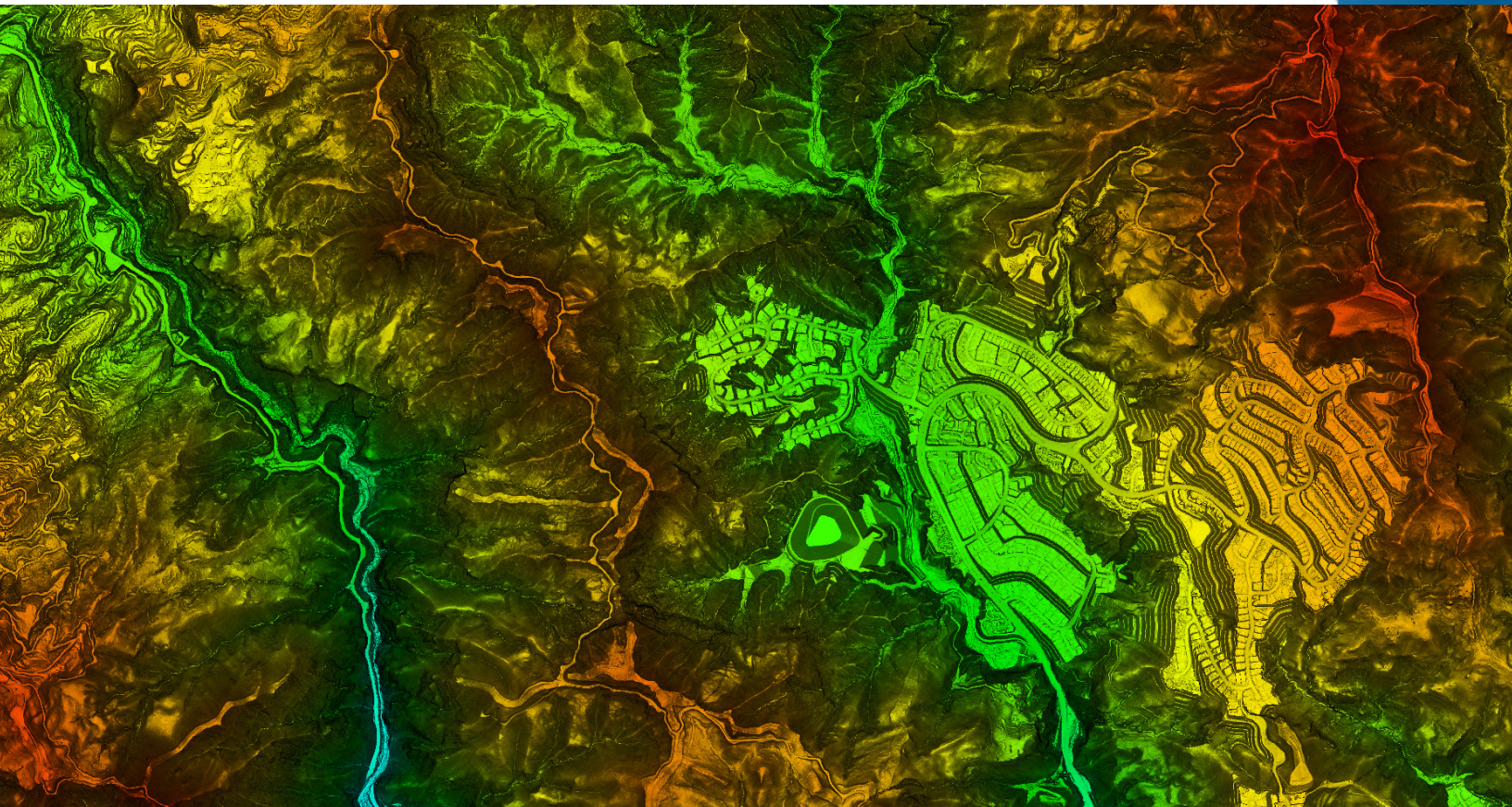




Submitted: March 25, 2025

CA LA PostWildfire Eaton C25 LIDAR PROCESSING REPORT

2025

Project ID: 300415
Work Unit: 300866

Prepared for:



Prepared by:

N|V|5 GEOSPATIAL

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1. Summary / Scope

1.1. Summary

This report contains a summary of the CA_LA_PostWildfire_Eaton_C25, lidar acquisition task order, issued by USGS. The task order yielded a work unit area covering approximately 60 square miles over California at Quality Level 1. 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
16 pts / m2	3000 m	40°	60%	≤ 10 cm

1.3. Coverage

The work unit boundary covers approximately 60 square miles over Los Angeles, California. Work unit extents are shown in Figure 1.

1.4. Duration

Lidar data was acquired from January 21, 2025 to January 22, 2025 in two total lifts. See “Section: 2.4. Time Period” for more details.

1.5. Issues

No Issues to report.

CA_LA_PostWildfire_Eaton_C25 Projected Coordinate System: UTM11 Horizontal Datum: NAD83 (2011) Vertical Datum: NAVD88 (GEOID 18) Units: Meters	
Lidar Point Cloud	Classified Point Cloud in .LAZ 1.4 format
Rasters	0.5-meter Hydro-flattened Bare Earth Digital Elevation Model (DEM) in GeoTIFF format 0.5-meter Intensity images in GeoTIFF format 1-meter Maximum Surface Height Raster 1-meter Swath Separation Images
Vectors	Shapefiles (*.shp) - Project Boundary - Lidar Tile Index - Calibration and QC Checkpoints (NVA/VVA) Geodatabase (*.gdb) - Continuous Hydro-flattened Breaklines - Flightlines Swath Geopackage (*.gpkg) - Calibration and QC Checkpoints (NVA/VVA)
Reports	Reports in PDF format - Focus on Delivery - Focus on Accuracy - Survey Report - Processing Report
Metadata	XML Files (*.xml) - Breaklines - Classified Point Cloud - DEM - Highest Hit DSM - Intensity Imagery

CA LA PostWildfire Eaton C25 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 VQ1560iiS lidar sensors (Figure 2), serial number 4040, for data acquisition.

The Riegl 1560iiS system (System ID: R15S) is a dual channel waveform processing airborne scanning system with a pulse repetition rate of 4MHz, or up to 3900m AGL at a pulse repetition rate of 540kHz. This improved range increases the system's productivity. The system also 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 VQ1560iiS (Eaton)
Terrain and Aircraft Scanner	Flying Height	3,201 m
	Recommended Ground Speed	120 kts
Scanner	Field of View	40°
	Scan Rate Setting Used	170 Hz
Laser	Laser Pulse Rate Used	1,130 kHz
	Multi Pulse in Air Mode	Yes
Coverage	Swath Width	2,330 m
	Line Spacing	0.791 m
Point Spacing and Density	Average Nominal Point Spacing	0.25 m
	Average Point Density	16 pts / m ²

Figure 2. Riegl VQ1560iiS 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

- Cessna Caravan (single-turboprop), Tail Number(s): N473TW

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 January 21, 2025 and January 22, 2025. Two aircraft lifts were completed. Accomplished lifts are listed below.

Lift	Start UTC	End UTC
01212025B (SN4040,N473TW)	1/21/2025 10:32:31 PM	1/21/2025 11:49:24 PM
01222025A (SN4040,N473TW)	1/22/2025 6:40:34 PM	1/22/2025 10:05:24 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 Trimble's RTX technology 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. Using data from a dedicated global network of tracking stations, POSPac PP-RTX uses this data to post-process the GNSS-Inertial Trajectory. The default processing reference frame for PP-RTX is WGS84. We then utilize proprietary software to convert the SBET to NAD83(2011) before we process the raw data to LAS.

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.

Each sensor is initially factory calibrated. Further adjustment is performed on each sensor by periodically flying boresight locations and using this data to update boresight values used in data processing. Various proprietary tools and methodologies are used during this process. Once all data has been processed with updated boresight values, FL to FL match is performed by using strip align and other proprietary tools/processes.

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	8.9
RiPROCESS	1.9.3.6
Microstation Connect	10.16.02.34
GeoCue	2020.1.22.3
Global Mapper	19.1;20.1
TerraModeler	23.013
TerraScan	23.025
TerraMatch	23.013
StripAlign	2.21

3.3. LAS Classification Scheme

The classification classes are determined by Lidar Base Specifications 2024 Rev. 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.
6	Buildings	Points falling on buildings, structures inside of water bodies, docks, and piers.
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.

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 1.5 feet/0.5 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 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 0.5-meter. 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.

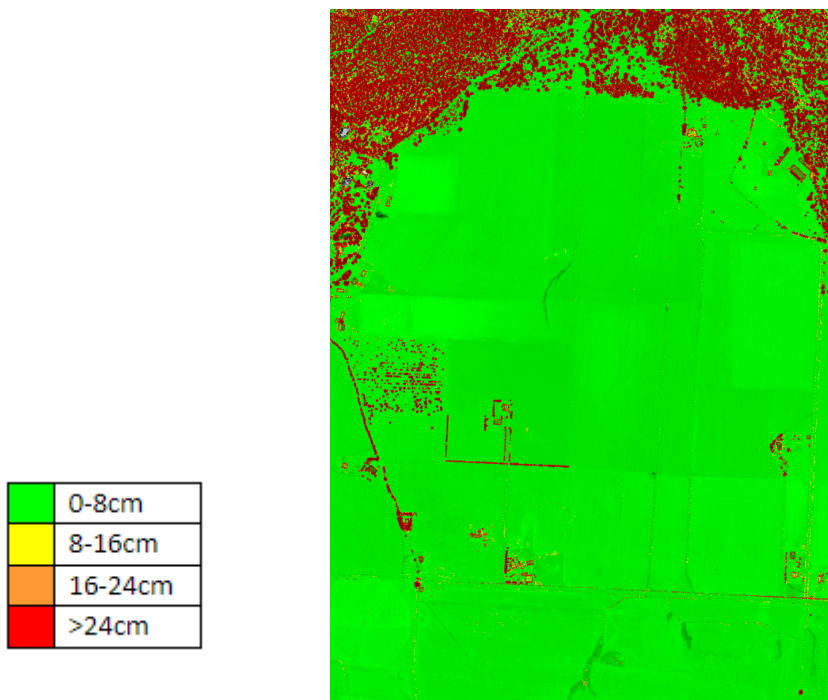
3.8. Maximum Surface Height Raster Processing

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 0.5-meter 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 0.5-meter. 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.

3.9. 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 1-meter 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.

Figure 4. Example of Swath Separation Raster



3.10. Point Density

The acquisition parameters were designed to acquire an average first-return density of 16 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 45.11 points/m² while the average ground classified density was 44.84 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 5 and 6.

CA LA PostWildfire Eaton C25 First Return Point Density

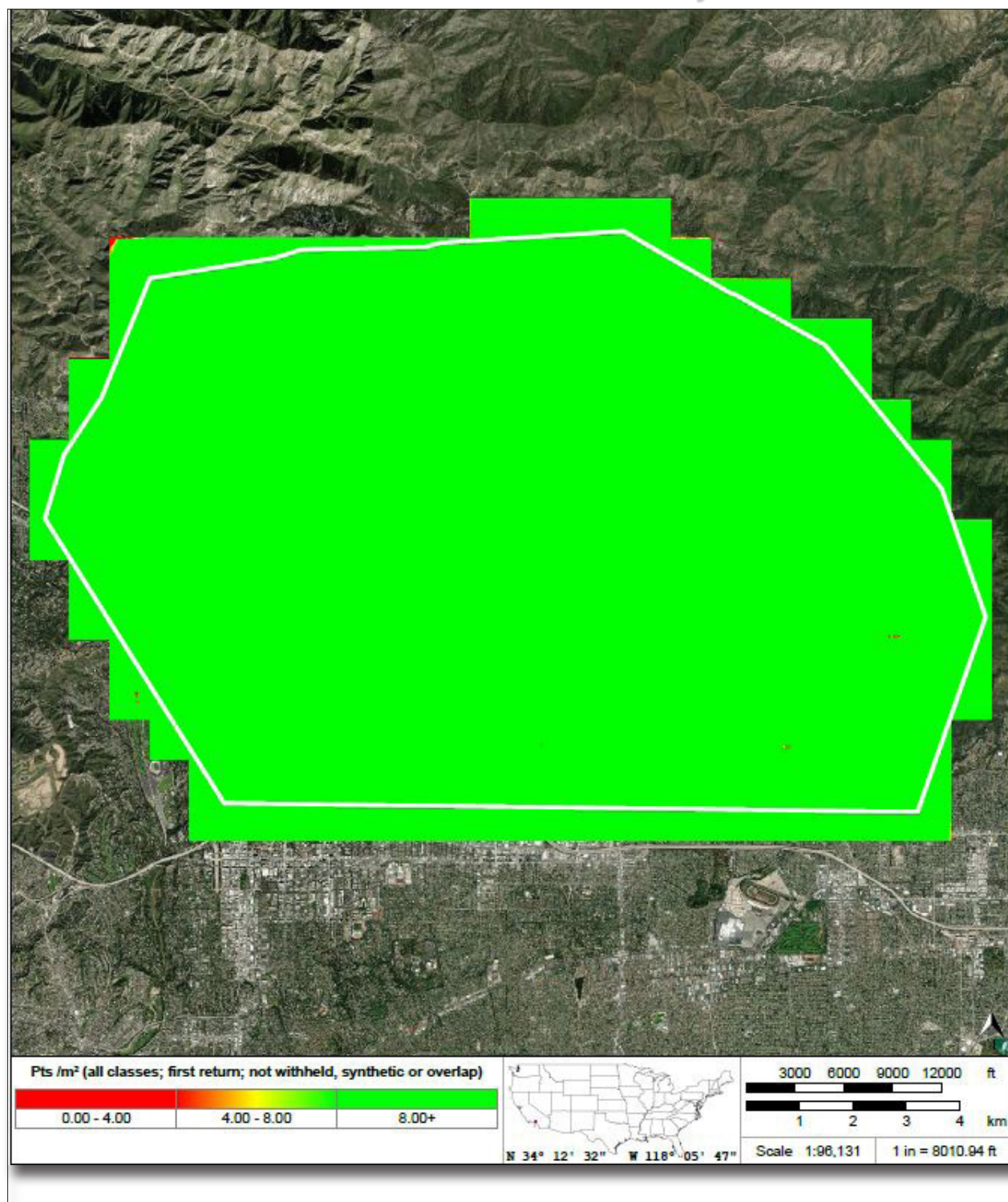


Figure 5. First Return Point Density

CA LA PostWildfire Eaton C25 Ground Point Density

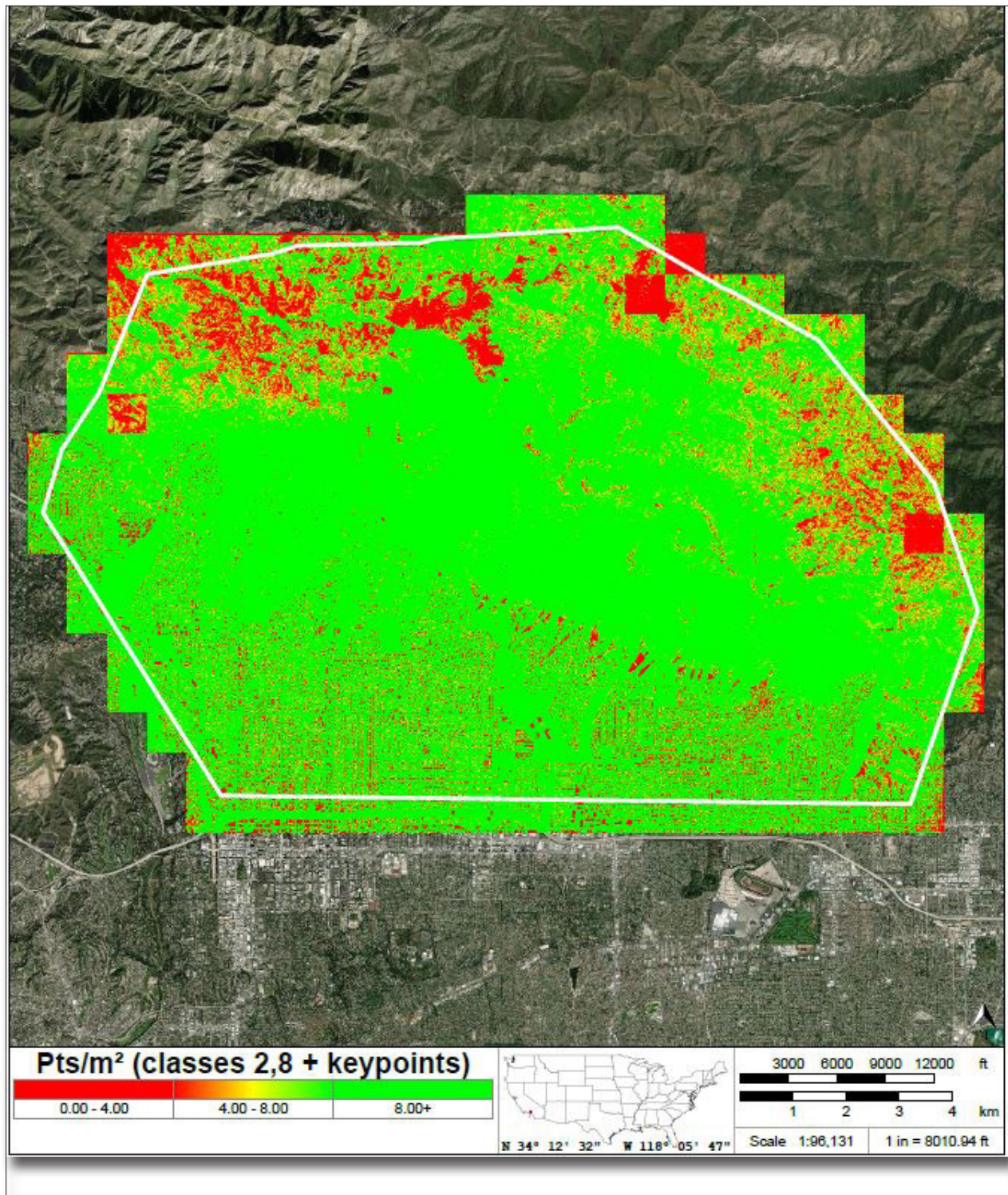


Figure 6. Ground First Return Point Density

CA LA PostWildfire Eaton C25 Tile Layout

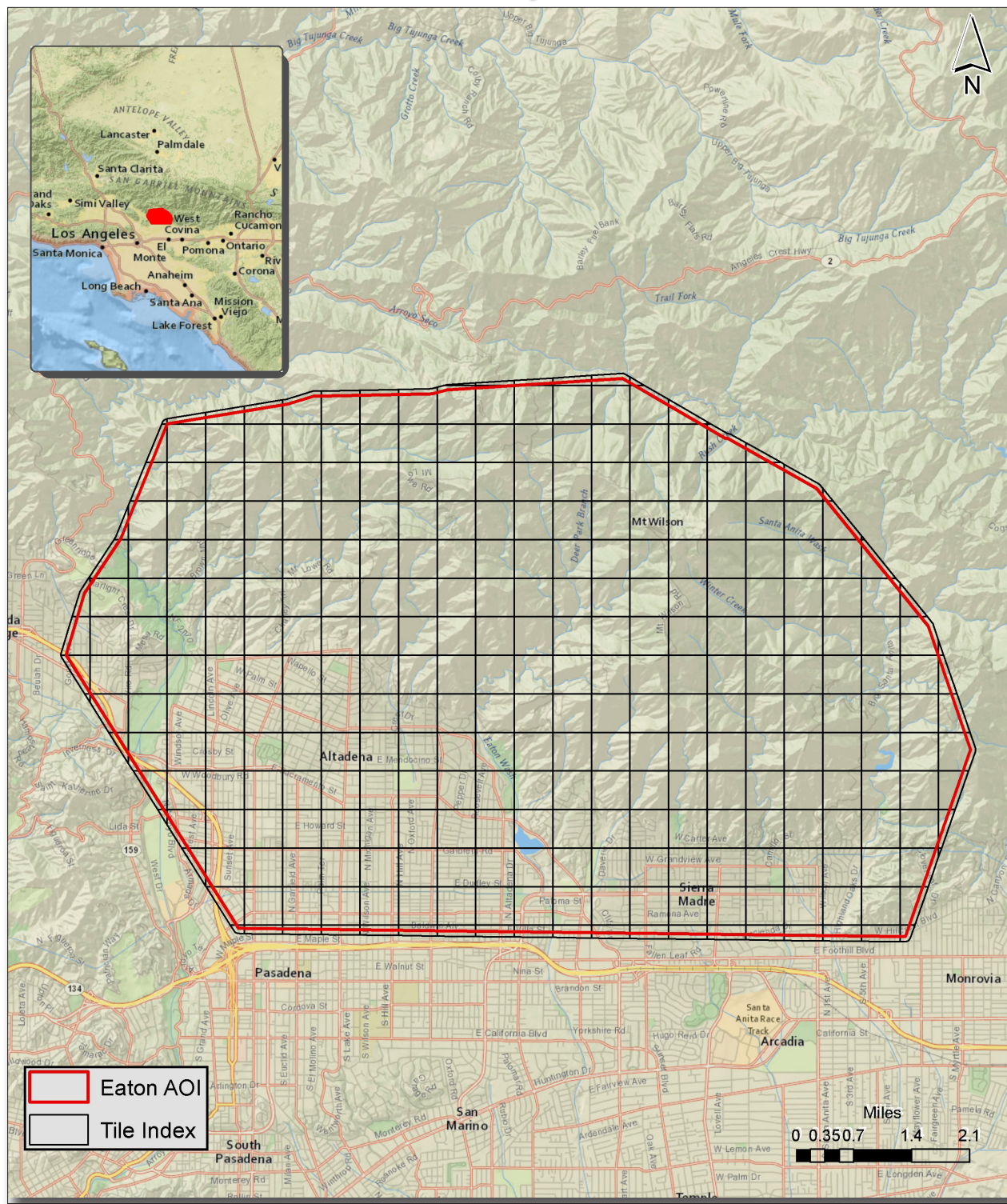


Figure 7. Lidar Tile Layout

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 8.

CA LA PostWildfire Eaton C25 Lidar Coverage

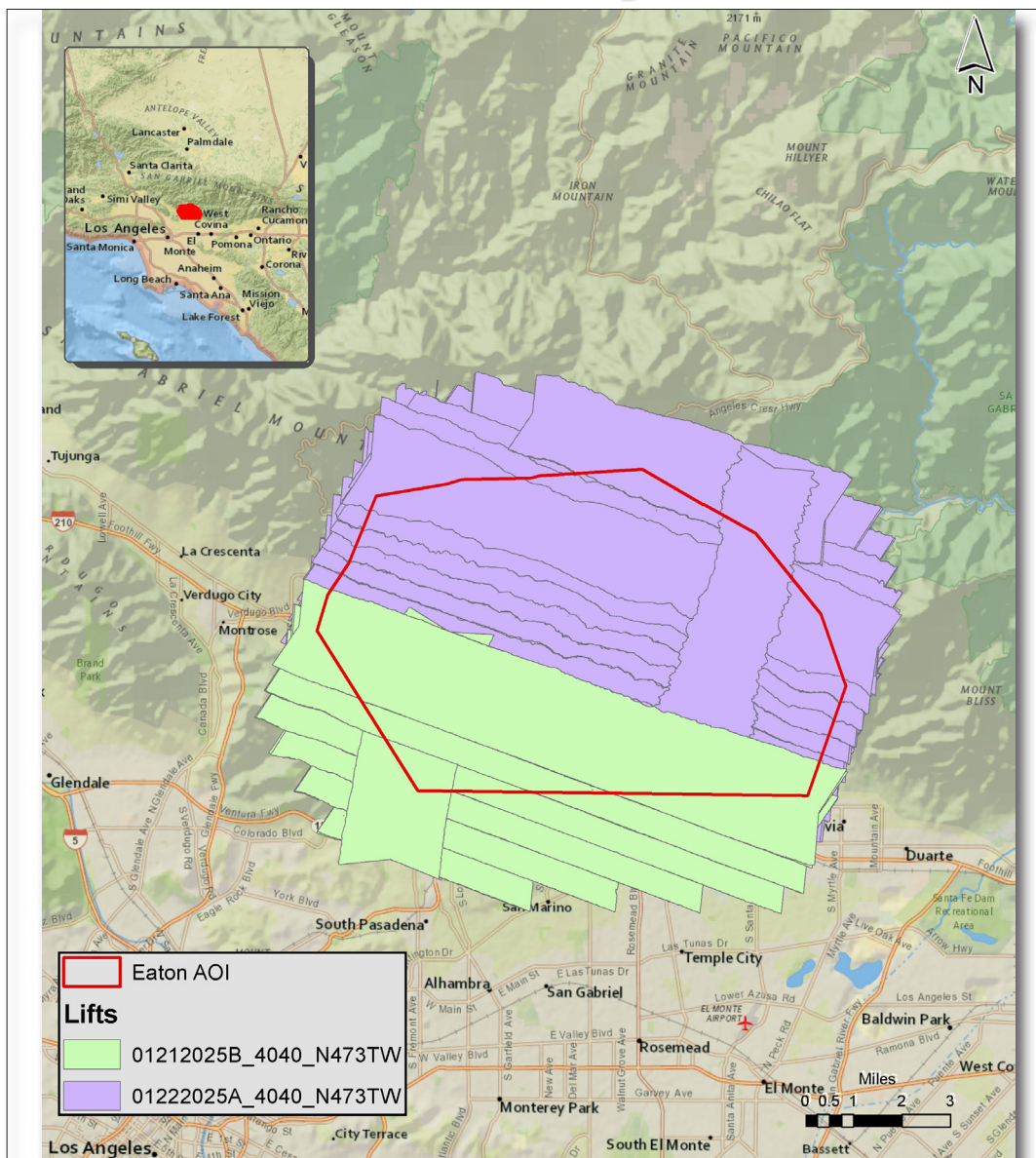


Figure 8. Lidar Coverage

5. Accuracy Testing

5.1. Calibration Control Point Testing

Figure 9 shows the location of each bare earth calibration point for the project area. TerraScan was used to perform a quality assurance check using the lidar bare earth calibration points. The results of the surface calibration are not an independent assessment of the accuracy of these project deliverables, but the statistical results do provide additional feedback as to the overall quality of the elevation surface.

5.2. Point Cloud Testing

The project specifications require that only Non-Vegetated Vertical Accuracy (NVA) be computed for raw lidar point cloud swath files. The required accuracy (ACCz) is: 19.6 cm at a 95% confidence level, derived according to NSSDA, i.e., based on RMSE of 10 cm in the “bare earth” and “urban” land cover classes. The NVA was tested with 16 checkpoints located in bare earth and urban (non-vegetated) areas. These check points were not used in the calibration or post processing of the lidar point cloud data. The checkpoints were distributed throughout the project area and were surveyed using GPS techniques. See survey report for additional survey methodologies.

Elevations from the unclassified lidar surface were measured for the x,y location of each check point. Elevations interpolated from the lidar surface were then compared to the elevation values of the surveyed control points. AccuracyZ has been tested to meet 19.6 cm or better Non-Vegetated Vertical Accuracy at 95% confidence level using $RMSE(z) \times 1.9600$ as defined by the National Standards for Spatial Data Accuracy (NSSDA); assessed and reported using National Digital Elevation Program (NDEP)/ASPRS Guidelines.

5.3. Digital Elevation Model (DEM) Testing

The project specifications require the accuracy (ACCz) of the derived DEM be calculated and reported in two ways:

1. The required NVA is: 19.6 cm at a 95% confidence level, derived according to NSSDA, i.e., based on RMSE of 10 cm in the “bare earth” and “urban” land cover classes. This is a required accuracy. The NVA was tested with 16 checkpoints located in bare earth and urban (non-vegetated) areas. See Figure 10.
2. Vegetated Vertical Accuracy (VVA): VVA shall be reported for “brushlands/low trees” and “tall weeds/crops” land cover classes. The target VVA is: 29.4 cm at the 95th percentile, derived according to ASPRS Guidelines, Vertical Accuracy Reporting for lidar Data, i.e., based on the 95th percentile error in all vegetated land cover classes combined. This is a target accuracy. The VVA was tested with 12 checkpoints located in tall weeds/crops and brushlands/low trees (vegetated) areas. The checkpoints were distributed throughout the project area. See Figure 11.

AccuracyZ has been tested to meet 19.6 cm or better Non-Vegetated Vertical Accuracy at 95% confidence level using $RMSE(z) \times 1.9600$ as defined by the National Standards for Spatial Data Accuracy (NSSDA); assessed and reported using National Digital Elevation Program (NDEP)/ASRPS Guidelines.

A brief summary of results are listed below.

Table 4. NVA and VVA Accuracy Results

	Target	Measured	Point Count
Raw NVA	0.196 m	0.072 m	16
NVA	0.196 m	0.071 m	16
VVA	0.294 m	0.29 m	12

CA LA PostWildfire Eaton C25 Calibration Points



Figure 9. Calibration Control Point Locations

CA LA PostWildfire Eaton C25 NVA Points



Figure 10. QC Checkpoint Locations - NVA

CA LA PostWildfire Eaton C25 VVA Points



Figure 11. QC Checkpoint Locations - VVA

6. Geometric Accuracy

6.1. Horizontal Accuracy

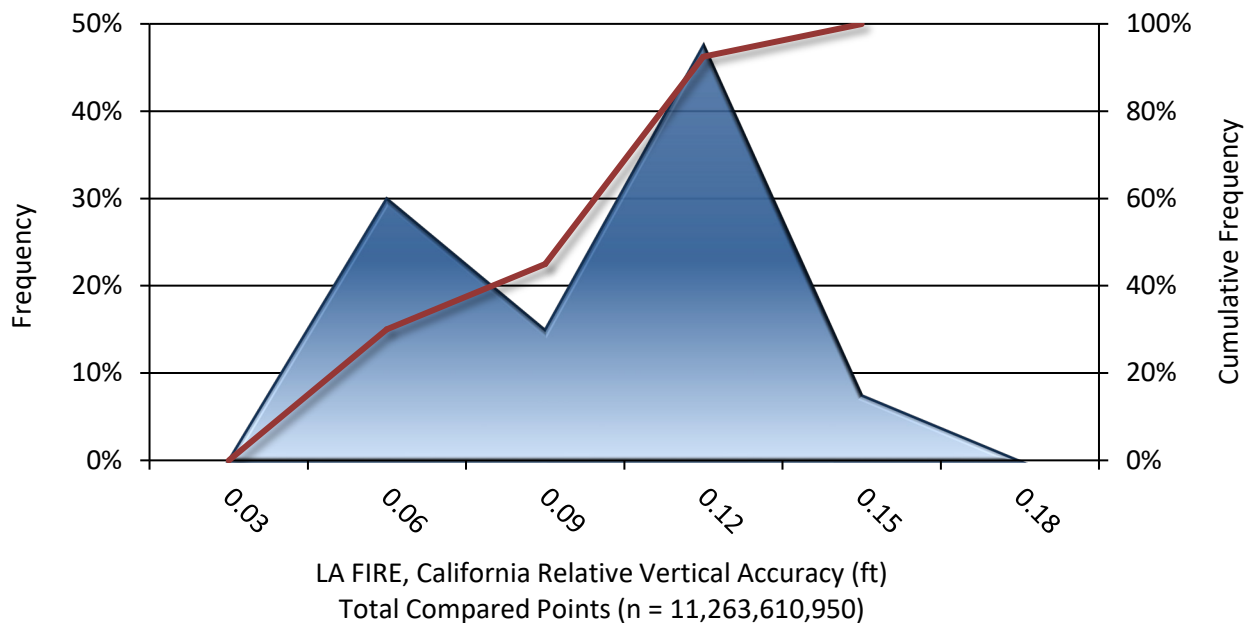
Lidar horizontal accuracy is a function of Global Navigation Satellite System (GNSS) derived positional error, flying altitude, and INS derived attitude error. The obtained $RMSE_r$ value is multiplied by a conversion factor of 1.7308 to yield the horizontal component of the National Standards for Spatial 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 3,201 meters, an IMU error of 0.002 decimal degrees, and a GNSS positional error of 0.019 meters, this project was compiled to meet 0.2 meter horizontal accuracy at the 95% confidence level. A summary is shown below.

Horizontal Accuracy	
$RMSE_r$	0.66 ft
	0.2 m
ACC_r	1.14 ft
	0.35 m

6.2. Relative Vertical Accuracy (Interswath Accuracy)

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 CA_LA_PostWildfire_Eaton_C25 project was 0.079 feet (0.024 meters). A summary is shown below.

Relative Vertical Accuracy	
Sample	40 flight line surfaces
Average	0.079 ft
	0.024 m
Median	0.096 ft
	0.029 m
RMSE	0.090 ft
	0.027 m
Standard Deviation (1 σ)	0.029 ft
	0.009 m
1.96 σ	0.057 ft
	0.017m



6.3. Intrawath Precision (Smooth Surface Precision)

Intrawath 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:

$$\text{Precision} = \text{Range} - (\text{Slope} \times \text{Cellsize} \times 1.414)$$

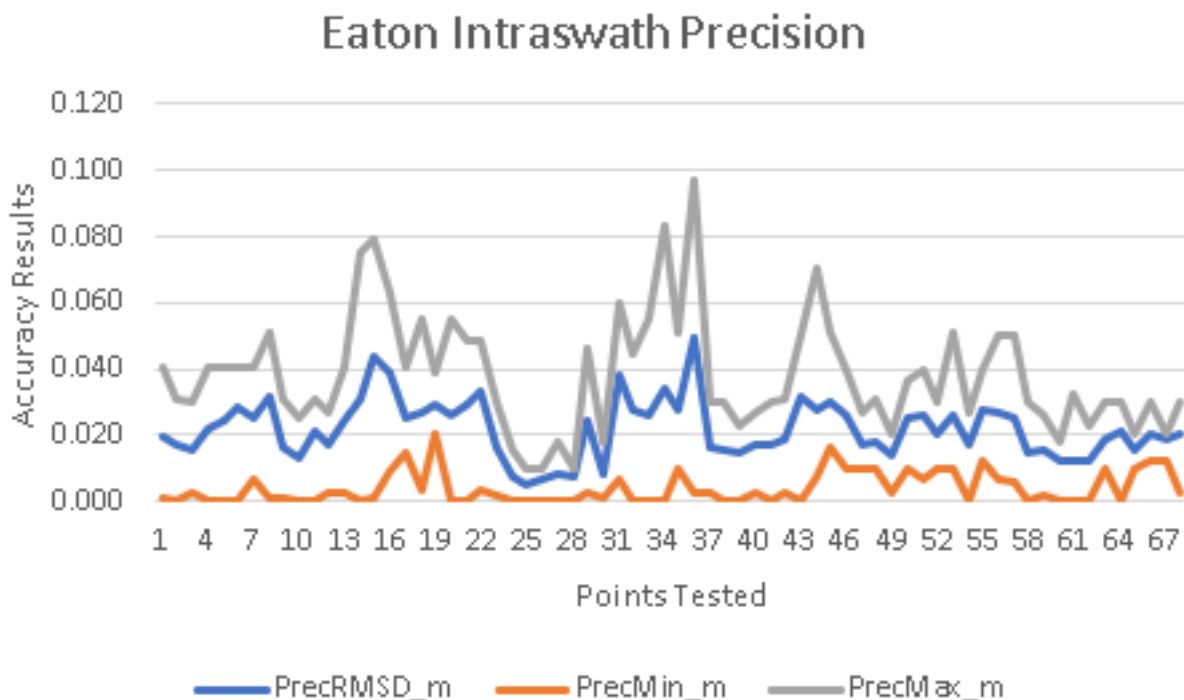
Range – Is the difference between the highest and lowest lidar points in each cell

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 2.1 cm, minimum slope-corrected range to be 0.39 cm, and the maximum slope-corrected range to be 3.8 cm.

Table 5. Intrawath Accuracy Results



Project Report Appendices

The following section contains the appendices as listed in the CA LA Post Wildfire Eaton C25 Lidar Project Report.

Appendix A

Flight Logs

[illegible]

Line Name	Line Length [nm]	Flying Alt. [ft MSL]	Date	Mission #	Sensor SN#	Op	Time Stamp	Accept/Refly? (office QC)	Refly Date & Mission, & SN #	Refly Timestamp	Notes (Direction, Atmos. Conditions, Speed, PR, Errors)
1	11.36	6991	20250121	A	4040	LH	184953	In QC			W
2	11.75	7021	20250121	A	4040	LH	185723	In QC			E
3	11.87	6995	20250121	A	4040	LH	190520	In QC			W
4	12	6962	20250121	A	4040	LH	191319	In QC			E
5	12.22	6890	20250121	A	4040	LH	192058	In QC			W
6	12.46	6850	20250121	A	4040	LH	192837	In QC			E
7	12.72	6841	20250121	A	4040	LH	193558	In QC			W
8	12.92	6818	20250121	A	4040	LH	194414	In QC			E
9	13.12	6729	20250121	A	4040	LH	195109	In QC			W
10	13.39	6699	20250121	A	4040	LH	195923	In QC			E
11	13.75	6693	20250121	A	4040	LH	200638	In QC			W
12	14.14	6627	20250121	A	4040	LH	201510	In QC			E
13	14.23	6430	20250121	A	4040	LH	202241	In QC			W
14	14.31	6387	20250121	A	4040	LH	203123	In QC			E
15	14.29	6358	20250121	A	4040	LH	203854	In QC			W
16	14.2	6309	20250121	A	4040	LH	204715	In QC			E
17	14.1	6289	20250121	A	4040	LH	205515	In QC			W
18	14	6240	20250121	A	4040	LH	210350	In QC			E
19	13.9	6237	20250121	A	4040	LH	211156	In QC			W
20	13.79	6237	20250121	A	4040	LH	203031	In QC			E, first attempt aborted for traffic, reflew
21	13.65	6237	20250121	A	4040	LH	213800	In QC			W
22	13.31	6194	20250121	A	4040	LH	214622	In QC			E
23	12.76	6194	20250121	A	4040	LH	215356	In QC			W
24	4.35	6194	20250121	A	4040	LH	220418	In QC			E
25	3.11	6214	20250121	A	4040	LH	220731	In QC			W, crosstie 221022

Appendix B

SBET and POSPac Reports

General Information

Mission Information

Project name	01212025B_4040
Processing date	2025-01-22 02:47:45
Mission date	2025-01-21 22:26:50
Mission duration	01:34:56.037
Processing mode	IN-Fusion PP-RTX

Rover Hardware Information

Product	POS AV 610 VER6 HW2.5-12
Serial number	S/N10451
IMU type	57
Receiver type	BD982
Antenna type	AV59

Project File List

Rover Data Files

File name	File type
250121_222633_INS-GPS_1.raw	POS Data

Input Files

File Name	File Type
BRDC00IGN_R_20250210000_01D_MN.rnx	GPS, GLONASS, GALILEO Broadcast Ephemeris
Ephm0210.25g	GLONASS Broadcast Ephemeris
Ephm0210.25n	GPS Broadcast Ephemeris
Ephm0220.25g	GLONASS Broadcast Ephemeris
Ephm0220.25n	GPS Broadcast Ephemeris

Output Files

Filename	File type
sbt_01212025B_4040.out	SBET Trajectory File

Rover Data Summary

First raw data file	250121_222633_INS-GPS_1.raw		
Last raw data file	250121_222633_INS-GPS_1.raw		
Start GPS week	2350		
Start time	253591.728 (1/21/2025 10:26:31 PM)		
End time	259287.765 (1/22/2025 12:01:27 AM)		
Start of fine alignment	253631.545 (1/21/2025 10:27:11 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)	-0.034	-0.010	-0.374
Gimbal to IMU mounting angles (deg)	0.000	0.000	0.000
Gimbal to Primary GNSS lever arm (m)	0.000	0.000	-0.900
Gimbal to Primary GNSS lever arm std dev (m)	-1.000		
Aircraft to Reference mounting angles (deg)	0.000	0.000	0.000

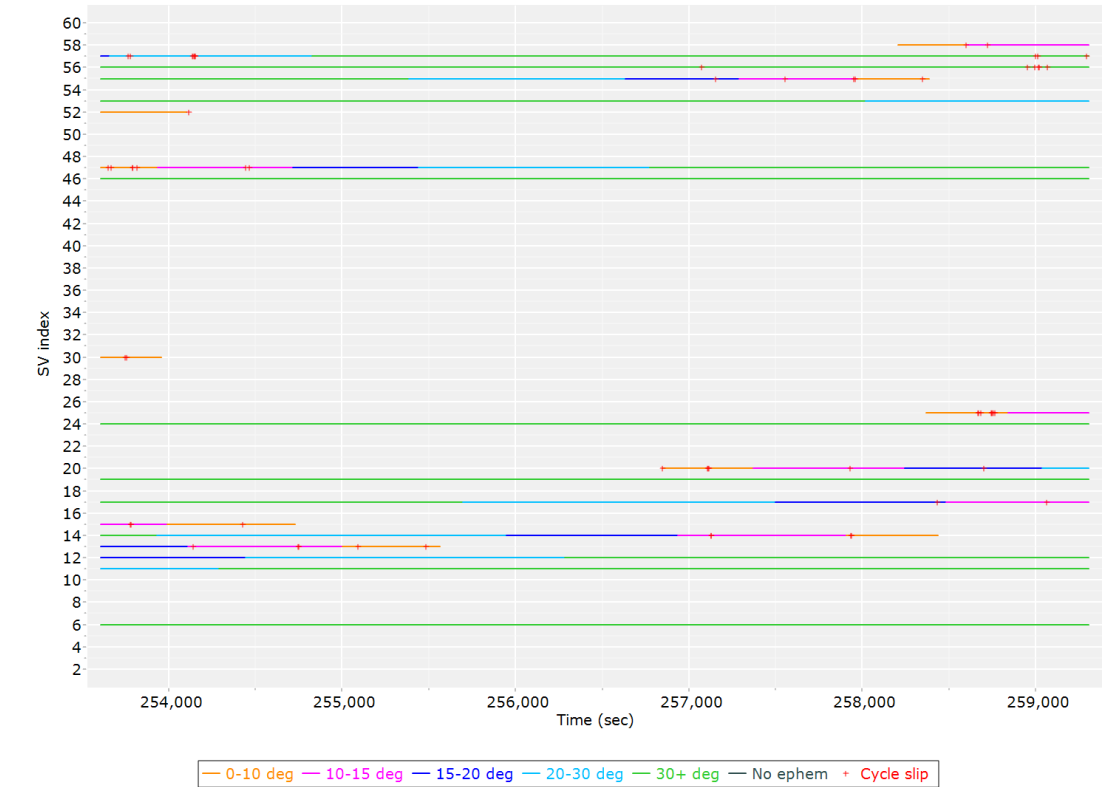
Rover Data QC

Raw IMU Import QC Summary

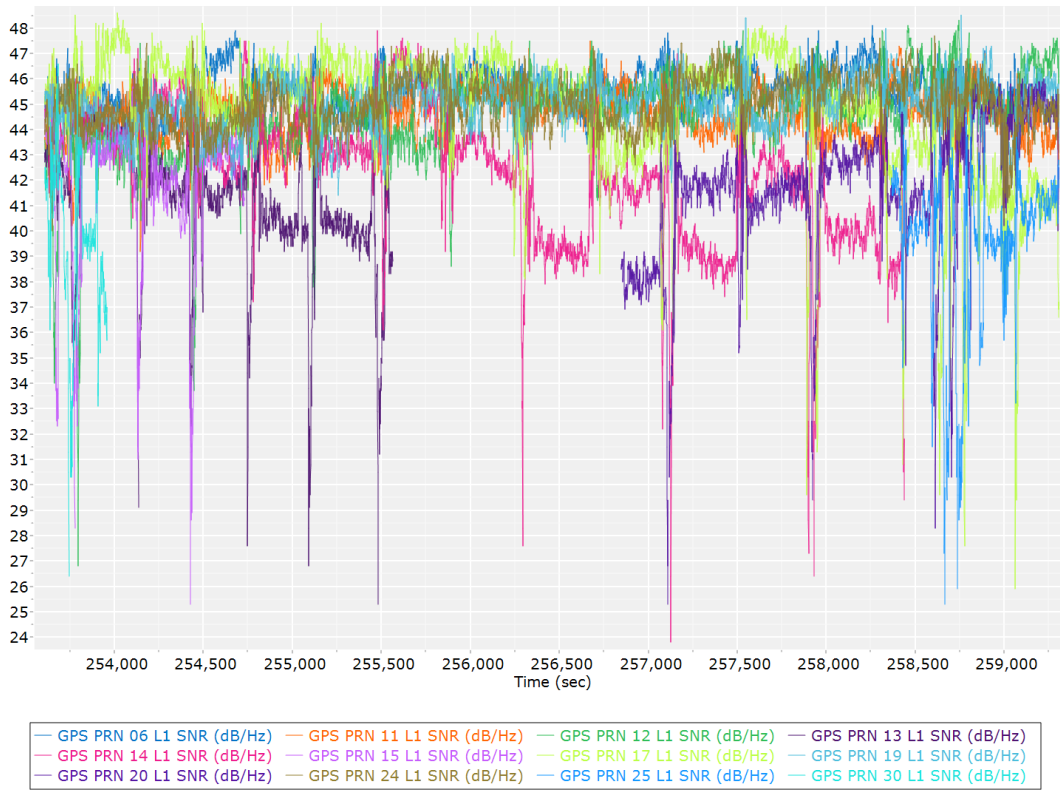
IMU data input file	imu_Mission 1.dat
IMU data check log file	imudt_01212025B_4040.log
IMU Records Processed	1139135
Termination Status	Normal
IMU Anomalies	0

