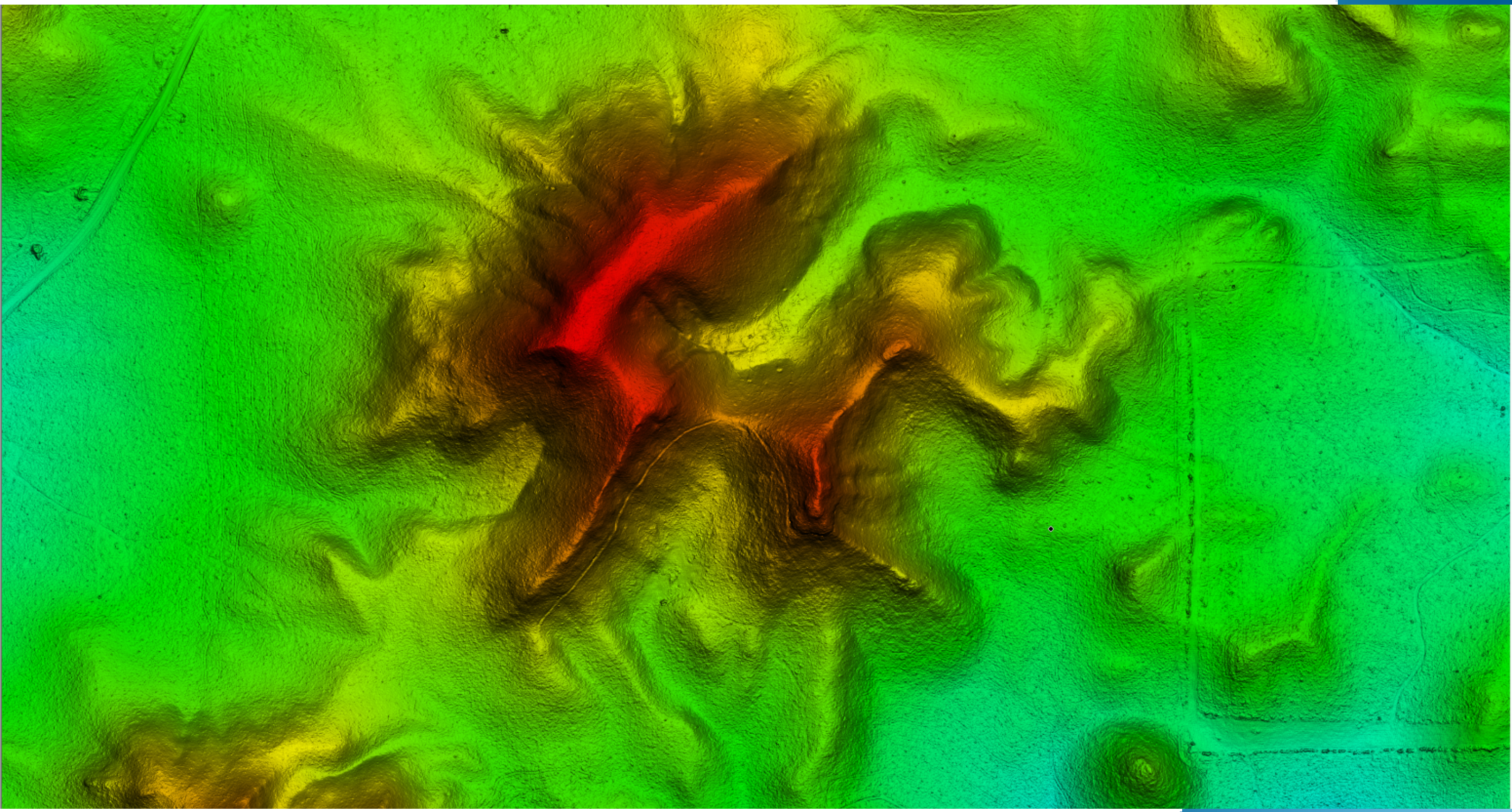
NV5 GEOSPATIAL



WI 12 County 3 B22 Green LIDAR PROCESSING REPORT

2023

Submitted: August 31, 2023

Project ID: 230110
Work Unit: 300206

Prepared for:

USGS
science for a changing world

Prepared by:

NV5 GEOSPATIAL

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1. Summary / Scope

1.1. Summary

This report contains a summary of the WI_12County_3_B22 , Work Unit 300206 lidar acquisition task order, issued by USGS under their Contract 140G0221D0012 on March 28, 2022. The task order yielded a work unit area covering 590 square miles over Wisconsin at Quality Level 2. The intent of this document is only to provide specific validation information for the data acquisition/collection, processing, and production of deliverables completed as specified in the task order.

1.2. Scope

Aerial topographic lidar was acquired using state of the art technology along with the necessary surveyed ground control points (GCPs) and airborne GPS and inertial navigation systems. The aerial data collection was designed with the following specifications listed in Table 1 below.

Table 1. Originally Planned Lidar Specifications

Average Point Density	Flight Altitude (AGL)	Field of View	Minimum Side Overlap	RMSEz
2 pts / m2	2300 m	58.5°	20%	≤ 10 cm

1.3. Coverage

The work unit boundary covers 590 square miles over Green County, Wisconsin. Work unit extents are shown in Figure 1.

1.4. Duration

Lidar data was acquired from April 11, 2022 to April 12, 2022 in 2 total lifts. See “Section: 2.4. Time Period” for more details.

1.5. Issues

There were no issues to report.

WI_12County_3_B22 Work Unit 300206 Projected Coordinate System: Wisconsin Coordinate Reference System - Green & Lafayette Horizontal Datum: NAD83 (2011) Vertical Datum: NAVD88 (GEOID 18) Units: Survey Feet	
Lidar Point Cloud	Classified Point Cloud in .LAS 1.4 format
Rasters	• 2-foot Hydro-flattened Bare Earth Digital Elevation Model (DEM) in GeoTIFF format • 2-foot Intensity images in GeoTIFF format • 4-foot Maximum Surface Height Raster • 4-foot Swath Seperation Images
Vectors	Shapefiles (*.shp) • Project Boundary • Lidar Tile Index Geodatabase (*.gdb) • Continuous Hydro-flattened Breaklines • Flightlines Swath
Reports	Reports in PDF format • Focus on Delivery • Survey Report • Processing Report
Metadata	XML Files (*.xml) • Breaklines • Classified Point Cloud • DEM • Intensity Imagery

WI_12County_3_B22
Work Unit 300206 Boundary

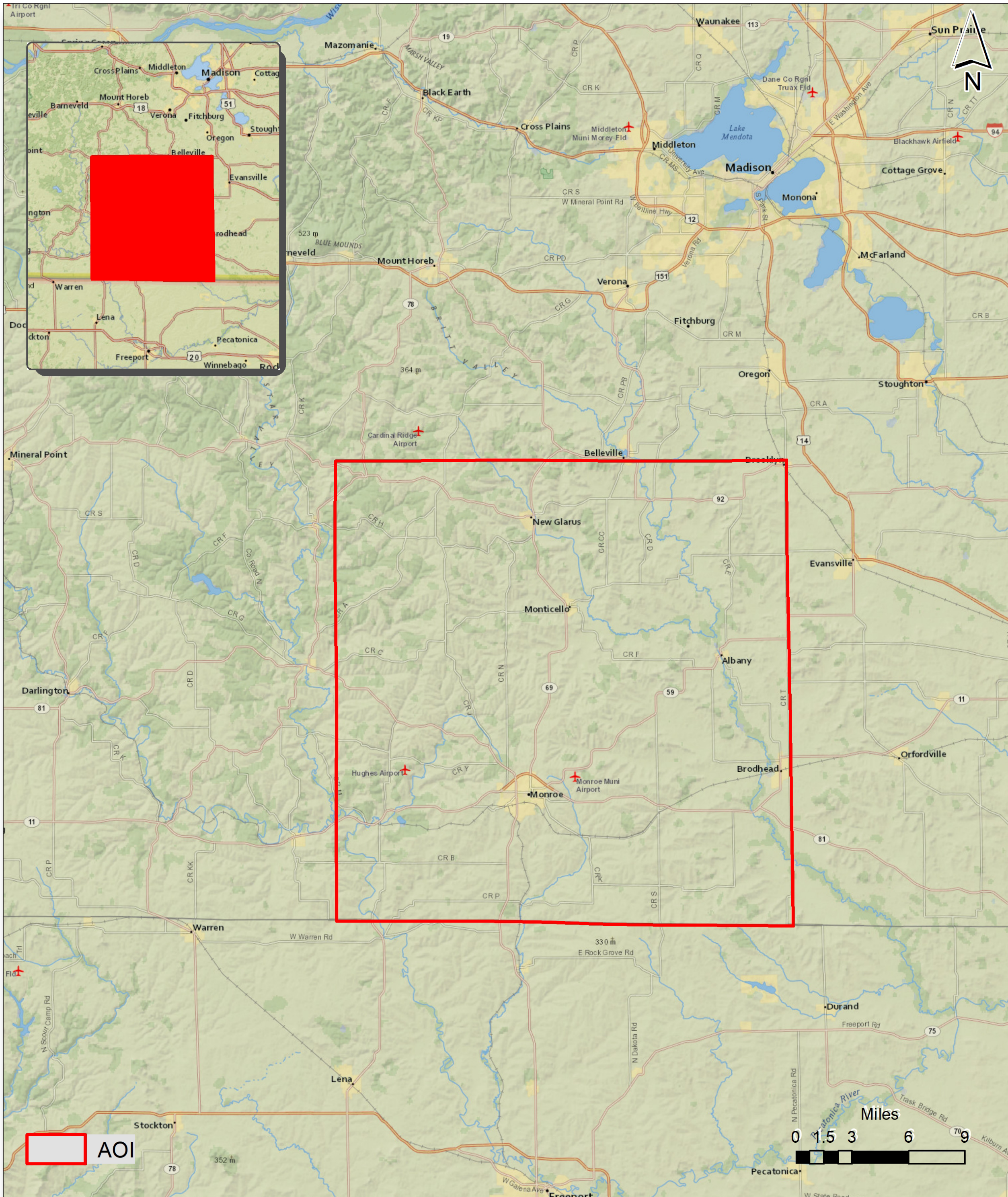


Figure 1. Work Unit Boundary

2. Planning / Equipment

2.1. Flight Planning

Flight planning was based on the unique project requirements and characteristics of the project site. The basis of planning included: required accuracies, type of development, amount / type of vegetation within project area, required data posting, and potential altitude restrictions for flights in project vicinity.

Detailed project flight planning calculations were performed for the project using RiPARAMETER planning software.

2.2. Lidar Sensor

NV5 Geospatial utilized Riegl VQ1560ii lidar sensors (Figure 2), serial number(s) 3062 and 3543, for data acquisition.

The Riegl 1560ii system is a dual channel waveform processing airborne scanning system. It has a laser pulse repetition rate of up to 4 MHz resulting in up to 2.66 million measurements per second. The system utilizes a Multi-Pulse in the Air option (MPIA) and an integrated IMU/GNSS unit.

A brief summary of the aerial acquisition parameters for the project are shown in the lidar System Specifications in Table 2.

Table 2. Lidar System Specifications

		Riegl VQ1560ii (SN3062)
Terrain and Aircraft Scanner	Flying Height	2300 m
	Recommended Ground Speed	160 kts
Scanner	Field of View	60°
	Scan Rate Setting Used	100 lps
Laser	Laser Pulse Rate Used	500 kHz
	Multi Pulse in Air Mode	yes
Coverage	Full Swath Width	3147 m
	Line Spacing	2517 m
Point Spacing and Density	Average Point Spacing	0.71 m
	Average Point Density	2 pts / m^2

Figure 2. Riegl VQ1560ii Lidar Sensor

2.3. Aircraft

All flights for the project were accomplished through the use of customized aircraft. Plane type and tail numbers are listed below.

Lidar Collection Planes
- Piper PA-31, Tail Number(s): C-GAYY

These aircraft provided an ideal, stable aerial base for lidar acquisition. These aerial platforms have relatively fast cruise speeds, which are beneficial for project mobilization / demobilization while maintaining relatively slow stall speeds, proving ideal for collection of high-density, consistent data posting using a state-of-the-art lidar system. NV5 Geospatial's operating aircraft can be seen in Figure 3 below.

Figure 3. NV5 Geospatial's Aircraft

2.4. Time Period

Project specific flights were conducted between April 11, 2022 and April 12, 2022. Two aircraft lifts were completed. Accomplished lifts are listed below.

Lift	Start UTC	End UTC
04112022A (SN3062,C-GAYY)	4/11/2022 4:15:18 PM	4/11/2022 8:23:56 PM
04122022A (SN3062,C-GAYY)	4/12/2022 1:28:46 PM	4/12/2022 2:10:59 PM

3. Processing Summary

3.1. Flight Logs

Flight logs were completed by Lidar sensor technicians for each mission during acquisition. These logs depict a variety of information, including:

- Job / Project #
- Flight Date / Lift Number
- FOV (Field of View)
- Scan Rate (HZ)
- Pulse Rate Frequency (Hz)
- Ground Speed
- Altitude
- Base Station
- PDOP avoidance times
- Flight Line #
- Flight Line Start and Stop Times
- Flight Line Altitude (AMSL)
- Heading
- Speed
- Returns
- Crab

Notes: (Visibility, winds, ride, weather, temperature, dew point, pressure, etc). Project specific flight logs for each sortie are available in Appendix A.

3.2. Lidar Processing

Applanix + POSPac software was used for post-processing of airborne GPS and inertial data (IMU), which is critical to the positioning and orientation of the lidar sensor during all flights. Applanix POSPac combines aircraft raw trajectory data with stationary GPS base station data yielding a "Smoothed Best Estimate Trajectory" (SBET) necessary for additional post processing software to develop the resulting geo-referenced point cloud from the lidar missions.

During the sensor trajectory processing (combining GPS & IMU datasets) certain statistical graphs and tables are generated within the Applanix POSPac processing environment which are commonly used as indicators of processing stability and accuracy. This data for analysis include: max horizontal / vertical GPS variance, separation plot, altitude plot, PDOP plot, base station baseline length, processing mode, number of satellite vehicles, and mission trajectory.

Point clouds in flightline swath format were created using the RiPROCESS software. The generated point cloud is the mathematical three dimensional composite of all returns from all laser pulses as determined from the aerial mission. Each flightline swath point cloud was calibrated using Strip Align software that corrects systematic geometric errors and improves the relative and absolute accuracy of the flightline swath point cloud. The calibrated point cloud swaths were imported into GeoCue distributive processing software and the imported data was then tiled so further processing could take place in TerraScan software. Using TerraScan, the vertical accuracy of the surveyed ground control was tested and any vertical bias was removed from the data. TerraScan and TerraModeler software packages were then used for automated data classification and manual cleanup. The data were manually reviewed and any remaining artifacts removed using functionality provided by TerraScan and TerraModeler.

DEMs and Intensity Images are then generated using proprietary software. In the bare earth surface model, above-ground features are excluded from the data set. Global Mapper is used as a final check of the bare earth dataset.

Finally, proprietary software is used to perform statistical analysis of the LAS files.

Software	Version
Applanix + POSPac	8.6
RiPROCESS	1.8.6
GeoCue	2020.1.22.1
Global Mapper	19.1;20.1
Microstation Connect	10.16.02.34
TerraModeler	21.008
TerraScan	21.016
StripAlign	2.21

3.3. LAS Classification Scheme

The classification classes are determined by Lidar Base Specifications 2021, Revision A and are an industry standard for the classification of lidar point clouds. All data starts the process as Class 1 (Unclassified), and then through automated classification routines, the classifications are determined using TerraScan macro processing.

The classes used in the dataset are as follows and have the following descriptions:

Table 3. LAS Classifications

	Classification Name	Description
1	Processed, but Unclassified	Laser returns that are not included in the bare earth class, or any other project classification
2	Bare earth	Laser returns that are determined to be bare earth using automated and manual cleaning algorithms
7	Low Noise	Laser returns that are often associated with scattering from reflective surfaces, or artificial points below the bare earth surface
9	Water	Laser returns that are found inside of hydro features
17	Bridge Deck	Laser returns falling on bridge decks
18	High Noise	Laser returns that are often associated with birds or artificial points above the bare earth surface
20	Ignored Ground	Bare earth points that fall within the given threshold of a collected hydro feature.
21	Snow	Bare earth points that fall on snow, where identifiable
22	Temporal Exclusion	Points that are excluded due to differences in collection dates

3.4. Classified LAS Processing

The bare earth surface is then manually reviewed to ensure correct classification on the Class 2 (Ground) points. After the bare- earth surface is finalized, it is then used to generate all hydro-breaklines through heads-up digitization.

All ground (ASPRS Class 2) lidar data inside of the Lake Pond and Double Line Drain hydro flattening breaklines were then classified to water (ASPRS Class 9) using proprietary tools. A buffer of 3 feet/1 meter was also used around each hydro flattened feature to classify these ground (ASPRS Class 2) points to Ignored ground (ASPRS Class 20). All Lake Pond Island and Double Line Drain Island features were checked to ensure that the ground (ASPRS Class 2) points were reclassified to the correct classification after the automated classification was completed.

Any noise that was identified either through manual review or automated routines was classified to the appropriate class (ASPRS Class 7 and/or ASPRS Class 18) followed by flagging with the withheld bit.

All data was manually reviewed and any remaining artifacts removed using functionality provided by TerraScan and TerraModeler. Global Mapper is used as a final check of the bare earth dataset. GeoCue was then used to create the deliverable industry-standard LAS files for all point cloud data. NV5 Geospatial's proprietary software was used to perform final statistical analysis of the classes in the LAS files, on a per tile level to verify final classification metrics and full LAS header information.

3.5. Hydro-Flattened Breakline Processing

Using heads-up digitization, all Lake-Ponds, Double Line Drains, and Islands are manually collected that are within the project size specification. This includes Lake-Ponds greater than 2 acres in size, Double Line Drains with greater than a 100 foot nominal width, and Islands greater than 1 acre in size within a collected hydro feature. Lidar intensity imagery and bare-earth surface models are used to ensure appropriate and complete collection of these features.

Elevation values are assigned to all collected hydro features via NV5 Geospatial's proprietary software. This software sets Lake-Ponds to an appropriate, single elevation to allow for the generation of hydro-flattened digital elevation models (DEM). Double Line Drain elevations are assigned based on lidar elevations and surrounding terrain feature to ensure all breaklines match the lidar within acceptable tolerances. Some deviation is expected between breakline and lidar elevations due to monotonicity, connectivity, and flattening rules that are enforced on the breaklines. Once complete, horizontal placement, and vertical variances are reviewed, all breaklines are evaluated for topological consistency and data integrity using a combination of proprietary tools and manual review of hydro-flattened DEMs.

Breaklines are combined into one seamless shapefile, clipped to the project boundary, and imported into an Esri file geodatabase for delivery.

3.6. Hydro-Flattened Raster DEM Processing

Hydro-Flattened DEMs (topographic) represent a lidar-derived product illustrating the grounded terrain and associated breaklines (as described above) in raster form. NV5 Geospatial's proprietary software was used to take all input sources (bare earth lidar points, bridge and hydro breaklines, etc.) and create a Triangulated Irregular Network (TIN) on a tile-by-tile basis. Data extending past the tile edge is incorporated in this process so that proper triangulation can occur. From the TIN, linear interpolation is used to calculate the cell values for the raster product. The raster product is then clipped back to the tile edge so that no overlapping cells remain across the project area. A 32-bit floating point GeoTIFF DEM was generated for each tile with a pixel size of 2-foot. NV5 Geospatial's proprietary software was used to write appropriate horizontal and vertical projection information as well as applicable header values into the file during product generation. Each DEM is reviewed in Global Mapper to check for any surface anomalies and to ensure a seamless dataset. NV5 Geospatial ensures there are no void or no-data values (-999999) in each derived DEM. This is achieved by using propriety software checking all cell values that fall within the project boundary. NV5 Geospatial uses a proprietary tool called FOCUS on Delivery to check all formatting requirements of the DEMs against what is required before final delivery.

3.7. Intensity Image Processing

Intensity images represent reflectivity values collected by the lidar sensor during acquisition. Proprietary software generates intensity images using first returns and excluding those flagged with a withheld bit. Intensity images are linearly scaled to a value range specific to the project area to standardize the images and reduce differences between individual tiles. Appropriate horizontal projection information as well as applicable header values are written during product generation.

3.8. Swath Separation Raster Processing

Swath Separation Images are rasters that represent the interswath alignment between flight lines and provide a qualitative evaluation of the positional quality of the point cloud. NV5 Geospatial proprietary software generated 4-foot raster images in GeoTIFF format using last returns, excluding points flagged with the withheld bit, and using a point-in-cell algorithm. Images are generated with a 75% intensity opacity and (4) absolute 8-cm intervals, see below for interval coloring. Intensity images are linearly scaled to a value range specific to the project area to standardize the images and reduce differences between individual tiles. Appropriate horizontal projection information as well as applicable header values are written to the file during product generation. NV5 Geospatial uses a proprietary tool called FOCUS on Delivery to check all formatting requirements of the images against what is required before final delivery.

Green	0-8cm
Yellow	8-16cm
Orange	16-24cm
Red	>24cm

3.9. Maximum Surface Height Raster Processing

Maximum Surface Height rasters (topographic) represent a lidar-derived product illustrating natural and built-up features. NV5 Geospatial's proprietary software was used to take all classified lidar points, excluding those flagged with a withheld bit, and create a raster on a tile-by-tile basis. Data extending past the tile edge is incorporated in this process so that proper gridding can occur. The raster is created by laying a 4-foot DEM cell size over the area and assigning the values to cells by using the maximum lidar point that intersects that grid cell. The raster product is then clipped back to the tile edge so that no overlapping cells remain across the project area. A 32-bit floating point GeoTIFF was then generated for each tile with a pixel size of 4-foot. There is no interpolation type being used in creating the raster product. NV5 Geospatial's proprietary software was used to write appropriate horizontal and vertical projection information as well as applicable header values into the file during product generation. Each maximum surface height raster is reviewed in Global Mapper to check for any anomalies and to ensure a seamless dataset. NV5 Geospatial uses a proprietary tool called FOCUS on Delivery to check all formatting requirements of the DEMs against what is required before final delivery.

3.10. Point Density

The acquisition parameters were designed to acquire an average first-return density of 2 points/m2. First return density describes the density of pulses emitted from the laser that return at least one echo to the system. Multiple returns greater than 1 from a single pulse were not considered in first return density analysis. Some types of surfaces (e.g., breaks in terrain, water, and steep slopes) may have returned fewer pulses than originally emitted by the laser. First returns typically reflect off the highest feature on the landscape within the footprint of the pulse. In forested or urban areas, the highest feature could be a tree, building or power line, while in areas of unobstructed ground, the first return will be the only echo and represents the bare earth surface.

The density of ground-classified lidar returns was also analyzed for this project. Terrain character, land cover, and ground surface reflectivity all influenced the density of ground surface returns. In vegetated areas, fewer pulses may penetrate the canopy, resulting in lower ground density.

The average first-return density of lidar data for the project was 4.85 points/m2) while the average ground classified density was 4.64 points/m2). The statistical and spatial distributions of first return densities and classified ground return densities per 100 m x 100 m cell are portrayed in Figures 4 and 5.

WI_12County_3_B22
Work Unit 300206 First Return Density

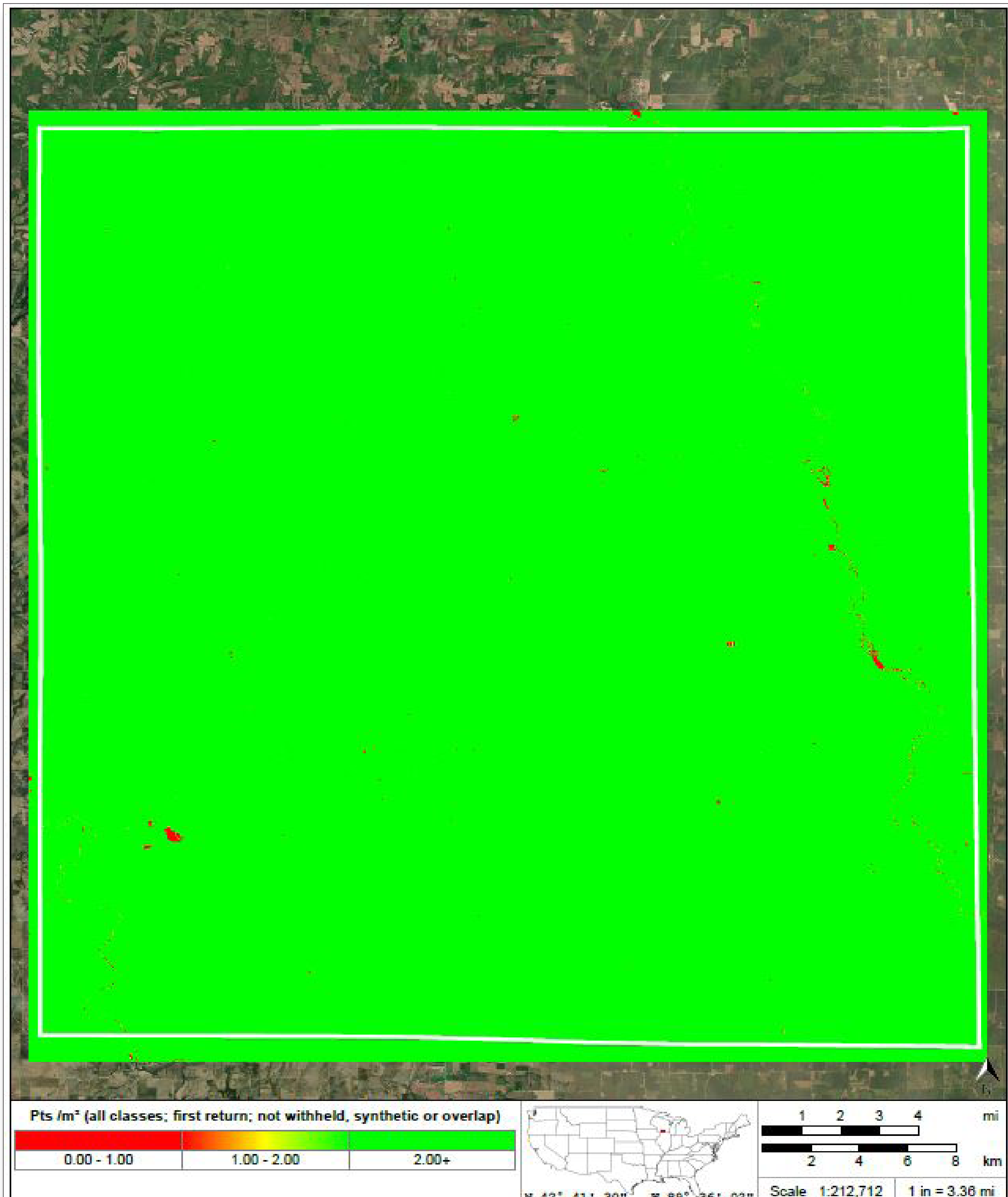


Figure 4. First Return Point Density

WI_12County_3_B22
Work Unit 300206 Ground Density

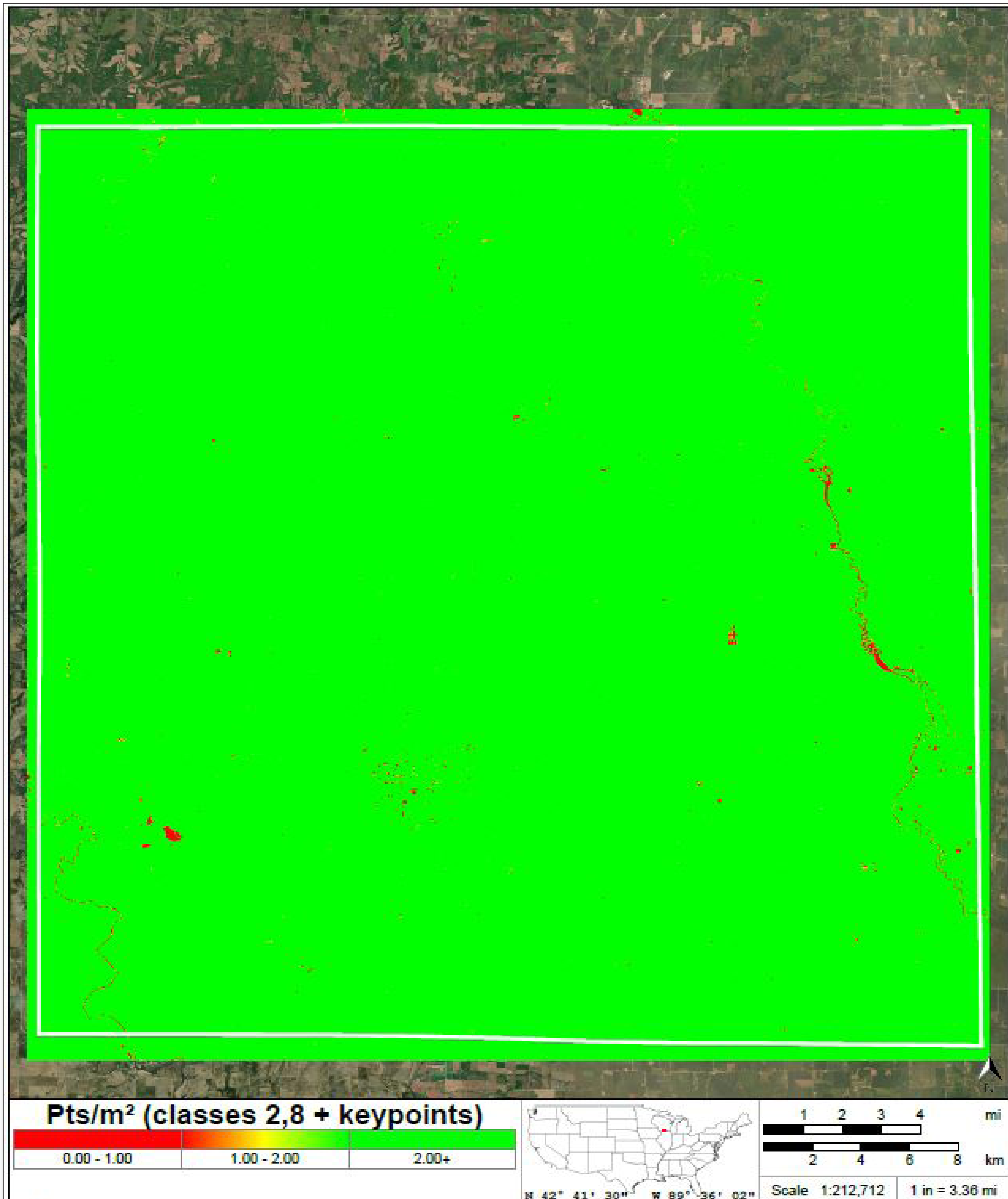


Figure 5. Ground Density

WI_12County_3_B22
Work Unit 300206 Tile Layout

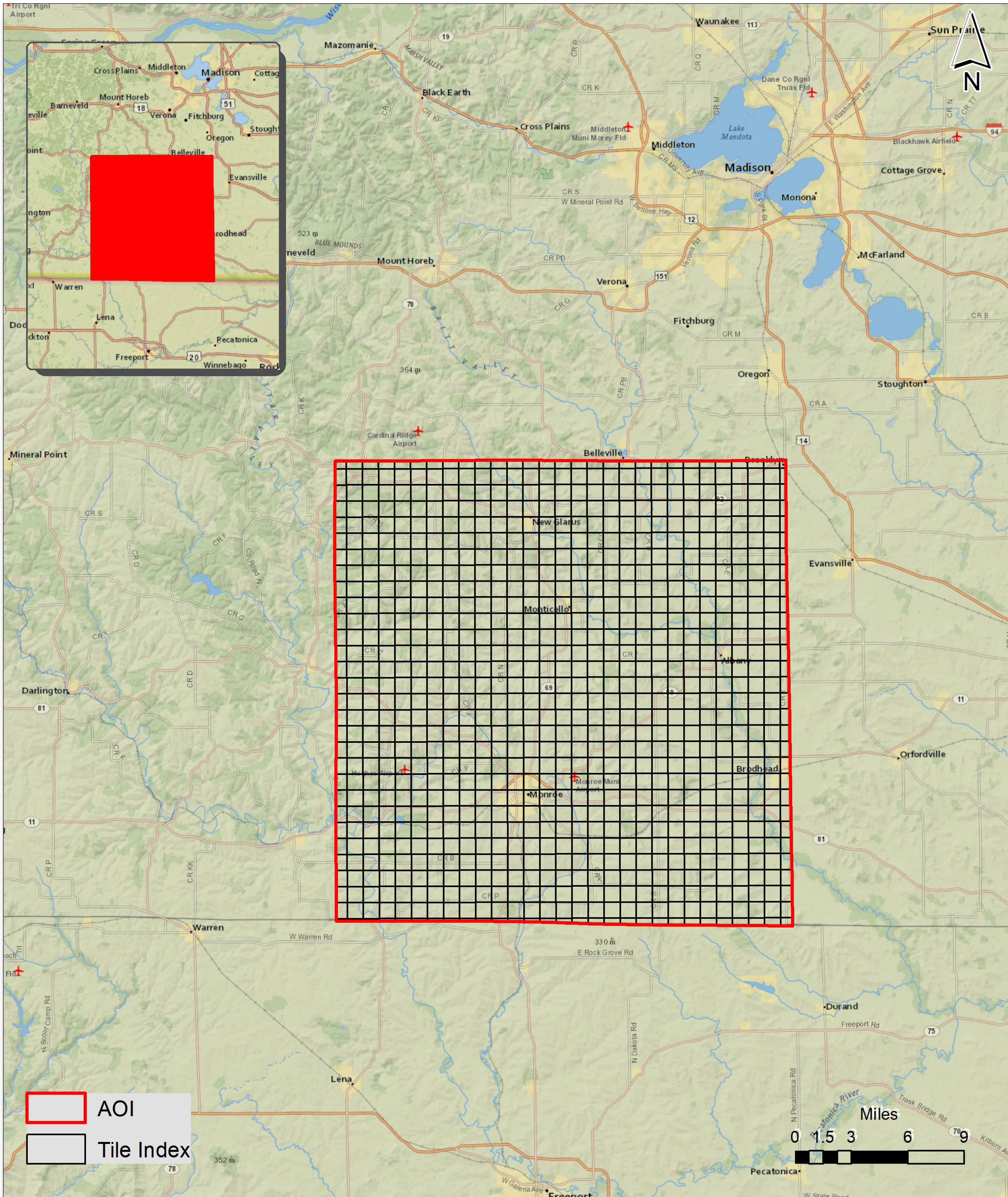


Figure 6. Lidar Tile Layout

4. Project Coverage Verification

A proprietary tool (FOCUS on Flight) produces grid-based polygons of each flightline, depicting exactly where lidar points exist. These swath polygons are reviewed against the project boundary to verify adequate project coverage. Please refer to Figure 5.

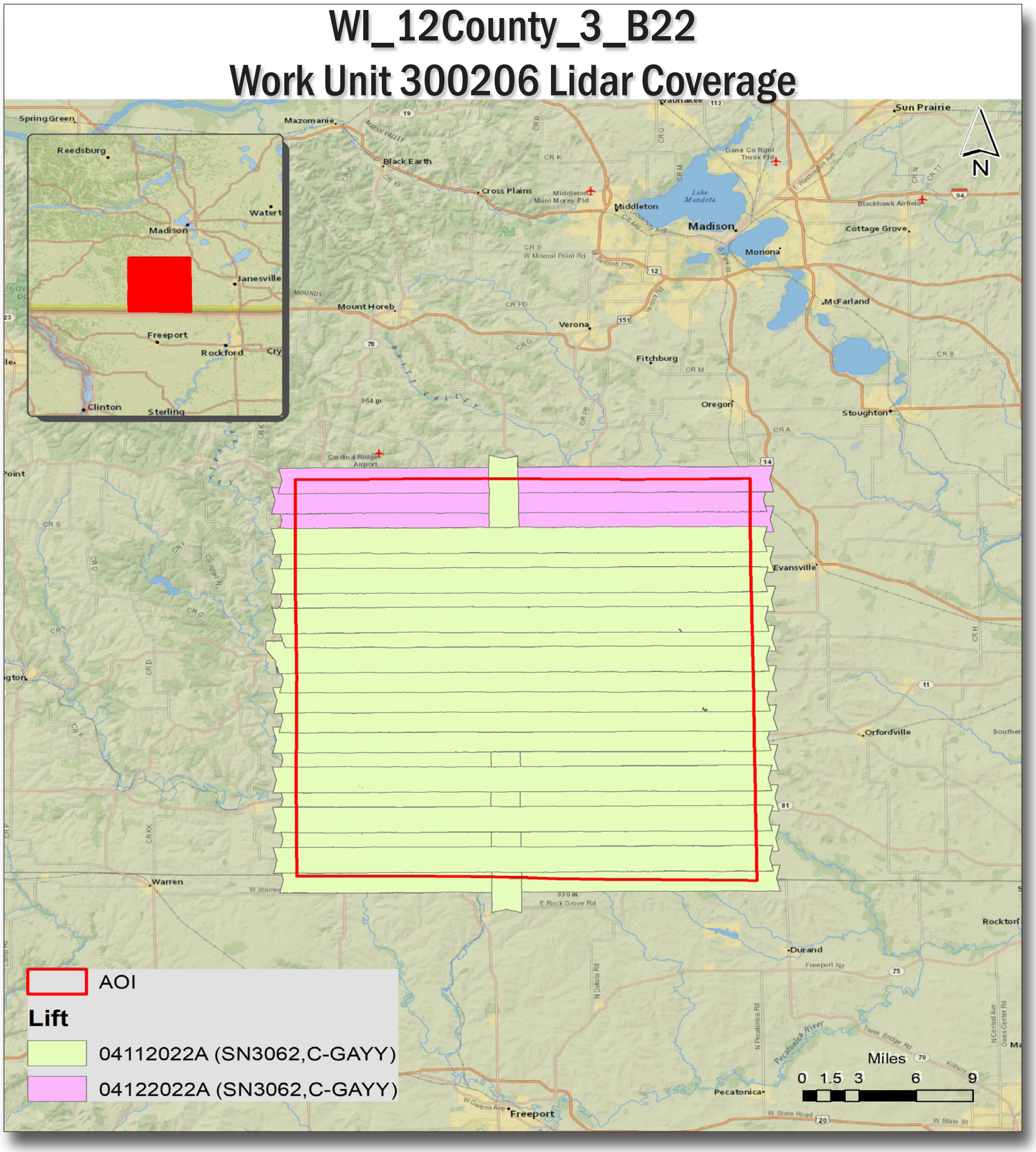


Figure 7. Lidar Coverage

5. Geometric Accuracy

5.1. Horizontal Accuracy

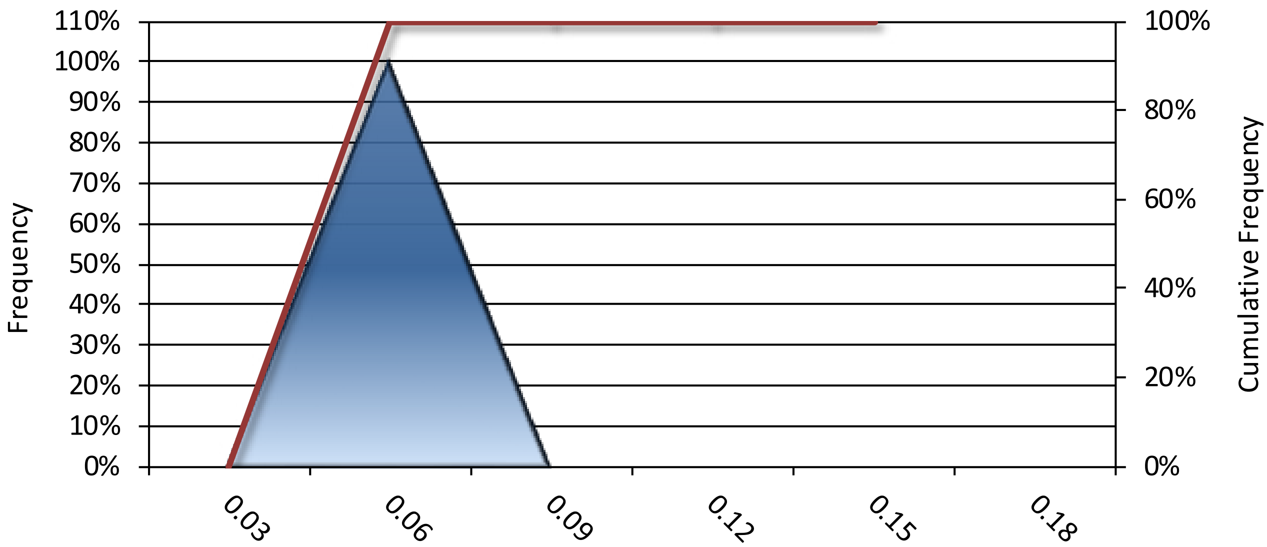
Lidar horizontal accuracy is a function of Global Navigation Satellite System (GNSS) derived positional error, flying altitude, and INS derived attitude error. The obtained $RMSE_r$ value is multiplied by a conversion factor of 1.7308 to yield the horizontal component of the National Standards for Spatial Data Accuracy (NSSDA) reporting standard where a theoretical point will fall within the obtained radius 95% of the time. Based on a flying altitude of 2300 meters, an IMU error of 0.002 decimal degrees, and a GNSS positional error of 0.015 meters, this project was compiled to meet 0.25 meter horizontal accuracy at the 95% confidence level. A summary is shown below.

Horizontal Accuracy	
$RMSE_r$	0.47 ft
	0.14 m
ACC_r	0.82 ft
	0.25 m

5.2. Relative Vertical Accuracy (Interswath Precision)

Relative vertical accuracy refers to the internal consistency of the data set as a whole: the ability to place an object in the same location given multiple flight lines, GPS conditions, and aircraft attitudes. When the lidar system is well calibrated, the swath-to-swath vertical divergence is low (<0.10 meters). The relative vertical accuracy was computed by comparing the ground surface model of each individual flight line with its neighbors in overlapping regions. The average (mean) line to line relative vertical accuracy for the WI_12County_3_B22 project was 0.040 feet (0.012 meters). A summary is shown below.

Relative Vertical Accuracy	
Sample	25 flight line surfaces
Average	0.040 ft
	0.012 m
Median	0.050 ft
	0.015 m
RMSE	0.050 ft
	0.015 m
Standard Deviation (1σ)	0.002 ft
	0.000 m
1.96σ	0.003 ft
	0.001 m



Wisconsin 12 County - Green, Wisconsin Relative Vertical Accuracy (ft)
Total Compared Points (n = 2,474,227,248)

5.3. Intraswath Precision (Smooth Surface Precision)

Intraswath Precision (smooth surface precision) is the measure of reliability of the lidar point cloud elevations along a planar surface. This measurement is performed on hard surfaces against a single flightline. NV5 digitized several large parking lots as polygons across the project area. These polygons were then used to calculate precision on a single FL basis using the below formula:

Precision = Range – (Slope x Cellsize x 1.414)

Range – Is the difference between the highest and lowest lidar points in each cell
Slope – is the maximum slope of the cell to its 8 neighbors
Cellsize – is set to the ANPS, rounded up to the next integer, and then doubled

NV5 calculated the RMSDz to be 3.7 cm, minimum slope-corrected range to be 0 cm, and the maximum slope-corrected range to be 16 cm.

Project Report Appendices

The following section contains the appendices as listed in the WI_12County_3_B22 Lidar Project Report.

Appendix A

Flight Logs

Julian Day	100	Flight	A

LIDAR Flight Log

AIRBORNE IMAGING
A Clean Harbors Company

Date	April 10th, 2022	Aircraft	C-GAYY
Project	3237_NV5_WI3DEP_QL2	Pilot	P. Goodman
Location	KMSN	Operator	R. Gemmel
Mission Objective			

System	Reigl VQ1560ii
Unit	S2223062
IMU	Applanix AP60
GPS Rx	Trimble GNSS17
Scanner 1 Drive	A1
Scanner 2 Drive	A2

Additional Notes

GPS trajectory Files: ALS.010-061
-Riaquire froze on 2089, curious if it's just swatch image that was effected?
-Will confirm maintenance scheduling.

Time to next maintenance: ??? ○ 50 hr ◉ 100 hr

Aircraft Block Time					
Engine On	13:54	Takeoff	14:14		
Engine Off	20:23	Landing	20:14		
Total	6.5 hrs	Total	6.0 hrs		

Mission Plan				
AGL Height	2300	m	Pulse Rate	500 kHz
Target Speed	160	kts	Scan Rate	100 (102 plane)
Laser Current	100	%	FOV	60 ° degs

Static Alignment	GPS Time	
	Start	End
Pre Mission	14:04	14:09
Post Mission	20:17	20:22

Flight Line	LiDAR File Name	Flight Direction	GPS Time		Line Aborted		Mission ID	Comments
			Start	End	Time	nmi to End	Time Stamp 220410	
							220410_140417	
Figure 8		8	14:31	14:35				8150 ft +/-
2100 (X-Tie)	622210001	182.7	14:39	14:51			220410_143907	8107 ft
2099	622210002	092.4	14:57	15:07			145722	8242 ft
2098	622210003	273.1	15:11	15:22			151109	8245 ft
2097	622210004	092.3	15:25	15:35			152502	8248 ft
2096	622210005	273.2	15:38	18:49			153832	8255 ft
2095	622210006	092.3	15:52	16:02			155235	8268 ft
2094	622210007	237.1	16:05	16:50			160559	8278 ft
2093	622210008	092.3	16:20	16:30			162002	8294 ft
2092	622210009	273.1	16:33	16:44			163347	8317 ft
2091	622210010	092.4	16:47	16:58			164757	8330 ft
2090	622210011	273.2	17:01	17:11			170127	8353 ft
2089	622210012	092.4	17:15	17:25		Refly east 12	171513	8307 ft,Riaquire froze up, seems okay?
2089	622210013	273.3	17:29	17:34		east 12.2NM	172940	8307 ft, no swatch, so maybe just buffer

Julian Day 100	Flight A

LIDAR Flight Log

AIRBORNE IMAGING
A Clean Harbors Company

Date	April 10th, 2022	**Aircraft**	C-GAYY
Project	3237_NV5_WI3DEP_QL2	**Pilot**	P. Goodman
Location	KMSN	**Operator**	R. Gemmel
Mission Objective			

System	Reigl VQ1560ii
Unit	S2223062
IMU	Applanix AP60
GPS Rx	Trimble GNSS17
Scanner 1 Drive	A1
Scanner 2 Drive	A2

Additional Notes

GPS trajectory Files: ALS.010-061
-Riaquire froze on 2089, curious if it's just swatch image that was effected?
-Will confirm maintenance scheduling.

Time to next maintenance: ??? ◉ 50 hr ○ 100 hr

Aircraft Block Time					
Engine On	13:54	**Takeoff**	14:14		
Engine Off	20:23	**Landing**	20:14		
Total	6.5 hrs	**Total**	6.0 hrs		

Mission Plan				
AGL Height	2300	m	**Pulse Rate**	500 kHz
Target Speed	160	kts	**Scan Rate**	100 (102 plane)
Laser Current	100	%	**FOV**	60 ° degs

Static Alignment	GPS Time Start	GPS Time End
Pre Mission	14:04	14:09
Post Mission	20:17	20:22

Flight Line	LiDAR File Name	Flight Direction	GPS Time Start	GPS Time End	Line Aborted Time	Line Aborted nmi to End	Mission ID Time Stamp 220410	Comments
2088	622210014	273.1	17:43	17:53			220410_174321	8255 ft, cloud dropping
2087	622210015	092.3	17:57	18:08			175755	8215 ft
2086	622210016	273.3	18:11	18:22			181141	8196 ft
2085	622210017	092.4	18:25	18:36			182535	8189 ft
2084	622210018	273.2	18:39	18:49			183903	8173 ft
2083	622210019	092.4	18:53	19:03			185303	8156 ft
2082	622210020	273.2	19:06	19:17			190639	8137 ft
2081	622210021	092.4	19:20	19:30			192020	8133 ft
2080	622210022	273.2	19:34	19:45			193423	8130 ft
2079	622210023	092.4	19:48	19:58			194838	8120 ft Tail wind
Figure 8		8	19:59	20:03				8150 ft +/-

Julian Day 100	Flight A

LIDAR Flight Log

AIRBORNE IMAGING
A Clean Harbors Company

Date April 10th, 2022		**Aircraft** C-GAYY	
Project 3237_NV5_WI3DEP_QL2		**Pilot** P. Goodman	
Location KMSN		**Operator** R. Gemmel	
Mission Objective			

System	Reigl VQ1560ii
Unit	S2223062
IMU	Applanix AP60
GPS Rx	Trimble GNSS17
Scanner 1 Drive	A1
Scanner 2 Drive	A2

Additional Notes

GPS trajectory Files: ALS.010-061
-Riaquire froze on 2089, curious if it's just swatch image that was effected?
-Will confirm maintenance scheduling.

Time to next maintenance: ??? ◉ 50 hr ○ 100 hr

Aircraft Block Time		
Engine On 13:54	**Takeoff** 14:14	
Engine Off 20:23	**Landing** 20:14	
Total 6.5 hrs	**Total** 6.0 hrs	

Mission Plan				
AGL Height	2300	m	**Pulse Rate**	500 kHz
Target Speed	160	kts	**Scan Rate**	100 (102 plane)
Laser Current	100	%	**FOV**	60 ° degs

Static Alignment	GPS Time	
	Start	End
Pre Mission	14:04	14:09
Post Mission	20:17	20:22

Flight Line	LiDAR File Name	Flight Direction	GPS Time		Line Aborted		Mission ID	Comments
			Start	End	Time	nmi to End	Time Stamp 220410	

Julian Day	100	Flight	A

LIDAR Flight Log

AIRBORNE IMAGING
A Clean Harbors Company

Date	April 10th, 2022	**Aircraft**	C-GAYY
Project	3237_NV5_WI3DEP_QL2	**Pilot**	P. Goodman
Location	KMSN	**Operator**	R. Gemmel
Mission Objective			

System	Reigl VQ1560ii
Unit	S2223062
IMU	Applanix AP60
GPS Rx	Trimble GNSS17
Scanner 1 Drive	A1
Scanner 2 Drive	A2

Additional Notes

GPS trajectory Files: ALS.010-061
-Riaquire froze on 2089, curious if it's just swatch image that was effected?
-Will confirm maintenance scheduling.

