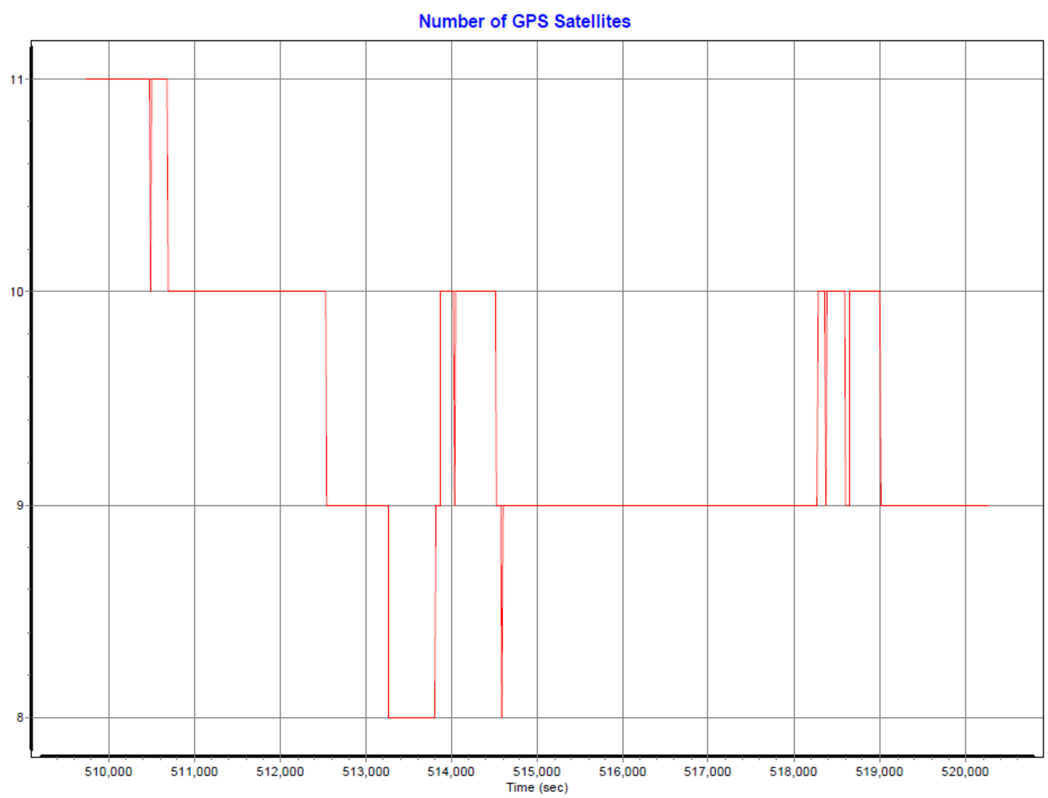


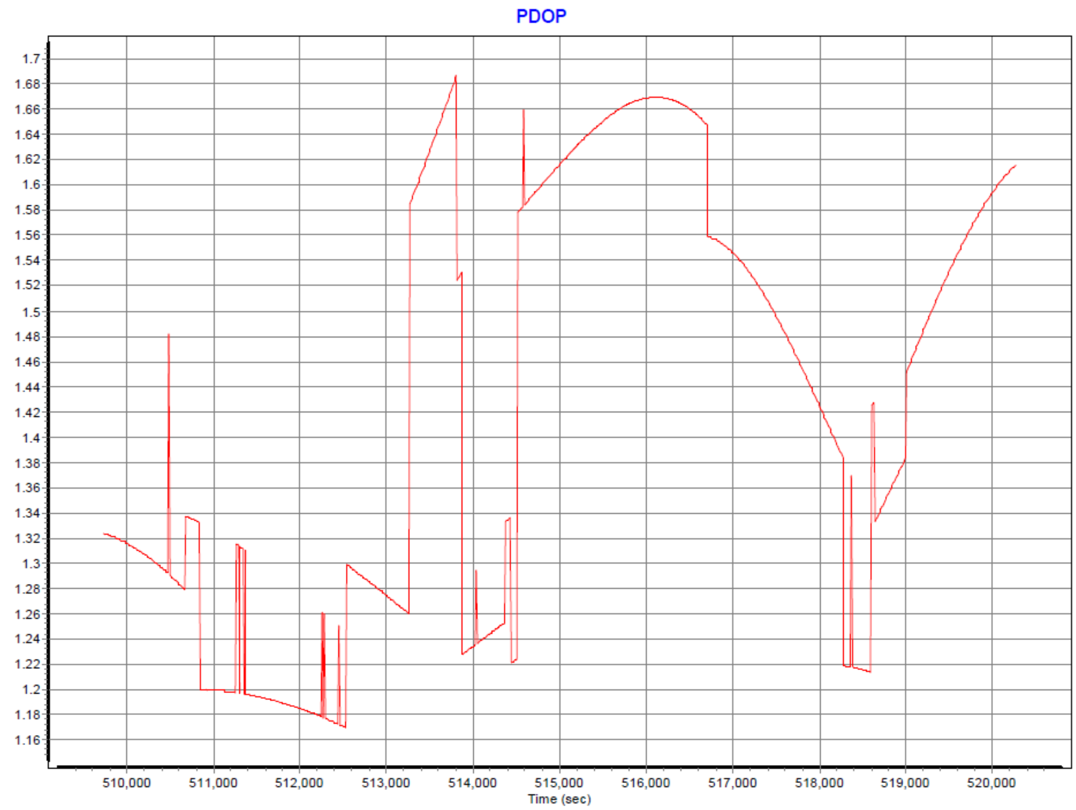
UNB15114B

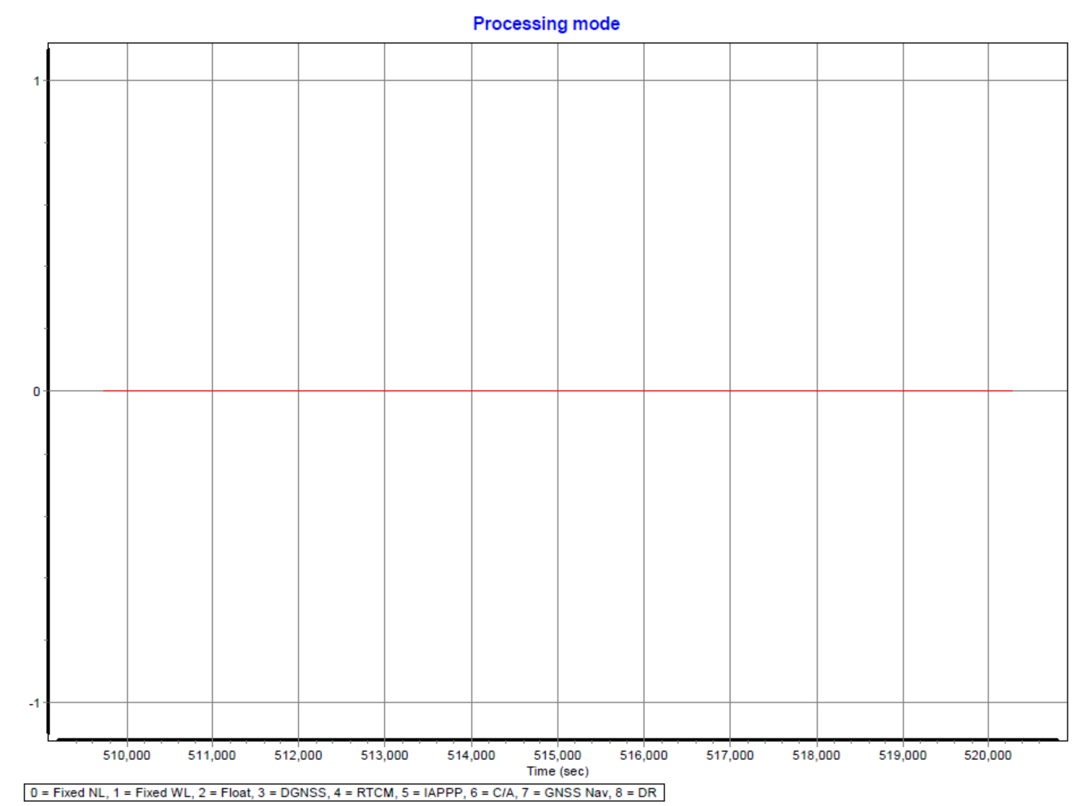

Altitude (m)
1,150
1,100
1,050
1,000
950
900
850
800
750