Primary Observables & Satellite Data

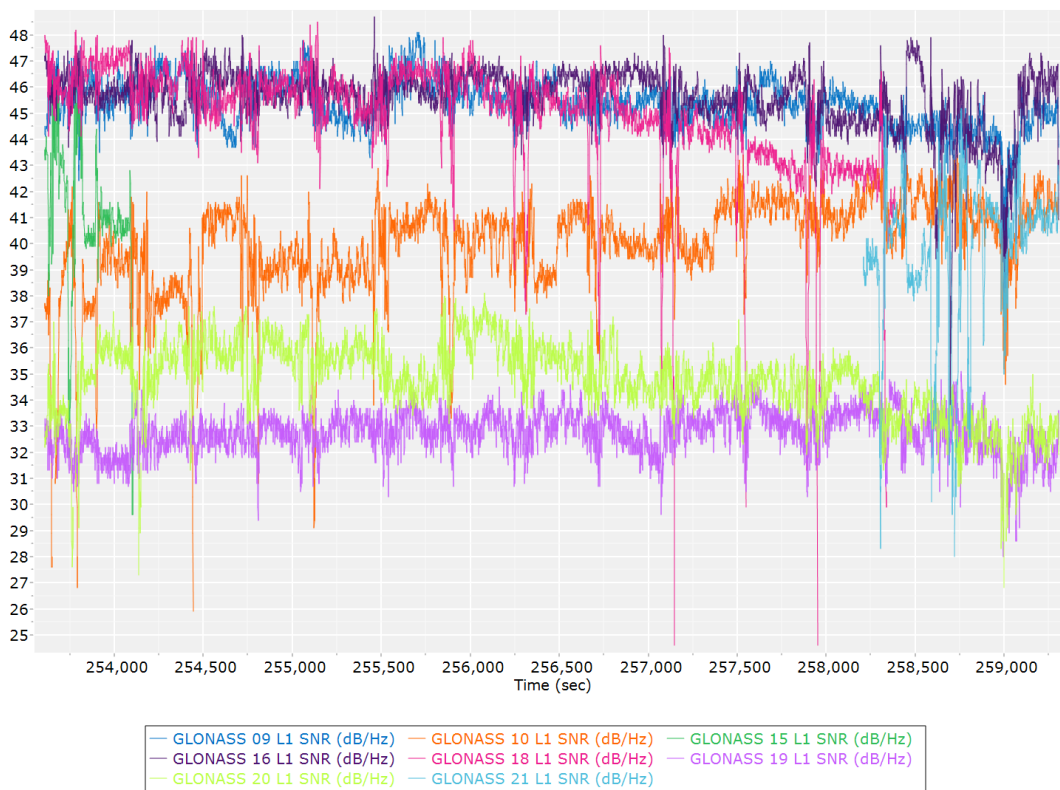
GPS/GLONASS L1 Satellite Lock/Elevation



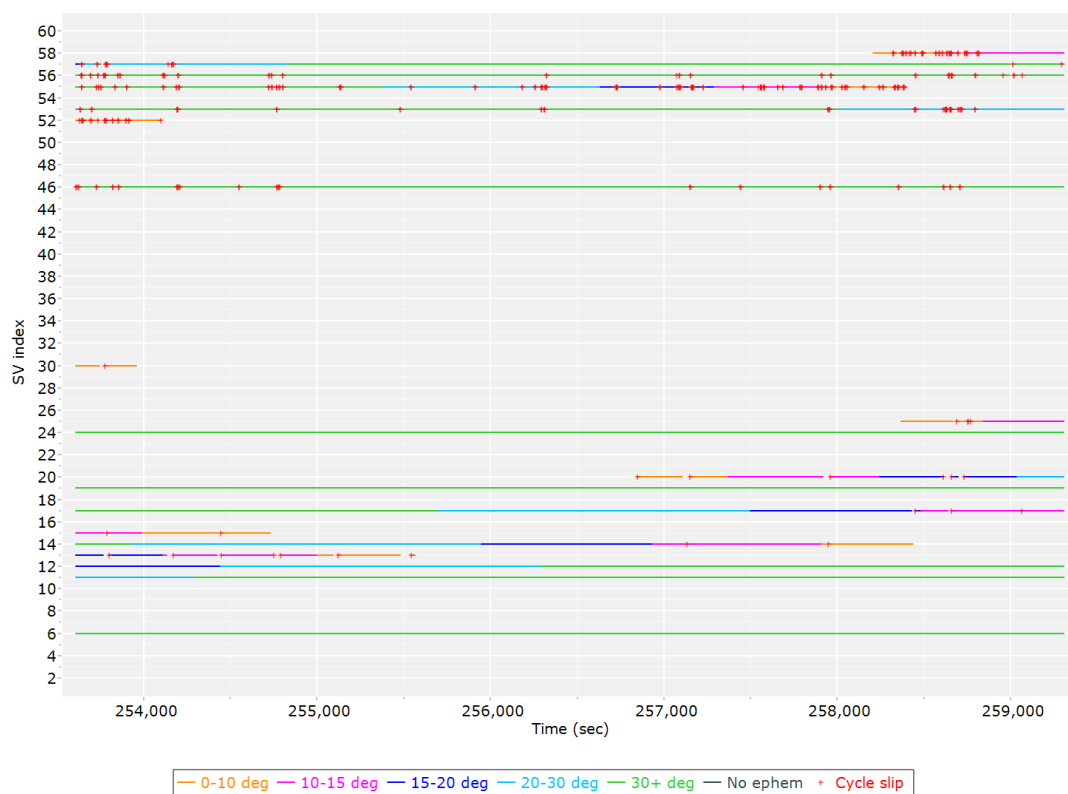
GPS L1 SNR



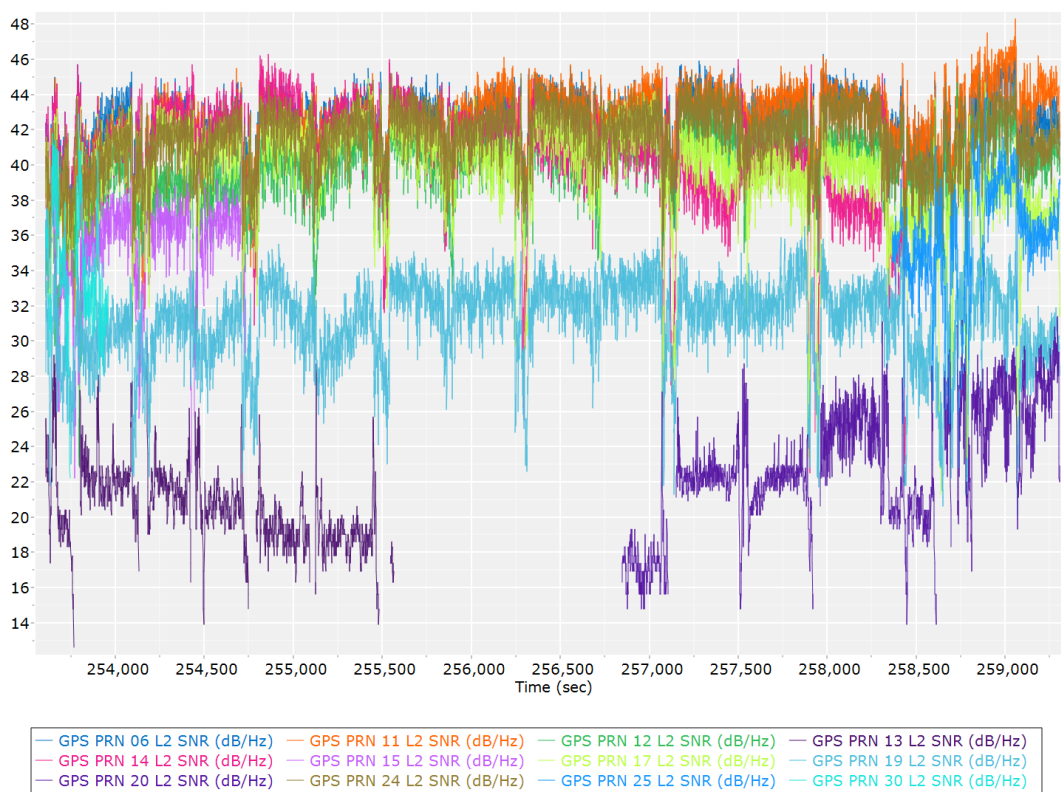
GLONASS L1 SNR



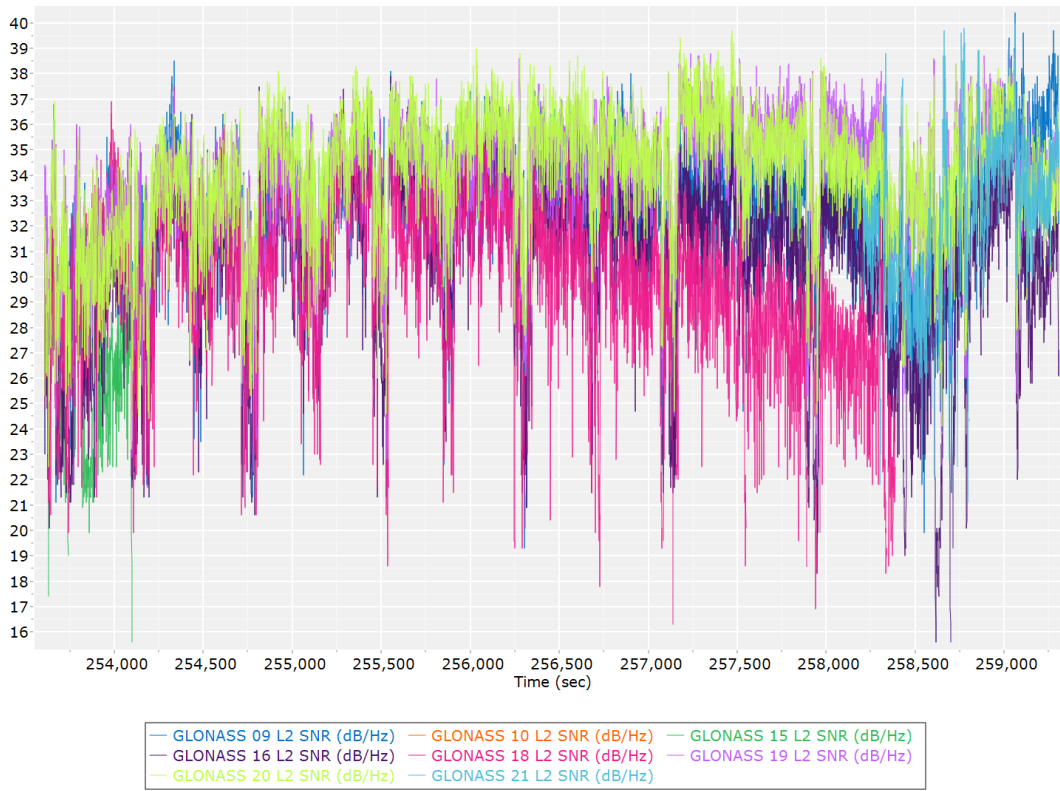
GPS/GLONASS L2 Satellite Lock/Elevation



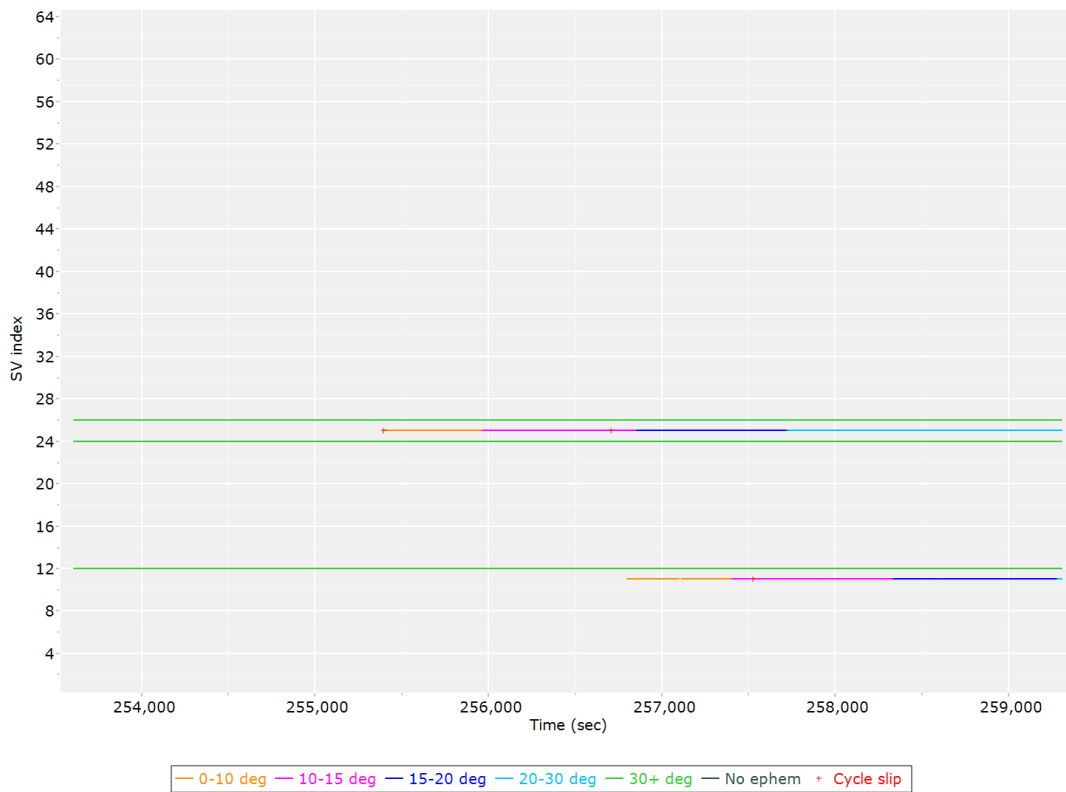
GPS L2 SNR



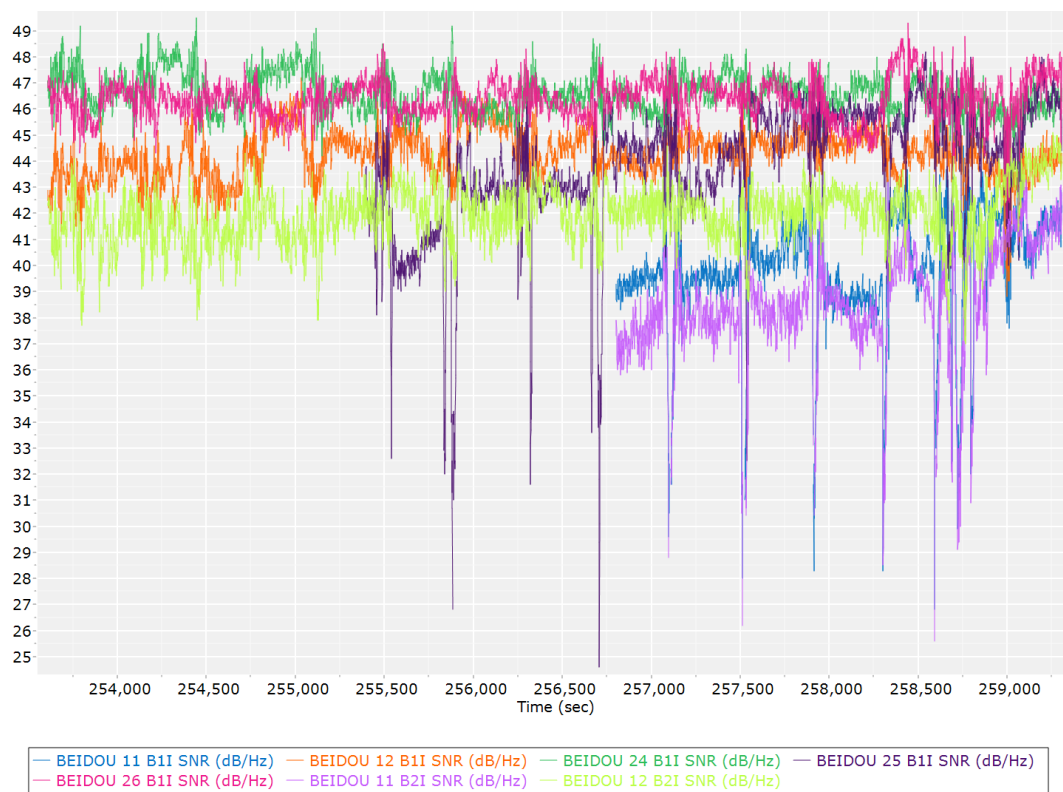
GLONASS L2 SNR



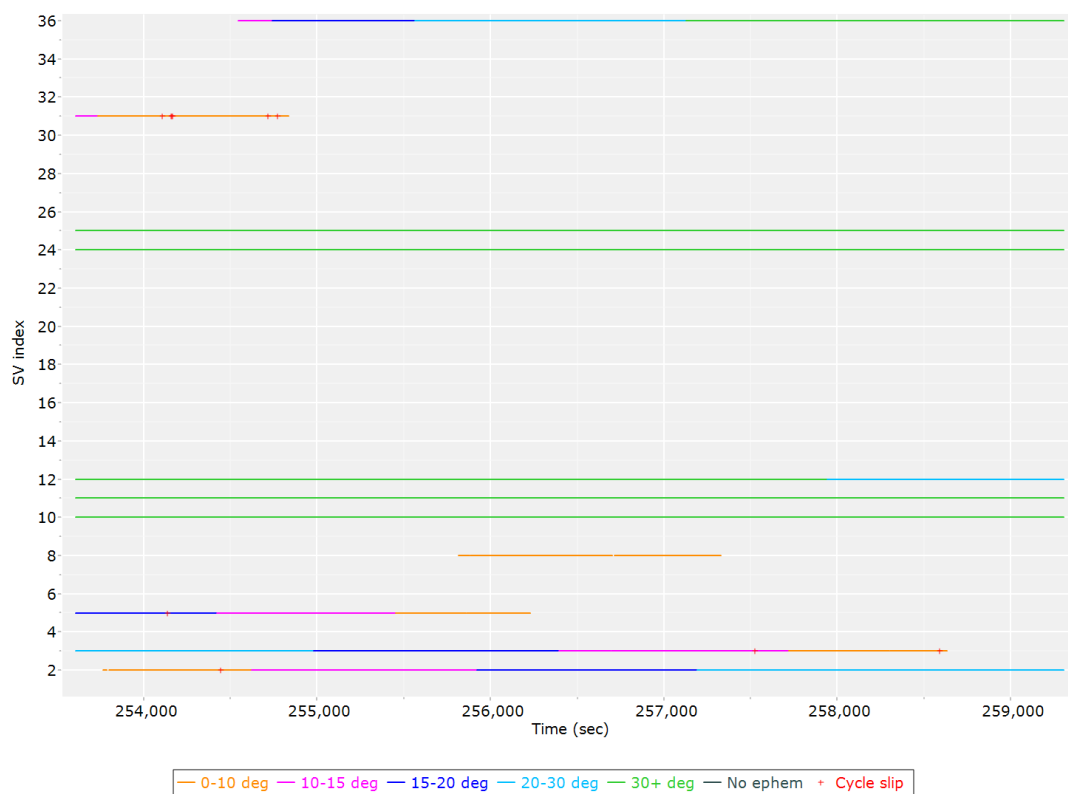
BEIDOU Satellite Lock/Elevation



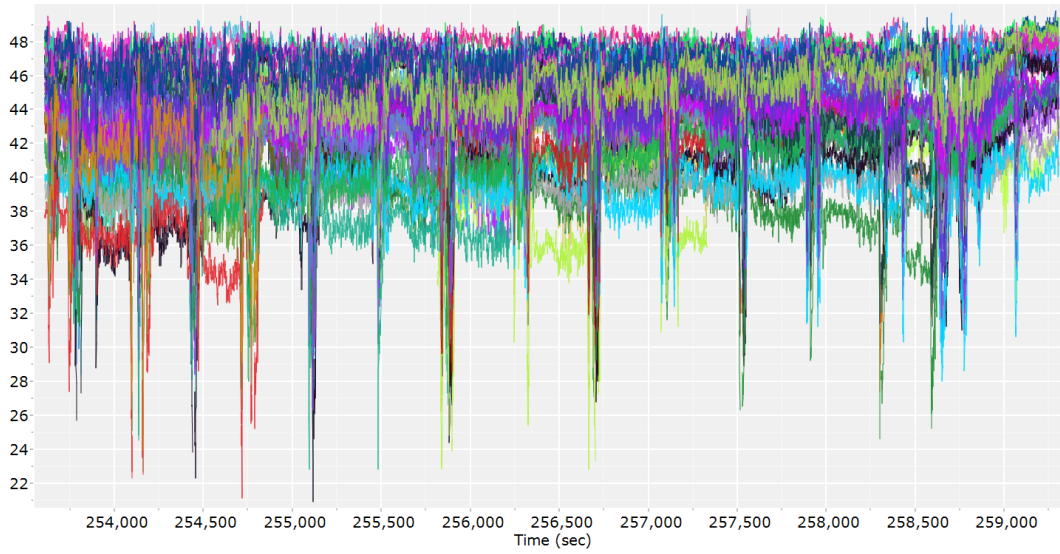
BEIDOU SNR



GALILEO Satellite Lock/Elevation



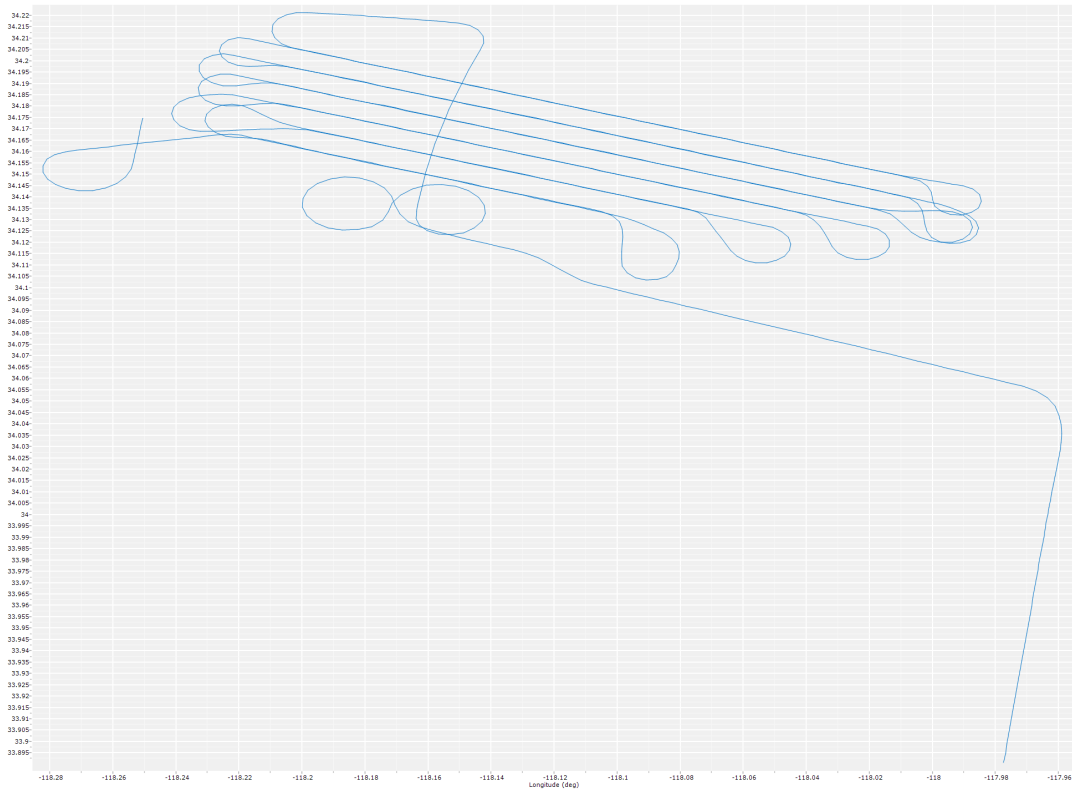
GALILEO SNR



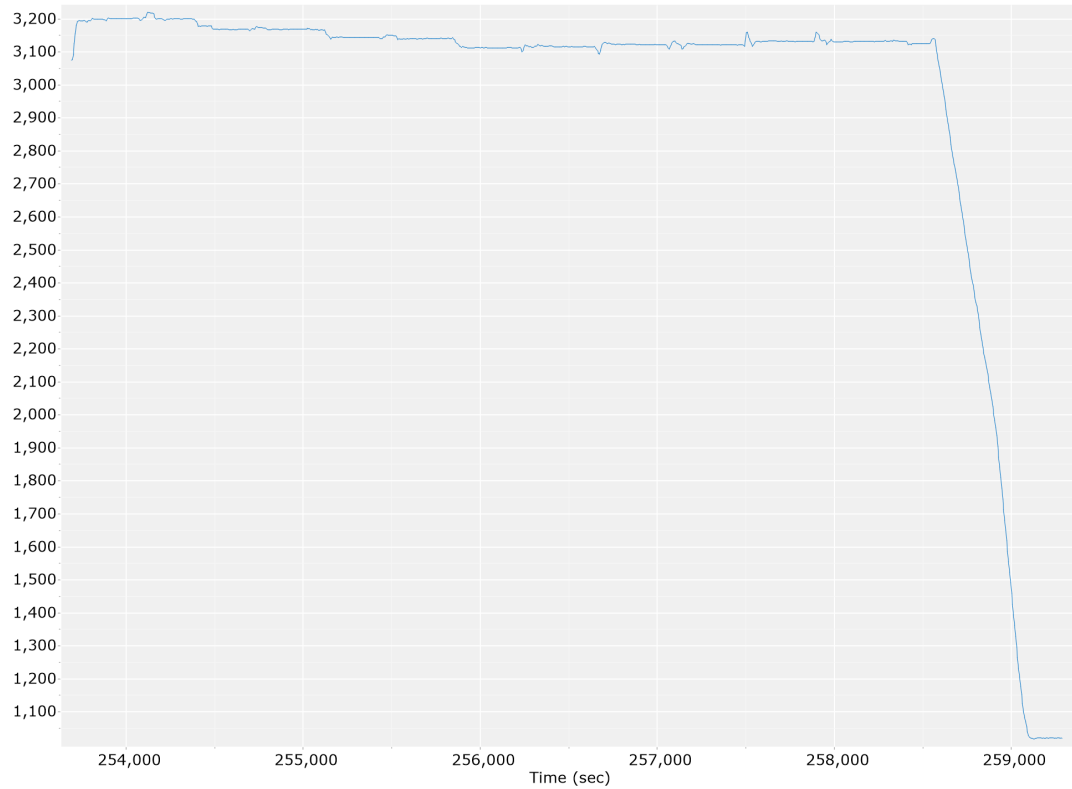
— GALILEO 02 E1CBOC SNR (dB/Hz)	— GALILEO 03 E1CBOC SNR (dB/Hz)	— GALILEO 05 E1CBOC SNR (dB/Hz)
— GALILEO 08 E1CBOC SNR (dB/Hz)	— GALILEO 10 E1CBOC SNR (dB/Hz)	— GALILEO 11 E1CBOC SNR (dB/Hz)
— GALILEO 12 E1CBOC SNR (dB/Hz)	— GALILEO 24 E1CBOC SNR (dB/Hz)	— GALILEO 25 E1CBOC SNR (dB/Hz)
— GALILEO 31 E1CBOC SNR (dB/Hz)	— GALILEO 36 E1CBOC SNR (dB/Hz)	— GALILEO 02 E5A SNR (dB/Hz)
— GALILEO 03 E5A SNR (dB/Hz)	— GALILEO 05 E5A SNR (dB/Hz)	— GALILEO 08 E5A SNR (dB/Hz)
— GALILEO 10 E5A SNR (dB/Hz)	— GALILEO 11 E5A SNR (dB/Hz)	— GALILEO 12 E5A SNR (dB/Hz)
— GALILEO 24 E5A SNR (dB/Hz)	— GALILEO 25 E5A SNR (dB/Hz)	— GALILEO 31 E5A SNR (dB/Hz)
— GALILEO 36 E5A SNR (dB/Hz)	— GALILEO 02 E5B SNR (dB/Hz)	— GALILEO 03 E5B SNR (dB/Hz)
— GALILEO 05 E5B SNR (dB/Hz)	— GALILEO 08 E5B SNR (dB/Hz)	— GALILEO 10 E5B SNR (dB/Hz)
— GALILEO 11 E5B SNR (dB/Hz)	— GALILEO 12 E5B SNR (dB/Hz)	— GALILEO 24 E5B SNR (dB/Hz)

