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Chesapeake Bay LiDAR

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 over several counties of Virginia.

The LiDAR data were processed and classified according to project specifications. Detailed breaklines and bare-earth Digital Elevation Models (DEMs) were produced for the project area. Data was formatted according to tiles with each tile covering an area of 5000 ft by 5000 ft. A total of 4255 tiles were produced for the project encompassing an area of approximately 3,753 sq. miles.

The project area intersected both Virginia State Plane North and Virginia State Plane South map projection areas so 3811 tiles were delivered in Virginia State Plane South and 444 tiles were delivered in Virginia State Plane North.

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 collected ground control and LiDAR calibration points used during LiDAR data acquisition and processing. 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 Albemarie, Buckingham, Cumberland, Powhatan, Augusta, Rockingham, Greene, Fluvanna, Goochland, Nelson, and Appomattox as well as the City of Charlottesville.

DATE OF SURVEY

The LiDAR aerial acquisition was conducted from November 15, 2015 thru March 30, 2016.

COORDINATE REFERENCE SYSTEM

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

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 and Virginia State Plane North
Units: Horizontal units are in U.S. Survey Feet, Vertical units are in Survey Feet.
Geiod Model: Geoid12B (Geoid 12B was used to convert ellipsoid heights to orthometric heights).

LIDAR VERTICAL ACCURACY

For the Chesapeake Bay, VA LiDAR Project, the tested $RMSE_z$ of the classified LiDAR data for checkpoints in non-vegetated terrain equaled **0.28 ft** compared with the 0.33 ft (10 cm) specification; and the NVA of the classified LiDAR data computed using $RMSE_z$ x 1.9600 was equal to **0.55 ft (16.8 cm)**, compared with the 0.64 ft (19.6 cm) specification.

For the Chesapeake Bay, VA LiDAR Project, the tested VVA of the classified LiDAR data computed using the 95^{th} percentile was equal to **0.74 ft (22.6 cm),** compared with the 0.96 ft (29.4 cm) specification.

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

PROJECT DELIVERABLES

The deliverables for the project are listed below.

1. 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

PROJECT TILING FOOTPRINT

Four thousand two hundred and fifty-five (4255) tiles were delivered for the project. Of these tiles, 3811 tiles were delivered in Virginia State Plane South and 444 tiles were delivered in Virginia State Plane North. Each tile's extent is 5000 feet by 5000 feet (see Appendix B for a complete listing of delivered tiles).

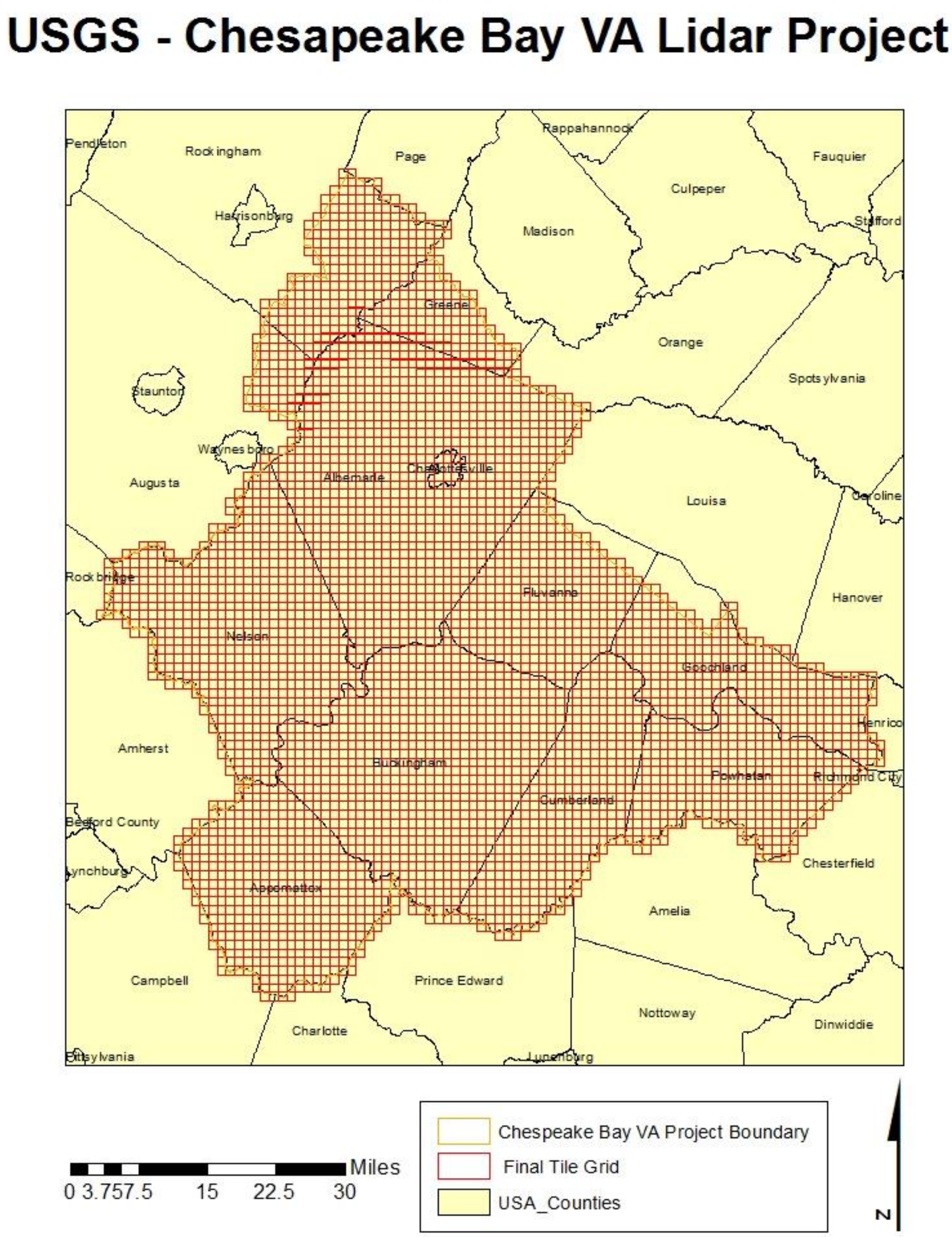

Figure 1 - Project Map

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 January 16.

LIDAR ACQUISITION DETAILS

LEG planned 988 passes for the project area as a series of parallel flight lines. 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, LEG followed FEMA's Appendix A "guidelines" for flight planning and, at a minimum, includes the following criteria:

- A digital flight line layout using LEICA MISSION PRO flight design software for direct integration into the aircraft flight navigation system.
- Planned flight lines; flight line numbers; and coverage area.
- LiDAR coverage extended by a predetermined margin beyond all project borders to ensure necessary over-edge coverage appropriate for specific task order deliverables.
- Local restrictions related to air space and any controlled areas have been investigated so that required permissions can be obtained in a timely manner with respect to schedule. Additionally, 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.

LEG 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 Leading Edge Geomatics system parameters for LiDAR acquisition on this project.

Item	Parameter
System	Riegl 680i
Altitude (AGL meters)	900
Approx. Flight Speed (knots)	100
Scanner Pulse Rate (kHz)	200
Scan Frequency (hz)	82
Pulse Duration of the Scanner (nanoseconds)	5
Pulse Width of the Scanner (m)	0.8994
Swath width (m)	1039
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)	1039
Swath Overlap (%)	55
Total Sensor Scan Angle (degree)	60
Computed Down Track spacing (m) per beam	0.45
Computed Cross Track Spacing (m) per beam	0.45
Nominal Pulse Spacing (single swath), (m)	0.66
Nominal Pulse Density (single swath) (ppsm), (m)	2.30
Aggregate NPS (m) (if ANPS was designed to be met through single coverage, ANPS and NPS will be equal)	0.66
Aggregate NPD (m) (if ANPD was designed to be met through single coverage, ANPD and NPD will be equal)	2.30
Maximum Number of Returns per Pulse	infinite

Table 1: LEG 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.

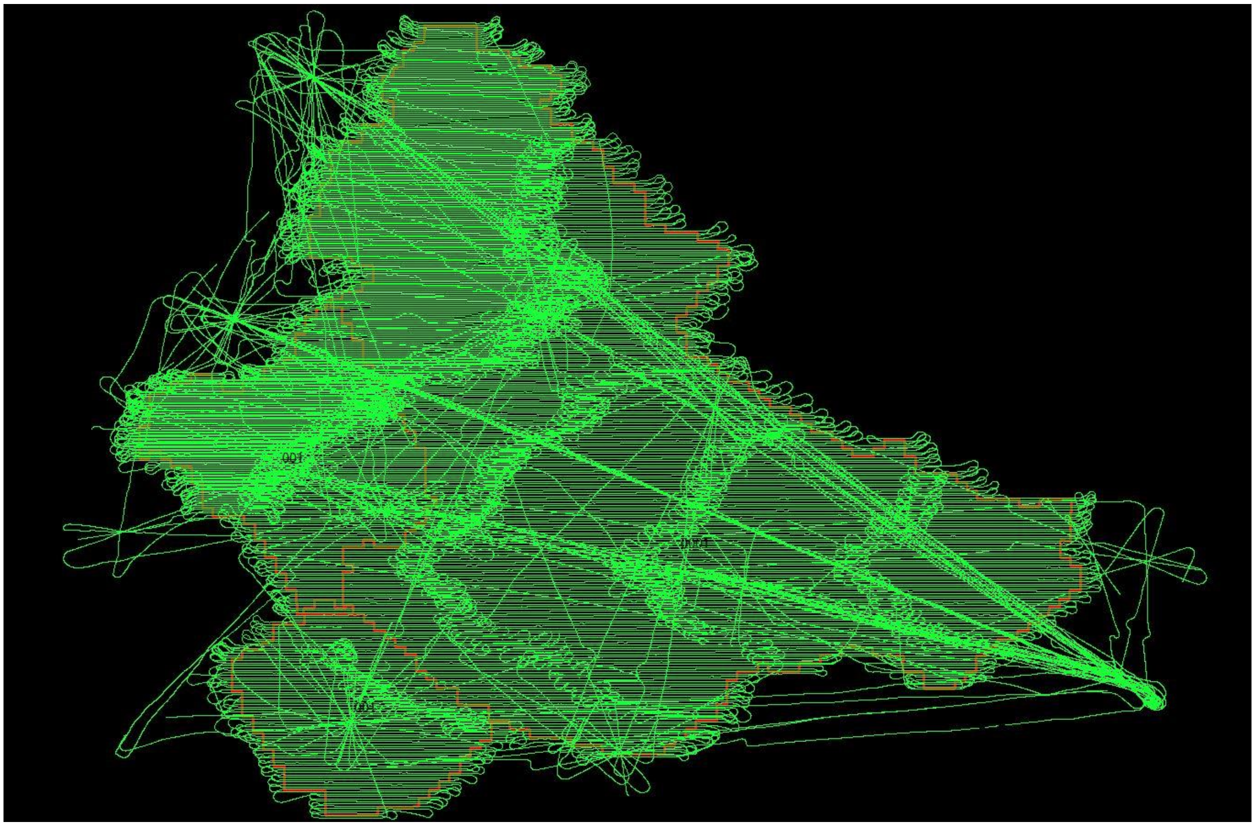

Figure 2: Trajectories as flown by LEG

LIDAR CONTROL

Seventeen active base stations from Leica Smartnet were to control the LiDAR acquisition. All stations were adjusted to CORS (2011). 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	Lat/Long		Ellipsoid Ht (m)
	Easting X (DD)	Northing Y (DD)	
LOY3	37.62293472	77.50442703	36.59
LOY8	38.28296994	77.45263015	-4.909
LOYA	37.30270836	79.32449333	205.777
LOYH	37.30270836	79.32449333	205.777
LOYI	38.03317375	78.51178031	156.283
LOYJ	38.47247028	78.01004083	105.16
LOYC	39.12015178	78.20072483	203.096
LOYY	38.88848536	78.49915097	222.2
VAGV	38.79575914	77.60131221	81.84

LOYU	37.161785	80.43309586	601.292
LOYV	36.57810864	79.37959753	98.648
LOYY	38.88848536	78.49915097	222.2
LS04	37.36309428	79.95749161	325.463
LOYM	38.31058858	76.63277217	6.099
LOYP	38.02050769	79.01867778	393.357
LOYZ	36.86358872	76.57355803	-19.502
VACC	37.26663728	76.02286672	-29.972

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 3 cm average or better but no larger than 10 cm being recorded.

GPS processing reports for each mission were delivered with the data for each flight.

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

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.

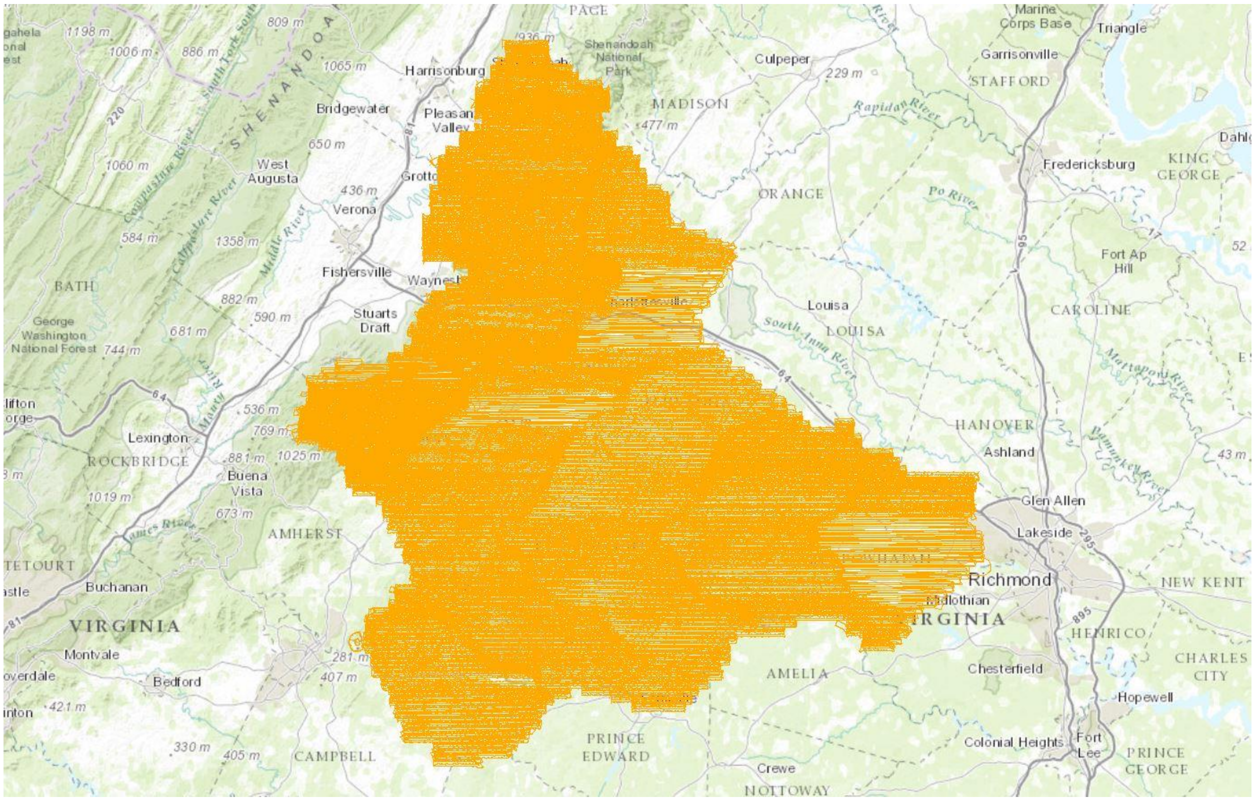

Figure 3 – LiDAR Swath output showing complete coverage.

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 RMSEZ within individual swaths and <=8 cm RMSD
Z or within swath overlap (between adjacent swaths).

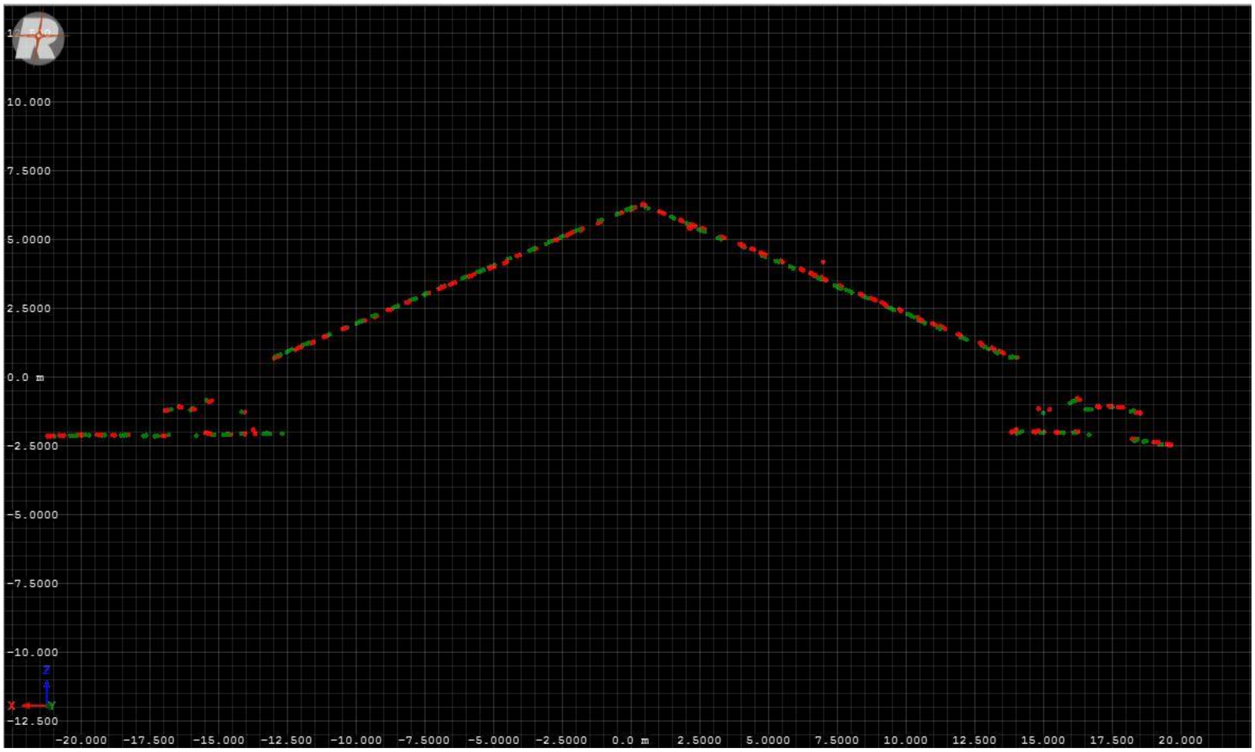

Figure 4 – Profile views cross section of multiple swaths.

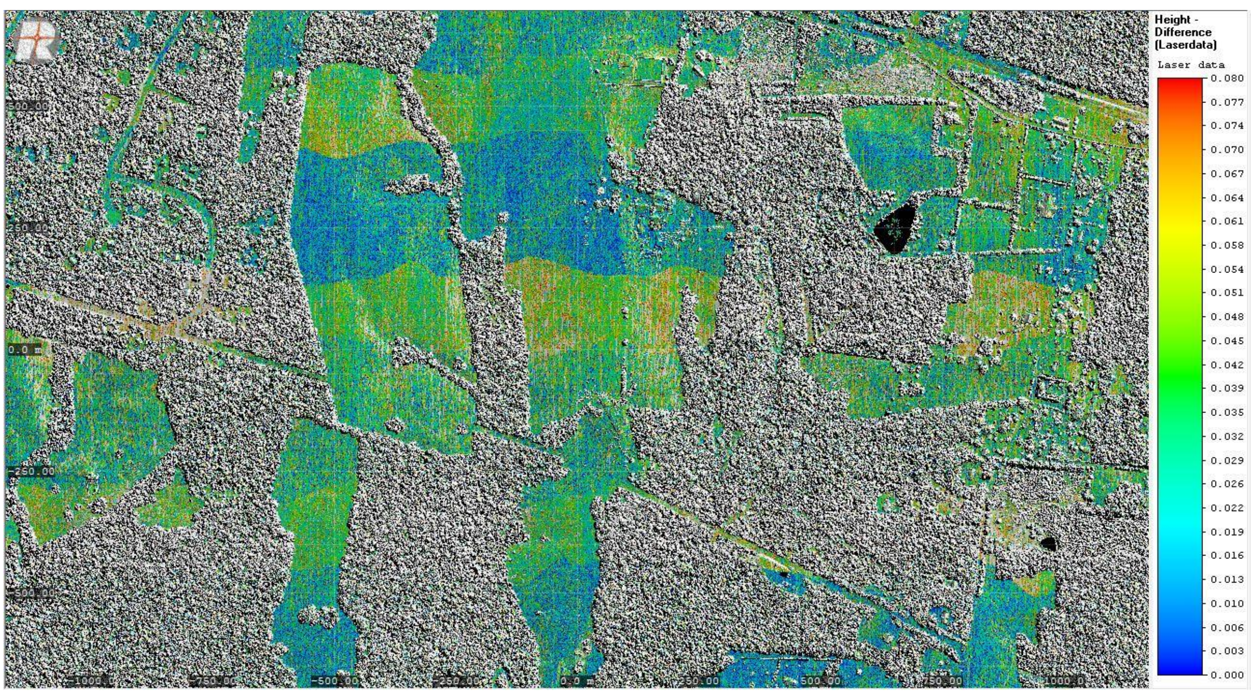

Figure 5 – QC block colored by distance to ensure accuracy at swath edges.

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

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. 20% 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/0.33 ft (NSSDA $Accuracy_z$ 95% = 19.6 cm/0.64 ft) 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 0.132 m (0.43 ft) vertical accuracy at 95% confidence level based on consolidated $RMSE_z$ (0.0674m x 1.9600) when compared to 845 RTK collected static check points.

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

Average dz	+0.057 m
Root mean square	0.0674 m
Std deviation	0.0472 m

Overall the calibrated LiDAR data products collected by Leading Edge Geomatics meet or exceed the requirements set out in the Statement of Work. The quality control requirements of Leading Edge Geomatics 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 one hundred and twelve non-vegetated (open terrain and urban) independent survey check points. The vertical accuracy is tested by comparing survey checkpoints in non-vegetated terrain to a triangulated irregular network (TIN) that is created from the raw swath points. Only checkpoints in non-vegetated terrain can be tested against raw swath data because the data has not undergone classification techniques to remove vegetation, buildings, and other artifacts from the ground surface. Checkpoints are always compared to interpolated surfaces from the LiDAR point cloud because it is unlikely that a survey checkpoint will be located at the location of a discrete LiDAR point. Dewberry typically uses LP360 software to test the swath LIDAR vertical accuracy, Terrascan software to test the classified LiDAR vertical accuracy, and Esri ArcMap to test the DEM vertical accuracy so that three different software programs are used to validate the vertical accuracy for each project. Project specifications require a NVA of 0.64 ft (19.6 cm) based on the $RMSE_z$ (0.33 ft/10 cm) x 1.96. The dataset for the Chesapeake Bay 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 $RMSE_z$ = 0.29 ft (8.84 cm), equating to +/- 0.56 ft (17.1 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	112	0.29	0.56	0.01	-0.01	0.13	0.29	-0.72	0.69	0.20

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

Three checkpoints (NVA-6, 31, and 82) where removed from the raw swath vertical accuracy testing due to their location underneath a power line or vehicles. 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-31, and 82 are located in open terrain, the overhead power lines are modeled by the LiDAR point cloud. NVA-6 is located under a truck at the time of LiDAR collection. These high points caused erroneous high values during the swath vertical accuracy testing so these point where removed from the final calculations. Once the data underwent the classification process, the high points were removed from the final ground classification and these points could be used in the final vertical accuracy testing for the fully classified LiDAR data. Table 4, below, provides the coordinates for these checkpoints and the vertical accuracy results from the raw swath data. Table 5, below, provides the usable vertical accuracy results of these checkpoints from the fully classified LiDAR. The differences in the tables show how above ground features can cause erroneous vertical accuracy results in the raw swath data. Figure 6, below, shows a 3D model of the LiDAR point cloud and the location of the checkpoint beneath a power line.

Point ID	NAD83 (2011) VA State Plane South		NAVD88 (Geoid 12B)
	Easting X (ft)	Northing Y (ft)	Survey Z (ft)
NVA-6	11394521.91	3898626.293	842.619
NVA-31	11521543.01	3749951.332	510.518
NVA-82	11681782.74	3756862.957	275.726

Table 4: Checkpoints removed from raw swath vertical accuracy testing

Point ID	NAD83 (2011) VA State Plane South		NAVD88 (Geoid 12B)	LiDAR Z (ft)	Delta Z	AbsDeltaZ
	Easting X (ft)	Northing Y (ft)	Survey Z (ft)			
NVA-6	11394521.91	3898626.293	842.619	842.610	-0.009	0.009
NVA-31	11521543.01	3749951.332	510.518	510.820	0.302	0.302
NVA-82	11681782.74	3756862.957	275.726	275.920	0.194	0.194

Table 5: Final tested vertical accuracy for NVA 6, NVA 31, and NVA 82 post ground classification

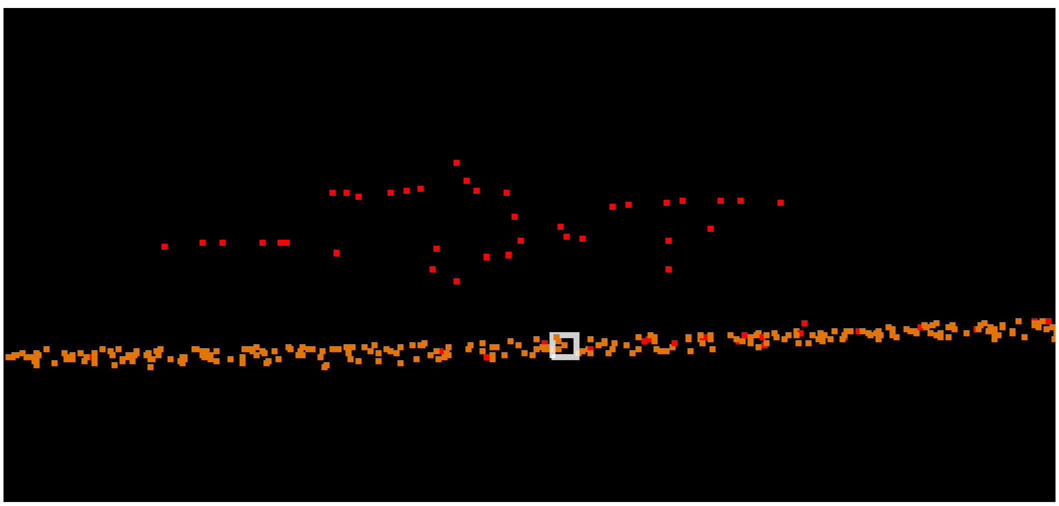

Figure 6– Non-vegetated terrain checkpoint 6 shown as the white square, is located underneath a truck. This point was removed from raw swath vertical accuracy testing because above ground features, including vehicles, have not been separated from the ground classification yet.

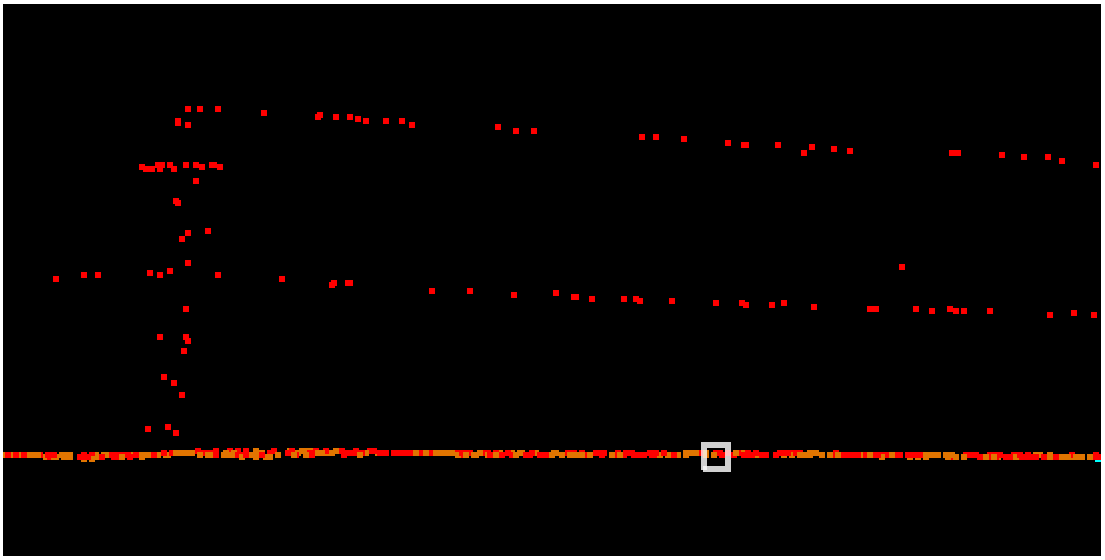

Figure 7 – Non-vegetated terrain checkpoint 31 shown as the white square, is located underneath power lines. This point was removed from raw swath vertical accuracy testing because above ground features, including power lines, have not been separated from the ground classification yet.

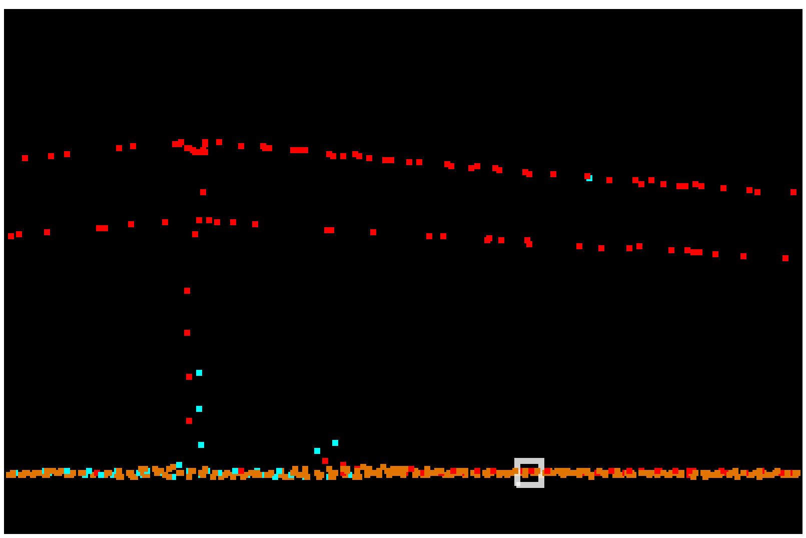

Figure 8 – Non-vegetated terrain checkpoint 82 shown as the white square, is located underneath power lines. This point was removed from raw swath vertical accuracy testing because above ground features, including power lines, have not been separated from the ground classification yet.

Inter-Swath (Between Swath) Relative Accuracy

Dewberry verified inter-swath or between swath relative accuracy of the dataset by creating Delta-Z (DZ) orthos. According to the SOW, USGS LiDAR Base Specifications v1.2, and ASPRS Positional Accuracy Standards for Digital Geospatial Data, 10 cm Vertical Accuracy Class or QL2 data must meet inter-swath relative accuracy of 8 cm RMSDz or less with maximum differences less than 16 cm. These measurements are to be taken in non-vegetated and flat open terrain using single or only returns from all classes. Measurements are calculated in the DZ orthos on 1-meter pixels or cell sizes. Areas in the dataset where overlapping flight lines are within 8 cm of each other within each pixel are colored green, areas in the dataset where overlapping flight lines have elevation differences in each pixel between 8 cm -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 Chesapeake are shown in the figure below; this project meets inter-swath relative accuracy specifications.

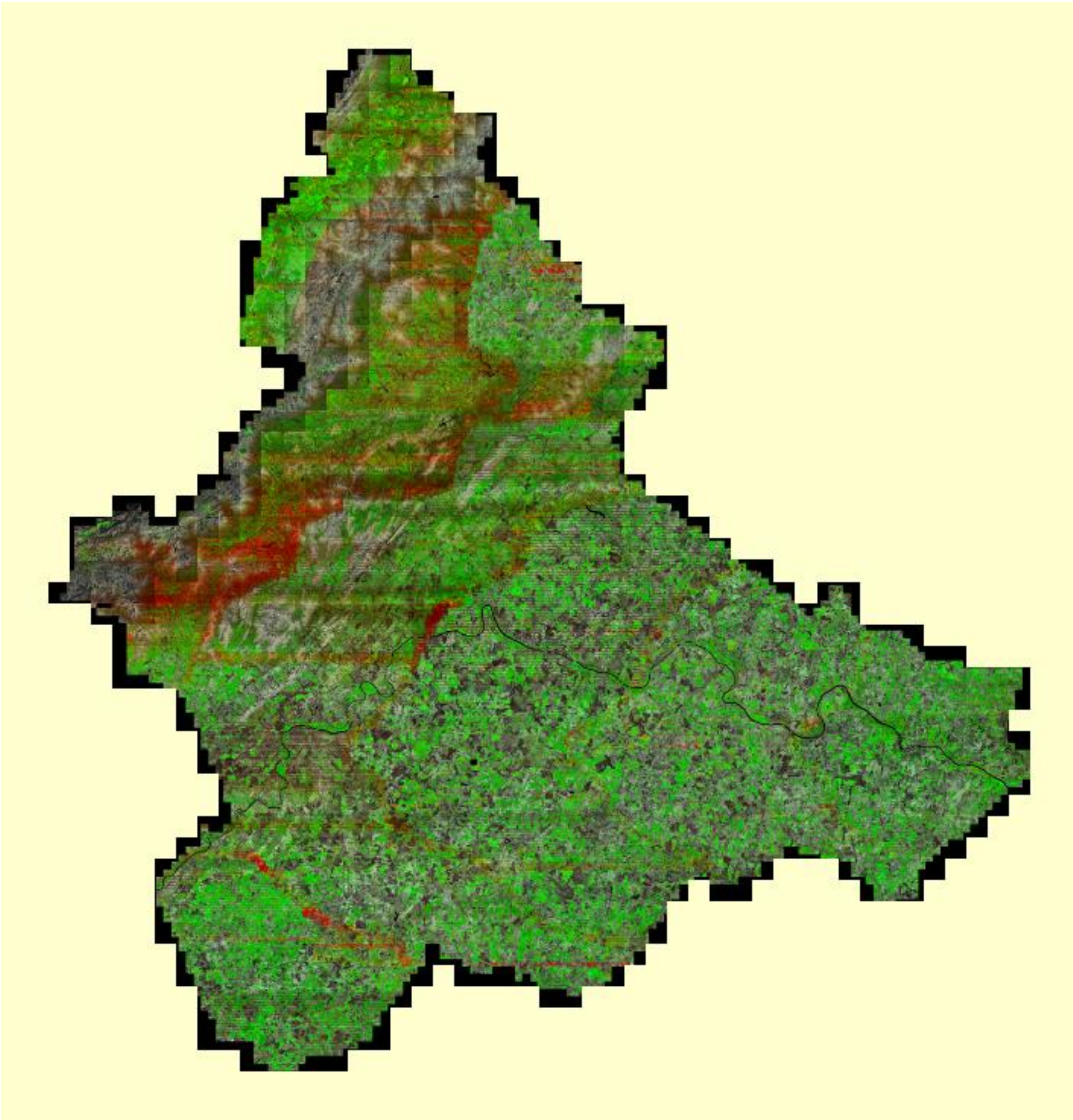

Figure 9– Single return DZ Orthos for the Chesapeake Lidar Project. Inter-swath relative accuracy passes specifications.

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

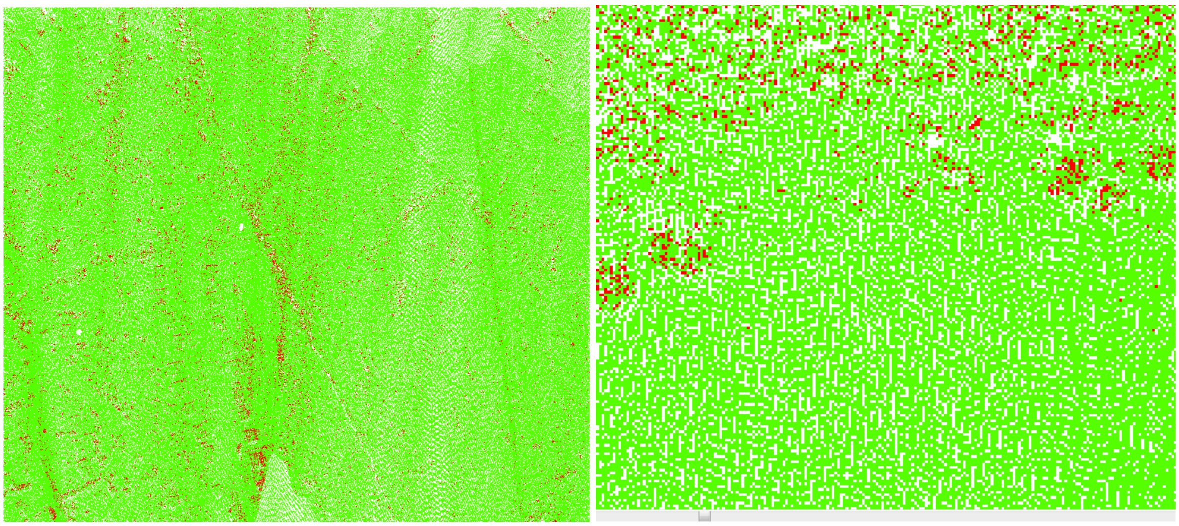

Figure 10–Intra-swath relative accuracy. The left image shows a large portion of the dataset; flat, open areas are colored green as they are within 6 cm whereas sloped terrain is colored red because it exceeds 6 cm maximum difference, as expected, due to actual slope/terrain change. The right image is a close-up of a flat area. With the exception of few trees (shown in red as the elevation/height difference in vegetated areas will exceed 6 cm) this open flat area is acceptable for repeatability testing. Intra-swath relative accuracy passes specifications.

Horizontal Alignment

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

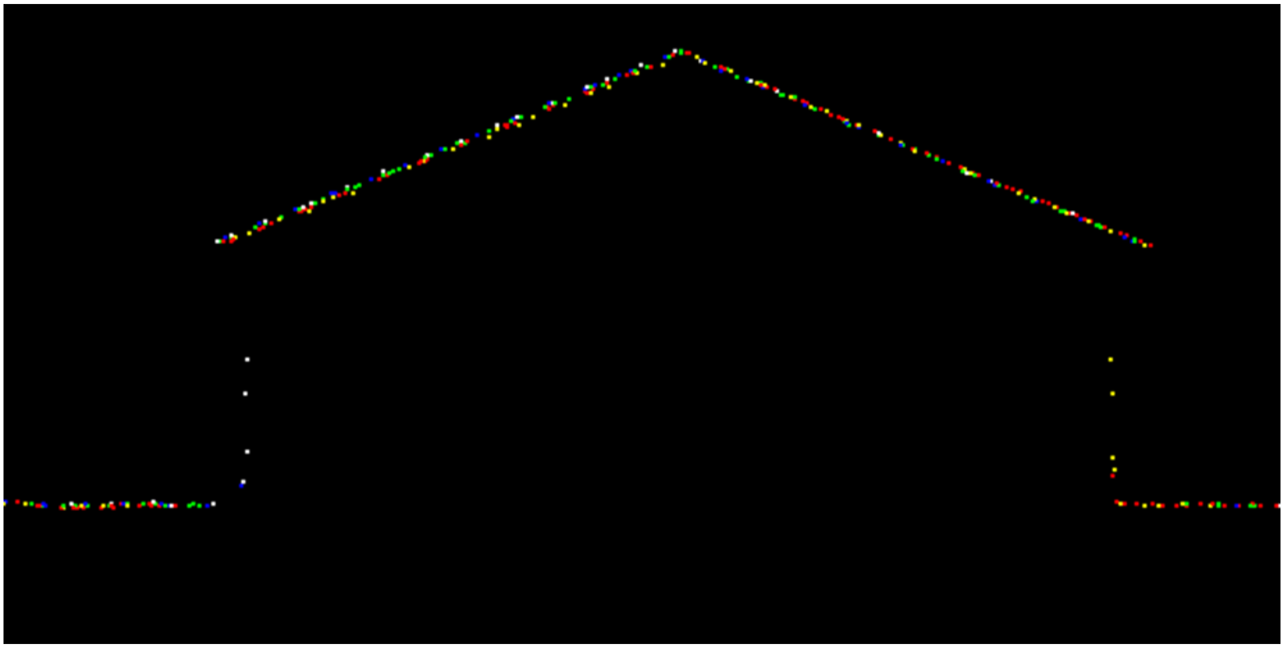

Figure 11– Horizontal Alignment. Several flightlines differentiated by color are shown in this profile. There is no visible offset between these two flight lines. No horizontal alignment issues were identified.

Point Density and Spatial Distribution

The required Aggregate Nominal Point Spacing (ANPS) for this project is no greater than 0.70 meters, which equates to an Aggregate Nominal Point Density (ANPD) of 2 points per square meter or greater. Density calculations were performed using first return data only located in the geometrically usable center portion (typically ~90%) of each swath. By utilizing statistics, the project area was determined to have an ANPS of 0.26 meters or an ANPD of 14.8 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.

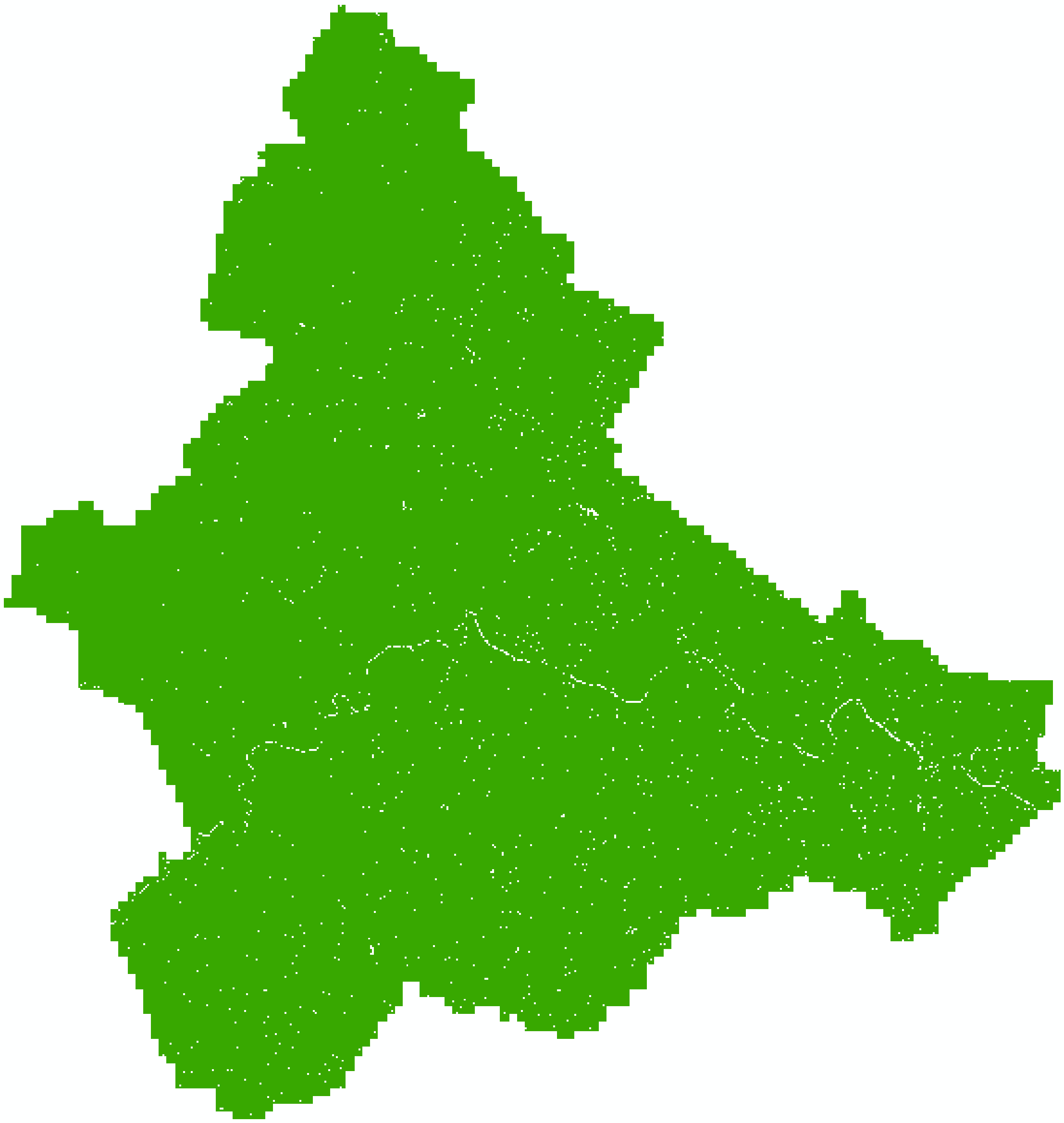

Figure 12– Spatial Distribution. The spatial distribution raster is shown. The cell size is 2*NPS (4.6 feet). Cells with at least one return are shown as green, cells with no returns are shown as white. The cells with no returns are acceptable data voids within water bodies.

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. An algorithm thinning the ground is performed to create class 8, model key points. Overage points are then identified in Terrascan and GeoCue is used to set the overlap bit for the overage points and the withheld bit is set on the withheld points previously identified in Terrascan before the ground classification routine was performed.

The LiDAR tiles were classified to the following classification schema:

- Class 1 = Unclassified, used for all other features that do not fit into the Classes 2, 7, 9, 10, 17, or 18, including vegetation, buildings, etc.
- Class 2 = Bare-Earth Ground
- Class 7 = Low Noise
- Class 8 = Model Key Points
- 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 Chesapeake Bay.

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) and Class 8 (model key points) 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 Chesapeake Bay LiDAR project.

Artifacts

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

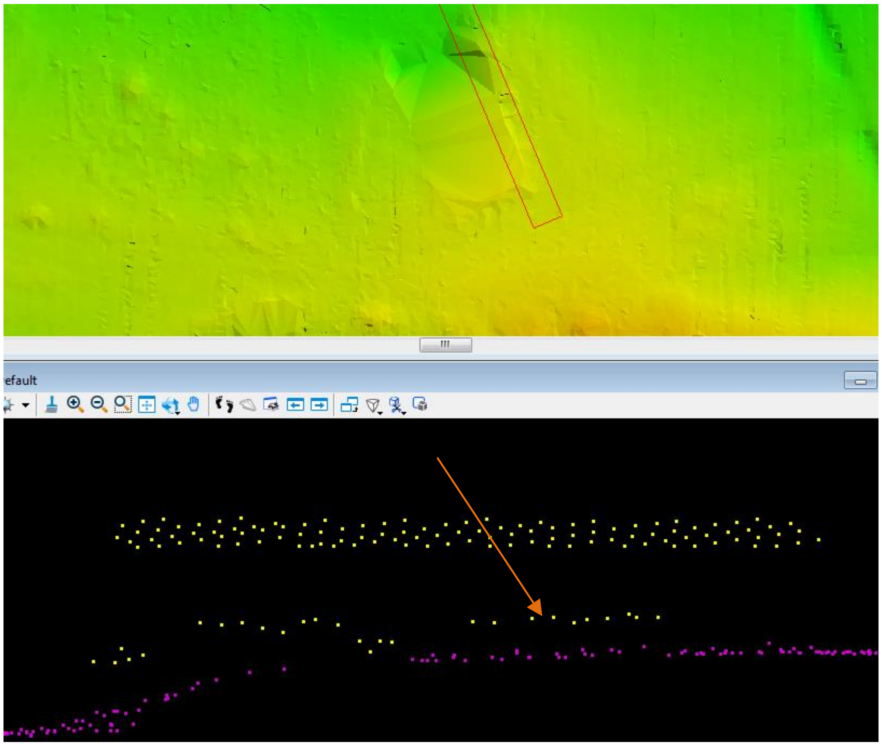

Figure 13 – Tile number LAS_S13_3687_10. Profile with points colored by class (class 1=yellow, class 2=pink) is shown in the bottom view and a TIN of the surface is shown in the top view. The arrow identifies low vegetation points. A limited number of these small features are still classified as ground but do not impact the usability of the dataset.

Bridge Removal Artifacts

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

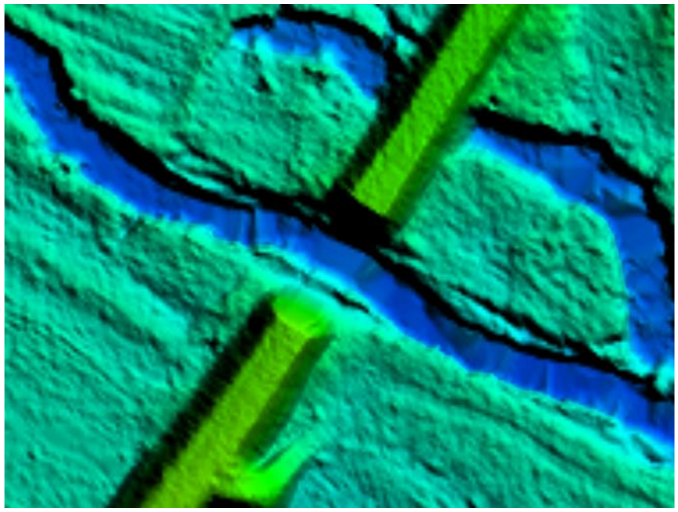

Figure 14 – Tile number DEM_S13_4688_30. The DEM shows an area where a bridge has been removed from ground. The surface model must make a continuous model and in order to do so, points are connected through interpolation. This results in less detail where the surface must be interpolated.

Culverts and Bridges

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

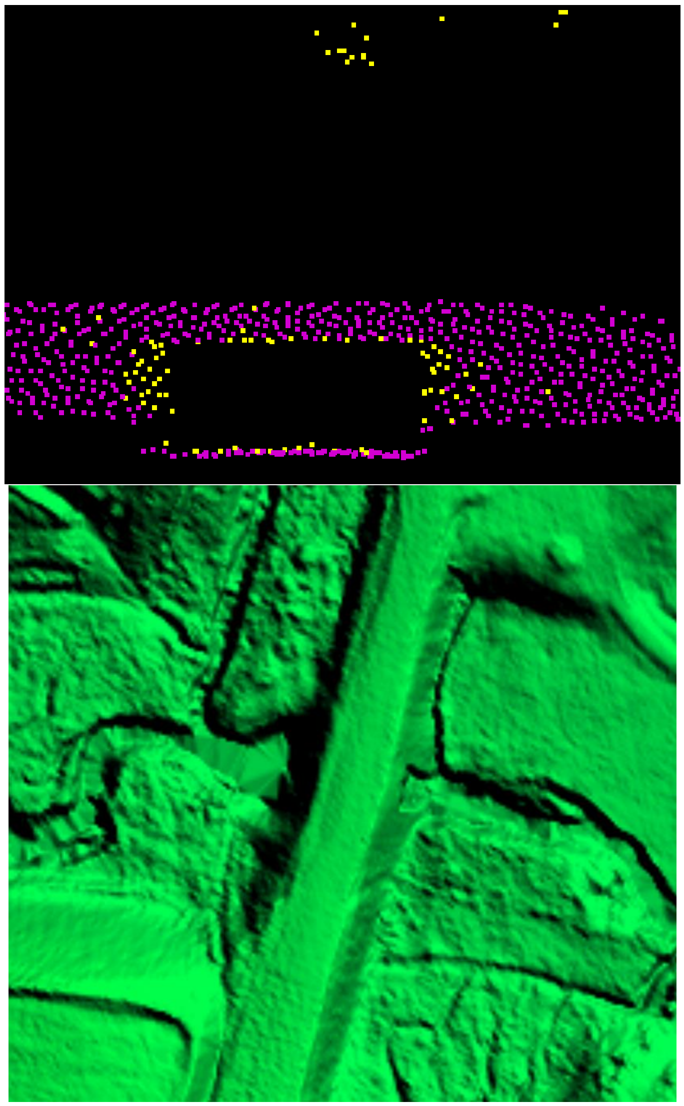

Figure 15– Tile number LAS_S13_7727_10. Profile with points colored by class (class 1=yellow, class 2=pink) is shown in the top view and the DEM is shown in the bottom view. This culvert remains in the bare earth surface. Bridges have been removed from the bare earth surface and classified to class 17.

Elevation Change Within Breaklines

While water bodies are flattened in the final DEMs, other features such as linear hydrographic features can have significant changes in elevation within a small distance. Dewberry has reviewed the DEMs to ensure that changes in elevation are shown from bank to bank. These changes are often shown as steps to reduce the presence of artifacts while ensuring consistent downhill flow. An example is shown below.

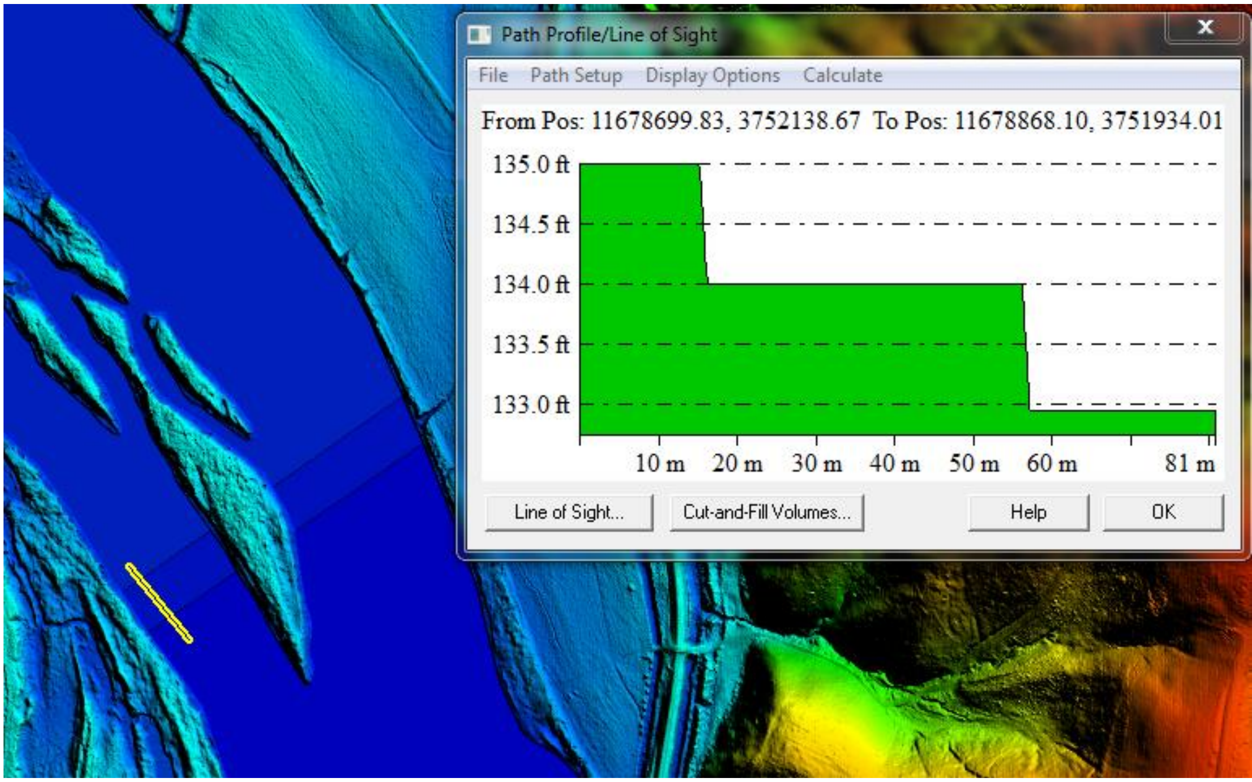

Figure 16 – Tile number LAS_S13_6775_40. Elevation change has been stair stepped. The steps are flat from bank to bank and flow consistently downhill.

Flight line Ridges

Ridges occur when there is a difference between the elevations of adjoining flight lines or swaths. Some flight line 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.

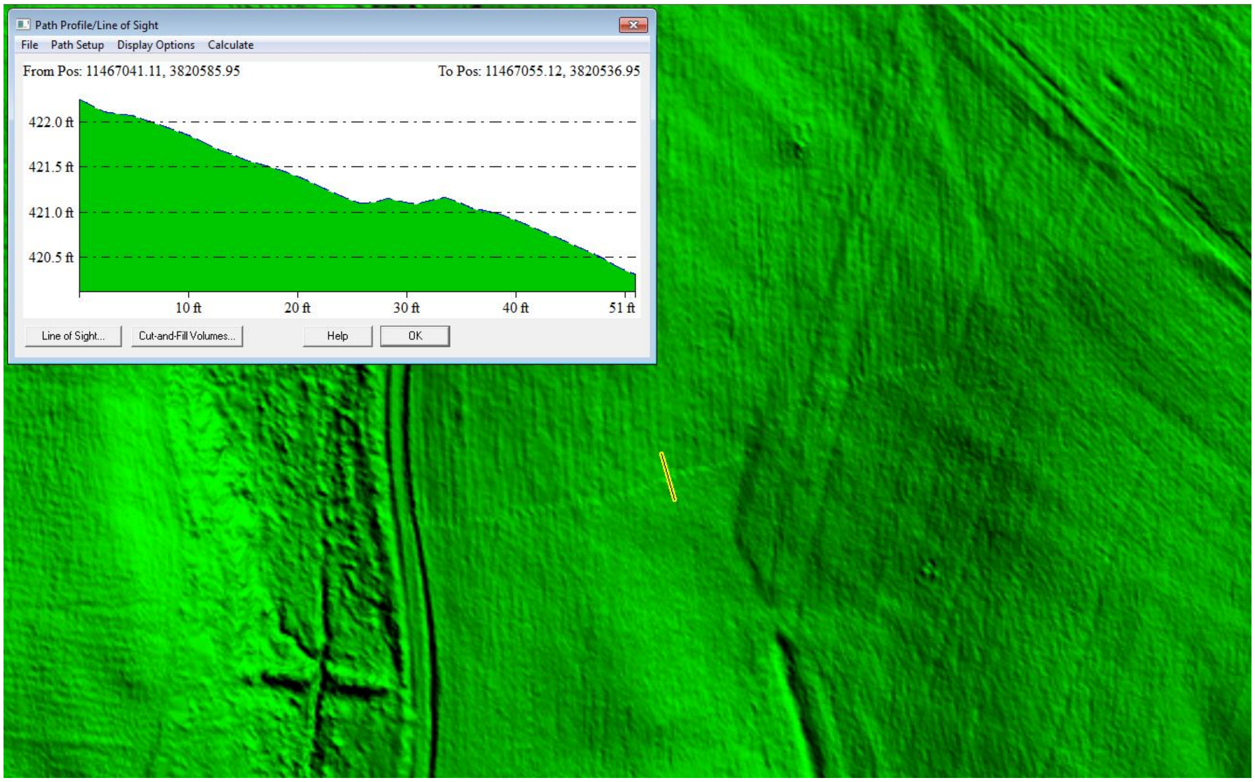

Figure 17– Tile number DEM_S13_4862_40. The flight line ridge is less than 0.25 ft (7.6 cm). Overall, the Chesapeake Bay LiDAR data meets the project specifications for 0.26 ft (8 cm) RMSDz relative accuracy.

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, U.S. Survey Feet and NAVD88 (Geoid 12B), Feet in WKT Format NAD83 (2011) State Plane Virginia North, U.S. Survey Feet and NAVD88 (Geoid 12B), Feet in WKT Format	Pass
Global Encoder Bit	Should be set to 17 for Adjusted GPS Time	Pass
Time Stamp	Adjusted GPS Time (unique timestamps)	Pass
System ID	Should be set to the processing system/software and is set to NIIRS10 for GeoCue software	Pass
Multiple Returns	The sensor shall be able to collect multiple returns per pulse and the return numbers are recorded	Pass
Intensity	16 bit intensity values are recorded for each pulse	Pass
Classification	Required Classes include: Class 1: Unclassified Class 2: Ground Class 7: Low Noise Class 8: Model Key Points Class 9: Water Class 10: Ignored Ground Class 17: Bridge Decks Class 18: High Noise	Pass
Overlap and Withheld Points	Overlap (Overage) and Withheld points are set to the Overlap and Withheld bits	Pass
Scan Angle	Recorded for each pulse	Pass
XYZ Coordinates	Unique Easting, Northing, and Elevation coordinates are recorded for each pulse	Pass

LiDAR Positional Accuracy

BACKGROUND

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

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

SURVEY VERTICAL ACCURACY CHECKPOINTS

For the vertical accuracy assessment, two hundred and two (202) check points were surveyed for the project and are located within bare earth/open terrain, urban, grass/weeds/crops, and forested/fully grown land cover categories. Please see appendix A to view the survey report which details and validates how the survey was completed for this project.

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

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

Point ID	NAD83 (2011) Virginia State Plane South		NAVD88 (Geoid 12B)
	Easting X (ft)	Northing Y (ft)	Elevation (ft)
NVA-1	11420979.03	4036642.52	1246.16
NVA-10	11551175.96	3837036.72	301.13
NVA-100	11604329.38	3701833.97	387.63
NVA-101	11548152.9	3656232.31	408.47
NVA-102	11511652.68	3687693.92	379.62
NVA-103	11489146.66	3651276.29	456.36
NVA-104	11485026.01	3714514.59	672
NVA-105	11427576.17	3709074.52	660.03
NVA-106	11394620.43	3700283.05	656.03
NVA-107	11351772.63	3684428.53	785.98

NVA-108	11386784.33	3657168.54	874.73
NVA-109	11441349.03	3645549.09	628.95
NVA-11	11439317.03	3874029.57	770.26
NVA-110	11407530.64	3620389.41	673.82
NVA-111	11363724.83	3641954.22	754.38
NVA-112	11435580.23	4049180.18	1238.31
NVA-113	11466327.9	4030330.02	1388.49
NVA-114	11429710.14	4017119.14	1014.82
NVA-115	11482309.01	3882991.96	528.16
NVA-12	11418922.59	3838080.77	686
NVA-13	11375090.15	3847941.82	678.73
NVA-14	11362736.26	3841072.75	831.77
NVA-15	11300518.36	3834607.25	2600.33
NVA-16	11318803.84	3785718.24	744.56
NVA-17	11376203.78	3800720.58	761.64
NVA-18	11467521.45	3858928.01	438.71
NVA-19	11454840.03	3826414.07	617.06
NVA-2	11469518.93	4018075.32	2347.52
NVA-20	11539491.34	3780803.2	340.41
NVA-21	11652635.43	3798130.49	358.24
NVA-22	11710908.26	3777724.83	346.44
NVA-23	11722838.12	3737574.74	274.71
NVA-24	11688320.61	3712423.37	361.17
NVA-25	11655926.77	3756795.14	306.95
NVA-26	11591456.33	3763655.66	355.27
NVA-27	11644837.8	3725841.08	377.28
NVA-28	11599722.75	3723440.43	360.92
NVA-29	11585763.02	3695840.38	362.82
NVA-3	11390379.35	3984331.24	1120.05
NVA-30	11524035.98	3706615.16	399.92
NVA-31	11521543.01	3749951.33	510.52
NVA-32	11483735.07	3813927.4	272.61
NVA-33	11418065.74	3756442.03	352.77
NVA-34	11352397.36	3770637.36	766.93
NVA-35	11373108.91	3732604.06	664.65

NVA-36	11445307.33	3760206.22	563.11
NVA-37	11504512.35	3731328.93	600.12
NVA-38	11493037.57	3690607.66	557.86
NVA-39	11519918.01	3656417.25	509.85
NVA-4	11514587.81	3959721.86	528.05
NVA-40	11560512.42	3675888.05	382.31
NVA-41	11525392.98	3639084.76	305.91
NVA-42	11468568.07	3670979.74	610.61
NVA-43	11449402.16	3719240.39	509.05
NVA-44	11366574.35	3700153.86	676.59
NVA-45	11406117.69	3673626.33	826.31
NVA-46	11344936.57	3648747.82	884.86
NVA-47	11413809.14	3629420.52	723.53
NVA-48	11386142.68	3639869.95	854.4
NVA-49	11430368.06	3906721.31	641.47
NVA-5	11382014.81	3944003	1254.53
NVA-50	11520618.94	3928588.32	543.76
NVA-51	11483677.63	3996894.13	795.15
NVA-52	11595071.4	3824468.27	448.88
NVA-53	11446359.57	4053225.54	951.25
NVA-54	11450553.59	4037488.73	1019.05
NVA-55	11471954.05	3982699.44	676.25
NVA-56	11498926.43	3981270.67	616.5
NVA-57	11411172.38	3963040.86	2326.78
NVA-58	11388700.57	3966141.6	1224.32
NVA-59	11468409.87	3966721.68	622.83
NVA-6	11394521.91	3898626.29	842.62
NVA-60	11535299.85	3941101.56	500.9
NVA-61	11535147.78	3907331.31	458.92
NVA-62	11500484	3936818.56	591.05
NVA-63	11435830.83	3931108.42	729.62
NVA-64	11400881.55	3936796.17	2713.03
NVA-65	11407573.55	3903136.02	738.34
NVA-66	11455240.51	3908254.13	520.28
NVA-67	11508232.8	3893872.95	392.97

NVA-68	11553923.19	3857832.35	417.31
NVA-69	11506477.03	3844268.85	547.93
NVA-7	11432665.27	3947894.96	719.63
NVA-70	11474010.34	3835197.17	432.49
NVA-71	11409351.77	3878463.89	883.26
NVA-72	11376168.03	3878550.11	927.87
NVA-73	11384687.08	3857871.56	602.91
NVA-74	11329920.18	3834086.79	1029.29
NVA-75	11339032.82	3811677.25	734.02
NVA-76	11396214.32	3832097.77	565.06
NVA-77	11458236.31	3809248.48	406.42
NVA-78	11523118.62	3816391.93	503.68
NVA-79	11579042.14	3800881.37	248.83
NVA-8	11481483.27	3907450.72	486.47
NVA-80	11633169.71	3794672.86	329.37
NVA-81	11692713.26	3785204.69	359.86
NVA-82	11681782.74	3756862.96	275.73
NVA-83	11668510.41	3733234.08	336.27
NVA-84	11674937.03	3683133.7	305.17
NVA-85	11643753.76	3704217.96	330.66
NVA-86	11633242.17	3757413.62	335.28
NVA-87	11510673.72	3872168.99	320.79
NVA-88	11580625.09	3744804.63	379.38
NVA-89	11556706.24	3716408.72	419.19
NVA-9	11529853.62	3886372.83	460.93
NVA-90	11537467.99	3742548.82	428.08
NVA-91	11502745.94	3781406.53	378.65
NVA-92	11453546.19	3778921.15	566.26
NVA-93	11415806.78	3794928.56	486.78
NVA-94	11359280.07	3795713.5	722.17
NVA-95	11391204.93	3758691.43	367.63
NVA-96	11382995.67	3728364.81	634.63
NVA-97	11437101.43	3737594.58	592.61
NVA-98	11510233.93	3738007.79	602.42
NVA-99	11543503.29	3690425.89	475.53

VVA-1	11441359.19	4053473.43	961.17
VVA-10	11480309.88	3970994.1	623.55
VVA-11	11559243.47	3929949.19	518.48
VVA-12	11512059.99	3914191.71	599.38
VVA-13	11468912.01	3930287.07	586.47
VVA-14	11434007.59	3944048.12	679.03
VVA-15	11404542.15	3943565.93	2985.2
VVA-16	11425731.89	3918769.96	725.71
VVA-17	11498834.79	3884998.22	537.22
VVA-18	11525229.93	3859373.06	363.11
VVA-19	11572585.12	3847387.43	420.32
VVA-2	11463402.05	4040766.71	1223.12
VVA-20	11459003.36	3867185.78	659.72
VVA-21	11425063.18	3892555.54	549.04
VVA-22	11395476.83	3885053.22	803.76
VVA-23	11384833.91	3866724.49	698.73
VVA-24	11404107.95	3856095.11	858.38
VVA-25	11488413.1	3851754.33	489.62
VVA-26	11466612.26	3838714.53	554.34
VVA-27	11531828.14	3832281.06	388
VVA-28	11568507.5	3818535.79	218.21
VVA-29	11622202.45	3807393.79	373.32
VVA-3	11486440.81	4039139.05	3137.85
VVA-30	11610915.62	3783912.83	331.3
VVA-31	11679224.8	3795662.96	340.66
VVA-32	11687645.67	3773283.04	344.65
VVA-33	11724235.43	3775602.18	262.47
VVA-34	11702575.48	3724800.77	235.17
VVA-35	11670254.38	3699688.73	338.29
VVA-36	11661316.19	3747292.24	298.34
VVA-37	11638942.46	3713994.9	359.62
VVA-38	11633280.36	3740466.11	293.73
VVA-39	11579167.58	3785025.46	371.76
VVA-4	11489832.13	4003911.32	986.63
VVA-40	11546310.64	3804078.77	460.81

VVA-41	11486315.69	3810489.52	277.08
VVA-42	11469269.08	3819408.45	375.99
VVA-43	11413535.48	3826235.1	666.79
VVA-44	11372686.45	3847390.3	708.46
VVA-45	11313622.26	3855988.38	3297.53
VVA-46	11300550.31	3834451.84	2595
VVA-47	11337593.76	3823838.3	837.92
VVA-48	11325059.07	3806542.96	921.38
VVA-49	11372527.9	3820273.71	875.31
VVA-5	11432640.92	4037204.22	1082.64
VVA-50	11423047.38	3801496.77	552.85
VVA-51	11473671.09	3790875.18	457.12
VVA-52	11521629.11	3773456.42	433.4
VVA-53	11563369.87	3761869.24	365.36
VVA-54	11607033.83	3743230.53	307.3
VVA-55	11612735.67	3719391.37	294.58
VVA-56	11593068.44	3692980.8	348.96
VVA-57	11561232.09	3731033.9	360.33
VVA-58	11525912.83	3740407.03	474.82
VVA-59	11498972.82	3756215.57	401.92
VVA-6	11439676.71	4026597.9	1014.58
VVA-61	11396562.87	3783715.03	959.15
VVA-62	11361292.19	3777003.41	606.77
VVA-63	11360631.55	3752003.81	714.03
VVA-64	11394412.68	3750634.83	561.83
VVA-65	11426083.34	3746291.08	682.57
VVA-66	11464708.5	3729025.72	468.9
VVA-67	11508585.35	3708520.57	535.38
VVA-68	11551581.79	3698198.44	384.38
VVA-69	11568723.91	3682214.99	352.81
VVA-7	11456504	4004591.27	2296.44
VVA-70	11542604.96	3676690.81	391.74
VVA-71	11528351.34	3664060.61	496.39
VVA-72	11511690.81	3646874.4	384.67
VVA-73	11501529.27	3680653.8	377.02

VVA-74	11476601.77	3694203.8	585.54
VVA-75	11430666.18	3725978.27	583.3
VVA-76	11410507.38	3721648.18	850.83
VVA-77	11383166.66	3710245.25	602.44
VVA-78	11373234.88	3688973.91	805.59
VVA-79	11340437.57	3677084.47	776.79
VVA-8	11411203.68	4002454.96	1094.61
VVA-80	11380268.19	3665176.06	788.31
VVA-81	11421198.66	3689249.74	869.55
VVA-82	11456161.7	3679860.16	610.74
VVA-83	11478833.28	3661114.4	586.62
VVA-84	11441992.92	3662848.57	608.69
VVA-85	11410817.39	3649783.23	721.09
VVA-86	11387555.97	3631415.68	730.55
VVA-87	11373835.8	3628487.58	749.7
VVA-88	11418731.69	3613463.09	674.84
VVA-9	11417919.45	3971585.93	2790.35

Table 6: Chesapeake Bay LiDAR surveyed accuracy checkpoints

Two hundred and two checkpoints were surveyed for vertical accuracy testing. This was done in NAD 83 (2011) UTM zone 17 U.S. Survey Feet. Since the final delivery is in Virginia State Plane North and South U.S. Survey Feet the check points where converted to Virginia State Plane South U.S. Survey Feet to be used for accuracy testing. The revised coordinates and elevations were used in the final vertical accuracy testing. Table 6, above, includes all revised coordinates and contains the final coordinates as used in the vertical accuracy testing. The original coordinates provided by the surveyor can be found in Appendix A.

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

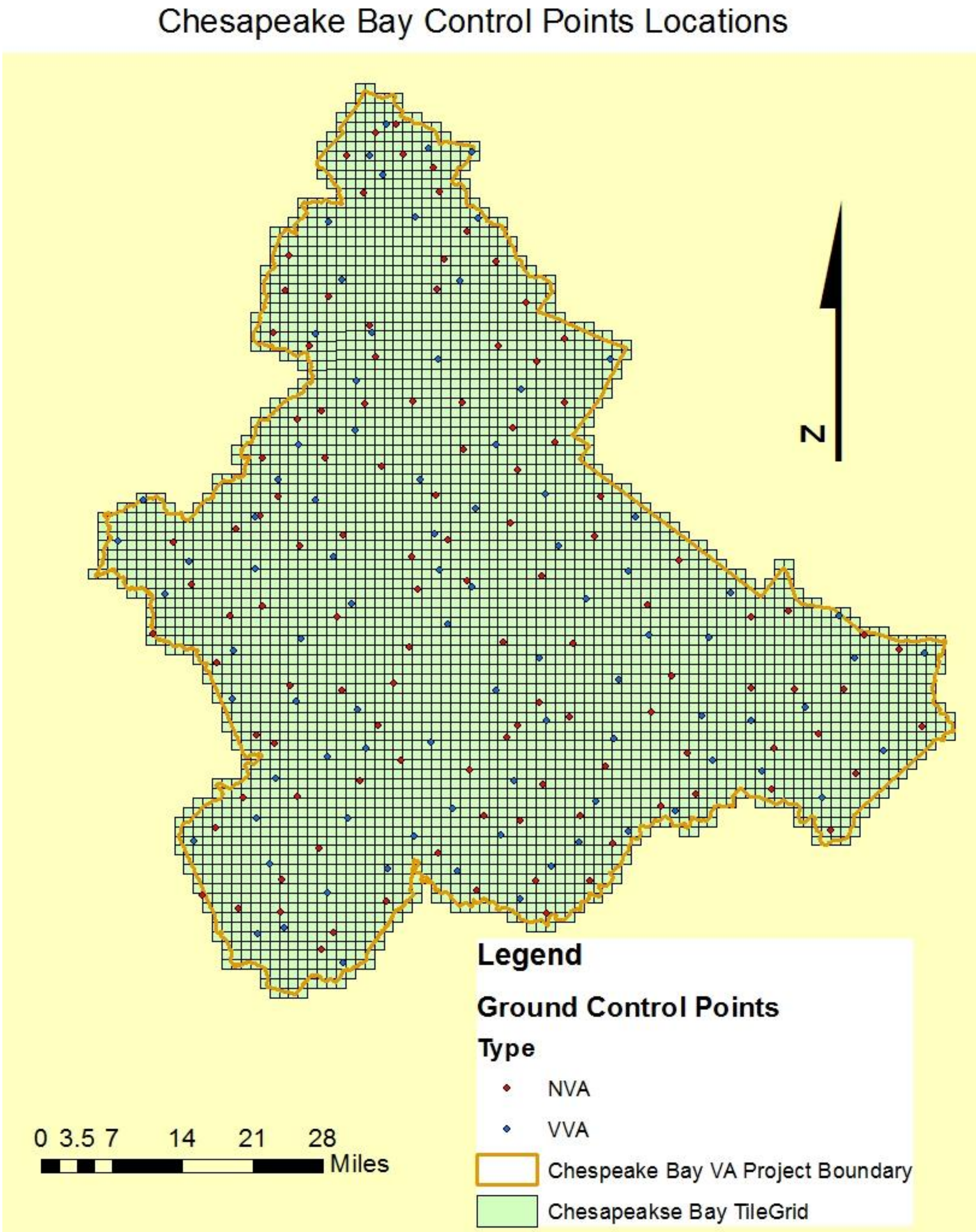

Figure 18 – Location of QA/QC Checkpoints

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 Chesapeake Bay LiDAR project, vertical accuracy must be 0.64 feet (19.6 cm) or less based on an $RMSE_z$ of 0.33 feet (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 Chesapeake Bay LiDAR Project VVA standard is 0.96 feet (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 feet (19.6 cm) (based on $RMSE_z$ (0.33 feet/10 cm) * 1.9600)
Vegetated Vertical Accuracy (VVA) in all vegetated land cover categories combined at the 95% confidence level	0.96 feet (29.4 cm) (based on combined 95th percentile)

Table 7 — Acceptance Criteria

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

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

VERTICAL ACCURACY RESULTS

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

Land Cover Category	# of Points	NVA – Non-vegetated Vertical Accuracy ($RMSE_z$ x	VVA – Vegetated Vertical Accuracy

		1.9600) Spec=0.64ft	(95th Percentile) Spec=0.96ft
NVA	115	0.55	
VVA	87		0.74

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 feet (10 cm) RMSEz Vertical Accuracy Class. Actual NVA accuracy was found to be $RMSE_z$ =0.28 feet (8.53 cm), equating to +/- 0.55 feet (16.8 cm) at 95% confidence level. Actual VVA accuracy was found to be +/- 0.74 feet (22.6 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 +/- 0.50 feet of the checkpoints elevations, but there were some outliers where LiDAR and checkpoint elevations differed by up to +1.03 feet.

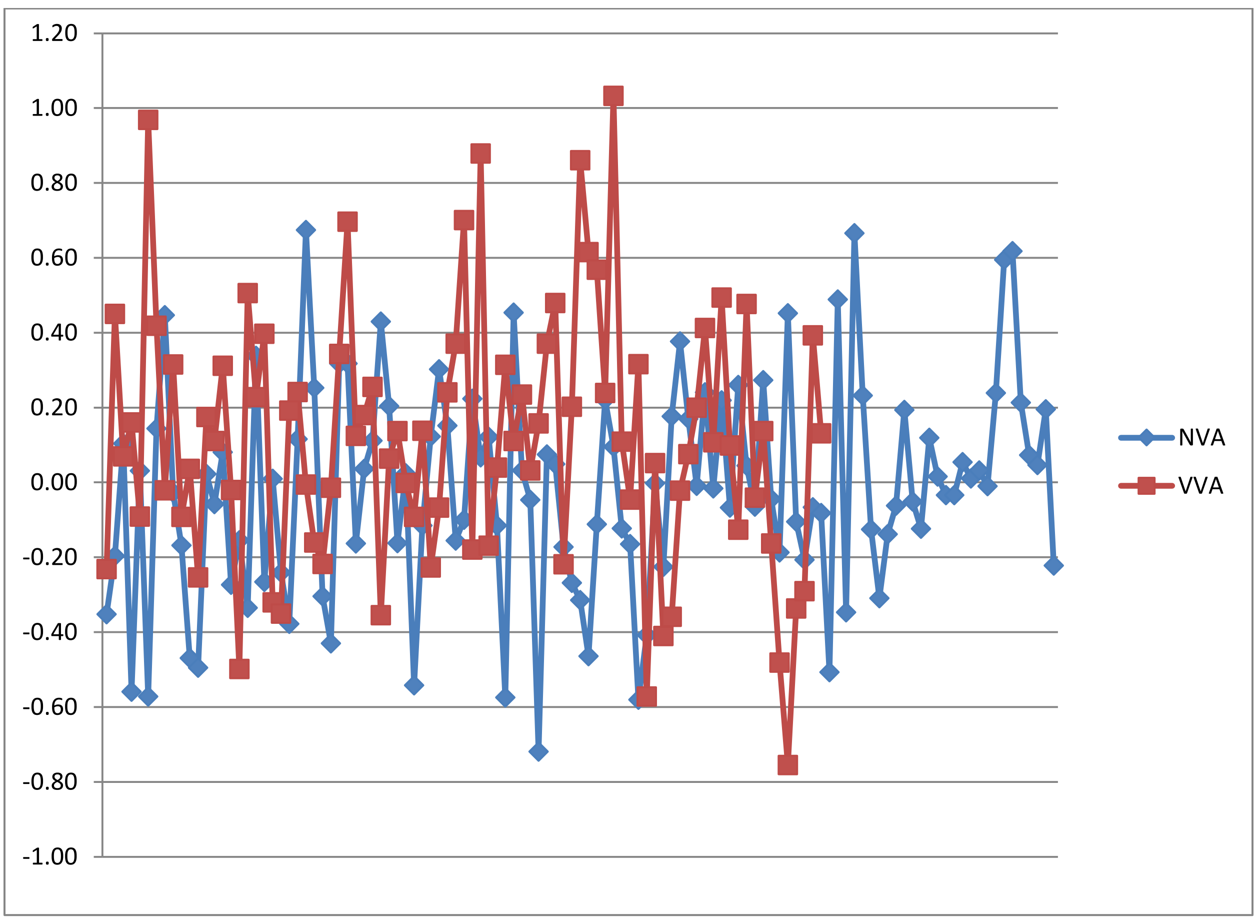

Figure 19 – Magnitude of elevation discrepancies per land cover category

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

Point ID	NAD83 (2011) Virginia State Plane South		NAVD88 (Geoid 12B)	LiDAR Z (ft)	Delta Z	AbsDeltaZ
	Easting X (ft)	Northing Y (ft)	Survey Z (ft)			
VVA-14	11434007.59	3944048.12	679.03	680.00	0.97	0.97
VVA-50	11423047.38	3801496.77	552.85	553.73	0.88	0.879
VVA-62	11361292.19	3777003.41	606.77	607.63	0.86	0.86
VVA-66	11464708.50	3729025.72	468.90	469.93	1.03	1.03
VVA-85	11410817.39	3649783.23	721.09	720.33	-0.75	0.76

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)
NVA	115.00	0.28	-0.02	-0.01	0.03	0.28	0.05	-0.72	0.67
VVA	87.00	N/A	0.11	0.11	0.27	0.34	0.40	-0.75	1.03

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 -0.75 feet and a high of +1.03 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 -0.65 feet to +0.65 feet.

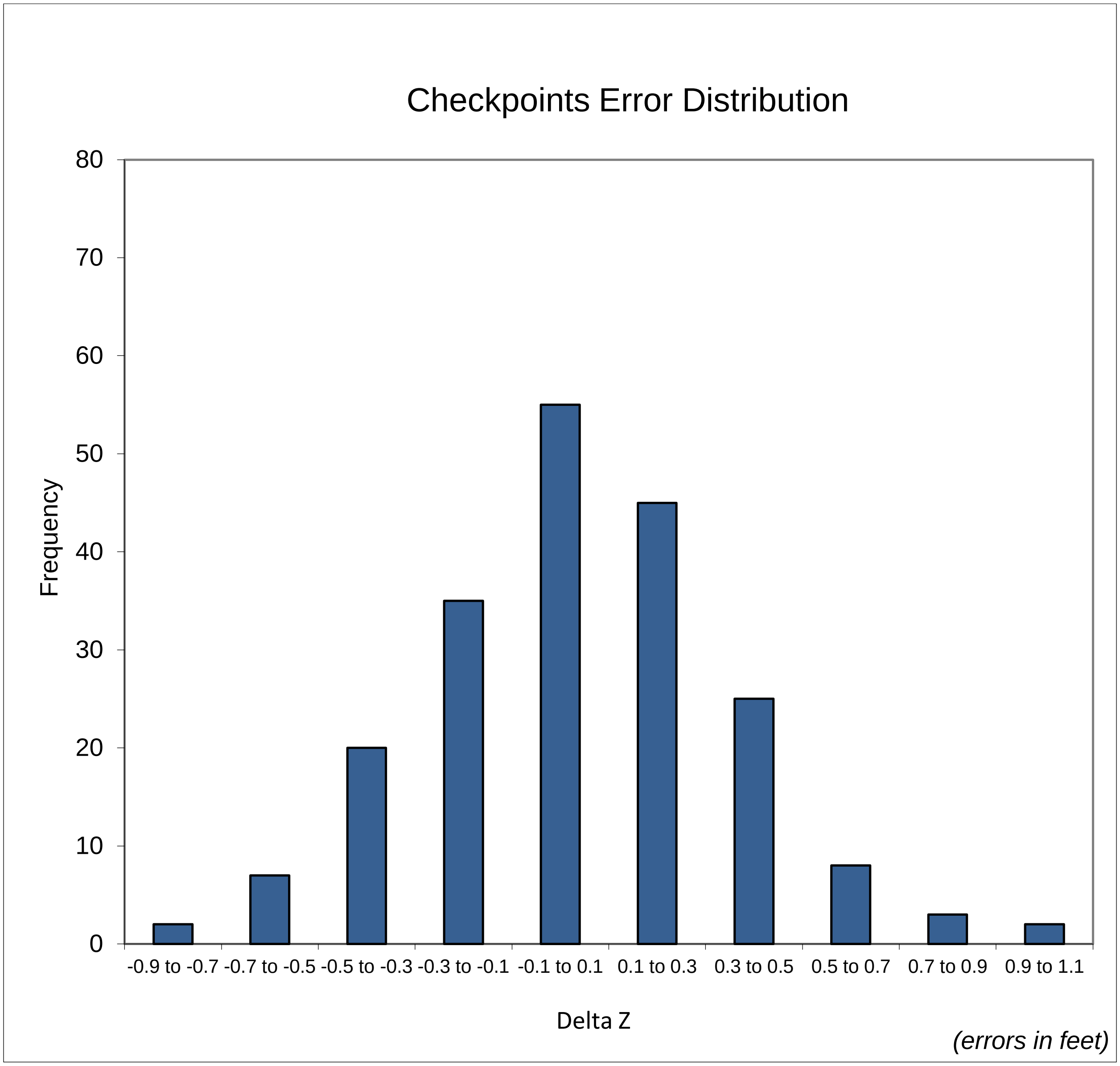

Figure 20 — Histogram of Elevation Discrepancies with errors in feet

Based on the vertical accuracy testing conducted by Dewberry, the LiDAR dataset for the Chesapeake Bay 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

Seven 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 seven (7) 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 (3.28 ft) or less.

# of Points	$RMSE_x$ (Target=1.34 ft)	$RMSE_y$ (Target=1.34 ft)	$RMSE_r$ (Target=1.9 ft)	$ACCURACY_r$ ($RMSE_r$ x 1.7308) Target=3.28 ft
7	0.50	0.52	0.72	1.25

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

Actual positional accuracy of this dataset was found to be RMSEx = 0.50 ft (15.2 cm) and RMSEy = 0.52 ft (15.8 cm) which equates to +/- 1.25 ft (38.1 cm) at 95% confidence level.

Breakline Production & Qualitative Assessment Report

BREAKLINE PRODUCTION METHODOLOGY

Dewberry used GeoCue software to develop LiDAR stereo models of the Chesapeake Bay 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 hydrographic hard breaklines in accordance with the project's Data Dictionary.

All drainage breaklines are monotonically enforced to show downhill flow. Water bodies are reviewed in stereo and the lowest elevation is applied to the entire waterbody.

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.

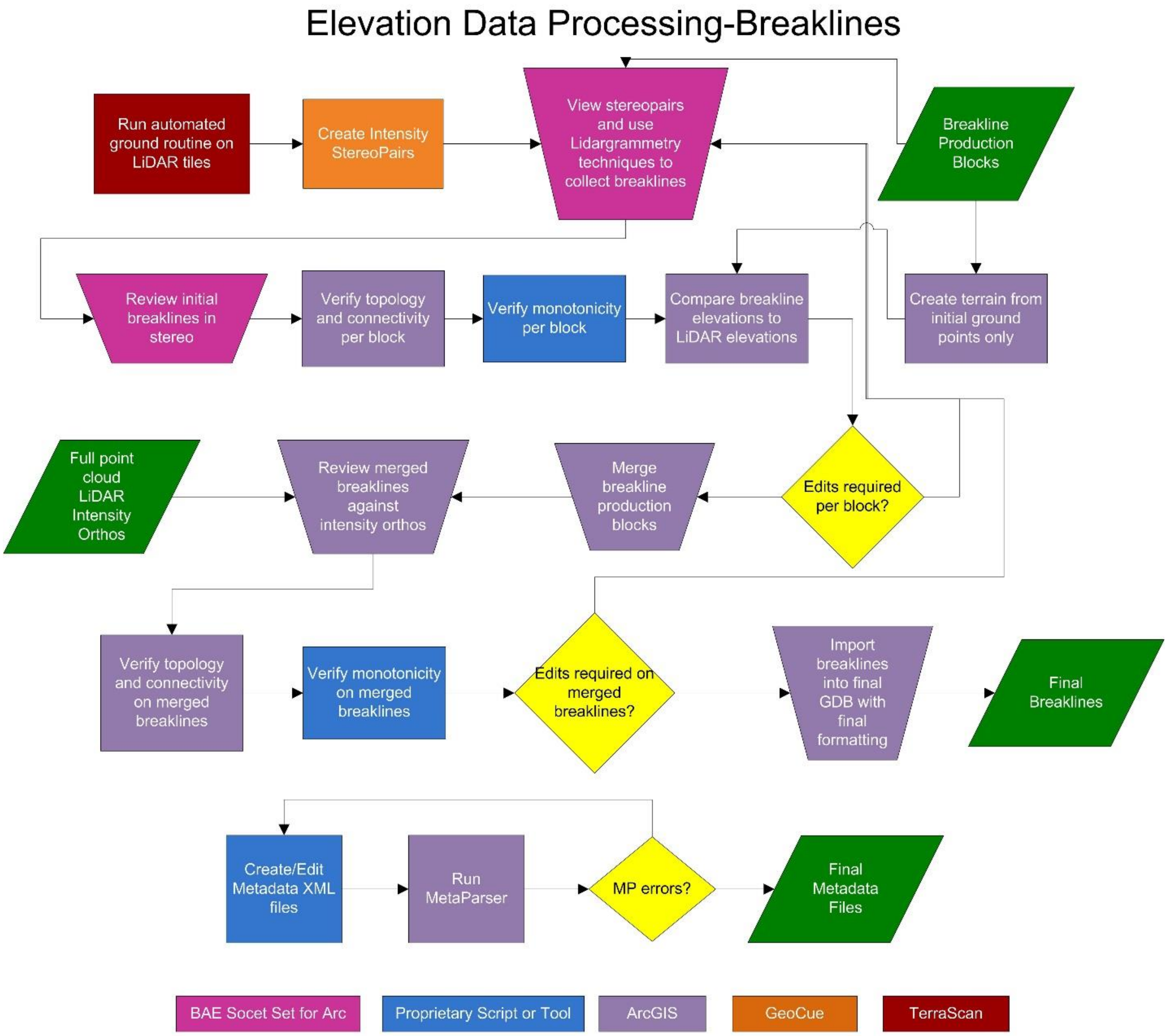

Figure 21-Breakline QA/QC workflow

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 Survey Feet. The vertical datum shall be referenced to the North American Vertical Datum of 1988 (NAVD 88), Units in Feet. Geoid12B 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 Survey Feet and Vertical Units in Survey Feet.

Inland Streams and Rivers

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

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

Description

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

Table Definition

Field Name	Data Type	Allow Null Values	Default Value	Domain	Precision	Scale	Length	Responsibility
OBJECTID	Object ID							Assigned by Software

SHAPE	Geometry							Assigned by Software
SHAPE_LENGTH	Double	Yes			0	0		Calculated by Software
SHAPE_AREA	Double	Yes			0	0		Calculated by Software

Feature Definition

Description	Definition	Capture Rules
Streams and Rivers	Linear hydrographic features such as streams, rivers, canals, etc. with an average width greater than 100 feet. In the case of embankments, if the feature forms a natural dual line channel, then capture it consistent with the capture rules. Other natural or manmade embankments will not qualify for this project.	Capture features showing dual line (one on each side of the feature). Average width shall be greater than 100 feet to show as a double line. Each vertex placed should maintain vertical integrity. Generally both banks shall be collected to show consistent downhill flow. There are exceptions to this rule where a small branch or offshoot of the stream or river is present. The banks of the stream must be captured at the same elevation to ensure flatness of the water feature. If the elevation of the banks appears to be different see the task manager or PM for further guidance. Breaklines must be captured at or just below the elevations of the immediately surrounding terrain. Under no circumstances should a feature be elevated above the surrounding LiDAR points. Acceptable variance in the negative direction will be defined for each project individually. These instructions are only for docks or piers that follow the coastline or water's edge, not for docks or piers that extend perpendicular from the land into the water. If it can be reasonably determined where the edge of water most probably falls, beneath the dock or pier, then the edge of water will be collected at the elevation of the water where it can be directly measured. If there is a clearly-indicated headwall or bulkhead adjacent to the dock or pier and it is evident that the waterline is most probably adjacent to the headwall or bulkhead, then the water line will follow the headwall or bulkhead at the elevation of the water where it can be directly measured. If there is no clear indication of the location of the water's edge beneath the dock or pier, then the edge of water will follow the outer edge of the dock or pier as it is adjacent to the water, at the measured elevation of the water. Every effort should be made to avoid breaking a stream or river into segments. Dual line features shall break at road crossings (culverts). In areas where a bridge is present the dual line feature shall continue through the bridge. Islands: The double line stream shall be captured around an island if the island is greater than 1 acre. In this case a segmented polygon shall be used around the island in order to allow for the island feature to remain as a "hole" in the feature.

Inland Ponds and Lakes

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

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

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

Table Definition

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

Feature Definition

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

		clear indication of the location of the water's edge beneath the dock or pier, then the edge of water will follow the outer edge of the dock or pier as it is adjacent to the water, at the measured elevation of the water.

Beneath Bridge Breaklines

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

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

Description

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

Table Definition

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

Feature Definition

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

DEM Production & Qualitative Assessment

DEM PRODUCTION METHODOLOGY

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

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

Figure 22-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 images below show an example of a bare earth DEM.

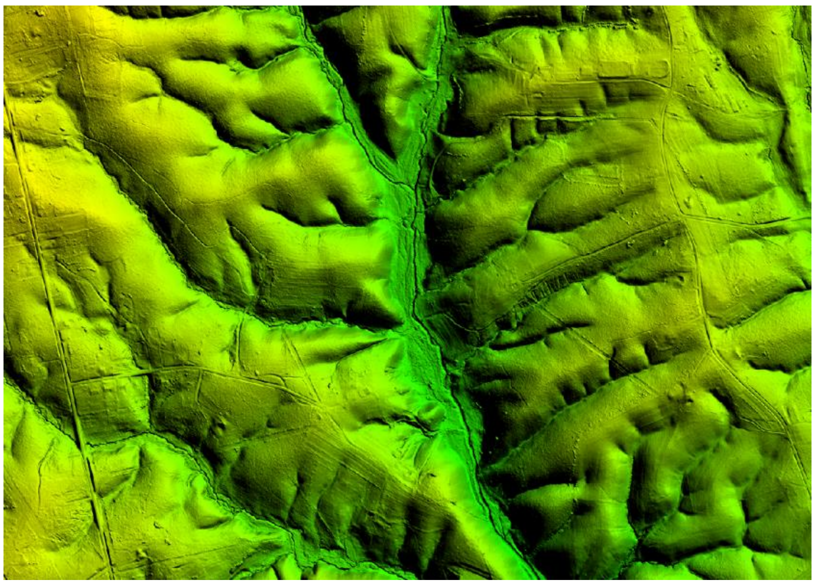

Figure 23 – LAS_S13_3693_10. The bare earth DEM is shown.

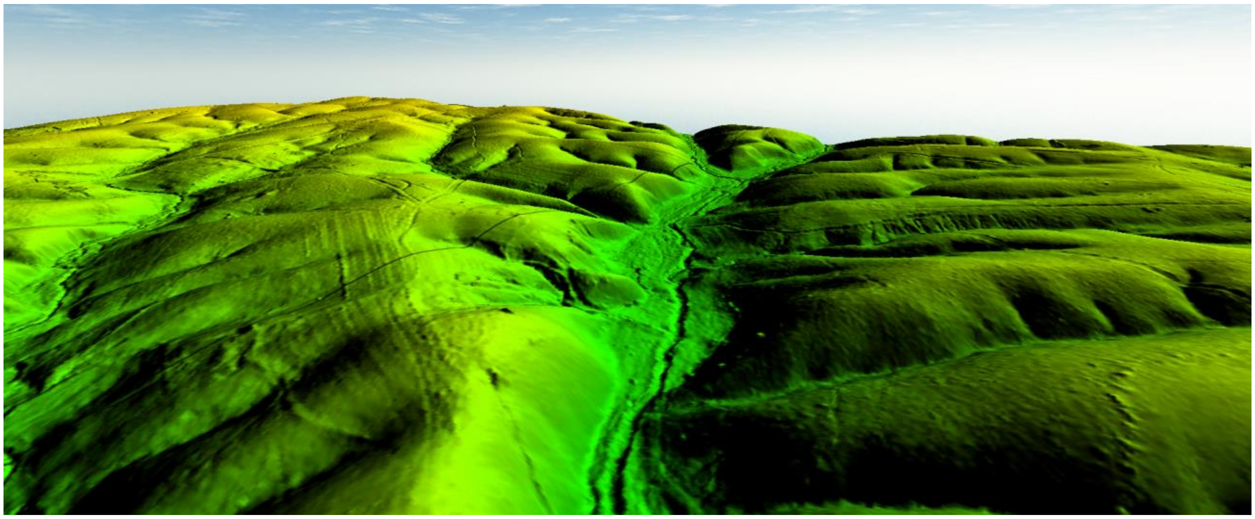

Figure 24- DEM_S13_3693_10. 3D Profile view of the bare earth DEM

When some bridges are removed from the ground surface, the distance from bridge abutment to bridge abutment is small enough that the DEM interpolates across the entire bridge opening, forming 'bridge saddles.' Dewberry collected 3D bridge breaklines in locations where bridge saddles were present and enforced these breaklines in the final DEM creation to help mitigate the bridge saddle artifacts. The image below on the left shows a bridge saddle while the image below on the right shows the same bridge after bridge breaklines have been enforced.

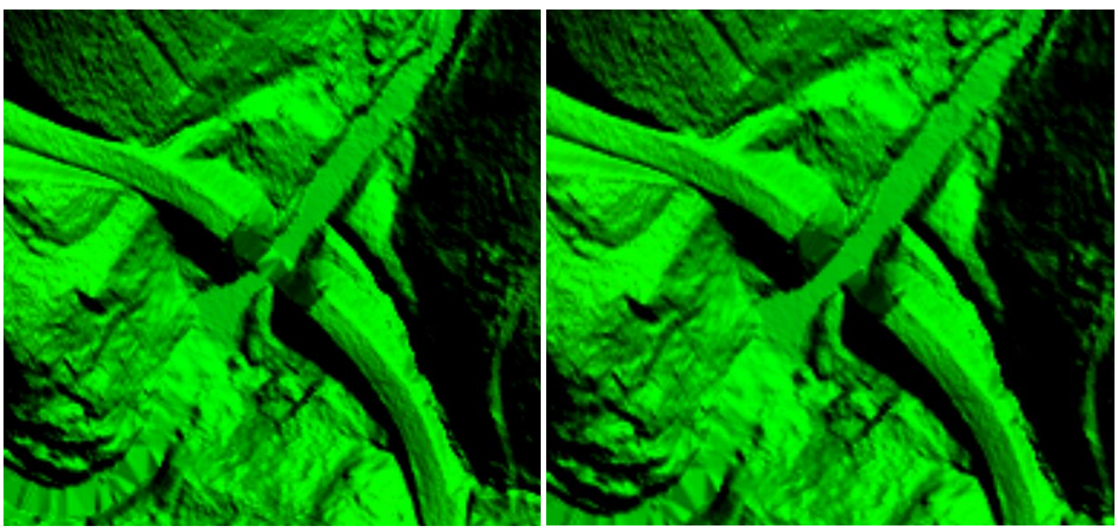

Figure 25-DEM_S13_4678_30. The DEM on the left shows a bridge saddle artifact while the DEM on the right shows the same location after bridge breaklines have been enforced.

DEM VERTICAL ACCURACY RESULTS

The same 202 checkpoints that were used to test the vertical accuracy of the LiDAR were used to validate the vertical accuracy of the final DEM products as well. Accuracy results may vary between the source LiDAR and final DEM deliverable. DEMs are created by averaging several LiDAR points within each pixel which may result in slightly different elevation values at each survey checkpoint when compared to the source LAS, which does not average several LiDAR points together but may interpolate (linearly) between two or three points to derive an elevation value. The vertical accuracy of the DEM is tested by extracting the elevation of the pixel that contains the x/y coordinates of the checkpoint and comparing these DEM elevations to the surveyed elevations. Dewberry typically uses LP360 software to test the swath LIDAR vertical accuracy, Terrascan software to test the classified LiDAR vertical accuracy, and Esri ArcMap to test the DEM vertical accuracy so that three different software programs are used to validate the vertical accuracy for each project.

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

Land Cover Category	# of Points	NVA – Non-vegetated Vertical Accuracy (RMSE$_z$ x 1.9600) Spec=0.64 ft	VVA – Vegetated Vertical Accuracy (95th Percentile) Spec=0.96 ft
NVA	115	0.55	
VVA	87		0.72

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$_z$ =0.28 ft (8.53 cm), equating to +/- 0.55 ft (16.8 cm) at 95% confidence level. Actual VVA accuracy was found to be +/- 0.72 ft (21.9 cm)at the 95th percentile.

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

Point ID	NAD83 (2011) Virginia State Plane South		NAVD88 (Geoid 12B)	DEM Z (ft)	Delta Z	AbsDeltaZ
	Easting X (ft)	Northing Y (ft)	Survey Z (ft)			
VVA-14	11434007.590	3944048.120	679.030	679.890	0.860	0.860
VVA-85	11410817.390	3649783.230	721.090	720.360	-0.730	0.730
VVA-50	11423047.380	3801496.770	552.850	553.730	0.880	0.880
VVA-62	11361292.190	3777003.410	606.770	607.620	0.850	0.850
VVA-66	11464708.500	3729025.720	468.900	469.910	1.010	1.010

Table 14 – 5% Outliers

Table 15 provides overall descriptive statistics.

100 % of Totals	# of Points	RMSEz (ft) NVA Spec=0.33ft	Mean (ft)	Median (ft)	Skew	Std Dev (ft)	Kurtosis	Min (ft)	Max (ft)
NVA	115.00	0.28	-0.02	-0.01	0.04	0.28	0.27	-0.70	0.66
VVA	87.00	N/A	0.13	0.12	0.17	0.33	0.37	-0.72	1.02

Table 15 – Overall Descriptive Statistics

Based on the vertical accuracy testing conducted by Dewberry, the DEM dataset for the Chesapeake Bay 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

1.1 *Project Summary*

Dewberry Consultants LLC is under contract to the United States Geological Survey to provide 202 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 November 18-21 & November 30 – December 5, 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 17 North, NAD83 in feet. Final Vertical elevations are referenced to NAVD88 in feet using Geoid model 2012B (Geoid12B).

1.2 *Points of Contact*

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

Dewberry Consultants LLC

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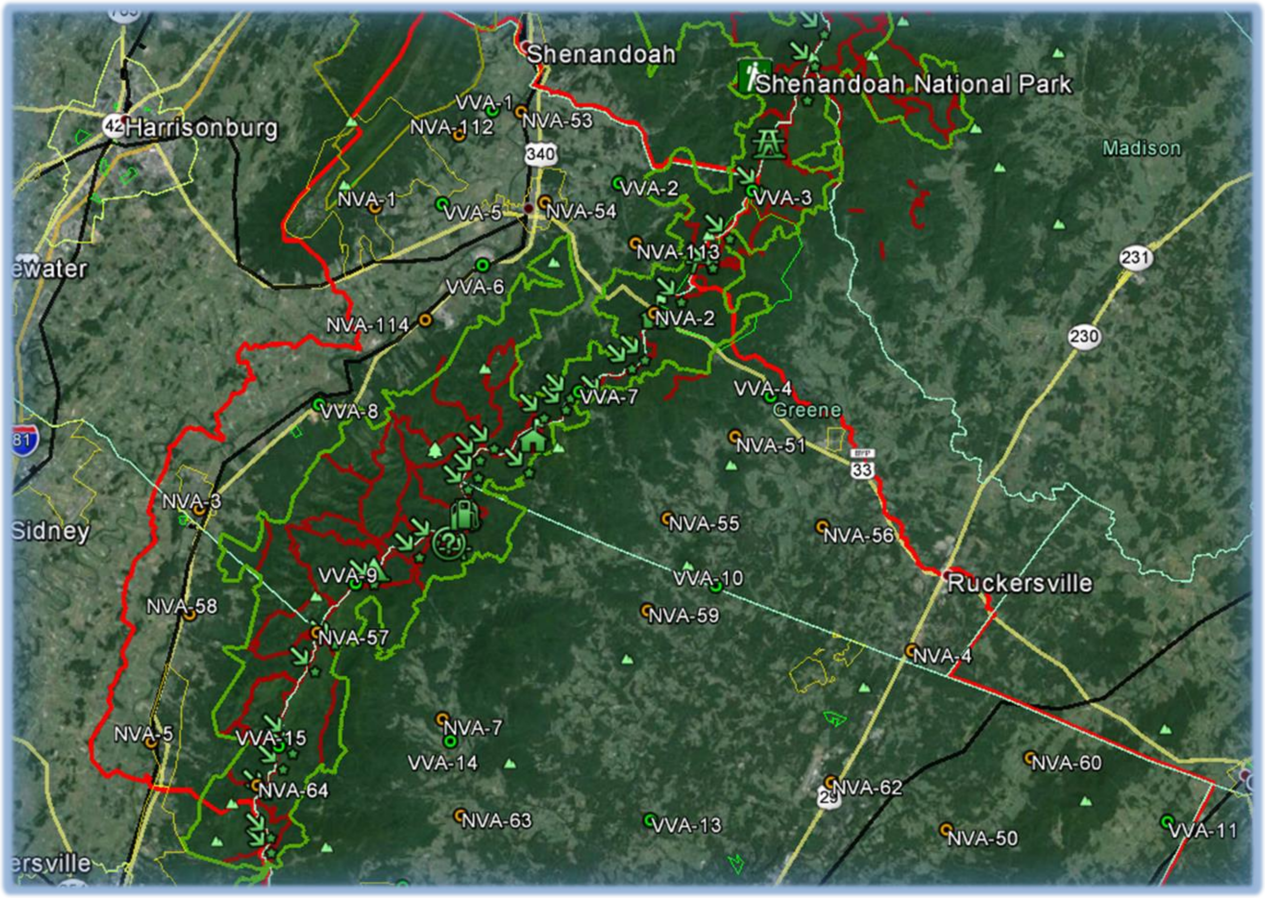
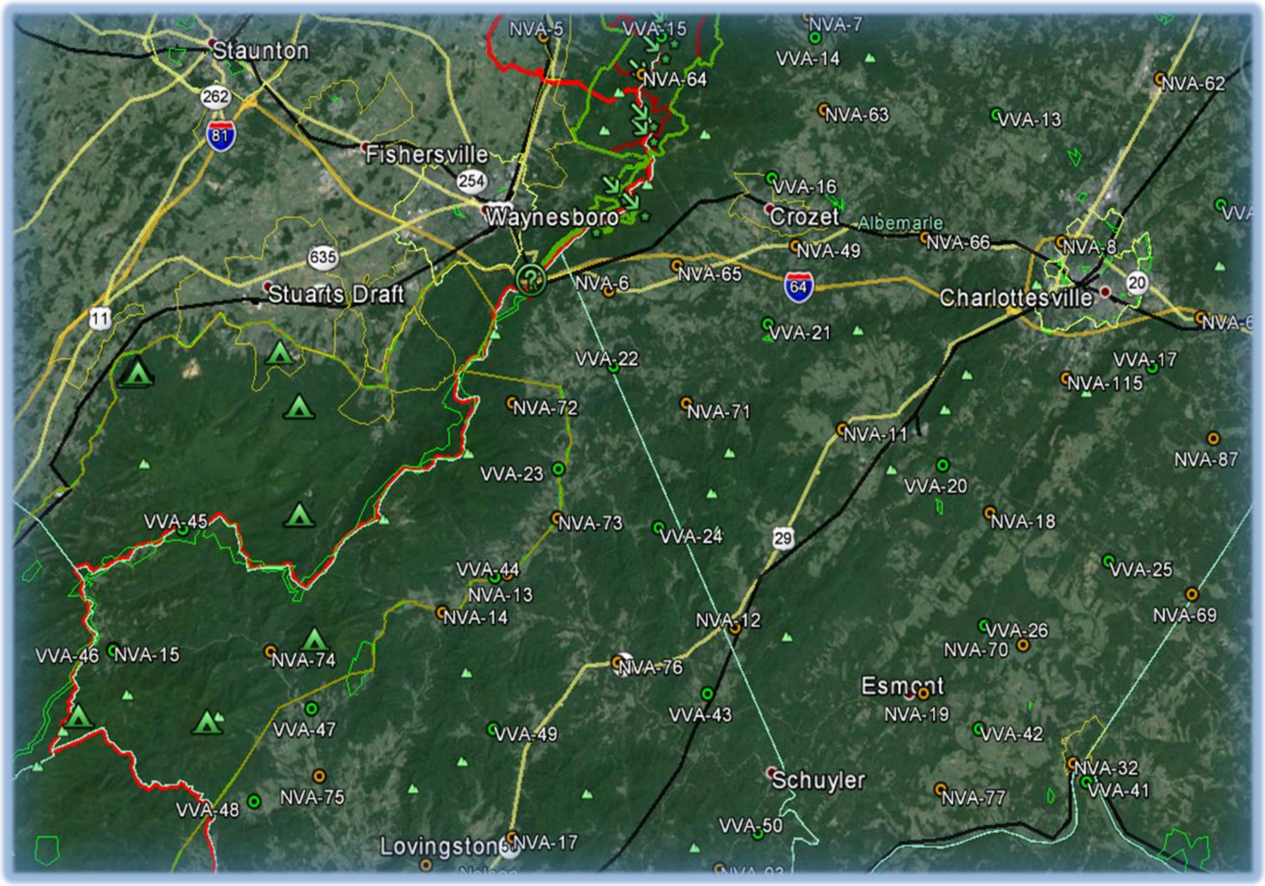
Senior Associate
10003 Derekwood Lane
Suite 204
Lanham, Maryland 20706
(301) 364-1855 direct
(301) 731-0188 fax

1.3 *Project Area*


Shenandoah
Shenandoah National Park
Harrisonburg
Madison
VVA-1
NVA-112
NVA-53
340
NVA-1
VVA-5
NVA-54
VVA-2
VVA-3
NVA-113
231
VVA-6
NVA-114
NVA-2
230
VVA-7
VVA-4
Greene
VVA-8
NVA-51
33
NVA-3
Sidney
NVA-55
NVA-56
VVA-9
VVA-10
Ruckersville
NVA-58
NVA-59
NVA-57
NVA-4
NVA-5
VVA-15
NVA-7
VVA-14
NVA-60
NVA-64
NVA-62
NVA-63
VVA-13
NVA-50
VVA-11


Staunton
262
81
Fishersville
254
Waynesboro
635
Stuarts Draft
11
NVA-5
VVA-15
NVA-64
NVA-7
VVA-14
NVA-63
VVA-13
NVA-62
VVA-16
Crozet
Albemarle
NVA-66
NVA-49
NVA-8
20
NVA-6
NVA-65
64
Charlottesville
VVA-21
VVA-22
VVA-17
NVA-115
NVA-72
NVA-71
NVA-11
NVA-87
VVA-23
VVA-20
VVA-45
NVA-73
VVA-24
29
NVA-18
VVA-25
VVA-44
NVA-13
NVA-14
NVA-12
NVA-69
VVA-26
NVA-70
VVA-46
NVA-15
NVA-74
NVA-76
Esmont
NVA-19
VVA-47
VVA-43
VVA-49
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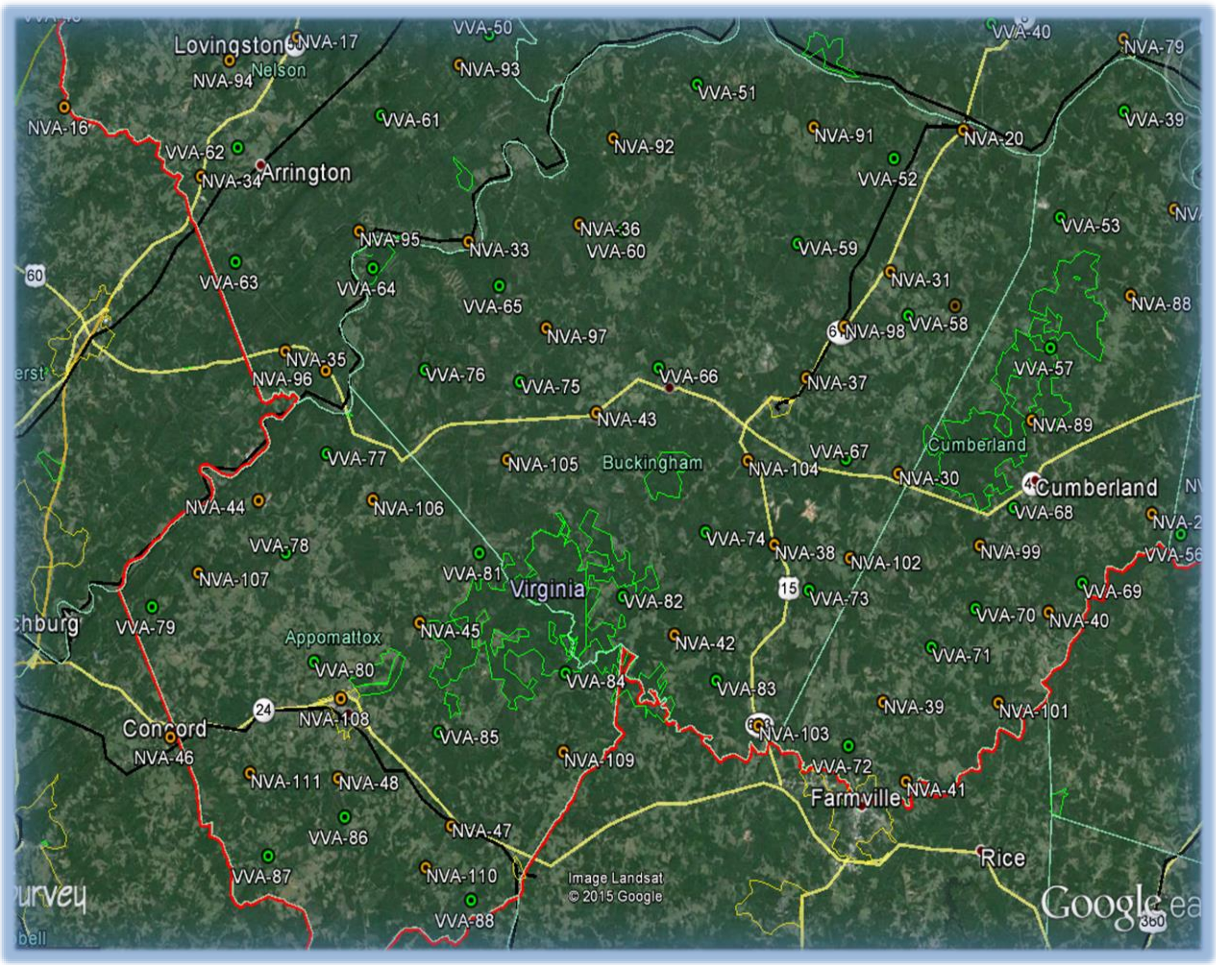
VVA-50
Lovingston
NVA-17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NVA-94
Nelson
NVA-16
VVA-62
NVA-34
Arrington
VVA-50
NVA-93
VVA-61
VVA-51
NVA-92
NVA-91
VVA-52
NVA-20
VVA-40
NVA-79
VVA-39
VVA-53
NVA-95
NVA-33
NVA-36
VVA-60
VVA-59
VVA-63
VVA-64
VVA-65
NVA-31
NVA-88
NVA-97
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Cumberland
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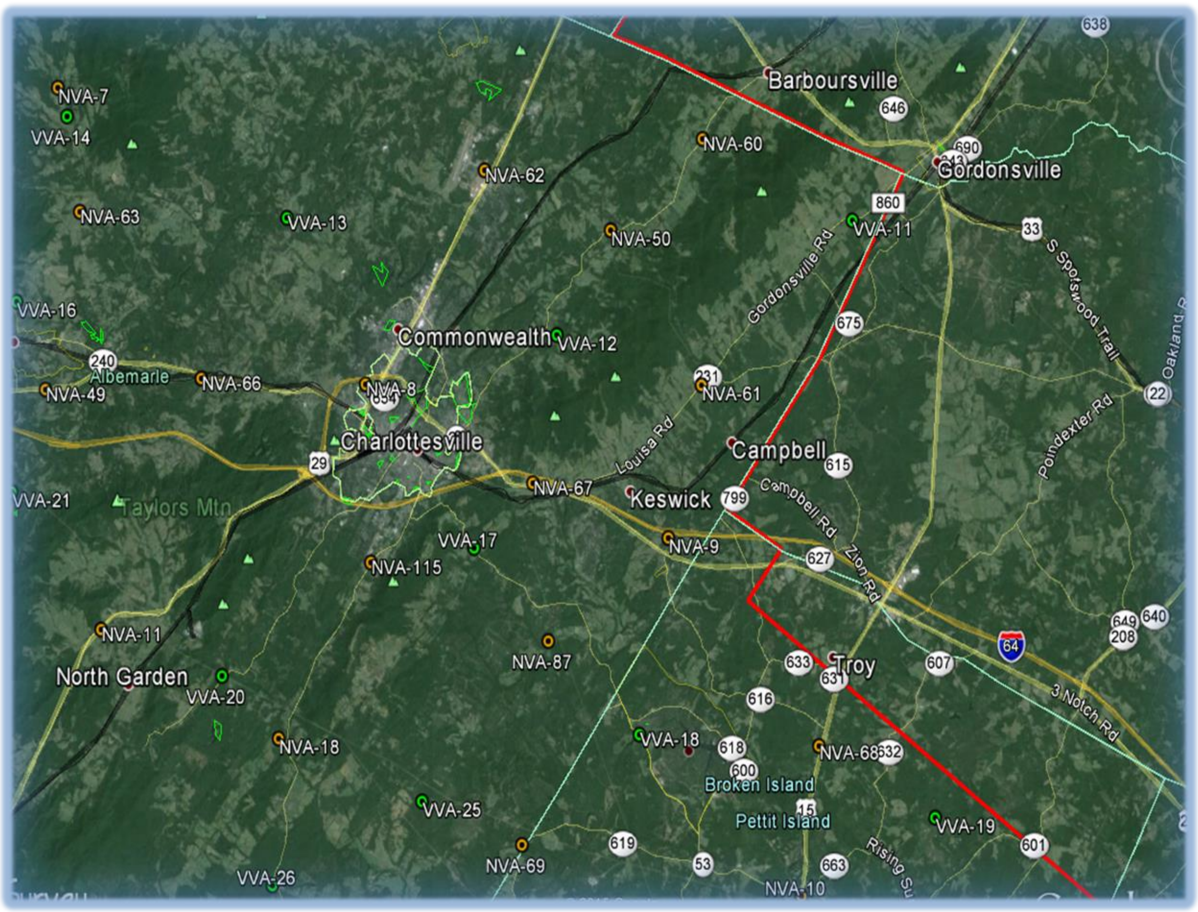
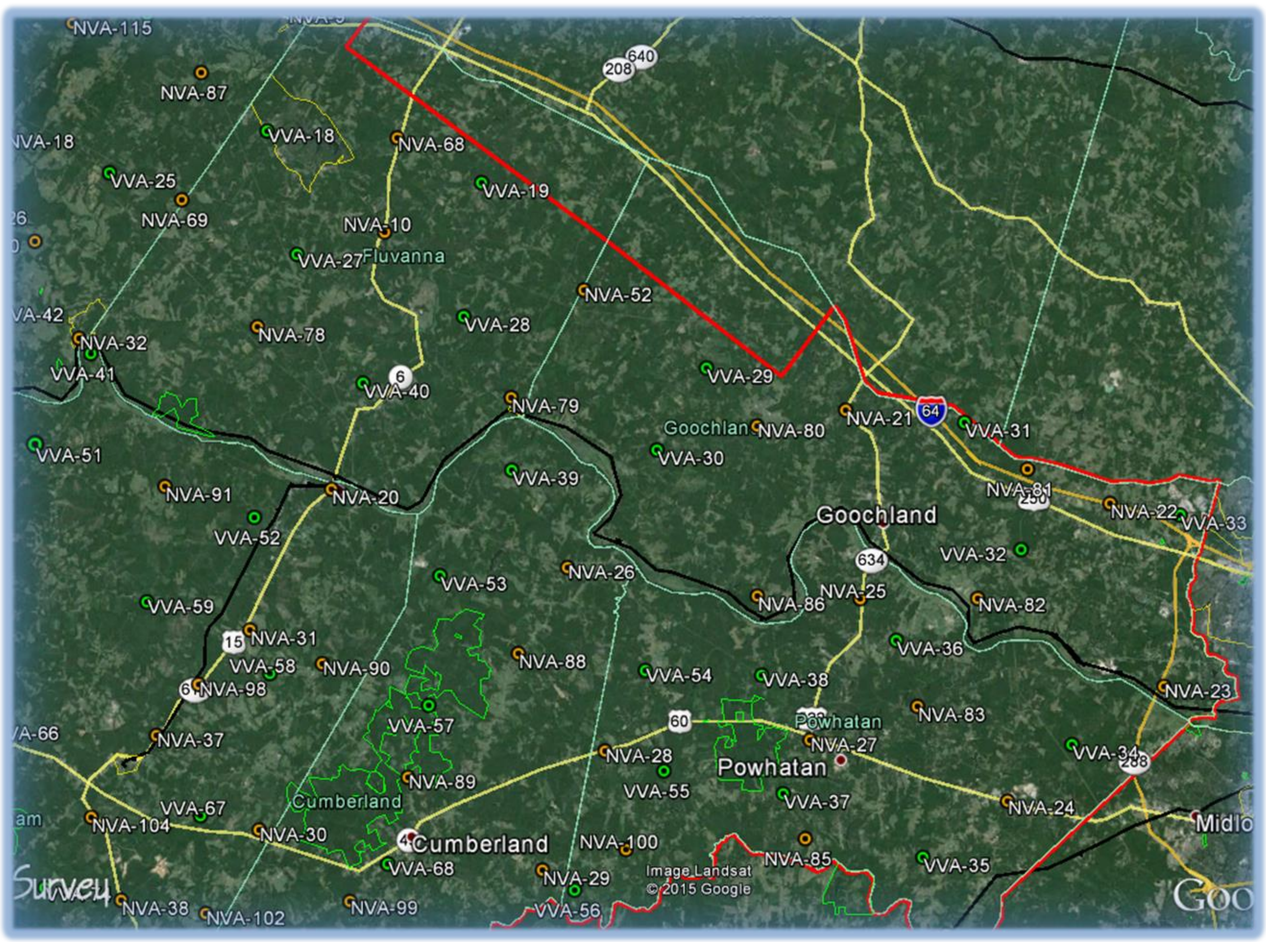
VVA-78
VVA-74
NVA-38
NVA-102
NVA-99
NVA-107
VVA-81
Virginia
VVA-82
VVA-73
VVA-70
NVA-40
VVA-69
VVA-79
NVA-45
Appomattox
NVA-42
VVA-71
VVA-80
VVA-84
VVA-83
NVA-39
NVA-101
Concord
NVA-108
VVA-85
NVA-103
NVA-46
NVA-109
VVA-72
NVA-111
NVA-48
Farmville
NVA-41
VVA-86
NVA-47
Rice
VVA-87
NVA-110
Image Landsat
© 2015 Google
VVA-88
Google


NVA-7
VVA-14
NVA-63
VVA-13
NVA-62
Barboursville
646
NVA-60
690
Gordonsville
860
VVA-11
33
NVA-50
S Sportswood Trail
Gordonsville Rd
VVA-16
675
Commonwealth
VVA-12
240
Albemarle
NVA-66
NVA-49
NVA-8
231
NVA-61
Oakland Rd
22
Poindexter Rd
Charlottesville
Louisa Rd
Campbell
615
29
NVA-67
Keswick
799
Campbell Rd
VVA-21
Taylors Mtn
VVA-17
NVA-9
627
Zion Rd
NVA-115
NVA-11
NVA-87
64
640
208
North Garden
VVA-20
633
Troy
631
607
616
3 Notch Rd
NVA-18
VVA-18
618
NVA-68
632
600
Broken Island
Pettit Island
15
VVA-25
VVA-19
601
NVA-69
619
53
663
VVA-26
NVA-10
638



Chesapeake Bay, Virginia QL2 LiDAR

Project Summery

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 202 LiDAR Check Points were well distributed throughout the project area.

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

2.3 *Network Design*

The GPS survey performed by Dewberry 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.

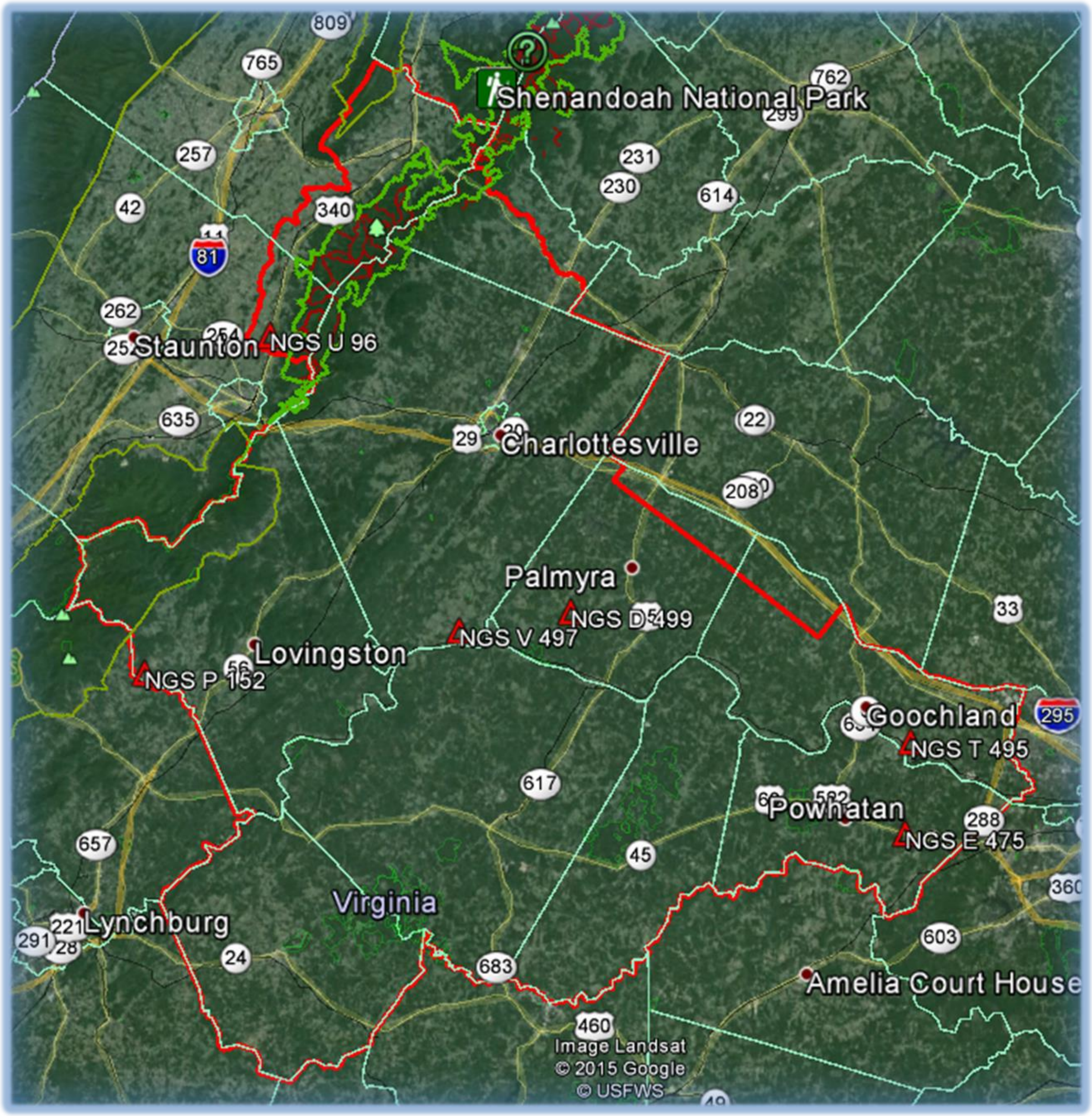
Each occupation which utilized OPUS (if used) was occupied between 20 and 30 minutes.