700
650
600
550
500
450
400
350
300
250
200
150
100
50
0
-50
510,000
512,000
514,000
516,000
518,000
520,000
Time (sec)

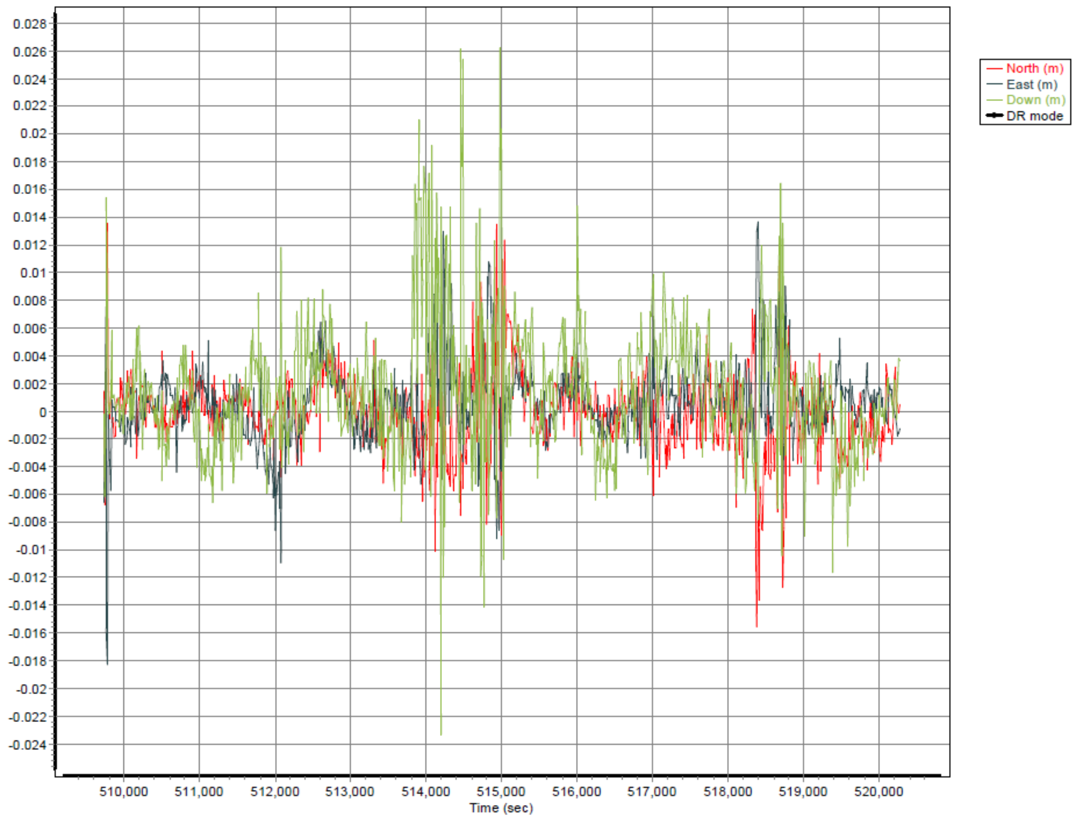

Baseline Length (m)
85,000
80,000
75,000
70,000
65,000
60,000
55,000
50,000
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
510,000
511,000
512,000
513,000
514,000
515,000
516,000
517,000
518,000
519,000
520,000
Time (sec)