Smoothed Trajectory Information

Top View



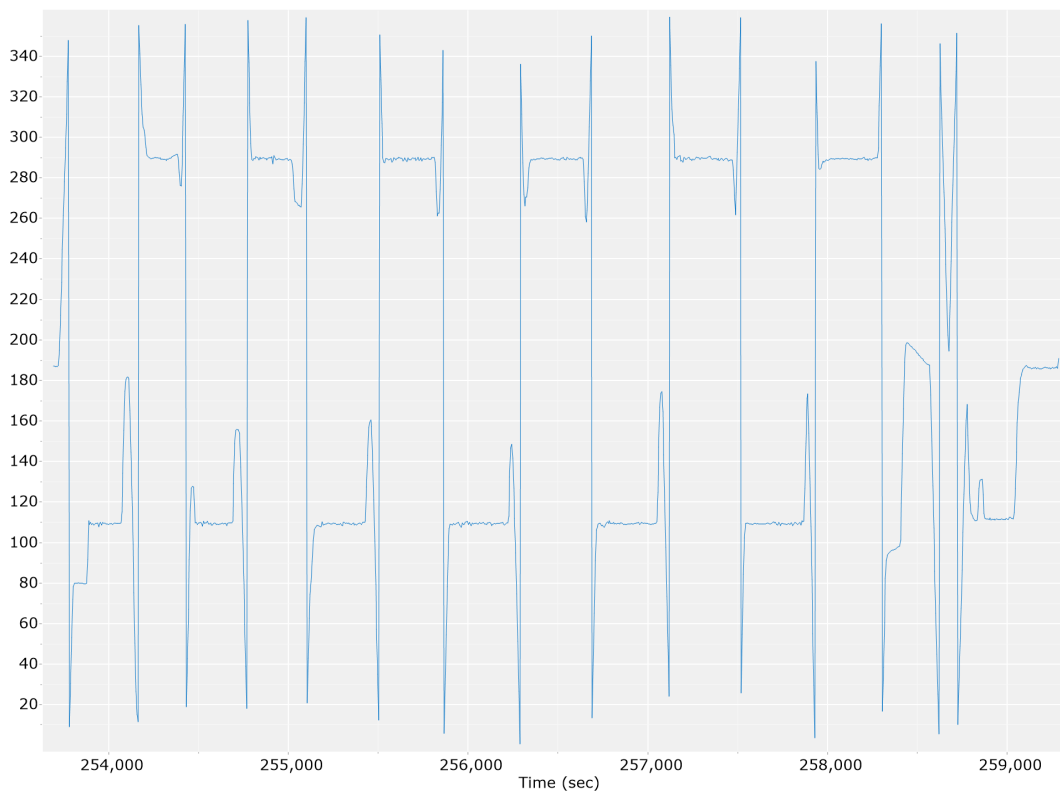
Altitude



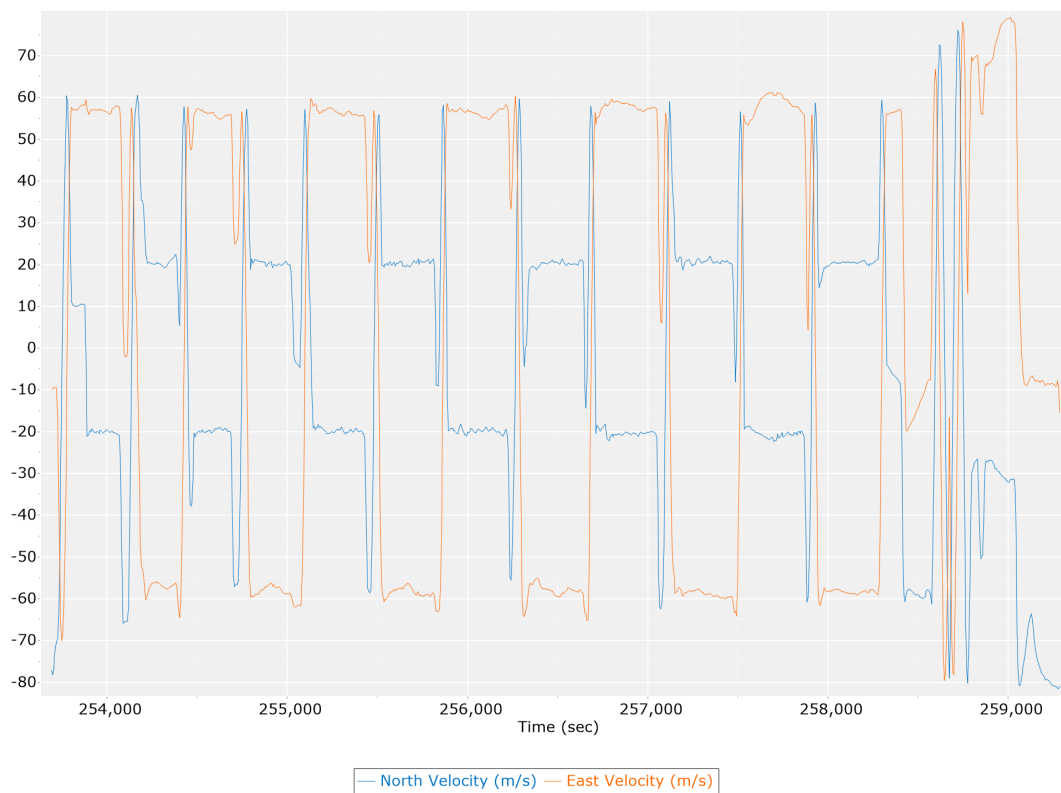
Roll/Pitch



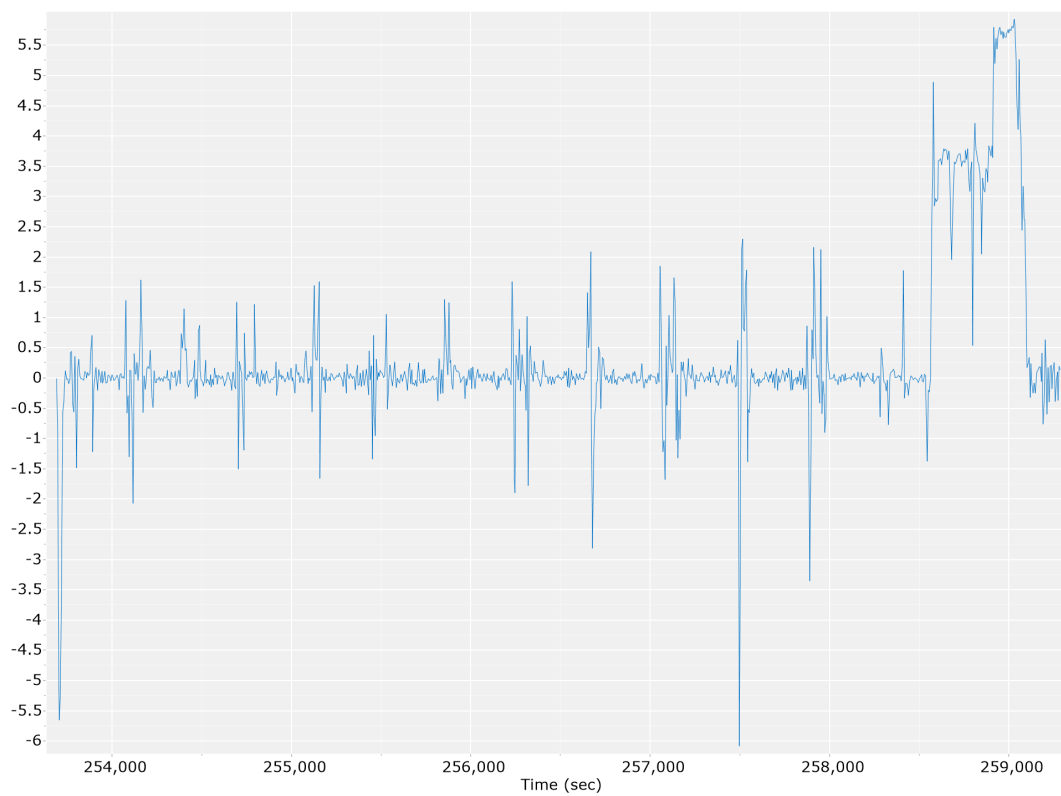
Heading



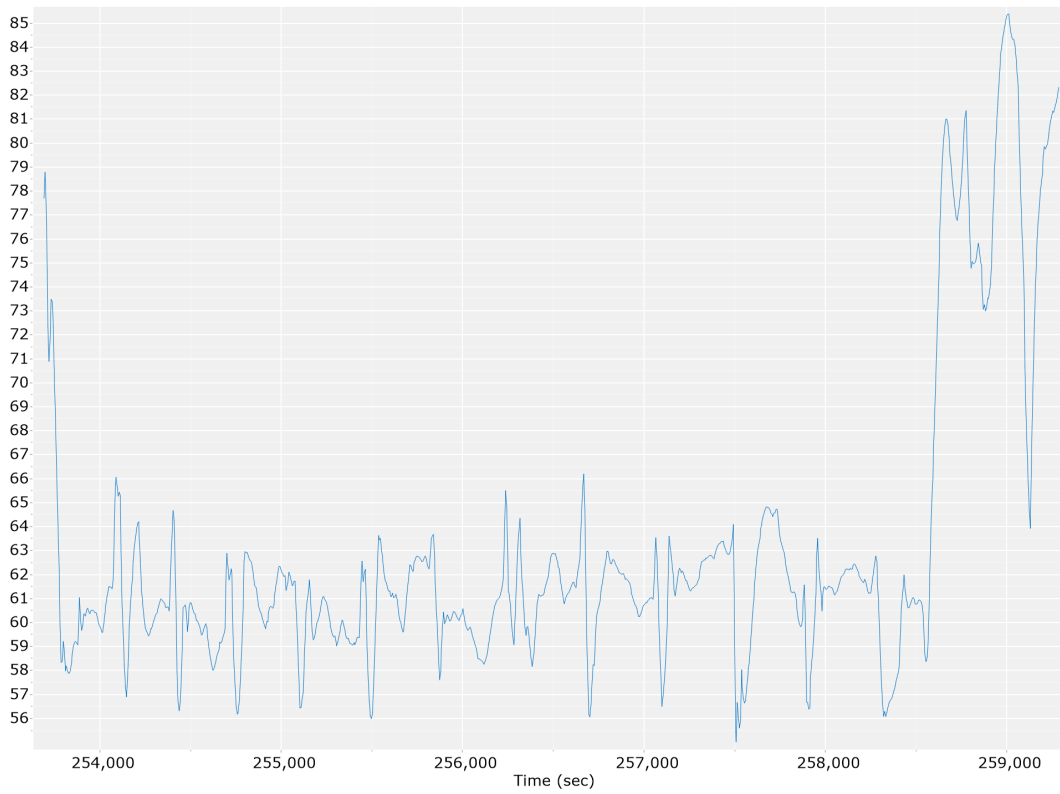
North/East Velocity



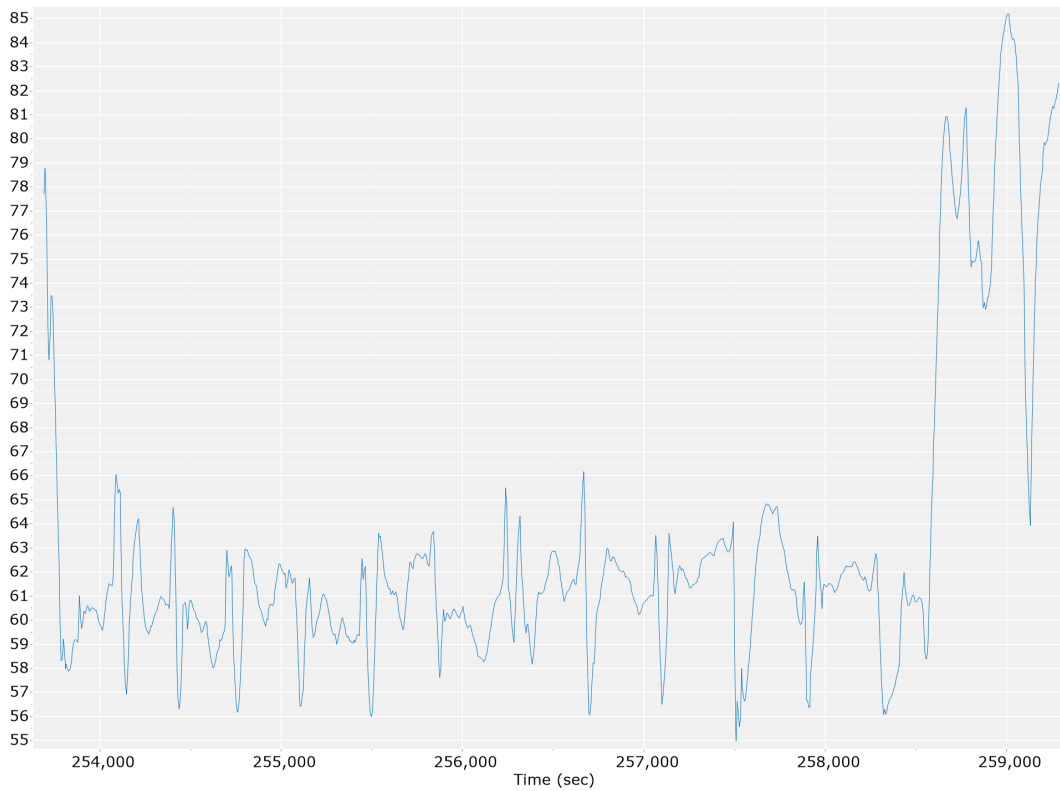
Down Velocity



Total Speed



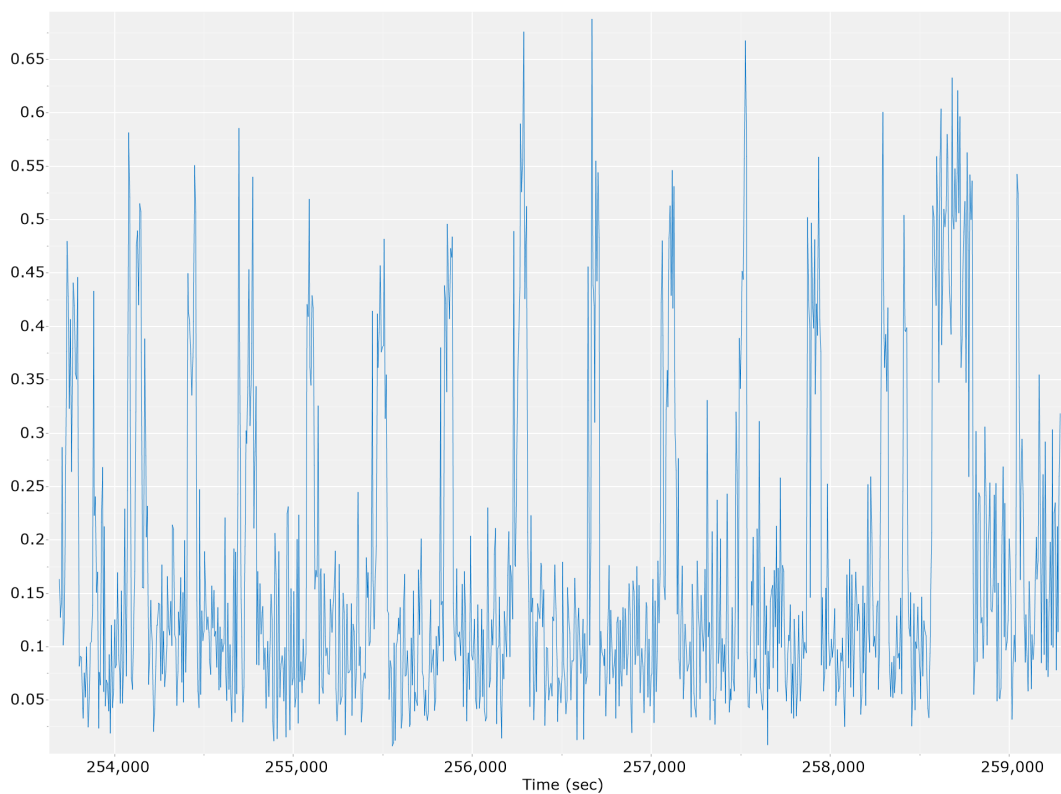
Ground Speed



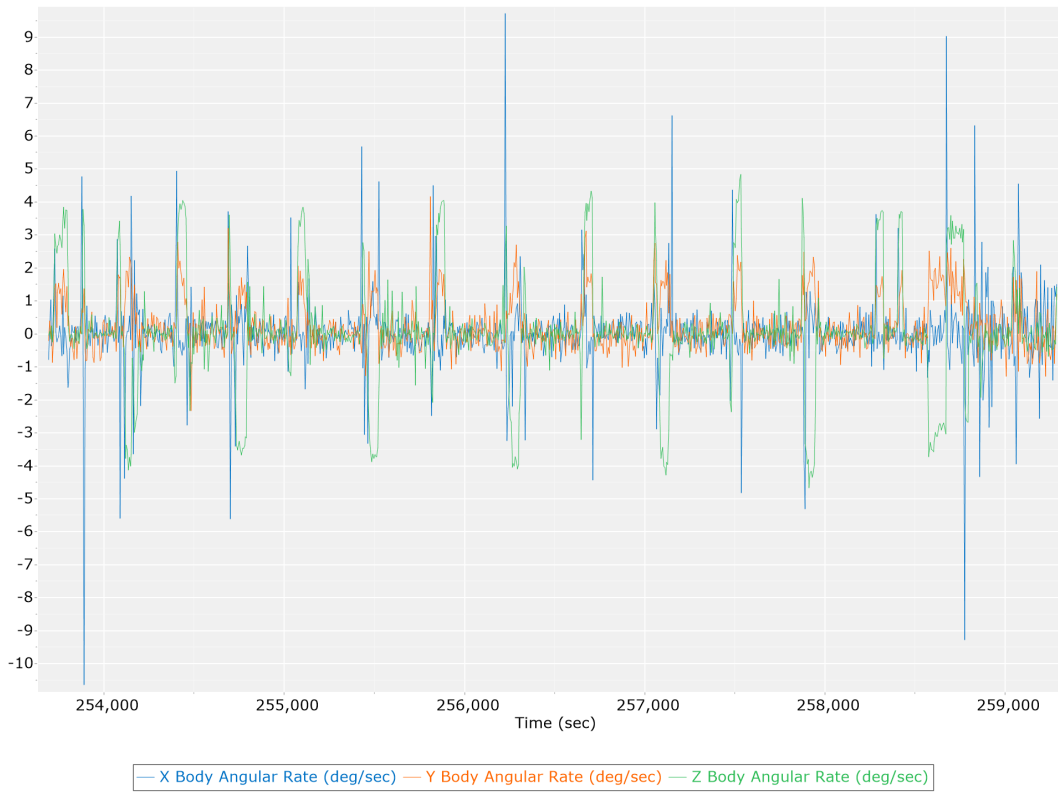
Body Acceleration



Total Body Acceleration

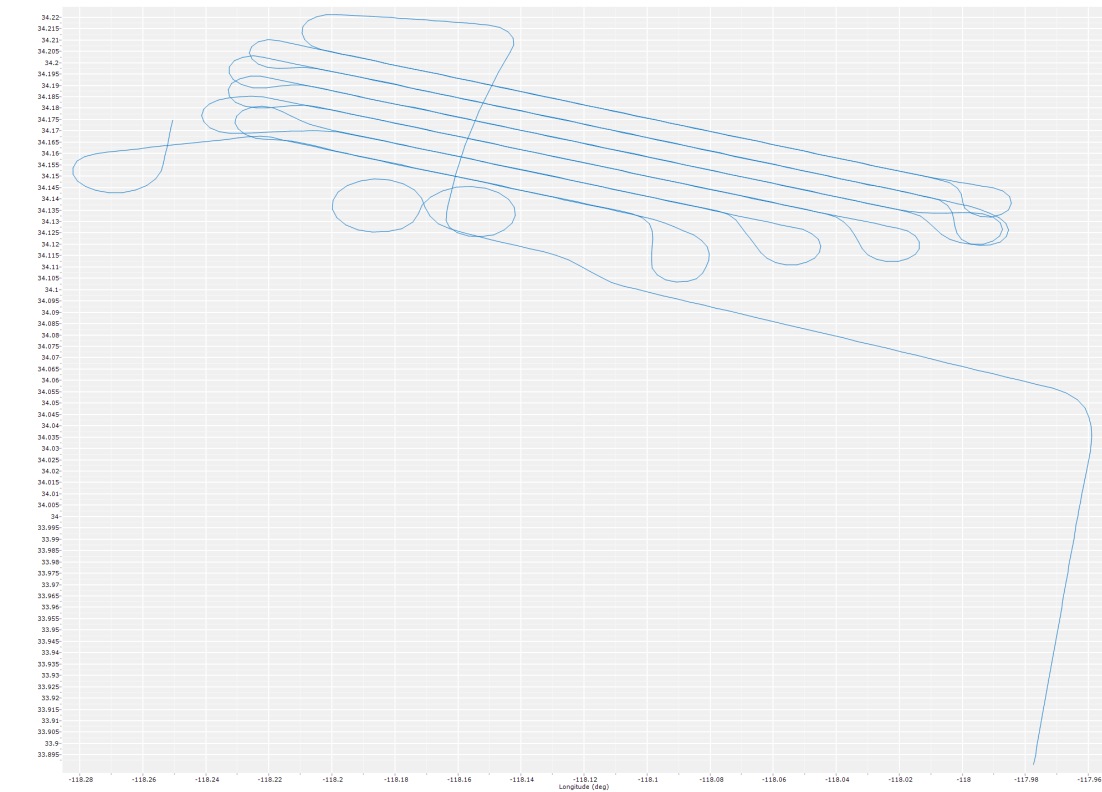


Body Angular Rate

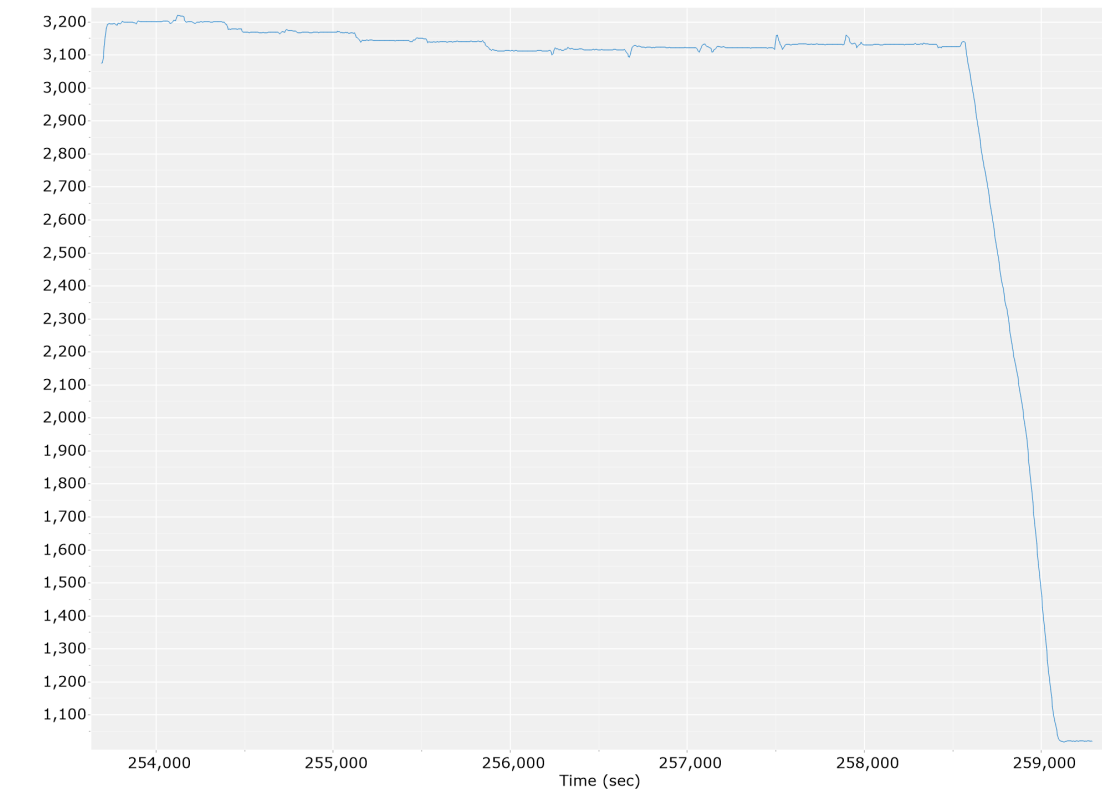


Forward Processed Trajectory Information

Top View



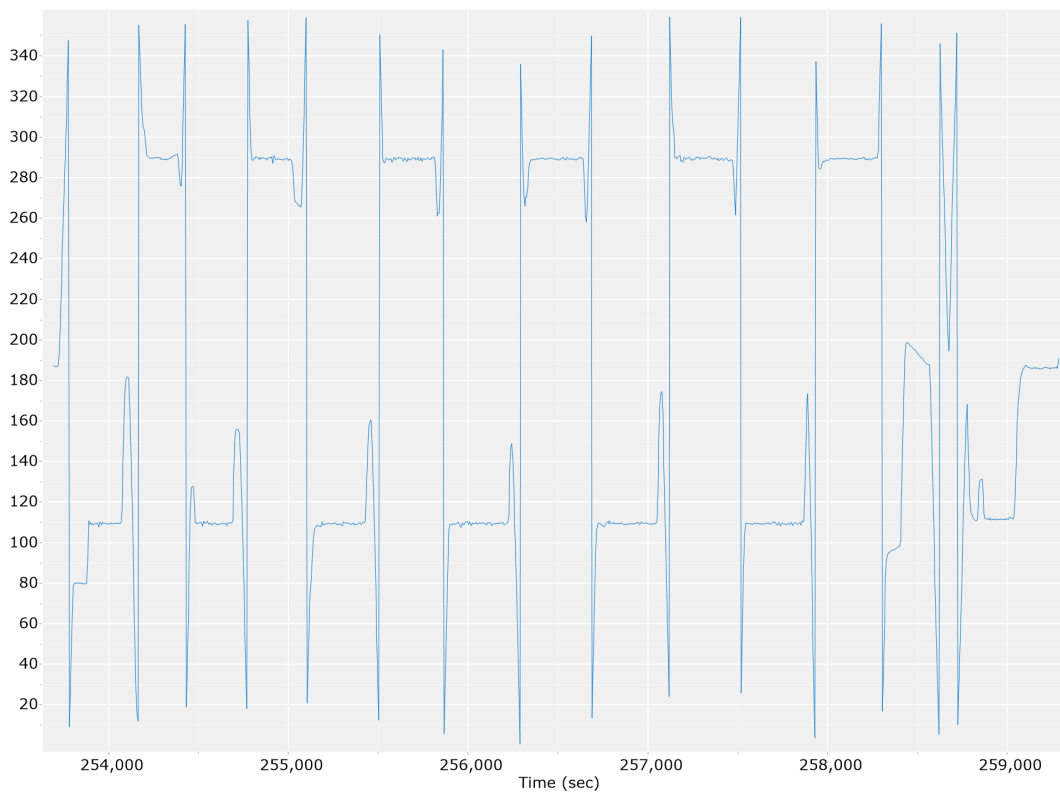
Altitude



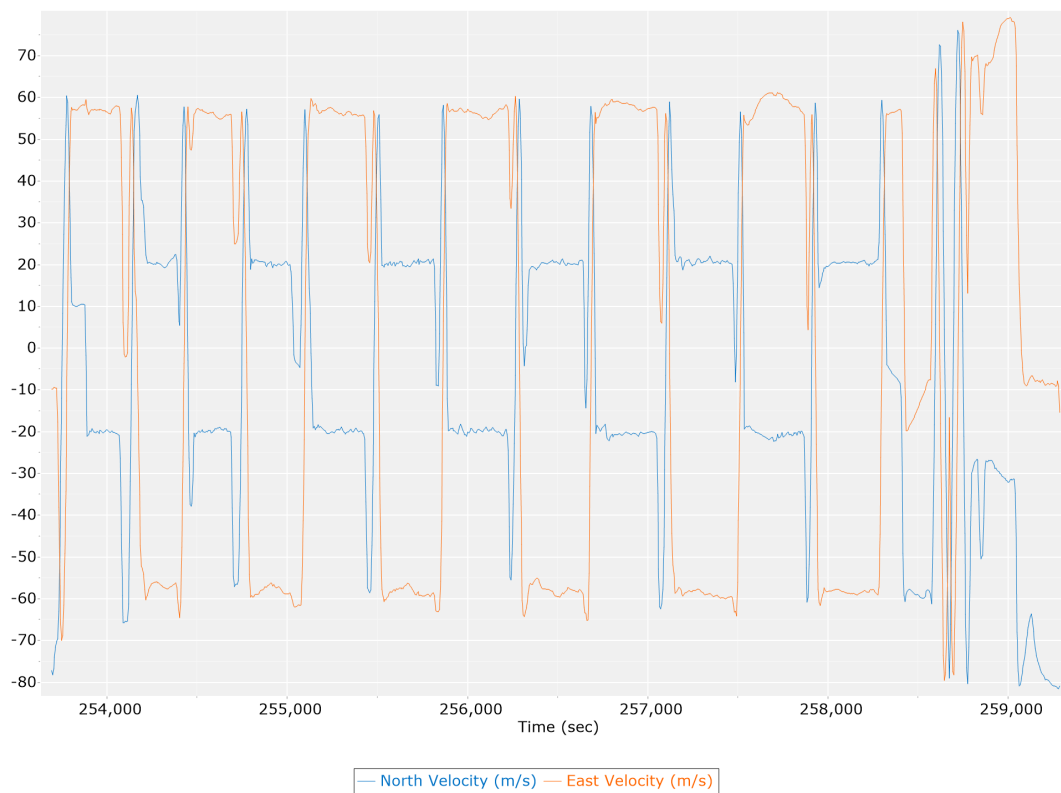
Roll/Pitch



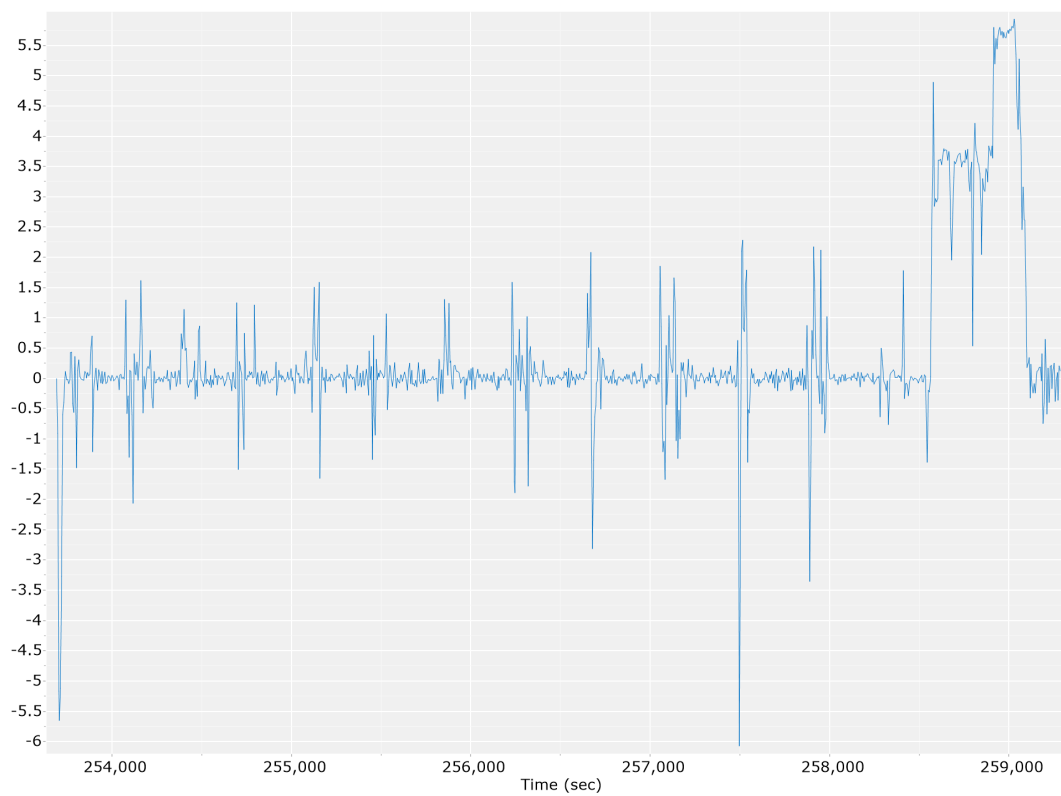
Heading



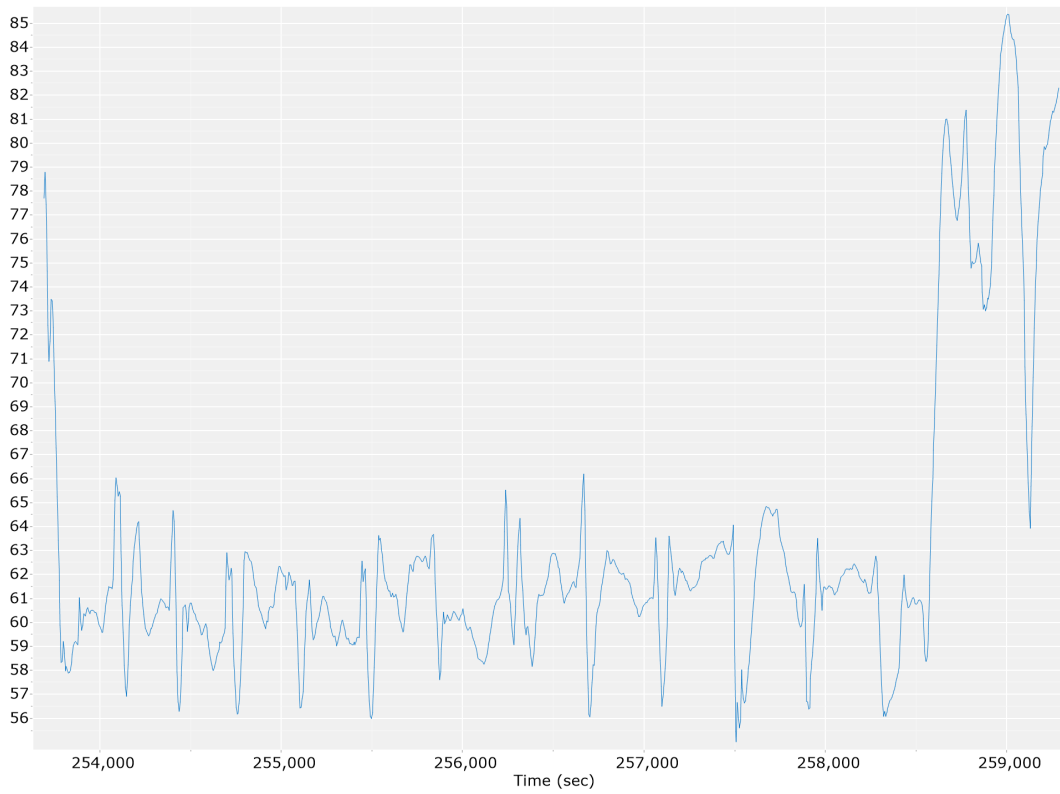
North/East Velocity



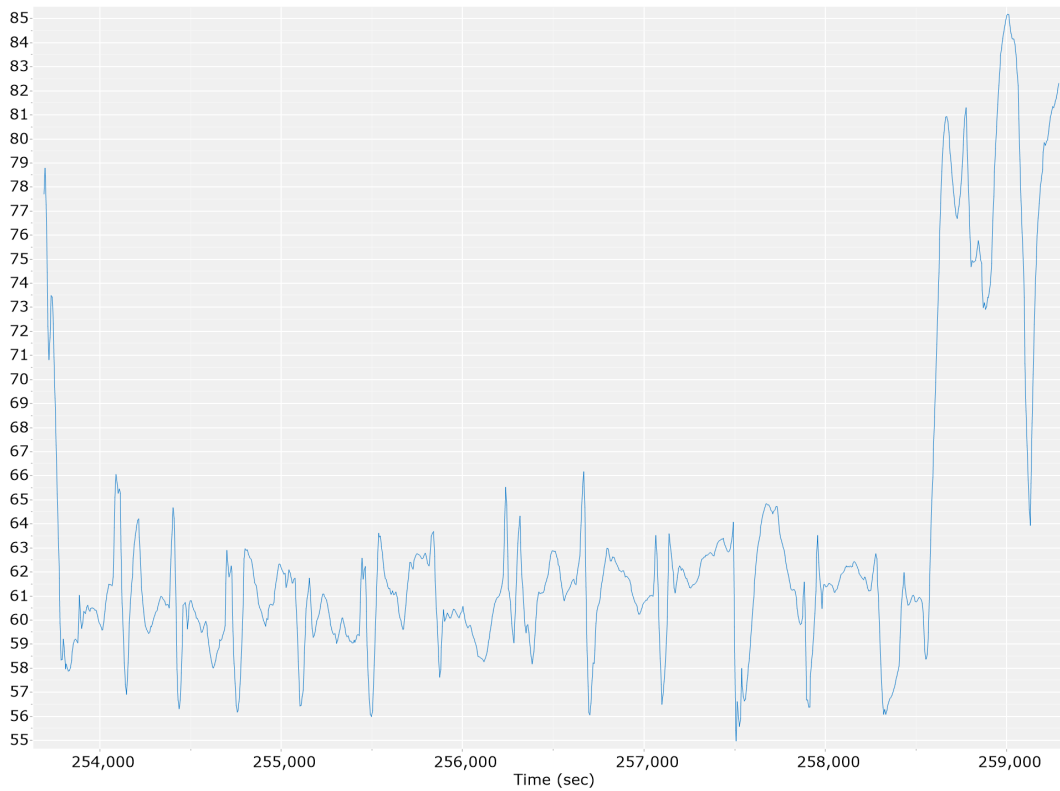
Down Velocity



Total Speed



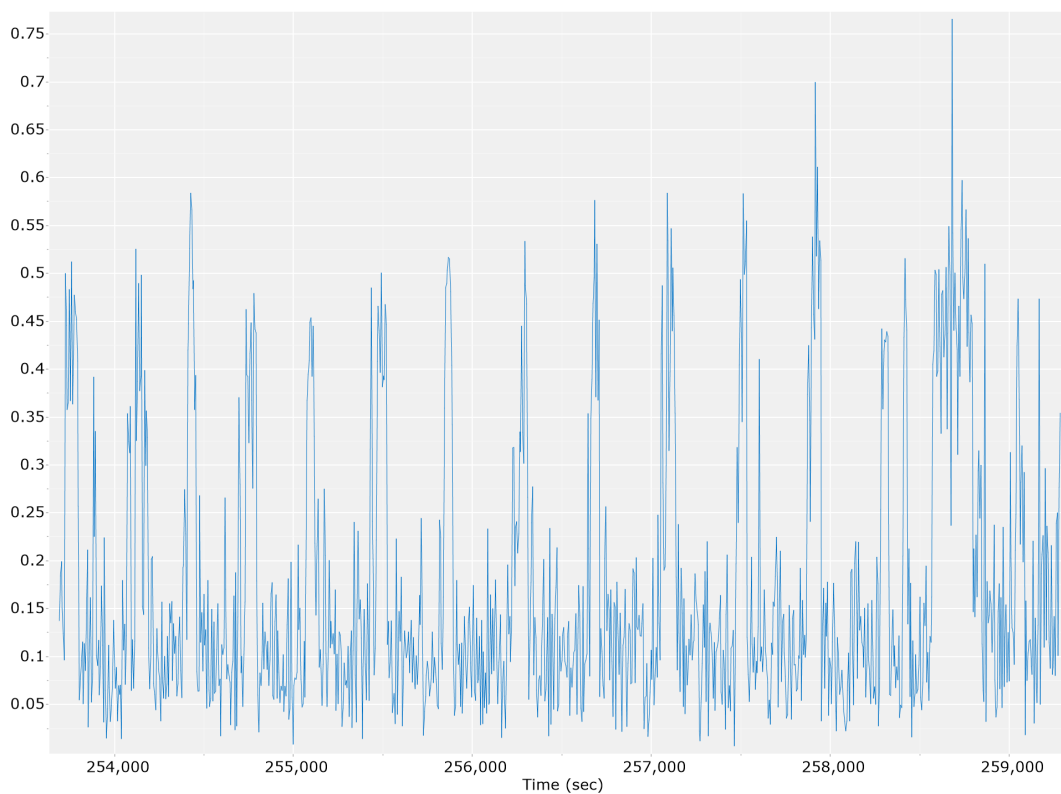
Ground Speed



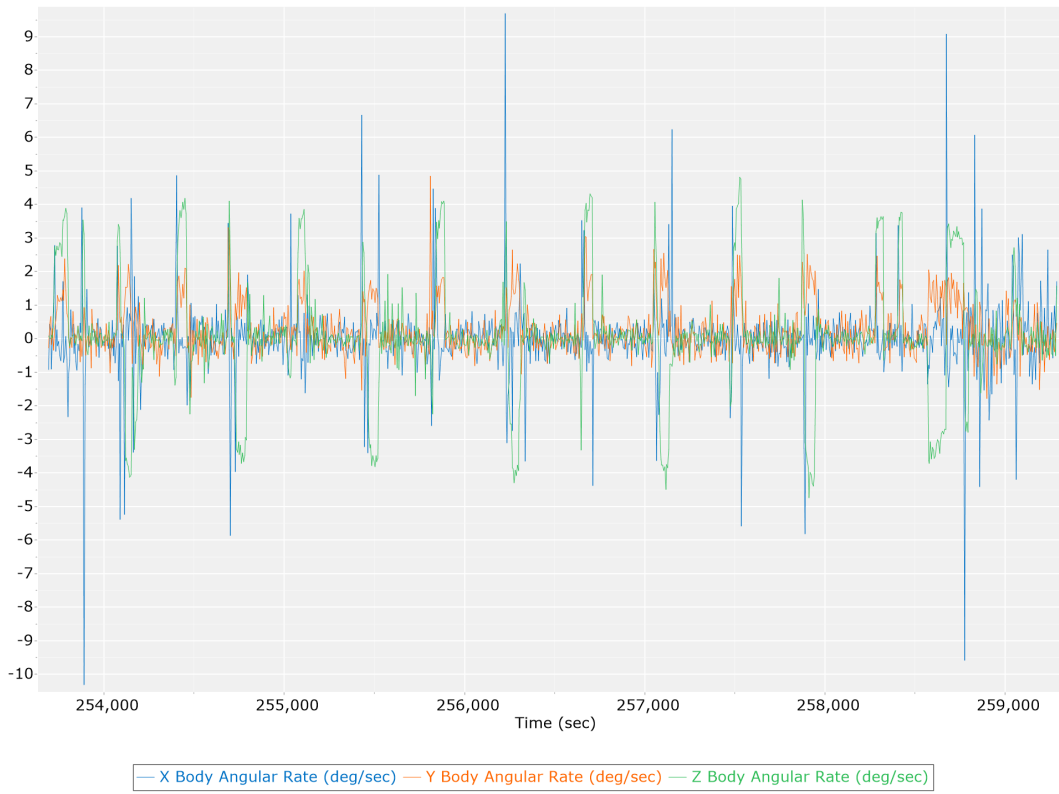
Body Acceleration



Total Body Acceleration



Body Angular Rate

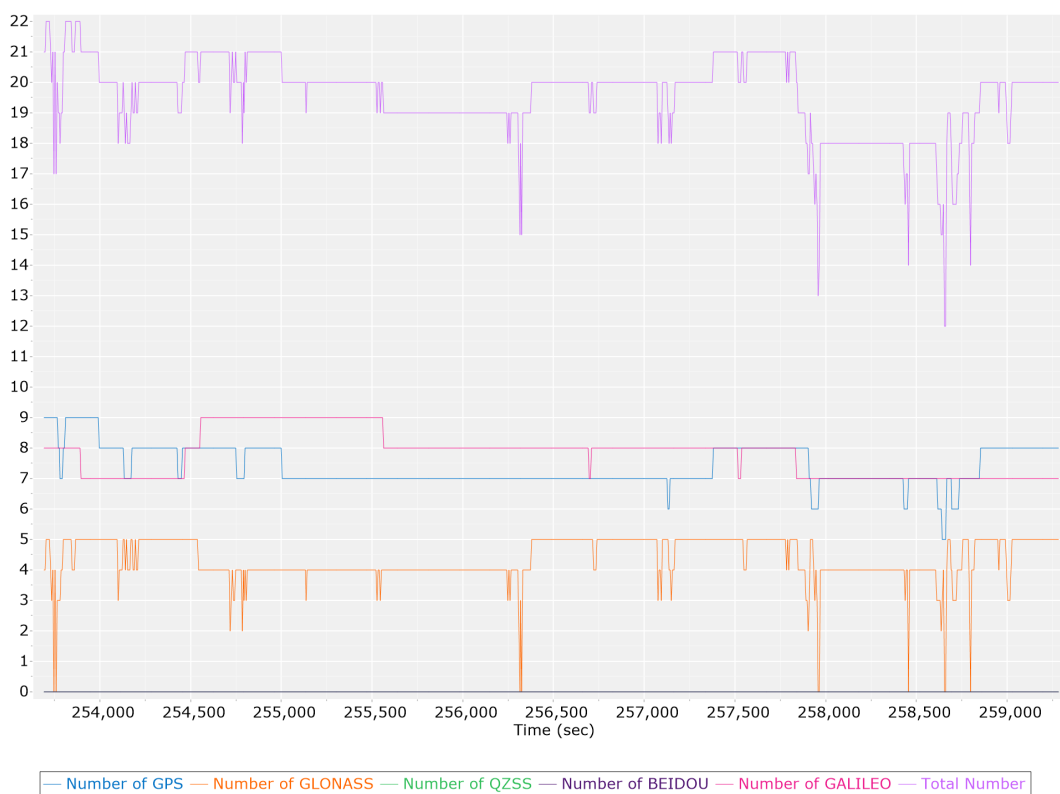


GNSS QC

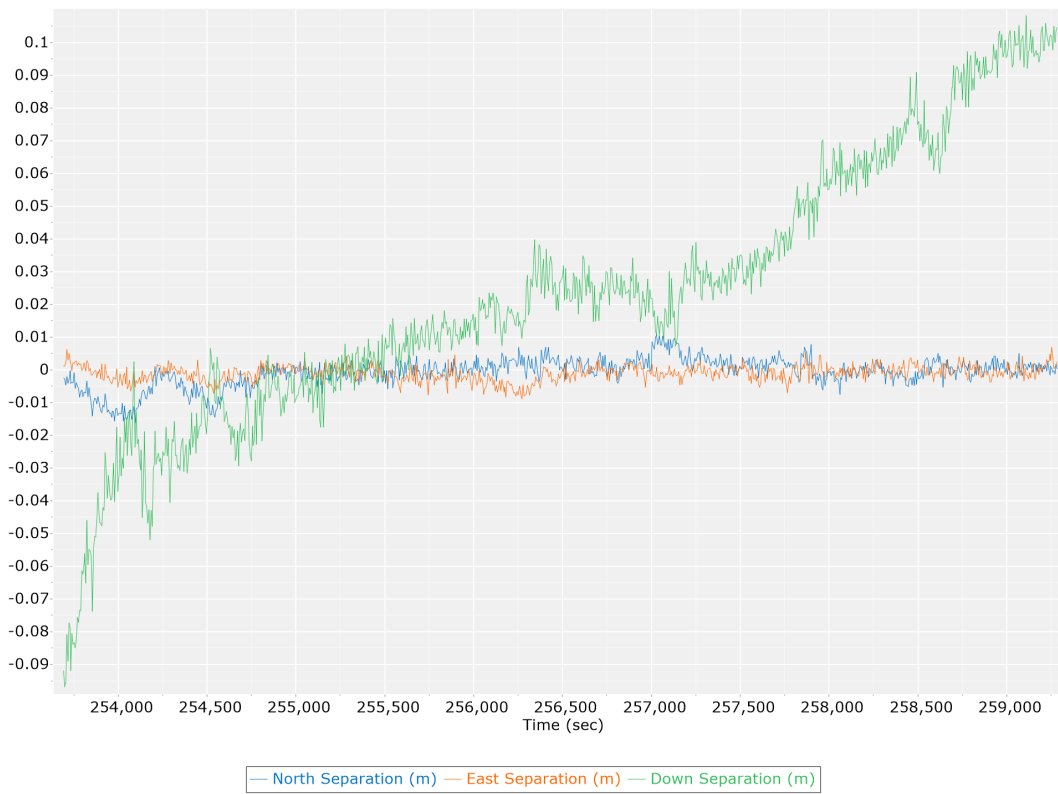
GNSS QC Statistics

Statistics	Min	Max	Mean
Number of GPS SV	5	9	7
Number of GLONASS SV	0	5	4
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Number of GALILEO SV	6	9	8
Total number of SV	12	22	20
PDOP	1.03	2.19	1.28
QC Solution Gaps	0.00	0.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	5692.00	0.00	0.00
Percentage	100.00	0.00	0.00

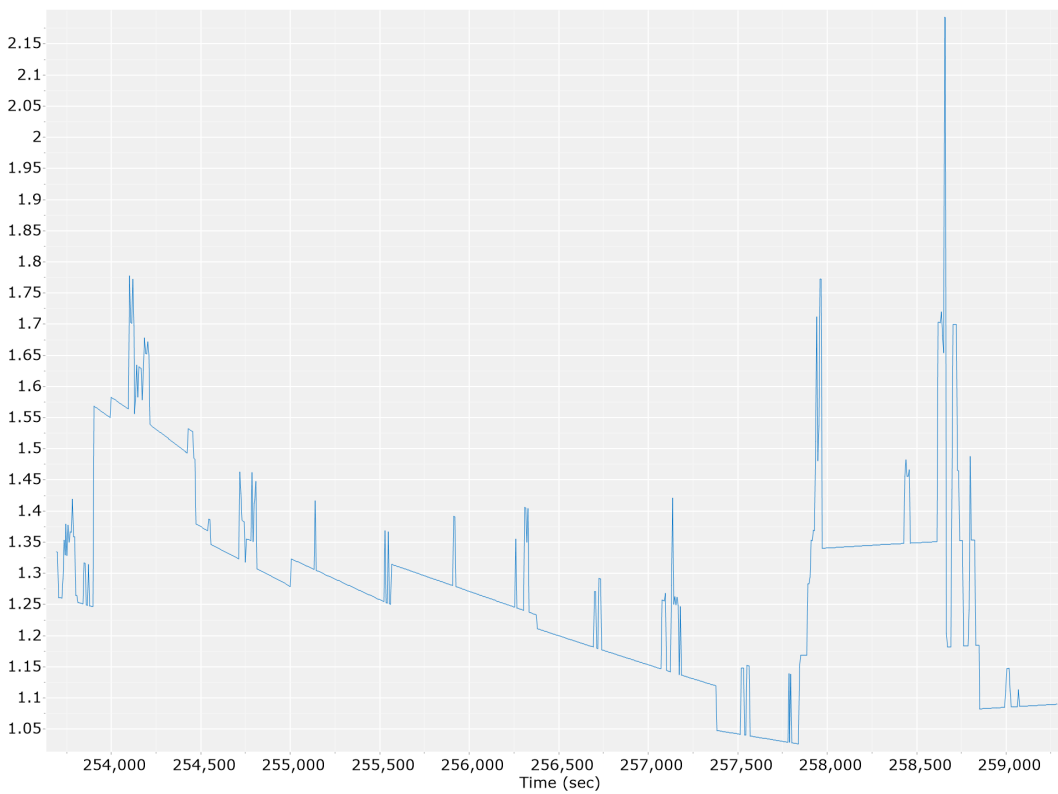
Num SVs in solution



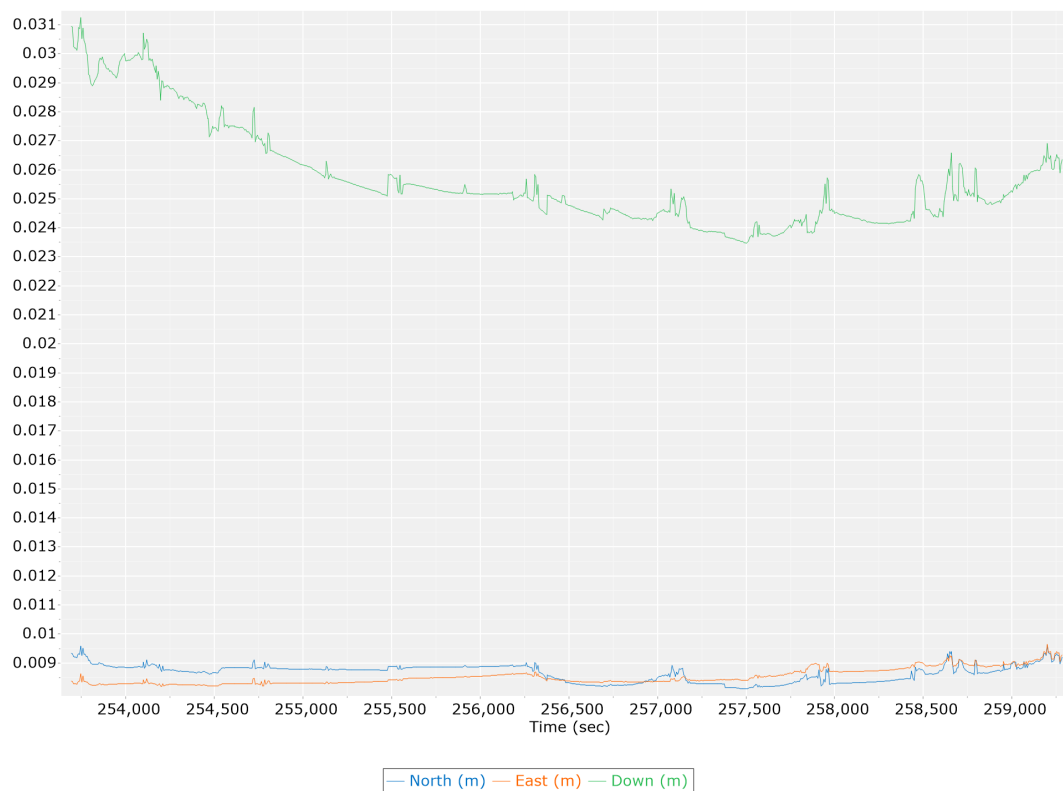
Forward/Reverse Separation



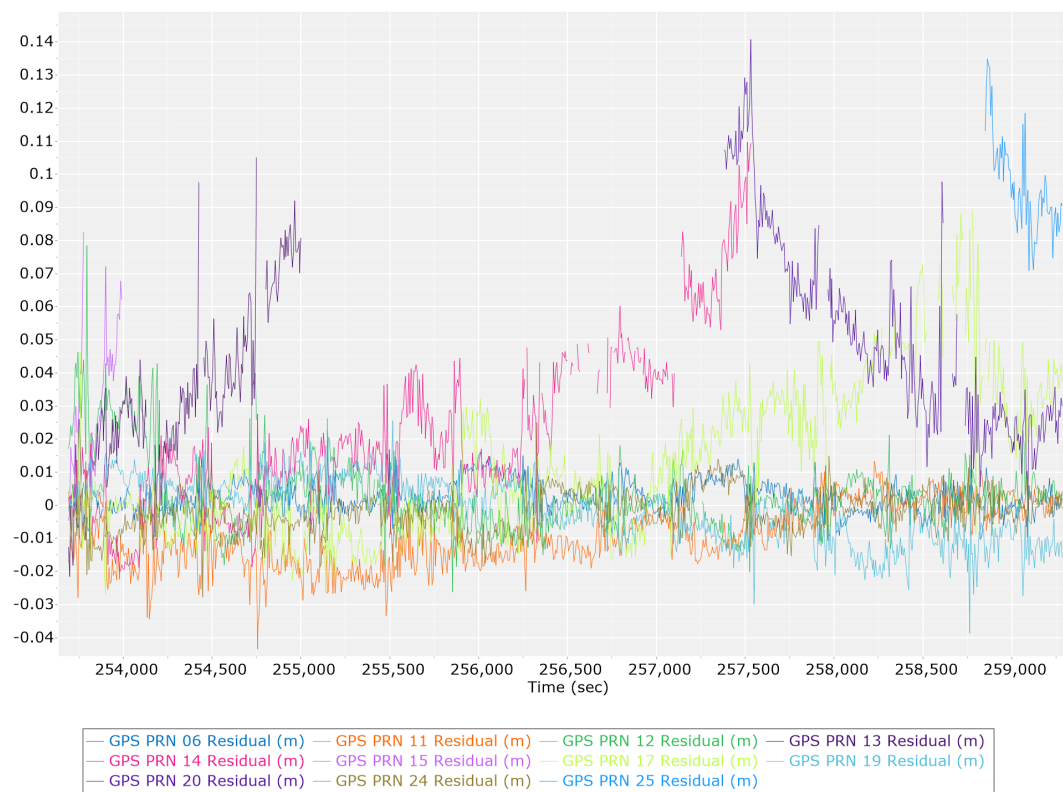
PDOP



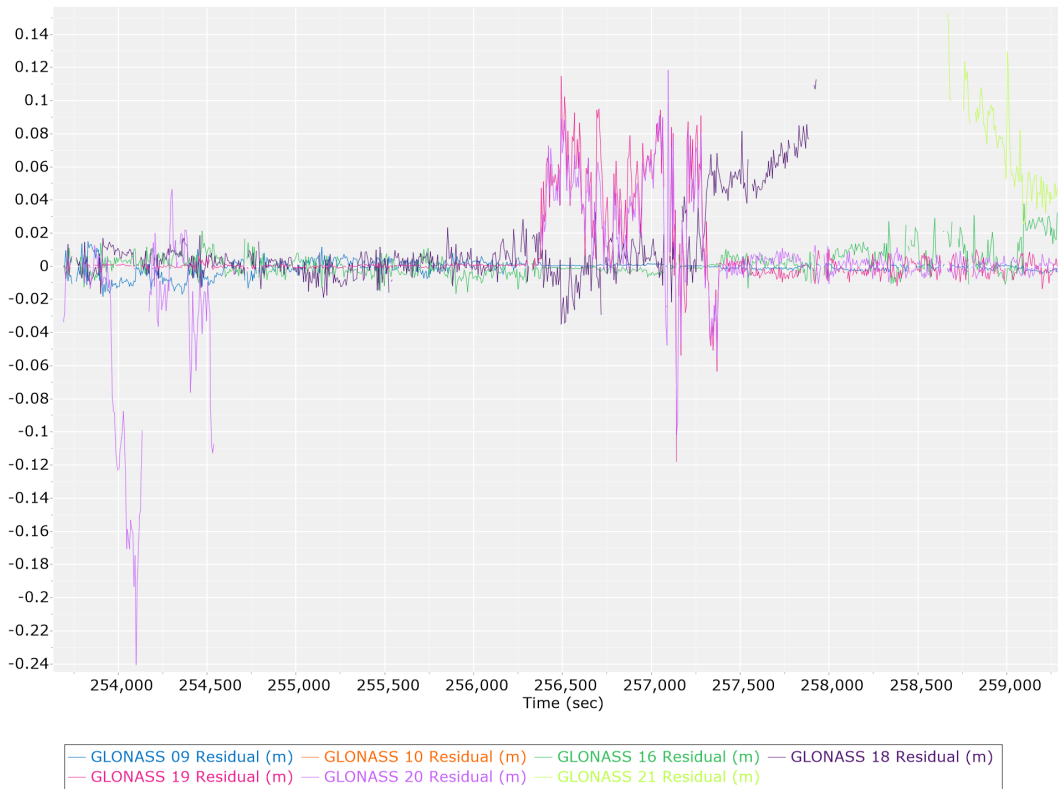
Estimated Position Accuracy



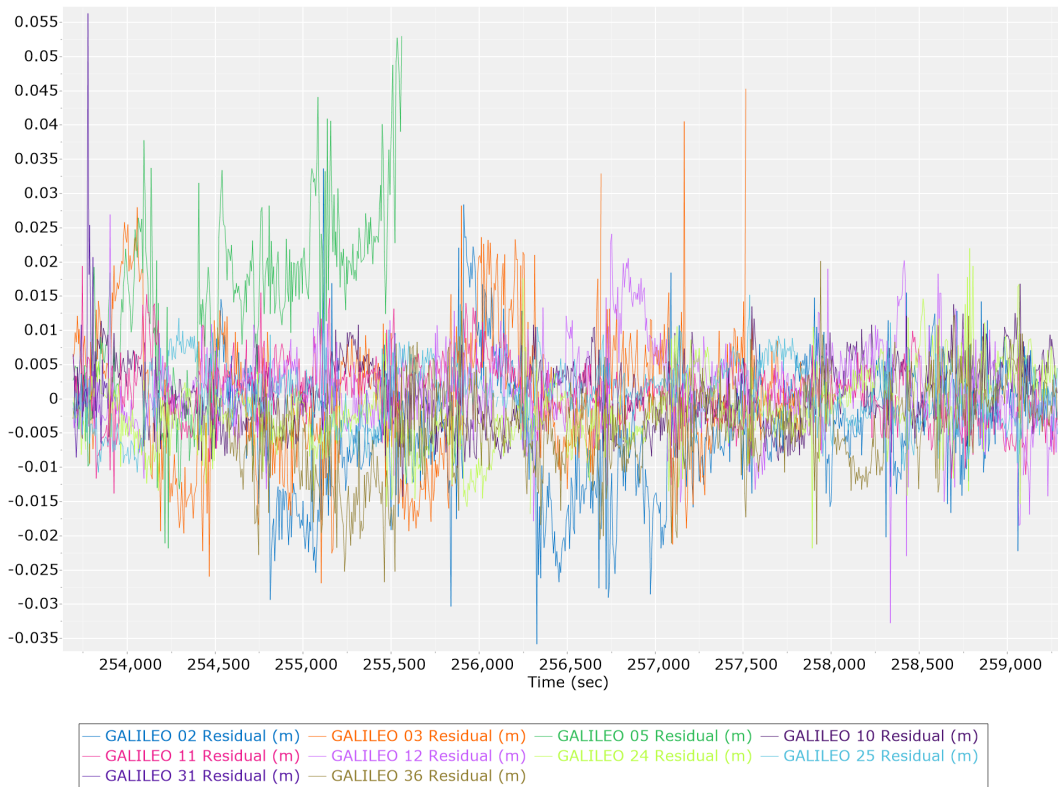
GPS Residuals



GLONASS Residuals



GALILEO Residuals



GNSS-Inertial Processor Configuration

Processing mode	IN-Fusion PP-RTX		
Stabilized mount	True		
Processing start time	253592.000 (1/21/2025 10:26:32 PM)		
Processing end time	259288.000 (1/22/2025 12:01:28 AM)		
Initial attitude source	Primary GNSS Track		
IMU Sensor Context	Processing with Onboard IMU		
Gimbal to IMU lever arm (m)	-0.034	-0.010	-0.374
Gimbal to IMU mounting angles (deg)	0.000	0.000	0.000
Gimbal to Primary GNSS lever arm (m)	0.062	0.050	-1.259
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