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

Six (6) existing NGS monuments listed in the NSRS database 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 GV3441, GW1042, HW0695, GW2026, GW2018 and GV3585. The results are as follows:

NGS PT. ID	As Surveyed (F)			Published (F)			Differences (F)		
	Northing(F)	Easting(F)	Elev.(F)	Northing(F)	Easting(F)	Elev. (F)	Δ N	Δ E	Δ Elev.
NGS P 152	3786628.73	11324591.91	785.68	3786628.52	11324591.8	786.06	0.21	0.09	0.38
NGS U96	6739308.75	11382064.71	1251.55	6739308.70	11382064.6	1251.58	0.05	0.07	0.03
NGS V 497	3807284.61	11471043.56	405.94	3807284.61	11471043.5	406.25	0.00	0.03	0.31
NGS-D499	3816354.60	11522955.93	502.13	3816354.67	11522955.9	502.19	0.07	0.04	0.06
NGS E475	3714345.14	11679534.21	409.11	3714345.23	11679534.3	409.00	0.10	0.08	0.11
NGS T495	3756890.88	11681749.28	276.04	3756890.79	11681749.3	276.18	0.09	0.03	0.14

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



NGS Monuments

2.5 *Adjustment*

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

The system is designed to provide a true Network RTK performance, the RTKNet software enables high-accuracy positioning in real time across a geographic region. The RTKNet software package uses real-time data streams from the 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 ID	NORTHING (FT)	EASTING (FT)	ELEV. (FT)
NVA			
NVA-1	13955511.186	2294655.240	1246.162
NVA-2	13938264.157	2343681.106	2347.520
NVA-3	13902393.679	2265480.088	1120.045
NVA-4	13881143.339	2390317.794	528.046
NVA-5	13861855.326	2258204.480	1254.529
NVA-6	13816830.045	2271926.381	842.619
NVA-7	13867109.221	2308733.480	719.628
NVA-8	13827989.047	2358628.536	486.469
NVA-9	13808215.566	2407559.132	460.929
NVA-10	13759455.288	2430205.621	301.126
NVA-11	13793442.096	2317369.158	770.257
NVA-12	13756955.455	2297942.877	685.996
NVA-13	13765640.844	2253858.862	678.730
NVA-14	13758443.540	2241692.671	831.771
NVA-15	13750317.973	2179670.370	2600.328
NVA-16	13701935.442	2199252.940	744.564
NVA-17	13718463.630	2256234.016	761.636
NVA-18	13779100.251	2345972.789	438.707
NVA-19	13746252.534	2334164.791	617.064
NVA-20	13702910.365	2420026.927	340.412
NVA-21	13723266.787	2532716.113	358.242
NVA-22	13704417.275	2591550.165	346.443
NVA-23	13664572.725	2604557.643	274.714
NVA-24	13638492.840	2570699.736	361.168
NVA-25	13682011.421	2537114.203	306.950
NVA-26	13687150.668	2472451.380	355.266
NVA-27	13650755.253	2526848.998	377.282
NVA-28	13647152.239	2481791.186	360.916
NVA-29	13619178.142	2468564.483	362.822
NVA-30	13628312.313	2406549.368	399.917

NVA-31	13671580.499	2402902.701	510.518
NVA-32	13734541.059	2363389.351	272.608
NVA-33	13675312.560	2299266.108	352.765
NVA-34	13687754.714	2233236.936	766.930
NVA-35	13650283.815	2254954.745	664.646
NVA-36	13679801.925	2326402.095	563.113
NVA-37	13652505.410	2386369.166	600.118
NVA-38	13611482.066	2375977.977	557.855
NVA-39	13578006.560	2403763.891	509.854
NVA-40	13598553.935	2443842.200	382.308
NVA-41	13560819.486	2409697.748	305.907
NVA-42	13591206.782	2352031.726	610.609
NVA-43	13638951.884	2331586.887	509.045
NVA-44	13617668.903	2249284.175	676.591
NVA-45	13592197.001	2289521.600	826.312
NVA-46	13565704.004	2229015.373	884.858
NVA-47	13548204.035	2298382.101	723.534
NVA-48	13557919.212	2270445.309	854.404
NVA-49	13825885.343	2307544.660	641.472
NVA-50	13850177.417	2397188.395	543.755
NVA-51	13917471.998	2358409.186	795.153
NVA-52	13748064.239	2474438.891	448.875
NVA-53	13972775.352	2319577.113	951.250
NVA-54	13957157.759	2324196.087	1019.048
NVA-55	13902963.979	2347072.410	676.252
NVA-56	13902264.652	2374076.983	616.495
NVA-57	13881671.340	2286839.360	2326.783
NVA-58	13884165.687	2264292.008	1224.323
NVA-59	13886894.605	2343960.647	622.830
NVA-60	13863085.206	2411529.723	500.899
NVA-61	13829314.569	2412288.525	458.916
NVA-62	13857863.343	2376834.679	591.051
NVA-63	13850412.700	2312350.111	729.617
NVA-64	13855158.421	2277258.466	2713.030
NVA-65	13821688.748	2284852.945	738.335
NVA-66	13828086.381	2332369.684	520.275
NVA-67	13815133.168	2385739.033	392.967
NVA-68	13780324.022	2432394.462	417.314

NVA-69	13765487.986	2385315.818	547.927
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NVA-74	13750582.947	2209074.722	1029.287
NVA-75	13728424.733	2218782.483	734.021
NVA-76	13750366.524	2275400.608	565.057
NVA-77	13729180.856	2338019.632	406.424
NVA-78	13738059.497	2402702.962	503.678
NVA-79	13724046.586	2459040.976	248.825
NVA-80	13719287.037	2513339.813	329.368
NVA-81	13711411.960	2573149.458	359.862
NVA-82	13682770.176	2562974.398	275.726
NVA-83	13658781.015	2550329.632	336.271
NVA-84	13608839.053	2558091.623	305.174
NVA-85	13629099.046	2526340.559	330.661
NVA-86	13682024.000	2514408.914	335.284
NVA-87	13793497.588	2388763.135	320.794
NVA-88	13668009.226	2462122.503	379.384
NVA-89	13638974.836	2438959.070	419.186
NVA-90	13664602.728	2419024.534	428.078
NVA-91	13702531.985	2383267.481	378.650
NVA-92	13698733.400	2334140.401	566.261
NVA-93	13713730.257	2295981.260	486.775
NVA-94	13713006.490	2239449.021	722.172
NVA-95	13676845.905	2272351.689	367.627
NVA-96	13646308.601	2264951.605	634.627
NVA-97	13656975.733	2318799.928	592.613
NVA-98	13659336.211	2391912.512	602.415
NVA-99	13612640.553	2426446.677	475.532
NVA-100	13625665.963	2486973.380	387.626
NVA-101	13578569.827	2432003.556	408.469
NVA-102	13609062.786	2394669.267	379.619
NVA-103	13572050.678	2373130.458	456.362
NVA-104	13635173.989	2367331.855	671.996
NVA-105	13628207.610	2310034.875	660.033
NVA-106	13618542.661	2277319.646	656.027

NVA-107	13601555.284	2234903.933	785.978
NVA-108	13575230.610	2270628.816	874.729
NVA-109	13565058.464	2325490.252	628.945
NVA-110	13539008.774	2292343.694	673.818
NVA-111	13559409.665	2247978.079	754.379
NVA-112	13968439.378	2308911.405	1238.313
NVA-113	13950428.715	2340159.150	1388.494
NVA-114	13936231.224	2303911.172	1014.815
NVA-115	13803556.899	2360111.763	528.162
VVA			
VVA-1	13972887.608	2314571.865	961.171
VVA-2	13960782.791	2336951.421	1223.124
VVA-3	13959780.328	2360027.222	3137.848
VVA-4	13924653.966	2364372.227	986.625
VVA-5	13956388.295	2306297.509	1082.639
VVA-6	13945976.221	2313617.835	1014.579
VVA-7	13924431.990	2331034.944	2296.442
VVA-8	13921072.348	2285807.628	1094.606
VVA-9	13890395.382	2293353.868	2790.349
VVA-10	13891487.286	2355742.382	623.550
VVA-11	13852580.414	2435772.154	518.480
VVA-12	13835552.125	2389018.702	599.380
VVA-13	13850482.243	2345445.094	586.471
VVA-14	13863299.662	2310179.025	679.031
VVA-15	13862024.412	2280735.727	2985.201
VVA-16	13837806.041	2302585.908	725.711
VVA-17	13806006.961	2376580.996	537.215
VVA-18	13781093.947	2403661.559	363.112
VVA-19	13770380.557	2451336.692	420.324
VVA-20	13787127.948	2337234.823	659.715
VVA-21	13811580.871	2302621.696	549.039
VVA-22	13803286.824	2273245.140	803.758
VVA-23	13784678.482	2263096.757	698.730
VVA-24	13774568.468	2282649.831	858.378
VVA-25	13772488.058	2367053.436	489.624
VVA-26	13758865.992	2345605.568	554.342
VVA-27	13754180.974	2410986.197	388.003
VVA-28	13741419.257	2448033.128	218.210

VVA-29	13731715.792	2502030.231	373.320
VVA-30	13707929.902	2491370.950	331.298
VVA-31	13721511.439	2559377.257	340.656
VVA-32	13699351.399	2568399.717	344.650
VVA-33	13702650.862	2604938.585	262.468
VVA-34	13651253.851	2584629.043	235.174
VVA-35	13625273.864	2552967.617	338.287
VVA-36	13672650.428	2542758.585	298.343
VVA-37	13638749.790	2521268.110	359.616
VVA-38	13665074.744	2514899.512	293.730
VVA-39	13708193.352	2459590.714	371.755
VVA-40	13726367.784	2426223.583	460.806
VVA-41	13731172.658	2366061.611	277.083
VVA-42	13739634.241	2348778.820	375.991
VVA-43	13744968.612	2292874.004	666.792
VVA-44	13765025.177	2251470.683	708.462
VVA-45	13772040.596	2192197.757	3297.527
VVA-46	13750163.472	2179706.458	2594.997
VVA-47	13740543.105	2217019.261	837.919
VVA-48	13722919.395	2204950.675	921.379
VVA-49	13737912.776	2252037.115	875.309
VVA-50	13720490.333	2303044.822	552.851
VVA-51	13711222.925	2353943.028	457.119
VVA-52	13695086.726	2402361.637	433.400
VVA-53	13684614.169	2444411.180	365.356
VVA-54	13667139.387	2488575.563	307.299
VVA-55	13643449.271	2494913.487	294.575
VVA-56	13616512.461	2475946.574	348.958
VVA-57	13653720.952	2443095.651	360.332
VVA-58	13662153.051	2407526.735	474.819
VVA-59	13677242.530	2380166.962	401.921
VVA-61	13702005.943	2277041.279	959.148
VVA-62	13694355.806	2241959.400	606.769
VVA-63	13669346.088	2241964.793	714.025
VVA-64	13668876.764	2275773.183	561.832
VVA-65	13665377.250	2307552.409	682.571
VVA-66	13649142.951	2346630.694	468.897
VVA-67	13629806.858	2391048.751	535.381

VVA-68	**13620627.851**	**2434318.778**	**384.376**
VVA-69	**13605099.156**	**2451886.138**	**352.814**
VVA-70	**13598881.505**	**2425912.994**	**391.738**
VVA-71	**13585873.283**	**2411994.440**	**496.390**
VVA-72	**13568246.119**	**2395789.771**	**384.669**
VVA-73	**13601754.335**	**2384733.301**	**377.022**
VVA-74	**13614641.418**	**2359448.224**	**585.544**
VVA-75	**13645190.332**	**2312674.936**	**583.300**
VVA-76	**13640325.053**	**2292635.358**	**850.827**
VVA-77	**13628198.231**	**2265604.107**	**602.443**
VVA-78	**13606668.726**	**2256239.614**	**805.586**
VVA-79	**13593912.861**	**2223767.026**	**776.791**
VVA-80	**13583063.520**	**2263902.131**	**788.313**
VVA-81	**13608217.261**	**2304185.043**	**869.551**
VVA-82	**13599757.002**	**2339391.400**	**610.743**
VVA-83	**13581614.648**	**2362557.355**	**586.623**
VVA-84	**13582372.250**	**2325675.814**	**608.691**
VVA-85	**13568483.436**	**2294852.084**	**721.085**
VVA-86	**13549504.367**	**2272081.940**	**730.547**
VVA-87	**13546214.105**	**2258442.635**	**749.700**
VVA-88	**13532379.885**	**2303725.550**	**674.837**

4. *GPS OBSERVATIONS*

POINT ID	OBSERV. DATE	JULIAN DATE	TIME OF DAY	RE-OBSERV. DATE	RE-OBSERV. TIME
NVA					
NVA-1	12/3/2015	337	15:52	N/A	N/A
NVA-2	12/3/2015	337	13:25	12/3/2015	20:06
NVA-3	12/3/2015	337	17:27	N/A	N/A
NVA-4	12/4/2015	338	12:48	N/A	N/A
NVA-5	12/13/2015	347	8:11	12/3/2015	18:21
NVA-6	12/5/2015	339	8:57	N/A	N/A
NVA-7	12/4/2015	338	17:11	N/A	N/A
NVA-8	12/4/2015	338	8:03	12/4/2015	19:19
NVA-9	12/4/2015	338	9:46	12/4/2015	20:48
NVA-10	12/2/2015	336	19:43	N/A	N/A
NVA-11	12/5/2015	339	11:11	N/A	N/A
NVA-12	12/1/2015	335	9:32	12/1/2015	19:21
NVA-13	12/3/2015	337	10:08	N/A	N/A
NVA-14	12/3/2015	337	10:37	12/4/2015	12:36
NVA-15	12/1/2015	335	18:40	N/A	N/A
NVA-16	12/1/2015	335	15:12	12/3/2015	5:51
NVA-17	12/1/2015	335	12:19	12/1/2015	20:37
NVA-18	11/30/2015	334	15:02	N/A	N/A
NVA-19	12/2/2015	336	10:03	12/3/2015	7:04
NVA-20	11/22/2015	326	15:30	N/A	N/A
NVA-21	11/20/2015	324	10:56	11/20/2015	20:16
NVA-22	11/20/2015	324	8:12	11/20/2015	18:08
NVA-23	11/20/2015	324	16:50	11/20/2015	20:59
NVA-24	11/22/2015	326	6:43	N/A	N/A
NVA-25	11/20/2015	324	15:40	N/A	N/A
NVA-26	11/20/2015	324	13:35	N/A	N/A
NVA-27	11/21/2015	325	17:05	N/A	N/A
NVA-28	11/21/2015	325	15:58	11/21/2015	18:35
NVA-29	11/22/2015	326	9:30	N/A	N/A
NVA-30	11/22/2015	326	13:52	N/A	N/A
NVA-31	11/22/2015	326	15:35	N/A	N/A

NVA-32	11/20/2015	324	16:59	N/A	N/A
NVA-33	11/21/2015	325	11:20	N/A	N/A
NVA-34	12/1/2015	335	14:11	N/A	N/A
NVA-35	11/21/2015	325	9:48	11/21/2015	19:33
NVA-36	12/3/2015	337	14:35	N/A	N/A
NVA-37	11/22/2015	326	14:34	N/A	N/A
NVA-38	11/22/2015	326	11:11	N/A	N/A
NVA-39	11/22/2015	326	12:01	11/22/2015	13:54
NVA-40	11/22/2015	326	10:17	N/A	N/A
NVA-41	11/22/2015	326	11:29	N/A	N/A
NVA-42	11/22/2015	326	9:27	N/A	N/A
NVA-43	11/21/2015	325	15:14	11/21/2015	20:25
NVA-44	11/20/2015	325	18:20	11/21/2015	18:45
NVA-45	11/20/2015	325	16:12	N/A	N/A
NVA-46	11/20/2015	325	7:39	11/20/2015	18:55
NVA-47	11/20/2015	325	11:51	11/20/2015	21:04
NVA-48	11/20/2015	325	15:07	N/A	N/A
NVA-49	12/5/2015	339	8:31	12/5/2015	12:32
NVA-50	12/4/2015	338	11:20	12/4/2015	22:13
NVA-51	12/4/2015	338	14:12	12/5/2015	5:26
NVA-52	12/2/2015	336	18:32	N/A	N/A
NVA-53	12/3/2015	337	14:39	N/A	N/A
NVA-54	12/3/2015	337	14:24	12/3/2015	21:08
NVA-55	12/4/2015	338	14:28	N/A	N/A
NVA-56	12/4/2015	338	13:13	12/5/2015	4:51
NVA-57	12/3/2015	337	10:02	12/3/2015	19:18
NVA-58	12/3/2015	337	17:41	N/A	N/A
NVA-59	12/4/2015	338	14:51	12/5/2015	6:01
NVA-60	12/4/2015	338	10:58	12/4/2015	21:46
NVA-61	12/4/2015	338	10:05	12/4/2015	21:04
NVA-62	12/4/2015	338	12:29	12/4/2015	22:57
NVA-63	12/4/2015	338	18:11	N/A	N/A
NVA-64	12/3/2015	337	8:54	12/3/2015	18:47
NVA-65	12/5/2015	339	8:44	N/A	N/A
NVA-66	12/5/2015	339	7:52	12/5/2015	12:20
NVA-67	12/4/2015	338	9:29	12/4/2015	20:31
NVA-68	12/2/2015	336	19:17	12/4/2015	8:14
NVA-69	12/2/2015	336	20:40	12/3/2015	8:09

NVA-70	**11/30/2015**	**334**	**16:26**	**12/3/2015**	**7:37**
NVA-71	**12/5/2015**	**339**	**10:35**	**12/5/2015**	**13:36**
NVA-72	**12/5/2015**	**339**	**9:43**	**N/A**	**N/A**
NVA-73	**12/3/2015**	**337**	**9:53**	**12/4/2015**	**13:03**
NVA-74	**12/1/2015**	**335**	**17:42**	**12/4/2015**	**12:15**
NVA-75	**12/1/2015**	**335**	**16:51**	**12/4/2015**	**11:20**
NVA-76	**12/1/2015**	**335**	**10:57**	**12/1/2015**	**19:33**
NVA-77	**12/2/2015**	**336**	**11:39**	**N/A**	**N/A**
NVA-78	**11/22/2015**	**326**	**17:36**	**N/A**	**N/A**
NVA-79	**12/2/2015**	**336**	**16:49**	**12/4/2015**	**5:59**
NVA-80	**11/20/2015**	**324**	**11:15**	**N/A**	**N/A**
NVA-81	**11/20/2015**	**324**	**9:50**	**11/20/2015**	**19:03**
NVA-82	**11/20/2015**	**324**	**16:20**	**11/20/2015**	**20:33**
NVA-83	**11/21/2015**	**325**	**7:00**	**11/21/2015**	**17:33**
NVA-84	**11/22/2015**	**326**	**7:25**	**N/A**	**N/A**
NVA-85	**11/22/2015**	**326**	**8:40**	**N/A**	**N/A**
NVA-86	**11/20/2015**	**324**	**14:20**	**N/A**	**N/A**
NVA-87	**12/3/2015**	**337**	**17:37**	**N/A**	**N/A**
NVA-88	**11/21/2015**	**325**	**8:48**	**11/21/2015**	**19:16**
NVA-89	**11/21/2015**	**325**	**10:45**	**11/21/2015**	**19:32**
NVA-90	**11/21/2015**	**325**	**9:45**	**N/A**	**N/A**
NVA-91	**12/2/2015**	**336**	**14:28**	**N/A**	**N/A**
NVA-92	**12/3/2015**	**337**	**15:19**	**N/A**	**N/A**
NVA-93	**12/3/2015**	**337**	**12:11**	**12/4/2015**	**9:57**
NVA-94	**12/1/2015**	**335**	**12:43**	**12/1/2015**	**20:51**
NVA-95	**11/21/2015**	**325**	**10:56**	**N/A**	**N/A**
NVA-96	**11/21/2015**	**325**	**9:29**	**11/21/2015**	**19:21**
NVA-97	**11/21/2015**	**325**	**14:26**	**N/A**	**N/A**
NVA-98	**11/22/2015**	**326**	**14:50**	**N/A**	**N/A**
NVA-99	**11/21/2015**	**325**	**15:19**	**11/21/2015**	**20:17**
NVA-100	**11/22/2015**	**326**	**9:00**		
NVA-101	**11/22/2015**	**326**	**11:06**	**11/22/2015**	**14:56**
NVA-102	**11/22/2015**	**326**	**10:53**	**N/A**	**N/A**
NVA-103	**11/22/2015**	**326**	**10:05**	**N/A**	**N/A**
NVA-104	**11/22/2015**	**326**	**13:00**	**N/A**	**N/A**
NVA-105	**11/21/2015**	**325**	**16:07**	**11/21/2015**	**20:51**
NVA-106	**11/21/2015**	**325**	**17:32**	**N/A**	**N/A**
NVA-107	**11/21/2015**	**325**	**8:19**	**N/A**	**N/A**

NVA-108	11/20/2015	324	15:30	N/A	N/A
NVA-109	11/20/2015	324	12:38	N/A	N/A
NVA-110	11/20/2015	324	11:33	11/20/2015	20:16
NVA-111	11/20/2015	324	8:49	11/20/2015	19:16
NVA-112	12/3/2015	337	15:23	N/A	N/A
NVA-113	12/3/2015	337	13:54	12/3/2015	20:35
NVA-114	12/3/2015	337	16:42	12/3/2015	21:56
NVA-115	12/4/2015	338	8:44	12/4/2015	19:59
VVA					
VVA-1	12/3/2015	337	15:10	N/A	N/A
VVA-2	12/3/2015	337	14:09	12/3/2015	20:48
VVA-3	12/3/2015	337	12:17	12/3/2015	19:49
VVA-4	12/4/2015	338	13:55	N/A	N/A
VVA-5	12/3/2015	337	15:38	N/A	N/A
VVA-6	12/3/2015	337	16:30	N/A	N/A
VVA-7	12/3/2015	337	11:10	12/3/2015	19:36
VVA-8	12/3/2015	337	17:00	N/A	N/A
VVA-9	12/3/2015	337	10:17	N/A	N/A
VVA-10	12/4/2015	338	15:25	12/5/2015	5:47
VVA-11	12/4/2015	338	10:34	N/A	N/A
VVA-12	12/4/2015	338	11:45	12/4/2015	22:30
VVA-13	12/5/2015	339	7:34	N/A	N/A
VVA-14	12/4/2015	338	17:42	N/A	N/A
VVA-15	12/3/2015	337	9:15	12/3/2015	19:02
VVA-16	12/4/2015	338	8:16	N/A	N/A
VVA-17	12/4/2015	337	9:12	12/4/2015	20:13
VVA-18	12/3/2015	337	18:03	12/4/2015	8:29
VVA-19	12/3/2015	337	18:57	12/4/2015	7:53
VVA-20	11/30/2015	334	14:38	12/4/2015	9:04
VVA-21	12/5/2015	339	10:52	12/5/2015	13:59
VVA-22	12/5/2015	339	9:13	12/5/2015	12:58
VVA-23	12/5/2015	339	10:13	N/A	N/A
VVA-24	12/3/2015	337	8:52	12/4/2015	13:18
VVA-25	12/3/2015	337	17:06	N/A	N/A
VVA-26	11/30/2015	334	15:42	12/3/2015	7:53
VVA-27	12/3/2015	337	16:34	N/A	N/A
VVA-28	12/2/2015	336	17:56	12/4/2015	7:18
VVA-29	11/20/2015	324	11:40	N/A	N/A

VVA-30	**11/20/2015**	**324**	**12:40**	**N/A**	**N/A**
VVA-31	**11/20/2015**	**324**	**10:20**	**11/20/2015**	**19:43**
VVA-32	**11/20/2015**	**324**	**9:35**	**N/A**	**N/A**
VVA-33	**11/20/2015**	**324**	**7:50**	**11/20/2015**	**17:47**
VVA-34	**11/21/2015**	**325**	**6:37**	**N/A**	**N/A**
VVA-35	**11/22/2015**	**326**	**7:48**	**N/A**	**N/A**
VVA-36	**11/21/2015**	**325**	**7:28**	**N/A**	**N/A**
VVA-37	**11/21/2015**	**325**	**16:45**	**N/A**	**N/A**
VVA-38	**11/21/2015**	**325**	**7:57**	**N/A**	**N/A**
VVA-39	**11/20/2015**	**324**	**13:15**	**N/A**	**N/A**
VVA-40	**12/2/2015**	**336**	**16:08**	**12/4/2015**	**6:53**
VVA-41	**12/2/2015**	**336**	**12:00**	**N/A**	**N/A**
VVA-42	**12/2/2015**	**336**	**10:50**	**12/3/2015**	**7:18**
VVA-43	**12/1/2015**	**335**	**9:55**	**12/1/2015**	**19:53**
VVA-44	**12/3/2015**	**337**	**10:21**	**12/4/2015**	**12:46**
VVA-45	**11/21/2015**	**325**	**13:24**	**N/A**	**N/A**
VVA-46	**12/1/2015**	**335**	**19:01**	**N/A**	**N/A**
VVA-47	**12/1/2015**	**335**	**17:13**	**12/4/2015**	**11:38**
VVA-48	**12/1/2015**	**335**	**16:03**	**12/4/2015**	**10:56**
VVA-49	**12/1/2015**	**335**	**11:36**	**12/4/2015**	**10:33**
VVA-50	**12/3/2015**	**337**	**13:16**	**12/4/2015**	**9:38**
VVA-51	**12/2/2015**	**336**	**13:15**	**N/A**	**N/A**
VVA-52	**12/2/2015**	**336**	**14:52**	**N/A**	**N/A**
VVA-53	**11/21/2015**	**325**	**9:20**	**11/21/2015**	**20:28**
VVA-54	**11/21/2015**	**325**	**8:20**	**11/21/2015**	**18:56**
VVA-55	**11/21/2015**	**325**	**16:20**	**11/21/2015**	**18:21**
VVA-56	**11/22/2015**	**326**	**9:19**	**N/A**	**N/A**
VVA-57	**11/21/2015**	**325**	**10:15**	**11/21/2015**	**20:28**
VVA-58	**11/22/2015**	**326**	**15:11**	**N/A**	**N/A**
VVA-59	**11/22/2015**	**326**	**15:58**	**N/A**	**N/A**
VVA-60	**12/3/2015**	**337**	**14:55**	**N/A**	**N/A**
VVA-61	**12/3/2015**	**337**	**11:43**	**12/4/2015**	**10:13**
VVA-62	**12/1/2015**	**335**	**13:13**	**12/1/2015**	**21:10**
VVA-63	**11/21/2015**	**325**	**10:16**	**N/A**	**N/A**
VVA-64	**11/21/2015**	**325**	**12:03**	**N/A**	**N/A**
VVA-65	**11/21/2015**	**325**	**14:01**	**N/A**	**N/A**
VVA-66	**11/21/2015**	**325**	**14:55**	**11/21/2015**	**20:11**
VVA-67	**11/22/2015**	**326**	**13:25**	**N/A**	**N/A**

VVA-68	11/21/2015	325	11:10	11/21/2015	20:08
VVA-69	11/22/2015	326	10:01	N/A	N/A
VVA-70	11/22/2015	326	10:50	11/22/2015	14:35
VVA-71	11/22/2015	326	12:15	11/22/2015	14:24
VVA-72	11/22/2015	326	12:54	11/22/2015	13:38
VVA-73	11/22/2015	326	10:35	N/A	N/A
VVA-74	11/22/2015	326	11:43	N/A	N/A
VVA-75	11/21/2015	325	13:06	N/A	N/A
VVA-76	11/21/2015	325	12:44	11/21/2015	19:53
VVA-77	11/21/2015	325	9:10	11/21/2015	19:01
VVA-78	11/20/2015	324	17:41	11/21/2015	18:17
VVA-79	11/21/2015	325	7:59	11/21/2015	18:01
VVA-80	11/20/2015	324	17:04	N/A	N/A
VVA-81	11/22/2015	326	8:59	N/A	N/A
VVA-82	11/21/2015	325	16:45	N/A	N/A
VVA-83	11/22/2015	326	9:45	N/A	N/A
VVA-84	11/20/2015	324	13:34	N/A	N/A
VVA-85	11/20/2015	324	14:15	N/A	N/A
VVA-86	11/20/2015	324	14:52	N/A	N/A
VVA-87	11/20/2015	324	9:40	11/20/2015	19:37
VVA-88	11/20/2015	324	11:05	11/20/2015	20:28

5. *POINT COMPARISON*

LiDAR QA/QC				
POINT ID	POINT CK	DELTA NORTH (F)	DELTA EAST (F)	VERT. DIFF (F)
NVA				
NVA-2	NVA-2 CK	0.03	0.02	0.00
NVA-5	NVA-5 CK	0.00	0.00	0.06

NVA-8	NVA-8 CK	0.02	0.01	0.03
NVA-9	NVA-9 CK	0.03	0.05	0.04
NVA-12	NVA-12 CK	0.02	0.03	0.03
NVA-14	NVA-14 CK	0.00	0.01	0.06
NVA-16	NVA-16 CK	0.02	0.02	0.06
NVA-17	NVA-17 CK	0.02	0.00	0.04
NVA-19	NVA-19 CK	0.01	0.02	0.03
NVA-21	NVA-21 CK	0.06	0.02	0.02
NVA-22	NVA-22 CK	0.00	0.00	0.01
NVA-23	NVA-23 CK	0.01	0.01	0.02
NVA-28	NVA-28 CK	0.09	0.02	0.05
NVA-35	NVA-35 CK	0.04	0.01	0.03
NVA-39	NVA-39 CK	0.00	0.00	0.01
NVA-43	NVA-43 CK	0.03	0.04	0.00
NVA-44	NVA-44 CK	0.02	0.02	0.04
NVA-46	NVA-46 CK	0.01	0.01	0.01
NVA-47	NVA-47 CK	0.03	0.01	0.07
NVA-49	NVA-49 CK	0.02	0.00	0.01
NVA-50	NVA-50 CK	0.00	0.01	0.05
NVA-51	NVA-51 CK	0.01	0.01	0.03
NVA-54	NVA-54 CK	0.03	0.00	0.17
NVA-56	NVA-56 CK	0.00	0.01	0.03
NVA-57	NVA-57 CK	0.02	0.01	0.14
NVA-59	NVA-59 CK	0.03	0.03	0.05
NVA-60	NVA-60 CK	0.03	0.00	0.05
NVA-61	NVA-61 CK	0.00	0.01	0.00
NVA-62	NVA-62 CK	0.01	0.01	0.01
NVA-64	NVA-64 CK	0.02	0.03	0.00
NVA-66	NVA-66 CK	0.01	0.01	0.02
NVA-67	NVA-67 CK	0.01	0.01	0.01
NVA-68	NVA-68 CK	0.01	0.02	0.09
NVA-69	NVA-69 CK	0.04	0.02	0.02
NVA-70	NVA-70 CK	0.02	0.01	0.03
NVA-71	NVA-71 CK	0.01	0.01	0.09
NVA-73	NVA-73 CK	0.02	0.04	0.02
NVA-74	NVA-74 CK	0.06	0.00	0.05
NVA-75	NVA-75 CK	0.02	0.01	0.03
NVA-76	NVA-76 CK	0.01	0.02	0.05

NVA-79	NVA-79 CK	0.05	0.03	0.01
NVA-81	NVA-81 CK	0.02	0.01	0.03
NVA-82	NVA-82 CK	0.00	0.00	0.05
NVA-83	NVA-83 CK	0.02	0.03	0.02
NVA-88	NVA-88 CK	0.01	0.02	0.04
NVA-89	NVA-89 CK	0.04	0.00	0.09
NVA-93	NVA-93 CK	0.01	0.00	0.04
NVA-94	NVA-94 CK	0.01	0.04	0.02
NVA-96	NVA-96 CK	0.03	0.02	0.03
NVA-99	NVA-99 CK	0.15	0.07	0.22
NVA-101	NVA-101 CK	0.00	0.01	0.02
NVA-105	NVA-105 CK	0.03	0.00	0.00
NVA-110	NVA-110 CK	0.02	0.03	0.01
NVA-111	NVA-111 CK	0.10	0.00	0.03
NVA-113	NVA-113 CK	0.01	0.00	0.01
NVA-114	NVA-114 CK	0.04	0.00	0.10
NVA-115	NVA-115 CK	0.00	0.01	0.01
VVA				
VVA-02	VVA-02 CK	0.02	0.03	0.06
VVA-03	VVA-03 CK	N/A	N/A	N/A
VVA-07	VVA-07 CK	N/A	N/A	N/A
VVA-10	VVA-10 CK	0.01	0.00	0.04
VVA-12	VVA-12 CK	0.01	0.00	0.00
VVA-15	VVA-15 CK	0.00	0.01	0.03
VVA-17	VVA-17 CK	0.01	0.01	0.08
VVA-18	VVA-18 CK	0.02	0.01	0.05
VVA-19	VVA-19 CK	0.00	0.02	0.00
VVA-20	VVA-20 CK	0.03	0.00	0.03
VVA-21	VVA-21 CK	0.02	0.02	0.01
VVA-22	VVA-22 CK	0.00	0.07	0.15
VVA-24	VVA-24 CK	0.00	0.00	0.02
VVA-26	VVA-26 CK	0.00	0.01	0.09
VVA-28	VVA-28 CK	0.00	0.04	0.02
VVA-31	VVA-31 CK	0.00	0.01	0.00
VVA-33	VVA-33 CK	0.08	0.05	0.06
VVA-40	VVA-40 CK	0.04	0.04	0.02
VVA-42	VVA-42 CK	0.04	0.01	0.06
VVA-43	VVA-43 CK	0.01	0.02	0.02

VVA-44	VVA-44 CK	0.00	0.03	0.02
VVA-47	VVA-47 CK	0.01	0.01	0.03
VVA-48	VVA-48 CK	0.02	0.02	0.11
VVA-49	VVA-49 CK	0.01	0.00	0.03
VVA-50	VVA-50 CK	0.07	0.08	0.30
VVA-53	VVA-53 CK	0.04	0.01	0.08
VVA-54	VVA-54 CK	0.02	0.01	0.04
VVA-55	VVA-55 CK	0.04	0.02	0.11
VVA-57	VVA-57 CK	0.01	0.01	0.01
VVA-61	VVA-61 CK	0.01	0.02	0.09
VVA-62	VVA-62 CK	0.01	0.05	0.03
VVA-66	VVA-66 CK	0.01	0.02	0.00
VVA-68	VVA-68 CK	0.01	0.02	0.08
VVA-70	VVA-70 CK	0.07	0.04	0.02
VVA-71	VVA-71 CK	0.07	0.09	0.22
VVA-72	VVA-72 CK	0.01	0.02	0.08
VVA-76	VVA-76 CK	0.05	0.05	0.15
VVA-77	VVA-77 CK	0.00	0.01	0.03
VVA-78	VVA-78 CK	0.00	0.03	0.08
VVA-79	VVA-79 CK	0.03	0.06	0.24
VVA-87	VVA-87 CK	0.01	0.01	0.02
VVA-88	VVA-88 CK	0.03	0.03	0.03

Appendix B: Complete List of Delivered Tiles

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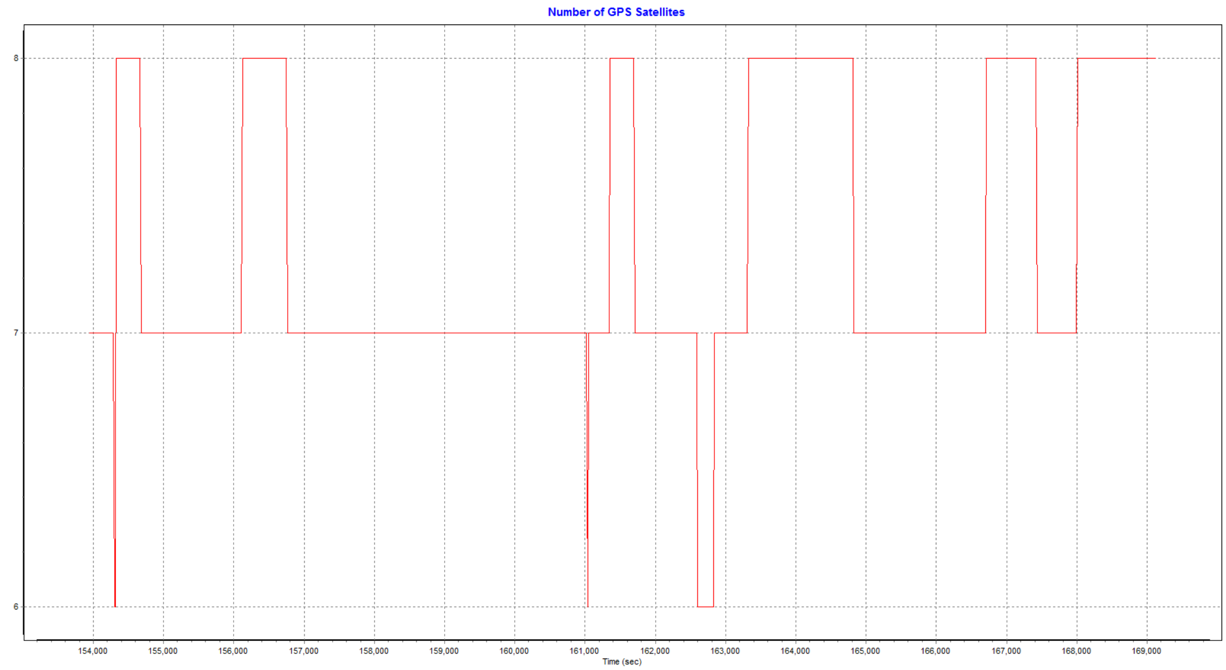
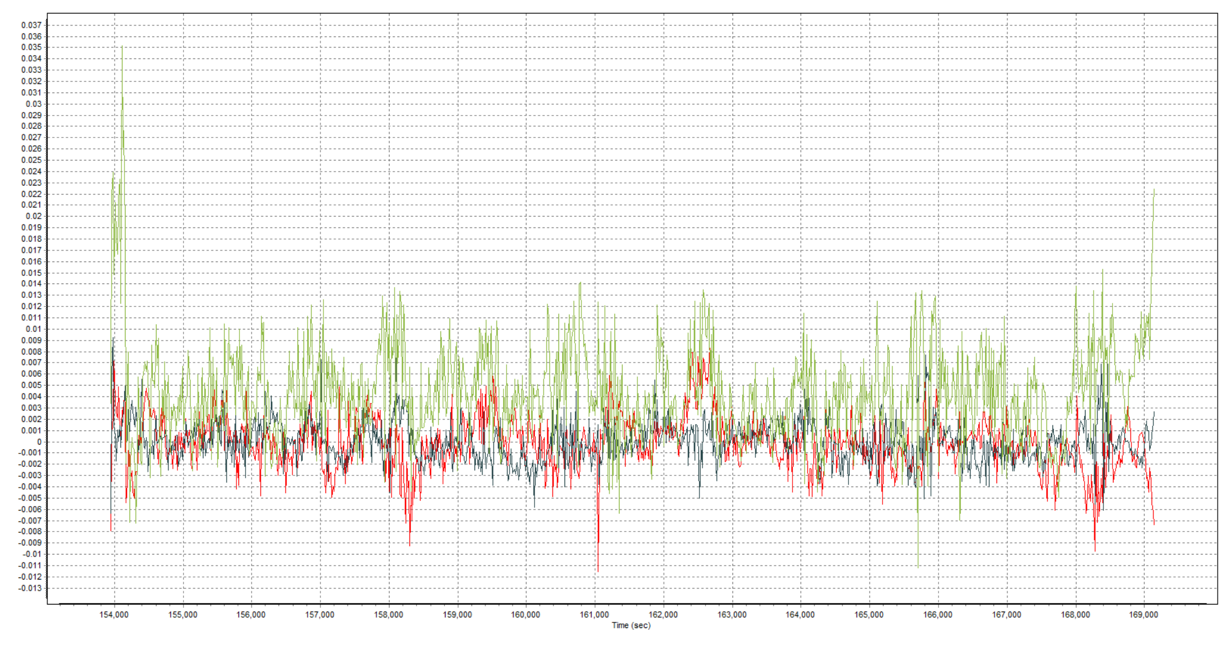
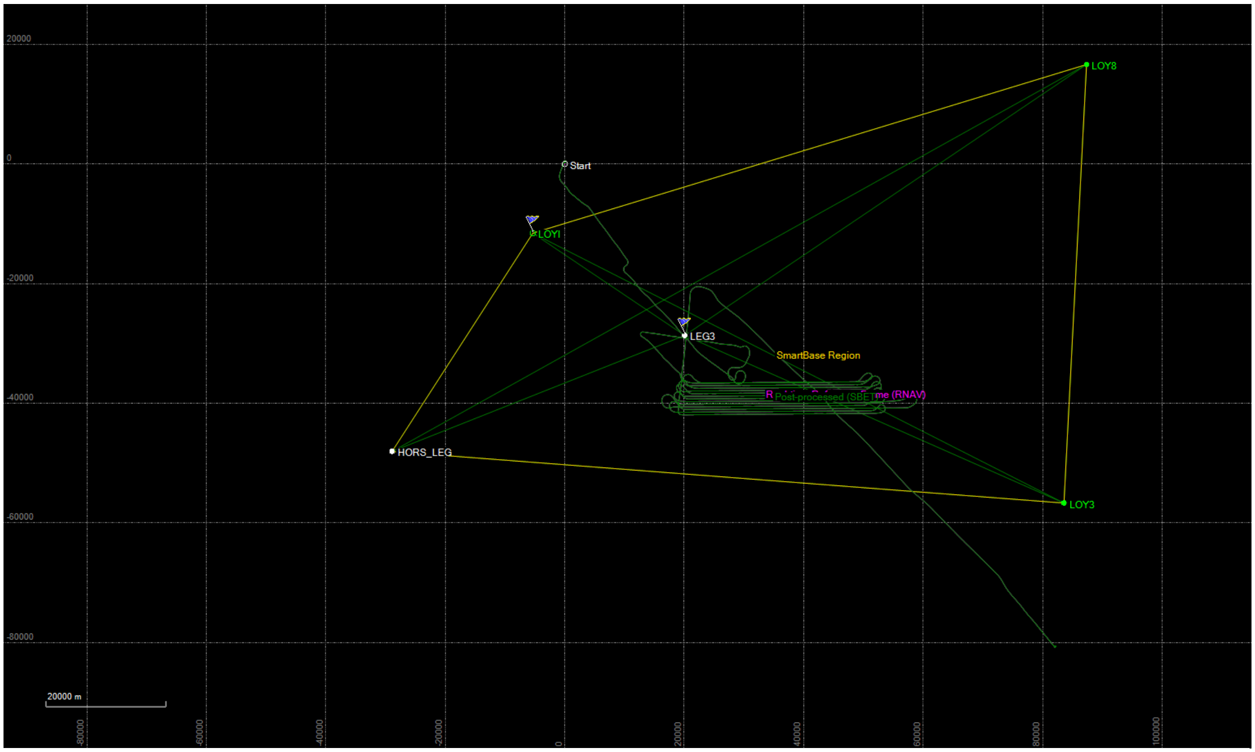
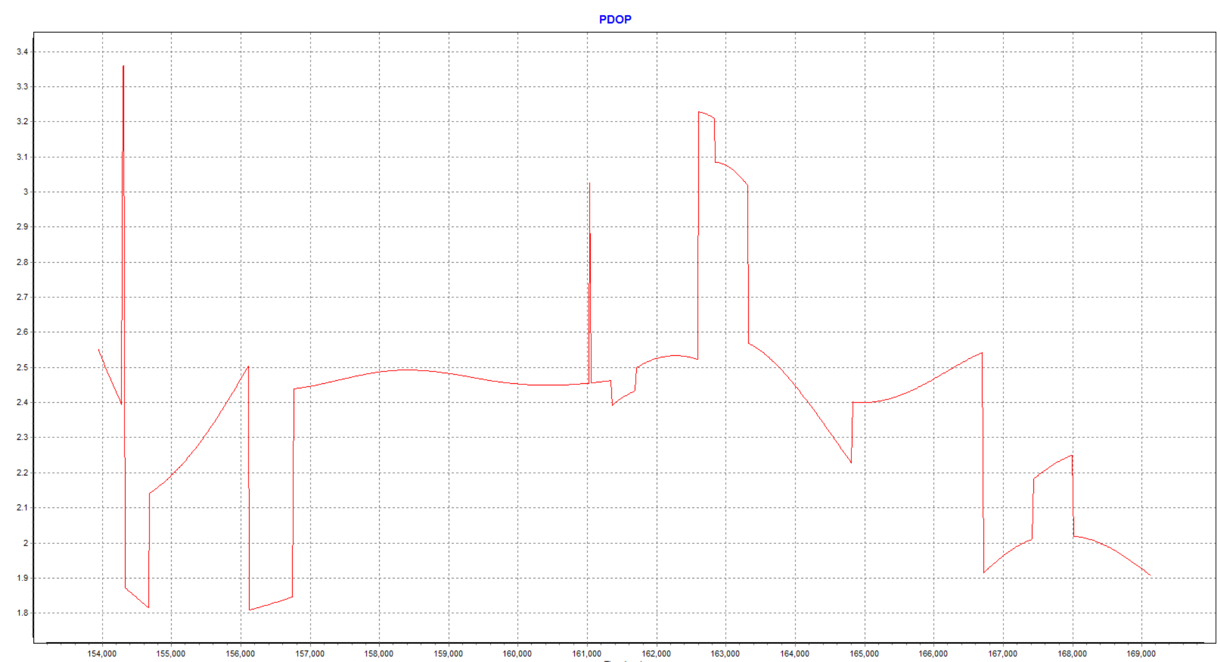
Appendix C: GPS Processing

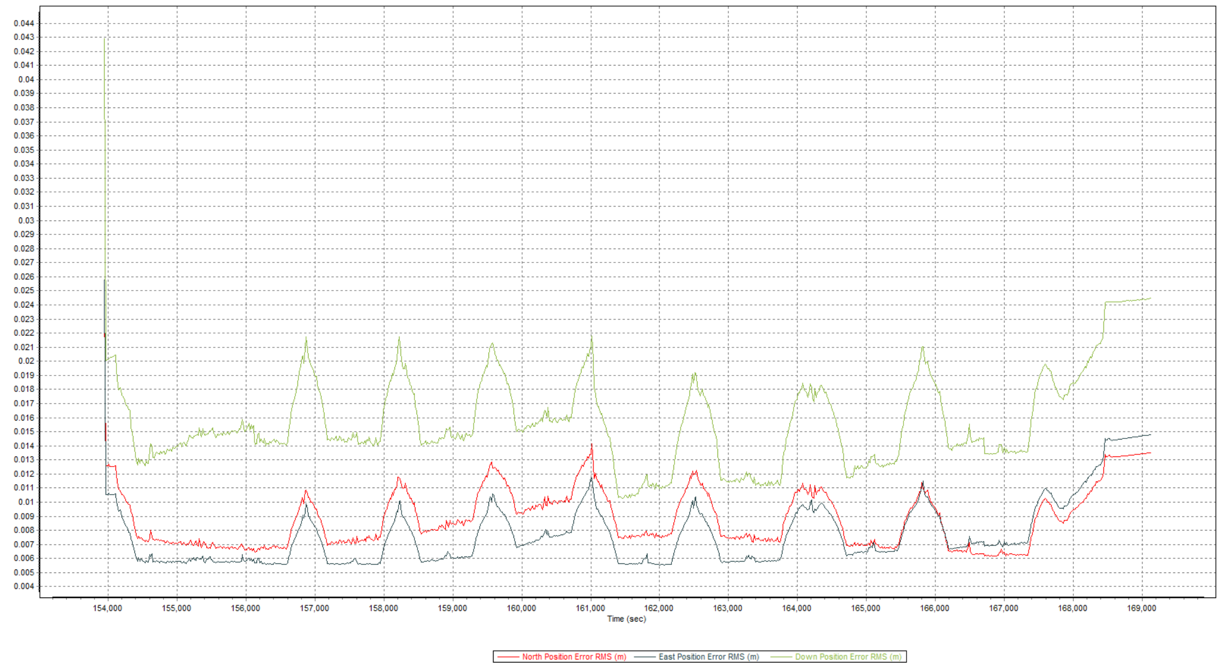
MNB15341B

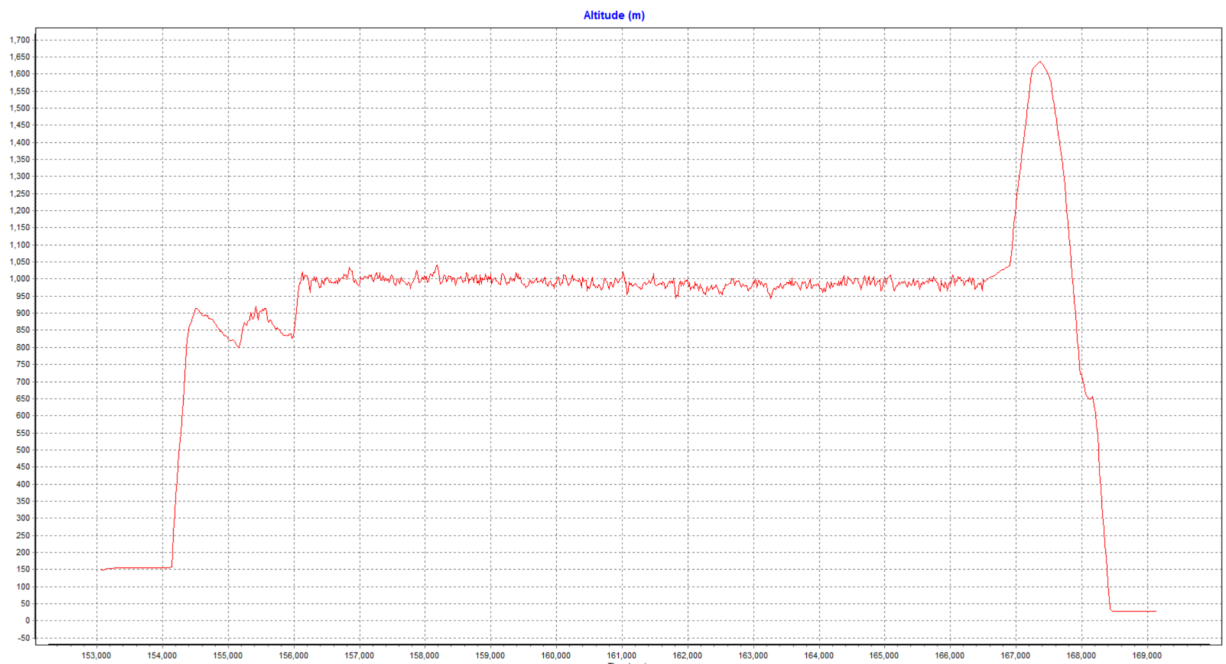


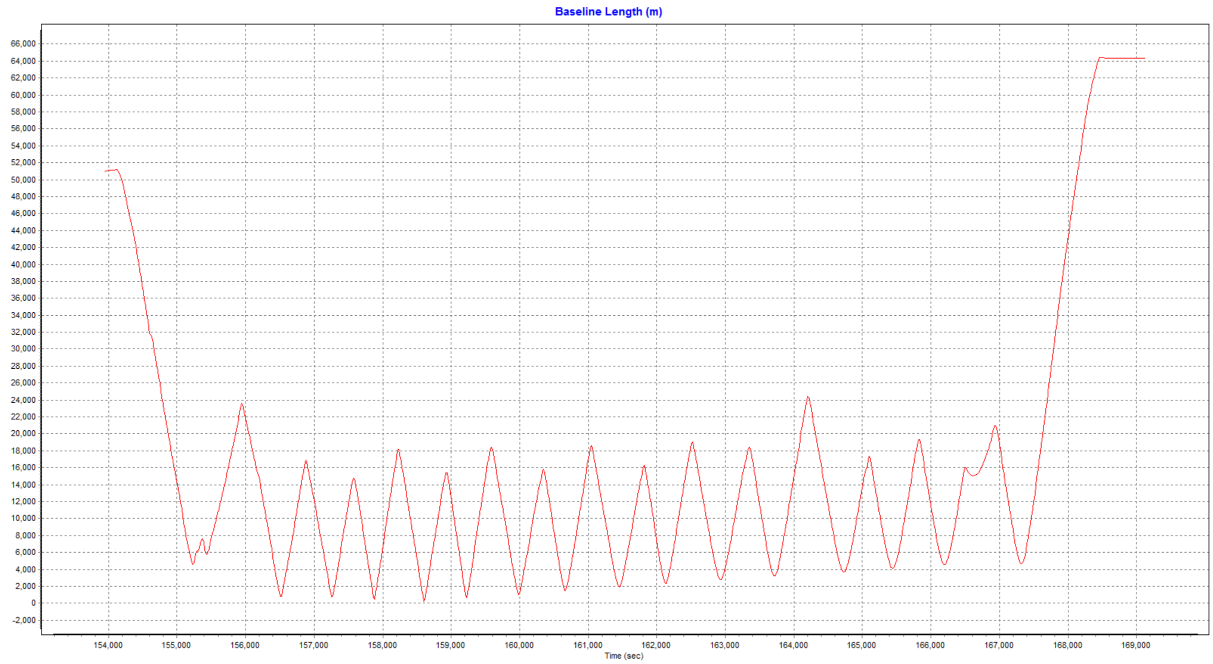



LOY8
Start
LOYI
LEG3
SmartBase Region
HORS_LEG
LOY3
20000 m


PDOP
Time (sec)


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


Altitude (m)
Time (sec)


Baseline Length (m)
66,000
64,000
62,000
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50,000
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44,000
42,000
40,000
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36,000
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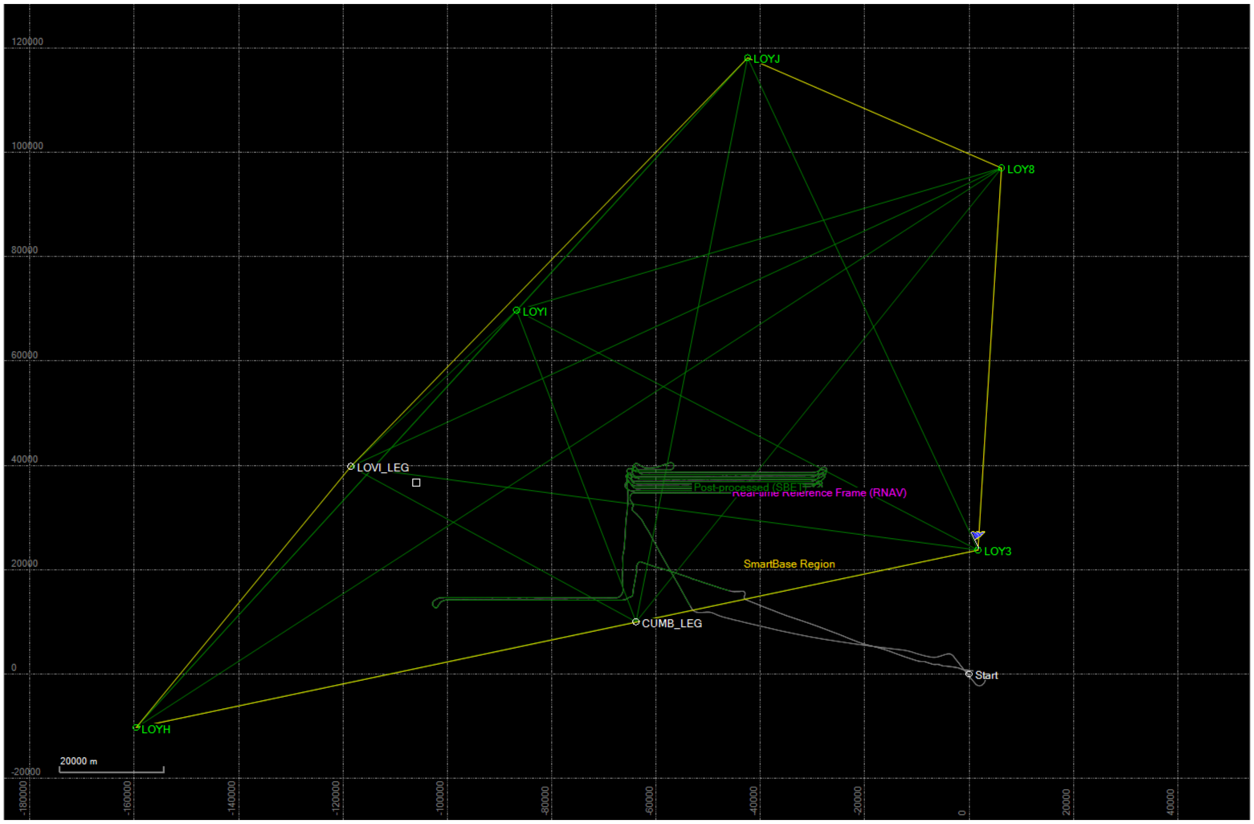
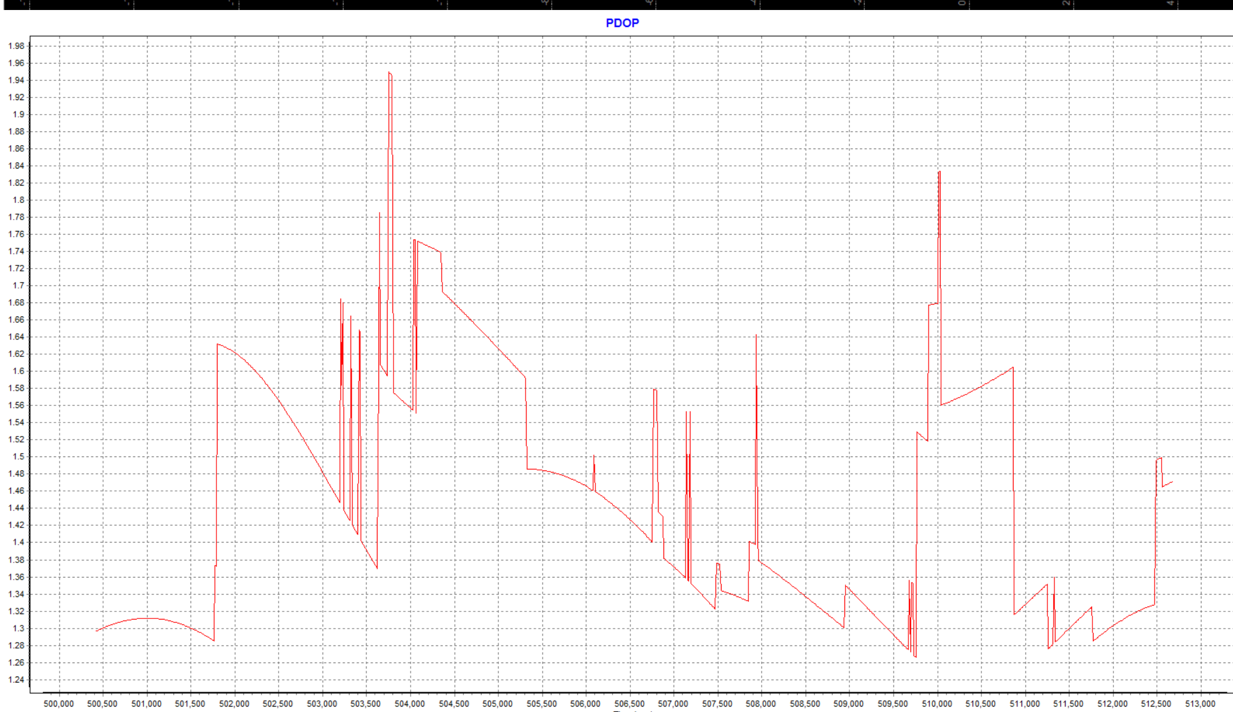
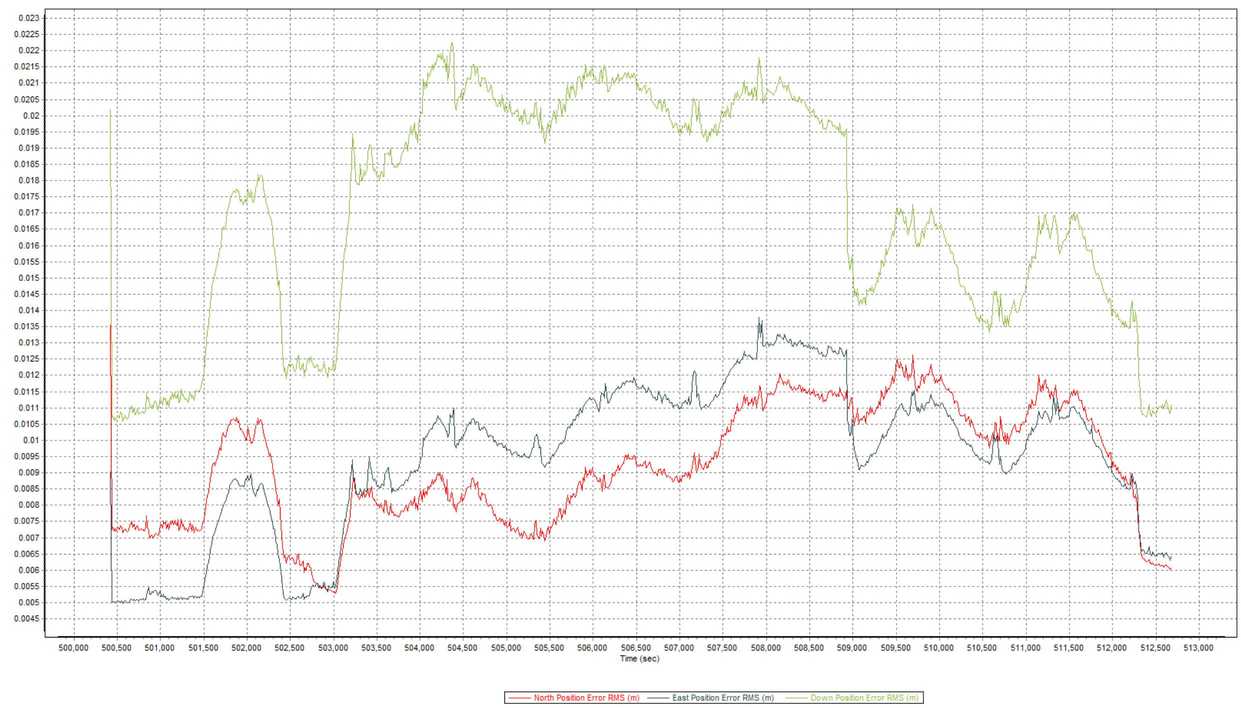
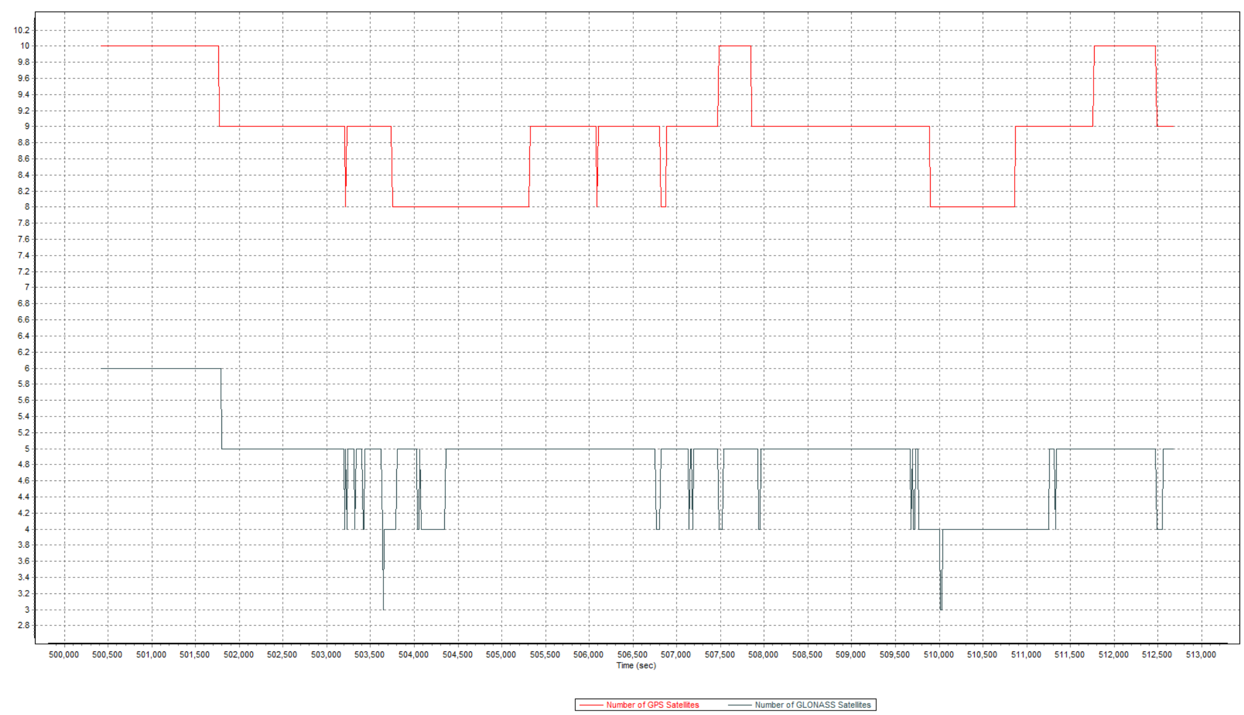
32,000
30,000
28,000
26,000
24,000
22,000
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
-2,000
154,000
155,000
156,000
157,000
158,000
159,000
160,000
161,000
162,000
163,000
164,000
165,000
166,000
167,000
168,000
169,000
Time (sec)

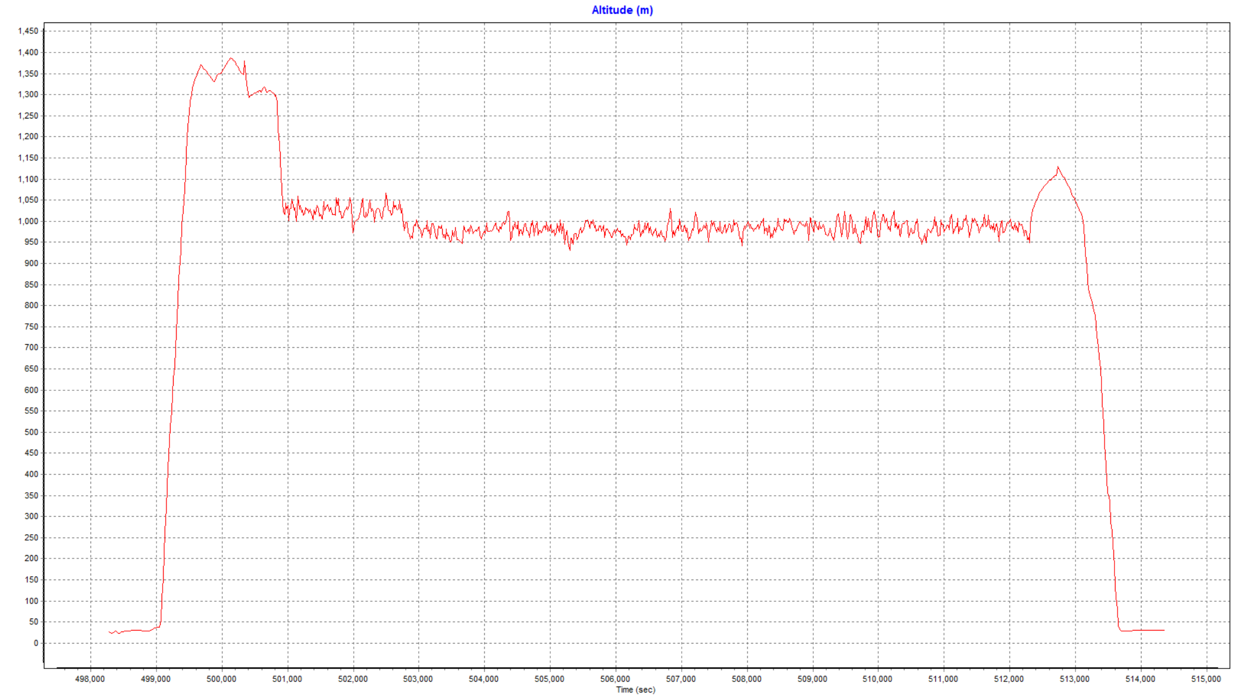
MNB15345B

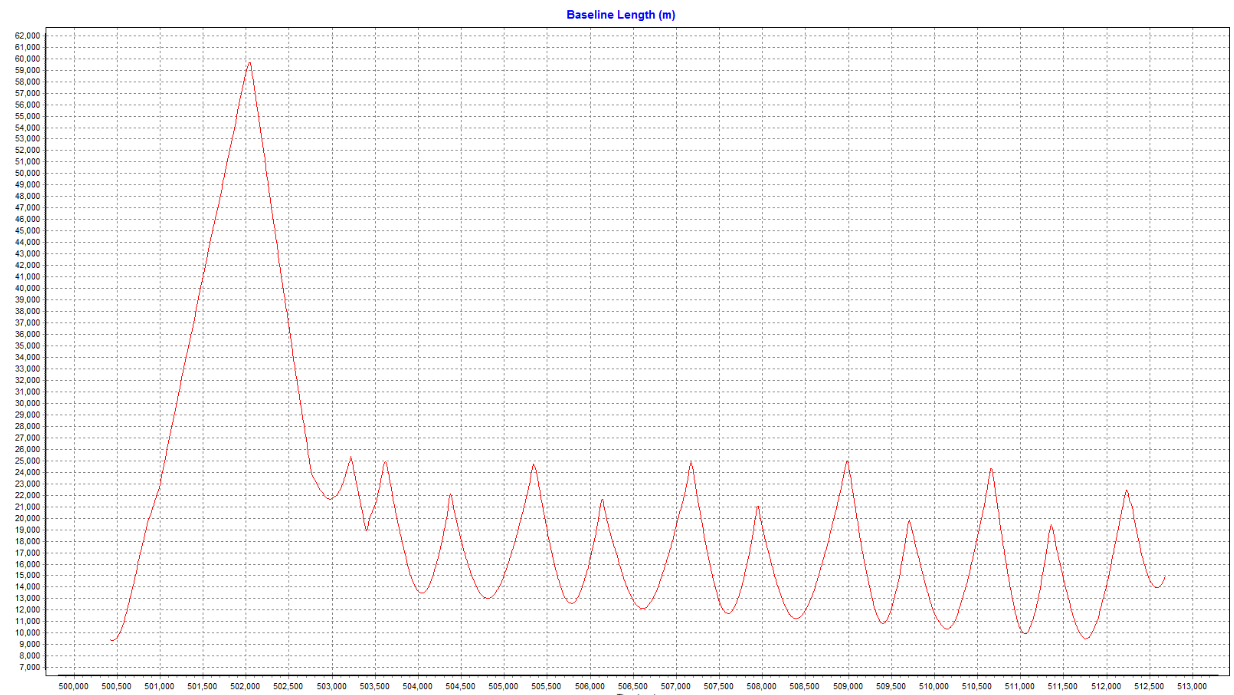

LOYJ
LOY8
LOYI
LOVI_LEG
Post-processed (SBET)
Real-time Reference Frame (RNAV)
LOY3
SmartBase Region
CUMB_LEG
Start
LOYH
20000 m

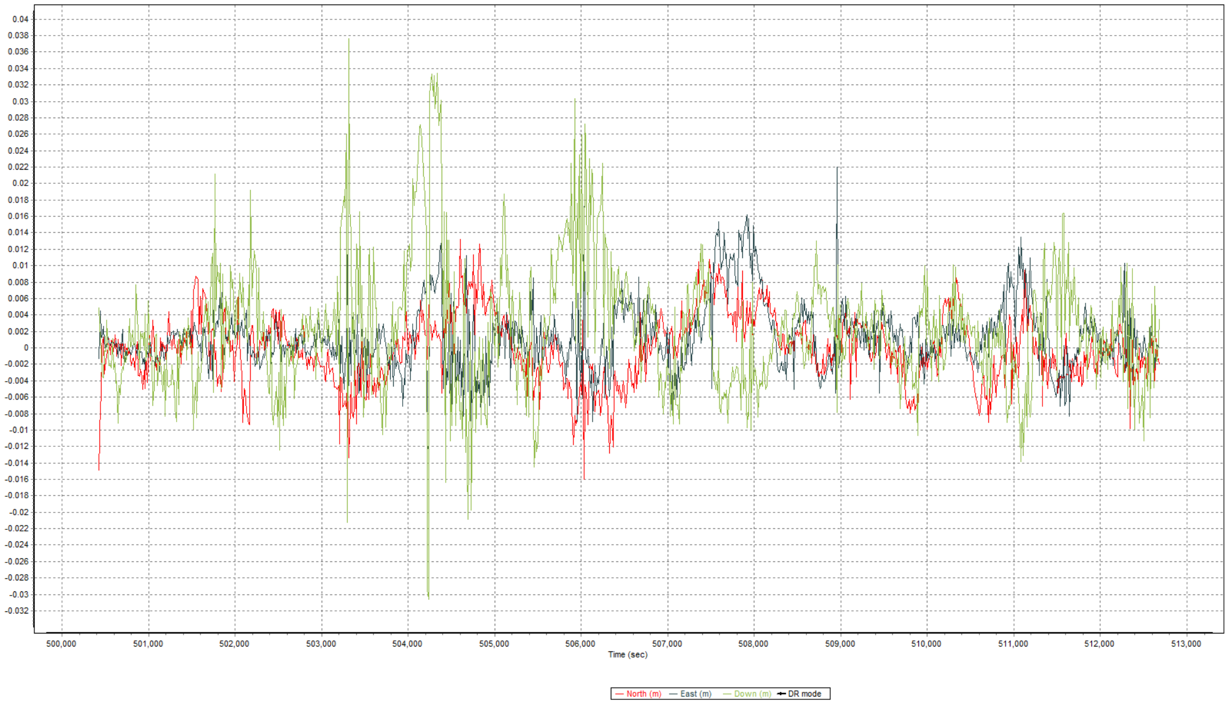

PDOP
Time (sec)


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


Time (sec)
Number of GPS Satellites
Number of GLONASS Satellites


Altitude (m)
Time (sec)


Baseline Length (m)
Time (sec)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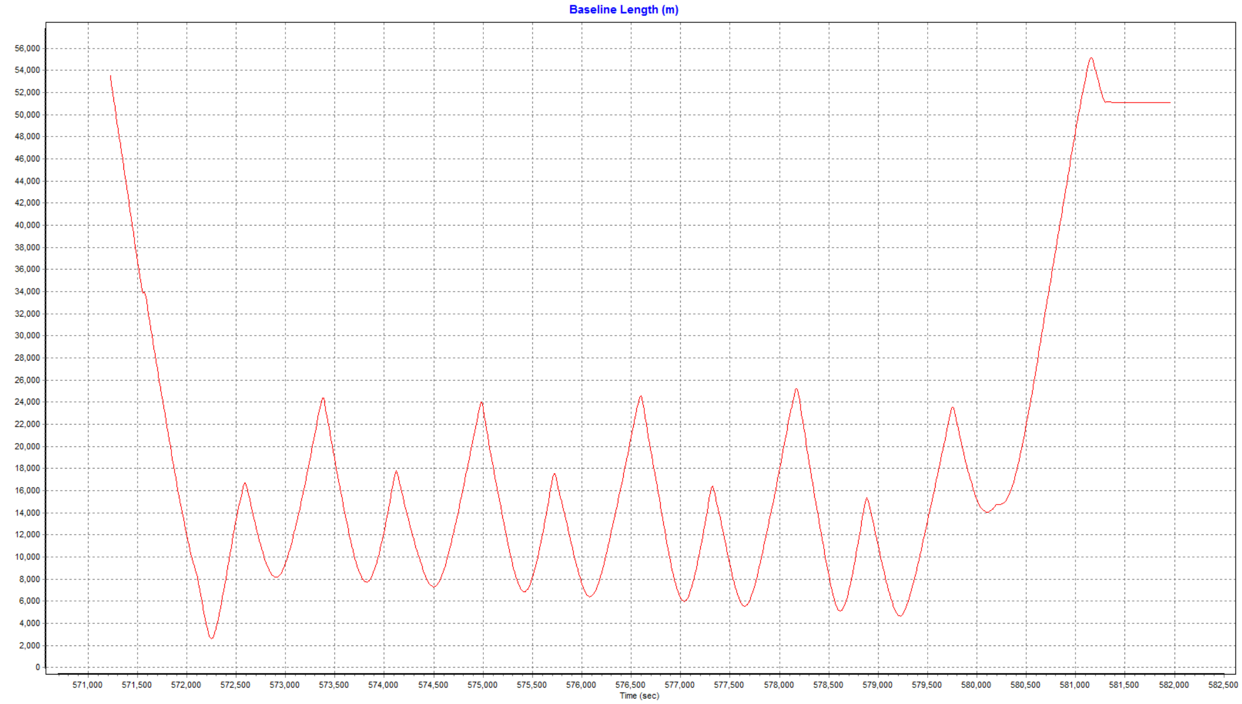
0.036
0.034
0.032
0.03
0.028
0.026
0.024
0.022
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
-0.002
-0.004
-0.006
-0.008
-0.01
-0.012
-0.014
-0.016
-0.018
-0.02
-0.022
-0.024
-0.026
-0.028
-0.03
-0.032
500,000
501,000
502,000
503,000
504,000
505,000
506,000
507,000
508,000
509,000
510,000
511,000
512,000
513,000
Time (sec)
North (m)
East (m)
Down (m)
DR mode

MNB15346A


Baseline Length (m)
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
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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
571,000
571,500
572,000
572,500
573,000
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574,000
574,500
575,000
575,500
576,000
576,500
577,000
577,500
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578,500
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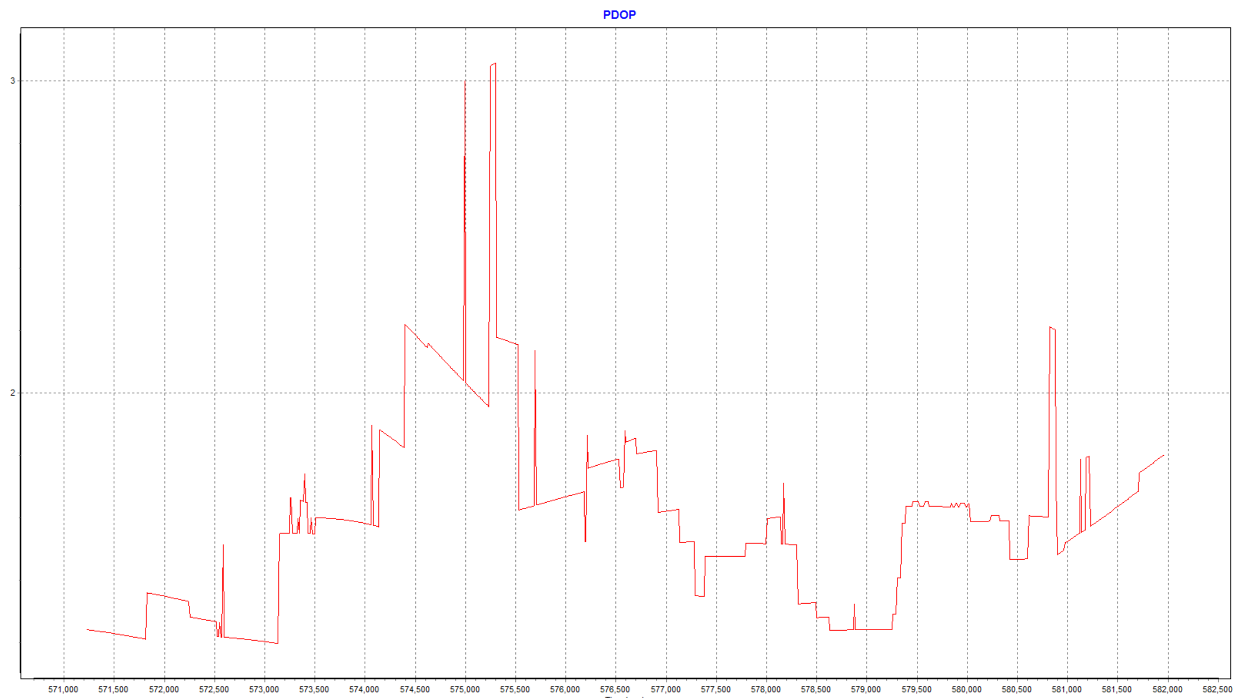
579,500
580,000
580,500
581,000
581,500
582,000
582,500
Time (sec)


PDOP
3
2
571,000
571,500
572,000
572,500
573,000
573,500
574,000
574,500
575,000
575,500
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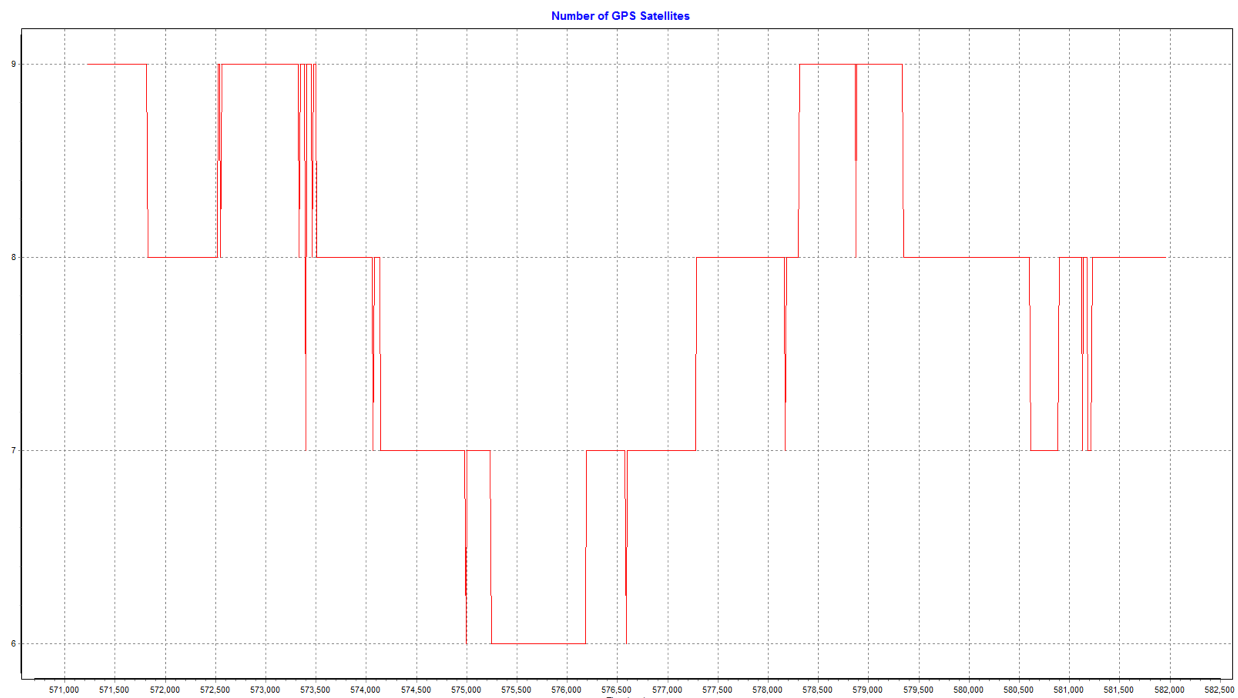
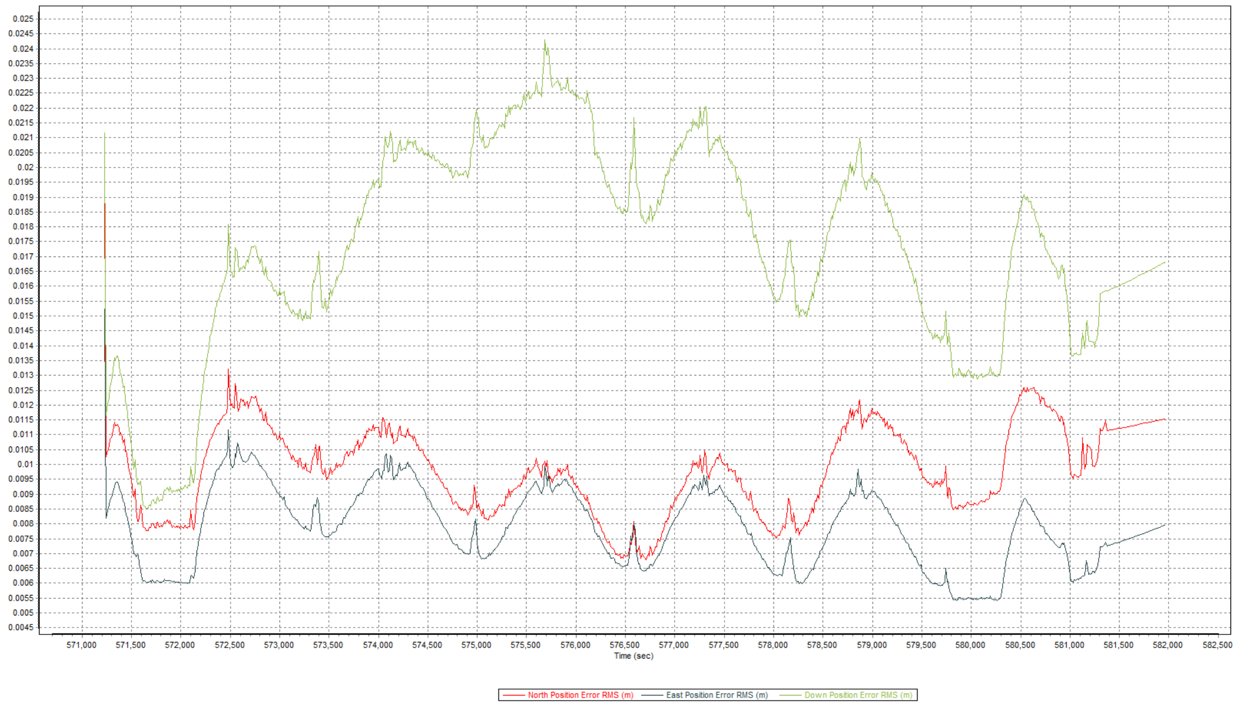
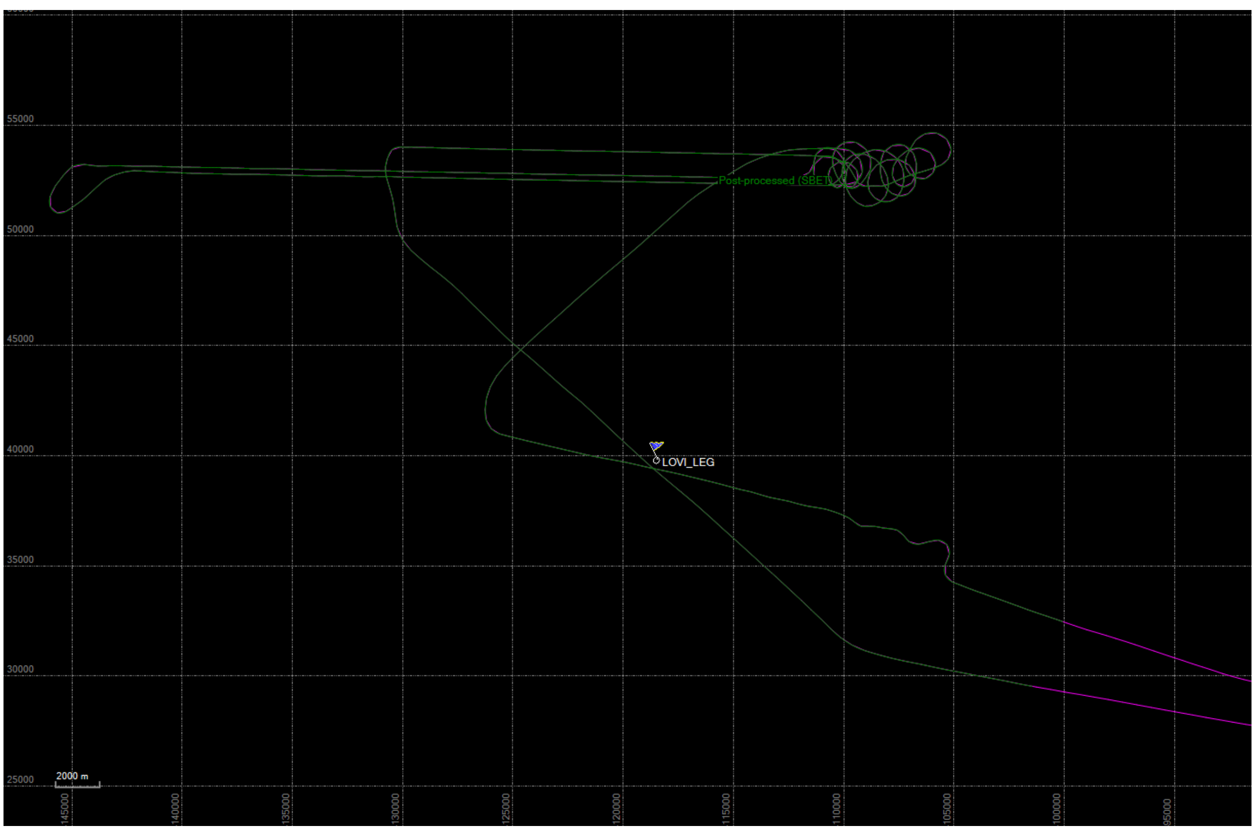
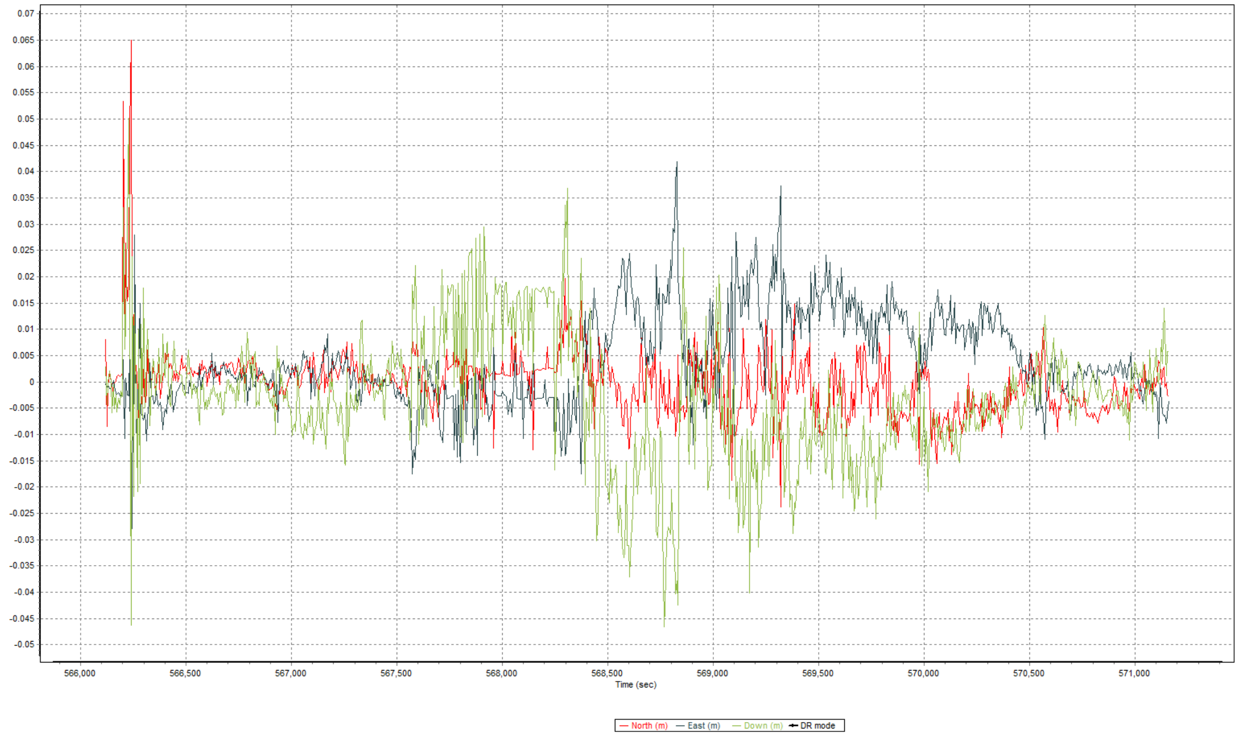
576,500
577,000
577,500
578,000
578,500
579,000
579,500
580,000
580,500
581,000
581,500
582,000
582,500
Time (sec)

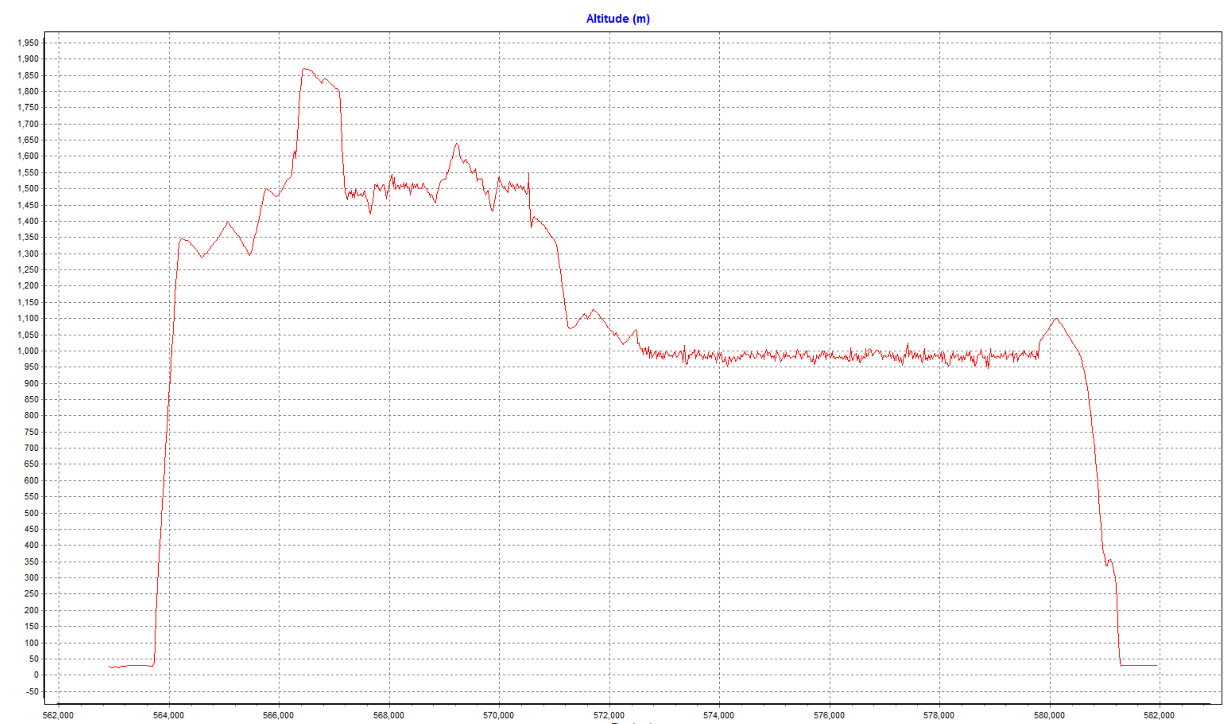

Number of GLONASS Satellites
Time (sec)

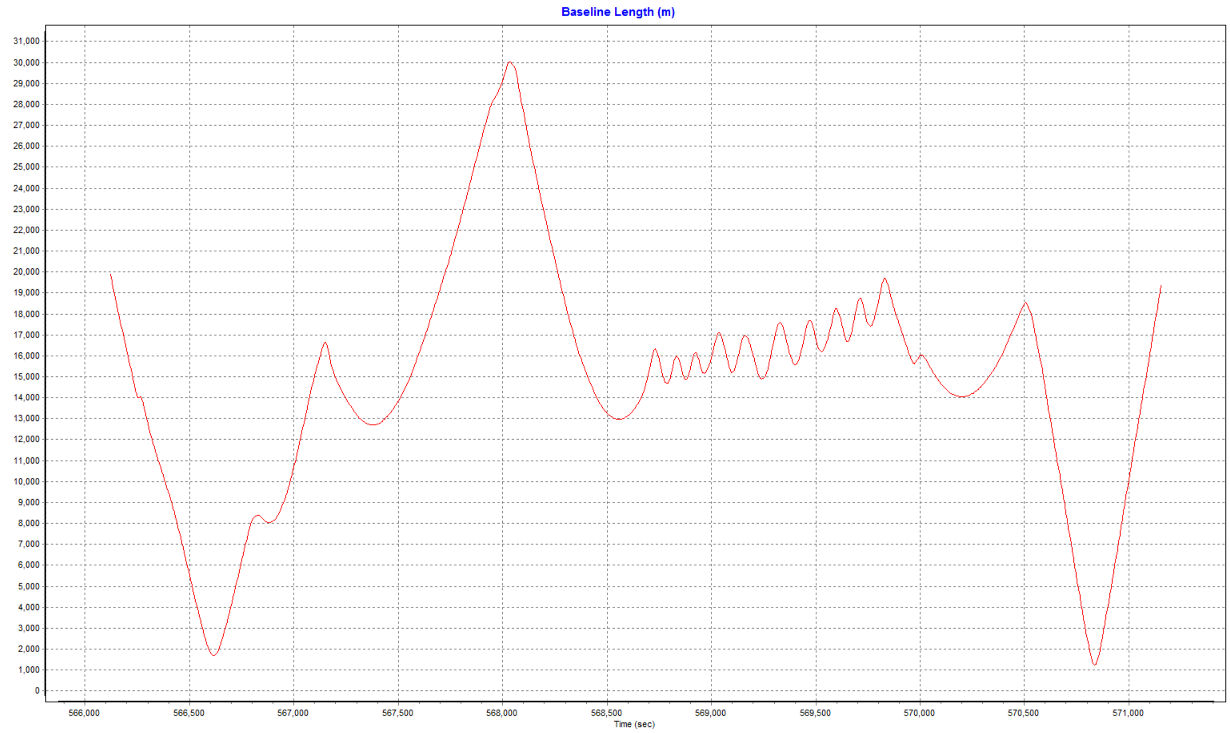

Number of GPS Satellites
Time (sec)


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

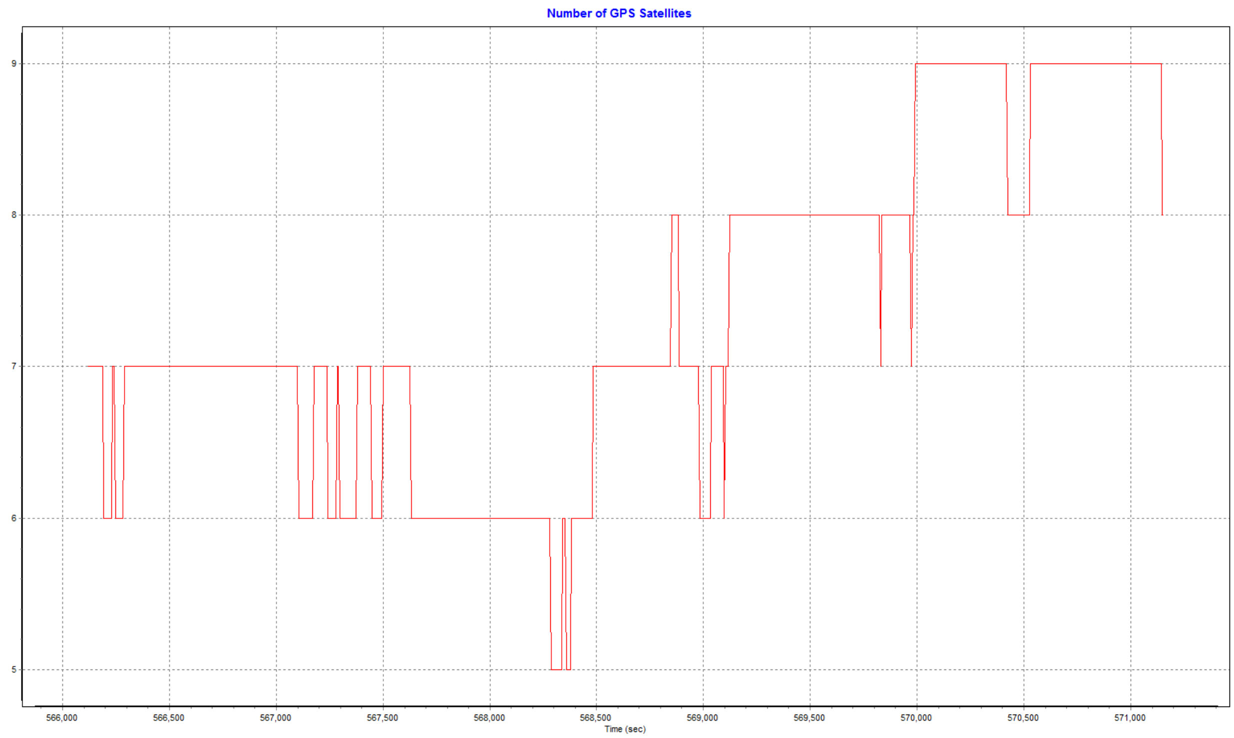

Post-processed (SBET)
LOVI_LEG
2000 m


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


Altitude (m)
Time (sec)


Baseline Length (m)
Time (sec)


PDOP
Time (sec)


Number of GPS Satellites
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8
7
6
5
566,000
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567,000
567,500
568,000
568,500
569,000
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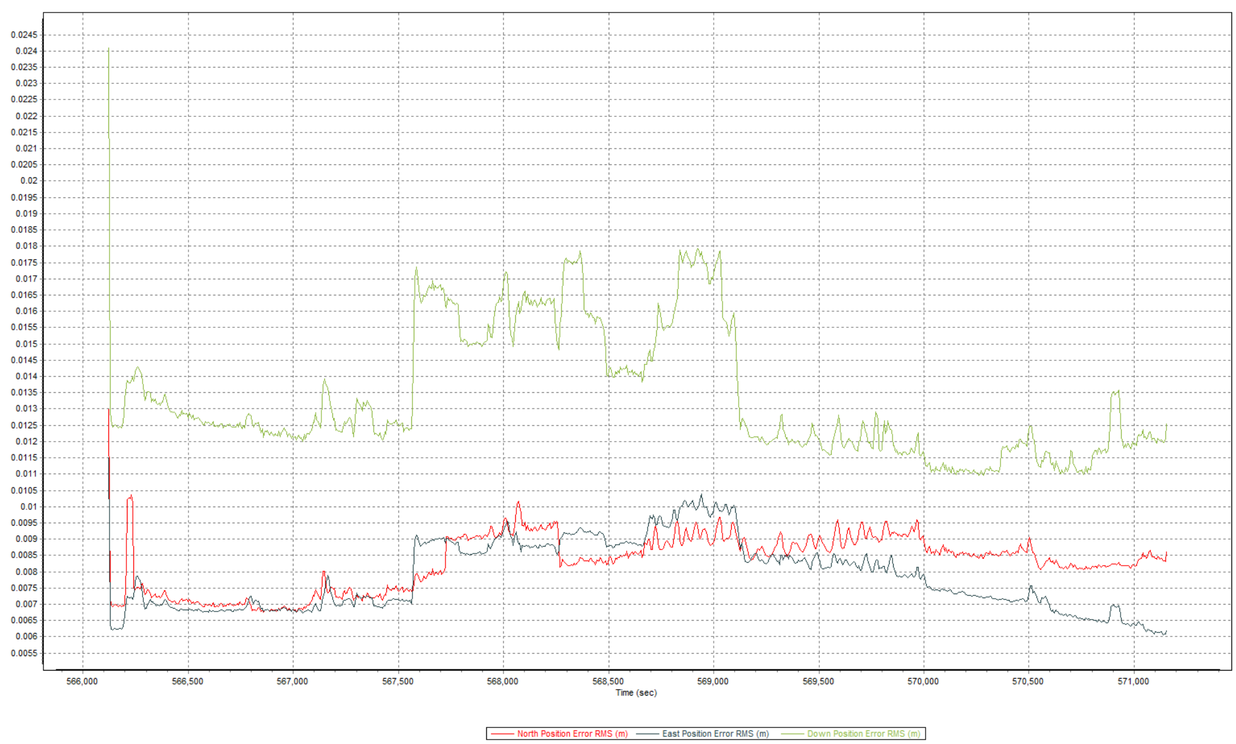
570,500
571,000
Time (sec)


0.0245
0.024
0.0235
0.023
0.0225
0.022
0.0215
0.021
0.0205
0.02
0.0195
0.019
0.0185
0.018
0.0175
0.017
0.0165
0.016
0.0155
0.015
0.0145
0.014
0.0135
0.013
0.0125
0.012
0.0115
0.011
0.0105
0.01
0.0095
0.009
0.0085
0.008
0.0075
0.007
0.0065
0.006
0.0055
566,000
566,500
567,000
567,500
568,000
568,500
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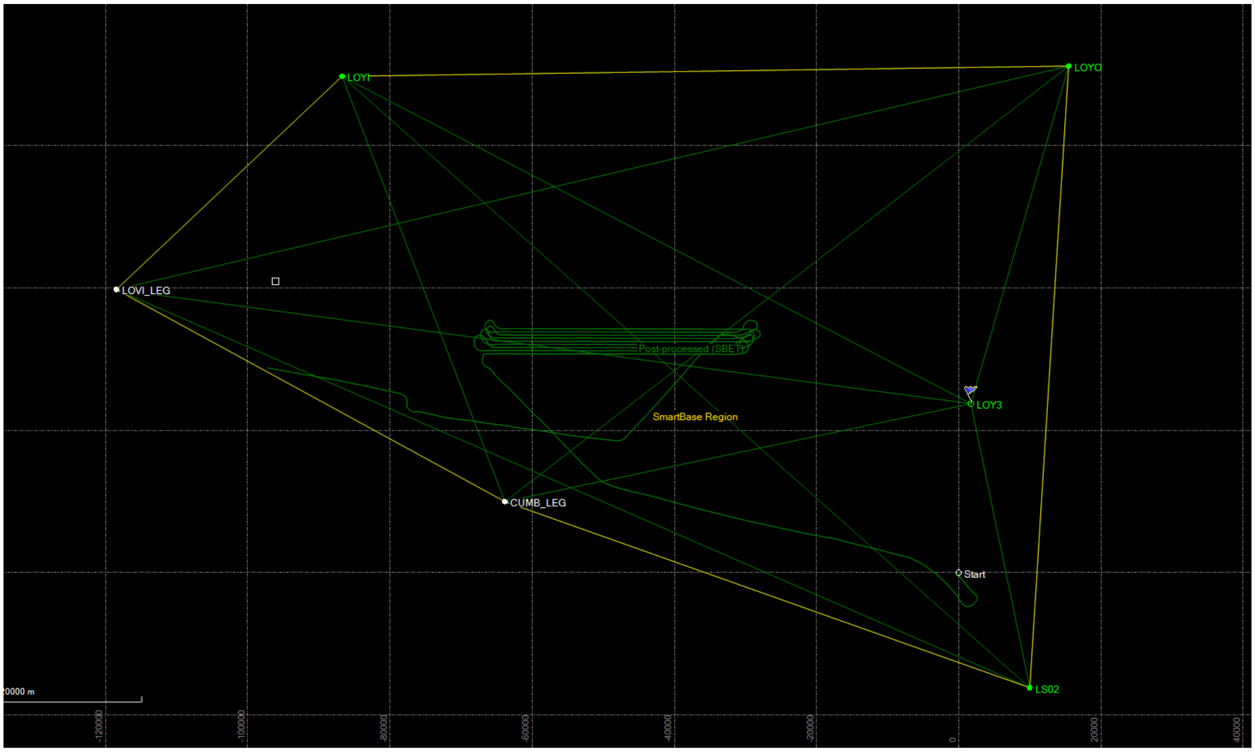
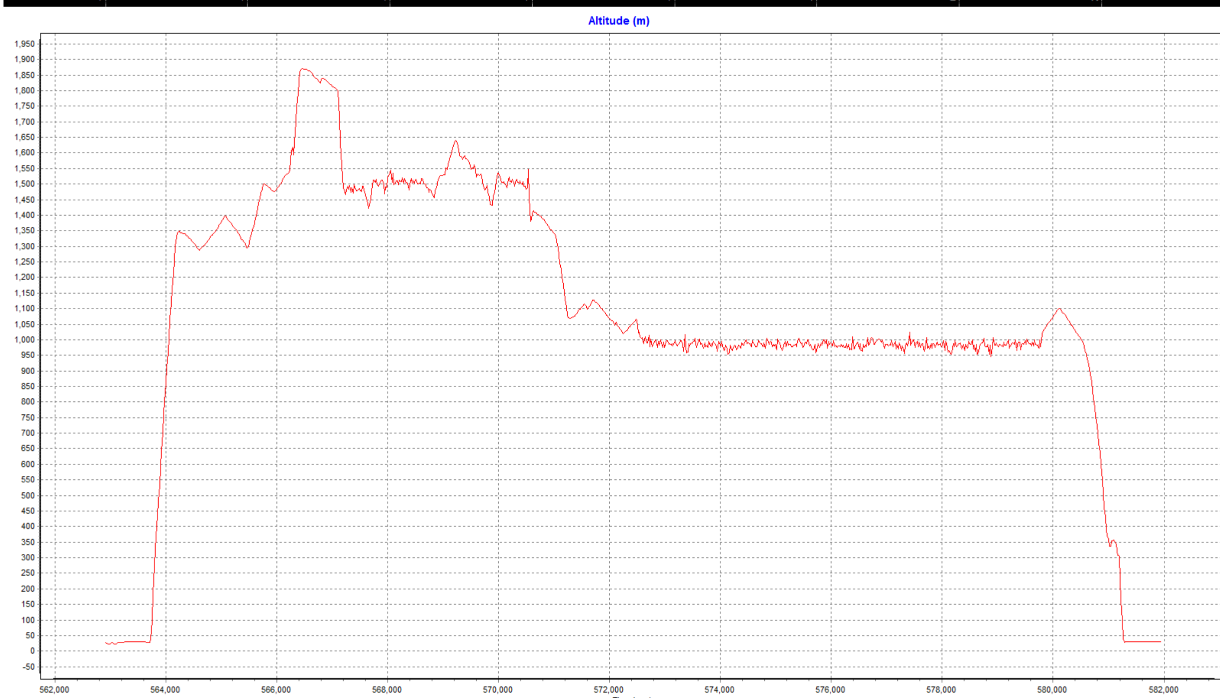
570,000
570,500
571,000
Time (sec)
North Position Error RMS (m)
East Position Error RMS (m)
Down Position Error RMS (m)


LOYI
LOYO
LOVI_LEG
Post-processed (SBET)
LOY3
SmartBase Region
CUMB_LEG
Start
LS02
20000 m
-120000
-100000
-80000
-60000
-40000
-20000
0
20000
40000


Altitude (m)
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1,900
1,850
1,800
1,750
1,700
1,650
1,600
1,550
1,500
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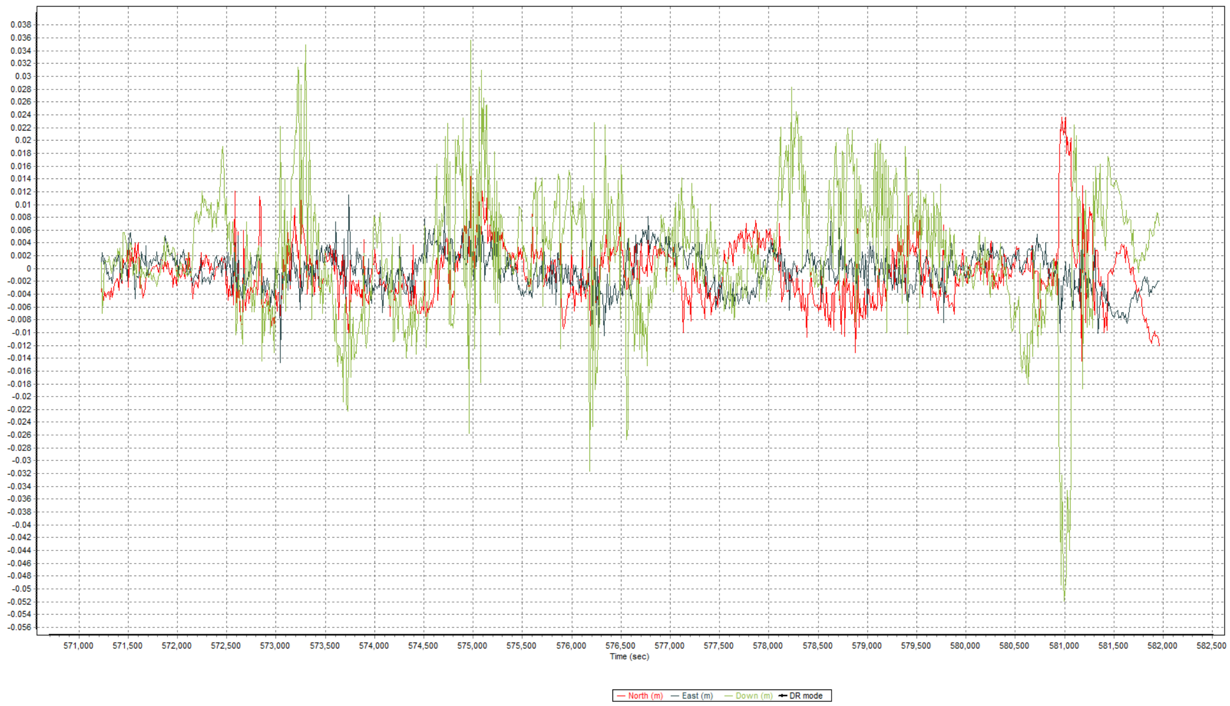
1,300
1,250
1,200
1,150
1,100
1,050
1,000
950
900
850
800
750
700
650
600
550
500
450
400
350
300
250
200
150
100
50
0
-50
562,000
564,000
566,000
568,000
570,000
572,000
574,000
576,000
578,000
580,000
582,000
Time (sec)


0.038
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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
-0.016
-0.018
-0.02
-0.022
-0.024
-0.026
-0.028
-0.03
-0.032
-0.034
-0.036
-0.038
-0.04
-0.042
-0.044
-0.046
-0.048
-0.05
-0.052
-0.054
-0.056
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579,000
579,500
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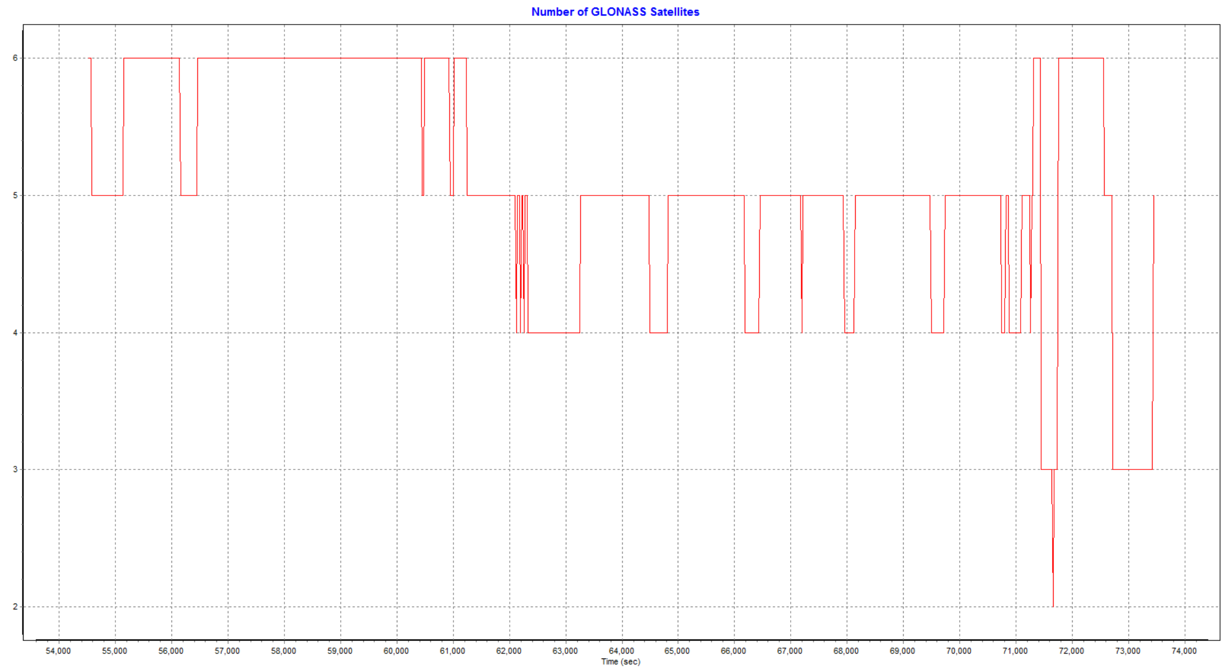
582,000
582,500
Time (sec)
North (m)
East (m)
Down (m)
DR mode

MNB15347B


Number of GLONASS Satellites
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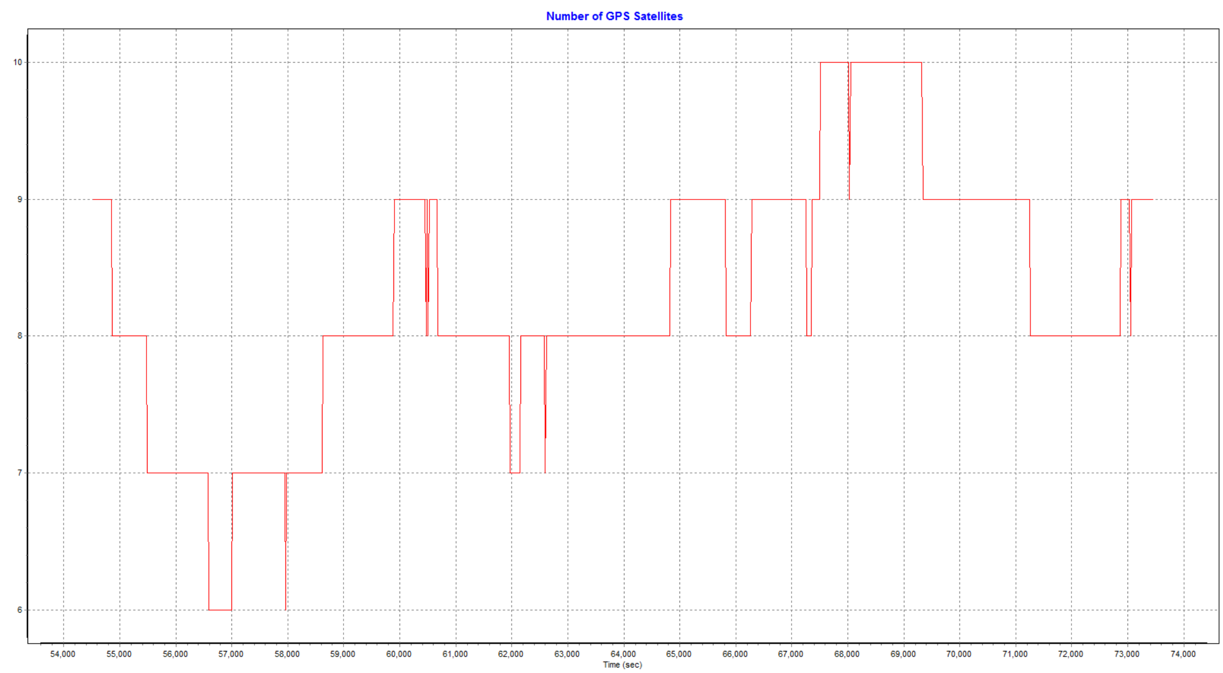
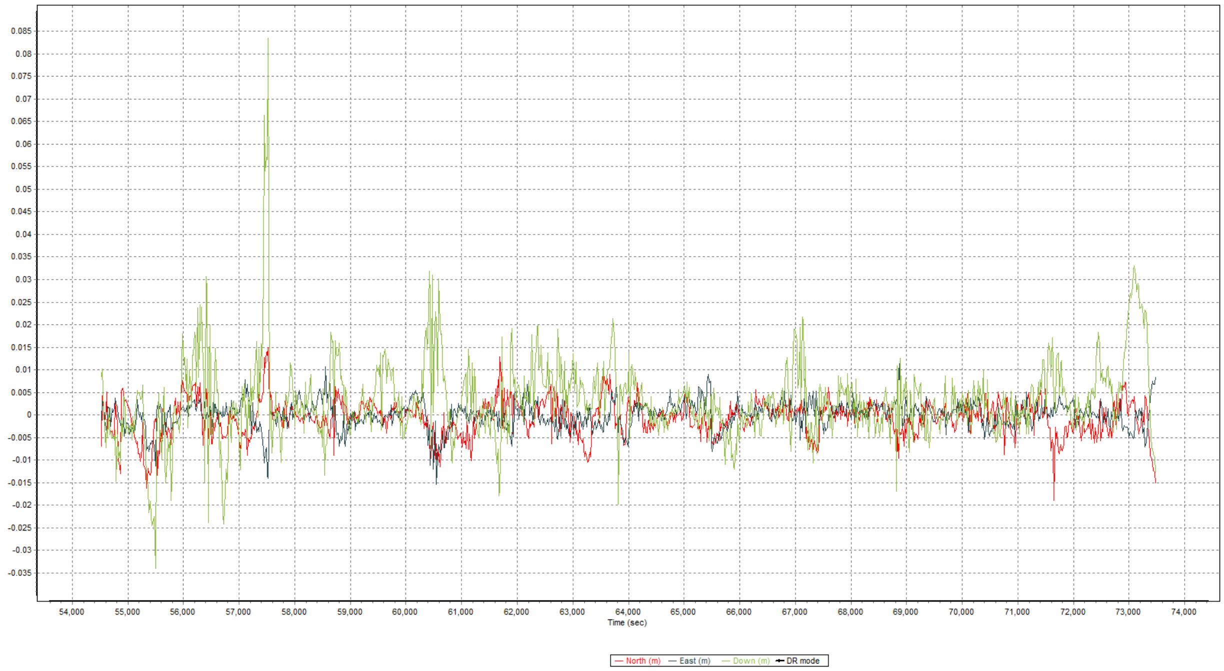
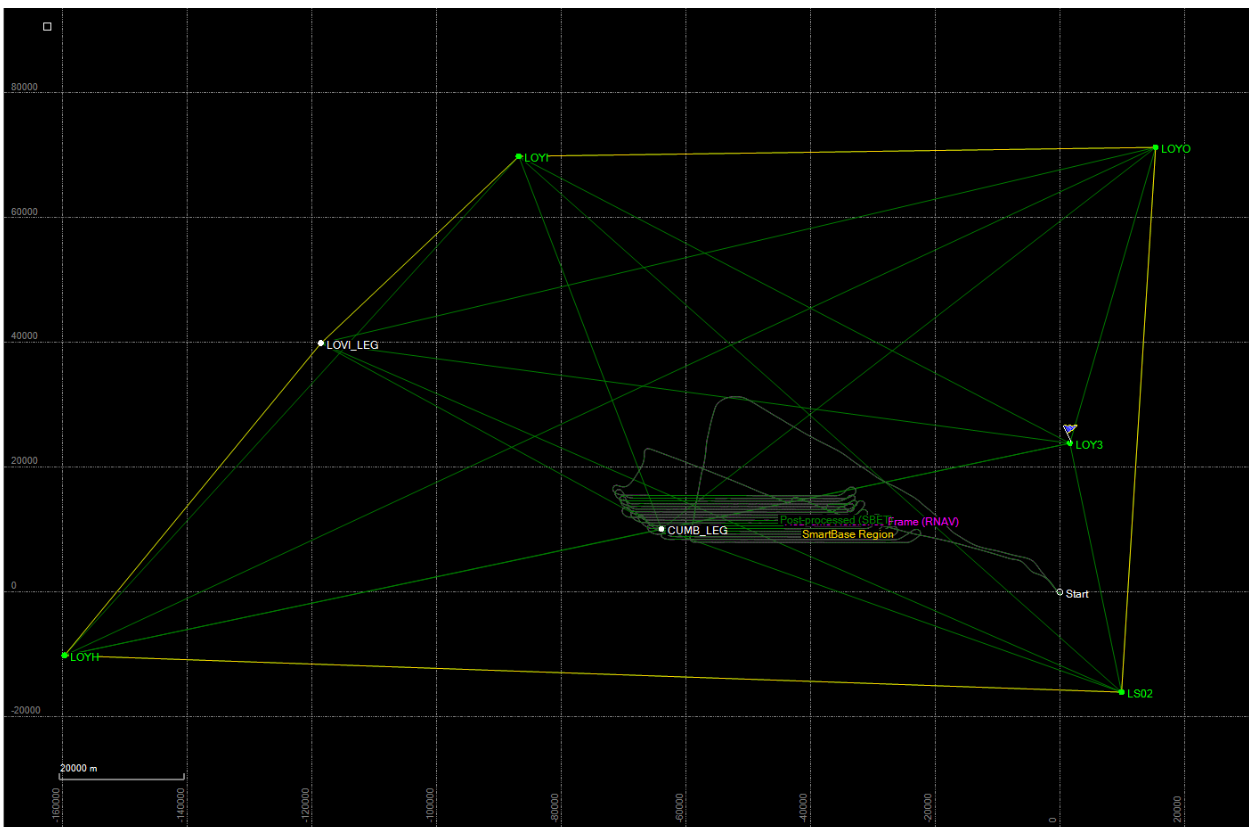
5
4
3
2
54,000
55,000
56,000
57,000
58,000
59,000
60,000
61,000
62,000
63,000
64,000
65,000
66,000
67,000
68,000
69,000
70,000
71,000
72,000
73,000
74,000
Time (sec)


Number of GPS Satellites
10
9
8
7
6
54,000
55,000
56,000
57,000
58,000
59,000
60,000
61,000
62,000
63,000
64,000
65,000
66,000
67,000
68,000
69,000
70,000
71,000
72,000
73,000
74,000
Time (sec)


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


LOYI
LOYO
LOVI_LEG
LOY3
CUMB_LEG
Post-processed (SBET)
Frame (RNAV)
SmartBase Region
Start
LOYH
LS02
20000 m


PDOP
2
54,000
55,000
56,000
57,000
58,000
59,000
60,000
61,000
62,000
63,000
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65,000
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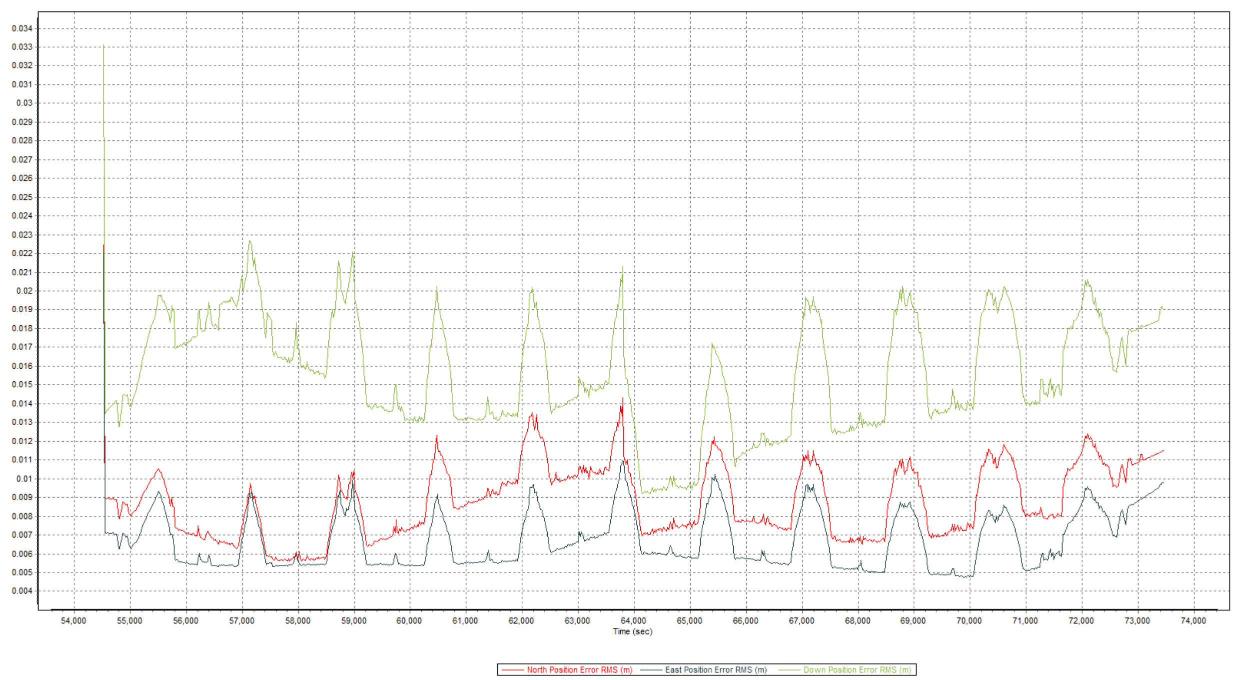
73,000
74,000
Time (sec)


0.034
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0.03
0.029
0.028
0.027
0.026
0.025
0.024
0.023
0.022
0.021
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
54,000
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62,000
63,000
64,000
65,000
66,000
67,000
68,000
69,000
70,000
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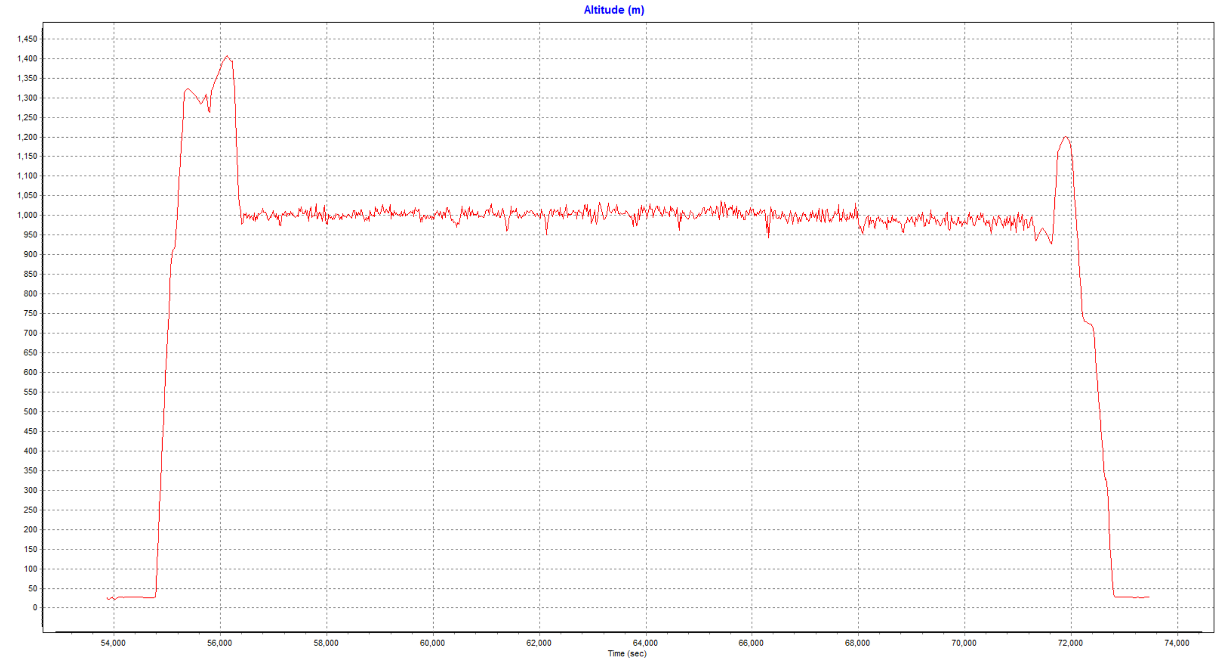
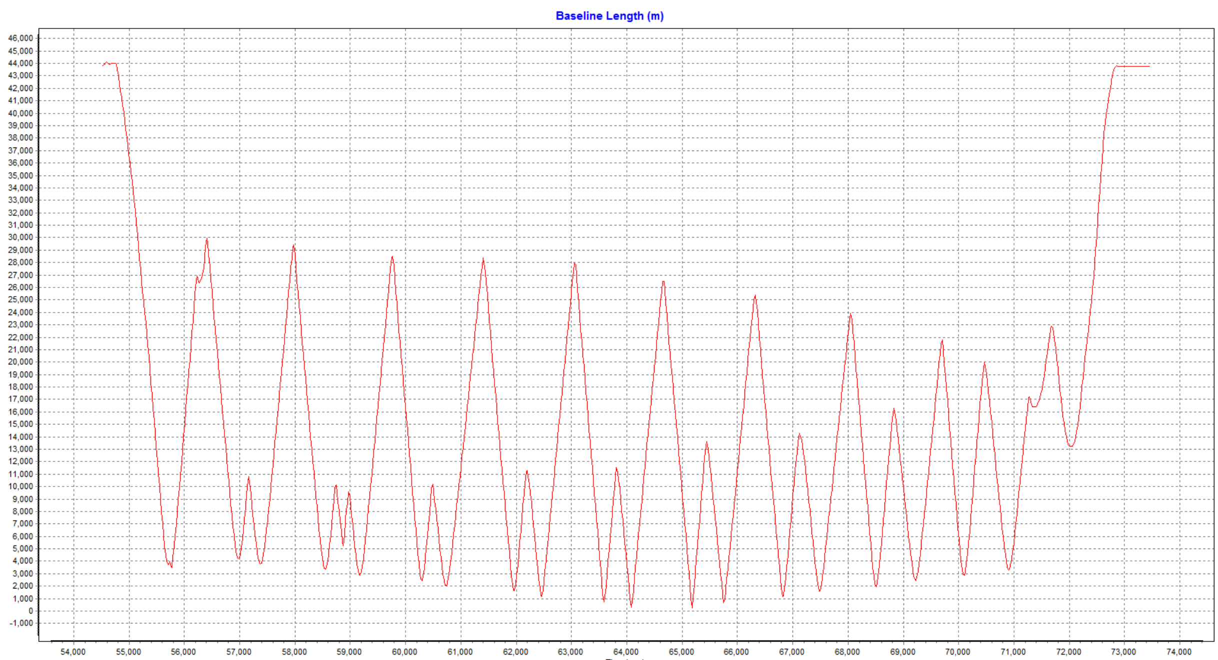
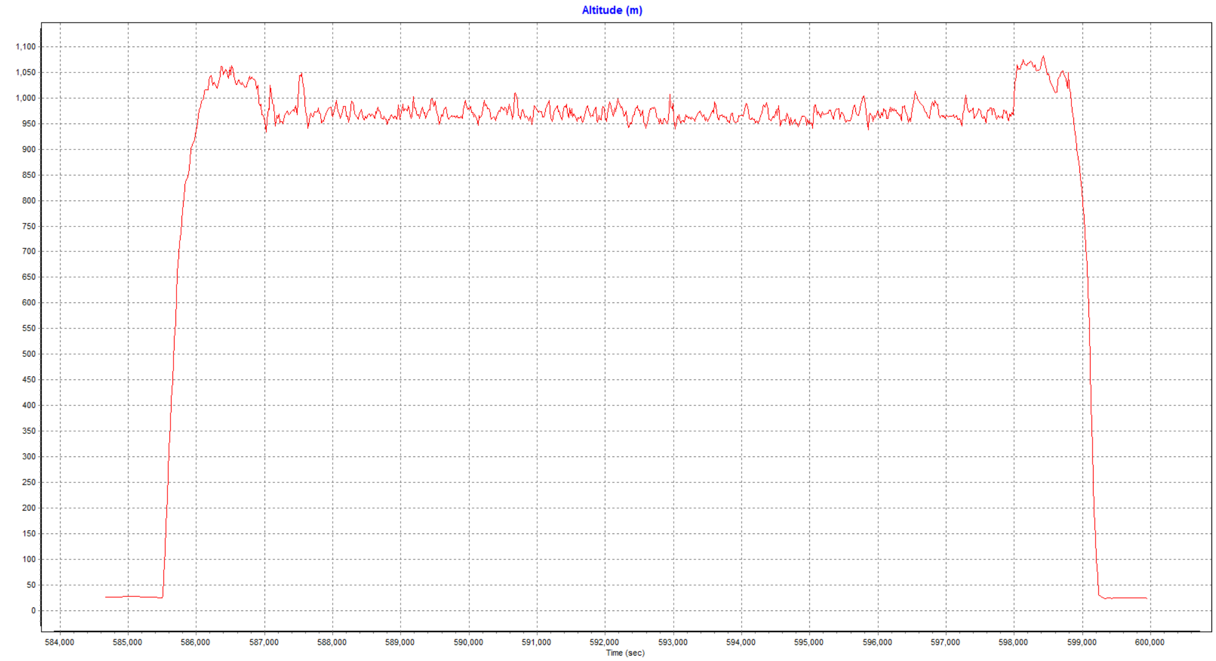
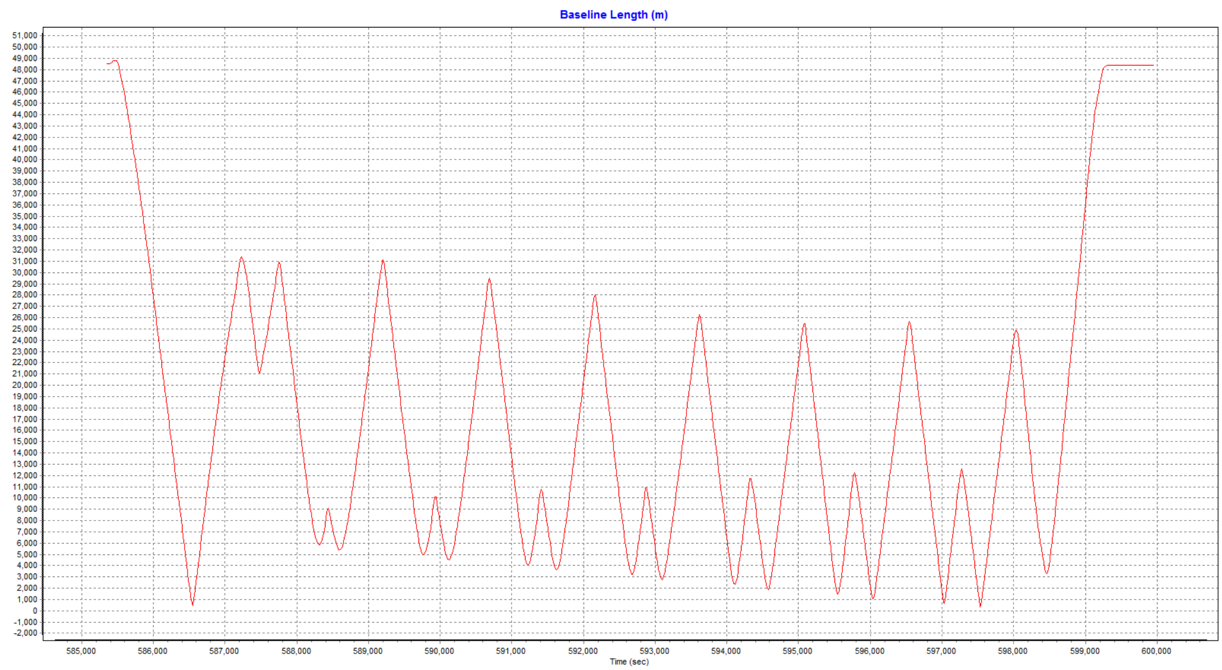
72,000
73,000
74,000
Time (sec)
North Position Error RMS (m)
East Position Error RMS (m)
Down Position Error RMS (m)