Time to next maintenance: ??? ⦿ 50 hr ○ 100 hr

Aircraft Block Time				
Engine On 13:54		**Takeoff** 14:14		
Engine Off 20:23		**Landing** 20:14		
Total 6.5	hrs	**Total** 6.0	hrs	

Mission Plan				
AGL Height	2300	m	**Pulse Rate**	500 kHz
Target Speed	160	kts	**Scan Rate**	100 (102 plane)
Laser Current	100	%	**FOV**	60 ° degs

Static Alignment	GPS Time	
	Start	End
Pre Mission	14:04	14:09
Post Mission	20:17	20:22

Flight Line	LiDAR File Name	Flight Direction	GPS Time		Line Aborted		Mission ID	Comments
			Start	End	Time	nmi to End	Time Stamp 220410	

Julian Day 100	Flight A

LIDAR Flight Log

AIRBORNE IMAGING
A Clean Harbors Company

Date	April 10th, 2022	**Aircraft**	C-GAYY
Project	3237_NV5_WI3DEP_QL2	**Pilot**	P. Goodman
Location	KMSN	**Operator**	R. Gemmel
Mission Objective			

System	Reigl VQ1560ii
Unit	S2223062
IMU	Applanix AP60
GPS Rx	Trimble GNSS17
Scanner 1 Drive	A1
Scanner 2 Drive	A2

Additional Notes

GPS trajectory Files: ALS.010-061
-Riaquire froze on 2089, curious if it's just swatch image that was effected?
-Will confirm maintenance scheduling.

Time to next maintenance: ??? ⦿ 50 hr ○ 100 hr

Aircraft Block Time		
Engine On 13:54	**Takeoff** 14:14	
Engine Off 20:23	**Landing** 20:14	
Total 6.5 hrs	**Total** 6.0 hrs	

Mission Plan				
AGL Height	2300	m	**Pulse Rate**	500 kHz
Target Speed	160	kts	**Scan Rate**	100 (102 plane)
Laser Current	100	%	**FOV**	60 ° degs

Static Alignment	GPS Time	
	Start	End
Pre Mission	14:04	14:09
Post Mission	20:17	20:22

Flight Line	LiDAR File Name	Flight Direction	GPS Time		Line Aborted		Mission ID	Comments
			Start	End	Time	nmi to End	Time Stamp 220410	

Julian Day	101	Flight	A

LIDAR Flight Log

Date	April 11th, 2022	**Aircraft**	C-GAYY
Project	3237_NV5_WI3DEP_QL2	**Pilot**	P. Goodman
Location	KMSN	**Operator**	R. Gemmel
Mission Objective			

System	Reigl VQ1560ii
Unit	S2223062
IMU	Applanix AP60
GPS Rx	Trimble GNSS17
Scanner 1 Drive	B1
Scanner 2 Drive	B2

Additional Notes

GPS trajectory Files: ALS.066-116

Time to next maintenance: 32.7 ○ 50 hr ⦿ 100 hr

Aircraft Block Time					
Engine On	14:28	**Takeoff**	14:46		
Engine Off	20:51	**Landing**	20:42		
Total	6.4 hrs	**Total**	5.9 hrs		

Mission Plan				
AGL Height	2300	m	**Pulse Rate**	500 kHz
Target Speed	160	kts	**Scan Rate**	100 (102 plane)
Laser Current	100	%	**FOV**	60 ° degs

Static Alignment	GPS Time Start	GPS Time End
Pre Mission	14:37	14:42
Post Mission	20:45	20:50

Flight Line	LiDAR File Name	Flight Direction	GPS Time Start	GPS Time End	Line Aborted Time	Line Aborted nmi to End	Mission ID Time Stamp 220411	Comments
							220411_143700	
Figure 8		8	14:54	14:59				8150 ft +/-
2078	622210101	273.6	15:04	15:17			220411_150401	8104 ft, heavy head wind
2077	622210102	092.4	15:21	15:31			152102	8094 ft , heavy tail wind
2076	622210103	273.2	15:34	15:47			153448	8100 ft, heavy head wind
2100	622210104	182.3	15:51	16:03			155146	8107 ft, heavy X wind, X-Tie
								Using to scout cloud, fly whole thing
2075	622210105	182.0	16:15	16:25			161518	8199 ft, might be cloud, scouting X-Tie
2074	622210106	093.0	16:34	16:42			163404	8199 ft, Wind the same, head/tail
2073	622210107	273.4	16:45	16:56			164536	8199 ft
2072	622210108	092.7	16:59	17:07			165935	8199 ft
2071	622210109	273.4	17:11	17:21			171107	8199 ft
2070	622210110	092.7	17:25	17:33			172503	8199 ft
2069	622210111	273.4	17:36	17:47			173659	8199 ft
2068	622210112	092.7	17:50	17:59			175038	8199 ft

Julian Day 101 | Flight A

LIDAR Flight Log

Airborne Imaging — A Clean Harbors Company

Date	April 11th, 2022	**Aircraft**	C-GAYY
Project	3237_NV5_WI3DEP_QL2	**Pilot**	P. Goodman
Location	KMSN	**Operator**	R. Gemmel
Mission Objective			

System	Reigl VQ1560ii
Unit	S2223062
IMU	Applanix AP60
GPS Rx	Trimble GNSS17
Scanner 1 Drive	B1
Scanner 2 Drive	B2

Additional Notes

GPS trajectory Files: ALS.066-116

Time to next maintenance: 32.7 ⦿ 50 hr ○ 100 hr

Aircraft Block Time			
Engine On	14:28	**Takeoff**	14:46
Engine Off	20:51	**Landing**	20:42
Total	6.4 hrs	**Total**	5.9 hrs

Mission Plan			
AGL Height	2300 m	**Pulse Rate**	500 kHz
Target Speed	160 kts	**Scan Rate**	100 (102 plane)
Laser Current	100 %	**FOV**	60 ° degs

Static Alignment	**GPS Time Start**	**GPS Time End**
Pre Mission	14:37	14:42
Post Mission	20:45	20:50

Flight Line	LiDAR File Name	Flight Direction	GPS Time Start	GPS Time End	Line Aborted Time	Line Aborted nmi to End	Mission ID (Time Stamp 220411)	Comments
2067	622210113	273.5	18:02	18:13			220411_180228	8199 ft, fuel gauge not reading proper
2066	622210114	092.8	18:16	18:24			181618	8199 ft
2065	622210115	273.4	18:28	18:39			182817	8199 ft
2064	622210116	092.8	18:42	18:51			184239	8199 ft
2063	622210117	273.4	18:54	19:05			185446	8199 ft
2062	622210118	092.7	19:08	19:17			190855	8199 ft
2061	622210119	273.4	19:21	19:31			192104	8199 ft
2060	622210120	092.8	19:35	19:43			193503	8199 ft
2059	622210121	273.5	19:47	19:57			194707	8199 ft
2058	622210122	092.8	20:01	20:09			200100	8301 ft
2057	622210123	273.5	20:13	20:23			201311	8301 ft
Figure 8		8	20:25	20:29				8350 ft +/-

v 20200520

Julian Day 101	Flight A

LIDAR Flight Log

AIRBORNE IMAGING
A Clean Harbors Company

Date	April 11th, 2022	**Aircraft**	C-GAYY
Project	3237_NV5_WI3DEP_QL2	**Pilot**	P. Goodman
Location	KMSN	**Operator**	R. Gemmel
Mission Objective			

System	Reigl VQ1560ii
Unit	S2223062
IMU	Applanix AP60
GPS Rx	Trimble GNSS17
Scanner 1 Drive	B1
Scanner 2 Drive	B2

Additional Notes

GPS trajectory Files: ALS.066-116

Time to next maintenance: 32.7 ⦿ 50 hr ○ 100 hr

Aircraft Block Time				
Engine On 14:28	**Takeoff** 14:46			
Engine Off 20:51	**Landing** 20:42			
Total 6.4 hrs	**Total** 5.9 hrs			

Mission Plan				
AGL Height	2300	m	**Pulse Rate**	500 kHz
Target Speed	160	kts	**Scan Rate**	100 (102 plane)
Laser Current	100	%	**FOV**	60 ° degs

Static Alignment	GPS Time	
	Start	End
Pre Mission	14:37	14:42
Post Mission	20:45	20:50

Flight Line	LiDAR File Name	Flight Direction	GPS Time		Line Aborted		Mission ID	Comments
			Start	End	Time	nmi to End	Time Stamp 220411	

Julian Day	101	Flight	A

LIDAR Flight Log

A I R B O R N E IMAGING
A Clean Harbors Company

Date	April 11th, 2022	**Aircraft**	C-GAYY
Project	3237_NV5_WI3DEP_QL2	**Pilot**	P. Goodman
Location	KMSN	**Operator**	R. Gemmel
Mission Objective			

System	Reigl VQ1560ii
Unit	S2223062
IMU	Applanix AP60
GPS Rx	Trimble GNSS17
Scanner 1 Drive	B1
Scanner 2 Drive	B2

Additional Notes

GPS trajectory Files: ALS.066-116

Time to next maintenance: 32.7 ⦿ 50 hr ○ 100 hr

Aircraft Block Time				
Engine On	14:28	**Takeoff**	14:46	
Engine Off	20:51	**Landing**	20:42	
Total	6.4 hrs	**Total**	5.9 hrs	

Mission Plan				
AGL Height	2300	m	**Pulse Rate**	500 kHz
Target Speed	160	kts	**Scan Rate**	100 (102 plane)
Laser Current	100	%	**FOV**	60 ° degs

Static Alignment	GPS Time Start	GPS Time End
Pre Mission	14:37	14:42
Post Mission	20:45	20:50

Flight Line	LiDAR File Name	Flight Direction	GPS Time		Line Aborted		Mission ID	Comments
			Start	End	Time	nmi to End	Time Stamp 220411	

v 20200520

Julian Day	101	Flight	A

LIDAR Flight Log

AIRBORNE IMAGING
A Clean Harbors Company

Date	April 11th, 2022	**Aircraft**	C-GAYY
Project	3237_NV5_WI3DEP_QL2	**Pilot**	P. Goodman
Location	KMSN	**Operator**	R. Gemmel
Mission Objective			

System	Reigl VQ1560ii
Unit	S2223062
IMU	Applanix AP60
GPS Rx	Trimble GNSS17
Scanner 1 Drive	B1
Scanner 2 Drive	B2

Additional Notes

GPS trajectory Files: ALS.066-116

Time to next maintenance: 32.7 ⦿ 50 hr ○ 100 hr

Aircraft Block Time				
Engine On	14:28	**Takeoff**	14:46	
Engine Off	20:51	**Landing**	20:42	
Total	6.4 hrs	**Total**	5.9 hrs	

Mission Plan				
AGL Height	2300	m	**Pulse Rate**	500 kHz
Target Speed	160	kts	**Scan Rate**	100 (102 plane)
Laser Current	100	%	**FOV**	60 ° degs

Static Alignment	GPS Time	
	Start	End
Pre Mission	14:37	14:42
Post Mission	20:45	20:50

Flight Line	LiDAR File Name	Flight Direction	GPS Time		Line Aborted		Mission ID	Comments
			Start	End	Time	nmi to End	Time Stamp 220411	

v 20200520

Julian Day 102 | Flight A

LIDAR Flight Log

AIRBORNE IMAGING — A Clean Harbors Company

Date	April 12th, 2022	**Aircraft**	C-GAYY
Project	3237_NV5_WI3DEP_QL2	**Pilot**	P. Goodman
Location	KMSN	**Operator**	R. Gemmel

Mission Objective
-2054-2056
-2033-2053, wx came in

System	Reigl VQ1560ii
Unit	
IMU	Applanix AP60
GPS Rx	Trimble GNSS17
Scanner 1 Drive	A1
Scanner 2 Drive	A2

Additional Notes
GPS trajectory Files: ALS.117-158

Time to next maintenance: 26.8 ○ 50 hr ◉ 100 hr

Aircraft Block Time				
Engine On	12:56	**Takeoff**	13:12	
Engine Off	18:06	**Landing**	17:57	
Total	5.2 hrs	**Total**	4.8 hrs	

Mission Plan				
AGL Height	2300	m	**Pulse Rate**	500 kHz
Target Speed	160	kts	**Scan Rate**	100 (102 plane)
Laser Current	100	%	**FOV**	60 ° degs

Static Alignment	GPS Time Start	GPS Time End
Pre Mission	13:03	13:08
Post Mission	17:59	18:04

Flight Line	LiDAR File Name	Flight Direction	GPS Time Start	GPS Time End	Line Aborted Time	Line Aborted nmi to End	Mission ID (Time Stamp 220410)	Comments
							220412_130323	
Figure 8		8	13:20	13:24				8200 ft +/-
2075 (N4.4NM)	622210201	183.2	13:28	13:30			220412_132845	8199 ft, trimmed to 4.4 NM for X-Tie
2056	622210202	093.1	13:38	13:46			133828	8301 ft
2055	622210203	273.5	13:50	13:59			135008	8301 ft
2054	622210204	092.8	14:02	14:10			140240	8301 ft
Figure 8		8	14:12	14:15				8300 ft +/-
Figure 8		8	14:41	14:45				8250 ft +/-
2053	622210205	093.5	14:48	14:57			144808	8199 ft, half over lake, do X-Tie north
2052	622210206	004.3	15:05	15:14			150537	8199 ft
2051	622210207	184.3	15:17	15:26			151719	8199 ft
2050	622210208	004.2	15:29	15:37			152909	8199 ft
2049	622210209	184.3	15:40	15:49			154052	8100 ft
2048	622210210	004.2	15:52	16:01			155249	8100 ft

Julian Day 102 | **Flight** A

LIDAR Flight Log

Date	April 12th, 2022	**Aircraft**	C-GAYY
Project	3237_NV5_WI3DEP_QL2	**Pilot**	P. Goodman
Location	KMSN	**Operator**	R. Gemmel

Mission Objective
-2054-2056
-2033-2053, wx came in

System	Reigl VQ1560ii
Unit	
IMU	Applanix AP60
GPS Rx	Trimble GNSS17
Scanner 1 Drive	A1
Scanner 2 Drive	A2

Additional Notes

GPS trajectory Files: ALS.117-158

Time to next maintenance: 26.8 ⦿ 50 hr ○ 100 hr

Aircraft Block Time		
Engine On 12:56	**Takeoff** 13:12	
Engine Off 18:06	**Landing** 17:57	
Total 5.2 hrs	**Total** 4.8 hrs	

Mission Plan				
AGL Height	2300	**m**	**Pulse Rate**	500 kHz
Target Speed	160	**kts**	**Scan Rate**	100 (102 plane)
Laser Current	100	**%**	**FOV**	60 ° degs

Static Alignment	GPS Time Start	GPS Time End
Pre Mission	13:03	13:08
Post Mission	17:59	18:04

Flight Line	LiDAR File Name	Flight Direction	GPS Time Start	GPS Time End	Line Aborted Time	Line Aborted nmi to End	Mission ID (Time Stamp 220410)	Comments
2047	622210211	184.3	16:04	16:13			220410_160407	8199 ft
2046	622210212	004.1	16:16	16:24			161601	8100 ft
2045	622210213	184.2	16:27	16:36			162727	8100 ft, low cloud virga/rain coming in.
2044	622210214	004.1	16:39	16:47			163917	8199 ft
2043	622210215	184.2	16:50	16:59			165035	8199 ft Rain almost on us, 1 more line.
								REFLY south 5 NM - rain, make it 7NM
2042	622210216	004.1	17:02	17:10			170234	8199 ft
								REFLY south 5 NM - rain, make it 7NM
X-Tie_42-52	622210217	095.0 +/-	17:13	17:18			171325	8200 ft +/-
								Extra X-Tie, more over land/less lake
Figure 8		8	17:19	17:23				8250 ft +/-

Julian Day	102	Flight	A

LIDAR Flight Log

Date	April 12th, 2022	**Aircraft**	C-GAYY
Project	3237_NV5_WI3DEP_QL2	**Pilot**	P. Goodman
Location	KMSN	**Operator**	R. Gemmel
Mission Objective	-2054-2056 -2033-2053, wx came in		

System	Reigl VQ1560ii
Unit	
IMU	Applanix AP60
GPS Rx	Trimble GNSS17
Scanner 1 Drive	A1
Scanner 2 Drive	A2

Additional Notes

GPS trajectory Files: ALS.117-158

Time to next maintenance: 26.8 ⦿ 50 hr ○ 100 hr

Aircraft Block Time				
Engine On 12:56		**Takeoff** 13:12		
Engine Off 18:06		**Landing** 17:57		
Total 5.2	hrs	**Total** 4.8	hrs	

Mission Plan				
AGL Height	2300	**m**	**Pulse Rate**	500 kHz
Target Speed	160	**kts**	**Scan Rate**	100 (102 plane)
Laser Current	100	**%**	**FOV**	60 ° degs

Static Alignment	GPS Time Start	GPS Time End
Pre Mission	13:03	13:08
Post Mission	17:59	18:04

Flight Line	LiDAR File Name	Flight Direction	GPS Time Start	GPS Time End	Line Aborted Time	Line Aborted nmi to End	Mission ID Time Stamp 220410	Comments

v 20200520

Julian Day 102 | **Flight** A

LIDAR Flight Log

AIRBORNE IMAGING
A Clean Harbors Company

Date	April 12th, 2022	**Aircraft**	C-GAYY
Project	3237_NV5_WI3DEP_QL2	**Pilot**	P. Goodman
Location	KMSN	**Operator**	R. Gemmel

Mission Objective
-2054-2056
-2033-2053, wx came in

System	Reigl VQ1560ii
Unit	
IMU	Applanix AP60
GPS Rx	Trimble GNSS17
Scanner 1 Drive	A1
Scanner 2 Drive	A2

Additional Notes

GPS trajectory Files: ALS.117-158

Time to next maintenance: 26.8 ⦿ 50 hr ○ 100 hr

Aircraft Block Time

Engine On 12:56		**Takeoff** 13:12		
Engine Off 18:06		**Landing** 17:57		
Total 5.2	hrs	**Total** 4.8	hrs	

Mission Plan

AGL Height	2300	m	**Pulse Rate**	500 kHz
Target Speed	160	kts	**Scan Rate**	100 (102 plane)
Laser Current	100	%	**FOV**	60 ° degs

Static Alignment	GPS Time Start	GPS Time End
Pre Mission	13:03	13:08
Post Mission	17:59	18:04

Flight Line	LiDAR File Name	Flight Direction	GPS Time Start	GPS Time End	Line Aborted Time	Line Aborted nmi to End	Mission ID Time Stamp 220410	Comments

Julian Day 102	Flight A

LIDAR Flight Log

AIRBORNE IMAGING
A Clean Harbors Company

Date April 12th, 2022		**Aircraft**	C-GAYY
Project 3237_NV5_WI3DEP_QL2		**Pilot**	P. Goodman
Location	KMSN	**Operator**	R. Gemmel

Mission Objective
-2054-2056
-2033-2053, wx came in

System	Reigl VQ1560ii
Unit	
IMU	Applanix AP60
GPS Rx	Trimble GNSS17
Scanner 1 Drive	A1
Scanner 2 Drive	A2

Additional Notes

GPS trajectory Files: ALS.117-158

Time to next maintenance: 26.8 ⦿ 50 hr ○ 100 hr

Aircraft Block Time					
Engine On	12:56	**Takeoff**	13:12		
Engine Off	18:06	**Landing**	17:57		
Total	5.2 hrs	**Total**	4.8 hrs		

Mission Plan				
AGL Height	2300	m	**Pulse Rate**	500 kHz
Target Speed	160	kts	**Scan Rate**	100 (102 plane)
Laser Current	100	%	**FOV**	60 ° degs

Static Alignment	GPS Time Start	GPS Time End
Pre Mission	13:03	13:08
Post Mission	17:59	18:04

Flight Line	LiDAR File Name	Flight Direction	GPS Time Start	GPS Time End	Line Aborted Time	Line Aborted nmi to End	Mission ID Time Stamp 220410	Comments

Appendix B

SBET and POSPAC Reports

General Information

Mission Information

Project name	04112022A_3062
Processing date	2022-04-13 16:05:30
Mission date	2022-04-11 14:37:19
Mission duration	06:13:05.285
Processing mode	IN-Fusion PP-RTX

Rover Hardware Information

Product	POS AV 610 VER6 HW2.5-12
Serial number	S/N8708
IMU type	57
Receiver type	BD982
Antenna type	Bilinmeyen harici

Project File List

Rover Data Files

File name	File type
220411_143700_INS-GPS_1.raw	POS Data

Input Files

File Name	File Type
Ephm1010.22g	GLONASS Broadcast Ephemeris
Ephm1010.22n	GPS Broadcast Ephemeris

Output Files

Filename	File type
sbet_04112022A_3062.out	SBET Trajectory File

Rover Data Summary

First raw data file	220411_143700_INS-GPS_1.raw		
Last raw data file	220411_143700_INS-GPS_1.raw		
Start GPS week	2205		
Start time	139020.521 (4/11/2022 2:37:00 PM)		
End time	161405.806 (4/11/2022 8:50:05 PM)		
Start of fine alignment	139075.543 (4/11/2022 2:37:55 PM)		
Available subsystems	Primary GNSS, Gimbal, IMU		
POS Event Input	None		
Correction data	None		
IMU Installation Lever Arms & Mounting Angles			
Gimbal to IMU lever arm (m)	0.000	0.000	0.000
Gimbal to IMU mounting angles (deg)	0.000	0.000	0.000
Gimbal to Primary GNSS lever arm (m)	0.142	-0.236	-1.269
Gimbal to Primary GNSS lever arm std dev (m)	-1.000		
Aircraft to Reference mounting angles (deg)	0.000	0.000	0.000

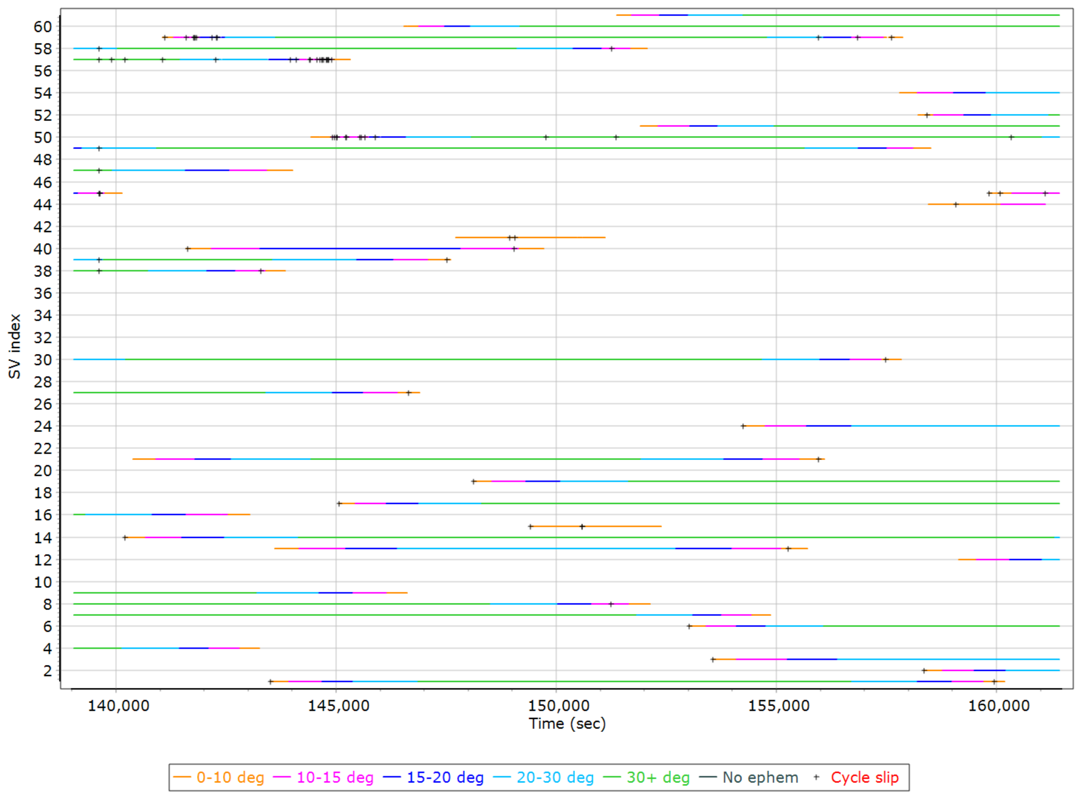
Rover Data QC

Raw IMU Import QC Summary

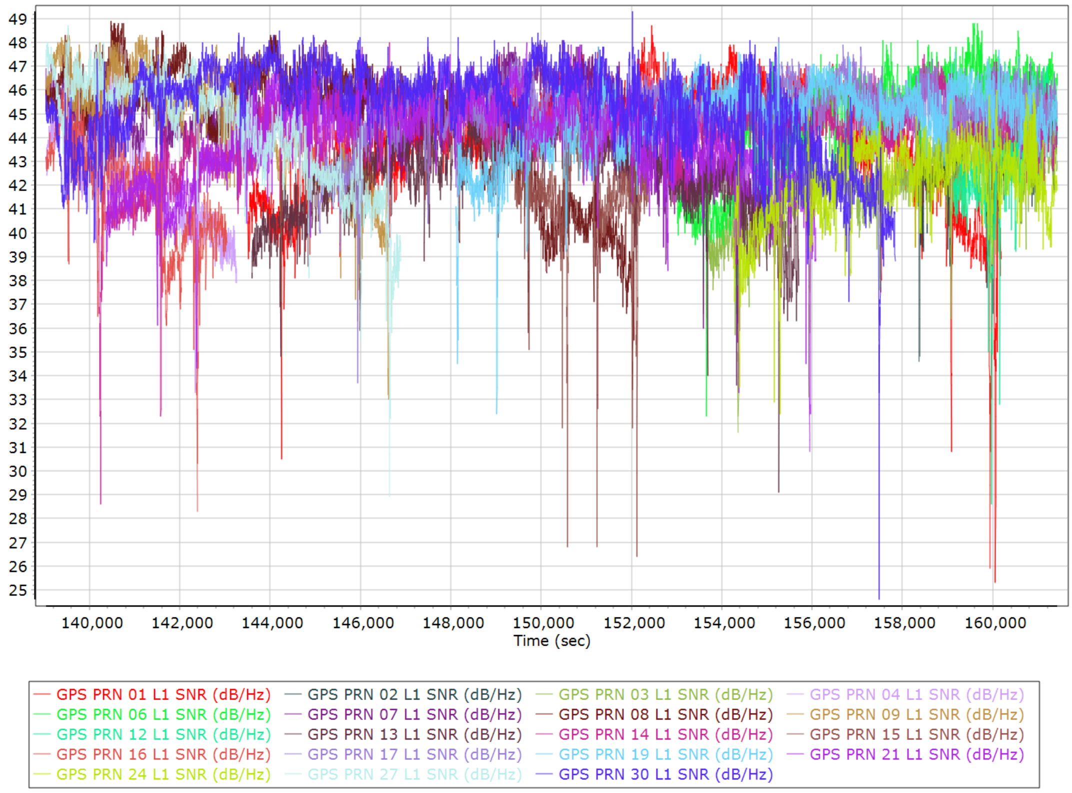
IMU data input file	imu_Mission 1.dat
IMU data check log file	imudt_04112022A_3062.log
IMU Records Processed	4477142
Termination Status	Normal
IMU Anomalies	0

Primary Observables & Satellite Data

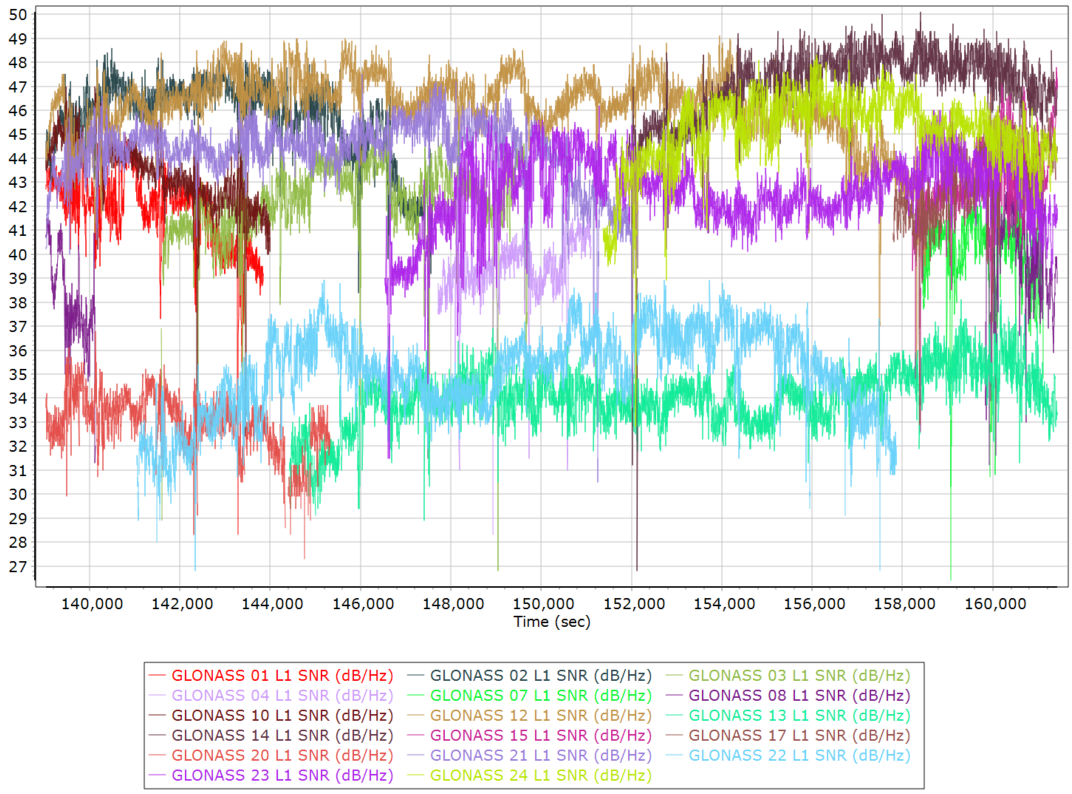
GPS/GLONASS L1 Satellite Lock/Elevation



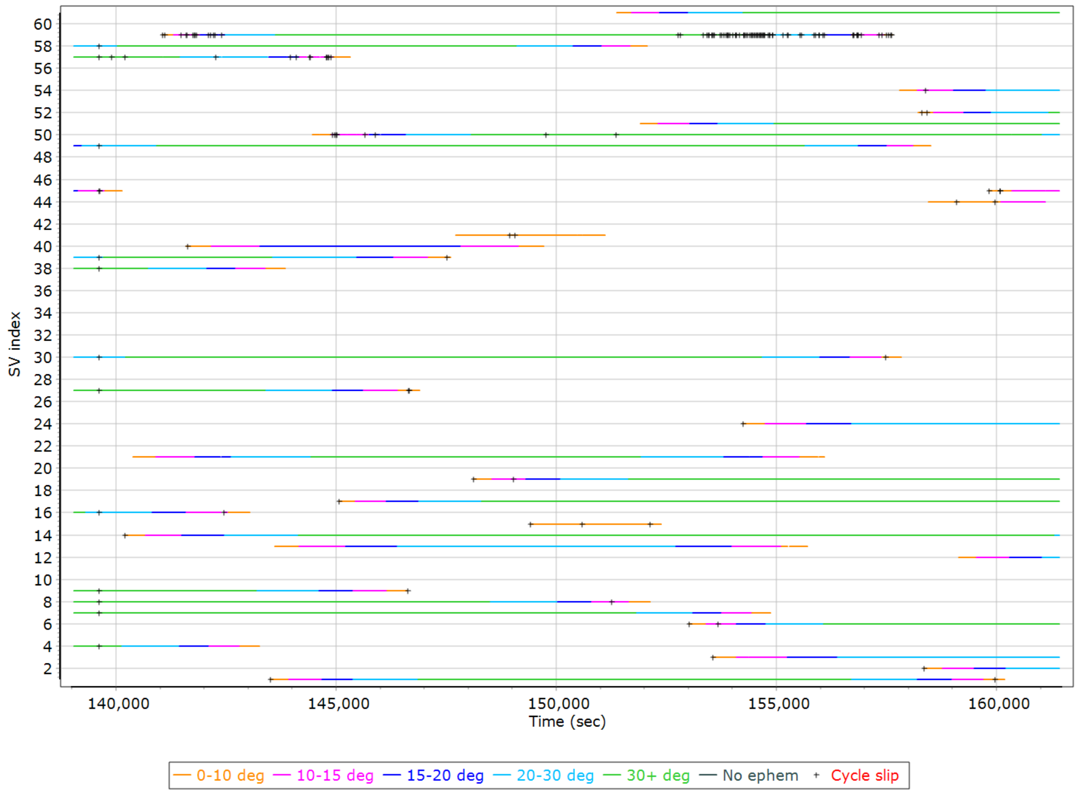
GPS L1 SNR



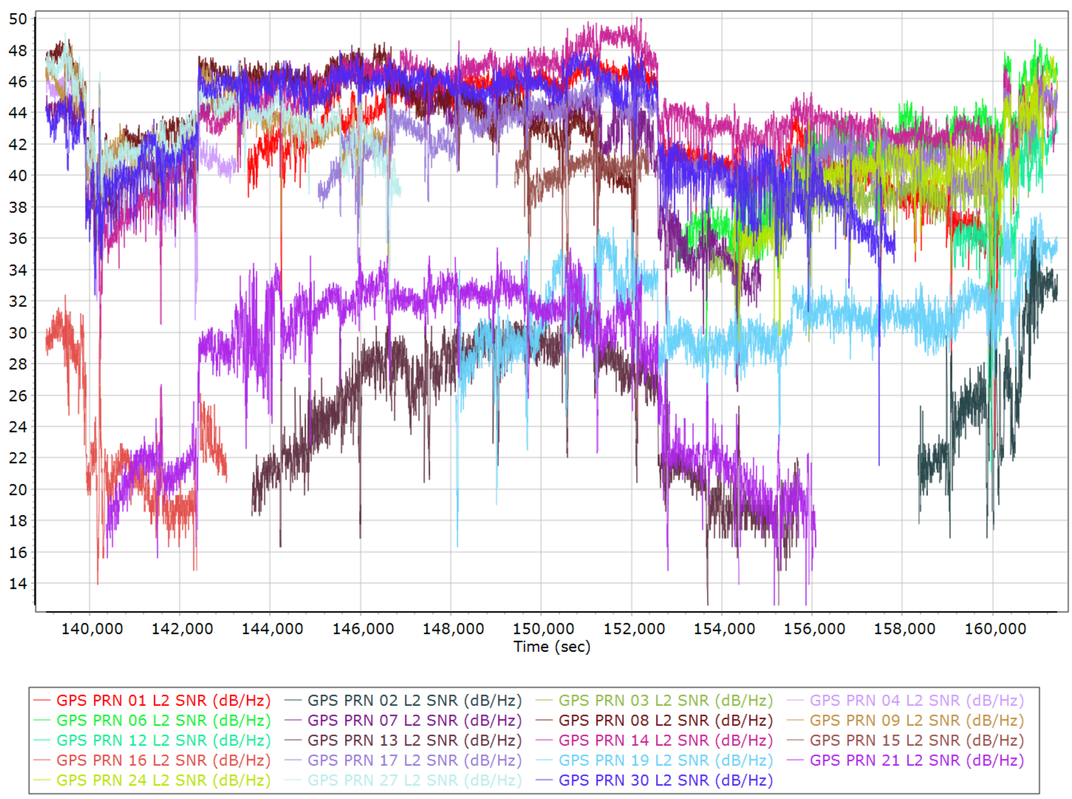
GLONASS L1 SNR



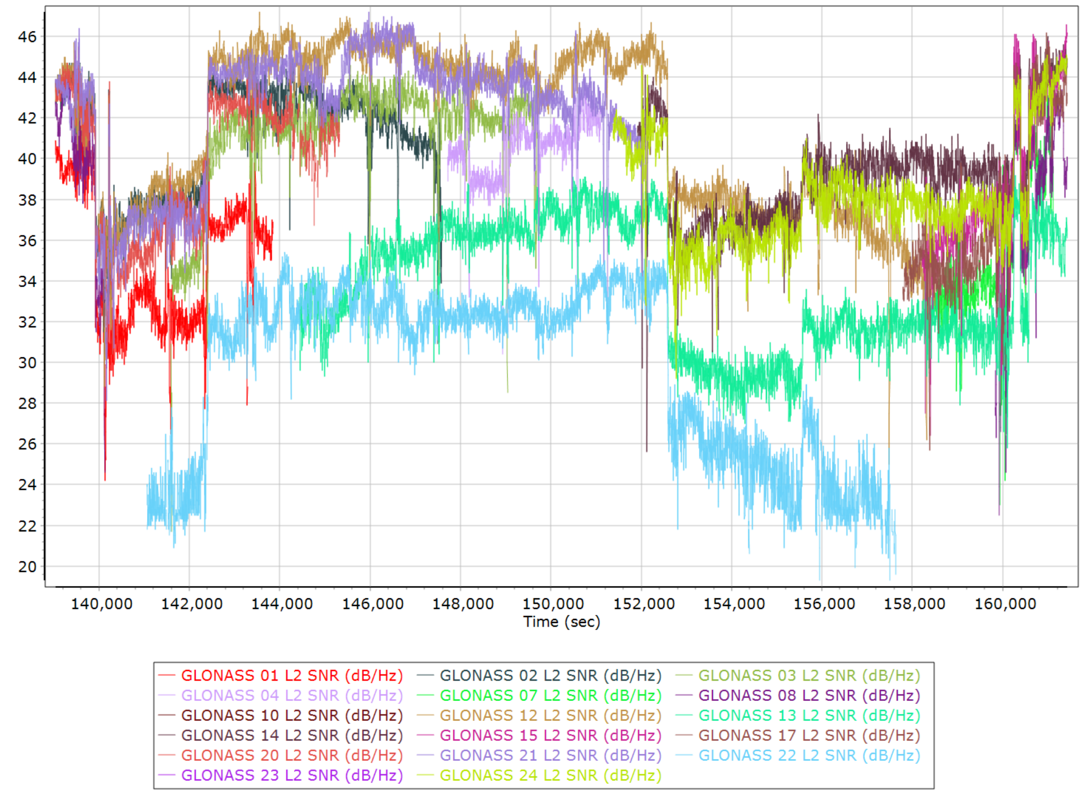
GPS/GLONASS L2 Satellite Lock/Elevation



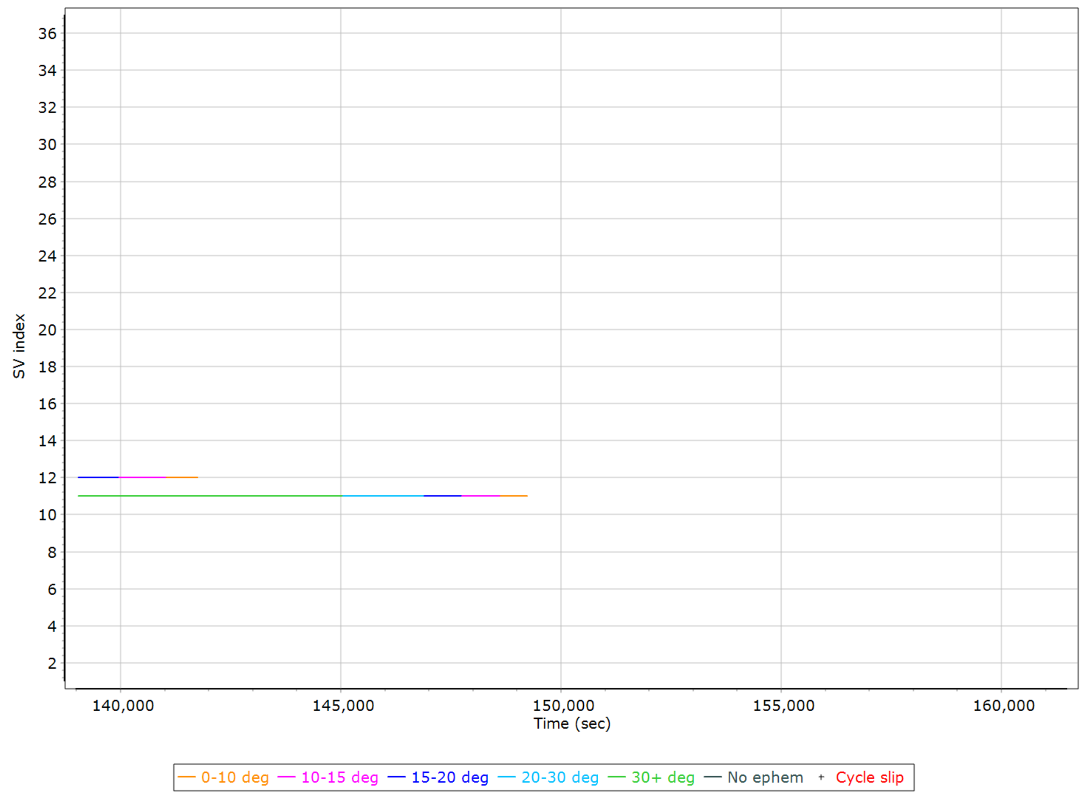
GPS L2 SNR



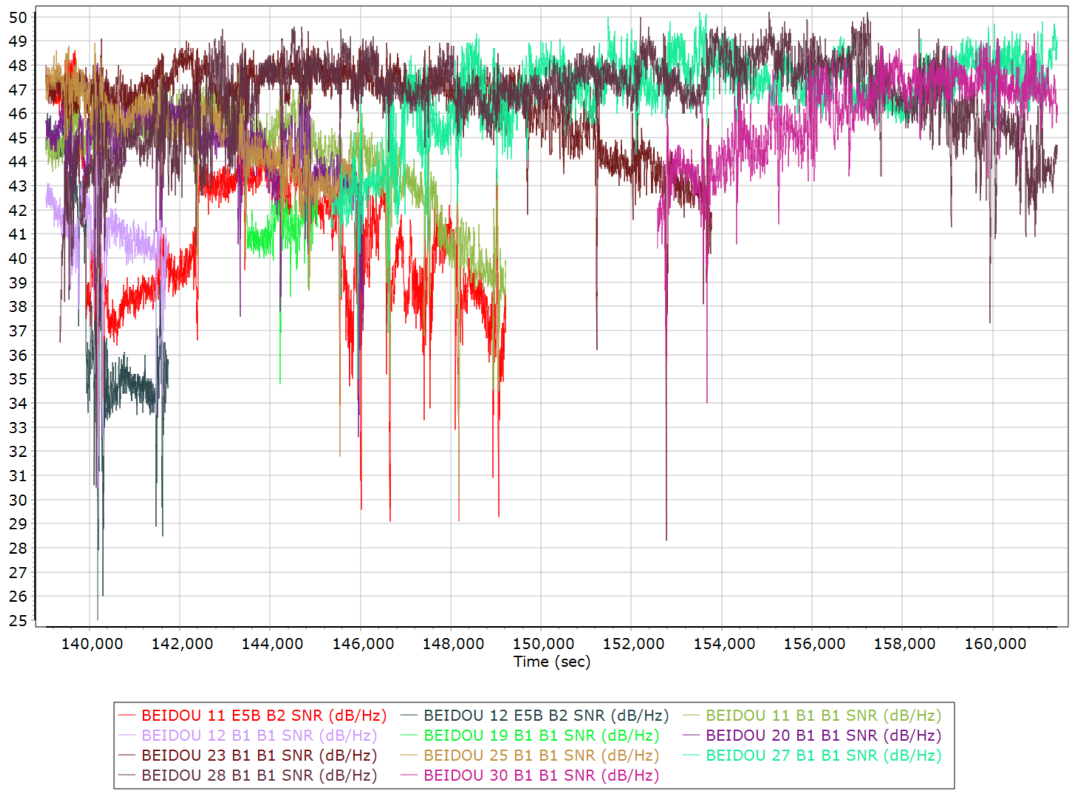
GLONASS L2 SNR



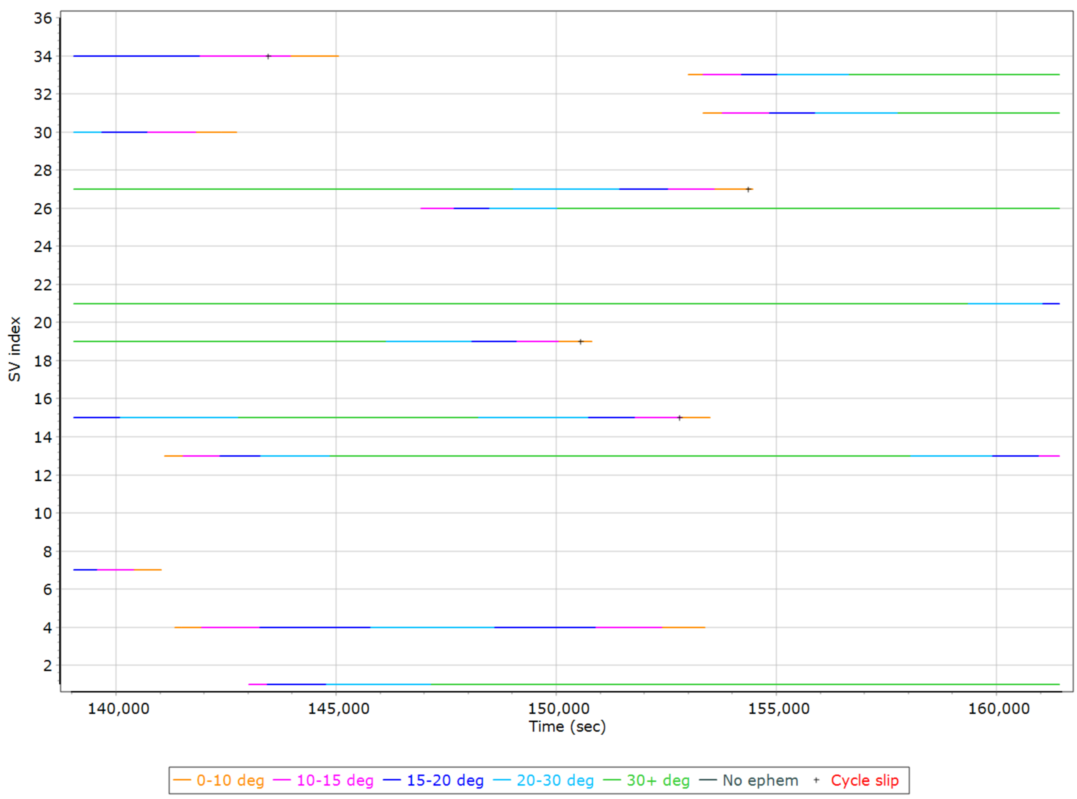
BEIDOU Satellite Lock/Elevation



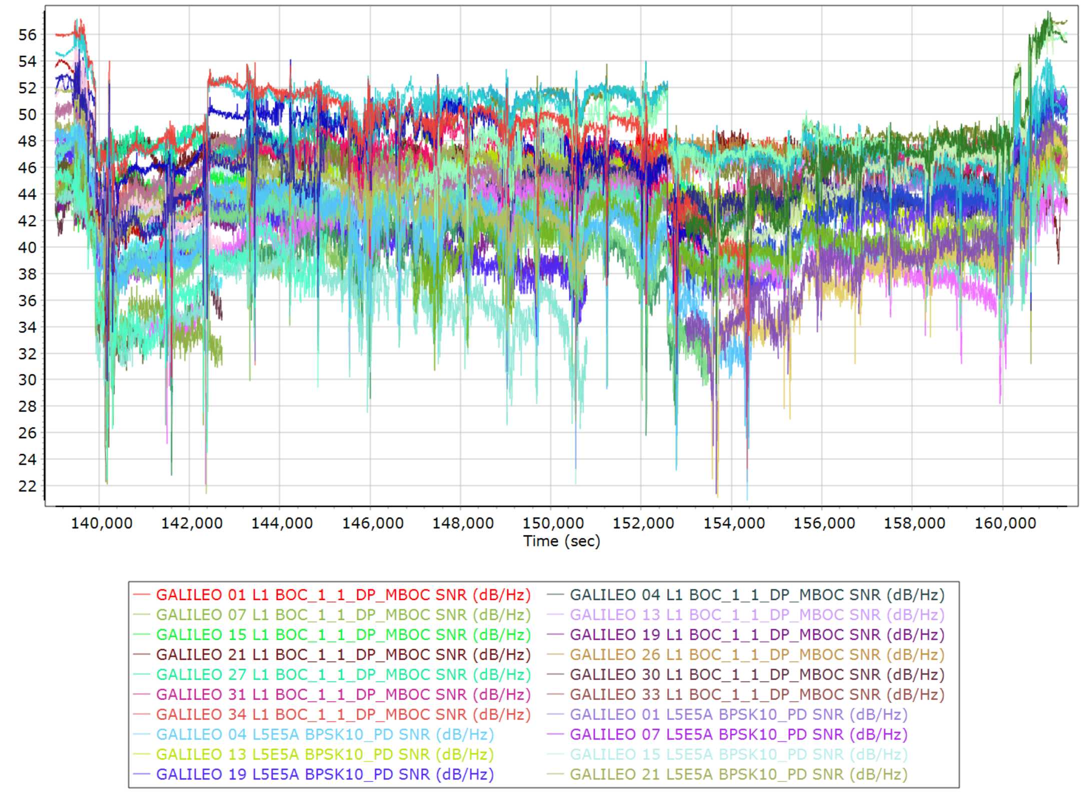
BEIDOU SNR



GALILEO Satellite Lock/Elevation



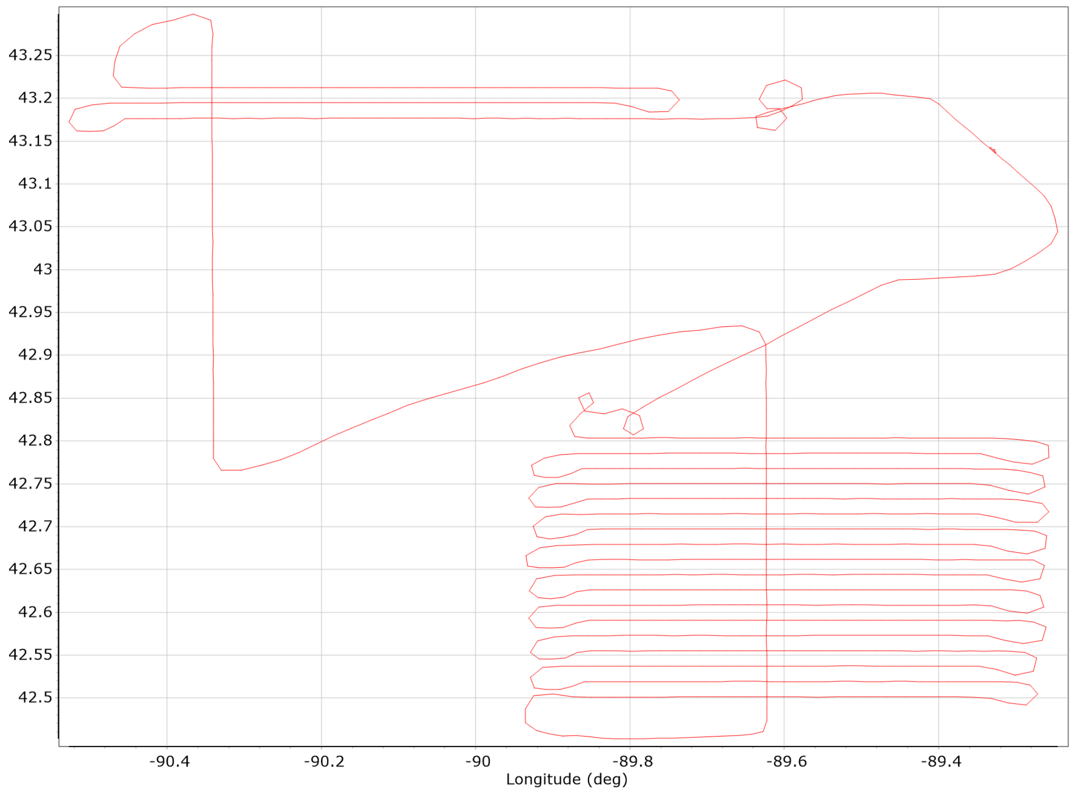
GALILEO SNR



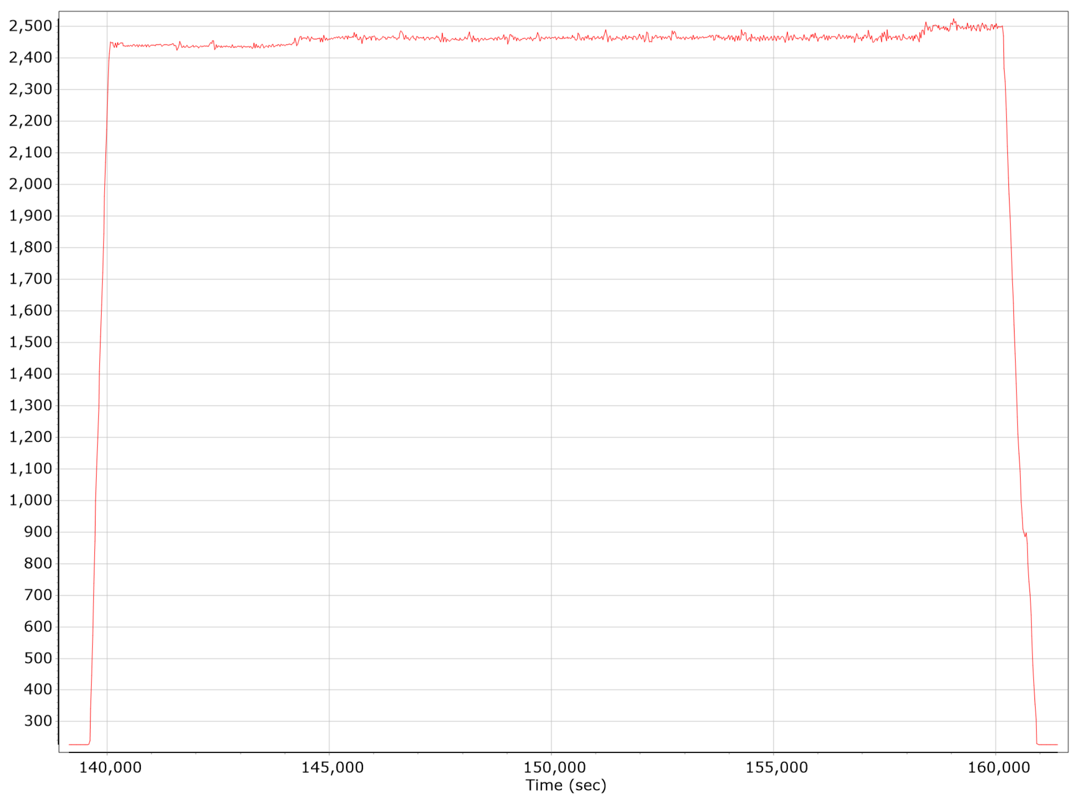
56
54
52
50
48
46
44
42
40
38
36
34
32
30
28
26
24
22
140,000
142,000
144,000
146,000
148,000
150,000
152,000
154,000
156,000
158,000
160,000
Time (sec)
GALILEO 01 L1 BOC_1_1_DP_MBOC SNR (dB/Hz)
GALILEO 04 L1 BOC_1_1_DP_MBOC SNR (dB/Hz)
GALILEO 07 L1 BOC_1_1_DP_MBOC SNR (dB/Hz)
GALILEO 13 L1 BOC_1_1_DP_MBOC SNR (dB/Hz)
GALILEO 15 L1 BOC_1_1_DP_MBOC SNR (dB/Hz)
GALILEO 19 L1 BOC_1_1_DP_MBOC SNR (dB/Hz)
GALILEO 21 L1 BOC_1_1_DP_MBOC SNR (dB/Hz)
GALILEO 26 L1 BOC_1_1_DP_MBOC SNR (dB/Hz)
GALILEO 27 L1 BOC_1_1_DP_MBOC SNR (dB/Hz)
GALILEO 30 L1 BOC_1_1_DP_MBOC SNR (dB/Hz)
GALILEO 31 L1 BOC_1_1_DP_MBOC SNR (dB/Hz)
GALILEO 33 L1 BOC_1_1_DP_MBOC SNR (dB/Hz)
GALILEO 34 L1 BOC_1_1_DP_MBOC SNR (dB/Hz)
GALILEO 01 L5E5A BPSK10_PD SNR (dB/Hz)
GALILEO 04 L5E5A BPSK10_PD SNR (dB/Hz)
GALILEO 07 L5E5A BPSK10_PD SNR (dB/Hz)
GALILEO 13 L5E5A BPSK10_PD SNR (dB/Hz)
GALILEO 15 L5E5A BPSK10_PD SNR (dB/Hz)
GALILEO 19 L5E5A BPSK10_PD SNR (dB/Hz)
GALILEO 21 L5E5A BPSK10_PD SNR (dB/Hz)