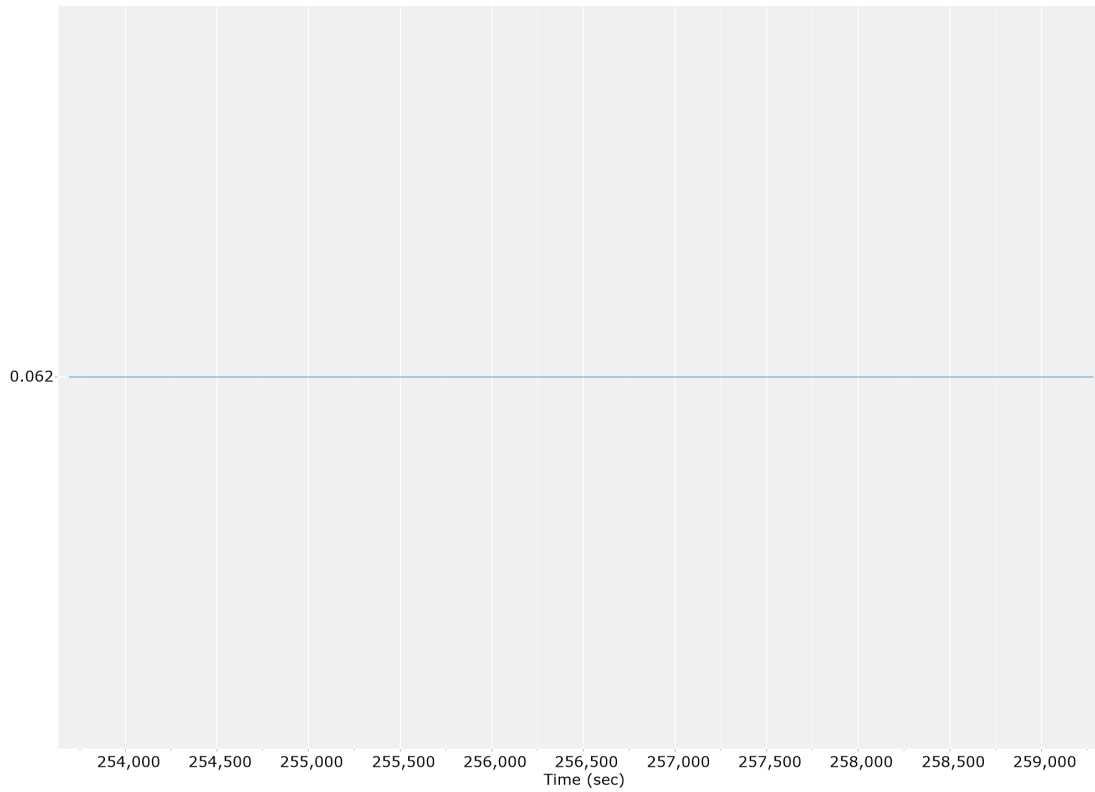
Calibrated Installation Parameters

Reference-Primary GNSS Lever Arm (m)

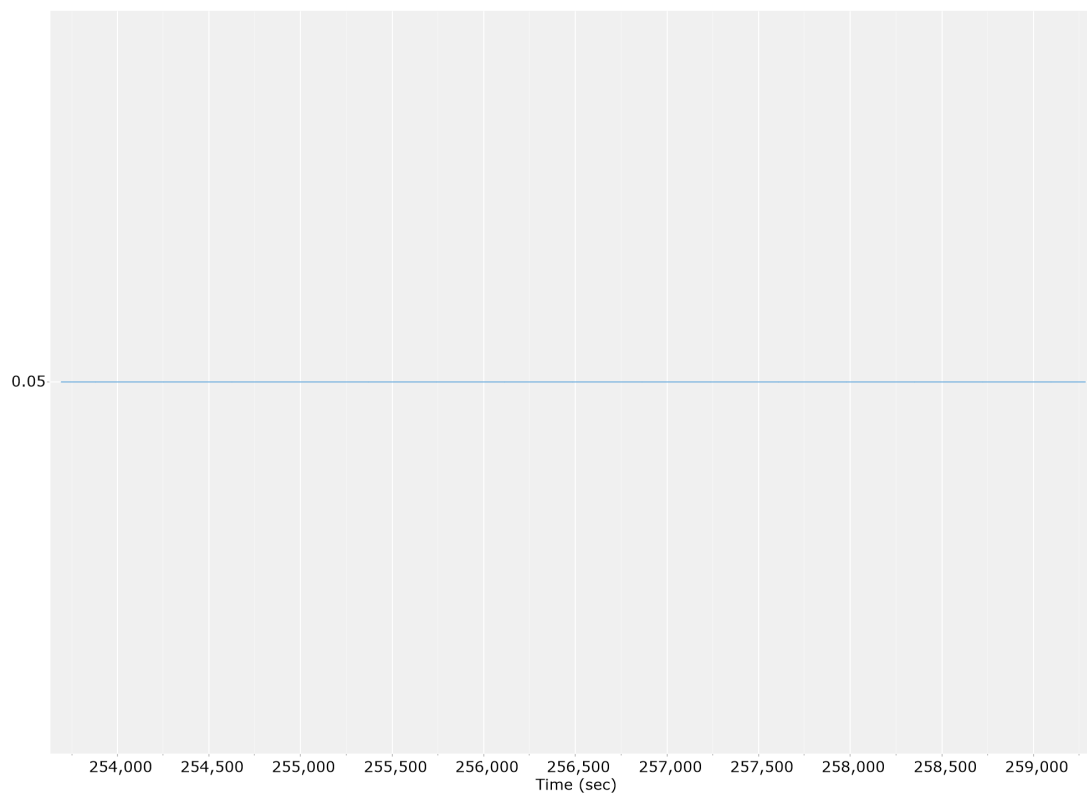
Reference-Primary GNSS Lever Arm Automatic Calibration Results

Original Reference to Primary GNSS lever arm (m)	0.061	0.038	-1.243
Iteration 1 Reference to Primary GNSS lever arm (m)	0.061	0.050	-1.259
Iteration 2 Reference to Primary GNSS lever arm (m)	0.062	0.050	-1.259
Primary GNSS Lever Arm In use	Iteration 2		

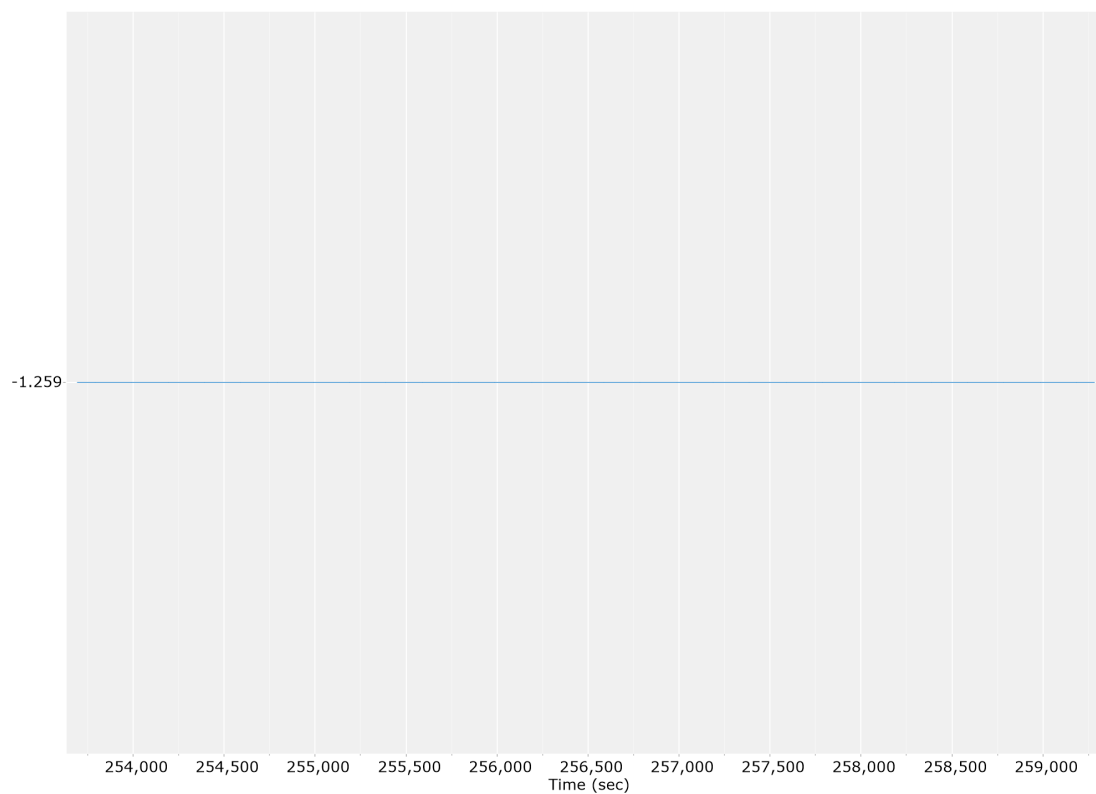
X Reference-Primary GNSS Lever Arm (m)



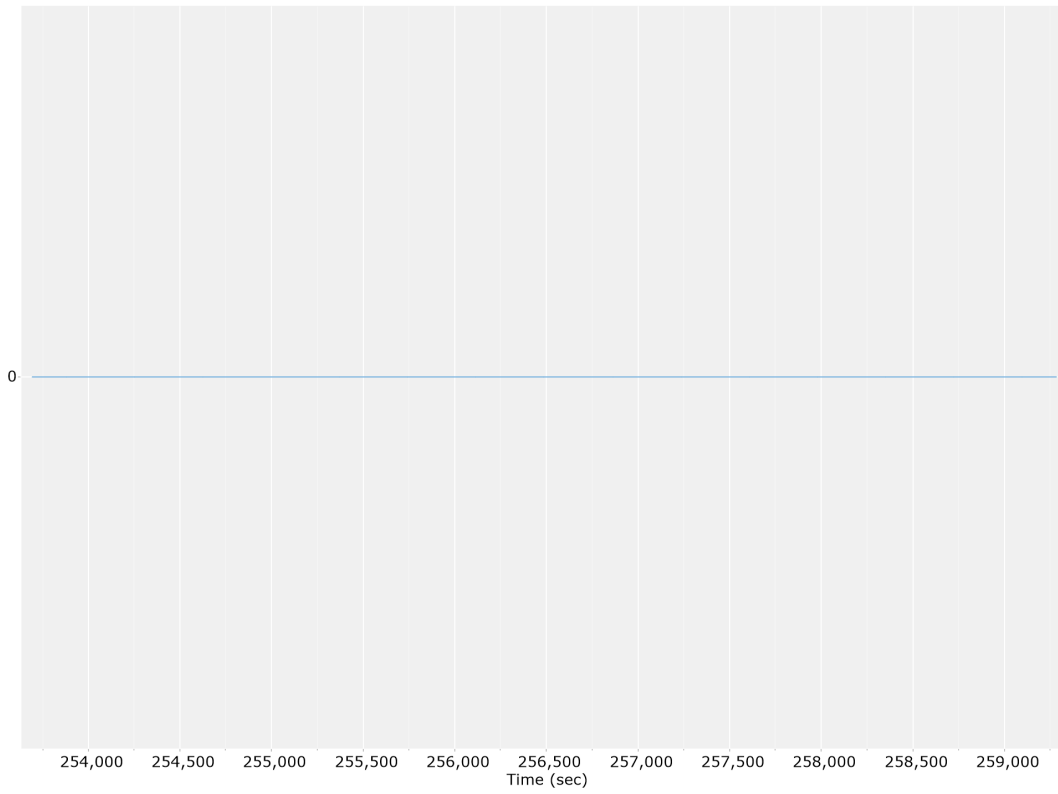
Y Reference-Primary GNSS Lever Arm (m)



Z Reference-Primary GNSS Lever Arm (m)



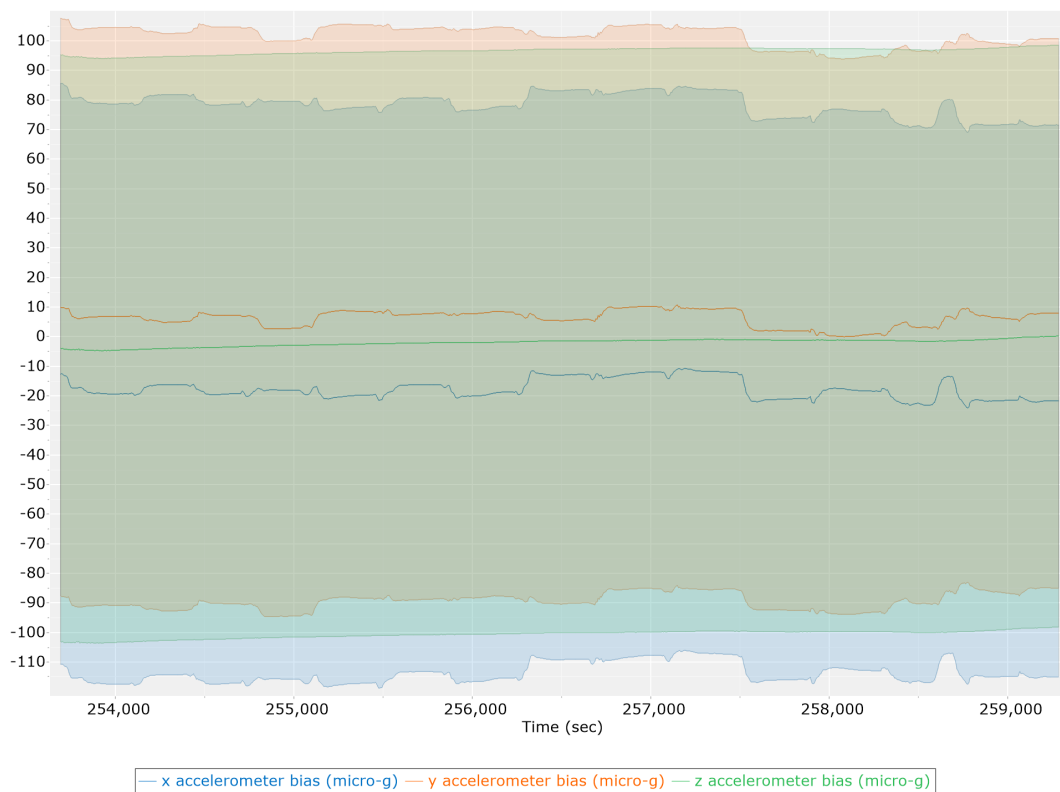
Reference-Primary GNSS Lever Arm Figure of Merit



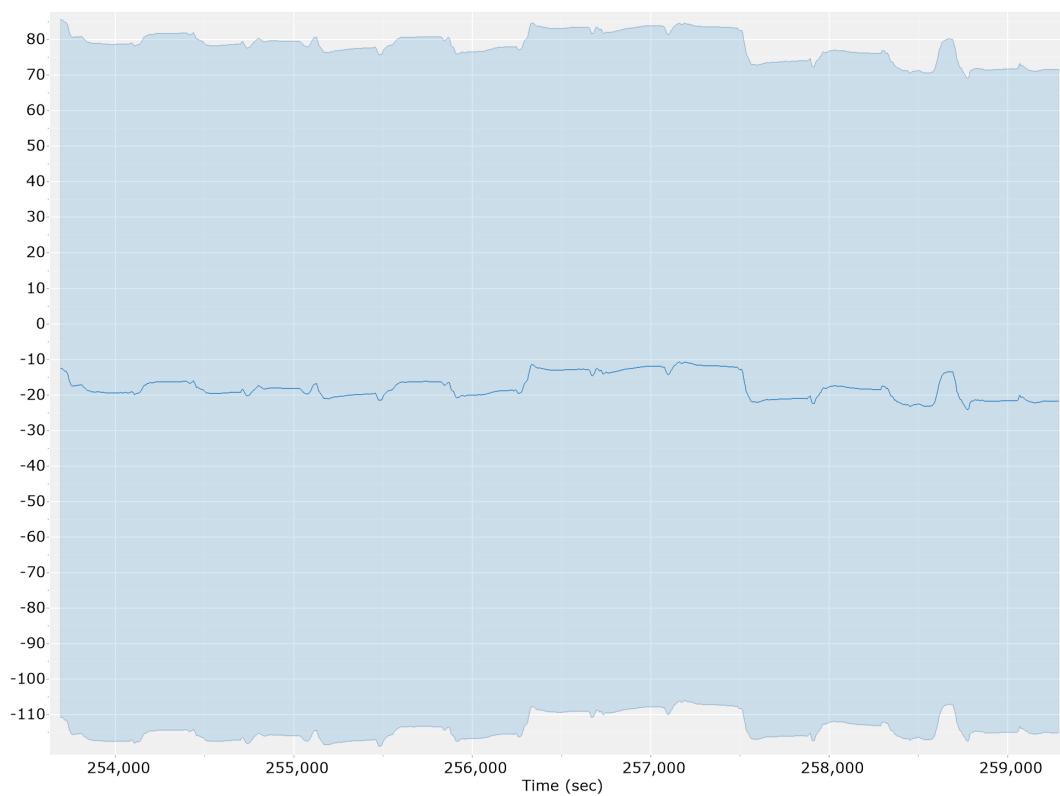
IN-Fusion QC

Forward Processed Estimated Errors, Reference Frame

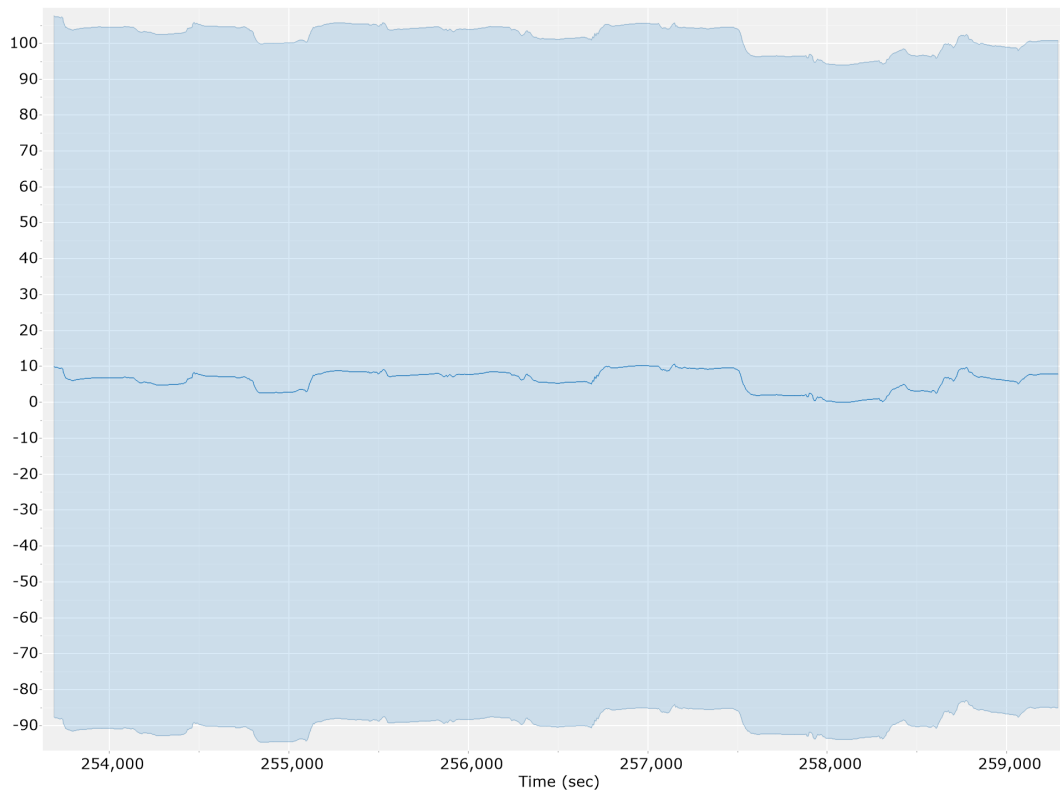
Accelerometer Bias (micro-g)



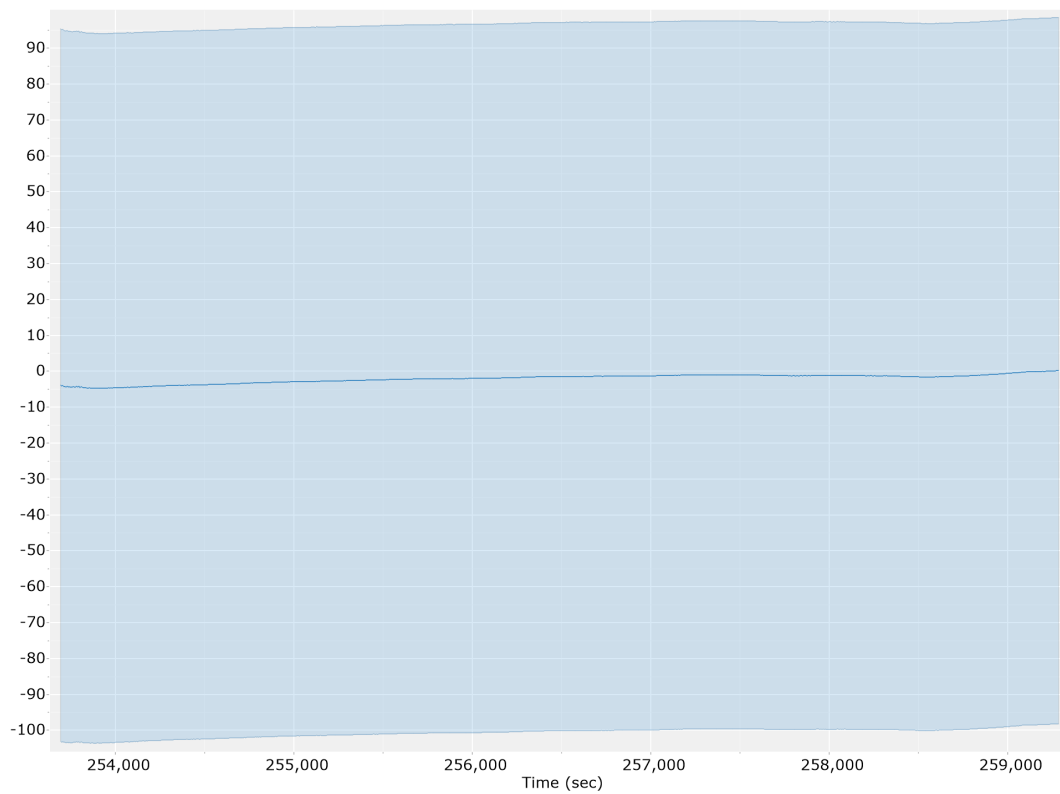
X Accelerometer Bias (micro-g)



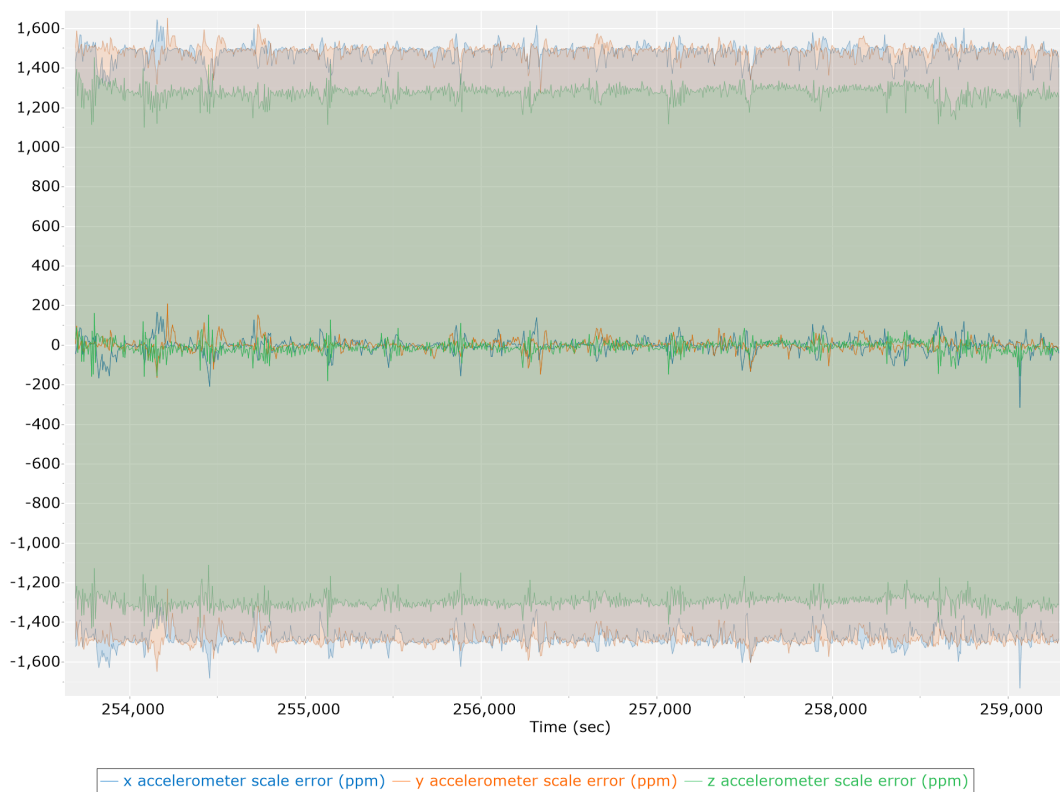
Y Accelerometer Bias (micro-g)



Z Accelerometer Bias (micro-g)



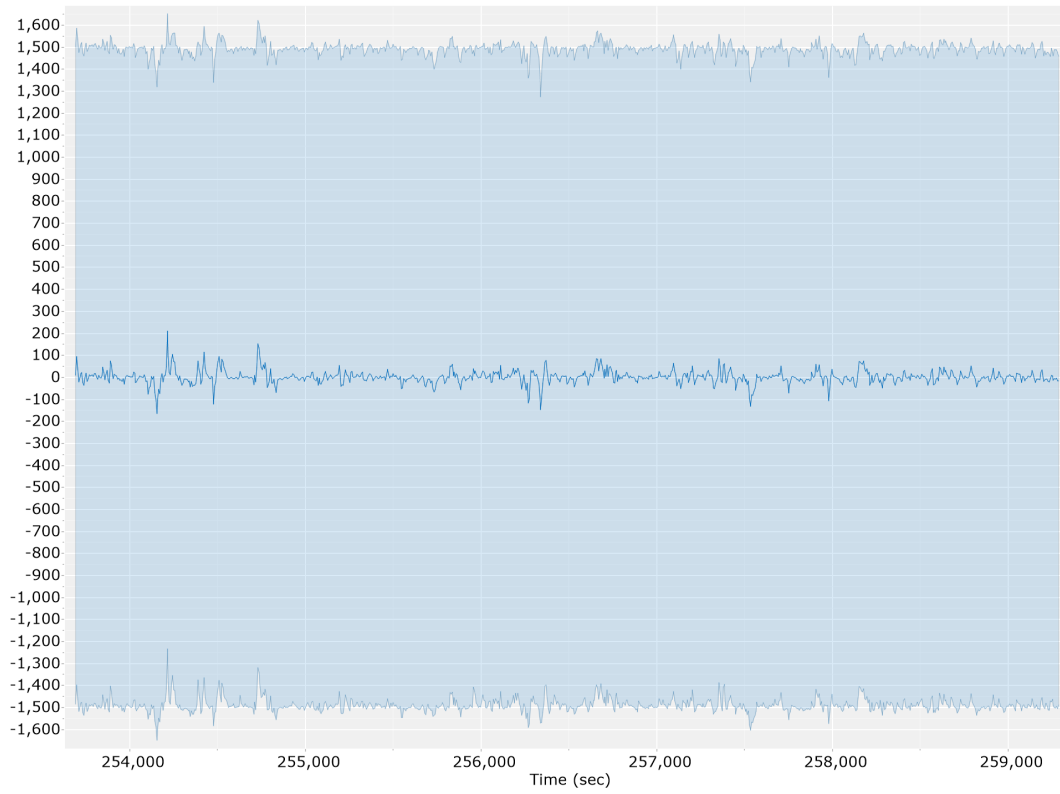
Accelerometer Scale Error (ppm)



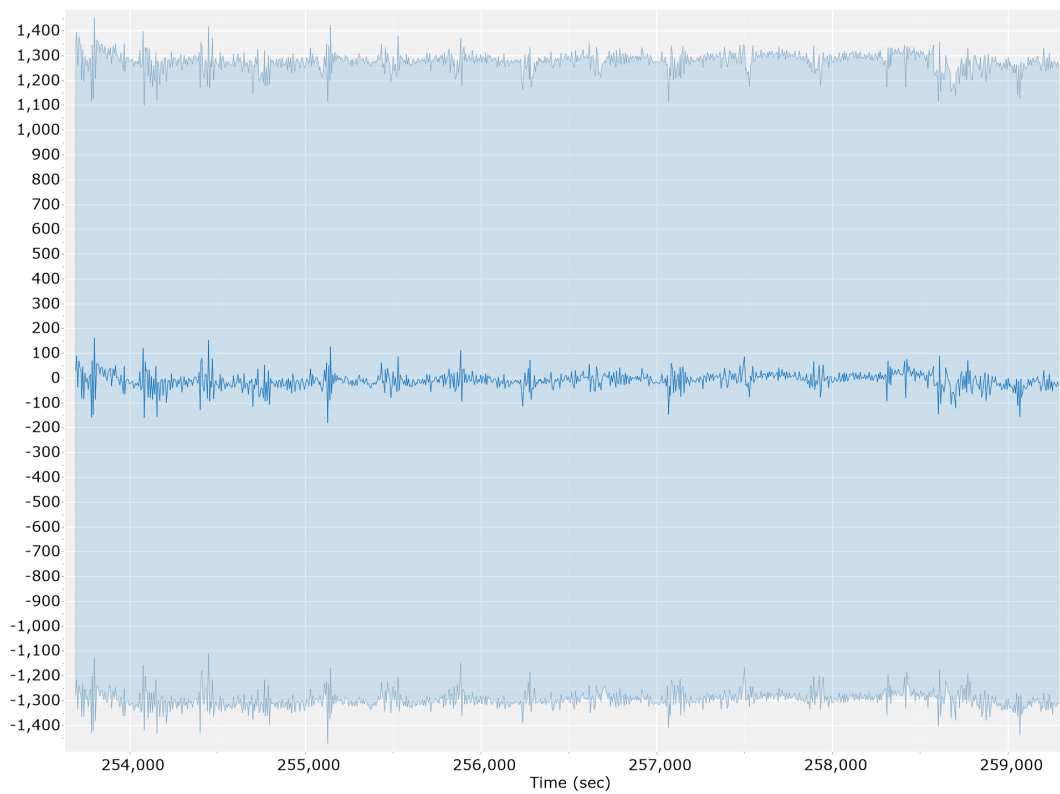
X Accelerometer Scale Error (ppm)



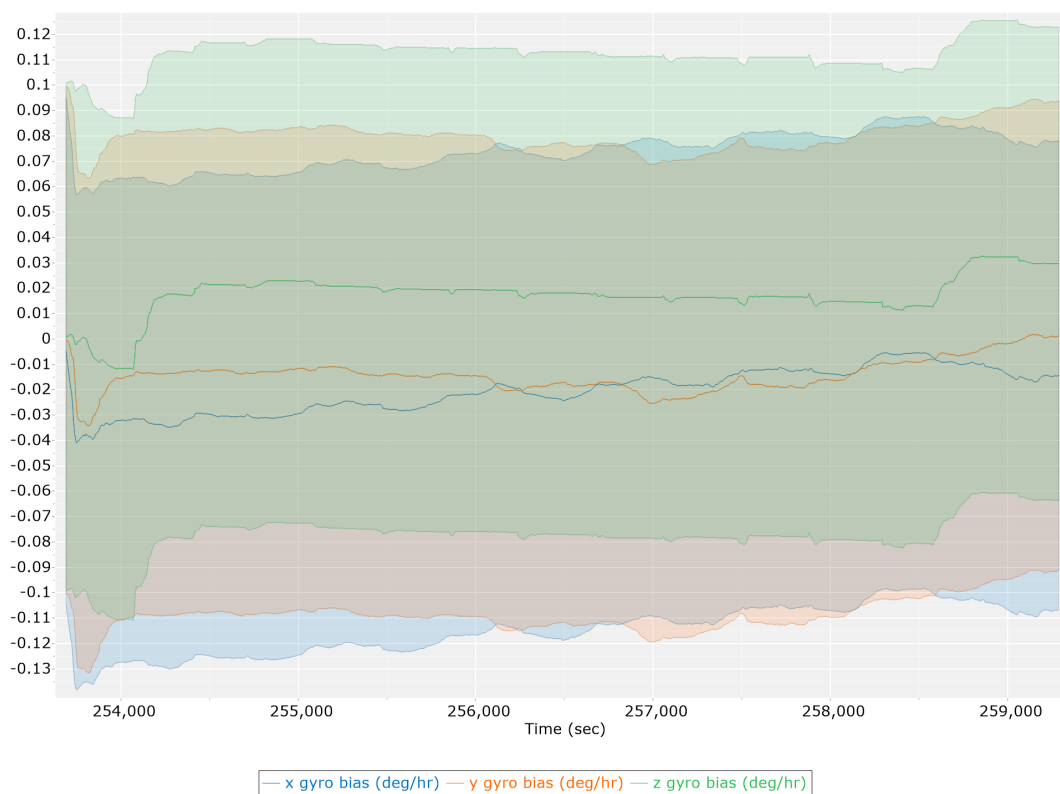
Y Accelerometer Scale Error (ppm)



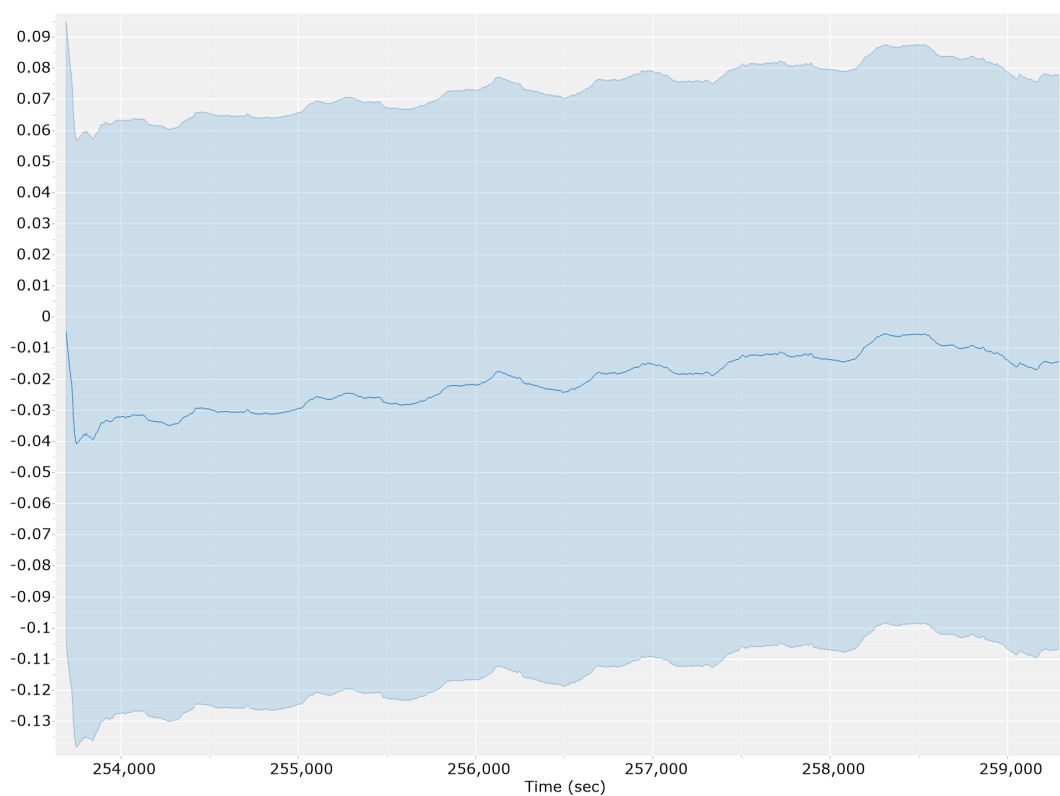
Z Accelerometer Scale Error (ppm)



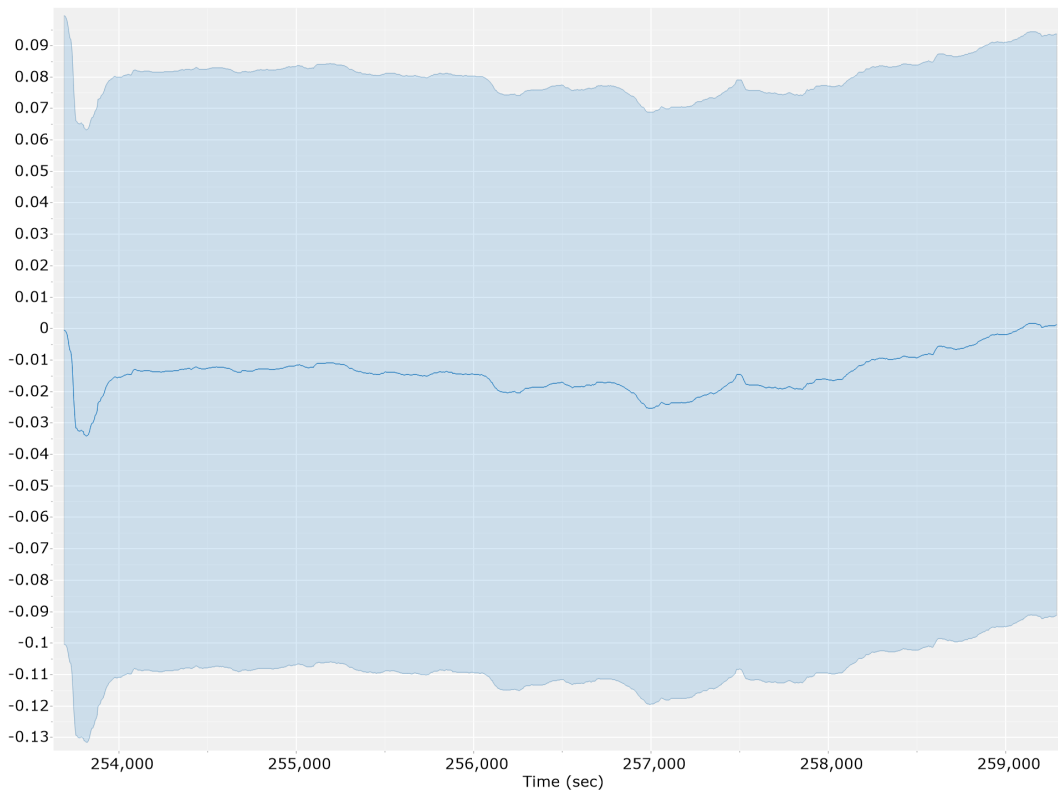
Gyro Bias (deg/h)



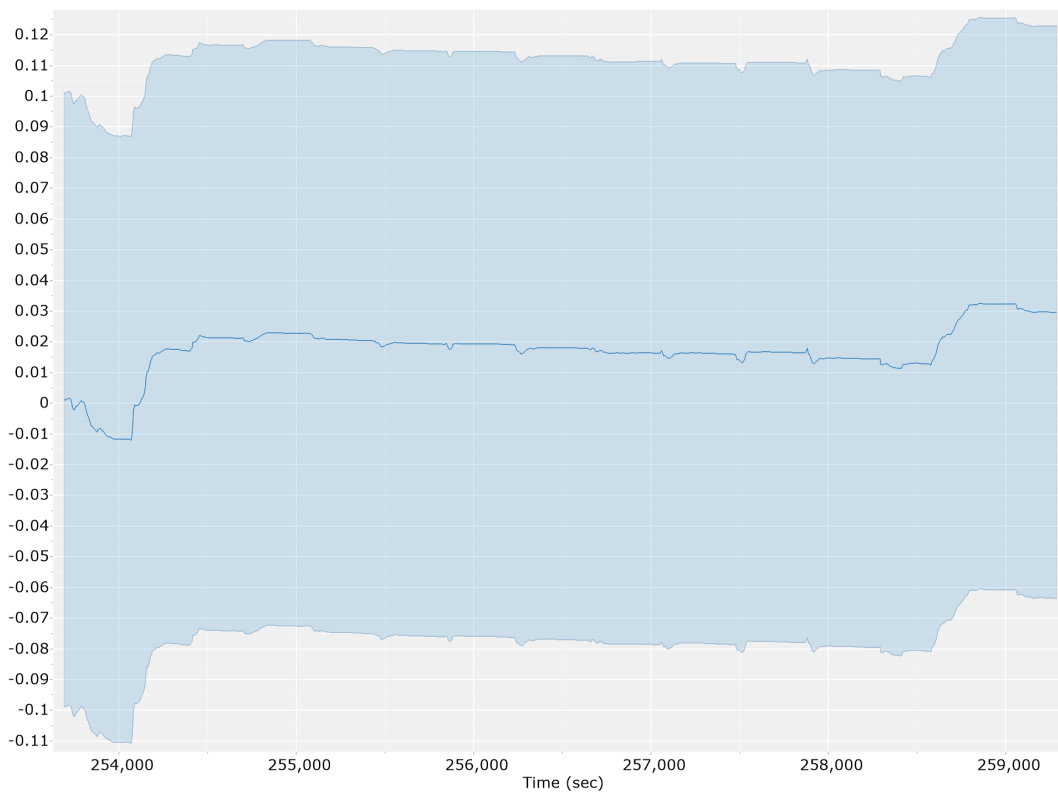
X Gyro Bias (deg/h)