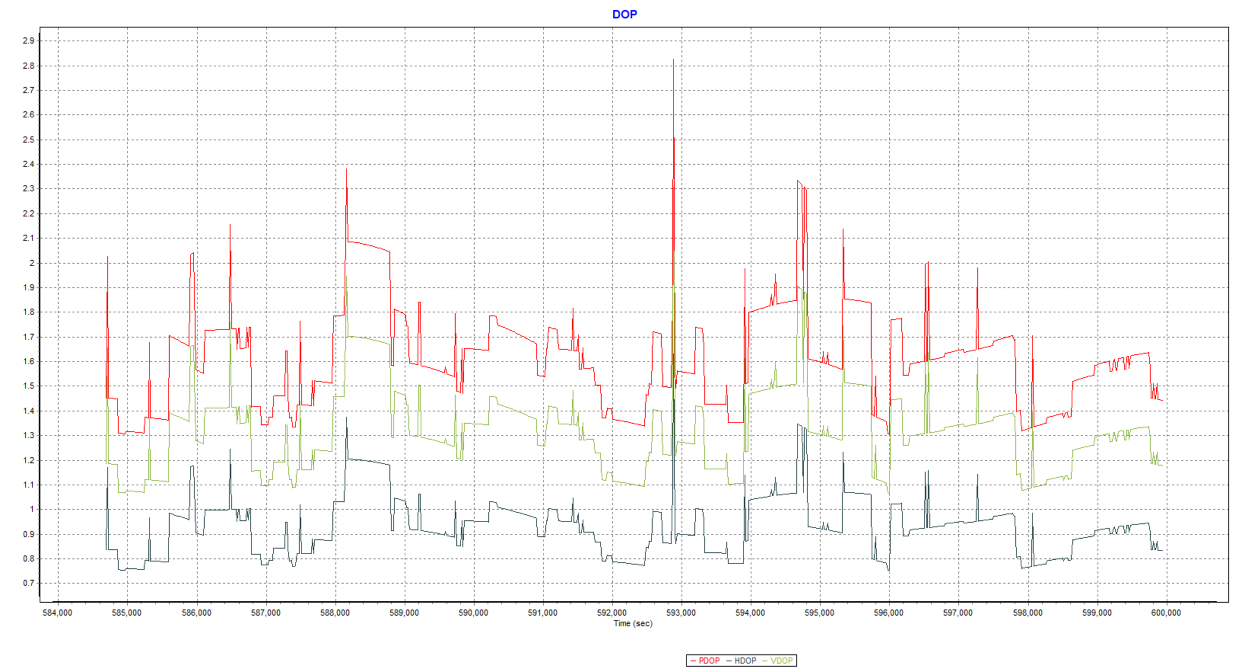

Altitude (m)
Time (sec)

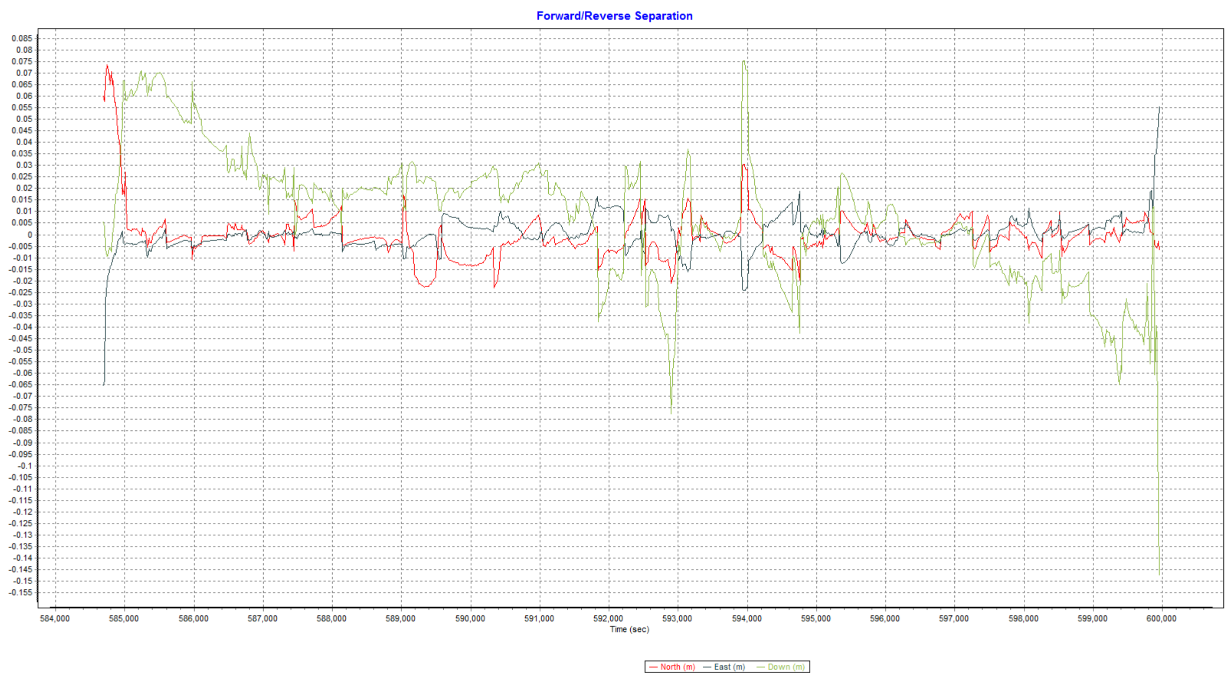

Baseline Length (m)
Time (sec)

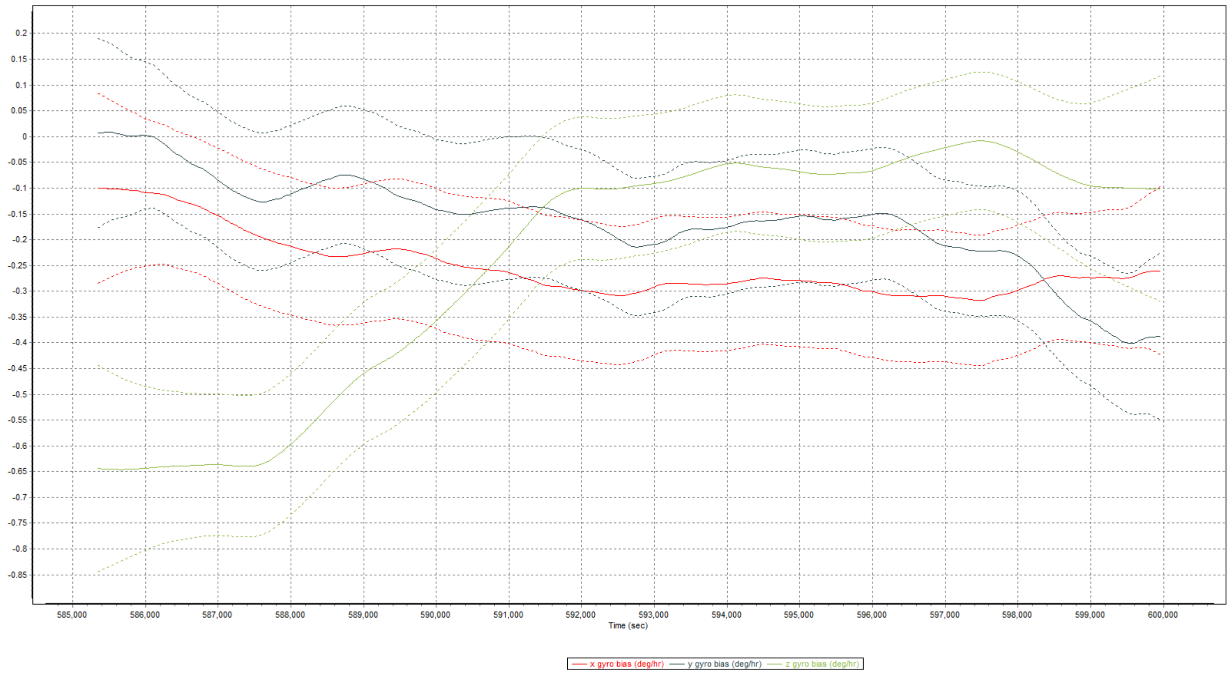
UNB15346A

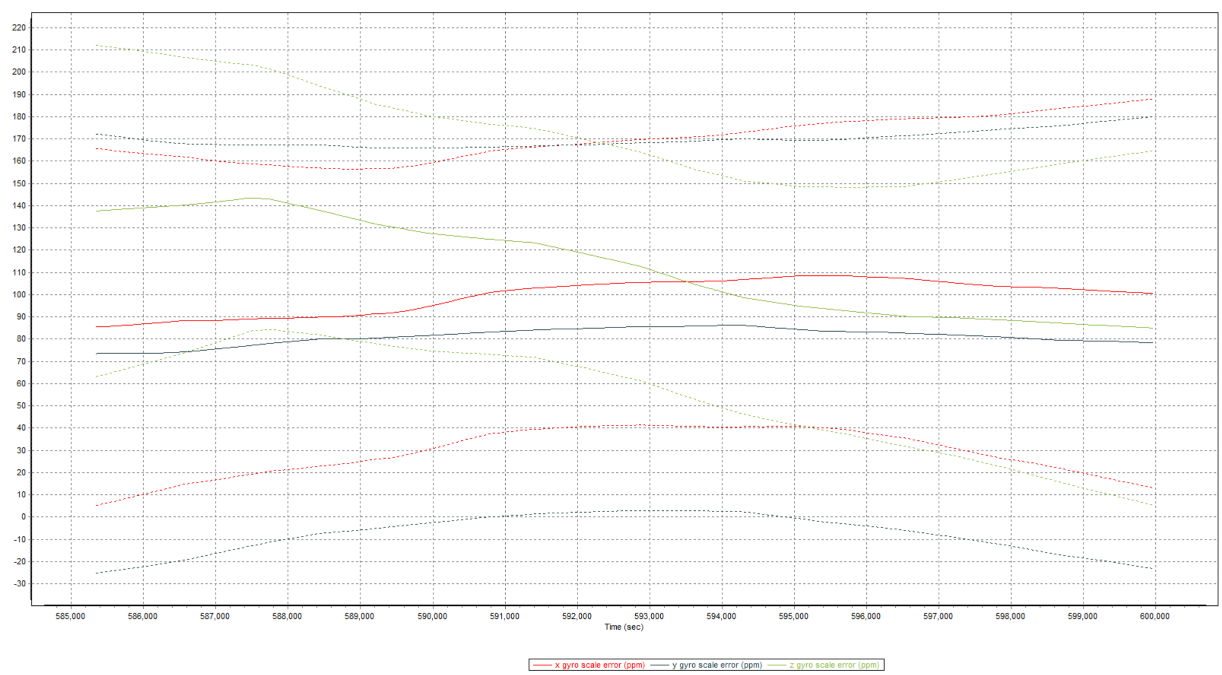


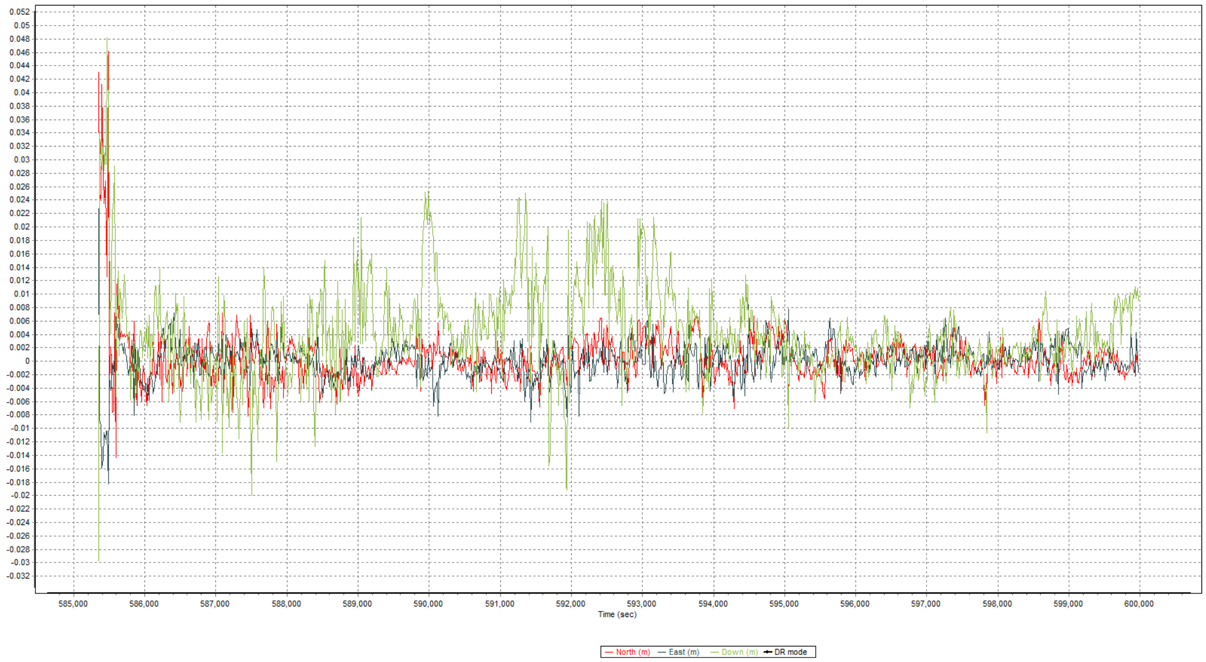


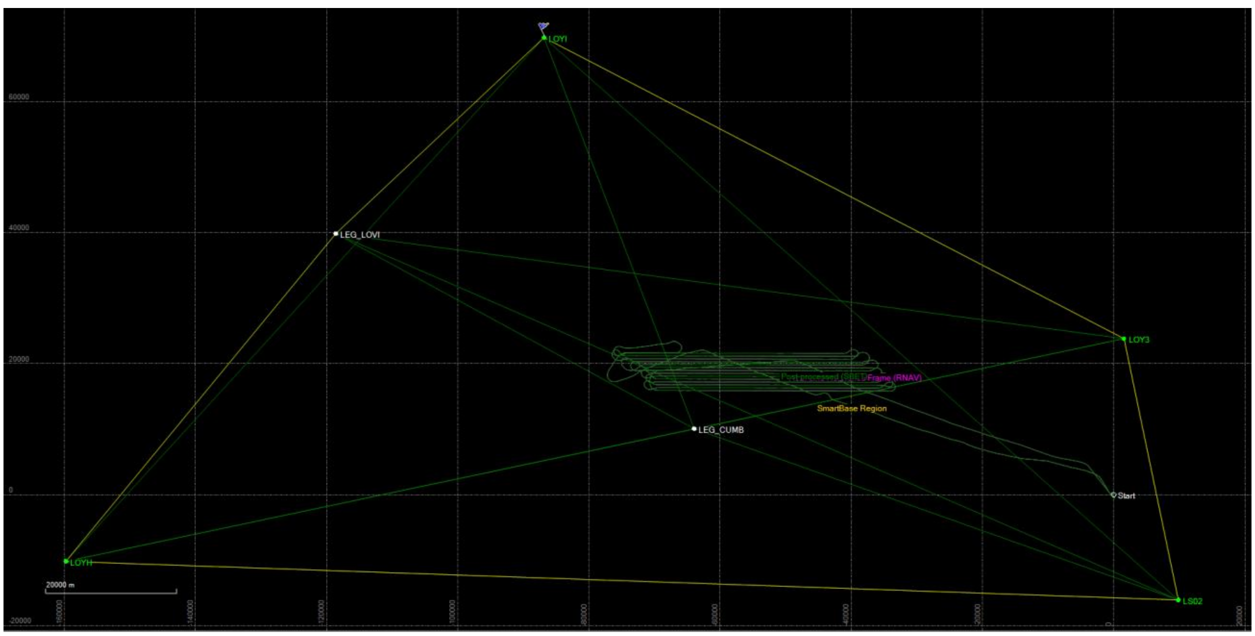

DOP
Time (sec)
PDOP
HDOP
VDOP

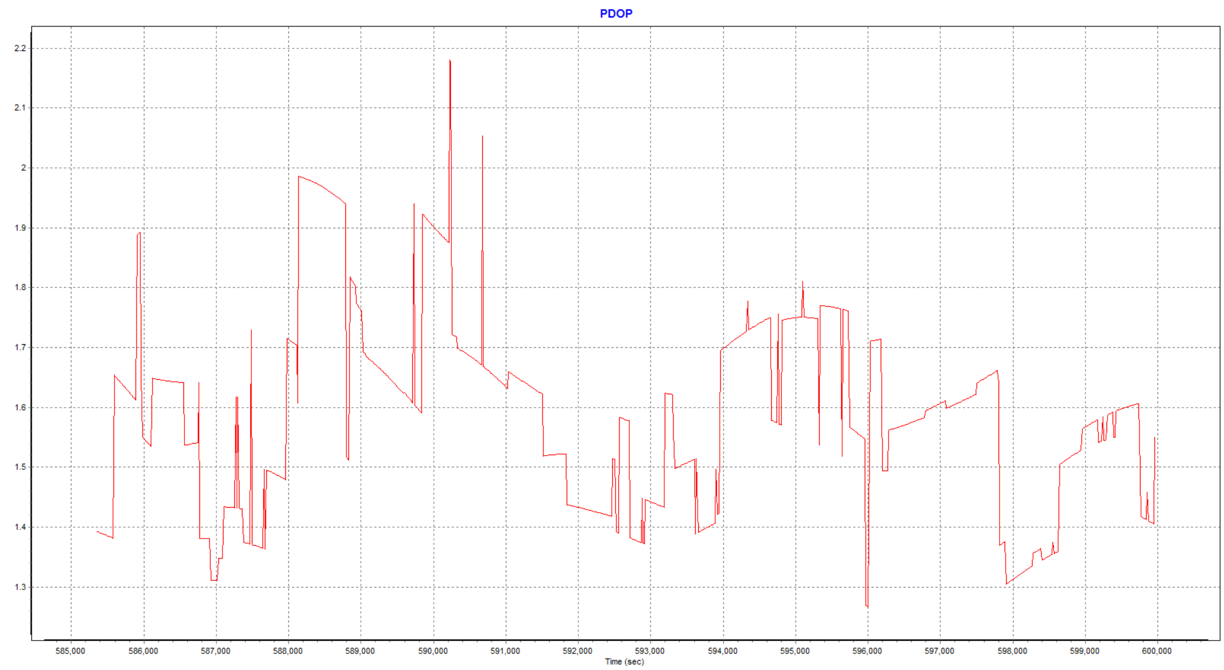

Forward/Reverse Separation
Time (sec)
North (m)
East (m)
Down (m)

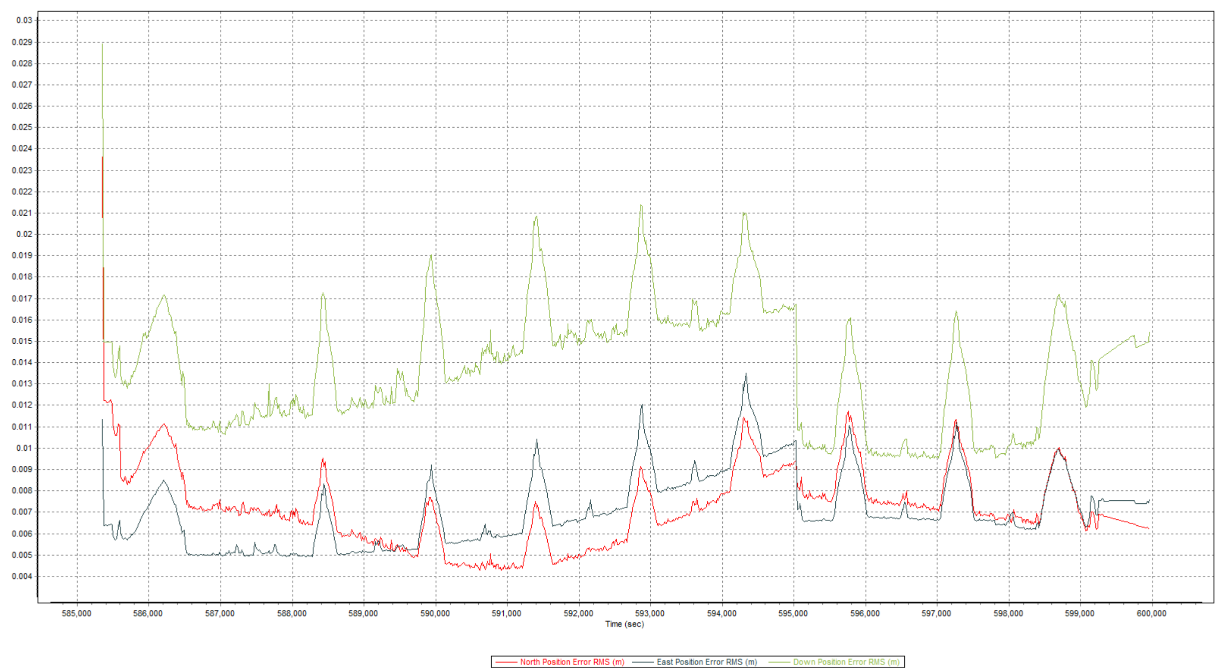

Time (sec)
x gyro bias (deg/hr)
y gyro bias (deg/hr)
z gyro bias (deg/hr)

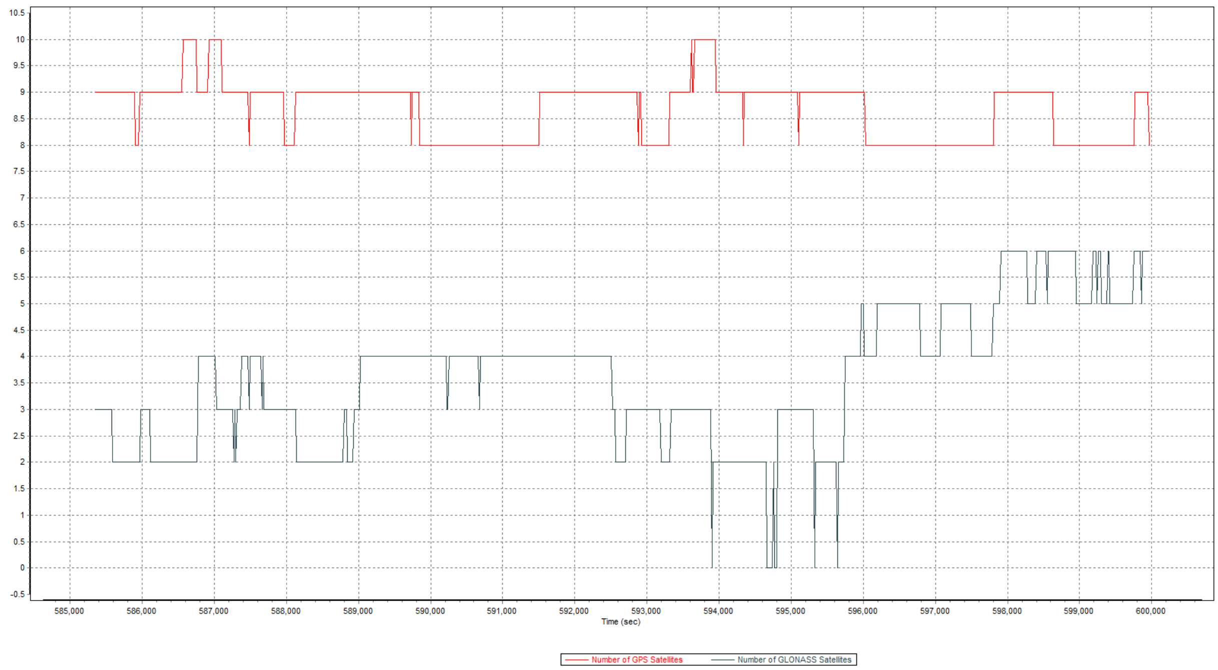

Time (sec)
x gyro scale error (ppm)
y gyro scale error (ppm)
z gyro scale error (ppm)

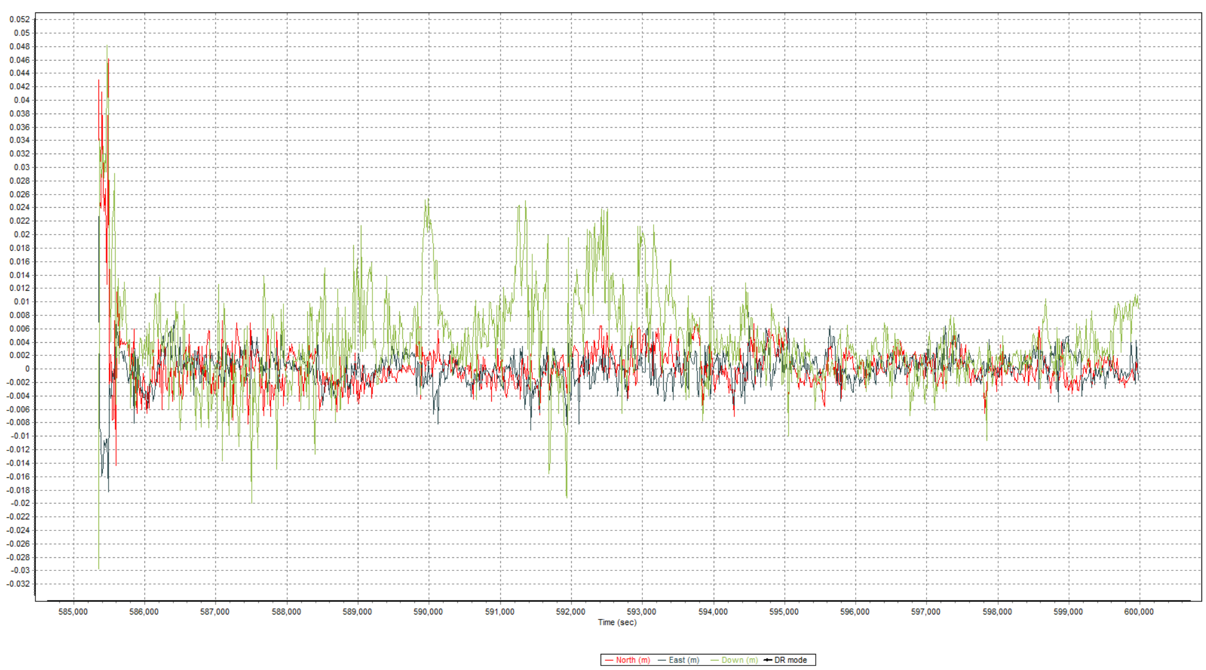

Time (sec)
North (m)
East (m)
Down (m)
DR mode

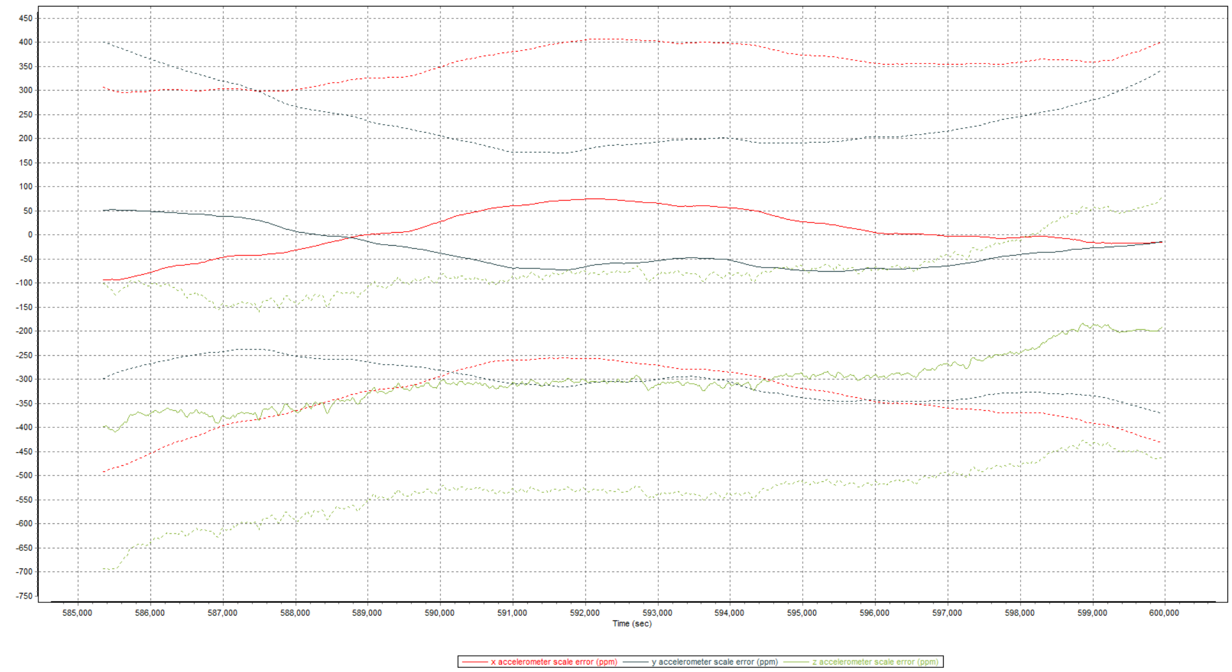

LOYI
LEG_LOVI
LOY3
LEG_CUMB
SmartBase Region
Start
LOYH
LS02
20000 m


PDOP
Time (sec)


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


Time (sec)
Number of GPS Satellites
Number of GLONASS Satellites


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


450
400
350
300
250
200
150
100
50
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-50
-100
-150
-200
-250
-300
-350
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-450
-500
-550
-600
-650
-700
-750
585,000
586,000
587,000
588,000
589,000
590,000
591,000
592,000
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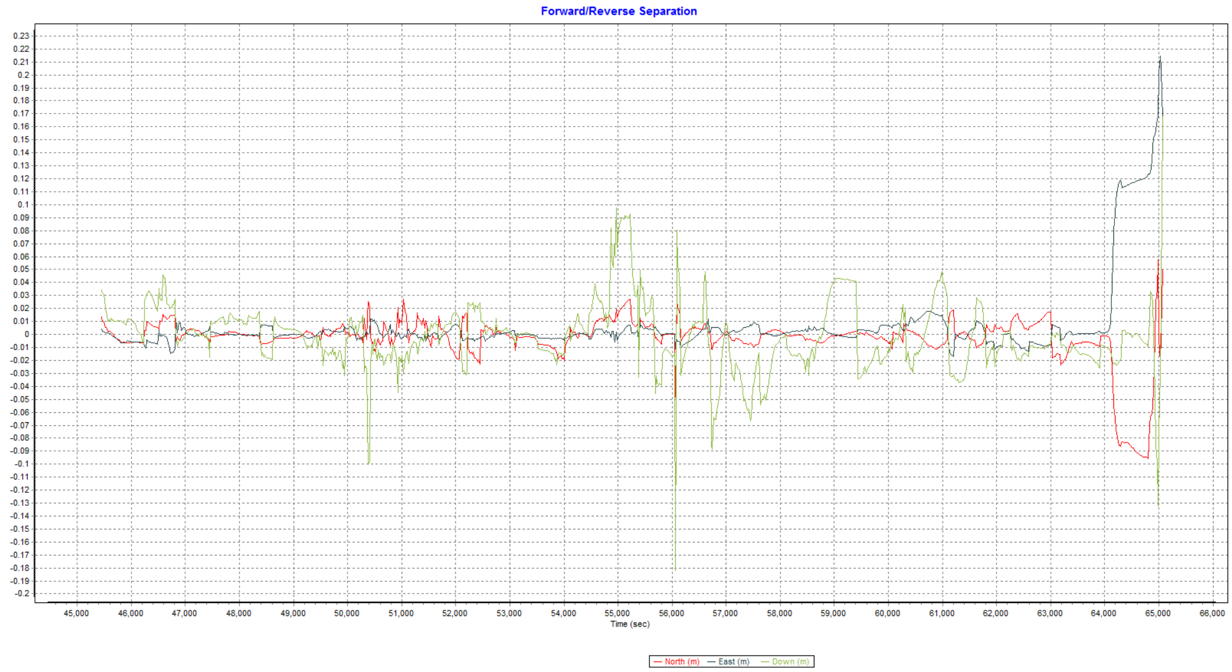
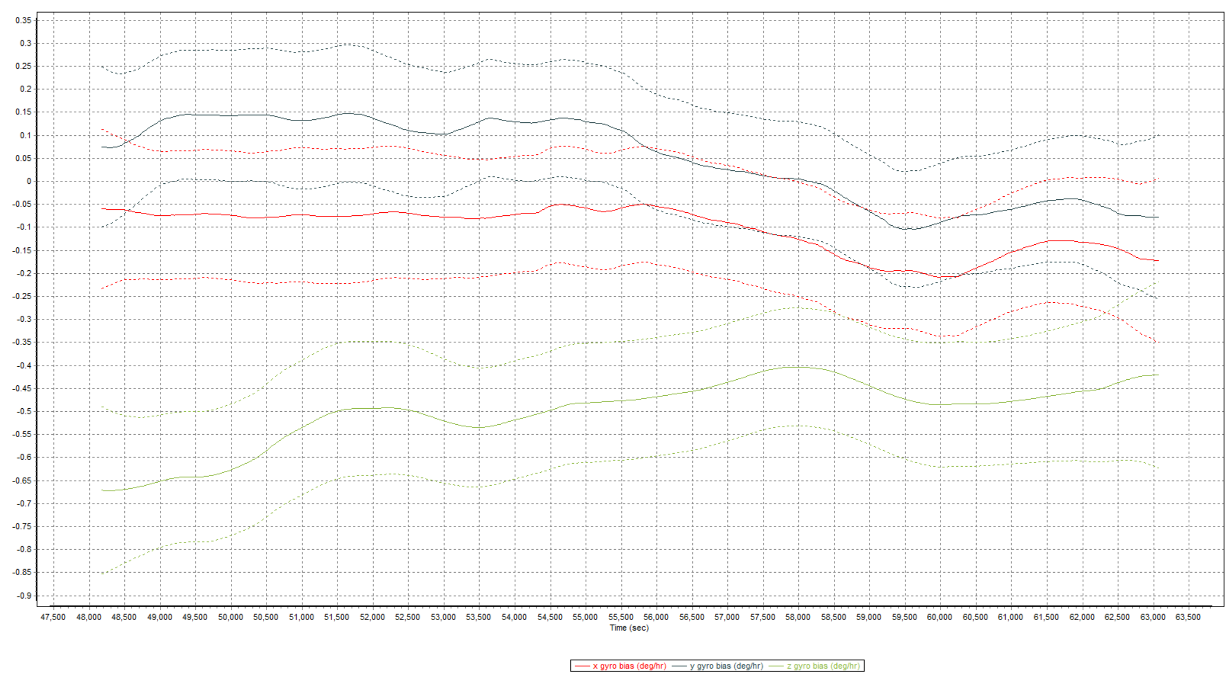
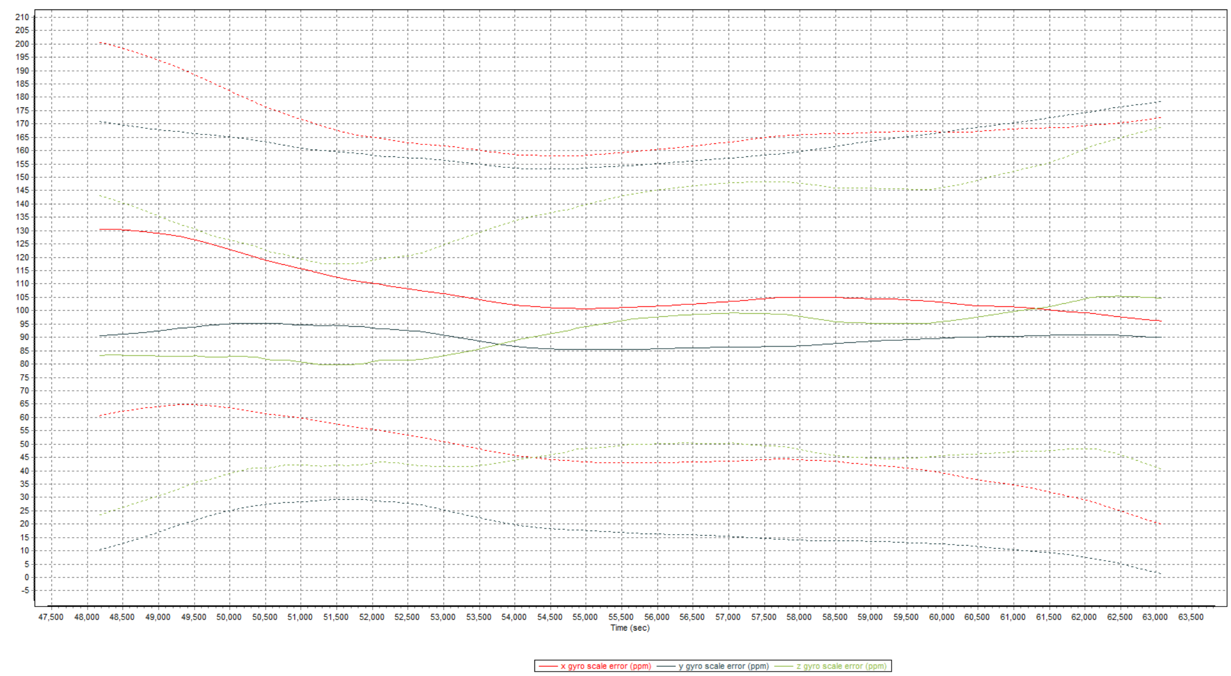
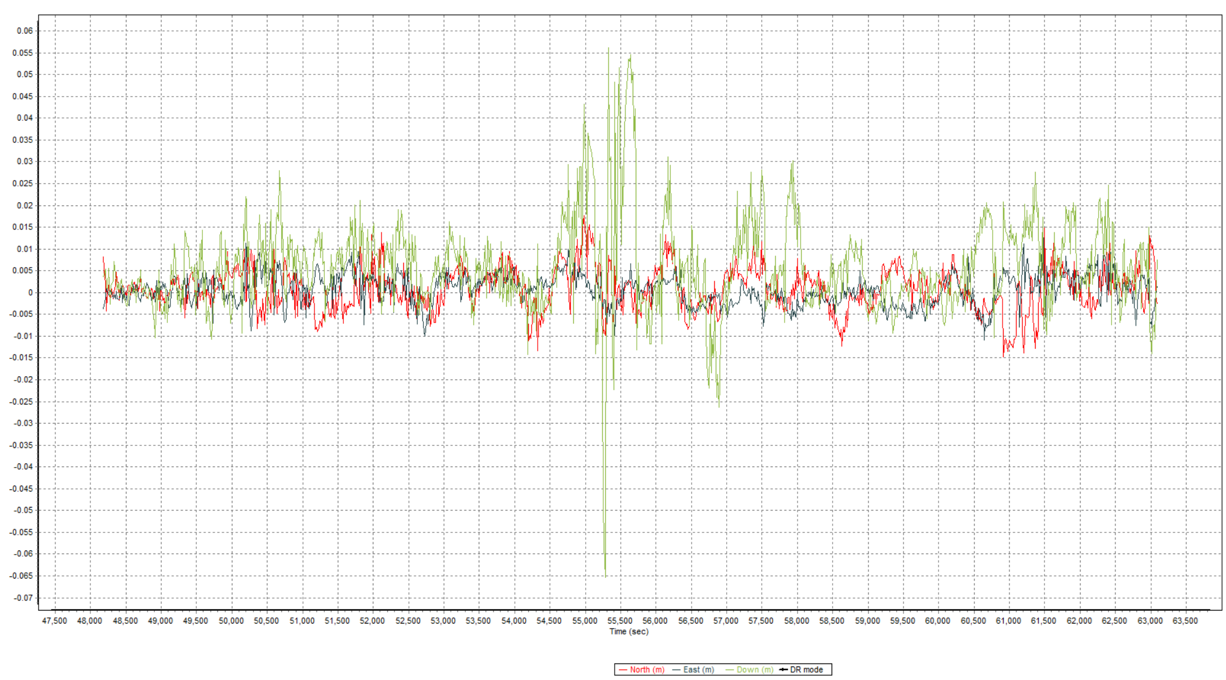
594,000
595,000
596,000
597,000
598,000
599,000
600,000
Time (sec)
x accelerometer scale error (ppm)
y accelerometer scale error (ppm)
z accelerometer scale error (ppm)

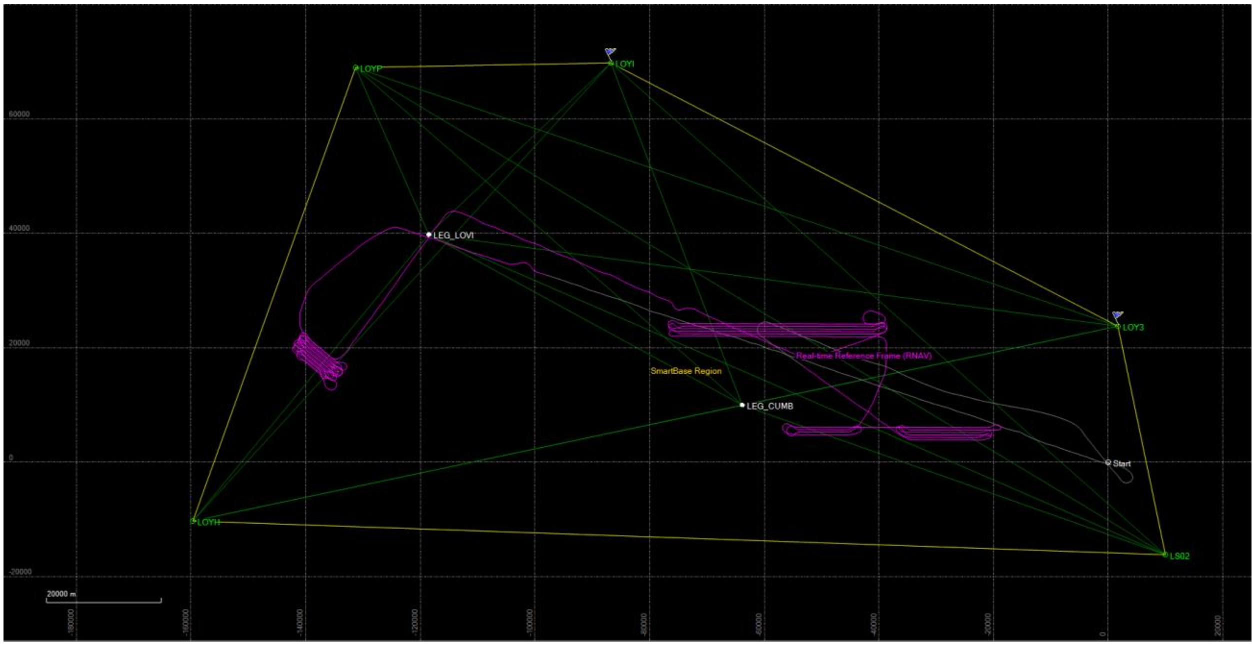
UNB15347A

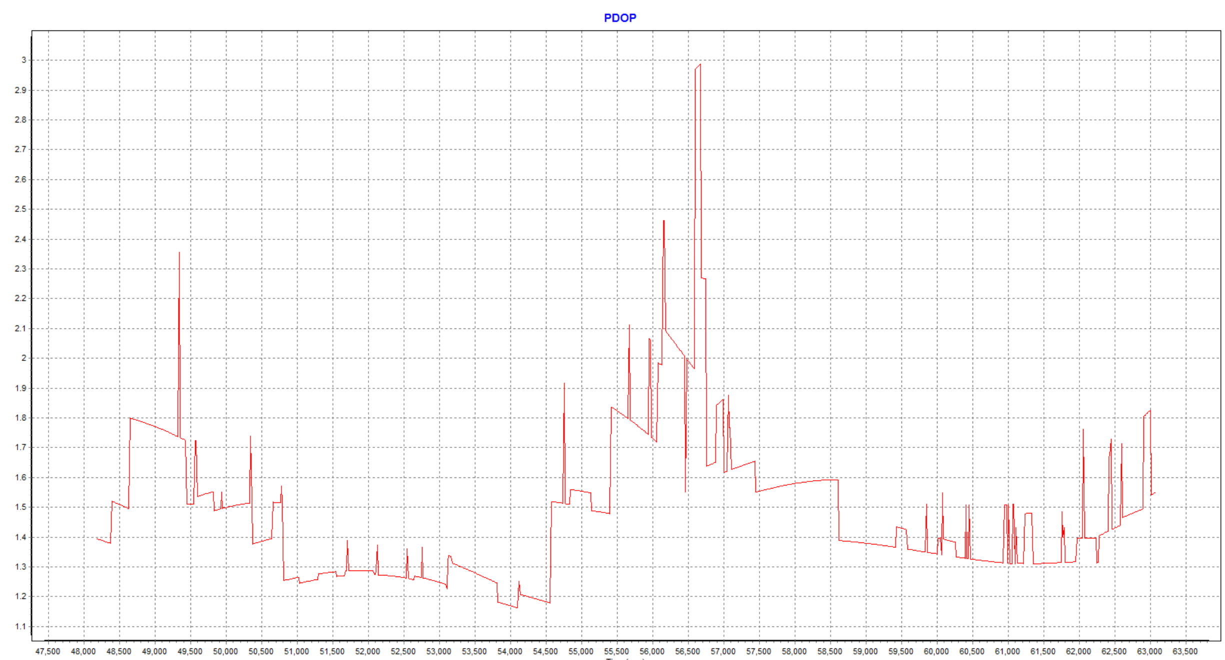

Forward/Reverse Separation
Time (sec)
North (m)
East (m)
Down (m)

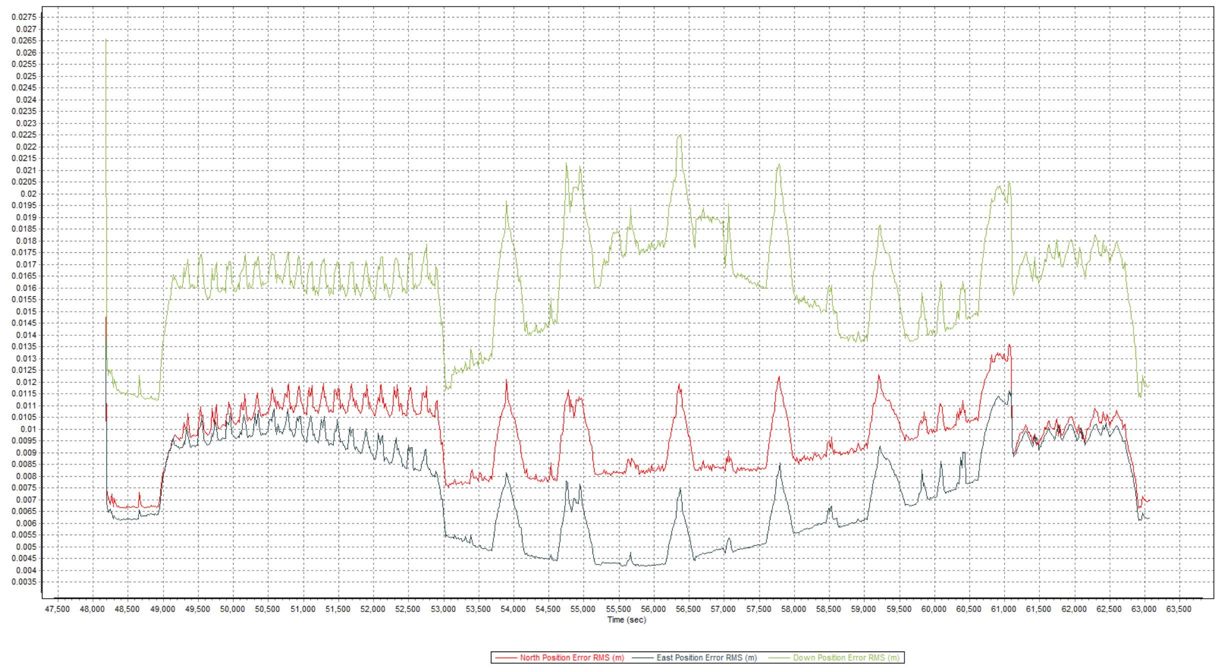

Time (sec)
x gyro bias (deg/hr)
y gyro bias (deg/hr)
z gyro bias (deg/hr)

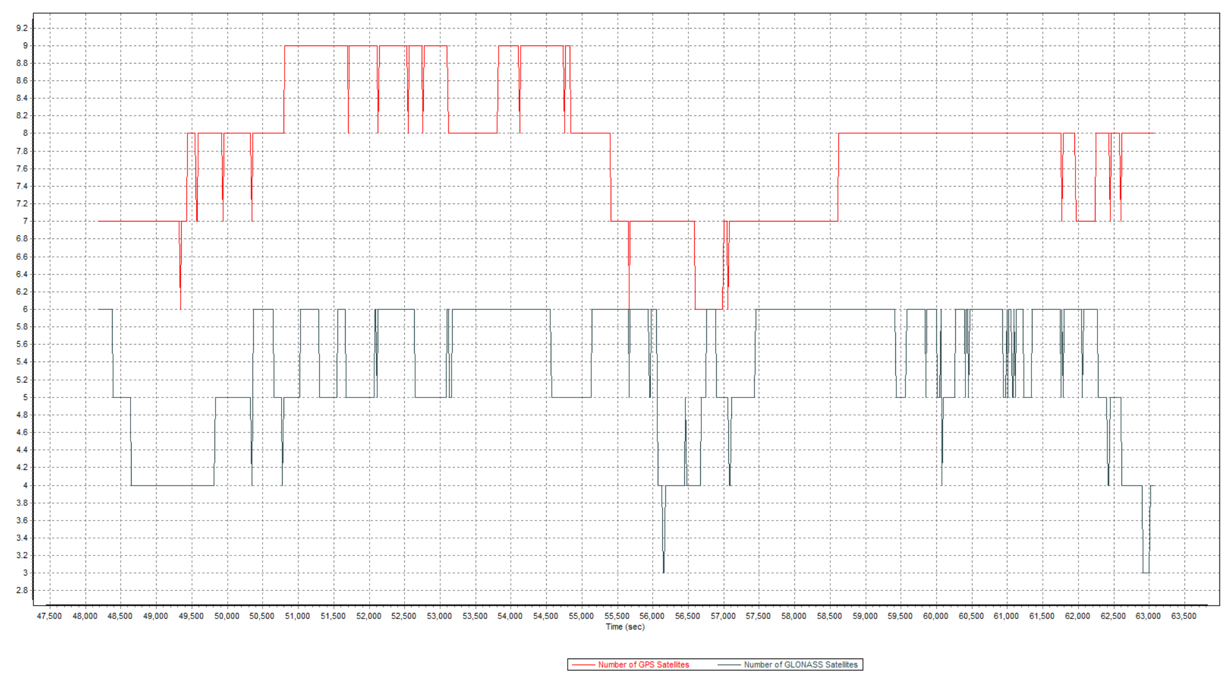

Time (sec)
x gyro scale error (ppm)
y gyro scale error (ppm)
z gyro scale error (ppm)

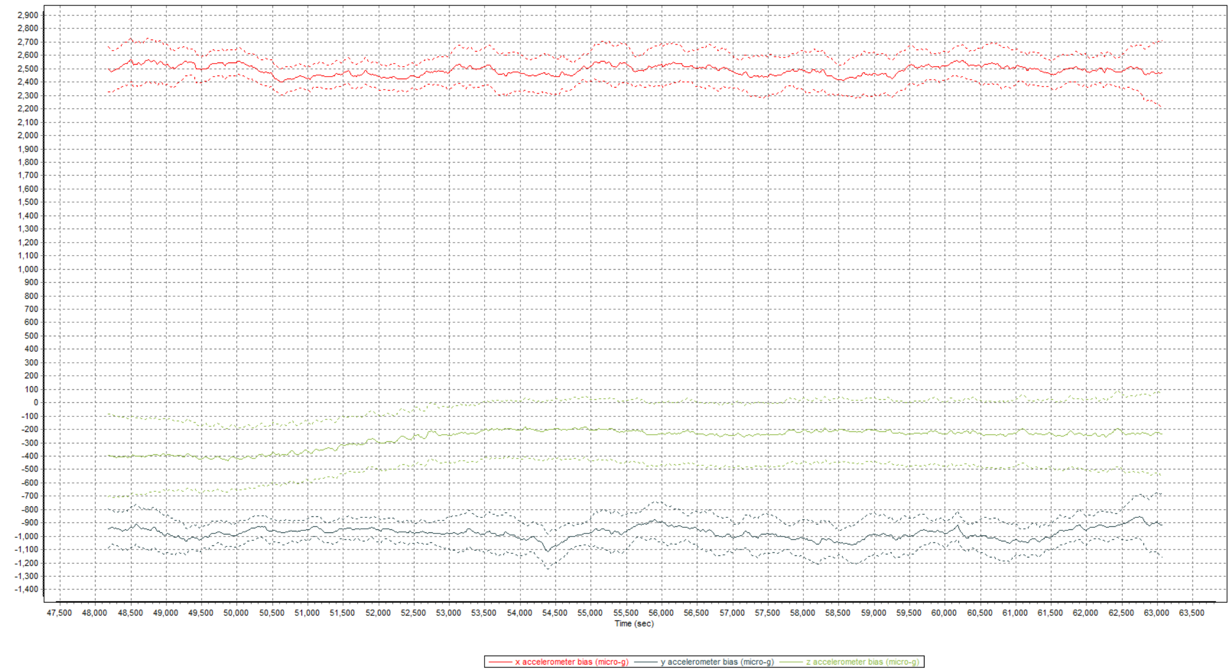

Time (sec)
North (m)
East (m)
Down (m)
DR mode

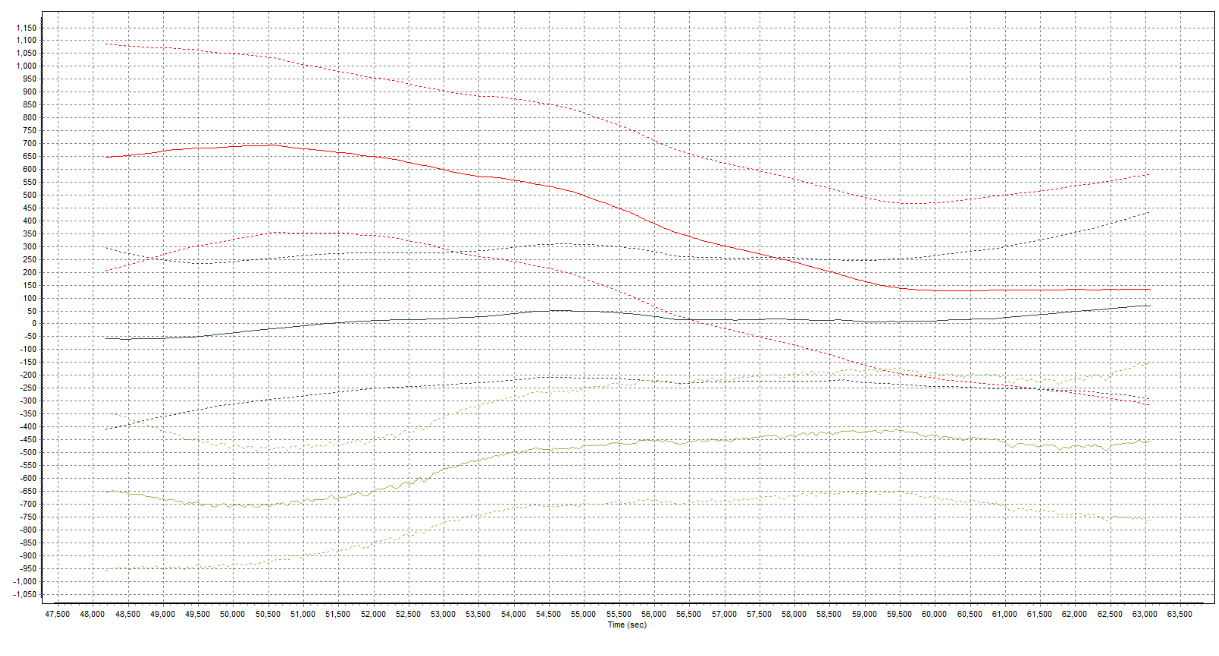

LOYP
LOYI
LEG_LOVI
LOY3
Real-time Reference Frame (RNAV)
SmartBase Region
LEG_CUMB
Start
LOYH
LS02
20000 m

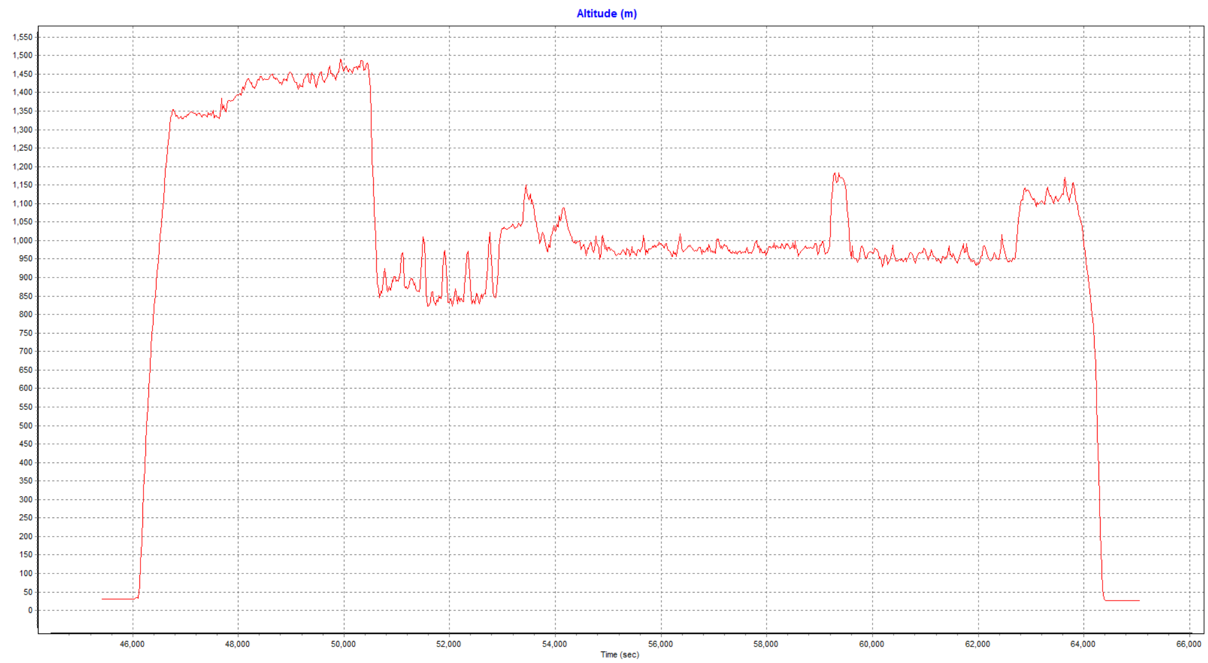

PDOP
Time (sec)

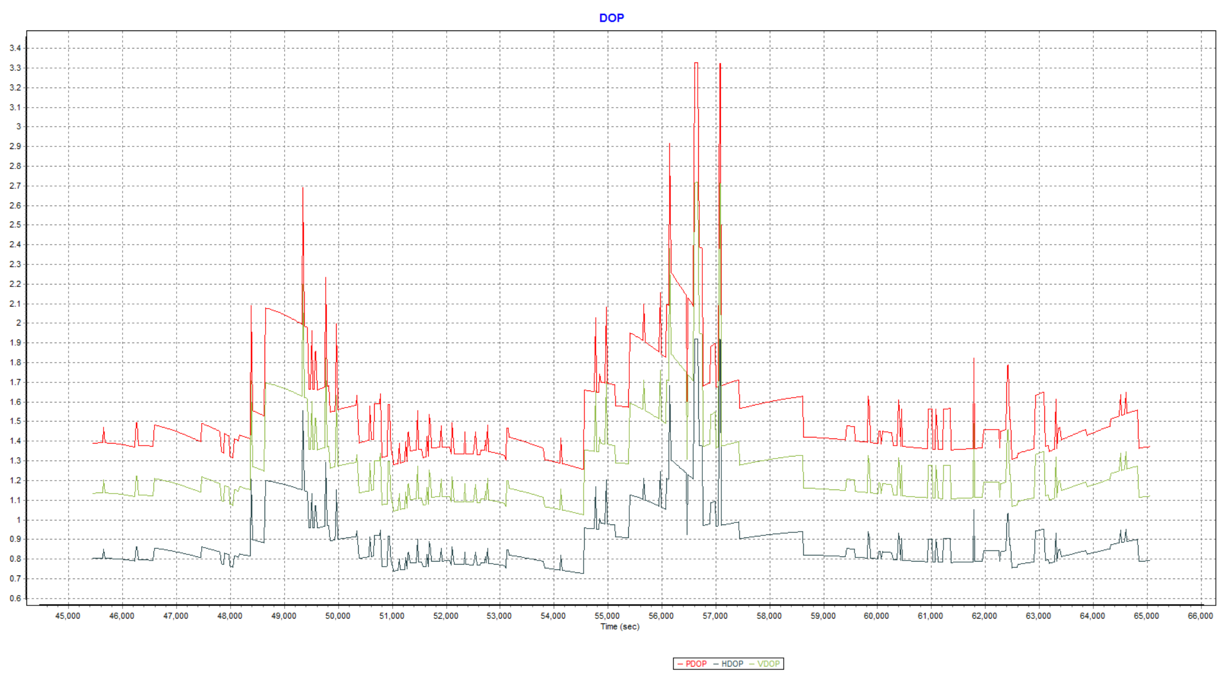

Time (sec)
North Position Error RMS (m)
East Position Error RMS (m)
Down Position Error RMS (m)


Time (sec)
Number of GPS Satellites
Number of GLONASS Satellites

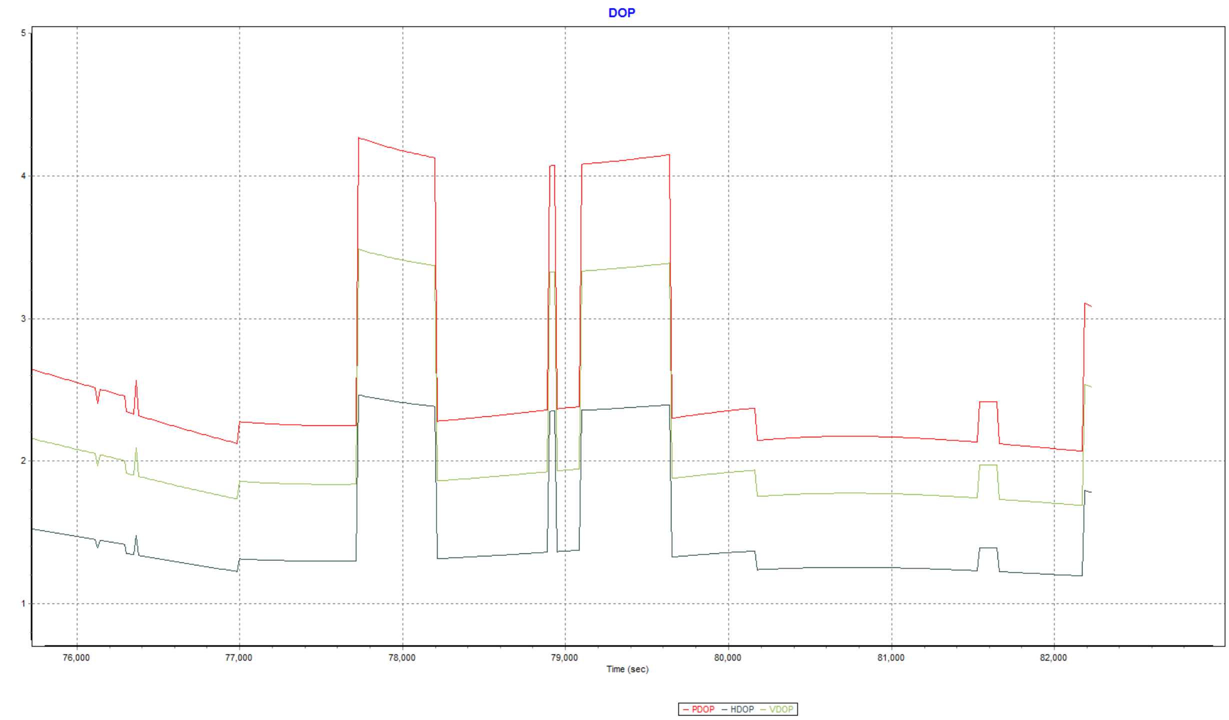

Time (sec)
x accelerometer bias (micro-g)
y accelerometer bias (micro-g)
z accelerometer bias (micro-g)

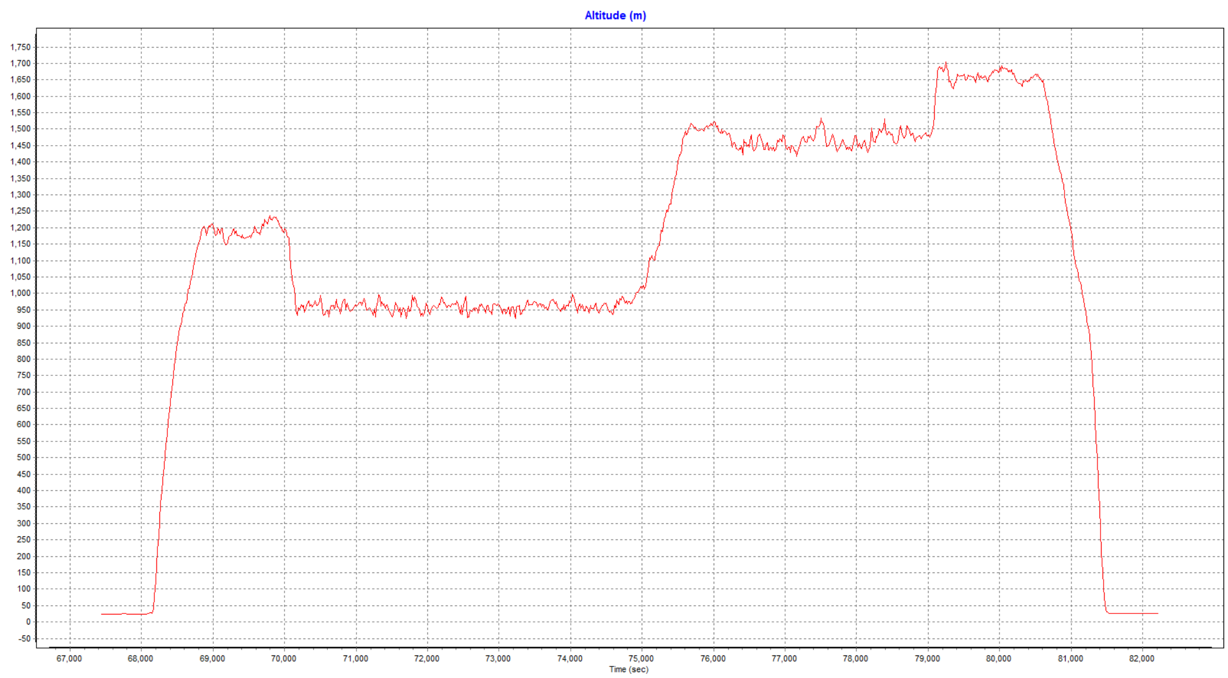

Time (sec)
x accelerometer scale error (ppm)
y accelerometer scale error (ppm)
z accelerometer scale error (ppm)


Altitude (m)
Time (sec)

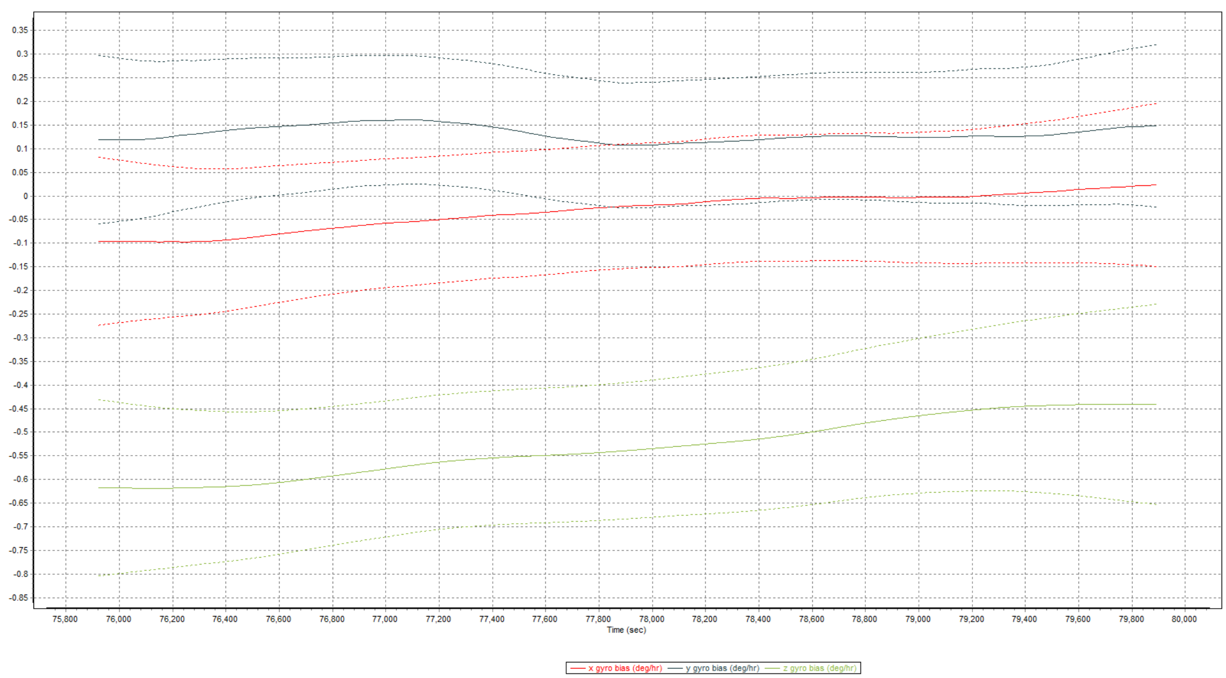

DOP
Time (sec)
PDOP
HDOP
VDOP

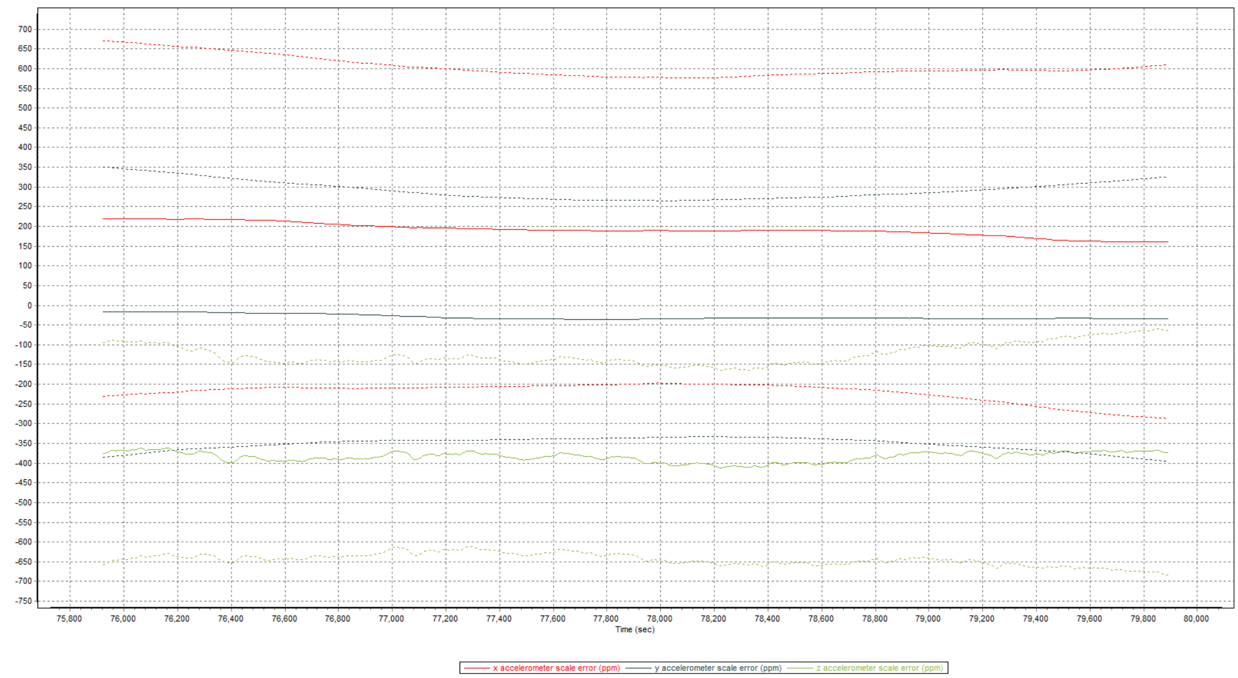
UNB15347B

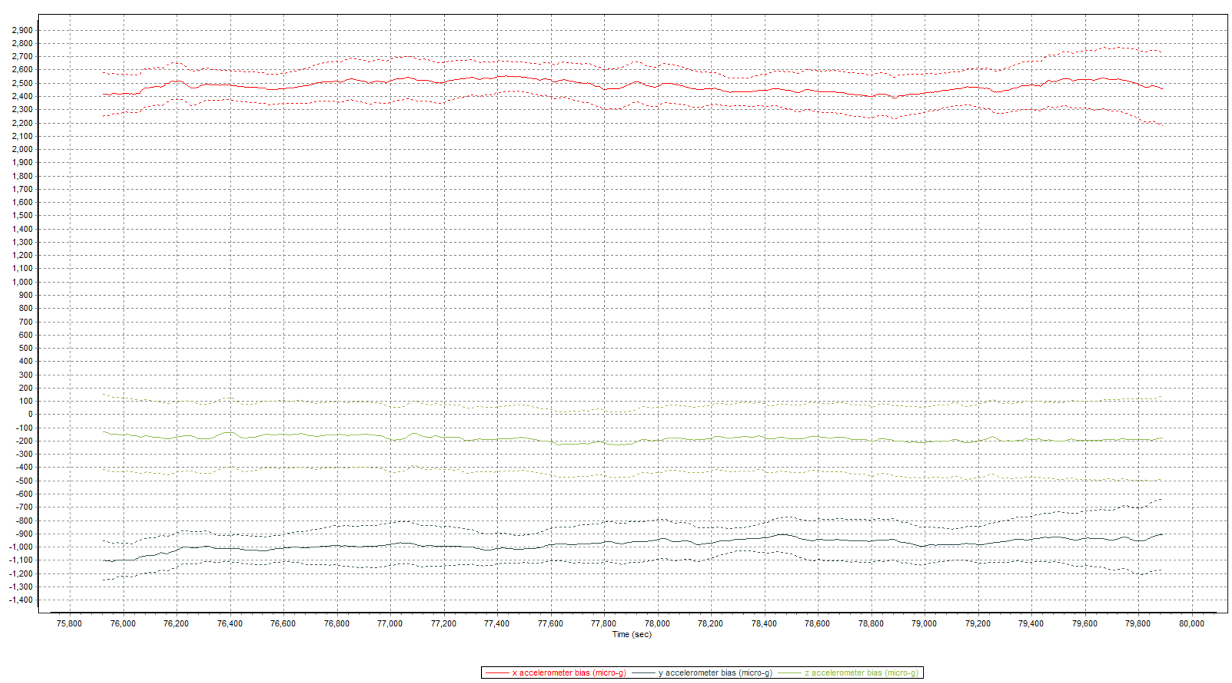

DOP
5
4
3
2
1
76,000
77,000
78,000
79,000
80,000
81,000
82,000
Time (sec)
PDOP
HDOP
VDOP

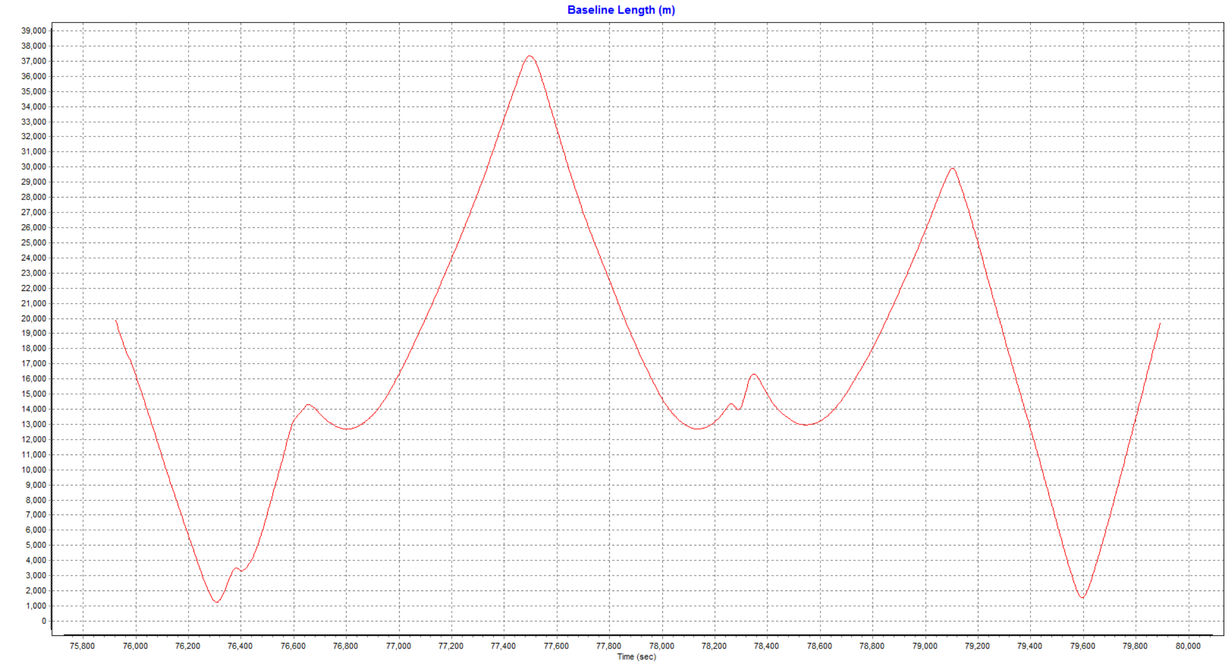

Altitude (m)
Time (sec)

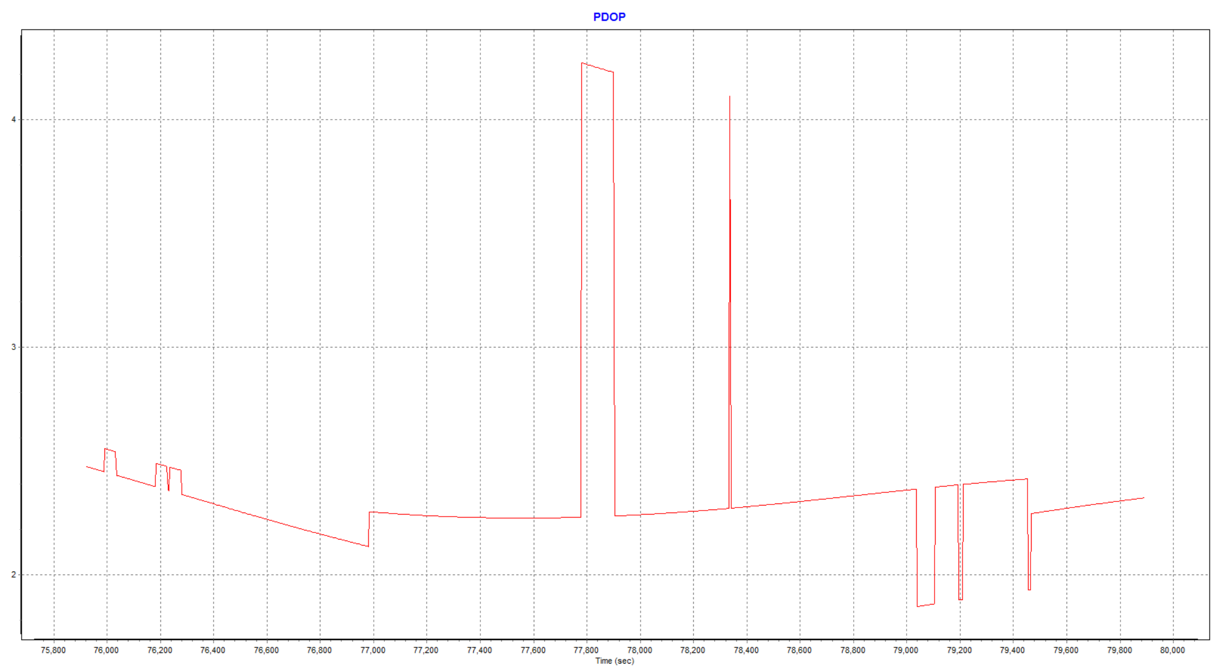

Time (sec)
x gyro scale error (ppm)
y gyro scale error (ppm)
z gyro scale error (ppm)

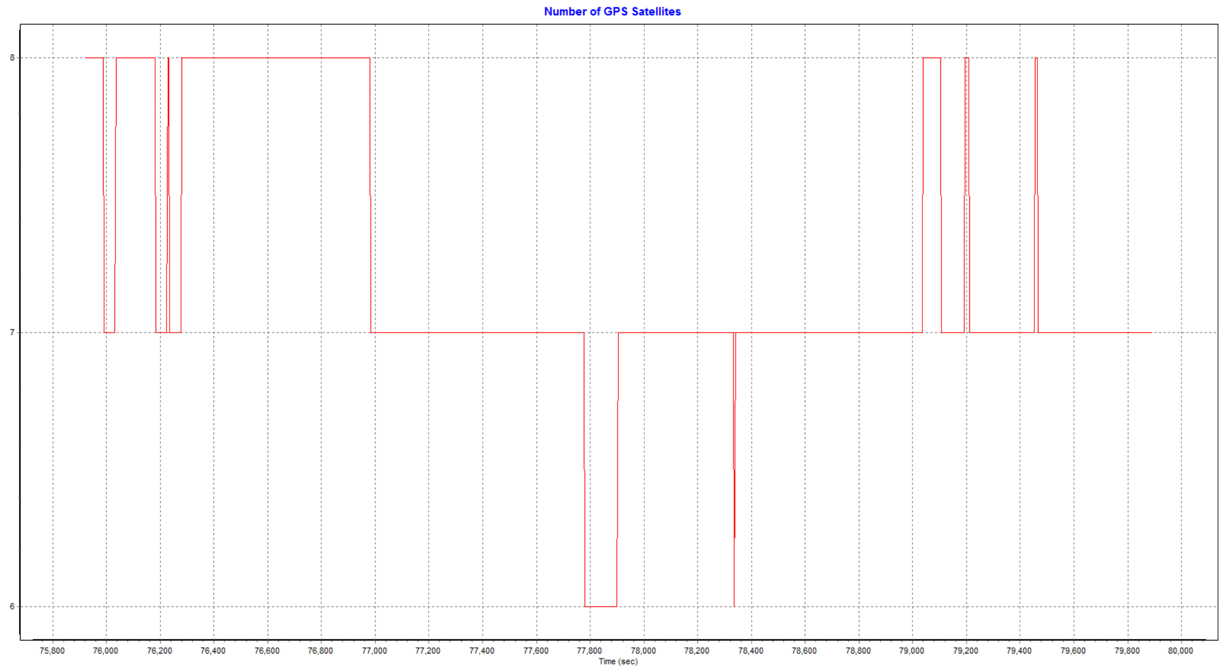

Time (sec)
x gyro bias (deg/hr)
y gyro bias (deg/hr)
z gyro bias (deg/hr)

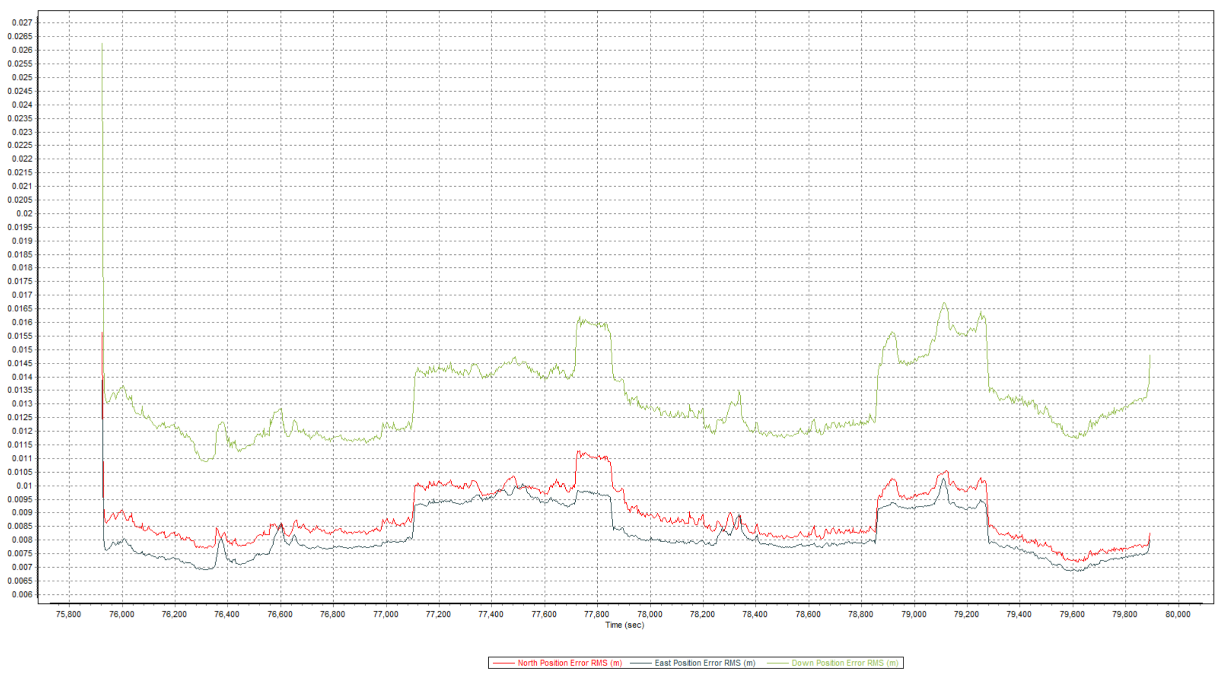

Time (sec)
x accelerometer scale error (ppm)
y accelerometer scale error (ppm)
z accelerometer scale error (ppm)

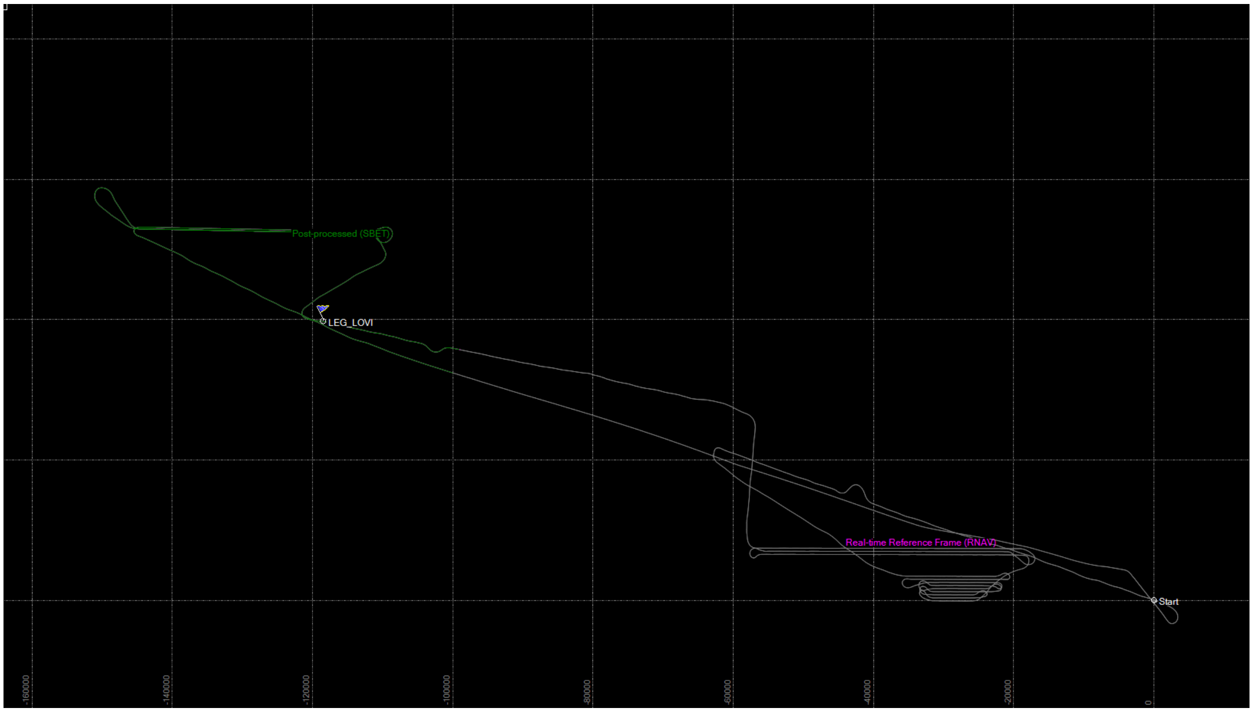

Time (sec)
x accelerometer bias (micro-g)
y accelerometer bias (micro-g)
z accelerometer bias (micro-g)

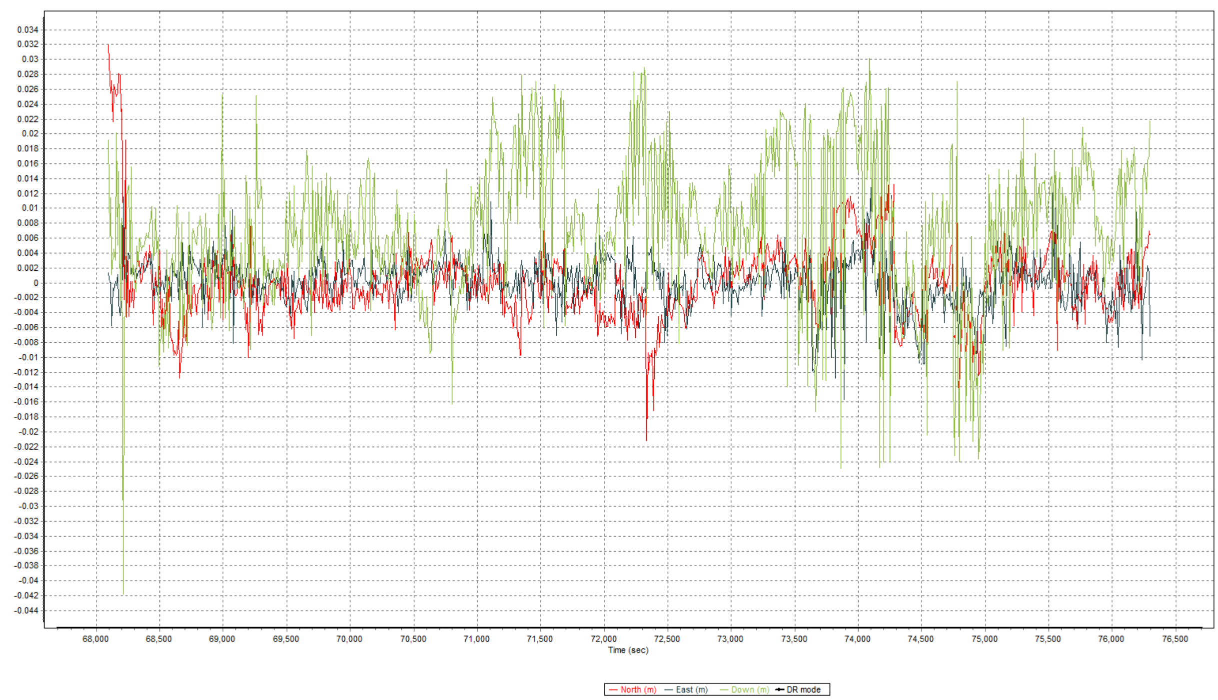

Baseline Length (m)
Time (sec)

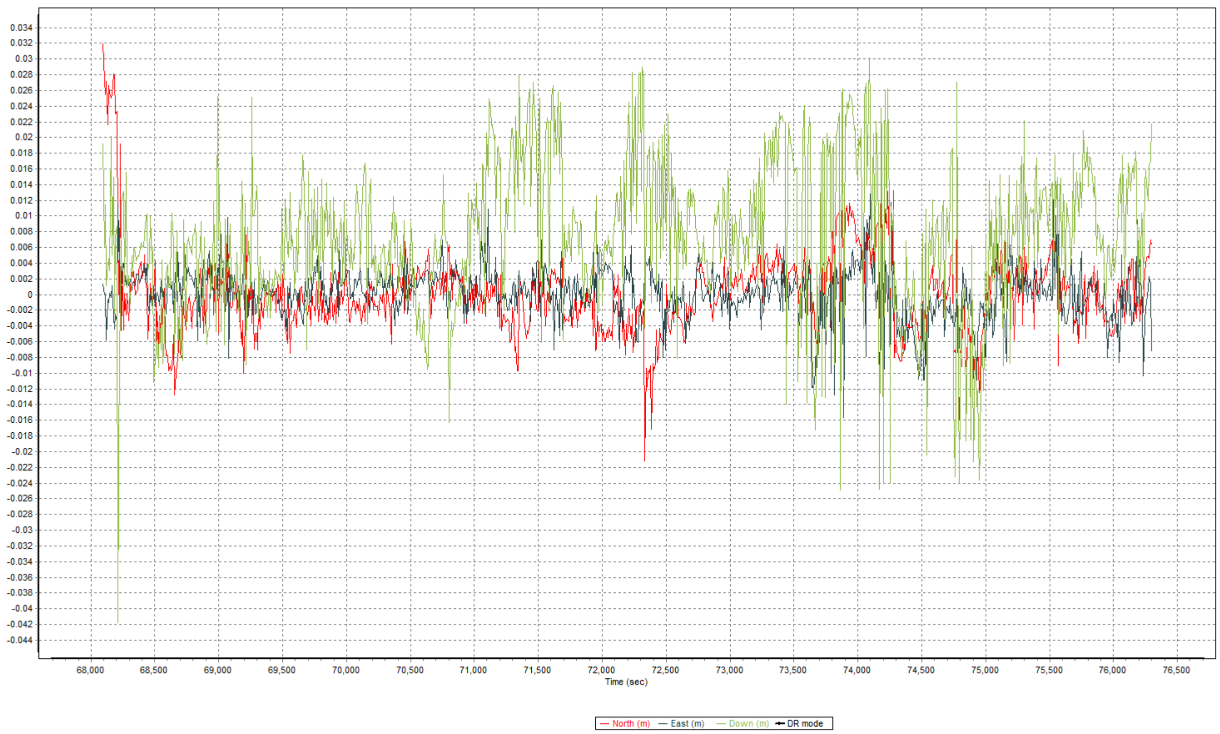

PDOP
Time (sec)

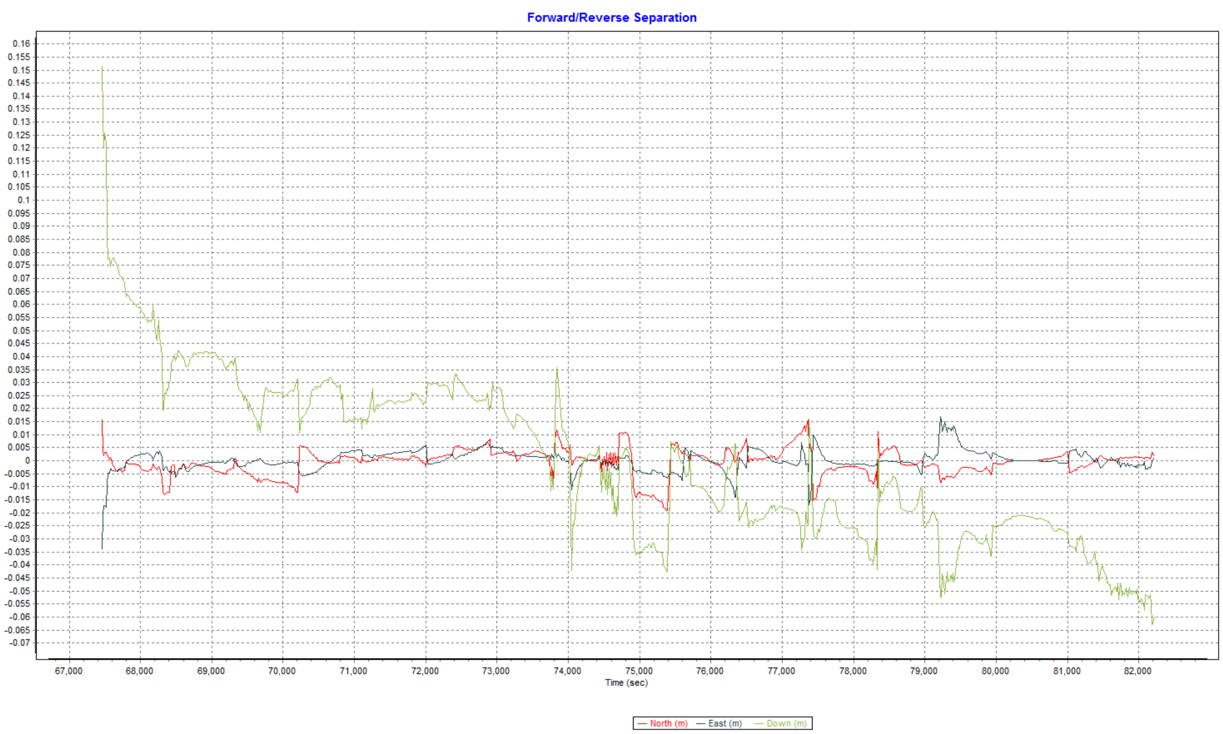

Number of GPS Satellites
8
7
6
75,800
76,000
76,200
76,400
76,600
76,800
77,000
77,200
77,400
77,600
77,800
78,000
78,200
78,400
78,600
78,800
79,000
79,200
79,400
79,600
79,800
80,000
Time (sec)


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

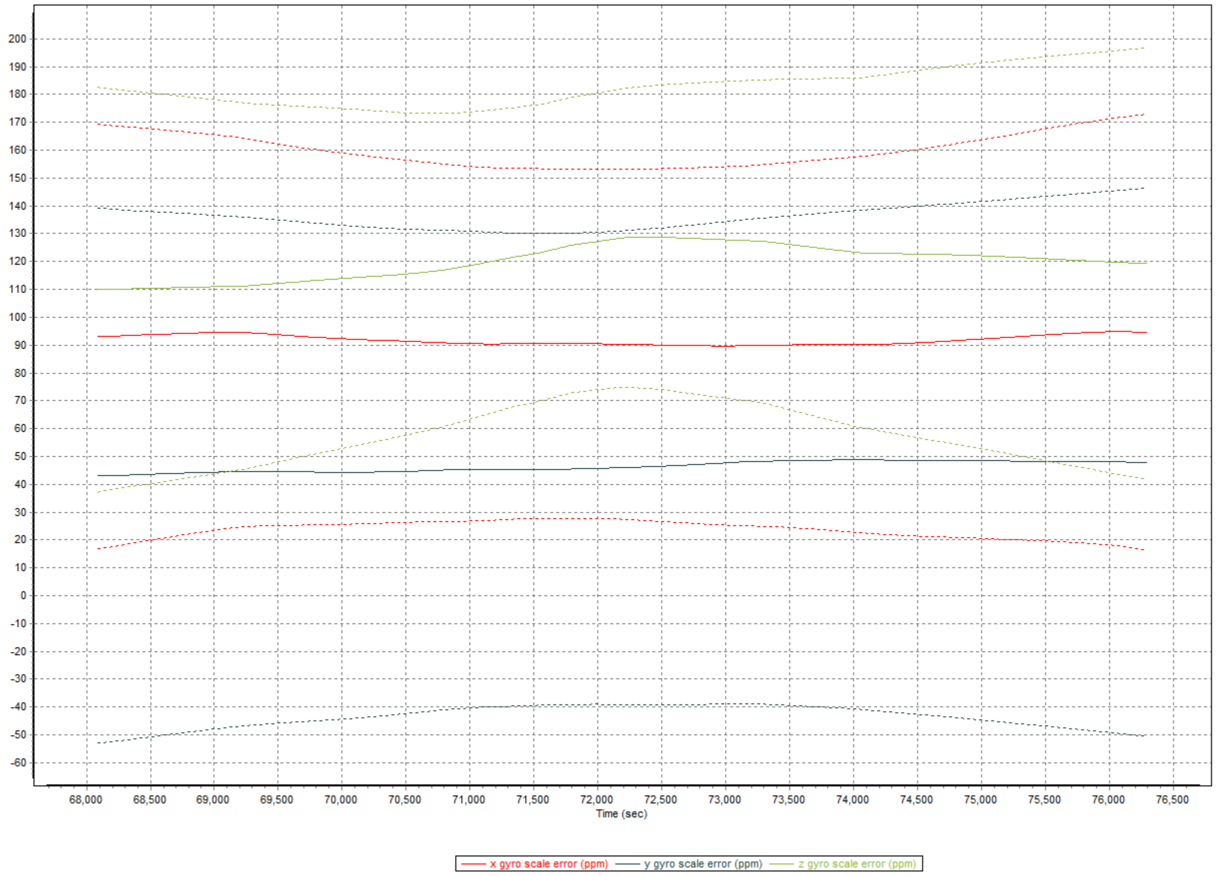

Post-processed (SBET)
LEG_LOVI
Real-time Reference Frame (RNAV)
Start

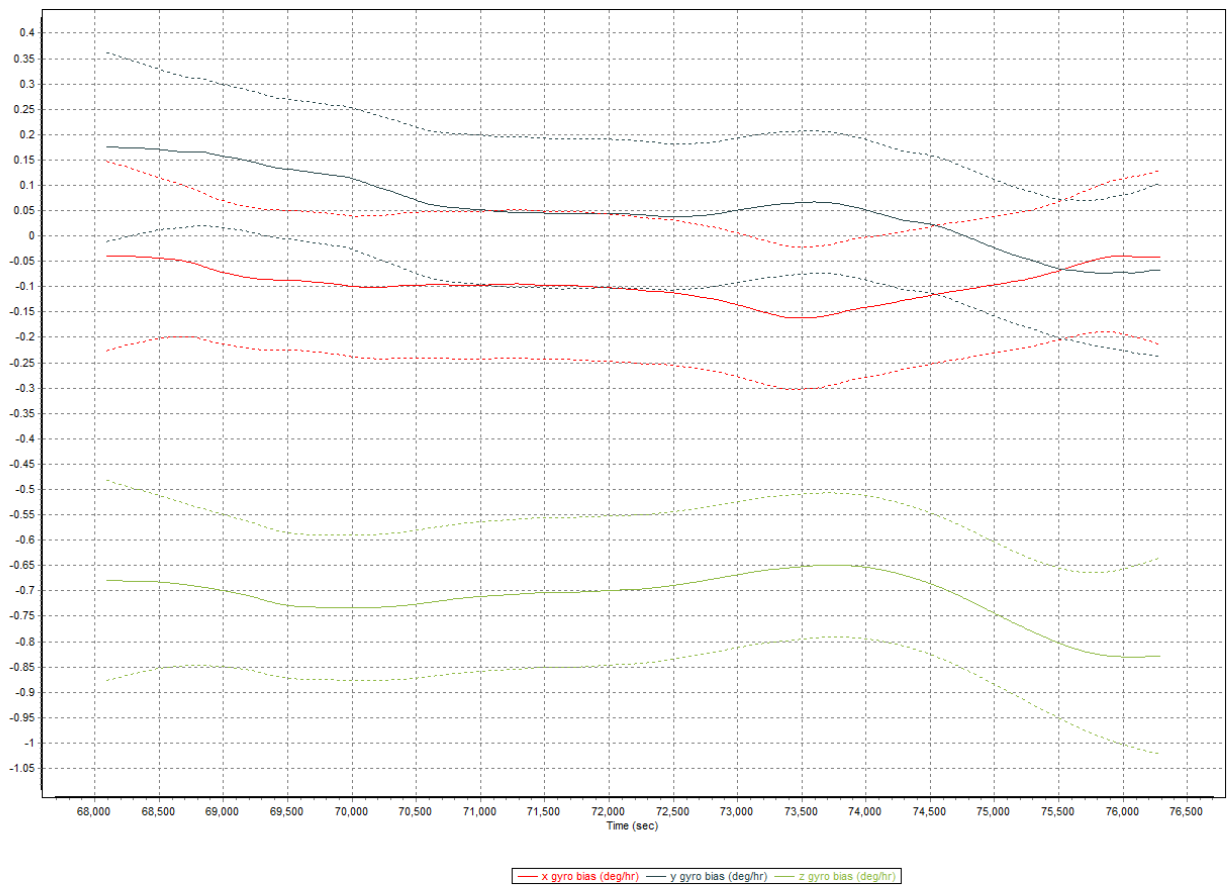

Time (sec)
North (m)
East (m)
Down (m)
DR mode

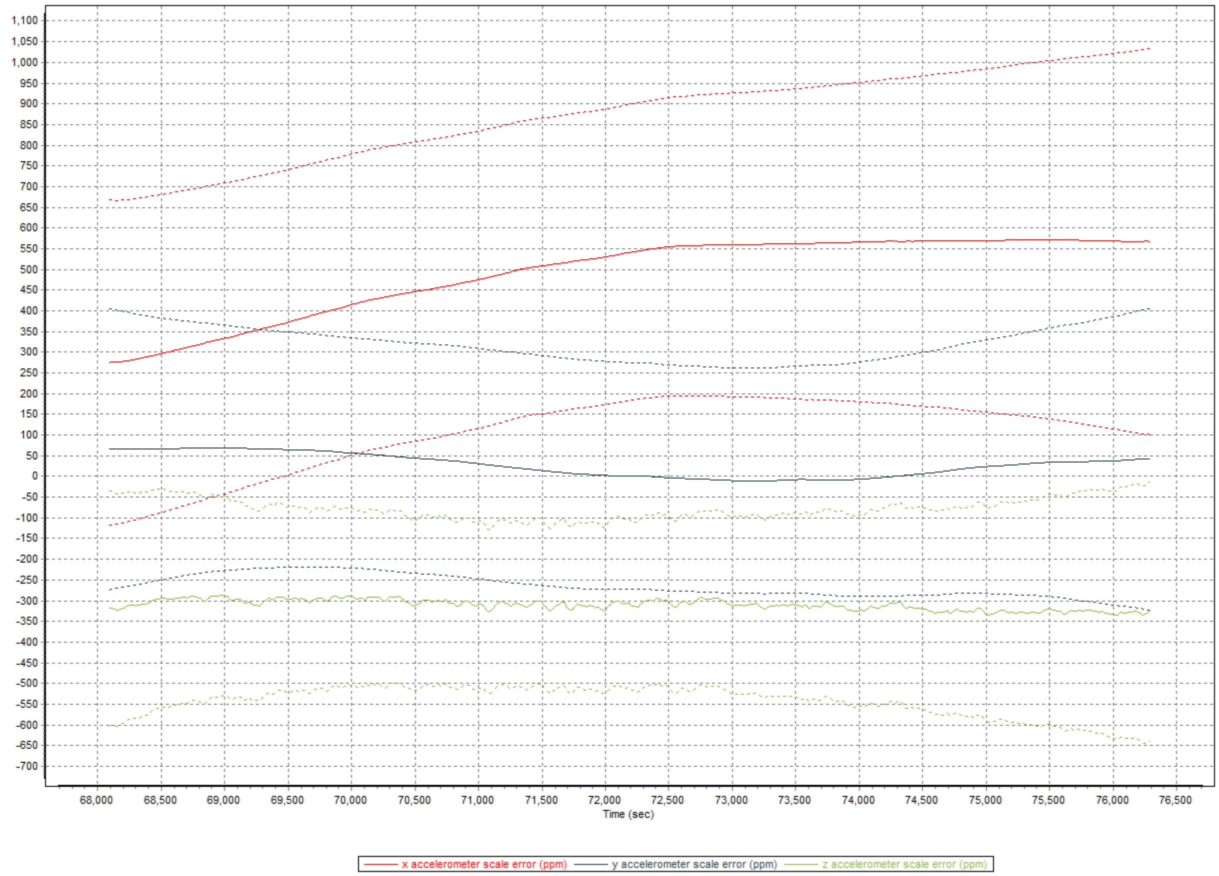

Time (sec)
North (m)
East (m)
Down (m)
DR mode

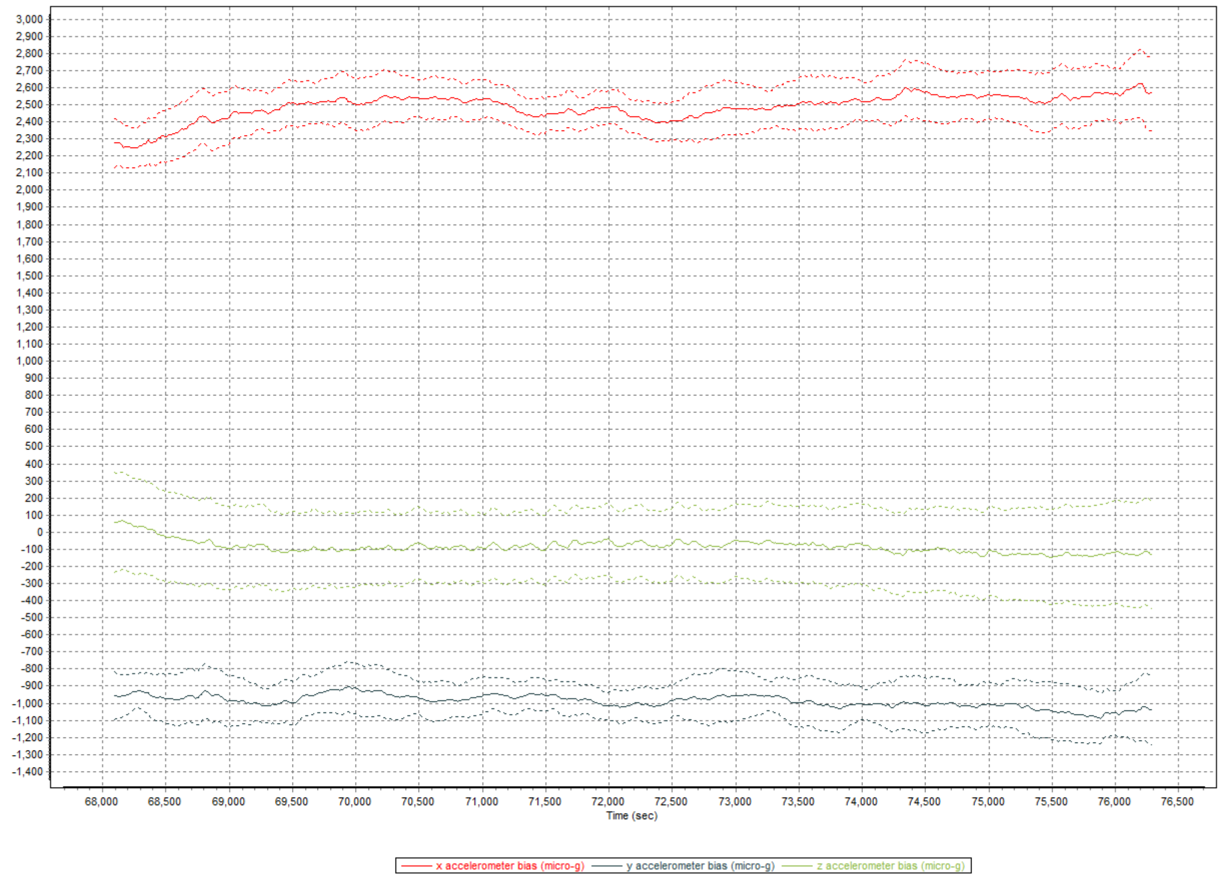

Forward/Reverse Separation
Time (sec)
North (m)
East (m)
Down (m)

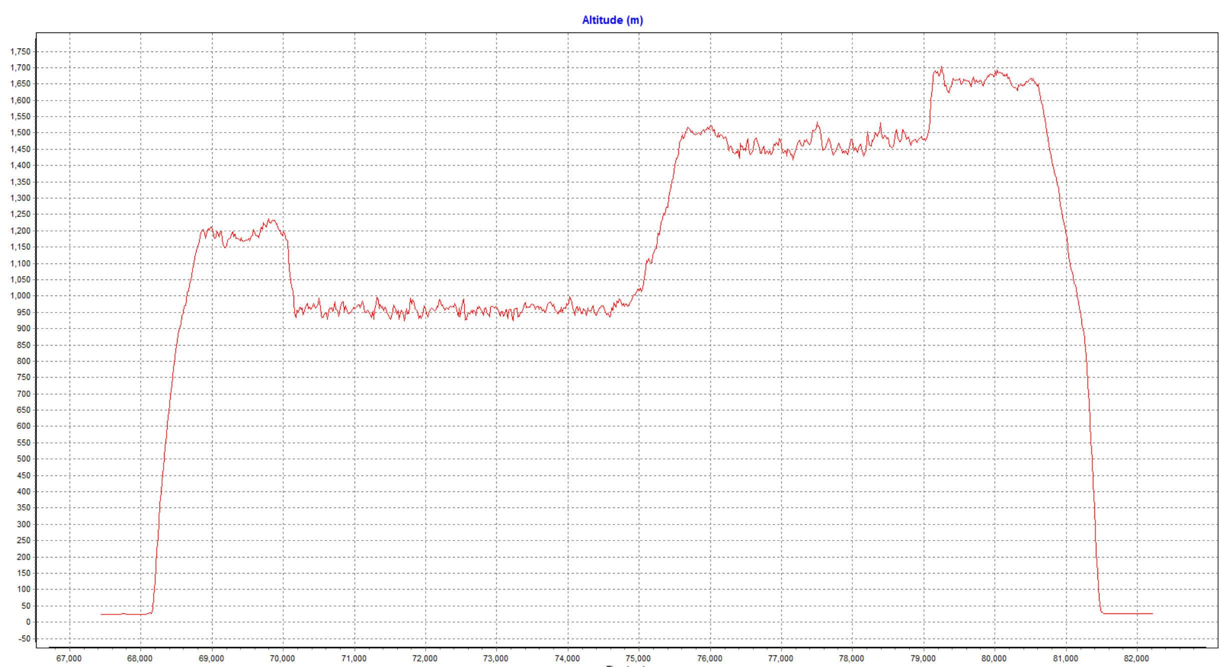

DOP
2.3
2.2
2.1
2
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
67,000
68,000
69,000
70,000
71,000
72,000
73,000
74,000
75,000
76,000
77,000
78,000
79,000
80,000
81,000
82,000
Time (sec)
PDOP
HDOP
VDOP

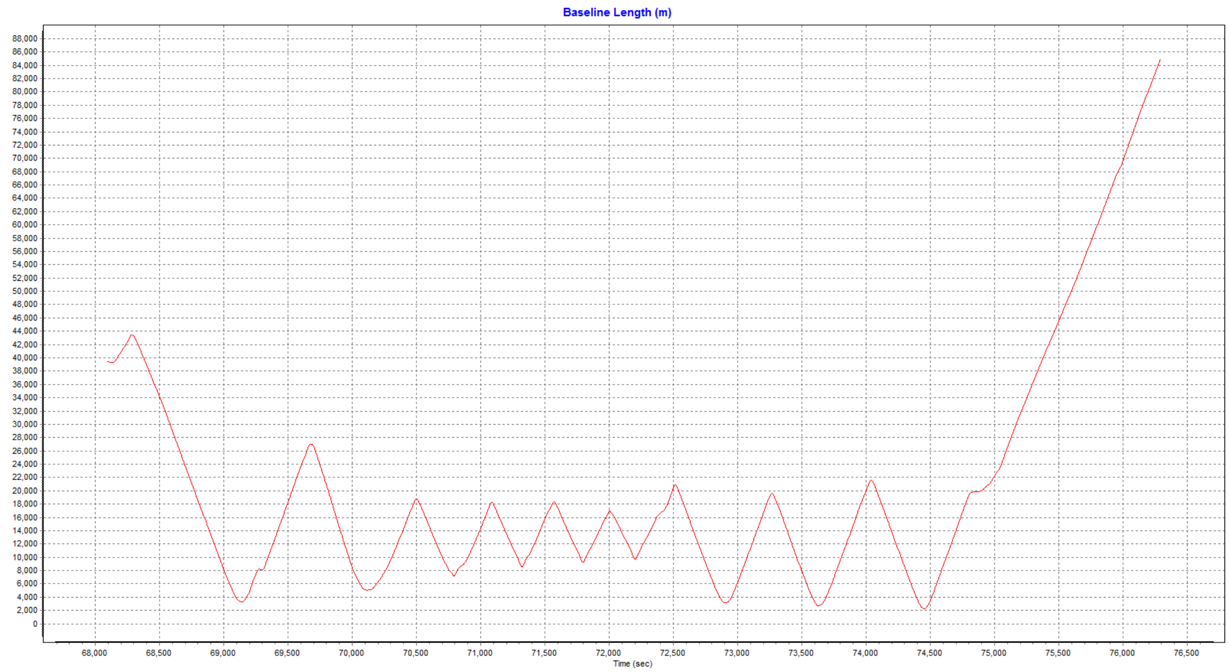

200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
68,000
68,500
69,000
69,500
70,000
70,500
71,000
71,500
72,000
72,500
73,000
73,500
74,000
74,500
75,000
75,500
76,000
76,500
Time (sec)
x gyro scale error (ppm)
y gyro scale error (ppm)
z gyro scale error (ppm)

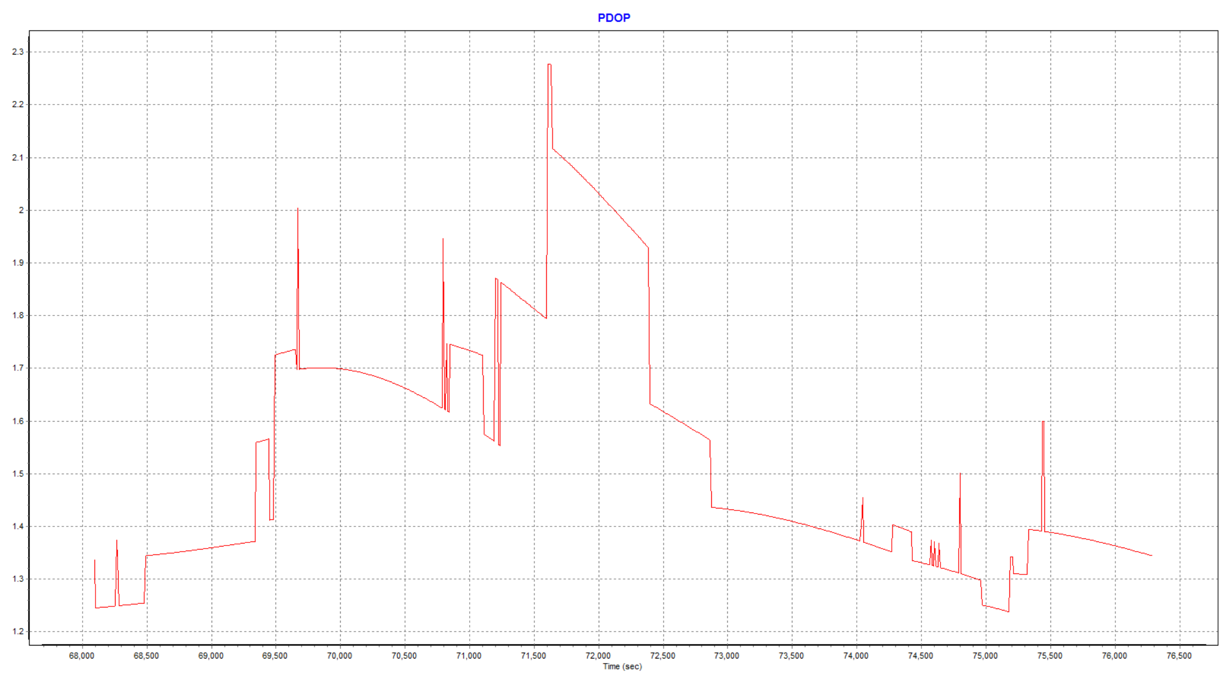

0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
-0.25
-0.3
-0.35
-0.4
-0.45
-0.5
-0.55
-0.6
-0.65
-0.7
-0.75
-0.8
-0.85
-0.9
-0.95
-1
-1.05
68,000
68,500
69,000
69,500
70,000
70,500
71,000
71,500
72,000
72,500
73,000
73,500
74,000
74,500
75,000
75,500
76,000
76,500
Time (sec)
x gyro bias (deg/hr)
y gyro bias (deg/hr)
z gyro bias (deg/hr)

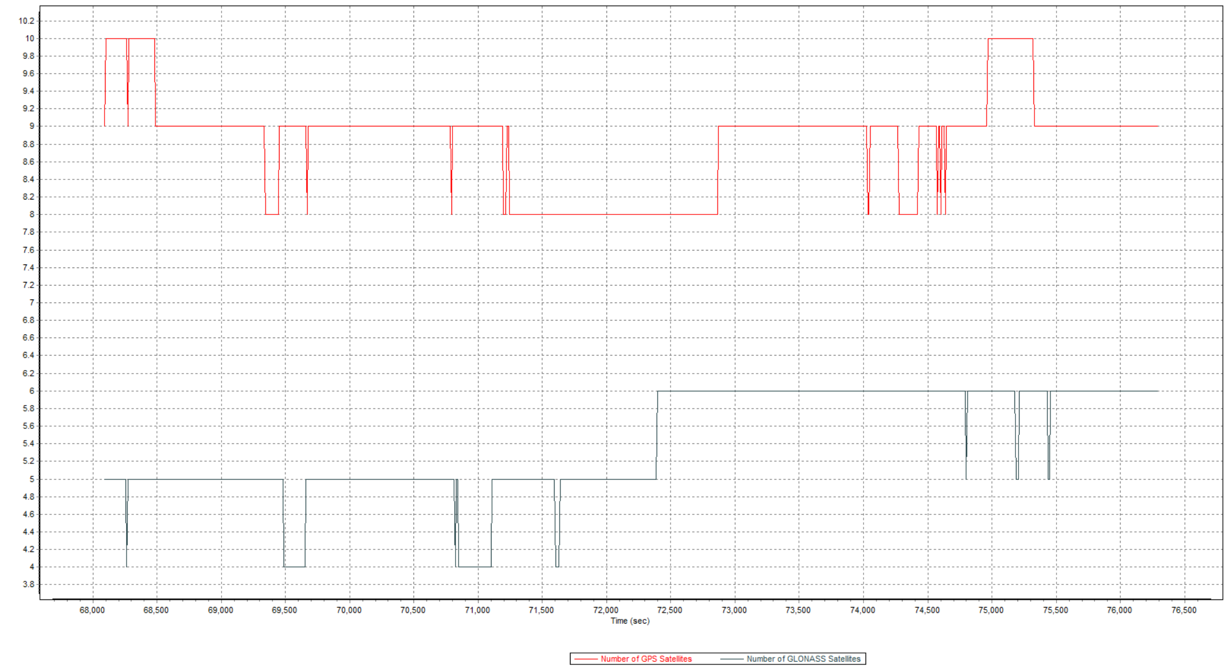

1,100
1,050
1,000
950
900
850
800
750
700
650
600
550
500
450
400
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
-350
-400
-450
-500
-550
-600
-650
-700
68,000
68,500
69,000
69,500
70,000
70,500
71,000
71,500
72,000
72,500
73,000
73,500
74,000
74,500
75,000
75,500
76,000
76,500
Time (sec)
x accelerometer scale error (ppm)
y accelerometer scale error (ppm)
z accelerometer scale error (ppm)

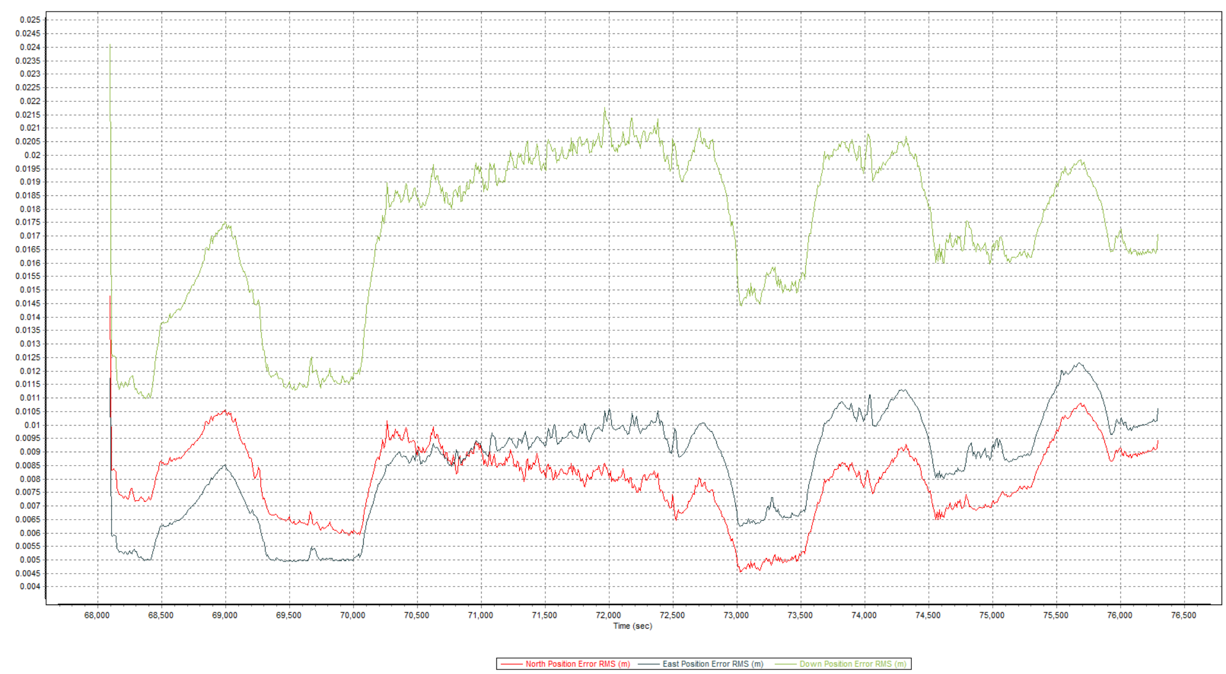

Time (sec)
x accelerometer bias (micro-g)
y accelerometer bias (micro-g)
z accelerometer bias (micro-g)

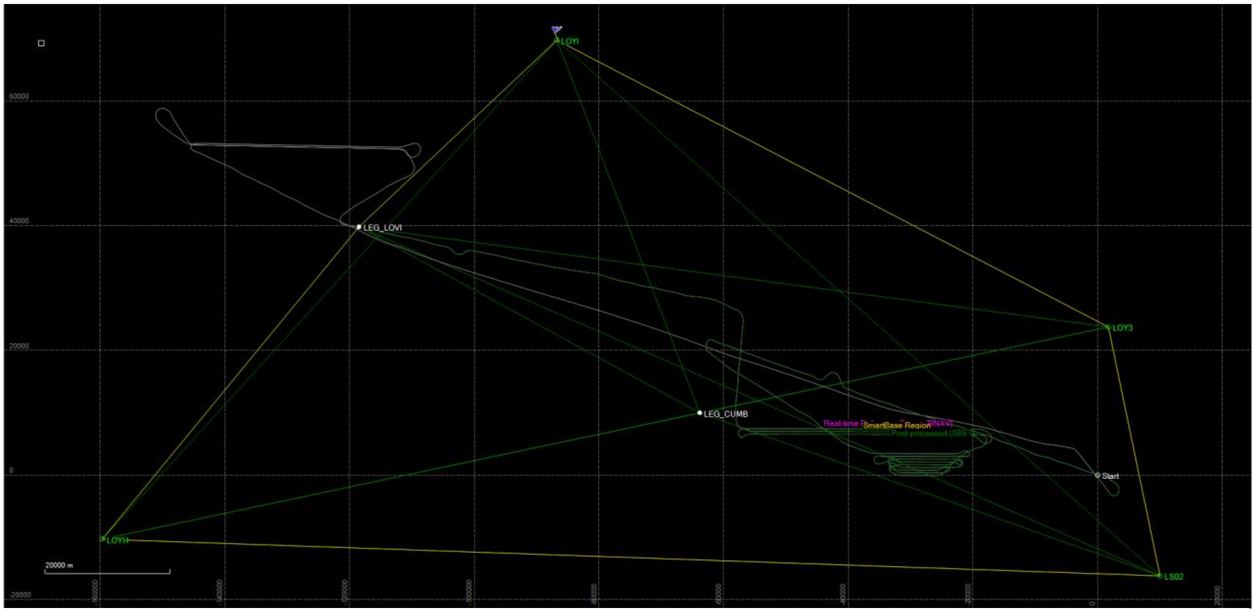

Altitude (m)
Time (sec)