Smoothed Trajectory Information

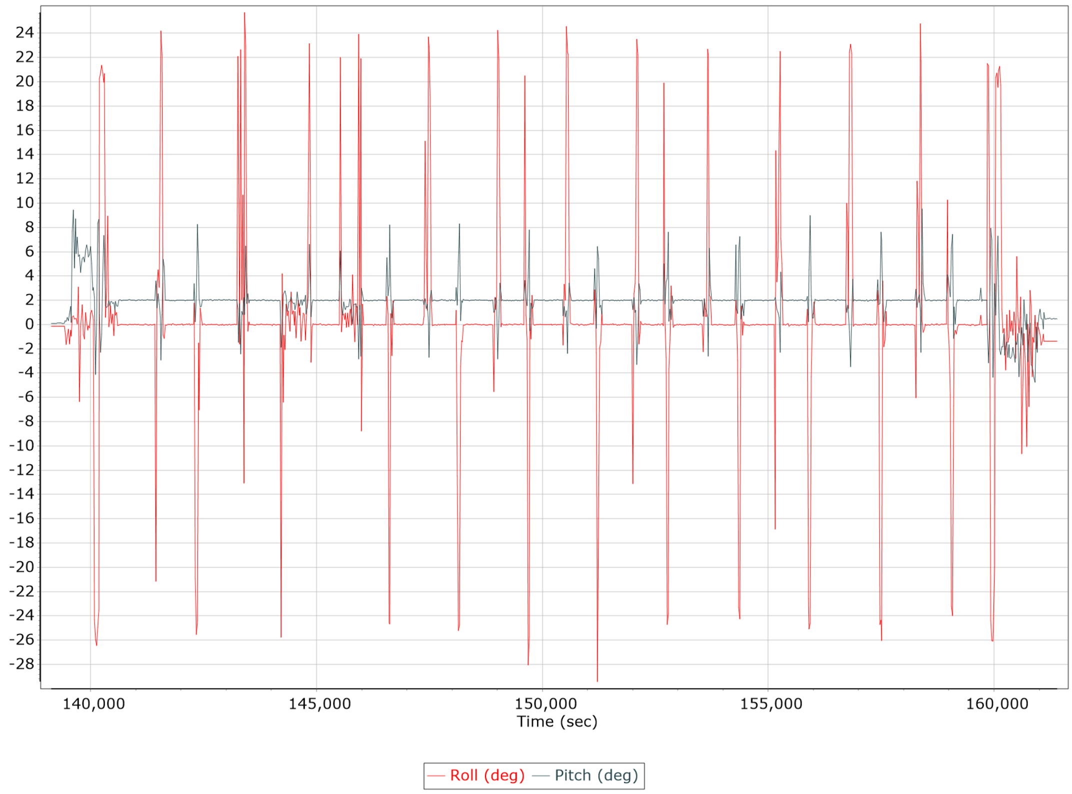
Top View



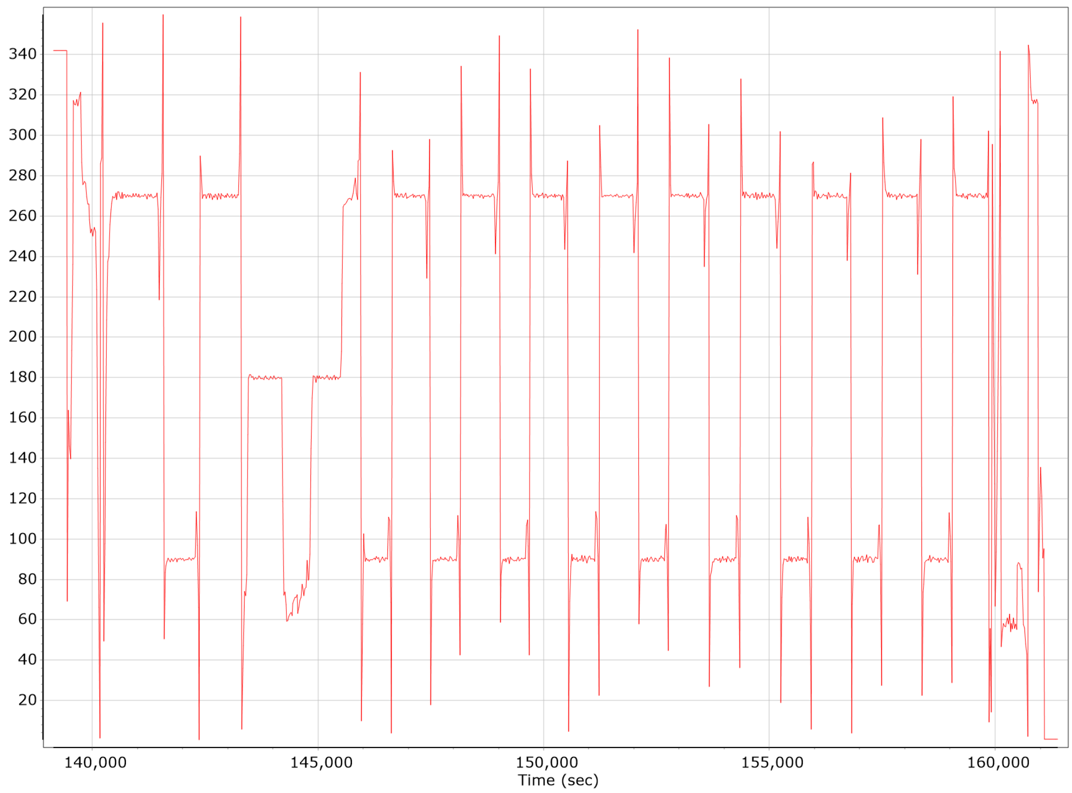
Altitude



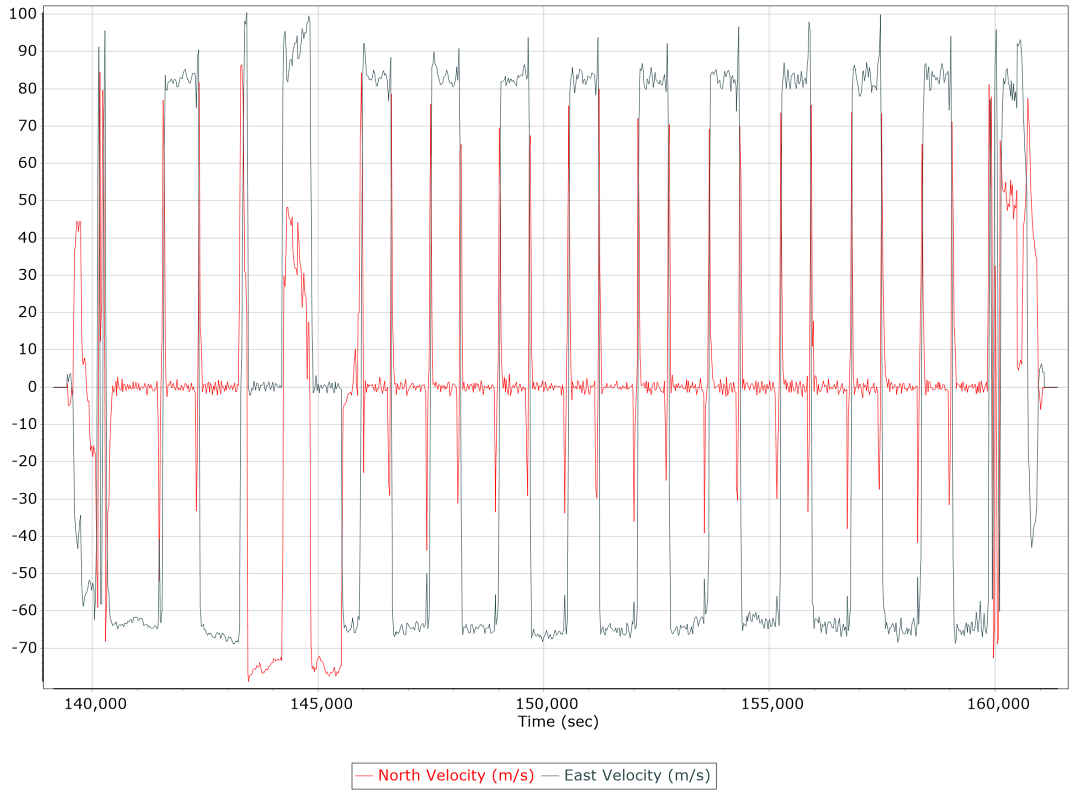
Roll/Pitch



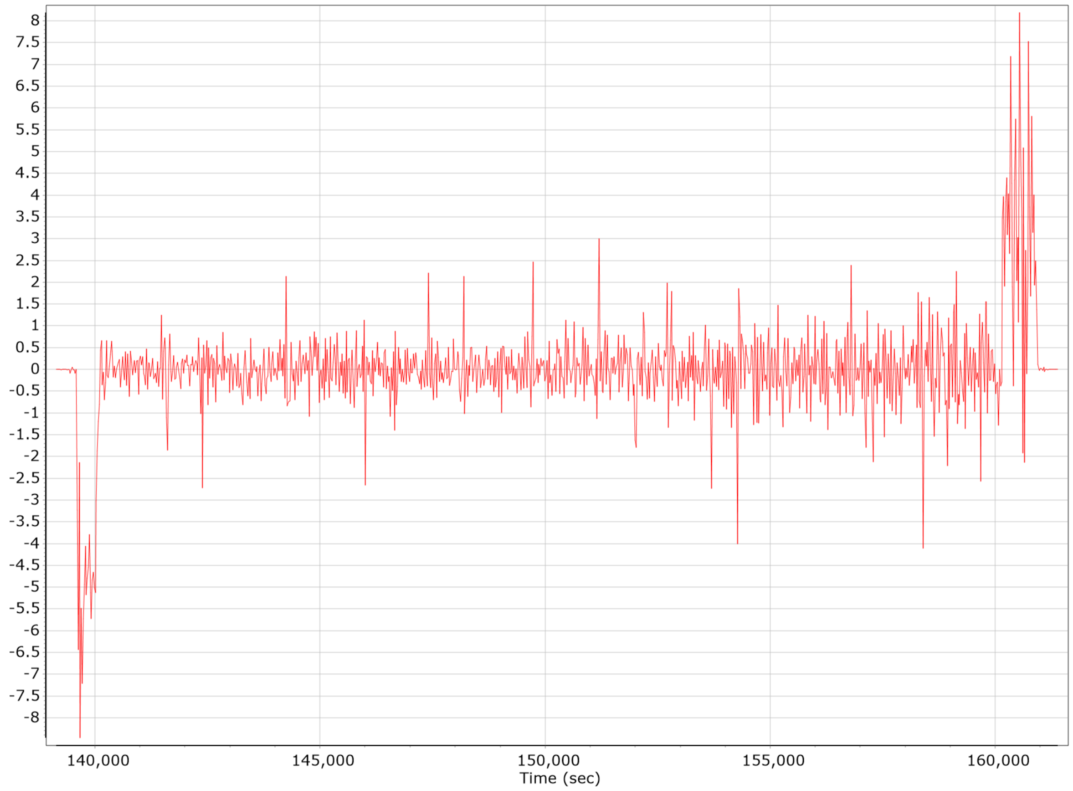
Heading



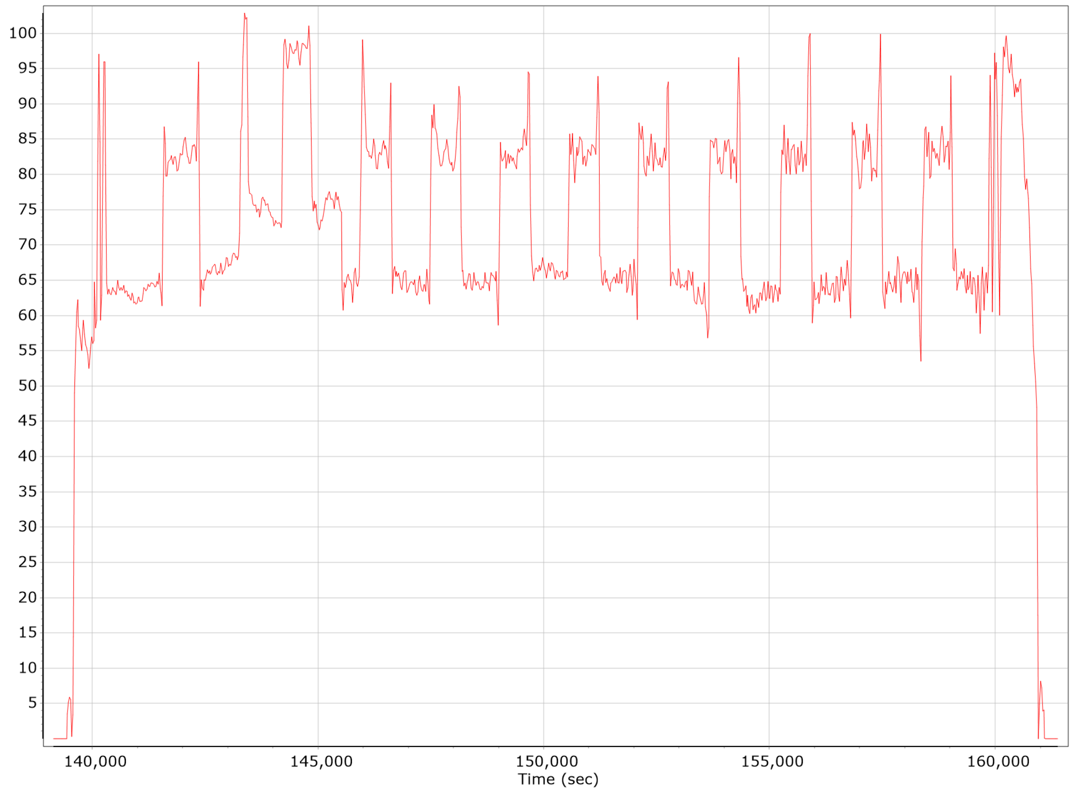
North/East Velocity



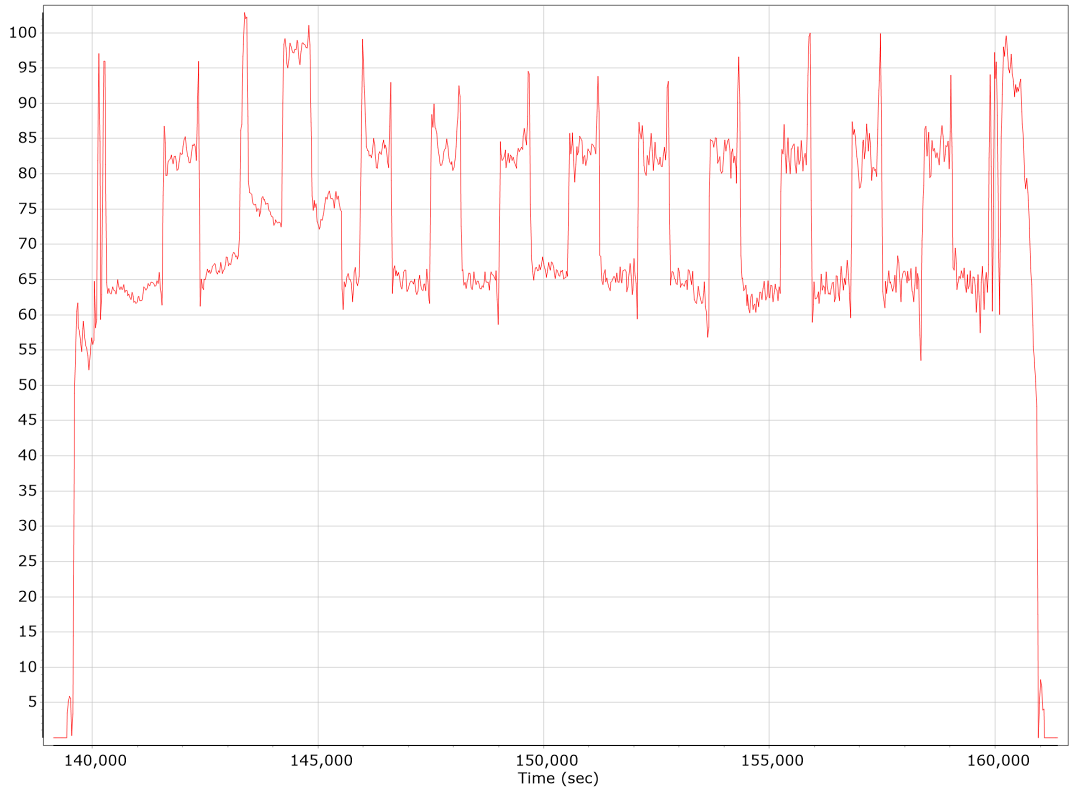
Down Velocity



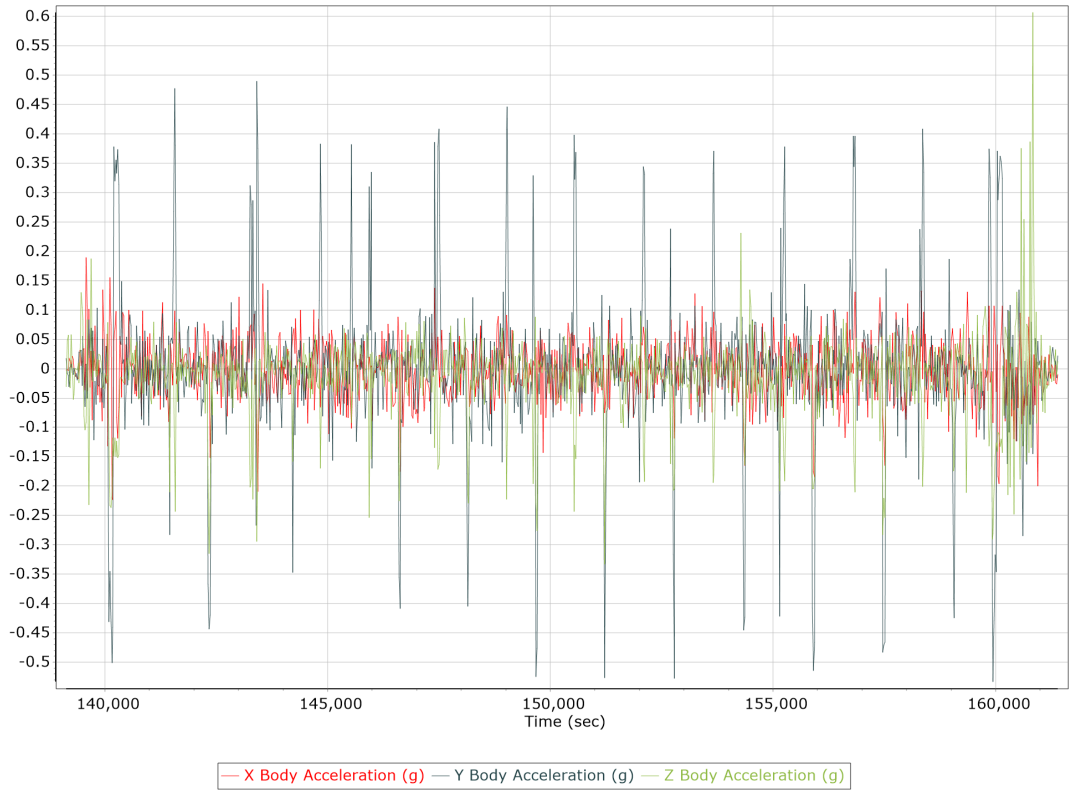
Total Speed



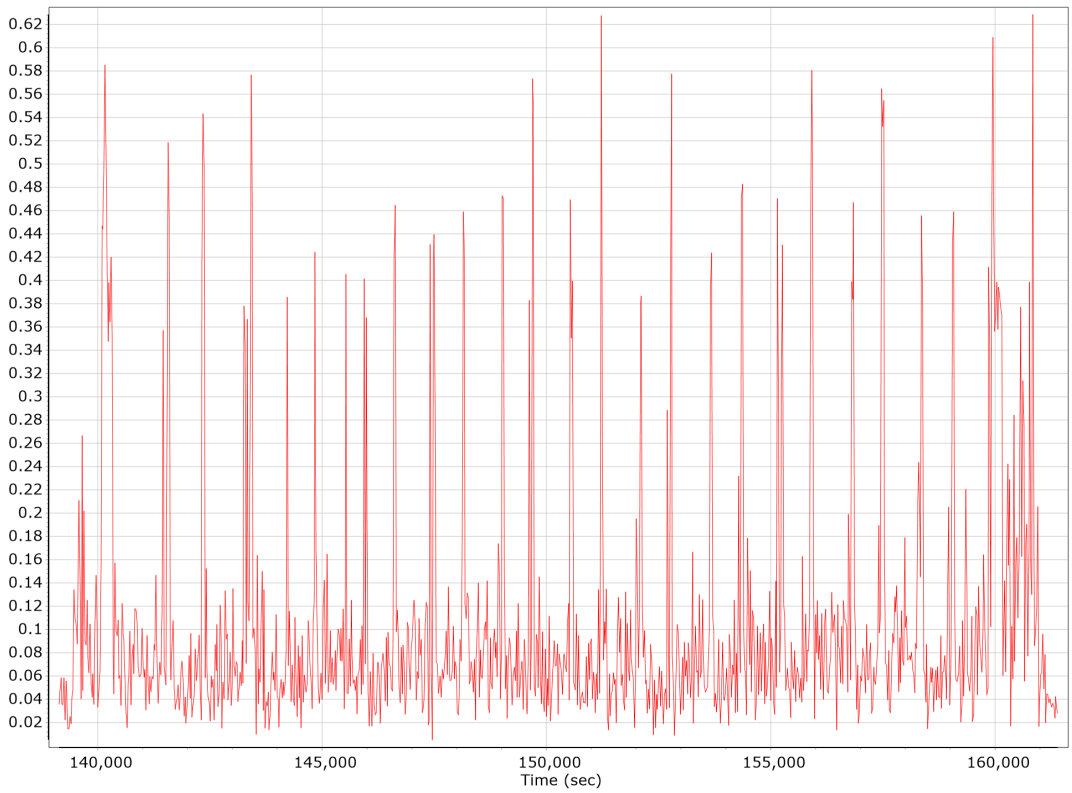
Ground Speed



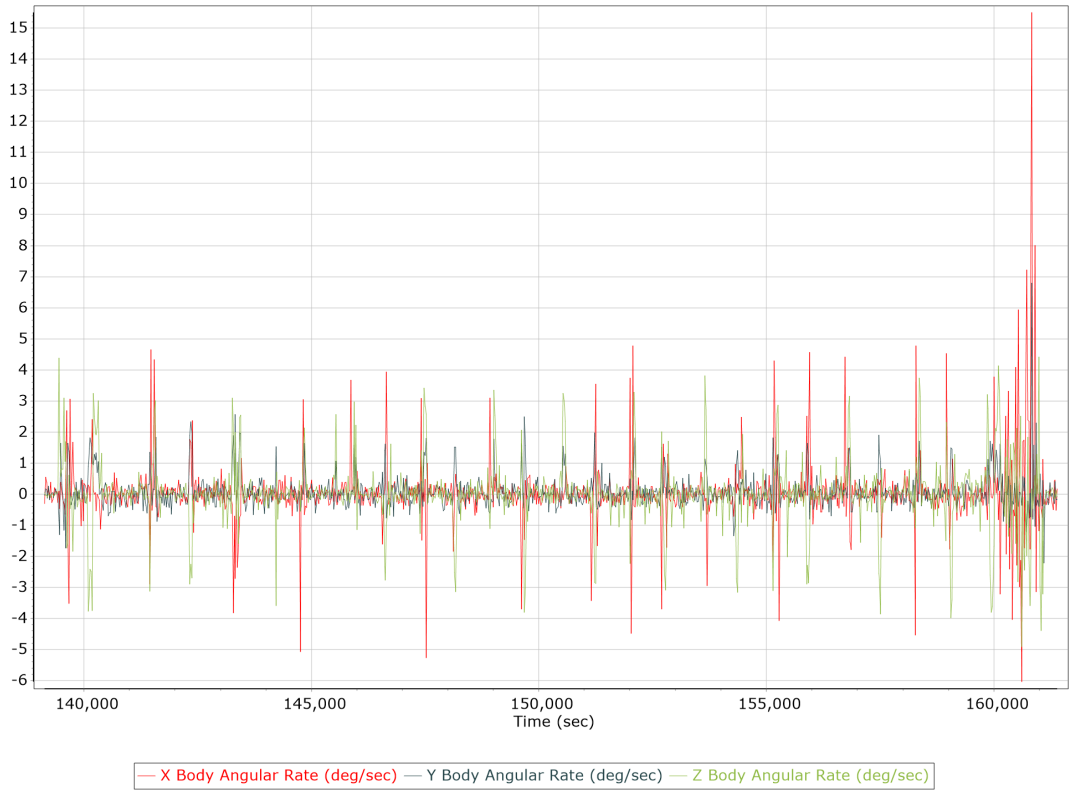
Body Acceleration



Total Body Acceleration

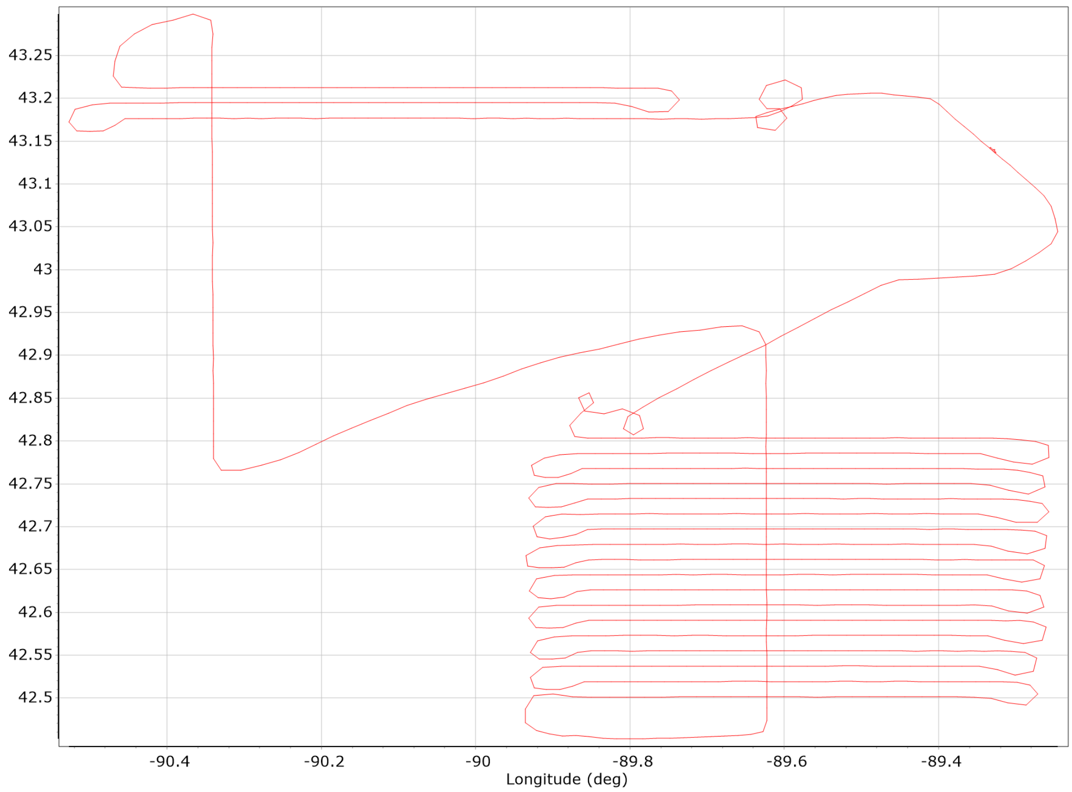


Body Angular Rate

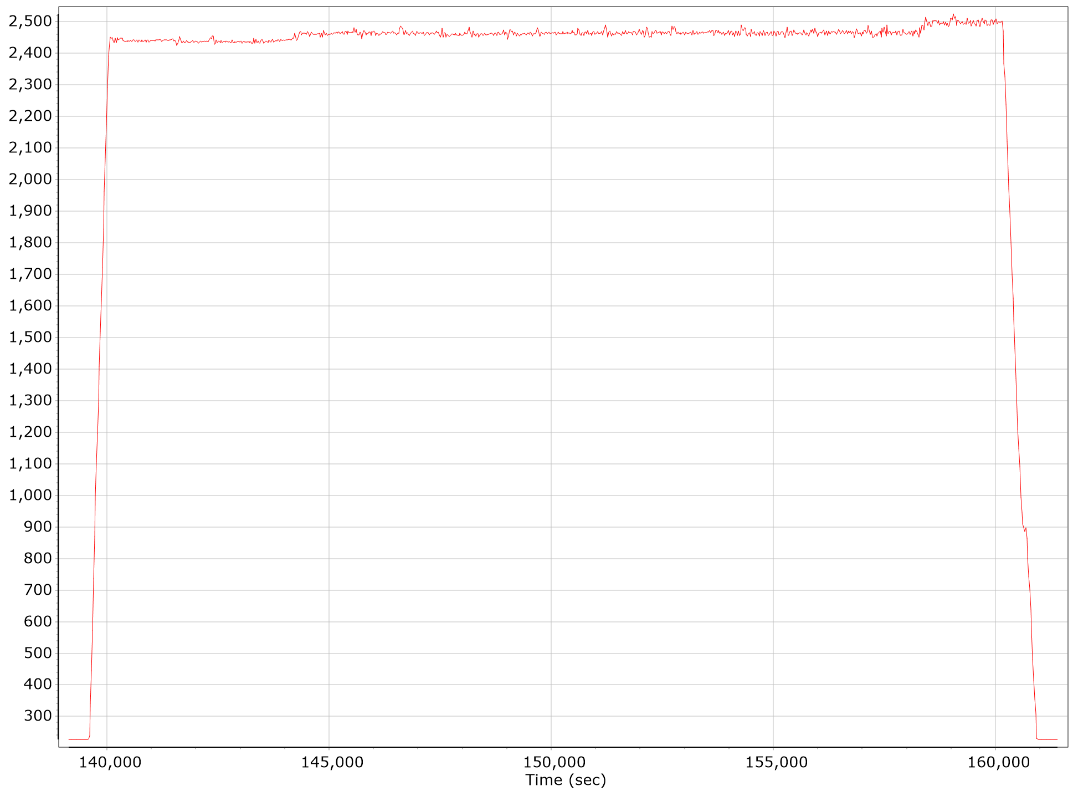


Forward Processed Trajectory Information

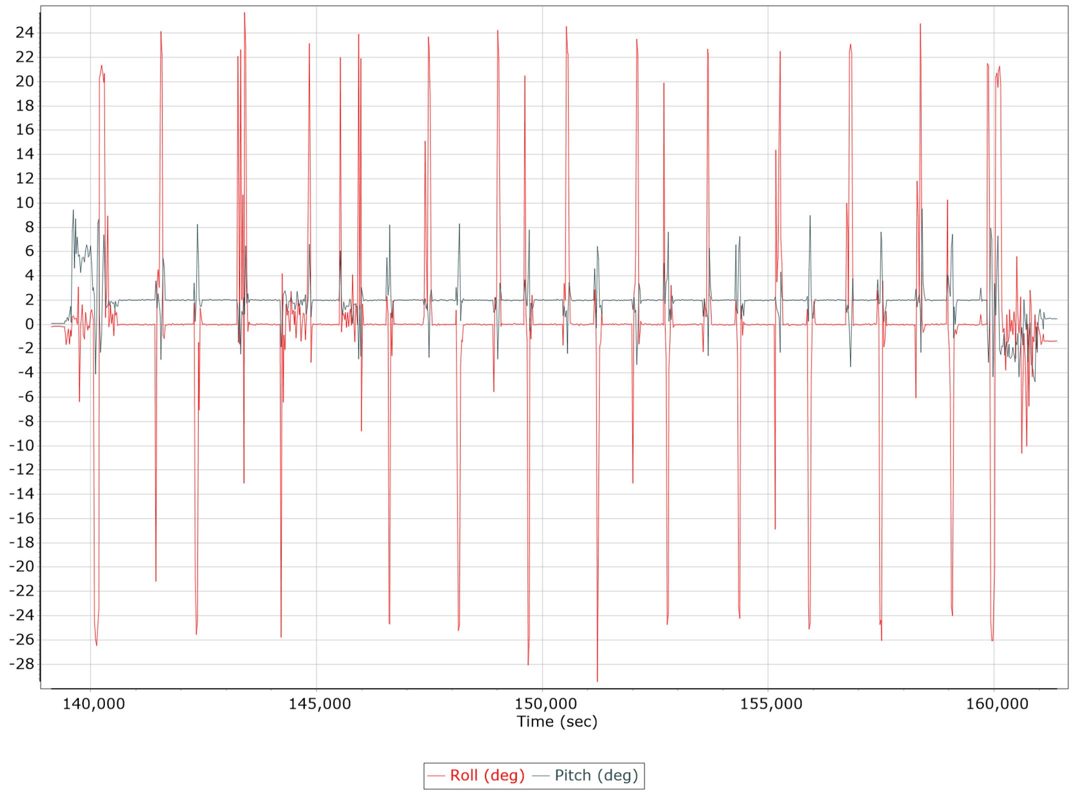
Top View



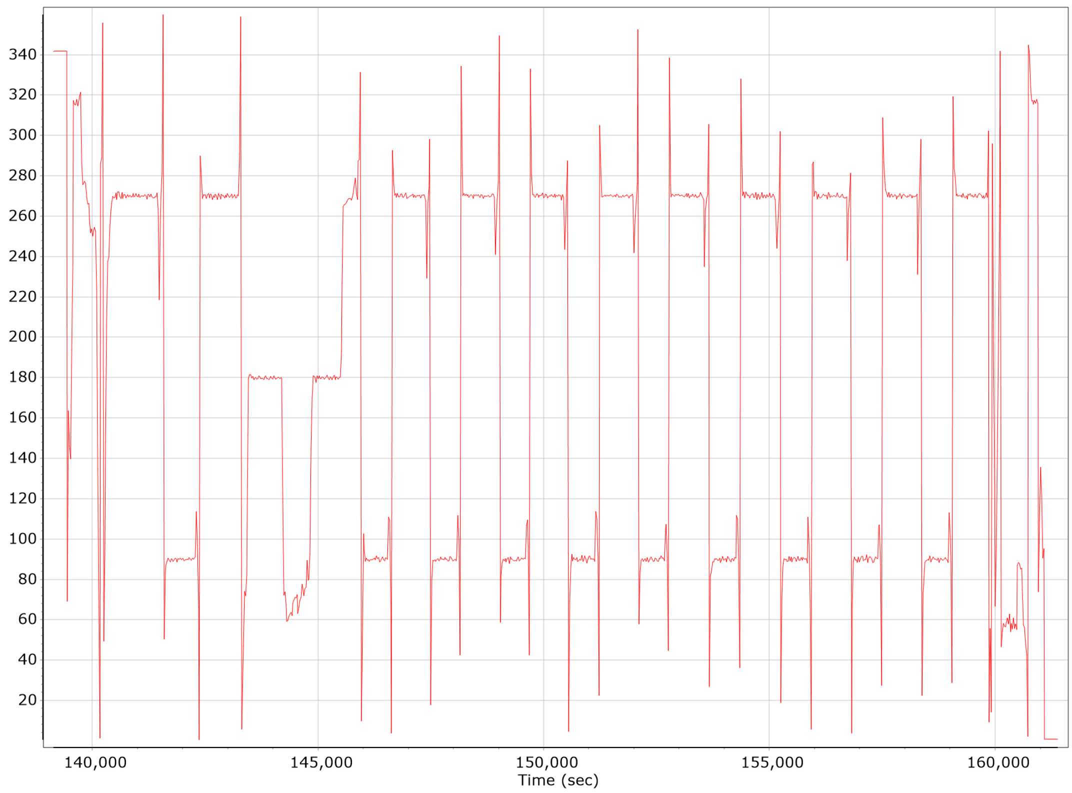
Altitude



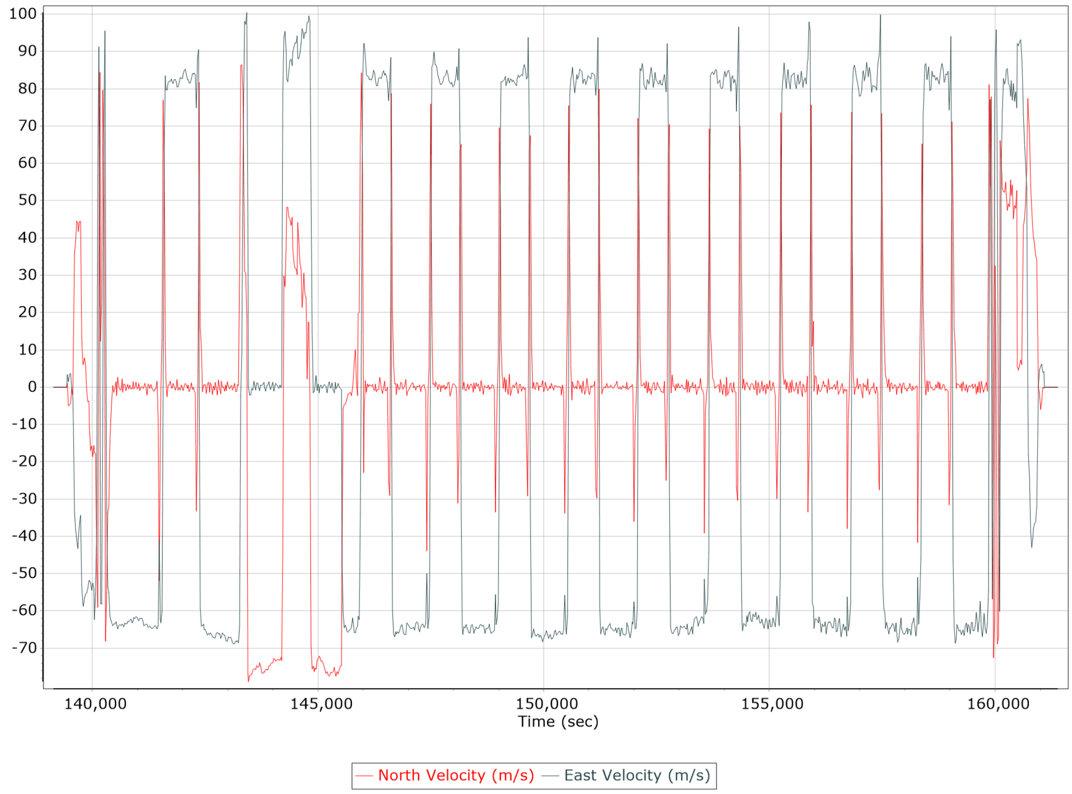
Roll/Pitch



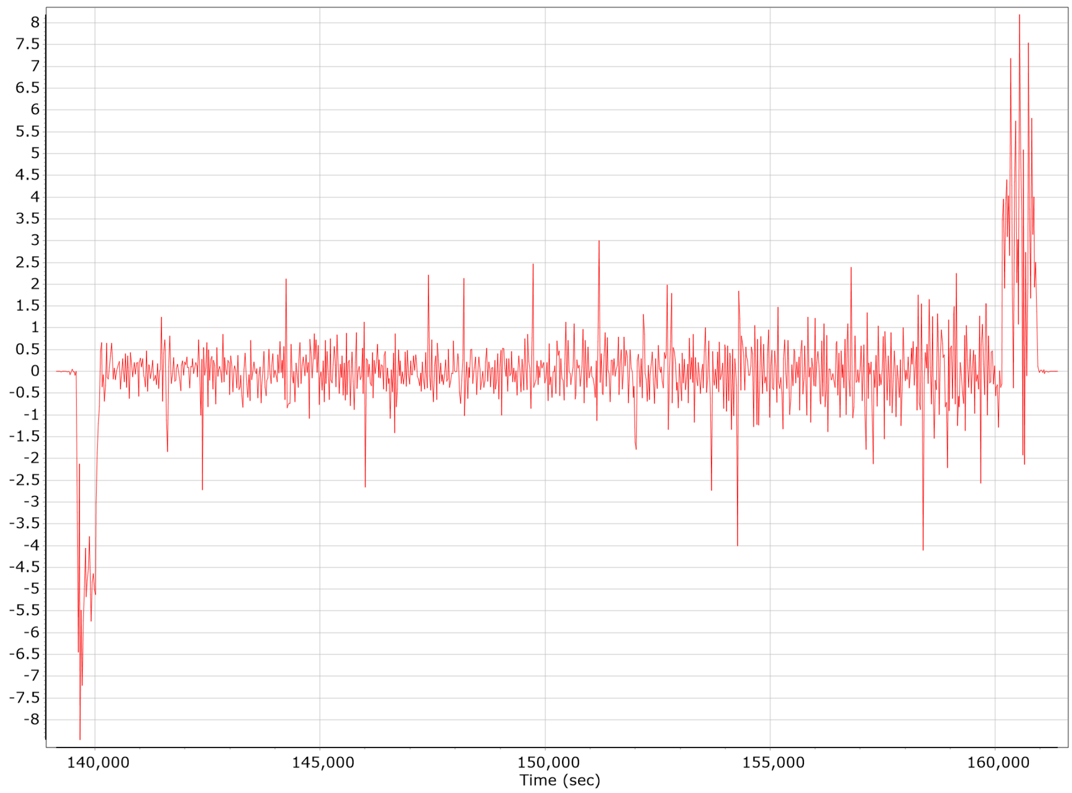
Heading



North/East Velocity



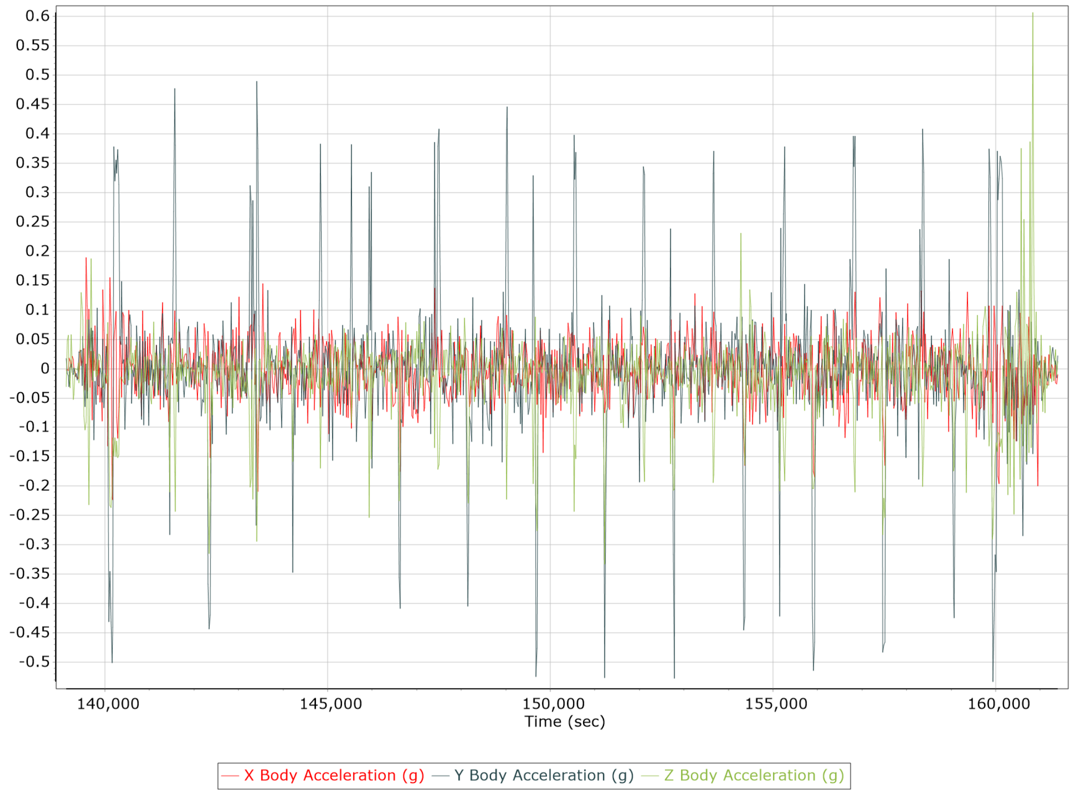
Down Velocity



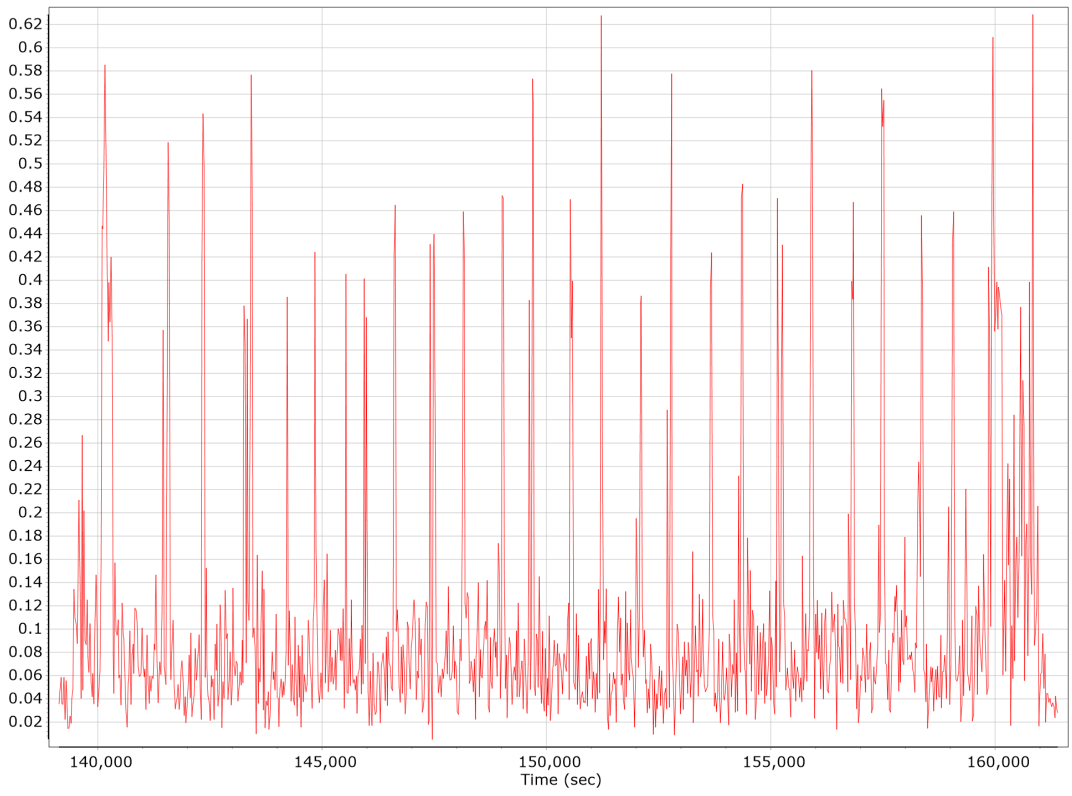
Total Speed

Ground Speed

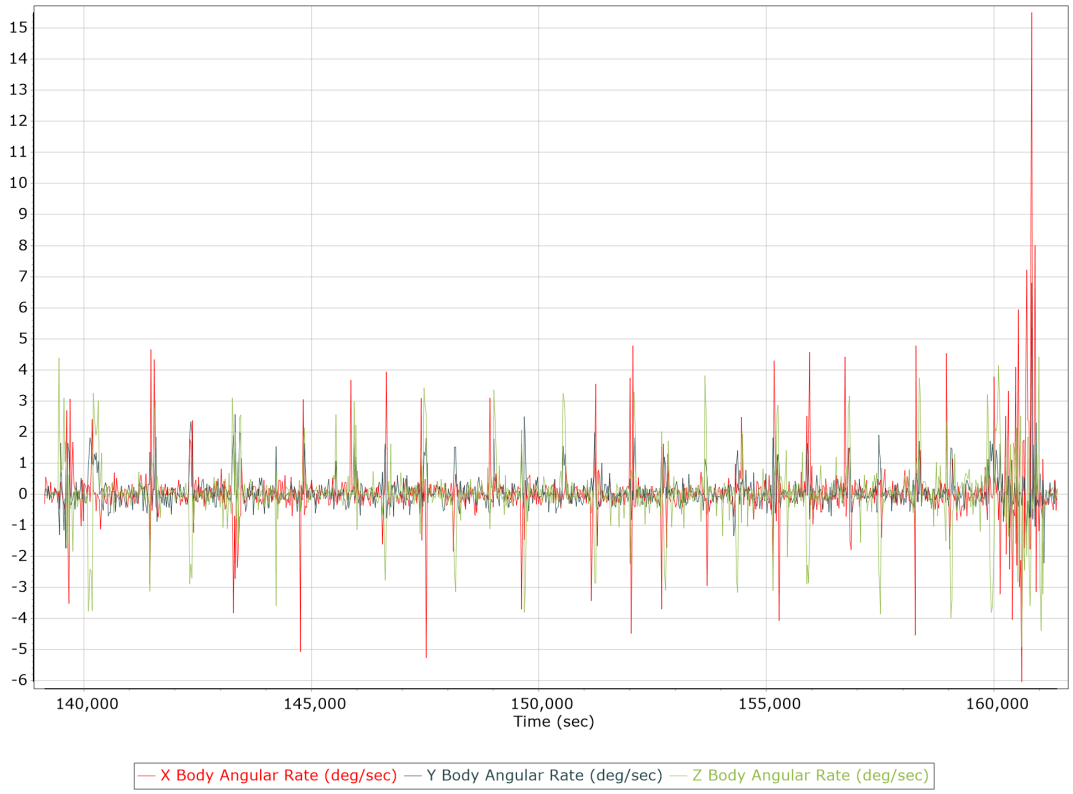
Body Acceleration



Total Body Acceleration



Body Angular Rate

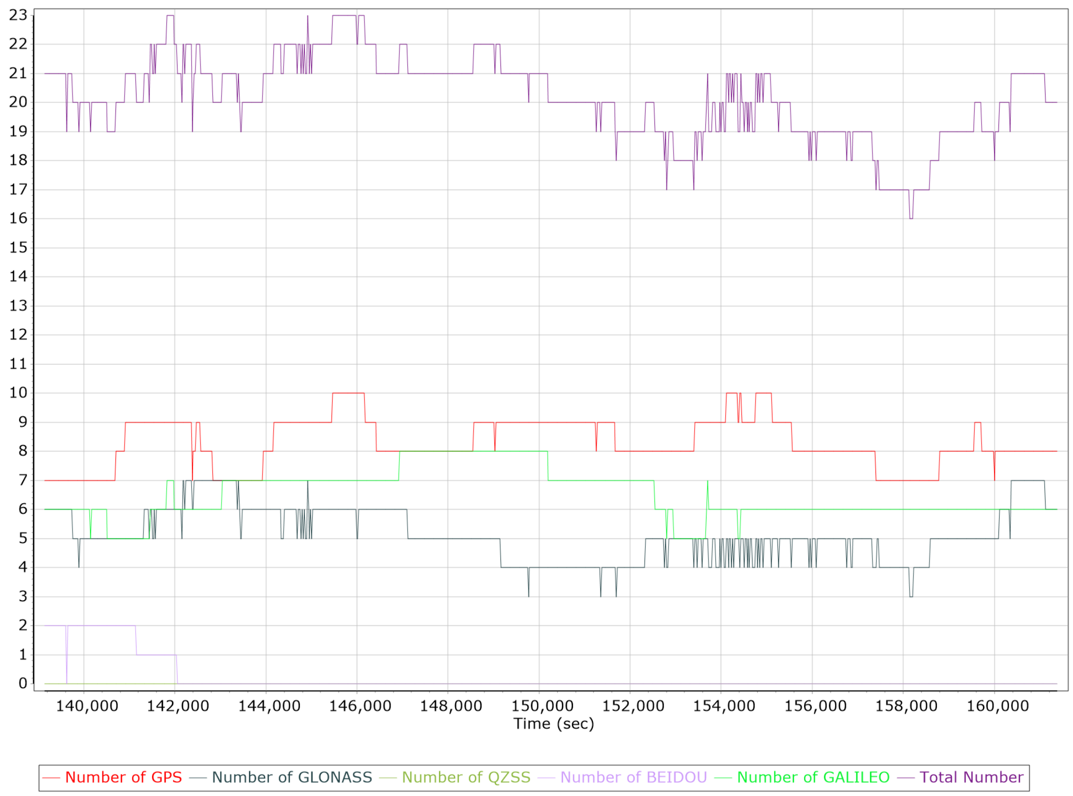


GNSS QC

GNSS QC Statistics

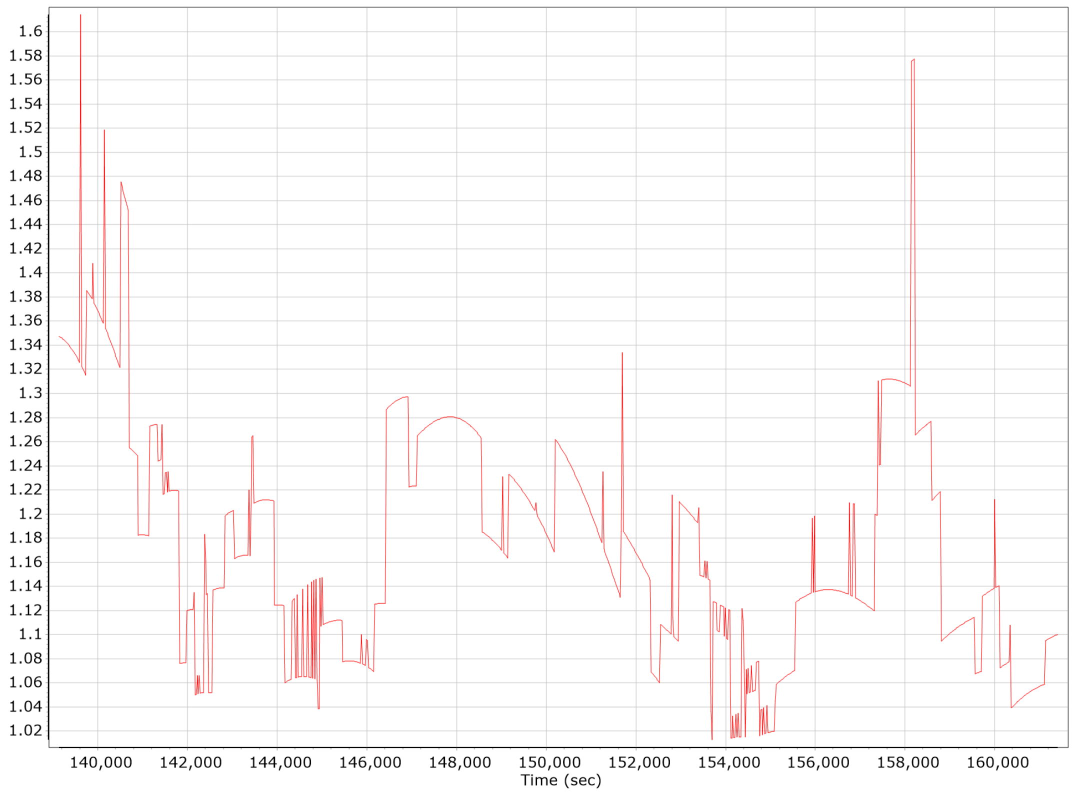
Statistics	Min	Max	Mean
Baseline length (km)	0.00	0.00	
Number of GPS SV	7	10	8
Number of GLONASS SV	0	7	5
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	2	0
Number of GALILEO SV	4	8	6
Total number of SV	13	23	20
PDOP	1.01	1.61	1.18
QC Solution Gaps	1.00	1.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	22352.00	0.00	4.00
Percentage	99.98	0.00	0.02

Num SVs in solution

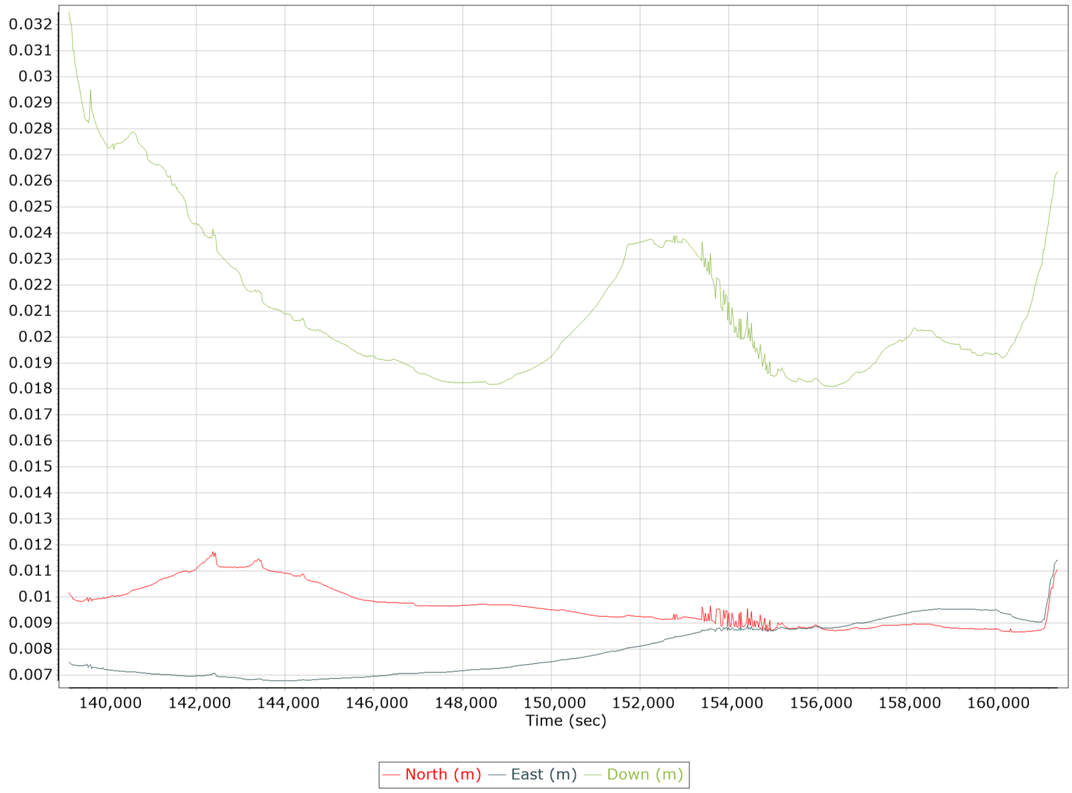


Forward/Reverse Separation

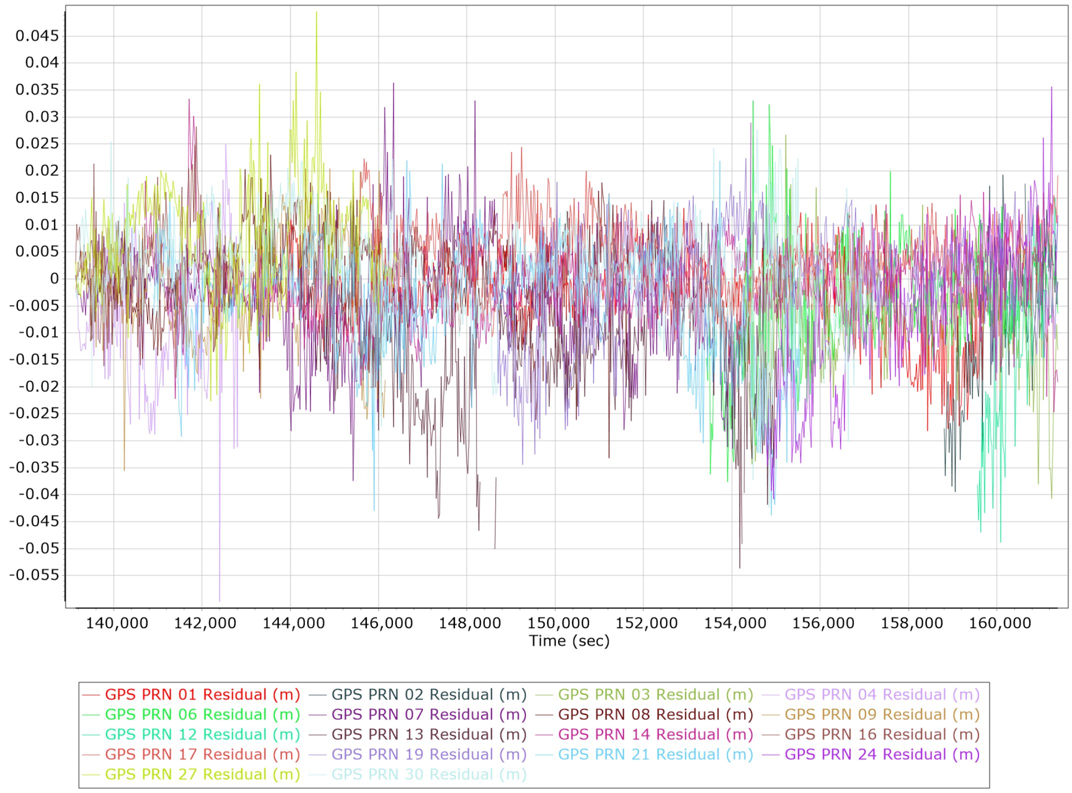
PDOP



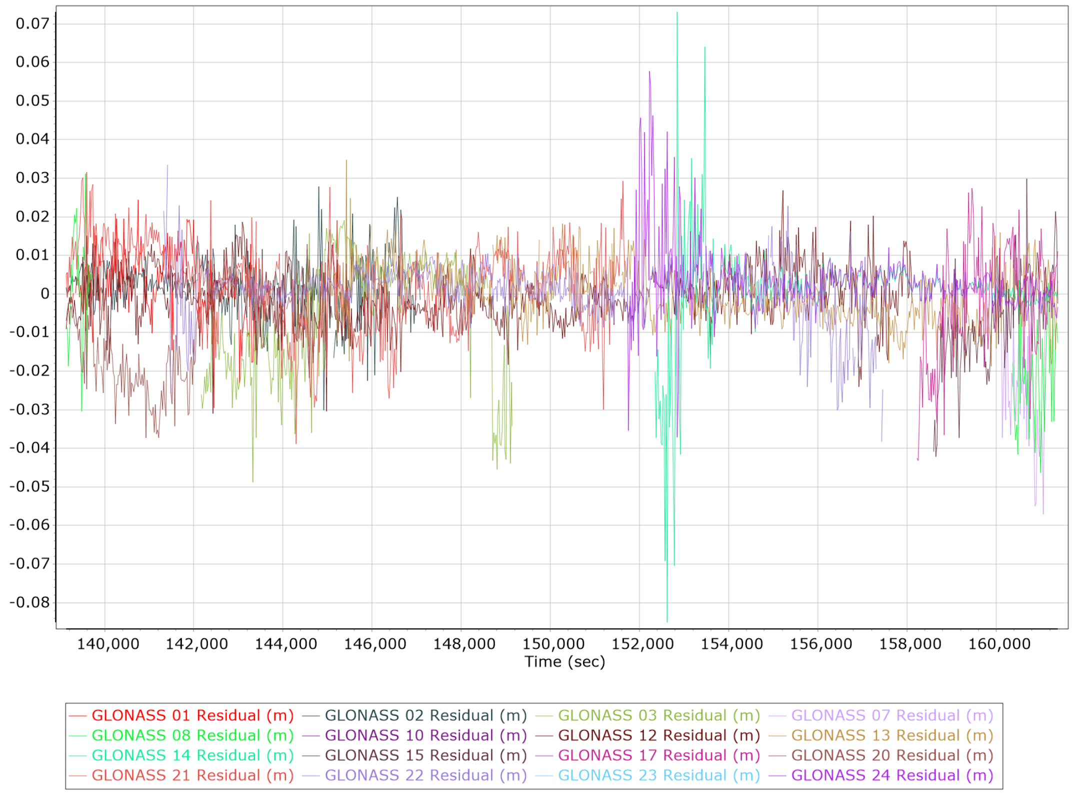