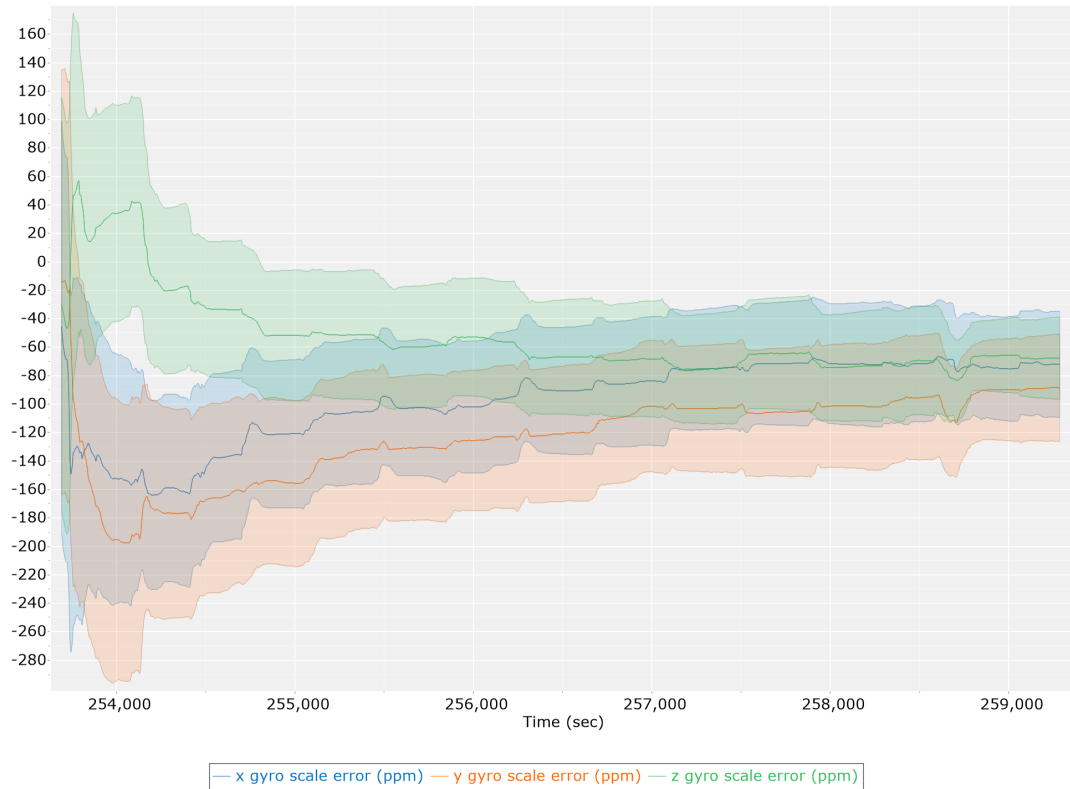
Y Gyro Bias (deg/h)



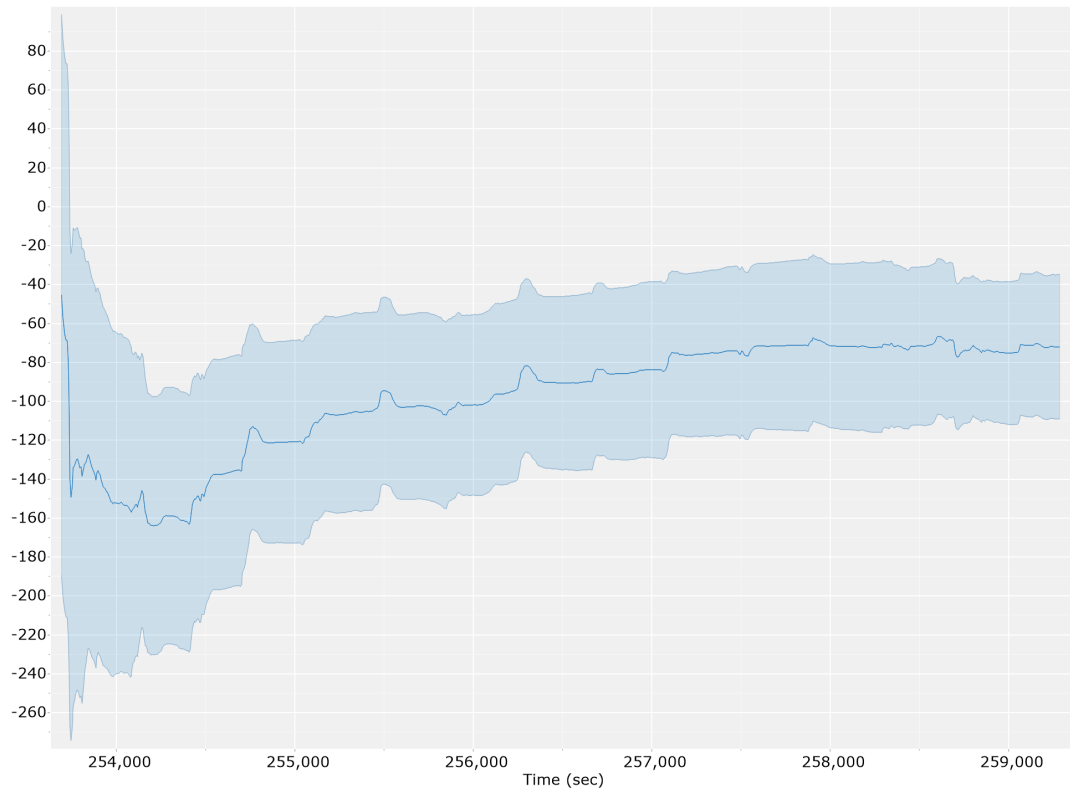
Z Gyro Bias (deg/h)



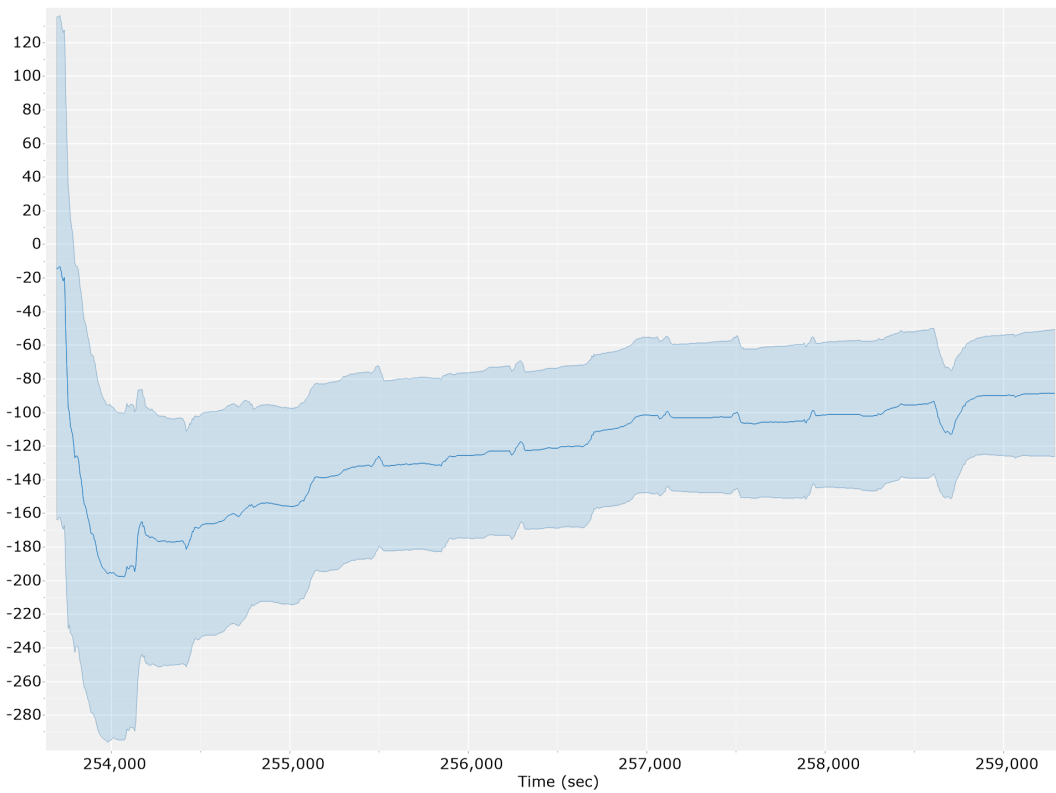
Gyro Scale Error (ppm)



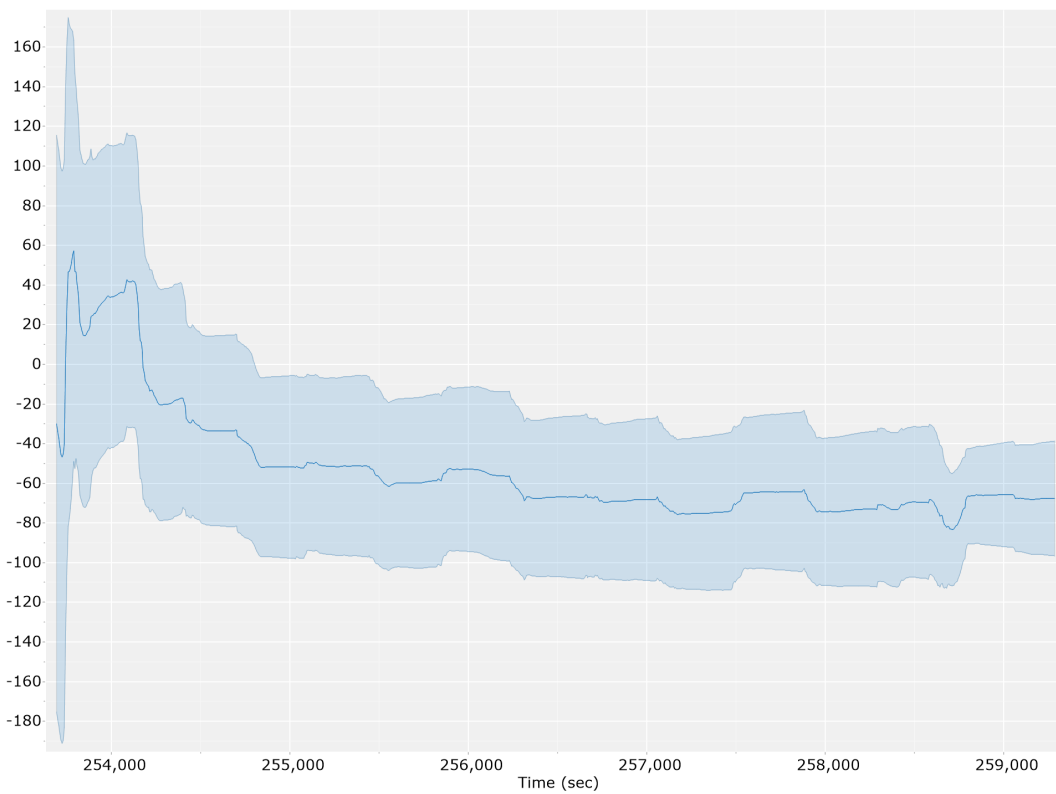
X Gyro Scale Error (ppm)



Y Gyro Scale Error (ppm)

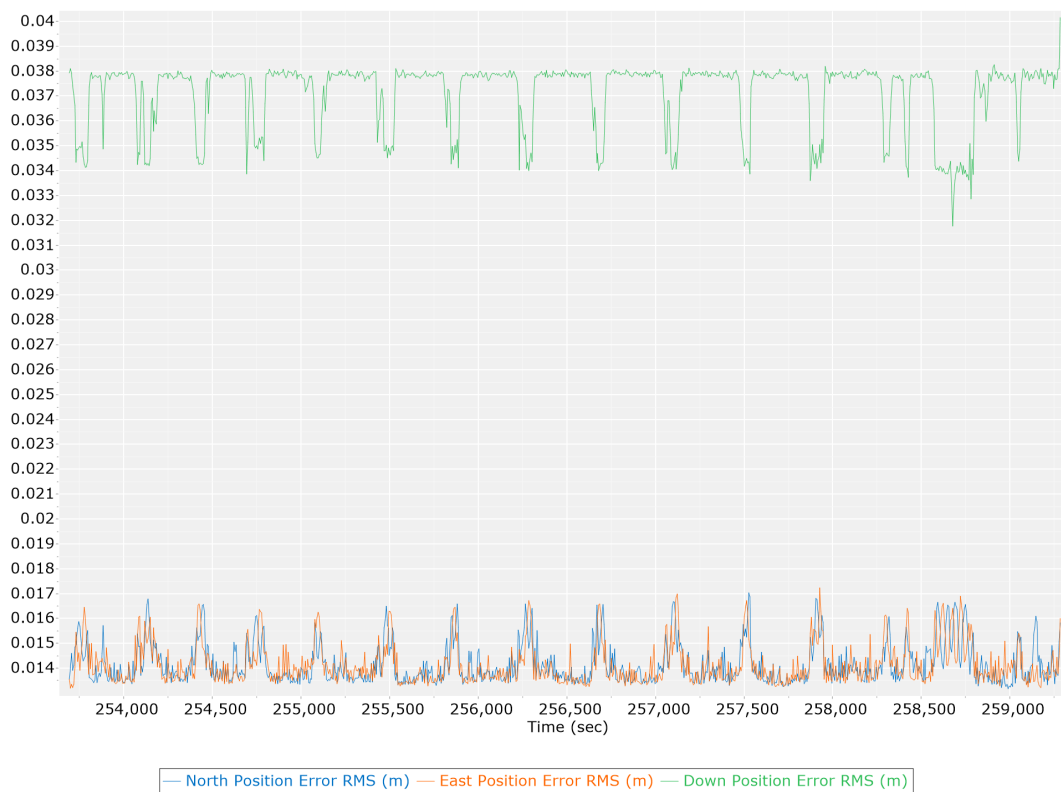


Z Gyro Scale Error (ppm)



Smoothed Performance Metrics

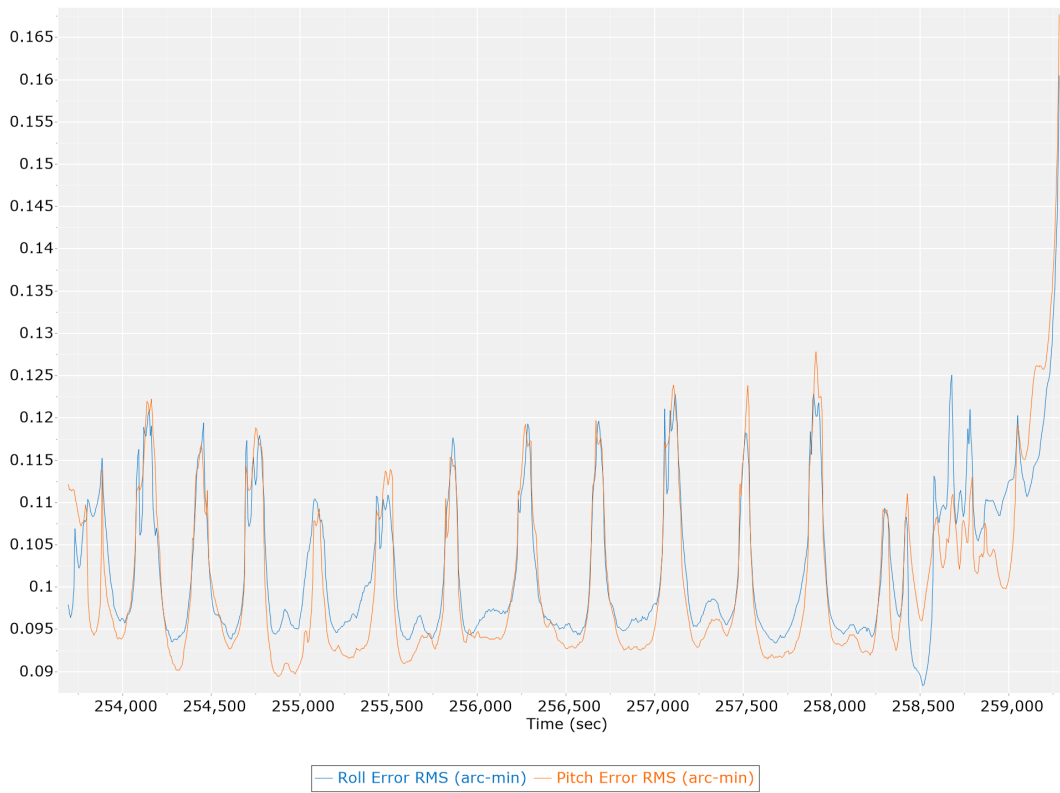
Position Error RMS (m)



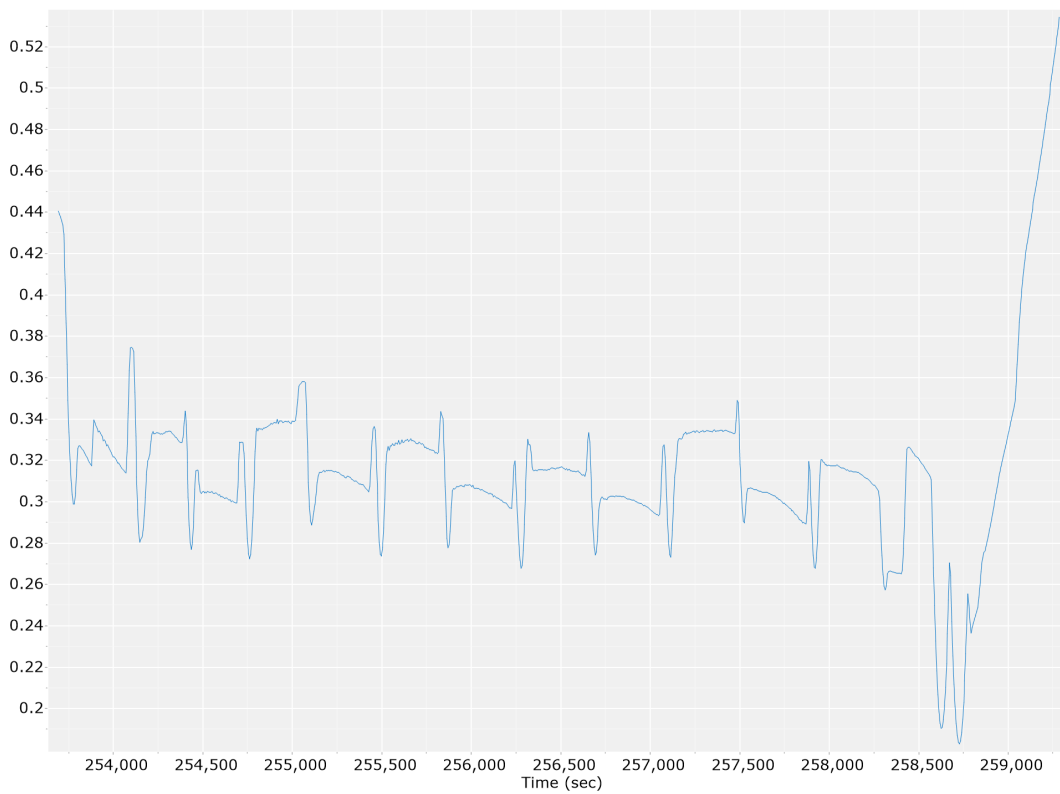
Velocity Error RMS (m/s)



Roll/Pitch Error RMS (arc-min)

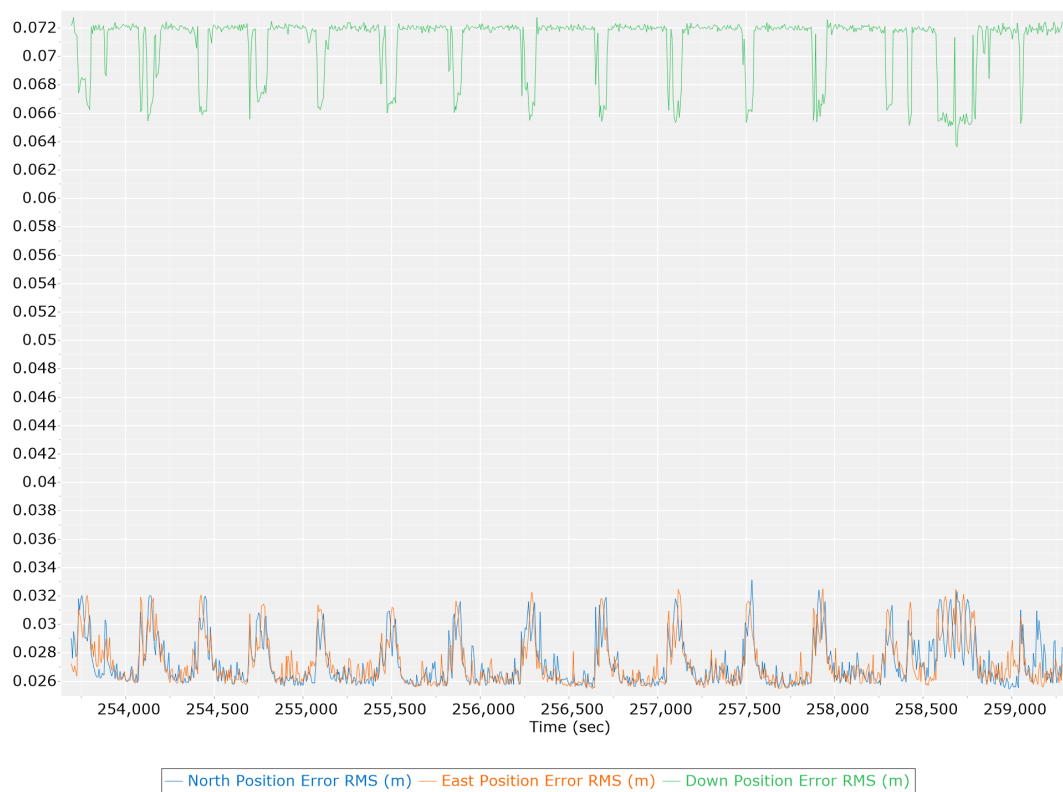


Heading Error RMS (arc-min)



Forward Processed Performance Metrics

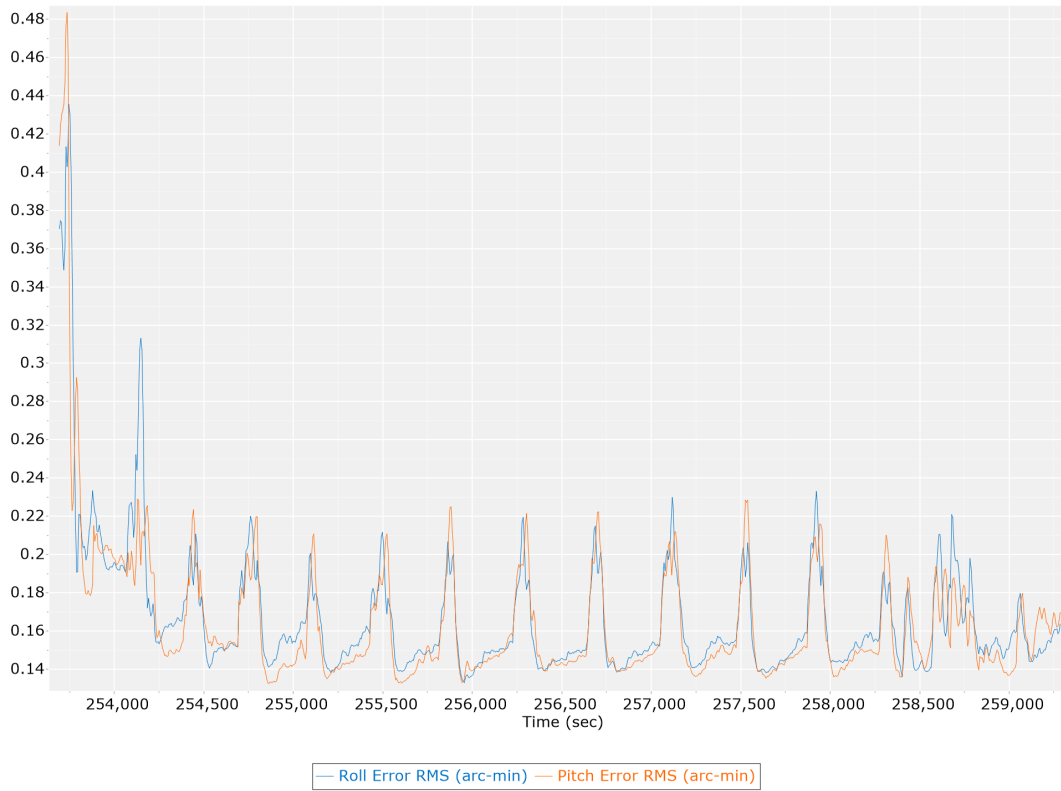
Position Error RMS (m)



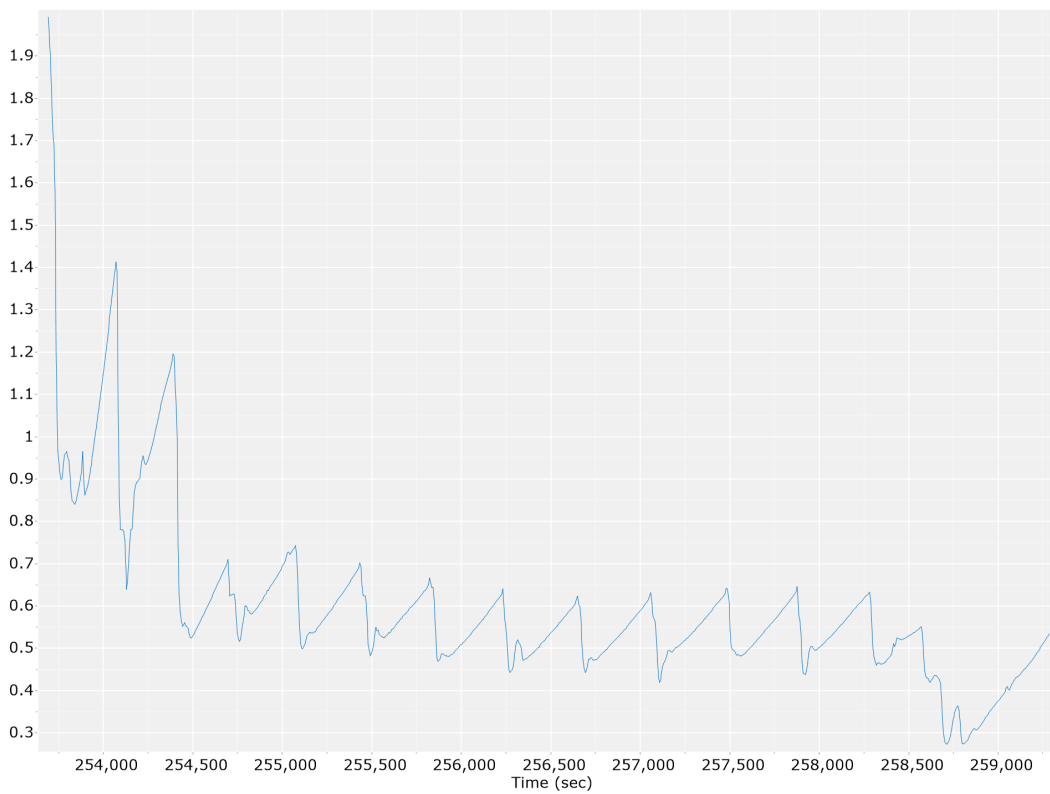
Velocity Error RMS (m/s)



Roll/Pitch Error RMS (arc-min)

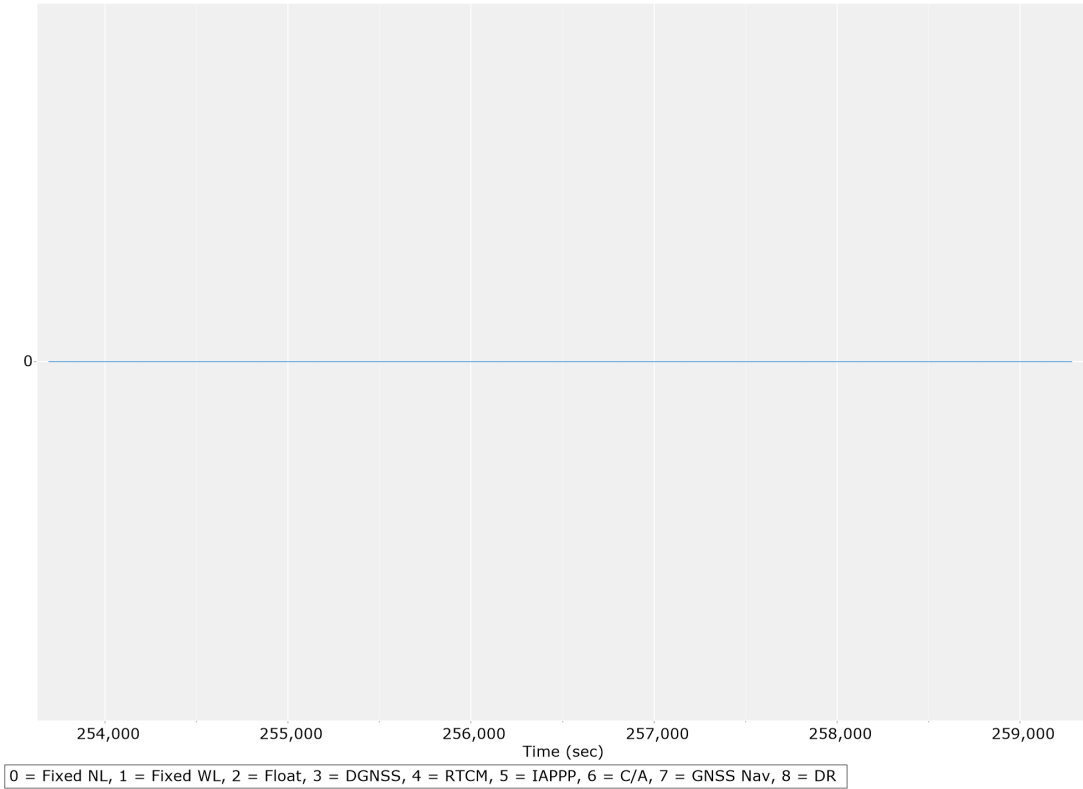


Heading Error RMS (arc-min)



Forward Processed Solution Status

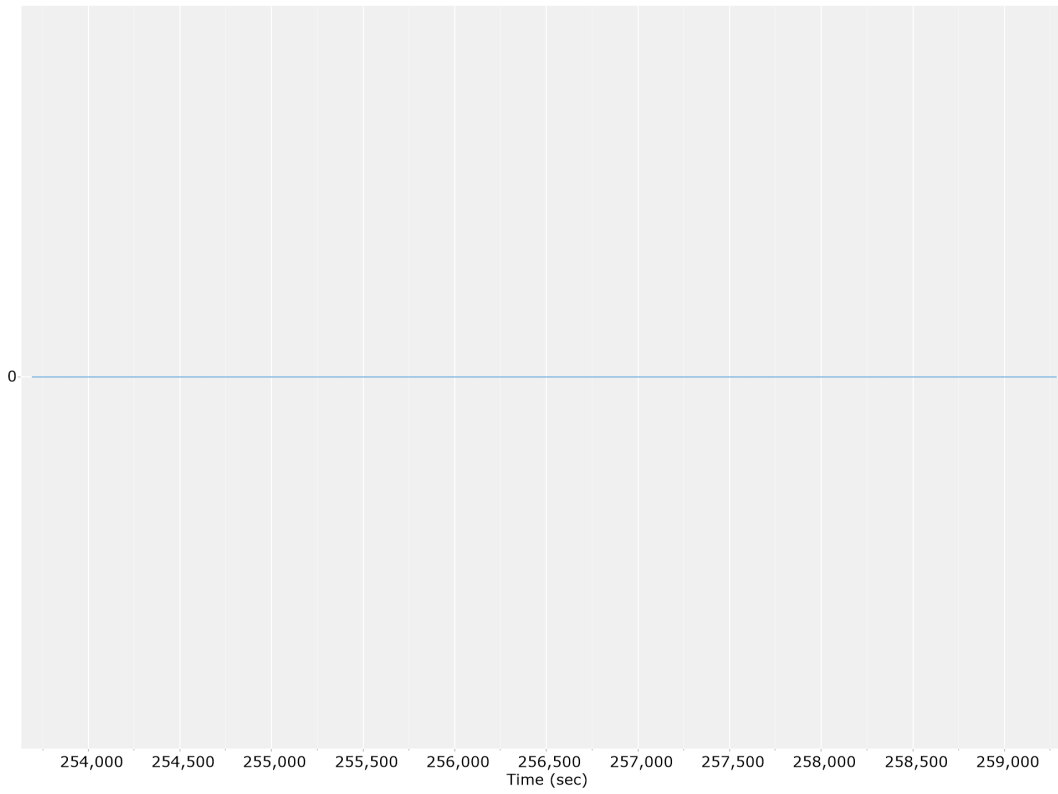
Processing Mode



Number of Satellites



Baseline Length



General Information

Mission Information

Project name	01222025A_4040
Processing date	2025-01-24 05:21:05
Mission date	2025-01-22 18:02:49
Mission duration	04:15:00.725
Processing mode	IN-Fusion PP-RTX

Rover Hardware Information

Product	POS AV 610 VER6 HW2.5-12
Serial number	S/N10451
IMU type	57
Receiver type	BD982
Antenna type	AV59

Project File List

Rover Data Files

File name	File type
250122_180230_INS-GPS_1.raw	POS Data

Input Files

File Name	File Type
BRDC00IGN_R_20250220000_01D_MN.rnx	GPS, GLONASS, GALILEO Broadcast Ephemeris
Ephm0220.25g	GLONASS Broadcast Ephemeris
Ephm0220.25n	GPS Broadcast Ephemeris

Output Files

Filename	File type
sbt_01222025A_4040.out	SBET Trajectory File

Rover Data Summary

First raw data file	250122_180230_INS-GPS_1.raw		
Last raw data file	250122_180230_INS-GPS_1.raw		
Start GPS week	2350		
Start time	324150.648 (1/22/2025 6:02:30 PM)		
End time	339451.373 (1/22/2025 10:17:31 PM)		
Start of fine alignment	324518.914 (1/22/2025 6:08:38 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)	-0.034	-0.010	-0.374
Gimbal to IMU mounting angles (deg)	0.000	0.000	0.000
Gimbal to Primary GNSS lever arm (m)	0.000	0.000	-0.900
Gimbal to Primary GNSS lever arm std dev (m)	-1.000		
Aircraft to Reference mounting angles (deg)	0.000	0.000	0.000

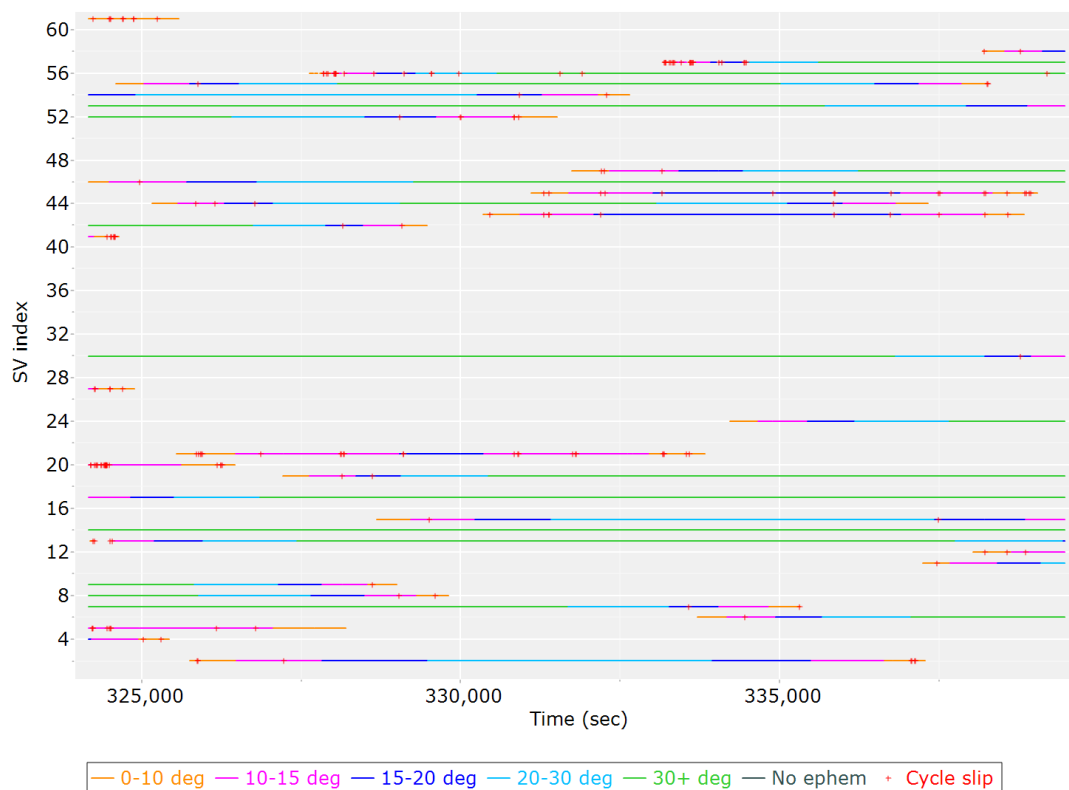
Rover Data QC

Raw IMU Import QC Summary

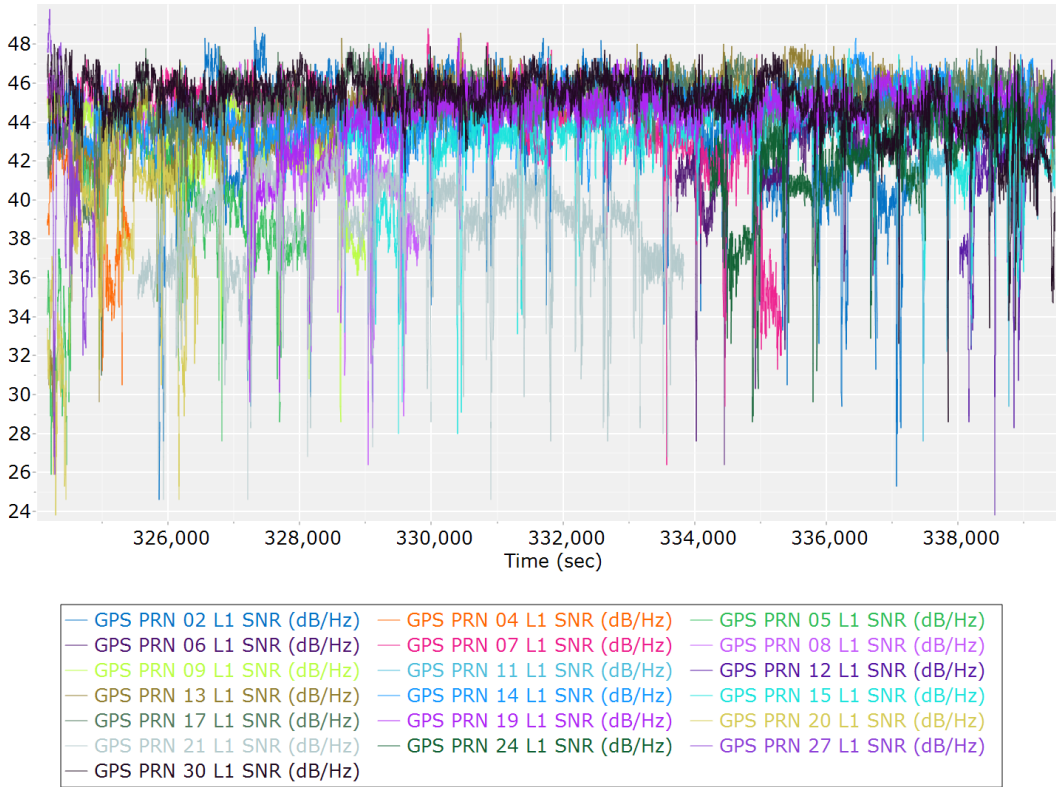
IMU data input file	imu_Mission 1.dat
IMU data check log file	imudt_01222025A_4040.log
IMU Records Processed	3059796
Termination Status	Normal
IMU Anomalies	0