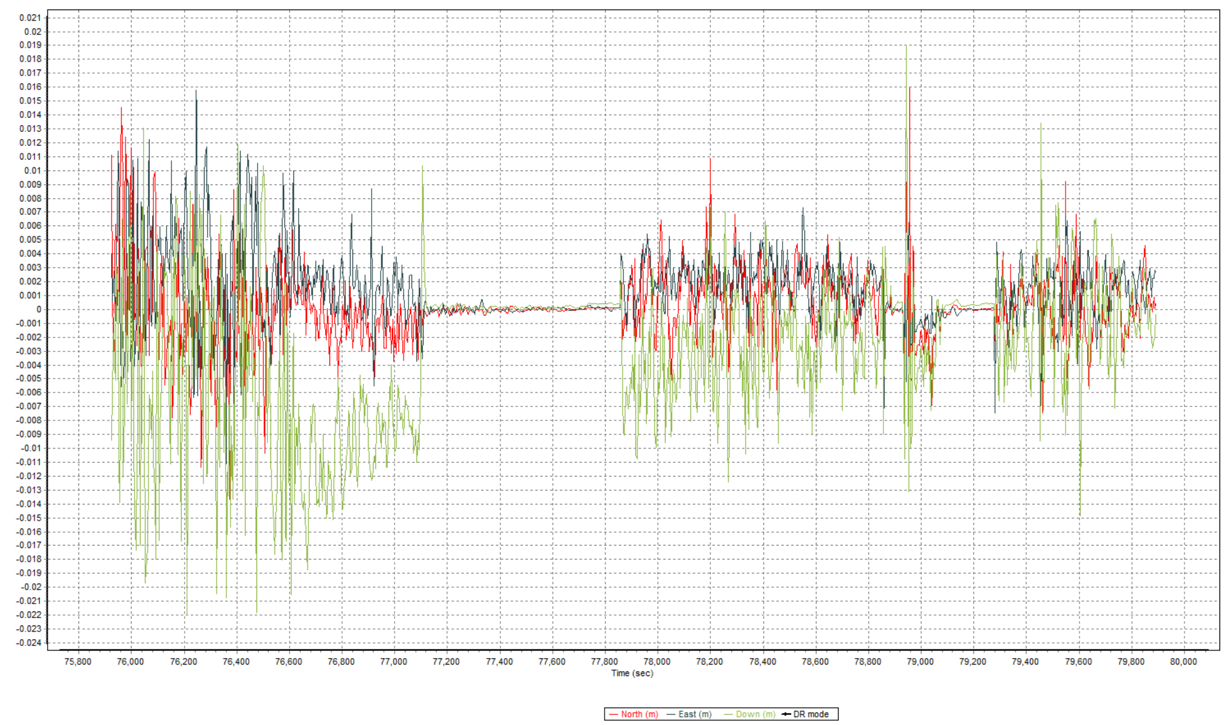

Baseline Length (m)
Time (sec)

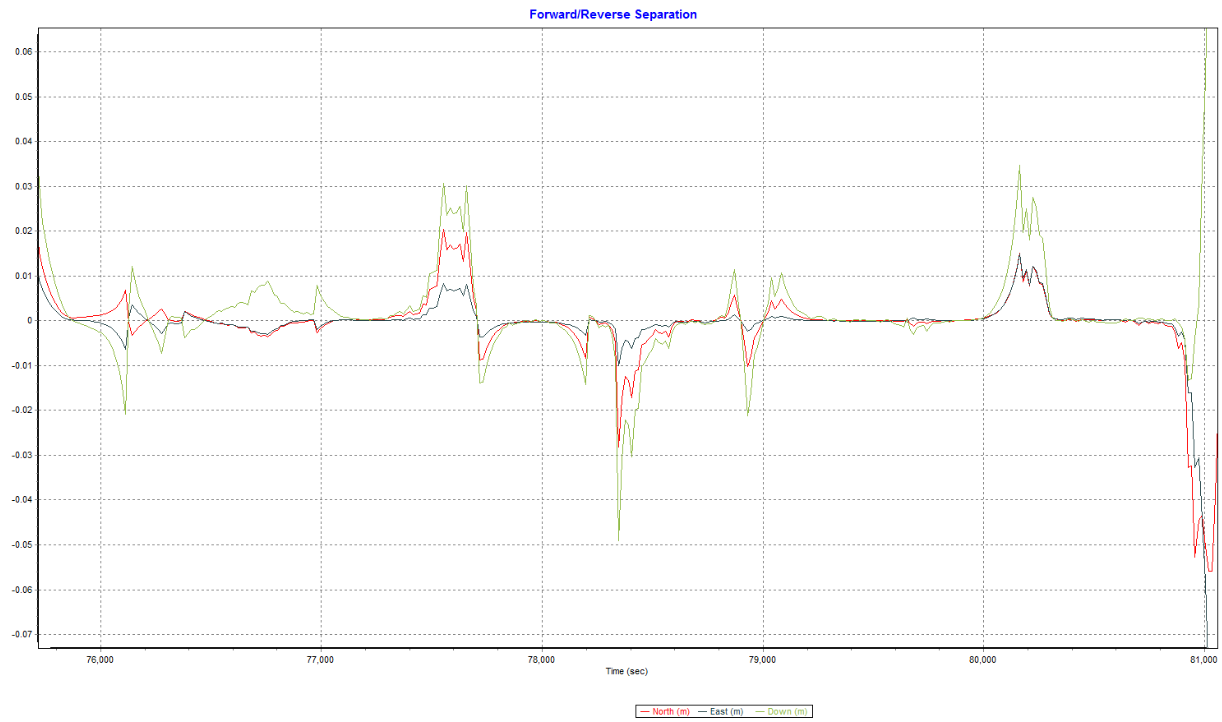

PDOP
Time (sec)


Time (sec)
Number of GPS Satellites
Number of GLONASS Satellites

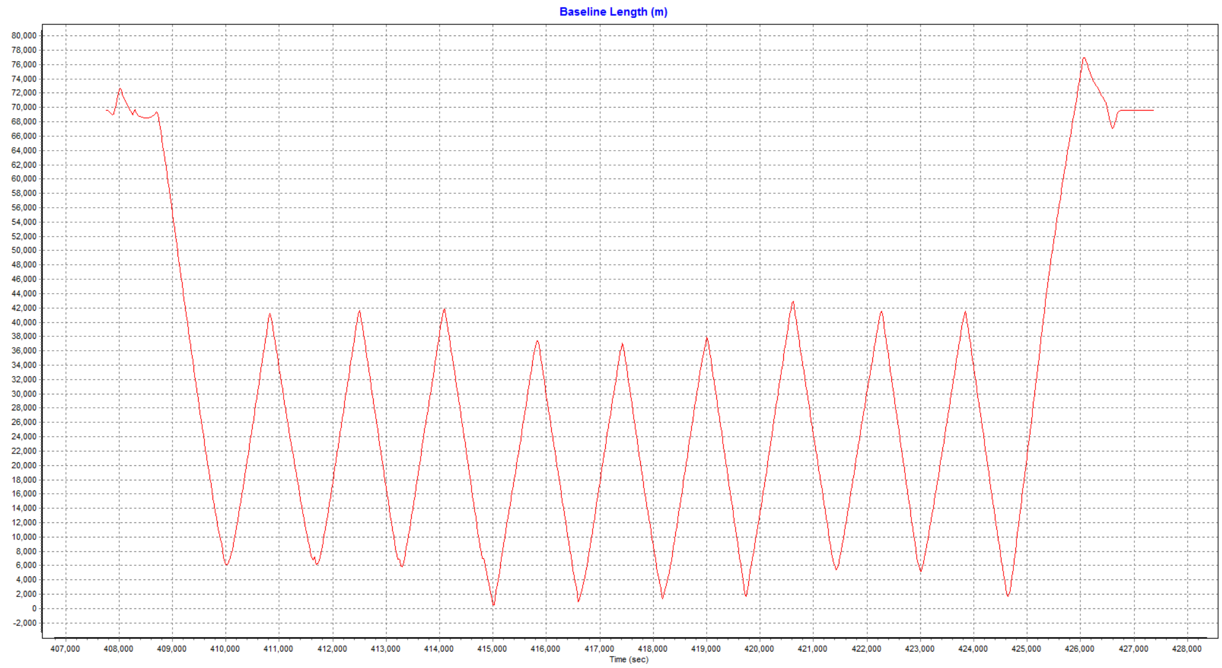

Time (sec)
North Position Error RMS (m)
East Position Error RMS (m)
Down Position Error RMS (m)

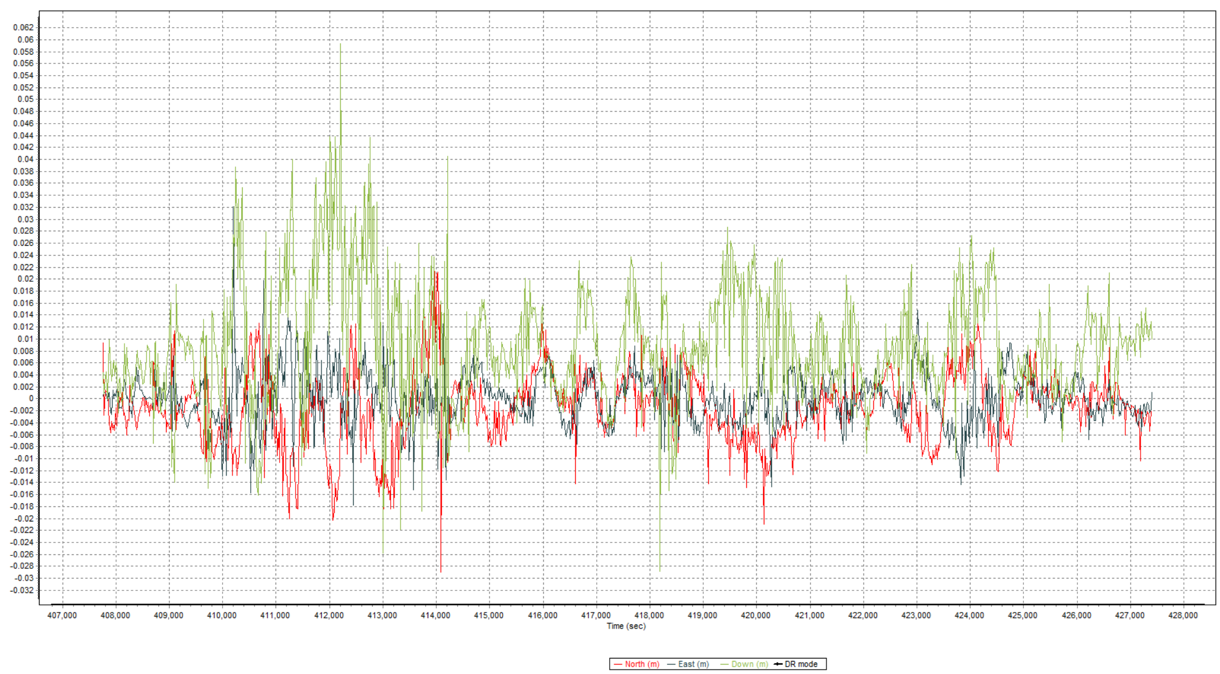

LOY1
LEG_LOVI
LOY3
LEG_CUMB
SmartBase Region
Start
LOYI
LS02
20000 m

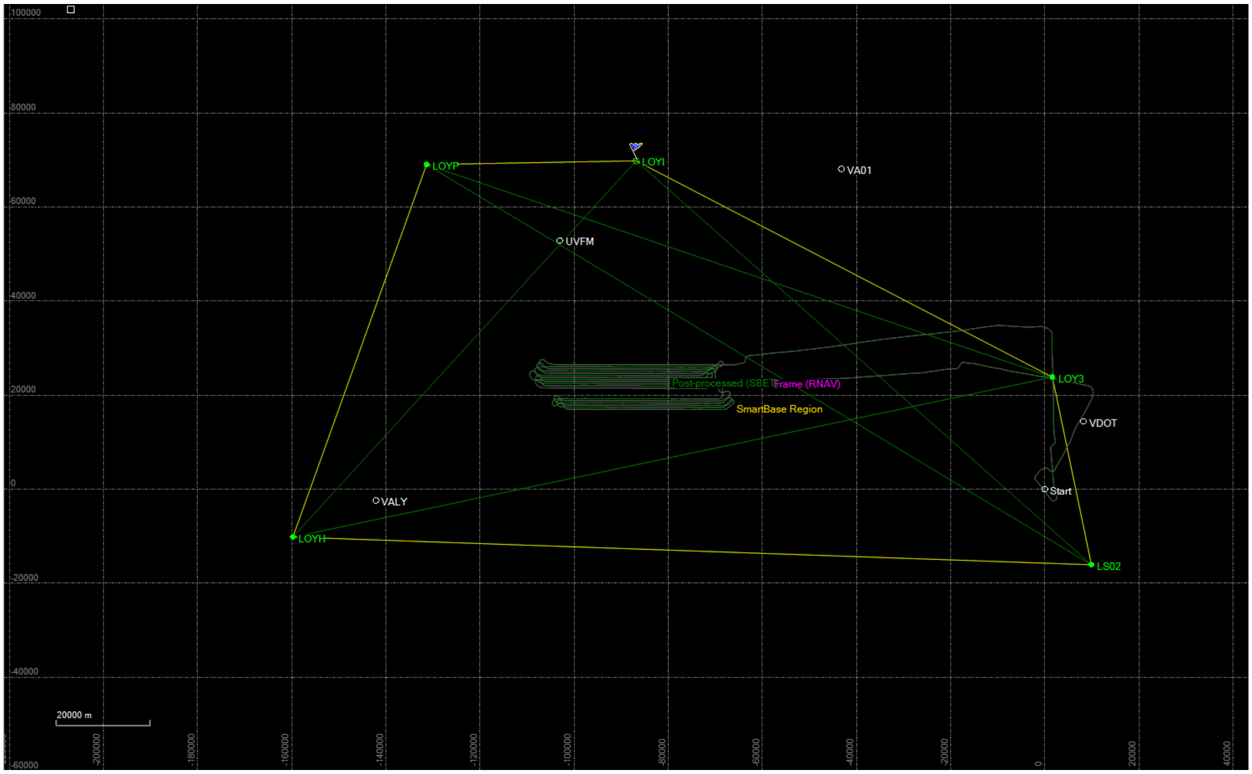

Time (sec)
North (m)
East (m)
Down (m)
DR mode

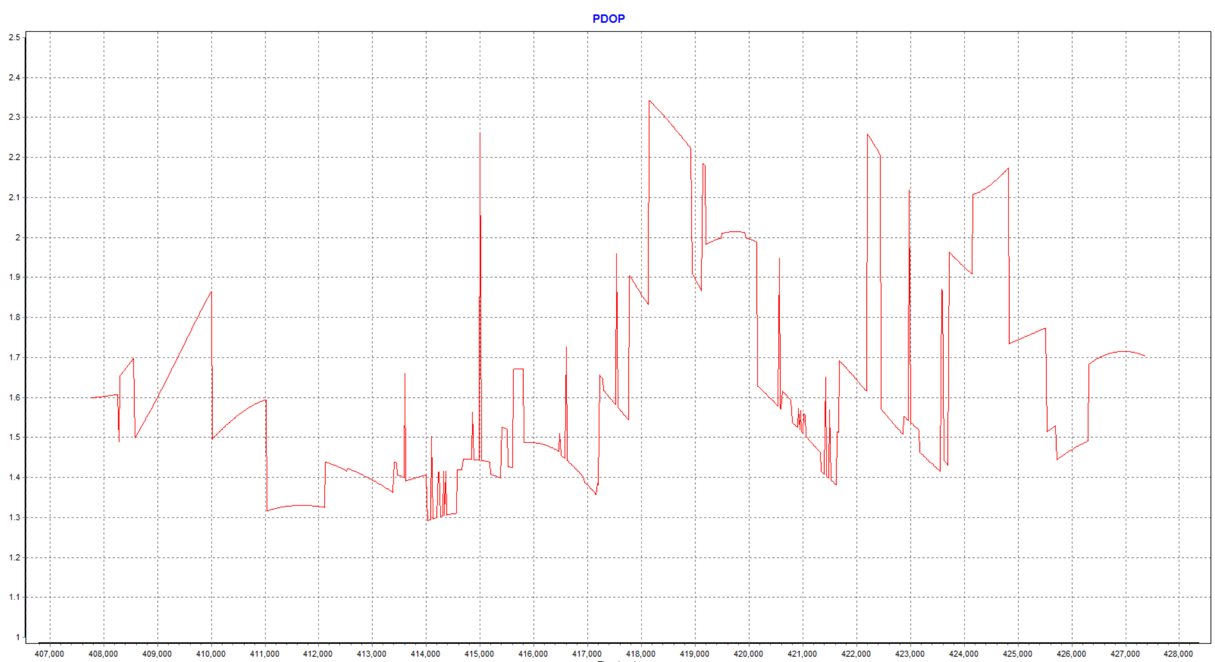

Forward/Reverse Separation
0.06
0.05
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
-0.05
-0.06
-0.07
76,000
77,000
78,000
79,000
80,000
81,000
Time (sec)
North (m)
East (m)
Down (m)

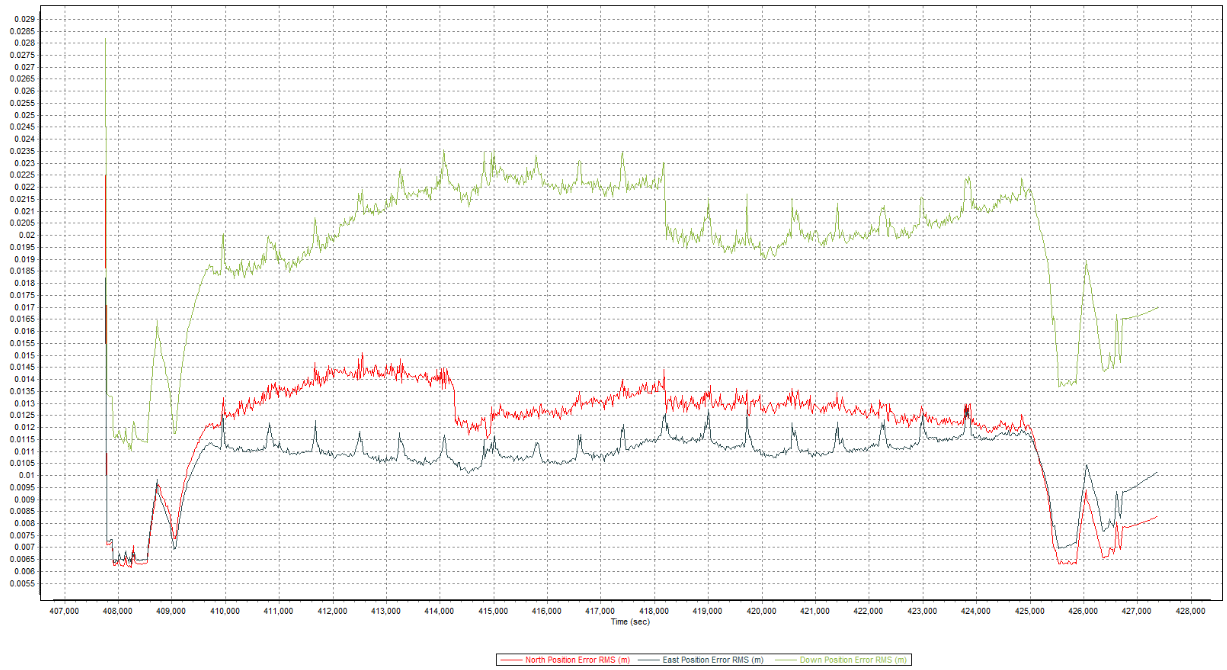
MNB15344A

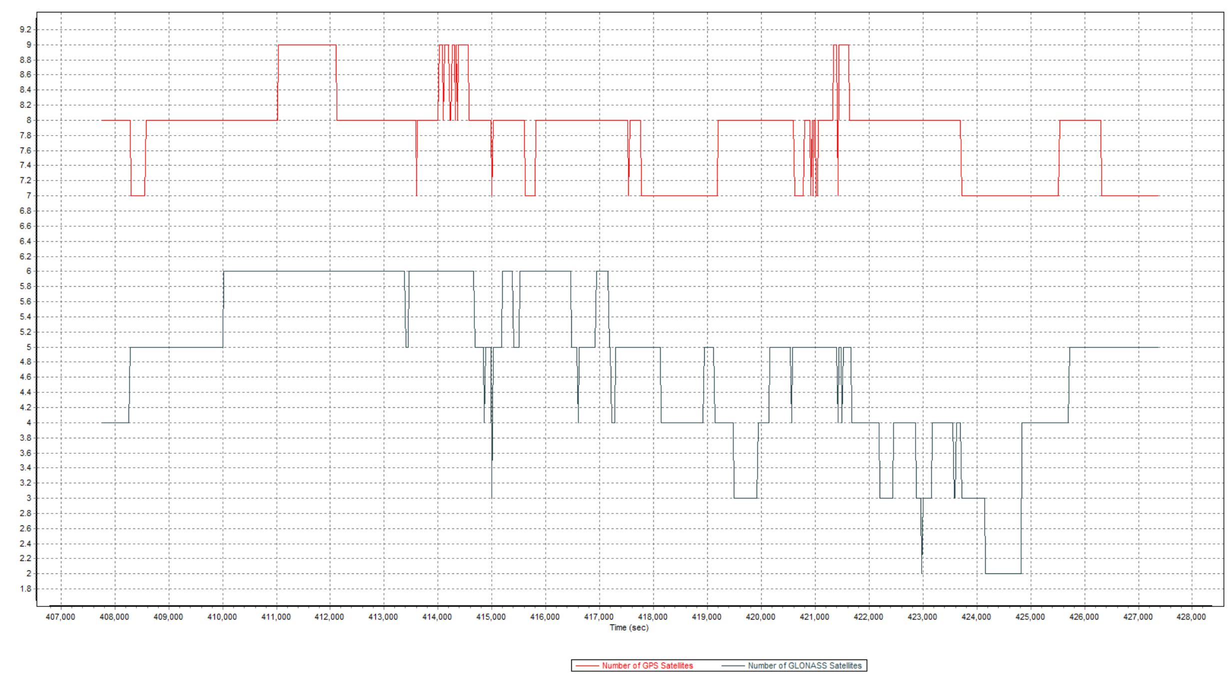

Baseline Length (m)
Time (sec)

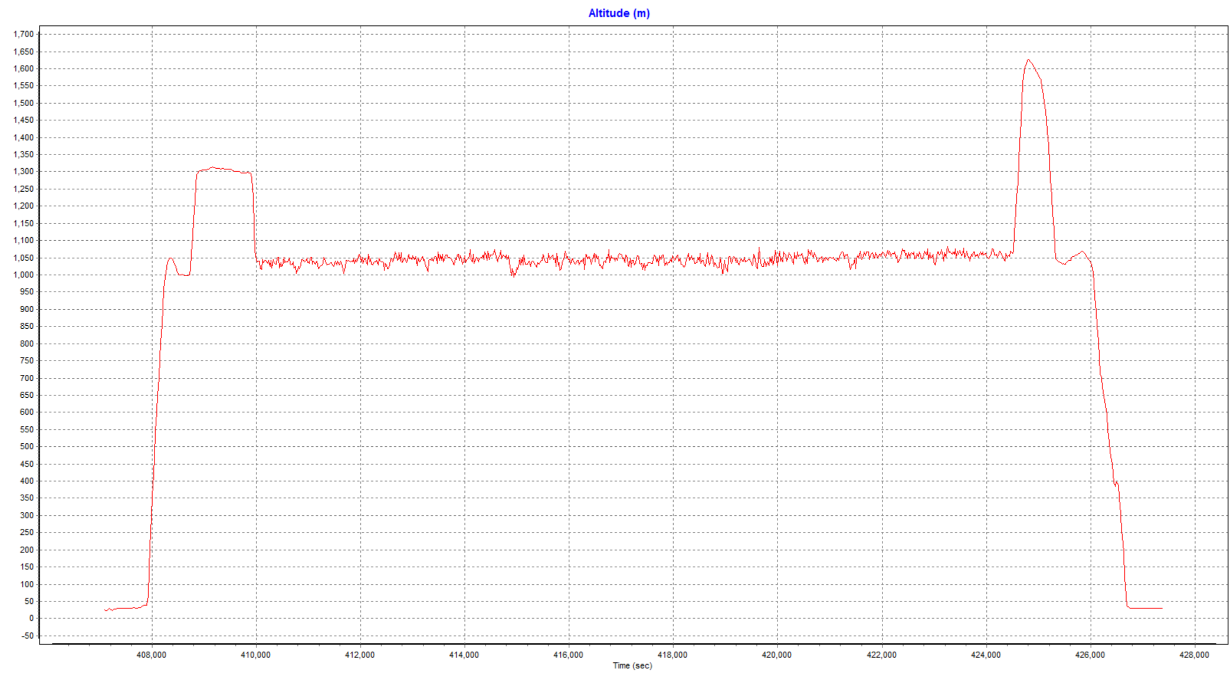

Time (sec)
North (m)
East (m)
Down (m)
DR mode


LOYP
LOYI
VA01
UVFM
LOY3
VDOT
Start
VALY
LOYH
LS02
Post-processed (SBET)
Frame (RNAV)
SmartBase Region
20000 m

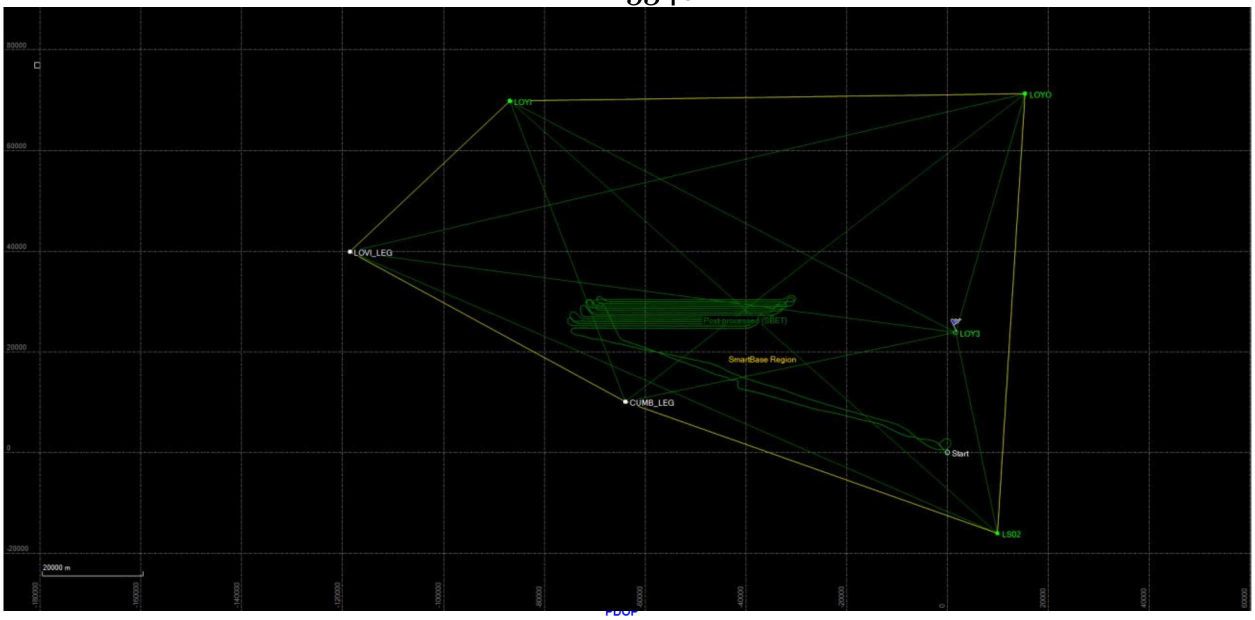

PDOP
Time (sec)

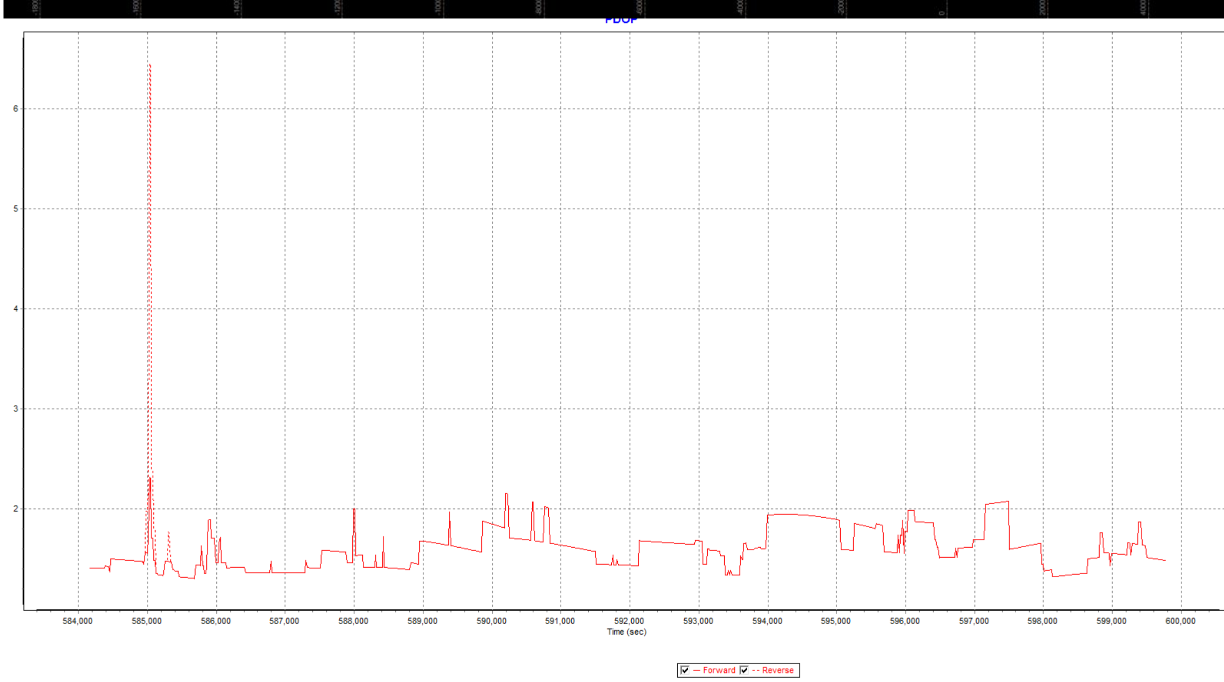

Time (sec)
North Position Error RMS (m)
East Position Error RMS (m)
Down Position Error RMS (m)

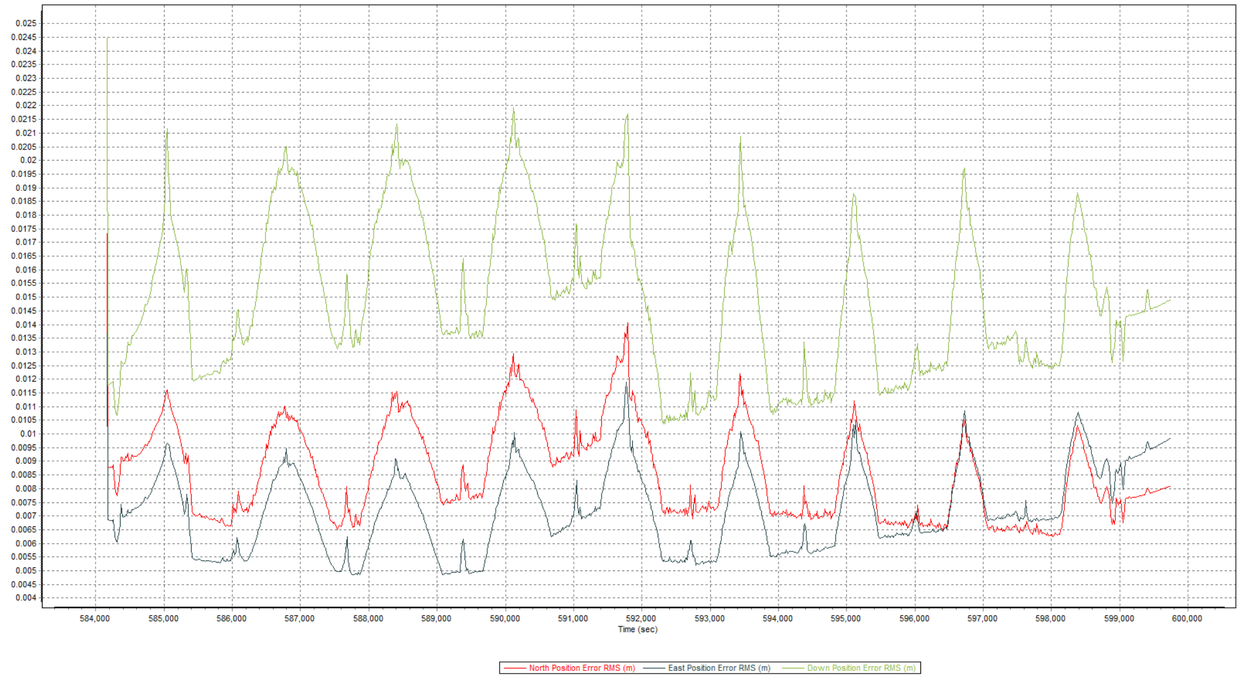

Time (sec)
Number of GPS Satellites
Number of GLONASS Satellites

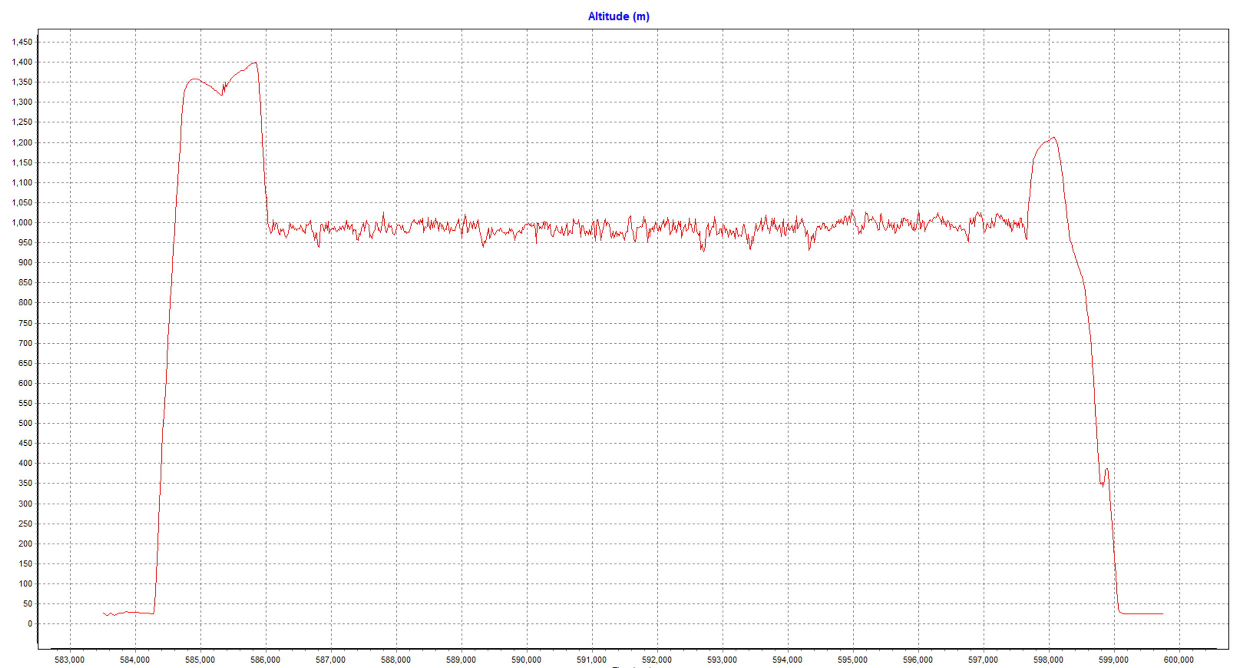

Altitude (m)
Time (sec)

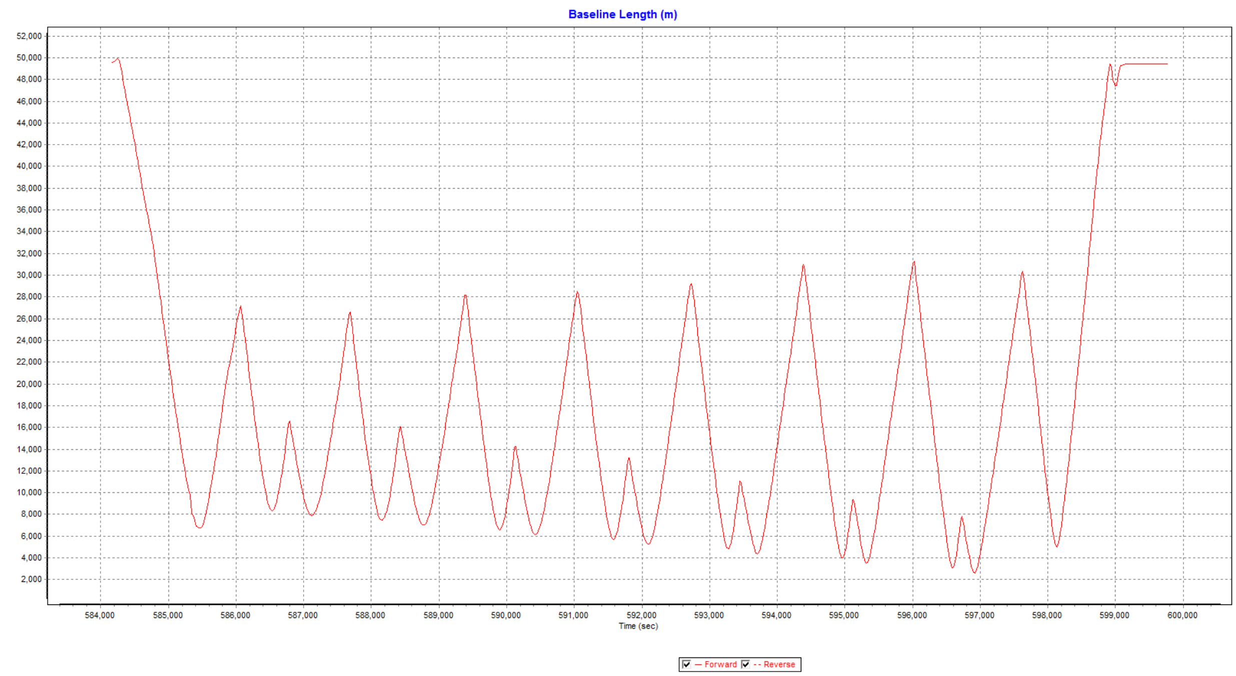
MNB15346B

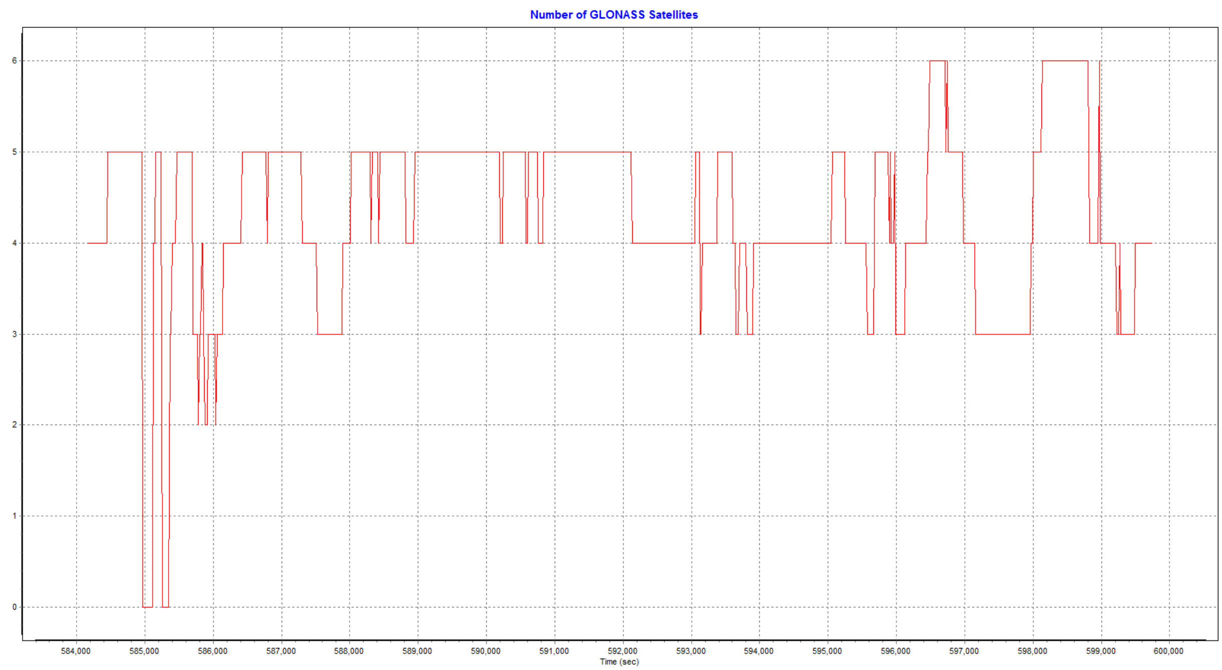

LOYI
LOYO
LOVI_LEG
LOY3
SmartBase Region
Post-processed (SBET)
CUMB_LEG
Start
LS02
20000 m

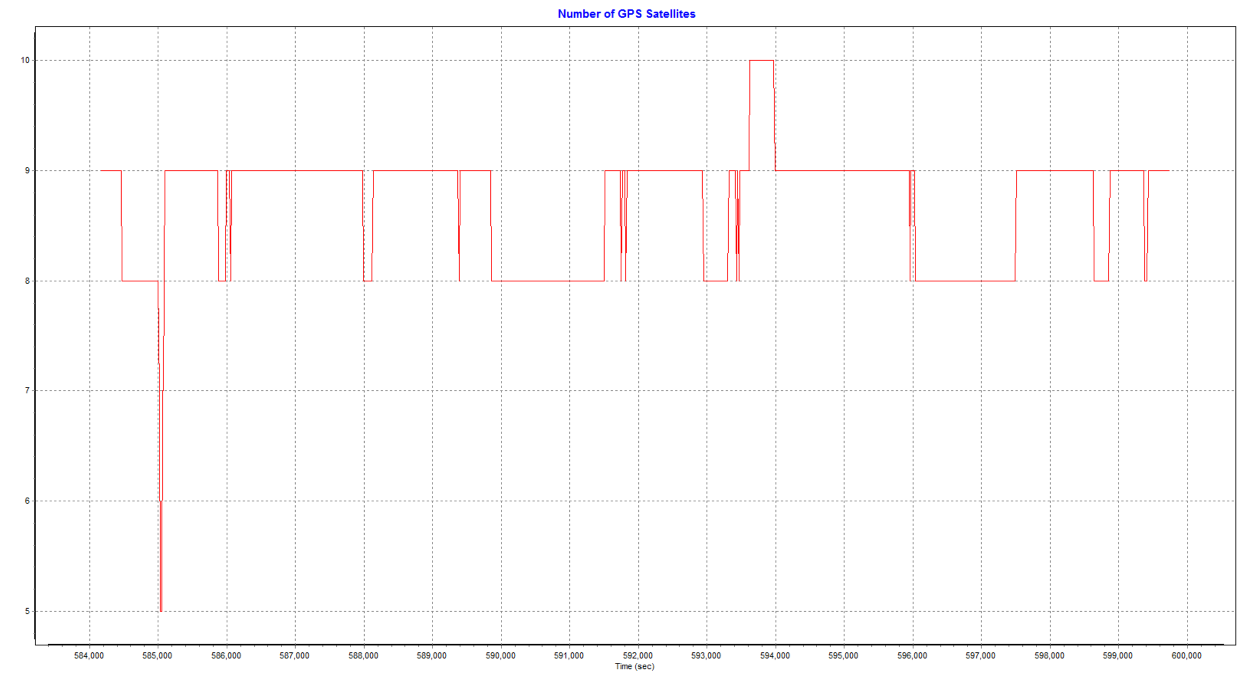

PDOP
Time (sec)
— Forward
-- Reverse


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


Altitude (m)
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
584,000
585,000
586,000
587,000
588,000
589,000
590,000
591,000
592,000
593,000
594,000
595,000
596,000
597,000
598,000
599,000
600,000
Time (sec)
— Forward
-- Reverse


Number of GLONASS Satellites
6
5
4
3
2
1
0
584,000
585,000
586,000
587,000
588,000
589,000
590,000
591,000
592,000
593,000
594,000
595,000
596,000
597,000
598,000
599,000
600,000
Time (sec)


Number of GPS Satellites
10
9
8
7
6
5
584,000
585,000
586,000
587,000
588,000
589,000
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595,000
596,000
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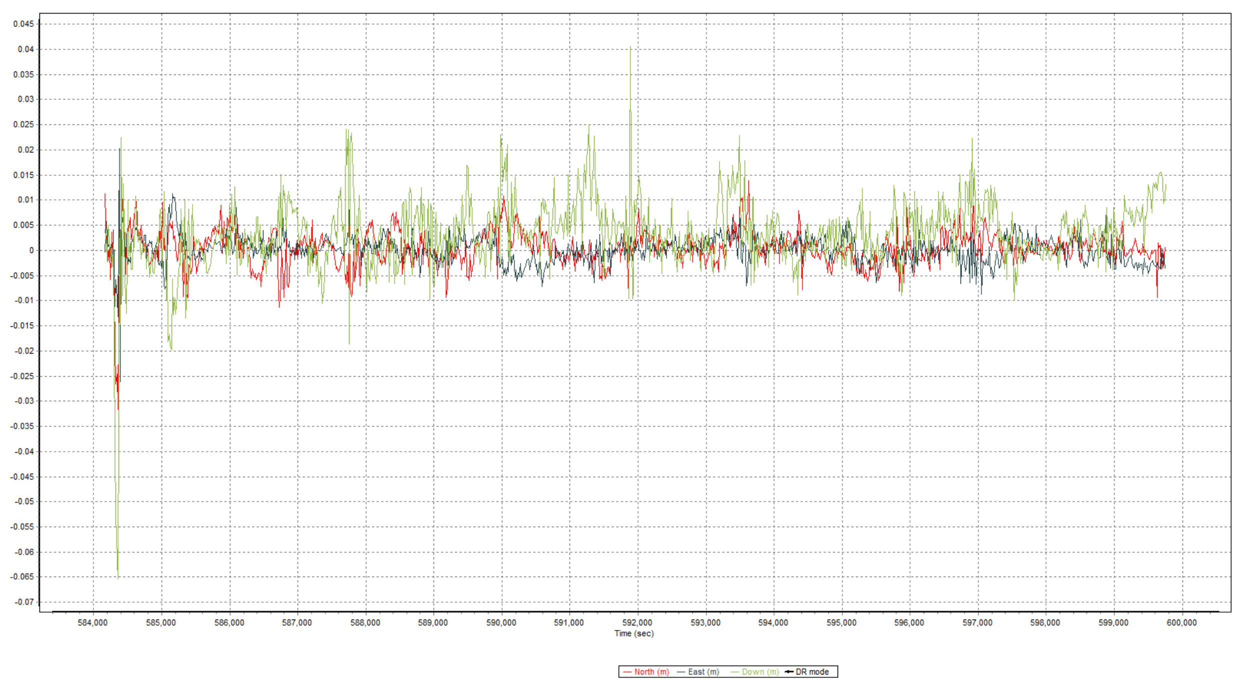
598,000
599,000
600,000
Time (sec)


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
-0.055
-0.06
-0.065
-0.07
584,000
585,000
586,000
587,000
588,000
589,000
590,000
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592,000
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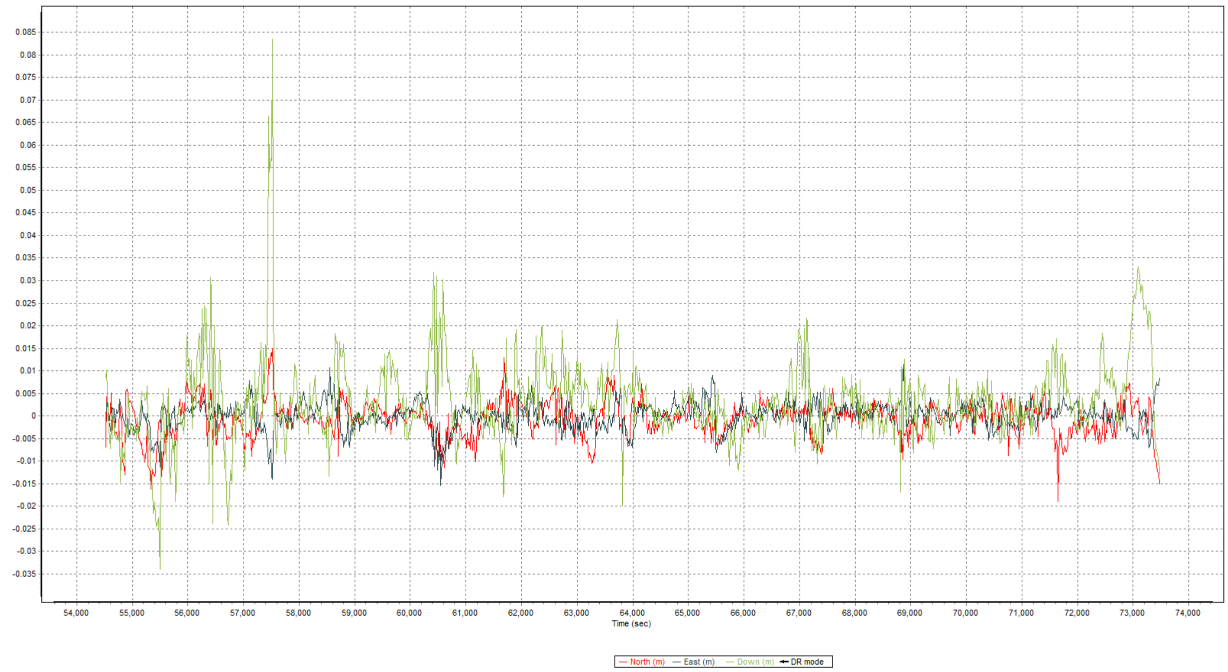
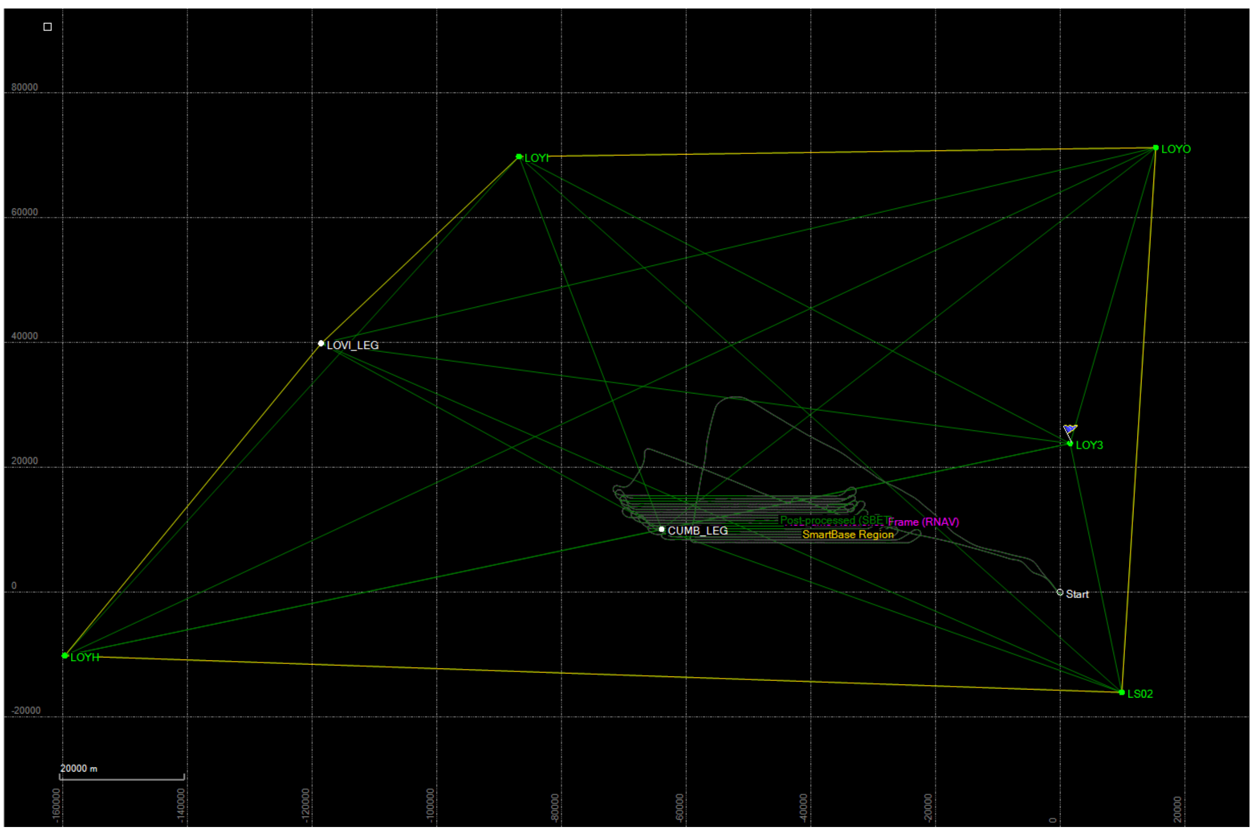
594,000
595,000
596,000
597,000
598,000
599,000
600,000
Time (sec)
North (m)
East (m)
Down (m)
DR mode

MNB15347B


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


LOYI
LOYO
LOVI_LEG
LOY3
CUMB_LEG
Post-processed (SBET)
Frame (RNAV)
SmartBase Region
Start
LOYH
LS02
20000 m


PDOP
2
54,000
55,000
56,000
57,000
58,000
59,000
60,000
61,000
62,000
63,000
64,000
65,000
66,000
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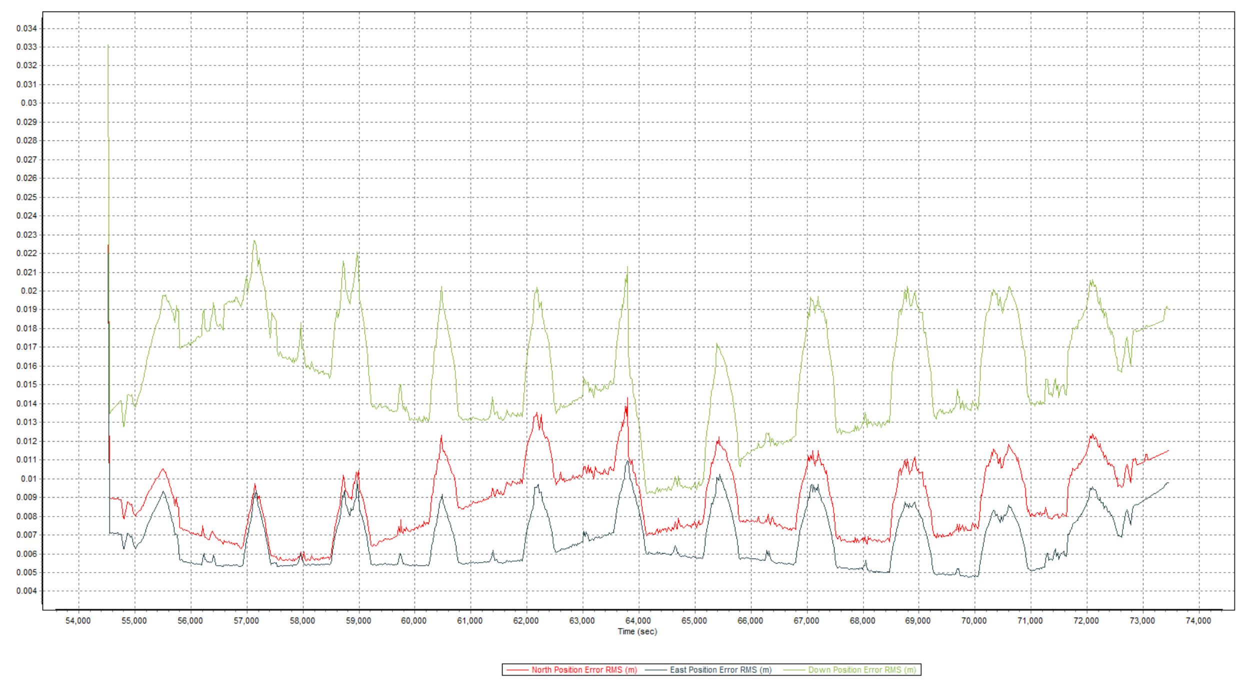
68,000
69,000
70,000
71,000
72,000
73,000
74,000
Time (sec)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0.022
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0.02
0.019
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0.017
0.016
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0.012
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0.009
0.008
0.007
0.006
0.005
0.004
54,000
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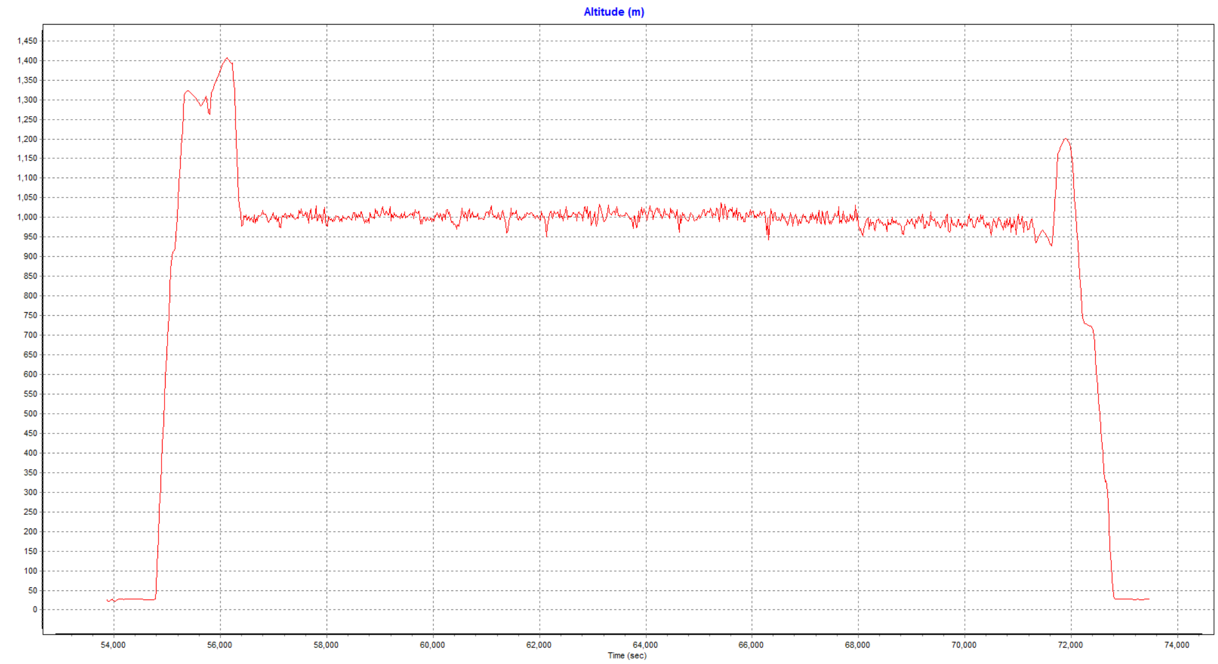
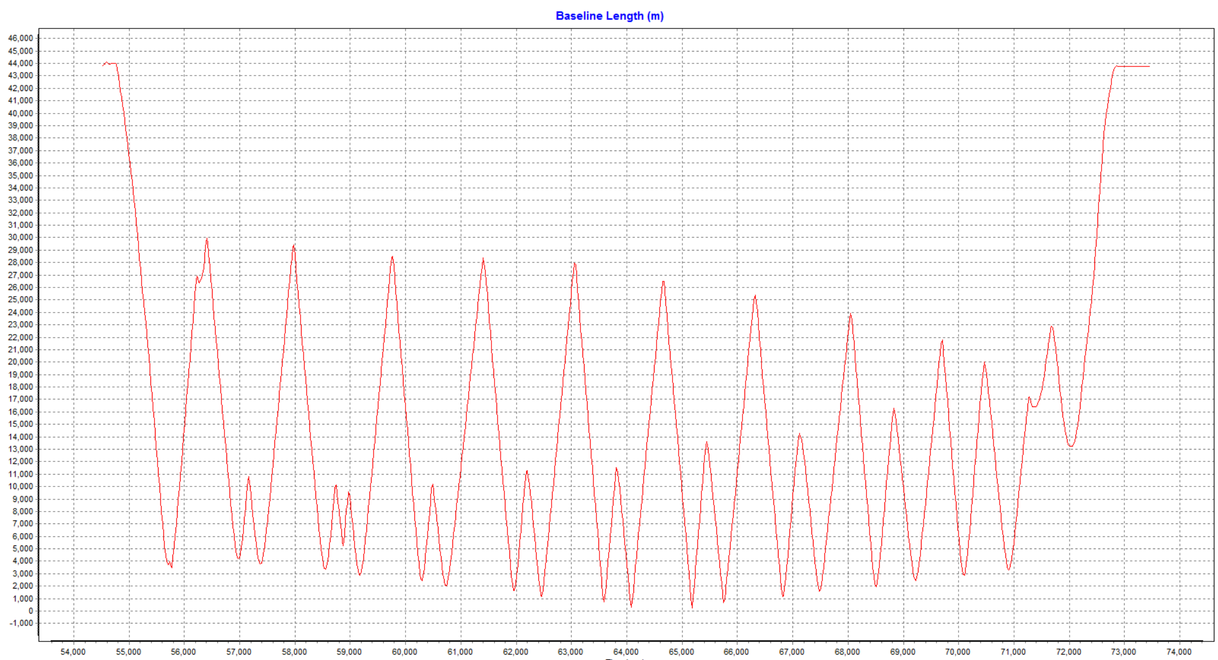
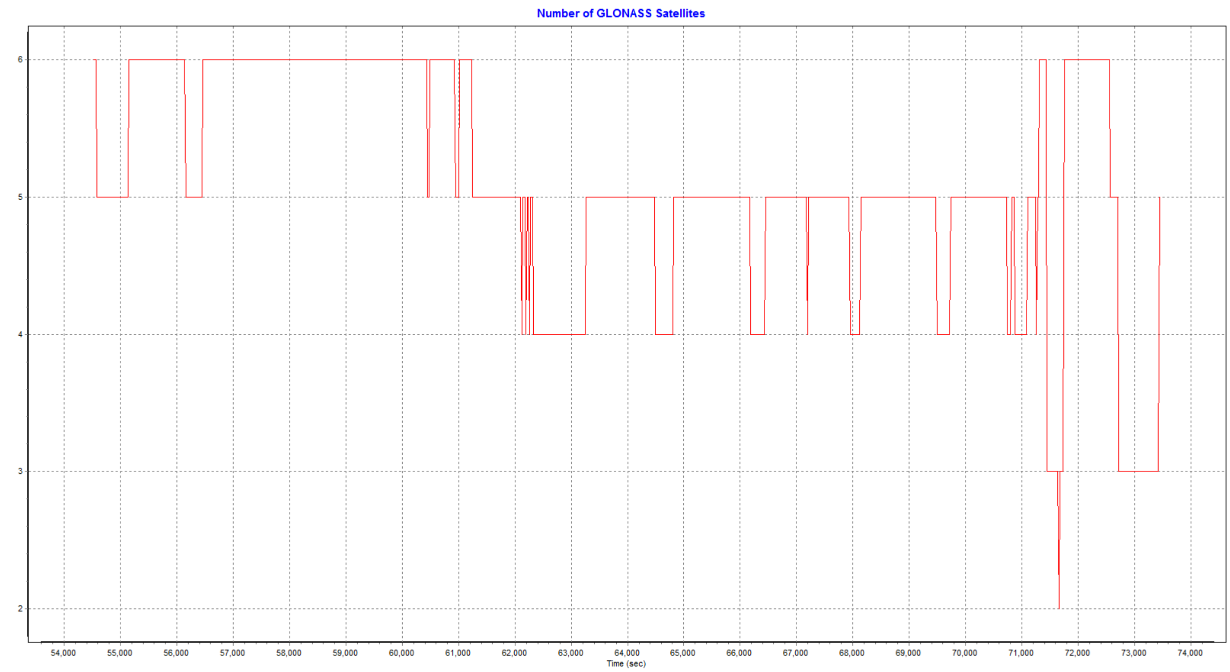
62,000
63,000
64,000
65,000
66,000
67,000
68,000
69,000
70,000
71,000
72,000
73,000
74,000
Time (sec)
North Position Error RMS (m)
East Position Error RMS (m)
Down Position Error RMS (m)


Altitude (m)
Time (sec)


Baseline Length (m)
Time (sec)


Number of GLONASS Satellites
6
5
4
3
2
54,000
55,000
56,000
57,000
58,000
59,000
60,000
61,000
62,000
63,000
64,000
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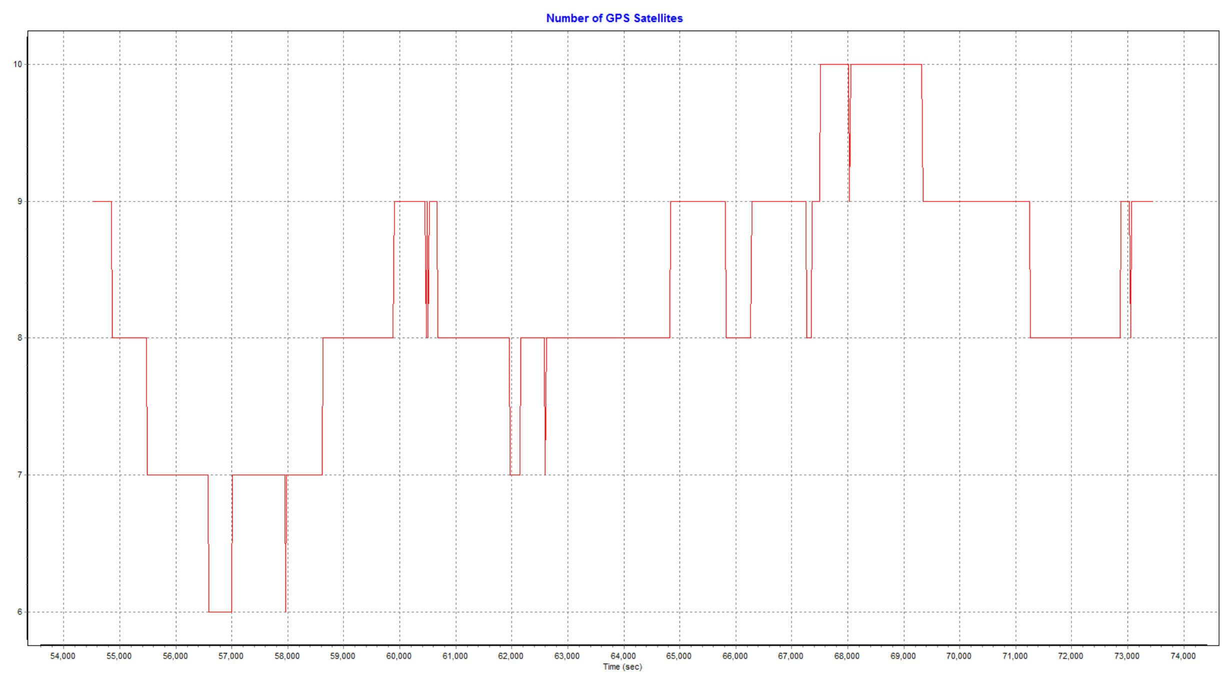
71,000
72,000
73,000
74,000
Time (sec)


Number of GPS Satellites
10
9
8
7
6
54,000
55,000
56,000
57,000
58,000
59,000
60,000
61,000
62,000
63,000
64,000
65,000
66,000
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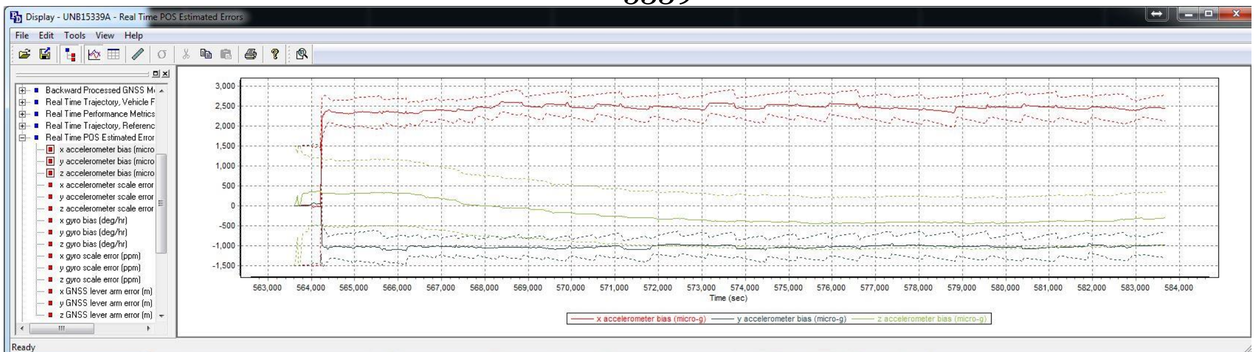
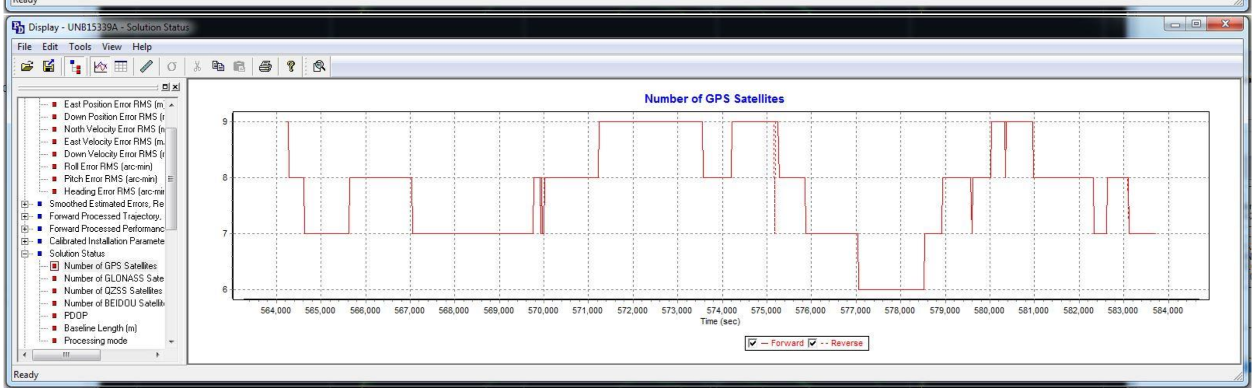
68,000
69,000
70,000
71,000
72,000
73,000
74,000
Time (sec)

UNB15339A


Display - UNB15339A - Real Time POS Estimated Errors
Time (sec)
x accelerometer bias (micro-g)
y accelerometer bias (micro-g)
z accelerometer bias (micro-g)
Ready


Display - UNB15339A - SBET IAKAR Separation
Time (sec)
North (m)
East (m)
Down (m)
DR mode
Ready

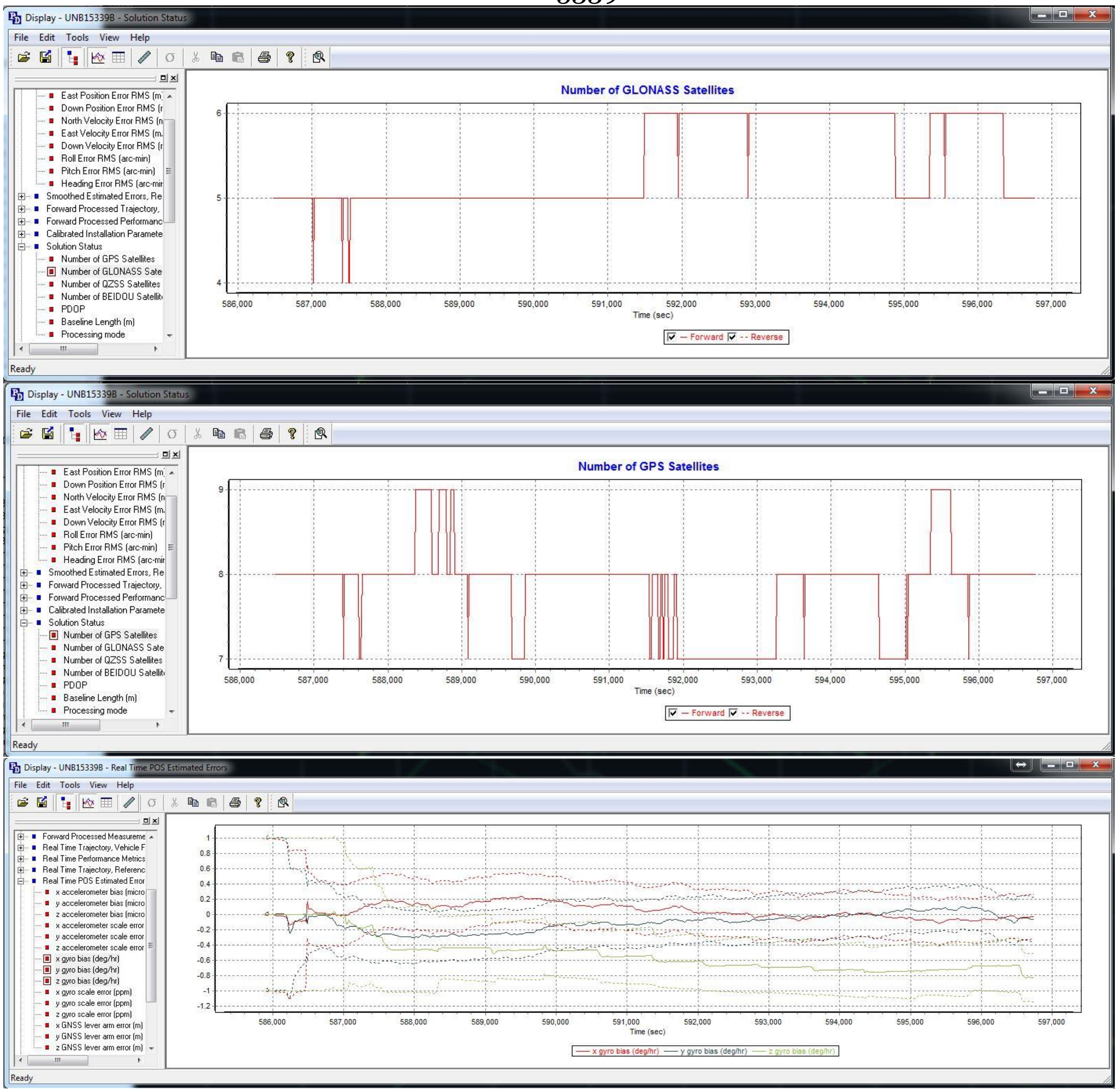

Display - UNB15339A - Solution Status
Number of GLONASS Satellites
Time (sec)
Forward
Reverse
Ready

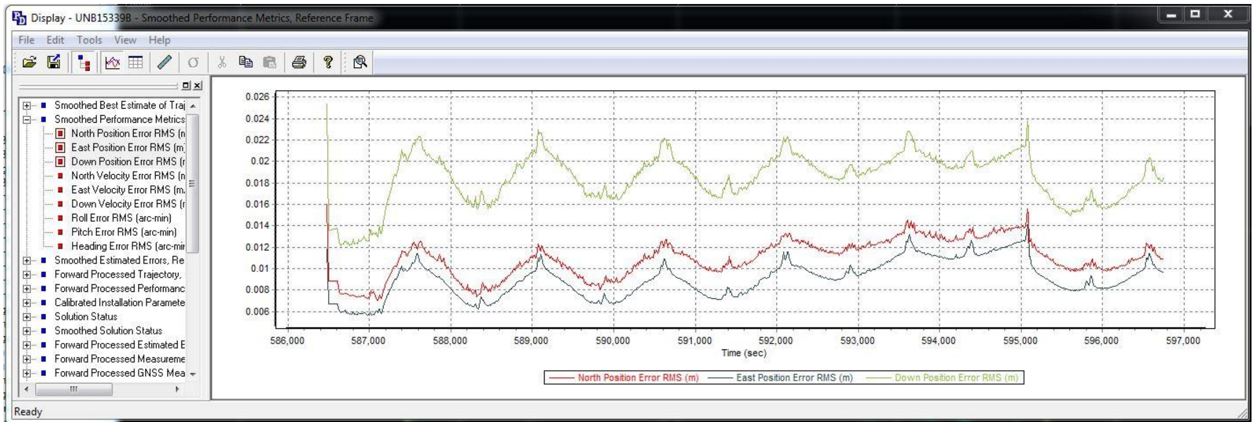

Display - UNB15339A - Solution Status
Number of GPS Satellites
Time (sec)
Forward
Reverse
Ready

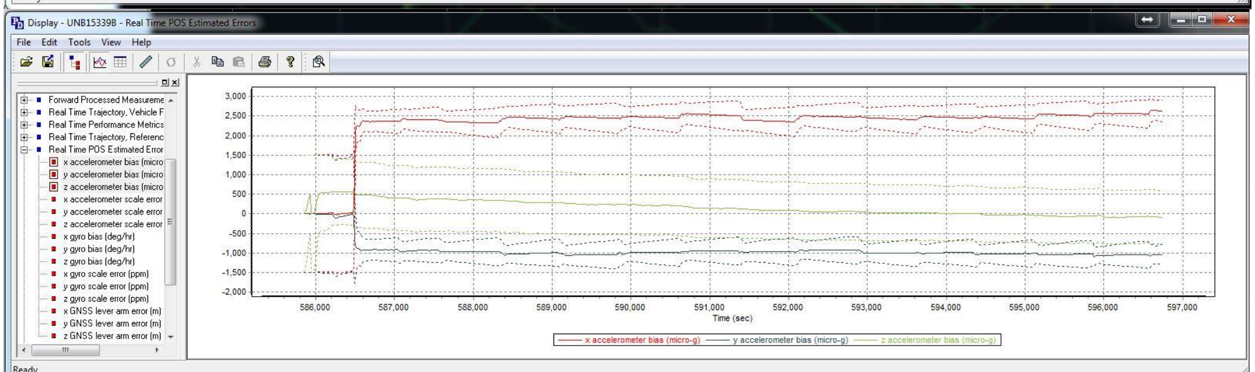

Display - UNB15339A - Solution Status
PDOP
Time (sec)
Forward
Reverse

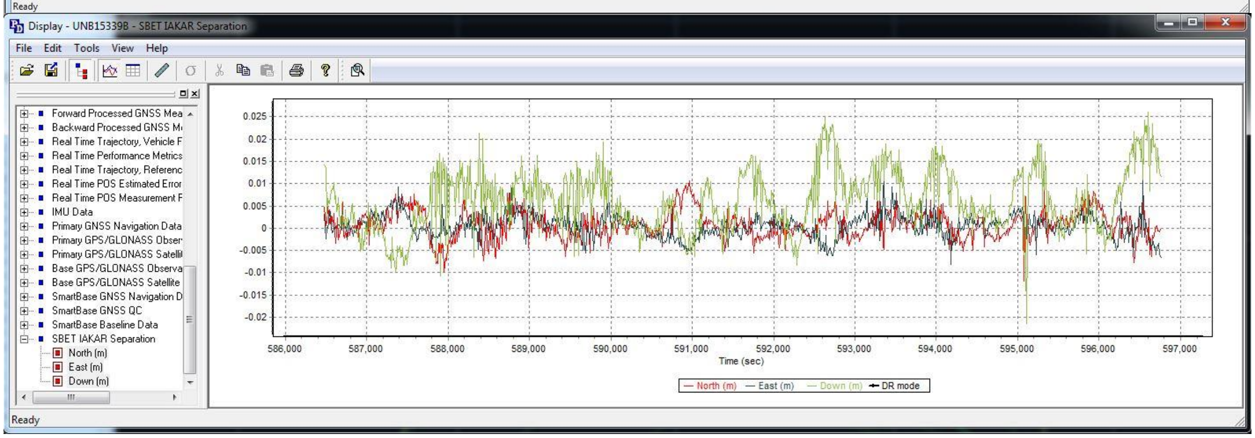

Display - UNB15339A - Smoothed Performance Metrics, Reference Frame
Time (sec)
North Position Error RMS (m)
East Position Error RMS (m)
Down Position Error RMS (m)

UNB15339B


Display - UNB15339B - Solution Status
Number of GLONASS Satellites
Time (sec)
Forward
Reverse
Display - UNB15339B - Solution Status
Number of GPS Satellites
Time (sec)
Forward
Reverse
Display - UNB15339B - Real Time POS Estimated Errors
Time (sec)
x gyro bias (deg/hr)
y gyro bias (deg/hr)
z gyro bias (deg/hr)


Display - UNB153398 - Smoothed Performance Metrics, Reference Frame
File Edit Tools View Help
Smoothed Best Estimate of Traj
Smoothed Performance Metrics
North Position Error RMS
East Position Error RMS
Down Position Error RMS
North Velocity Error RMS
East Velocity Error RMS
Down Velocity Error RMS
Roll Error RMS (arc-min)
Pitch Error RMS (arc-min)
Heading Error RMS
Smoothed Estimated Errors, Re
Forward Processed Trajectory,
Forward Processed Performanc
Calibrated Installation Paramete
Solution Status
Smoothed Solution Status
Forward Processed Estimated E
Forward Processed Measureme
Forward Processed GNSS Mea
Time (sec)
North Position Error RMS (m)
East Position Error RMS (m)
Down Position Error RMS (m)
Ready

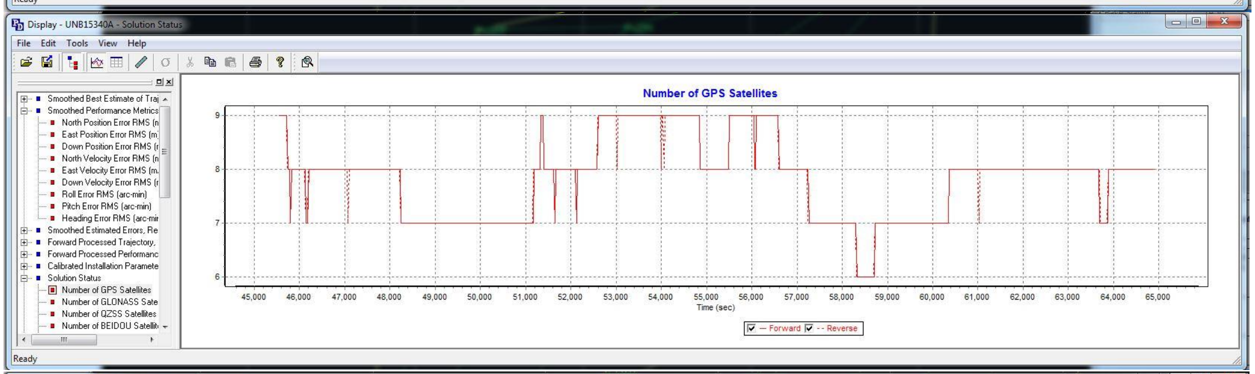

Display - UNB153398 - Real Time POS Estimated Errors
File Edit Tools View Help
Forward Processed Measureme
Real Time Trajectory, Vehicle F
Real Time Performance Metrics
Real Time Trajectory, Referenc
Real Time POS Estimated Error
x accelerometer bias
y accelerometer bias
z accelerometer bias
x accelerometer scale error
y accelerometer scale error
z accelerometer scale error
x gyro bias (deg/hr)
y gyro bias (deg/hr)
z gyro bias (deg/hr)
x gyro scale error (ppm)
y gyro scale error (ppm)
z gyro scale error (ppm)
x GNSS lever arm error (m)
y GNSS lever arm error (m)
z GNSS lever arm error (m)
Time (sec)
x accelerometer bias (micro-g)
y accelerometer bias (micro-g)
z accelerometer bias (micro-g)
Ready


Display - UNB153398 - SBET IAKAR Separation
File Edit Tools View Help
Forward Processed GNSS Mea
Backward Processed GNSS M
Real Time Trajectory, Vehicle F
Real Time Performance Metrics
Real Time Trajectory, Referenc
Real Time POS Estimated Error
Real Time POS Measurement F
IMU Data
Primary GNSS Navigation Data
Primary GPS/GLONASS Obser
Primary GPS/GLONASS Satelli
Base GPS/GLONASS Observa
Base GPS/GLONASS Satellite
SmartBase GNSS Navigation D
SmartBase GNSS QC
SmartBase Baseline Data
SBET IAKAR Separation
North (m)
East (m)
Down (m)
Time (sec)
North (m)
East (m)
Down (m)
DR mode
Ready

UNB15340A


Display - UNB15340A - SBET IAKAR Separation
Time (sec)
North (m)
East (m)
Down (m)
DR mode


Display - UNB15340A - Solution Status
Number of GLONASS Satellites
Time (sec)
Forward
Reverse


Display - UNB15340A - Solution Status
Number of GPS Satellites
Time (sec)
Forward
Reverse

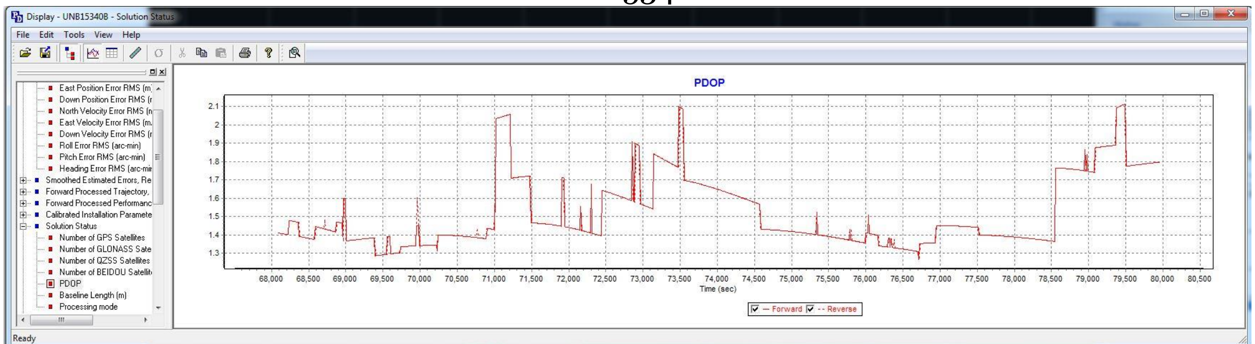

Display - UNB15340A - Real Time POS Estimated Errors
Time (sec)
x gyro bias (deg/hr)
y gyro bias (deg/hr)
z gyro bias (deg/hr)

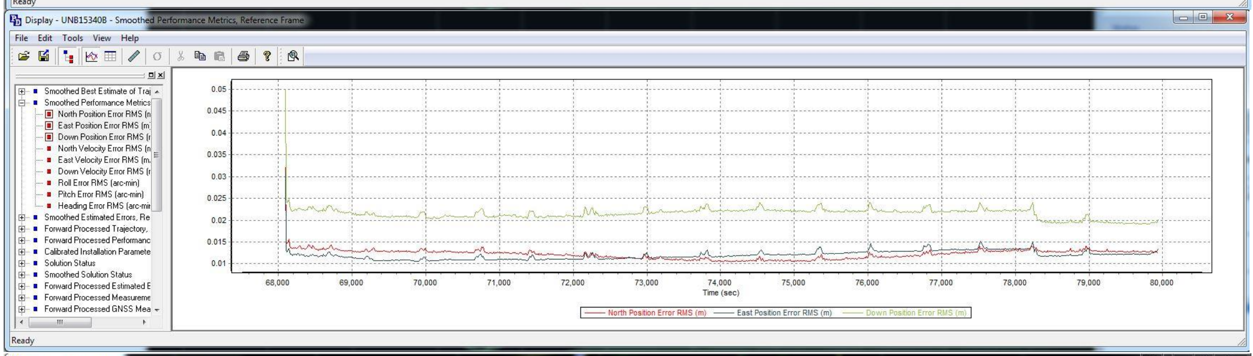

Display - UNB15340A - Solution Status
PDOP
Time (sec)
Forward
Reverse


Display - UNB15340A - Smoothed Performance Metrics, Reference Frame
Time (sec)
North Position Error RMS (m)
East Position Error RMS (m)
Down Position Error RMS (m)

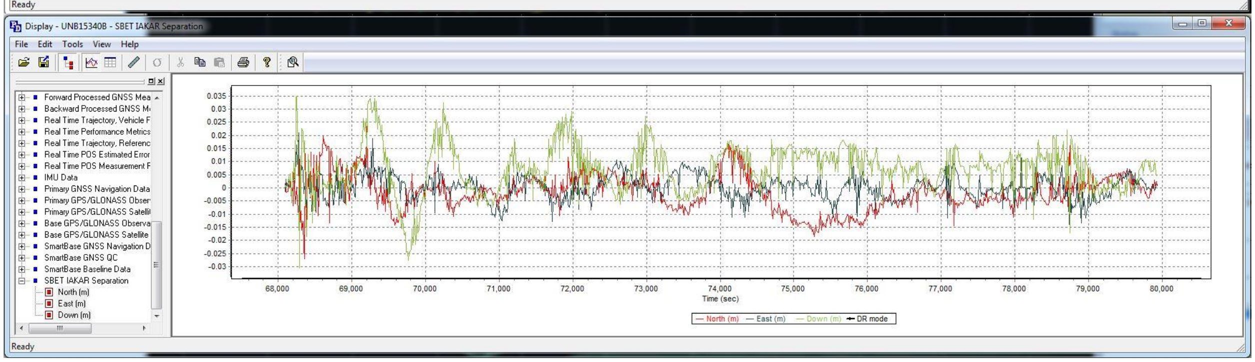

Display - UNB15340A - Real Time POS Estimated Errors
Time (sec)
x accelerometer bias (micro-g)
y accelerometer bias (micro-g)
z accelerometer bias (micro-g)

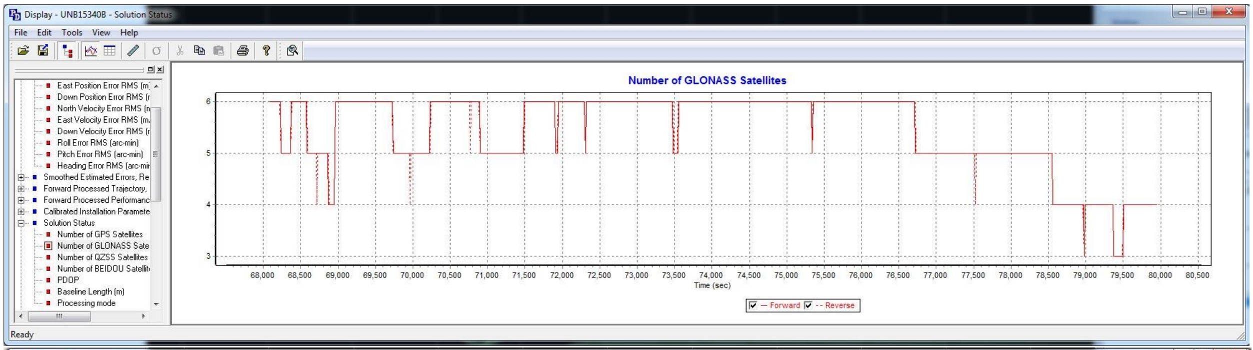
UNB15340B

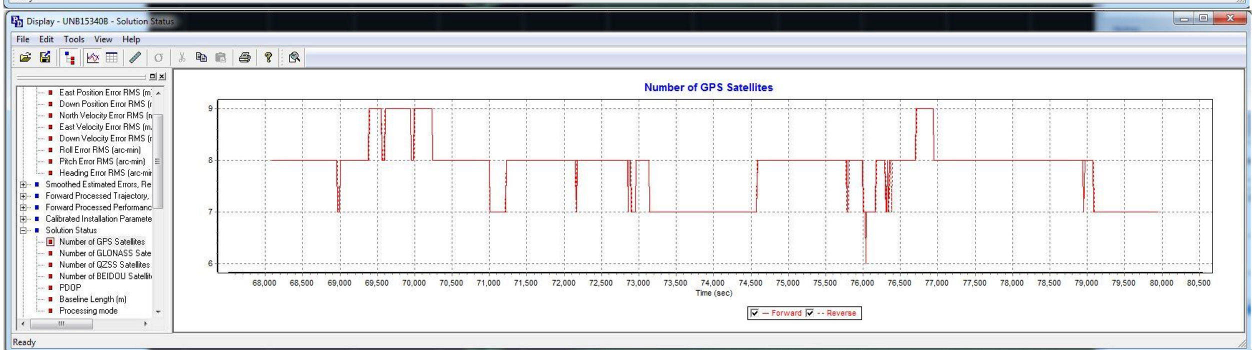

Display - UNB15340B - Solution Status
PDOP
Time (sec)
Forward
Reverse

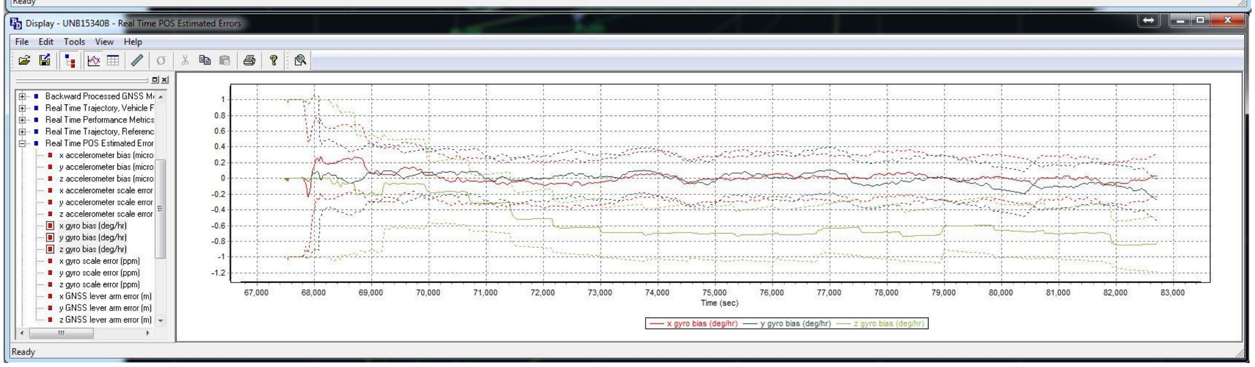

Display - UNB15340B - Smoothed Performance Metrics, Reference Frame
Time (sec)
North Position Error RMS (m)
East Position Error RMS (m)
Down Position Error RMS (m)


Display - UNB15340B - Real Time POS Estimated Errors
Time (sec)
x accelerometer bias (micro-g)
y accelerometer bias (micro-g)
z accelerometer bias (micro-g)

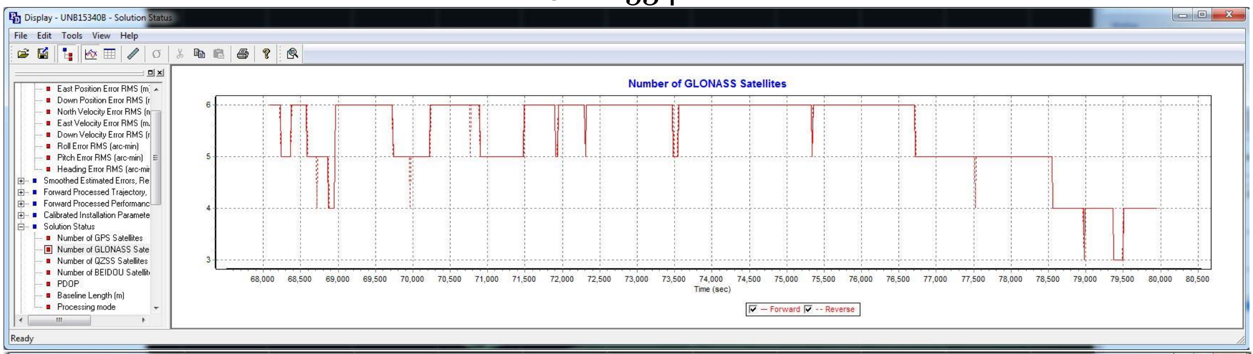

Display - UNB15340B - SBET IAKAR Separation
Time (sec)
North (m)
East (m)
Down (m)
DR mode

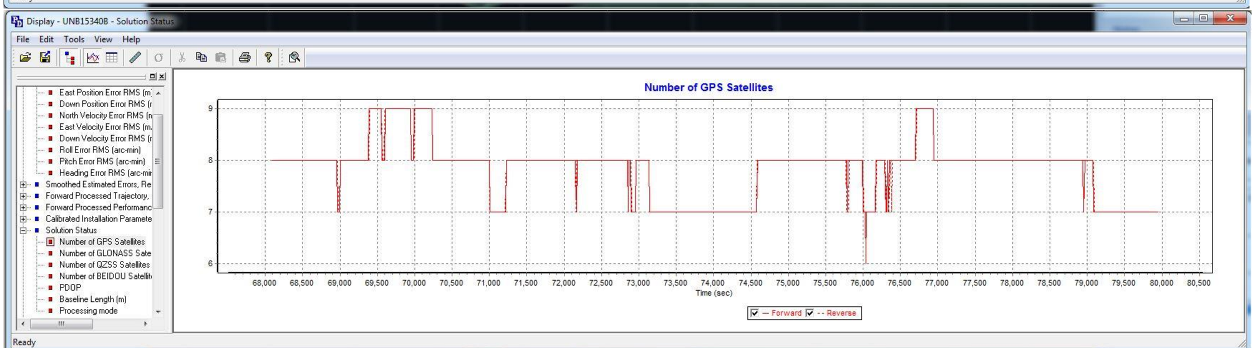

Display - UNB153408 - Solution Status
Number of GLONASS Satellites
Time (sec)
Forward
Reverse

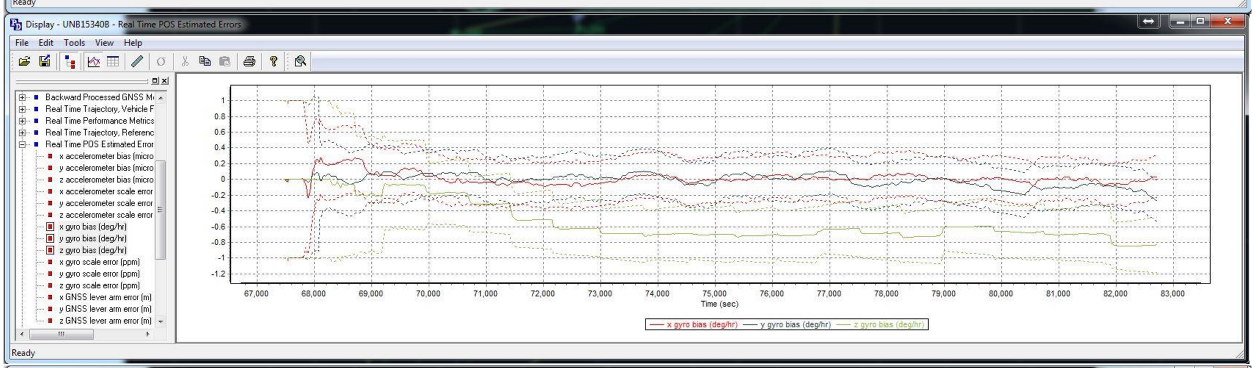

Display - UNB153408 - Solution Status
Number of GPS Satellites
Time (sec)
Forward
Reverse

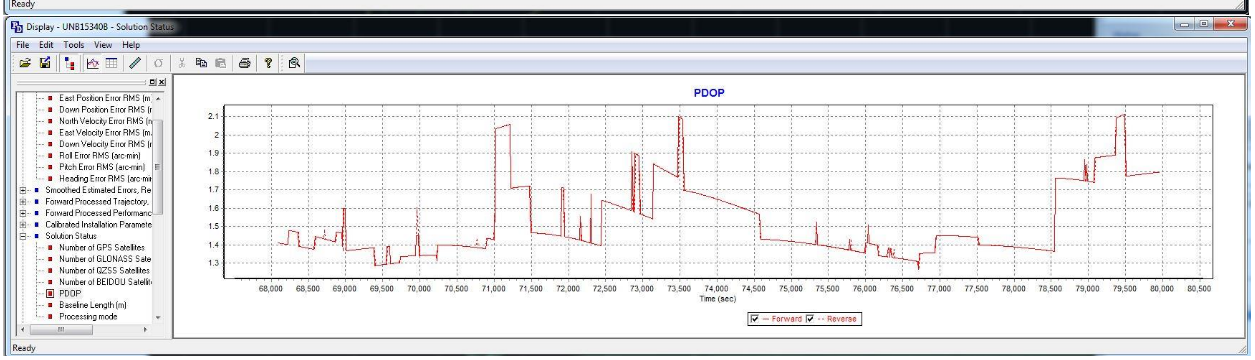

Display - UNB153408 - Real Time POS Estimated Errors
Time (sec)
x gyro bias (deg/hr)
y gyro bias (deg/hr)
z gyro bias (deg/hr)

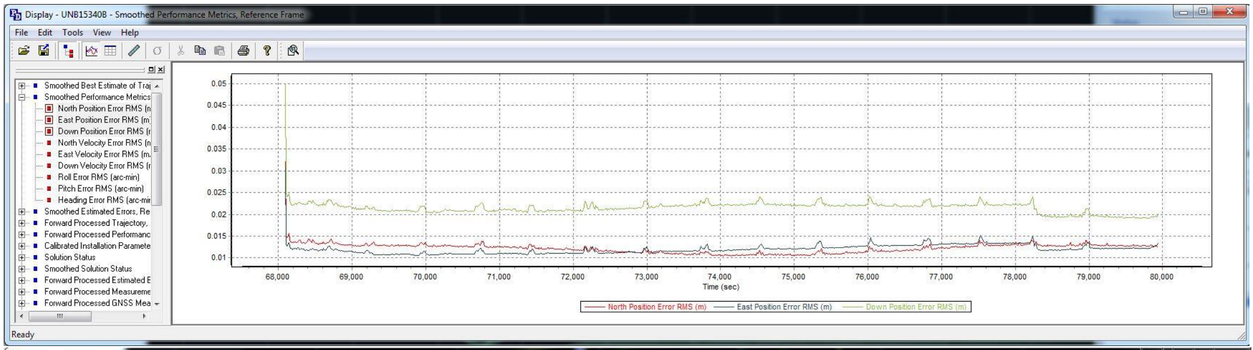
UNB15341A


Display - UNB153408 - Solution Status
Number of GLONASS Satellites
Time (sec)
Forward
Reverse
Ready


Display - UNB153408 - Solution Status
Number of GPS Satellites
Time (sec)
Forward
Reverse
Ready


Display - UNB153408 - Real Time POS Estimated Errors
Time (sec)
x gyro bias (deg/hr)
y gyro bias (deg/hr)
z gyro bias (deg/hr)
Ready

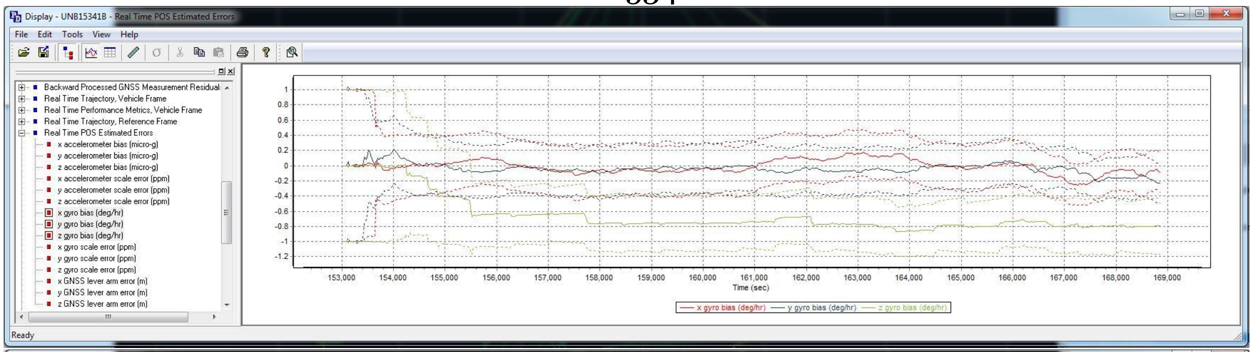

Display - UNB153408 - Solution Status
PDOP
Time (sec)
Forward
Reverse
Ready


Display - UNB153408 - Smoothed Performance Metrics, Reference Frame
Time (sec)
North Position Error RMS (m)
East Position Error RMS (m)
Down Position Error RMS (m)


Display - UNB153408 - Real Time POS Estimated Errors
Time (sec)
x accelerometer bias (micro-g)
y accelerometer bias (micro-g)
z accelerometer bias (micro-g)

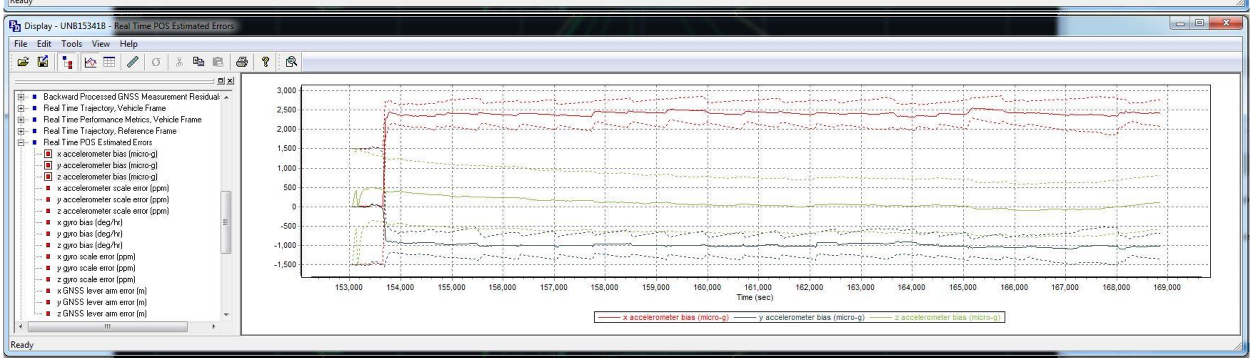

Display - UNB153408 - SBET IAKAR Separation
Time (sec)
North (m)
East (m)
Down (m)
DR mode

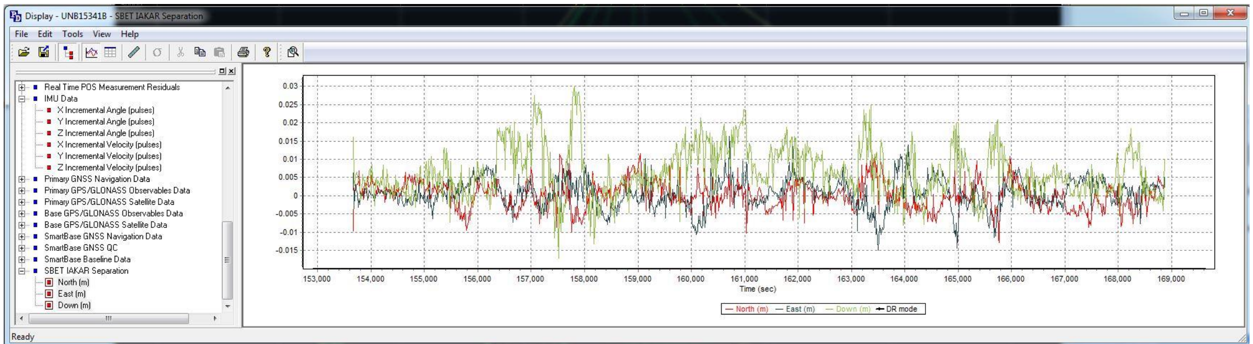
UNB15341B


Display - UNB15341B - Real Time POS Estimated Errors
Time (sec)
x gyro bias (deg/hr)
y gyro bias (deg/hr)
z gyro bias (deg/hr)

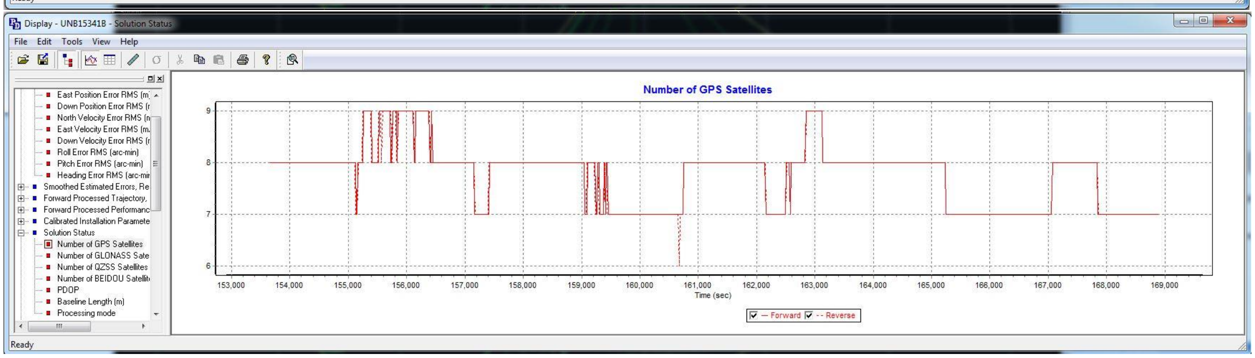

Display - UNB15341B - Solution Status
PDOP
Time (sec)
Forward
Reverse


Display - UNB15341B - Smoothed Performance Metrics, Reference Frame
Time (sec)
North Position Error RMS (m)
East Position Error RMS (m)
Down Position Error RMS (m)

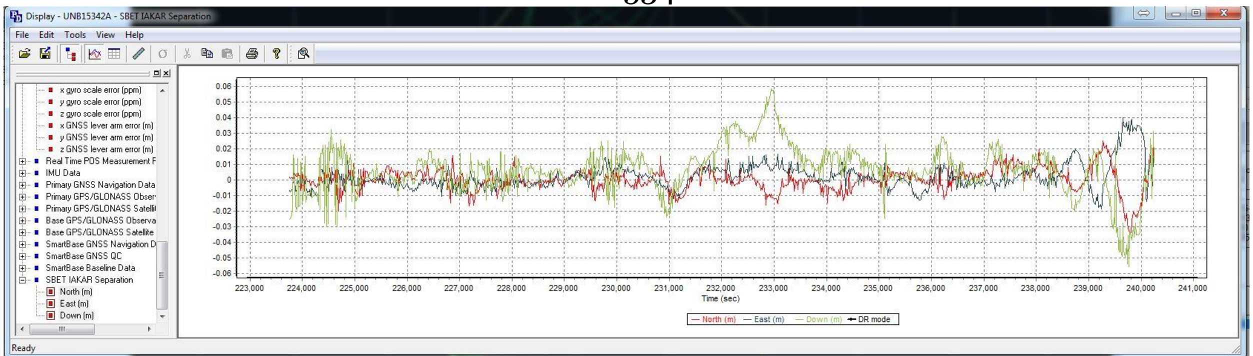

Display - UNB15341B - Real Time POS Estimated Errors
Time (sec)
x accelerometer bias (micro-g)
y accelerometer bias (micro-g)
z accelerometer bias (micro-g)

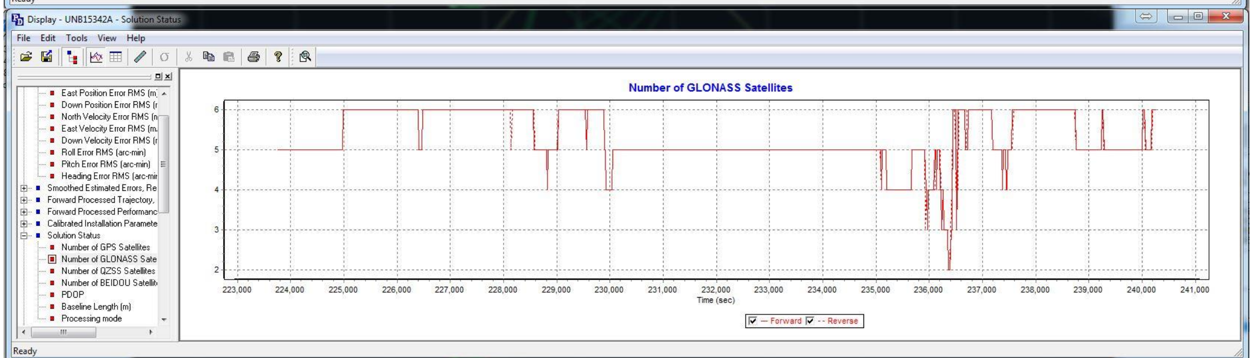

Display - UNB153418 - SBET IAKAR Separation
File Edit Tools View Help
Real Time POS Measurement Residuals
IMU Data
X Incremental Angle (pulses)
Y Incremental Angle (pulses)
Z Incremental Angle (pulses)
X Incremental Velocity (pulses)
Y Incremental Velocity (pulses)
Z Incremental Velocity (pulses)
Primary GNSS Navigation Data
Primary GPS/GLONASS Observables Data
Primary GPS/GLONASS Satellite Data
Base GPS/GLONASS Observables Data
Base GPS/GLONASS Satellite Data
SmartBase GNSS Navigation Data
SmartBase GNSS QC
SmartBase Baseline Data
SBET IAKAR Separation
North (m)
East (m)
Down (m)
Time (sec)
North (m)
East (m)
Down (m)
DR mode
Ready


Display - UNB153418 - Solution Status
File Edit Tools View Help
Number of GLONASS Satellites
Time (sec)
Forward
Reverse
Ready

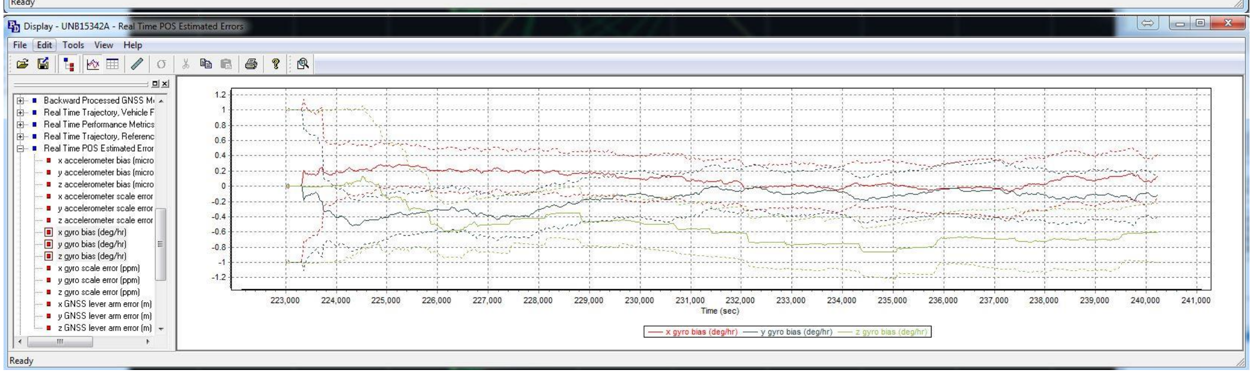

Display - UNB153418 - Solution Status
File Edit Tools View Help
Number of GPS Satellites
Time (sec)
Forward
Reverse
Ready

UNB15342A


Display - UNB15342A - SBET IAKAR Separation
Time (sec)
North (m)
East (m)
Down (m)
DR mode

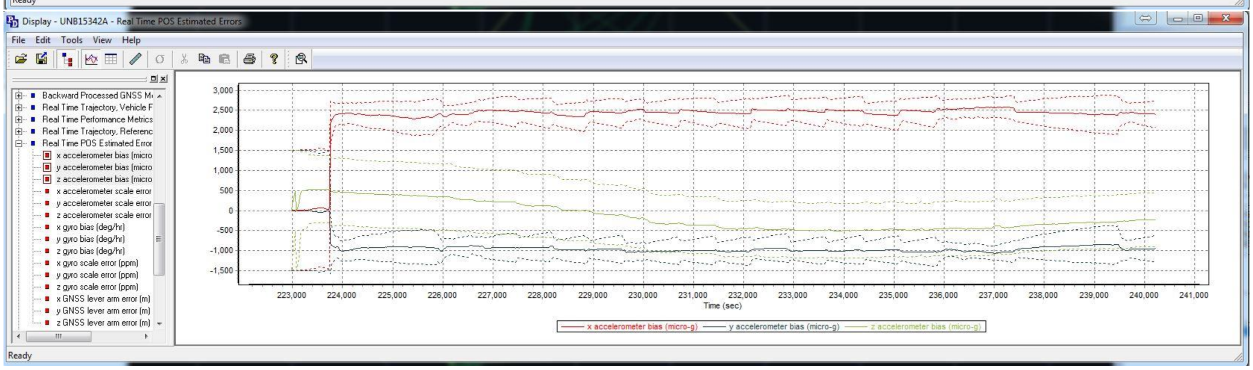

Display - UNB15342A - Solution Status
Number of GLONASS Satellites
Time (sec)
Forward
Reverse


Display - UNB15342A - Solution Status
Number of GPS Satellites
Time (sec)
Forward
Reverse

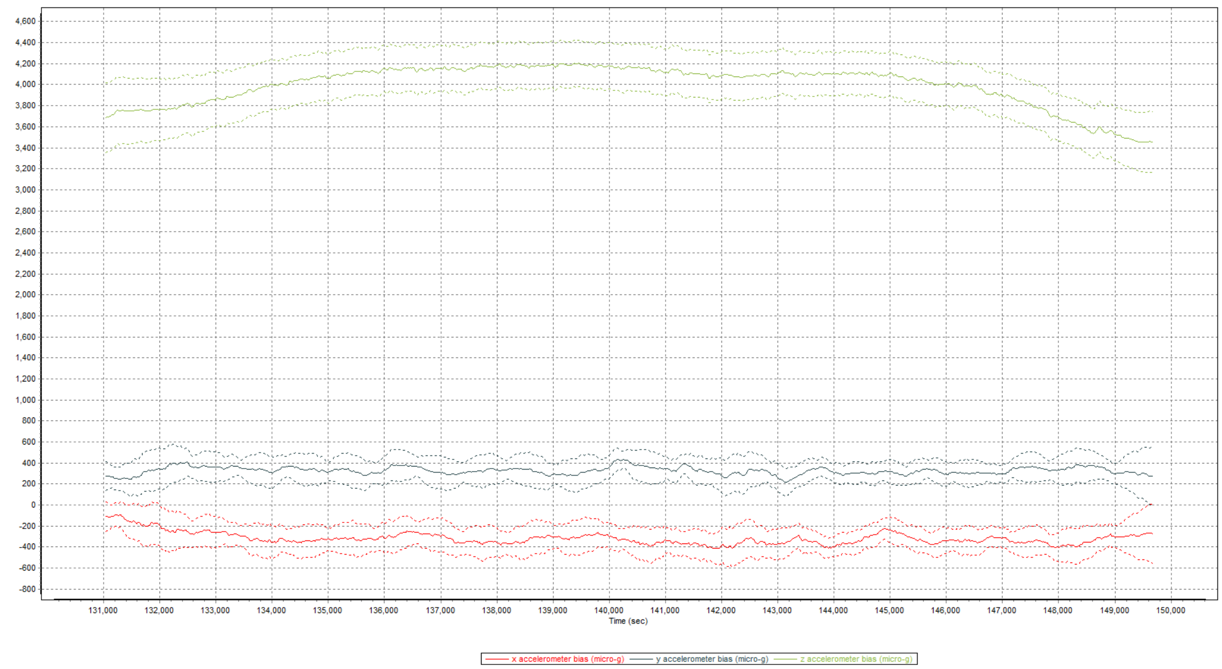

Display - UNB15342A - Real Time POS Estimated Errors
Time (sec)
x gyro bias (deg/hr)
y gyro bias (deg/hr)
z gyro bias (deg/hr)


Display - UNB15342A - Solution Status
PDOP
Time (sec)
Forward
Reverse


Display - UNB15342A - Smoothed Performance Metrics, Reference Frame
North Position Error RMS (m)
East Position Error RMS (m)
Down Position Error RMS (m)


Display - UNB15342A - Real Time POS Estimated Errors
Time (sec)
x accelerometer bias (micro-g)
y accelerometer bias (micro-g)
z accelerometer bias (micro-g)

MNB15341A


4,600
4,400
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3,200
3,000
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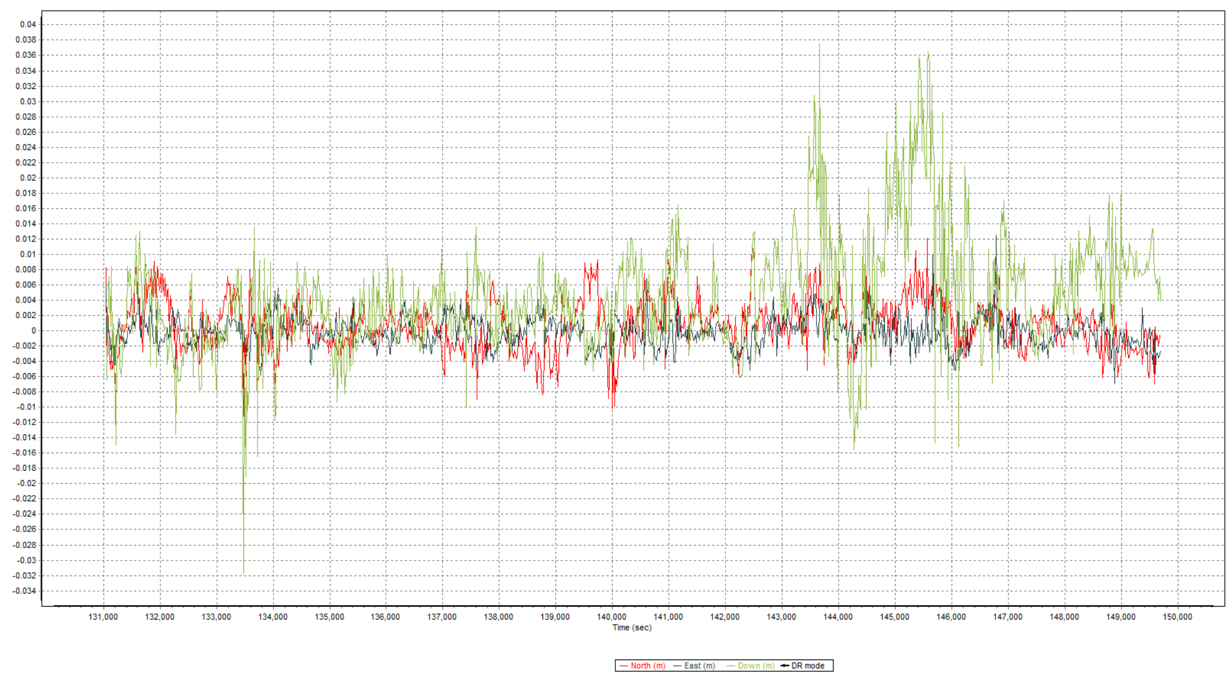
2,600
2,400
2,200
2,000
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
-200
-400
-600
-800
131,000
132,000
133,000
134,000
135,000
136,000
137,000
138,000
139,000
140,000
141,000
142,000
143,000
144,000
145,000
146,000
147,000
148,000
149,000
150,000
Time (sec)
x accelerometer bias (micro-g)
y accelerometer bias (micro-g)
z accelerometer bias (micro-g)


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
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-0.032
-0.034
131,000
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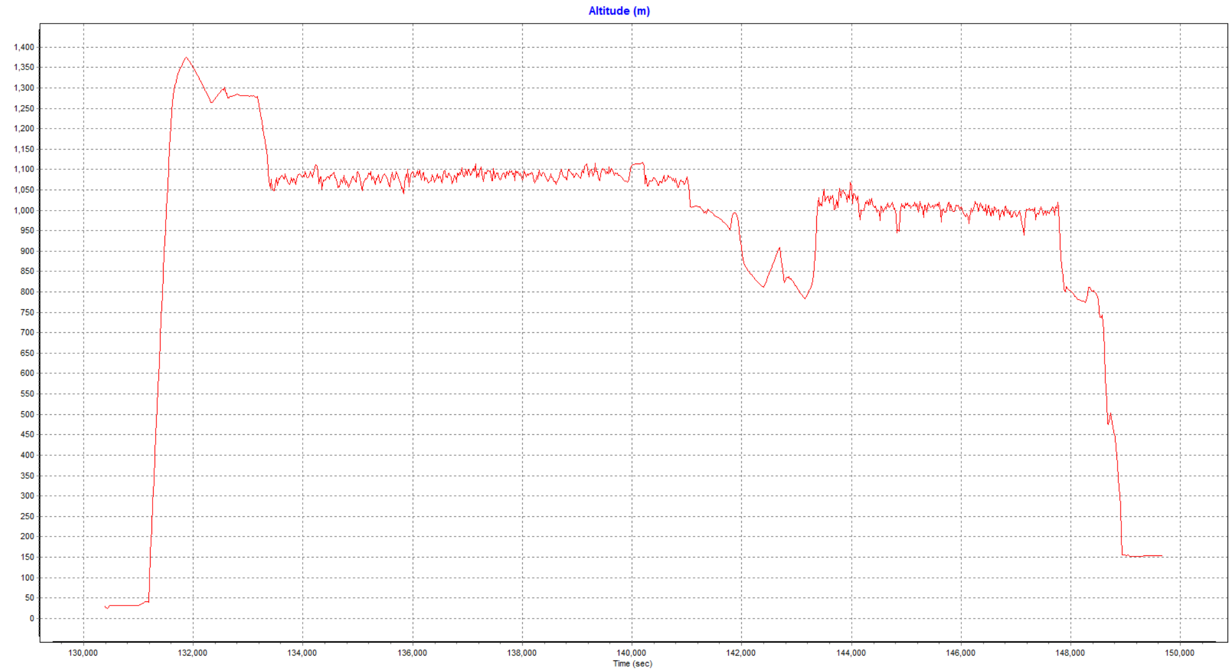
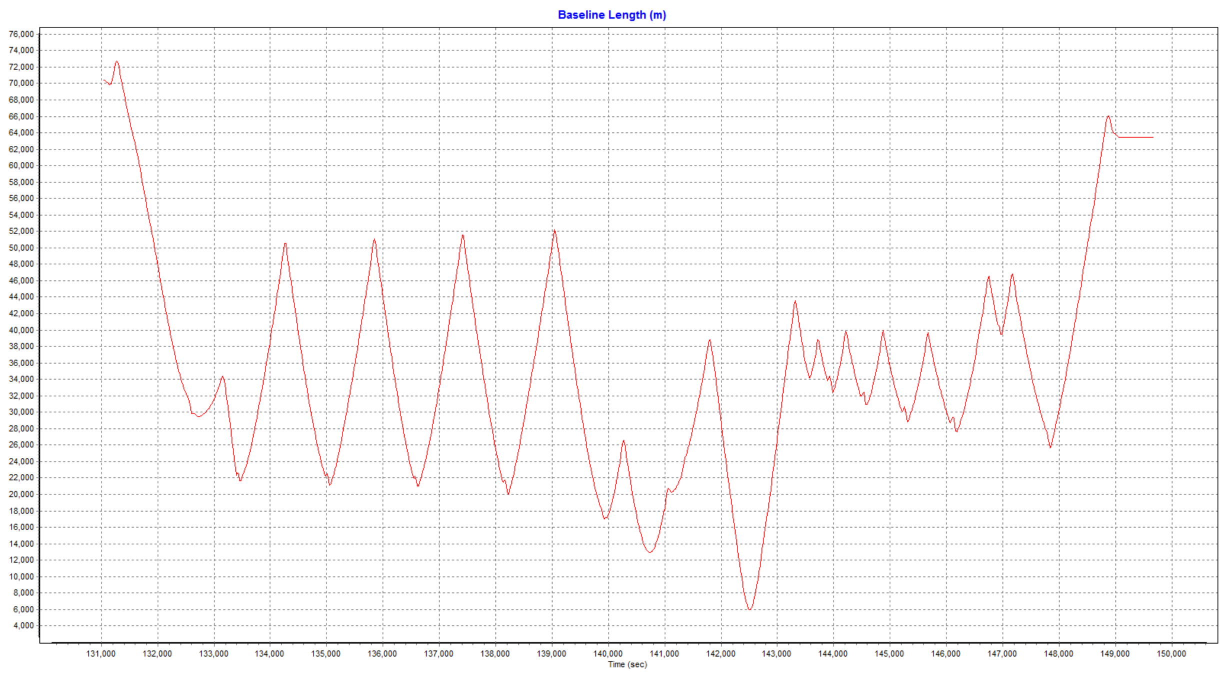
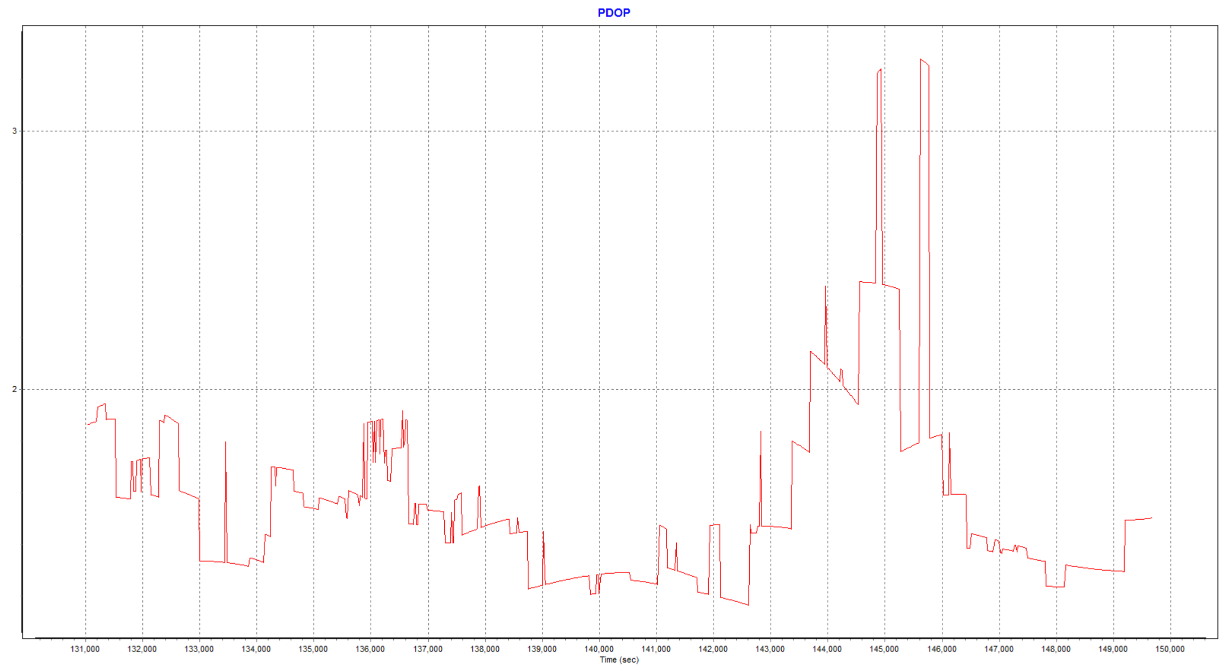
142,000
143,000
144,000
145,000
146,000
147,000
148,000
149,000
150,000
Time (sec)
North (m)
East (m)
Down (m)
DR mode


Altitude (m)
Time (sec)


Baseline Length (m)
Time (sec)