Estimated Position Accuracy



GPS Residuals

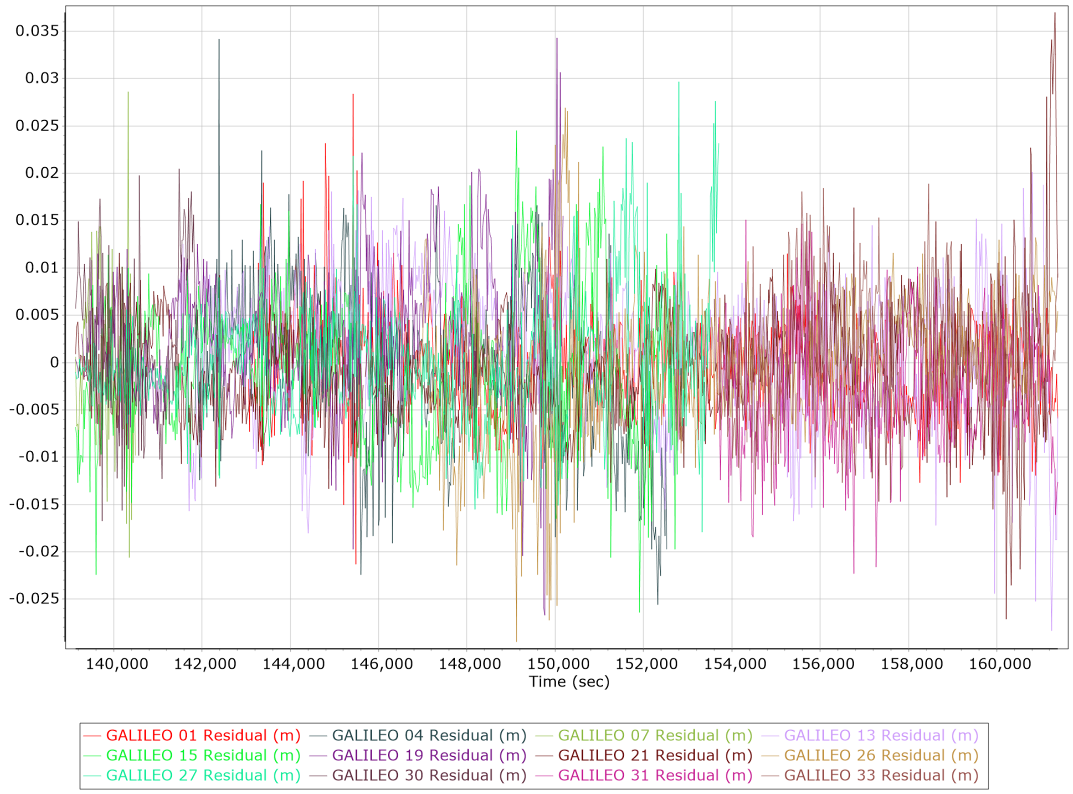


GLONASS Residuals



BEIDOU Residuals

GALILEO Residuals



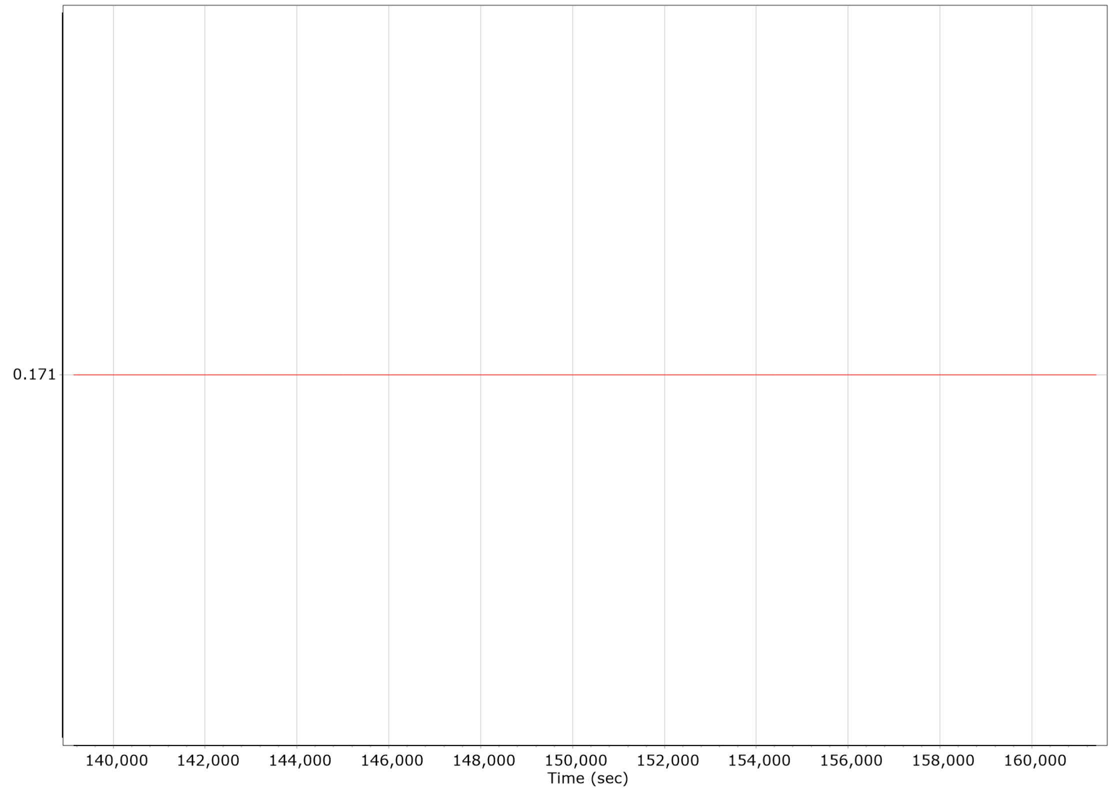
GNSS-Inertial Processor Configuration

Processing mode	IN-Fusion PP-RTX		
Stabilized mount	True		
Processing start time	139021.000 (4/11/2022 2:37:01 PM)		
Processing end time	161411.000 (4/11/2022 8:50:11 PM)		
Initial attitude source	Real-Time VNAV/RNAV Attitude		
IMU Sensor Context	Processing with Onboard IMU		
Gimbal to IMU lever arm (m)	0.000	0.000	0.000
Gimbal to IMU mounting angles (deg)	0.000	0.000	0.000
Gimbal to Primary GNSS lever arm (m)	0.171	-0.238	-1.273
Gimbal to Primary GNSS lever arm std dev (m)	0.030	0.030	0.030
Aircraft to Reference mounting angles (deg)	0.000	0.000	0.000

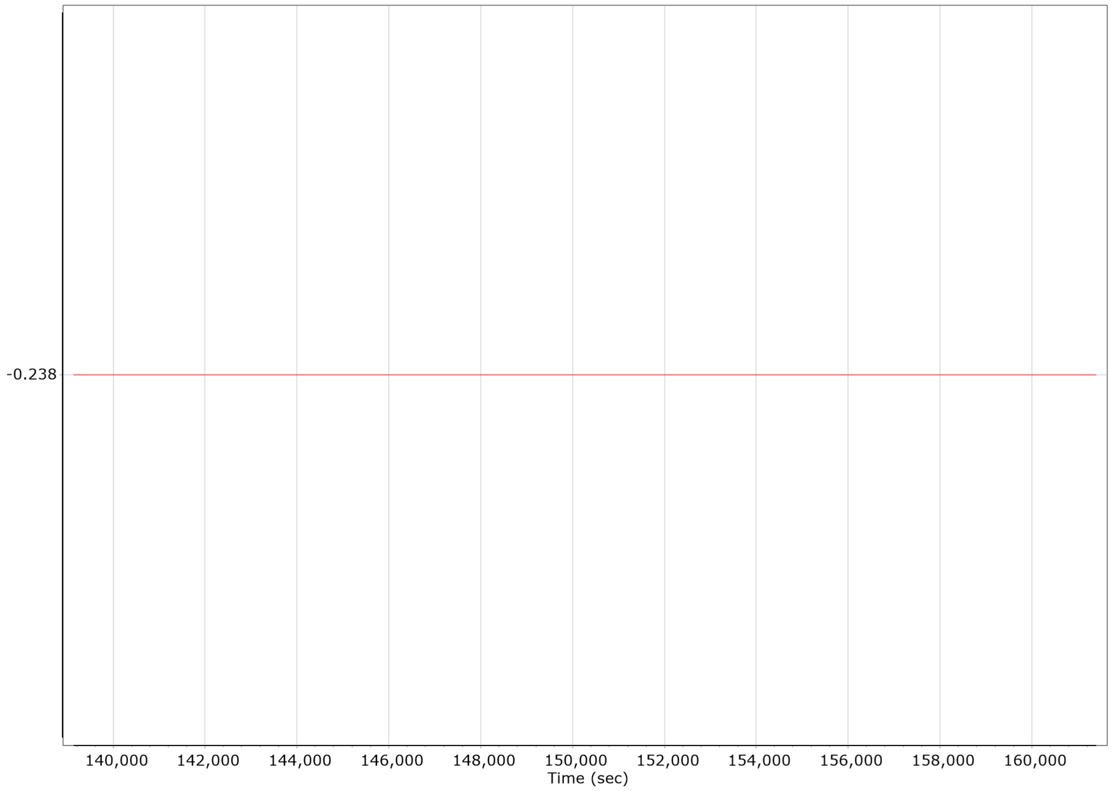
Calibrated Installation Parameters

Reference-Primary GNSS Lever Arm (m)

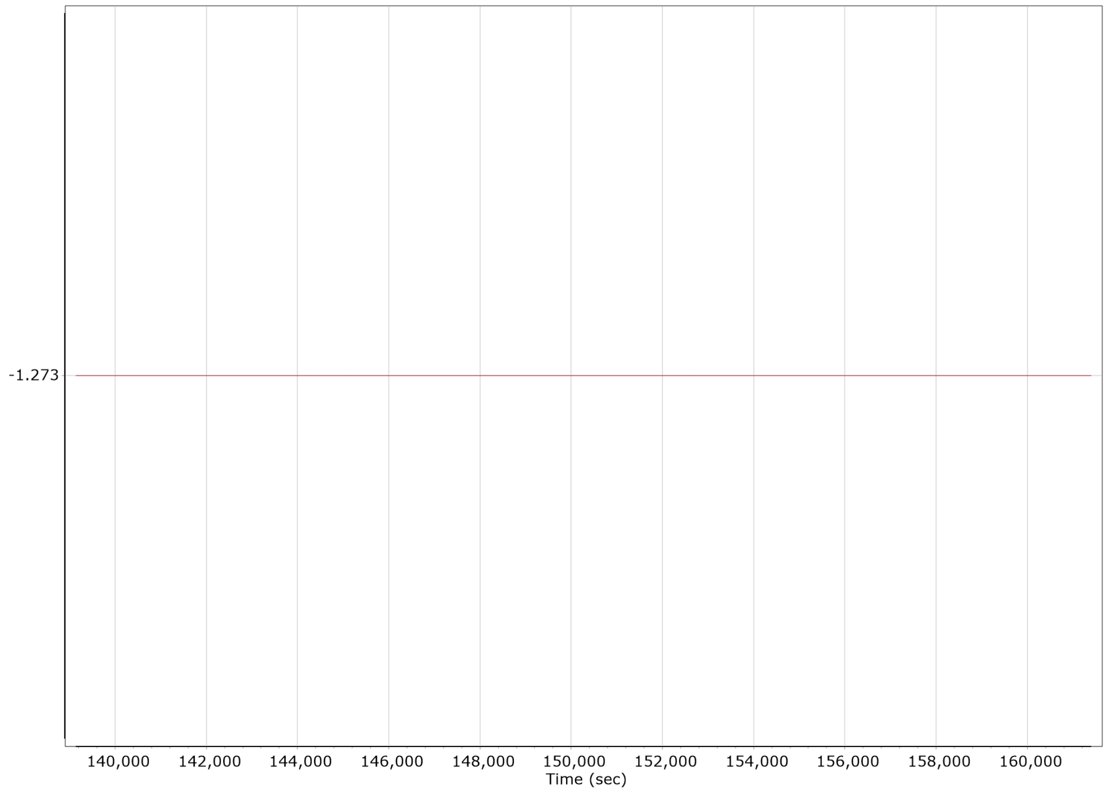
X Reference-Primary GNSS Lever Arm (m)



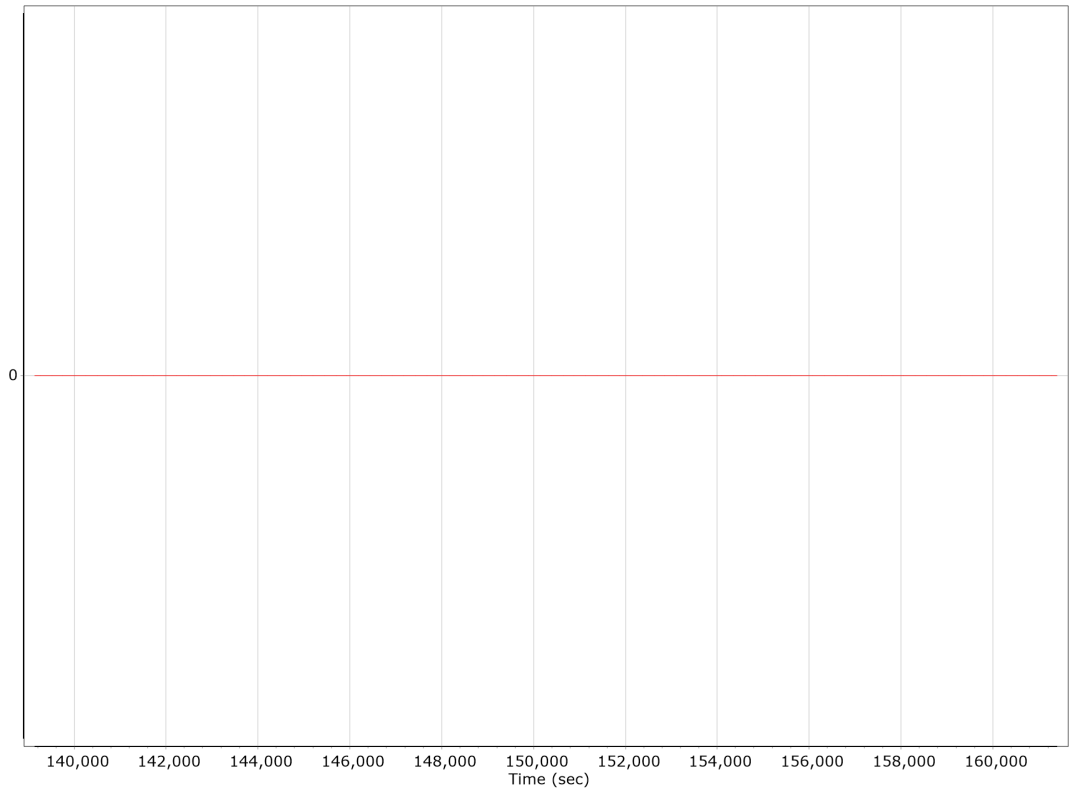
Y Reference-Primary GNSS Lever Arm (m)



Z Reference-Primary GNSS Lever Arm (m)



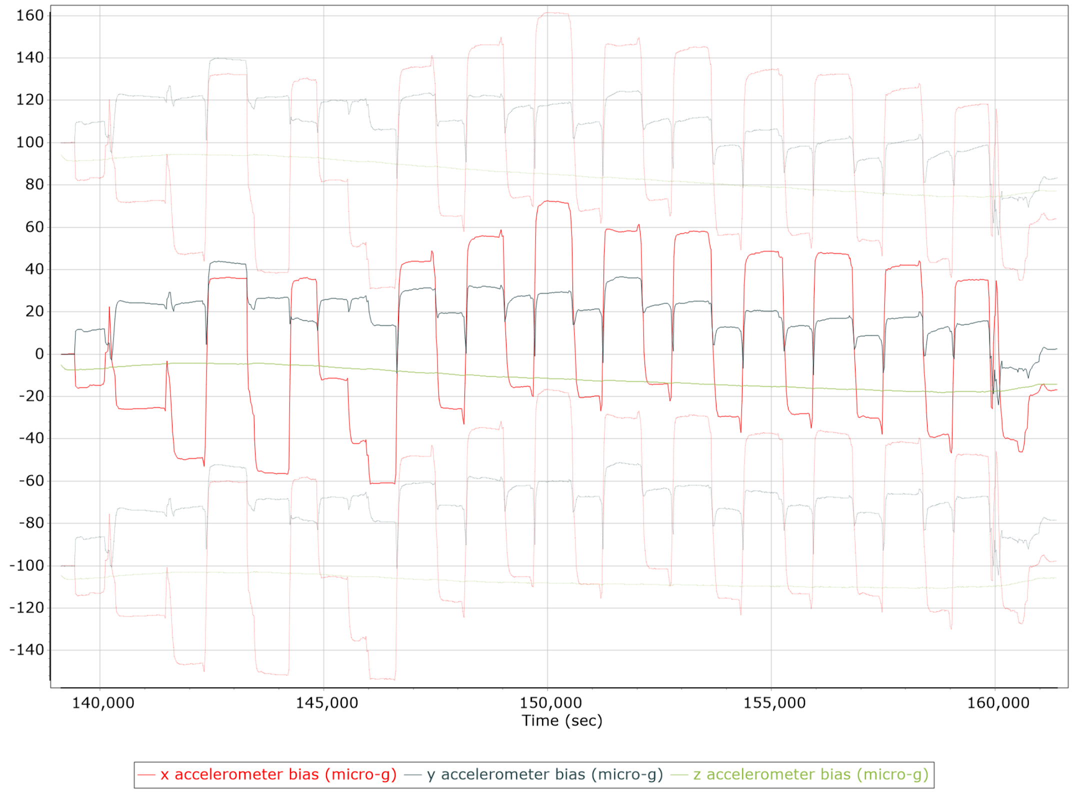
Reference-Primary GNSS Lever Arm Figure of Merit



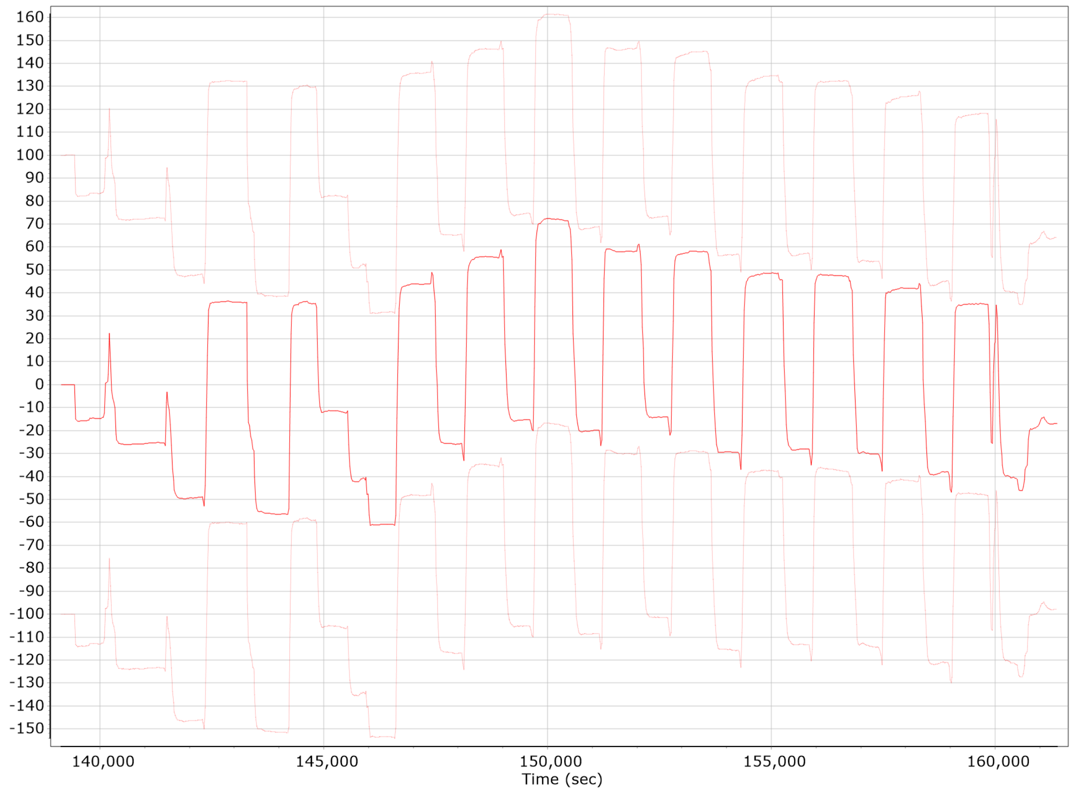
IN-Fusion QC

Forward Processed Estimated Errors, Reference Frame

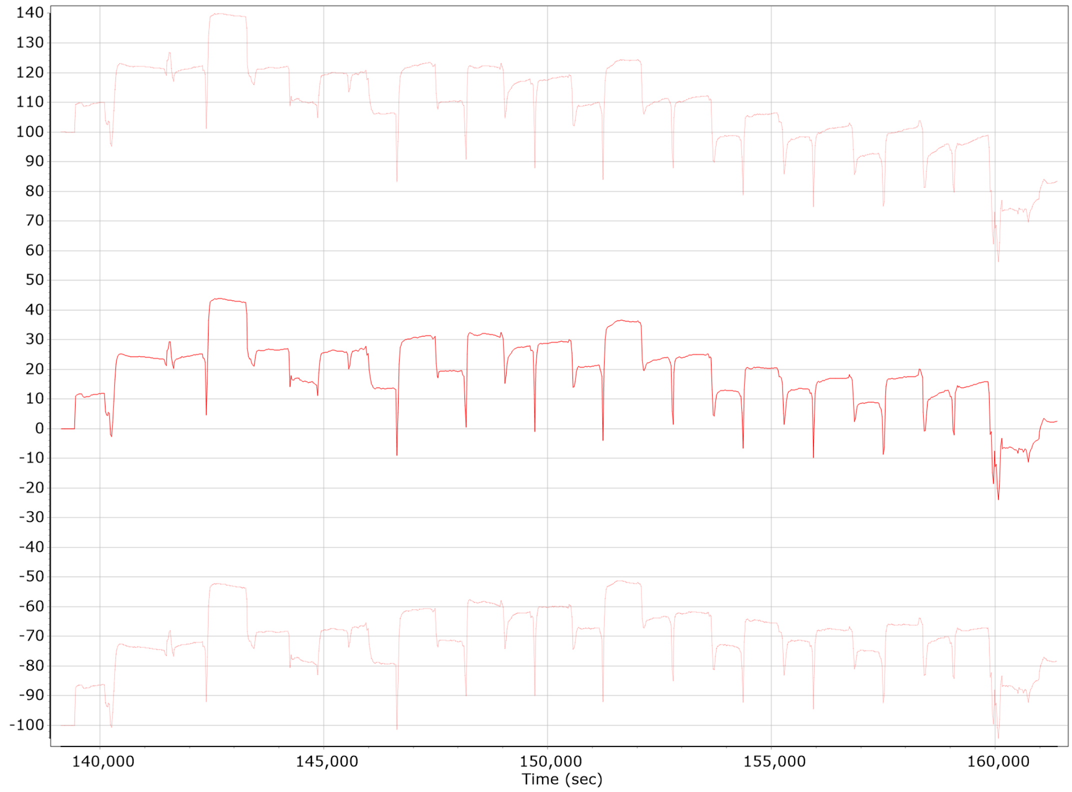
Accelerometer Bias (micro-g)



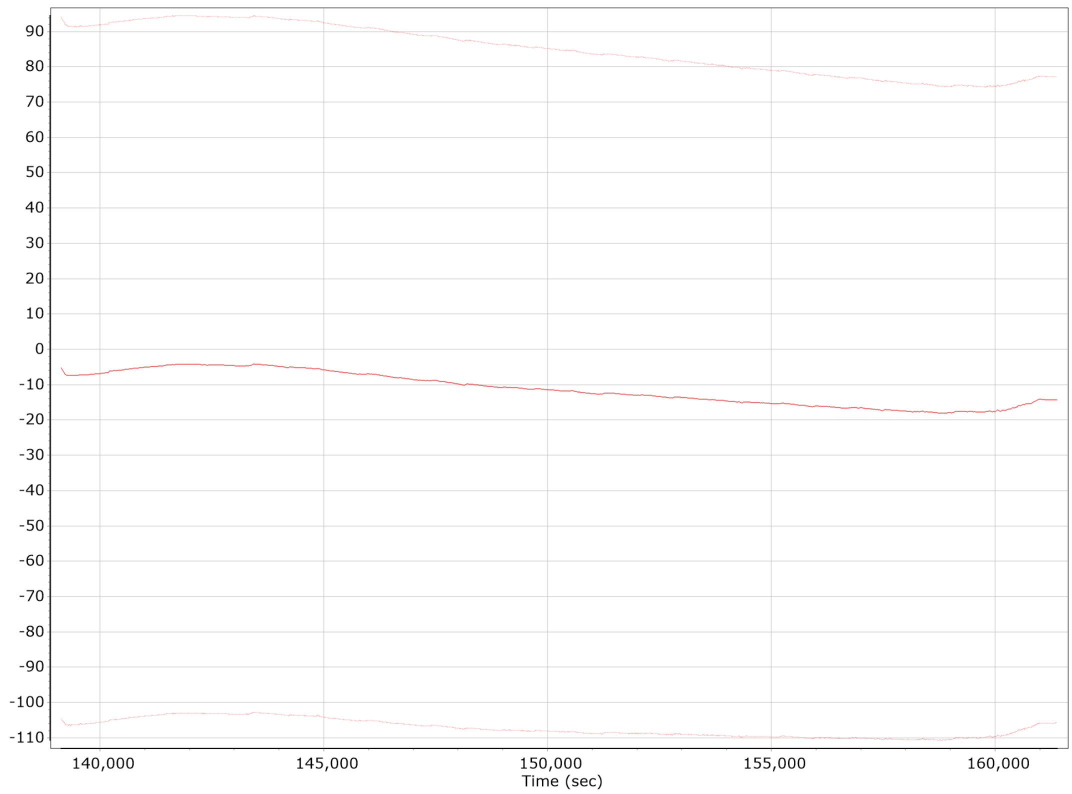
X Accelerometer Bias (micro-g)



Y Accelerometer Bias (micro-g)



Z Accelerometer Bias (micro-g)



Accelerometer Scale Error (ppm)

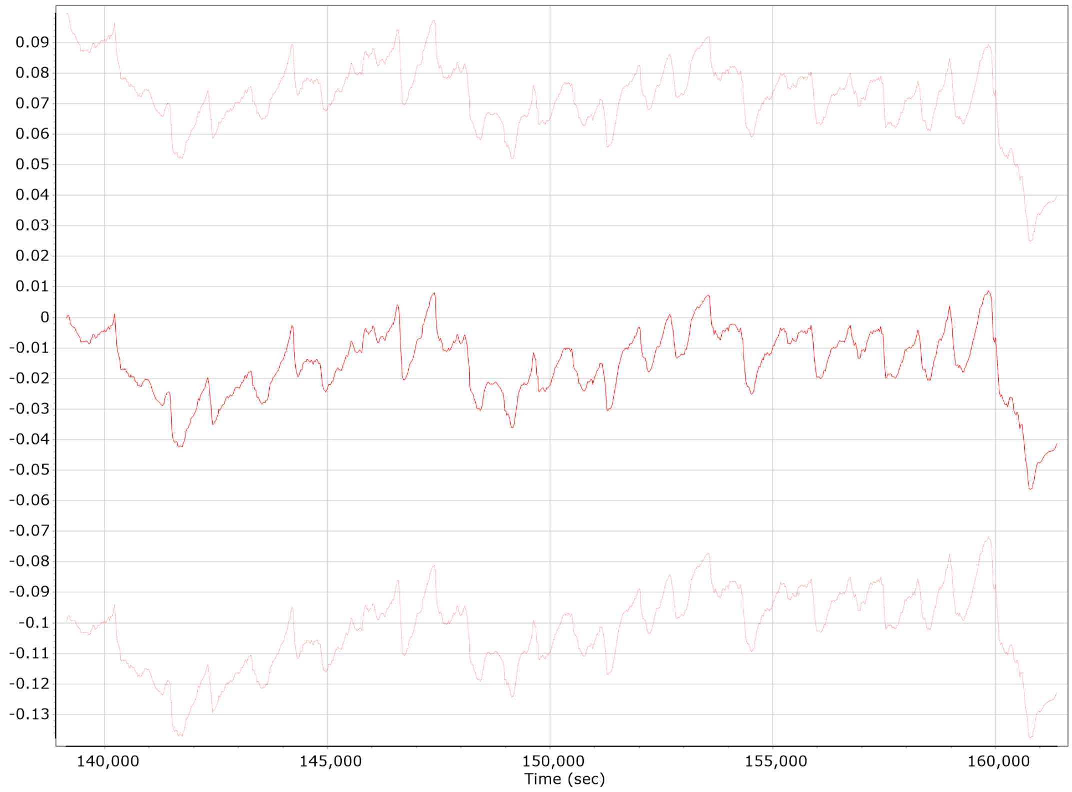
X Accelerometer Scale Error (ppm)

Y Accelerometer Scale Error (ppm)

Z Accelerometer Scale Error (ppm)

Gyro Bias (deg/h)

X Gyro Bias (deg/h)

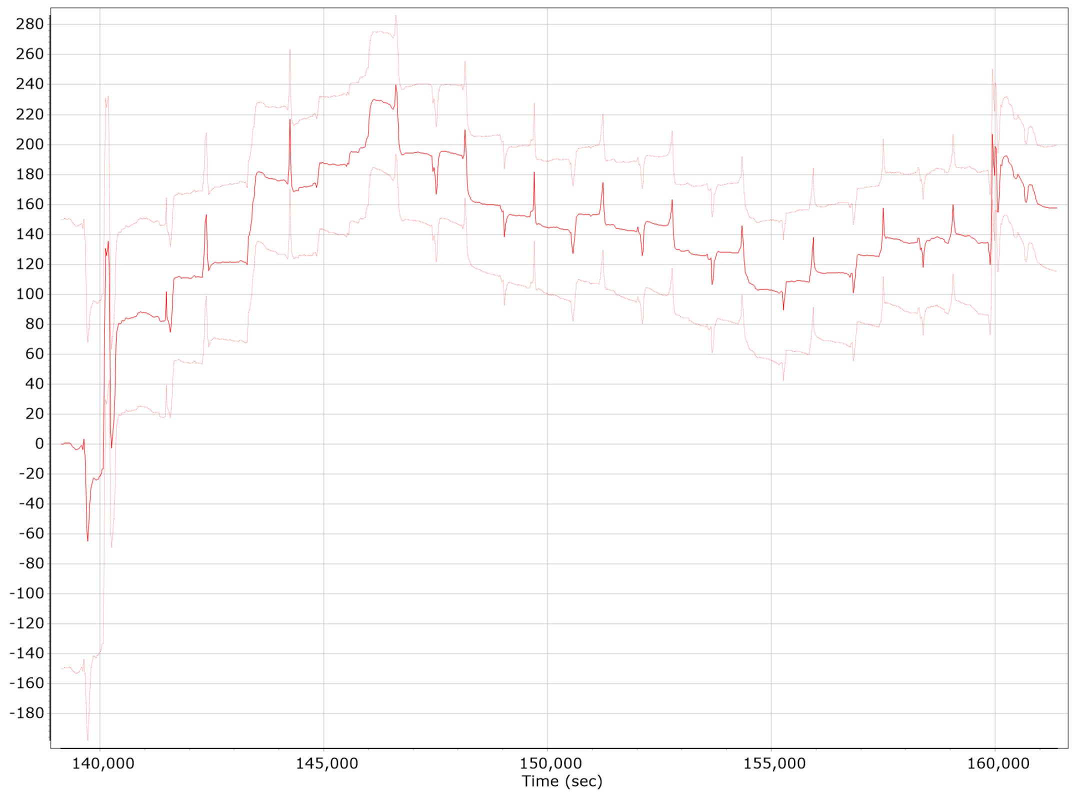


Y Gyro Bias (deg/h)