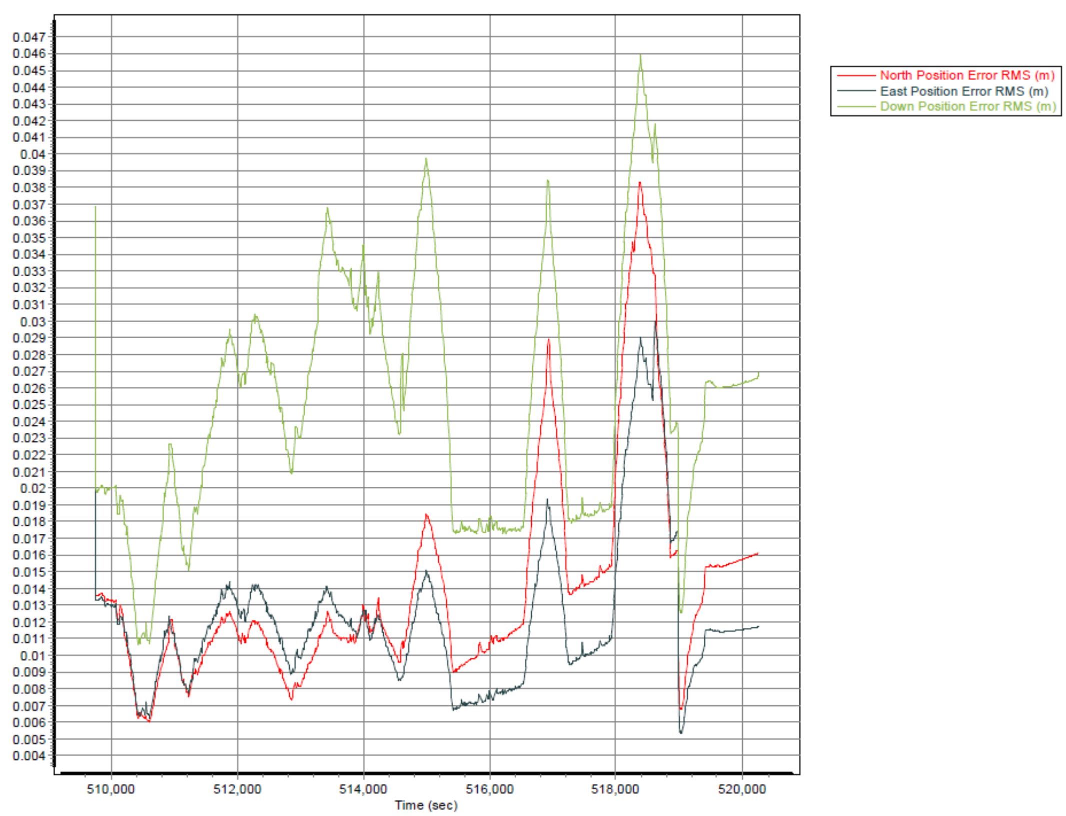

Project Settings
General Information
Units
View
Satellite Selection
GNSS-Inertial Processor
Timing, Multipath and Baseli
Initialization
Lever Arms and Mounting A
Export
Camera
LiDAR
SAR
Reference to IMU Lever Arm
X 0.034 m
Y 0.018 m
Z -0.155 m
Reference to IMU Mounting Angles
X 0.000 deg
Y 0.000 deg
Z 0.000 deg
Reference to Primary GNSS Lever Arm
X -0.094 m
Y -0.055 m
Z -1.020 m
Standard Deviation
<3cm 10cm 50cm 1m 10m
Aircraft to Reference Mounting Angles
X 0.000 deg
Y 0.000 deg
Z 0.000 deg
OK
Cancel