PDOP
3
2
131,000
132,000
133,000
134,000
135,000
136,000
137,000
138,000
139,000
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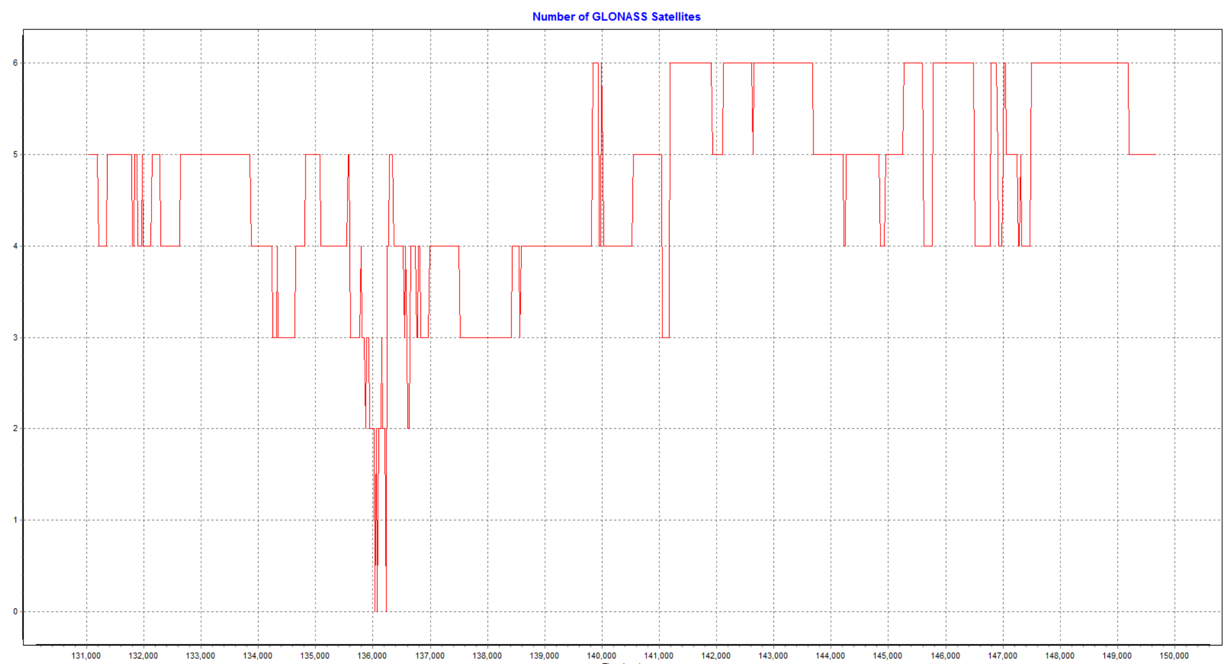
141,000
142,000
143,000
144,000
145,000
146,000
147,000
148,000
149,000
150,000
Time (sec)


Number of GLONASS Satellites
6
5
4
3
2
1
0
131,000
132,000
133,000
134,000
135,000
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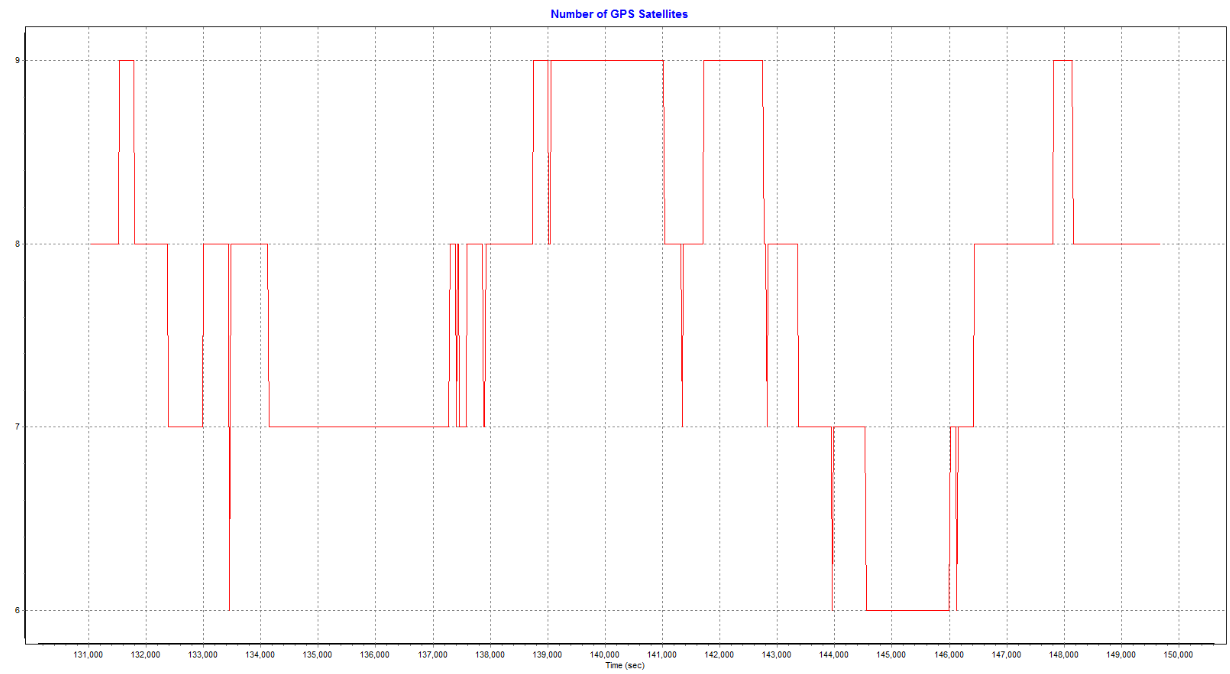
137,000
138,000
139,000
140,000
141,000
142,000
143,000
144,000
145,000
146,000
147,000
148,000
149,000
150,000
Time (sec)


Number of GPS Satellites
9
8
7
6
131,000
132,000
133,000
134,000
135,000
136,000
137,000
138,000
139,000
140,000
141,000
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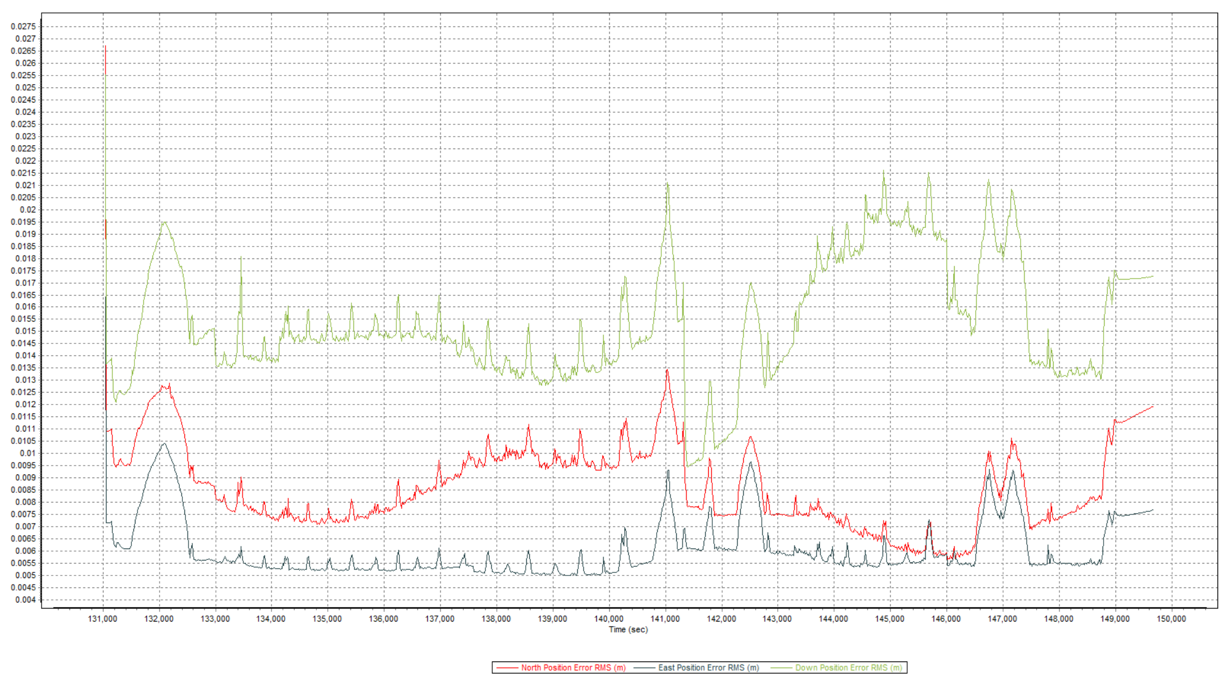
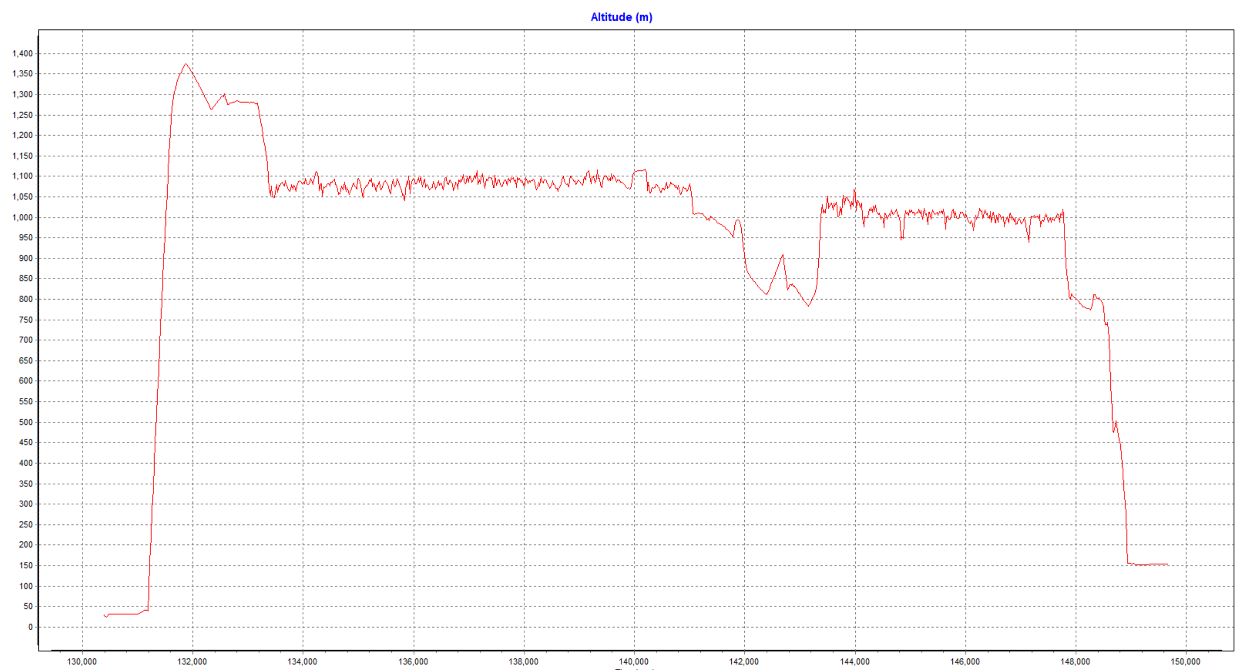
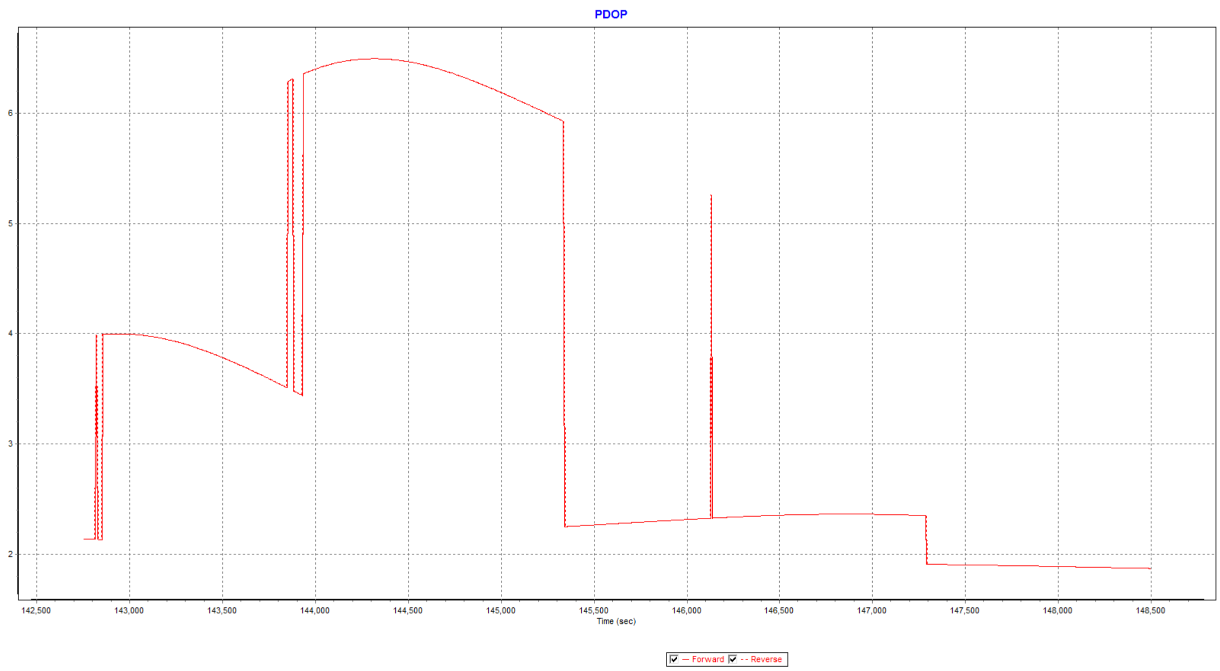
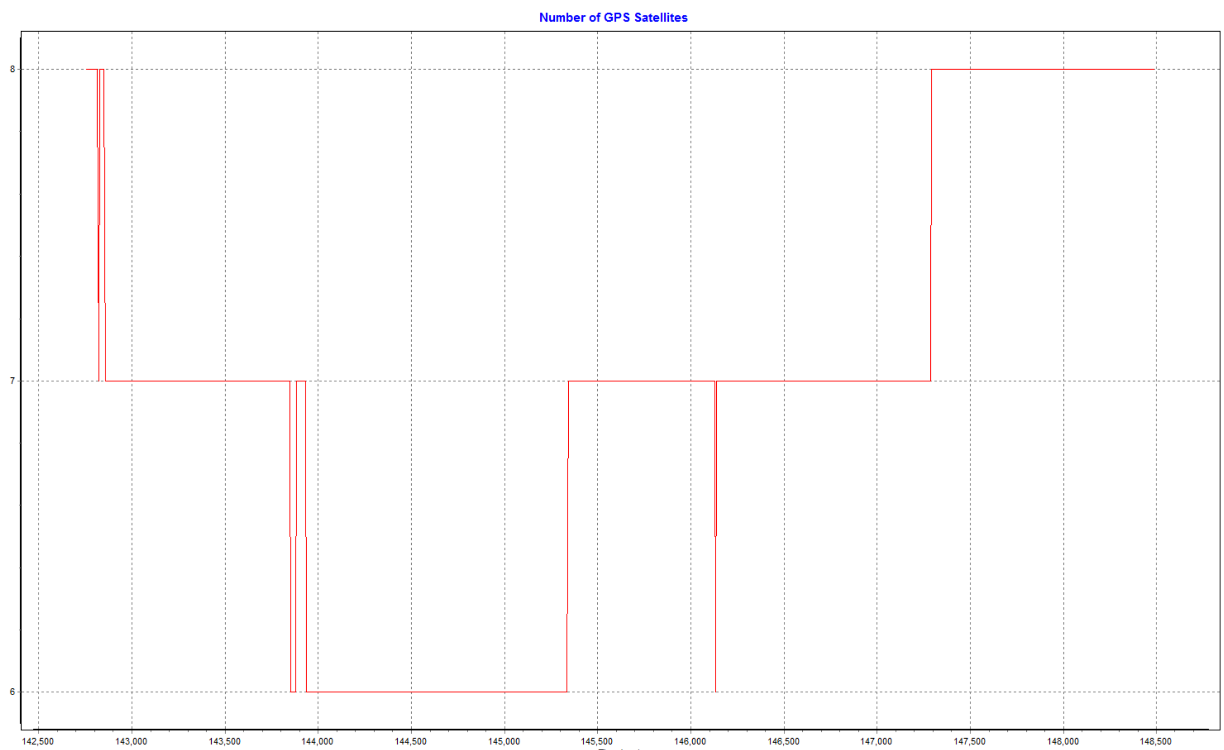
143,000
144,000
145,000
146,000
147,000
148,000
149,000
150,000
Time (sec)


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


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


Altitude (m)
Time (sec)


PDOP
6
5
4
3
2
142,500
143,000
143,500
144,000
144,500
145,000
145,500
146,000
146,500
147,000
147,500
148,000
148,500
Time (sec)
Forward
Reverse


Number of GPS Satellites
8
7
6
142,500
143,000
143,500
144,000
144,500
145,000
145,500
146,000
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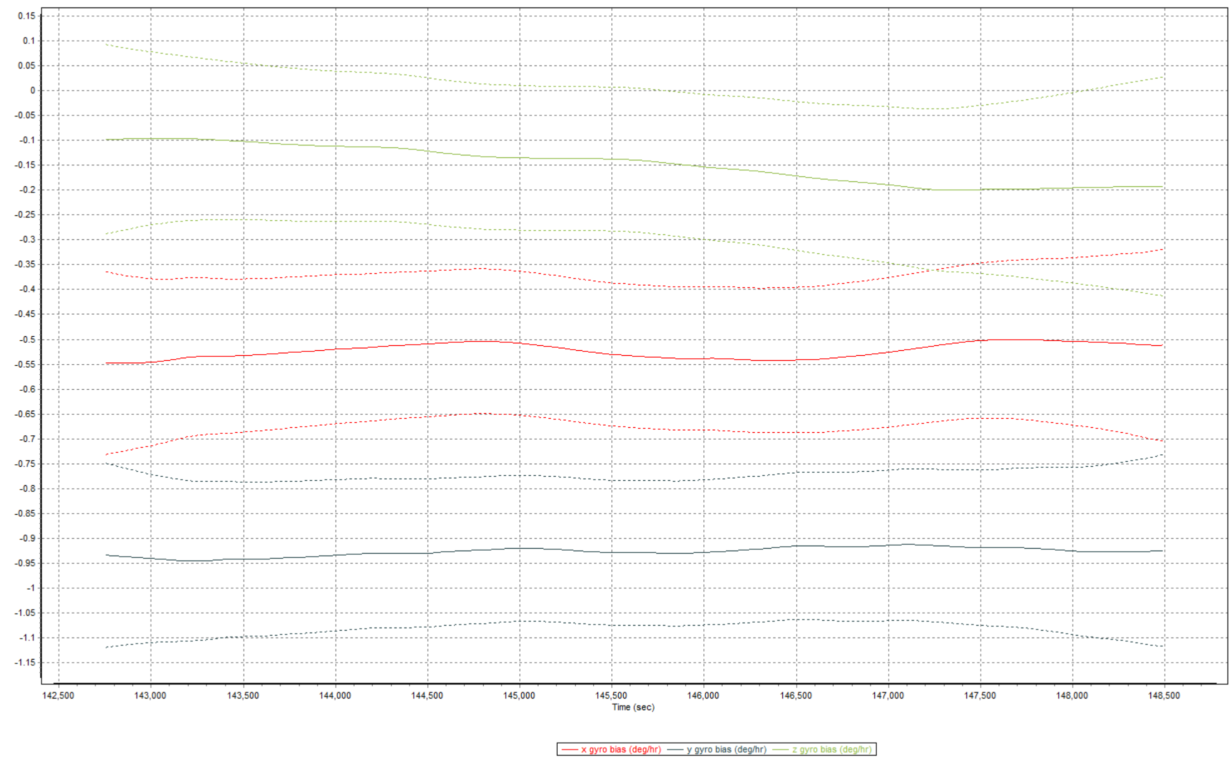
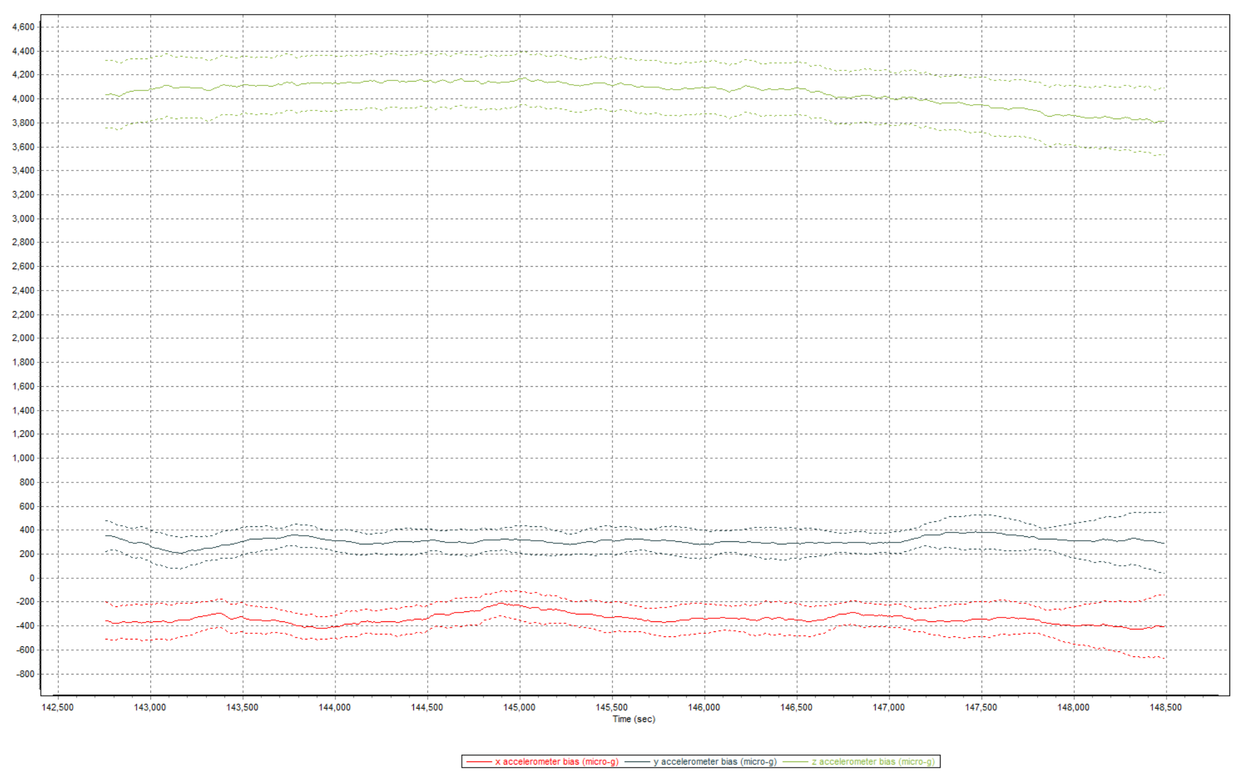
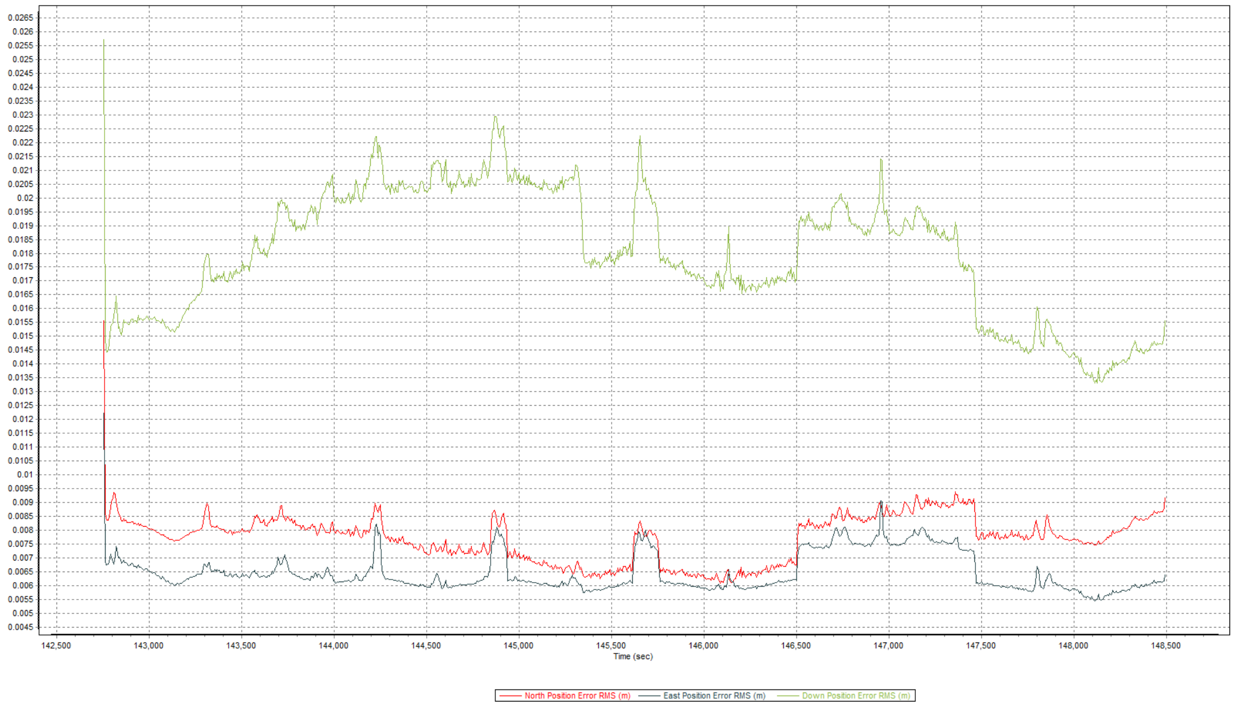
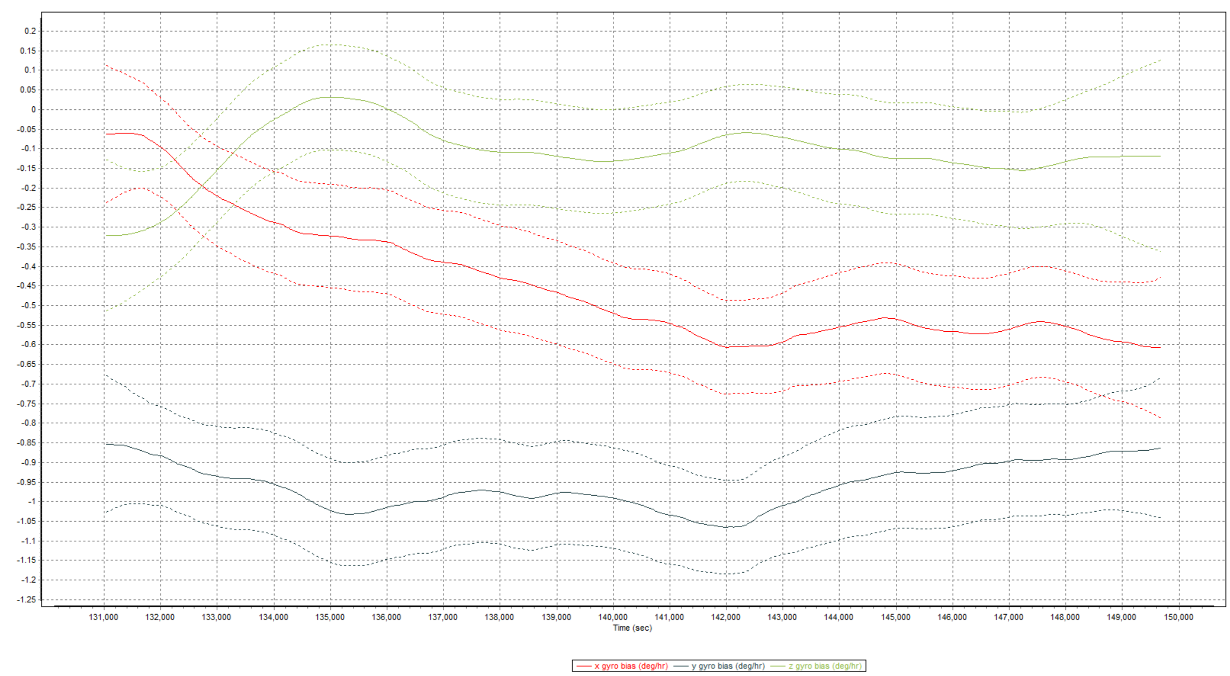
148,000
148,500
Time (sec)


Time (sec)
x gyro bias (deg/hr)
y gyro bias (deg/hr)
z gyro bias (deg/hr)


Time (sec)
x accelerometer bias (micro-g)
y accelerometer bias (micro-g)
z accelerometer bias (micro-g)


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


Time (sec)
x gyro bias (deg/hr)
y gyro bias (deg/hr)
z gyro bias (deg/hr)

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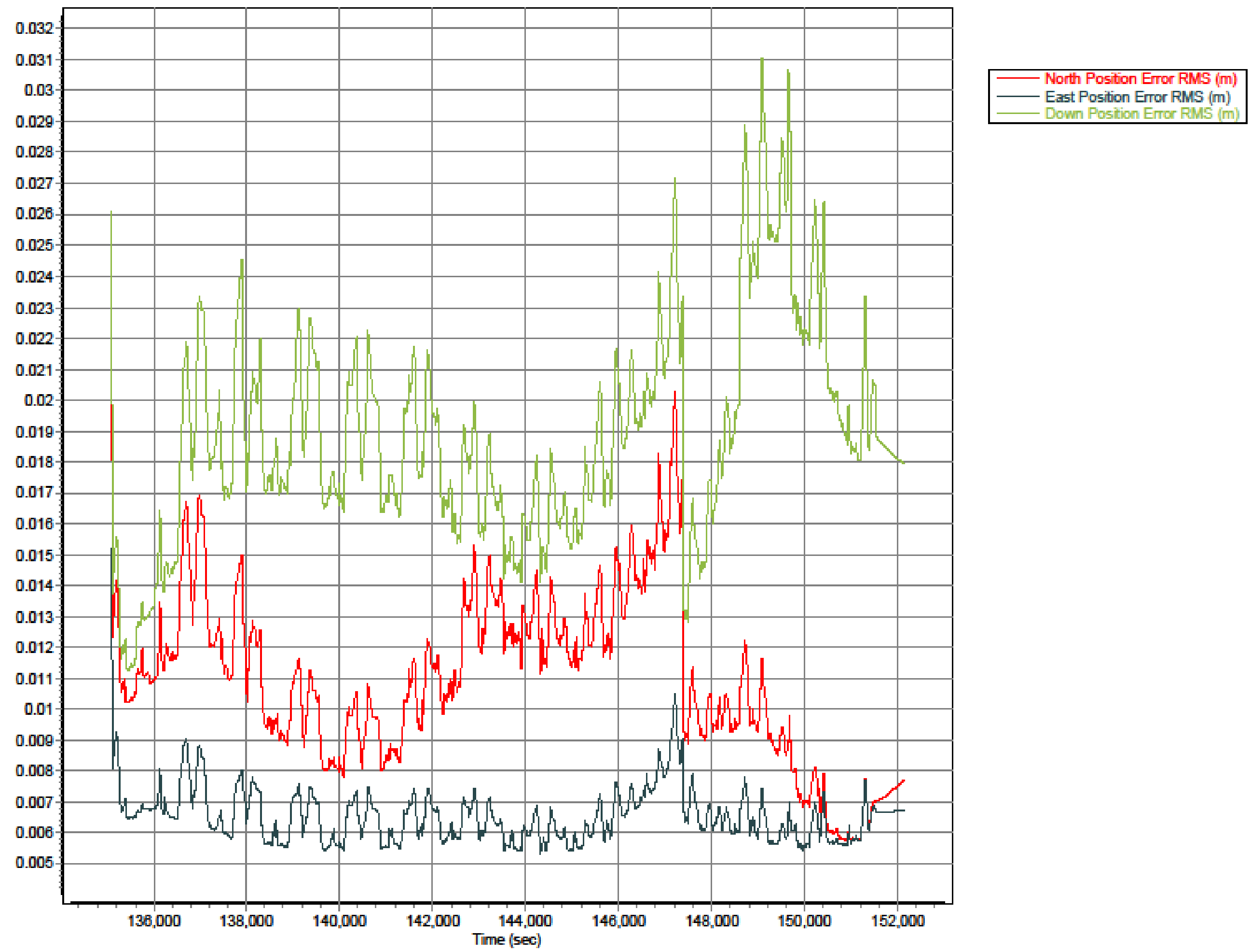
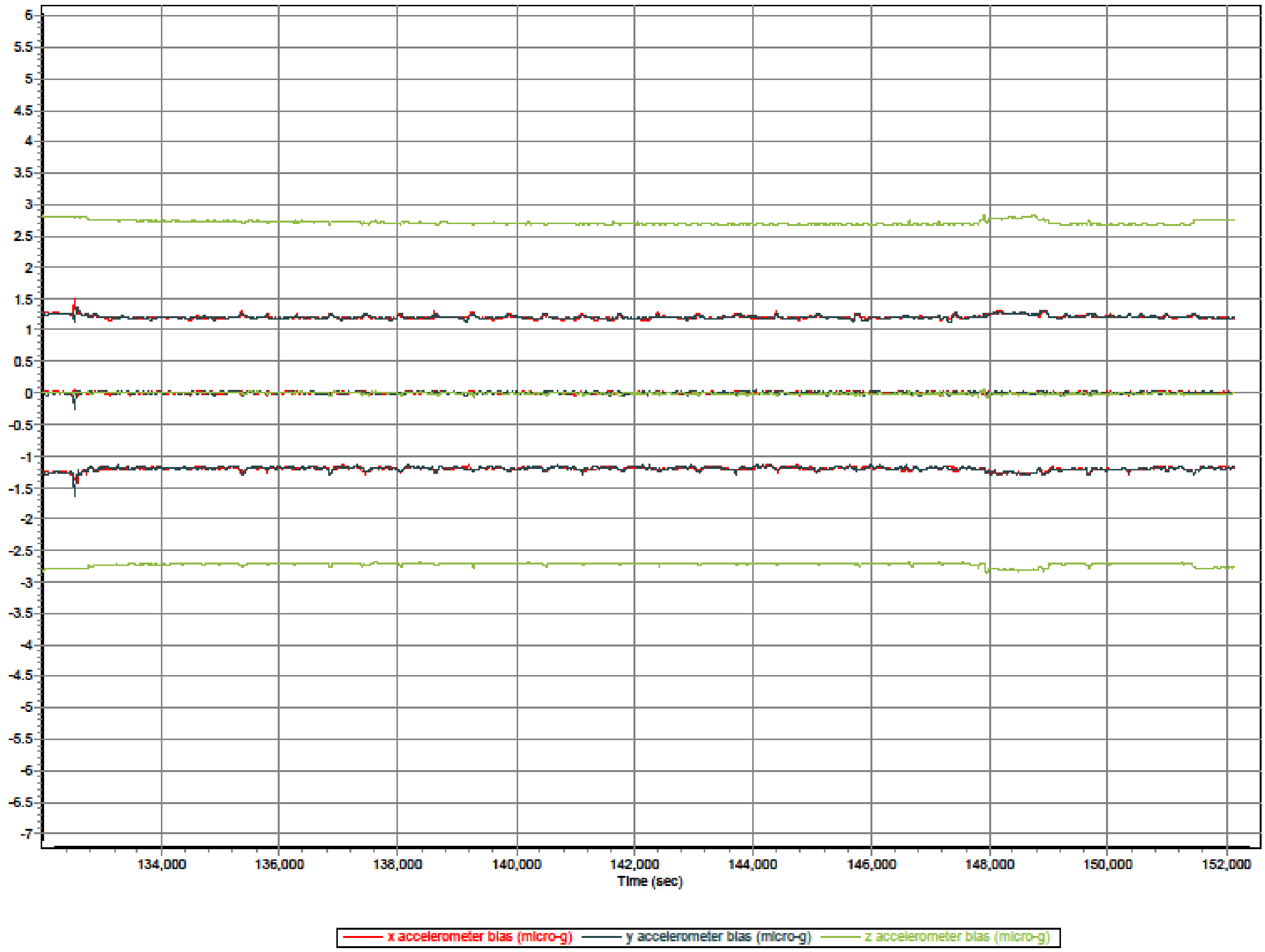
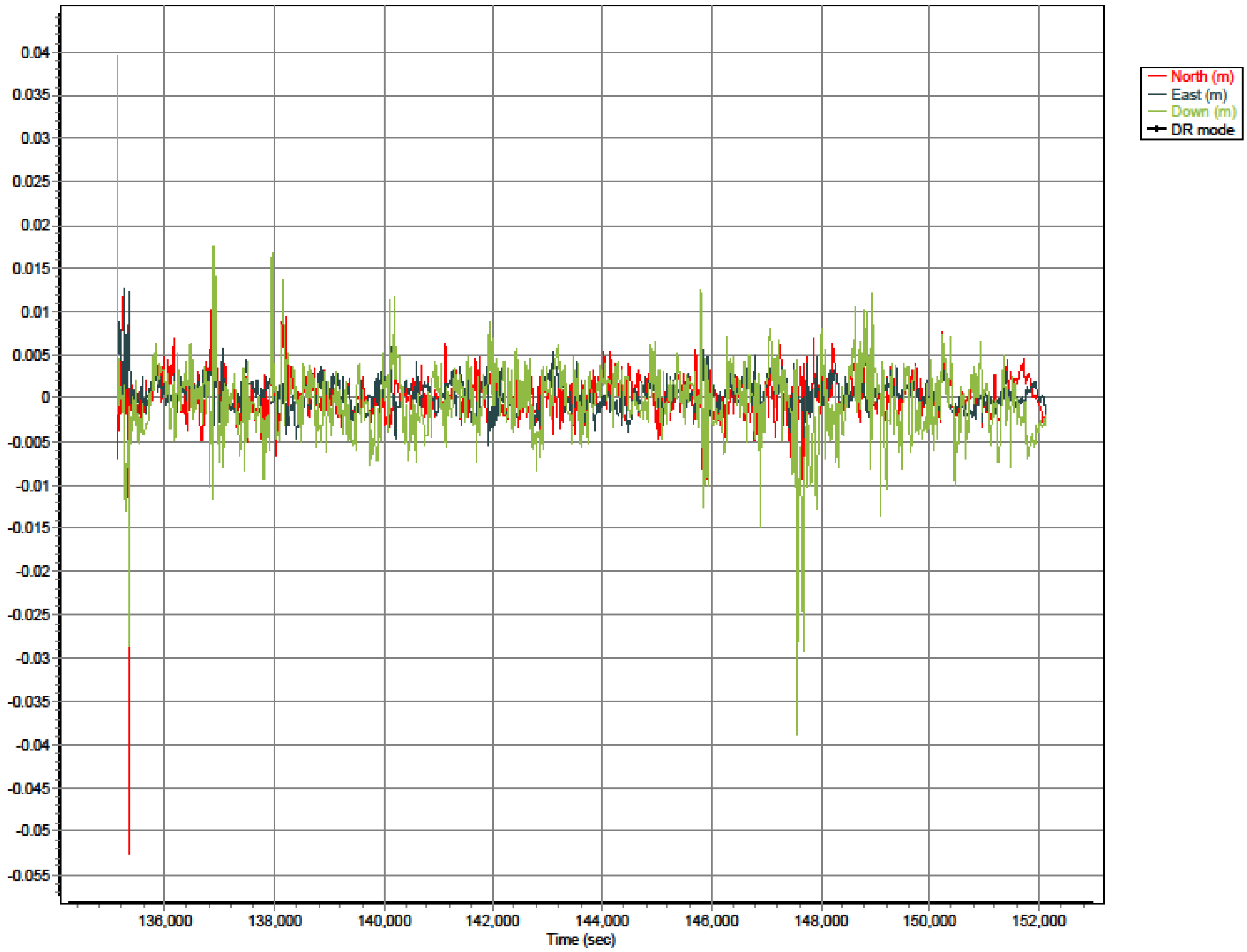
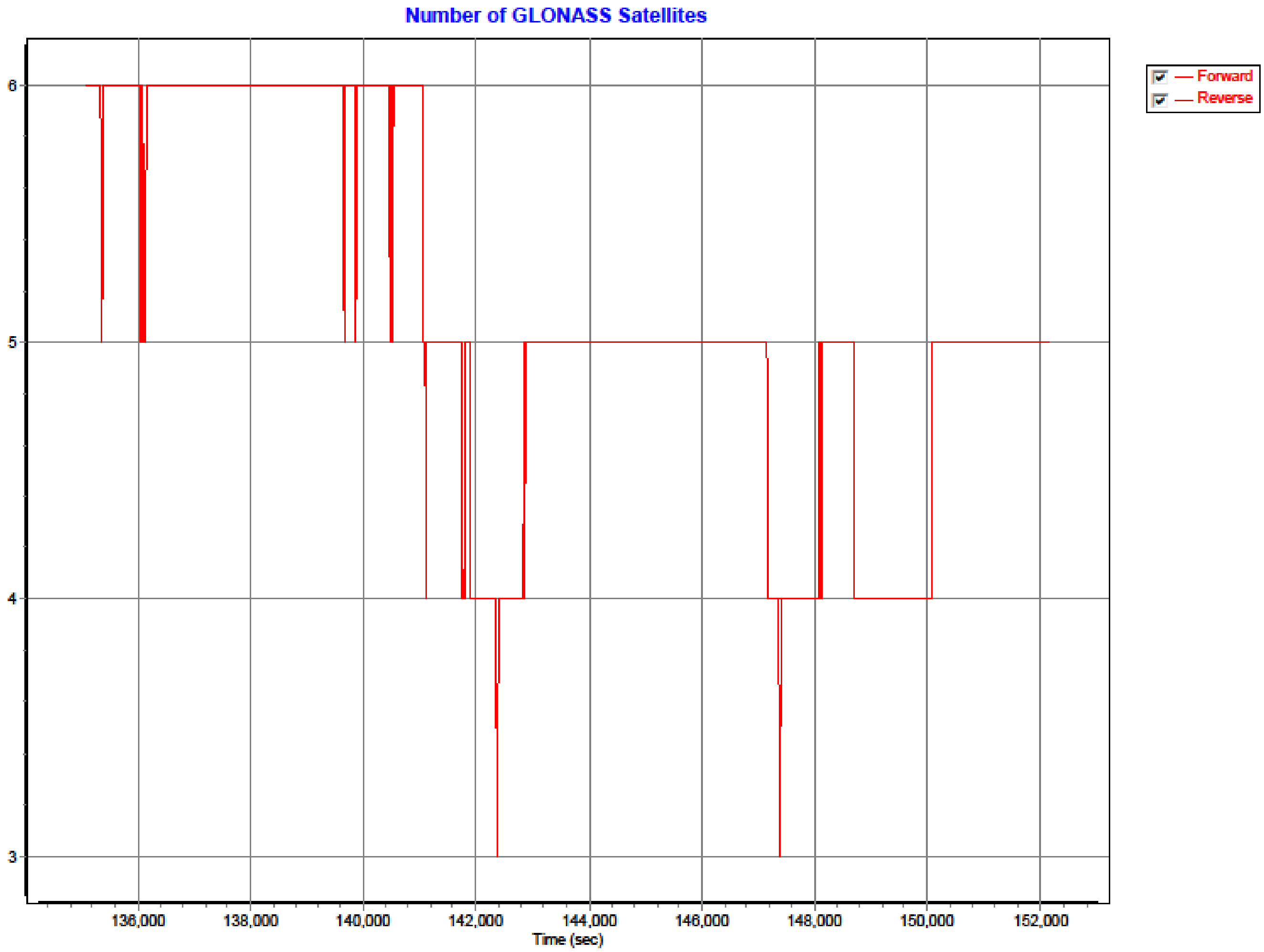
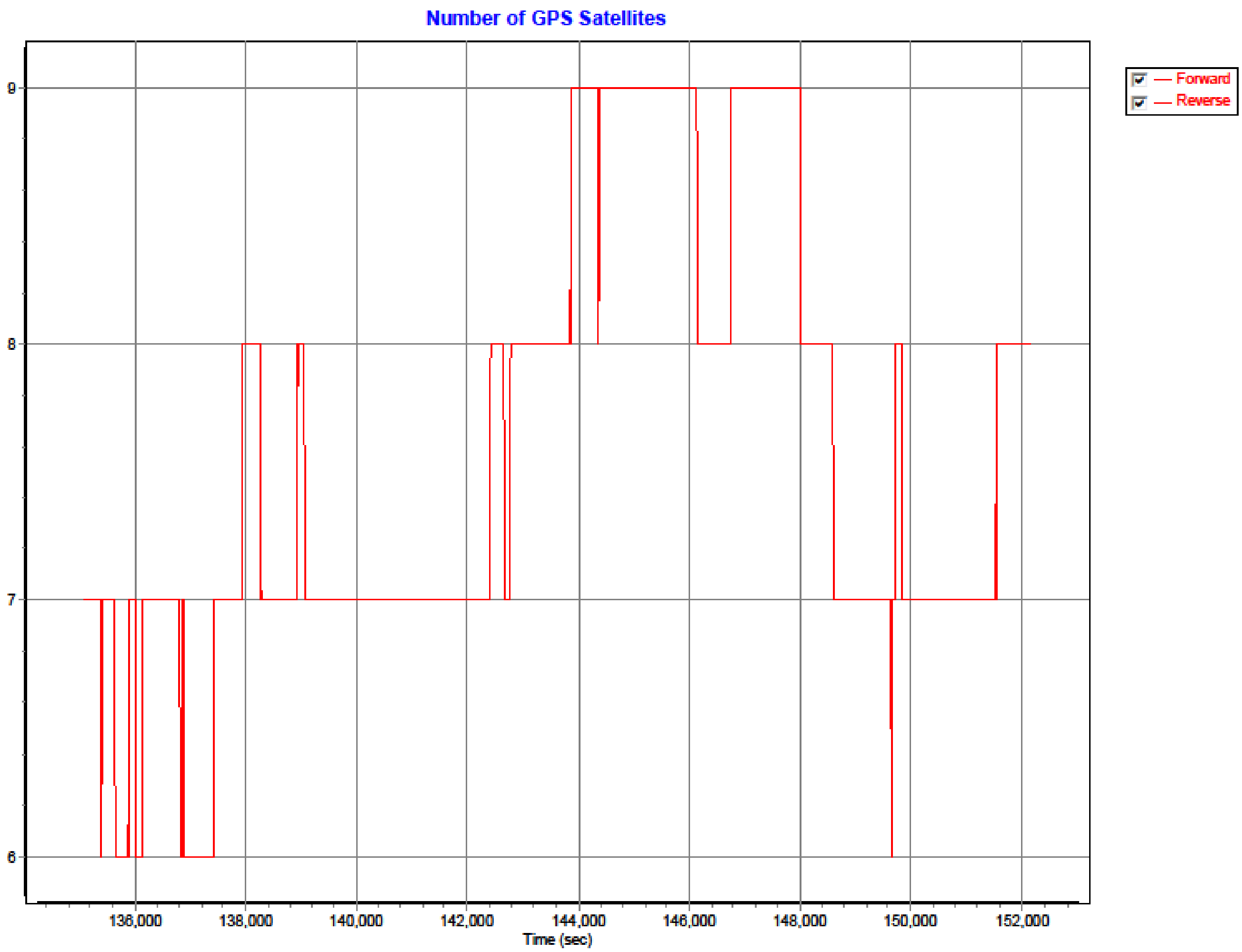
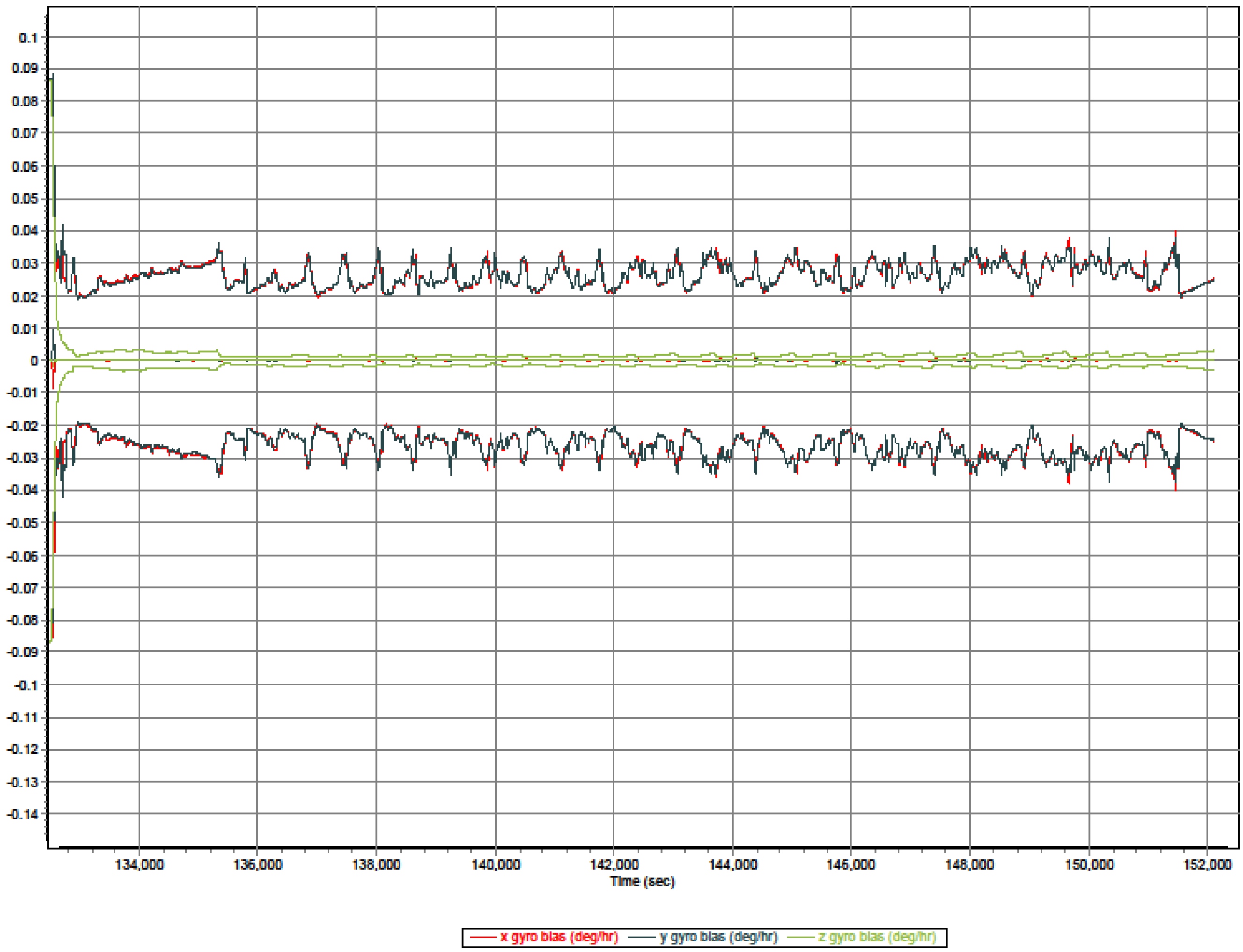

0.032
0.031
0.03
0.029
0.028
0.027
0.026
0.025
0.024
0.023
0.022
0.021
0.02
0.019
0.018
0.017
0.016
0.015
0.014
0.013
0.012
0.011
0.01
0.009
0.008
0.007
0.006
0.005
136,000
138,000
140,000
142,000
144,000
146,000
148,000
150,000
152,000
Time (sec)
North Position Error RMS (m)
East Position Error RMS (m)
Down Position Error RMS (m)

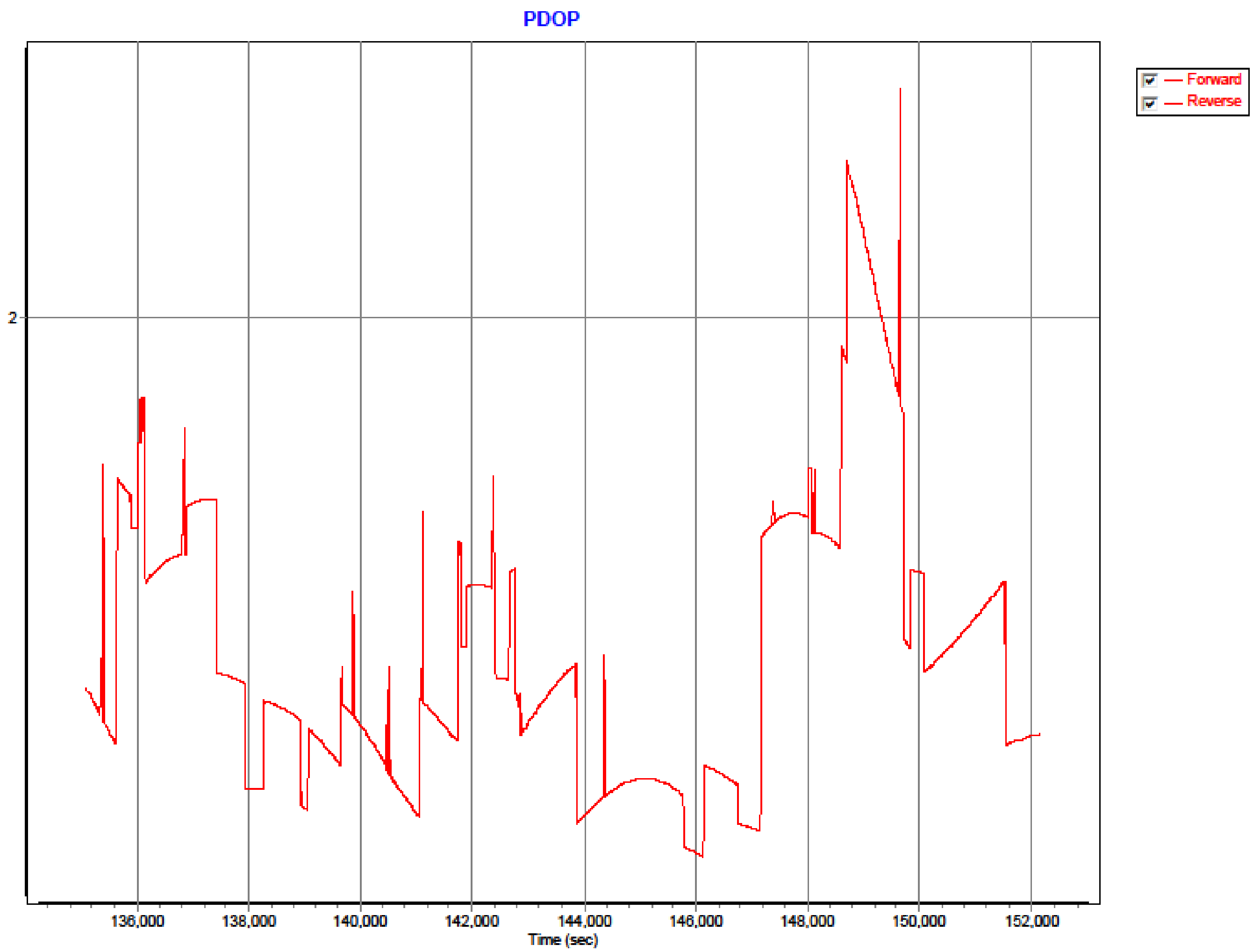

6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
-3.5
-4
-4.5
-5
-5.5
-6
-6.5
-7
134,000
136,000
138,000
140,000
142,000
144,000
146,000
148,000
150,000
152,000
Time (sec)
x accelerometer bias (micro-g)
y accelerometer bias (micro-g)
z accelerometer bias (micro-g)


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
-0.055
136,000
138,000
140,000
142,000
144,000
146,000
148,000
150,000
152,000
Time (sec)
North (m)
East (m)
Down (m)
DR mode

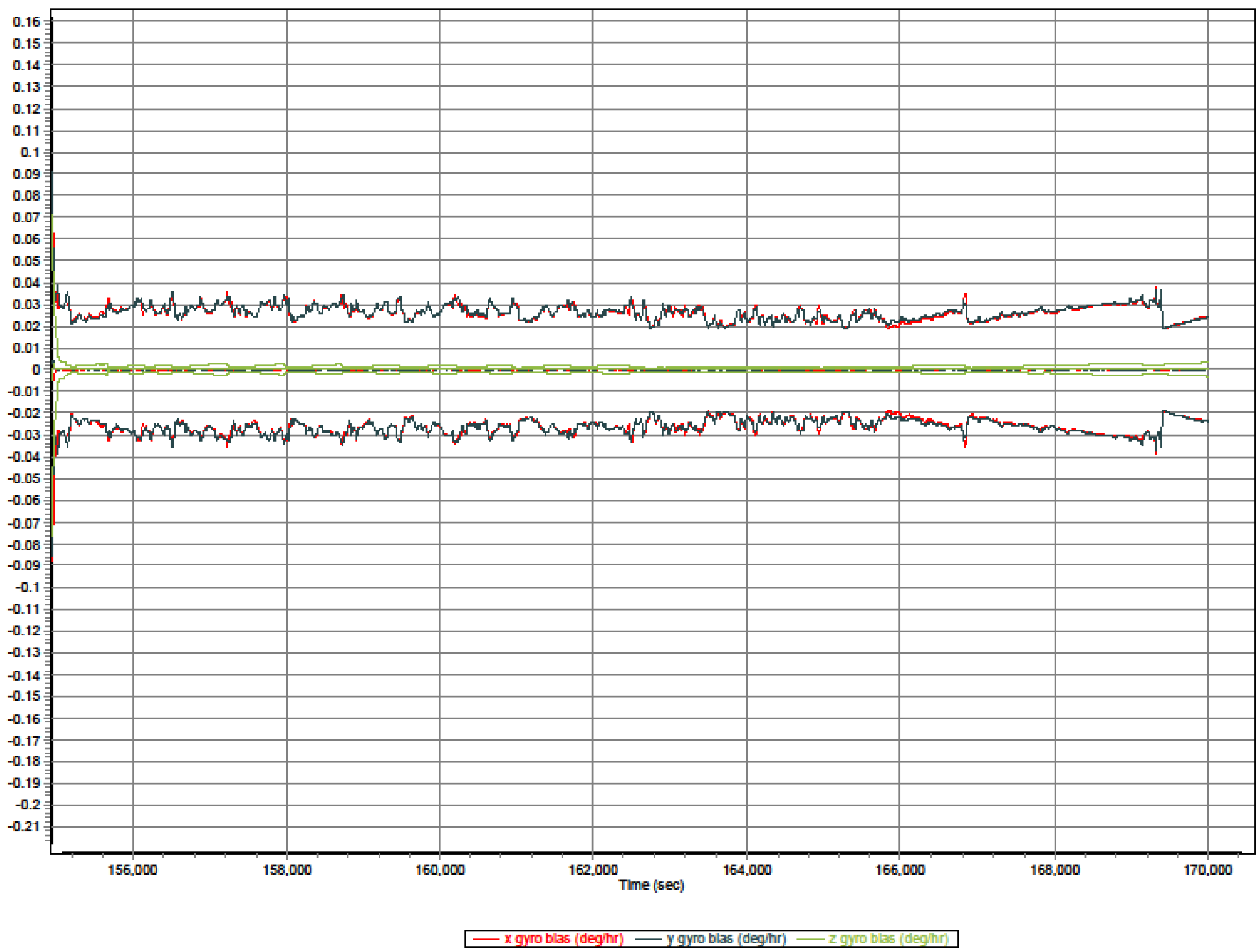

Number of GLONASS Satellites
Forward
Reverse
6
5
4
3
136,000
138,000
140,000
142,000
144,000
146,000
148,000
150,000
152,000
Time (sec)

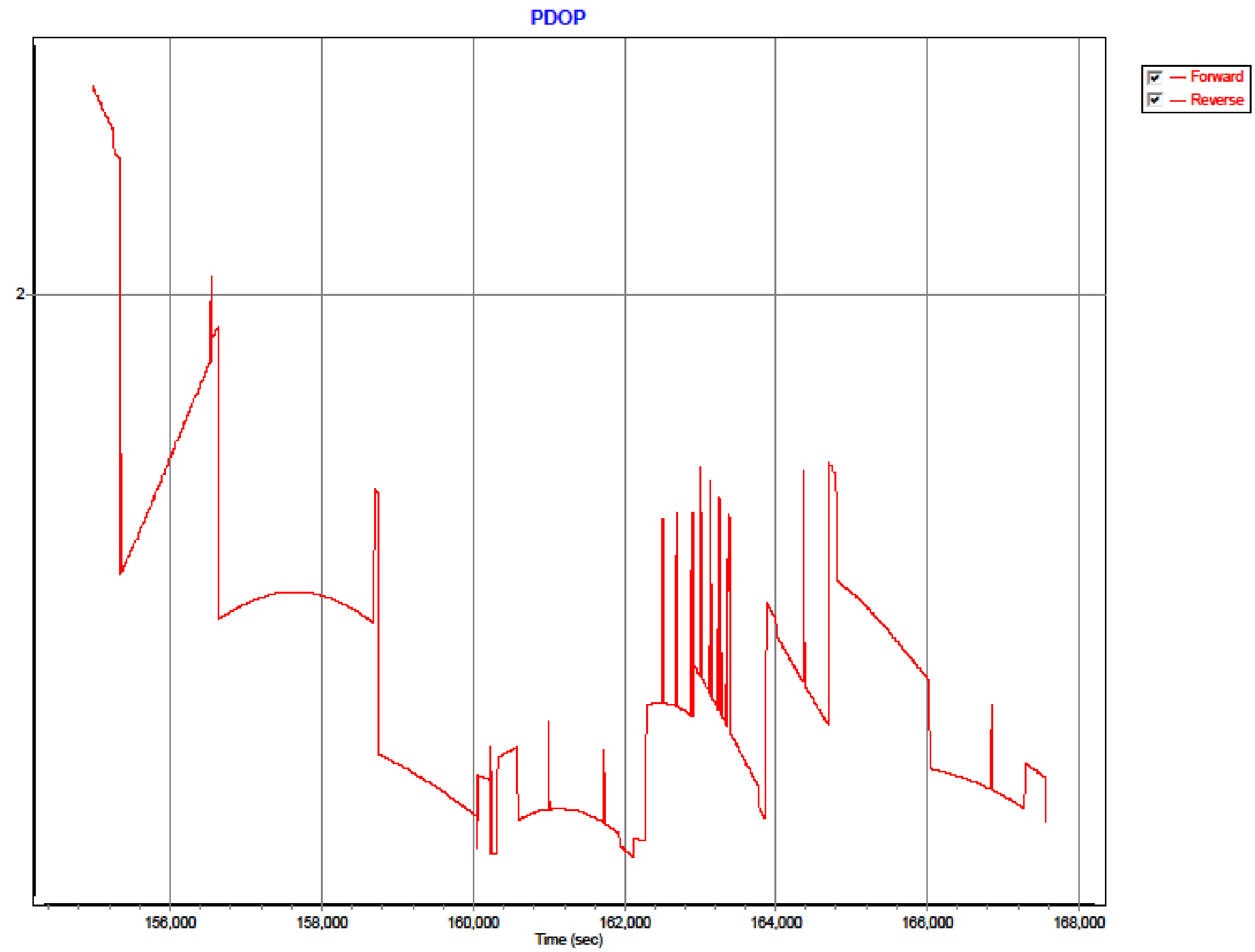

Number of GPS Satellites
Forward
Reverse
9
8
7
6
136,000
138,000
140,000
142,000
144,000
146,000
148,000
150,000
152,000
Time (sec)

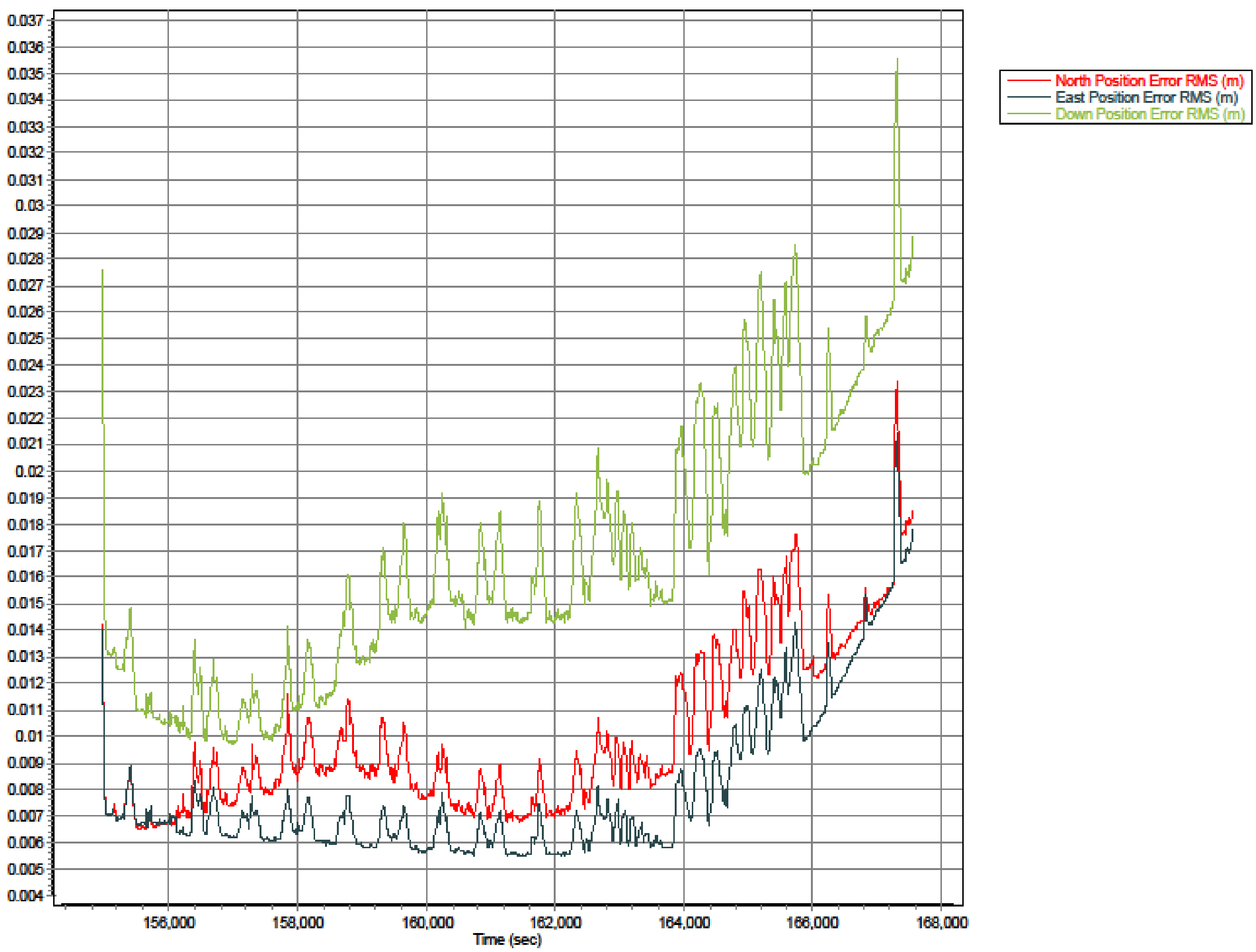

0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
-0.05
-0.06
-0.07
-0.08
-0.09
-0.1
-0.11
-0.12
-0.13
-0.14
134,000
136,000
138,000
140,000
142,000
144,000
146,000
148,000
150,000
152,000
Time (sec)
x gyro bias (deg/hr)
y gyro bias (deg/hr)
z gyro bias (deg/hr)


PDOP
Forward
Reverse
2
136,000
138,000
140,000
142,000
144,000
146,000
148,000
150,000
152,000
Time (sec)

UNB15320B


0.16
0.15
0.14
0.13
0.12
0.11
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
-0.05
-0.06
-0.07
-0.08
-0.09
-0.1
-0.11
-0.12
-0.13
-0.14
-0.15
-0.16
-0.17
-0.18
-0.19
-0.2
-0.21
156,000
158,000
160,000
162,000
164,000
166,000
168,000
170,000
Time (sec)
x gyro bias (deg/hr)
y gyro bias (deg/hr)
z gyro bias (deg/hr)


PDOP
Forward
Reverse
2
156,000
158,000
160,000
162,000
164,000
166,000
168,000
Time (sec)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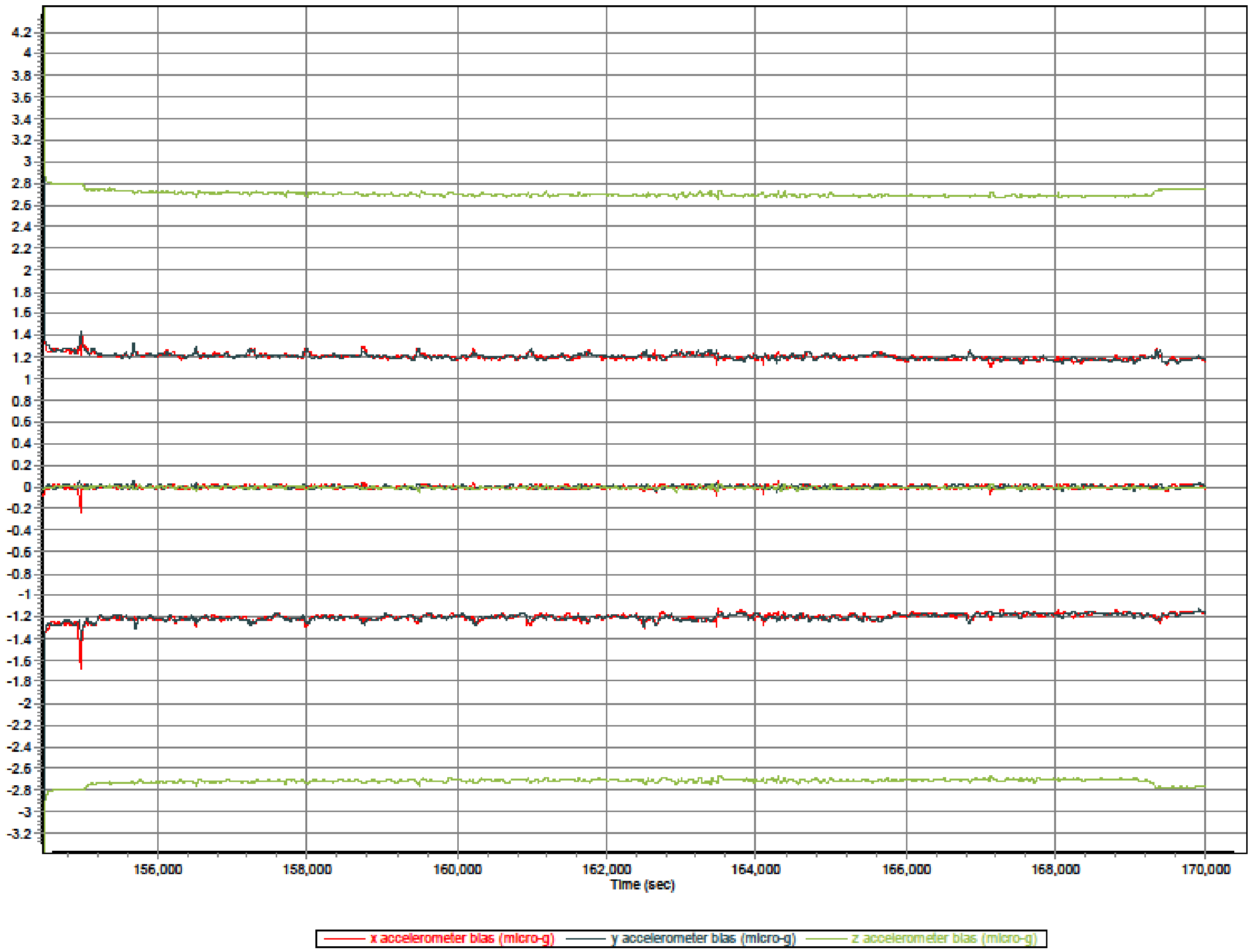
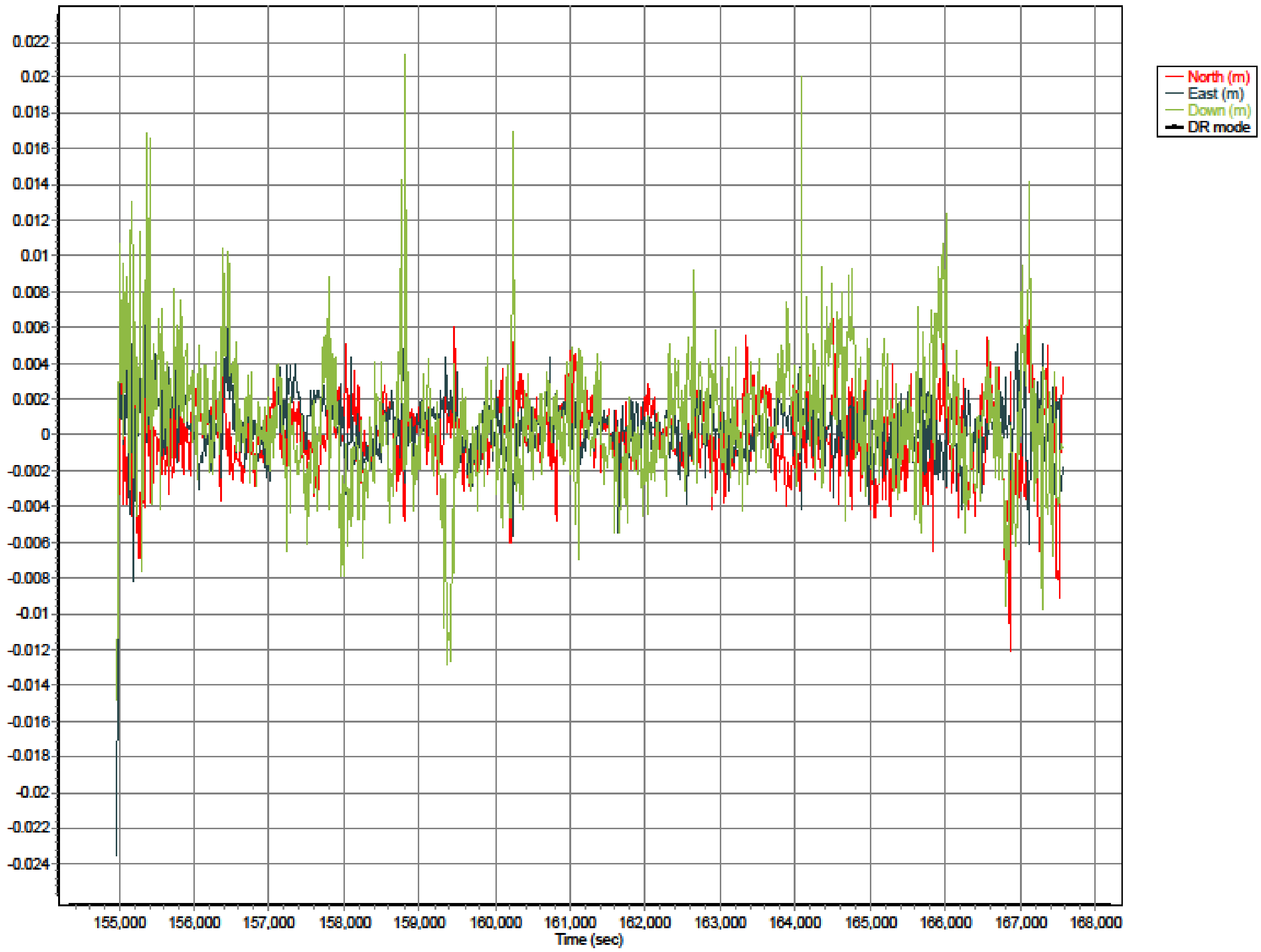
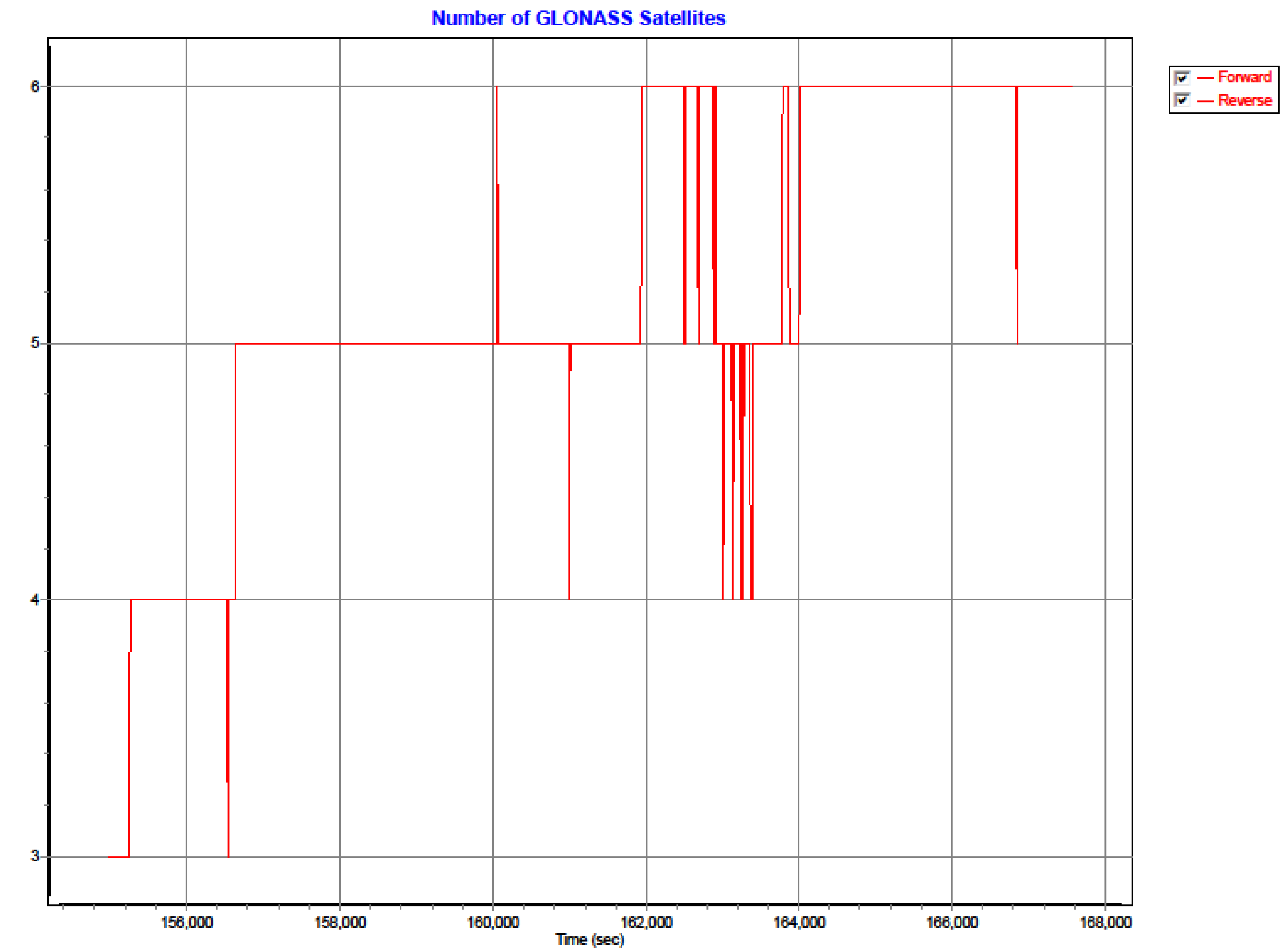
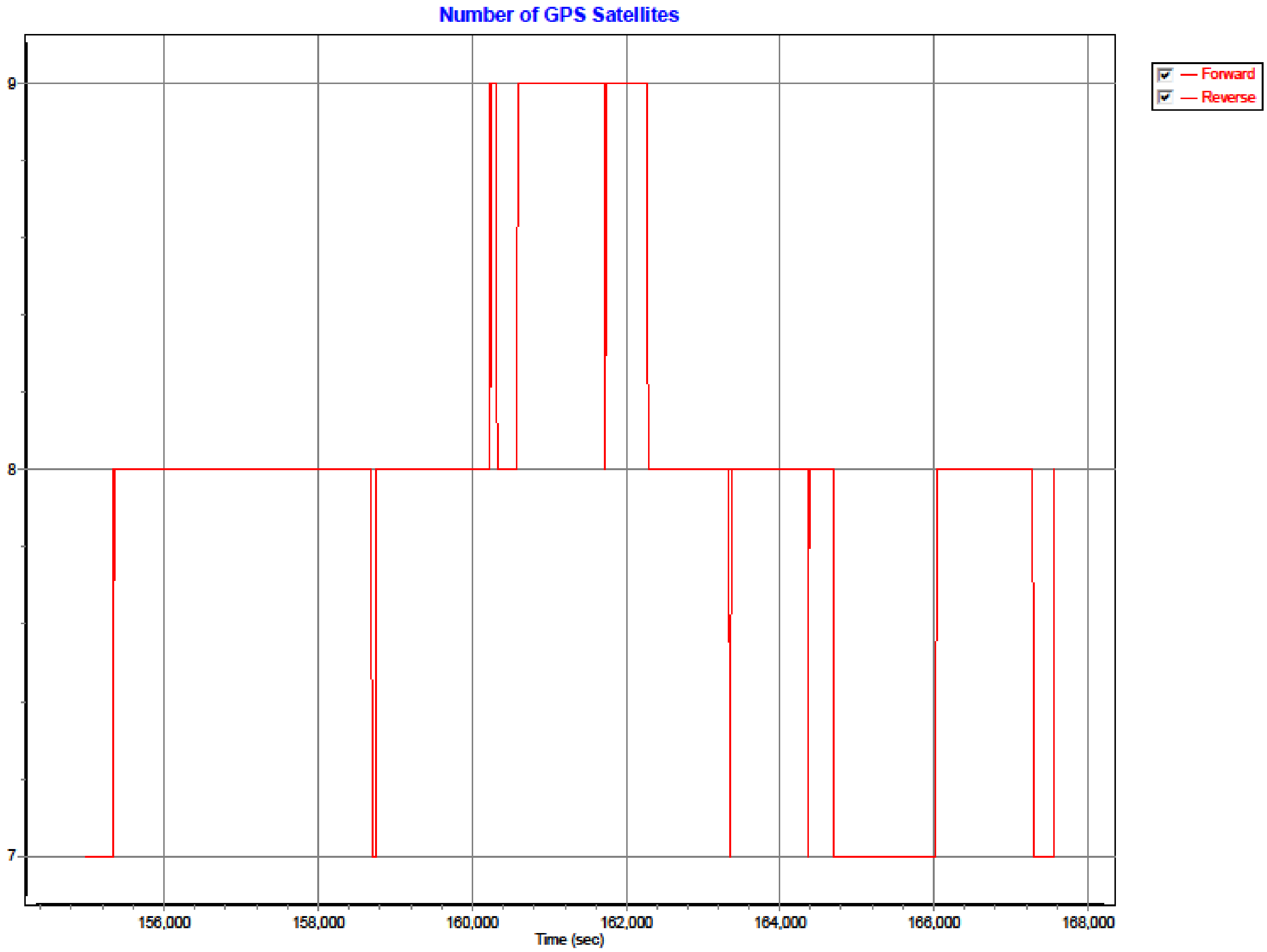
0.036
0.035
0.034
0.033
0.032
0.031
0.03
0.029
0.028
0.027
0.026
0.025
0.024
0.023
0.022
0.021
0.02
0.019
0.018
0.017
0.016
0.015
0.014
0.013
0.012
0.011
0.01
0.009
0.008
0.007
0.006
0.005
0.004
156,000
158,000
160,000
162,000
164,000
166,000
168,000
Time (sec)
North Position Error RMS (m)
East Position Error RMS (m)
Down Position Error RMS (m)


4.2
4
3.8
3.6
3.4
3.2
3
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
-1.4
-1.6
-1.8
-2
-2.2
-2.4
-2.6
-2.8
-3
-3.2
156,000
158,000
160,000
162,000
164,000
166,000
168,000
170,000
Time (sec)
x accelerometer bias (micro-g)
y accelerometer bias (micro-g)
z accelerometer bias (micro-g)


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


Number of GLONASS Satellites
Forward
Reverse
6
5
4
3
156,000
158,000
160,000
162,000
164,000
166,000
168,000
Time (sec)


Number of GPS Satellites
Forward
Reverse
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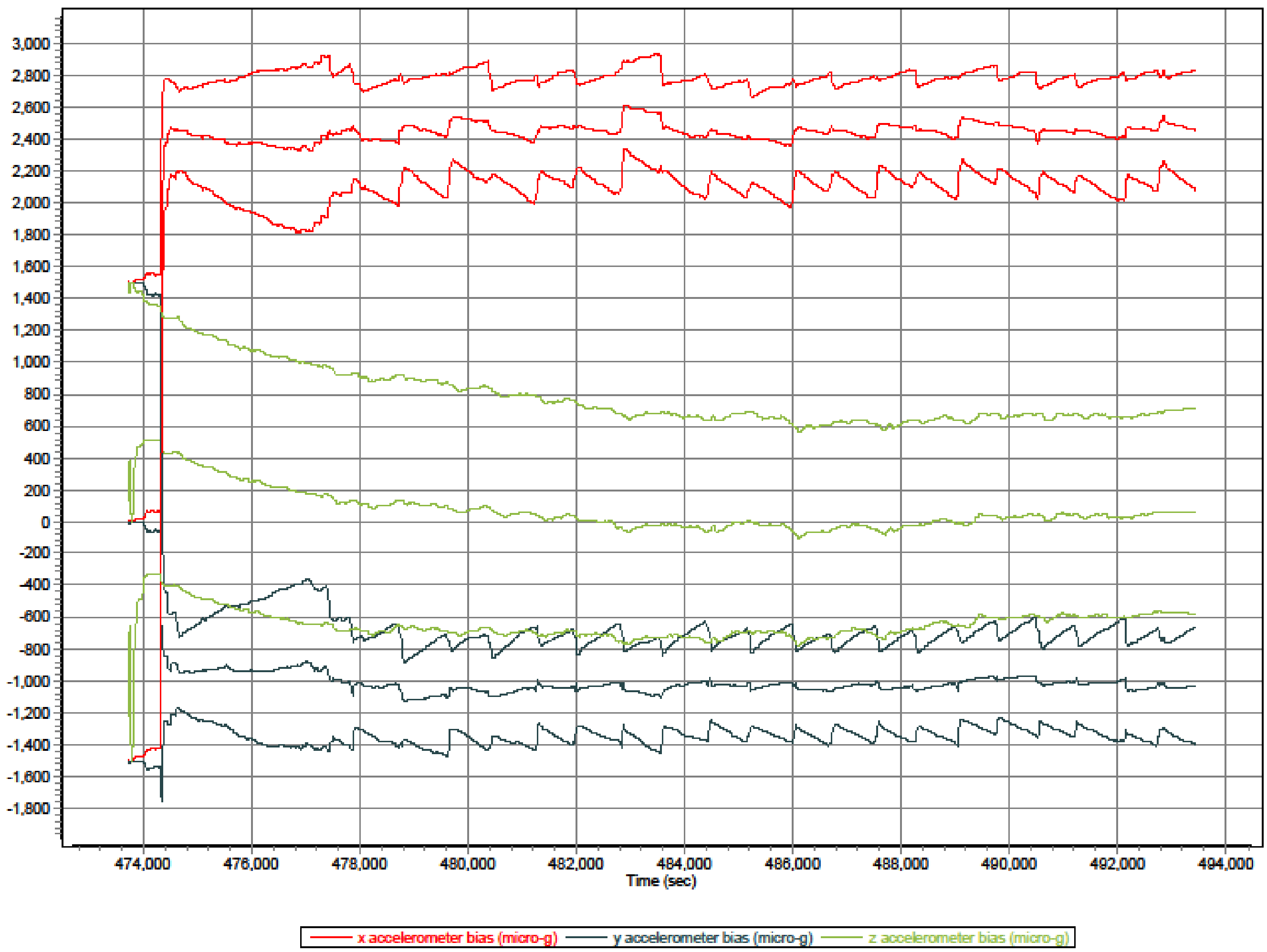
8
7
156,000
158,000
160,000
162,000
164,000
166,000
168,000
Time (sec)

UNB15324A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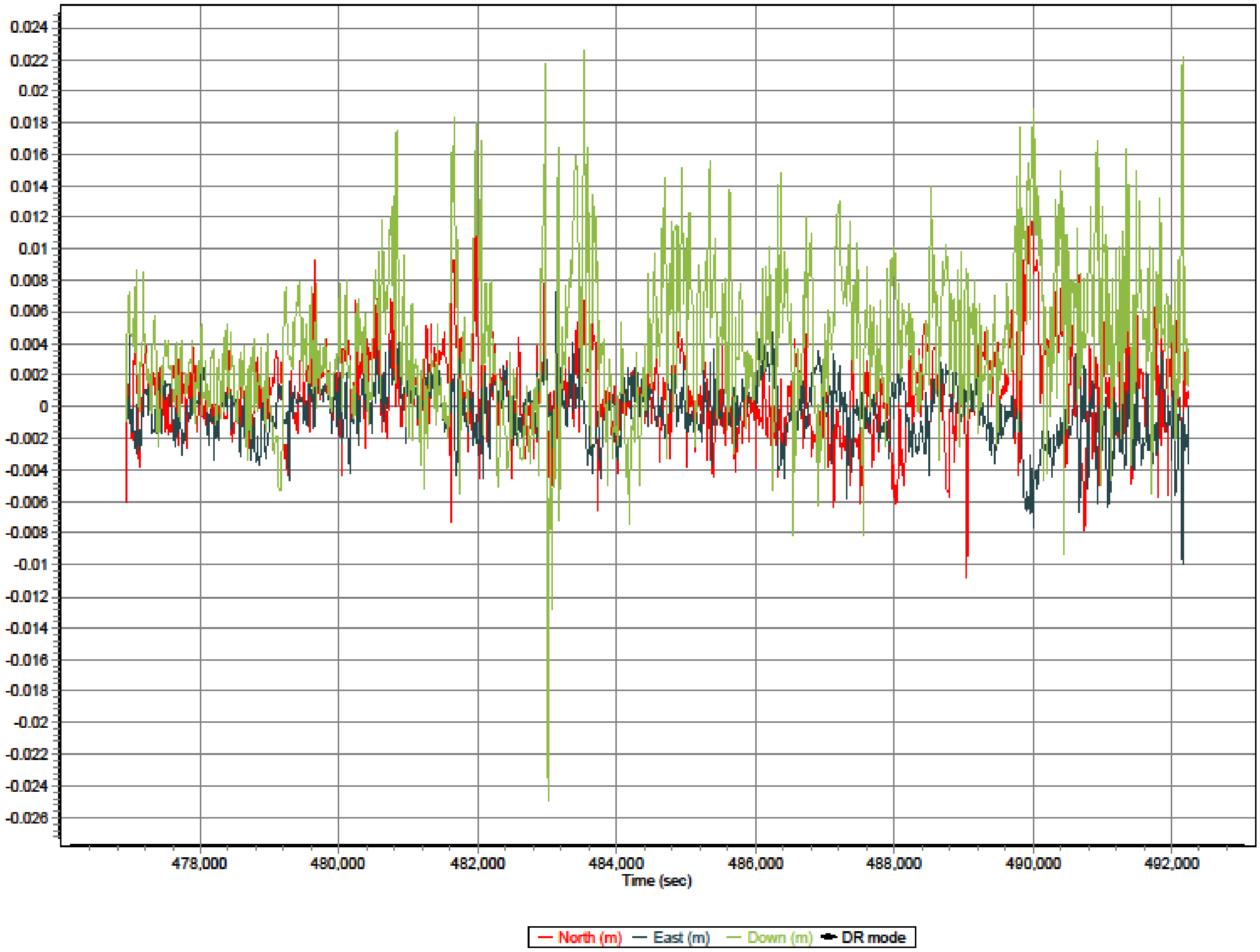
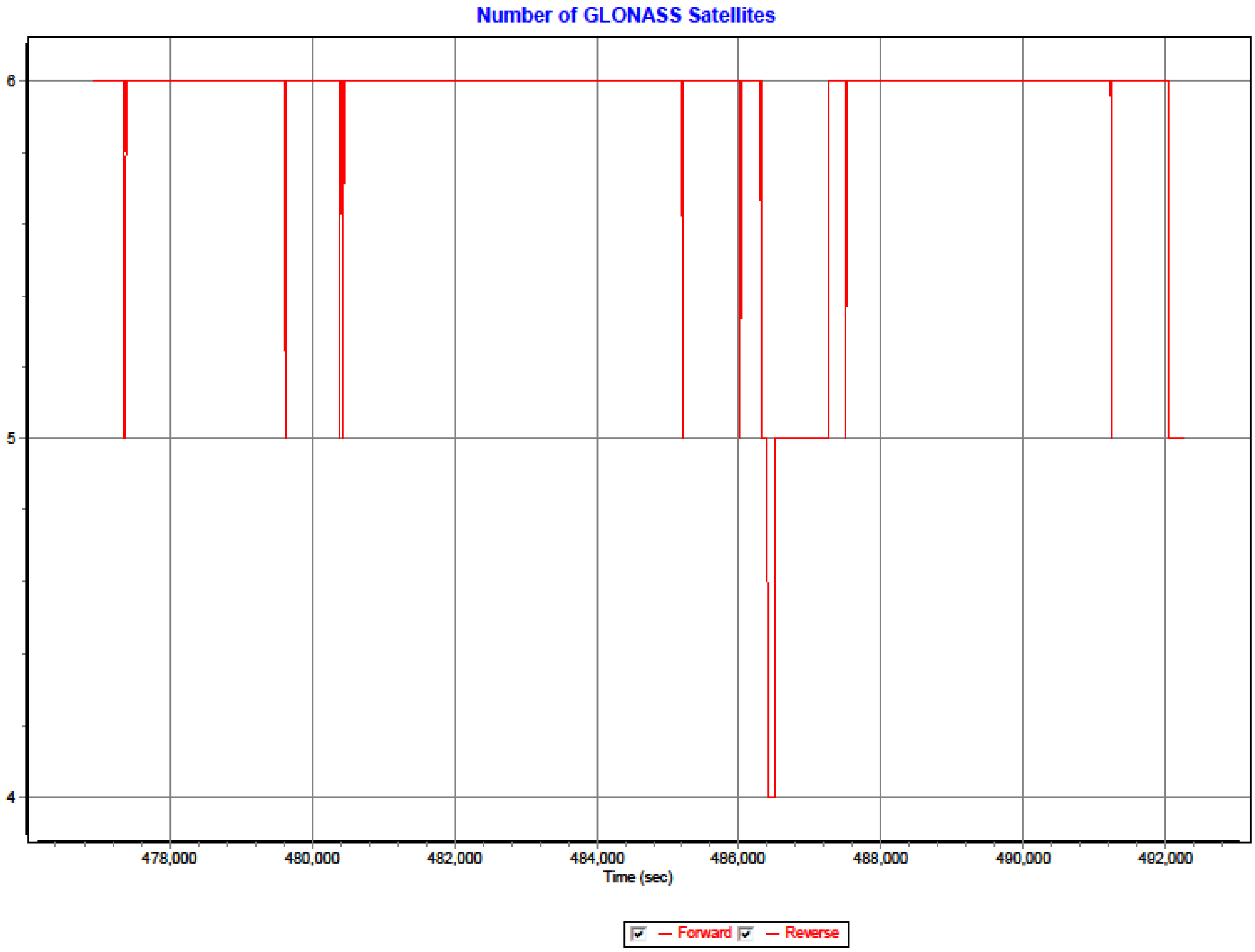
2,000
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
-200
-400
-600
-800
-1,000
-1,200
-1,400
-1,600
-1,800
474,000
476,000
478,000
480,000
482,000
484,000
486,000
488,000
490,000
492,000
494,000
Time (sec)
x accelerometer bias (micro-g)
y accelerometer bias (micro-g)
z accelerometer bias (micro-g)


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
-0.016
-0.018
-0.02
-0.022
-0.024
-0.026
478,000
480,000
482,000
484,000
486,000
488,000
490,000
492,000
Time (sec)
North (m)
East (m)
Down (m)
DR mode


Number of GLONASS Satellites
6
5
4
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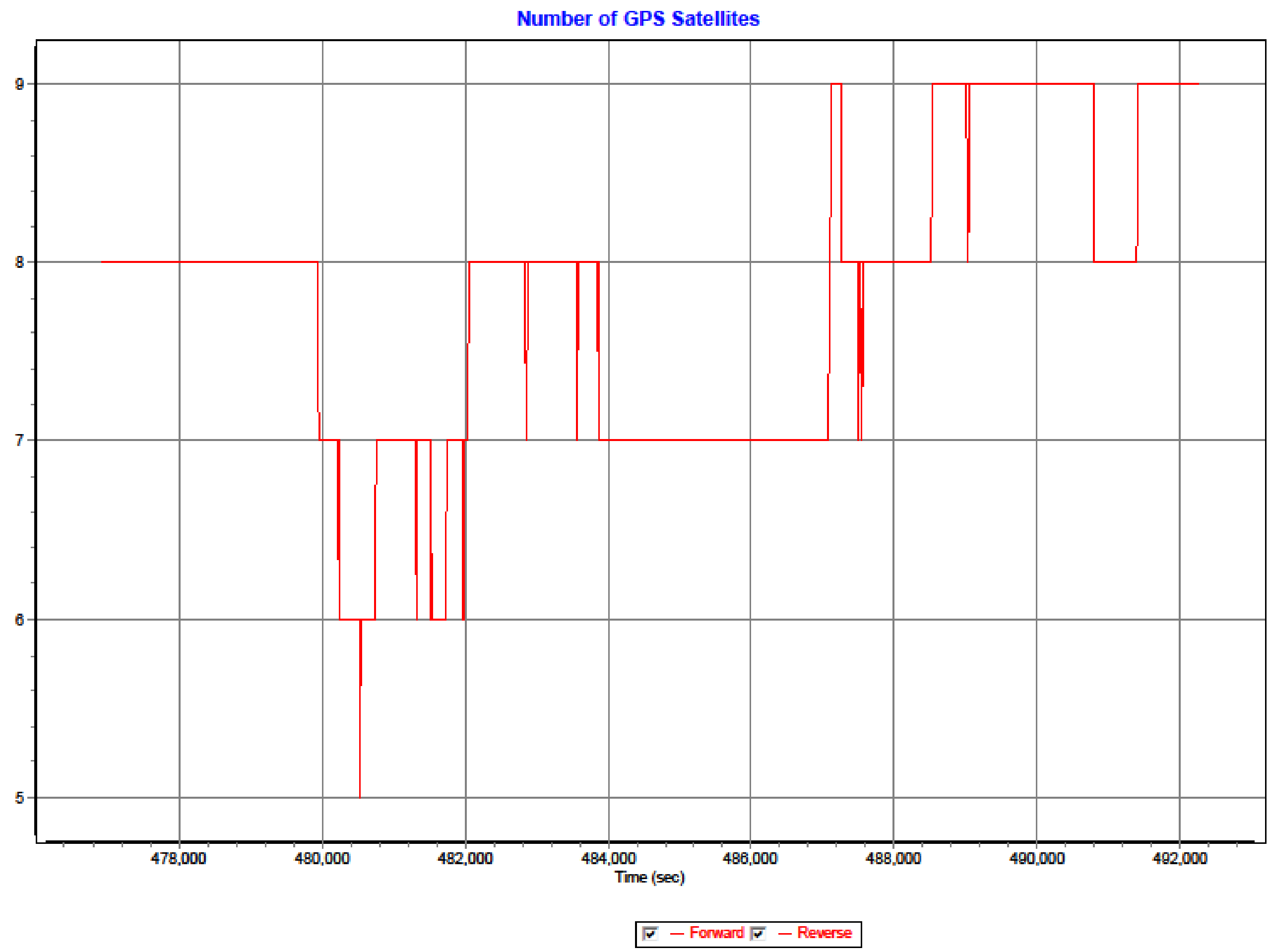
480,000
482,000
484,000
486,000
488,000
490,000
492,000
Time (sec)
Forward
Reverse


Number of GPS Satellites
9
8
7
6
5
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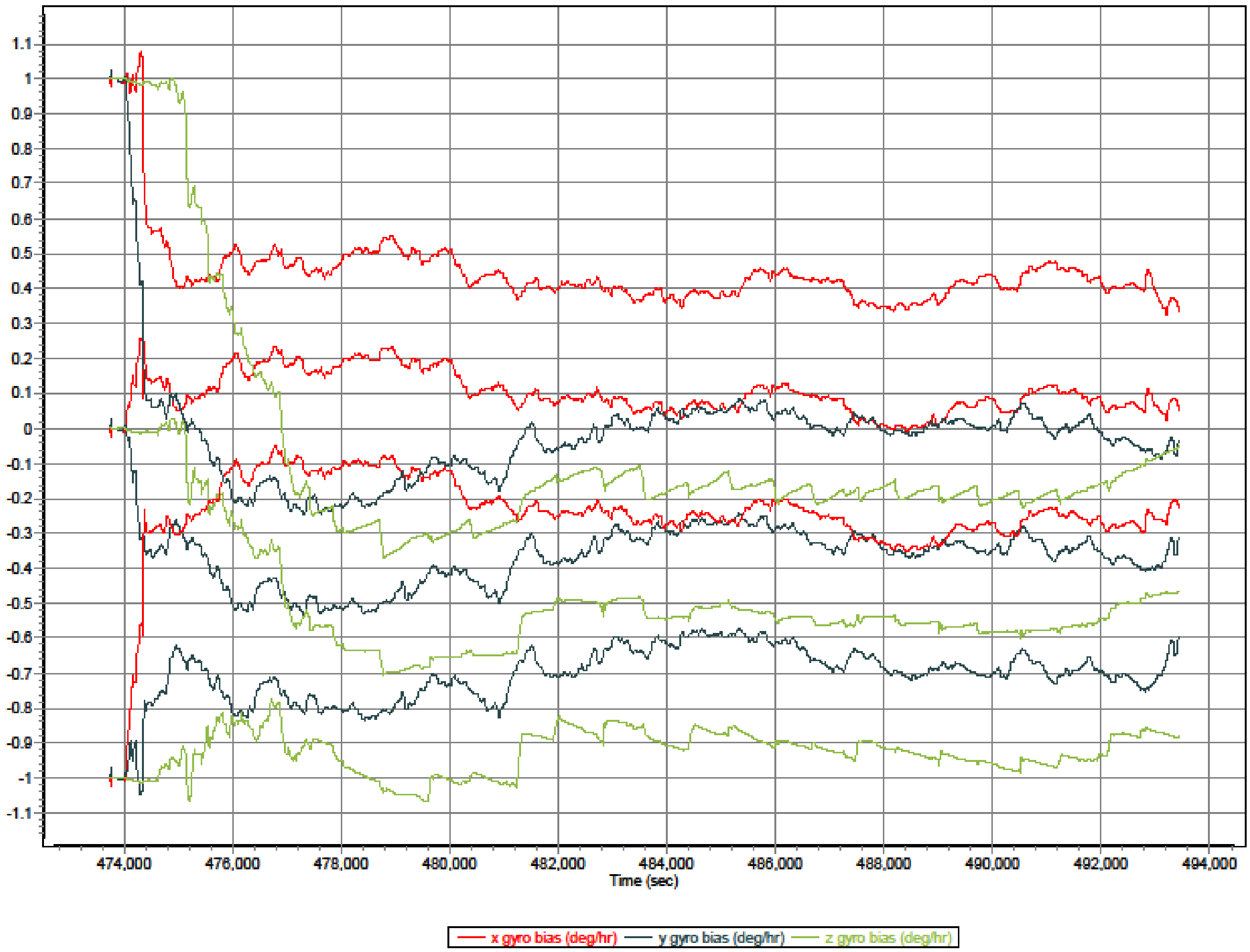
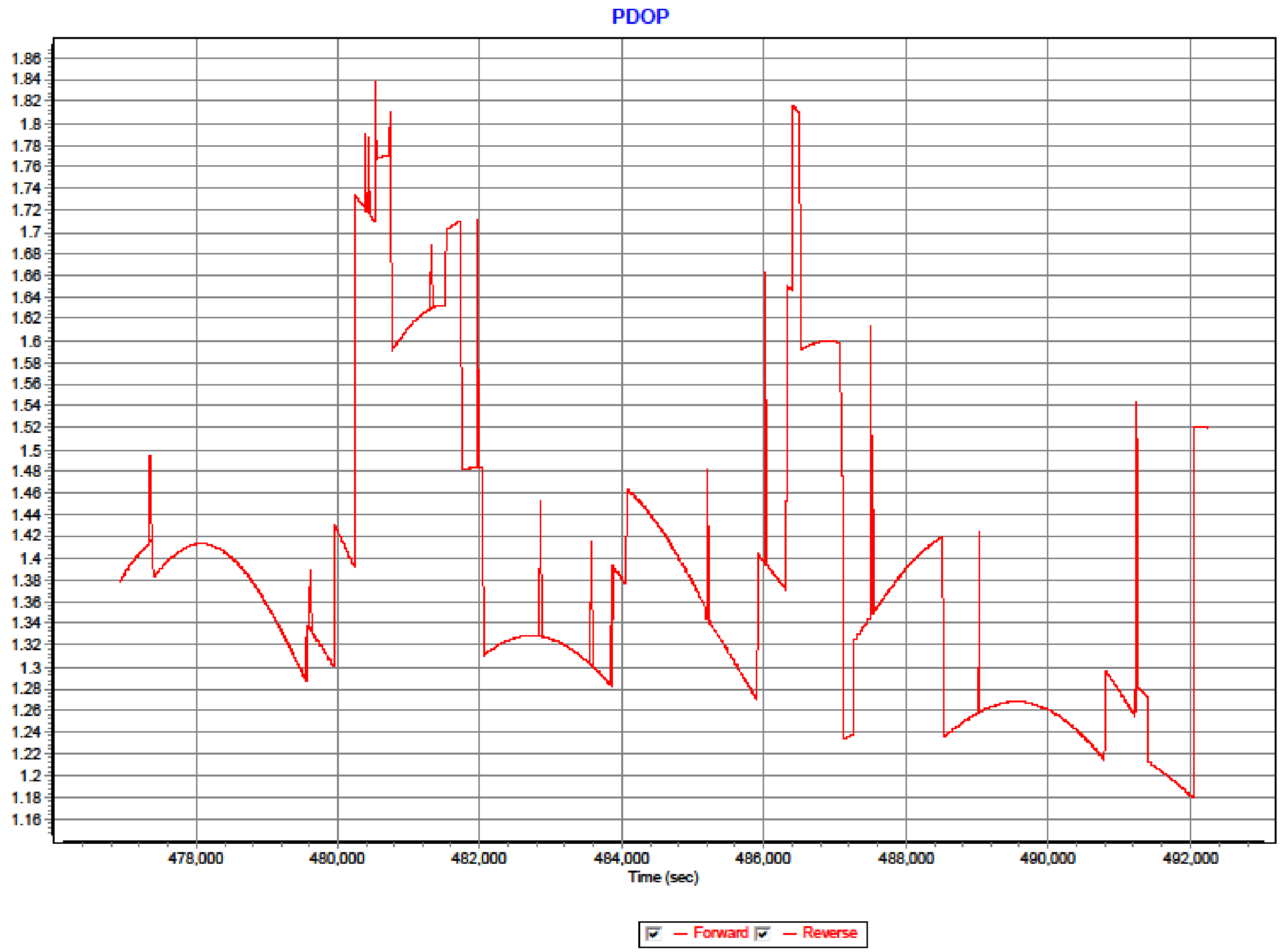
480,000
482,000
484,000
486,000
488,000
490,000
492,000
Time (sec)
Forward
Reverse


1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
-0.9
-1
-1.1
474,000
476,000
478,000
480,000
482,000
484,000
486,000
488,000
490,000
492,000
494,000
Time (sec)
x gyro bias (deg/hr)
y gyro bias (deg/hr)
z gyro bias (deg/hr)


PDOP
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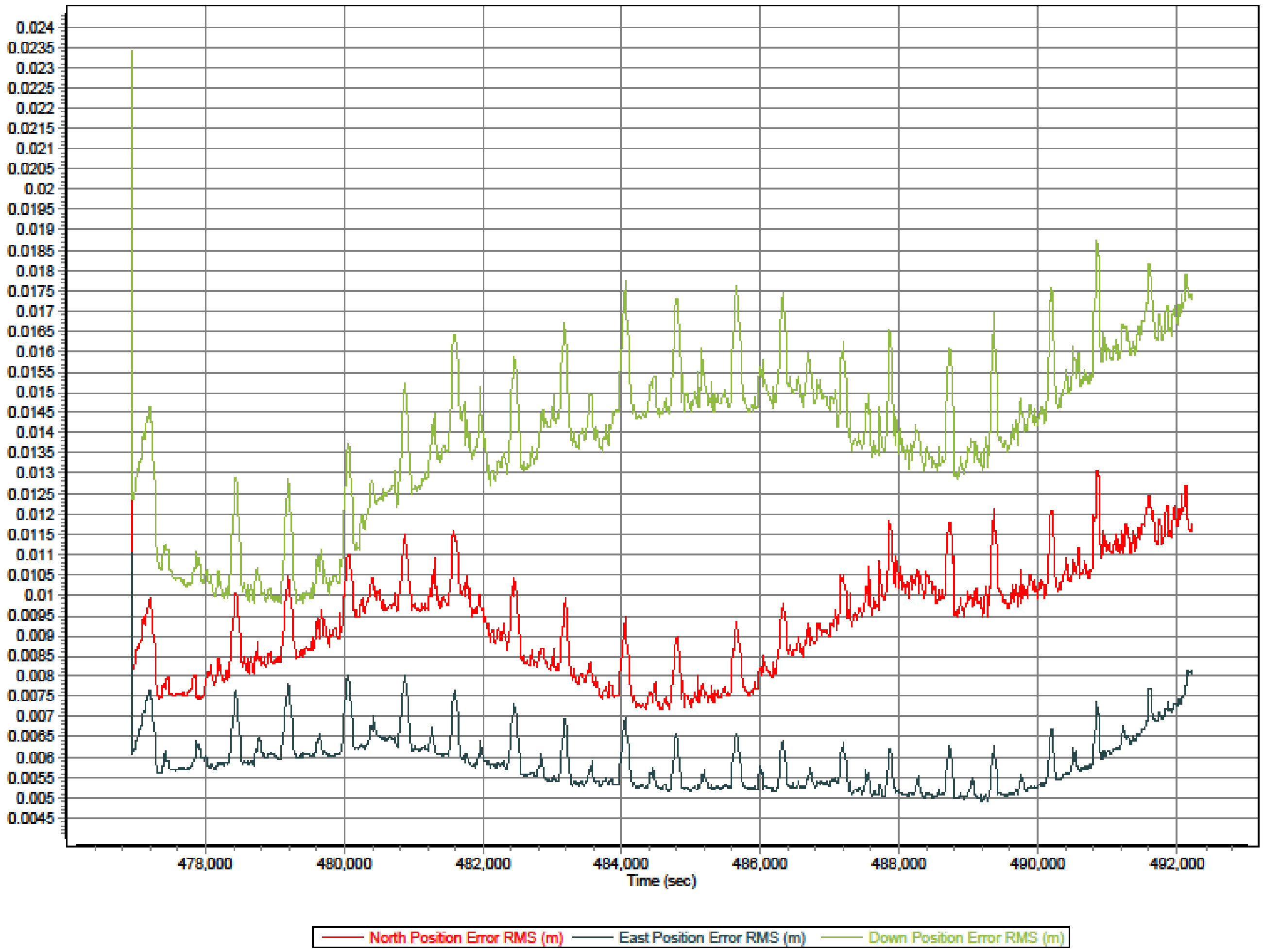
1.82
1.8
1.78
1.76
1.74
1.72
1.7
1.68
1.66
1.64
1.62
1.6
1.58
1.56
1.54
1.52
1.5
1.48
1.46
1.44
1.42
1.4
1.38
1.36
1.34
1.32
1.3
1.28
1.26
1.24
1.22
1.2
1.18
1.16
478,000
480,000
482,000
484,000
486,000
488,000
490,000
492,000
Time (sec)
Forward
Reverse


0.024
0.0235
0.023
0.0225
0.022
0.0215
0.021
0.0205
0.02
0.0195
0.019
0.0185
0.018
0.0175
0.017
0.0165
0.016
0.0155
0.015
0.0145
0.014
0.0135
0.013
0.0125
0.012
0.0115
0.011
0.0105
0.01
0.0095
0.009
0.0085
0.008
0.0075
0.007
0.0065
0.006
0.0055
0.005
0.0045
478,000
480,000
482,000
484,000
486,000
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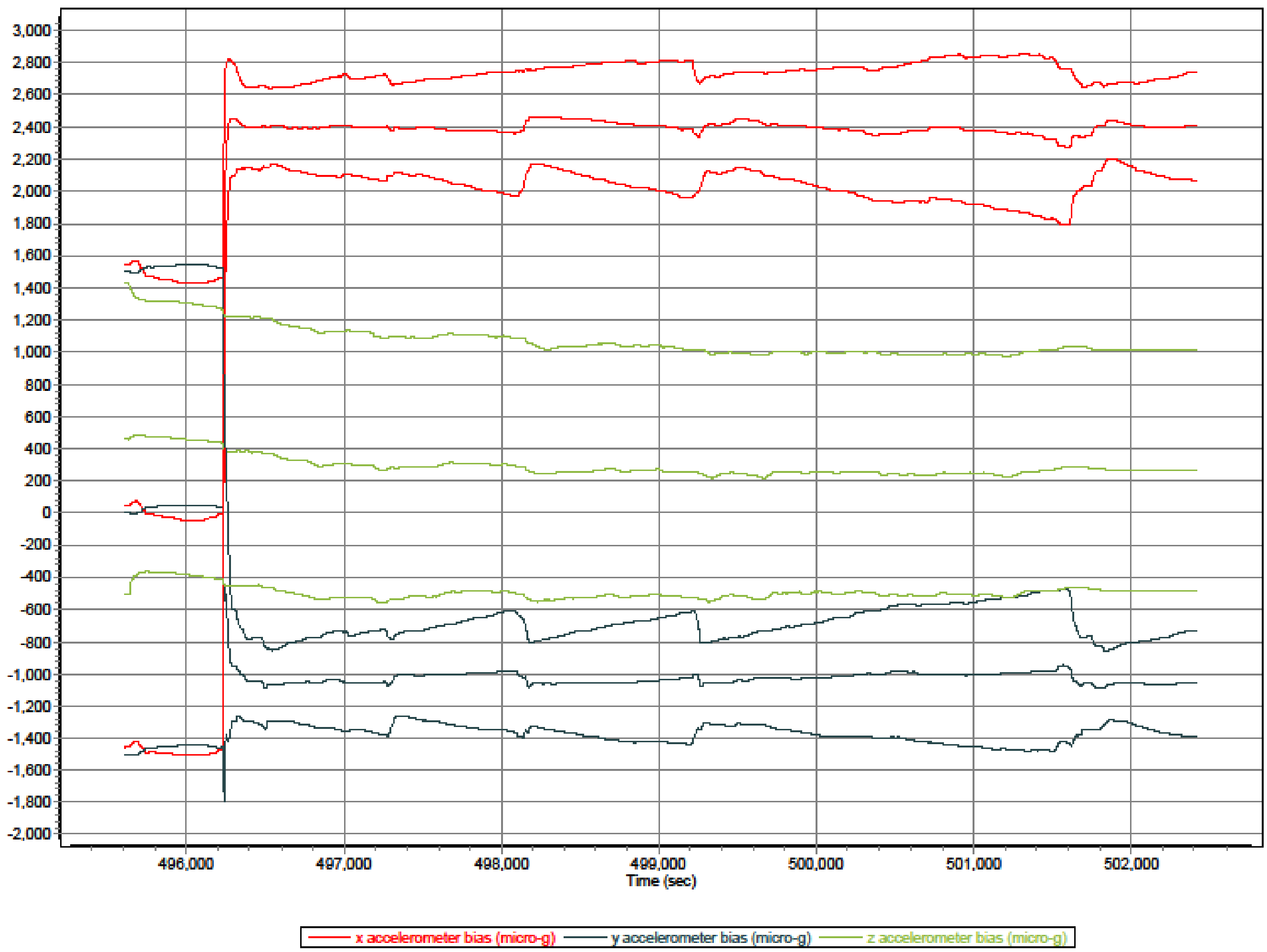
490,000
492,000
Time (sec)
North Position Error RMS (m)
East Position Error RMS (m)
Down Position Error RMS (m)

UNB15324B


3,000
2,800
2,600
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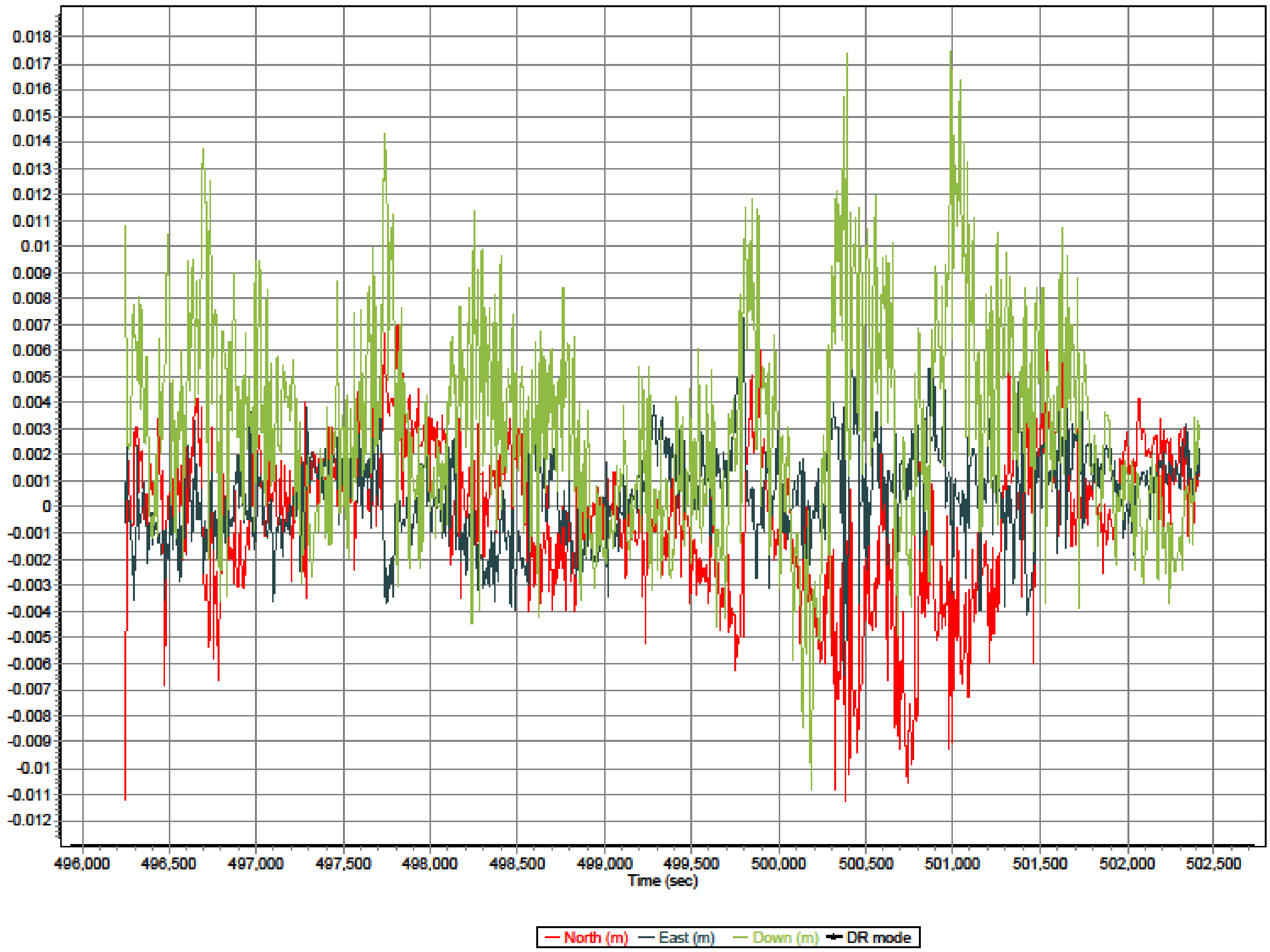
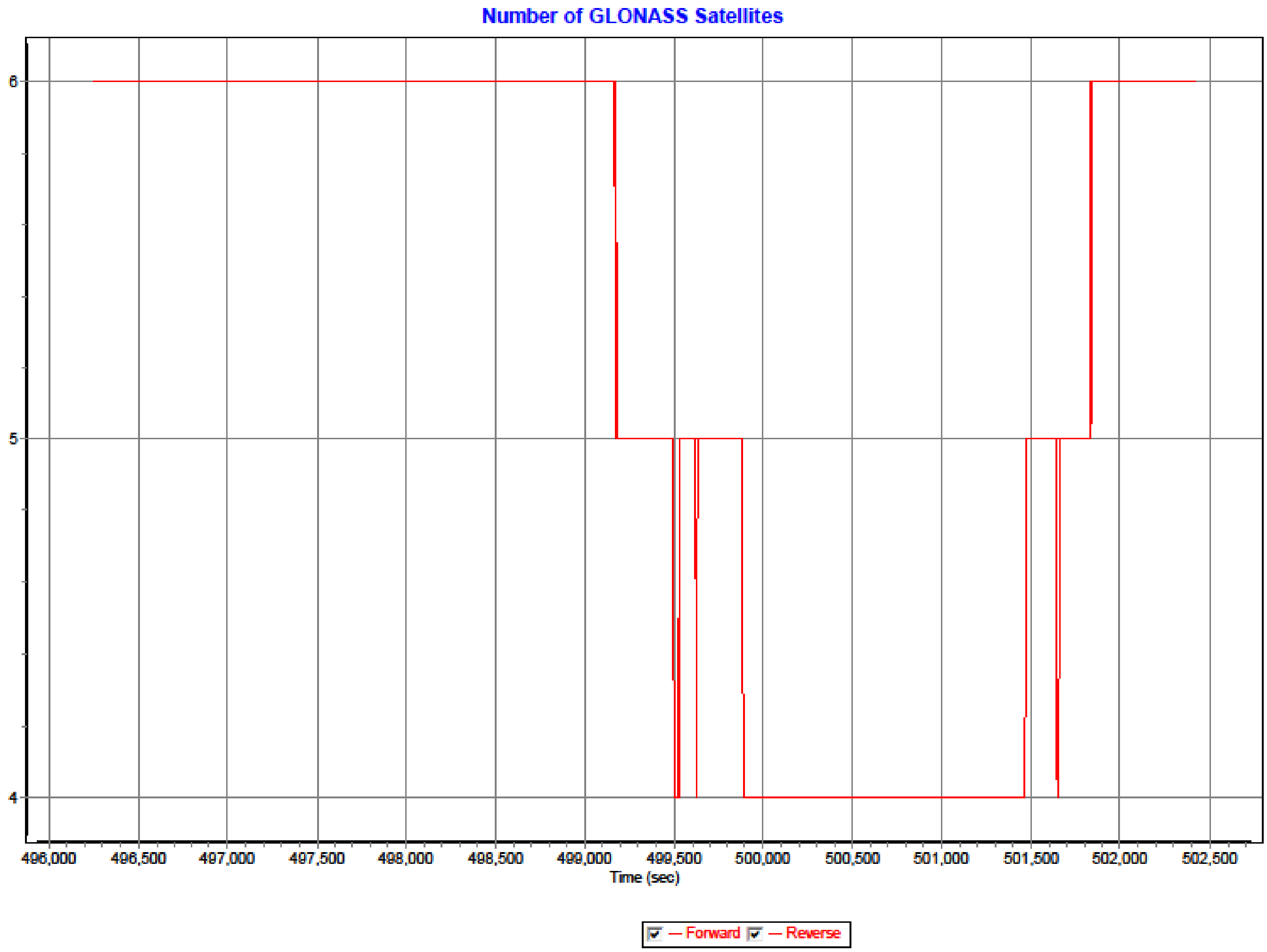
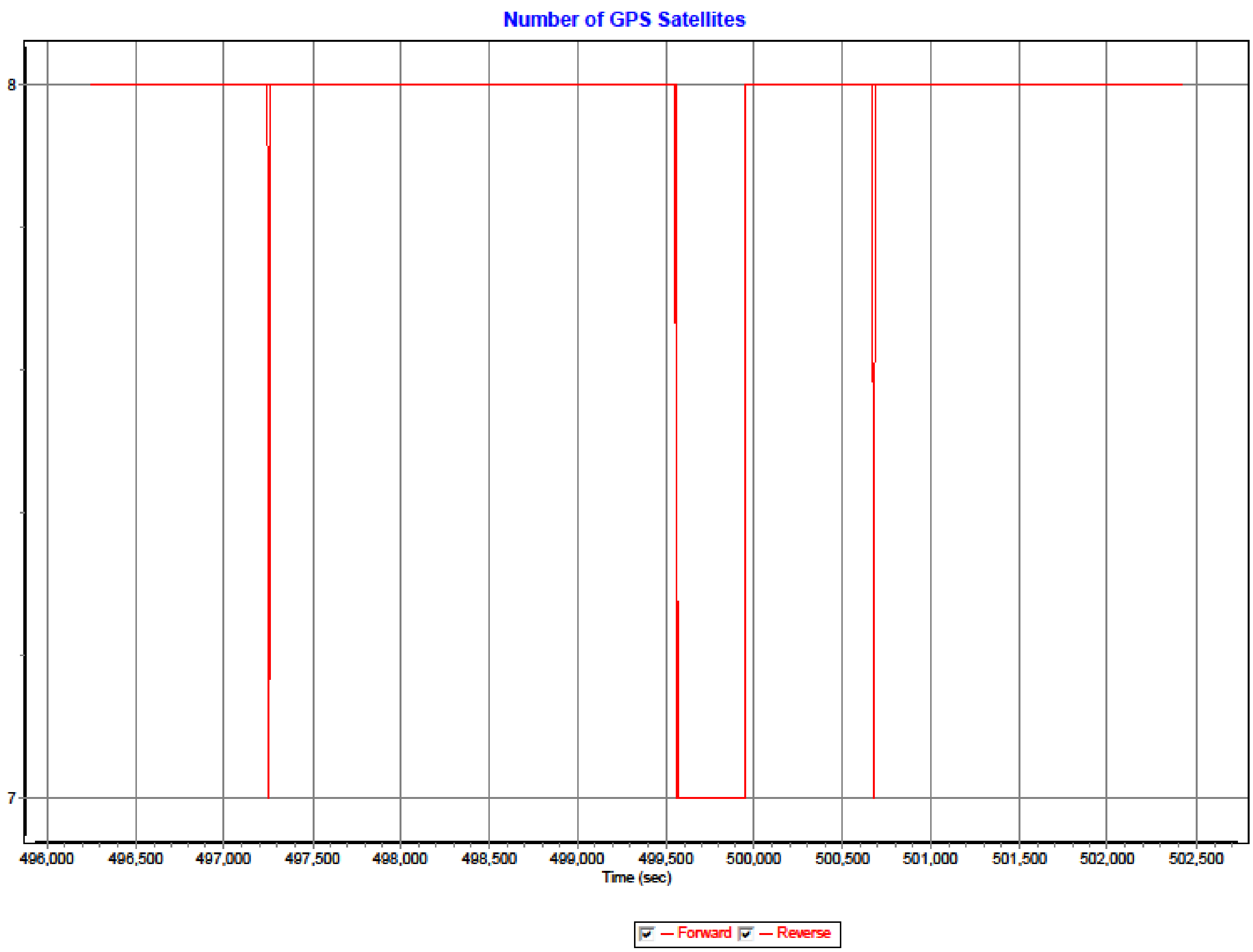
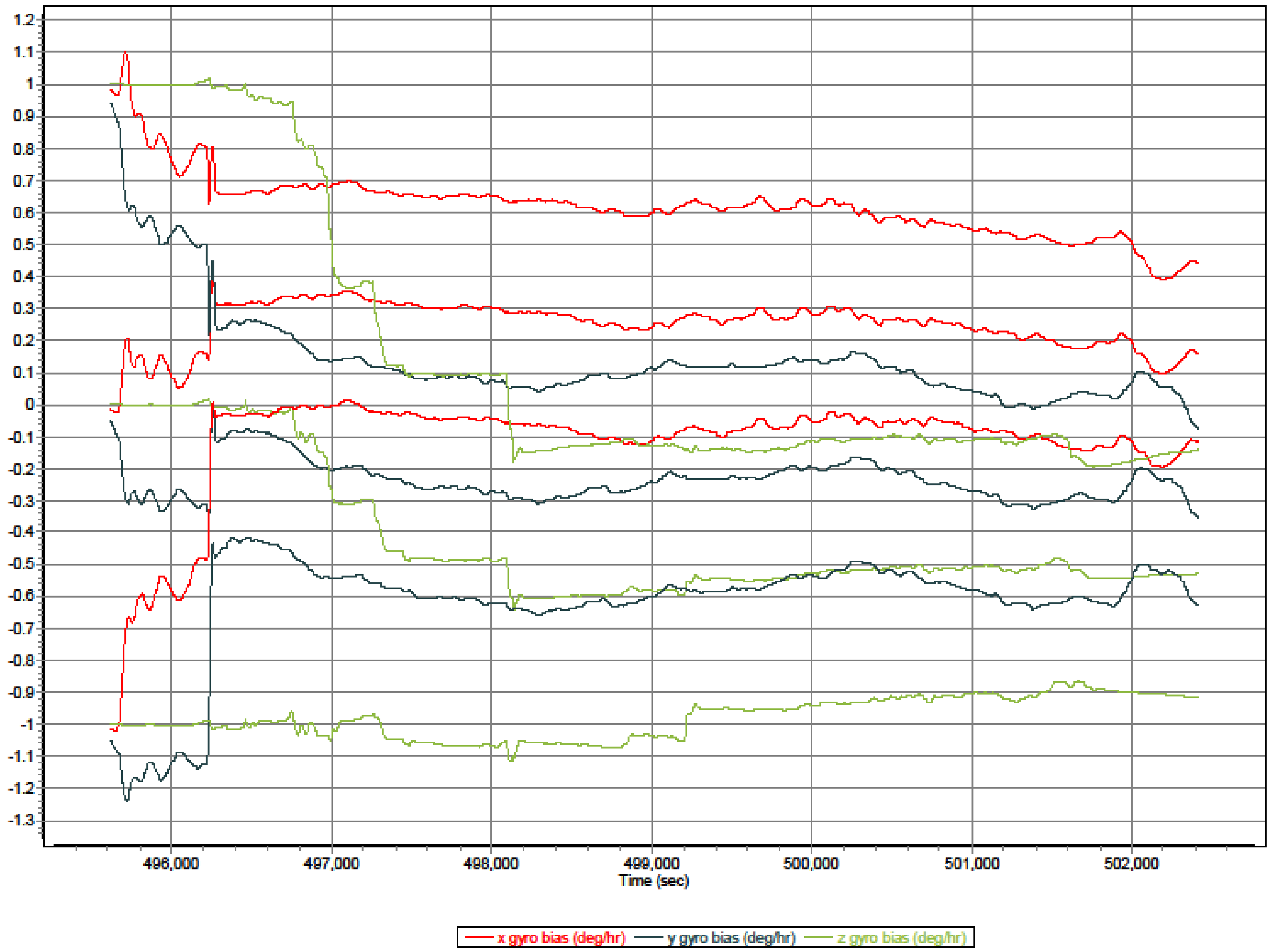
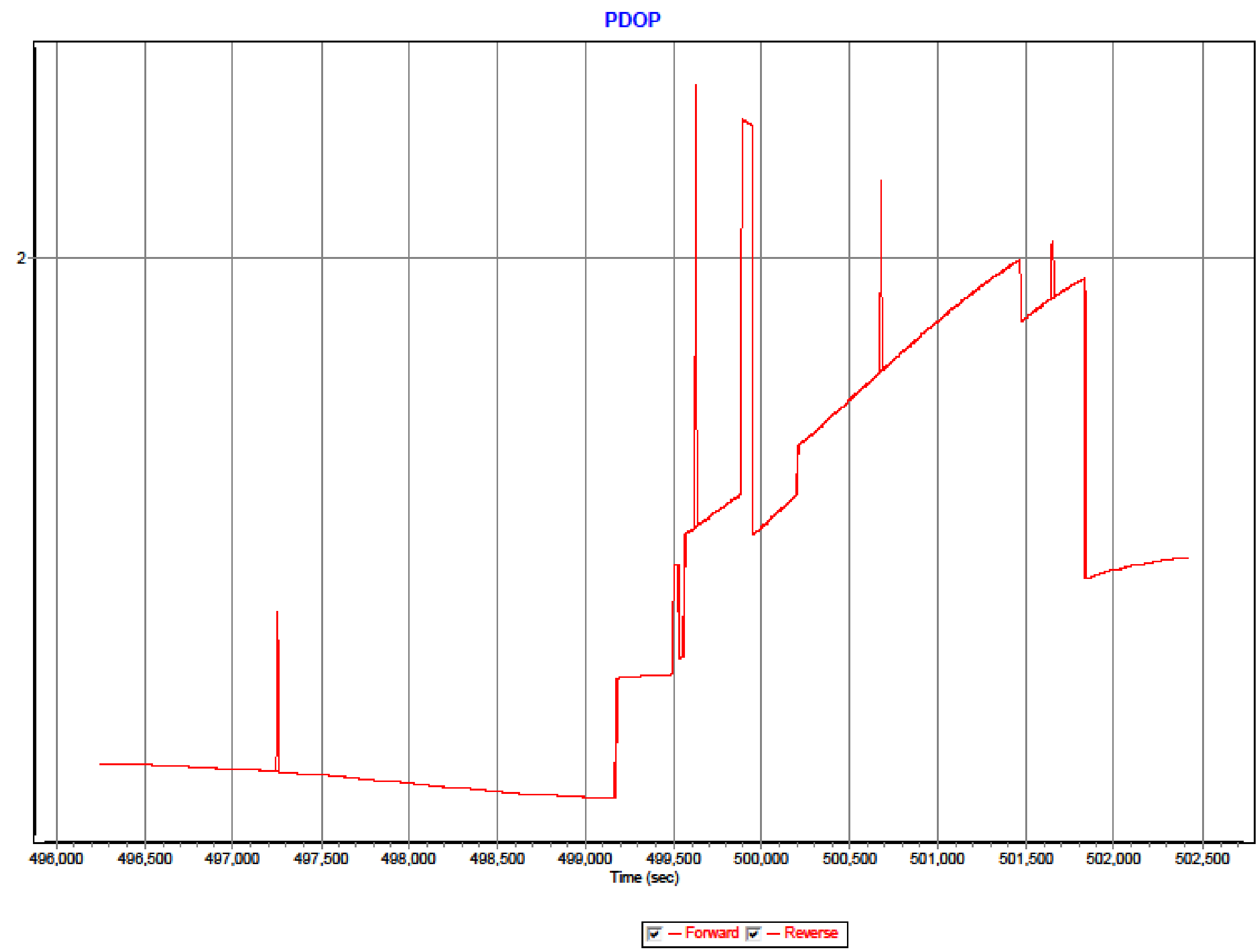
2,000
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
-200
-400
-600
-800
-1,000
-1,200
-1,400
-1,600
-1,800
-2,000
496,000
497,000
498,000
499,000
500,000
501,000
502,000
Time (sec)
x accelerometer bias (micro-g)
y accelerometer bias (micro-g)
z accelerometer bias (micro-g)