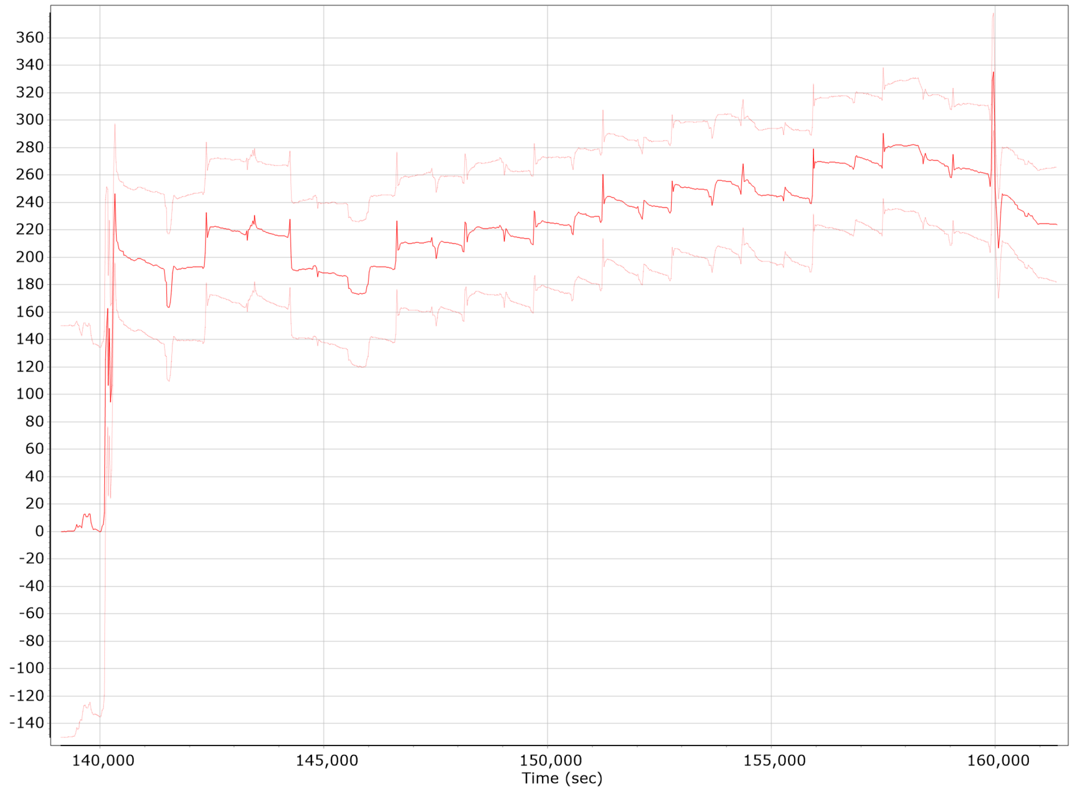
Z Gyro Bias (deg/h)

Gyro Scale Error (ppm)

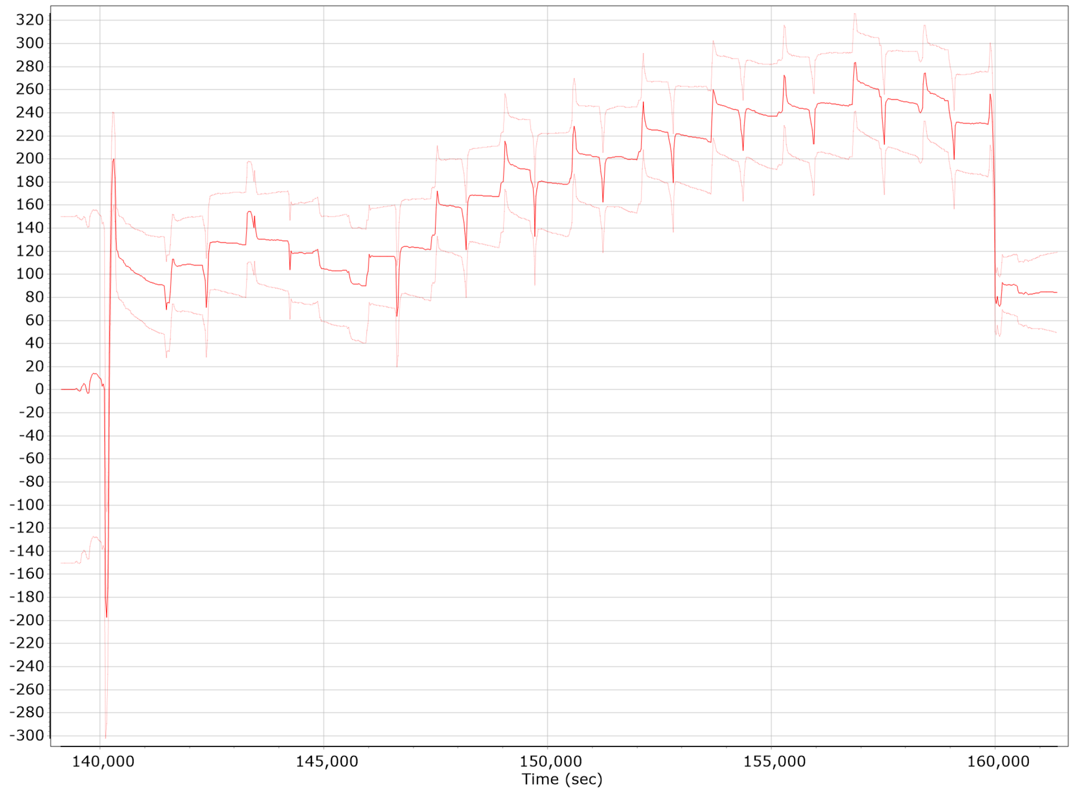
X Gyro Scale Error (ppm)



Y Gyro Scale Error (ppm)



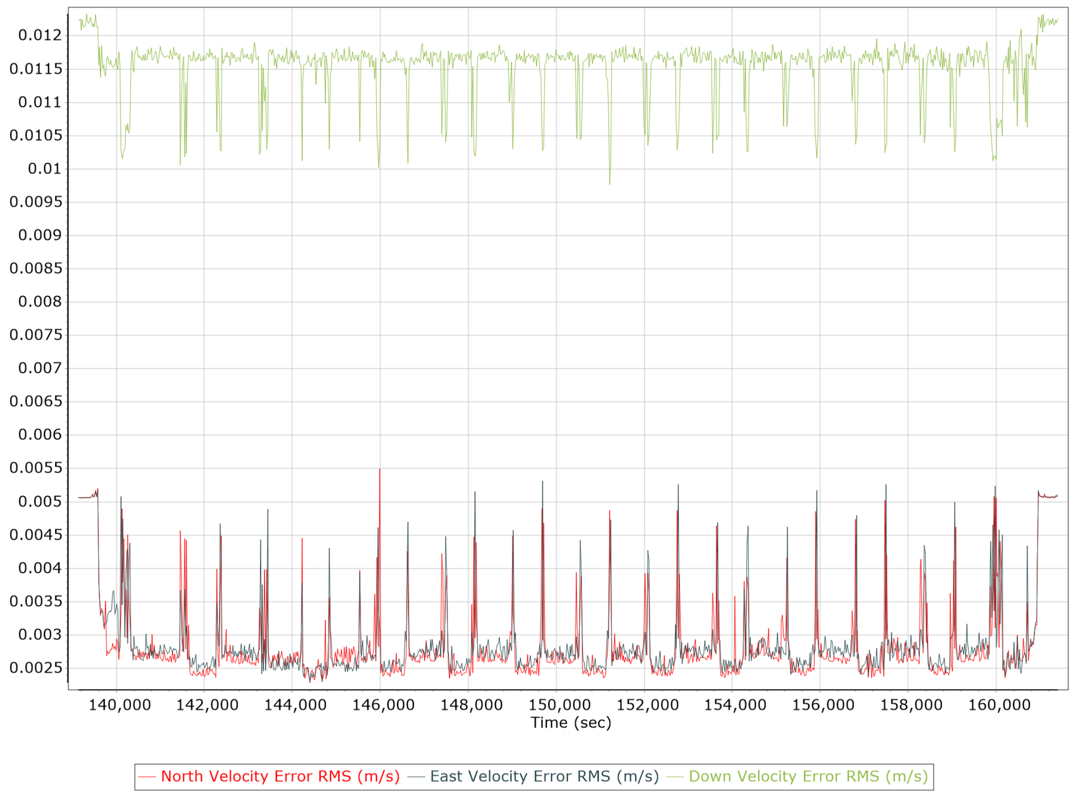
Z Gyro Scale Error (ppm)



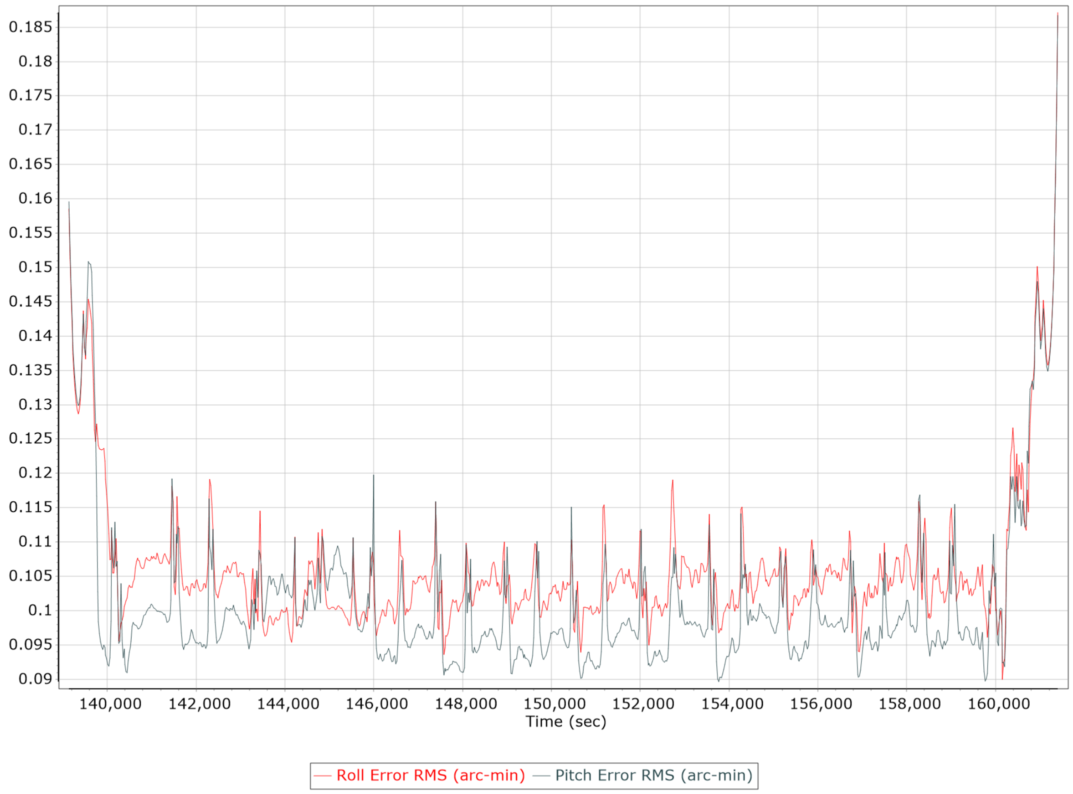
Smoothed Performance Metrics

Position Error RMS (m)

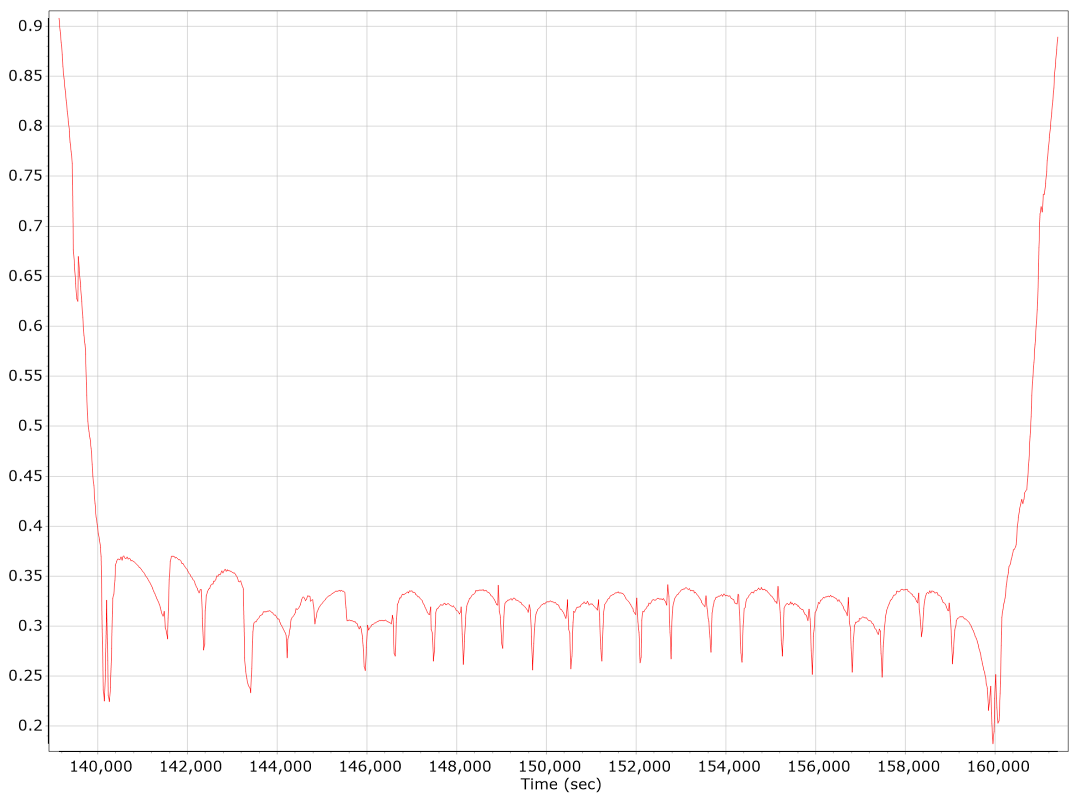
Velocity Error RMS (m/s)



Roll/Pitch Error RMS (arc-min)

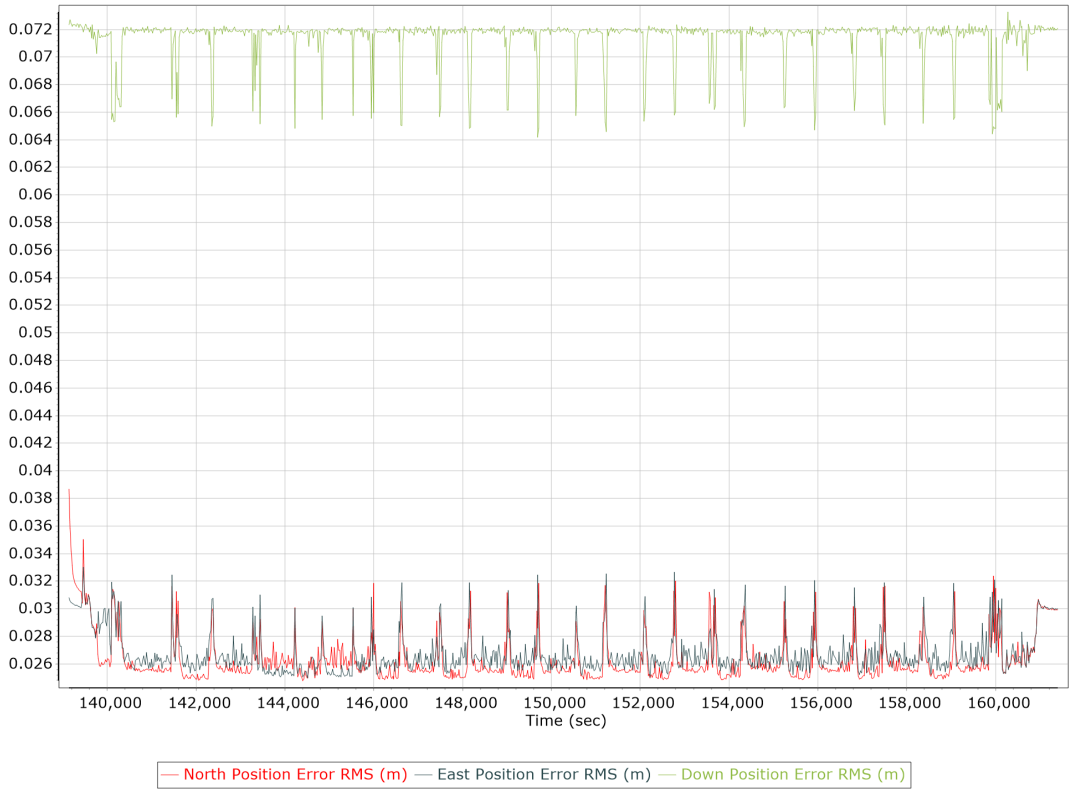


Heading Error RMS (arc-min)



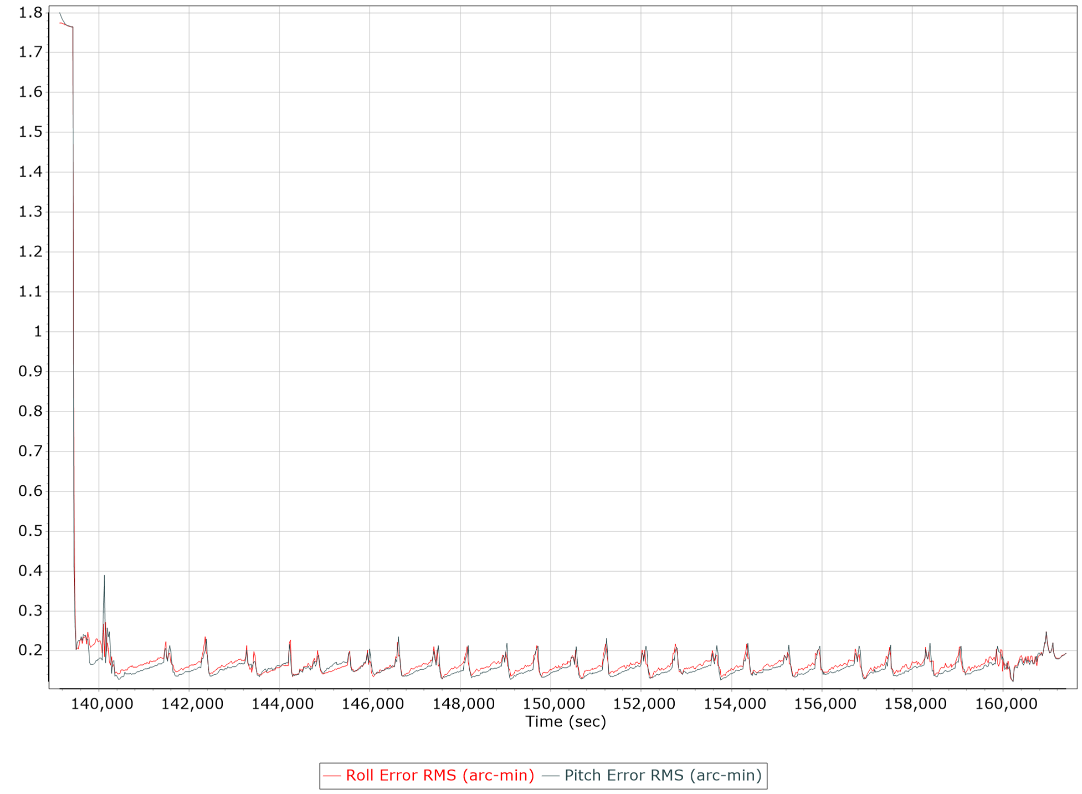
Forward Processed Performance Metrics

Position Error RMS (m)



Velocity Error RMS (m/s)

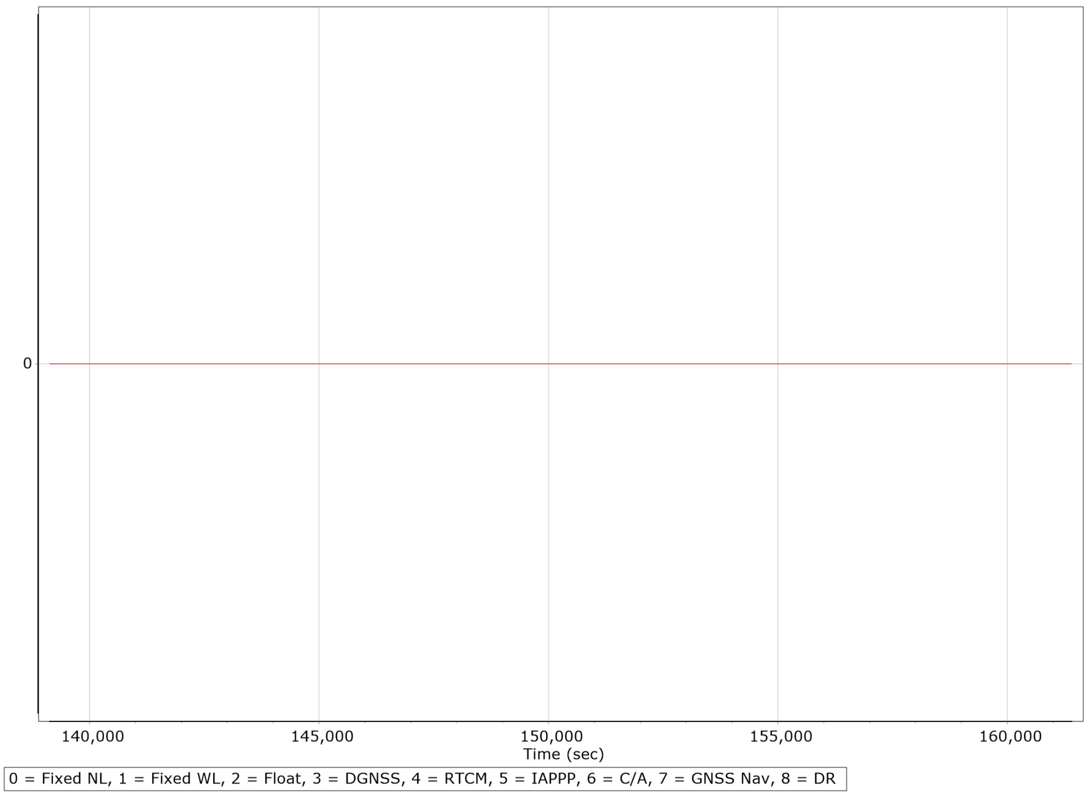
Roll/Pitch Error RMS (arc-min)



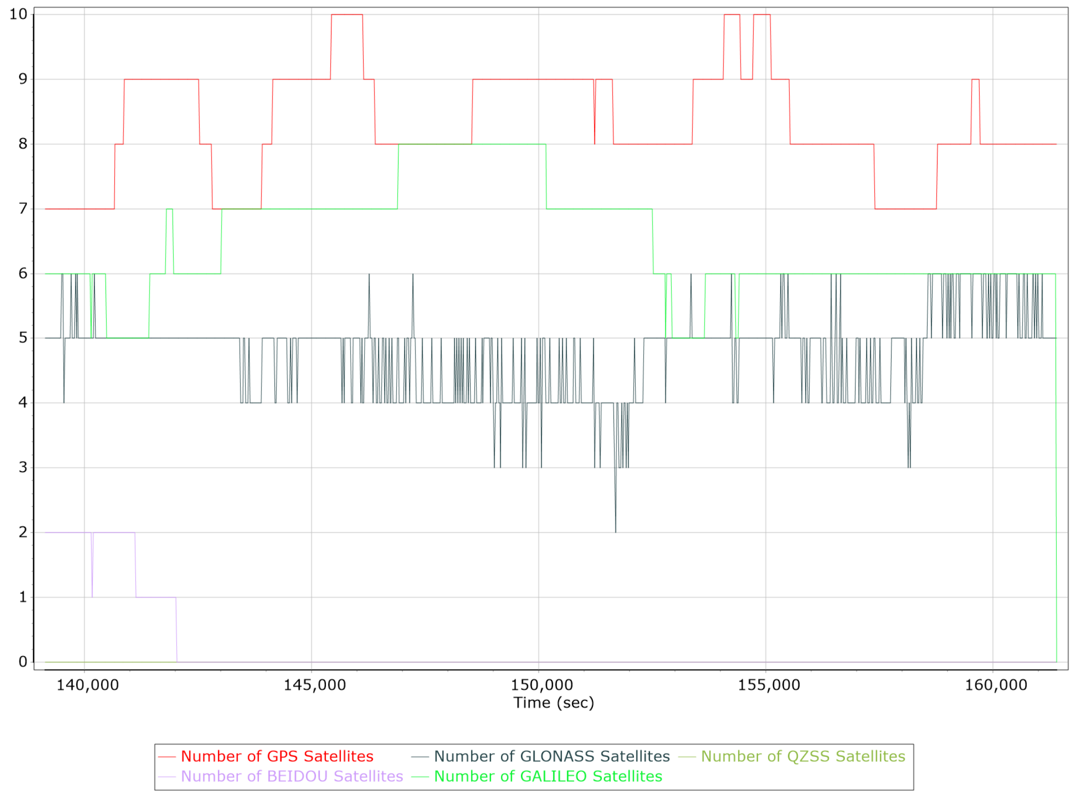
Heading Error RMS (arc-min)

Forward Processed Solution Status

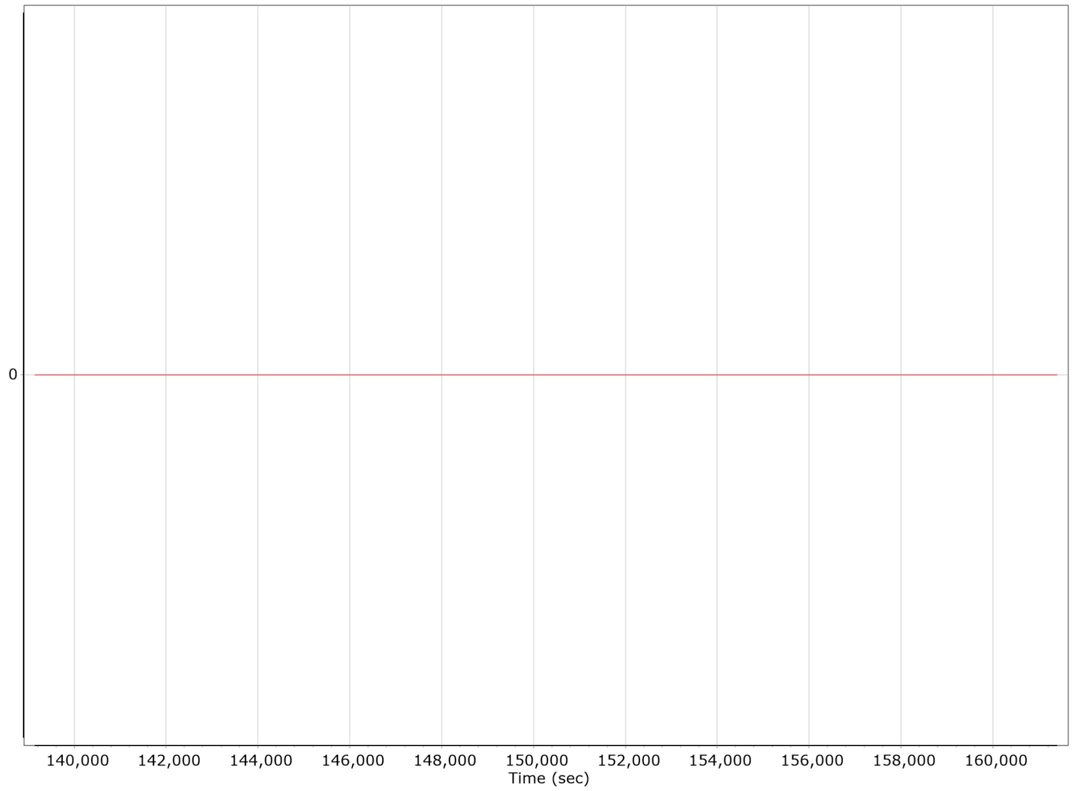
Processing Mode



Number of Satellites



Baseline Length



General Information

Mission Information

Project name	04122022A_3062
Processing date	2022-04-13 16:31:37
Mission date	2022-04-12 13:03:42
Mission duration	05:01:14.285
Processing mode	IN-Fusion PP-RTX

Rover Hardware Information

Product	POS AV 610 VER6 HW2.5-12
Serial number	S/N8708
IMU type	57
Receiver type	BD982
Antenna type	Bilinmeyen harici

Project File List

Rover Data Files

File name	File type
220412_130323_INS-GPS_1.raw	POS Data

Input Files

File Name	File Type
Ephm1020.22g	GLONASS Broadcast Ephemeris
Ephm1020.22n	GPS Broadcast Ephemeris

Output Files

Filename	File type
sbet_04122022A_3062.out	SBET Trajectory File

Rover Data Summary

First raw data file	220412_130323_INS-GPS_1.raw		
Last raw data file	220412_130323_INS-GPS_1.raw		
Start GPS week	2205		
Start time	219803.592 (4/12/2022 1:03:23 PM)		
End time	237877.877 (4/12/2022 6:04:37 PM)		
Start of fine alignment	220157.284 (4/12/2022 1:09:17 PM)		
Available subsystems	Primary GNSS, Gimbal, IMU		
POS Event Input	None		
Correction data	None		
IMU Installation Lever Arms & Mounting Angles			
Gimbal to IMU lever arm (m)	0.000	0.000	0.000
Gimbal to IMU mounting angles (deg)	0.000	0.000	0.000
Gimbal to Primary GNSS lever arm (m)	0.142	-0.236	-1.269
Gimbal to Primary GNSS lever arm std dev (m)	-1.000		
Aircraft to Reference mounting angles (deg)	0.000	0.000	0.000

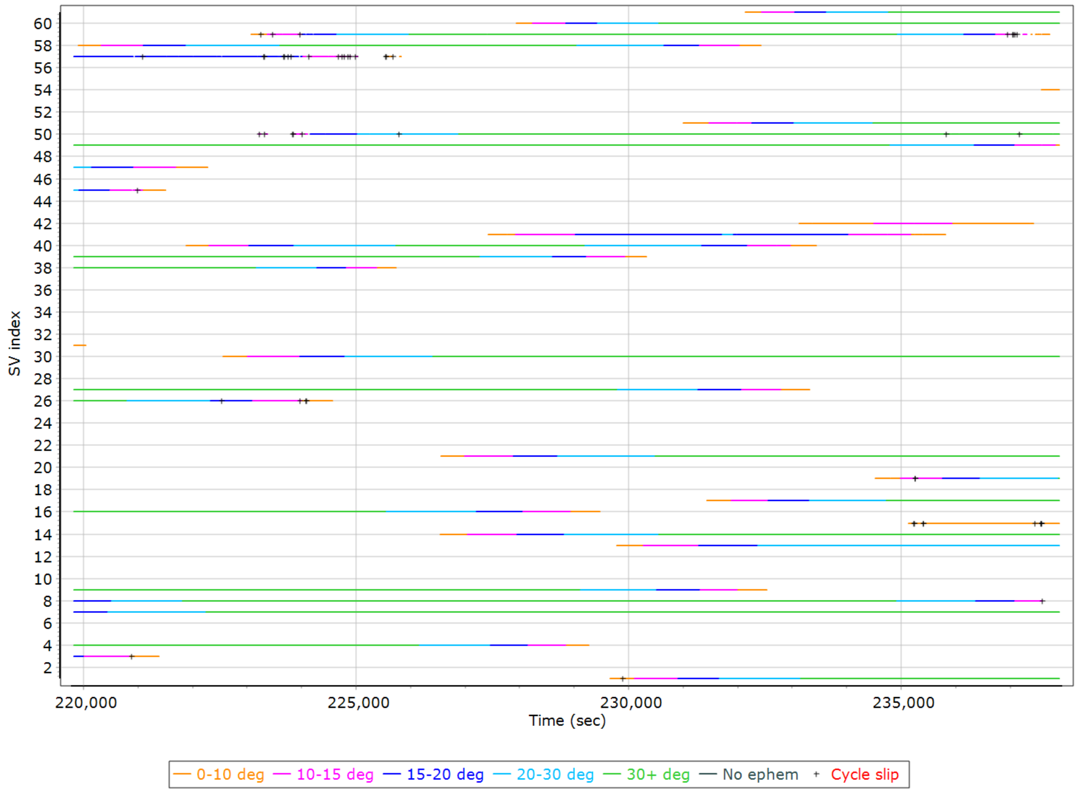
Rover Data QC

Raw IMU Import QC Summary

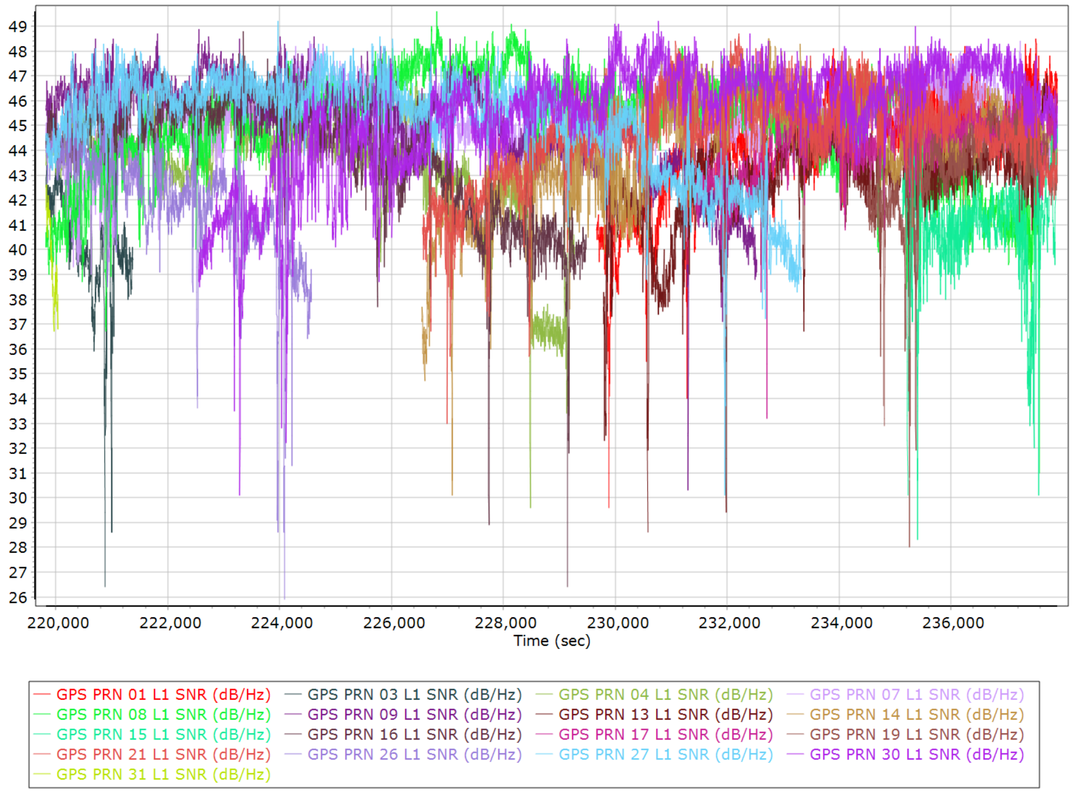
IMU data input file	imu_Mission 1.dat
IMU data check log file	imudt_04122022A_3062.log
IMU Records Processed	3614360
Termination Status	Normal
IMU Anomalies	0