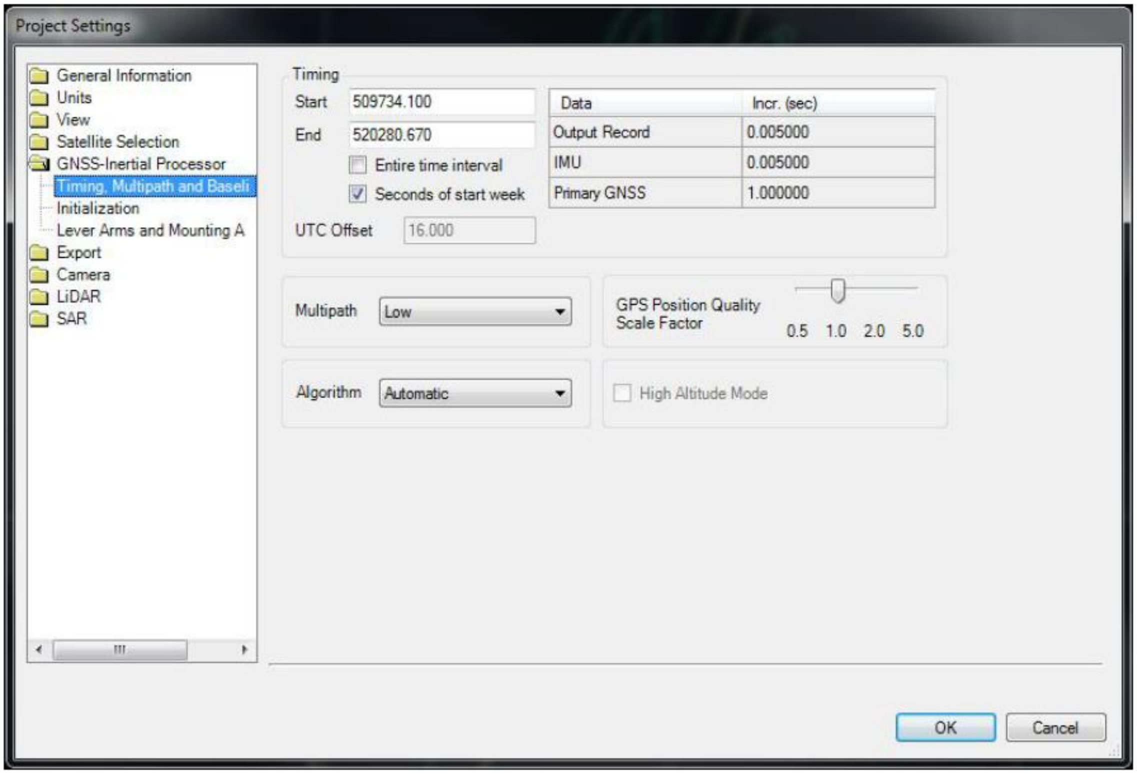

Number of GPS Satellites
11
10
9
8
510,000
511,000
512,000
513,000
514,000
515,000
516,000
517,000
518,000
519,000
520,000
Time (sec)