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
496,000
496,500
497,000
497,500
498,000
498,500
499,000
499,500
500,000
500,500
501,000
501,500
502,000
502,500
Time (sec)
North (m)
East (m)
Down (m)
DR mode


Number of GLONASS Satellites
6
5
4
496,000
496,500
497,000
497,500
498,000
498,500
499,000
499,500
500,000
500,500
501,000
501,500
502,000
502,500
Time (sec)
Forward
Reverse


Number of GPS Satellites
8
7
496,000
496,500
497,000
497,500
498,000
498,500
499,000
499,500
500,000
500,500
501,000
501,500
502,000
502,500
Time (sec)
Forward
Reverse


1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
-0.9
-1
-1.1
-1.2
-1.3
496,000
497,000
498,000
499,000
500,000
501,000
502,000
Time (sec)
x gyro bias (deg/hr)
y gyro bias (deg/hr)
z gyro bias (deg/hr)


PDOP
2
496,000
496,500
497,000
497,500
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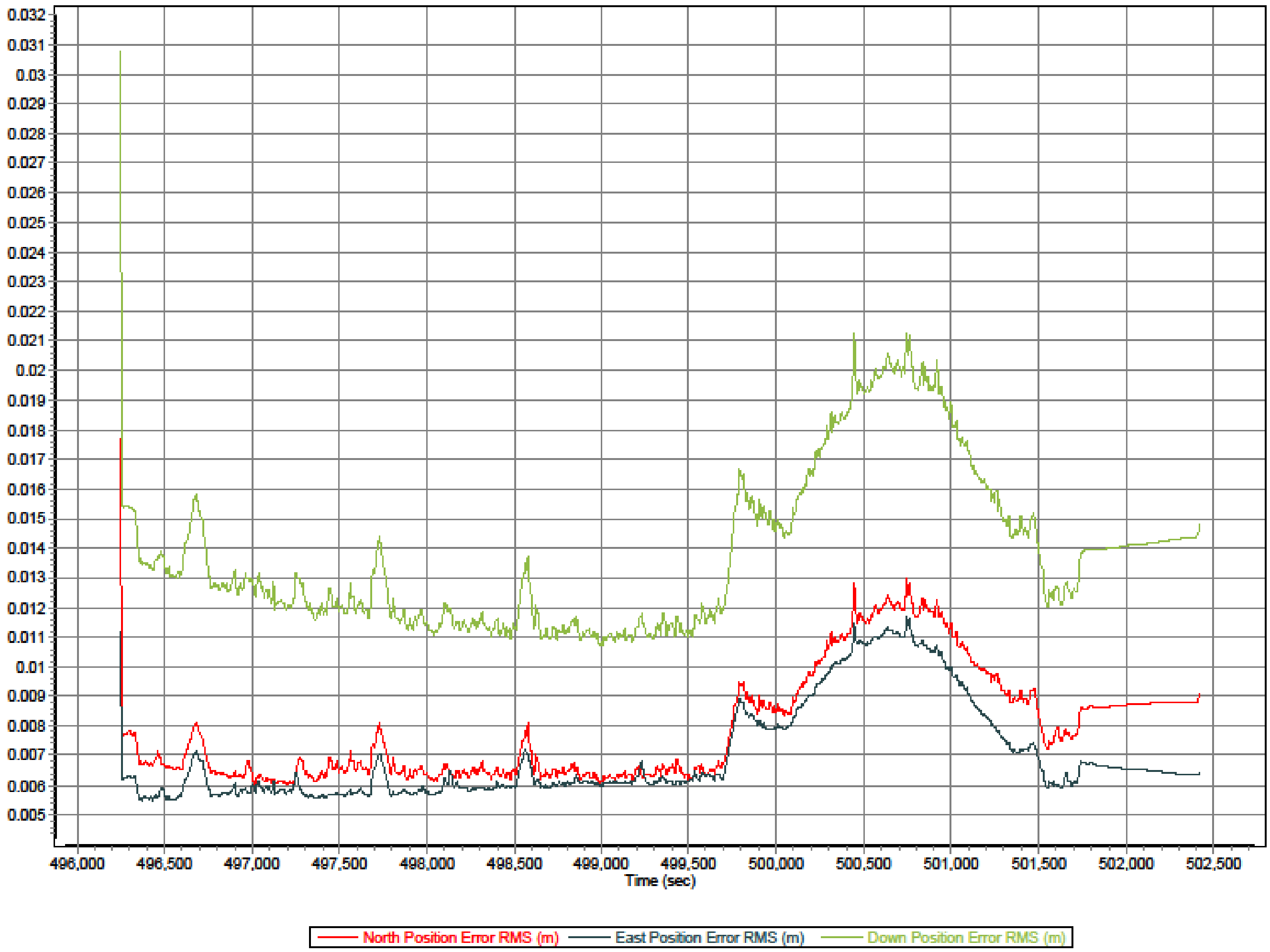
500,000
500,500
501,000
501,500
502,000
502,500
Time (sec)
Forward
Reverse


0.032
0.031
0.03
0.029
0.028
0.027
0.026
0.025
0.024
0.023
0.022
0.021
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
496,000
496,500
497,000
497,500
498,000
498,500
499,000
499,500
500,000
500,500
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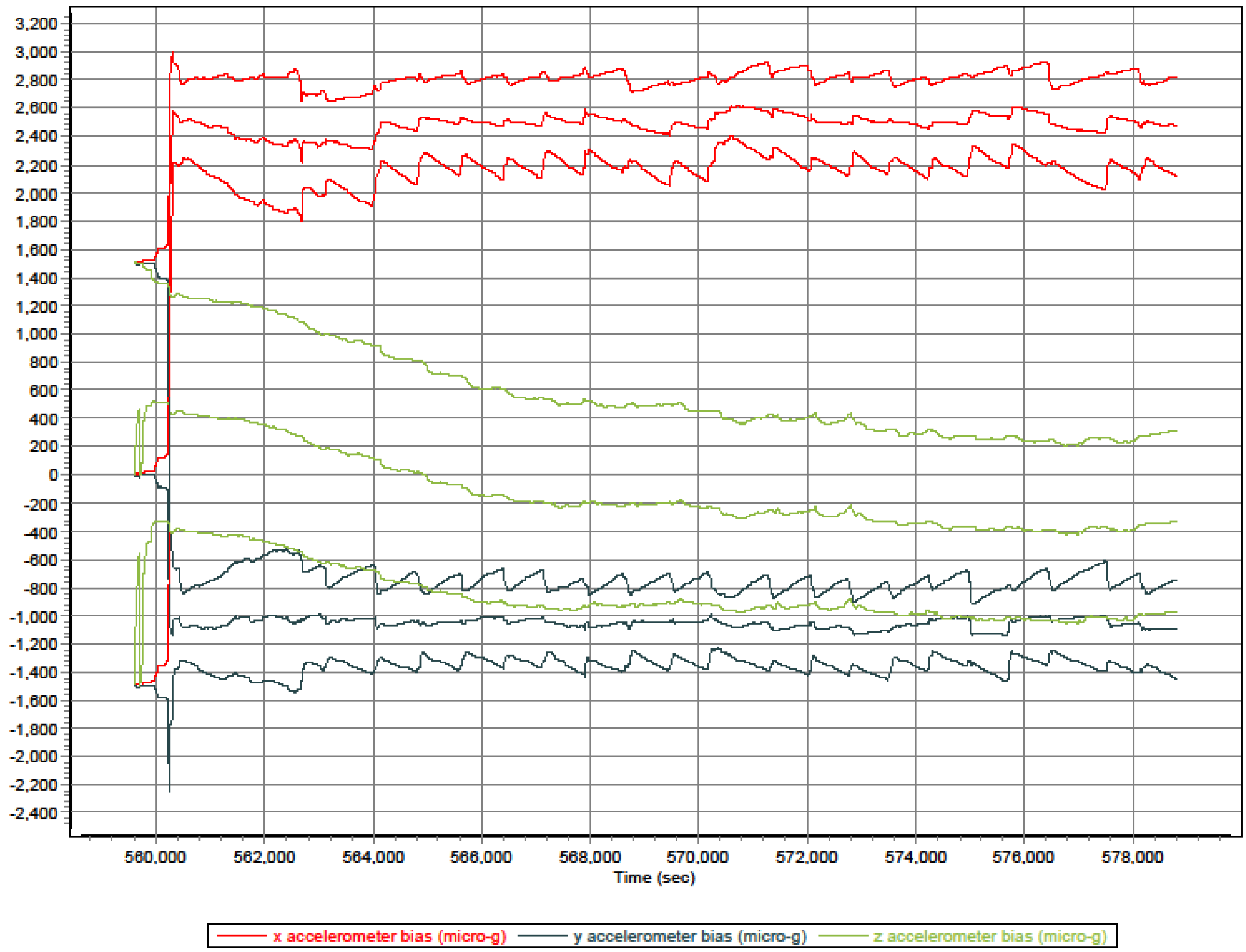
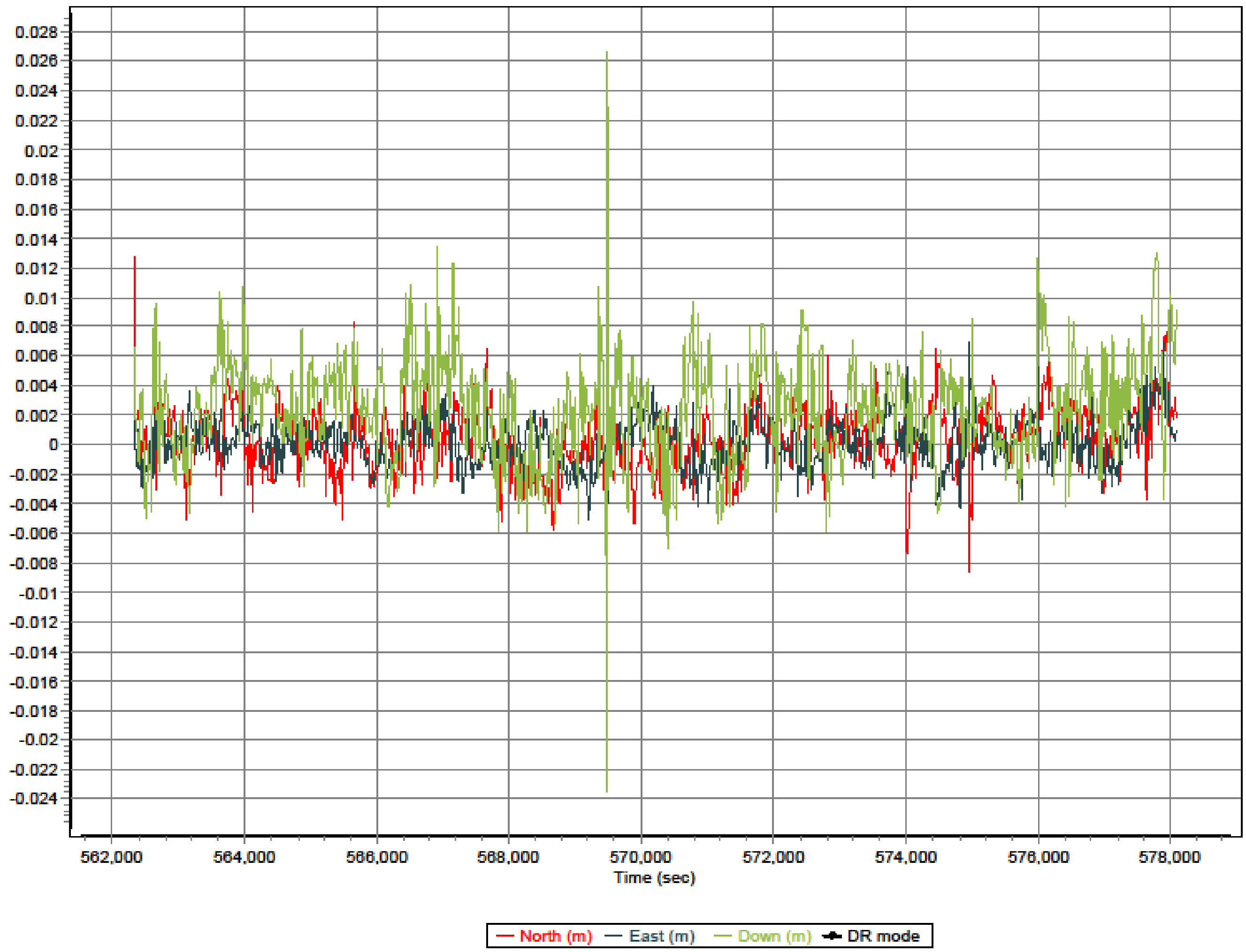
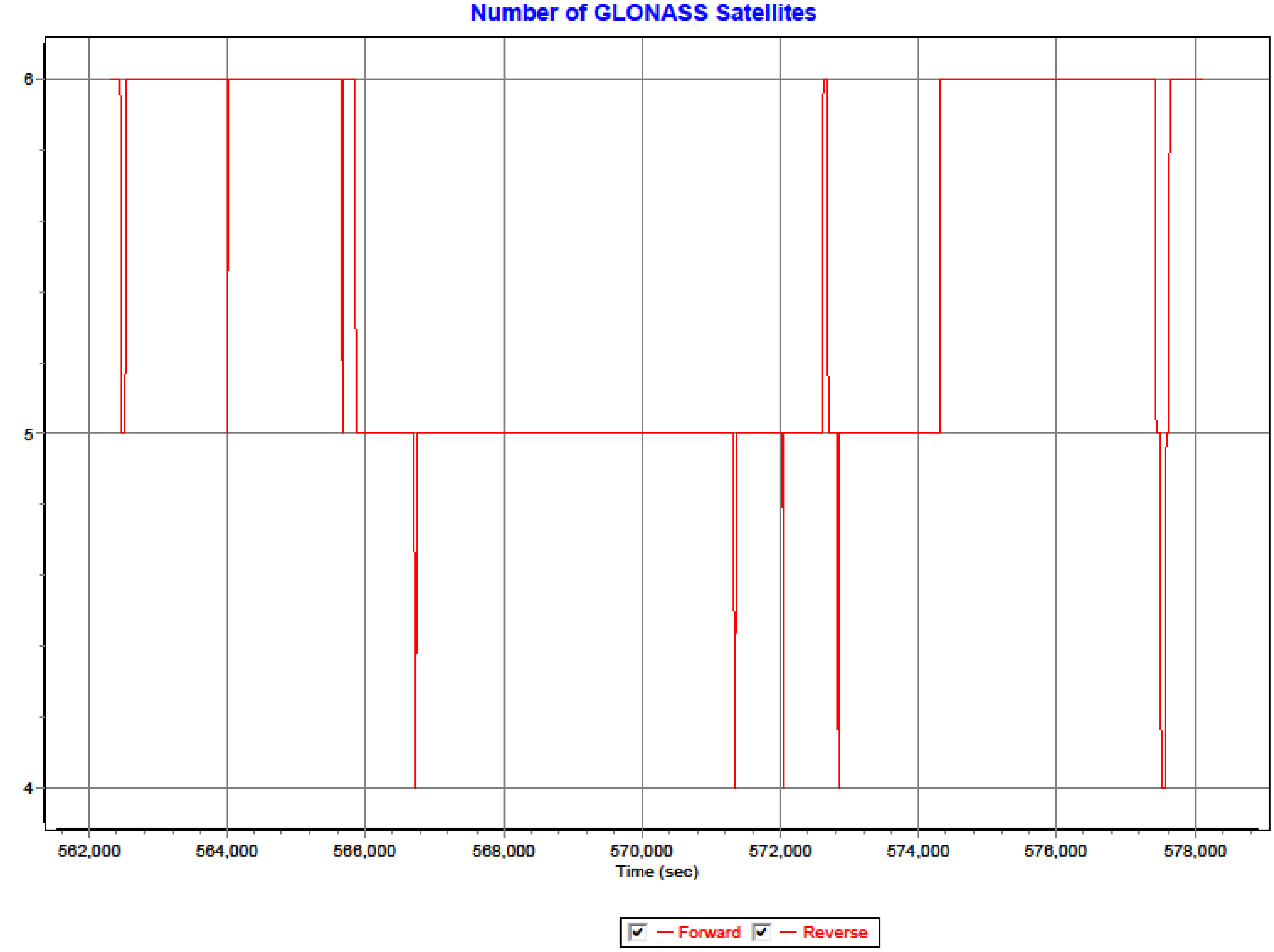
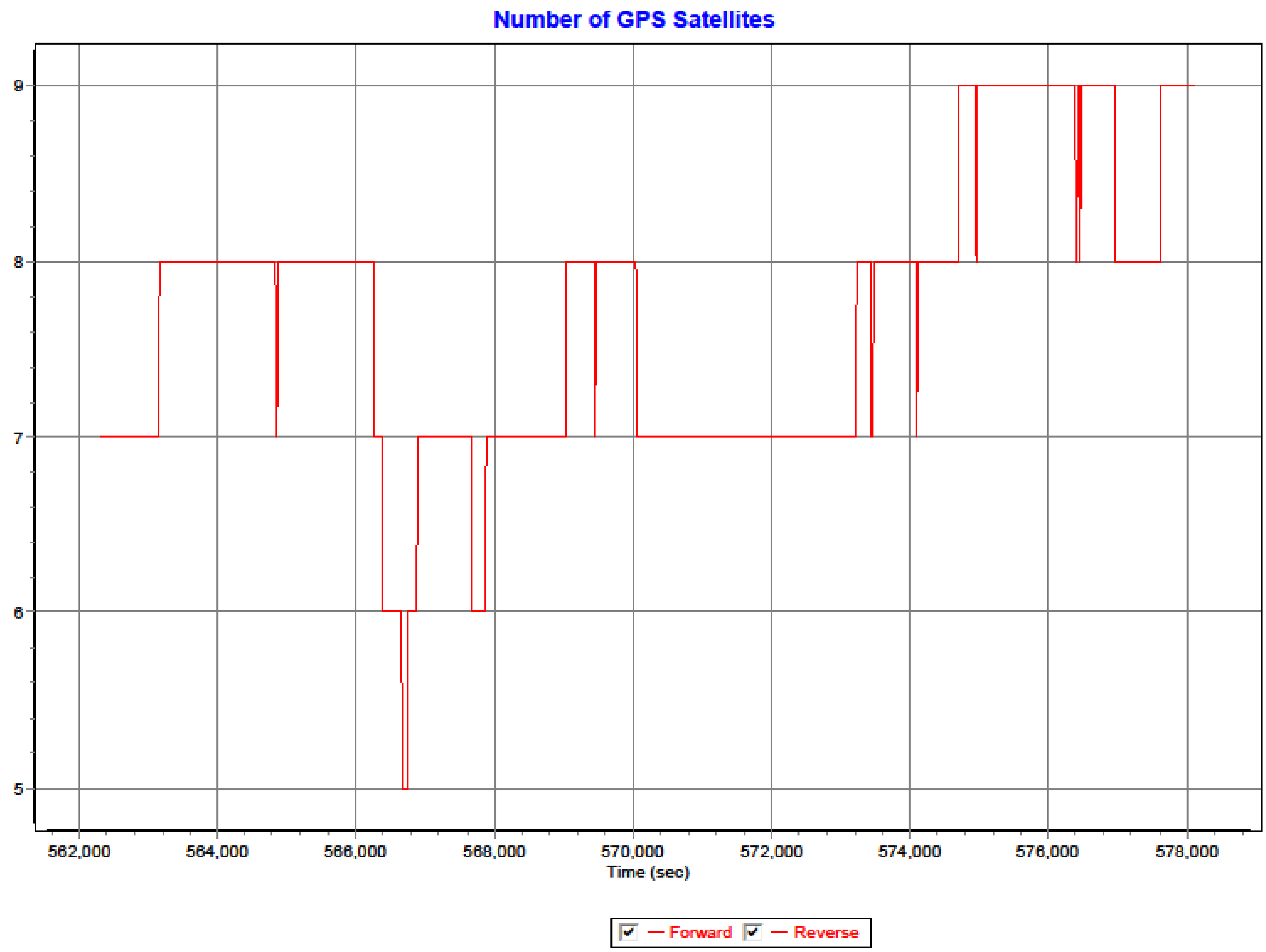
502,500
Time (sec)
North Position Error RMS (m)
East Position Error RMS (m)
Down Position Error RMS (m)

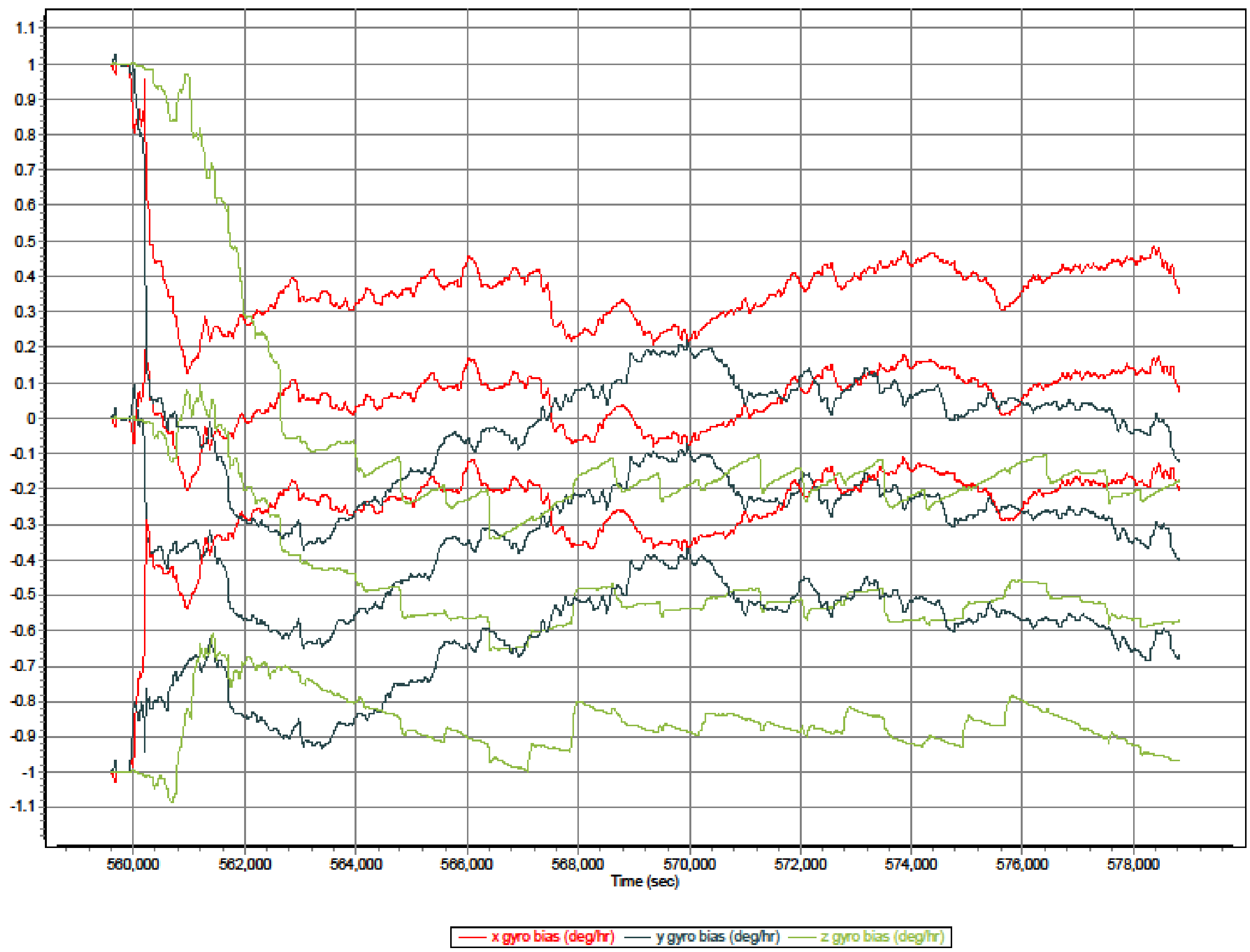
UNB15325A

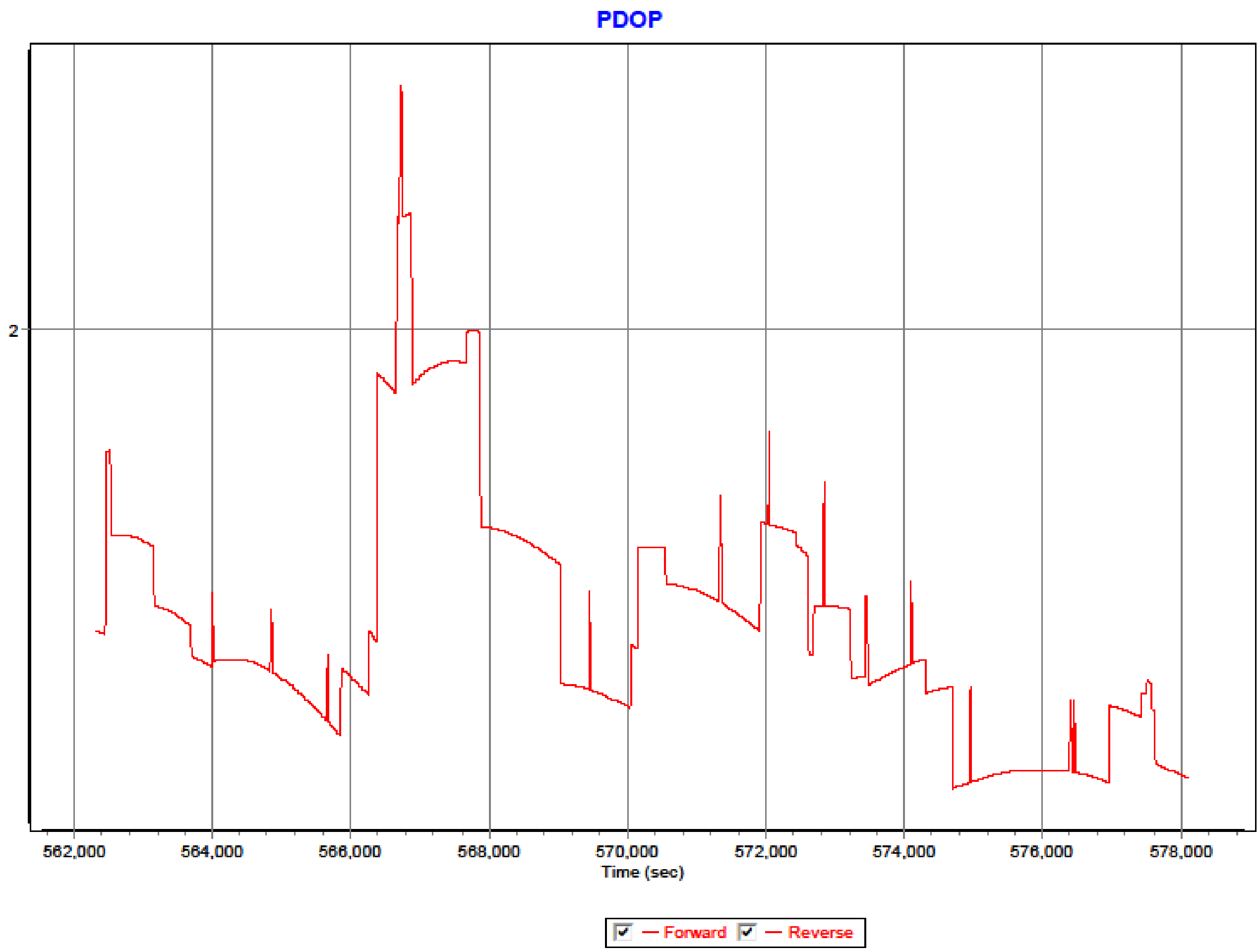

3,200
3,000
2,800
2,600
2,400
2,200
2,000
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
-200
-400
-600
-800
-1,000
-1,200
-1,400
-1,600
-1,800
-2,000
-2,200
-2,400
560,000
562,000
564,000
566,000
568,000
570,000
572,000
574,000
576,000
578,000
Time (sec)
x accelerometer bias (micro-g)
y accelerometer bias (micro-g)
z accelerometer bias (micro-g)

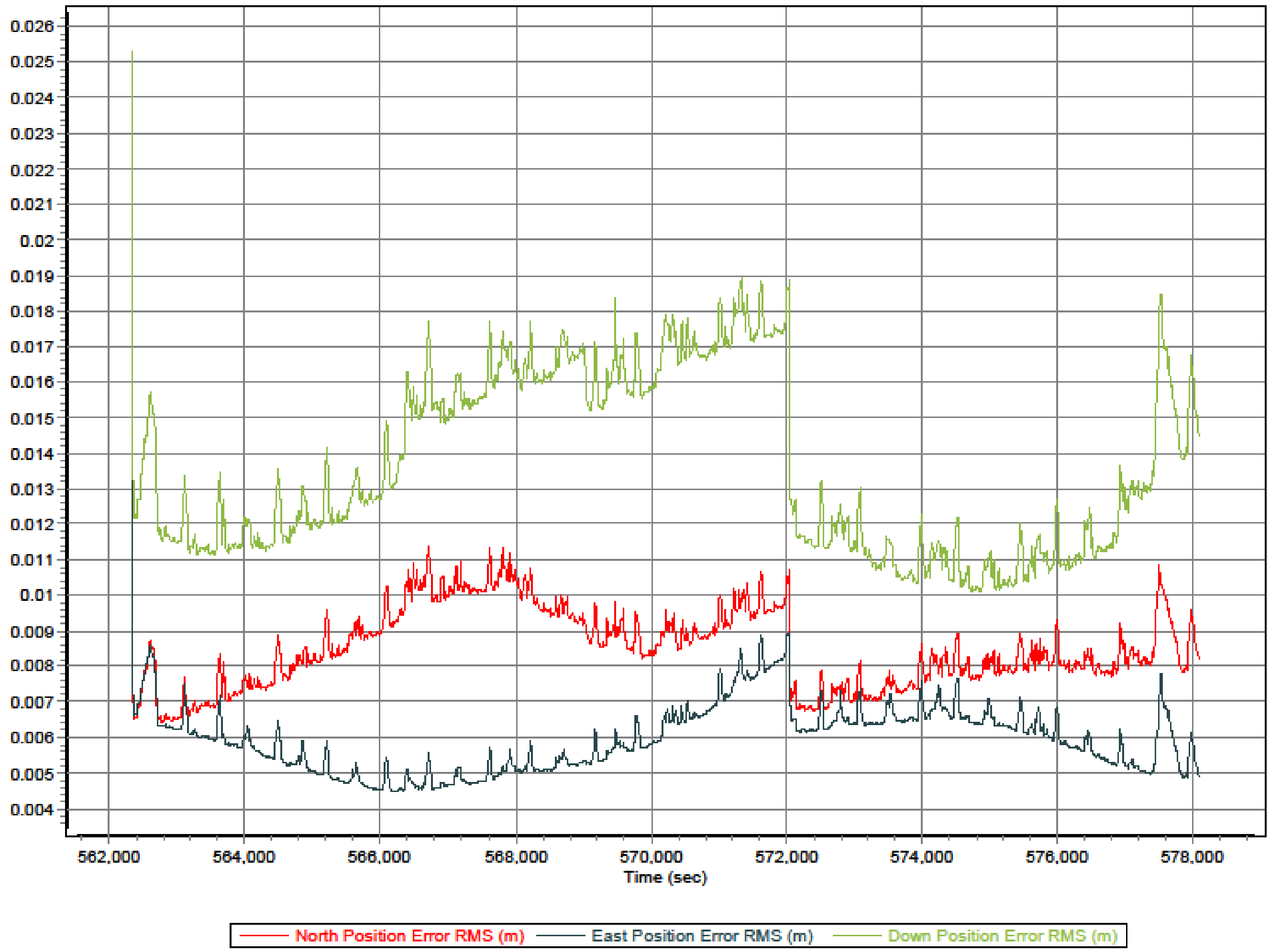

0.028
0.026
0.024
0.022
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
-0.002
-0.004
-0.006
-0.008
-0.01
-0.012
-0.014
-0.016
-0.018
-0.02
-0.022
-0.024
562,000
564,000
566,000
568,000
570,000
572,000
574,000
576,000
578,000
Time (sec)
North (m)
East (m)
Down (m)
DR mode


Number of GLONASS Satellites
6
5
4
562,000
564,000
566,000
568,000
570,000
572,000
574,000
576,000
578,000
Time (sec)
Forward
Reverse

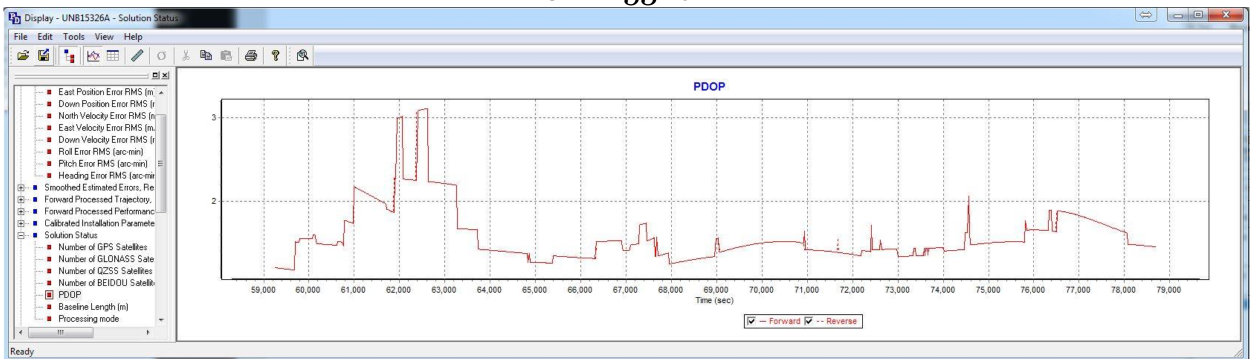

Number of GPS Satellites
9
8
7
6
5
562,000
564,000
566,000
568,000
570,000
572,000
574,000
576,000
578,000
Time (sec)
Forward
Reverse

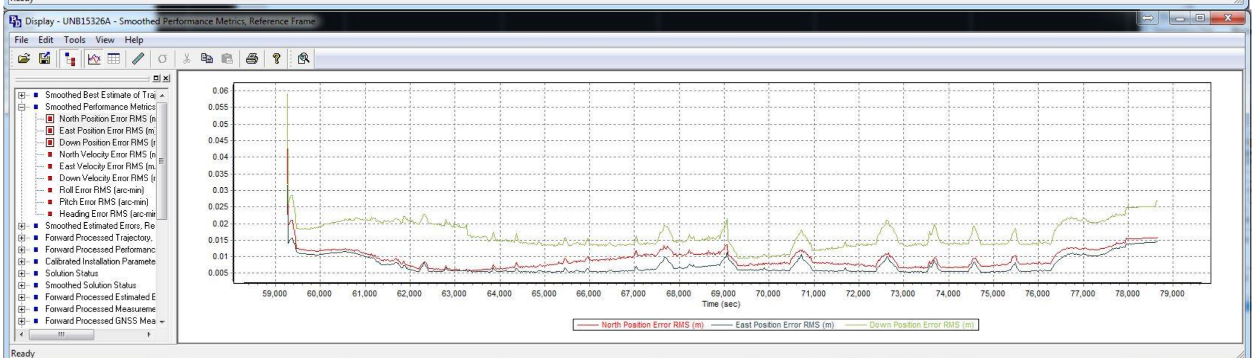

1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
-0.9
-1
-1.1
560,000
562,000
564,000
566,000
568,000
570,000
572,000
574,000
576,000
578,000
Time (sec)
x gyro bias (deg/hr)
y gyro bias (deg/hr)
z gyro bias (deg/hr)

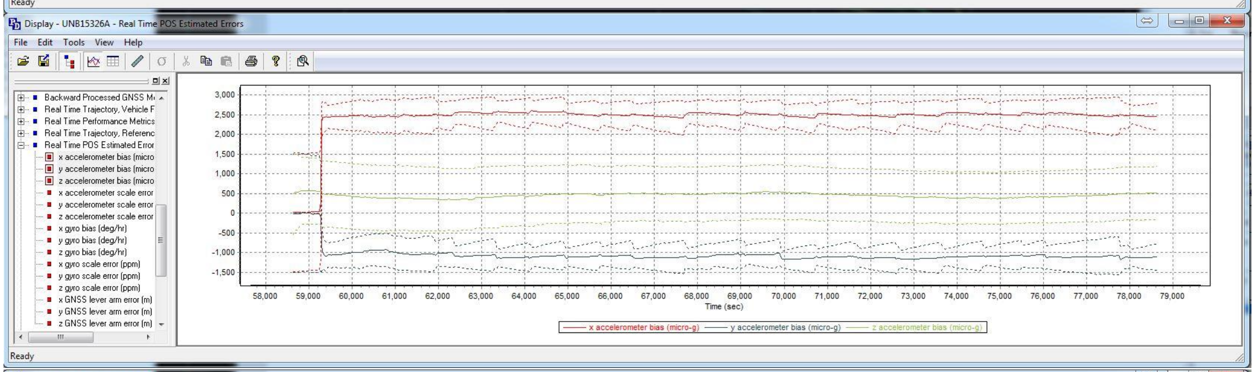

PDOP
2
562,000
564,000
566,000
568,000
570,000
572,000
574,000
576,000
578,000
Time (sec)
Forward
Reverse


0.026
0.025
0.024
0.023
0.022
0.021
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
562,000
564,000
566,000
568,000
570,000
572,000
574,000
576,000
578,000
Time (sec)
North Position Error RMS (m)
East Position Error RMS (m)
Down Position Error RMS (m)

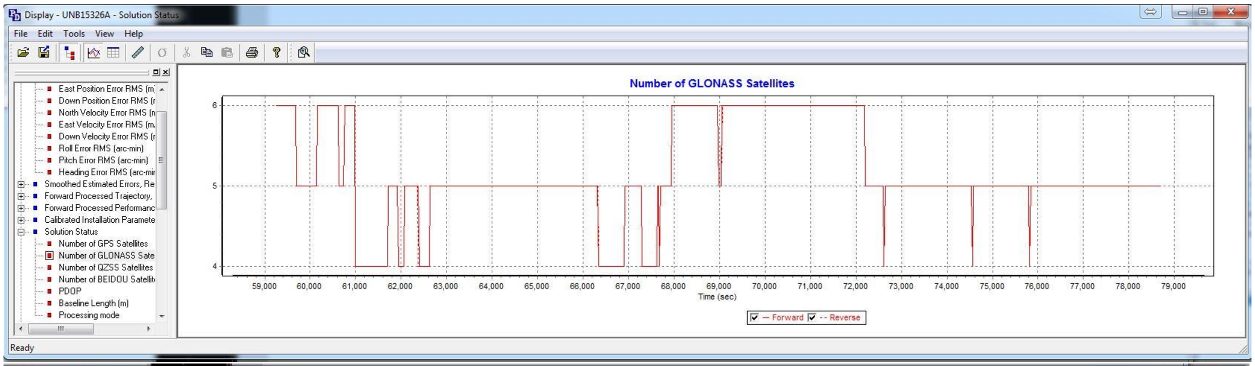
UNB15326A

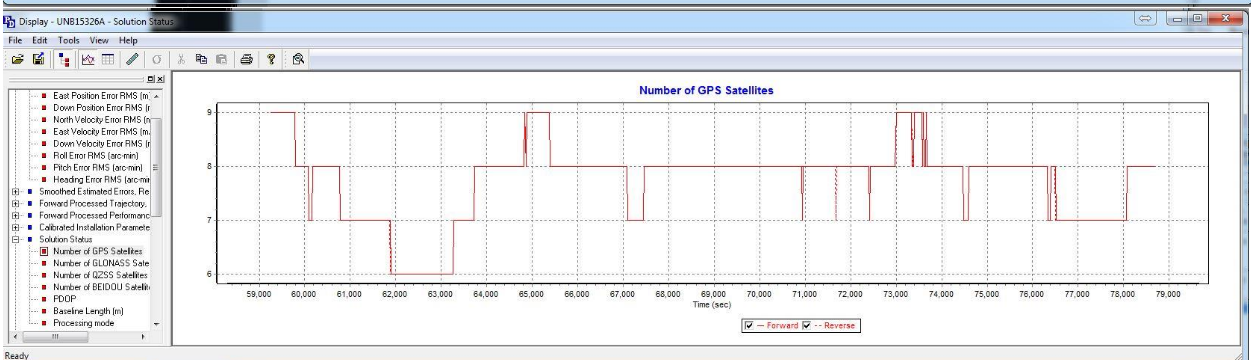

Display - UNB15326A - Solution Status
PDOP
Time (sec)
Forward
Reverse

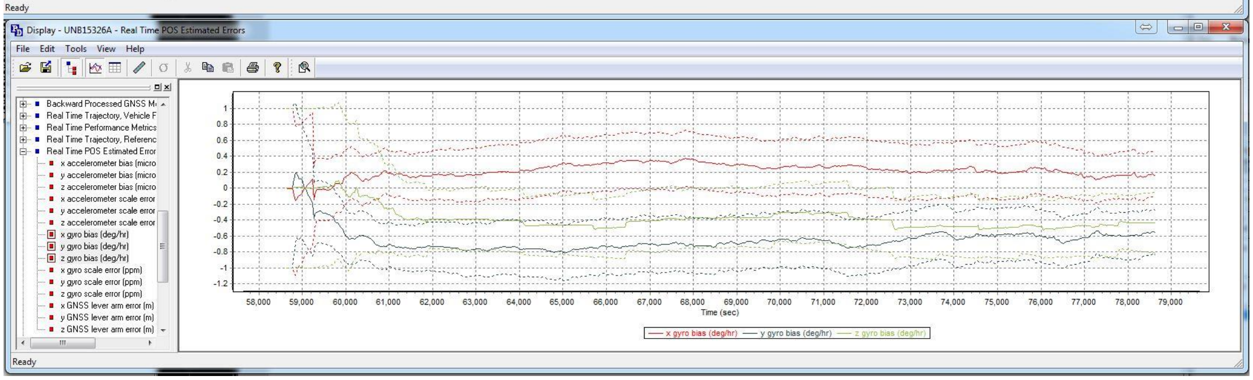

Display - UNB15326A - Smoothed Performance Metrics, Reference Frame
Time (sec)
North Position Error RMS (m)
East Position Error RMS (m)
Down Position Error RMS (m)


Display - UNB15326A - Real Time POS Estimated Errors
Time (sec)
x accelerometer bias (micro-g)
y accelerometer bias (micro-g)
z accelerometer bias (micro-g)

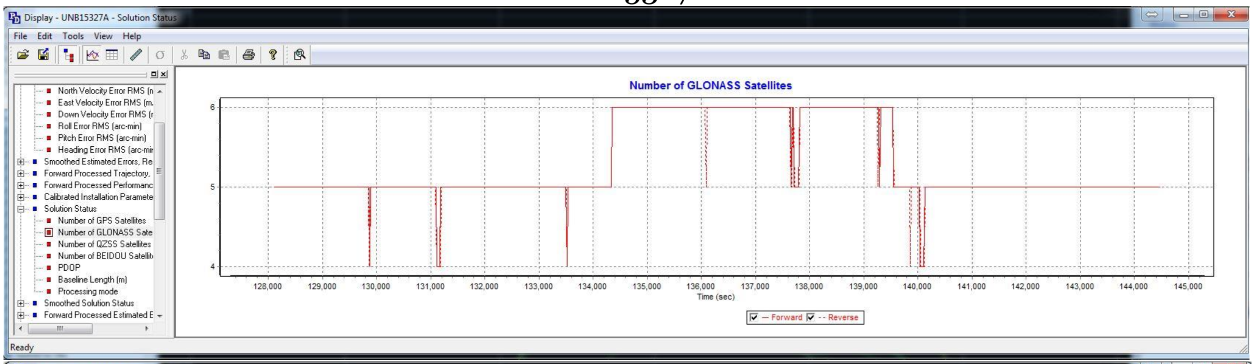

Display - UNB15326A - SBET IAKAR Separation
Time (sec)
North (m)
East (m)
Down (m)
DR mode

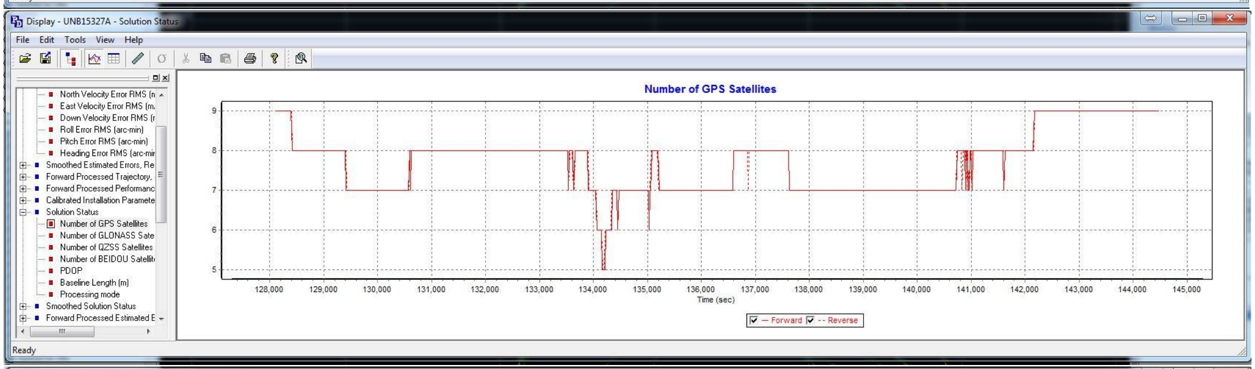

Display - UNB15326A - Solution Status
Number of GLONASS Satellites
Time (sec)
Forward
Reverse


Display - UNB15326A - Solution Status
Number of GPS Satellites
Time (sec)
Forward
Reverse

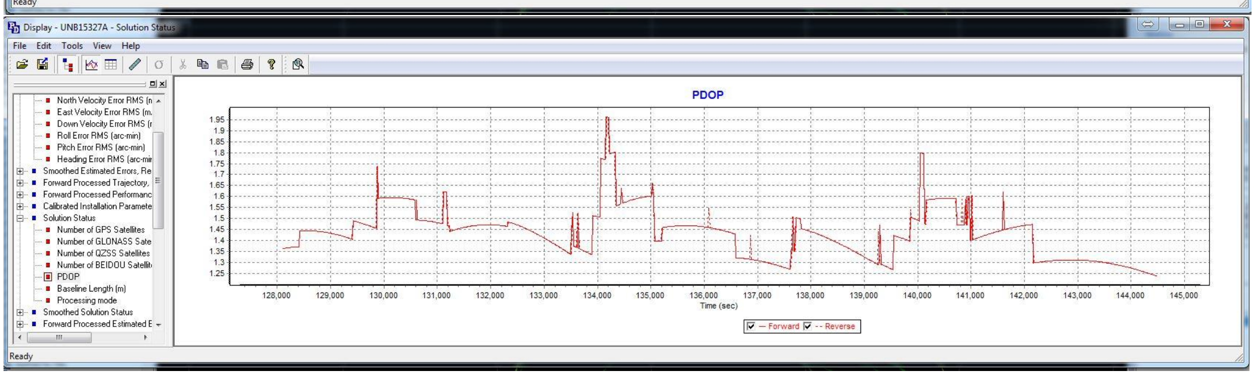

Display - UNB15326A - Real Time POS Estimated Errors
Time (sec)
x gyro bias (deg/hr)
y gyro bias (deg/hr)
z gyro bias (deg/hr)

UNB15327A


Display - UNB15327A - Solution Status
File Edit Tools View Help
Number of GLONASS Satellites
Time (sec)
Forward
Reverse
Ready


Display - UNB15327A - Solution Status
File Edit Tools View Help
Number of GPS Satellites
Time (sec)
Forward
Reverse
Ready


Display - UNB15327A - Real Time POS Estimated Errors
File Edit Tools View Help
Time (sec)
x gyro bias (deg/hr)
y gyro bias (deg/hr)
z gyro bias (deg/hr)
Ready

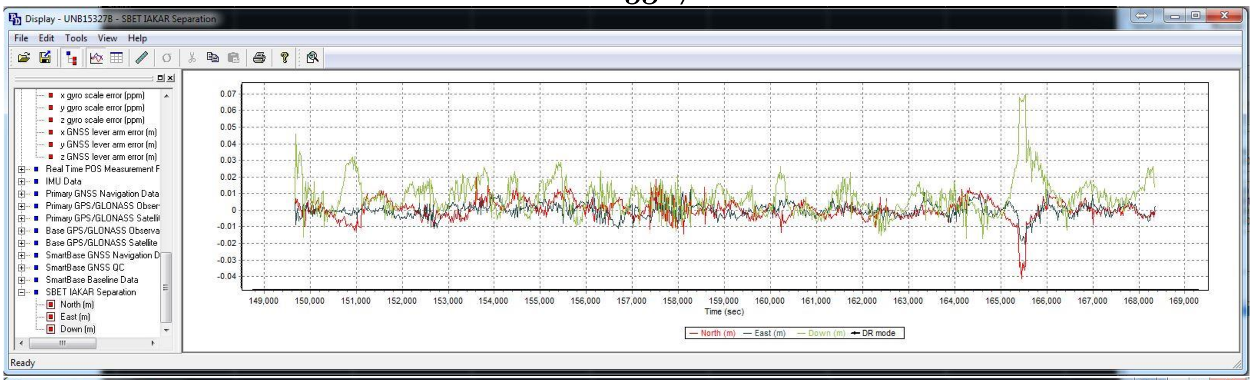

Display - UNB15327A - Solution Status
File Edit Tools View Help
PDOP
Time (sec)
Forward
Reverse
Ready

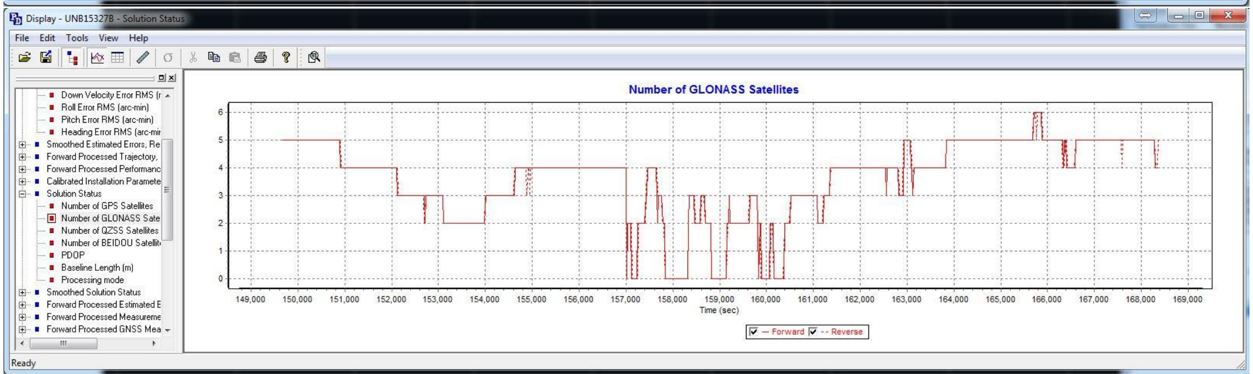

Display - UNB15327A - Smoothed Performance Metrics, Reference Frame
Time (sec)
North Position Error RMS (m)
East Position Error RMS (m)
Down Position Error RMS (m)

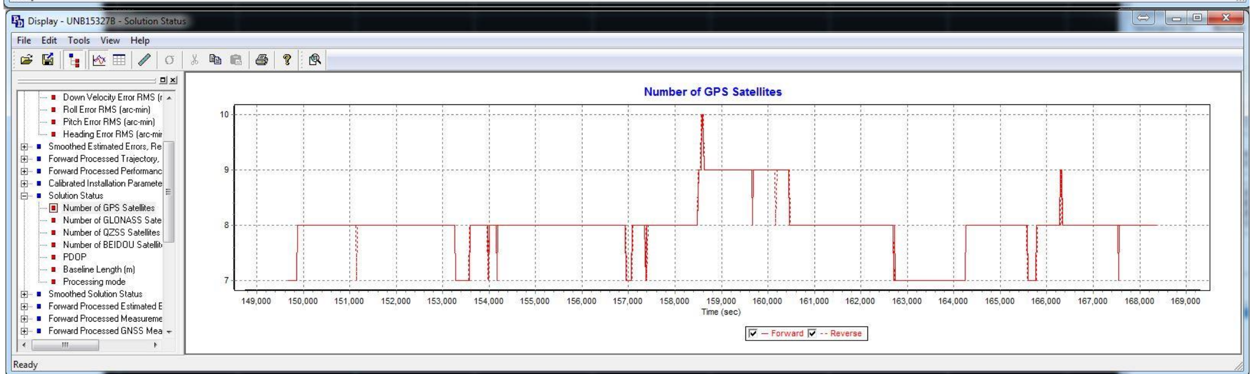

Display - UNB15327A - Real Time POS Estimated Errors
Time (sec)
x accelerometer bias (micro-g)
y accelerometer bias (micro-g)
z accelerometer bias (micro-g)

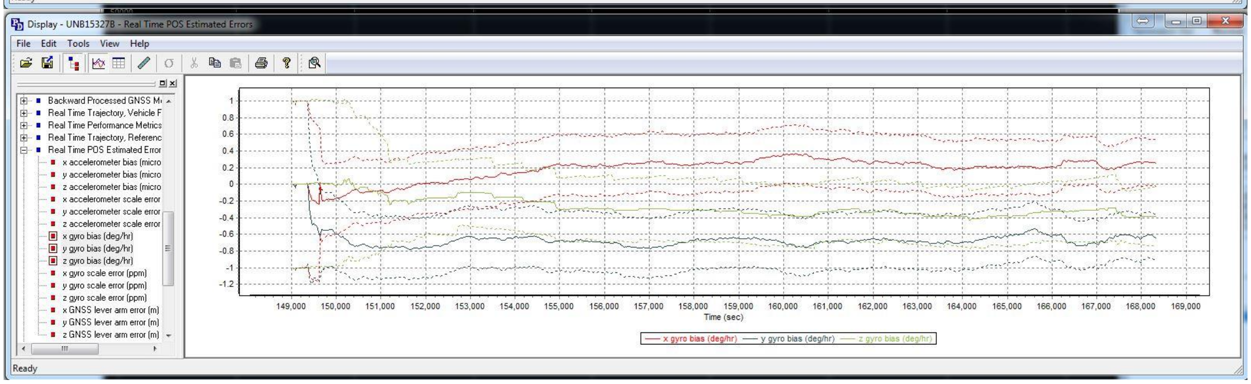

Display - UNB15327A - SBET IAKAR Separation
Time (sec)
North (m)
East (m)
Down (m)
DR mode

UNB15327B

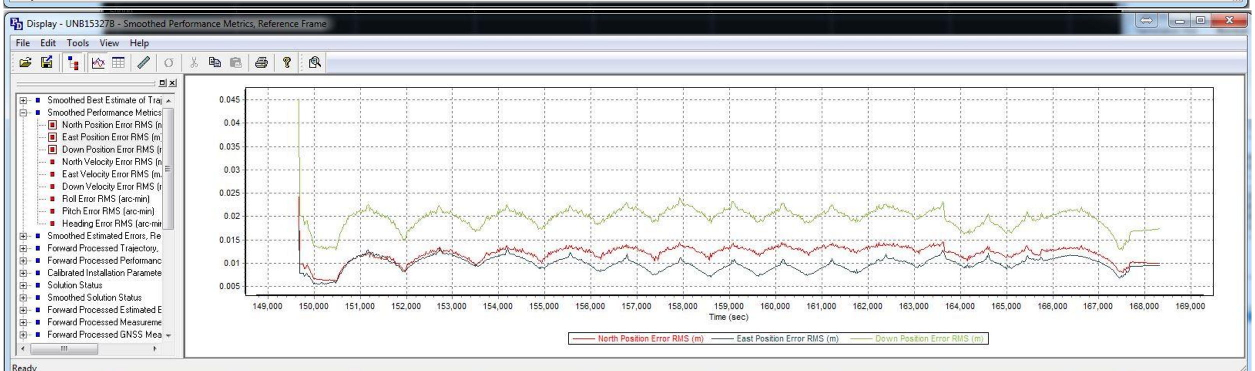

Display - UNB15327B - SBET IAKAR Separation
Time (sec)
North (m)
East (m)
Down (m)
DR mode

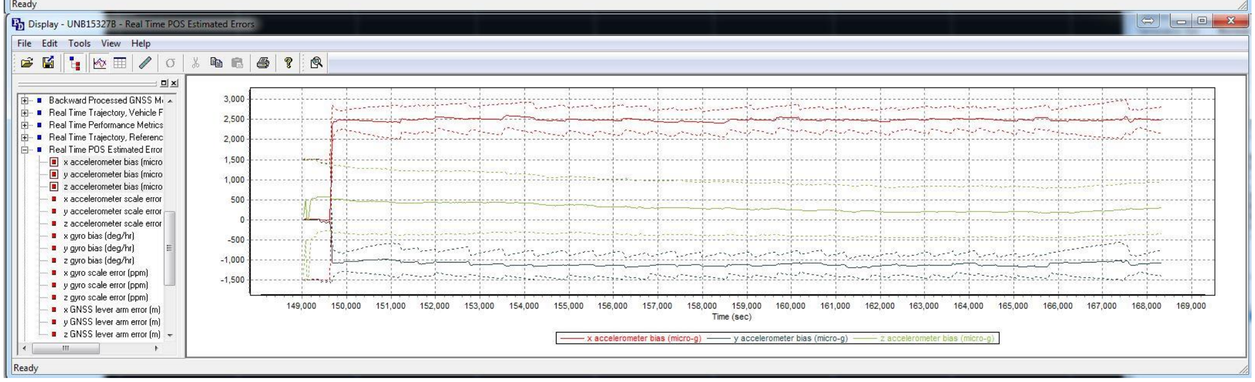

Display - UNB15327B - Solution Status
Number of GLONASS Satellites
Time (sec)
Forward
Reverse


Display - UNB15327B - Solution Status
Number of GPS Satellites
Time (sec)
Forward
Reverse

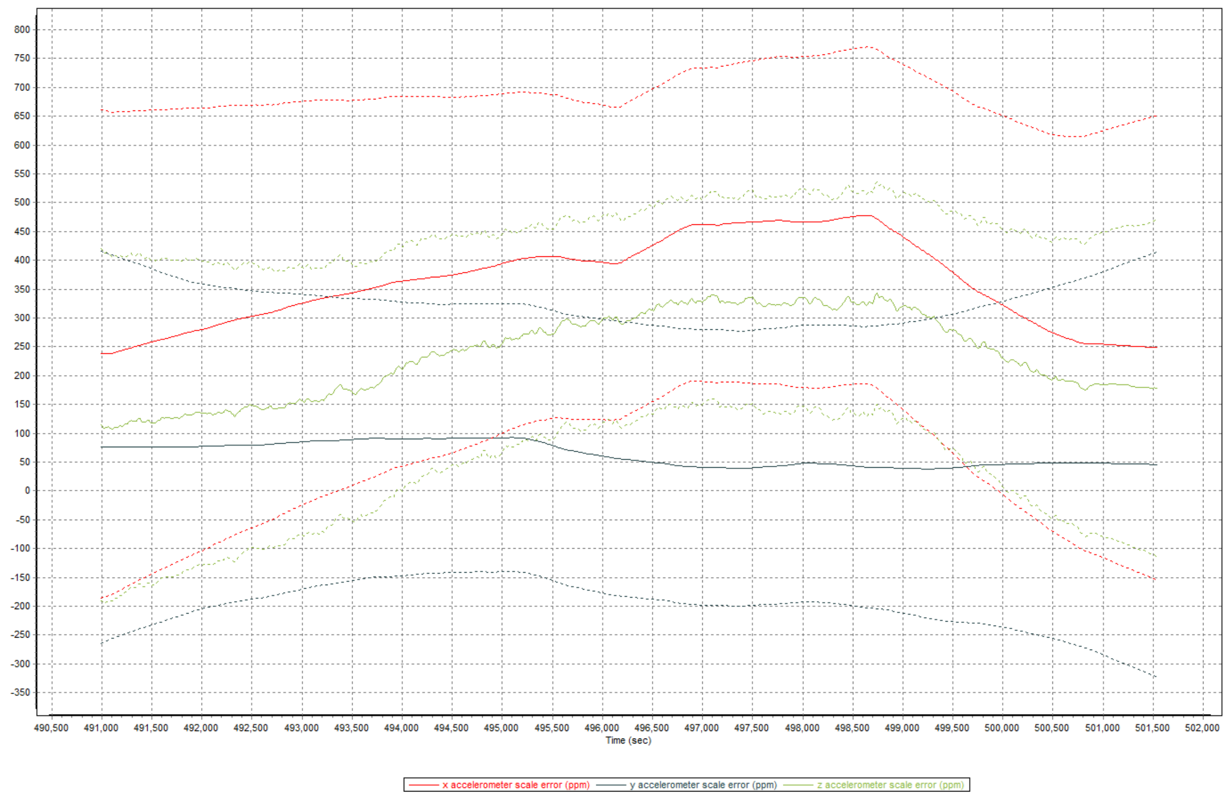

Display - UNB15327B - Real Time POS Estimated Errors
Time (sec)
x gyro bias (deg/hr)
y gyro bias (deg/hr)
z gyro bias (deg/hr)

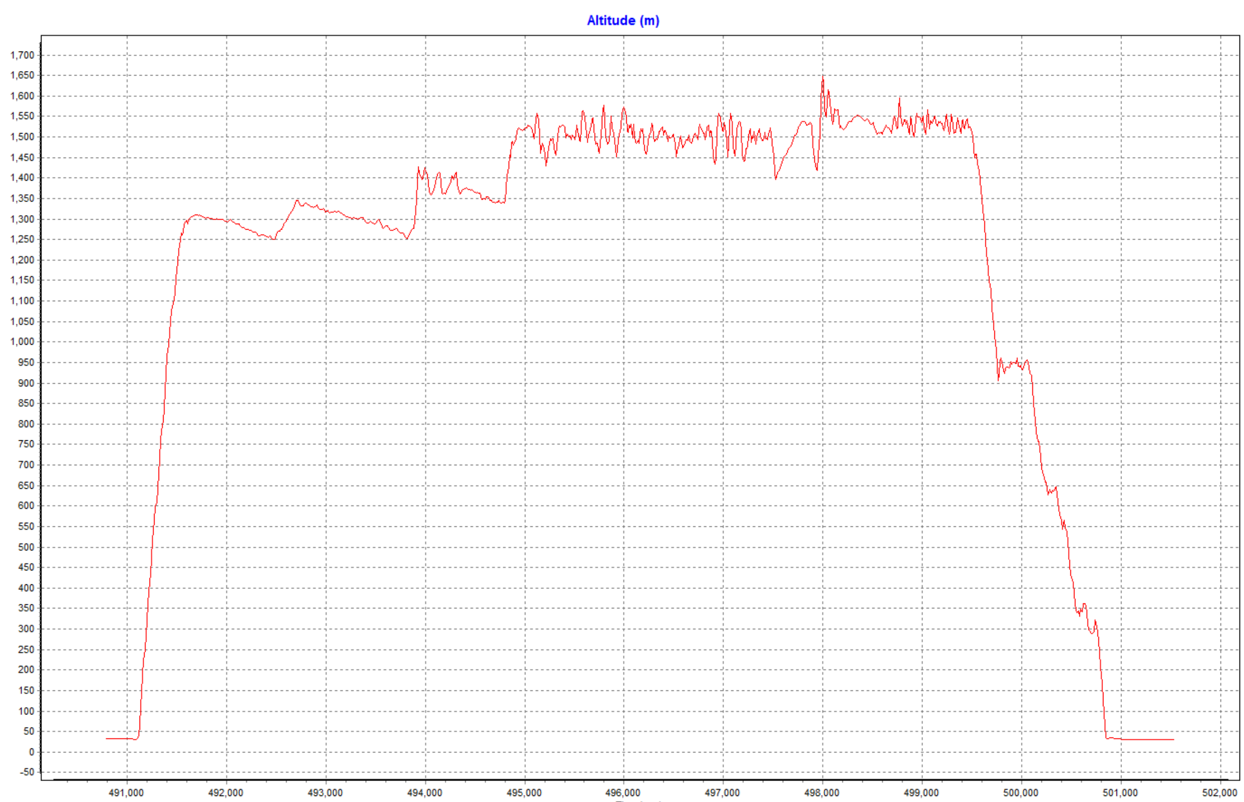

Display - UNB153278 - Solution Status
File Edit Tools View Help
PDOP
Time (sec)
— Forward -- Reverse
Ready

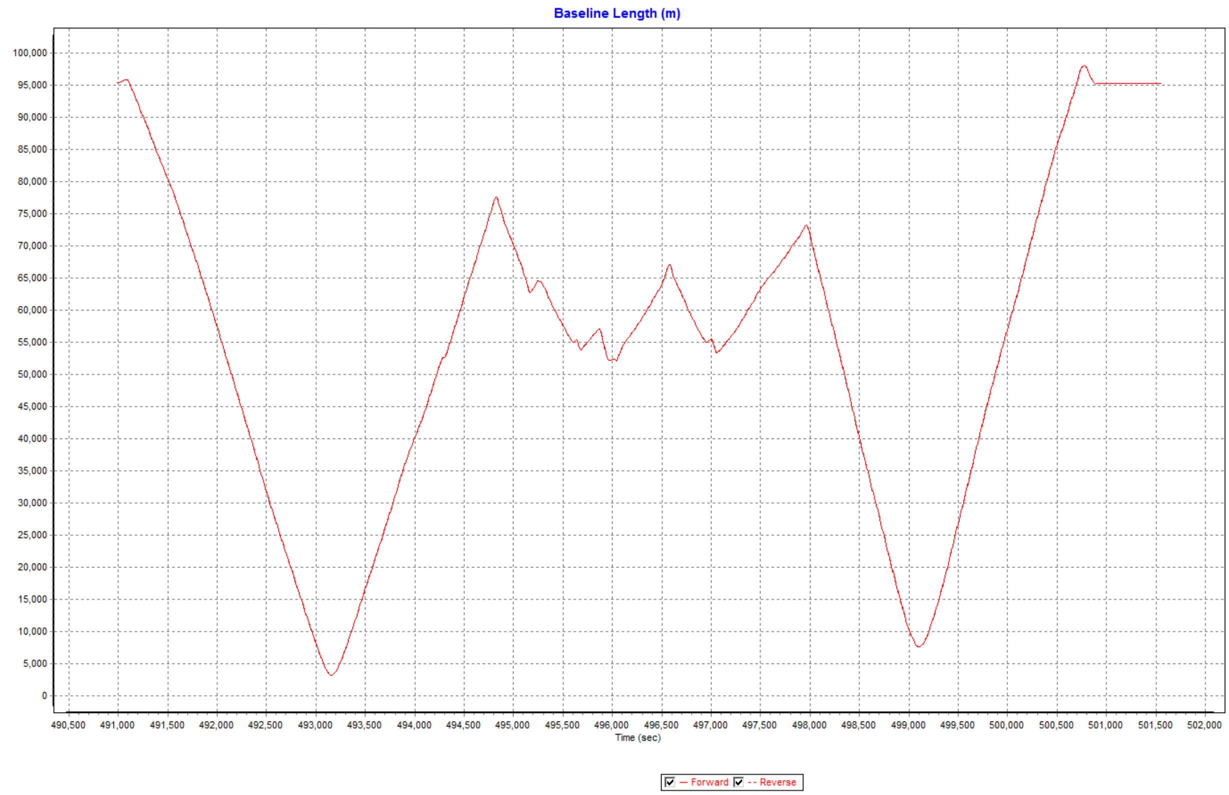

Display - UNB153278 - Smoothed Performance Metrics, Reference Frame
File Edit Tools View Help
Time (sec)
North Position Error RMS (m)
East Position Error RMS (m)
Down Position Error RMS (m)
Ready


Display - UNB153278 - Real Time POS Estimated Errors
File Edit Tools View Help
Time (sec)
x accelerometer bias (micro-g)
y accelerometer bias (micro-g)
z accelerometer bias (micro-g)
Ready

MNB15324A


Time (sec)
x accelerometer scale error (ppm)
y accelerometer scale error (ppm)
z accelerometer scale error (ppm)


Altitude (m)
Time (sec)


Baseline Length (m)
100,000
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90,000
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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
490,500
491,000
491,500
492,000
492,500
493,000
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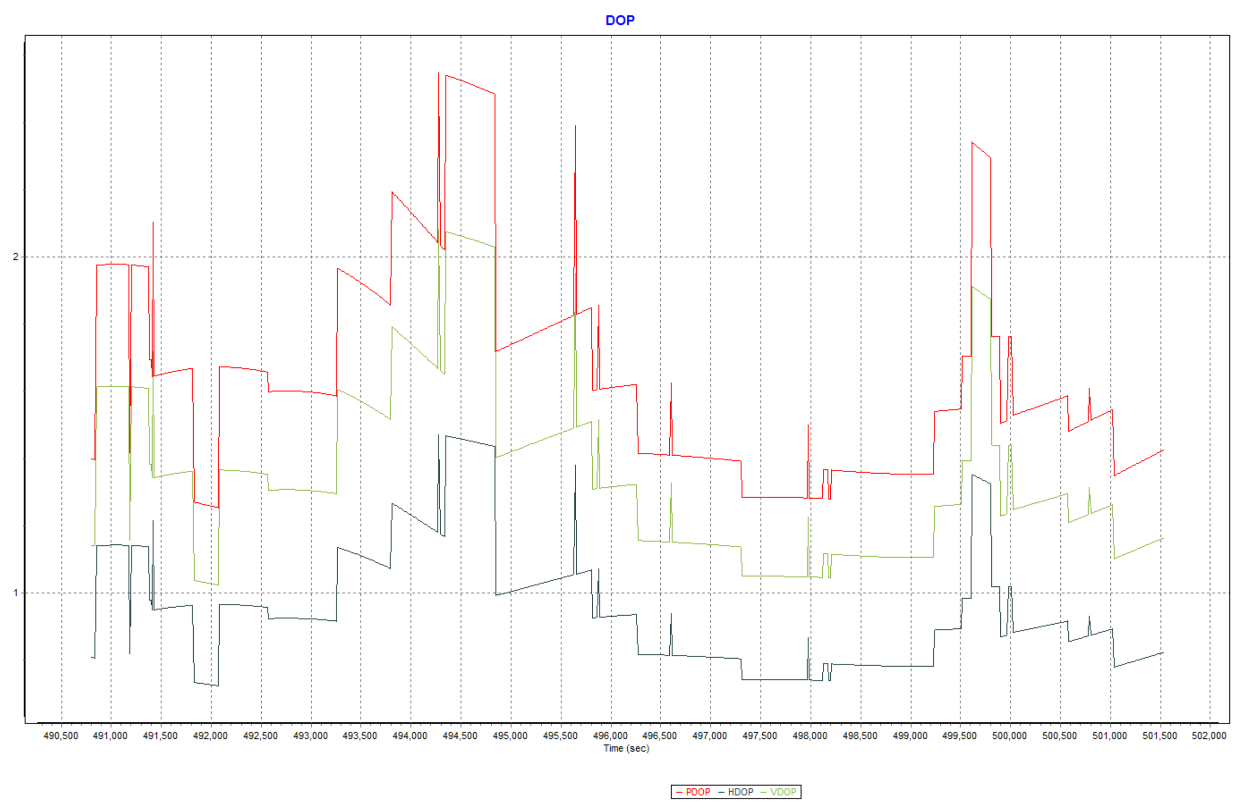
499,000
499,500
500,000
500,500
501,000
501,500
502,000
Time (sec)
Forward
Reverse


DOP
2
1
490,500
491,000
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492,000
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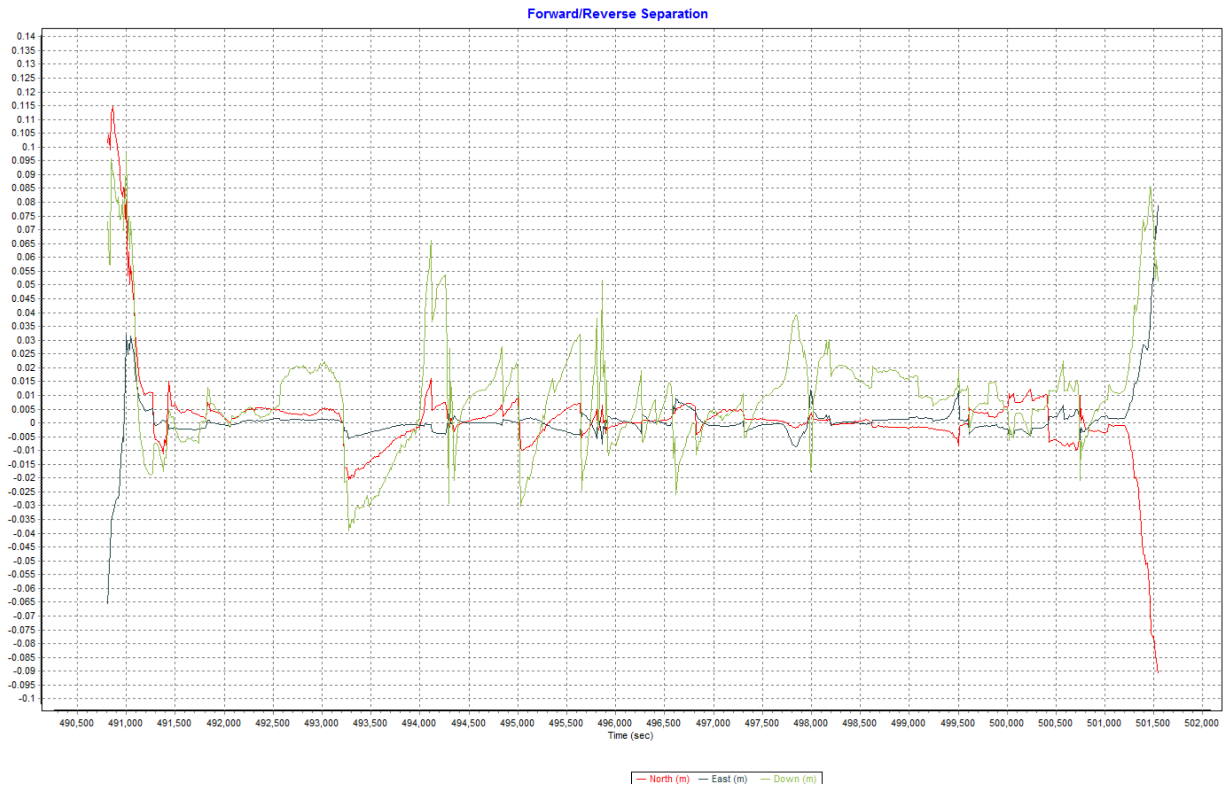
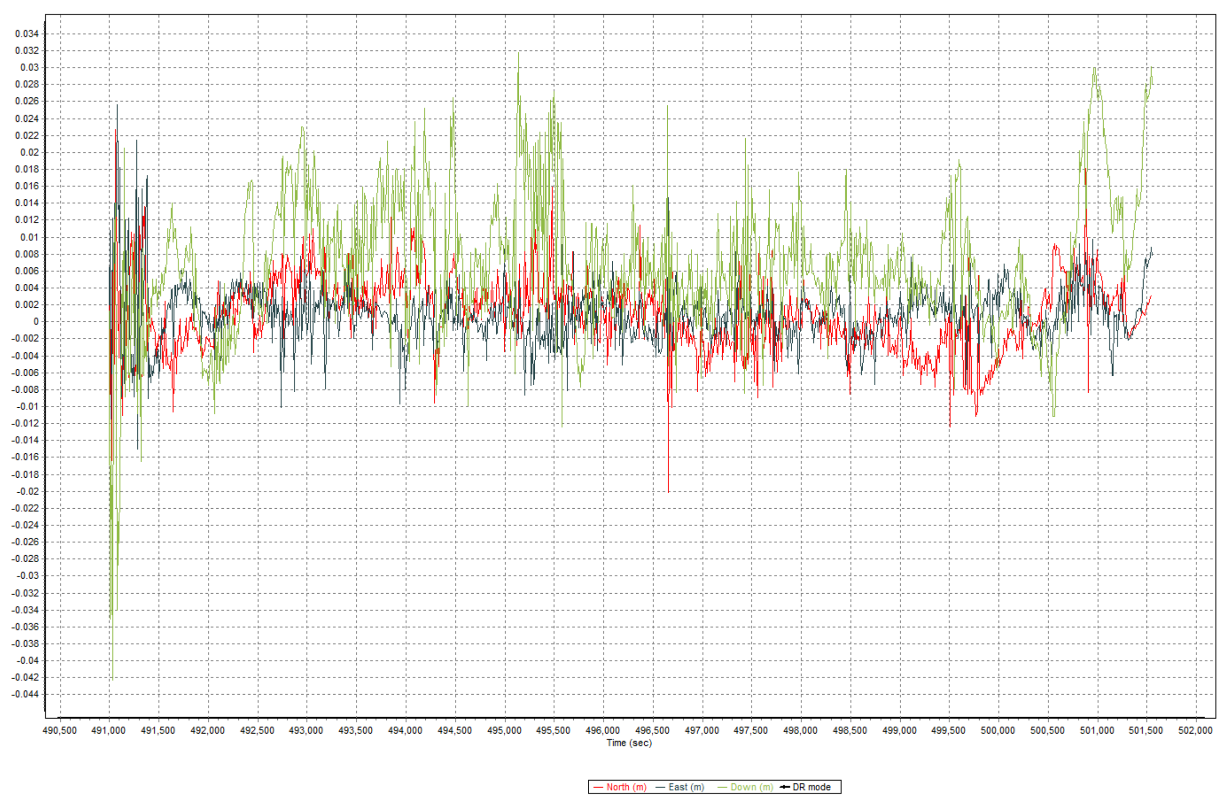
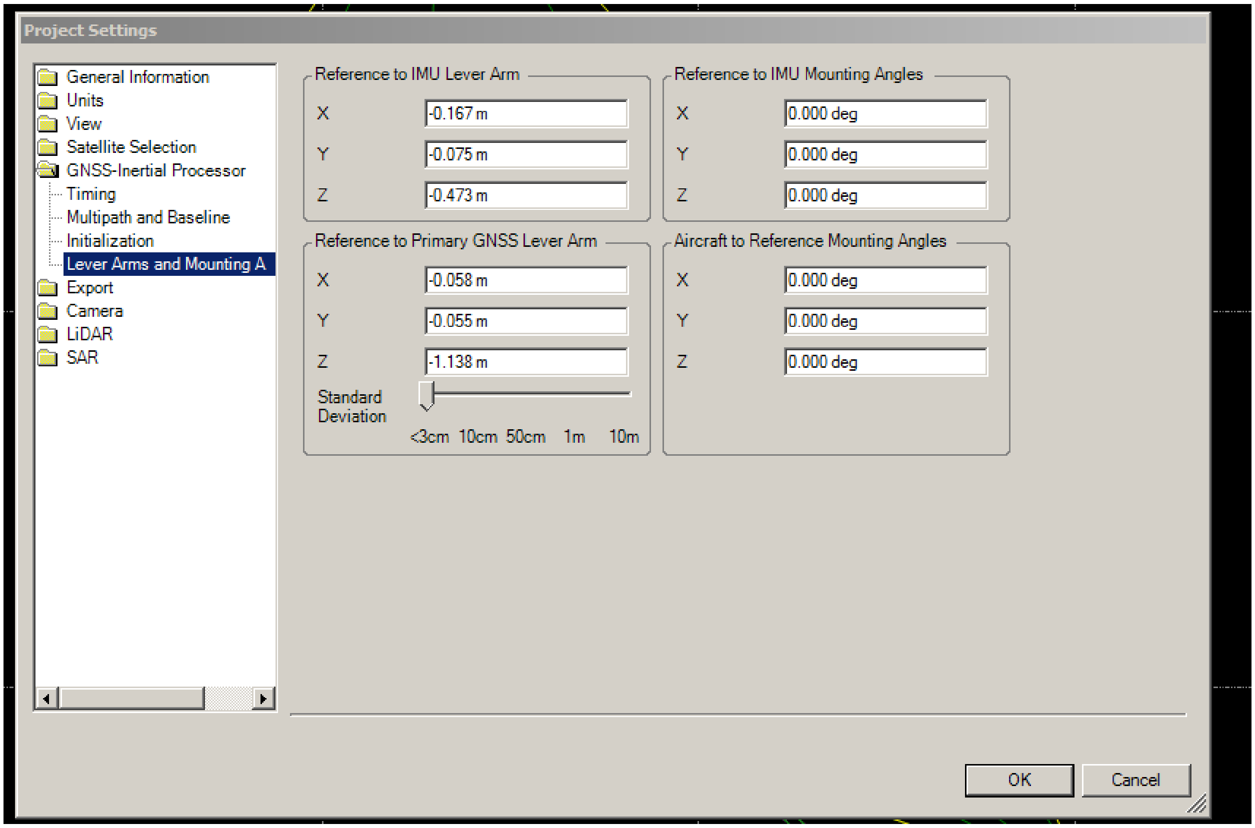
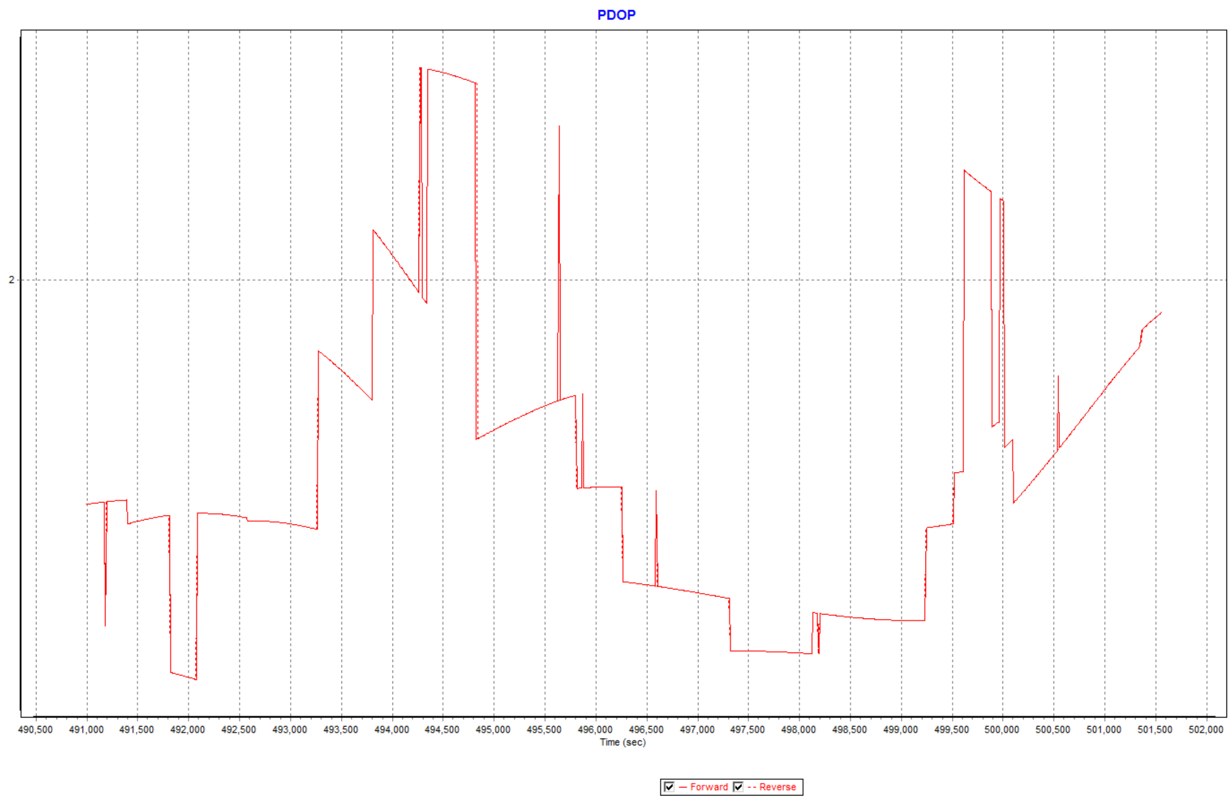
501,000
501,500
502,000
Time (sec)
PDOP
HDOP
VDOP


Forward/Reverse Separation
Time (sec)
North (m)
East (m)
Down (m)


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


Project Settings
General Information
Units
View
Satellite Selection
GNSS-Inertial Processor
Timing
Multipath and Baseline
Initialization
Lever Arms and Mounting A
Export
Camera
LiDAR
SAR
Reference to IMU Lever Arm
X -0.167 m
Y -0.075 m
Z -0.473 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 -0.058 m
Y -0.055 m
Z -1.138 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


PDOP
2
490,500
491,000
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496,500
497,000
497,500
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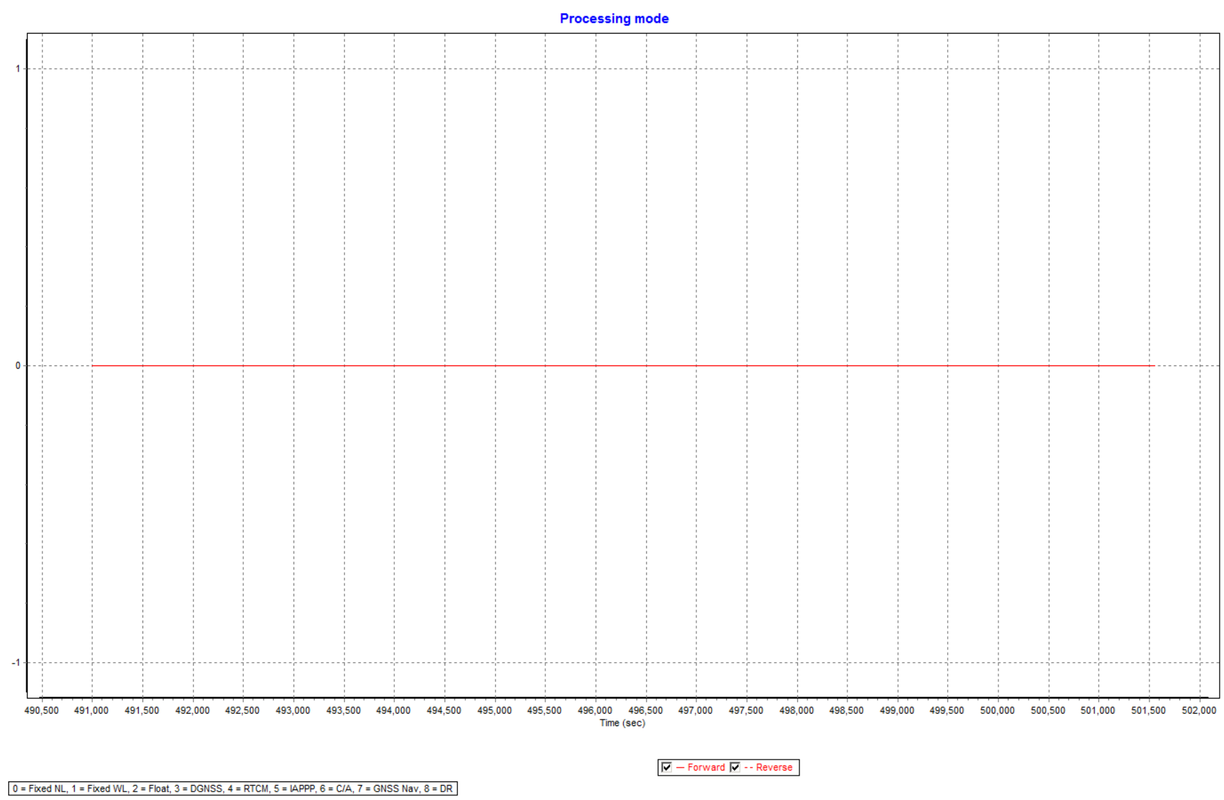
499,500
500,000
500,500
501,000
501,500
502,000
Time (sec)
— Forward
-- Reverse


Processing mode
1
0
-1
490,500
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497,000
497,500
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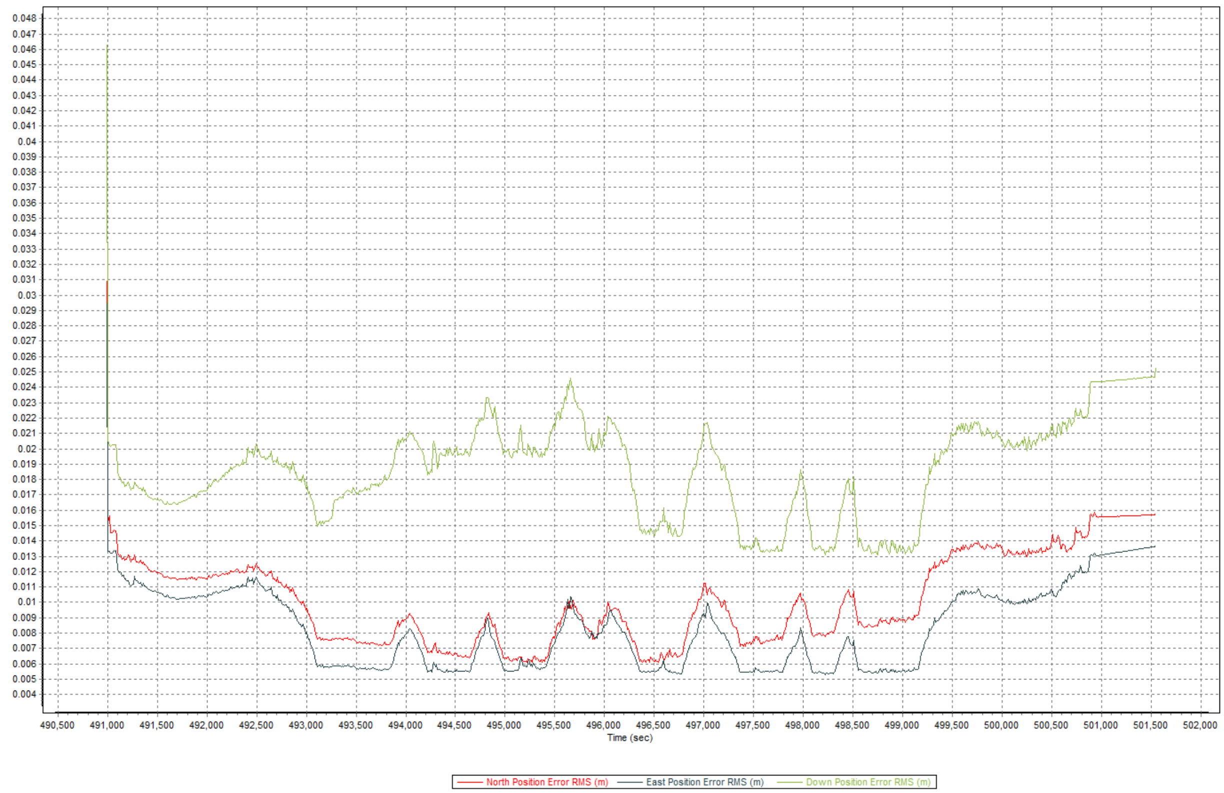
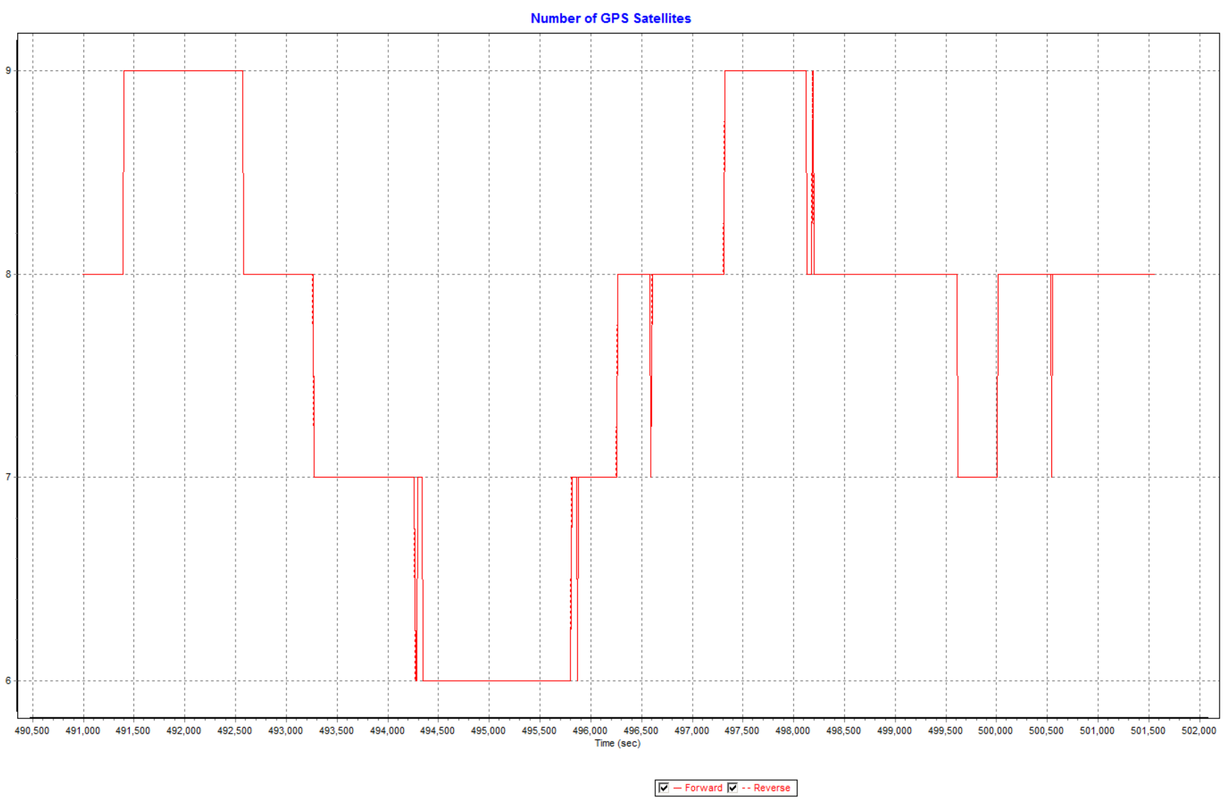
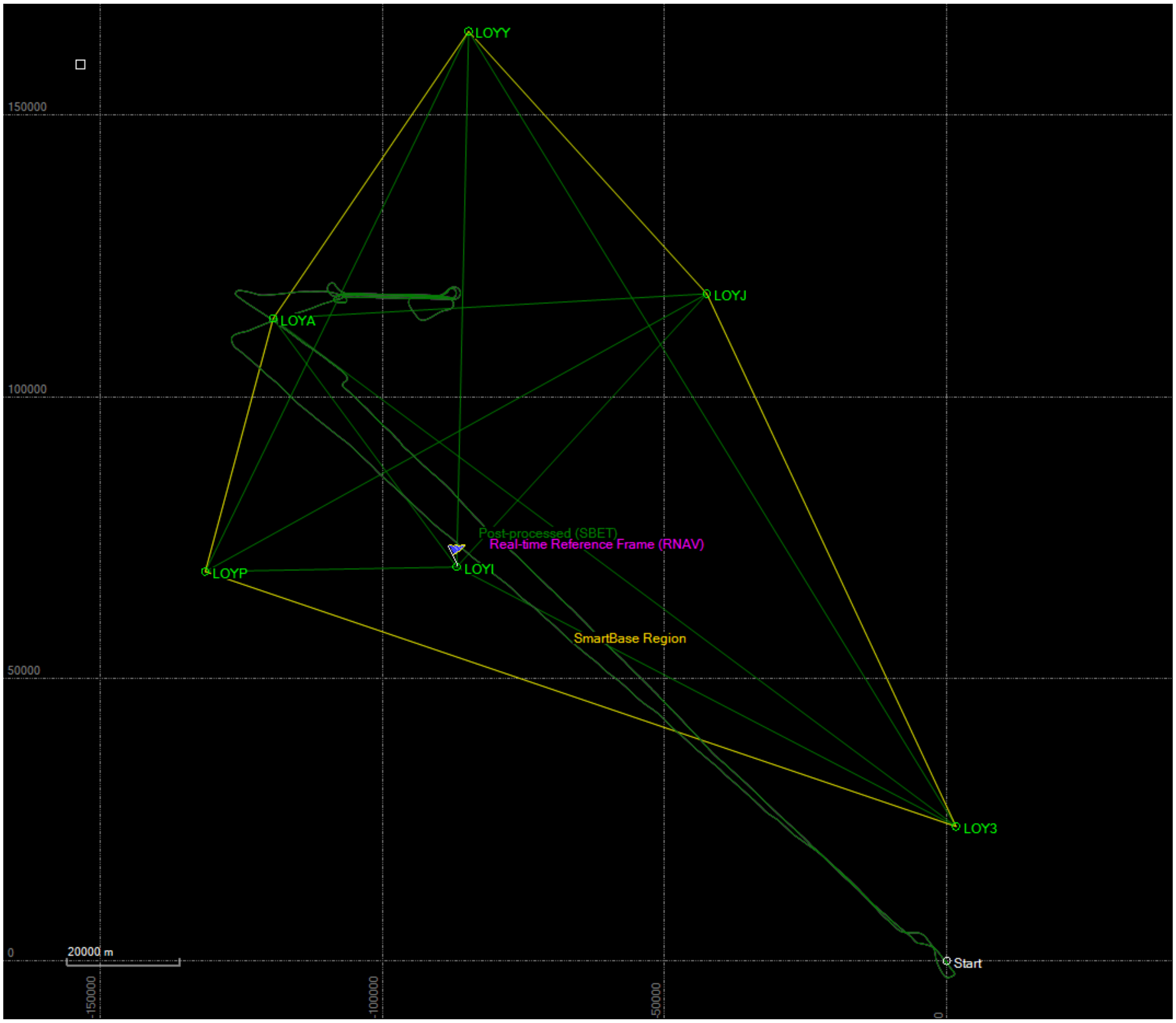
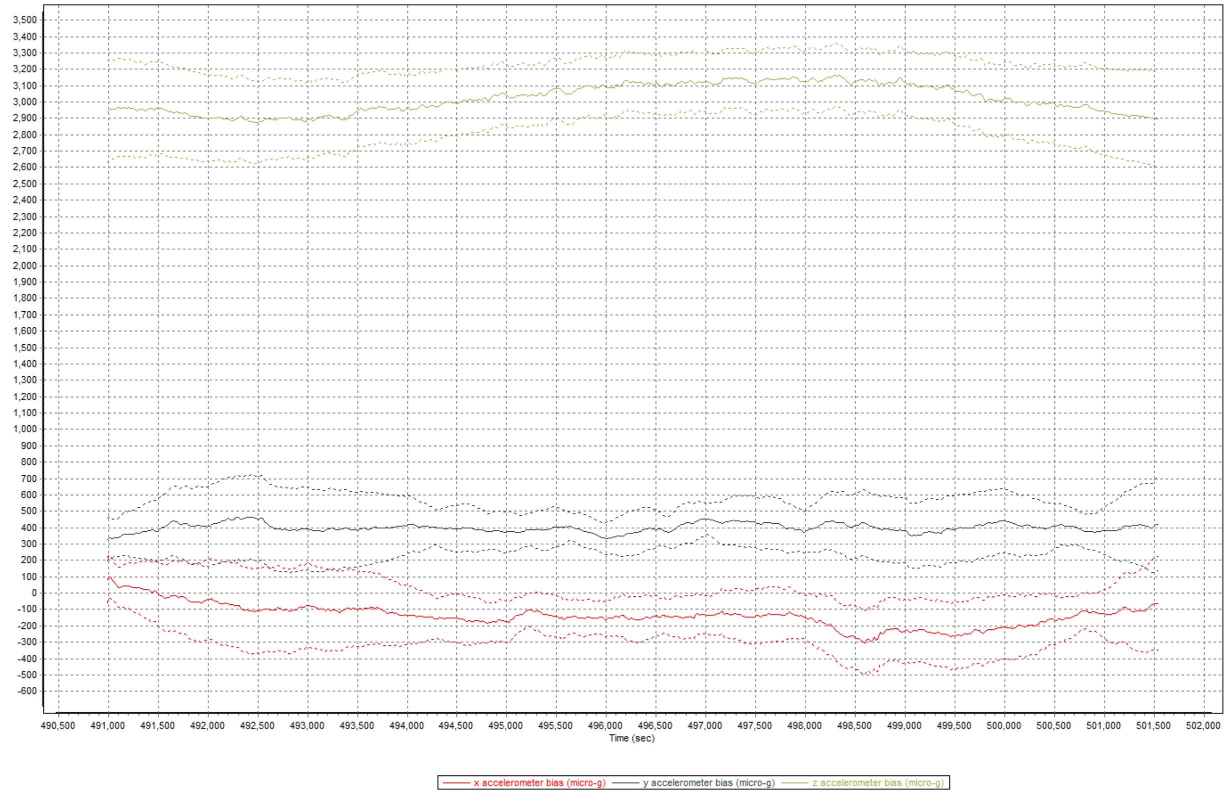
498,500
499,000
499,500
500,000
500,500
501,000
501,500
502,000
Time (sec)
— Forward
-- Reverse
0 = Fixed NL, 1 = Fixed WL, 2 = Float, 3 = DGNSS, 4 = RTCM, 5 = IAPPP, 6 = C/A, 7 = GNSS Nav, 8 = DR

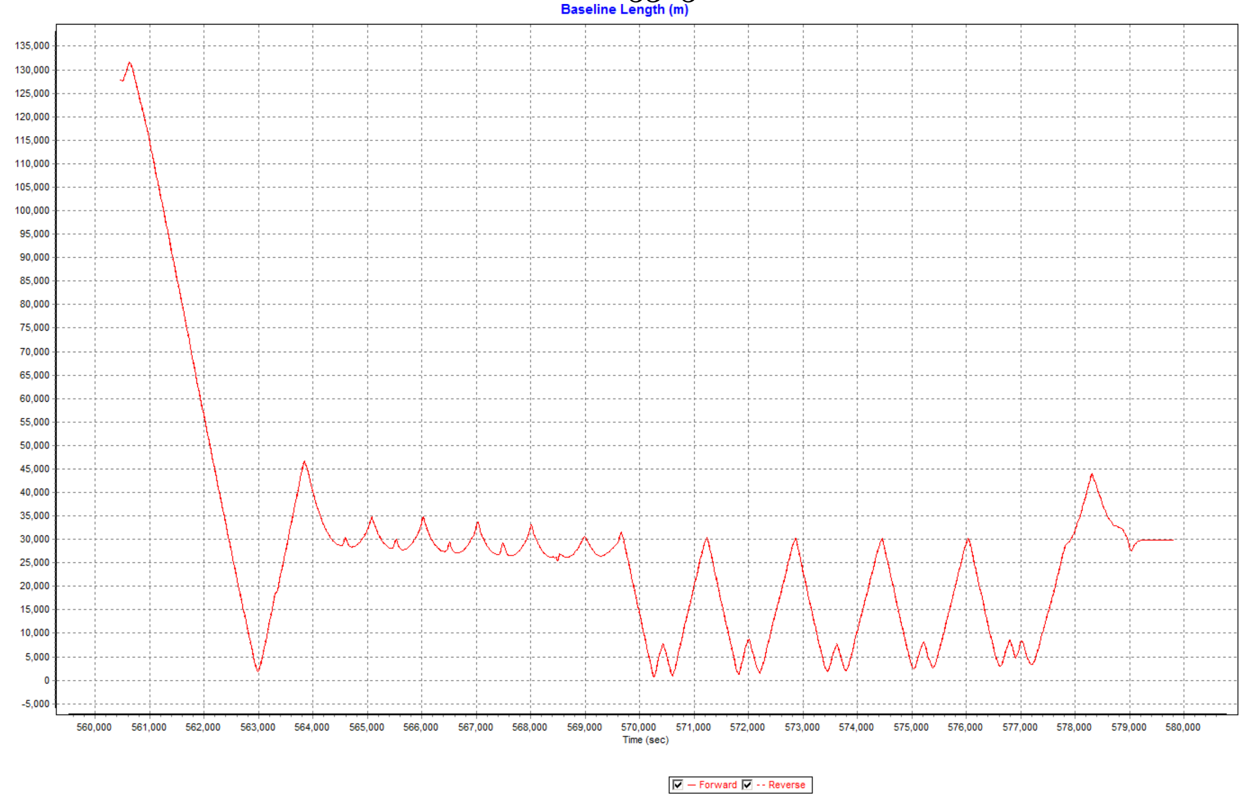

Time (sec)
North Position Error RMS (m)
East Position Error RMS (m)
Down Position Error RMS (m)

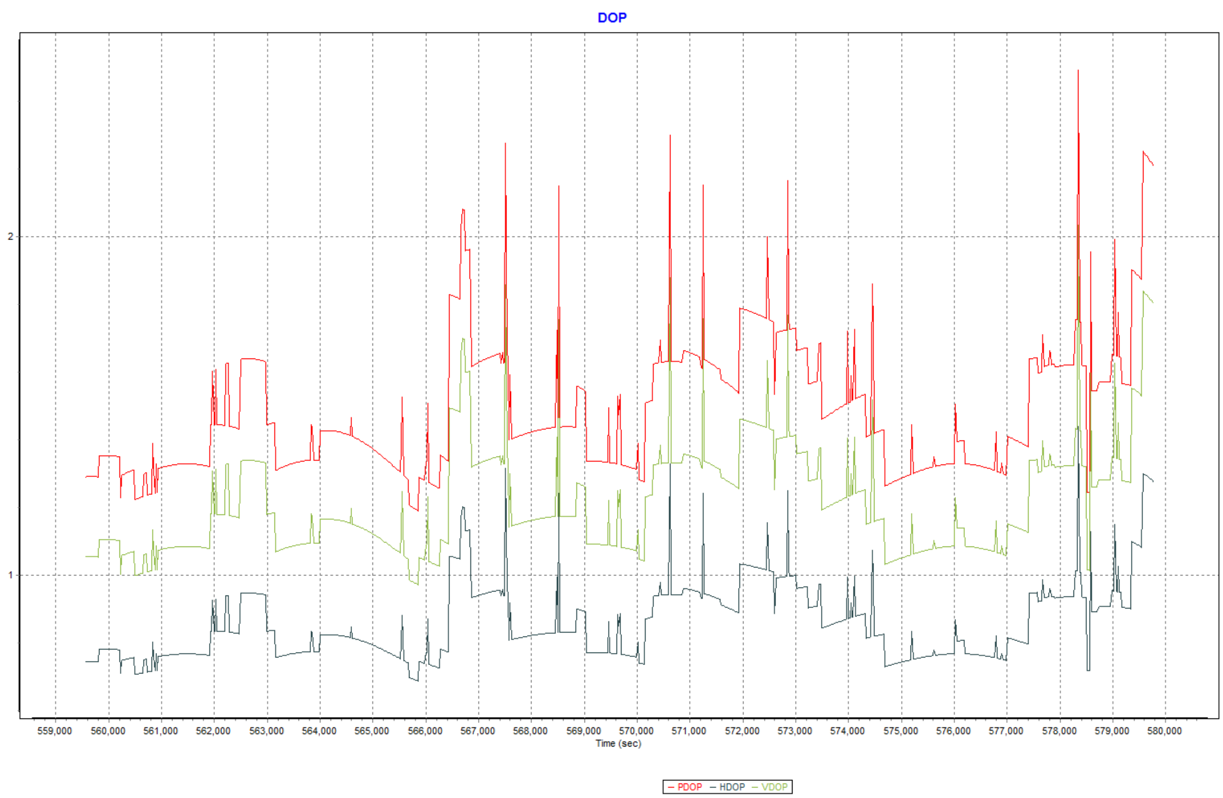

Number of GPS Satellites
Time (sec)
Forward
Reverse

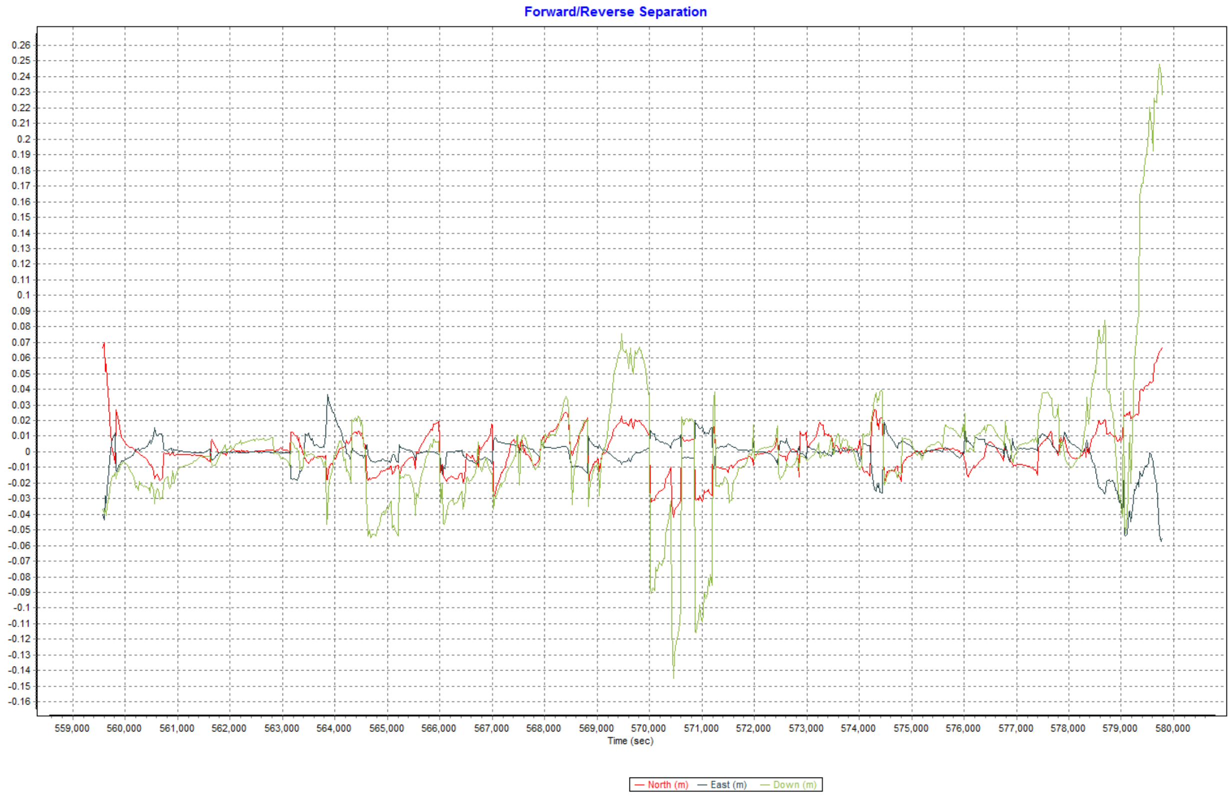

LOYY
150000
LOYJ
LOYA
100000
Post-processed (SBET)
Real-time Reference Frame (RNAV)
LOYP
LOYI
SmartBase Region
50000
LOY3
0
20000 m
Start
-150000
-100000
-50000
0


3,500
3,400
3,300
3,200
3,100
3,000
2,900
2,800
2,700
2,600
2,500
2,400
2,300
2,200
2,100
2,000
1,900
1,800
1,700
1,600
1,500
1,400
1,300
1,200
1,100
1,000
900
800
700
600
500
400
300
200
100
0
-100
-200
-300
-400
-500
-600
490,500
491,000
491,500
492,000
492,500
493,000
493,500
494,000
494,500
495,000
495,500
496,000
496,500
497,000
497,500
498,000
498,500
499,000
499,500
500,000
500,500
501,000
501,500
502,000
Time (sec)
x accelerometer bias (micro-g)
y accelerometer bias (micro-g)
z accelerometer bias (micro-g)

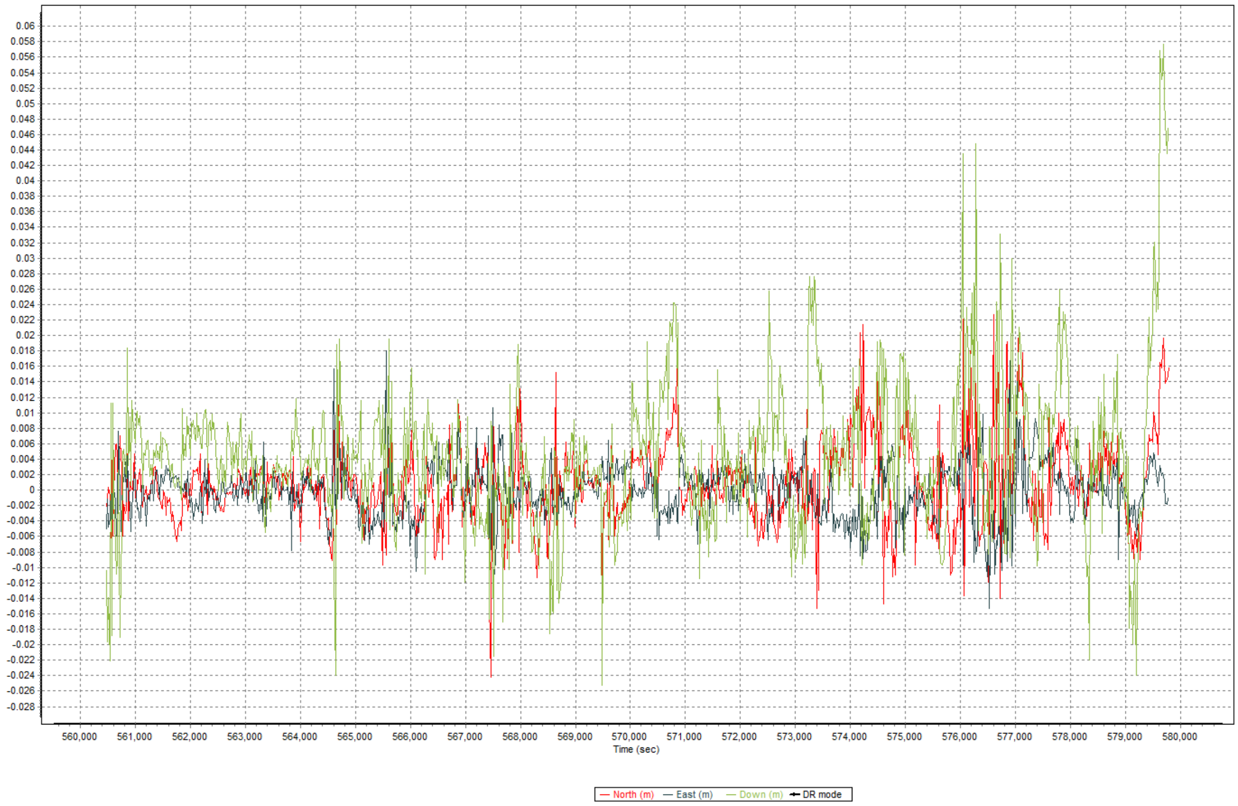
MNB15325A

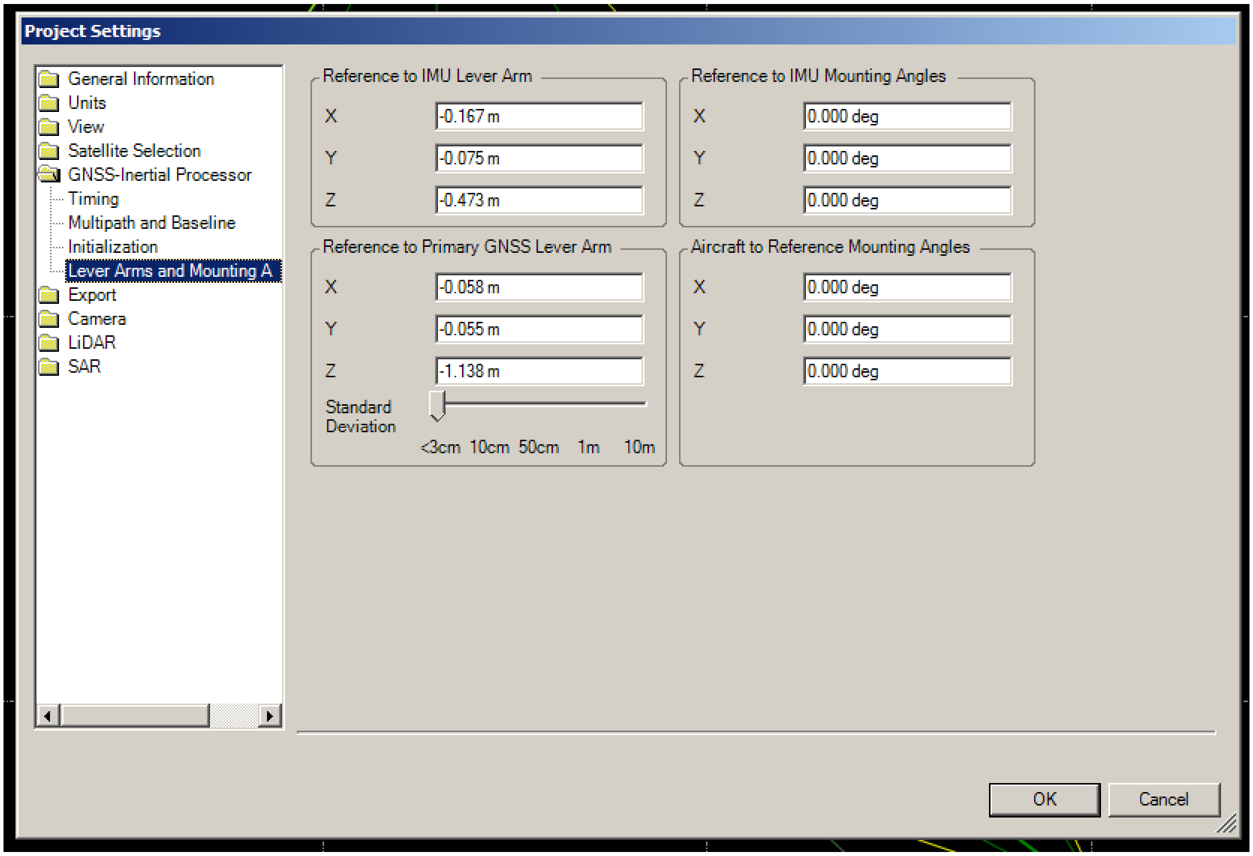

Baseline Length (m)
Time (sec)
Forward
Reverse

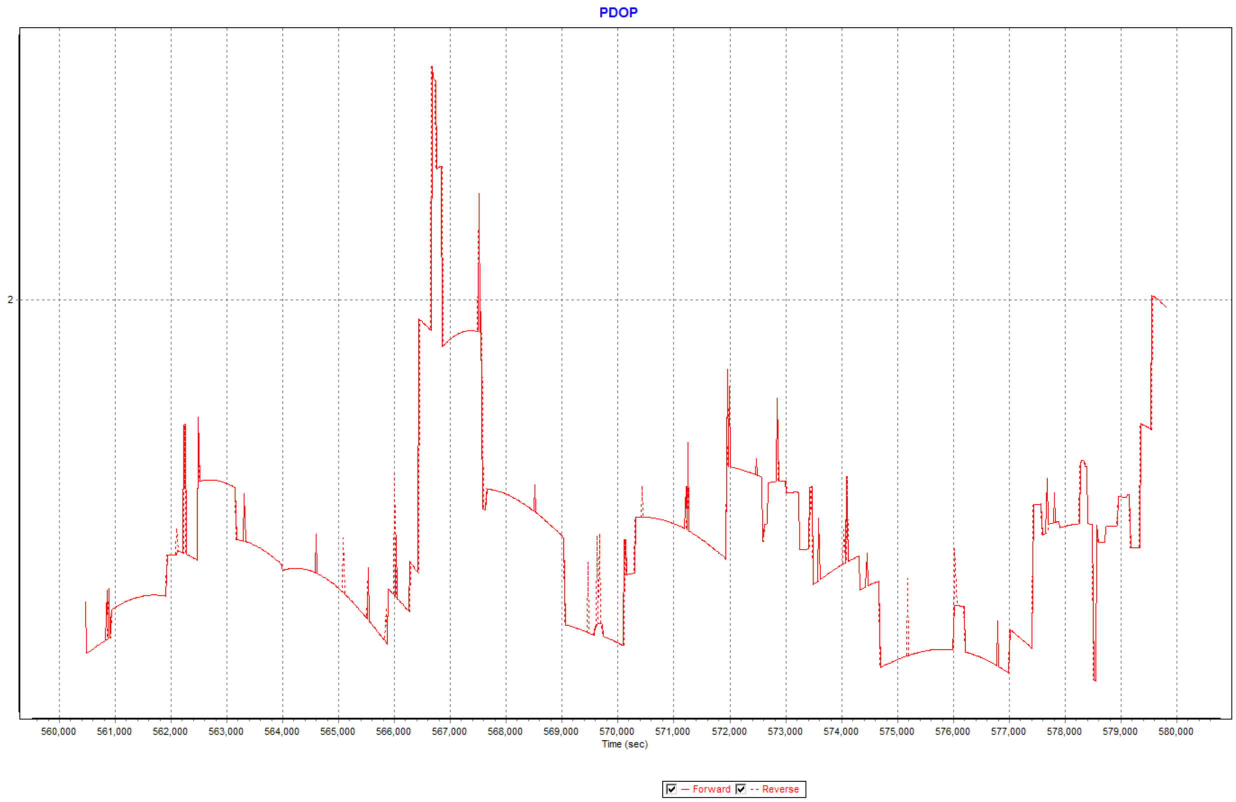

DOP
Time (sec)
PDOP
HDOP
VDOP

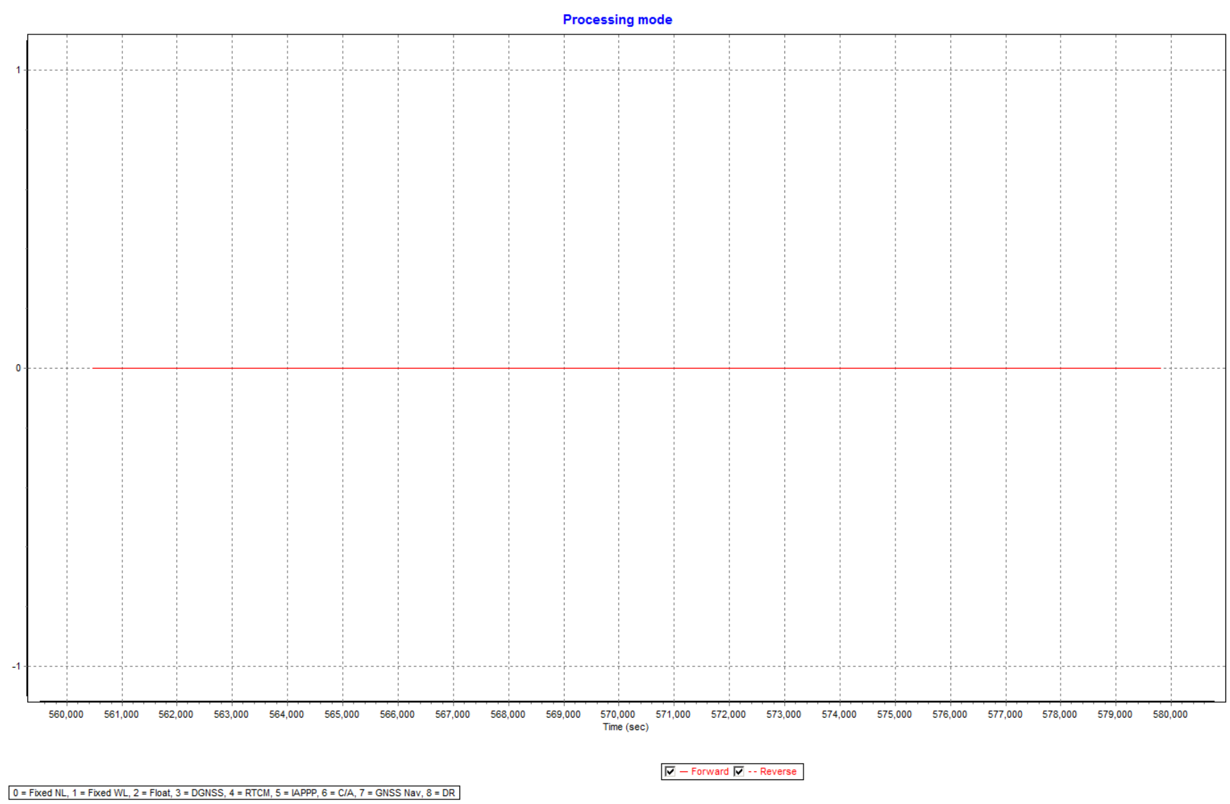

Forward/Reverse Separation
Time (sec)
North (m)
East (m)
Down (m)

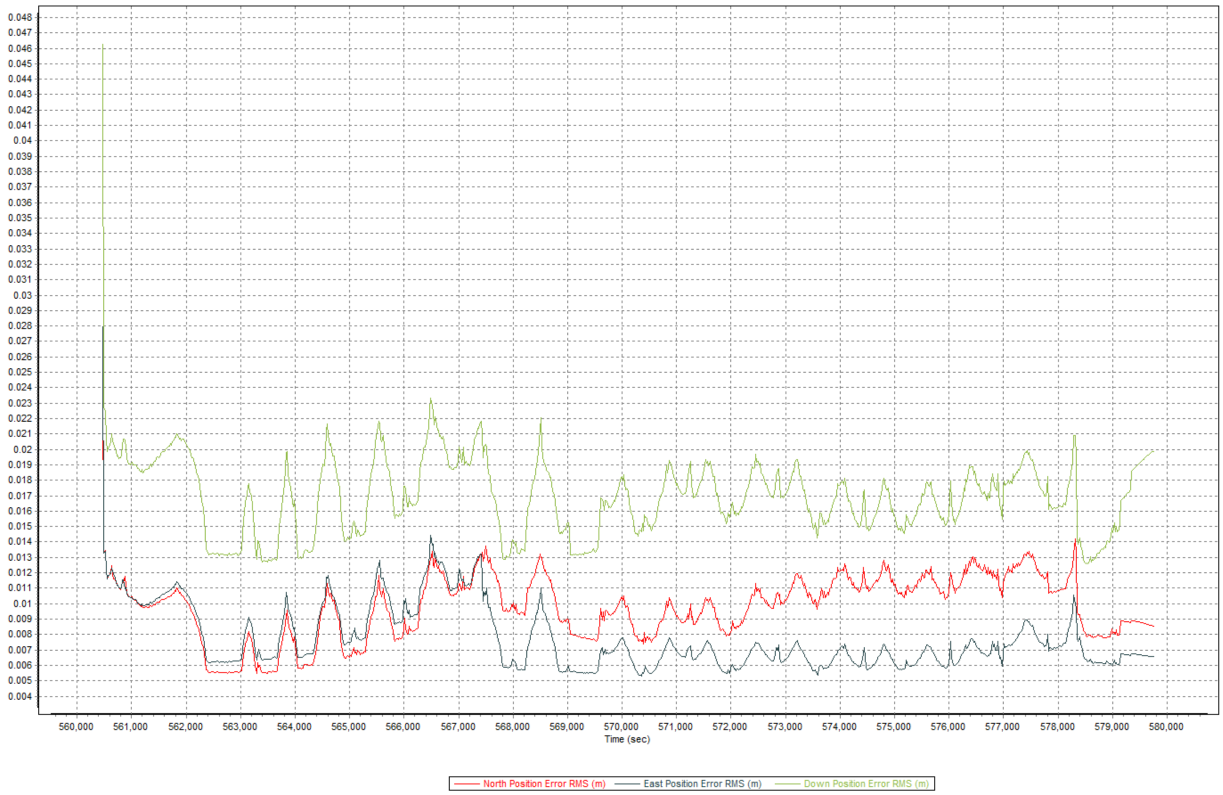

Number of GLONASS Satellites
Time (sec)
Forward
Reverse

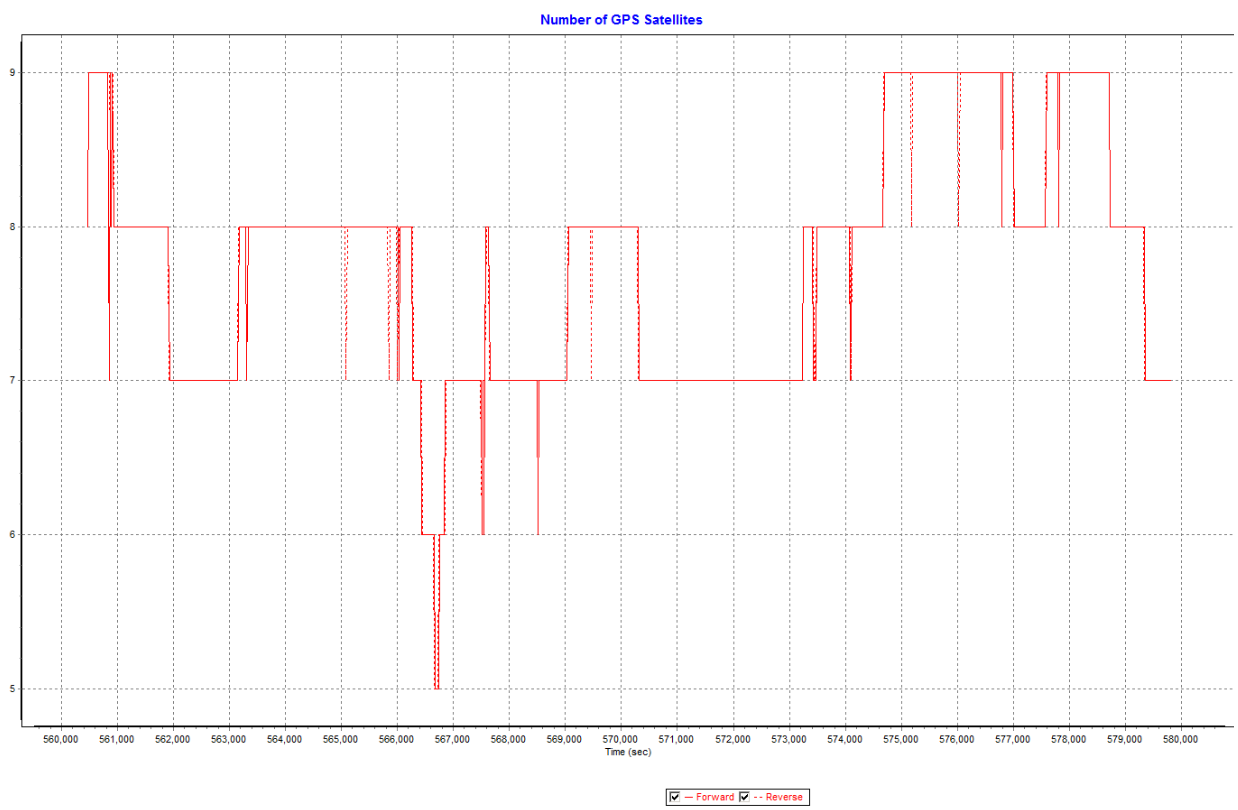

0.06
0.058
0.056
0.054
0.052
0.05
0.048
0.046
0.044
0.042
0.04
0.038
0.036
0.034
0.032
0.03
0.028
0.026
0.024
0.022
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
-0.002
-0.004
-0.006
-0.008
-0.01
-0.012
-0.014
-0.016
-0.018
-0.02
-0.022
-0.024
-0.026
-0.028
560,000
561,000
562,000
563,000
564,000
565,000
566,000
567,000
568,000
569,000
570,000
571,000
572,000
573,000
574,000
575,000
576,000
577,000
578,000
579,000
580,000
Time (sec)
North (m)
East (m)
Down (m)
DR mode