Primary Observables & Satellite Data

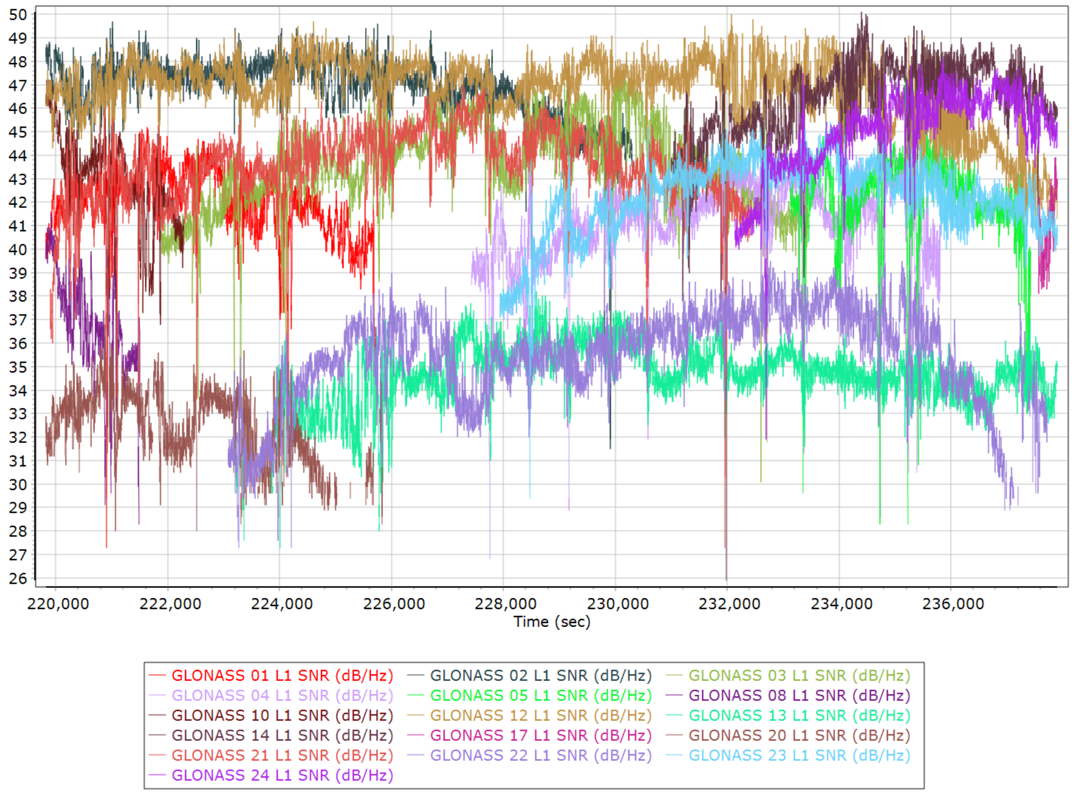
GPS/GLONASS L1 Satellite Lock/Elevation



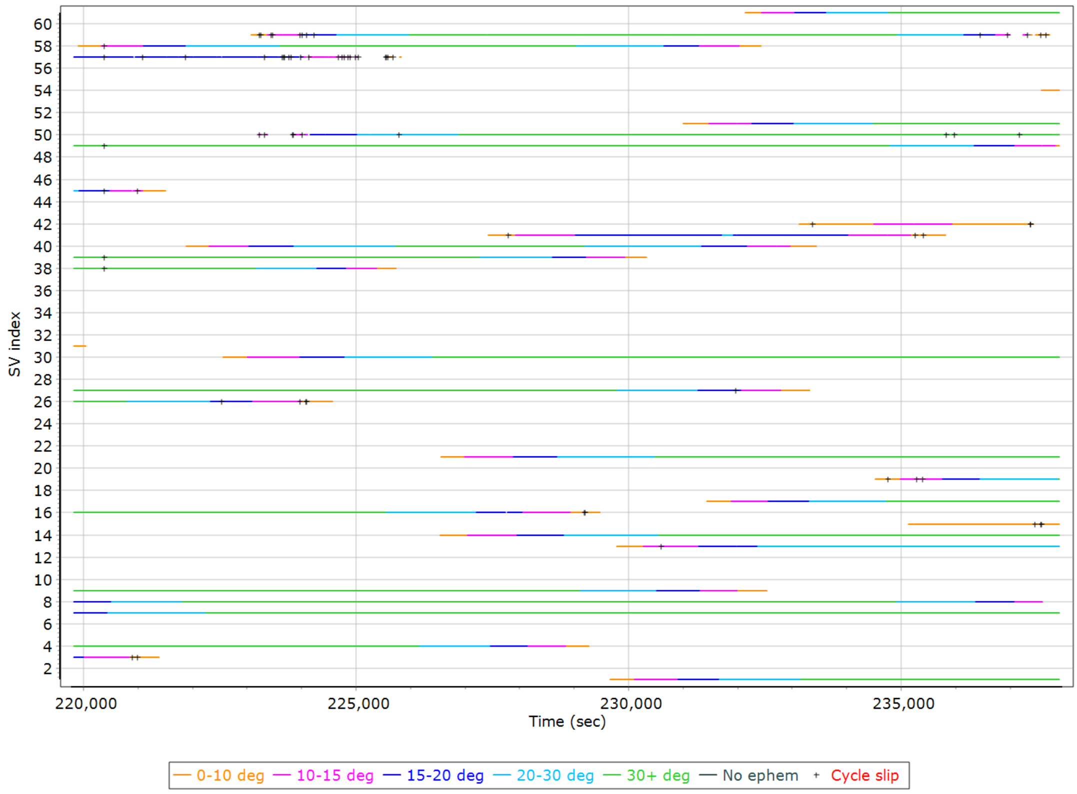
GPS L1 SNR



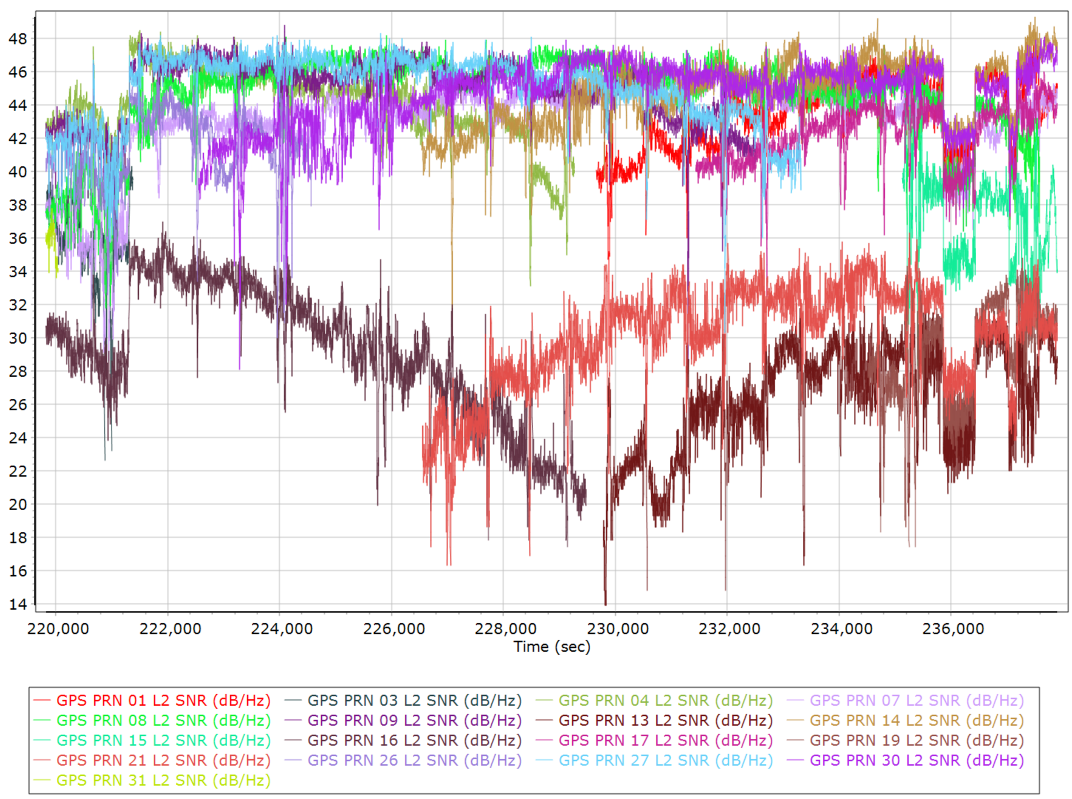
GLONASS L1 SNR



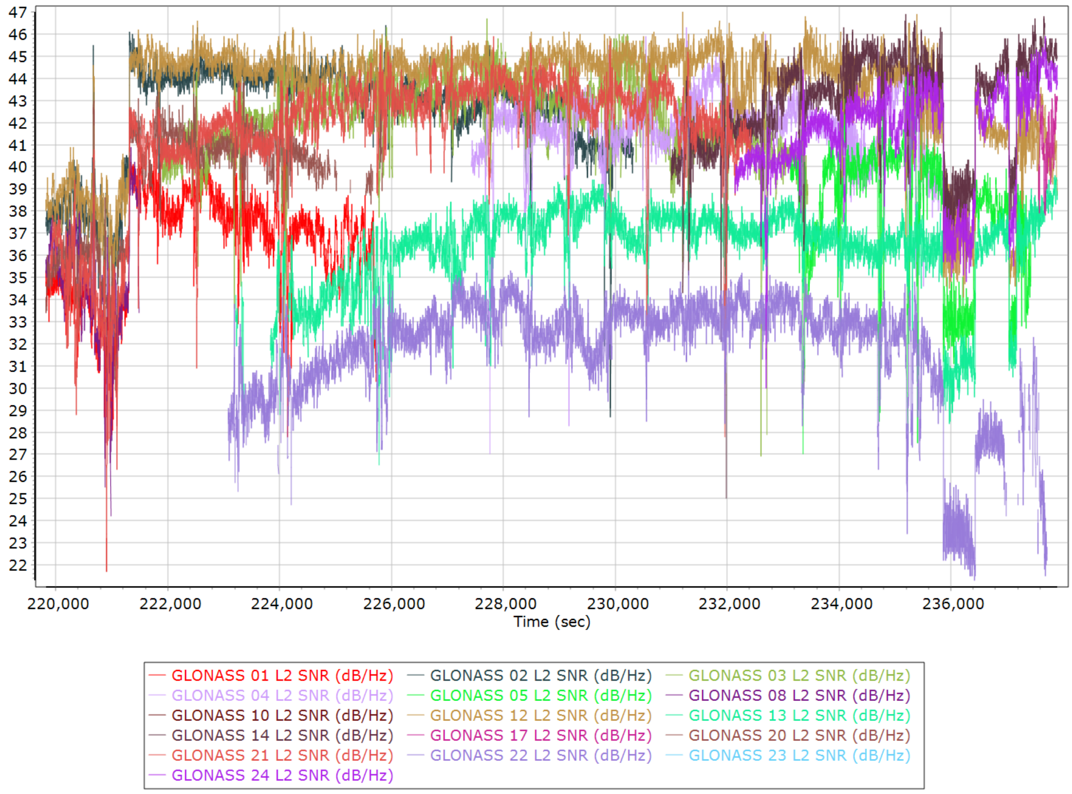
GPS/GLONASS L2 Satellite Lock/Elevation



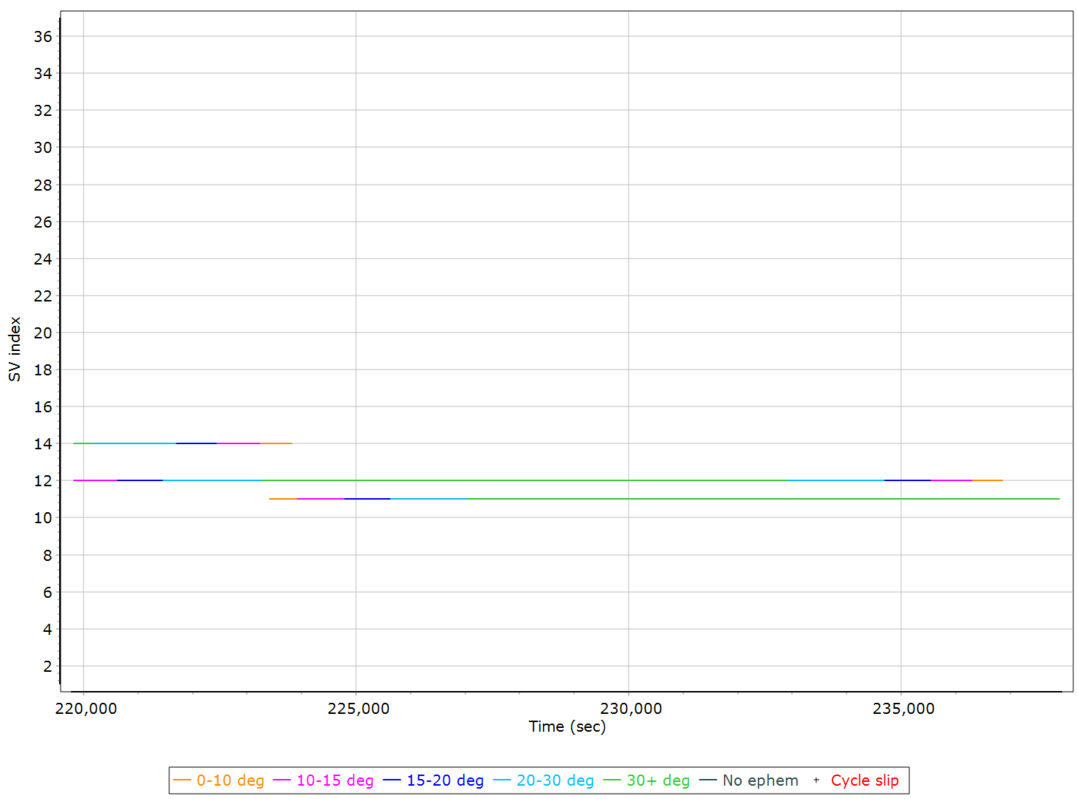
GPS L2 SNR



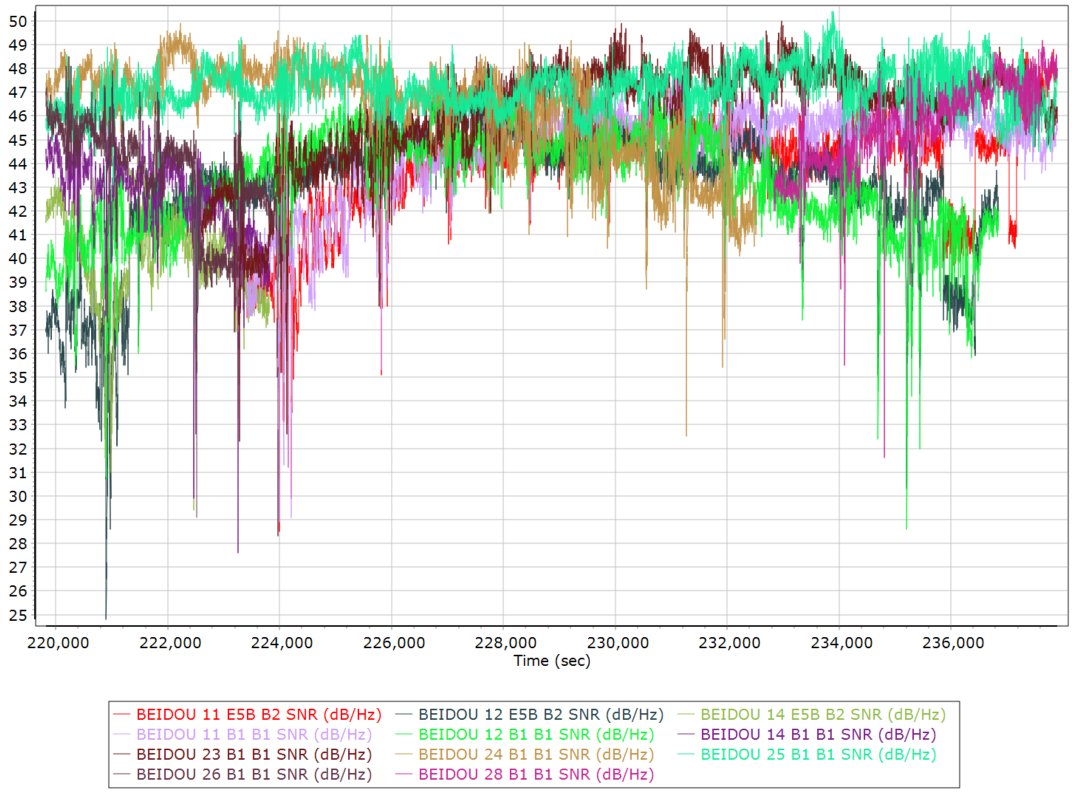
GLONASS L2 SNR



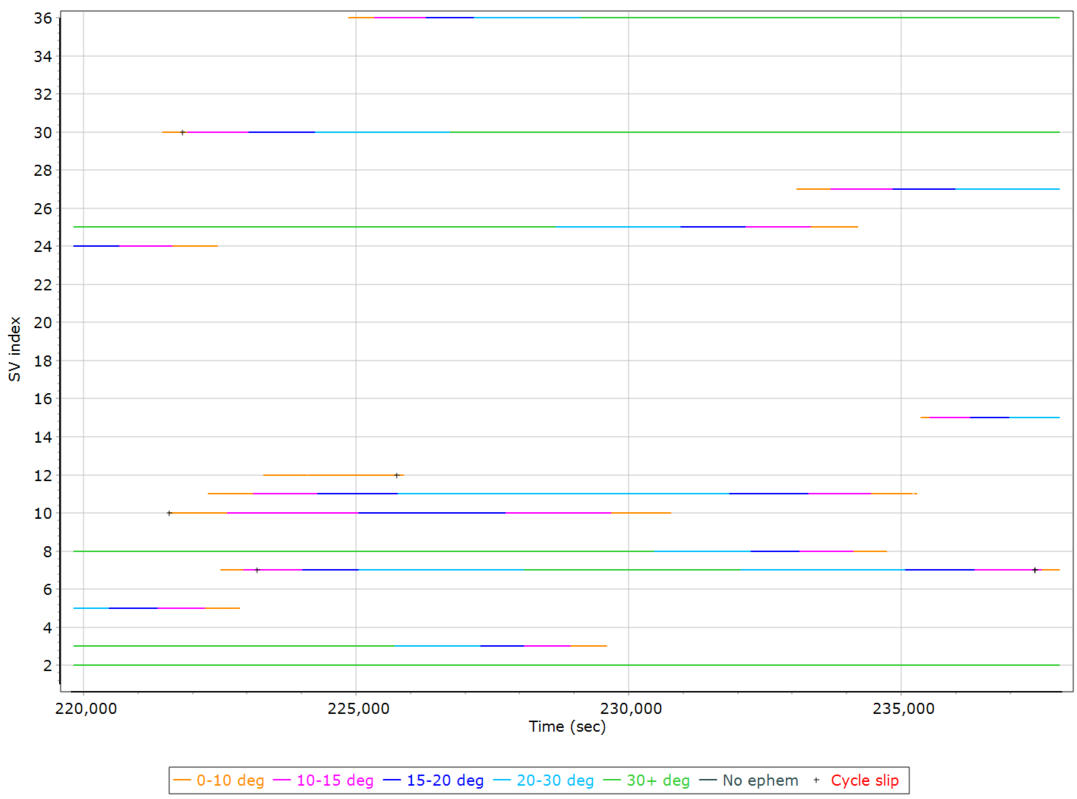
BEIDOU Satellite Lock/Elevation



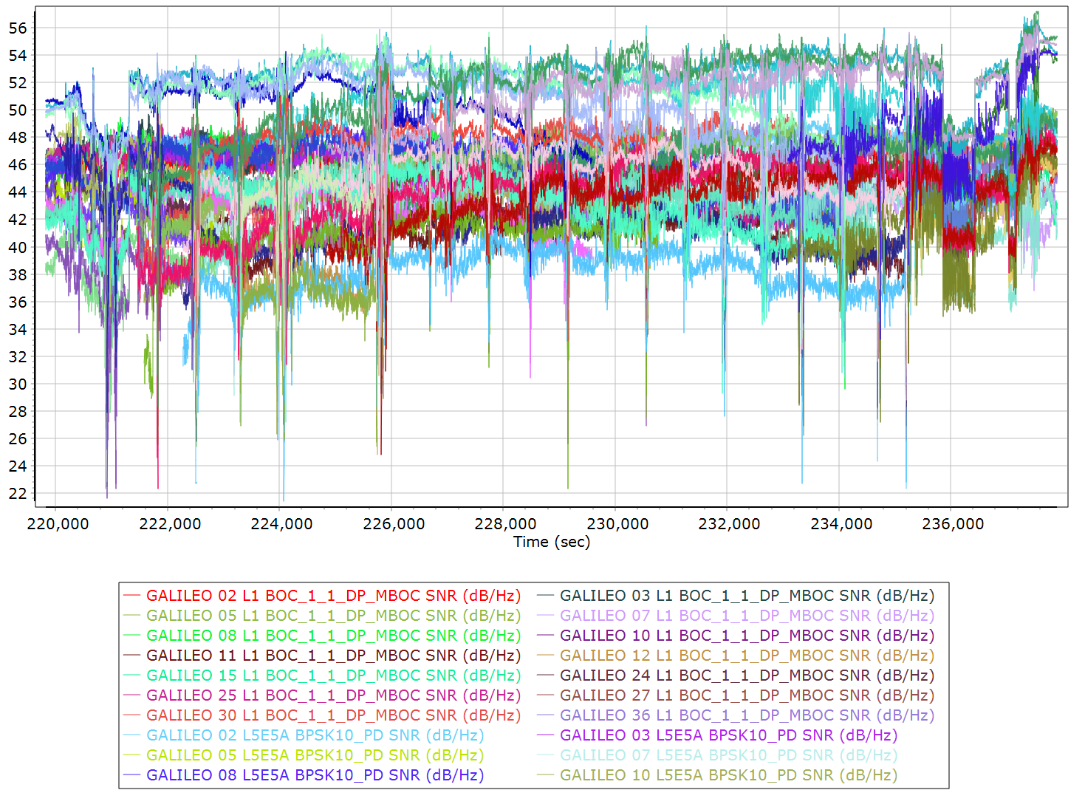
BEIDOU SNR



GALILEO Satellite Lock/Elevation

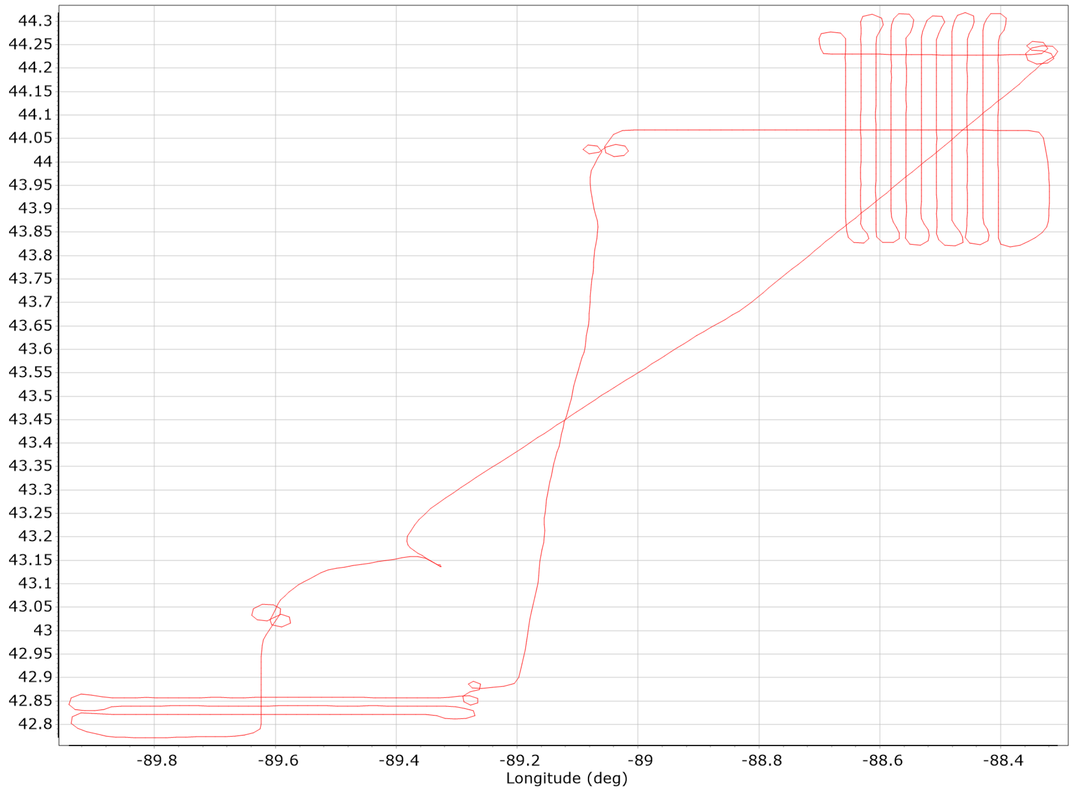


GALILEO SNR

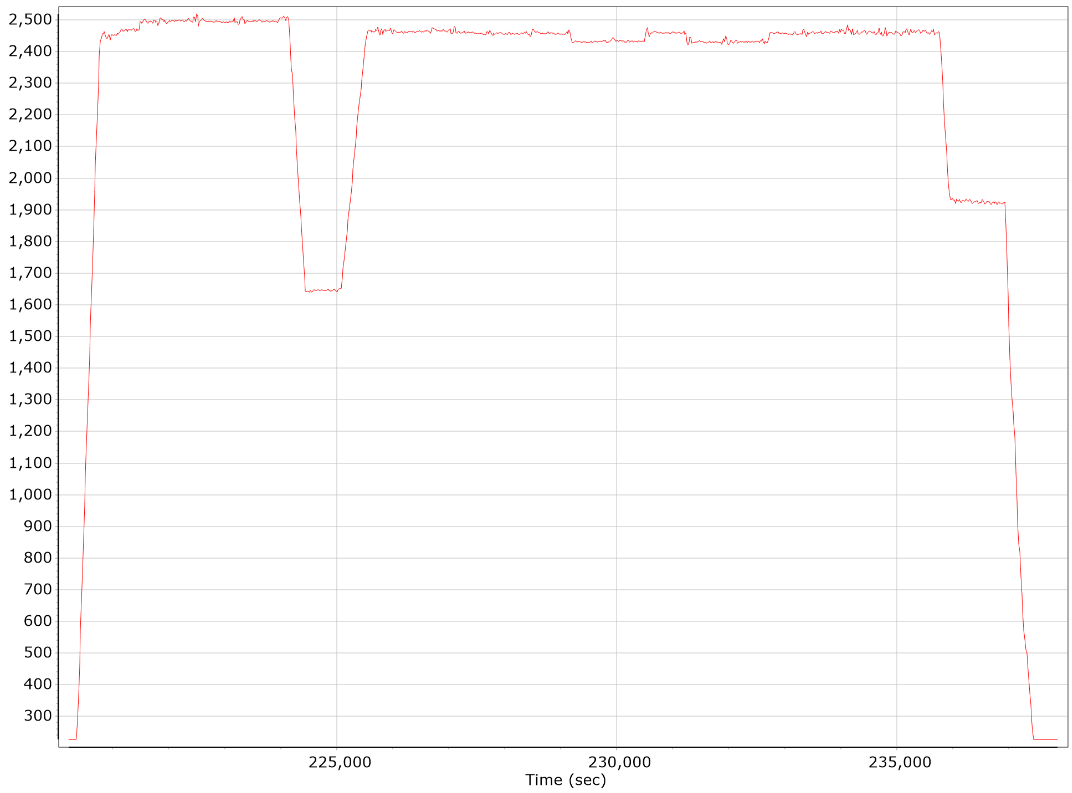

56
54
52
50
48
46
44
42
40
38
36
34
32
30
28
26
24
22
220,000
222,000
224,000
226,000
228,000
230,000
232,000
234,000
236,000
Time (sec)
GALILEO 02 L1 BOC_1_1_DP_MBOC SNR (dB/Hz)
GALILEO 03 L1 BOC_1_1_DP_MBOC SNR (dB/Hz)
GALILEO 05 L1 BOC_1_1_DP_MBOC SNR (dB/Hz)
GALILEO 07 L1 BOC_1_1_DP_MBOC SNR (dB/Hz)
GALILEO 08 L1 BOC_1_1_DP_MBOC SNR (dB/Hz)
GALILEO 10 L1 BOC_1_1_DP_MBOC SNR (dB/Hz)
GALILEO 11 L1 BOC_1_1_DP_MBOC SNR (dB/Hz)
GALILEO 12 L1 BOC_1_1_DP_MBOC SNR (dB/Hz)
GALILEO 15 L1 BOC_1_1_DP_MBOC SNR (dB/Hz)
GALILEO 24 L1 BOC_1_1_DP_MBOC SNR (dB/Hz)
GALILEO 25 L1 BOC_1_1_DP_MBOC SNR (dB/Hz)
GALILEO 27 L1 BOC_1_1_DP_MBOC SNR (dB/Hz)
GALILEO 30 L1 BOC_1_1_DP_MBOC SNR (dB/Hz)
GALILEO 36 L1 BOC_1_1_DP_MBOC SNR (dB/Hz)
GALILEO 02 L5E5A BPSK10_PD SNR (dB/Hz)
GALILEO 03 L5E5A BPSK10_PD SNR (dB/Hz)
GALILEO 05 L5E5A BPSK10_PD SNR (dB/Hz)
GALILEO 07 L5E5A BPSK10_PD SNR (dB/Hz)
GALILEO 08 L5E5A BPSK10_PD SNR (dB/Hz)
GALILEO 10 L5E5A BPSK10_PD SNR (dB/Hz)