Primary Observables & Satellite Data

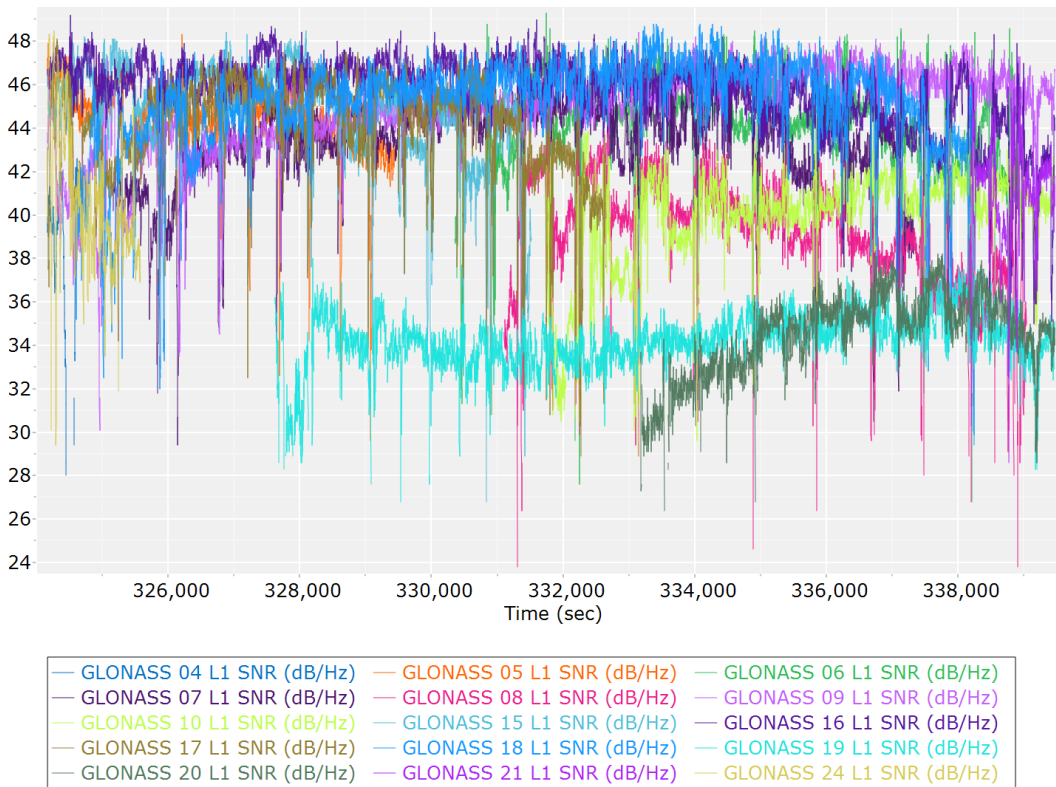
GPS/GLONASS L1 Satellite Lock/Elevation



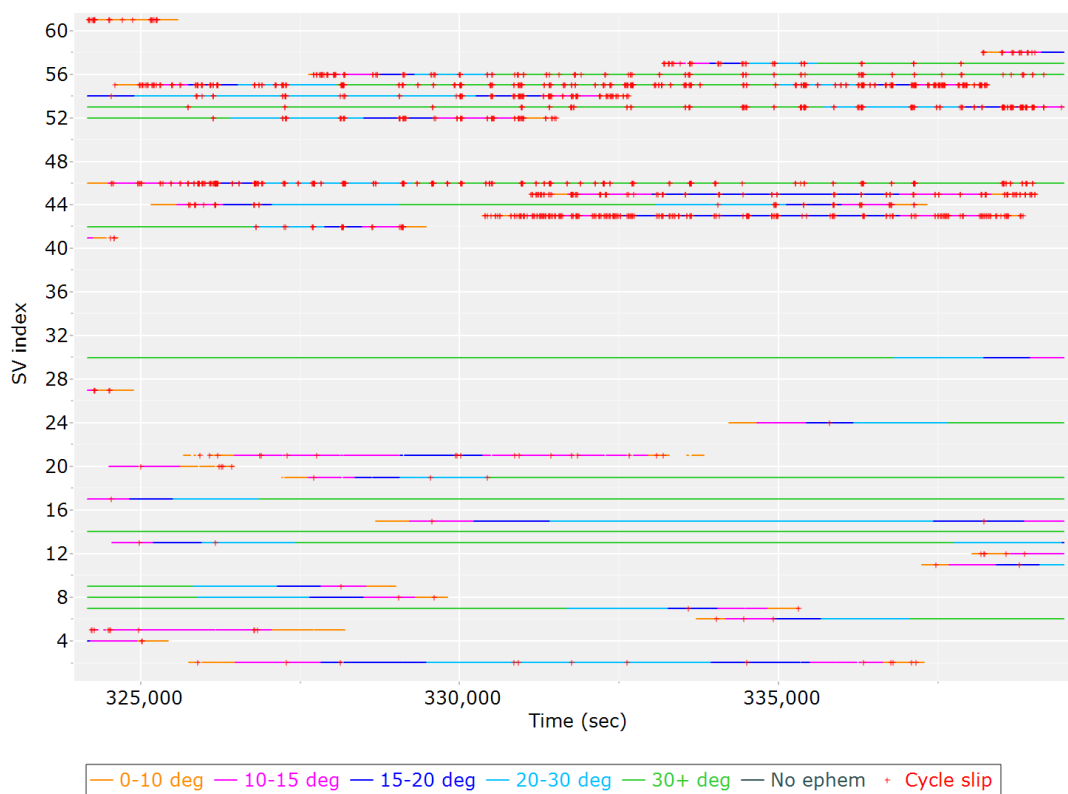
GPS L1 SNR



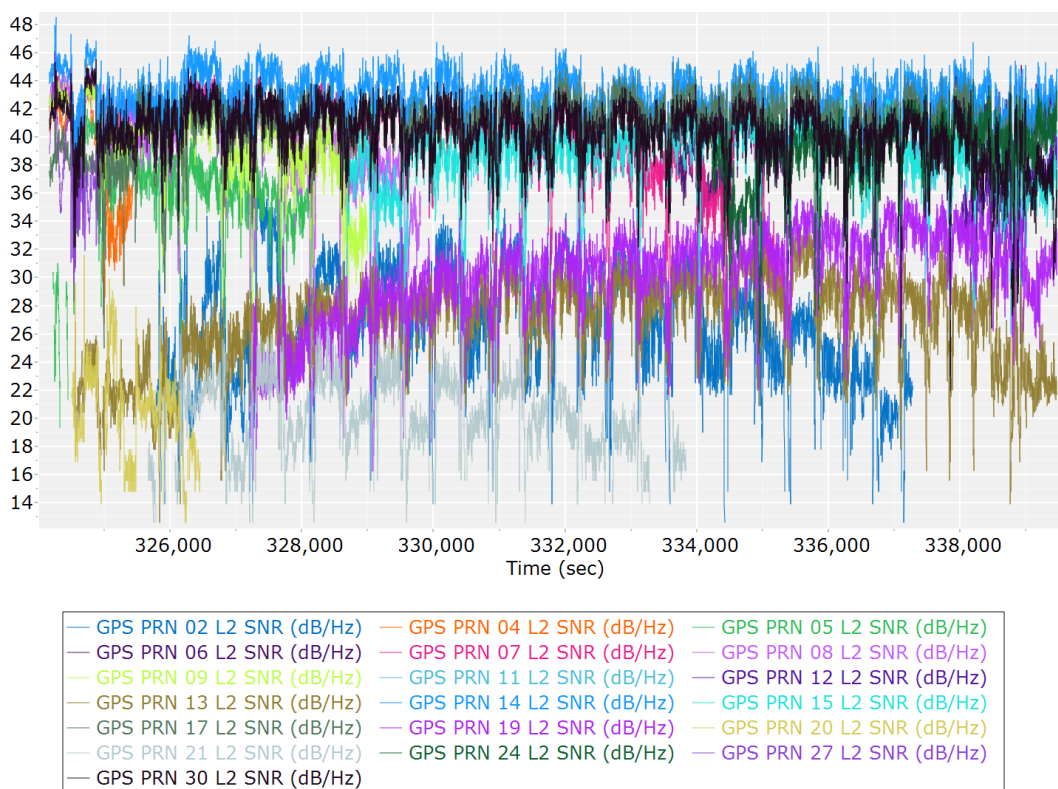
GLONASS L1 SNR



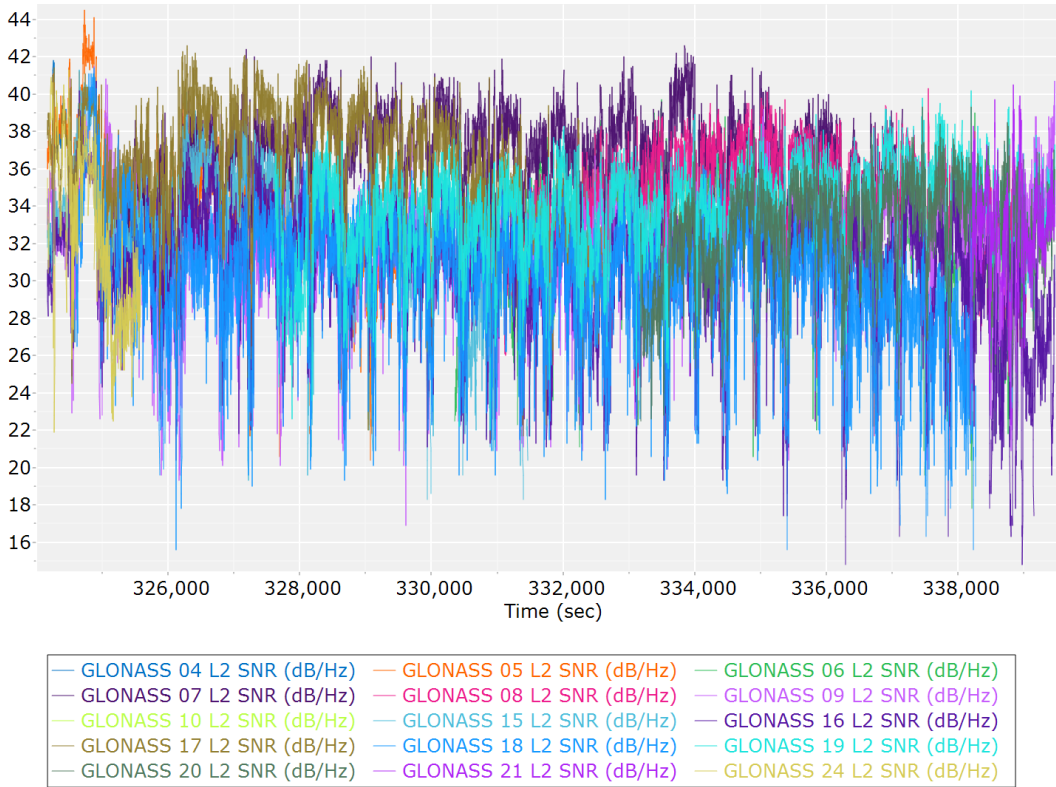
GPS/GLONASS L2 Satellite Lock/Elevation



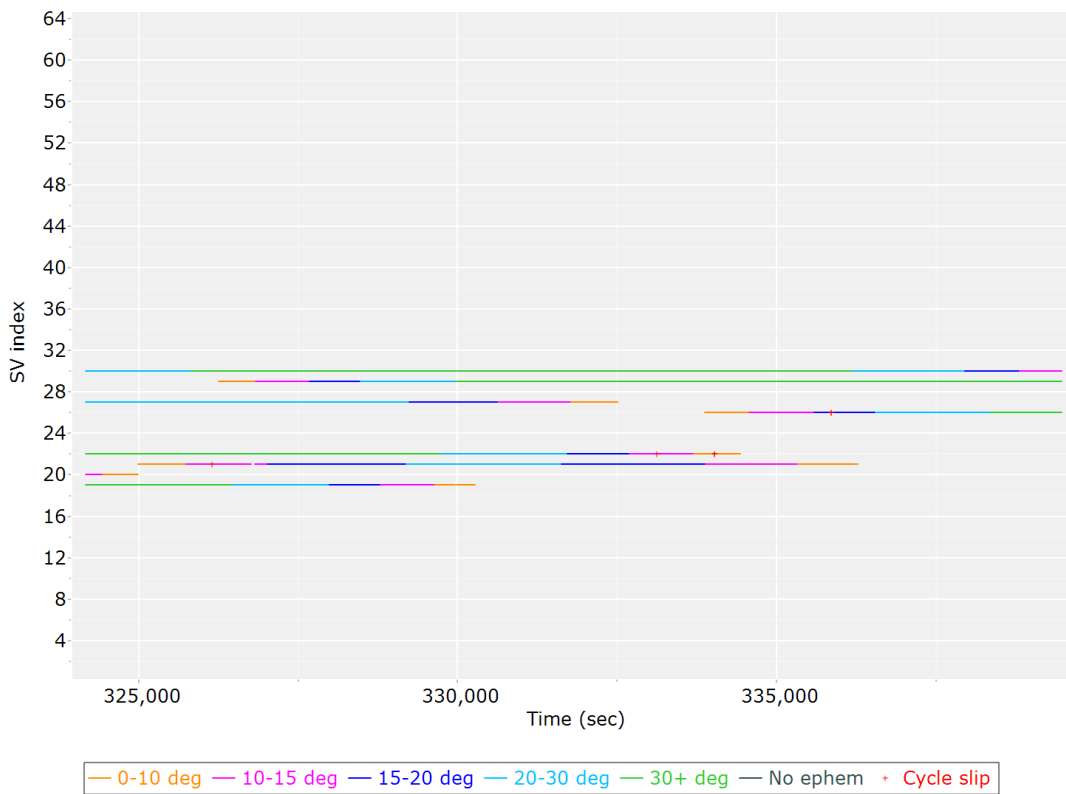
GPS L2 SNR



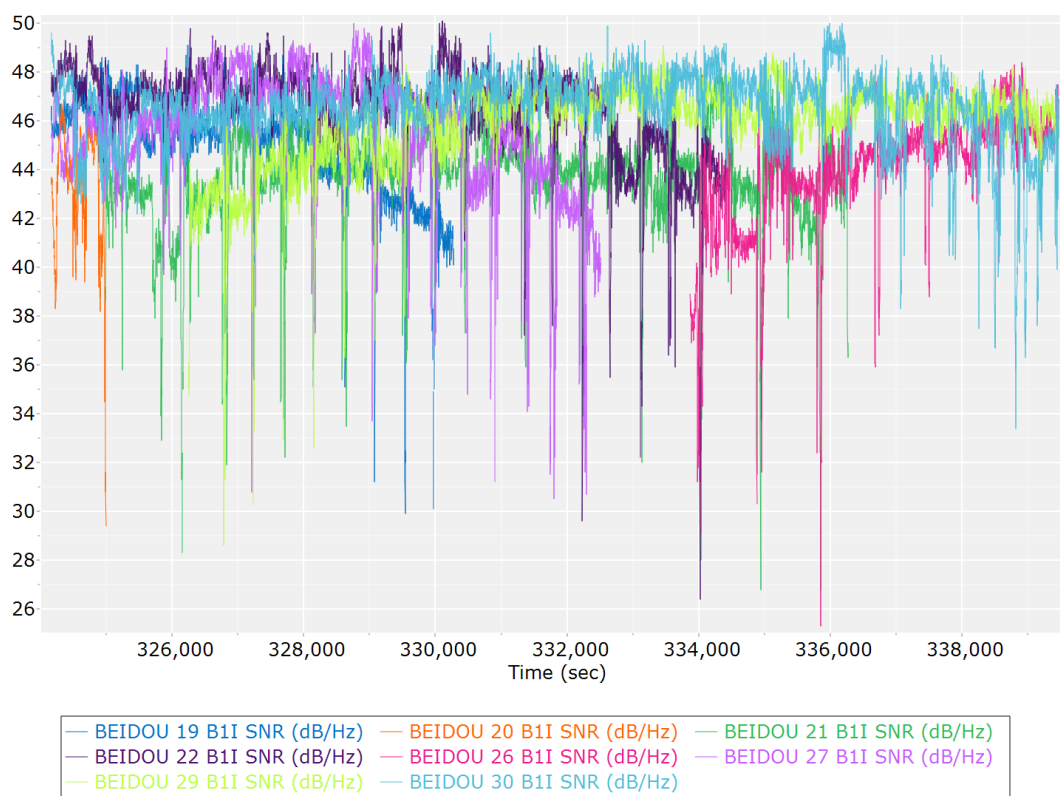
GLONASS L2 SNR



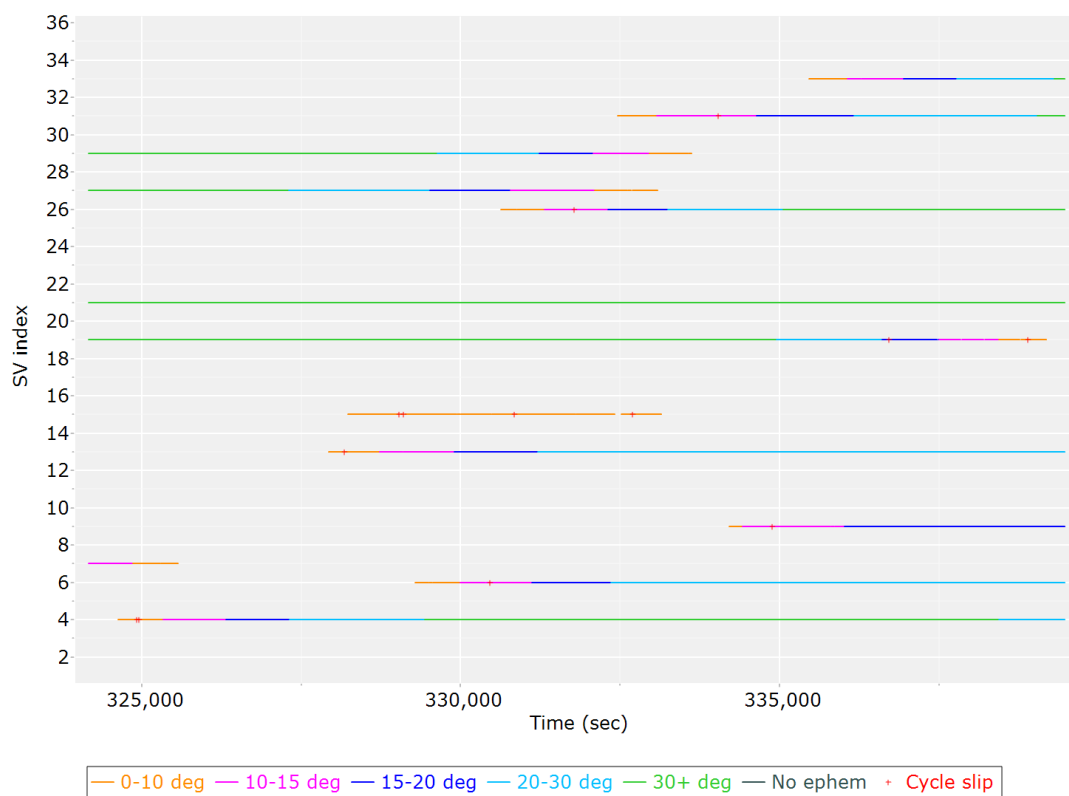
BEIDOU Satellite Lock/Elevation



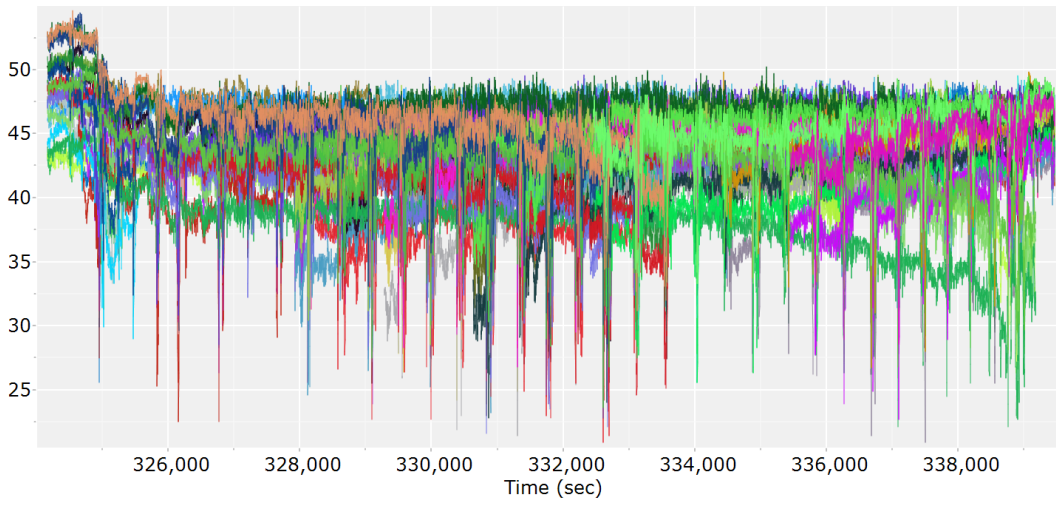
BEIDOU SNR



GALILEO Satellite Lock/Elevation



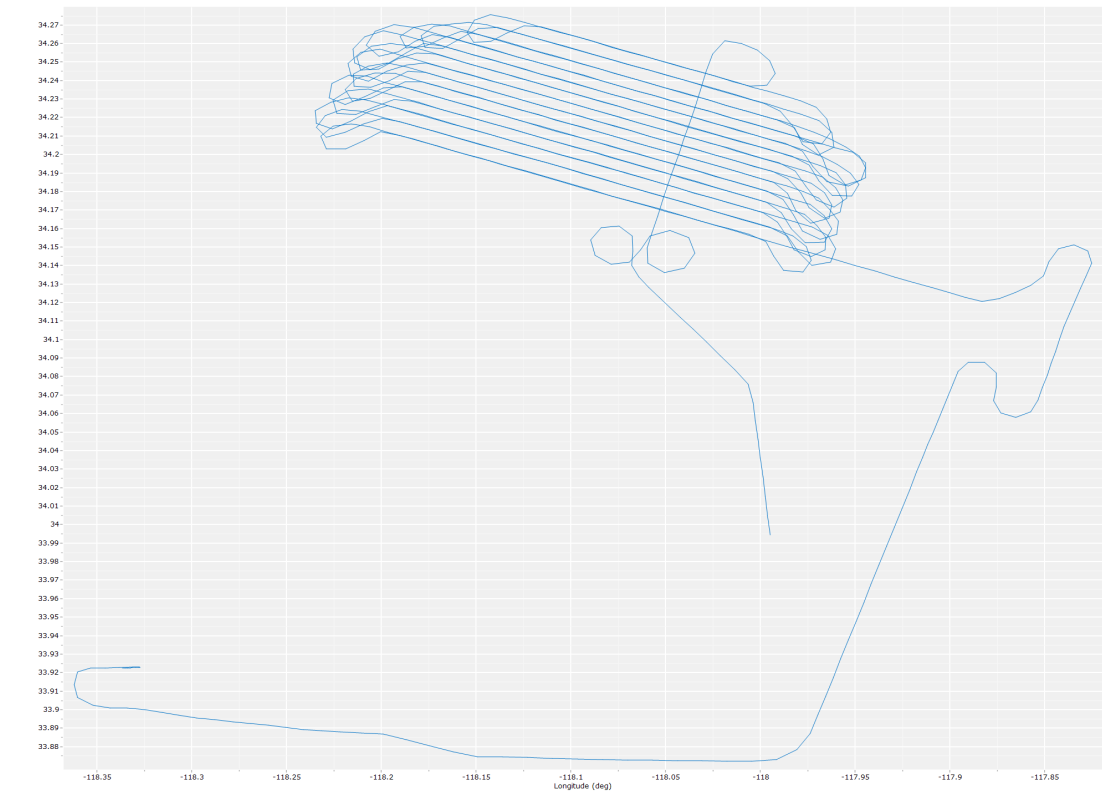
GALILEO SNR



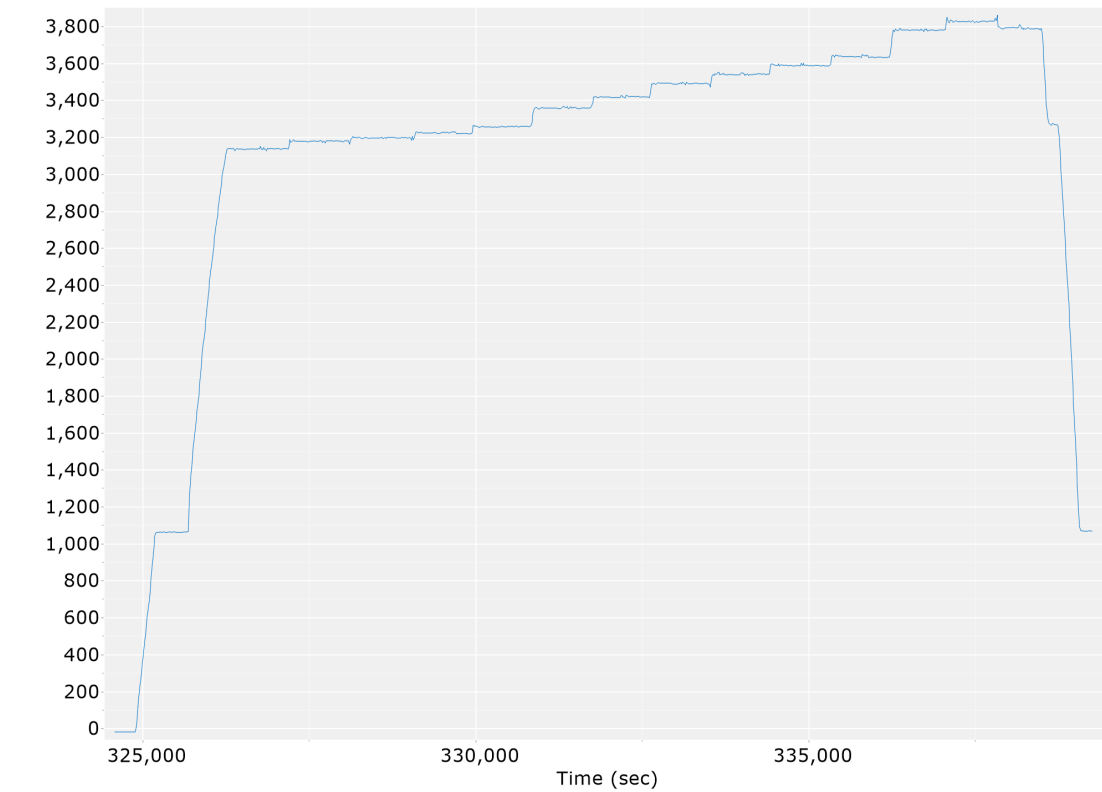
— GALILEO 04 E1CBOC SNR (dB/Hz)	— GALILEO 06 E1CBOC SNR (dB/Hz)
— GALILEO 07 E1CBOC SNR (dB/Hz)	— GALILEO 09 E1CBOC SNR (dB/Hz)
— GALILEO 13 E1CBOC SNR (dB/Hz)	— GALILEO 15 E1CBOC SNR (dB/Hz)
— GALILEO 19 E1CBOC SNR (dB/Hz)	— GALILEO 21 E1CBOC SNR (dB/Hz)
— GALILEO 26 E1CBOC SNR (dB/Hz)	— GALILEO 27 E1CBOC SNR (dB/Hz)
— GALILEO 29 E1CBOC SNR (dB/Hz)	— GALILEO 31 E1CBOC SNR (dB/Hz)
— GALILEO 33 E1CBOC SNR (dB/Hz)	— GALILEO 04 E5A SNR (dB/Hz)
— GALILEO 06 E5A SNR (dB/Hz)	— GALILEO 07 E5A SNR (dB/Hz)
— GALILEO 09 E5A SNR (dB/Hz)	— GALILEO 13 E5A SNR (dB/Hz)
— GALILEO 15 E5A SNR (dB/Hz)	— GALILEO 19 E5A SNR (dB/Hz)