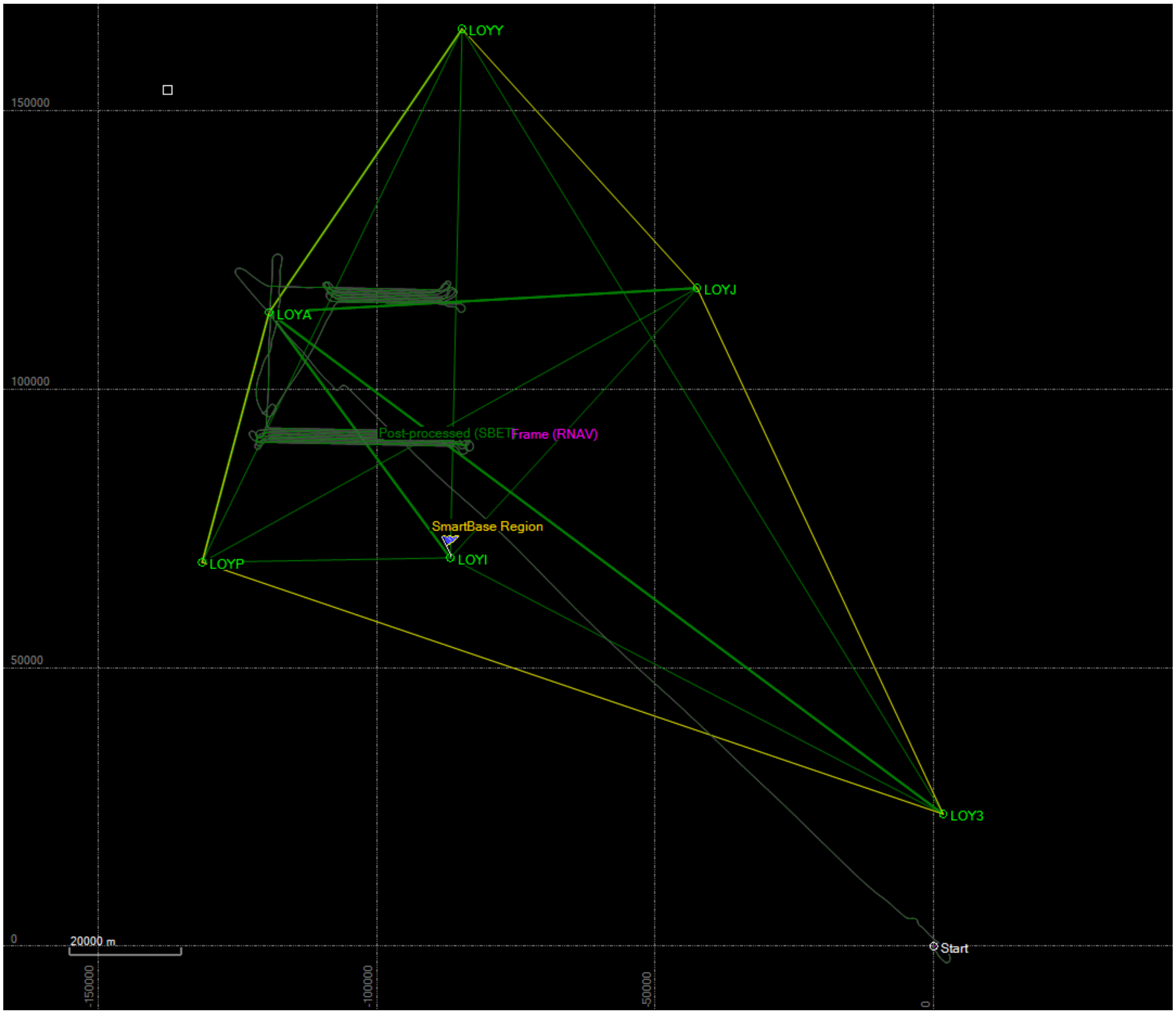

Project Settings
General Information
Units
View
Satellite Selection
GNSS-Inertial Processor
Timing
Multipath and Baseline
Initialization
Lever Arms and Mounting A
Export
Camera
LiDAR
SAR
Reference to IMU Lever Arm
X -0.167 m
Y -0.075 m
Z -0.473 m
Reference to IMU Mounting Angles
X 0.000 deg
Y 0.000 deg
Z 0.000 deg
Reference to Primary GNSS Lever Arm
X -0.058 m
Y -0.055 m
Z -1.138 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

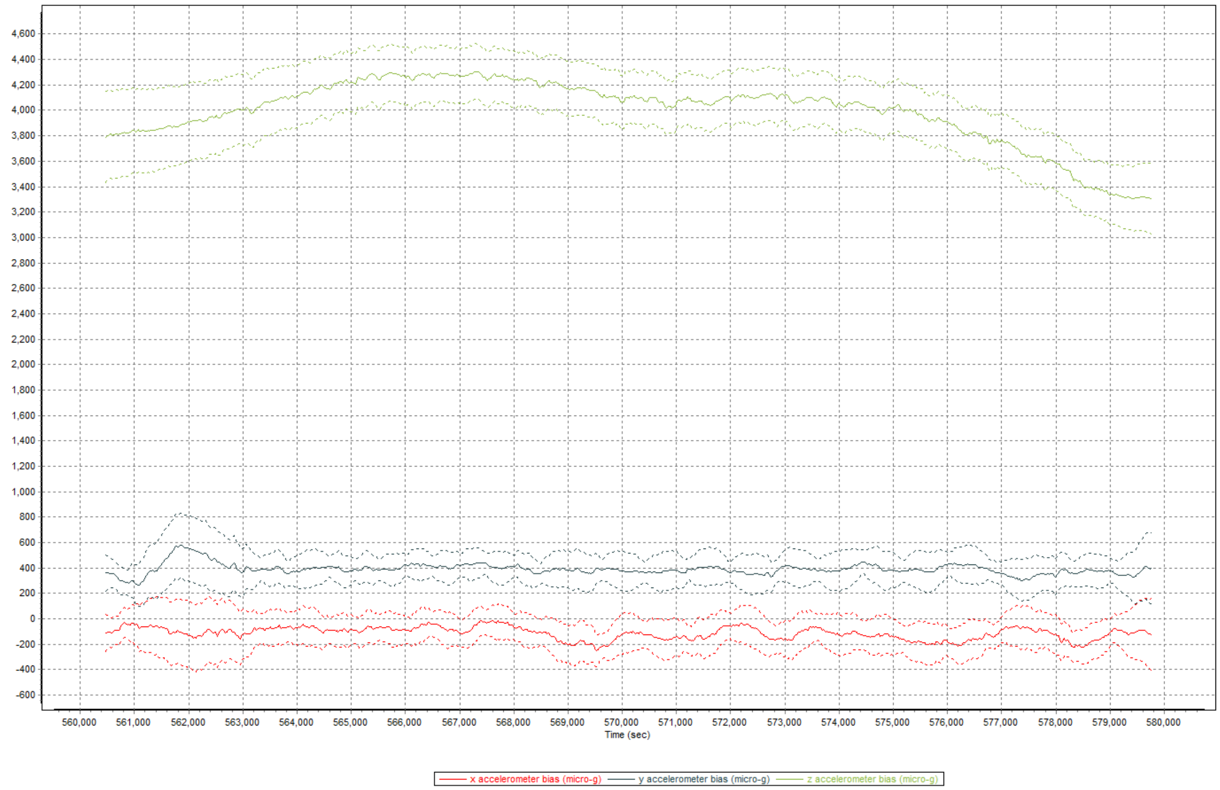

PDOP
2
560,000
561,000
562,000
563,000
564,000
565,000
566,000
567,000
568,000
569,000
570,000
571,000
572,000
573,000
574,000
575,000
576,000
577,000
578,000
579,000
580,000
Time (sec)
— Forward
-- Reverse

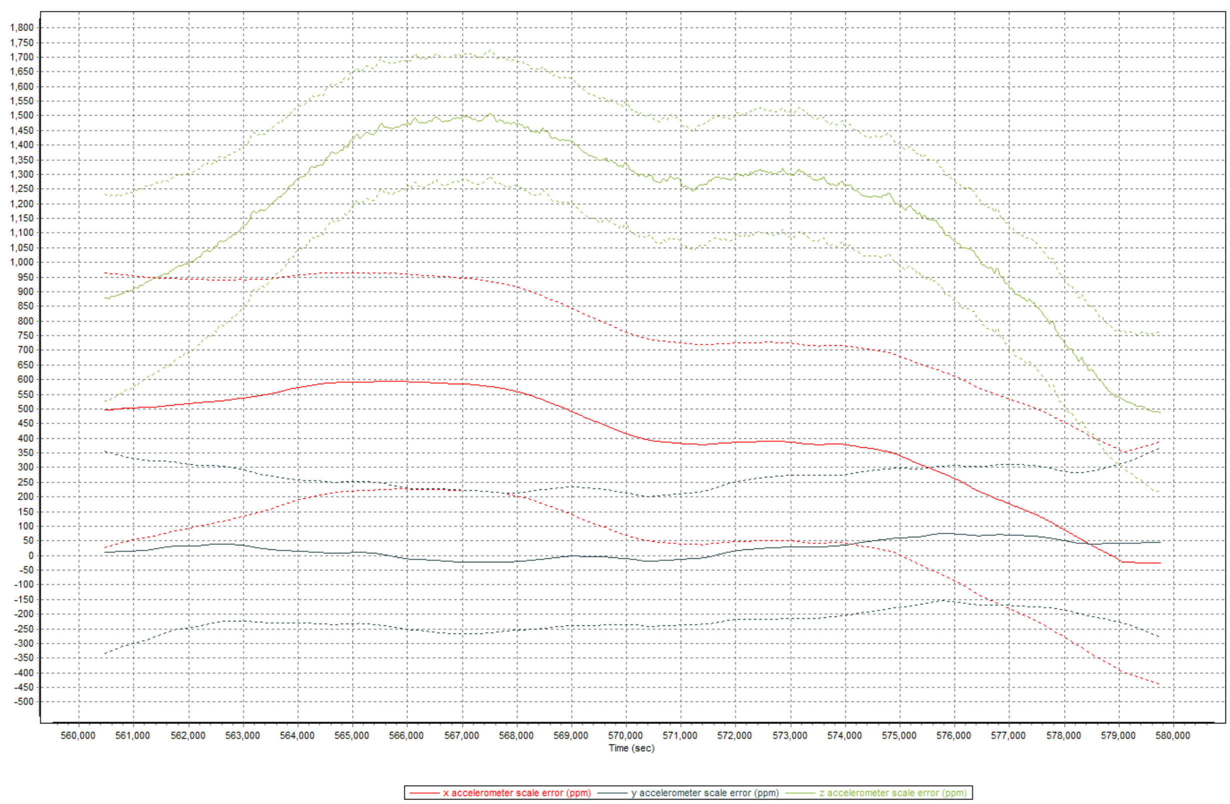

Processing mode
1
0
-1
560,000
561,000
562,000
563,000
564,000
565,000
566,000
567,000
568,000
569,000
570,000
571,000
572,000
573,000
574,000
575,000
576,000
577,000
578,000
579,000
580,000
Time (sec)
— Forward
-- Reverse
0 = Fixed NL, 1 = Fixed WL, 2 = Float, 3 = DGNSS, 4 = RTCM, 5 = IAPPP, 6 = C/A, 7 = GNSS Nav, 8 = DR

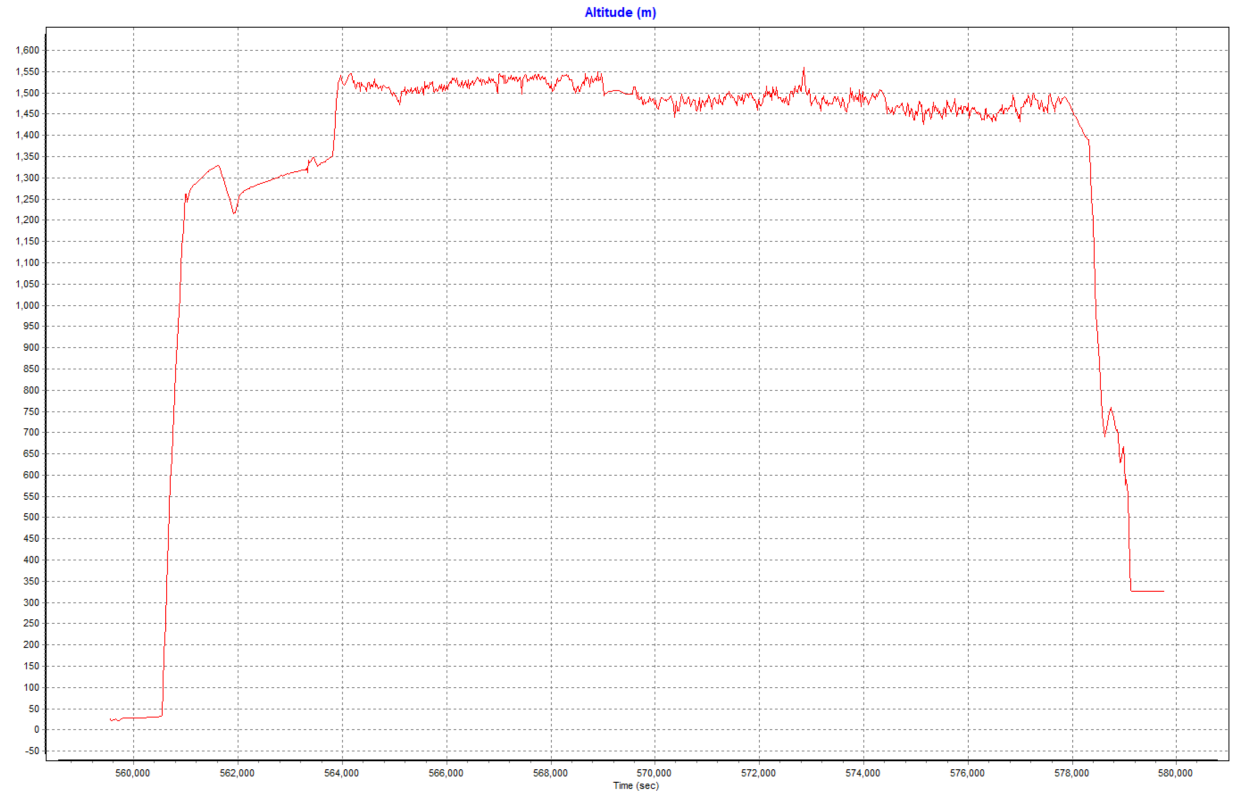

Time (sec)
North Position Error RMS (m)
East Position Error RMS (m)
Down Position Error RMS (m)


Number of GPS Satellites
Time (sec)
Forward
Reverse

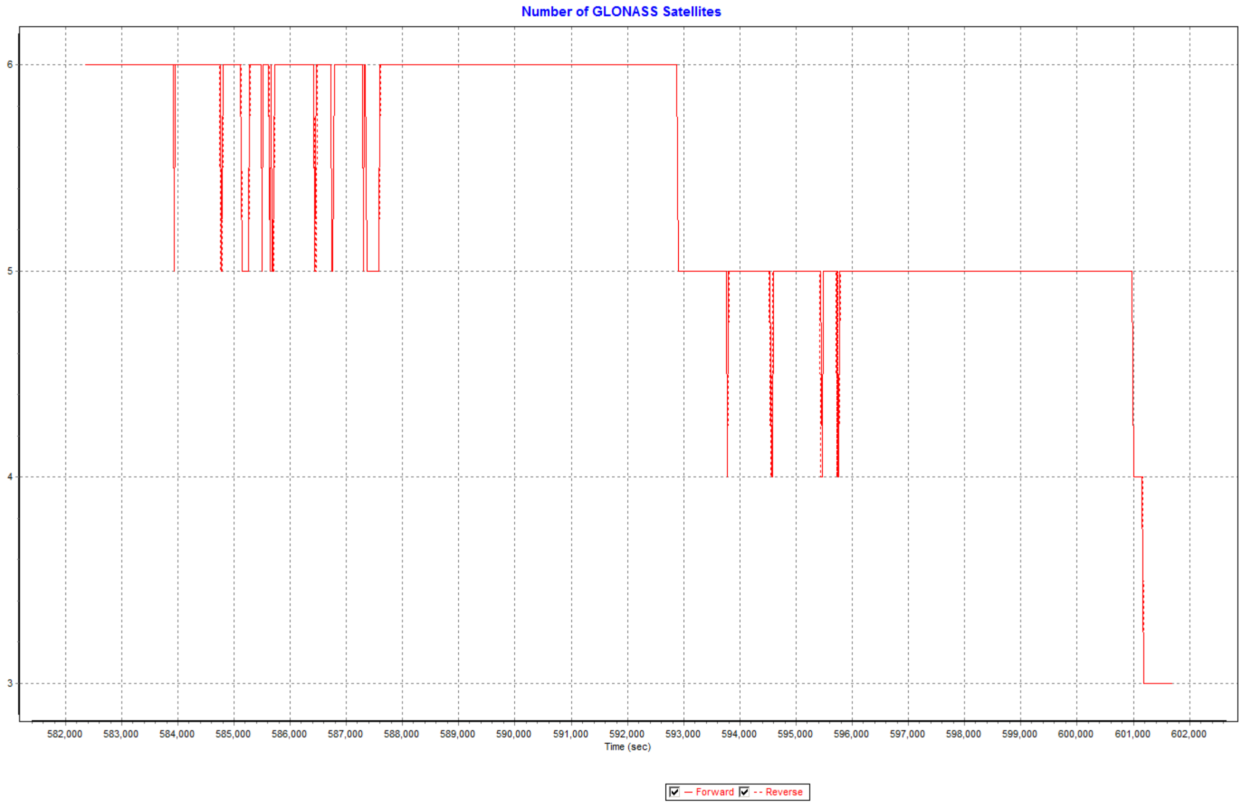

LOYY
150000
LOYJ
LOYA
100000
Post-processed (SBET)
Frame (RNAV)
SmartBase Region
LOYP
LOYI
50000
LOY3
0
20000 m
Start
-150000
-100000
-50000
0

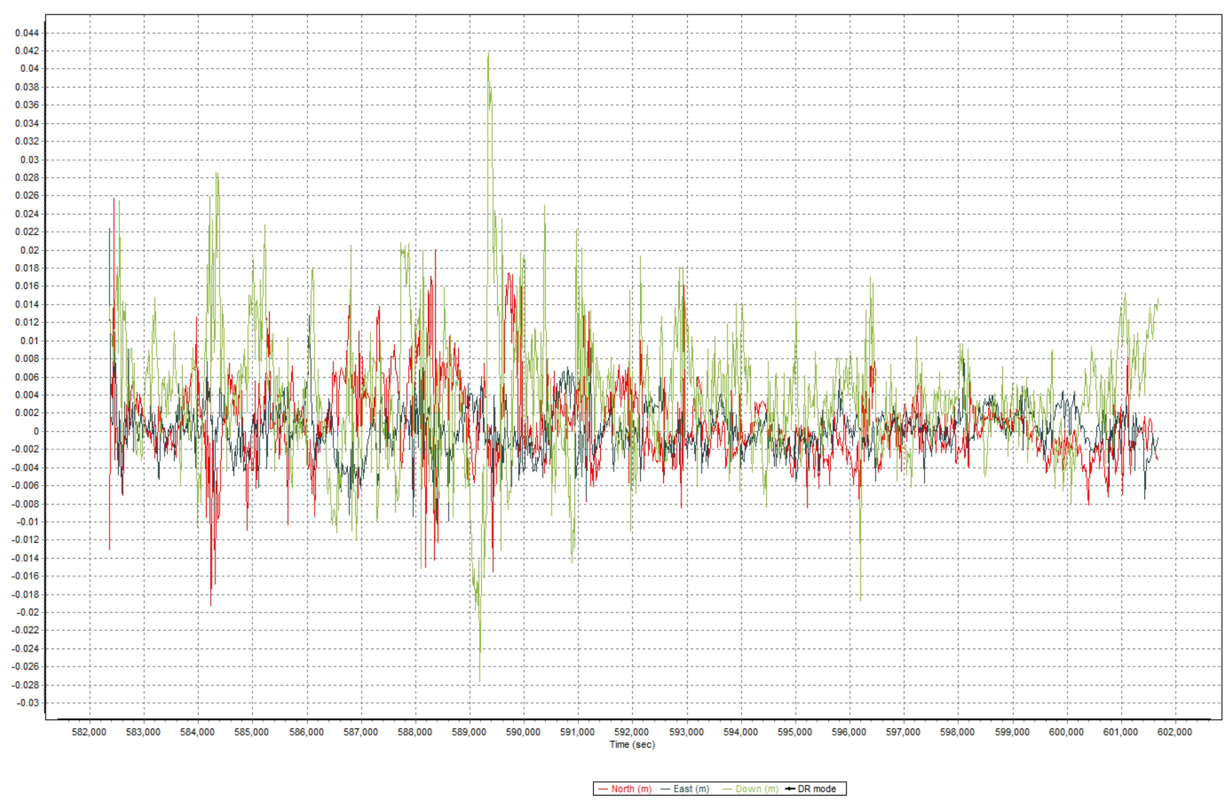

Time (sec)
x accelerometer bias (micro-g)
y accelerometer bias (micro-g)
z accelerometer bias (micro-g)

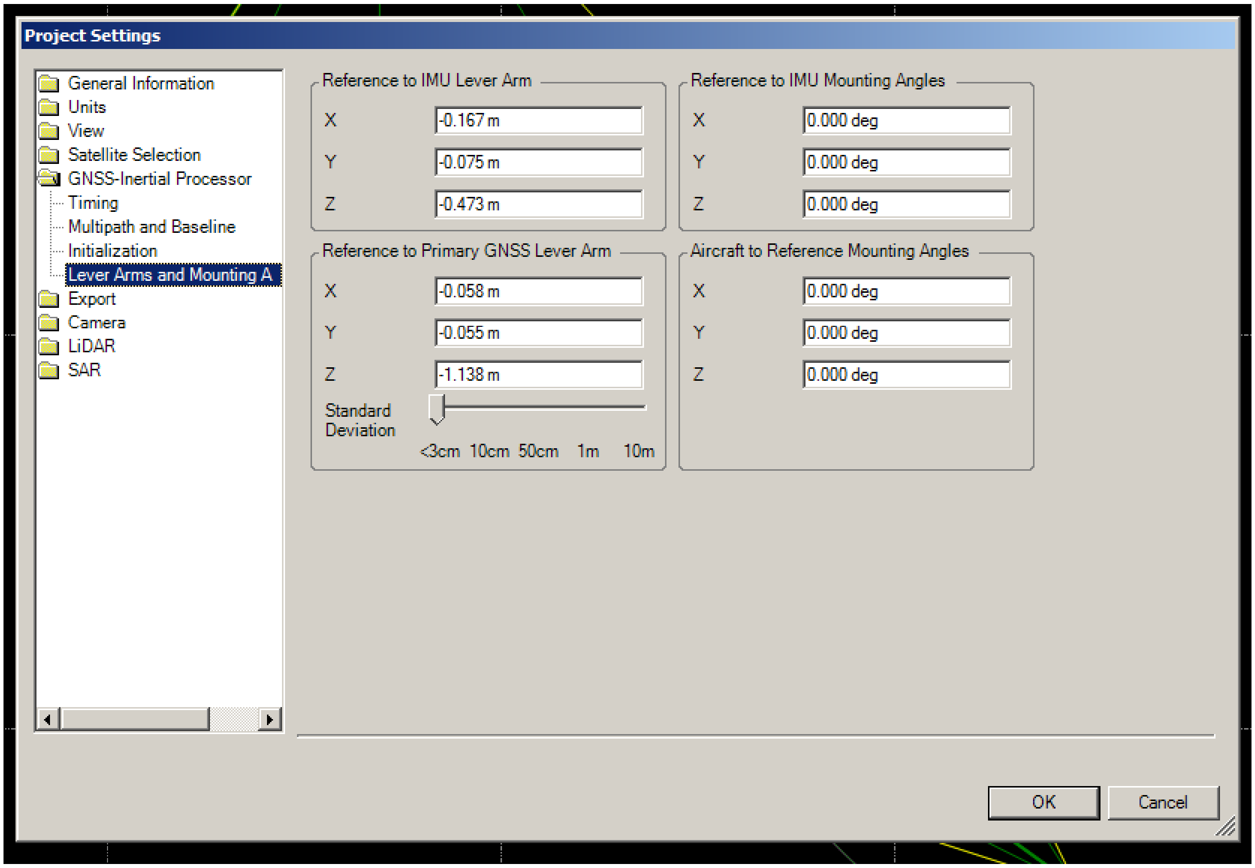

Time (sec)
x accelerometer scale error (ppm)
y accelerometer scale error (ppm)
z accelerometer scale error (ppm)

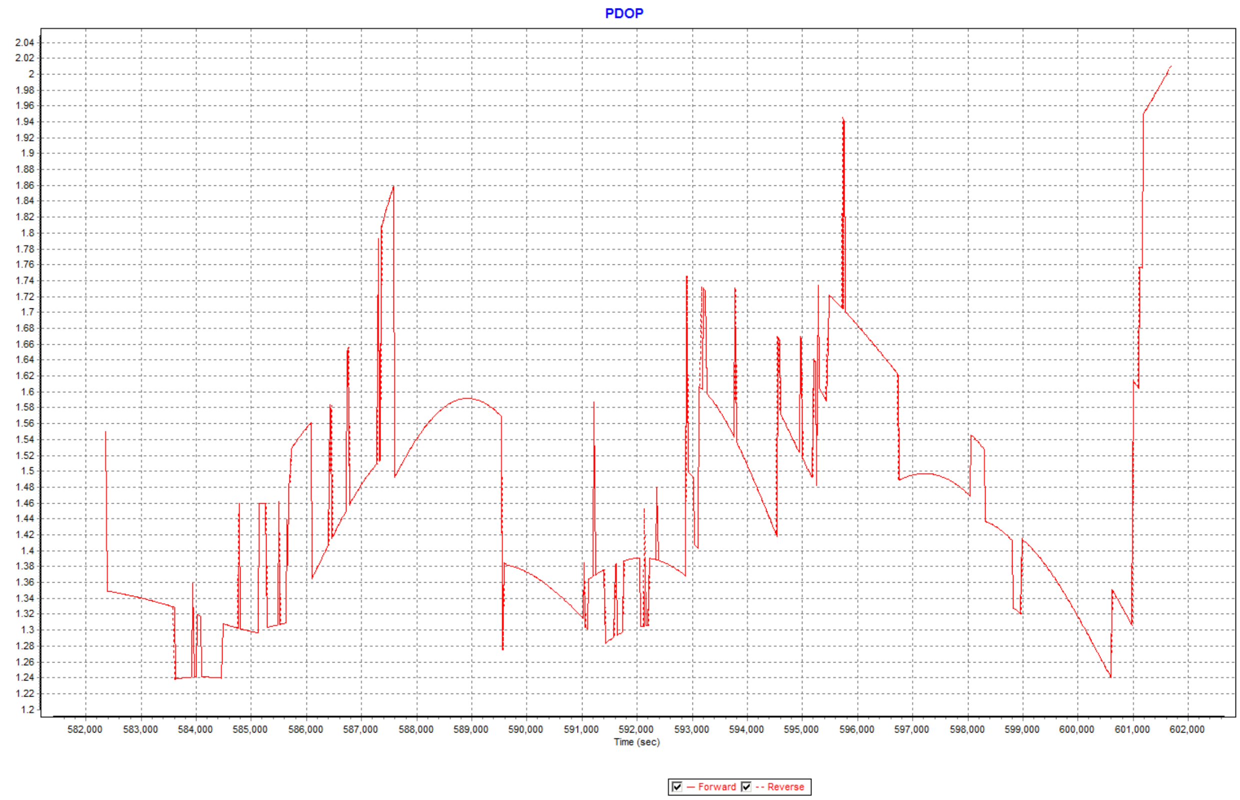

Altitude (m)
1,600
1,550
1,500
1,450
1,400
1,350
1,300
1,250
1,200
1,150
1,100
1,050
1,000
950
900
850
800
750
700
650
600
550
500
450
400
350
300
250
200
150
100
50
0
-50
560,000
562,000
564,000
566,000
568,000
570,000
572,000
574,000
576,000
578,000
580,000
Time (sec)

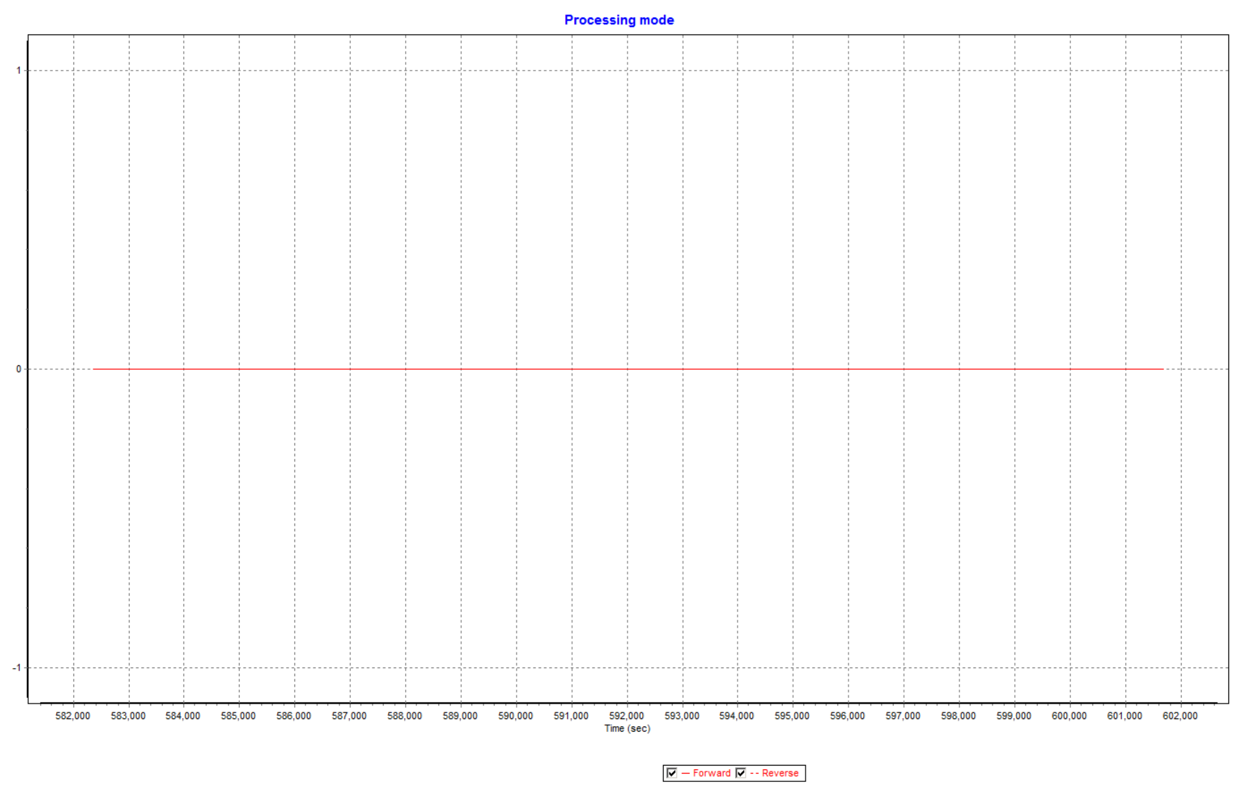
MNB15325B

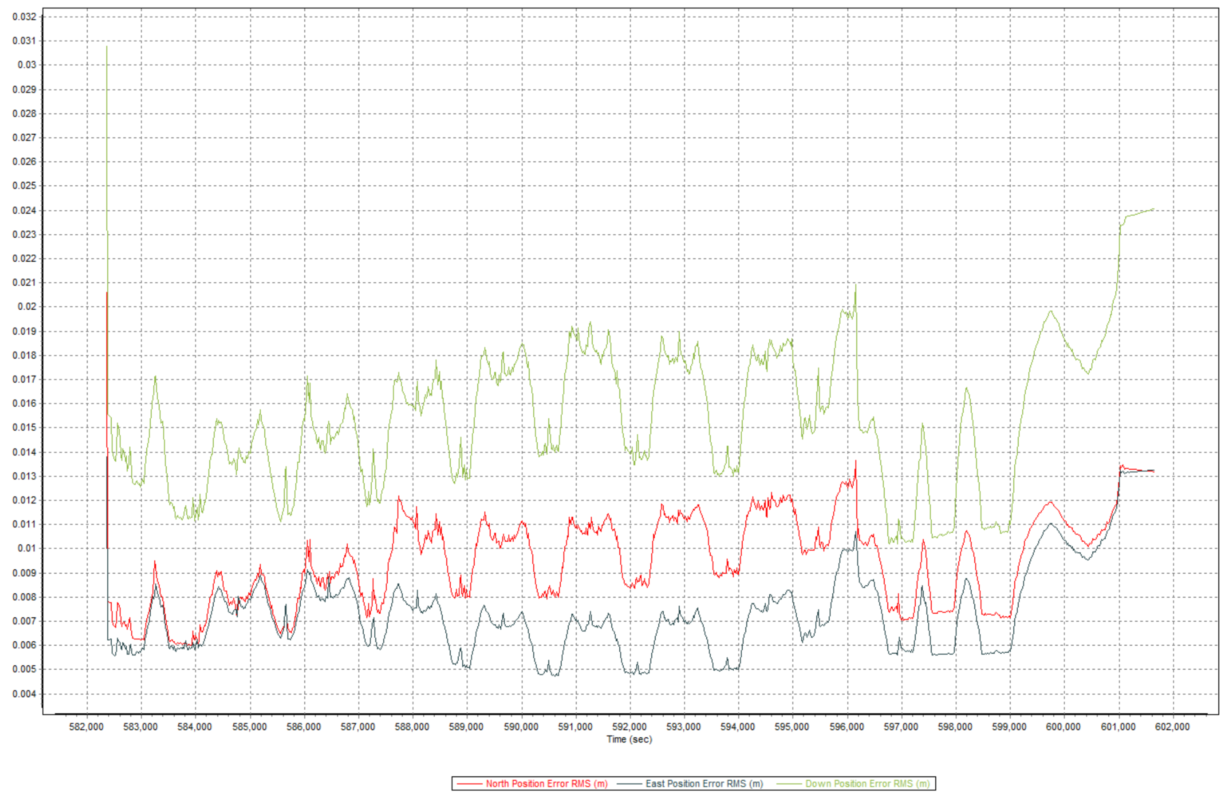

Number of GLONASS Satellites
6
5
4
3
582,000
583,000
584,000
585,000
586,000
587,000
588,000
589,000
590,000
591,000
592,000
593,000
594,000
595,000
596,000
597,000
598,000
599,000
600,000
601,000
602,000
Time (sec)
— Forward
-- Reverse

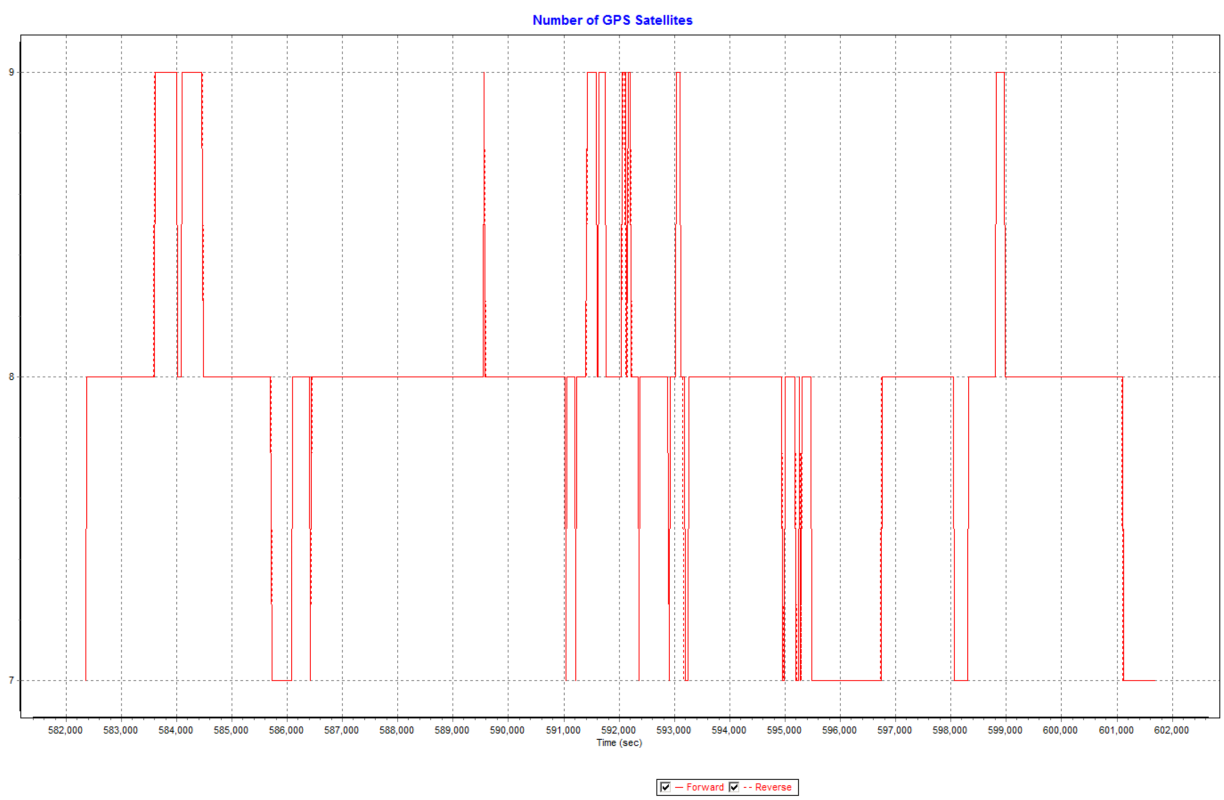

0.044
0.042
0.04
0.038
0.036
0.034
0.032
0.03
0.028
0.026
0.024
0.022
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
-0.002
-0.004
-0.006
-0.008
-0.01
-0.012
-0.014
-0.016
-0.018
-0.02
-0.022
-0.024
-0.026
-0.028
-0.03
582,000
583,000
584,000
585,000
586,000
587,000
588,000
589,000
590,000
591,000
592,000
593,000
594,000
595,000
596,000
597,000
598,000
599,000
600,000
601,000
602,000
Time (sec)
North (m)
East (m)
Down (m)
DR mode


Project Settings
General Information
Units
View
Satellite Selection
GNSS-Inertial Processor
Timing
Multipath and Baseline
Initialization
Lever Arms and Mounting A
Export
Camera
LiDAR
SAR
Reference to IMU Lever Arm
X -0.167 m
Y -0.075 m
Z -0.473 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 -0.058 m
Y -0.055 m
Z -1.138 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


PDOP
2.04
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
582,000
583,000
584,000
585,000
586,000
587,000
588,000
589,000
590,000
591,000
592,000
593,000
594,000
595,000
596,000
597,000
598,000
599,000
600,000
601,000
602,000
Time (sec)
— Forward
-- Reverse


Processing mode
1
0
-1
582,000
583,000
584,000
585,000
586,000
587,000
588,000
589,000
590,000
591,000
592,000
593,000
594,000
595,000
596,000
597,000
598,000
599,000
600,000
601,000
602,000
Time (sec)
— Forward
-- Reverse
0 = Fixed NL 1 = Fixed WL 2 = Float 3 = DGNSS 4 = RTCM 5 = IAPPP 6 = C/A 7 = GNSS Nav 8 = DR


0.032
0.031
0.03
0.029
0.028
0.027
0.026
0.025
0.024
0.023
0.022
0.021
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
582,000
583,000
584,000
585,000
586,000
587,000
588,000
589,000
590,000
591,000
592,000
593,000
594,000
595,000
596,000
597,000
598,000
599,000
600,000
601,000
602,000
Time (sec)
North Position Error RMS (m)
East Position Error RMS (m)
Down Position Error RMS (m)


Number of GPS Satellites
9
8
7
582,000
583,000
584,000
585,000
586,000
587,000
588,000
589,000
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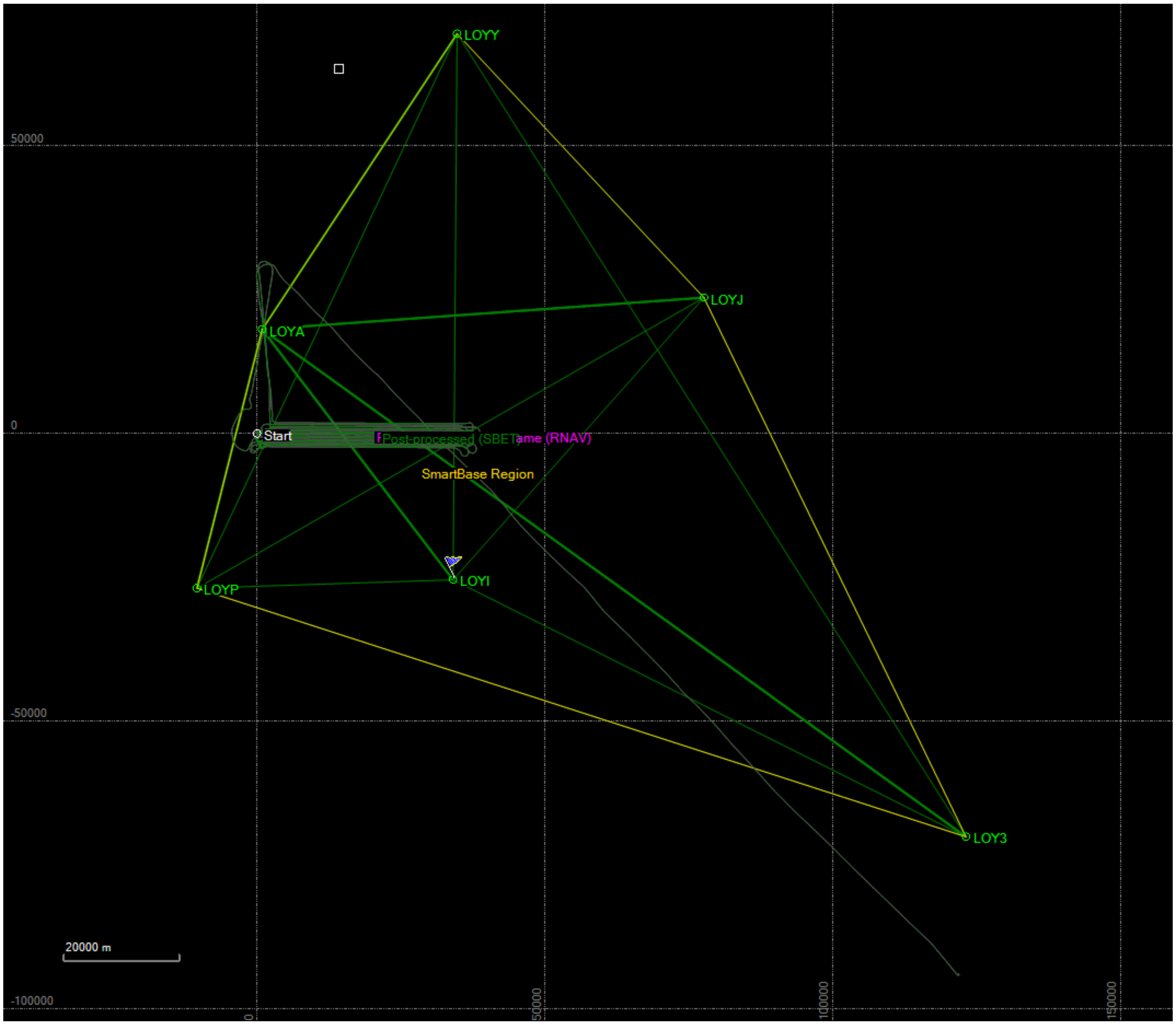
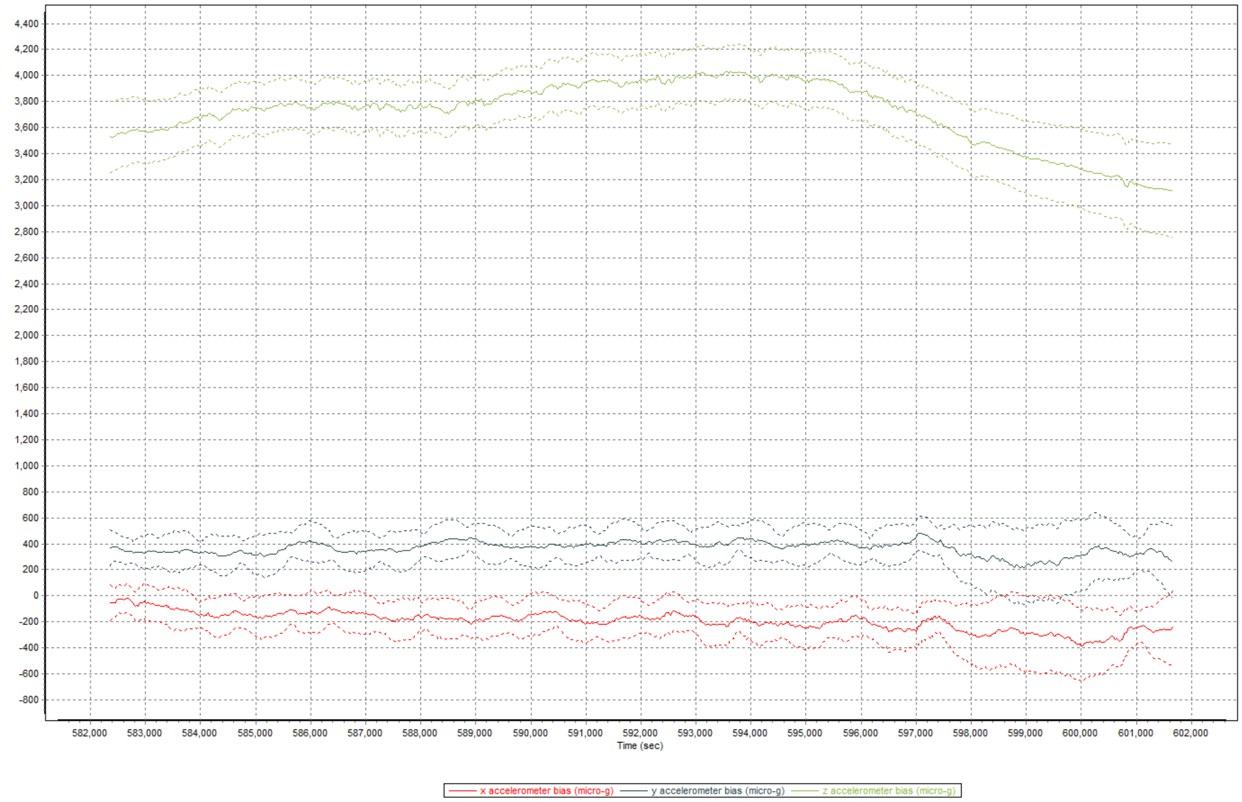
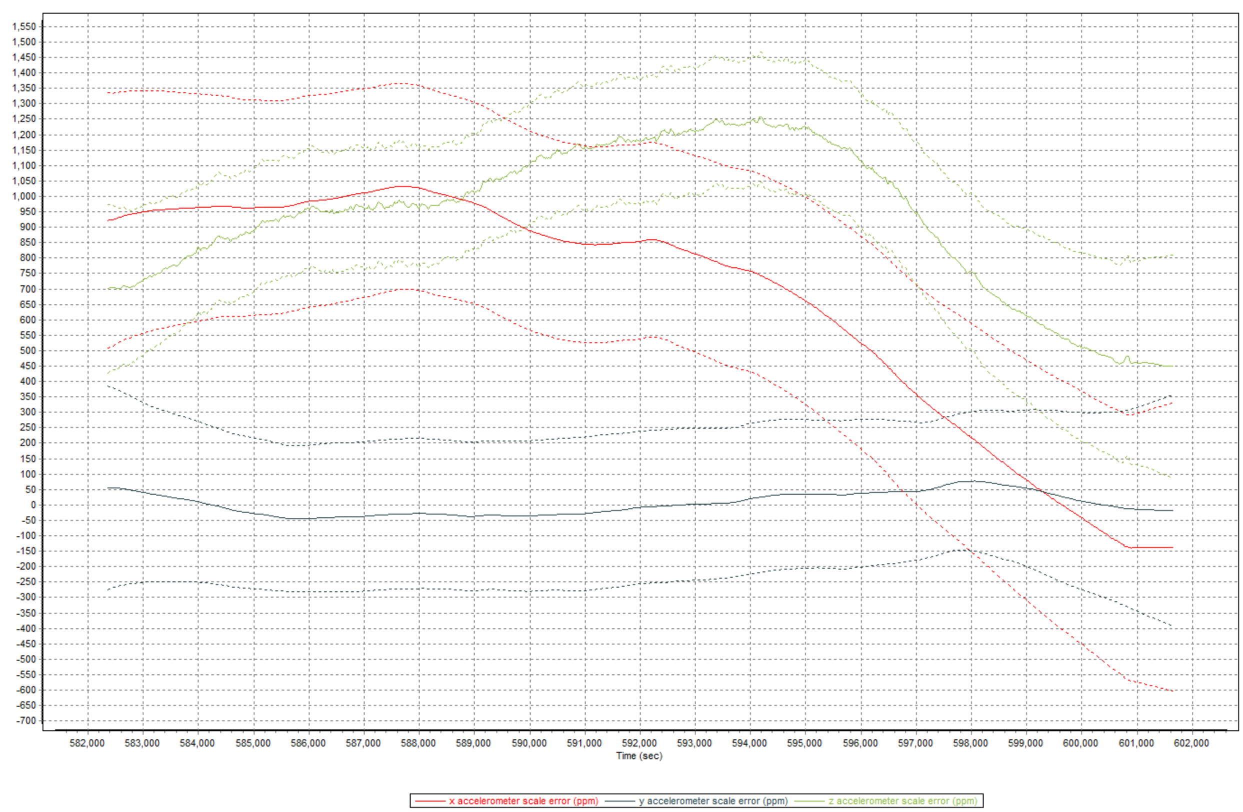
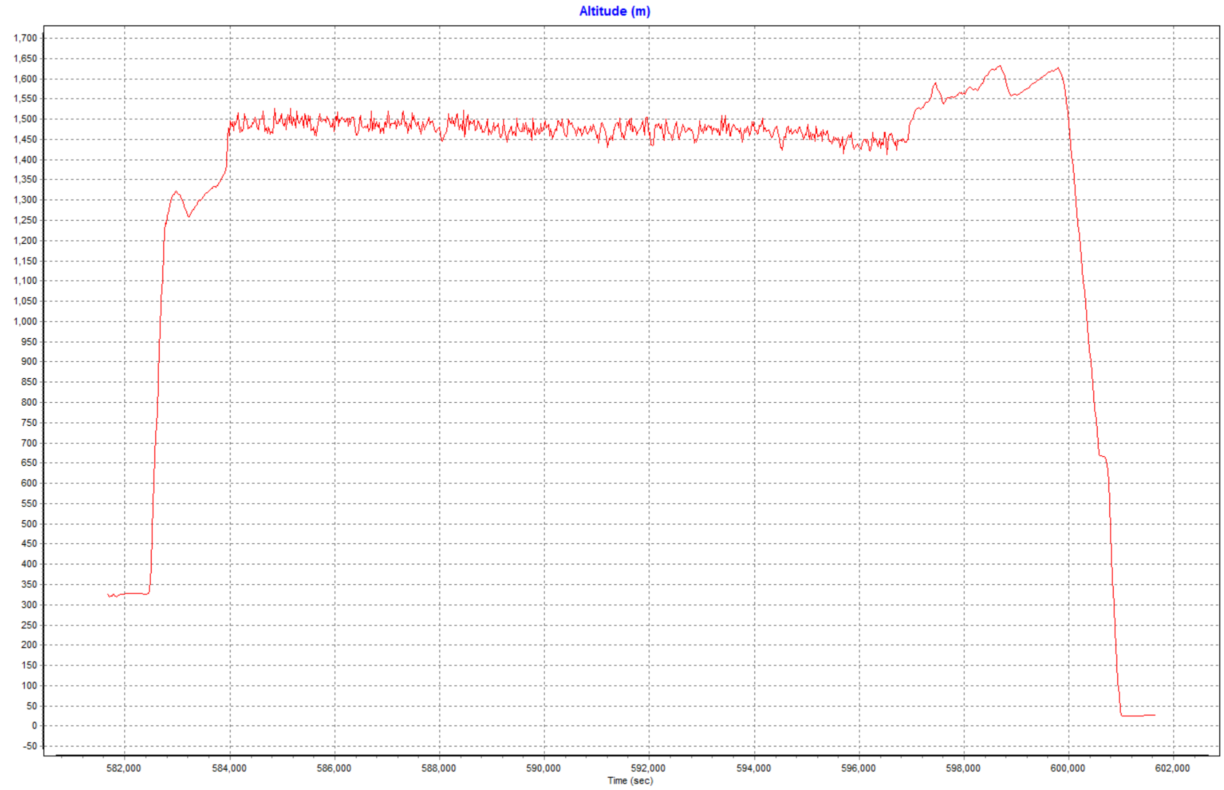
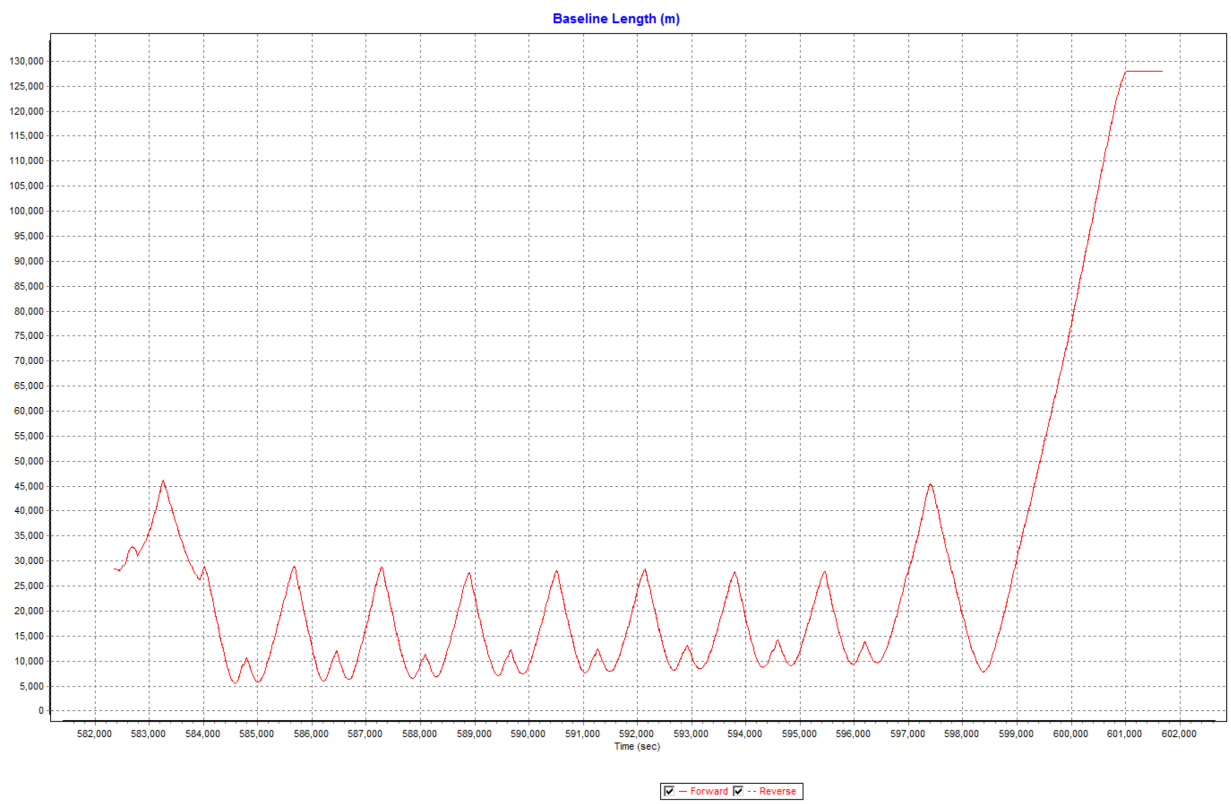
591,000
592,000
593,000
594,000
595,000
596,000
597,000
598,000
599,000
600,000
601,000
602,000
Time (sec)
Forward
Reverse

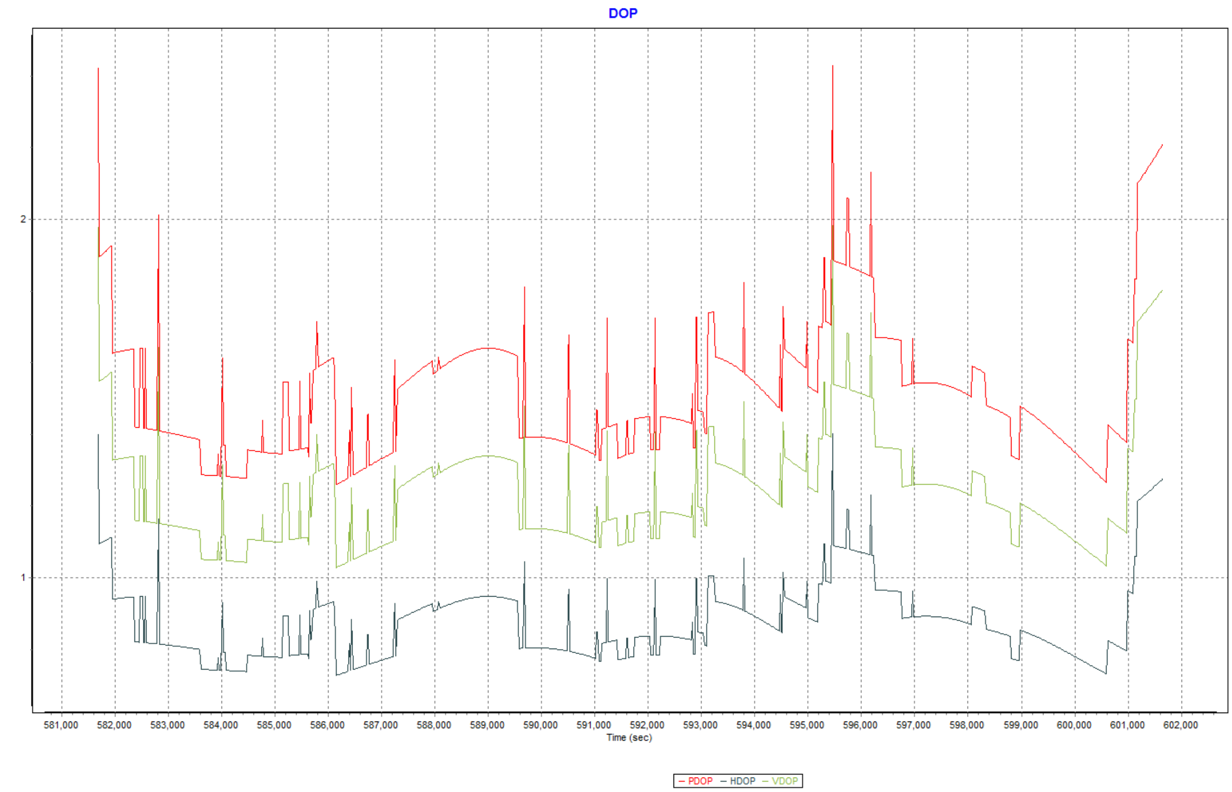

LOYY
50000
LOYJ
LOYA
0
Start
Post-processed (SBET
ame (RNAV)
SmartBase Region
LOYP
LOYI
-50000
LOY3
20000 m
-100000
0
50000
100000
150000


Time (sec)
x accelerometer bias (micro-g)
y accelerometer bias (micro-g)
z accelerometer bias (micro-g)


Time (sec)
x accelerometer scale error (ppm)
y accelerometer scale error (ppm)
z accelerometer scale error (ppm)


Altitude (m)
Time (sec)


Baseline Length (m)
Time (sec)
Forward
Reverse


DOP
2
1
581,000
582,000
583,000
584,000
585,000
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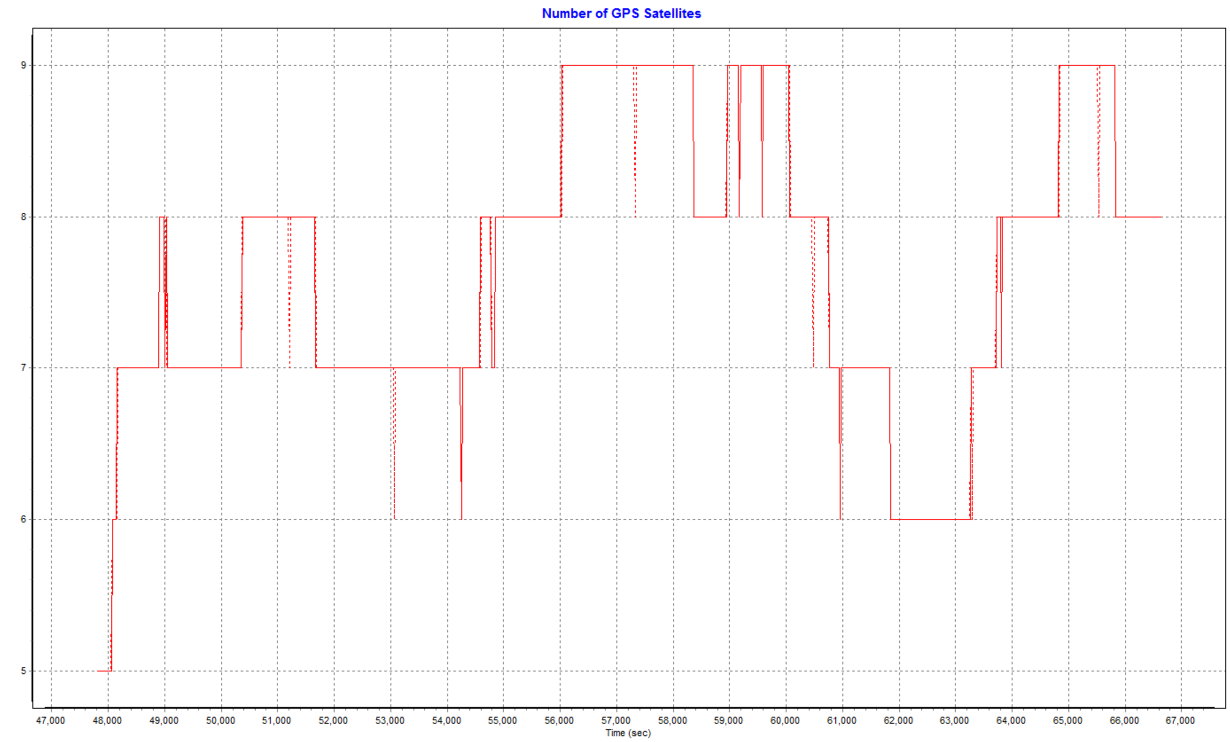
587,000
588,000
589,000
590,000
591,000
592,000
593,000
594,000
595,000
596,000
597,000
598,000
599,000
600,000
601,000
602,000
Time (sec)
PDOP
HDOP
VDOP


Forward/Reverse Separation
0.42
0.4
0.38
0.36
0.34
0.32
0.3
0.28
0.26
0.24
0.22
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
-0.08
-0.1
-0.12
-0.14
-0.16
-0.18
-0.2
-0.22
-0.24
-0.26
-0.28
-0.3
-0.32
-0.34
-0.36
-0.38
-0.4
582,000
584,000
586,000
588,000
590,000
592,000
594,000
596,000
598,000
600,000
602,000
Time (sec)
North (m)
East (m)
Down (m)

MNB15326A


Number of GPS Satellites
9
8
7
6
5
47,000
48,000
49,000
50,000
51,000
52,000
53,000
54,000
55,000
56,000
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63,000
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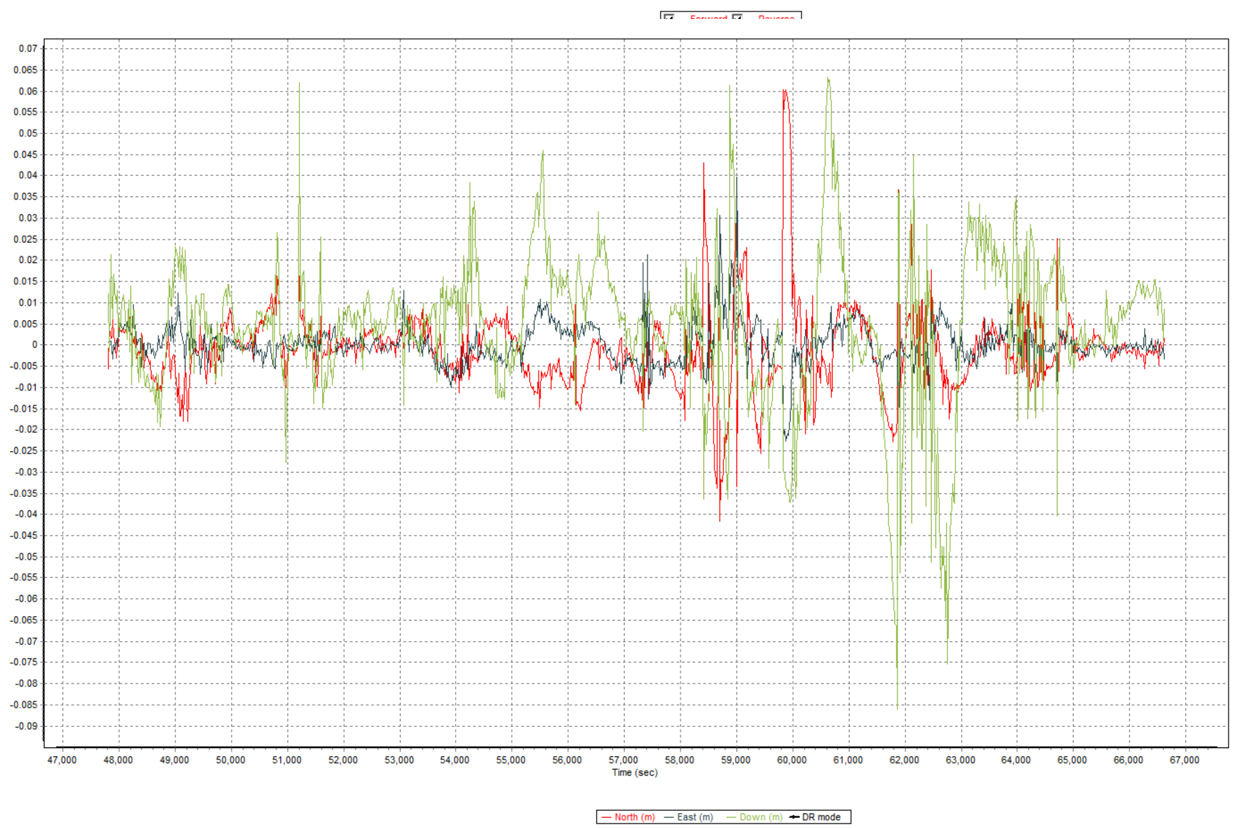
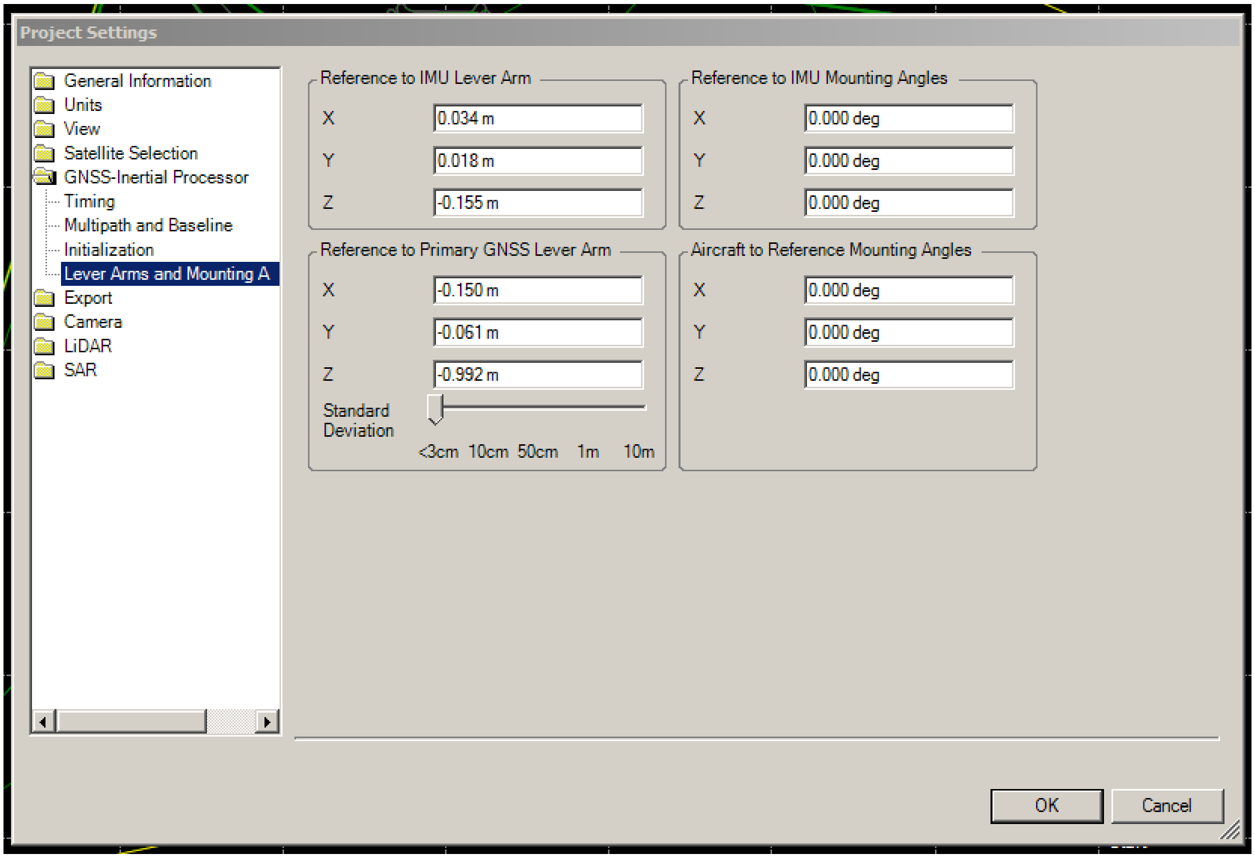
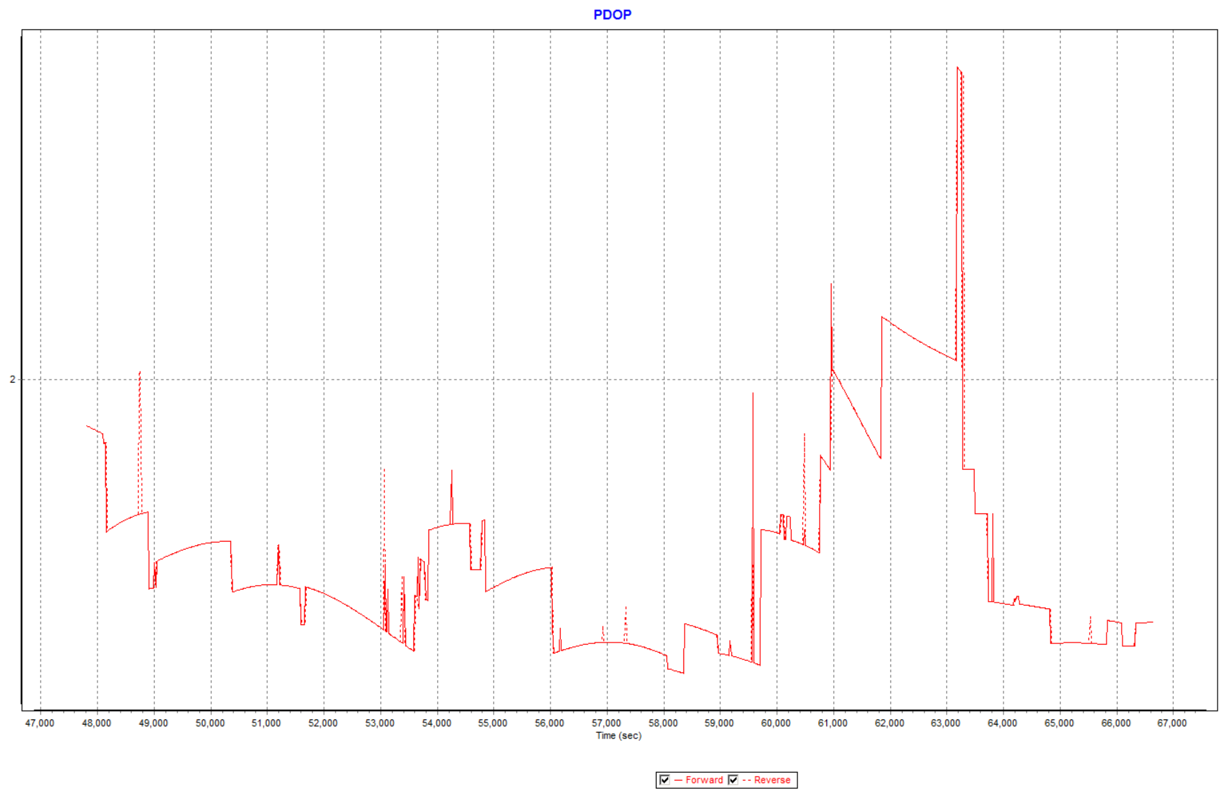
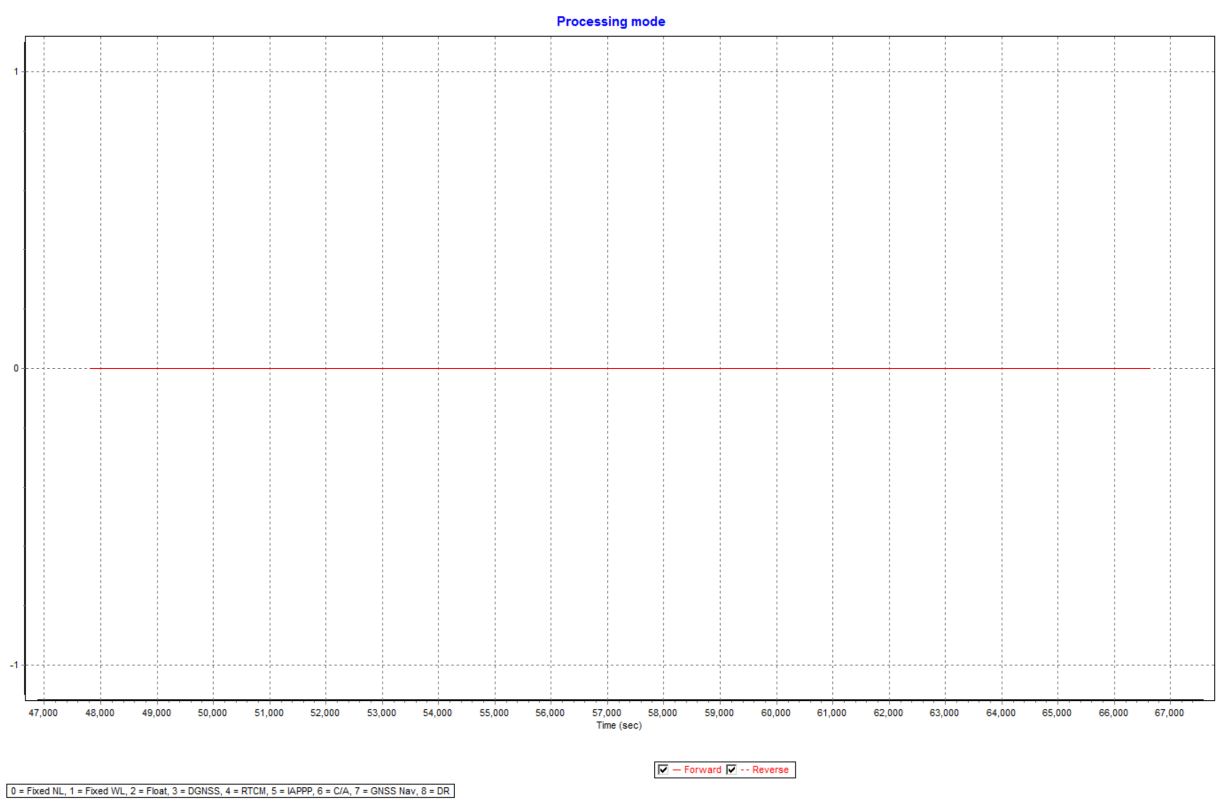
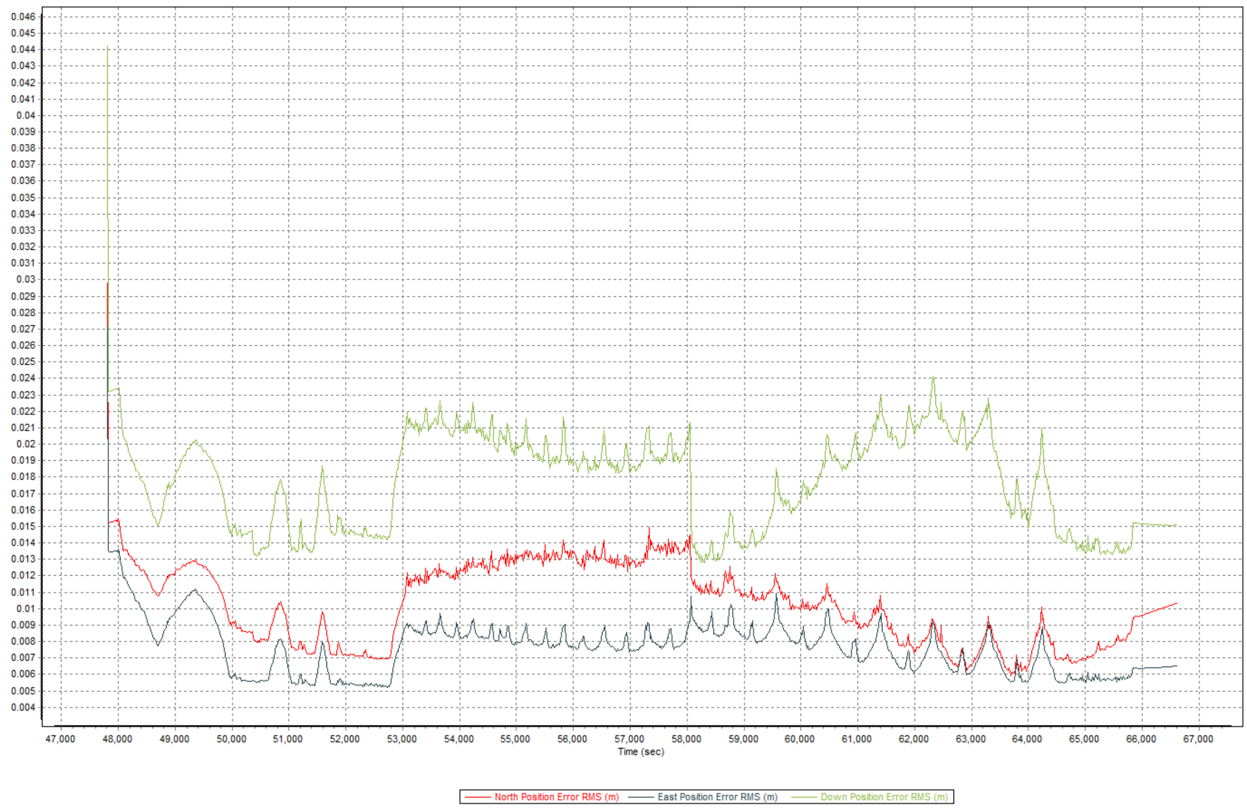
65,000
66,000
67,000
Time (sec)

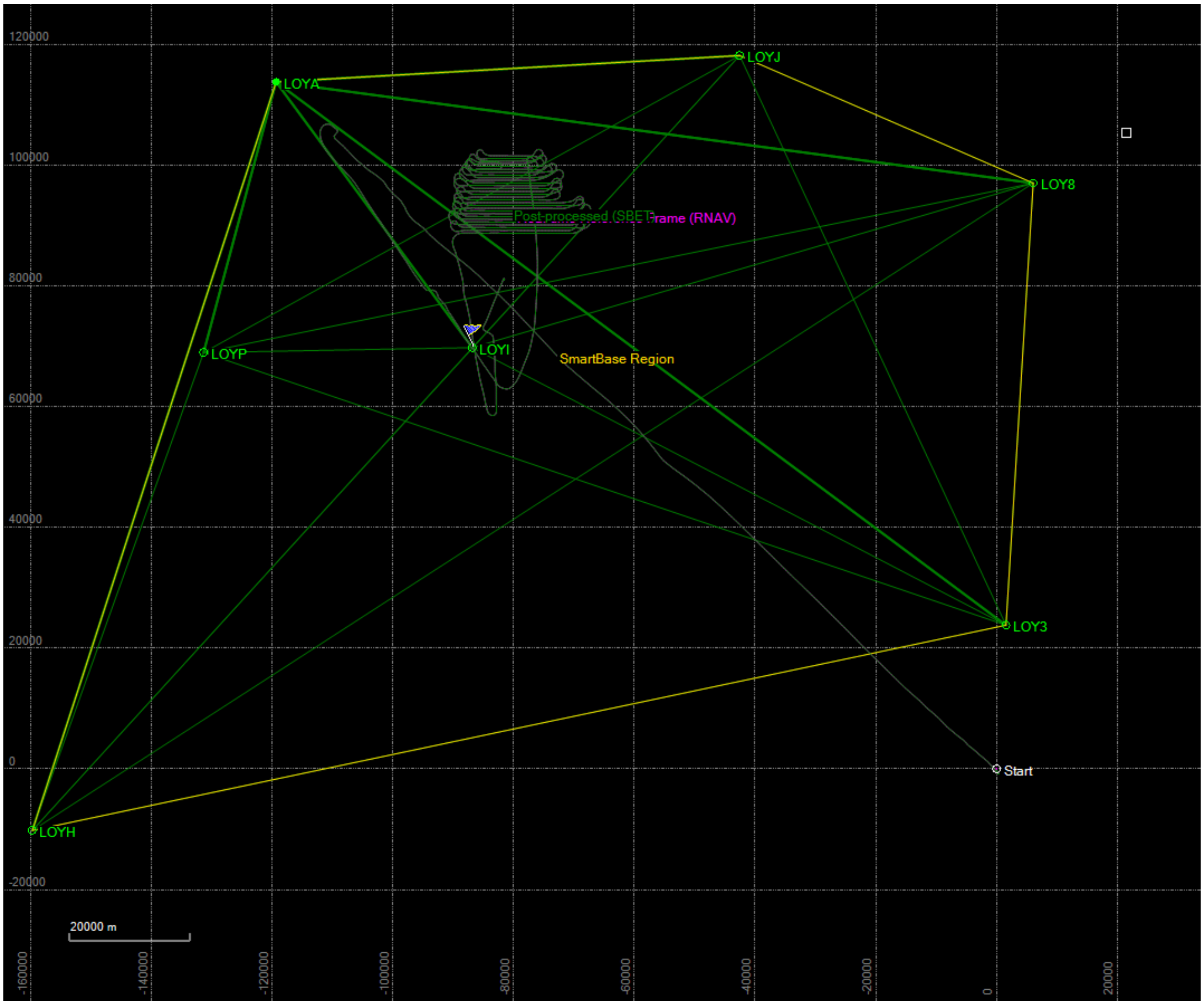

Time (sec)
North (m)
East (m)
Down (m)
DR mode

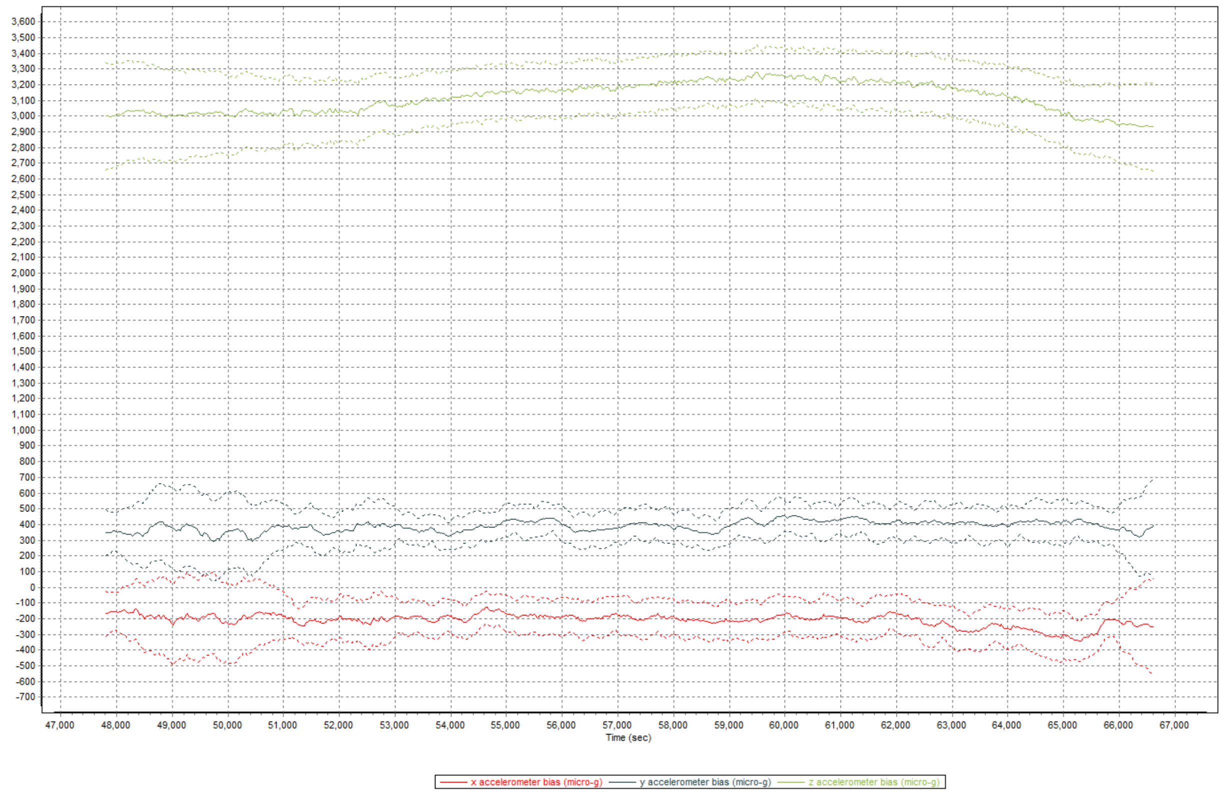

Project Settings
General Information
Units
View
Satellite Selection
GNSS-Inertial Processor
Timing
Multipath and Baseline
Initialization
Lever Arms and Mounting A
Export
Camera
LiDAR
SAR
Reference to IMU Lever Arm
X 0.034 m
Y 0.018 m
Z -0.155 m
Reference to IMU Mounting Angles
X 0.000 deg
Y 0.000 deg
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

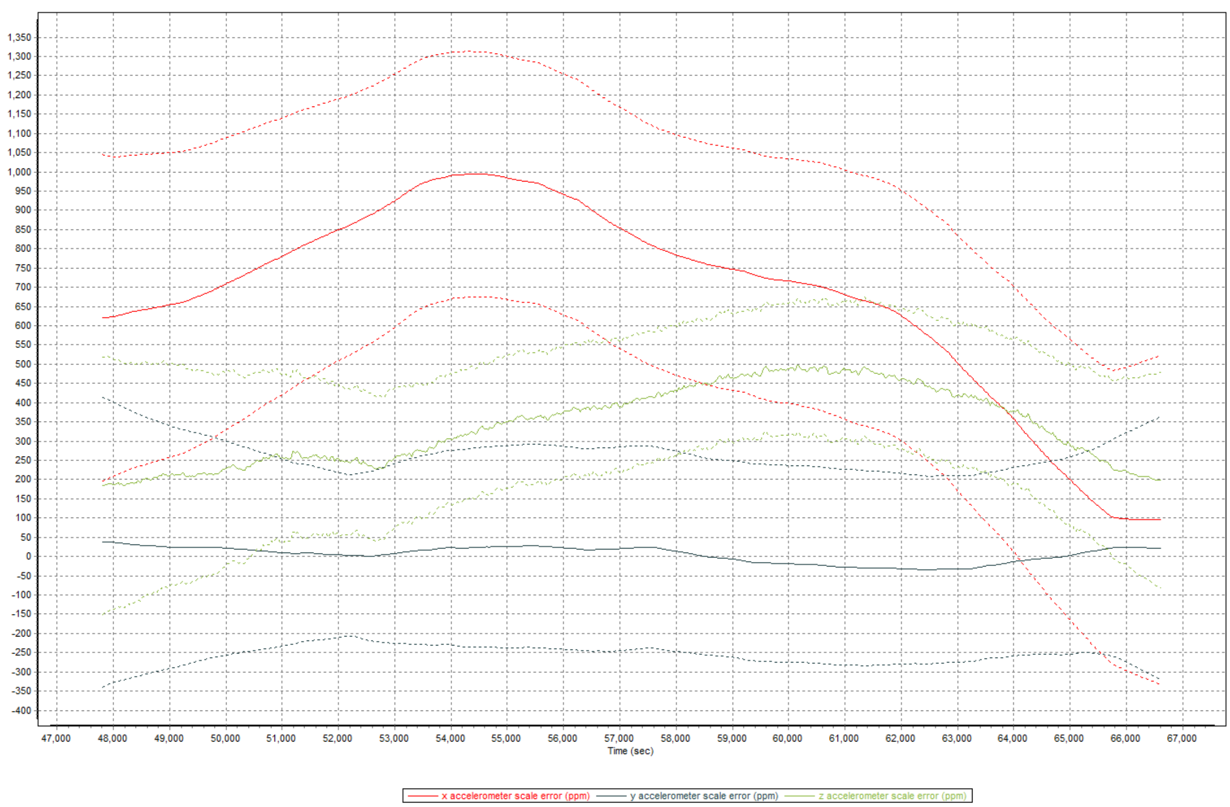

PDOP
2
47,000
48,000
49,000
50,000
51,000
52,000
53,000
54,000
55,000
56,000
57,000
58,000
59,000
60,000
61,000
62,000
63,000
64,000
65,000
66,000
67,000
Time (sec)
— Forward
-- Reverse

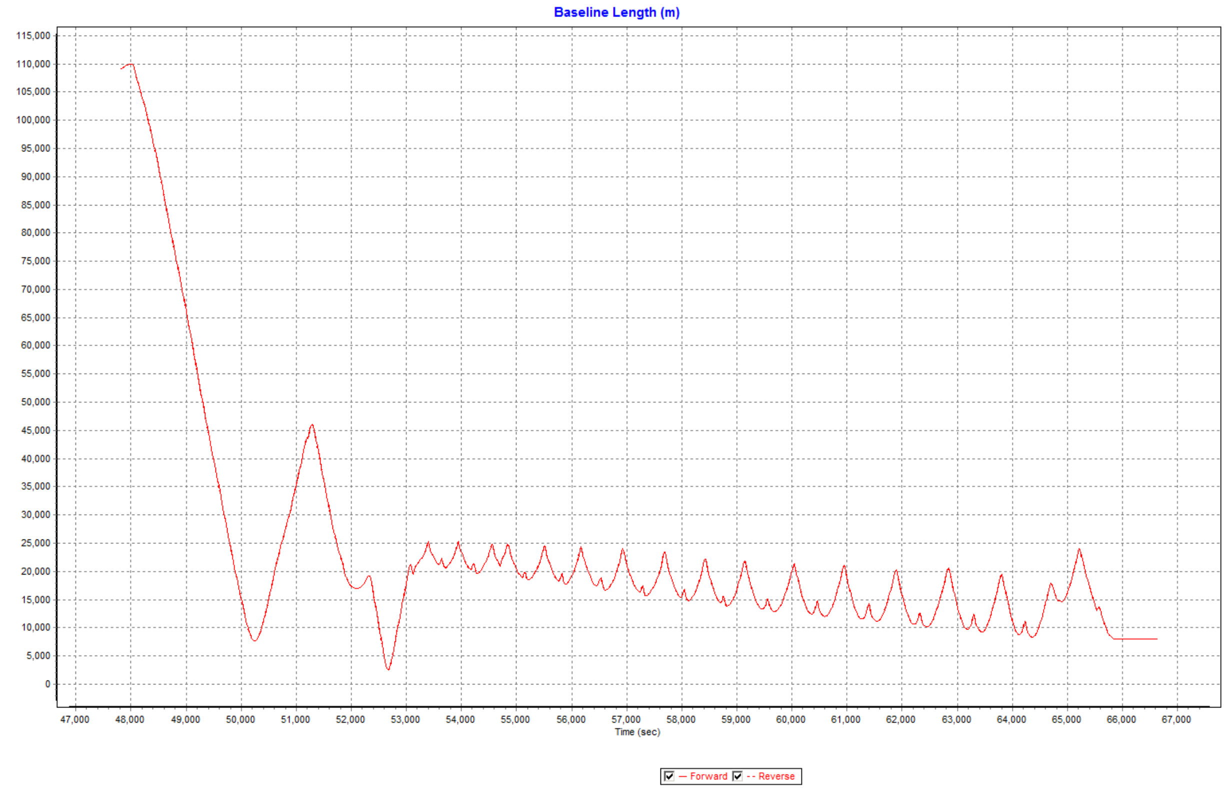

Processing mode
1
0
-1
47,000
48,000
49,000
50,000
51,000
52,000
53,000
54,000
55,000
56,000
57,000
58,000
59,000
60,000
61,000
62,000
63,000
64,000
65,000
66,000
67,000
Time (sec)
— Forward
-- Reverse
0 = Fixed NL, 1 = Fixed WL, 2 = Float, 3 = DGNSS, 4 = RTCM, 5 = IAPPP, 6 = C/A, 7 = GNSS Nav, 8 = DR

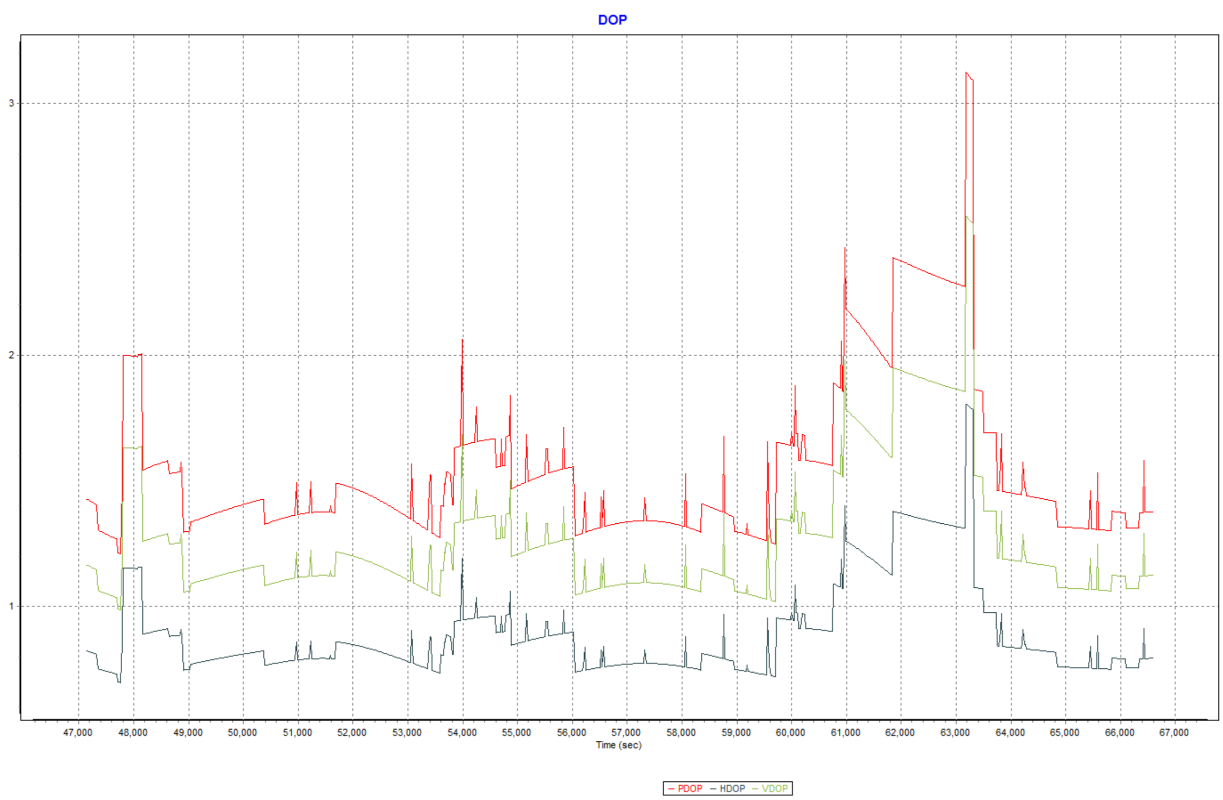

Time (sec)
North Position Error RMS (m)
East Position Error RMS (m)
Down Position Error RMS (m)

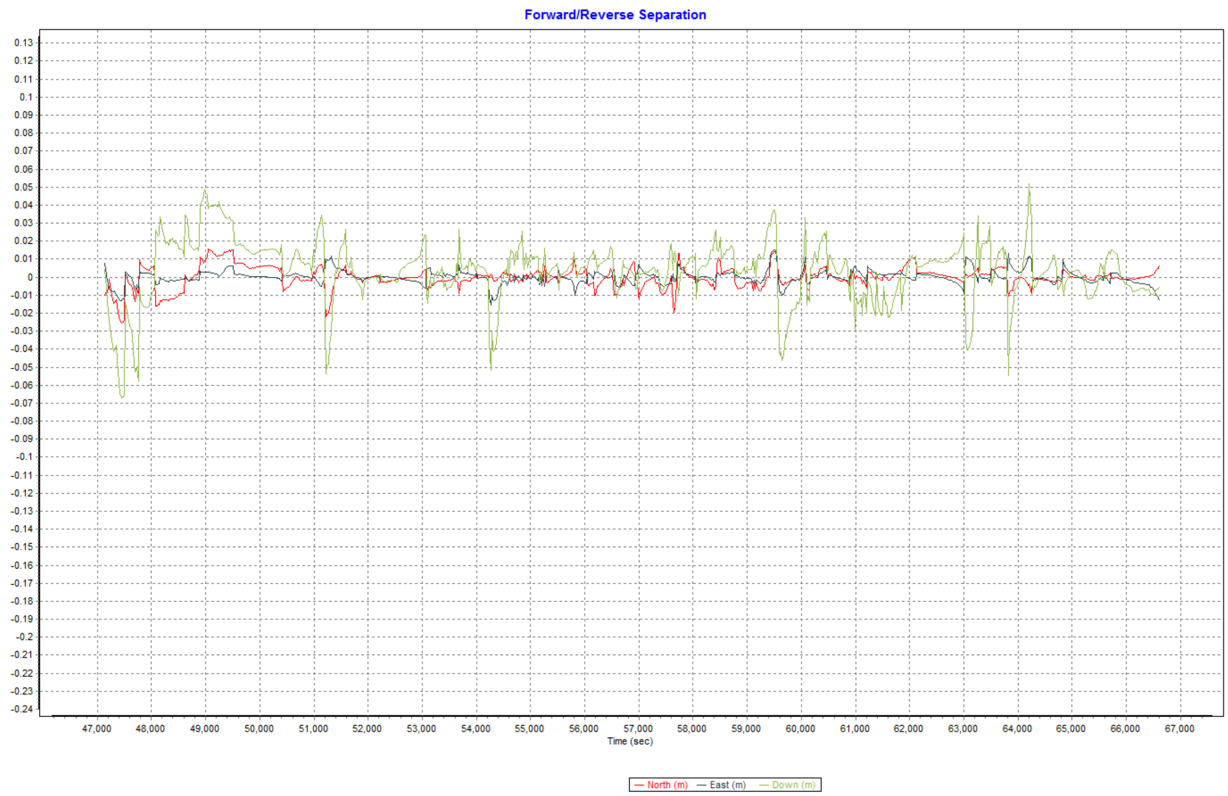

LOYA
LOYJ
LOY8
LOYP
LOYI
SmartBase Region
LOY3
Start
LOYH
Post-processed (SBET)
rame (RNAV)
20000 m
120000
100000
80000
60000
40000
20000
0
-20000
-160000
-140000
-120000
-100000
-80000
-60000
-40000
-20000
0
20000

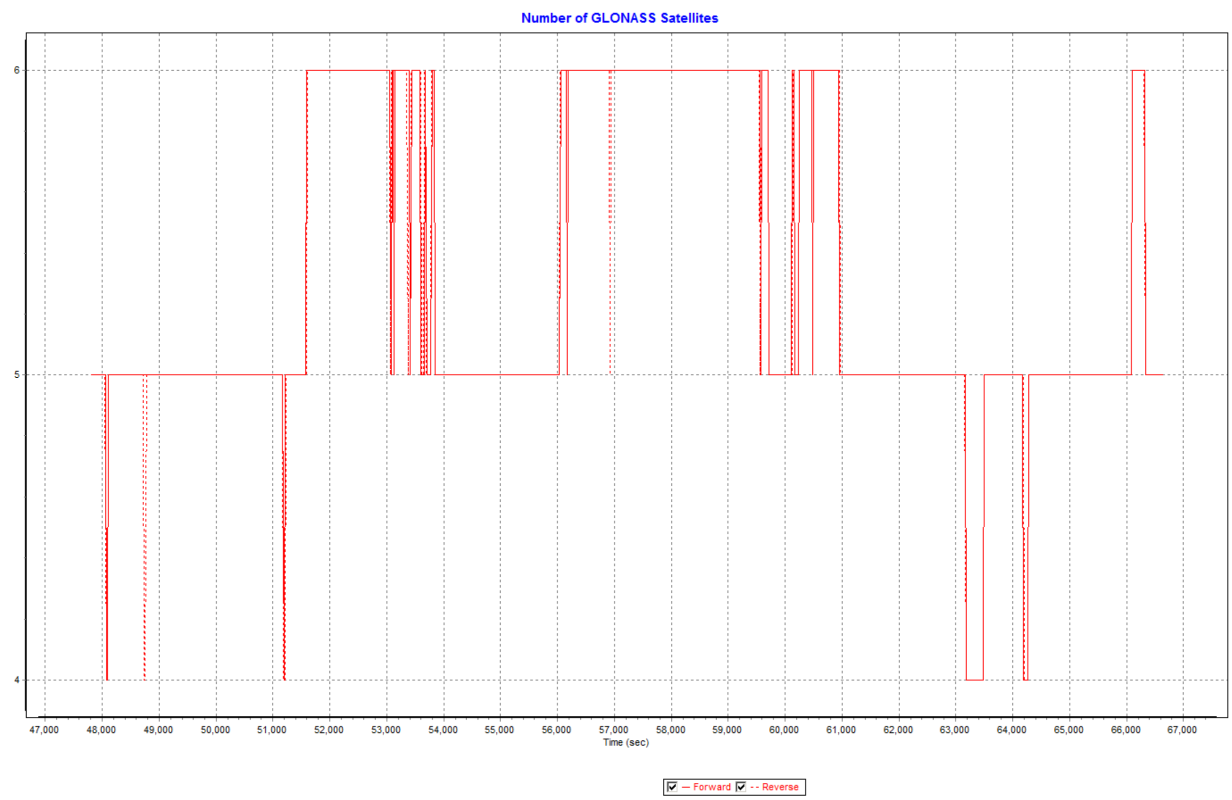

Time (sec)
x accelerometer bias (micro-g)
y accelerometer bias (micro-g)
z accelerometer bias (micro-g)


Time (sec)
x accelerometer scale error (ppm)
y accelerometer scale error (ppm)
z accelerometer scale error (ppm)

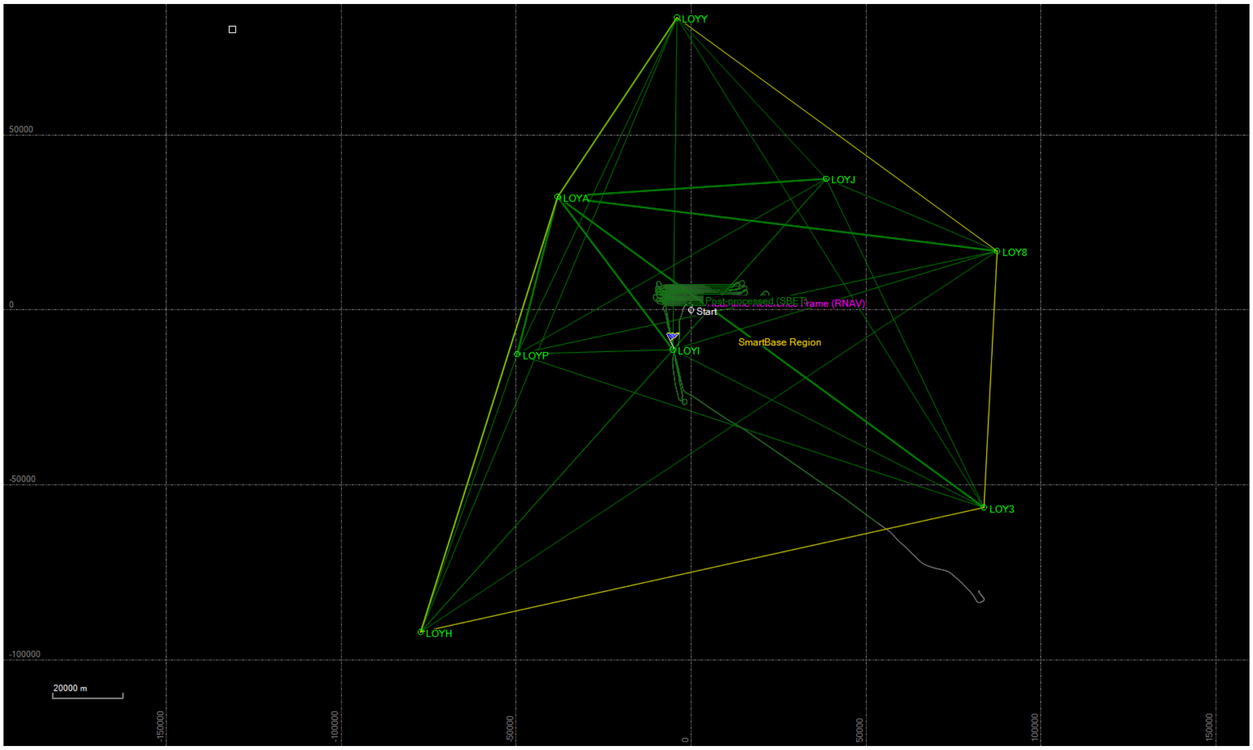

Baseline Length (m)
115,000
110,000
105,000
100,000
95,000
90,000
85,000
80,000
75,000
70,000
65,000
60,000
55,000
50,000
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
47,000
48,000
49,000
50,000
51,000
52,000
53,000
54,000
55,000
56,000
57,000
58,000
59,000
60,000
61,000
62,000
63,000
64,000
65,000
66,000
67,000
Time (sec)
Forward
Reverse

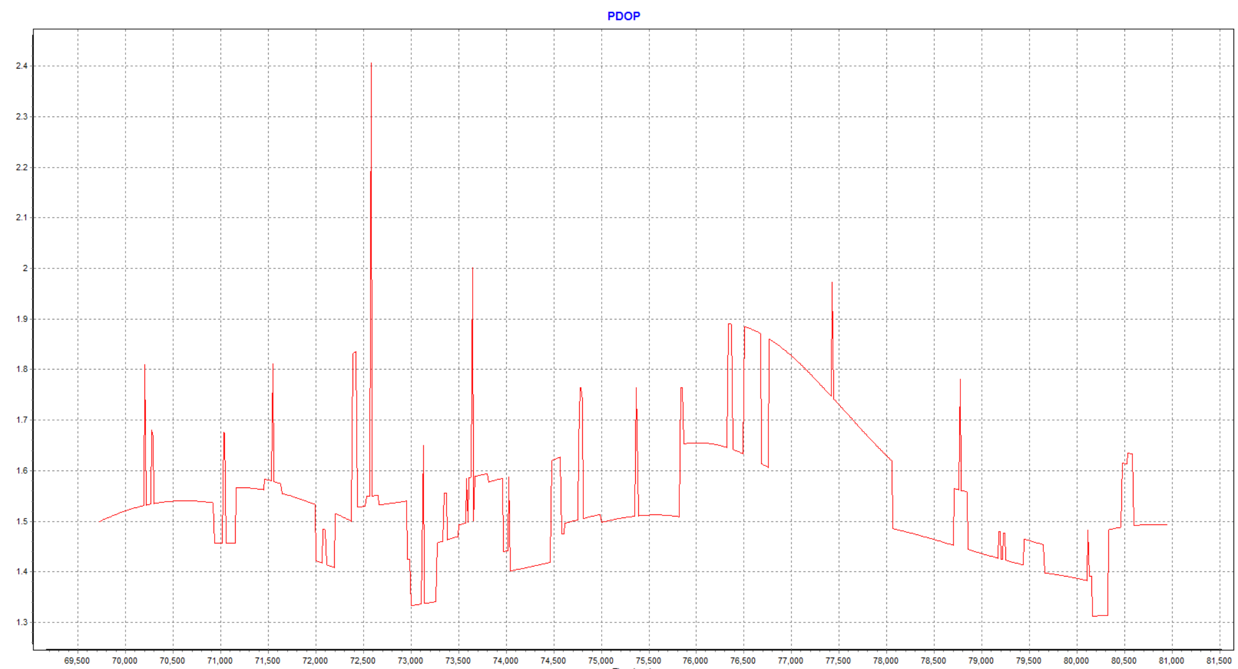

DOP
3
2
1
47,000
48,000
49,000
50,000
51,000
52,000
53,000
54,000
55,000
56,000
57,000
58,000
59,000
60,000
61,000
62,000
63,000
64,000
65,000
66,000
67,000
Time (sec)
PDOP
HDOP
VDOP

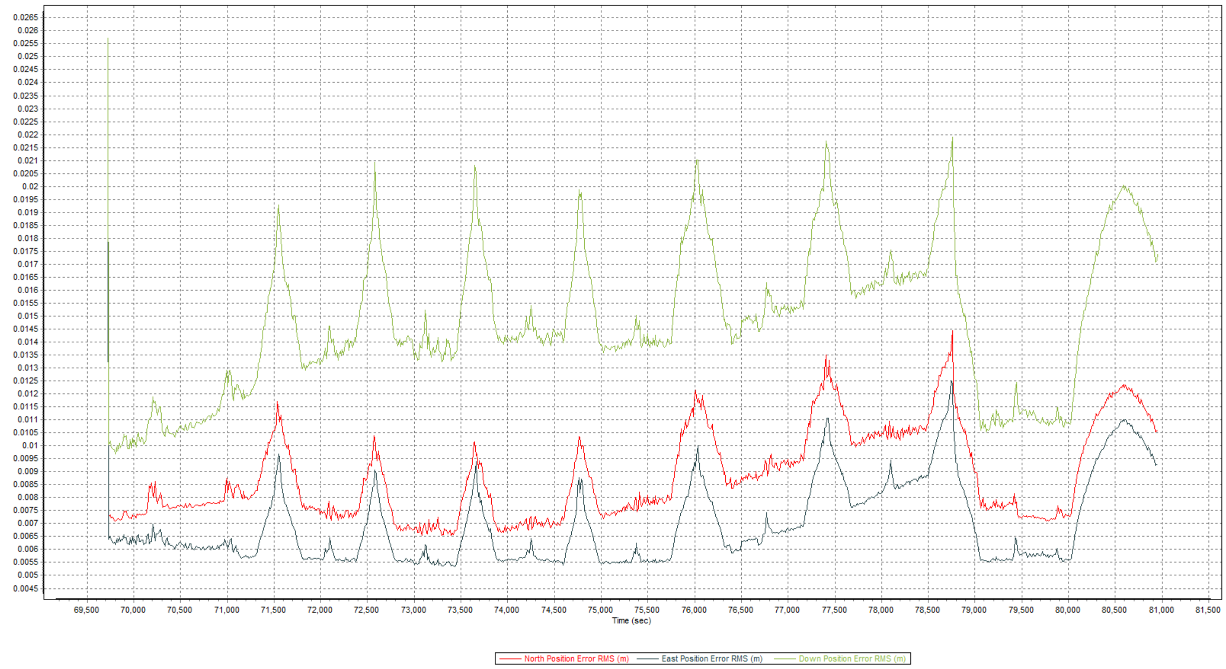

Forward/Reverse Separation
Time (sec)
North (m)
East (m)
Down (m)

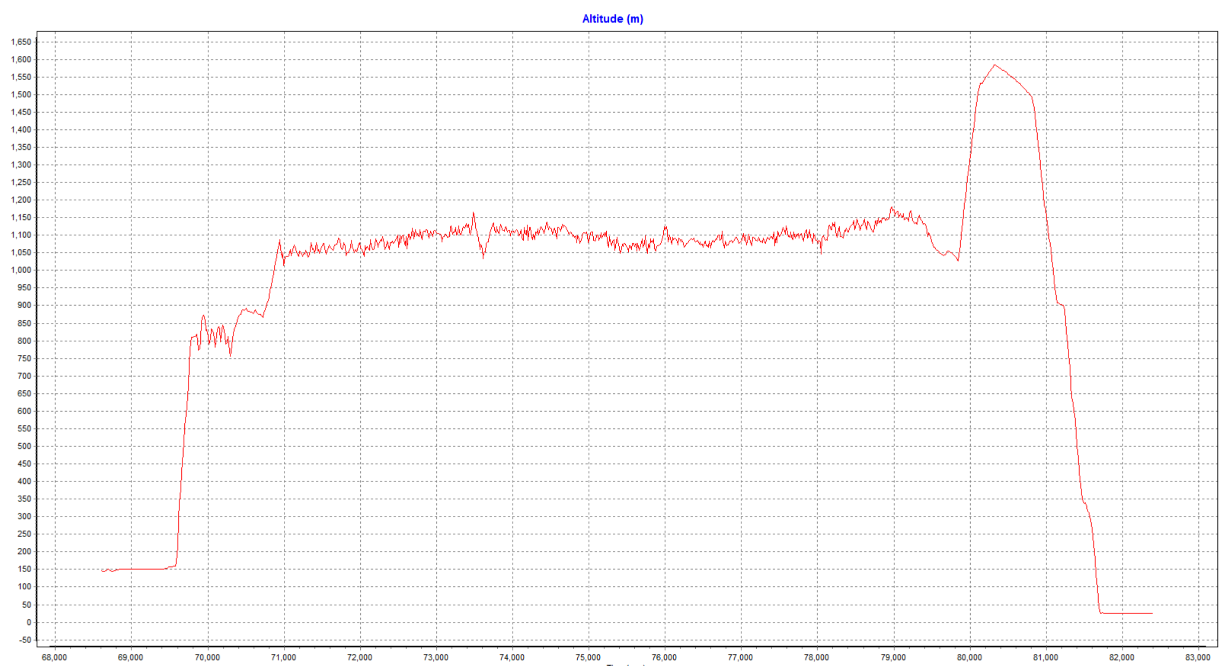

Number of GLONASS Satellites
Time (sec)
Forward
Reverse

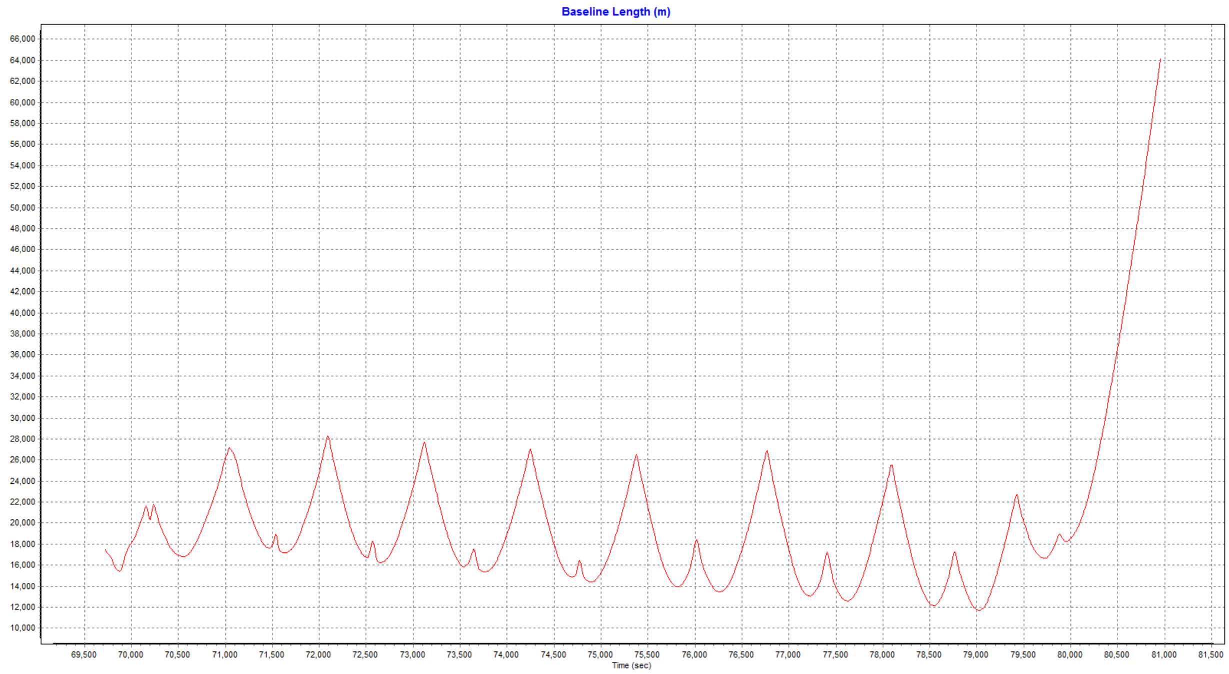
MNB15326B

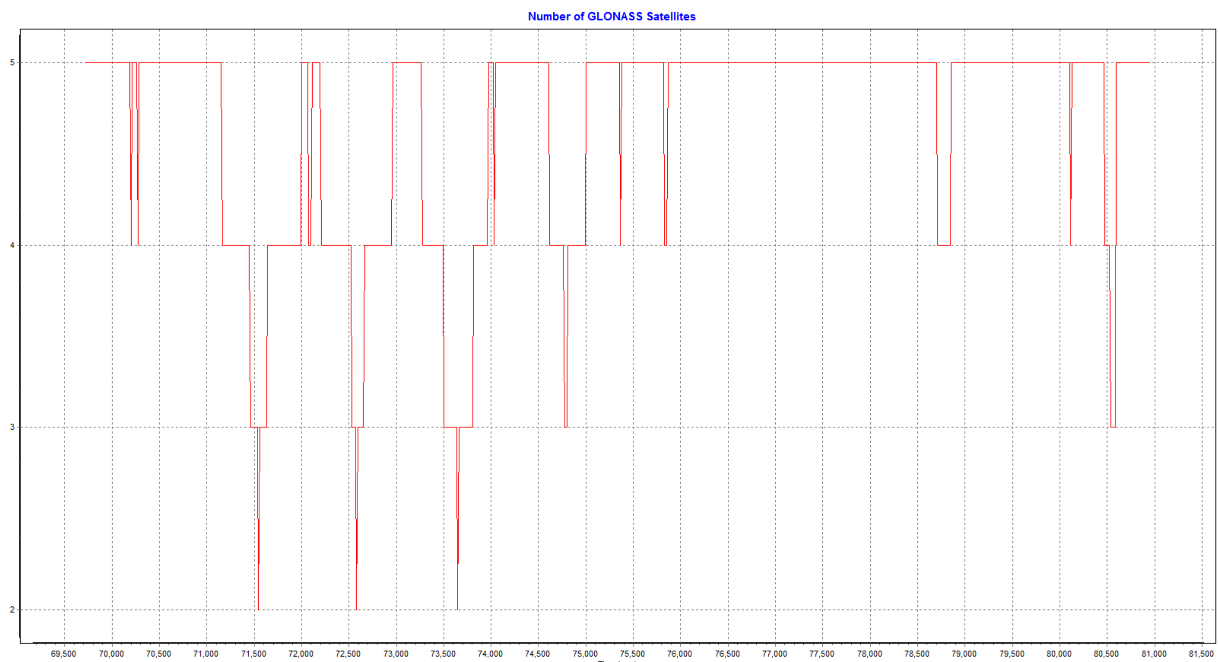

LOYY
LOYJ
LOYA
LOY8
Start
SmartBase Region
LOYP
LOYI
LOY3
LOYH
50000
0
-50000
-100000
20000 m
-150000
-100000
-50000
0
50000
100000
150000


PDOP
2.4
2.3
2.2
2.1
2
1.9
1.8
1.7
1.6
1.5
1.4
1.3
69,500
70,000
70,500
71,000
71,500
72,000
72,500
73,000
73,500
74,000
74,500
75,000
75,500
76,000
76,500
77,000
77,500
78,000
78,500
79,000
79,500
80,000
80,500
81,000
81,500
Time (sec)

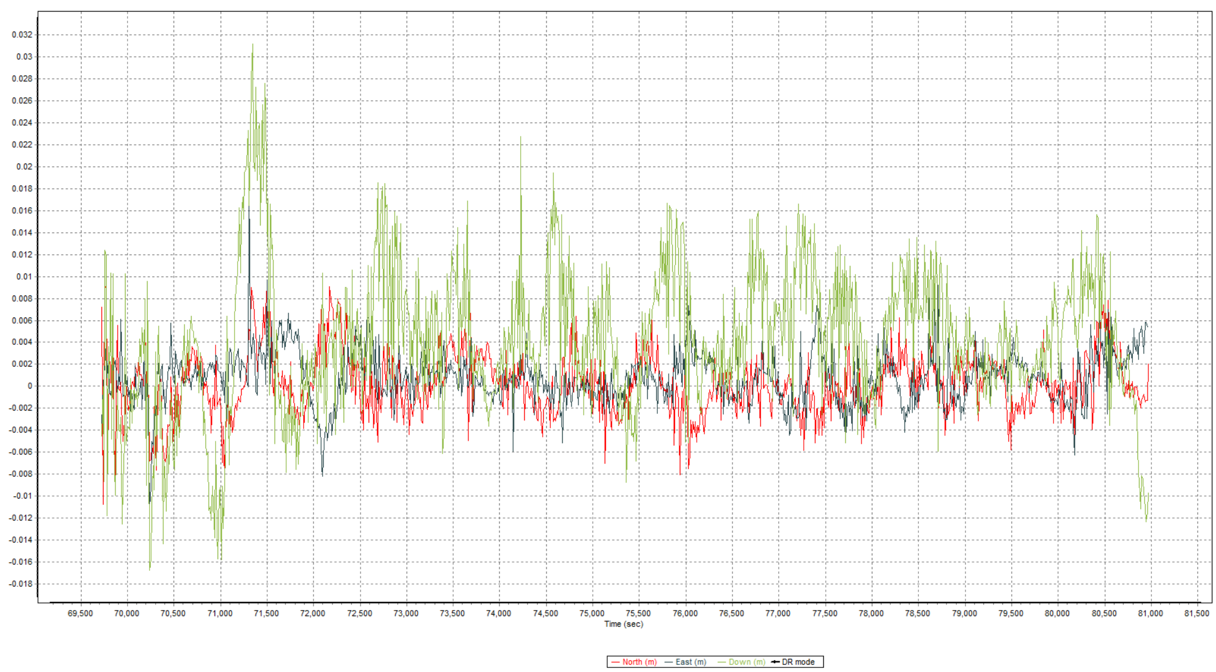

Time (sec)
North Position Error RMS (m)
East Position Error RMS (m)
Down Position Error RMS (m)


Altitude (m)
Time (sec)

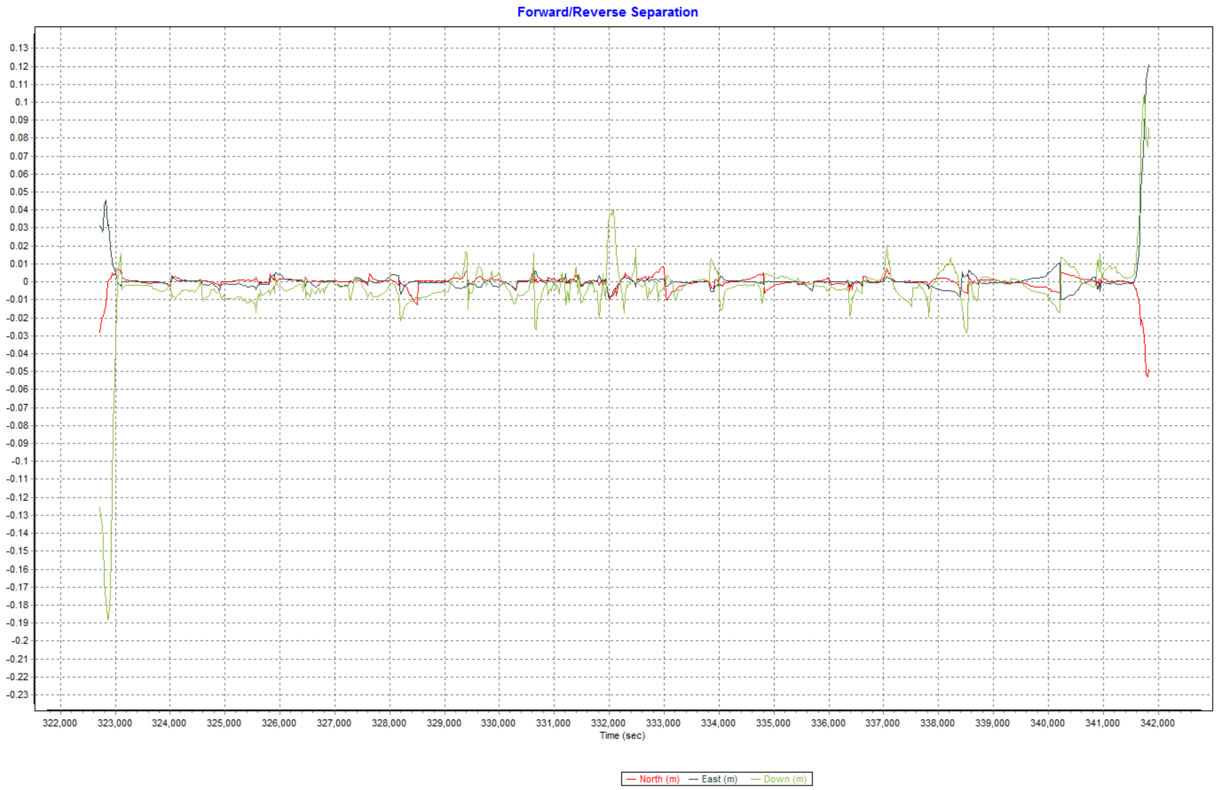

Baseline Length (m)
Time (sec)

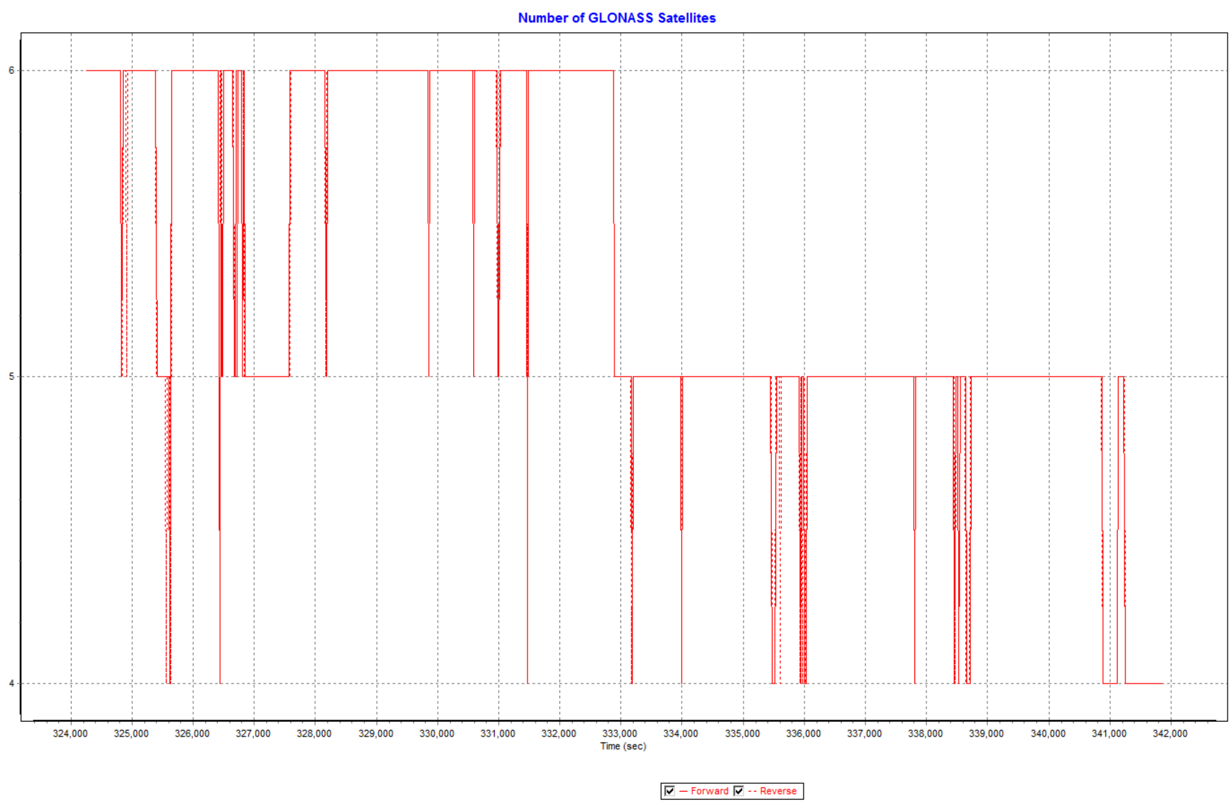

Number of GLONASS Satellites
Time (sec)