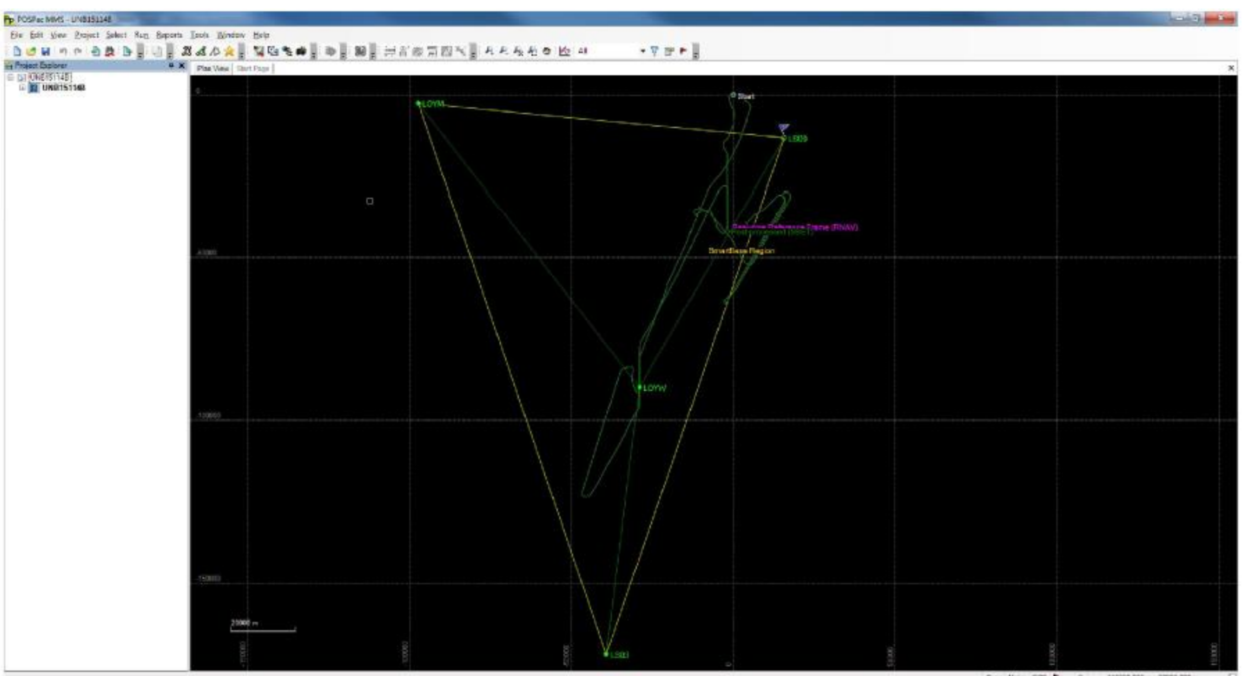

PDOP
1.7
1.68
1.66
1.64
1.62
1.6
1.58
1.56
1.54
1.52
1.5
1.48
1.46
1.44
1.42
1.4
1.38
1.36
1.34
1.32
1.3
1.28
1.26
1.24
1.22
1.2
1.18
1.16
510,000
511,000
512,000
513,000
514,000
515,000
516,000
517,000
518,000
519,000
520,000
Time (sec)


Processing mode
1
0
-1
510,000
511,000
512,000
513,000
514,000
515,000
516,000
517,000
518,000
519,000
520,000
Time (sec)
0 = Fixed NL, 1 = Fixed WL, 2 = Float, 3 = DGNSS, 4 = RTCM, 5 = IAPPP, 6 = C/A, 7 = GNSS Nav, 8 = DR


North (m)
East (m)
Down (m)
DR mode
Time (sec)


North Position Error RMS (m)
East Position Error RMS (m)
Down Position Error RMS (m)
Time (sec)


Project Settings
General Information
Units
View
Satellite Selection
GNSS-Inertial Processor
Timing, Multipath and Baseli
Initialization
Lever Arms and Mounting A
Export
Camera
LiDAR
SAR
Timing
Start 509734.100
End 520280.670
Entire time interval
Seconds of start week
UTC Offset 16.000
Data | Incr. (sec)
Output Record | 0.005000
IMU | 0.005000
Primary GNSS | 1.000000
Multipath Low
GPS Position Quality Scale Factor
0.5 1.0 2.0 5.0
Algorithm Automatic
High Altitude Mode
OK
Cancel


LOYM
Start
LS09
LOYW
SmartBase Region