Smoothed Trajectory Information

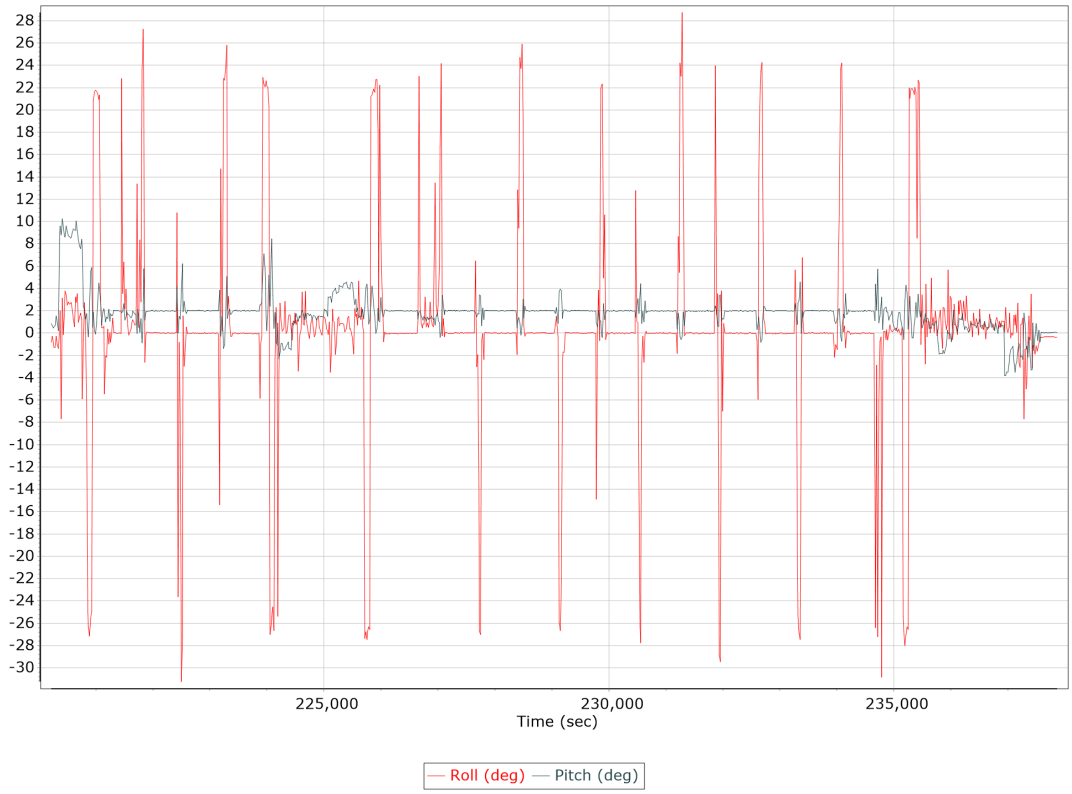
Top View



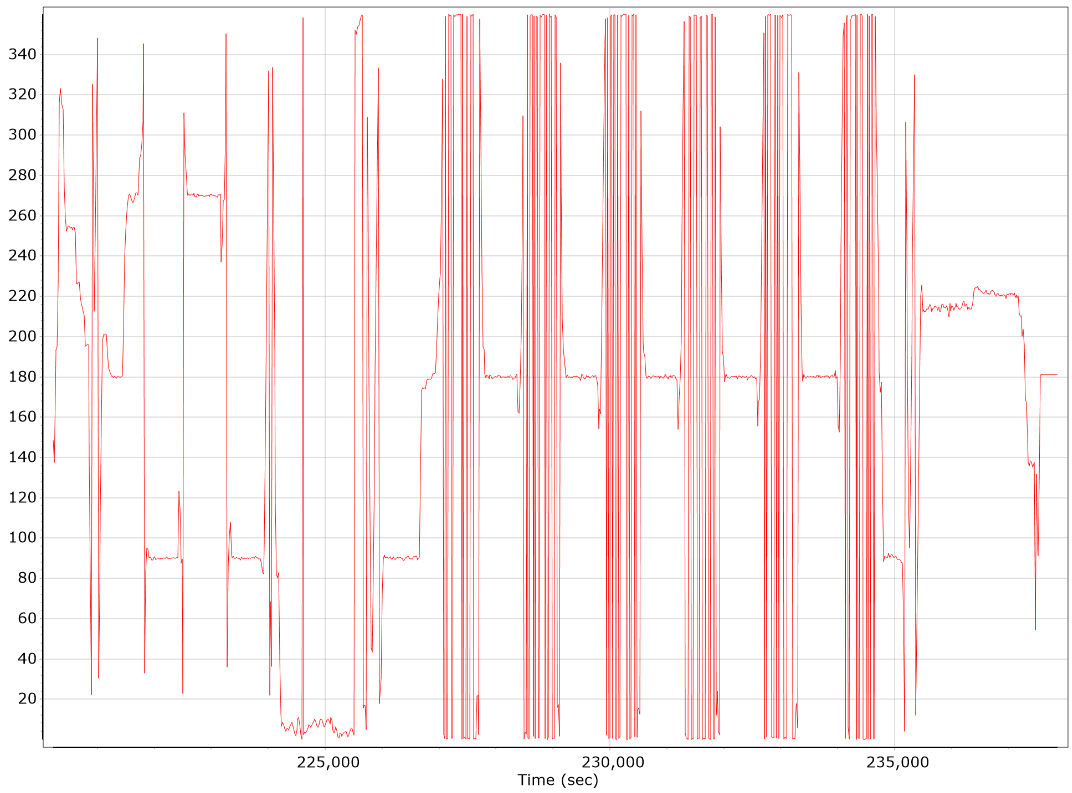
Altitude



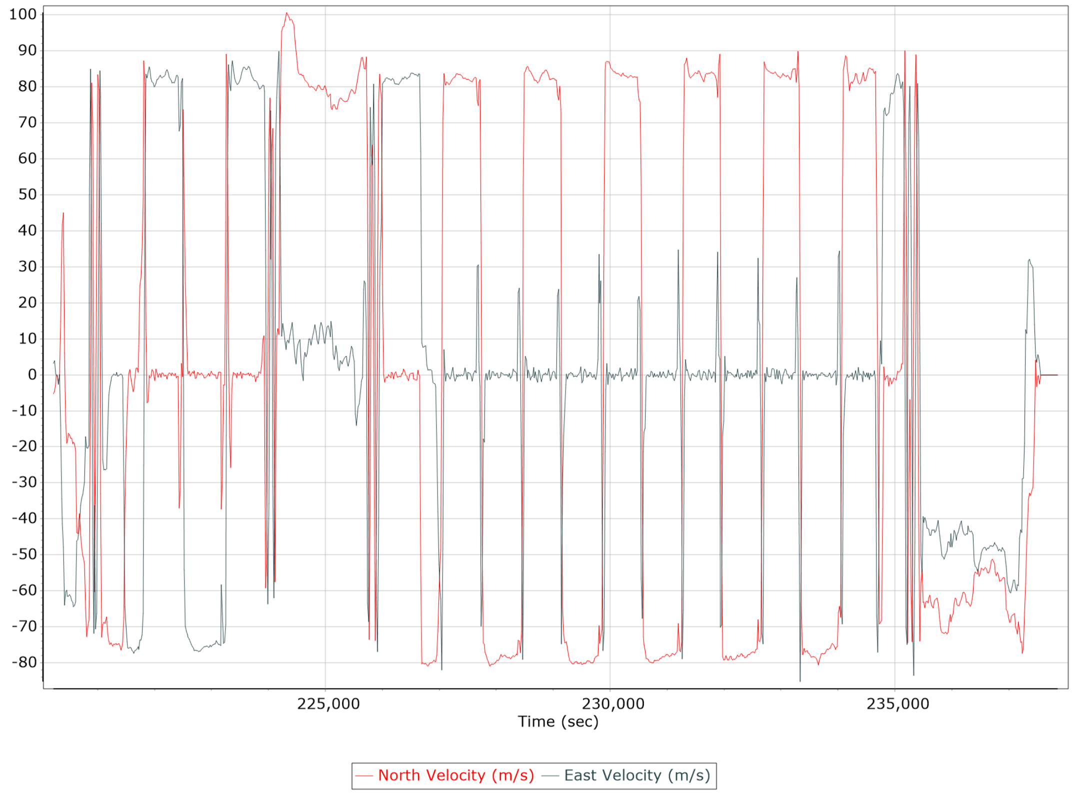
Roll/Pitch



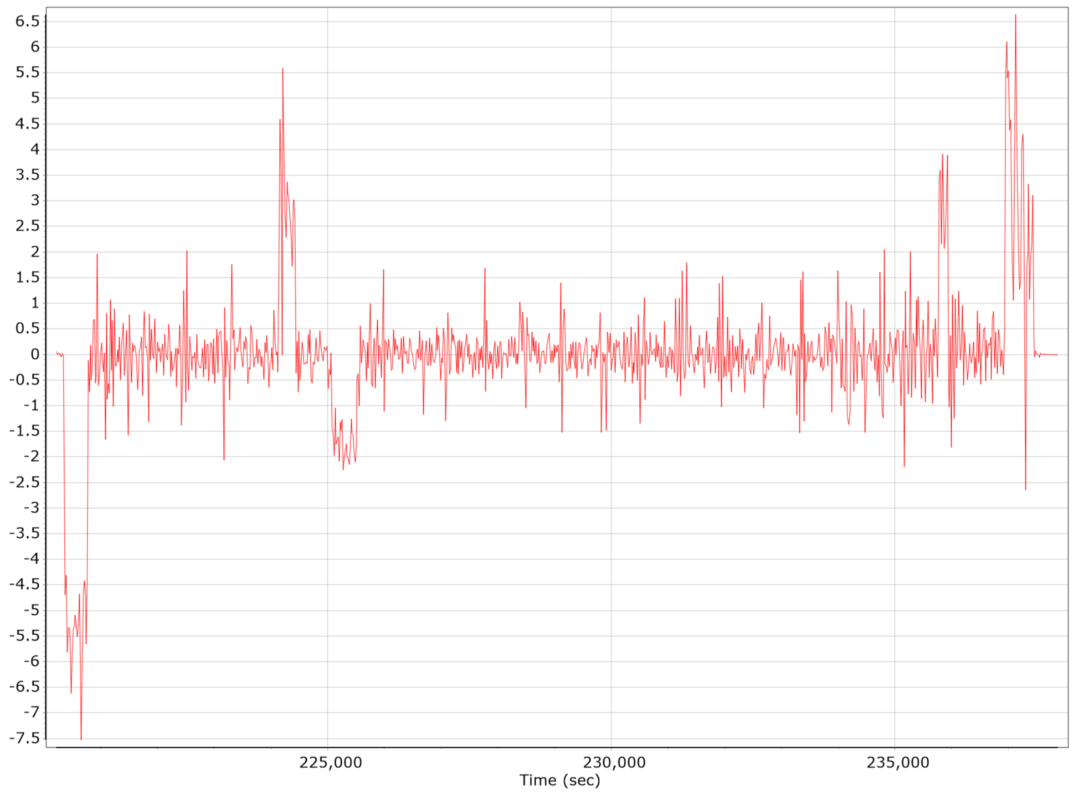
Heading



North/East Velocity

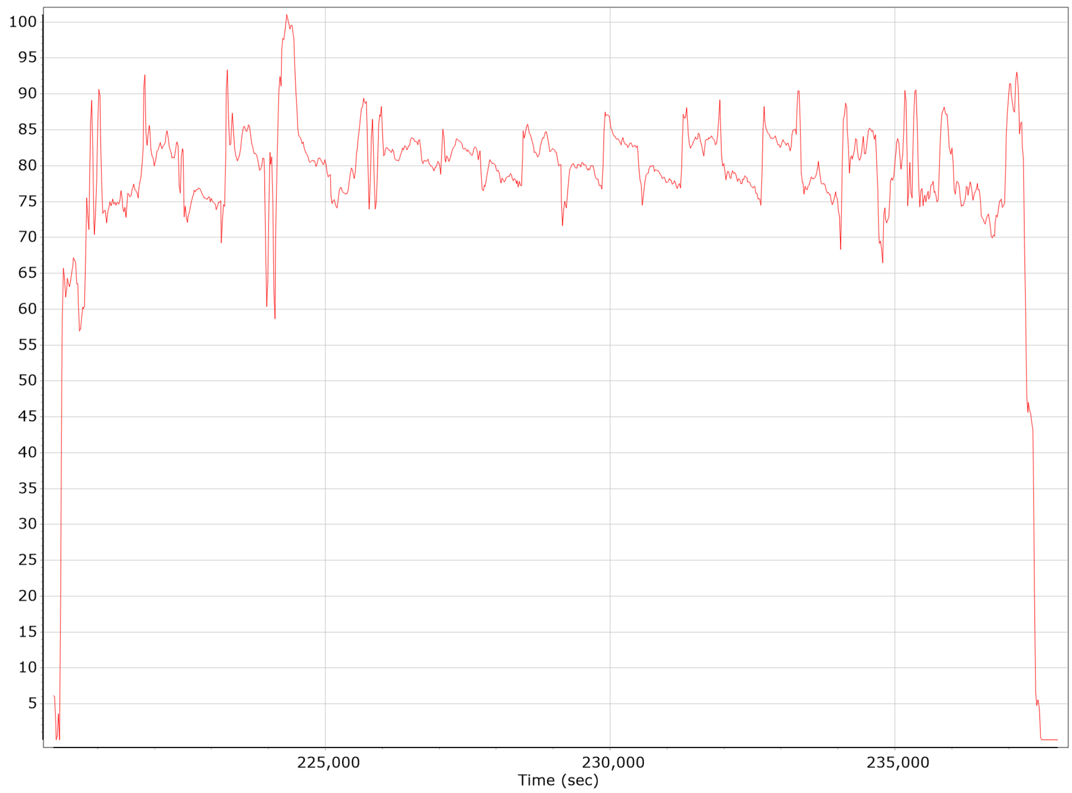


Down Velocity

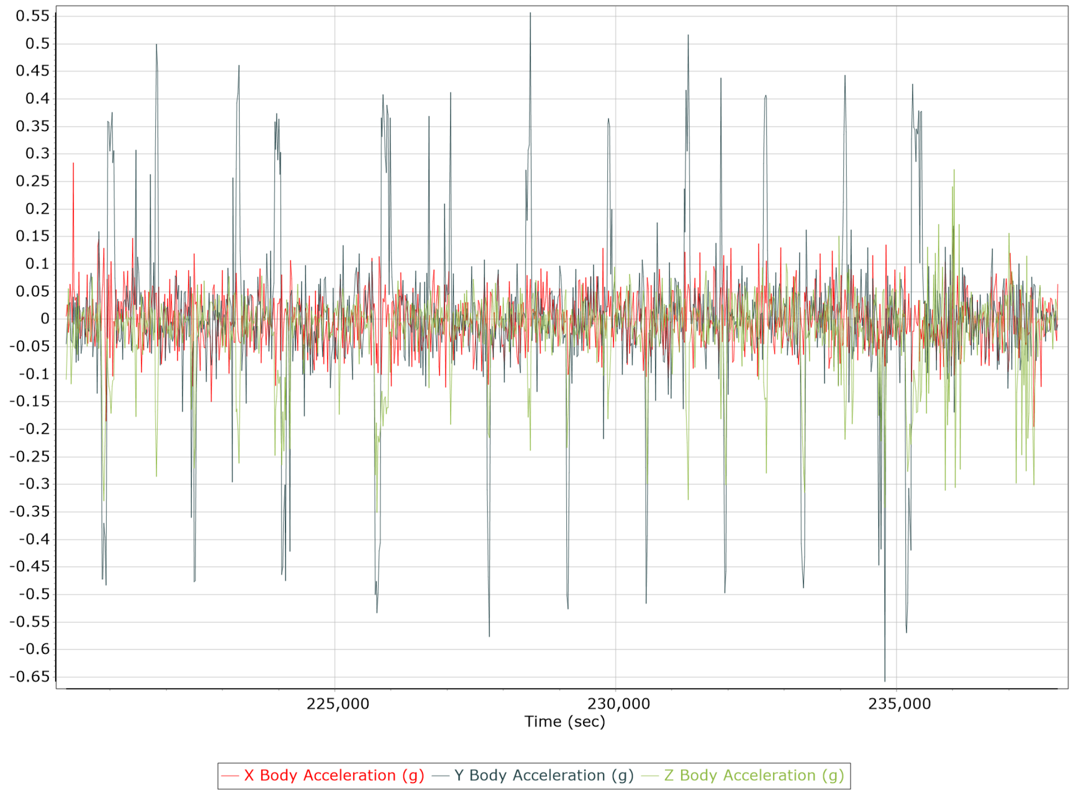


Total Speed

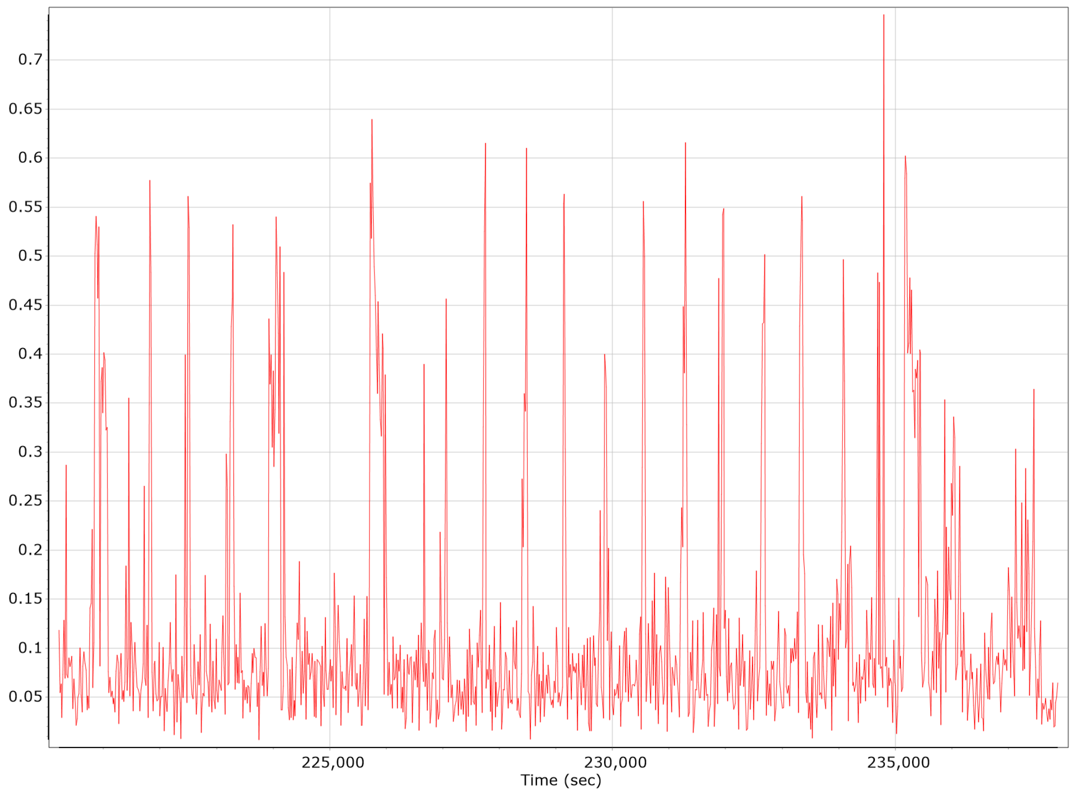
Ground Speed



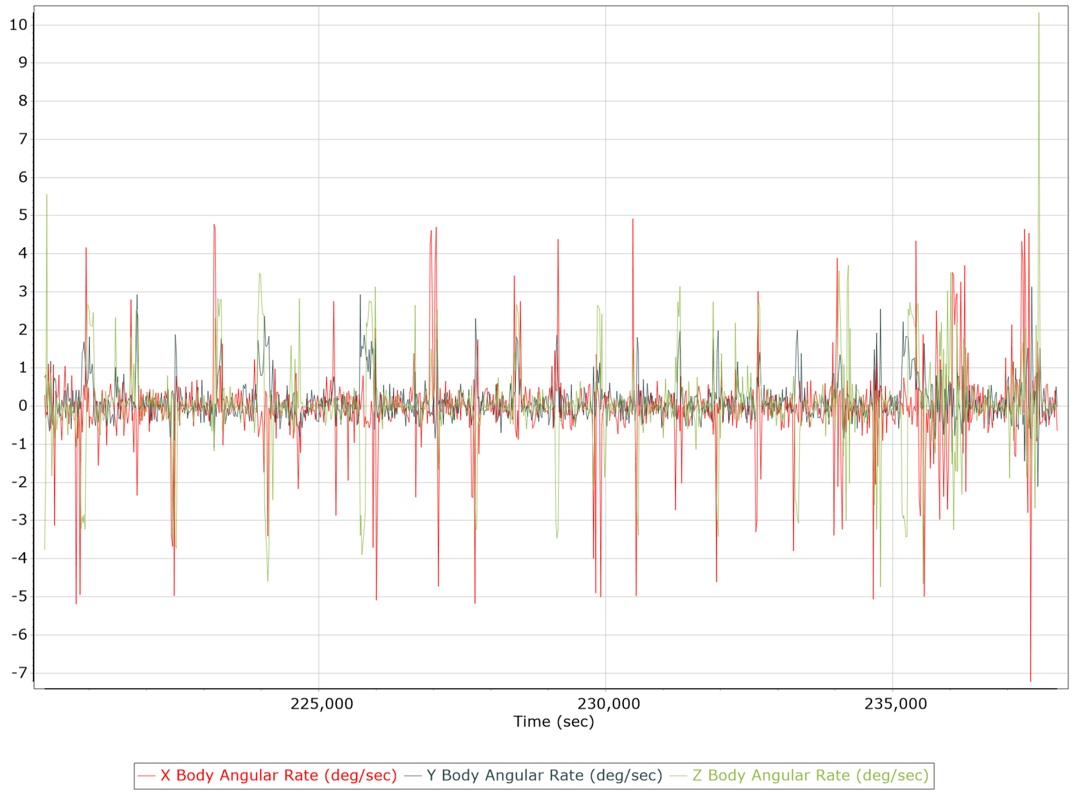
Body Acceleration



Total Body Acceleration

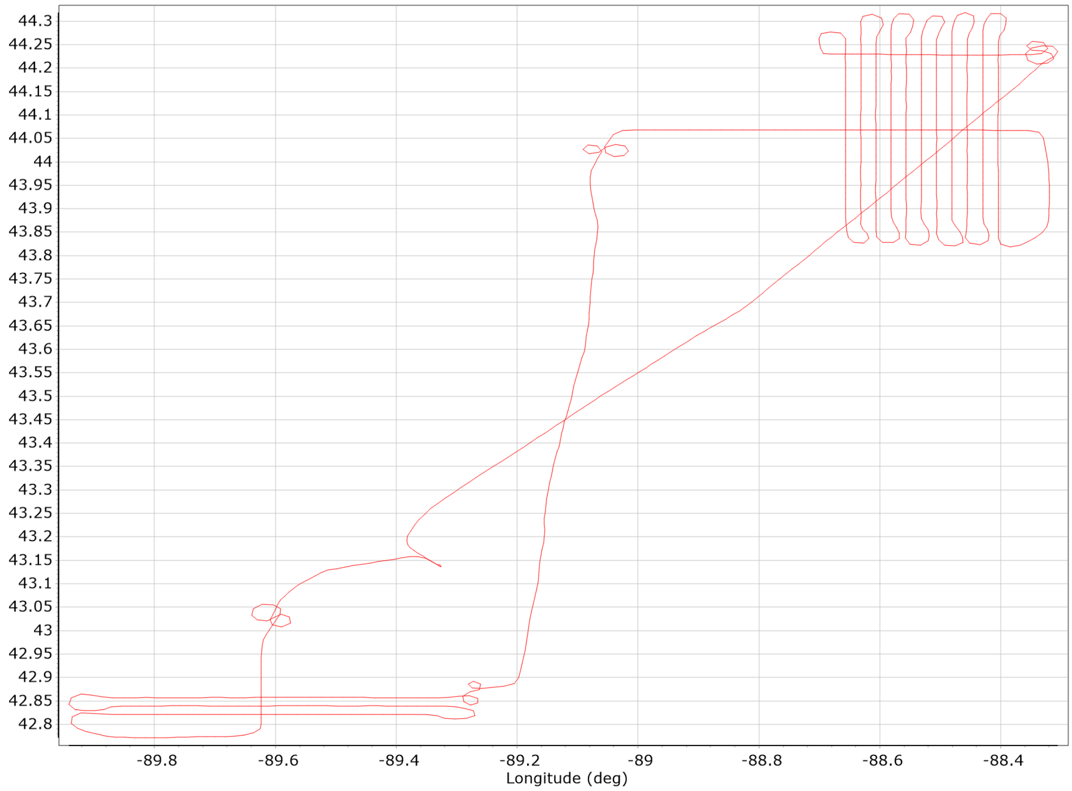


Body Angular Rate

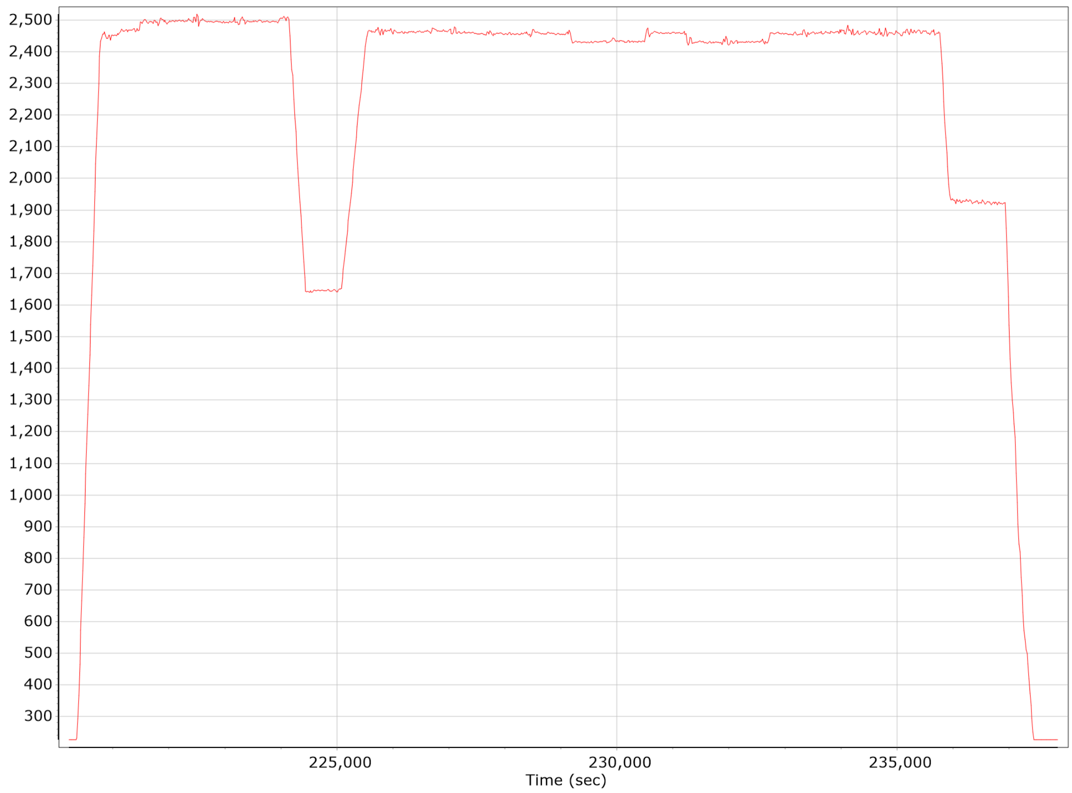


Forward Processed Trajectory Information

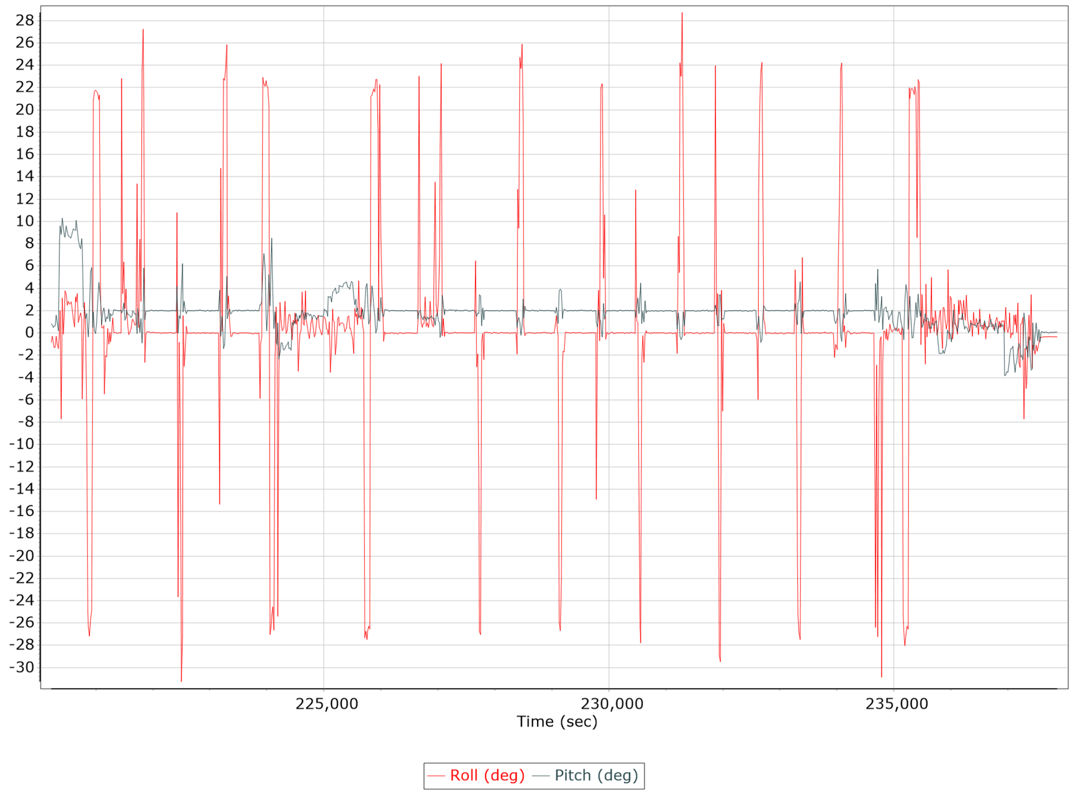
Top View



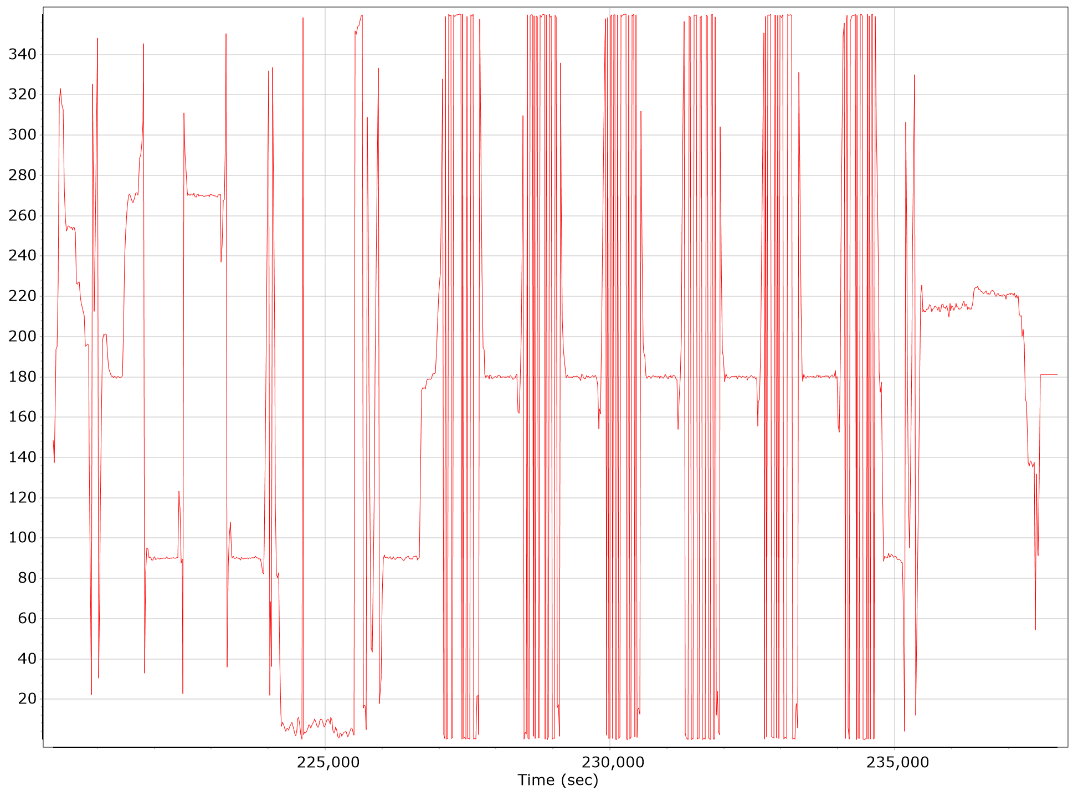
Altitude



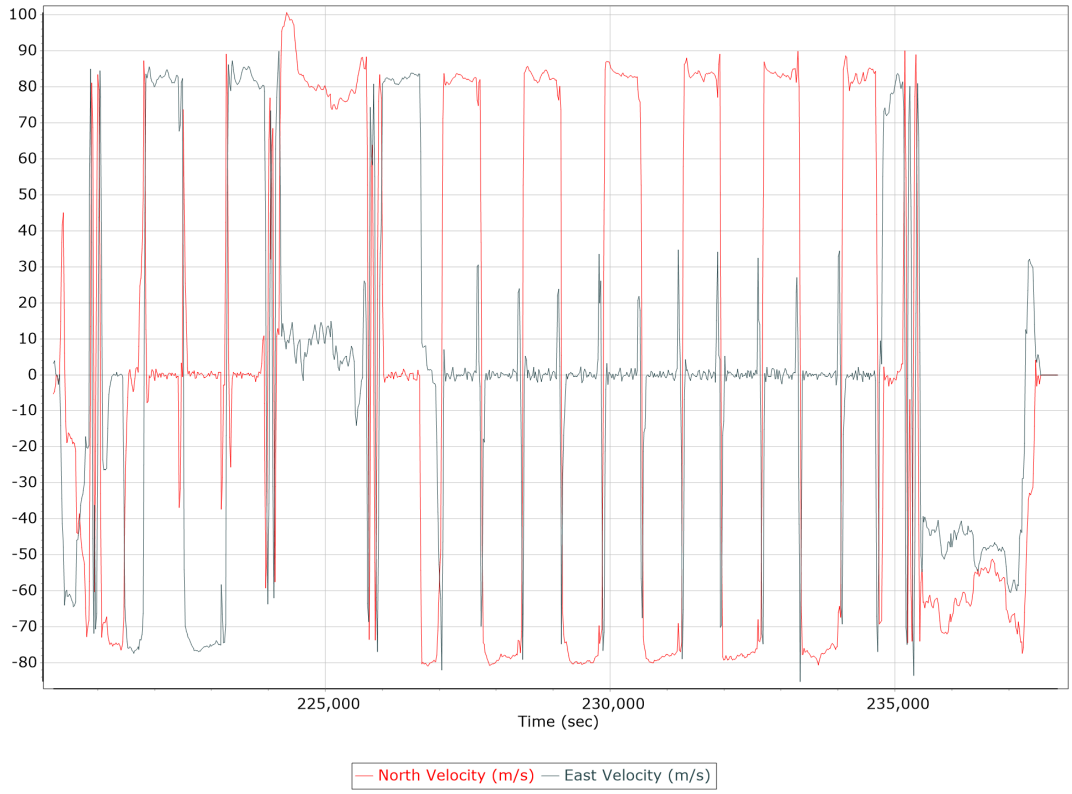
Roll/Pitch



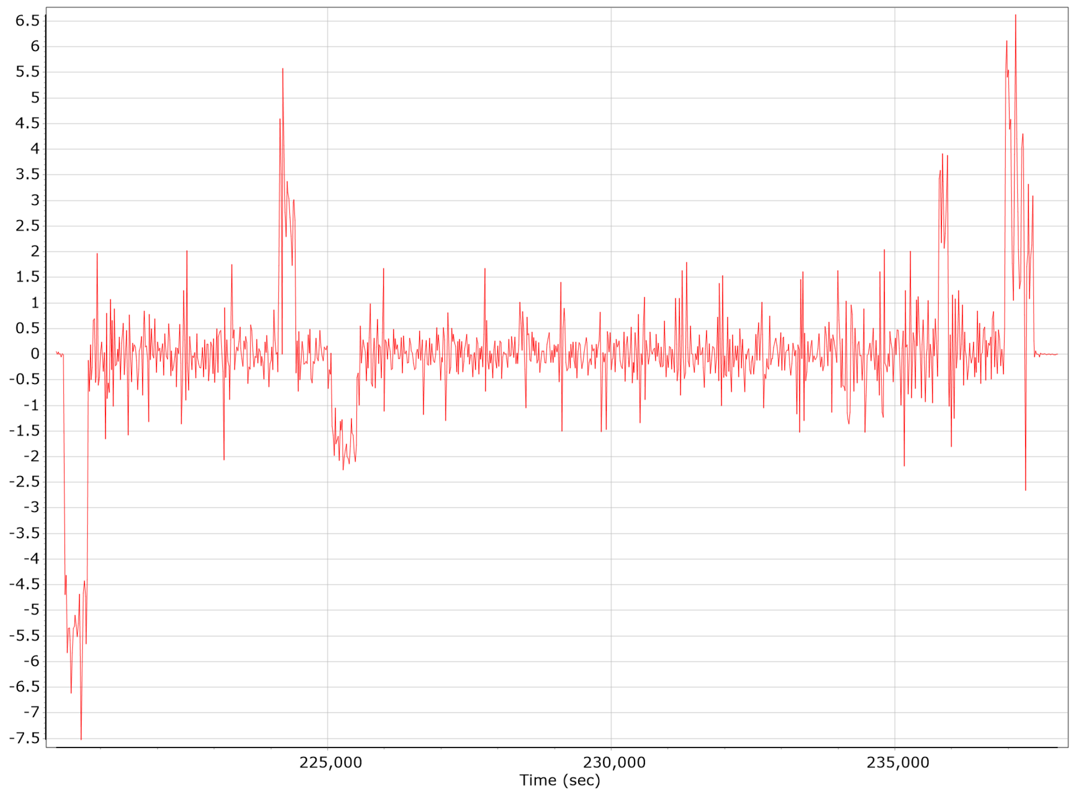
Heading



North/East Velocity

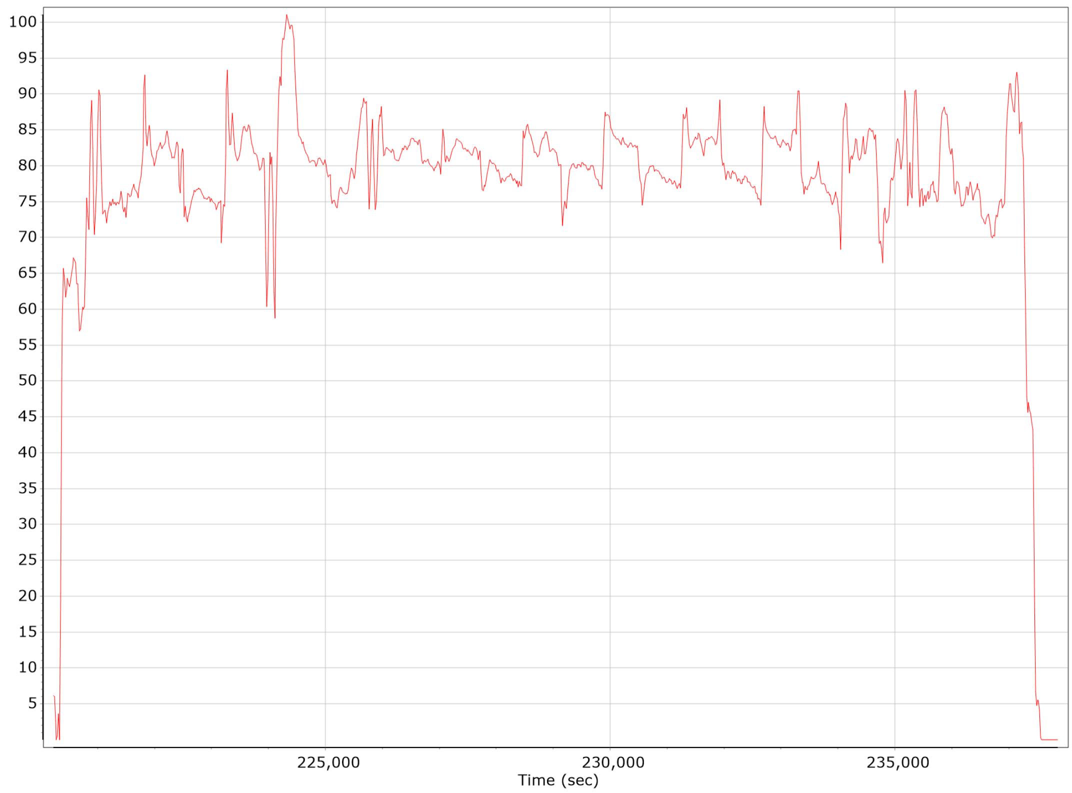


Down Velocity

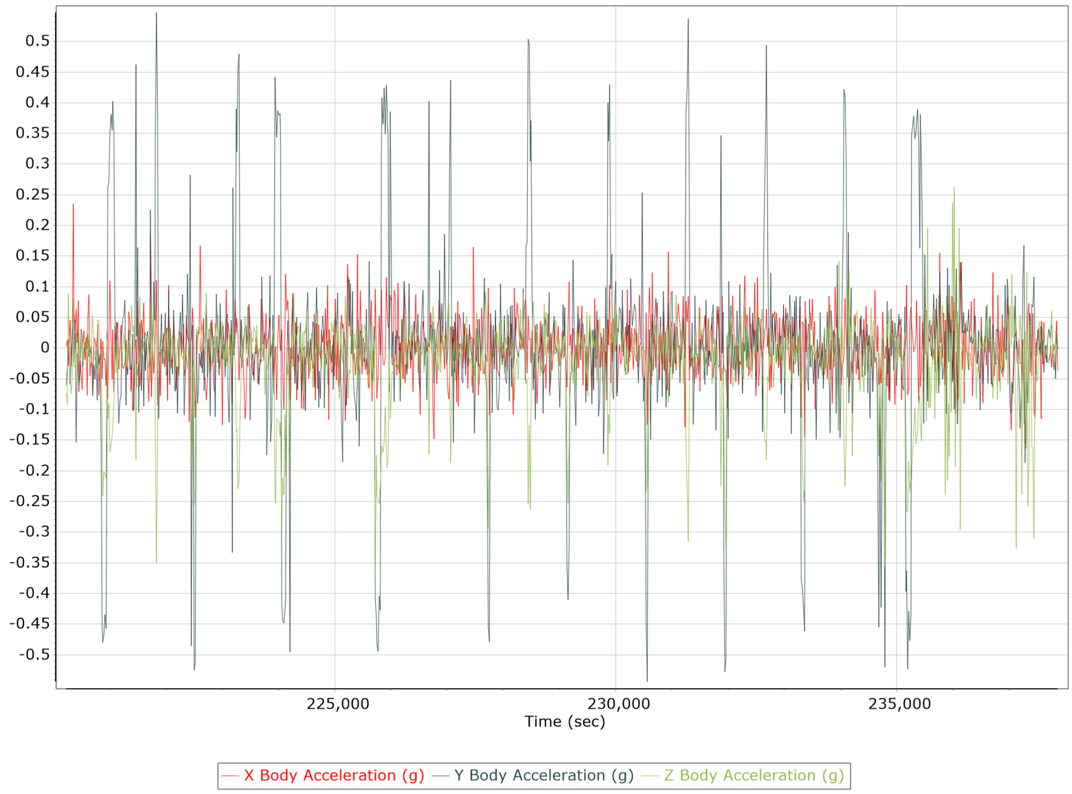


Total Speed

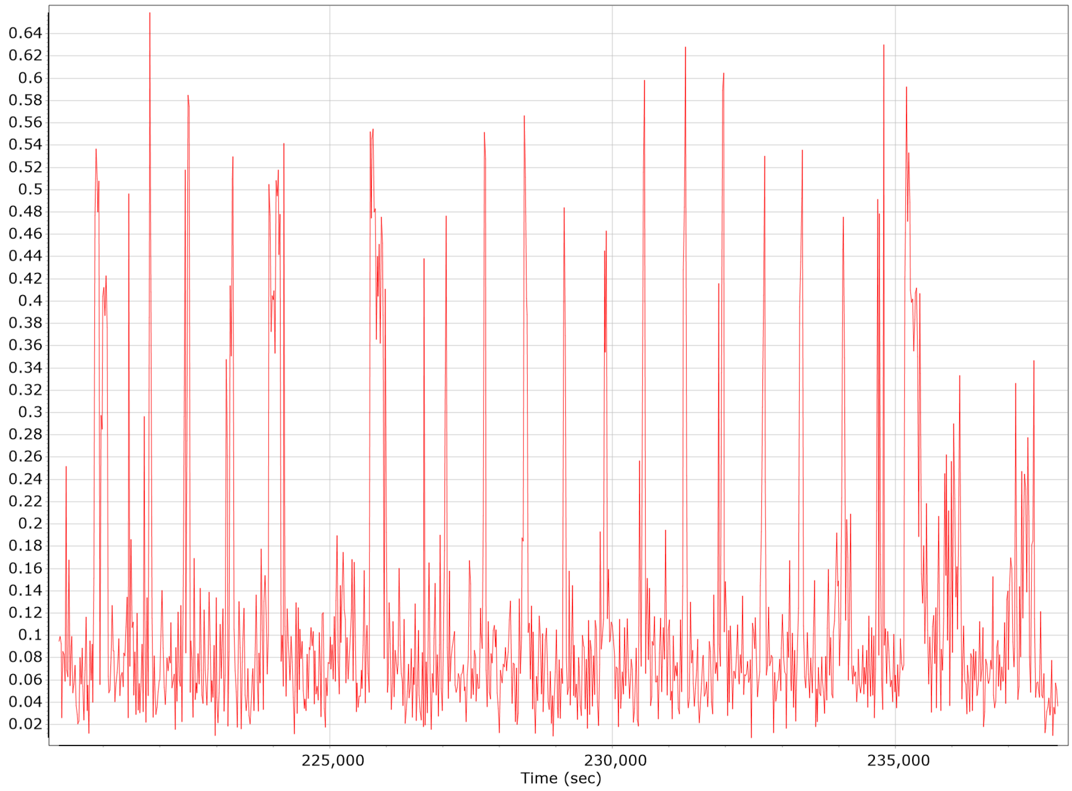
Ground Speed



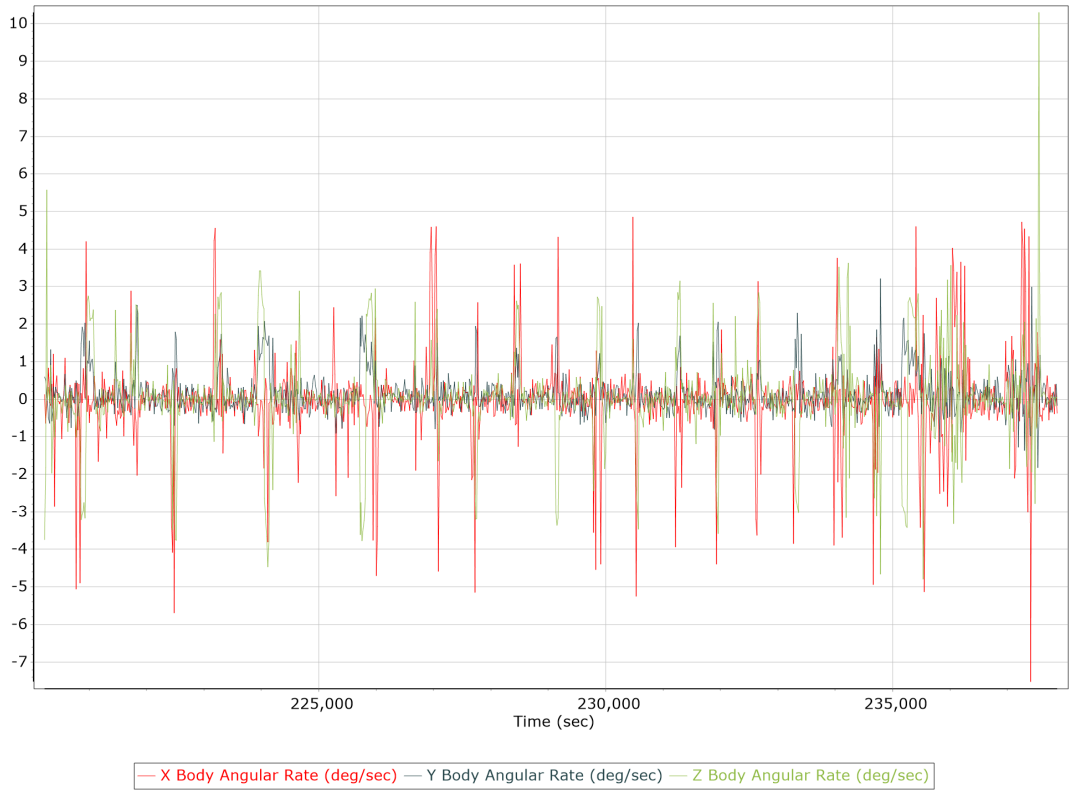
Body Acceleration



Total Body Acceleration



Body Angular Rate

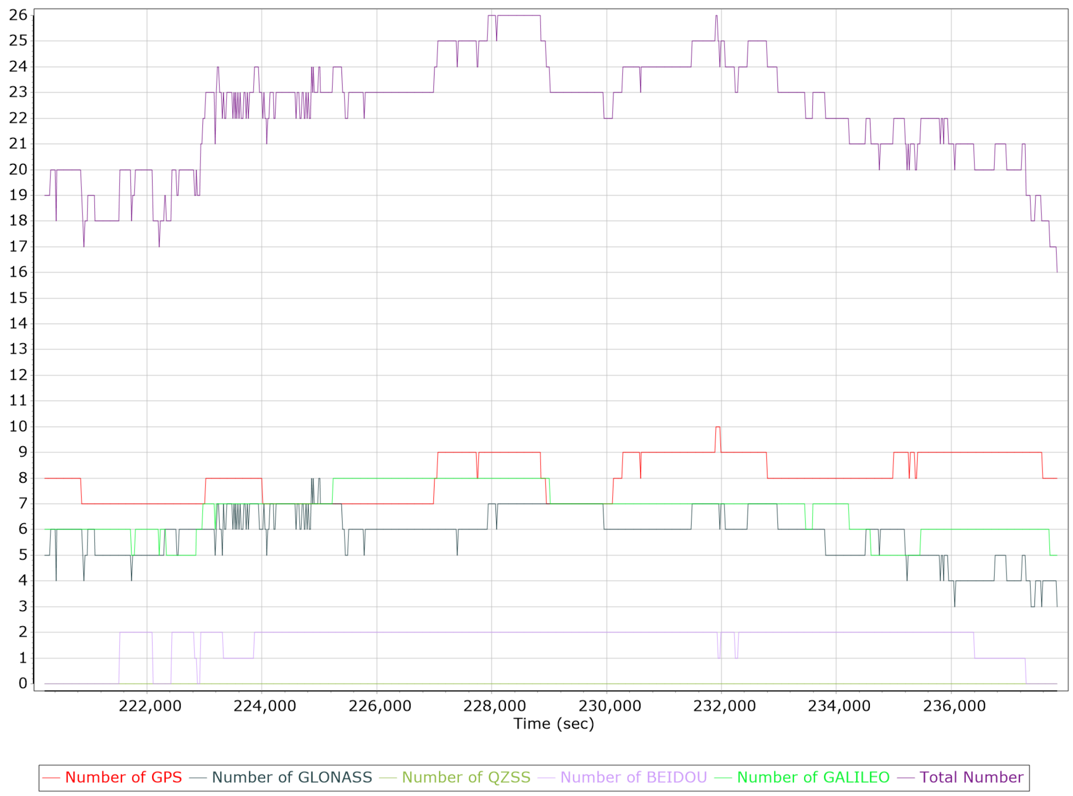


GNSS QC

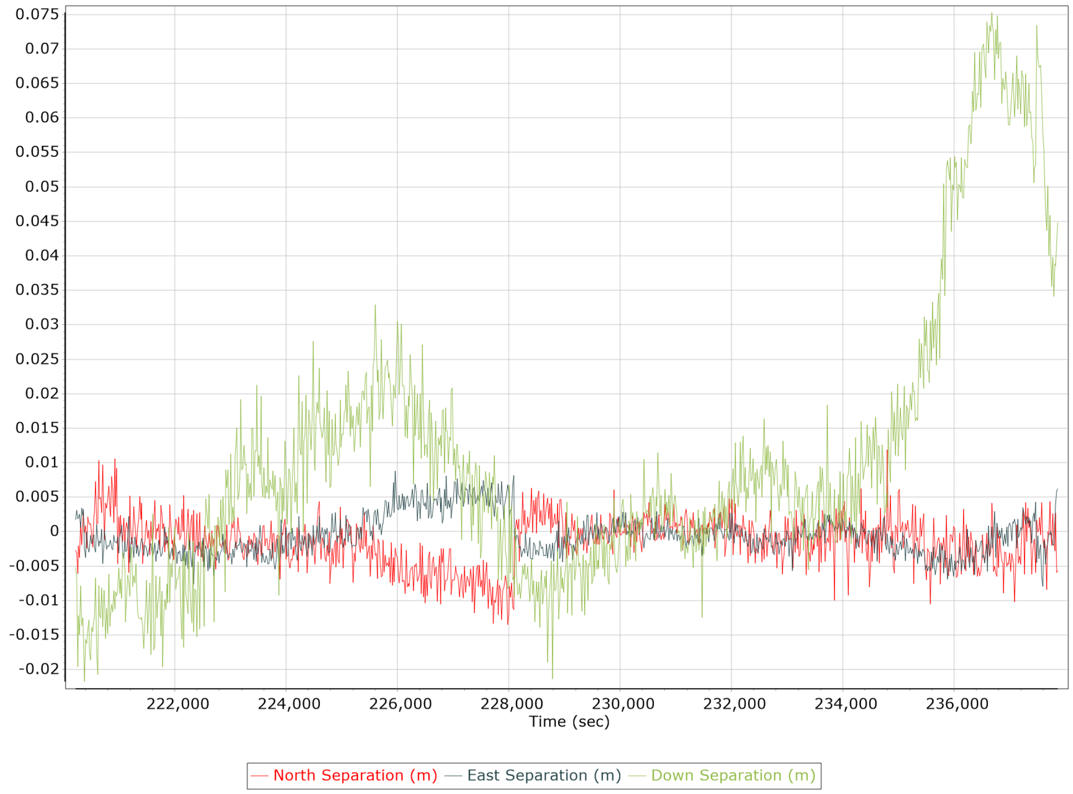
GNSS QC Statistics

Statistics	Min	Max	Mean
Baseline length (km)	0.00	0.00	
Number of GPS SV	4	10	8
Number of GLONASS SV	0	8	6
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	2	2
Number of GALILEO SV	5	8	7
Total number of SV	14	26	22
PDOP	0.95	1.82	1.17
QC Solution Gaps	1.00	1.00	
Solution Type	**Fixed**	**Float**	**No solution**
Epoch (sec)	18028.00	0.00	2.00
Percentage	99.99	0.00	0.01

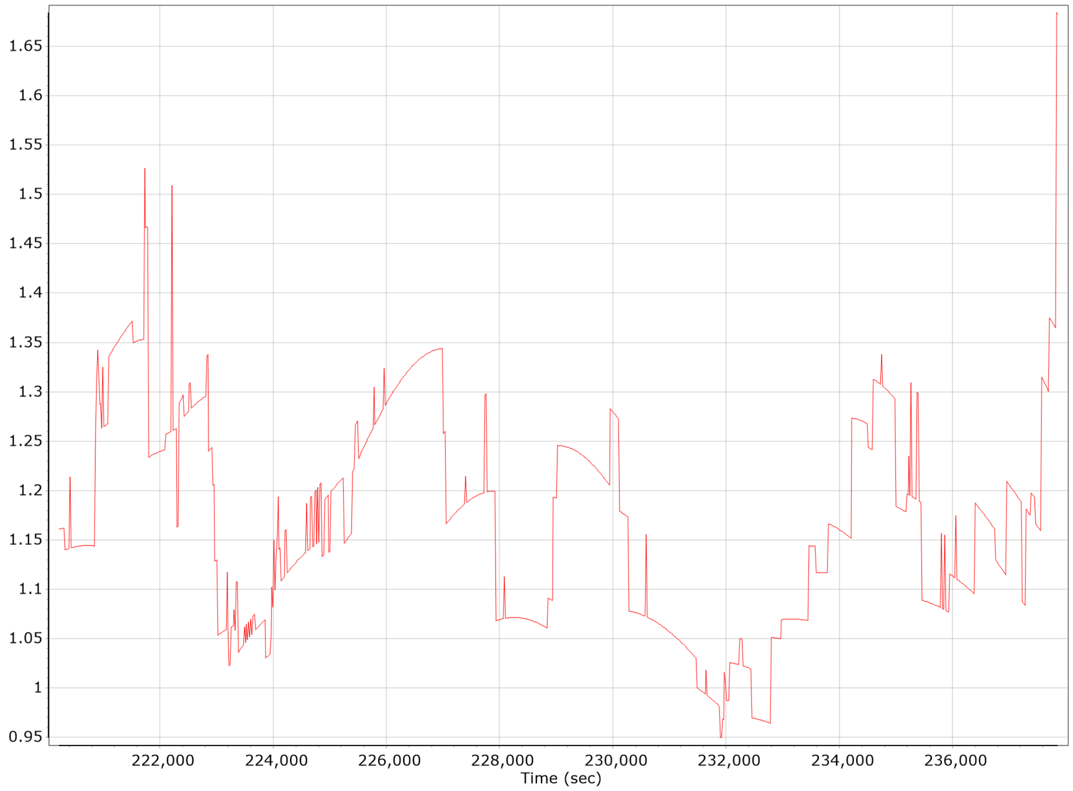
Num SVs in solution



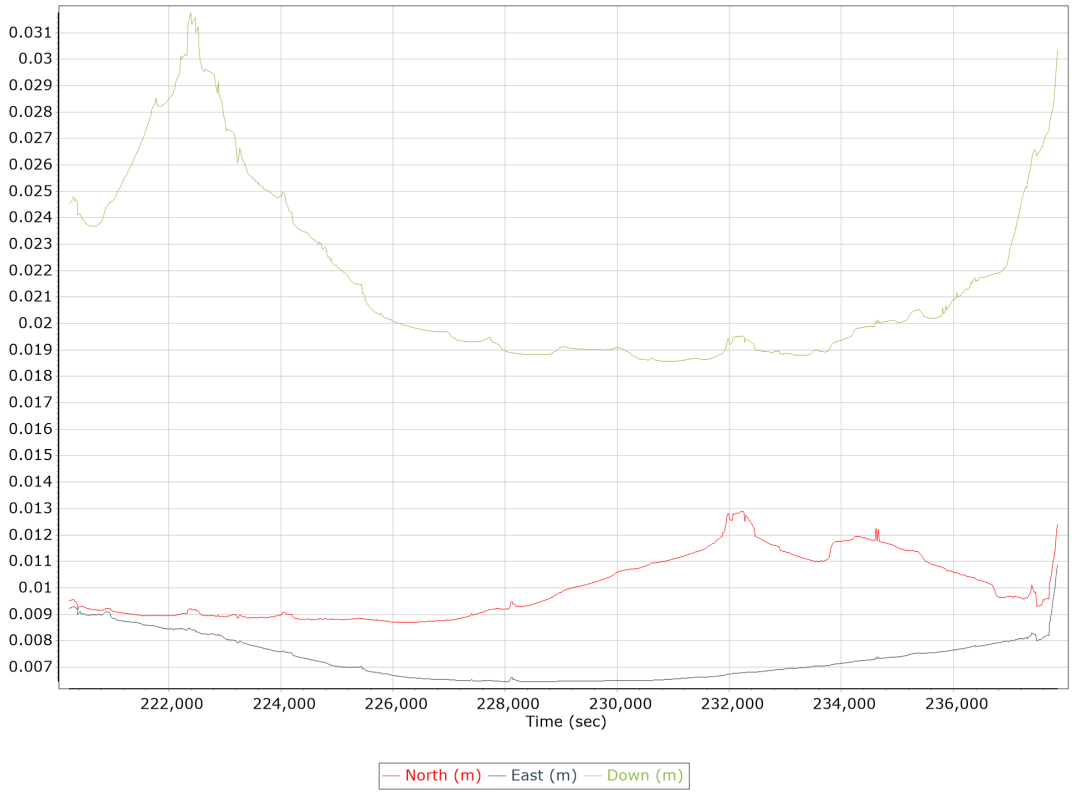
Forward/Reverse Separation



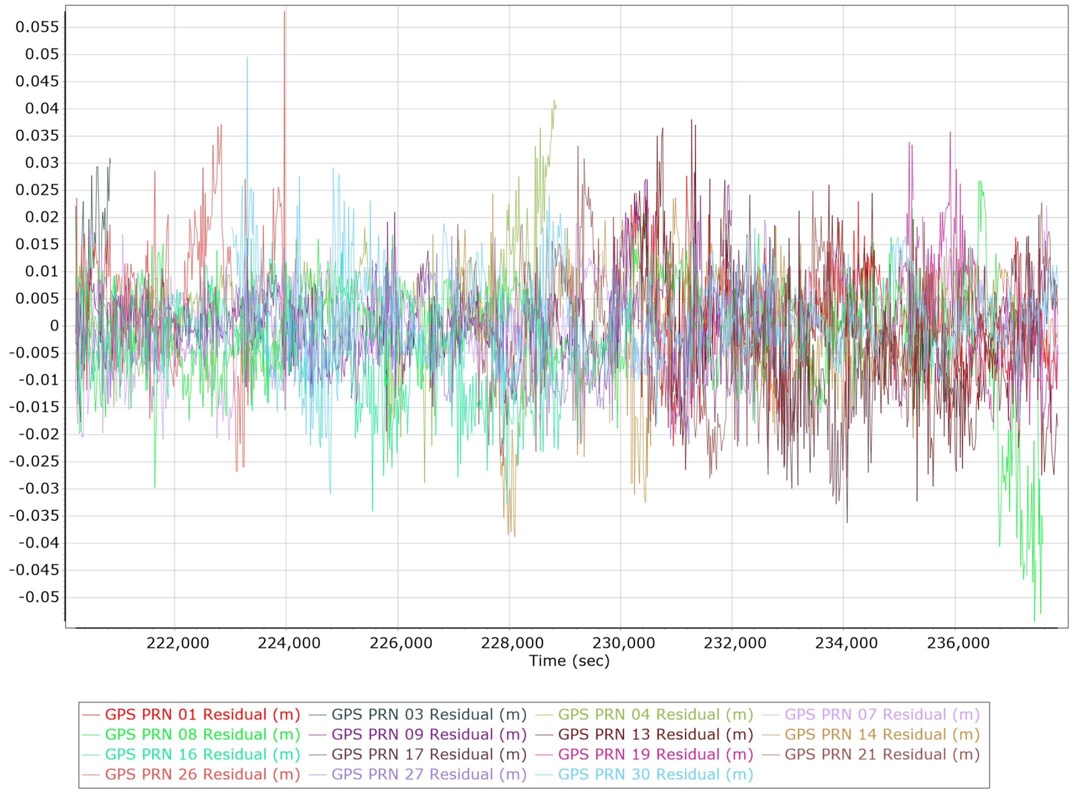
PDOP



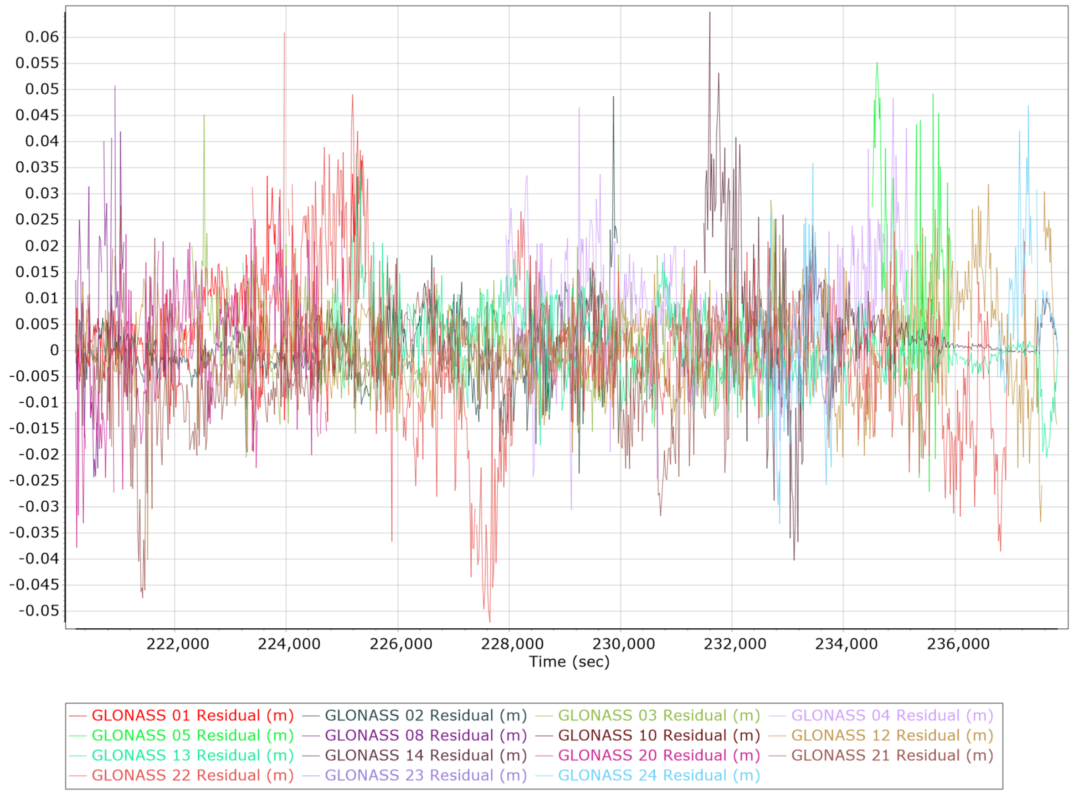
Estimated Position Accuracy



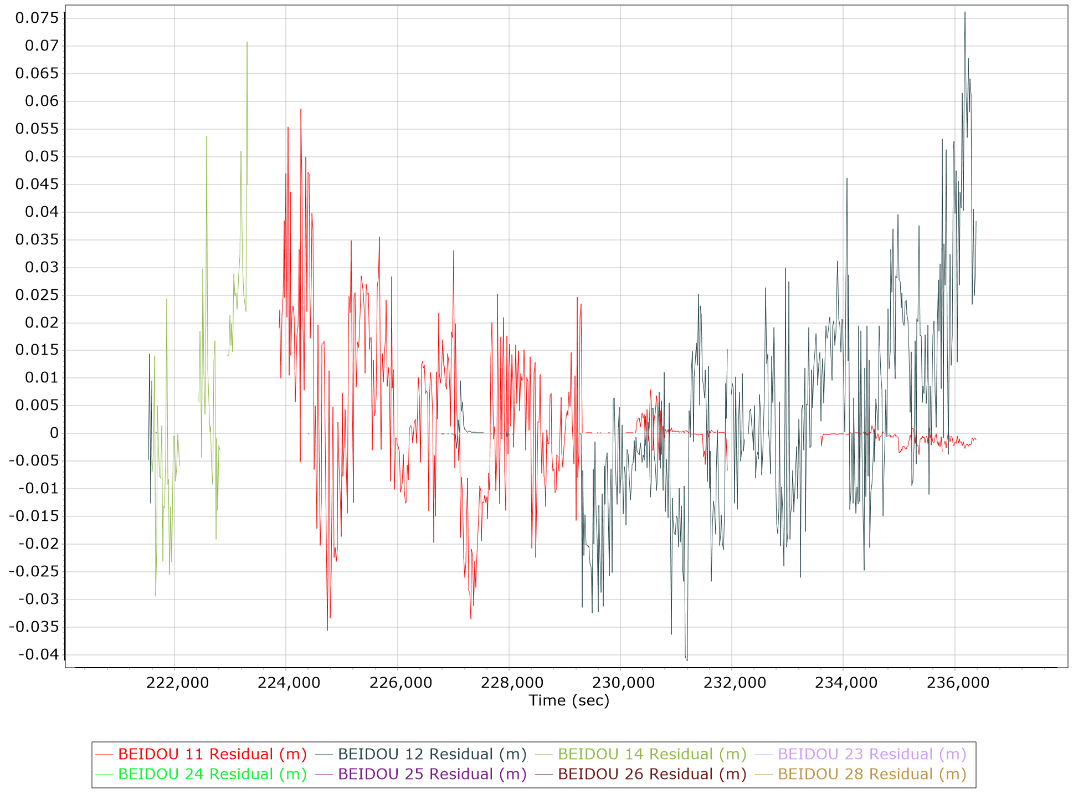
GPS Residuals



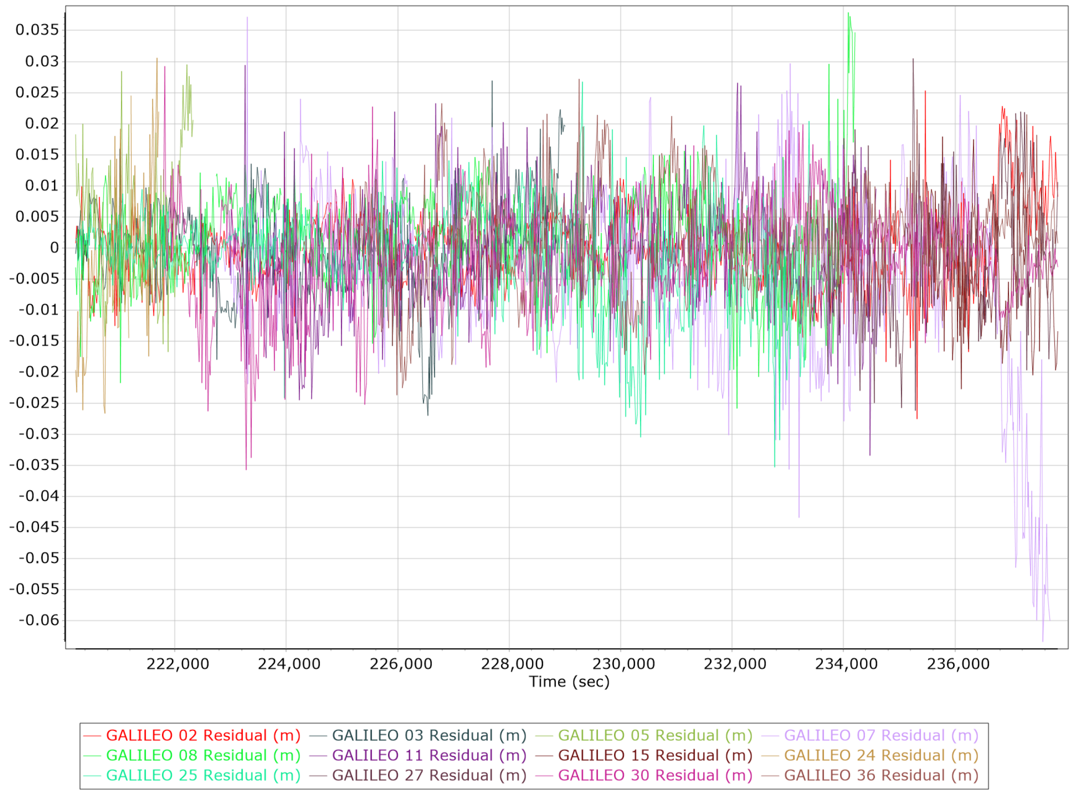
GLONASS Residuals



BEIDOU Residuals



GALILEO Residuals



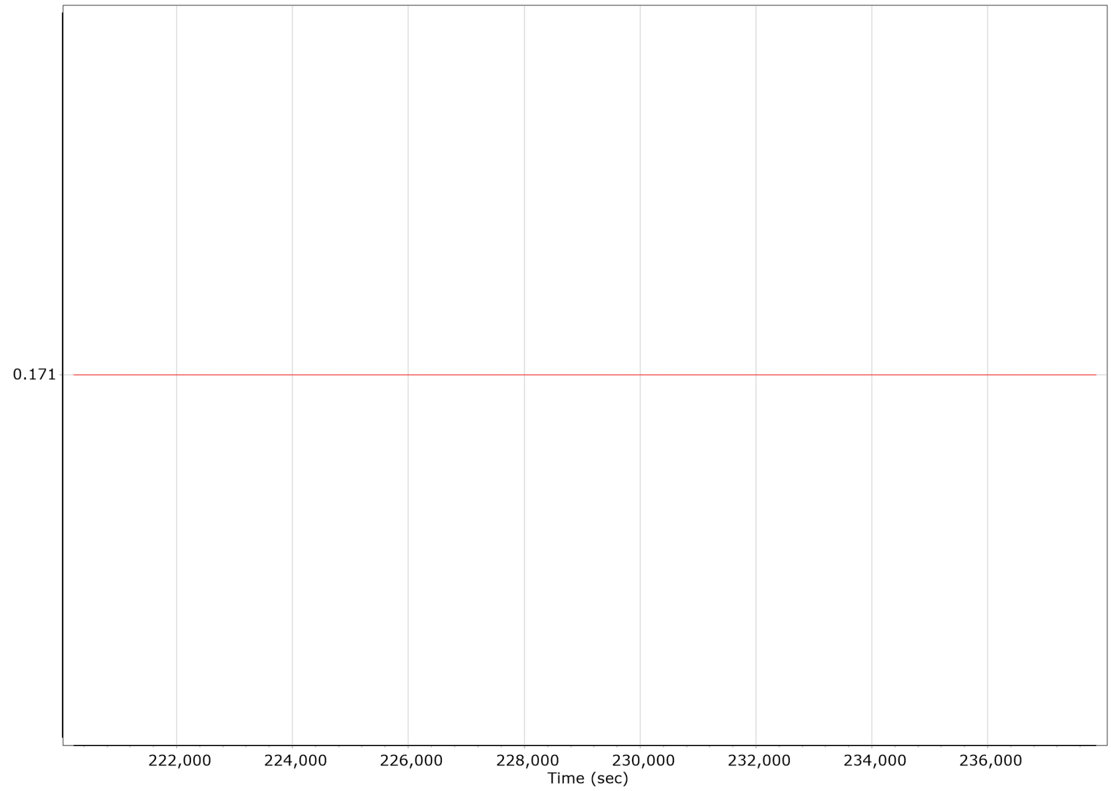
GNSS-Inertial Processor Configuration

Processing mode	IN-Fusion PP-RTX		
Stabilized mount	True		
Processing start time	219804.000 (4/12/2022 1:03:24 PM)		
Processing end time	237879.000 (4/12/2022 6:04:39 PM)		
Initial attitude source	Real-Time VNAV/RNAV Attitude		
IMU Sensor Context	Processing with Onboard IMU		
Gimbal to IMU lever arm (m)	0.000	0.000	0.000
Gimbal to IMU mounting angles (deg)	0.000	0.000	0.000
Gimbal to Primary GNSS lever arm (m)	0.171	-0.238	-1.273
Gimbal to Primary GNSS lever arm std dev (m)	0.030	0.030	0.030
Aircraft to Reference mounting angles (deg)	0.000	0.000	0.000

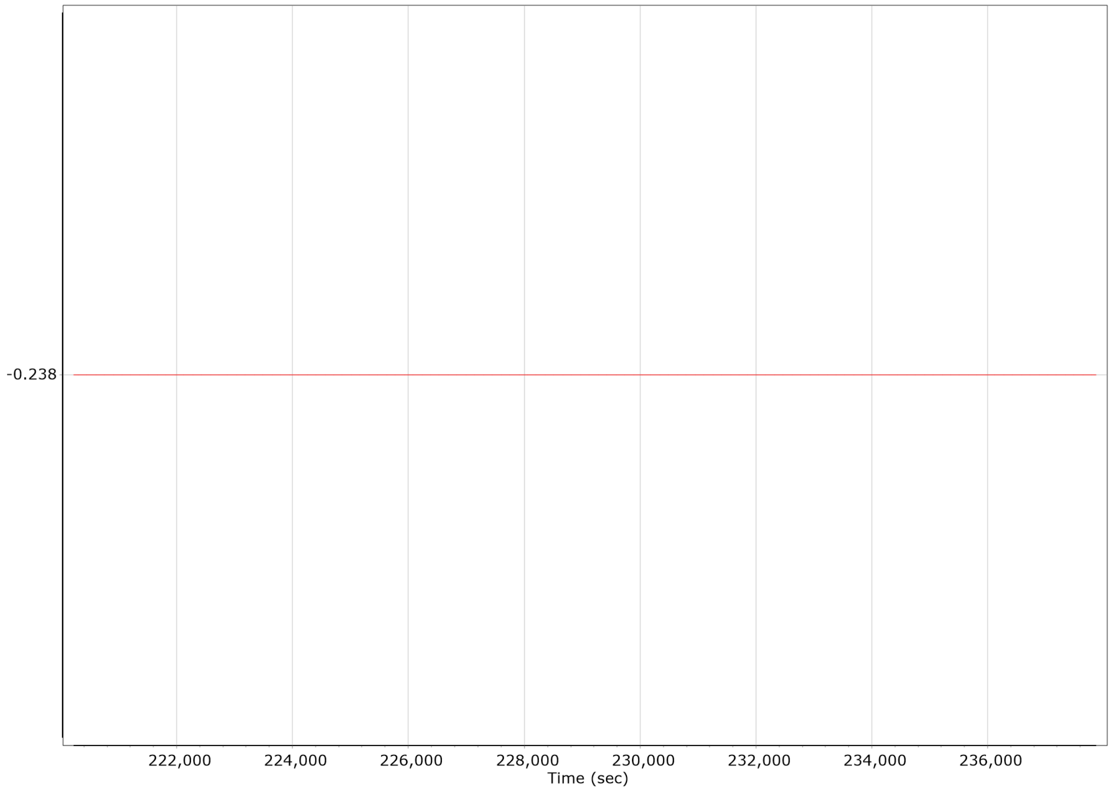
Calibrated Installation Parameters

Reference-Primary GNSS Lever Arm (m)

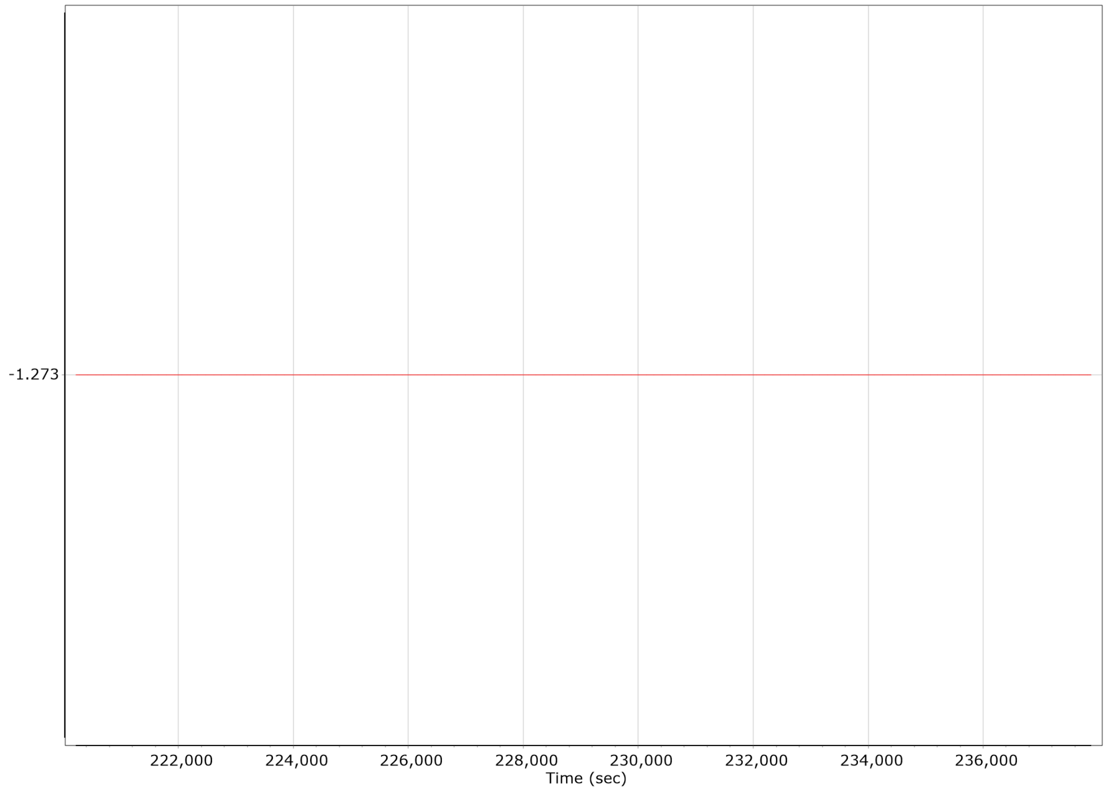
X Reference-Primary GNSS Lever Arm (m)



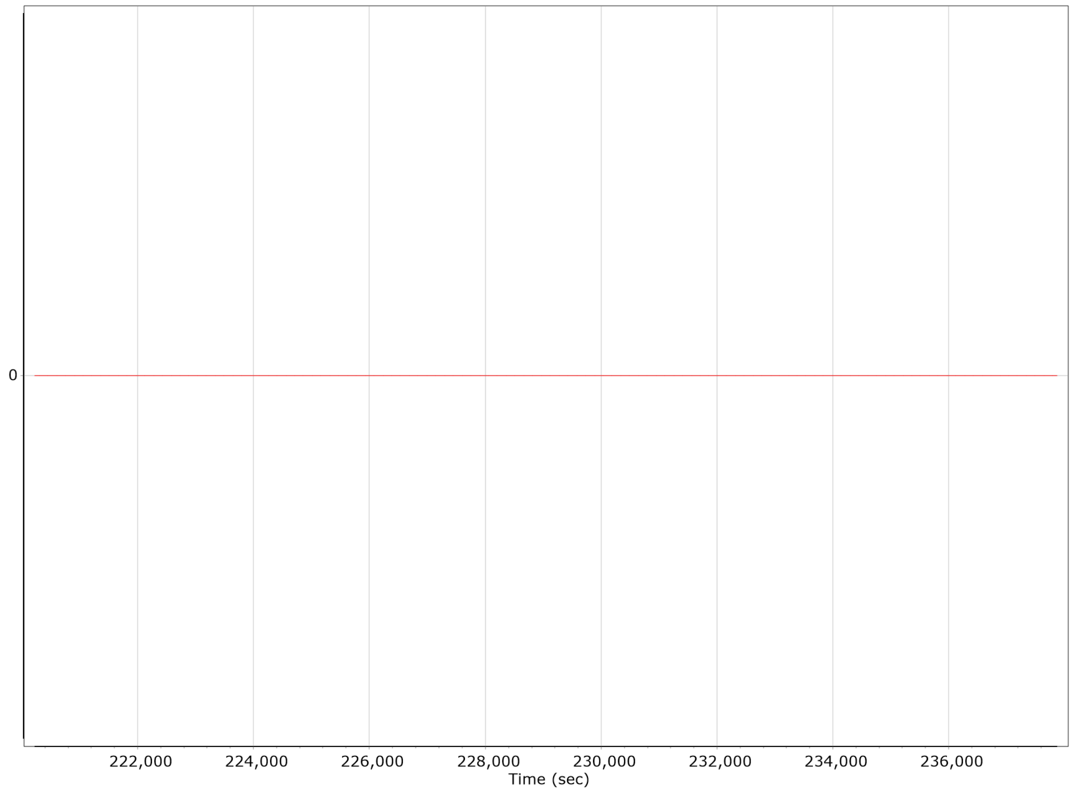
Y Reference-Primary GNSS Lever Arm (m)



Z Reference-Primary GNSS Lever Arm (m)



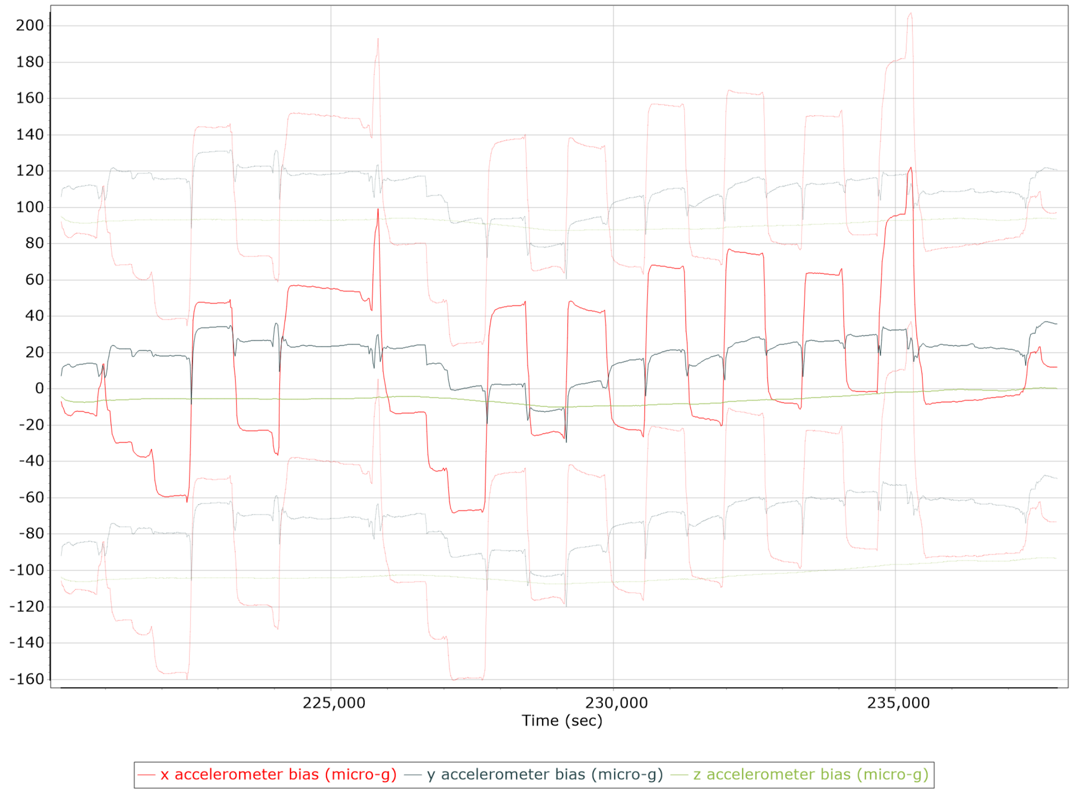
Reference-Primary GNSS Lever Arm Figure of Merit