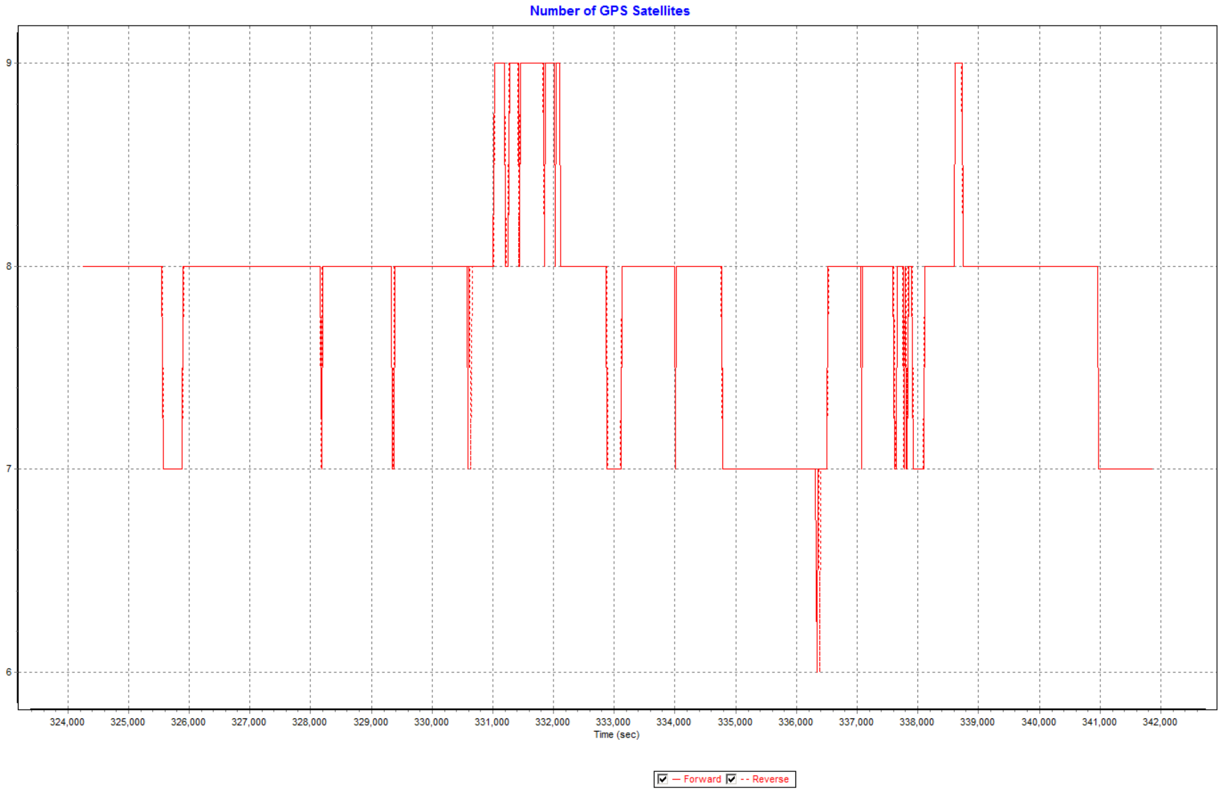

Number of GPS Satellites
Time (sec)

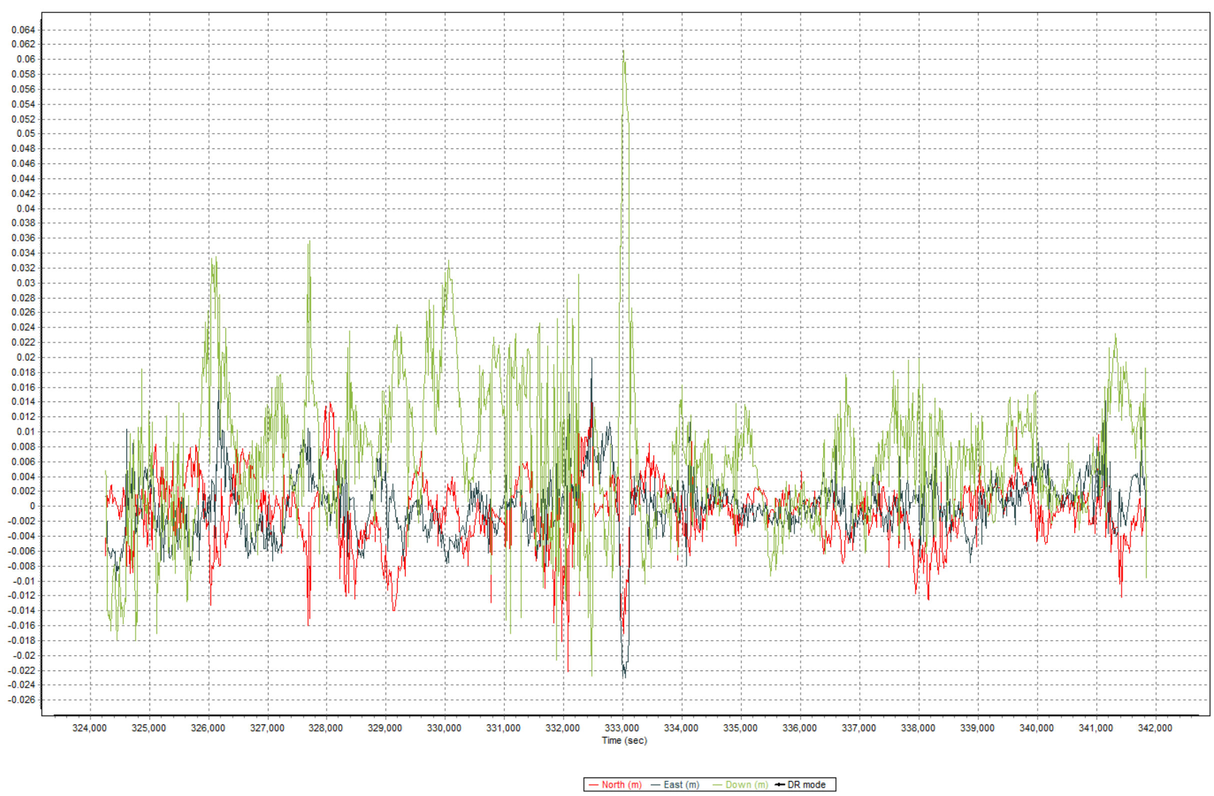

Time (sec)
North (m)
East (m)
Down (m)
DR mode

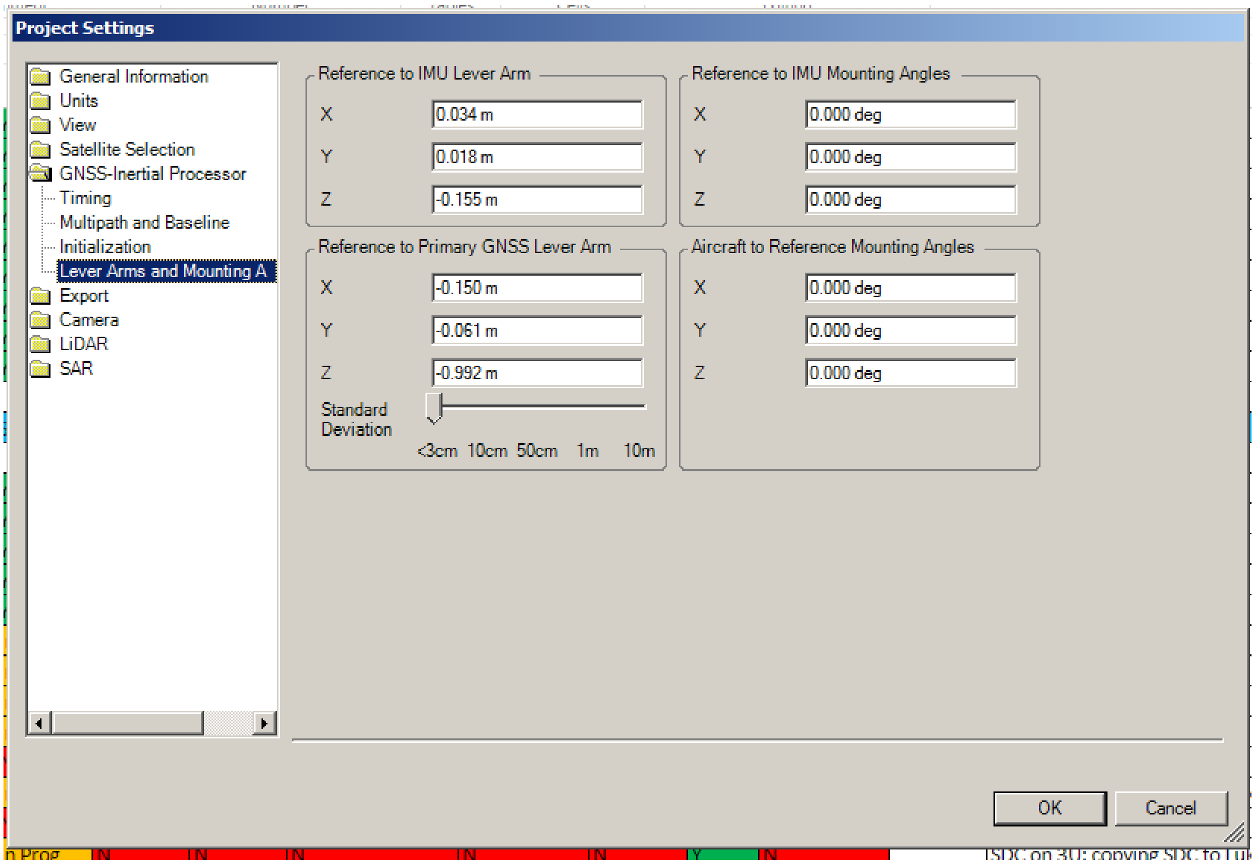
MNB15329B

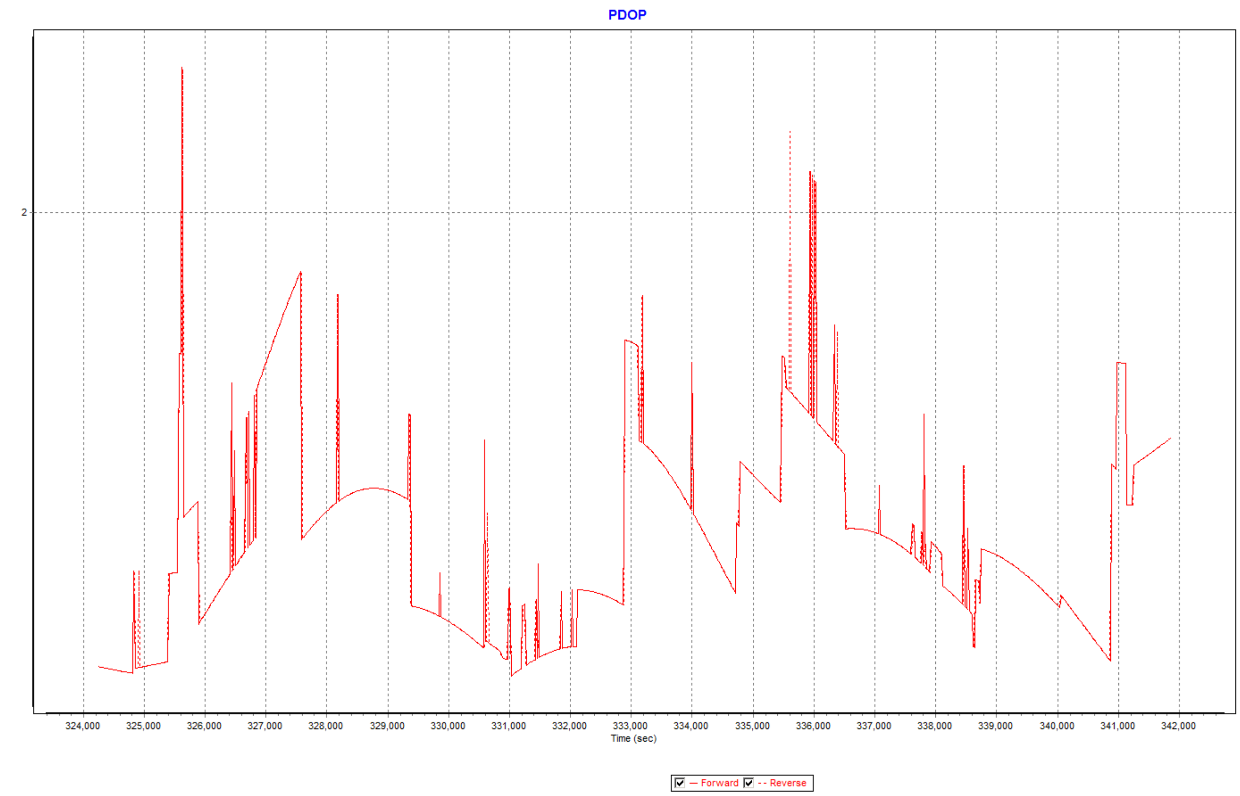

Forward/Reverse Separation
Time (sec)
North (m)
East (m)
Down (m)

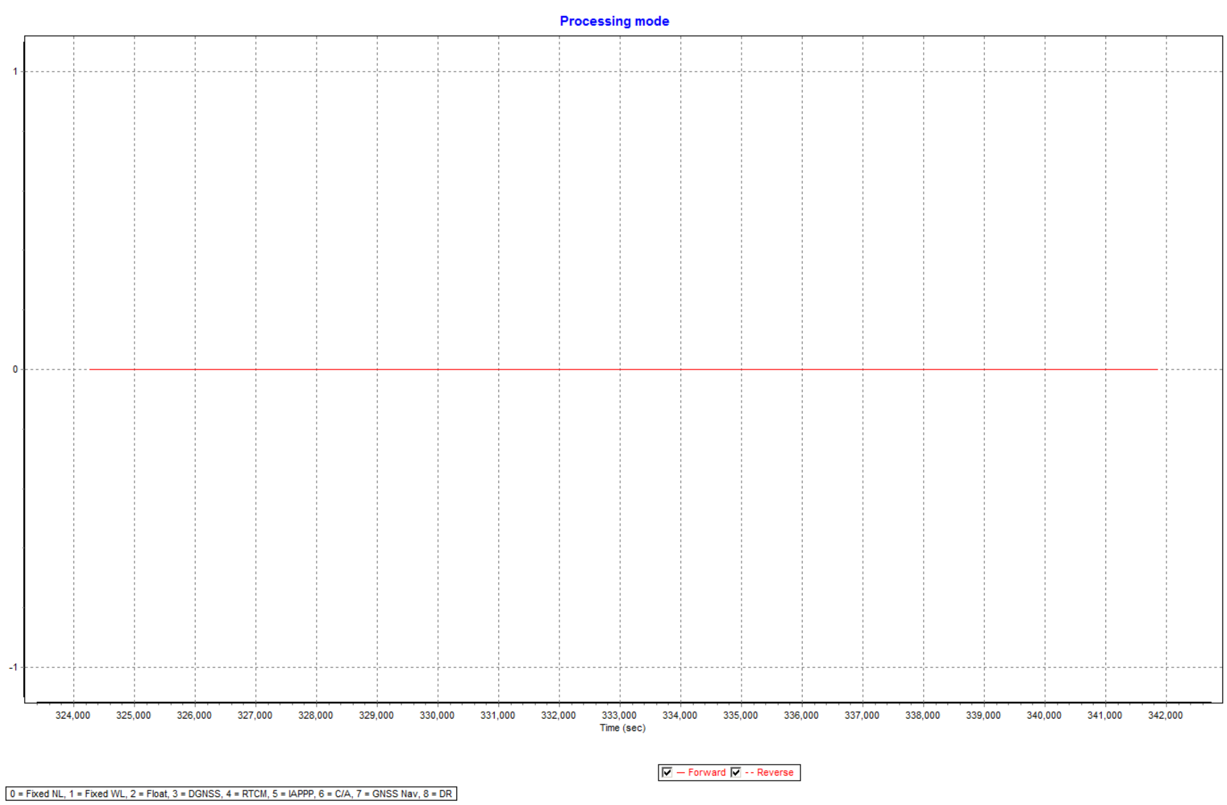

Number of GLONASS Satellites
Time (sec)
Forward
Reverse

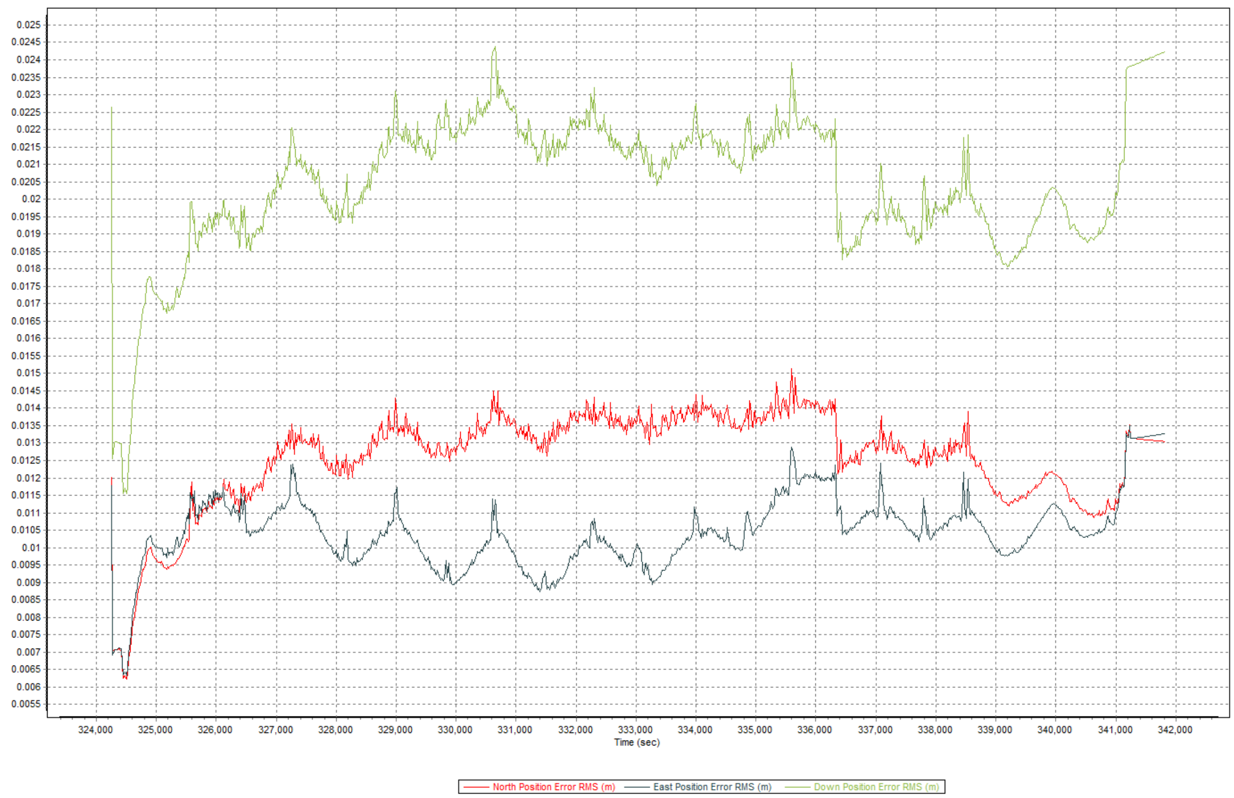

Number of GPS Satellites
9
8
7
6
324,000 325,000 326,000 327,000 328,000 329,000 330,000 331,000 332,000 333,000 334,000 335,000 336,000 337,000 338,000 339,000 340,000 341,000 342,000
Time (sec)
Forward
Reverse

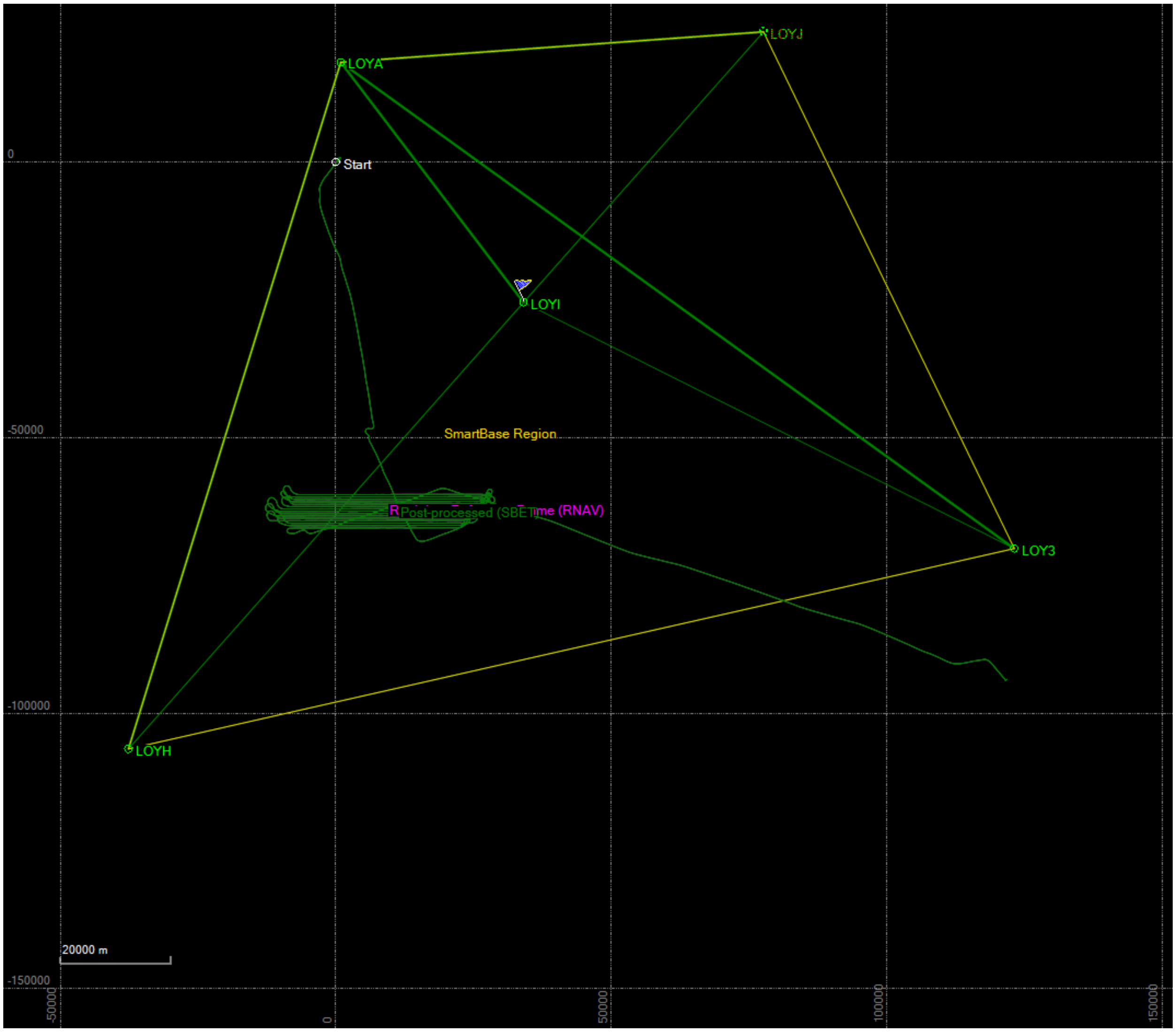

0.064 0.062 0.06 0.058 0.056 0.054 0.052 0.05 0.048 0.046 0.044 0.042 0.04 0.038 0.036 0.034 0.032 0.03 0.028 0.026 0.024 0.022 0.02 0.018 0.016 0.014 0.012 0.01 0.008 0.006 0.004 0.002 0 -0.002 -0.004 -0.006 -0.008 -0.01 -0.012 -0.014 -0.016 -0.018 -0.02 -0.022 -0.024 -0.026
324,000 325,000 326,000 327,000 328,000 329,000 330,000 331,000 332,000 333,000 334,000 335,000 336,000 337,000 338,000 339,000 340,000 341,000 342,000
Time (sec)
North (m)
East (m)
Down (m)
DR mode

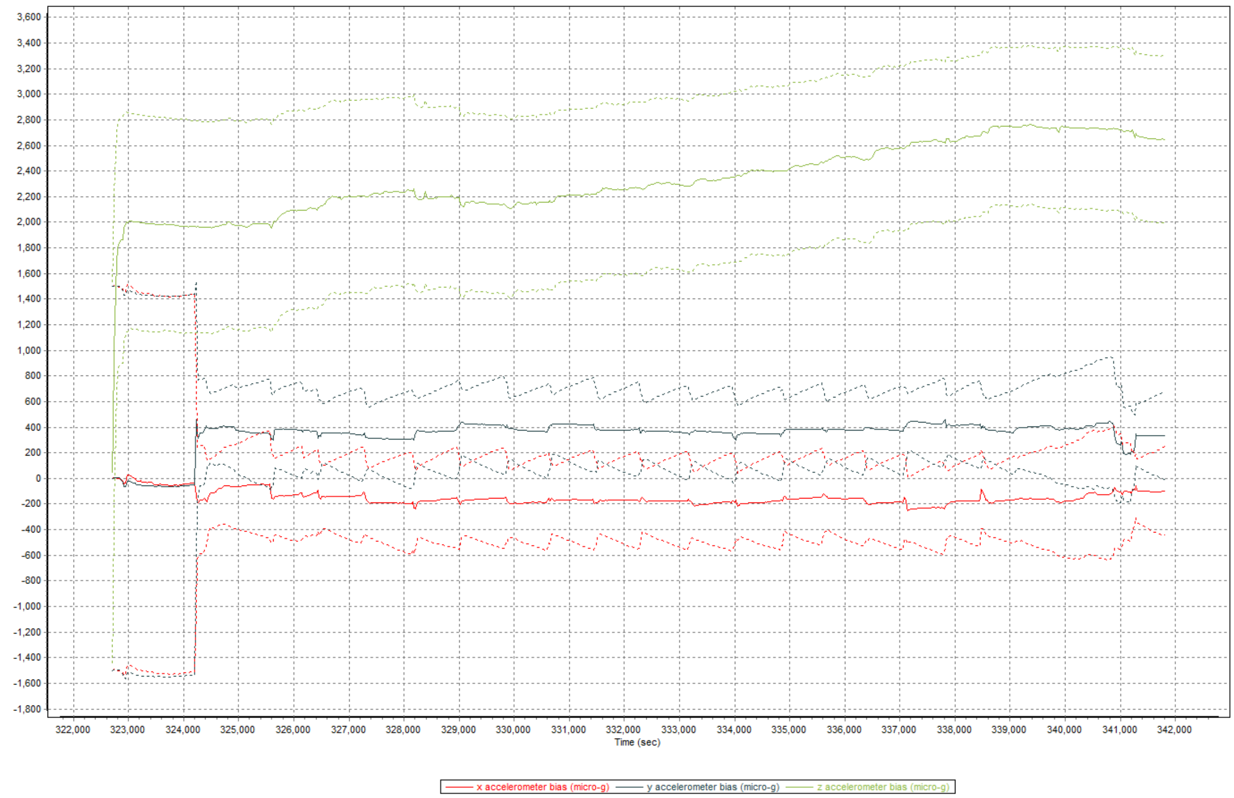

Project Settings
General Information
Units
View
Satellite Selection
GNSS-Inertial Processor
Timing
Multipath and Baseline
Initialization
Lever Arms and Mounting A
Export
Camera
LiDAR
SAR
Reference to IMU Lever Arm
X 0.034 m
Y 0.018 m
Z -0.155 m
Reference to IMU Mounting Angles
X 0.000 deg
Y 0.000 deg
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

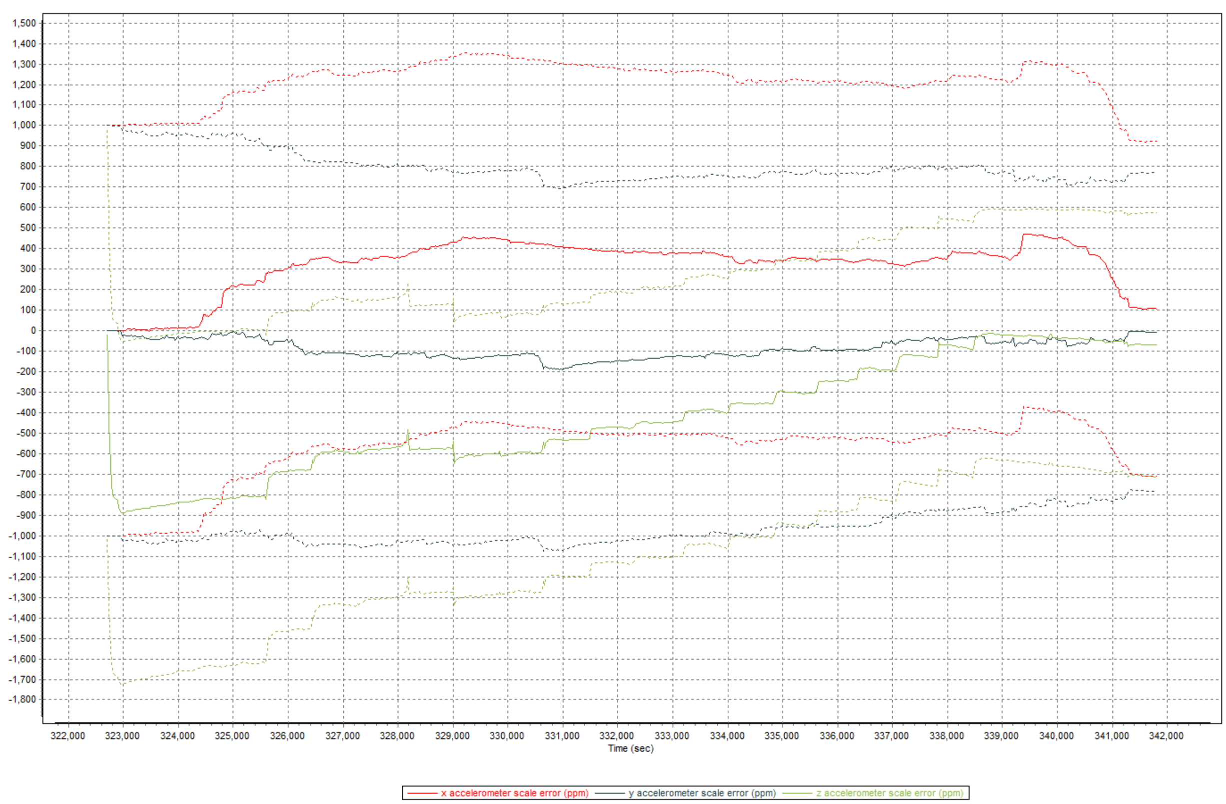

PDOP
2
324,000
325,000
326,000
327,000
328,000
329,000
330,000
331,000
332,000
333,000
334,000
335,000
336,000
337,000
338,000
339,000
340,000
341,000
342,000
Time (sec)
— Forward
-- Reverse

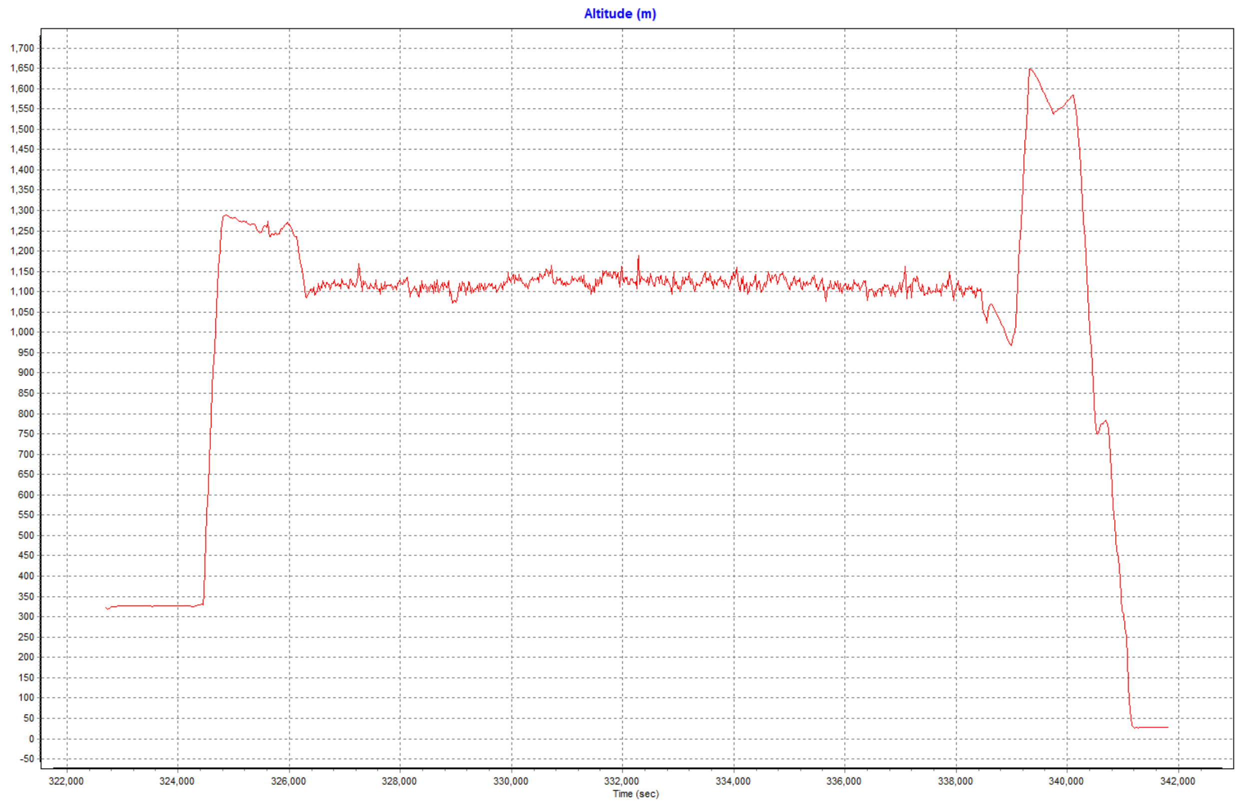

Processing mode
1
0
-1
324,000
325,000
326,000
327,000
328,000
329,000
330,000
331,000
332,000
333,000
334,000
335,000
336,000
337,000
338,000
339,000
340,000
341,000
342,000
Time (sec)
— Forward
-- Reverse
0 = Fixed NL, 1 = Fixed WL, 2 = Float, 3 = DGNSS, 4 = RTCM, 5 = IAPPP, 6 = C/A, 7 = GNSS Nav, 8 = DR

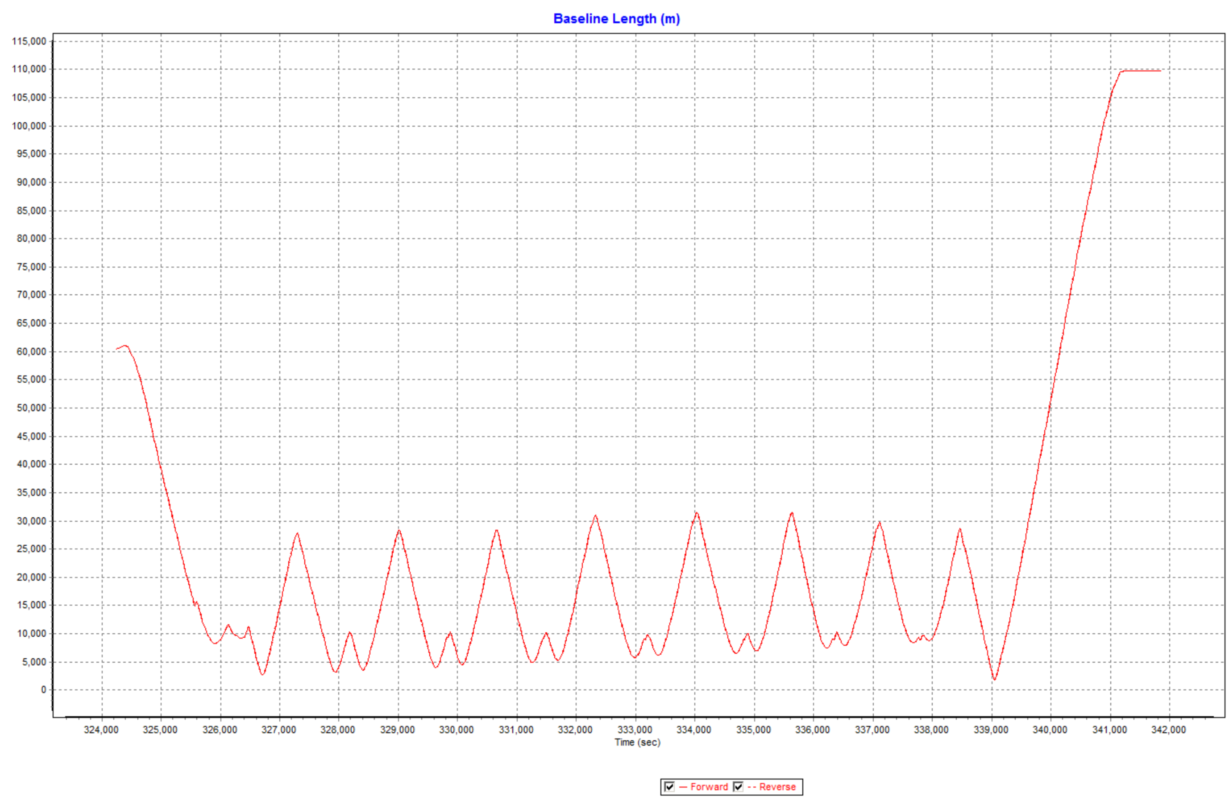

0.025
0.0245
0.024
0.0235
0.023
0.0225
0.022
0.0215
0.021
0.0205
0.02
0.0195
0.019
0.0185
0.018
0.0175
0.017
0.0165
0.016
0.0155
0.015
0.0145
0.014
0.0135
0.013
0.0125
0.012
0.0115
0.011
0.0105
0.01
0.0095
0.009
0.0085
0.008
0.0075
0.007
0.0065
0.006
0.0055
324,000
325,000
326,000
327,000
328,000
329,000
330,000
331,000
332,000
333,000
334,000
335,000
336,000
337,000
338,000
339,000
340,000
341,000
342,000
Time (sec)
North Position Error RMS (m)
East Position Error RMS (m)
Down Position Error RMS (m)

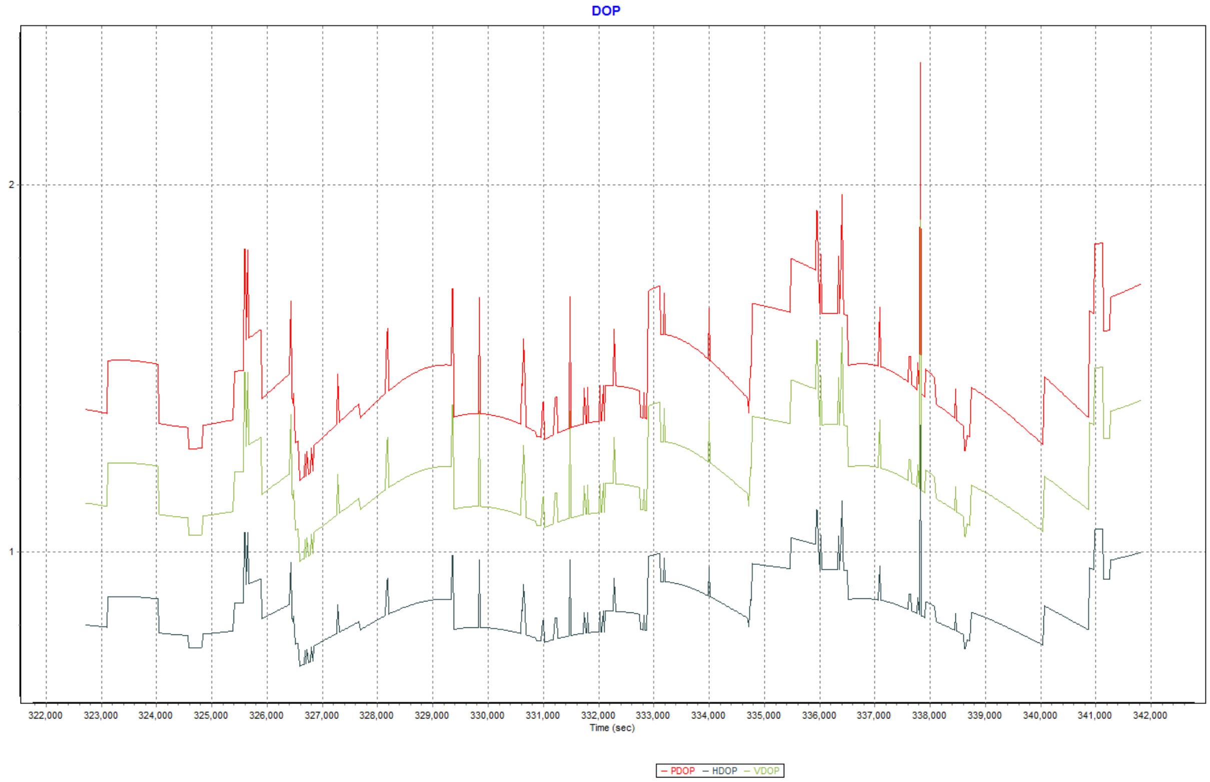

LOYJ
LOYA
Start
LOYI
SmartBase Region
Post-processed (SBET)
Real-time (RNAV)
LOY3
LOYH
20000 m
0
-50000
-100000
-150000
-50000
0
50000
100000
150000


Time (sec)
x accelerometer bias (micro-g)
y accelerometer bias (micro-g)
z accelerometer bias (micro-g)

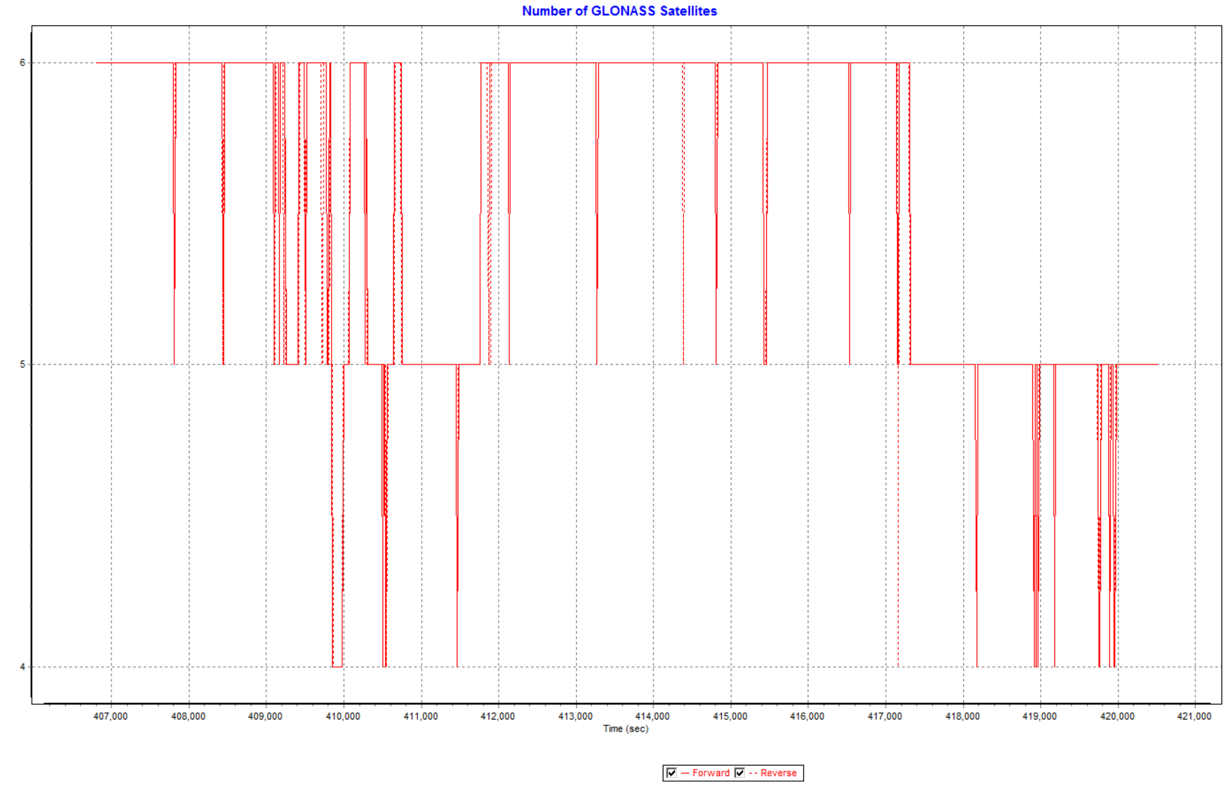

Time (sec)
x accelerometer scale error (ppm)
y accelerometer scale error (ppm)
z accelerometer scale error (ppm)

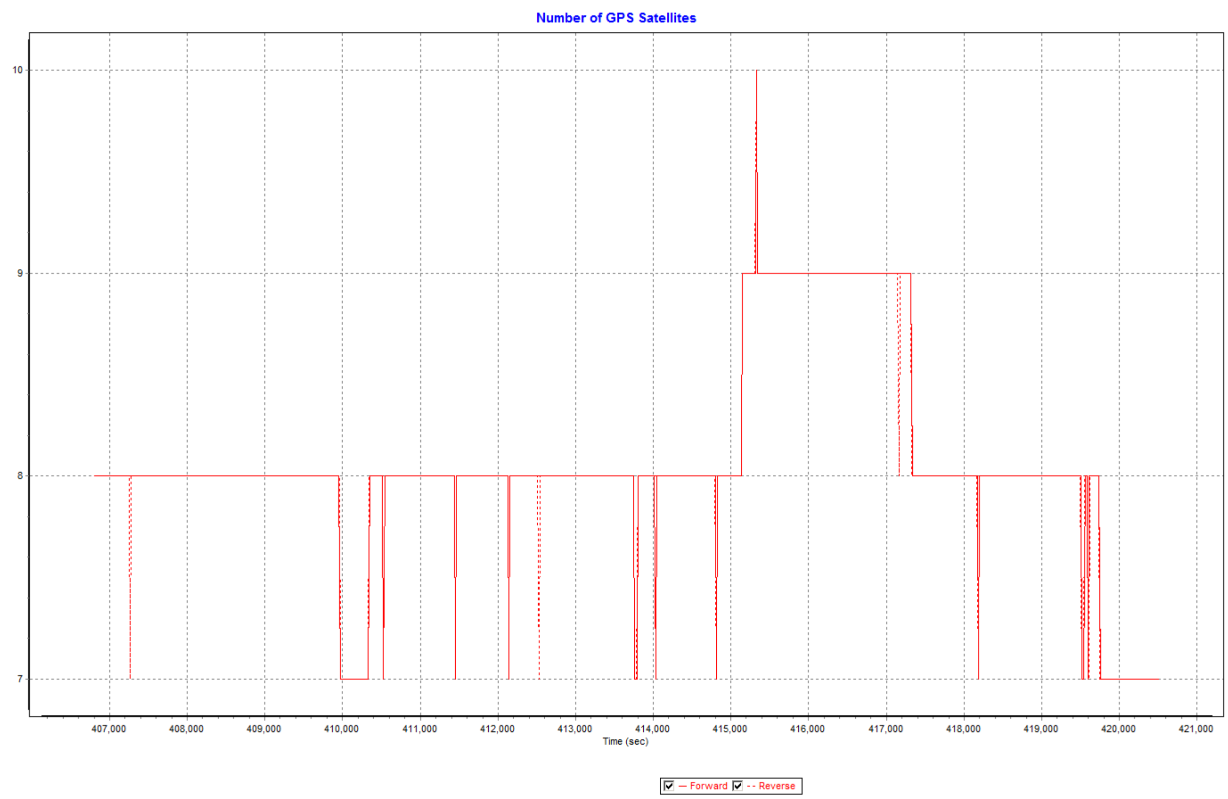

Altitude (m)
1,700
1,650
1,600
1,550
1,500
1,450
1,400
1,350
1,300
1,250
1,200
1,150
1,100
1,050
1,000
950
900
850
800
750
700
650
600
550
500
450
400
350
300
250
200
150
100
50
0
-50
322,000
324,000
326,000
328,000
330,000
332,000
334,000
336,000
338,000
340,000
342,000
Time (sec)

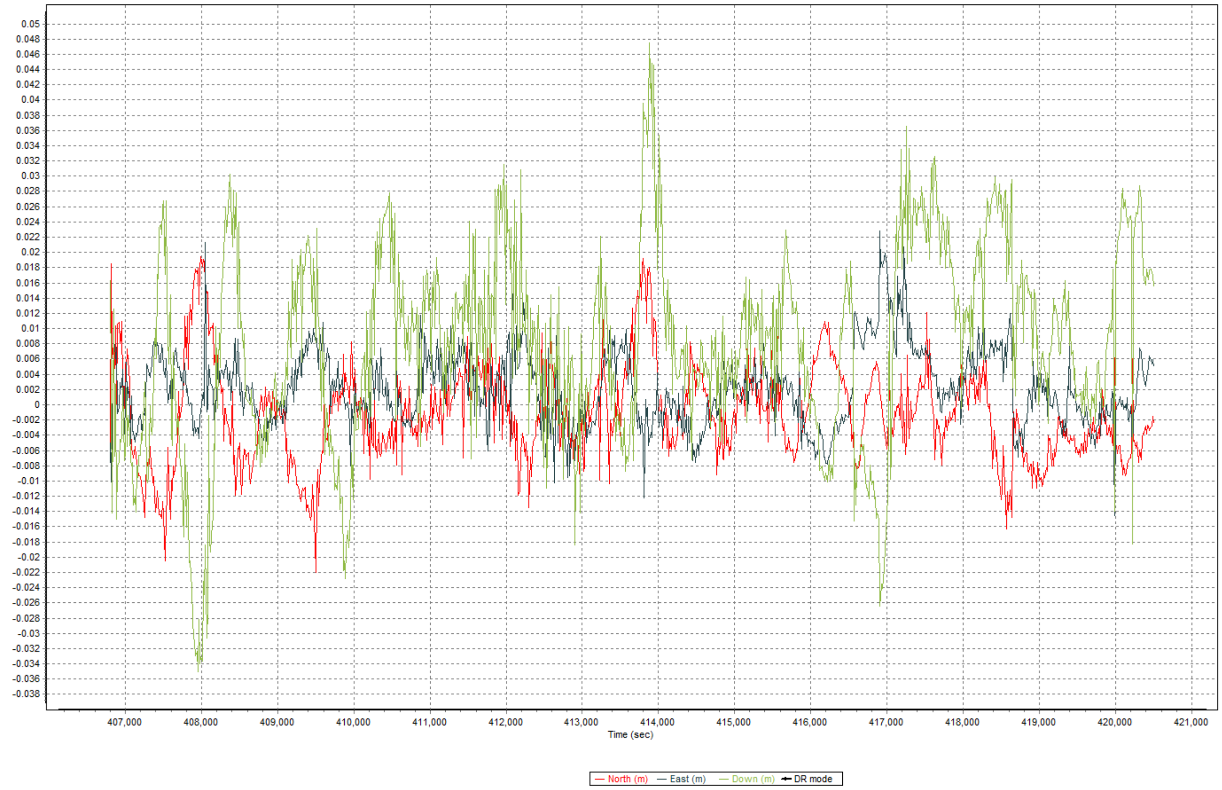

Baseline Length (m)
115,000
110,000
105,000
100,000
95,000
90,000
85,000
80,000
75,000
70,000
65,000
60,000
55,000
50,000
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
324,000
325,000
326,000
327,000
328,000
329,000
330,000
331,000
332,000
333,000
334,000
335,000
336,000
337,000
338,000
339,000
340,000
341,000
342,000
Time (sec)
Forward
Reverse

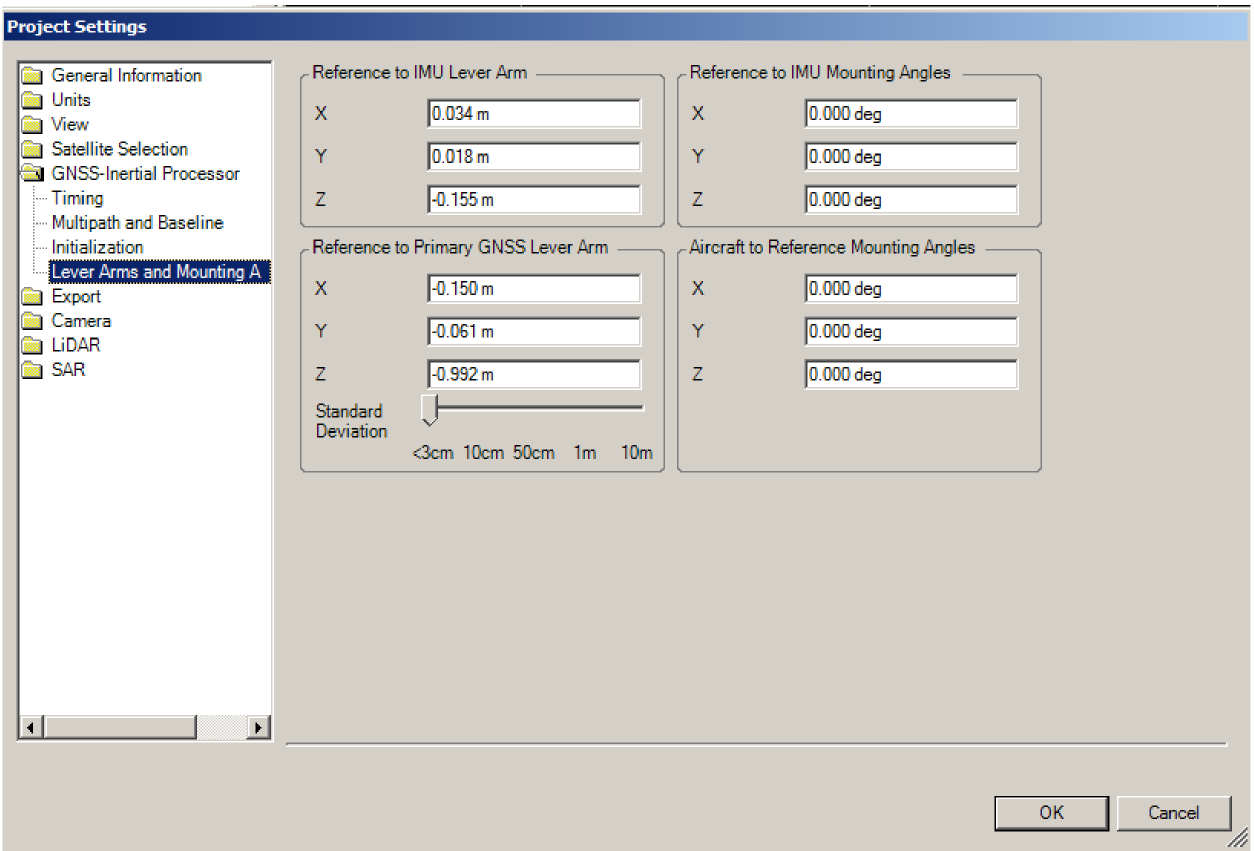

DOP
2
1
322,000
323,000
324,000
325,000
326,000
327,000
328,000
329,000
330,000
331,000
332,000
333,000
334,000
335,000
336,000
337,000
338,000
339,000
340,000
341,000
342,000
Time (sec)
PDOP
HDOP
VDOP

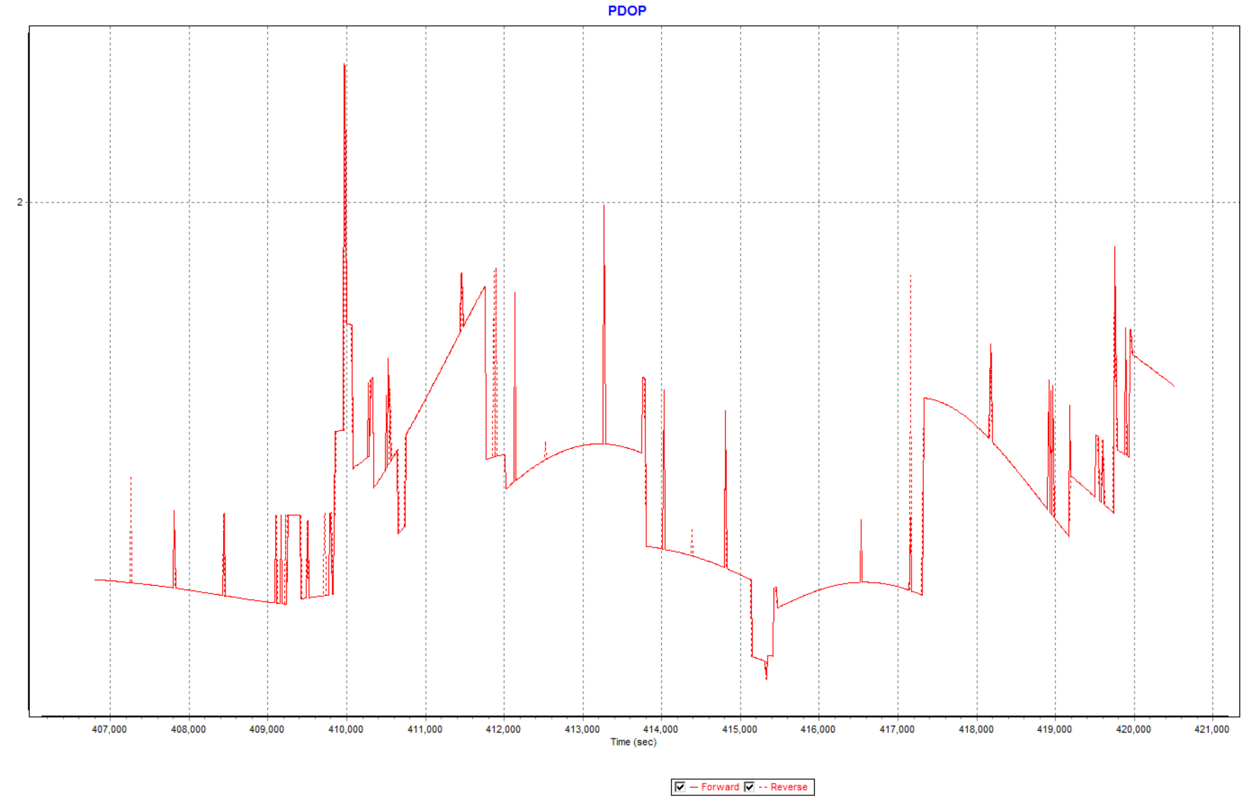
MNB15337A

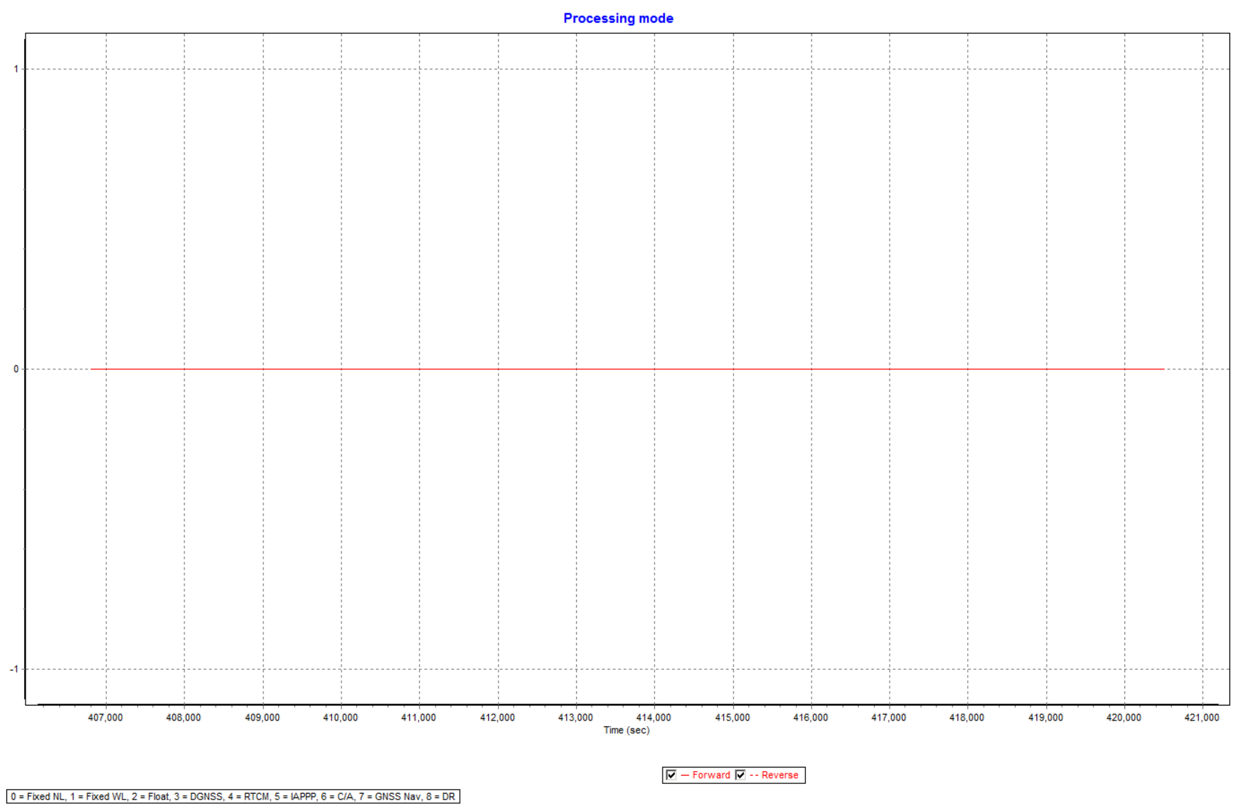

Number of GLONASS Satellites
6
5
4
407,000
408,000
409,000
410,000
411,000
412,000
413,000
414,000
415,000
416,000
417,000
418,000
419,000
420,000
421,000
Time (sec)
— Forward
-- Reverse

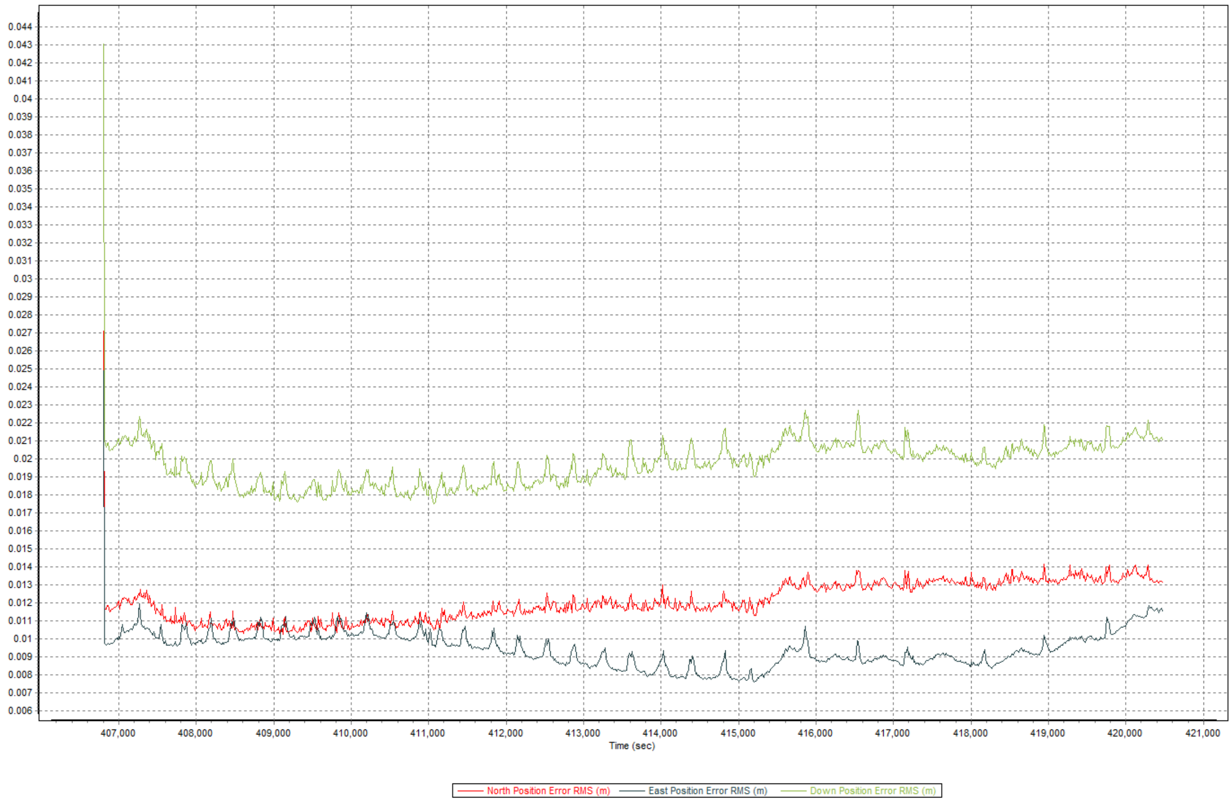

Number of GPS Satellites
10
9
8
7
407,000
408,000
409,000
410,000
411,000
412,000
413,000
414,000
415,000
416,000
417,000
418,000
419,000
420,000
421,000
Time (sec)
— Forward
-- Reverse

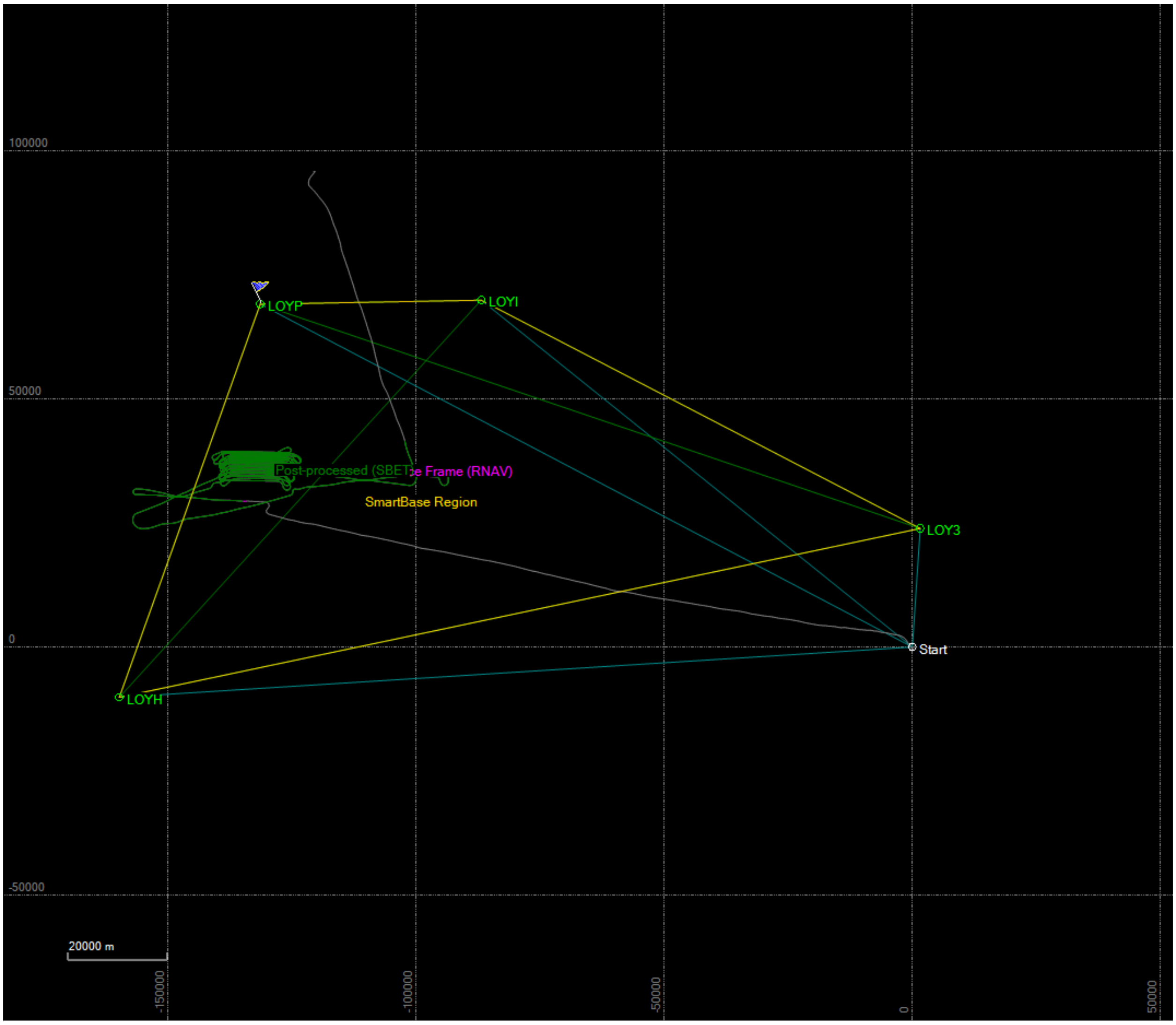

Time (sec)
North (m)
East (m)
Down (m)
DR mode

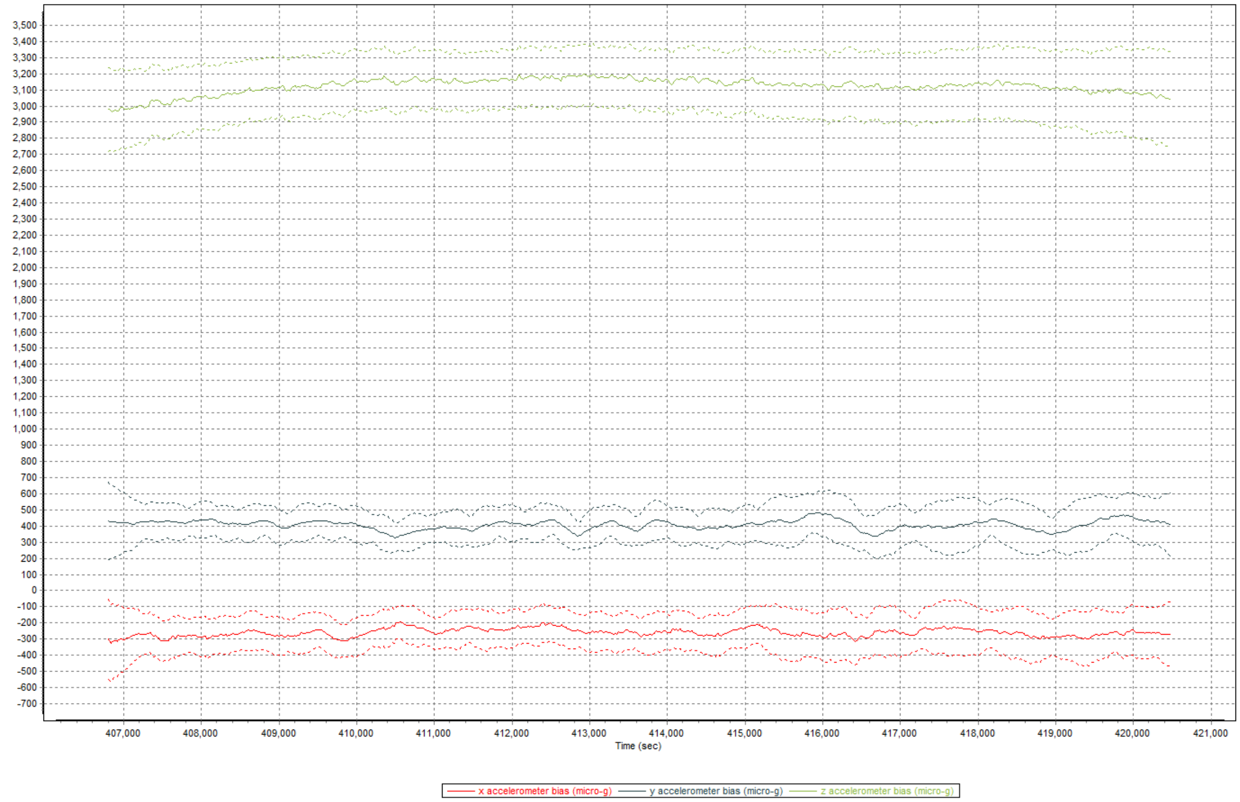

Project Settings
General Information
Units
View
Satellite Selection
GNSS-Inertial Processor
Timing
Multipath and Baseline
Initialization
Lever Arms and Mounting A
Export
Camera
LiDAR
SAR
Reference to IMU Lever Arm
X 0.034 m
Y 0.018 m
Z -0.155 m
Reference to IMU Mounting Angles
X 0.000 deg
Y 0.000 deg
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

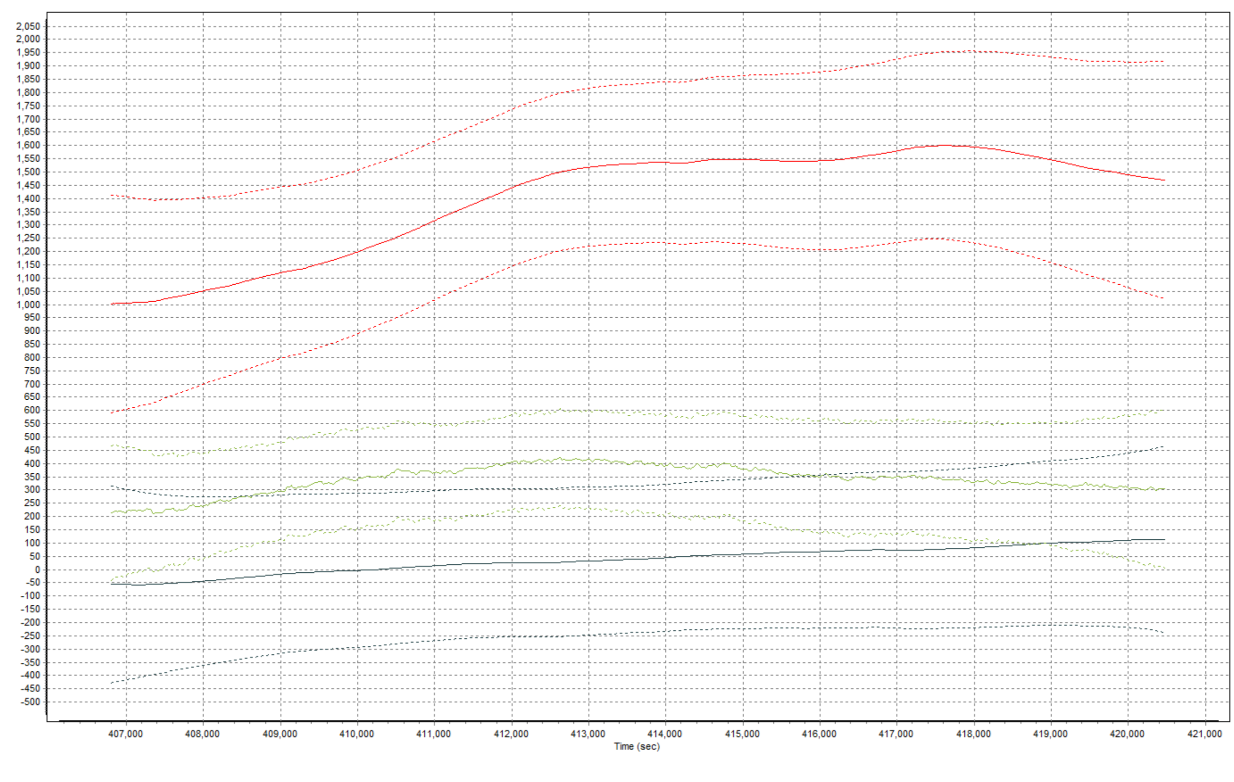

PDOP
2
407,000
408,000
409,000
410,000
411,000
412,000
413,000
414,000
415,000
416,000
417,000
418,000
419,000
420,000
421,000
Time (sec)
Forward
Reverse

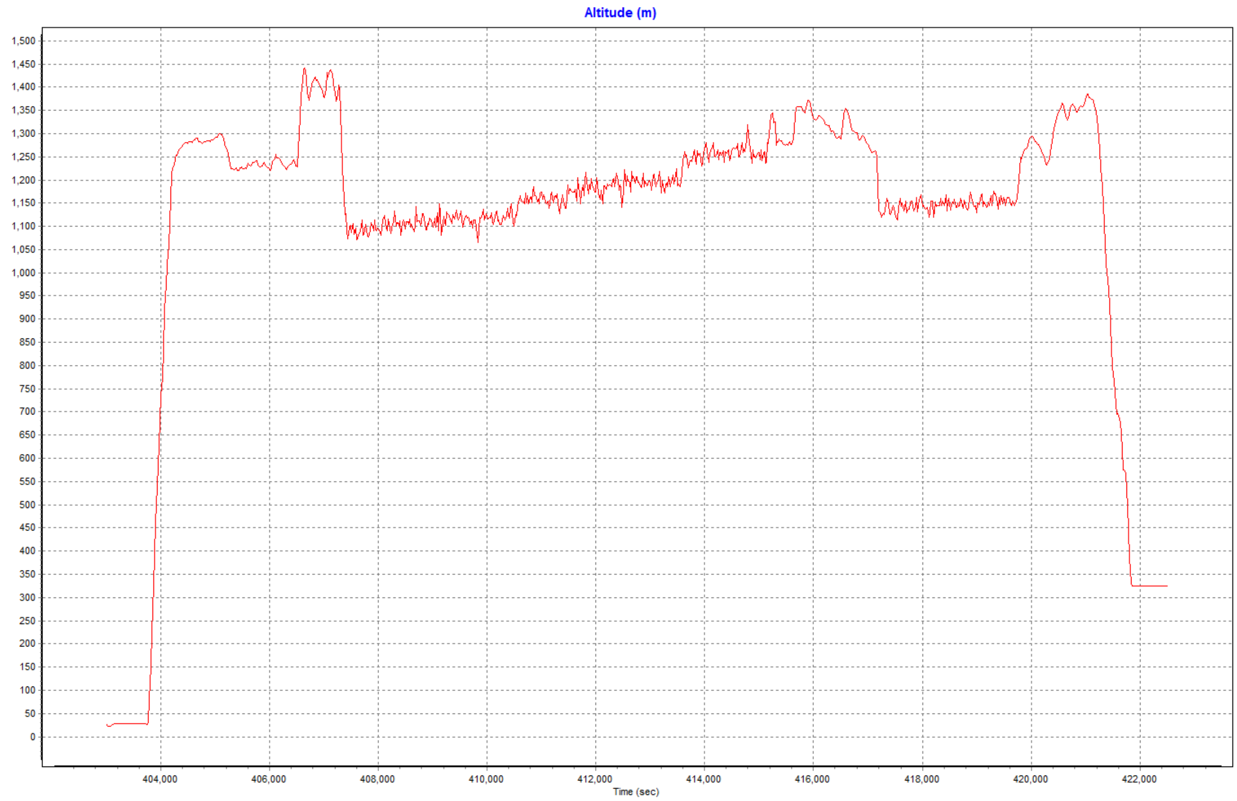

Processing mode
1
0
-1
407,000
408,000
409,000
410,000
411,000
412,000
413,000
414,000
415,000
416,000
417,000
418,000
419,000
420,000
421,000
Time (sec)
Forward
Reverse
0 = Fixed NL, 1 = Fixed WL, 2 = Float, 3 = DGNSS, 4 = RTCM, 5 = IAPPP, 6 = C/A, 7 = GNSS Nav, 8 = DR

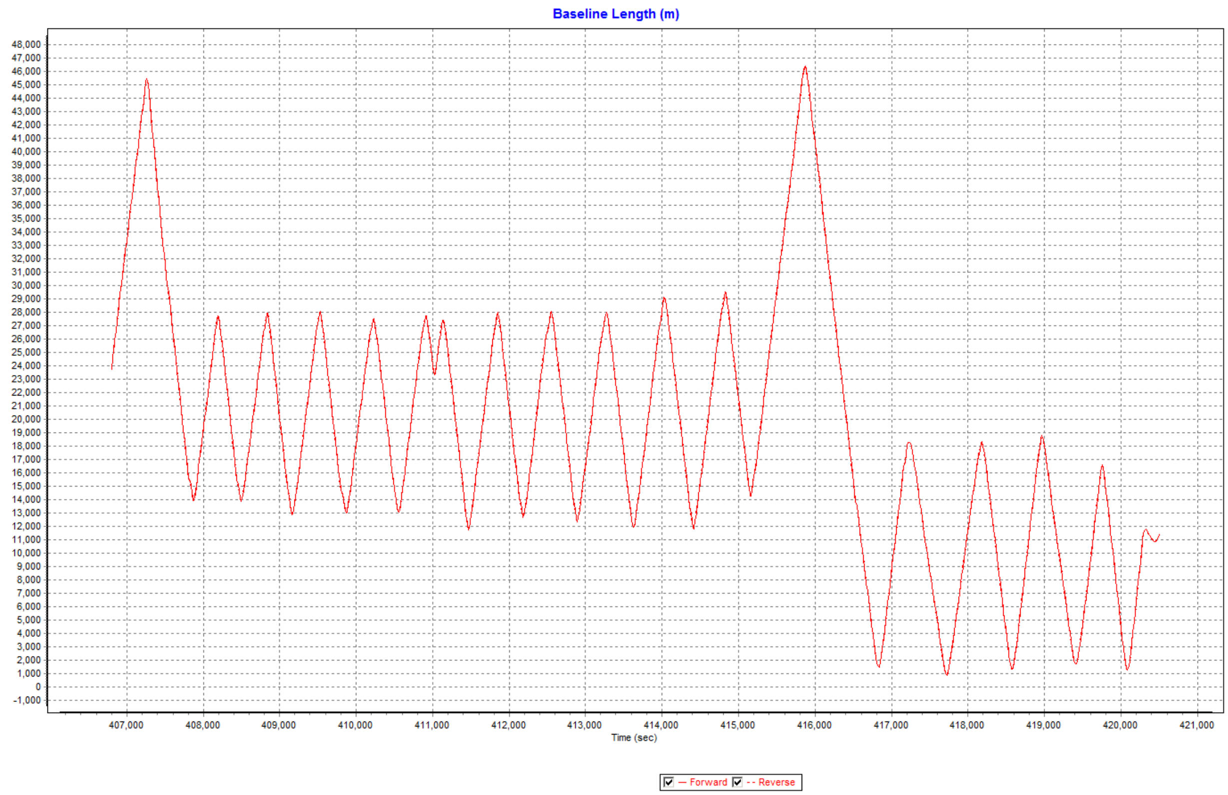

0.044
0.043
0.042
0.041
0.04
0.039
0.038
0.037
0.036
0.035
0.034
0.033
0.032
0.031
0.03
0.029
0.028
0.027
0.026
0.025
0.024
0.023
0.022
0.021
0.02
0.019
0.018
0.017
0.016
0.015
0.014
0.013
0.012
0.011
0.01
0.009
0.008
0.007
0.006
407,000
408,000
409,000
410,000
411,000
412,000
413,000
414,000
415,000
416,000
417,000
418,000
419,000
420,000
421,000
Time (sec)
North Position Error RMS (m)
East Position Error RMS (m)
Down Position Error RMS (m)

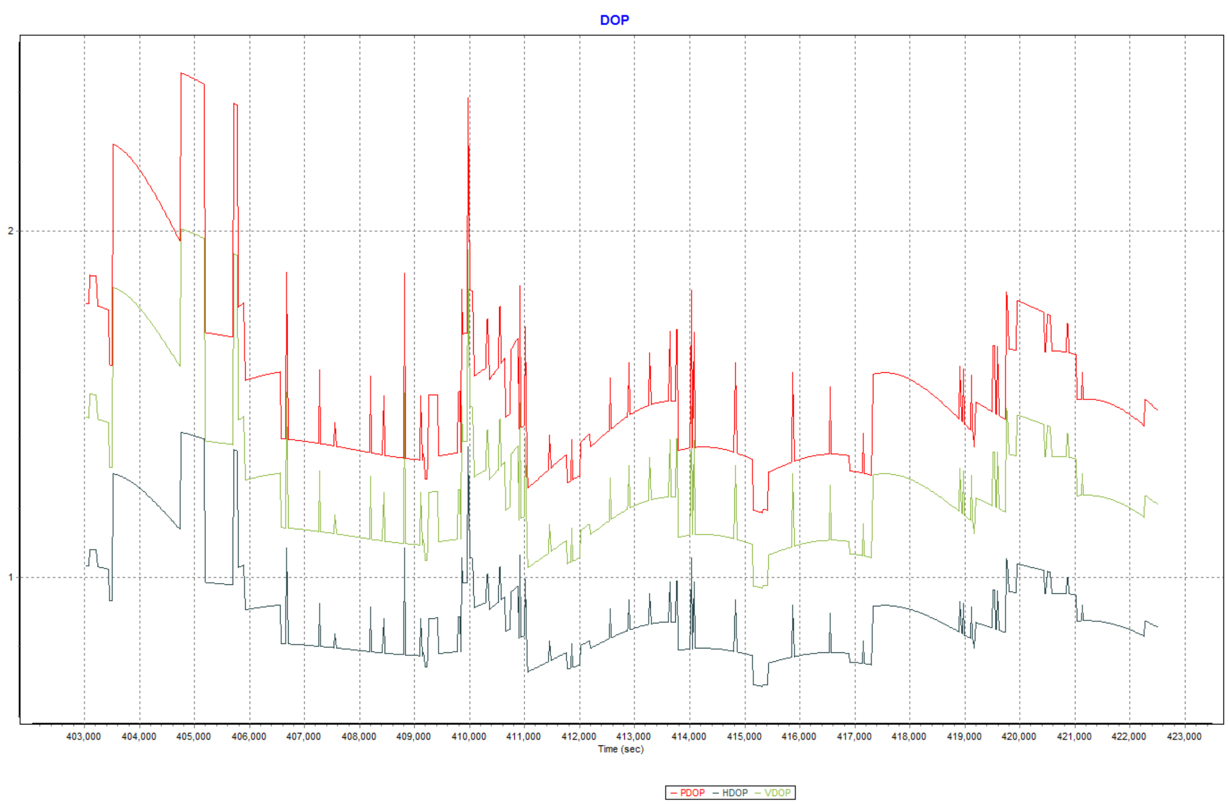

100000
50000
0
-50000
20000 m
-150000
-100000
-50000
0
50000
LOYP
LOYI
LOY3
LOYH
Start
Post-processed (SBET
e Frame (RNAV)
SmartBase Region


Time (sec)
x accelerometer bias (micro-g)
y accelerometer bias (micro-g)
z accelerometer bias (micro-g)

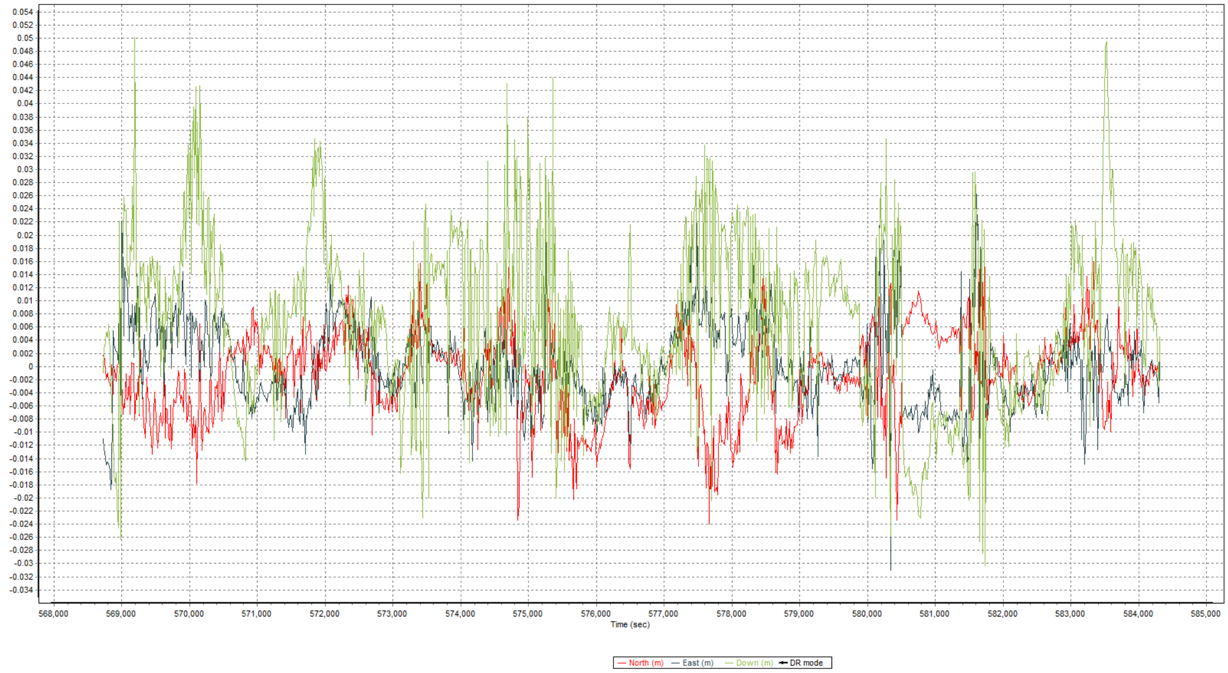

Time (sec)
x accelerometer scale error (ppm)
y accelerometer scale error (ppm)
z accelerometer scale error (ppm)

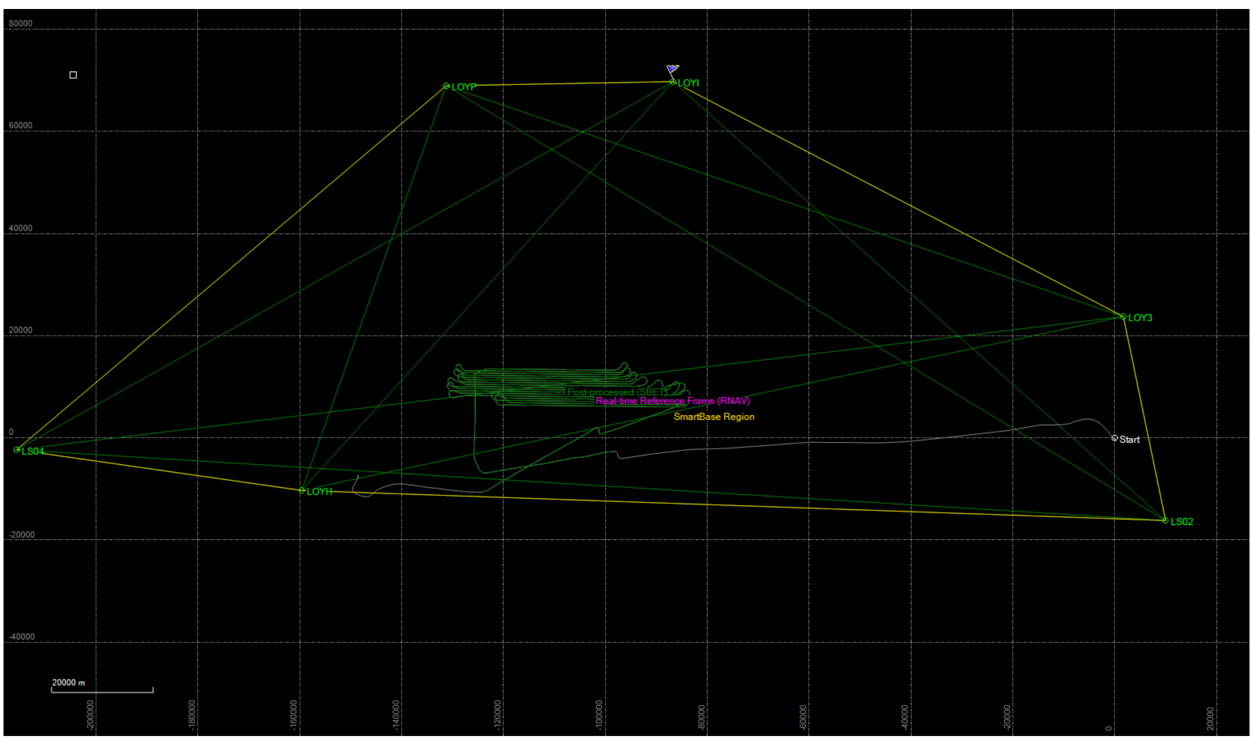

Altitude (m)
1,500
1,450
1,400
1,350
1,300
1,250
1,200
1,150
1,100
1,050
1,000
950
900
850
800
750
700
650
600
550
500
450
400
350
300
250
200
150
100
50
0
404,000
406,000
408,000
410,000
412,000
414,000
416,000
418,000
420,000
422,000
Time (sec)

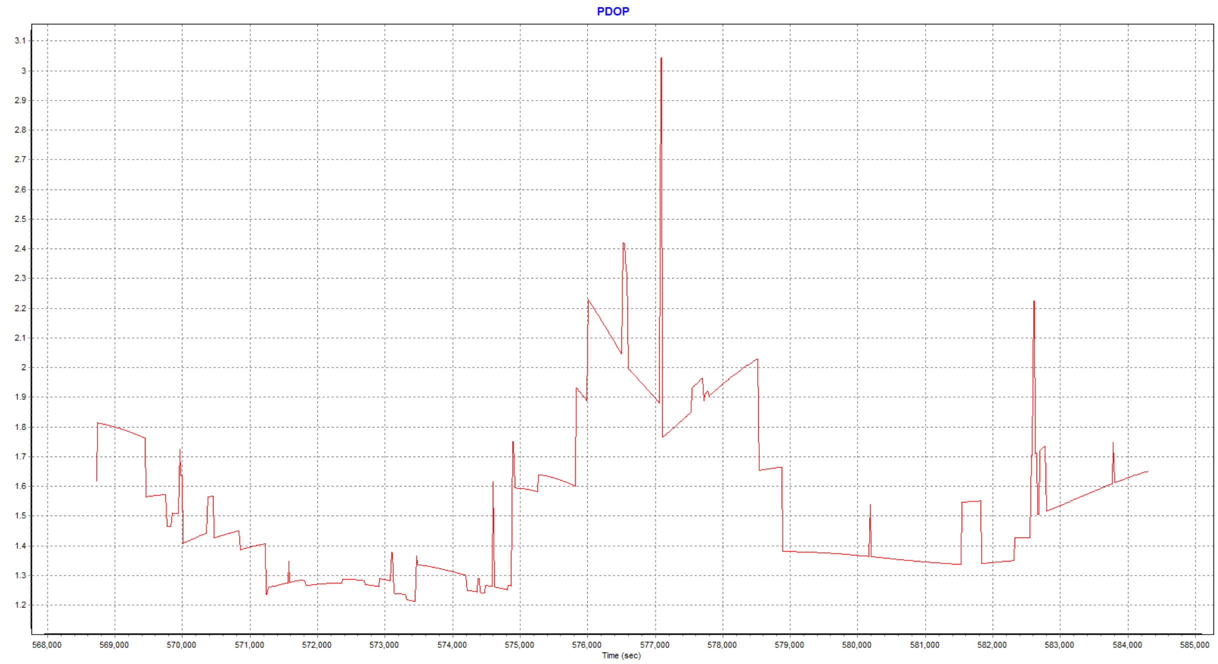

Baseline Length (m)
Time (sec)
Forward
Reverse

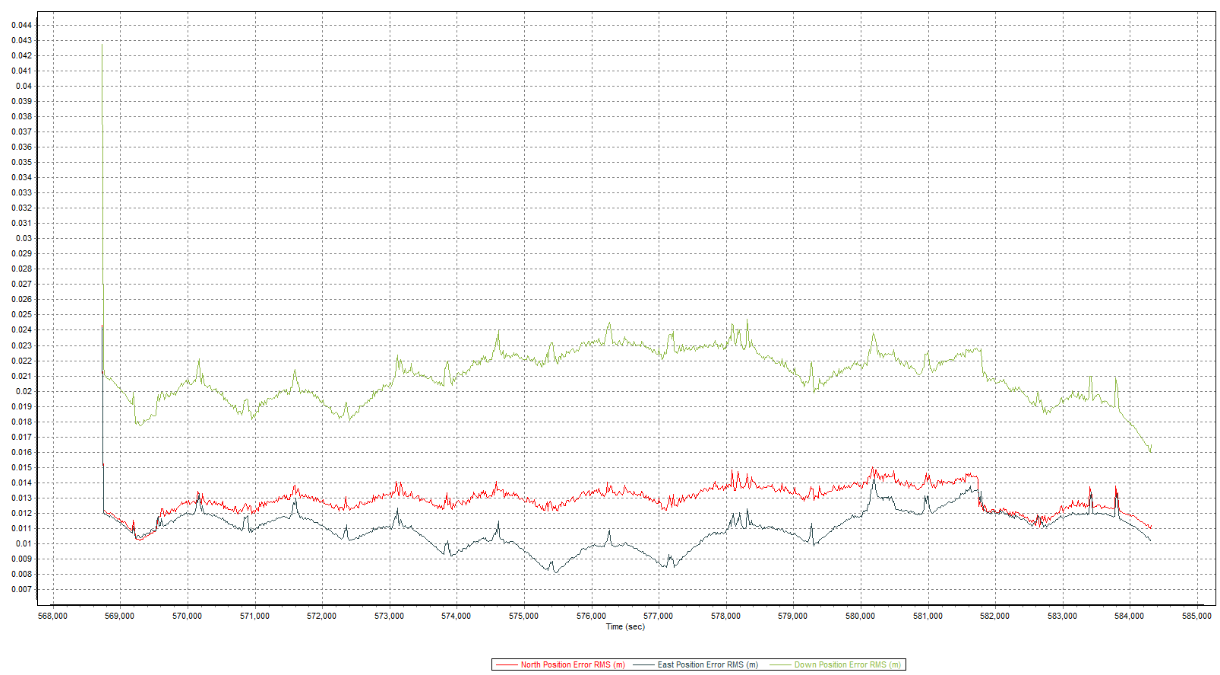

DOP
Time (sec)
PDOP
HDOP
VDOP

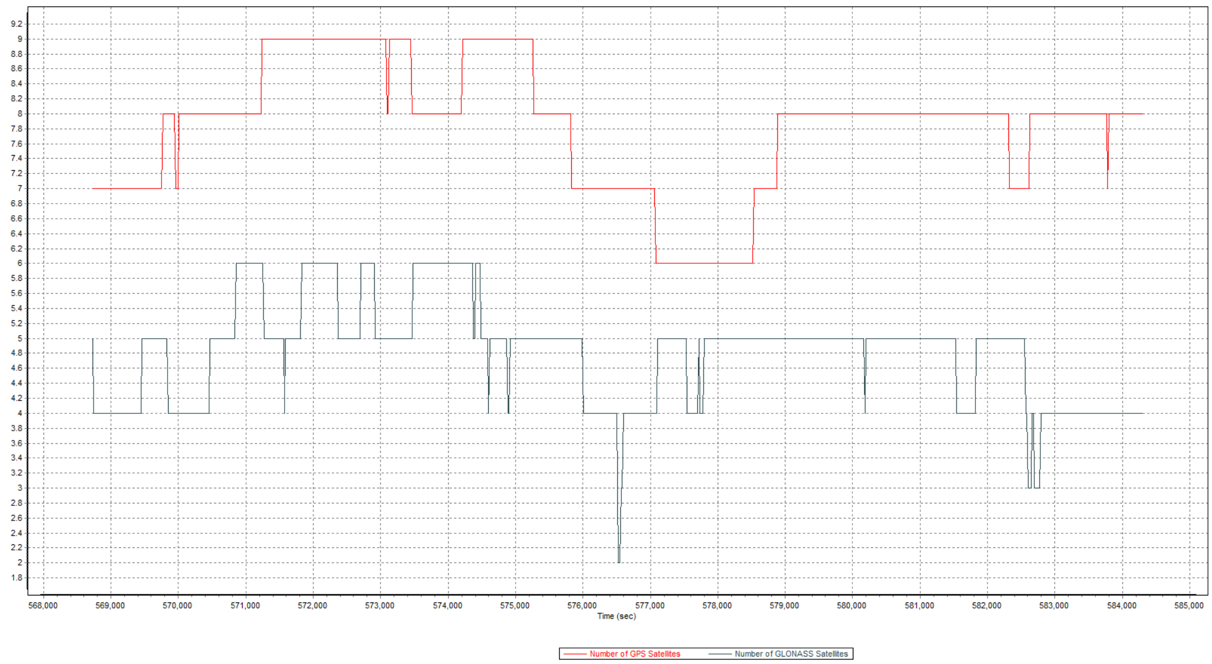
MNB15339A

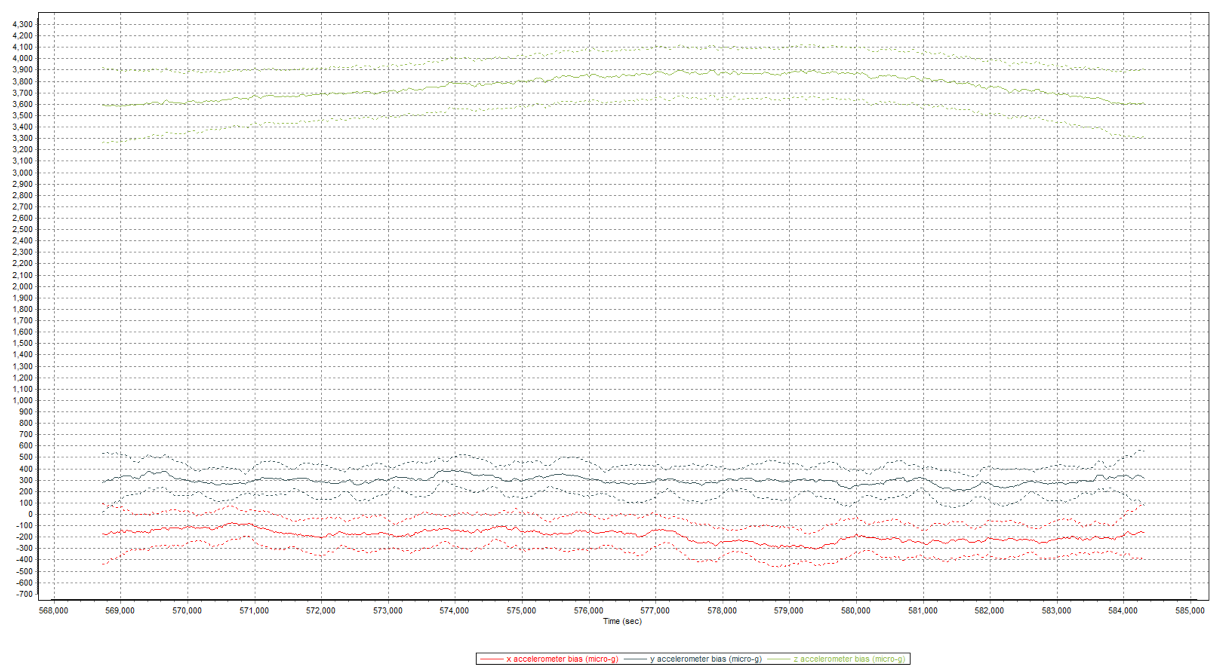

0.054
0.052
0.05
0.048
0.046
0.044
0.042
0.04
0.038
0.036
0.034
0.032
0.03
0.028
0.026
0.024
0.022
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
-0.002
-0.004
-0.006
-0.008
-0.01
-0.012
-0.014
-0.016
-0.018
-0.02
-0.022
-0.024
-0.026
-0.028
-0.03
-0.032
-0.034
568,000
569,000
570,000
571,000
572,000
573,000
574,000
575,000
576,000
577,000
578,000
579,000
580,000
581,000
582,000
583,000
584,000
585,000
Time (sec)
North (m)
East (m)
Down (m)
DR mode

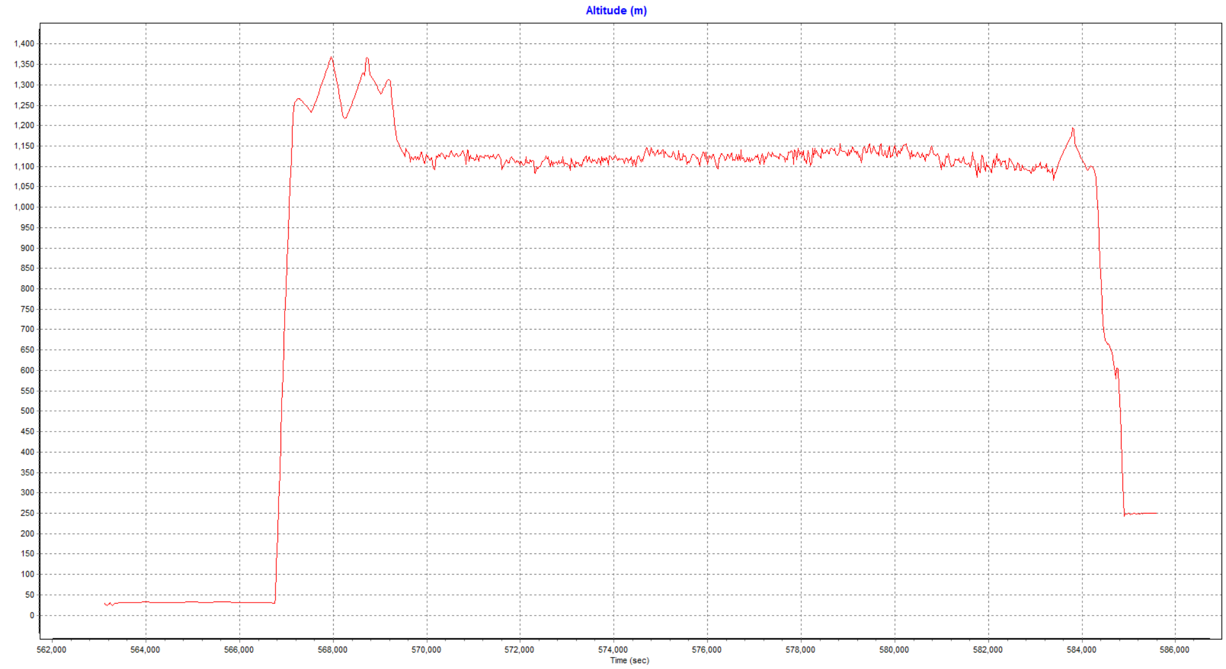

80000
60000
40000
20000
0
-20000
-40000
LOYP
LOYI
LOY3
LS04
LOYH
LS02
Start
Post-processed (SBET)
Real-time Reference Frame (RNAV)
SmartBase Region
20000 m
-200000
-180000
-160000
-140000
-120000
-100000
-80000
-60000
-40000
-20000
0
20000

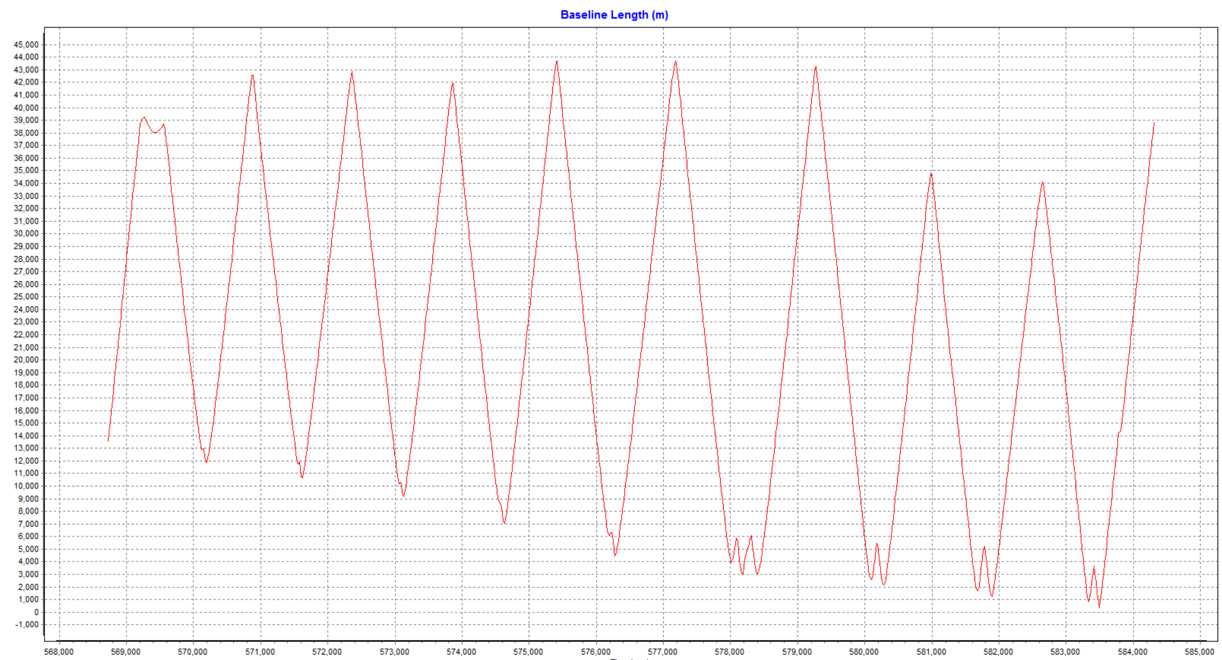

PDOP
3.1
3
2.9
2.8
2.7
2.6
2.5
2.4
2.3
2.2
2.1
2
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
568,000
569,000
570,000
571,000
572,000
573,000
574,000
575,000
576,000
577,000
578,000
579,000
580,000
581,000
582,000
583,000
584,000
585,000
Time (sec)

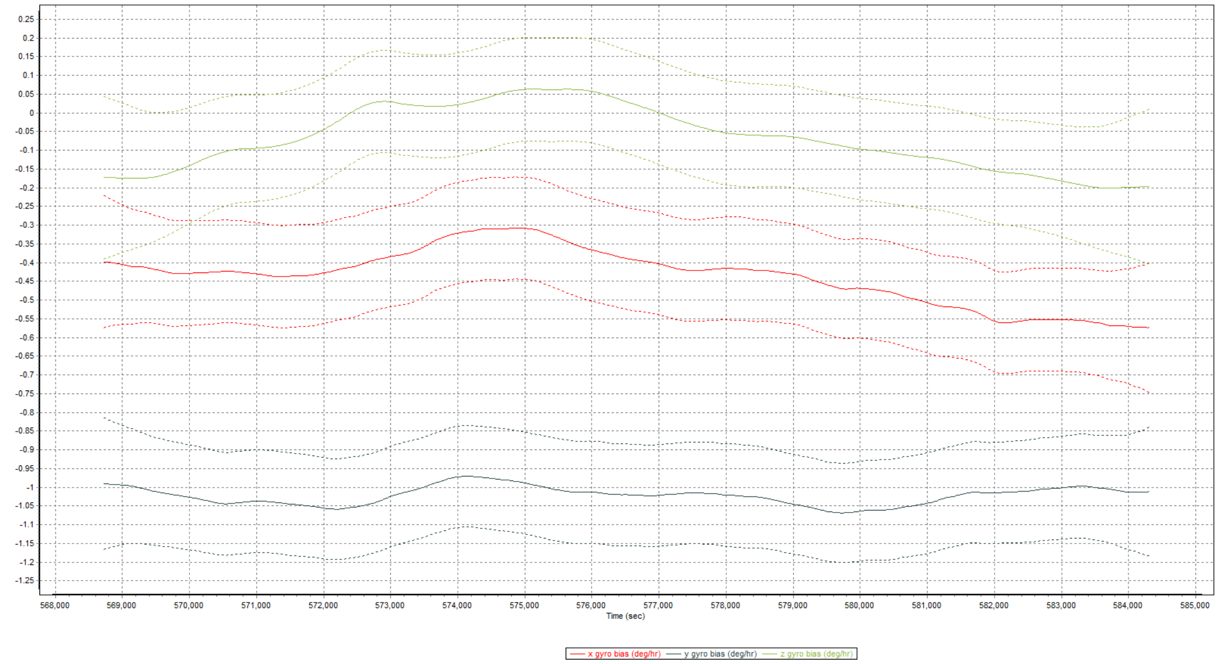

0.044
0.043
0.042
0.041
0.04
0.039
0.038
0.037
0.036
0.035
0.034
0.033
0.032
0.031
0.03
0.029
0.028
0.027
0.026
0.025
0.024
0.023
0.022
0.021
0.02
0.019
0.018
0.017
0.016
0.015
0.014
0.013
0.012
0.011
0.01
0.009
0.008
0.007
568,000
569,000
570,000
571,000
572,000
573,000
574,000
575,000
576,000
577,000
578,000
579,000
580,000
581,000
582,000
583,000
584,000
585,000
Time (sec)
North Position Error RMS (m)
East Position Error RMS (m)
Down Position Error RMS (m)


Time (sec)
Number of GPS Satellites
Number of GLONASS Satellites

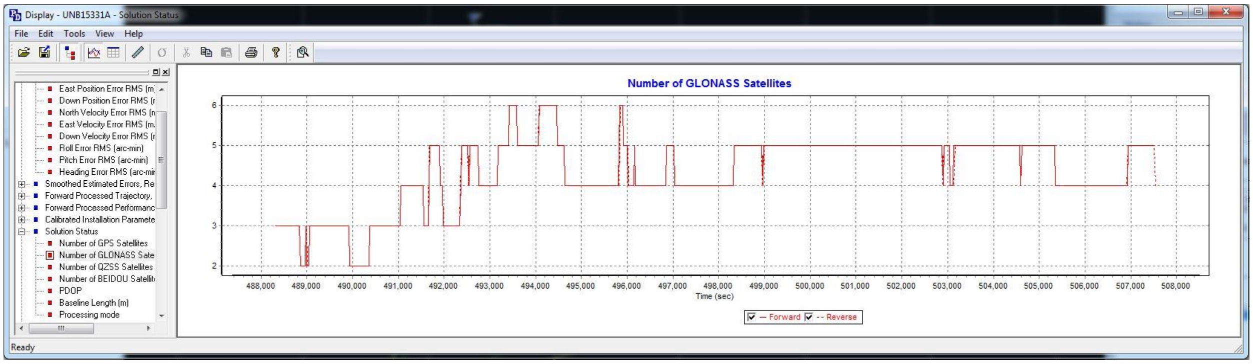

Time (sec)
x accelerometer bias (micro-g)
y accelerometer bias (micro-g)
z accelerometer bias (micro-g)

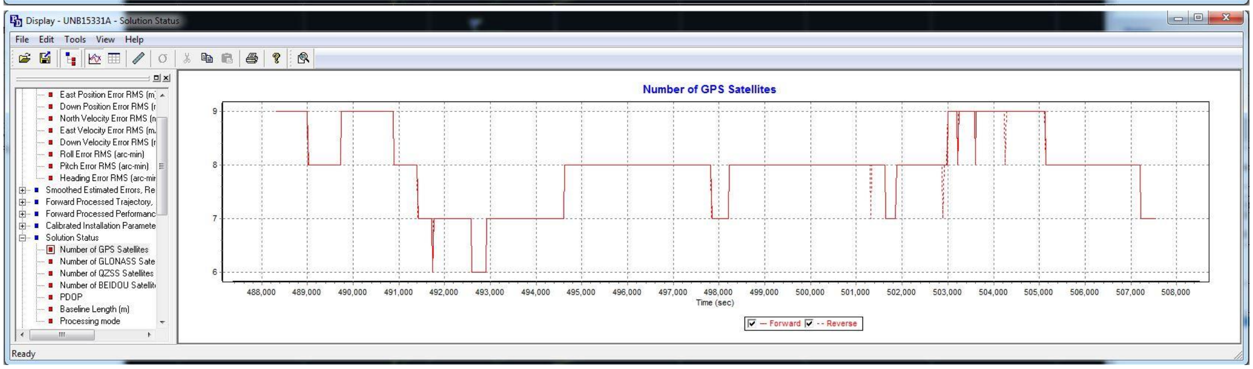

Altitude (m)
Time (sec)

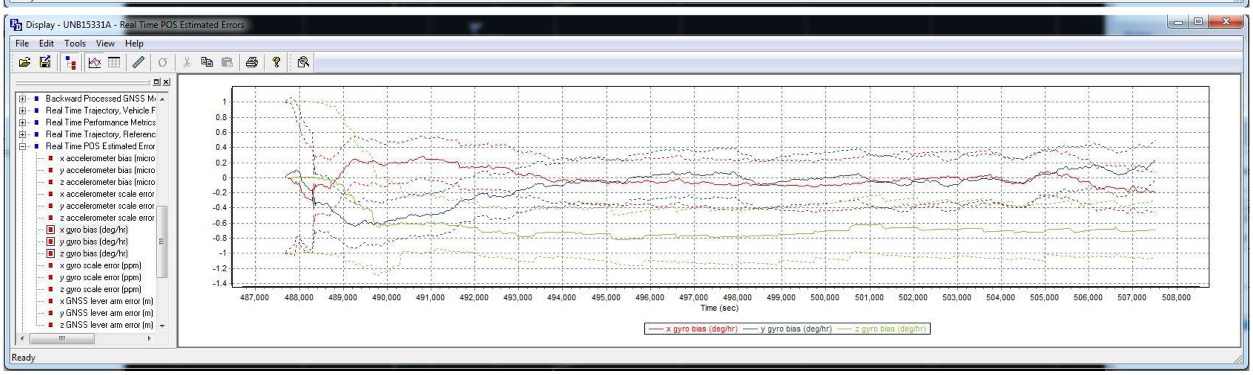

Baseline Length (m)
Time (sec)

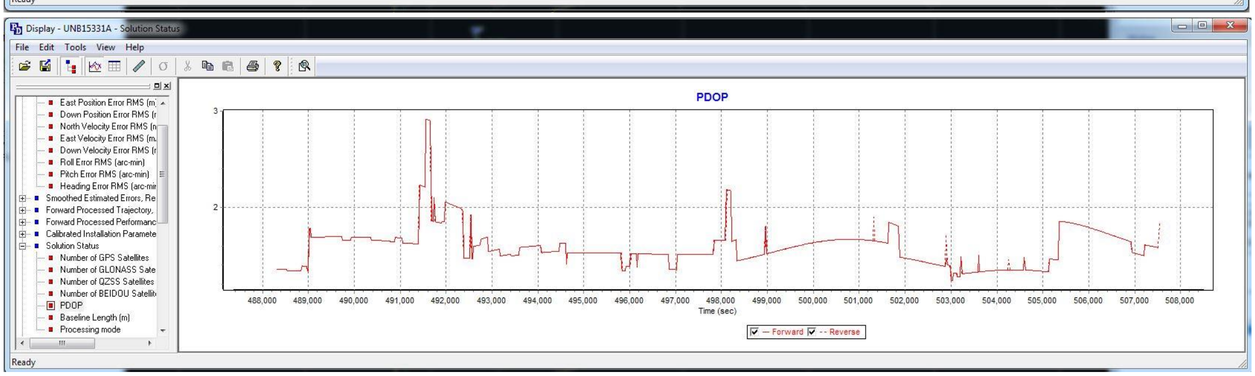

0.25
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
-0.25
-0.3
-0.35
-0.4
-0.45
-0.5
-0.55
-0.6
-0.65
-0.7
-0.75
-0.8
-0.85
-0.9
-0.95
-1
-1.05
-1.1
-1.15
-1.2
-1.25
568,000
569,000
570,000
571,000
572,000
573,000
574,000
575,000
576,000
577,000
578,000
579,000
580,000
581,000
582,000
583,000
584,000
585,000
Time (sec)
x gyro bias (deg/hr)
y gyro bias (deg/hr)
z gyro bias (deg/hr)

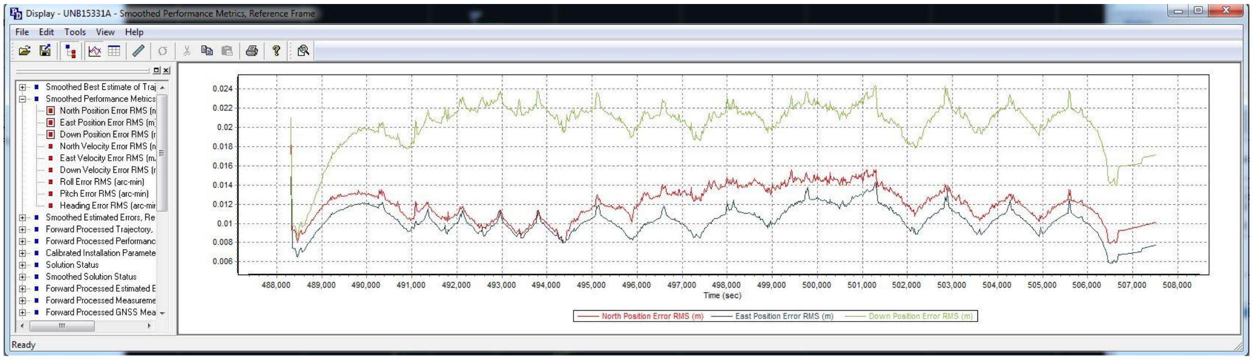
UNB15331A

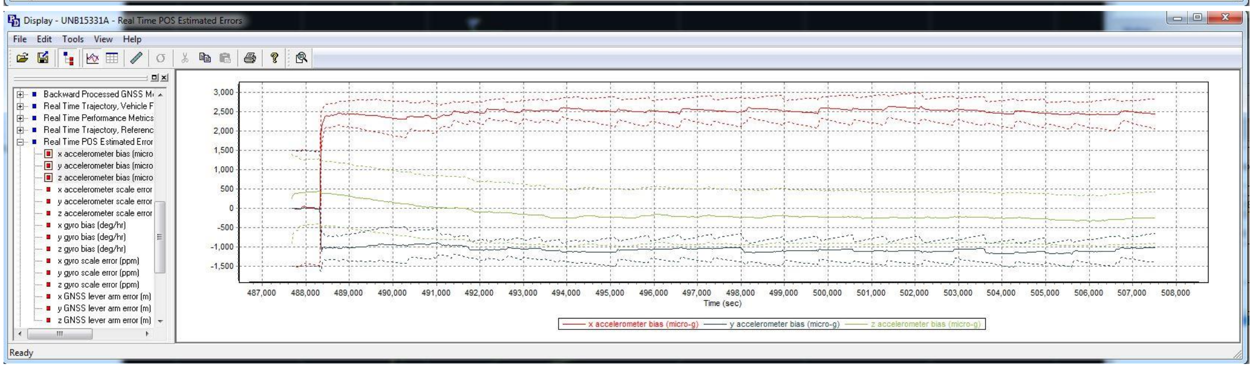

Display - UNB15331A - Solution Status
Number of GLONASS Satellites
Time (sec)
Forward
Reverse


Display - UNB15331A - Solution Status
Number of GPS Satellites
Time (sec)
Forward
Reverse


Display - UNB15331A - Real Time POS Estimated Errors
Time (sec)
x gyro bias (deg/hr)
y gyro bias (deg/hr)
z gyro bias (deg/hr)

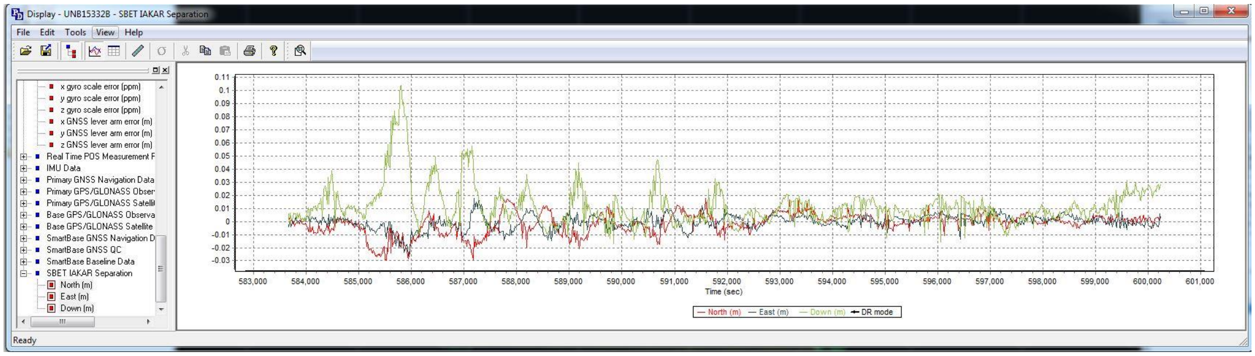

Display - UNB15331A - Solution Status
PDOP
Time (sec)
Forward
Reverse

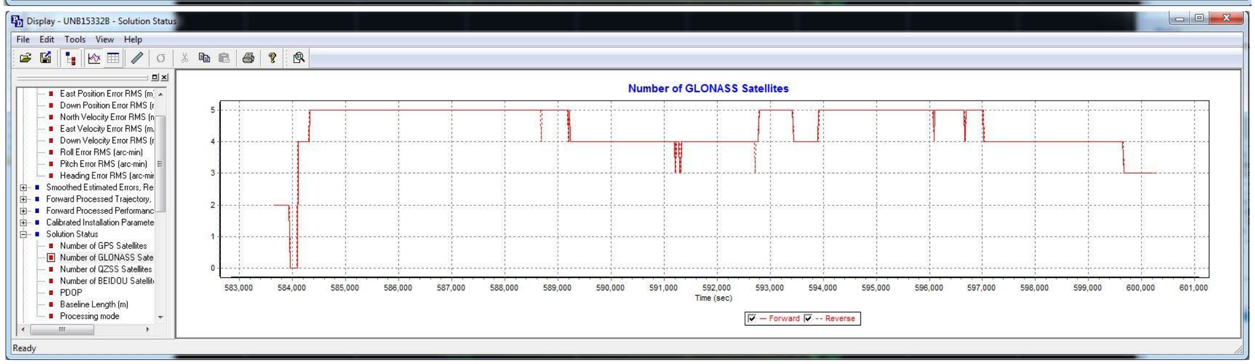

Display - UNB15331A - Smoothed Performance Metrics, Reference Frame
Time (sec)
North Position Error RMS (m)
East Position Error RMS (m)
Down Position Error RMS (m)

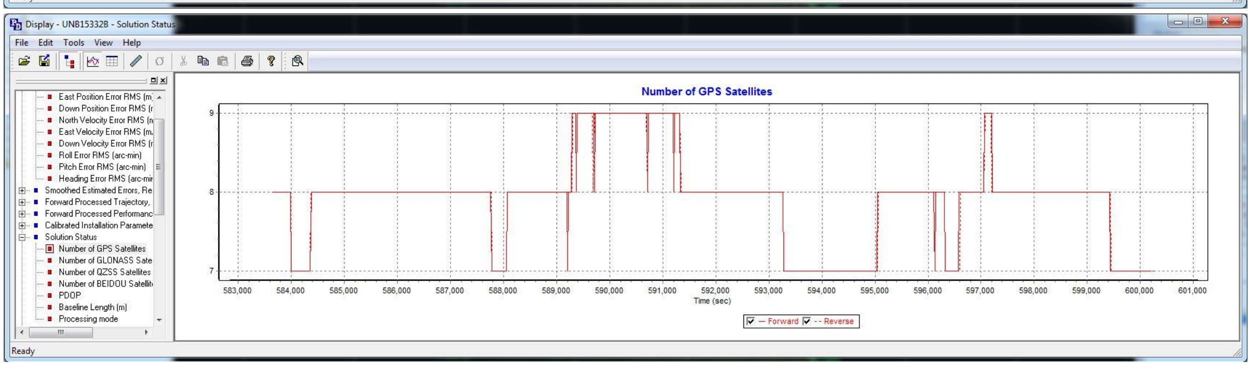

Display - UNB15331A - Real Time POS Estimated Errors
Time (sec)
x accelerometer bias (micro-g)
y accelerometer bias (micro-g)
z accelerometer bias (micro-g)

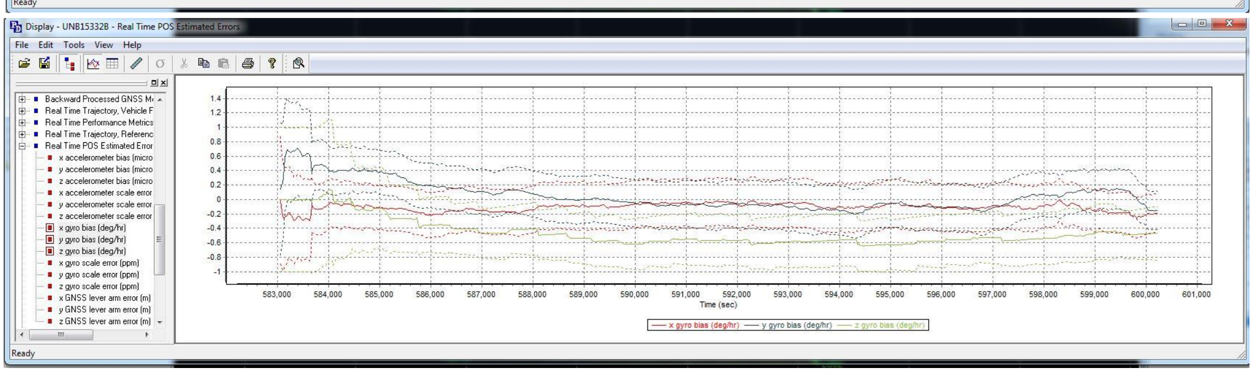

Display - UNB15331A - SBET IAKAR Separation
Time (sec)
North (m)
East (m)
Down (m)
DR mode

UNB15332B


Display - UNB15332B - SBET IAKAR Separation
File Edit Tools View Help
Time (sec)
North (m)
East (m)
Down (m)
DR mode
Ready

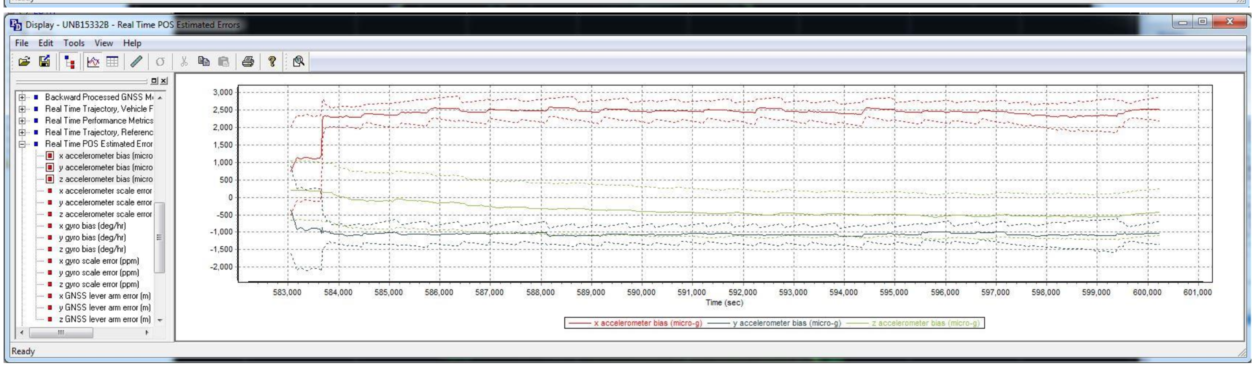

Display - UNB15332B - Solution Status
File Edit Tools View Help
Number of GLONASS Satellites
Time (sec)
Forward
Reverse
Ready


Display - UNB15332B - Solution Status
File Edit Tools View Help
Number of GPS Satellites
Time (sec)
Forward
Reverse
Ready


Display - UNB15332B - Real Time POS Estimated Errors
File Edit Tools View Help
Time (sec)
x gyro bias (deg/hr)
y gyro bias (deg/hr)
z gyro bias (deg/hr)
Ready


Display - UNB153328 - Solution Status
PDOP
Time (sec)
Forward
Reverse


Display - UNB153328 - Smoothed Performance Metrics, Reference Frame
Time (sec)
North Position Error RMS (m)
East Position Error RMS (m)
Down Position Error RMS (m)


Display - UNB153328 - Real Time POS Estimated Errors
Time (sec)
x accelerometer bias (micro-g)
y accelerometer bias (micro-g)
z accelerometer bias (micro-g)