Smoothed Trajectory Information

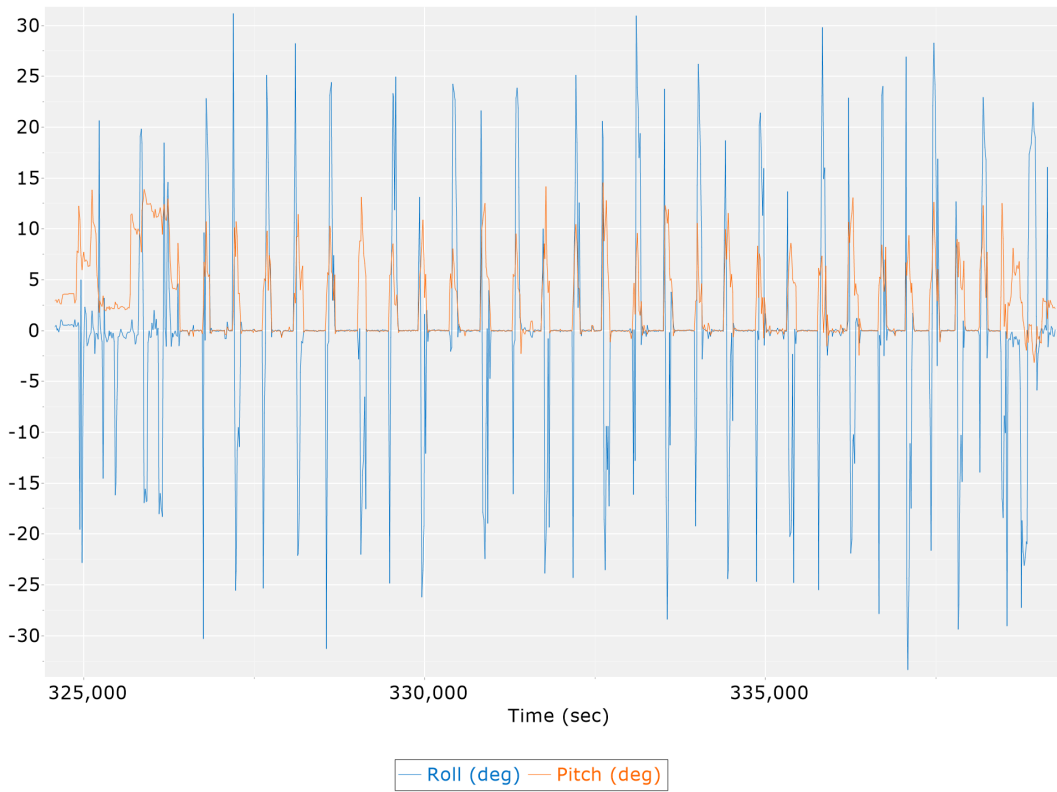
Top View



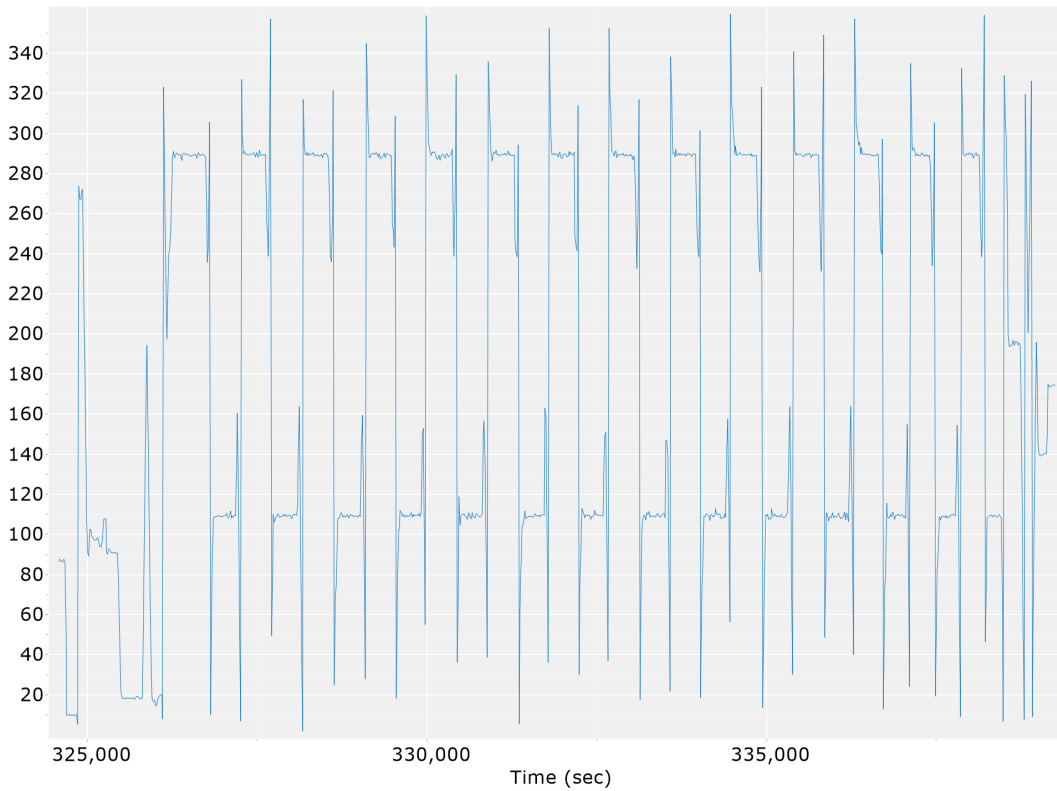
Altitude



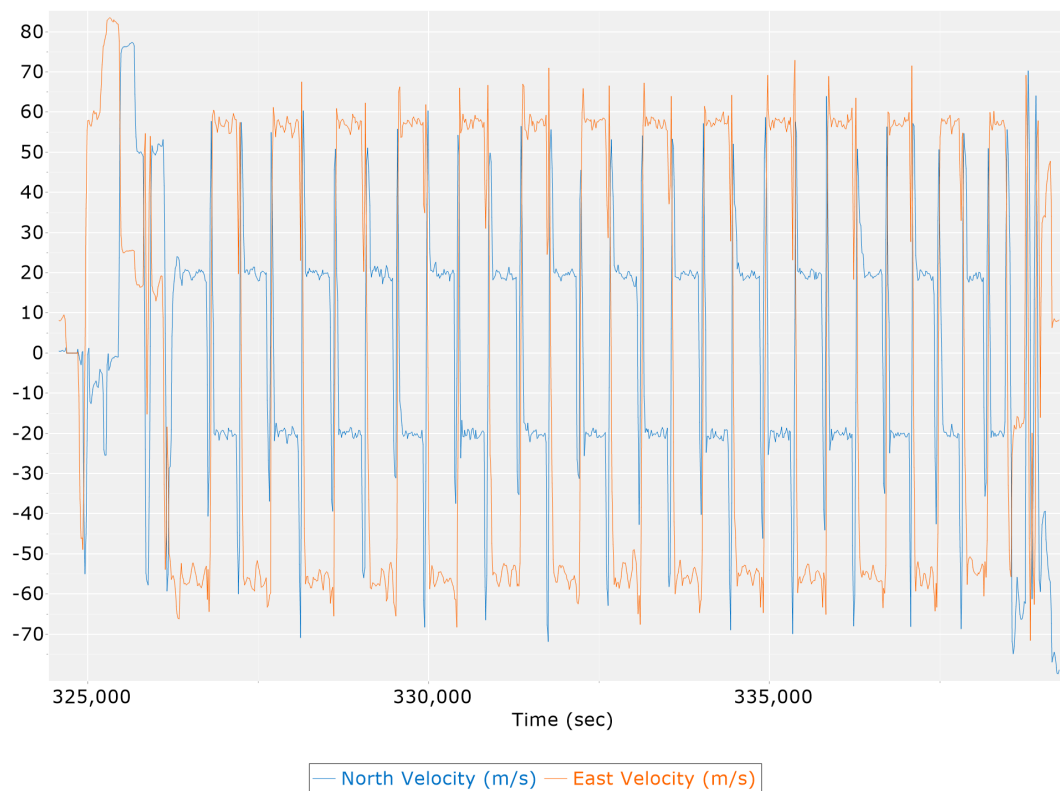
Roll/Pitch



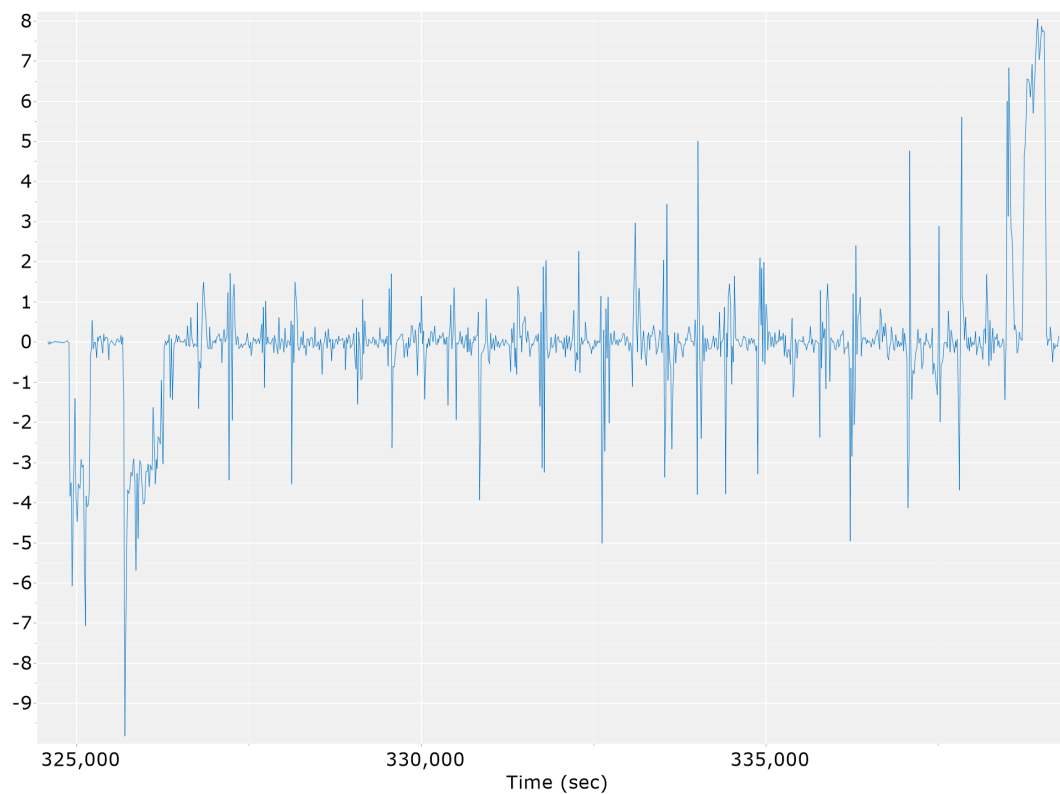
Heading



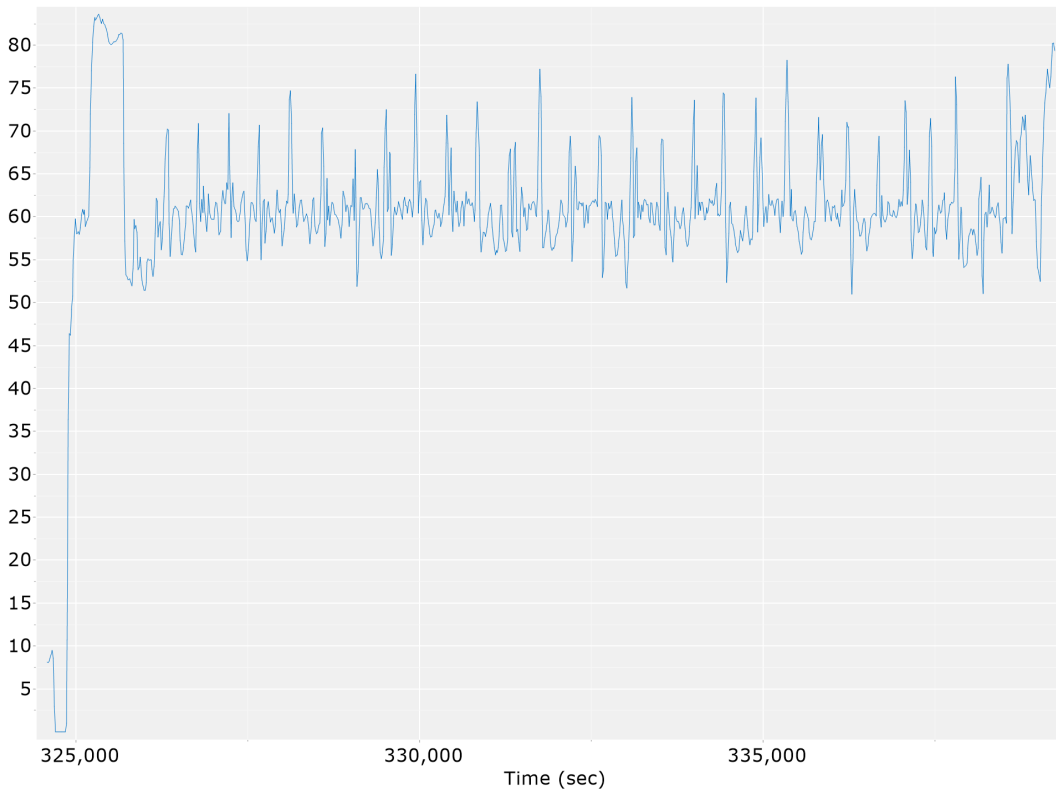
North/East Velocity



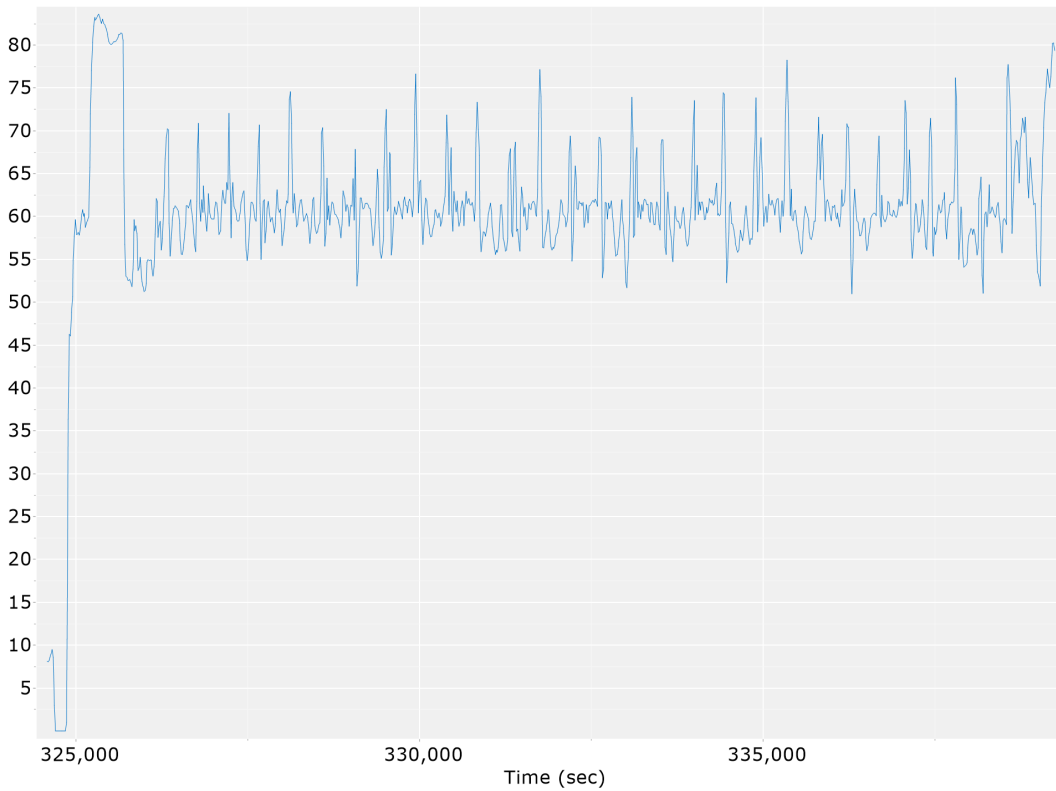
Down Velocity



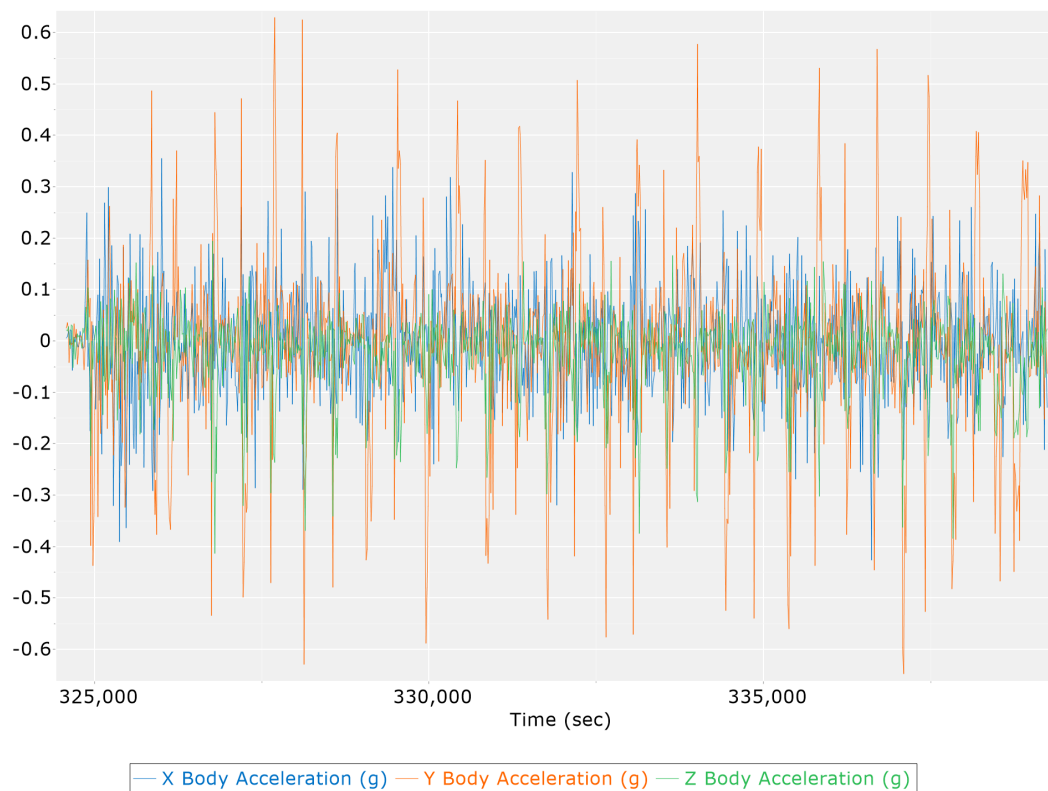
Total Speed



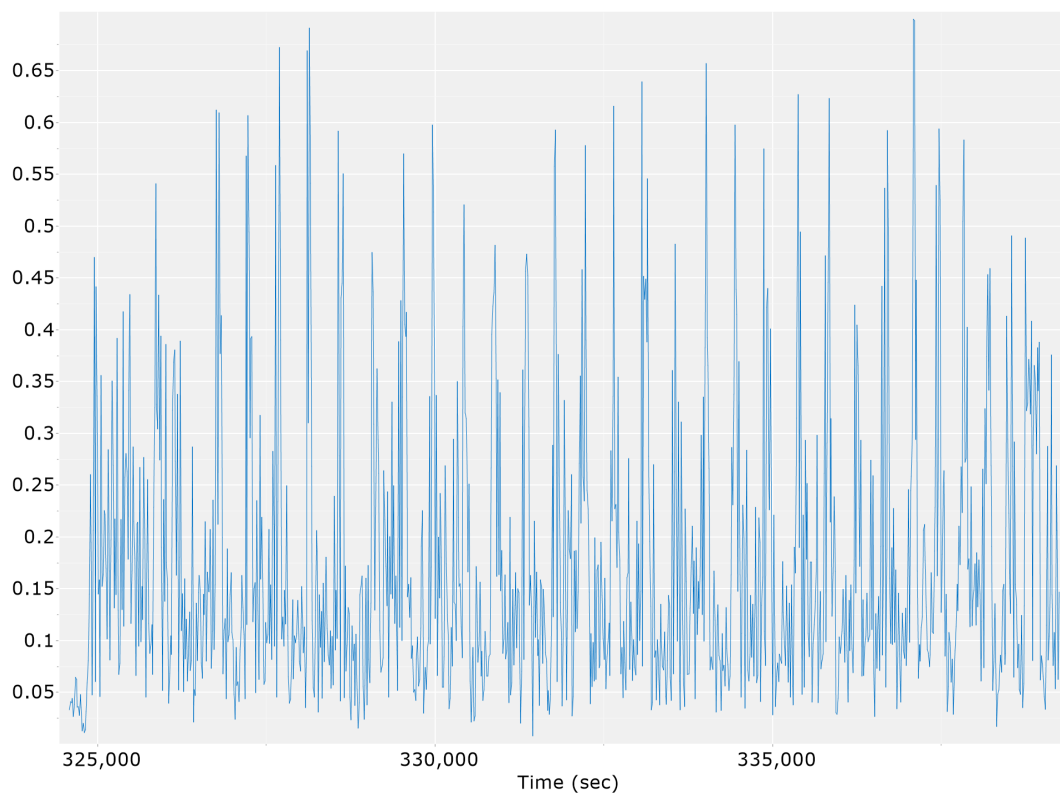
Ground Speed



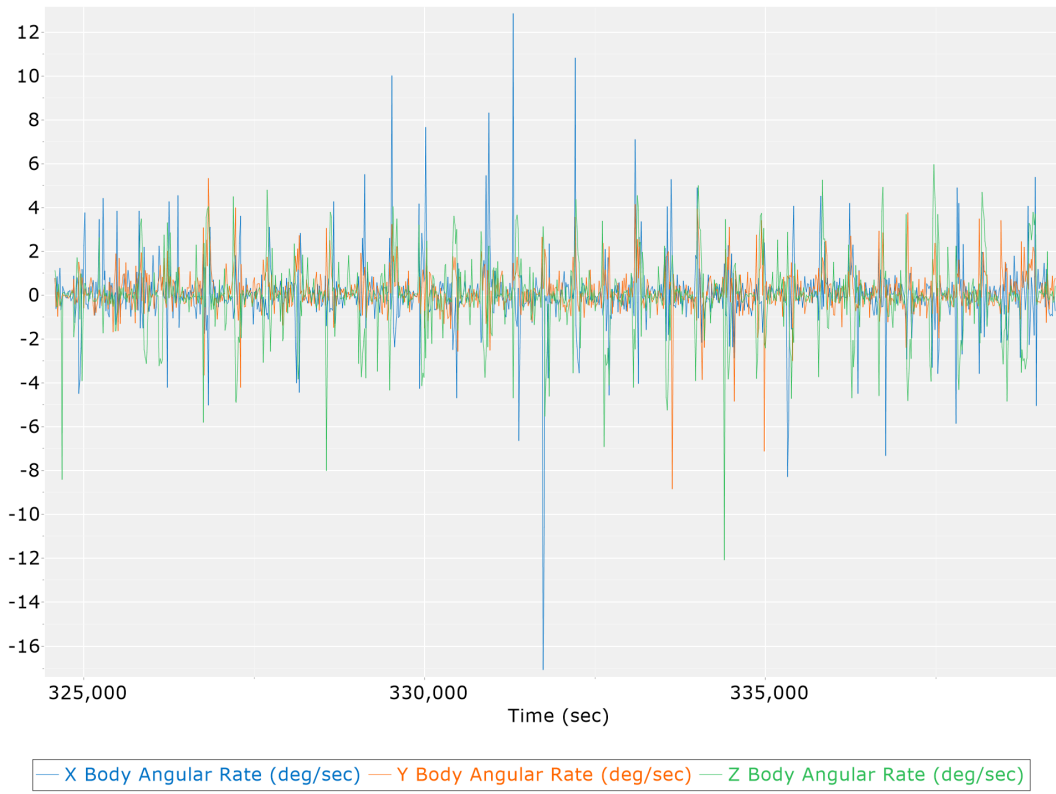
Body Acceleration



Total Body Acceleration

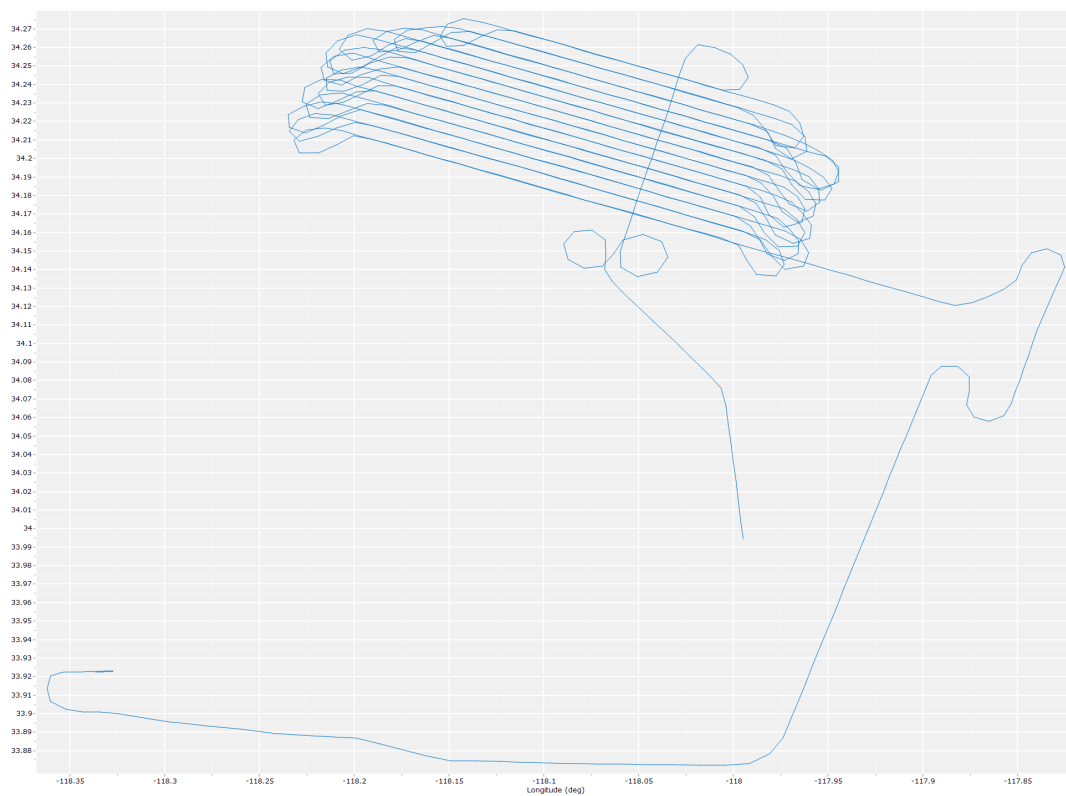


Body Angular Rate

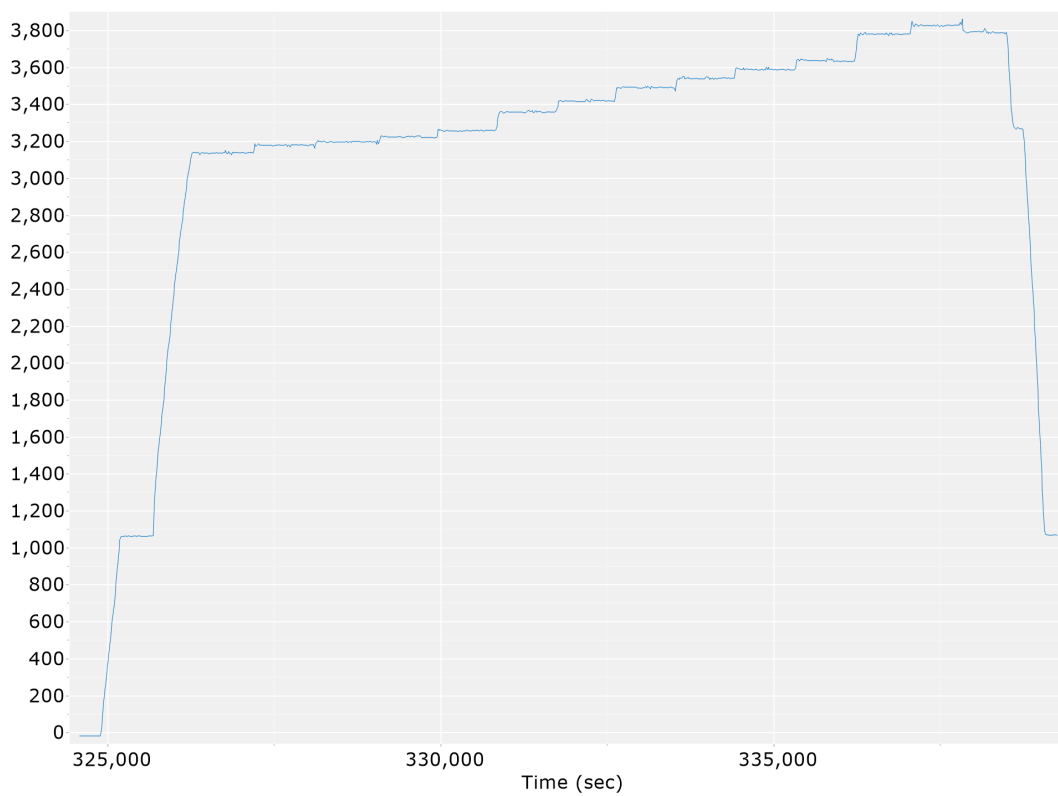


Forward Processed Trajectory Information

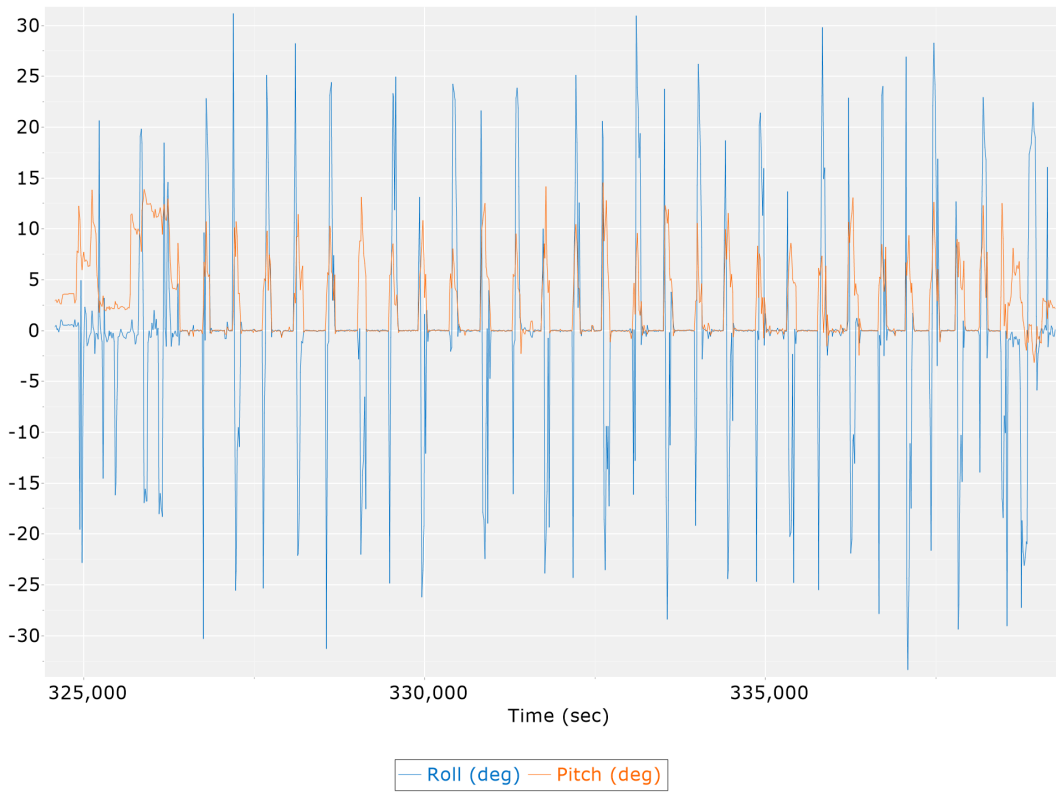
Top View



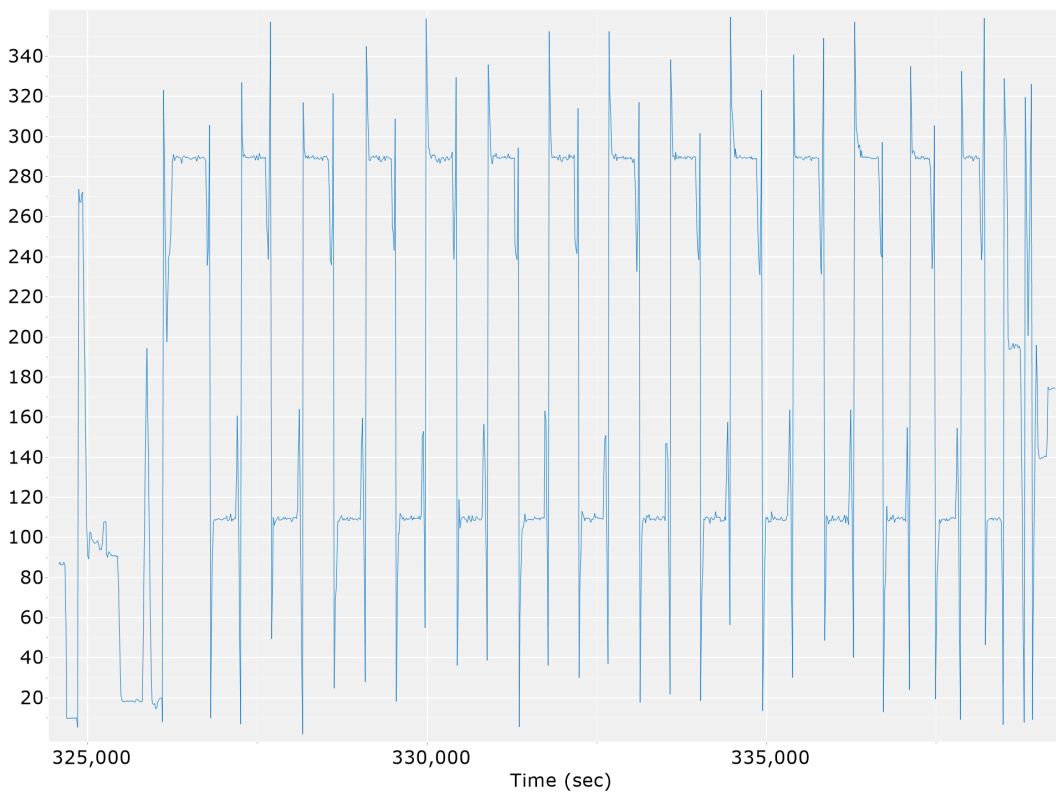
Altitude



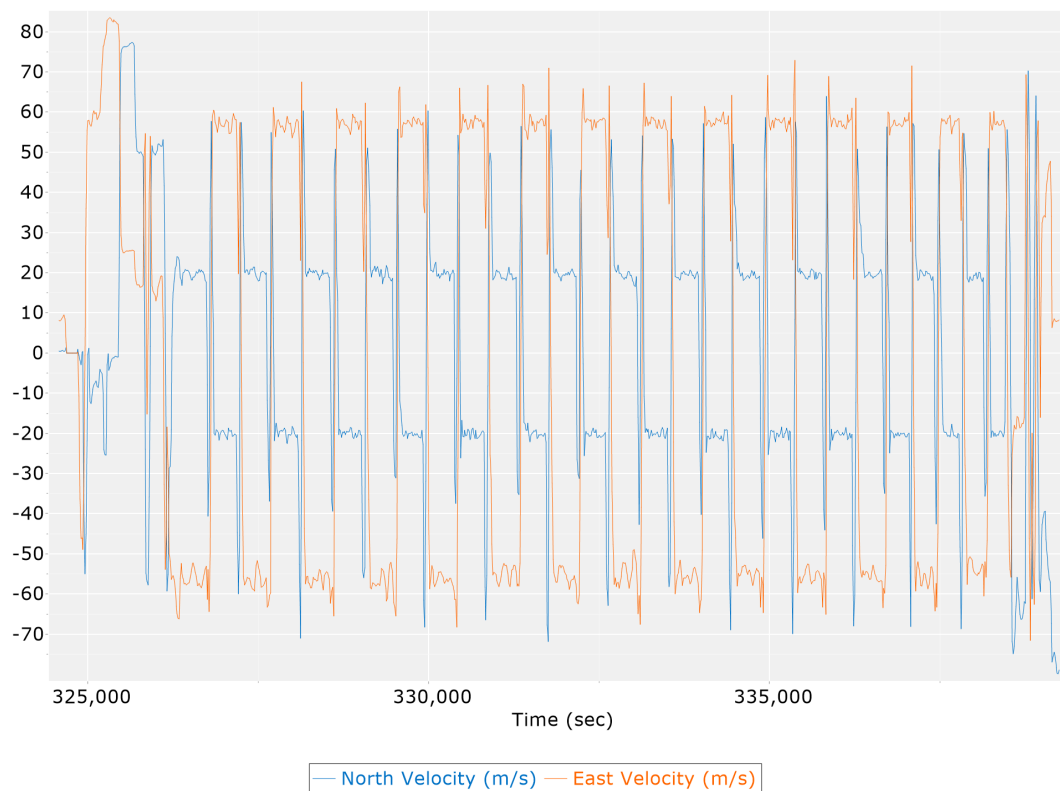
Roll/Pitch



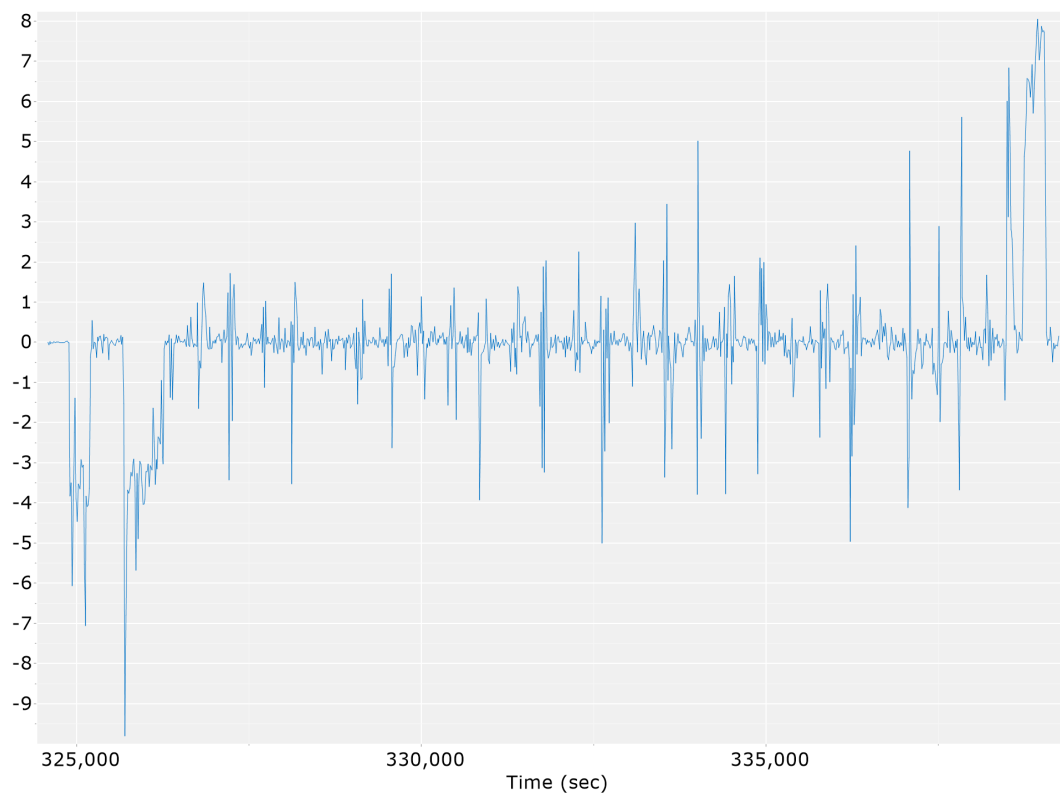
Heading



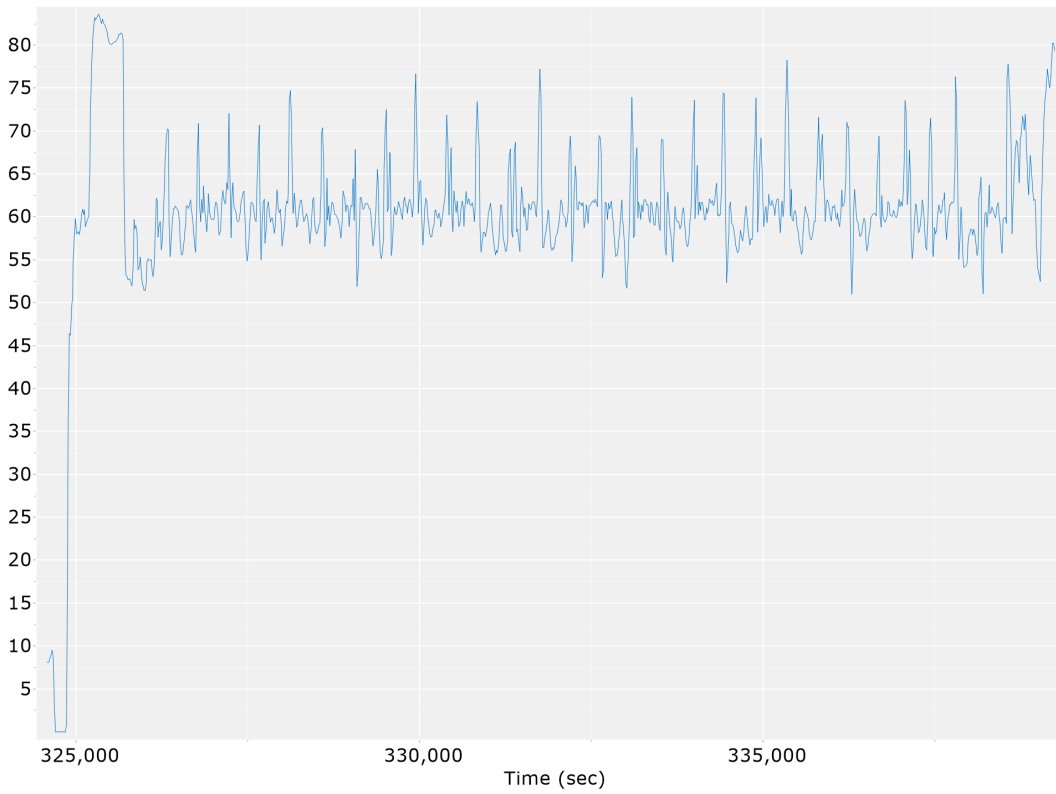
North/East Velocity



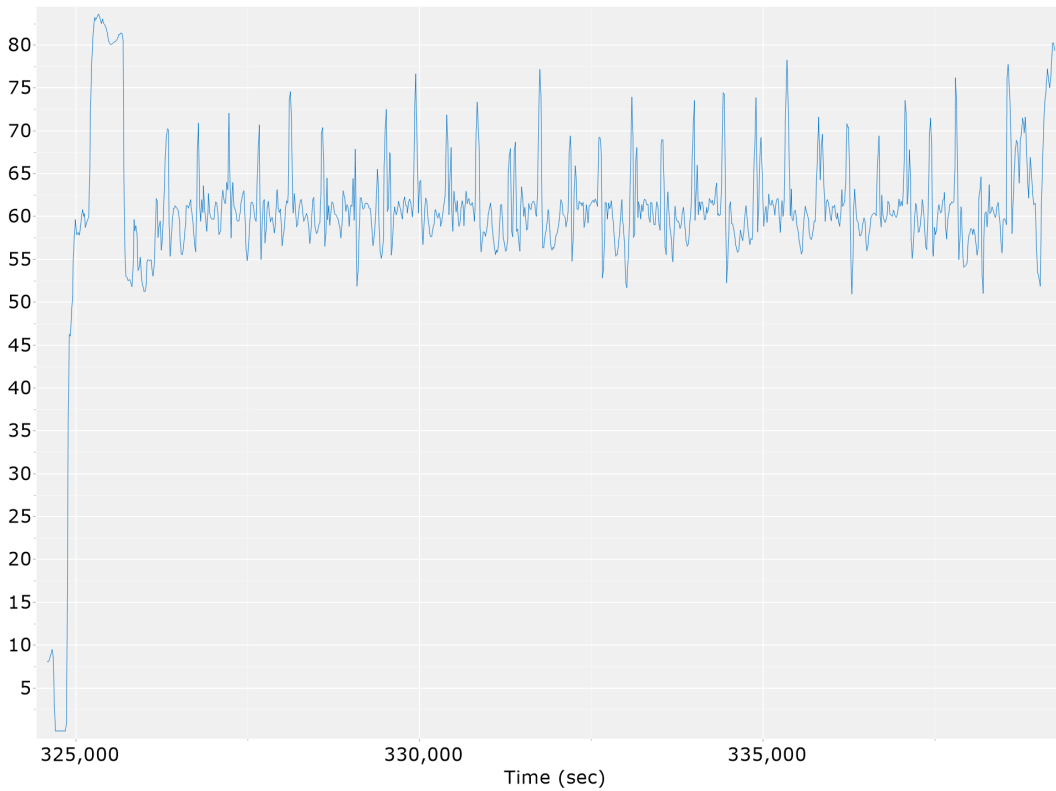
Down Velocity



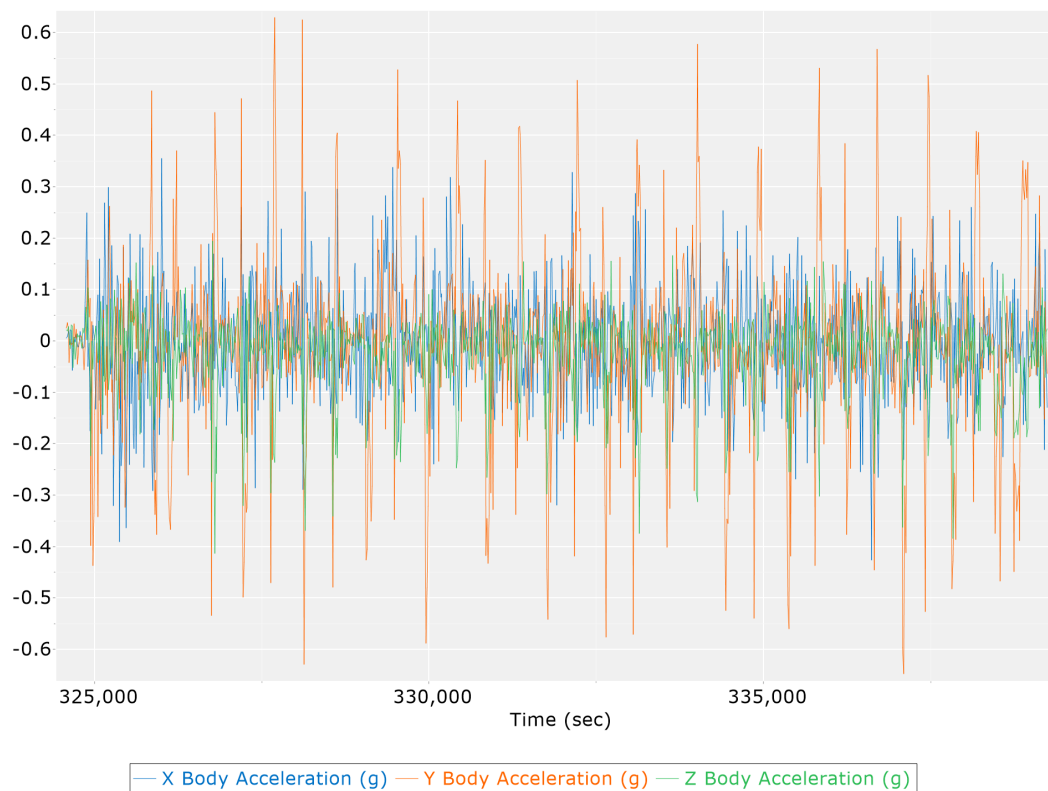
Total Speed



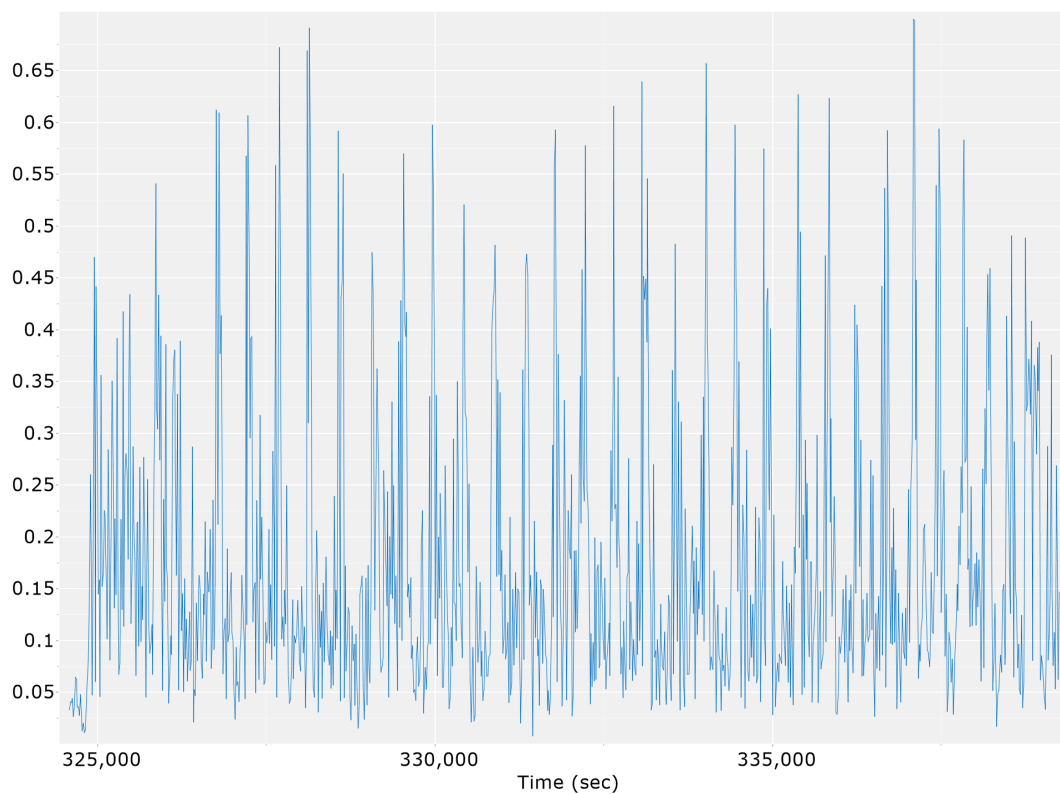
Ground Speed



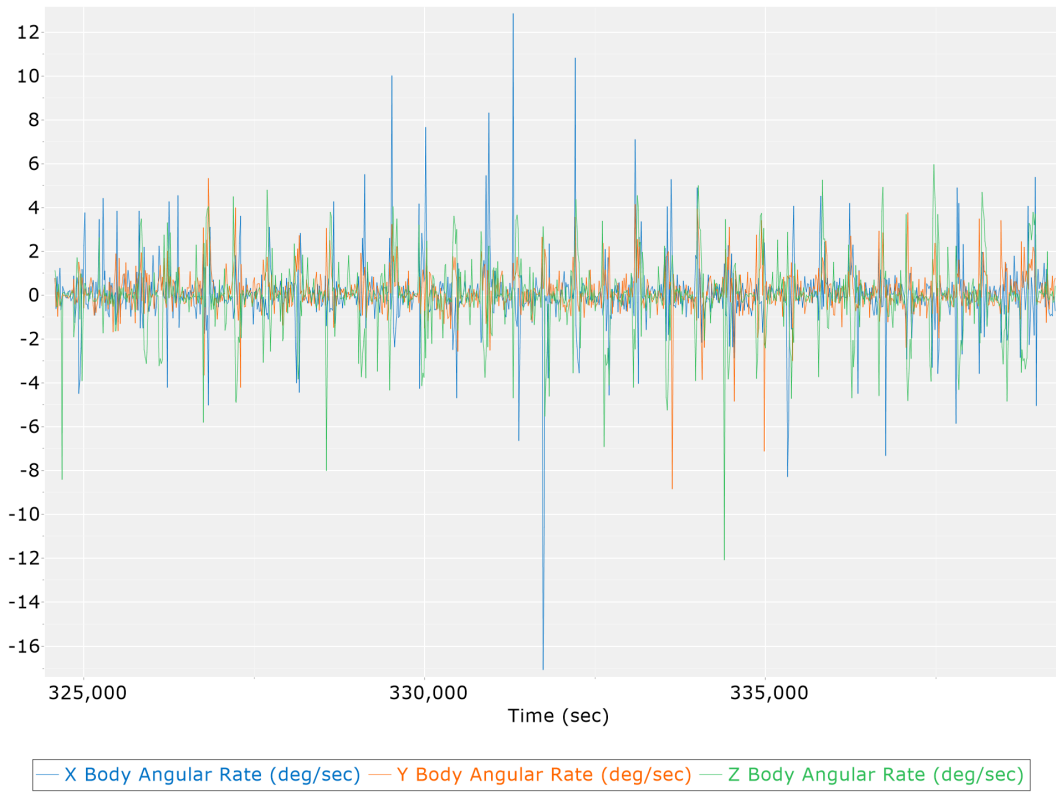
Body Acceleration



Total Body Acceleration



Body Angular Rate

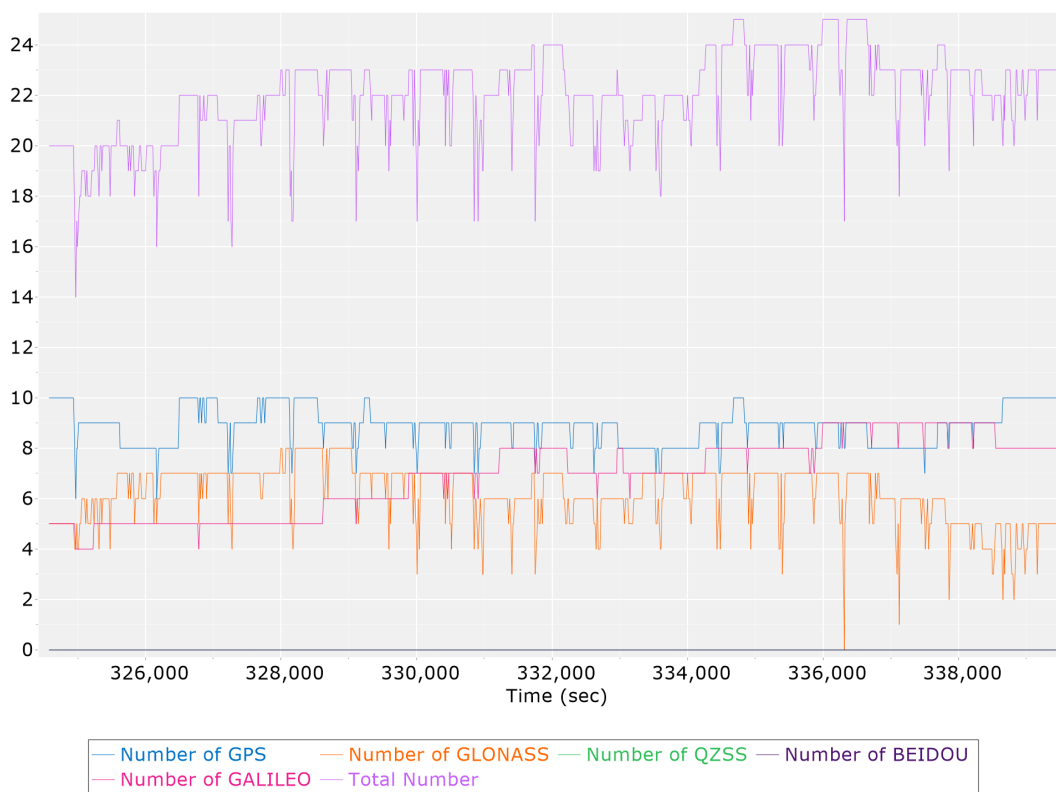


GNSS QC

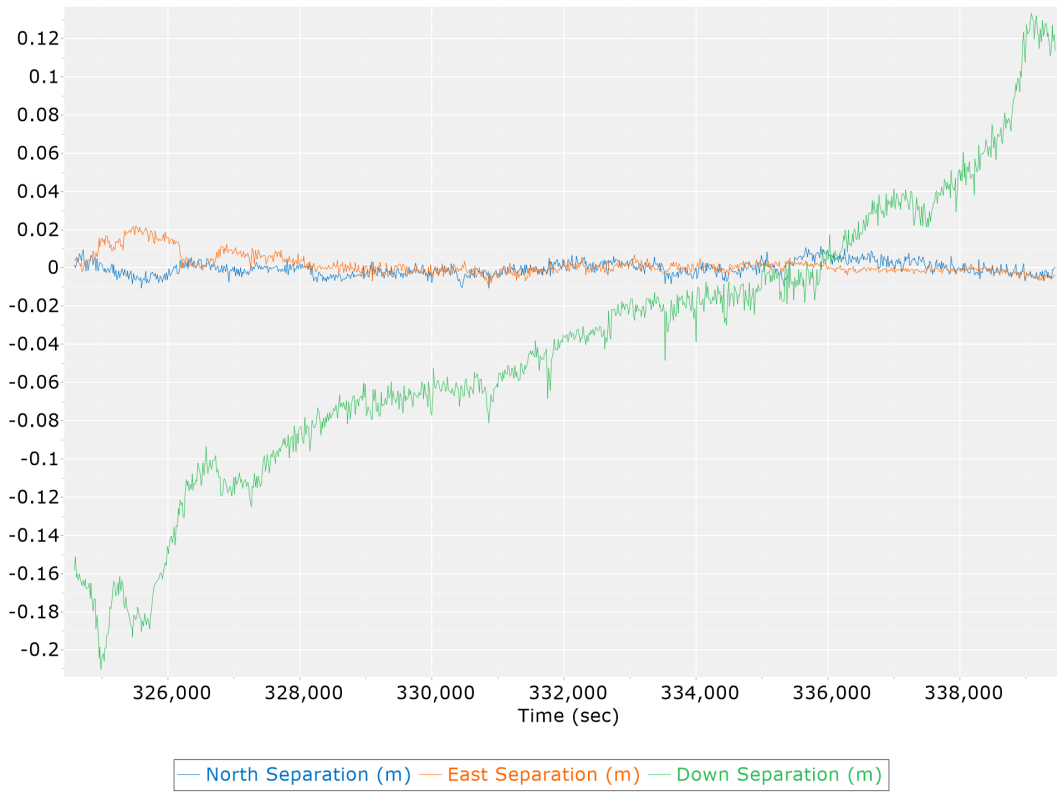
GNSS QC Statistics

Statistics	Min	Max	Mean
Number of GPS SV	6	10	9
Number of GLONASS SV	0	8	6
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Number of GALILEO SV	4	9	7
Total number of SV	13	25	22
PDOP	1.02	2.34	1.18
QC Solution Gaps	0.00	0.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	15297.00	0.00	0.00
Percentage	100.00	0.00	0.00