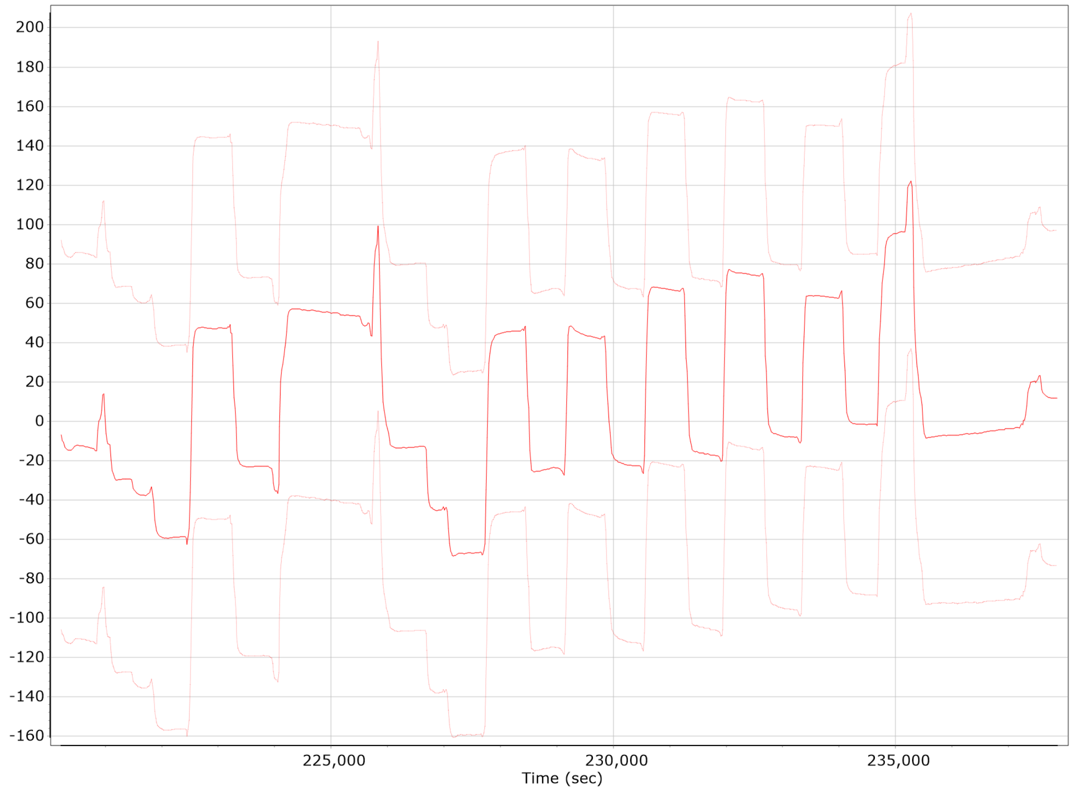
IN-Fusion QC

Forward Processed Estimated Errors, Reference Frame

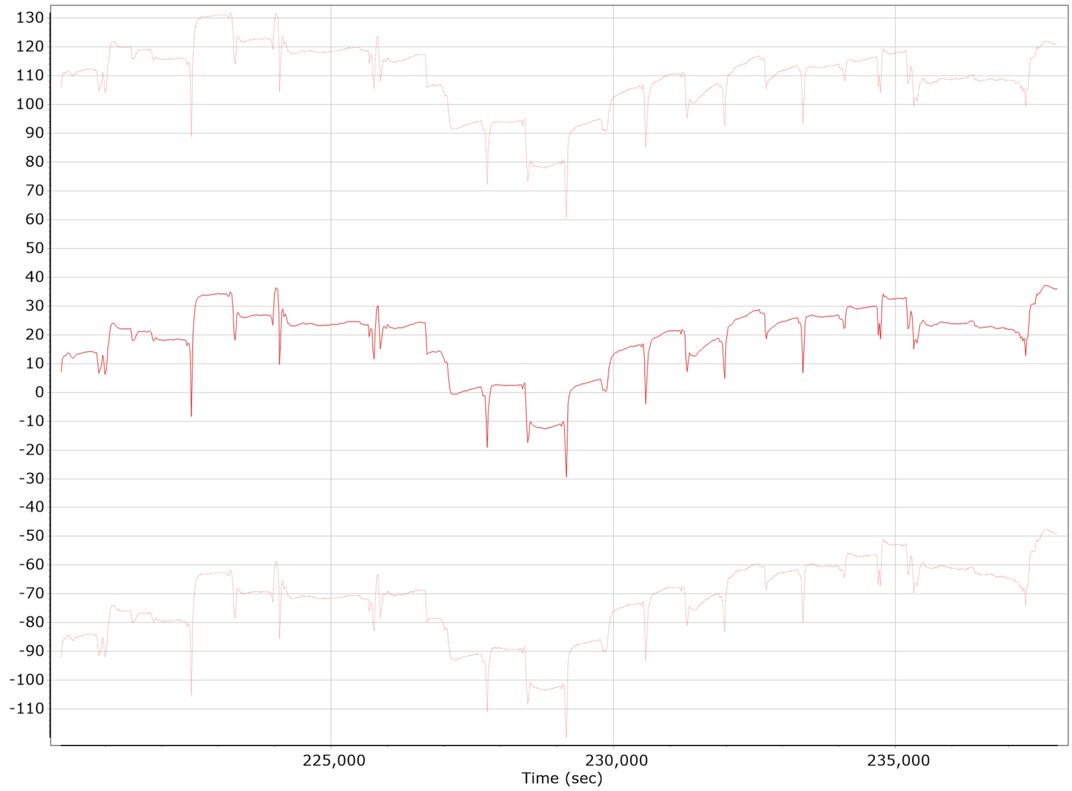
Accelerometer Bias (micro-g)



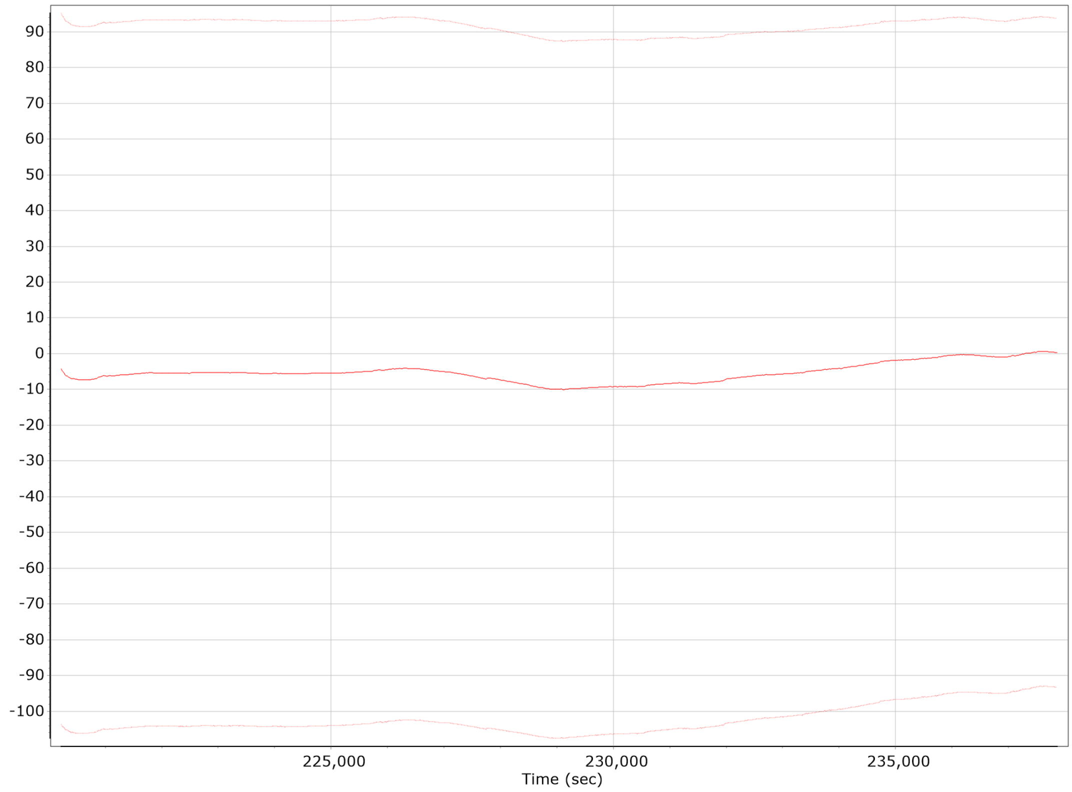
X Accelerometer Bias (micro-g)



Y Accelerometer Bias (micro-g)

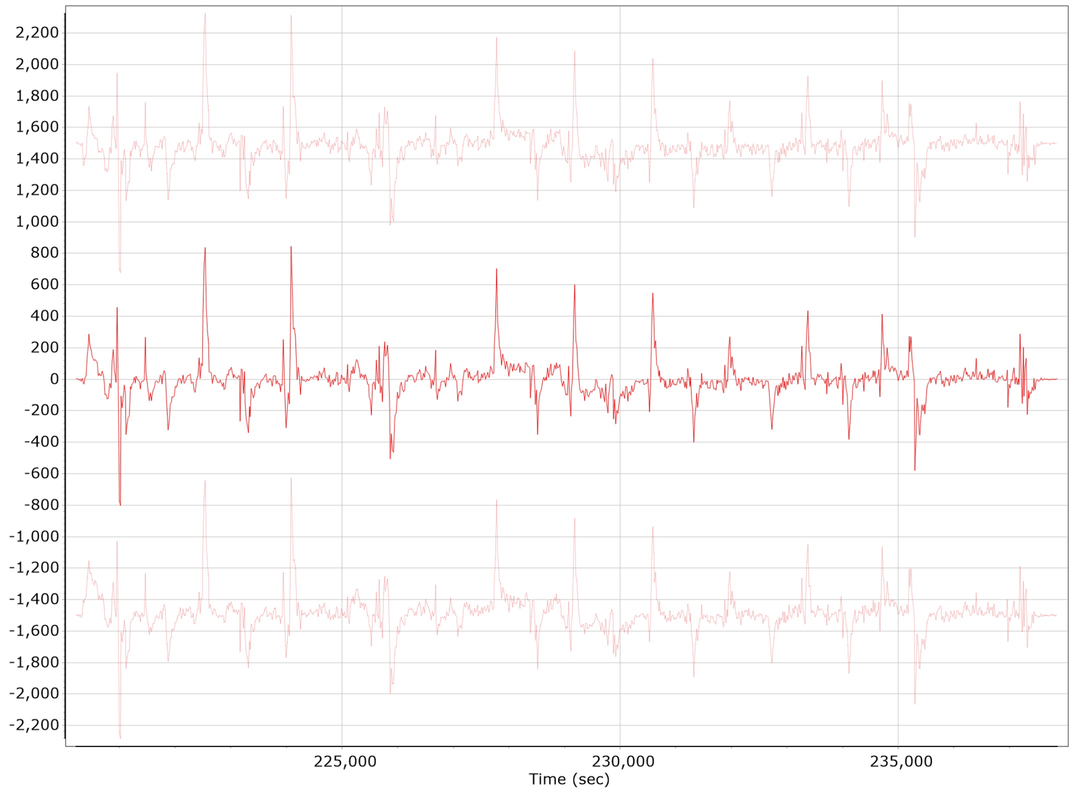


Z Accelerometer Bias (micro-g)



Accelerometer Scale Error (ppm)

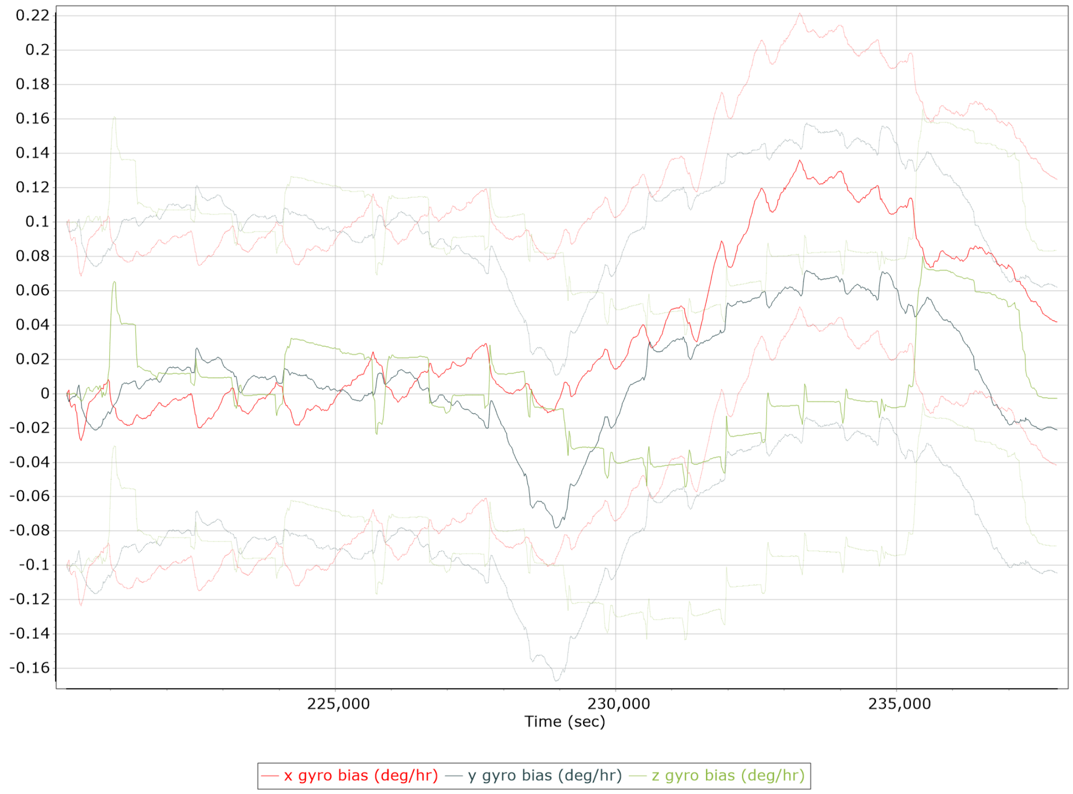
X Accelerometer Scale Error (ppm)



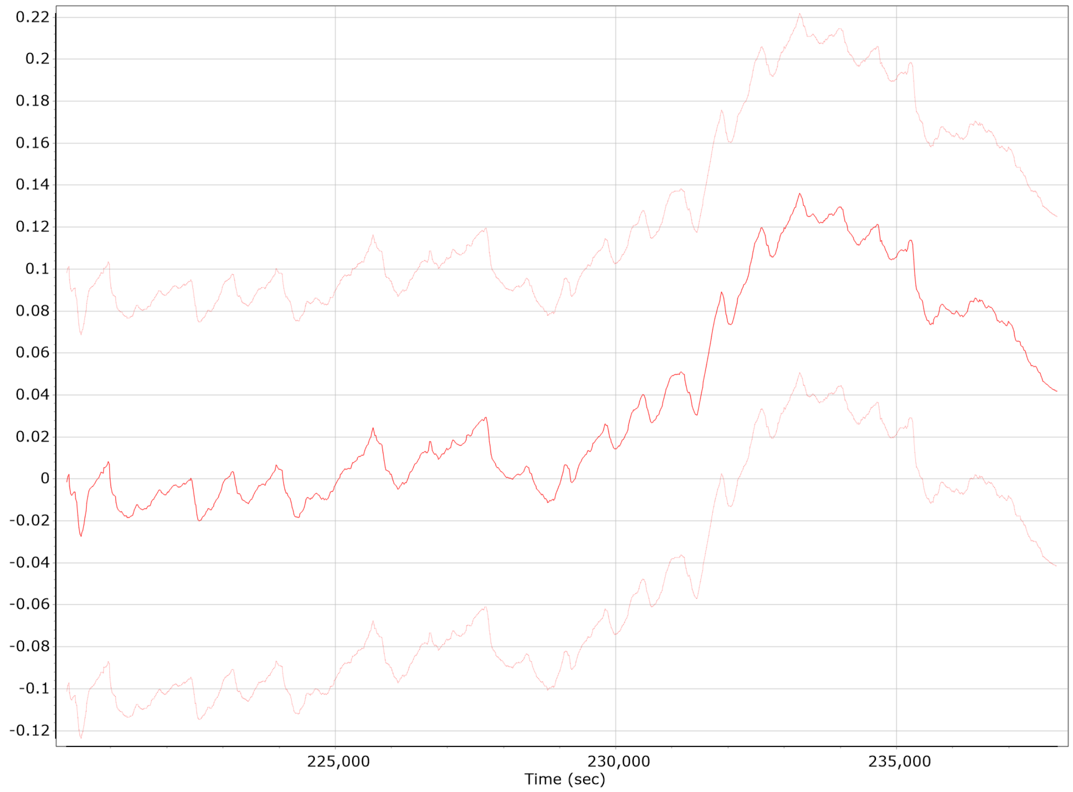
Y Accelerometer Scale Error (ppm)

Z Accelerometer Scale Error (ppm)

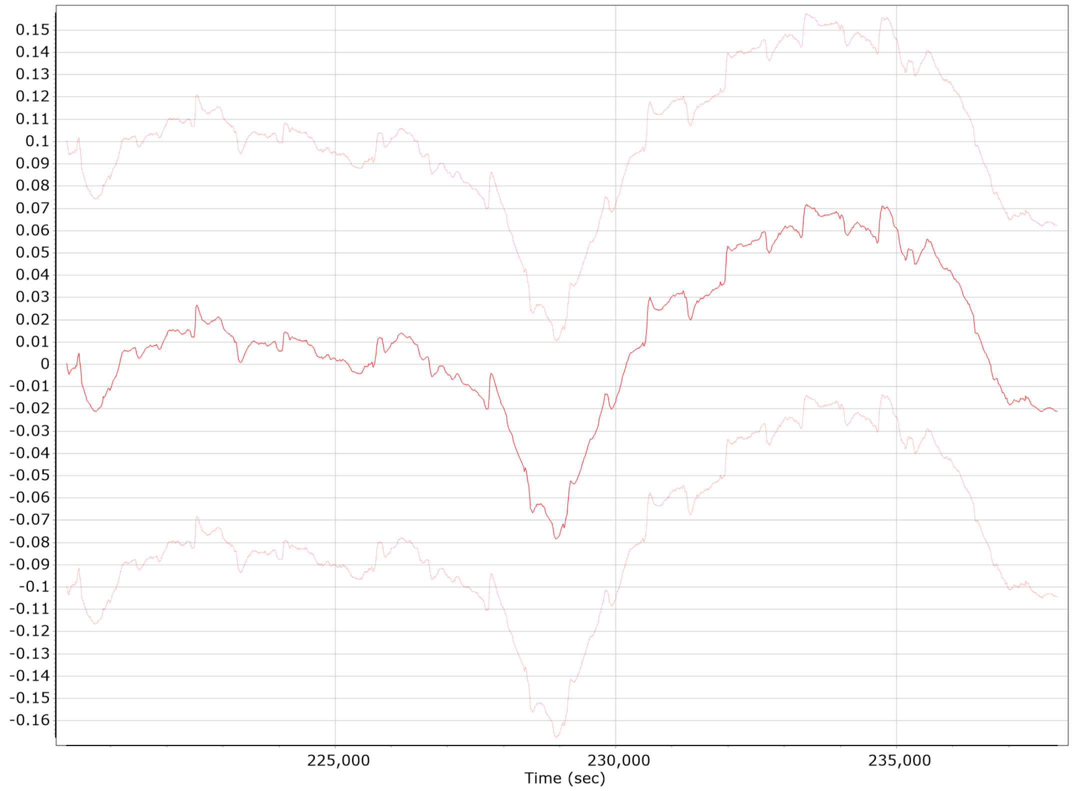
Gyro Bias (deg/h)



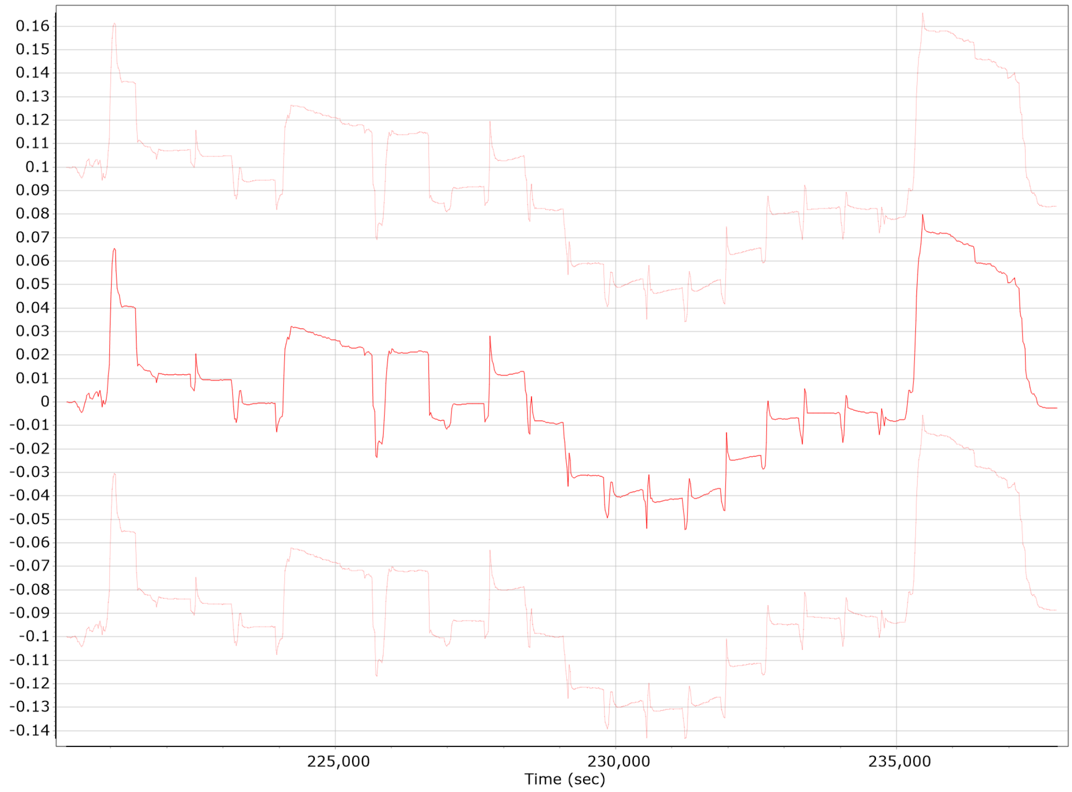
X Gyro Bias (deg/h)



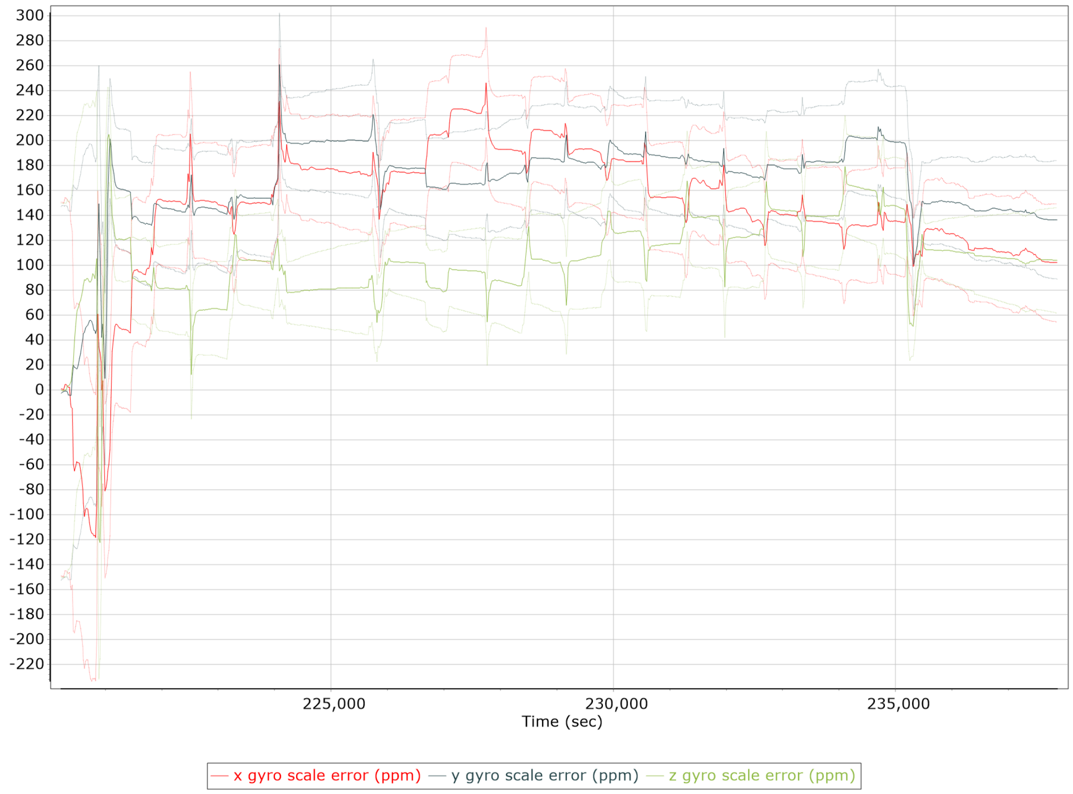
Y Gyro Bias (deg/h)



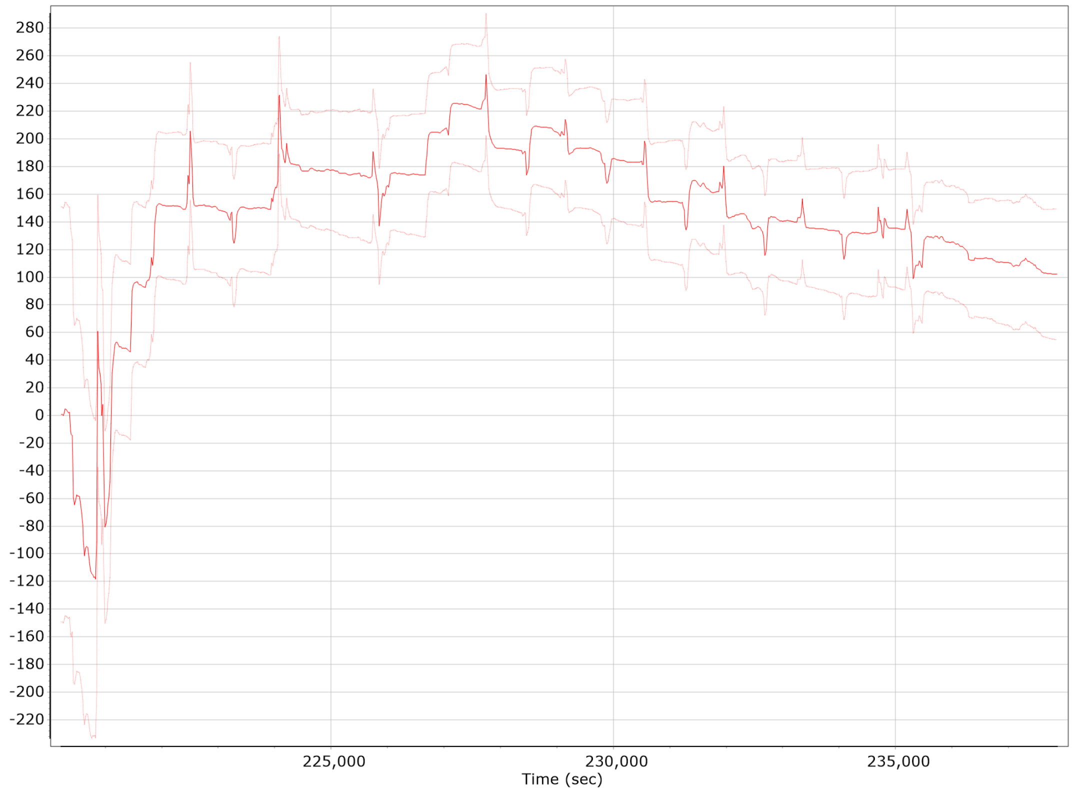
Z Gyro Bias (deg/h)



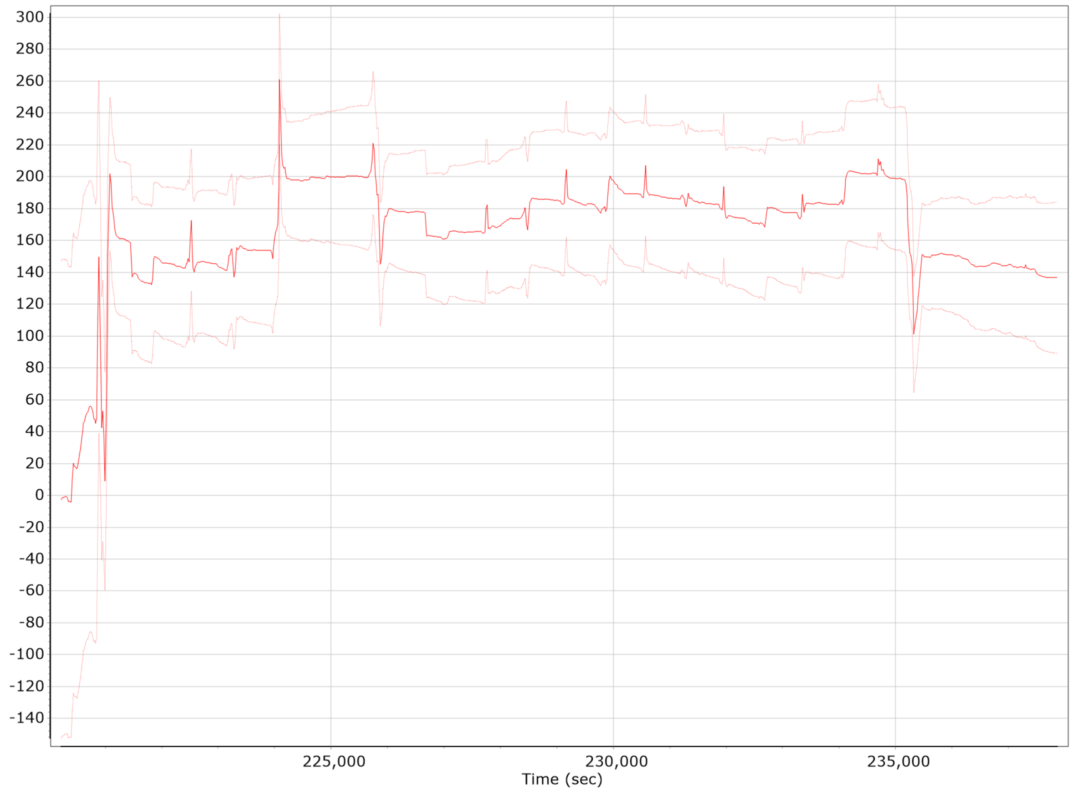
Gyro Scale Error (ppm)



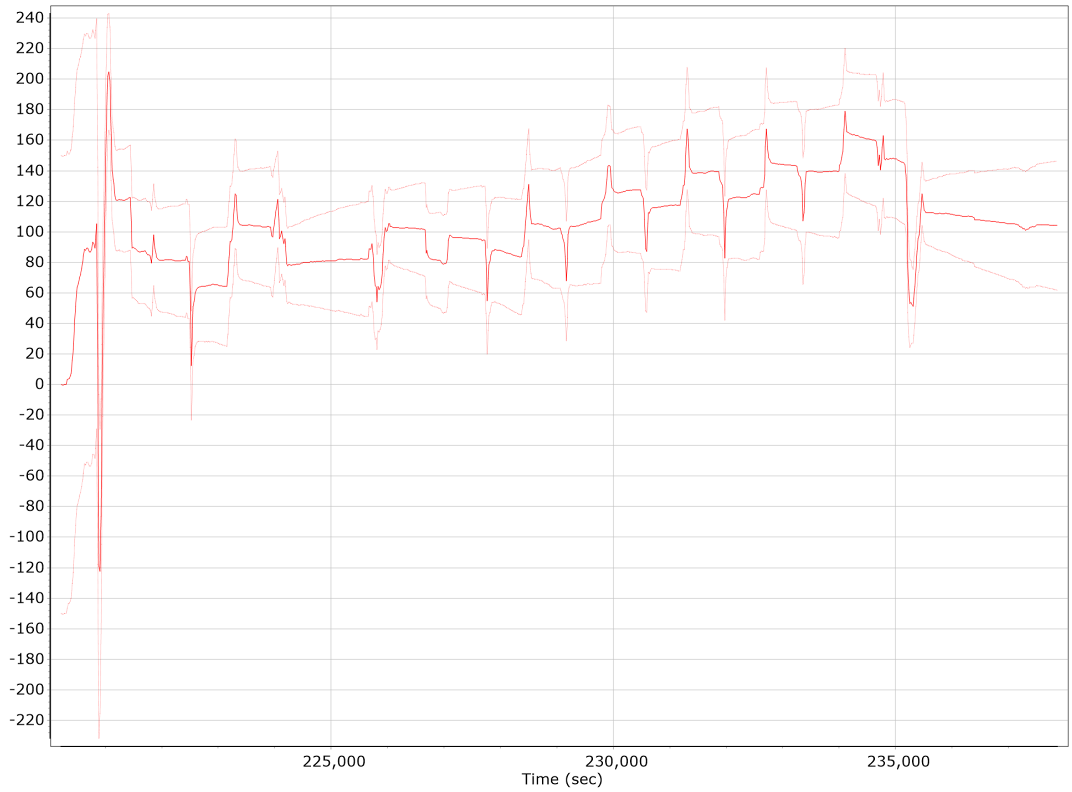
X Gyro Scale Error (ppm)



Y Gyro Scale Error (ppm)



Z Gyro Scale Error (ppm)

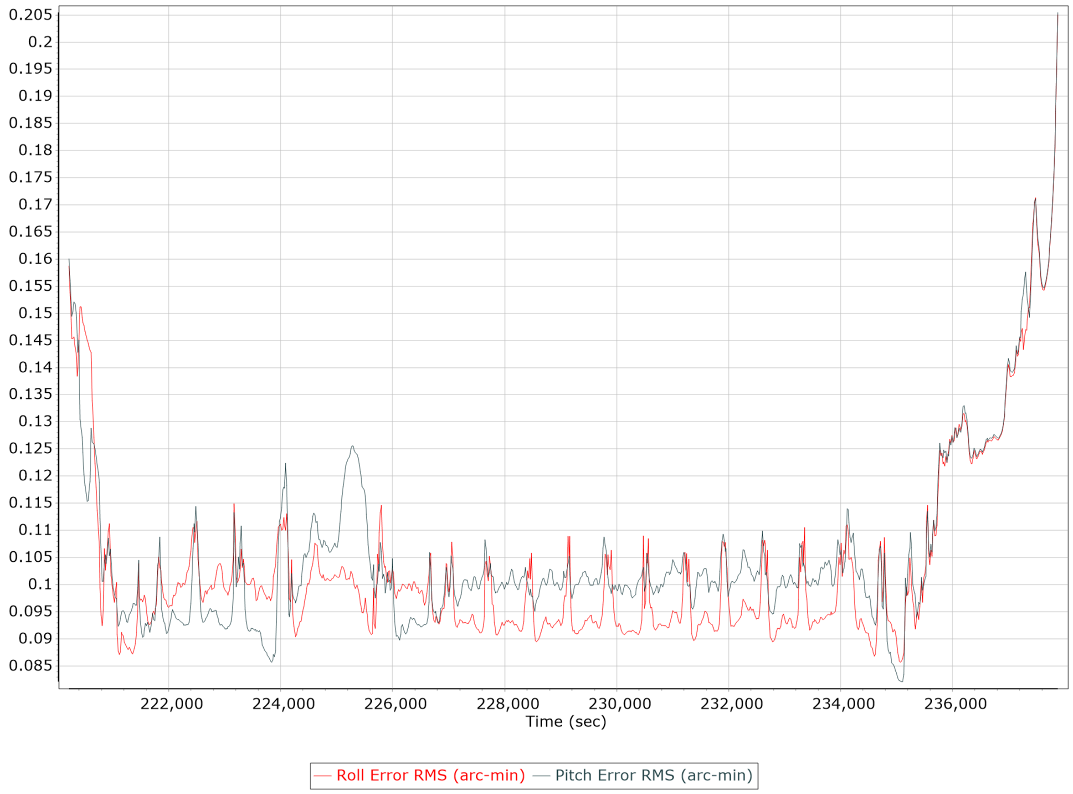


Smoothed Performance Metrics

Position Error RMS (m)

Velocity Error RMS (m/s)

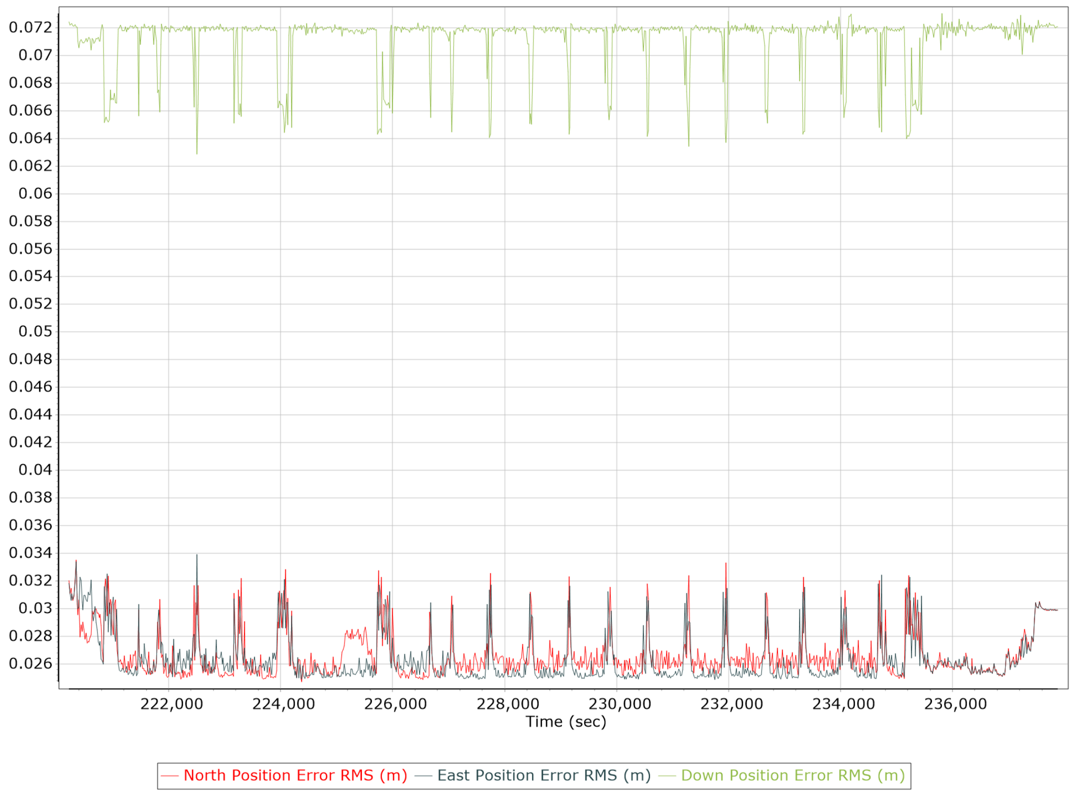
Roll/Pitch Error RMS (arc-min)



Heading Error RMS (arc-min)

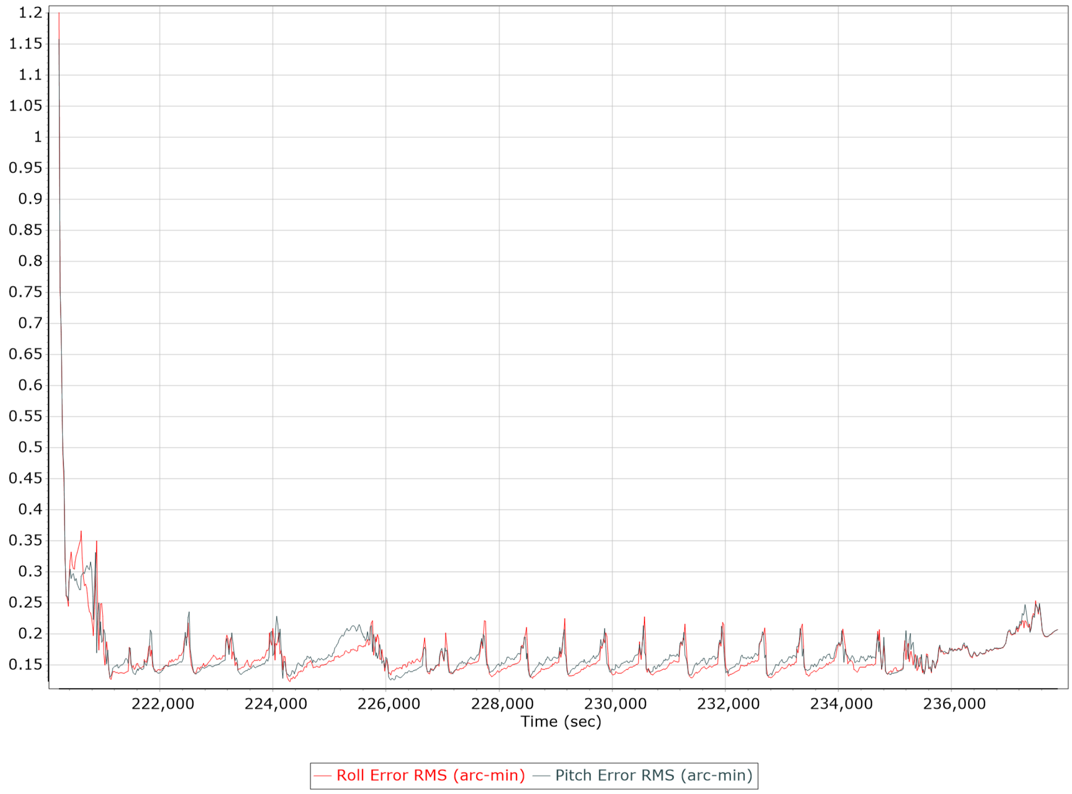
Forward Processed Performance Metrics

Position Error RMS (m)

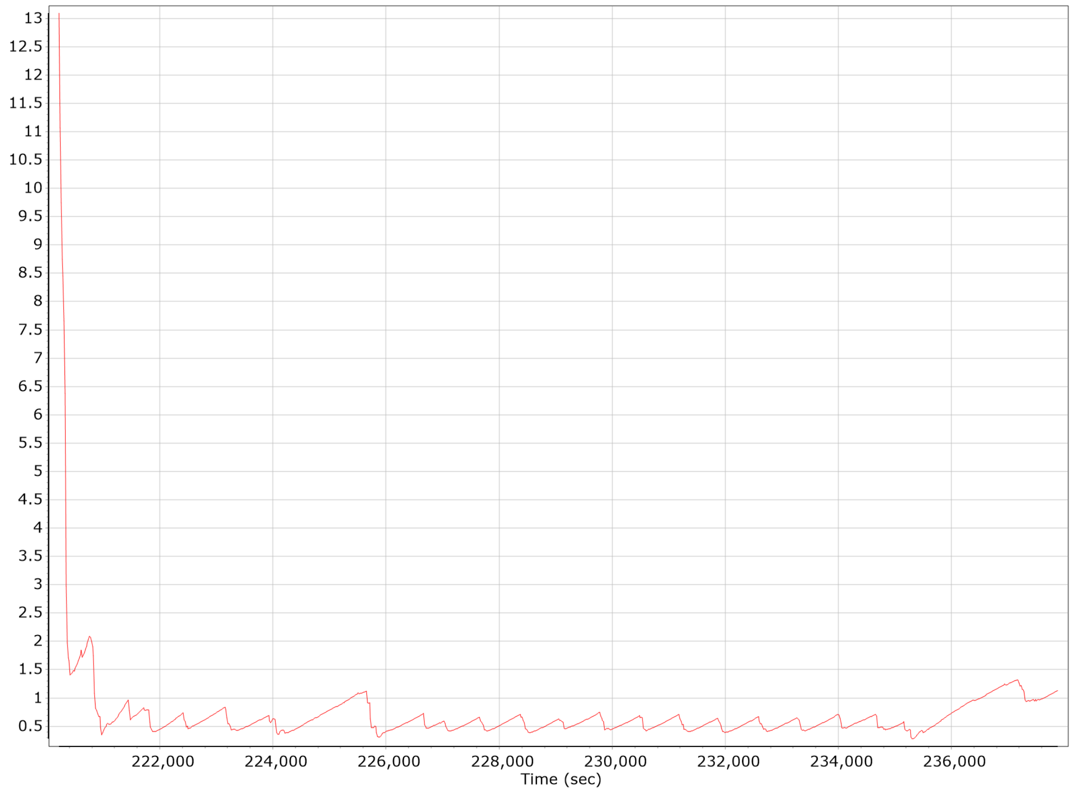


Velocity Error RMS (m/s)

Roll/Pitch Error RMS (arc-min)

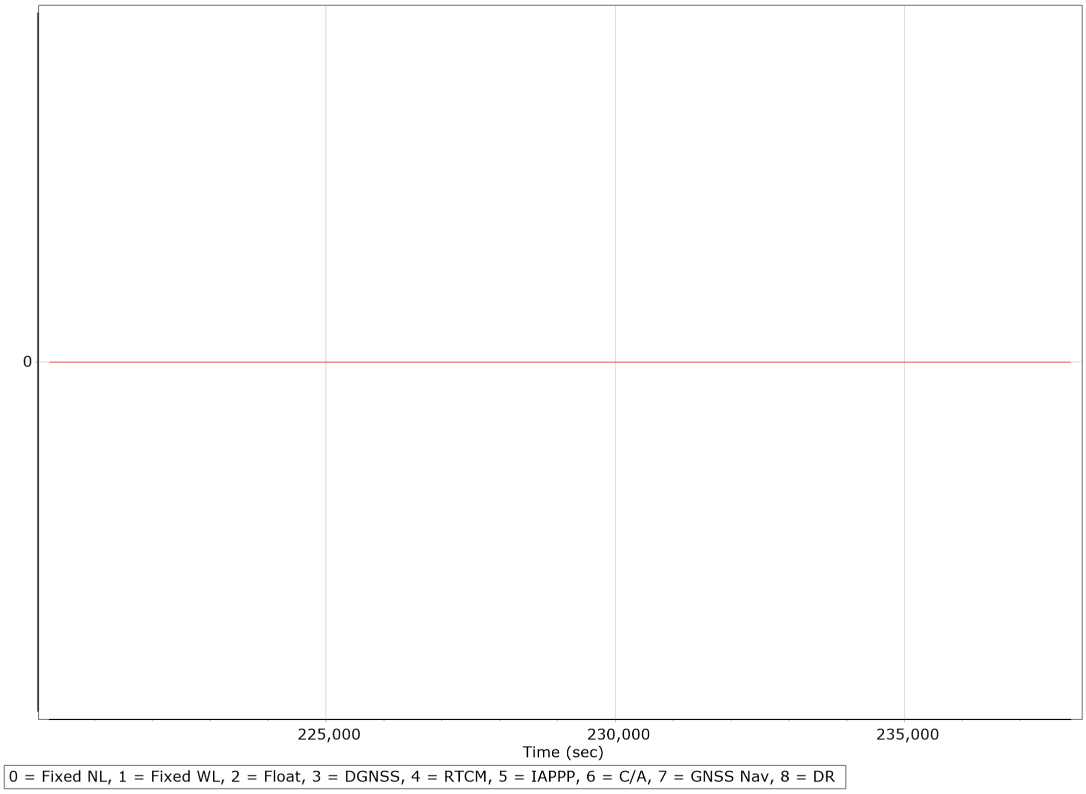


Heading Error RMS (arc-min)

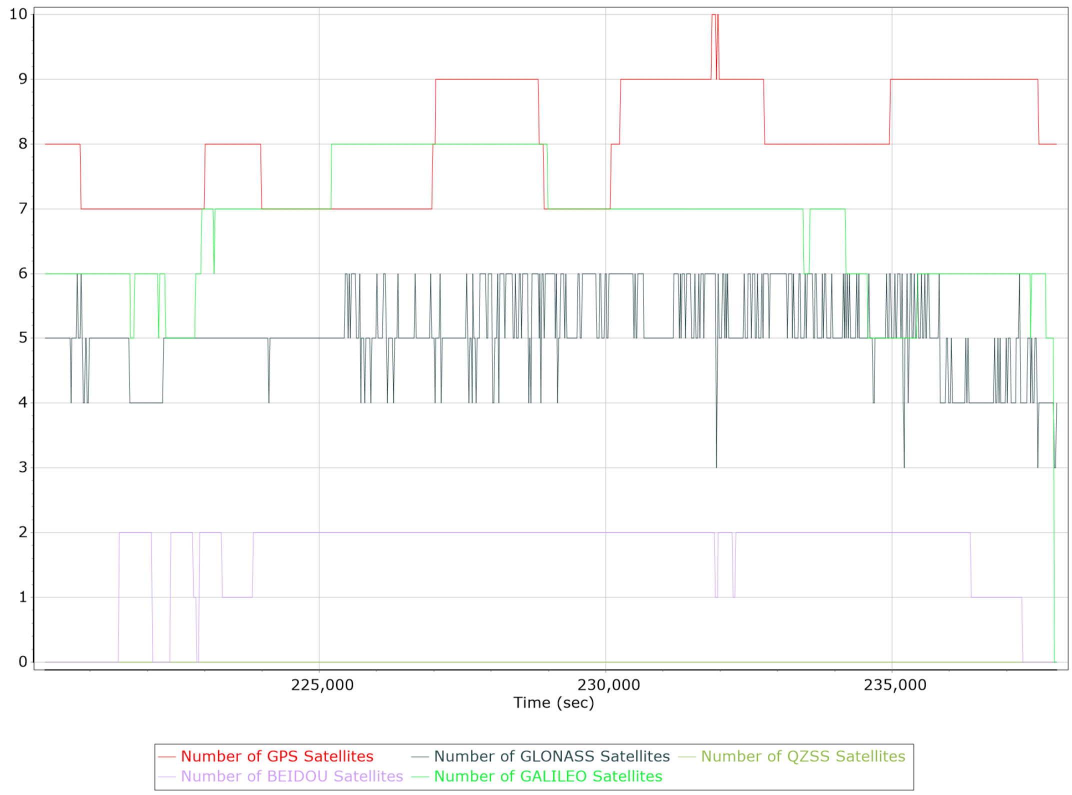


Forward Processed Solution Status

Processing Mode



Number of Satellites



Baseline Length