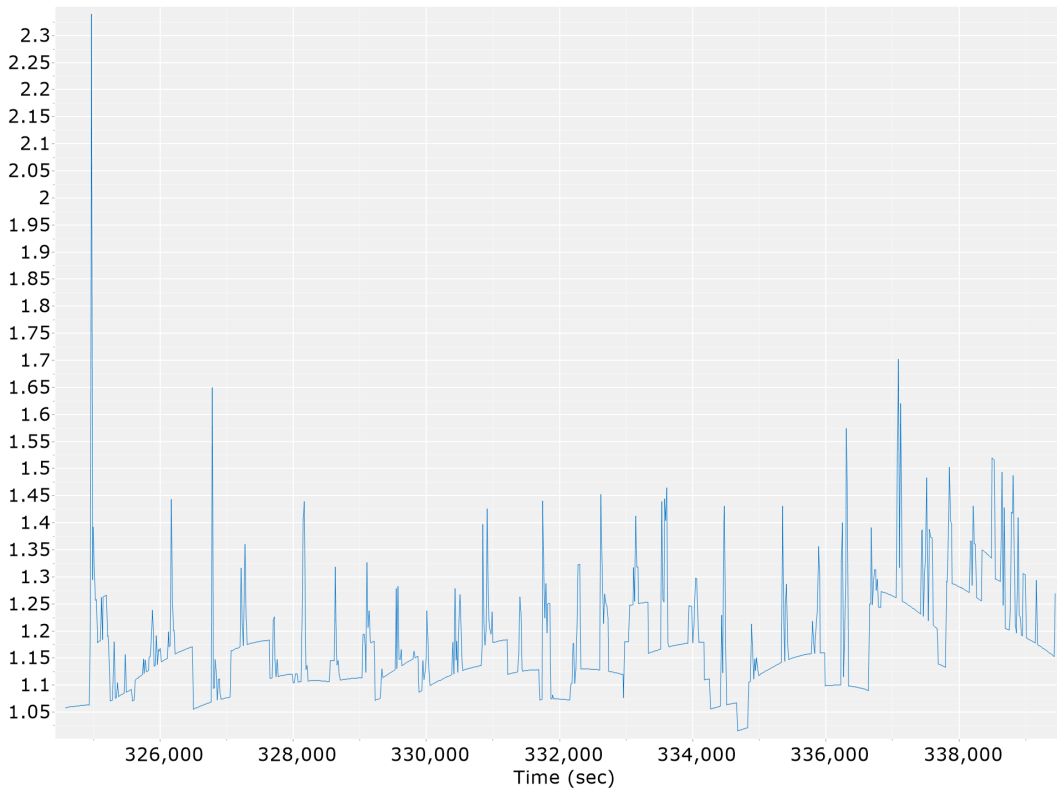
Num SVs in solution



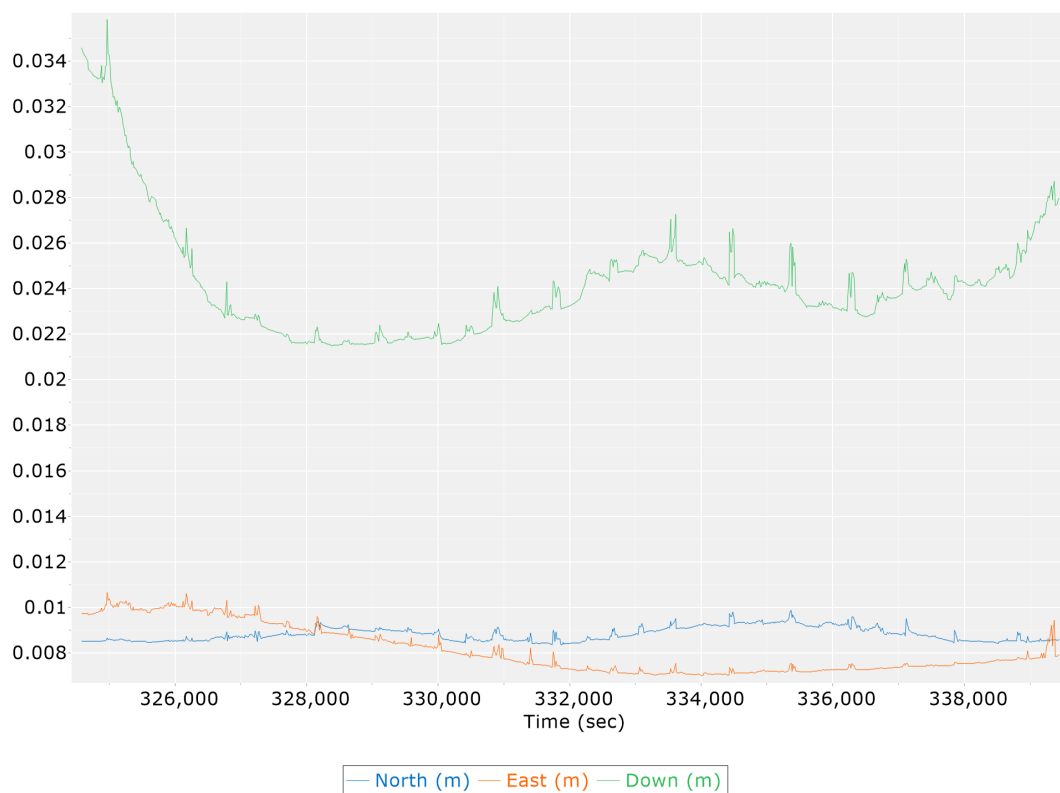
Forward/Reverse Separation



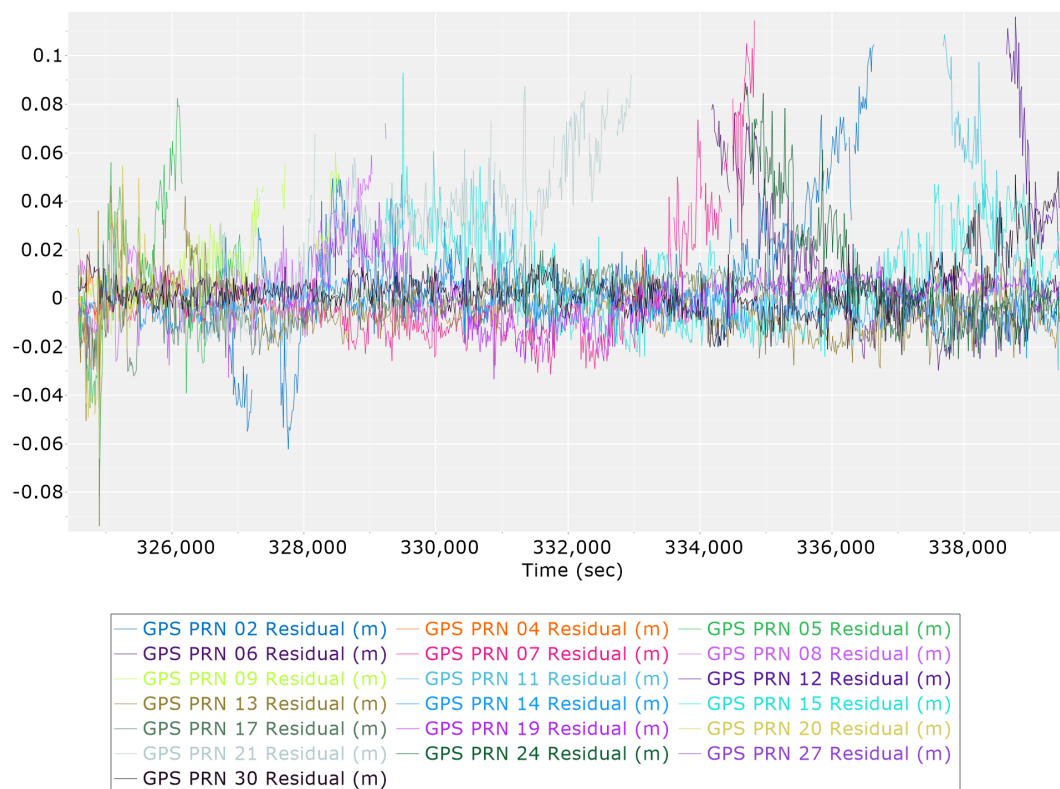
PDOP



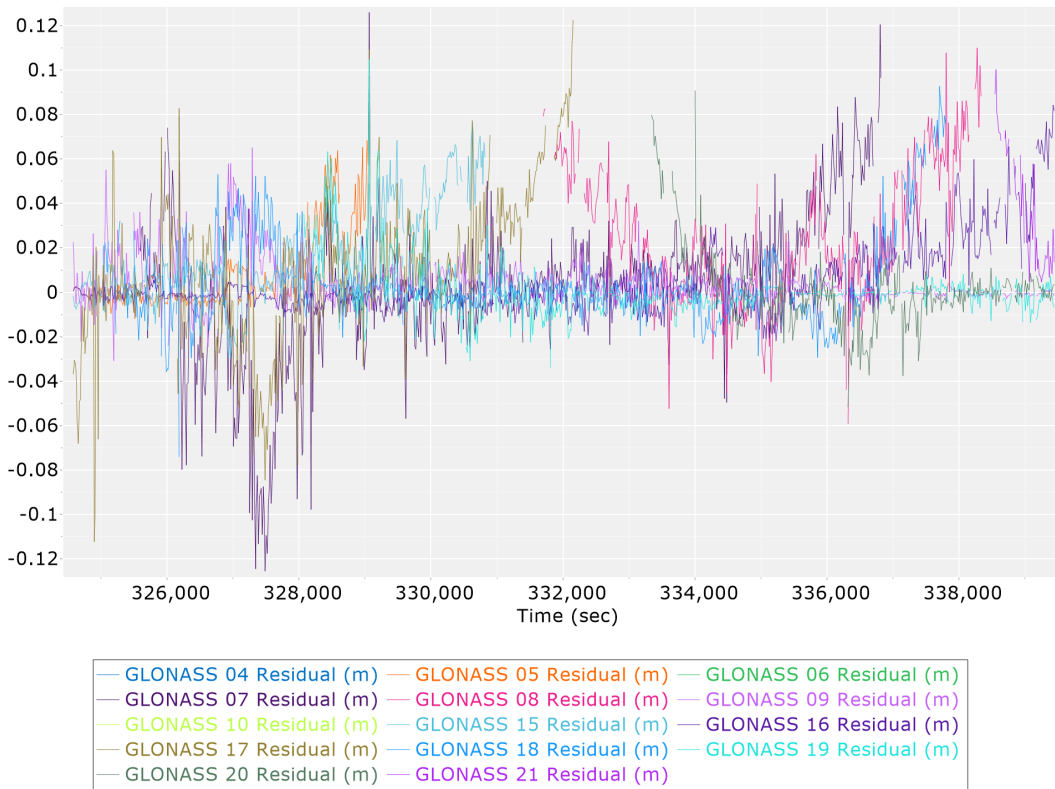
Estimated Position Accuracy



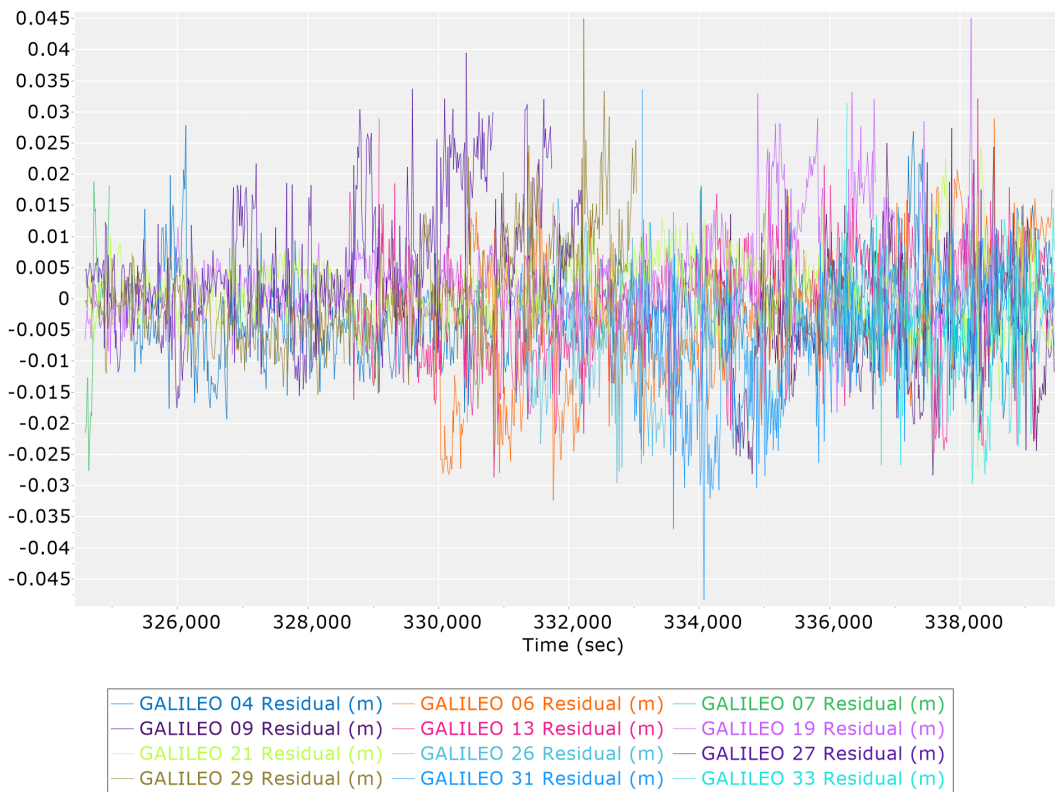
GPS Residuals



GLONASS Residuals



GALILEO Residuals



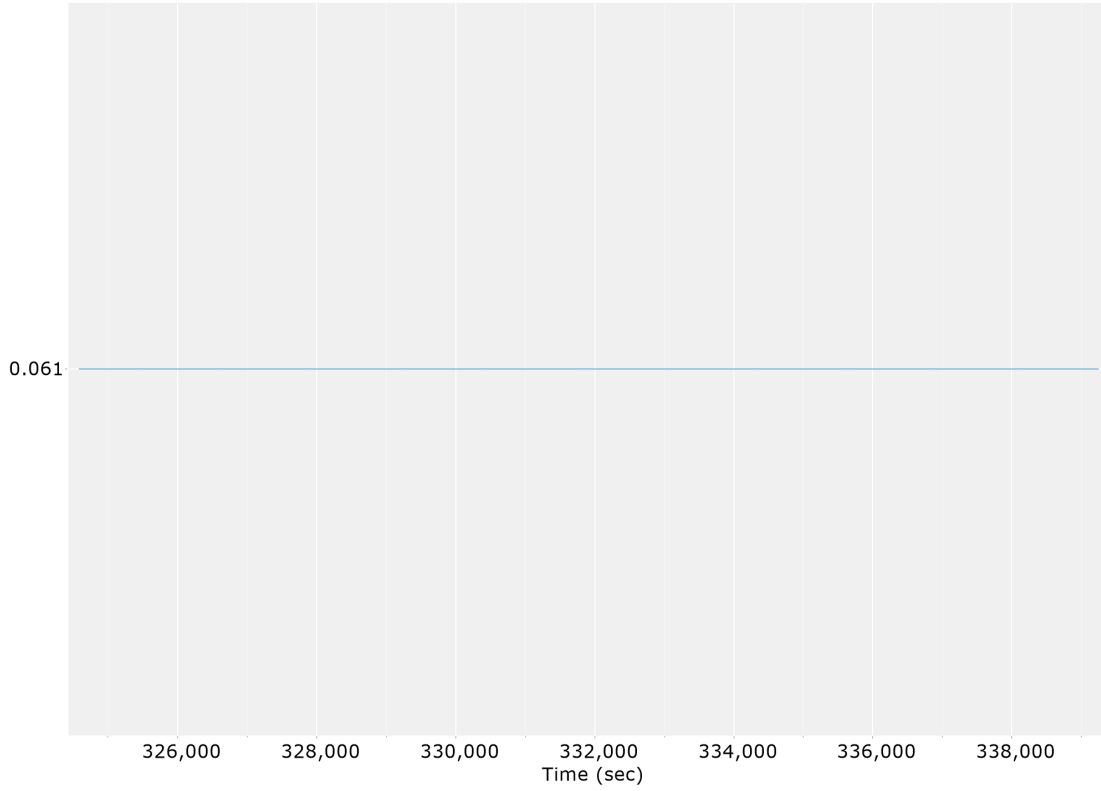
GNSS-Inertial Processor Configuration

Processing mode	IN-Fusion PP-RTX		
Stabilized mount	True		
Processing start time	324151.000 (1/22/2025 6:02:31 PM)		
Processing end time	339452.000 (1/22/2025 10:17:32 PM)		
Initial attitude source	Primary GNSS Track		
IMU Sensor Context	Processing with Onboard IMU		
Gimbal to IMU lever arm (m)	-0.034	-0.010	-0.374
Gimbal to IMU mounting angles (deg)	0.000	0.000	0.000
Gimbal to Primary GNSS lever arm (m)	0.061	0.038	-1.243
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

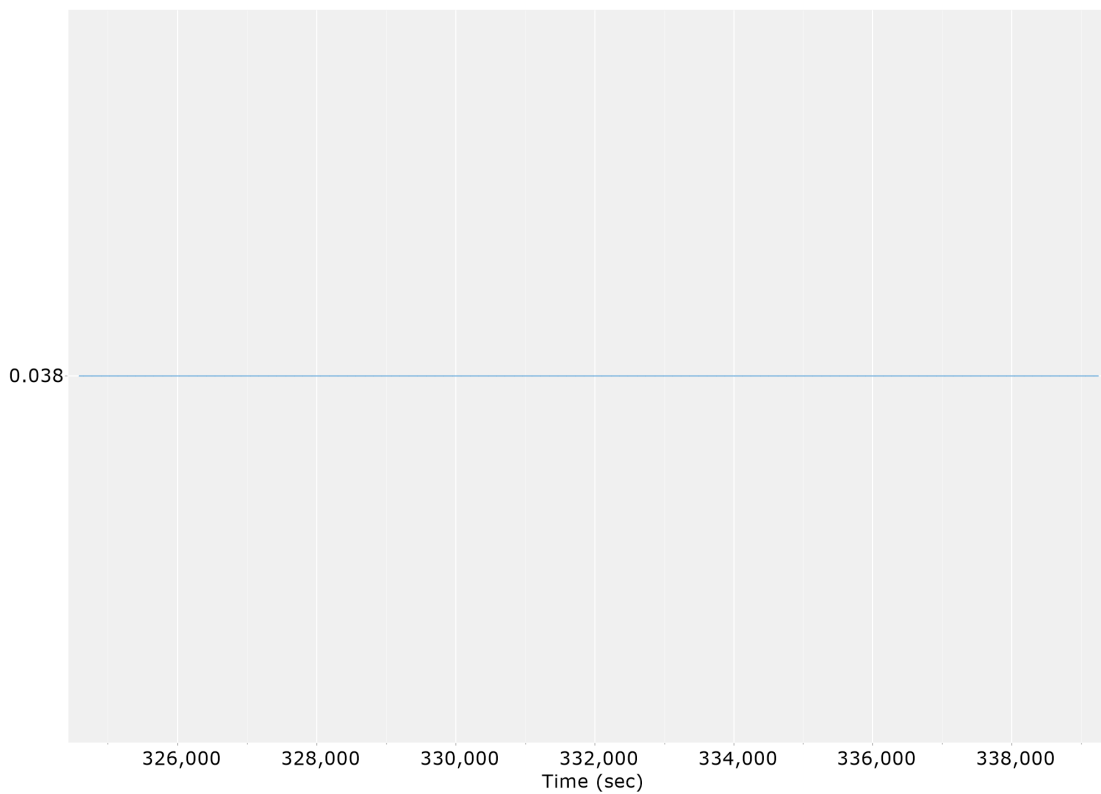
Calibrated Installation Parameters

Reference-Primary GNSS Lever Arm (m)

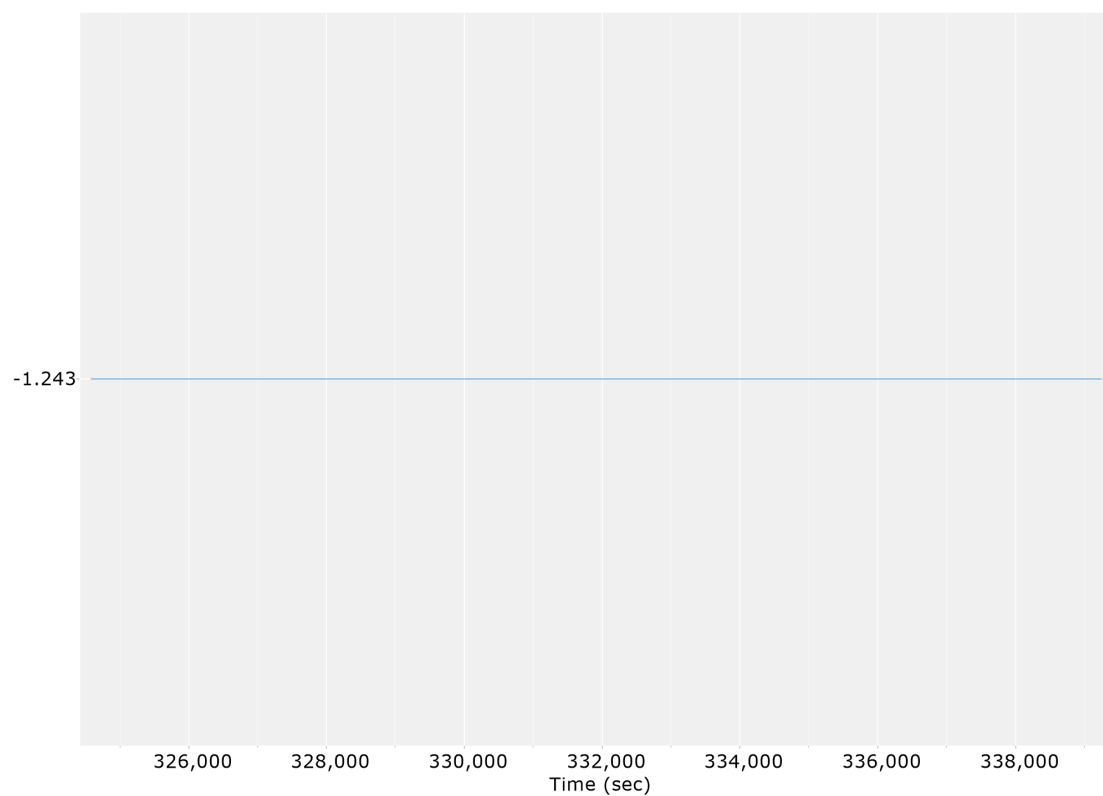
X Reference-Primary GNSS Lever Arm (m)



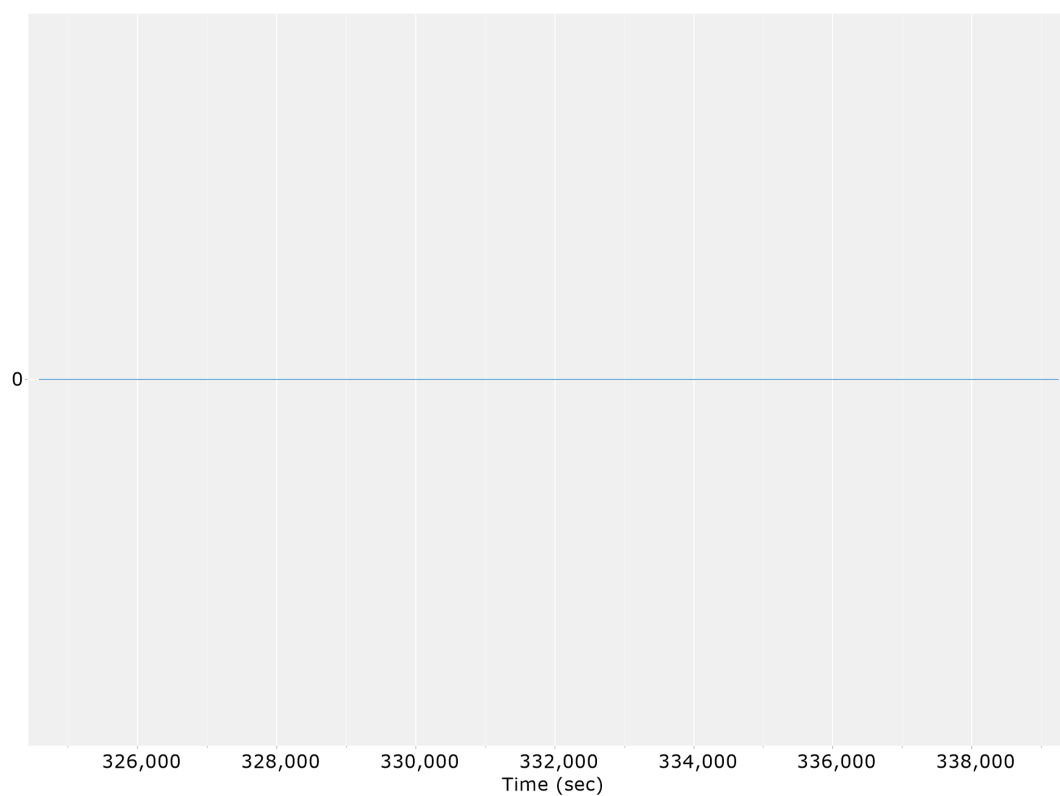
Y Reference-Primary GNSS Lever Arm (m)



Z Reference-Primary GNSS Lever Arm (m)



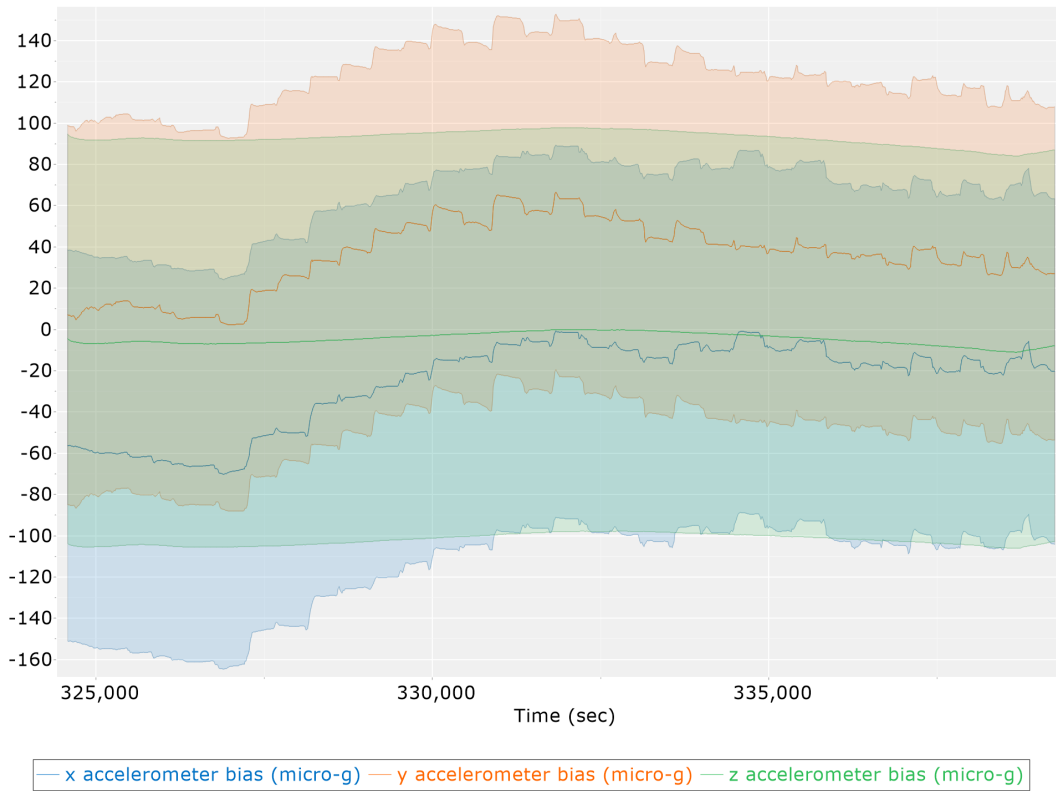
Reference-Primary GNSS Lever Arm Figure of Merit



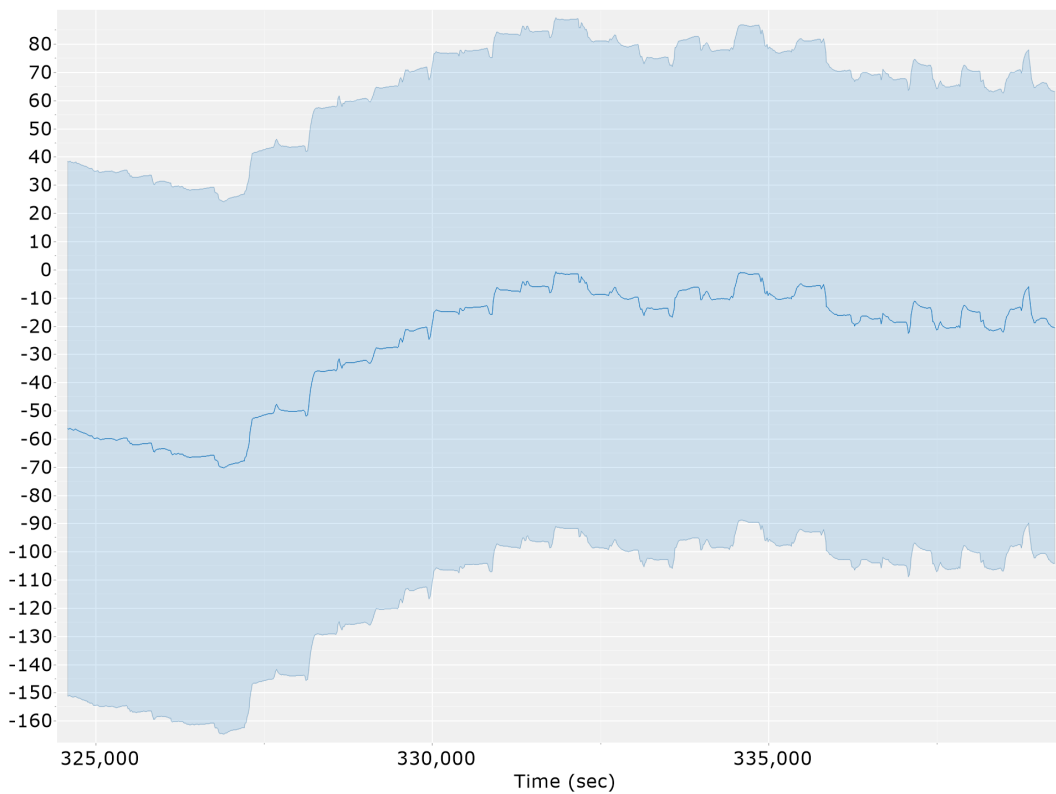
IN-Fusion QC

Forward Processed Estimated Errors, Reference Frame

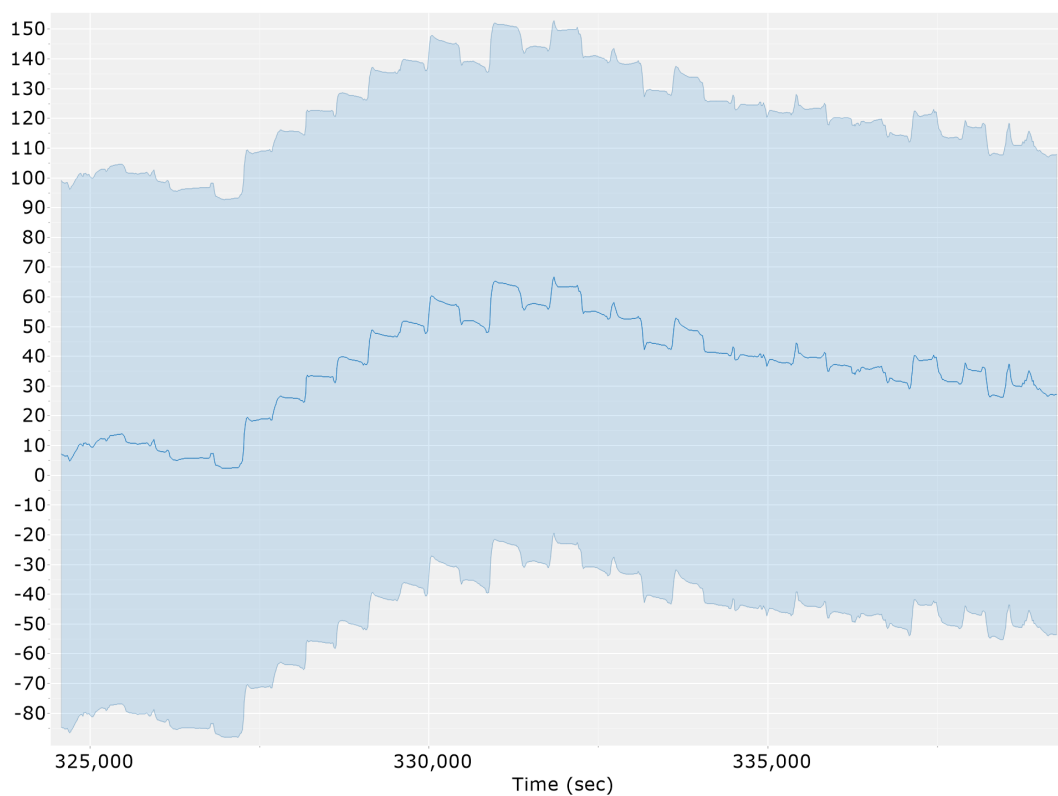
Accelerometer Bias (micro-g)



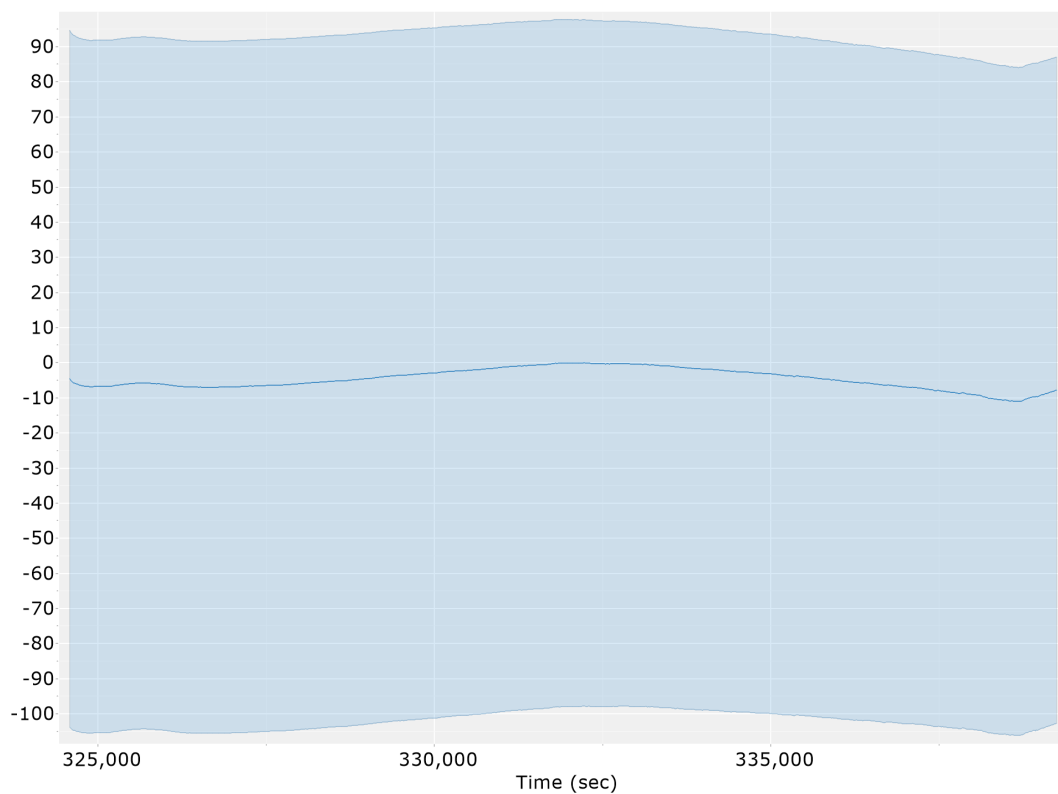
X Accelerometer Bias (micro-g)



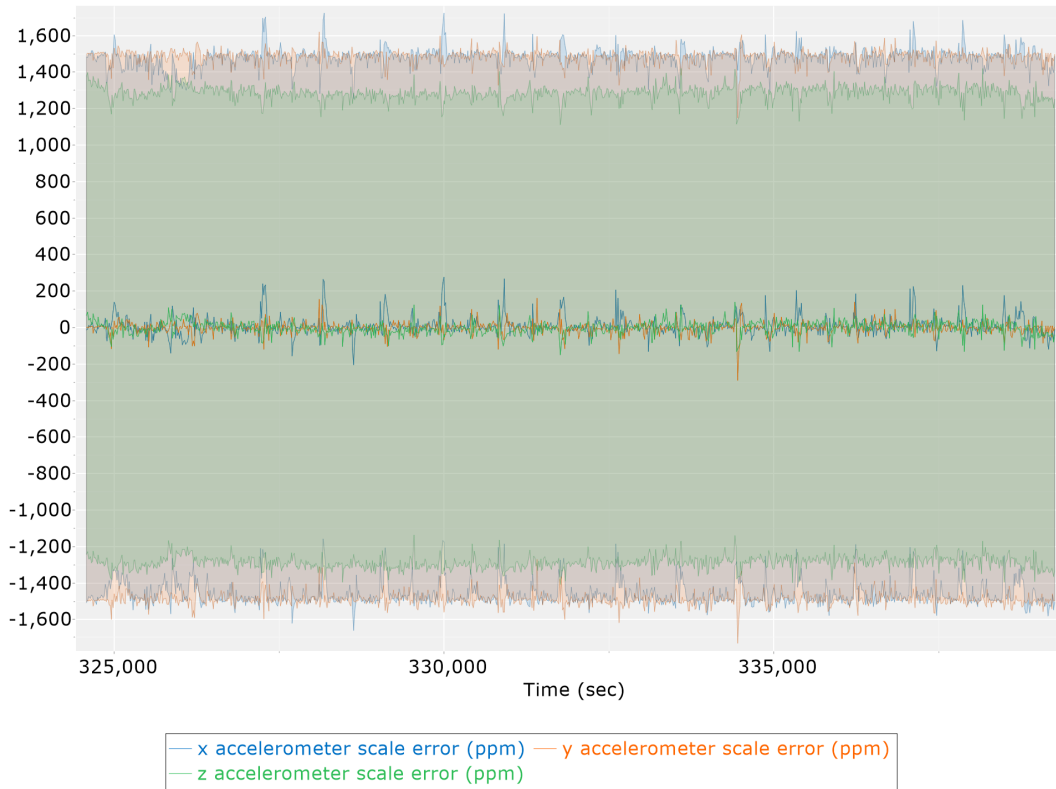
Y Accelerometer Bias (micro-g)



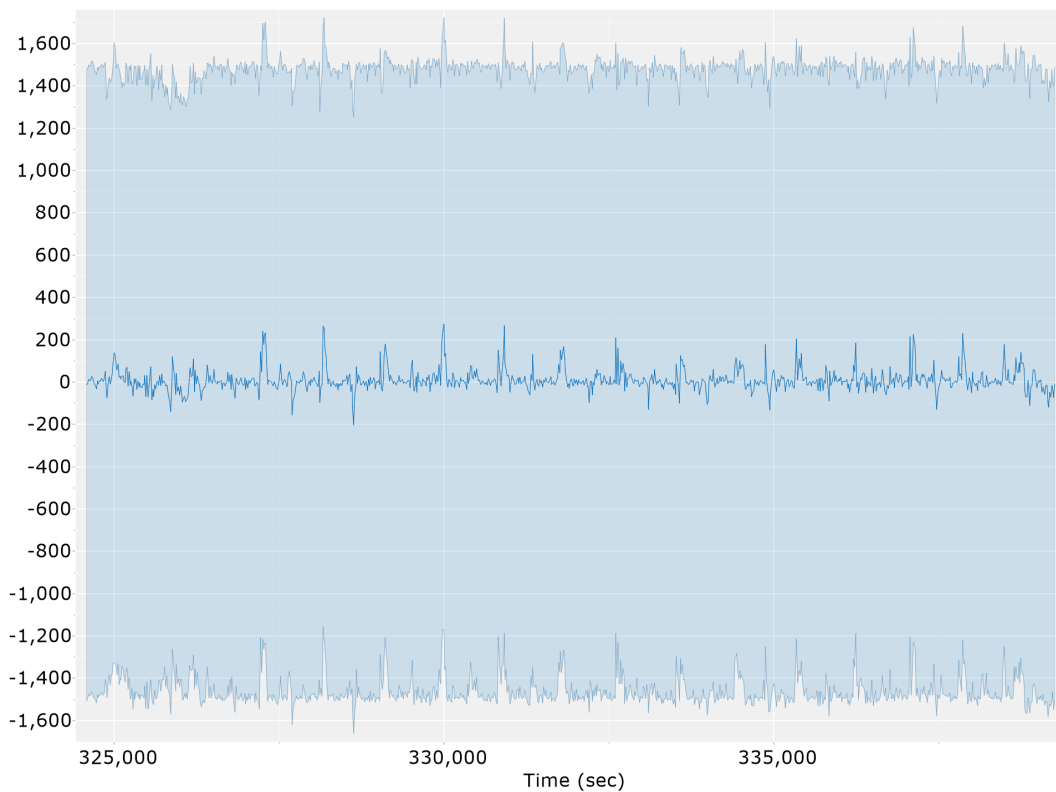
Z Accelerometer Bias (micro-g)



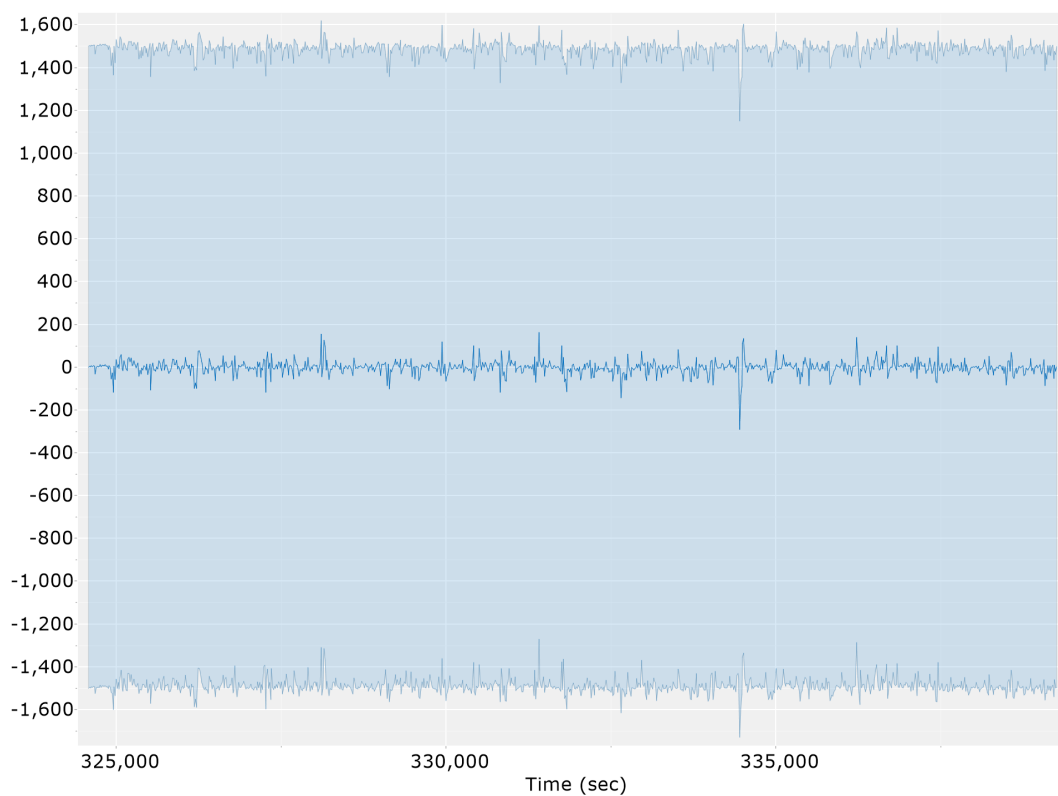
Accelerometer Scale Error (ppm)



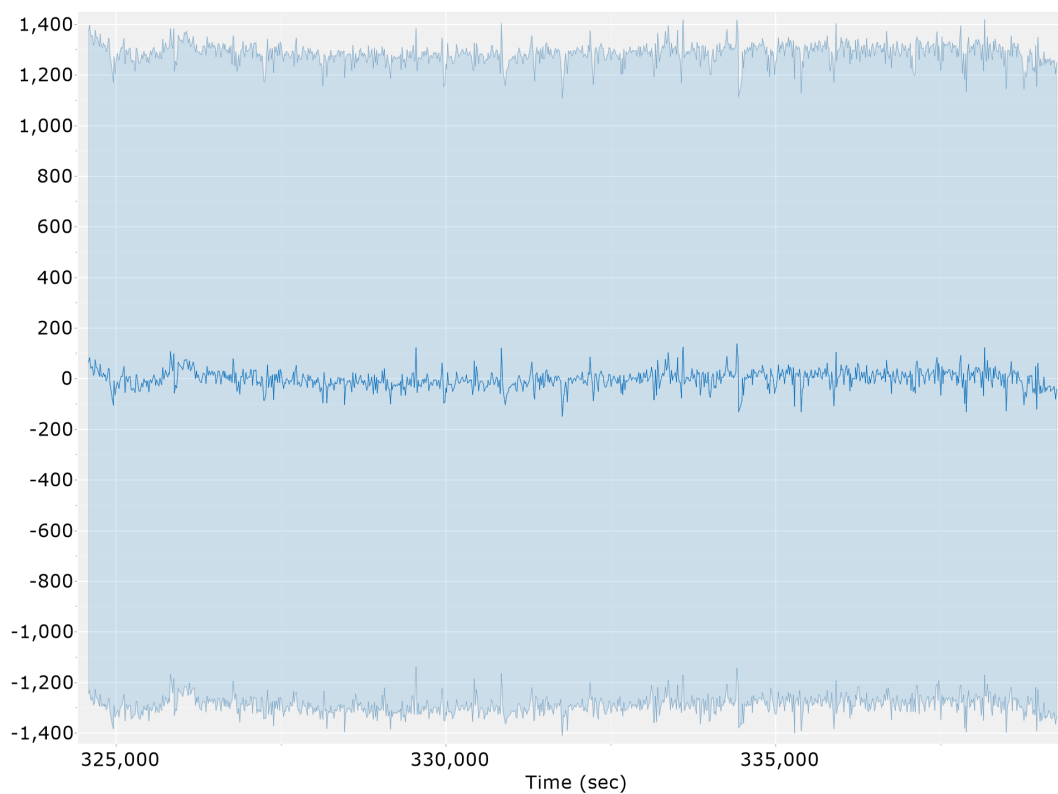
X Accelerometer Scale Error (ppm)



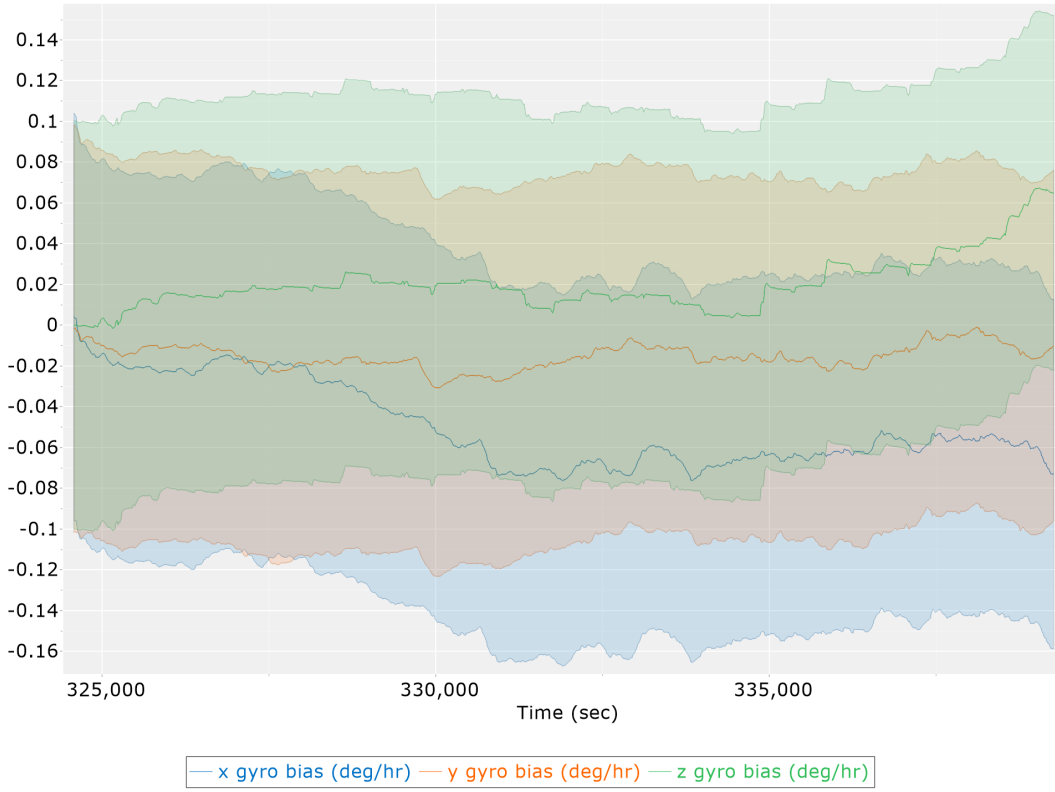
Y Accelerometer Scale Error (ppm)



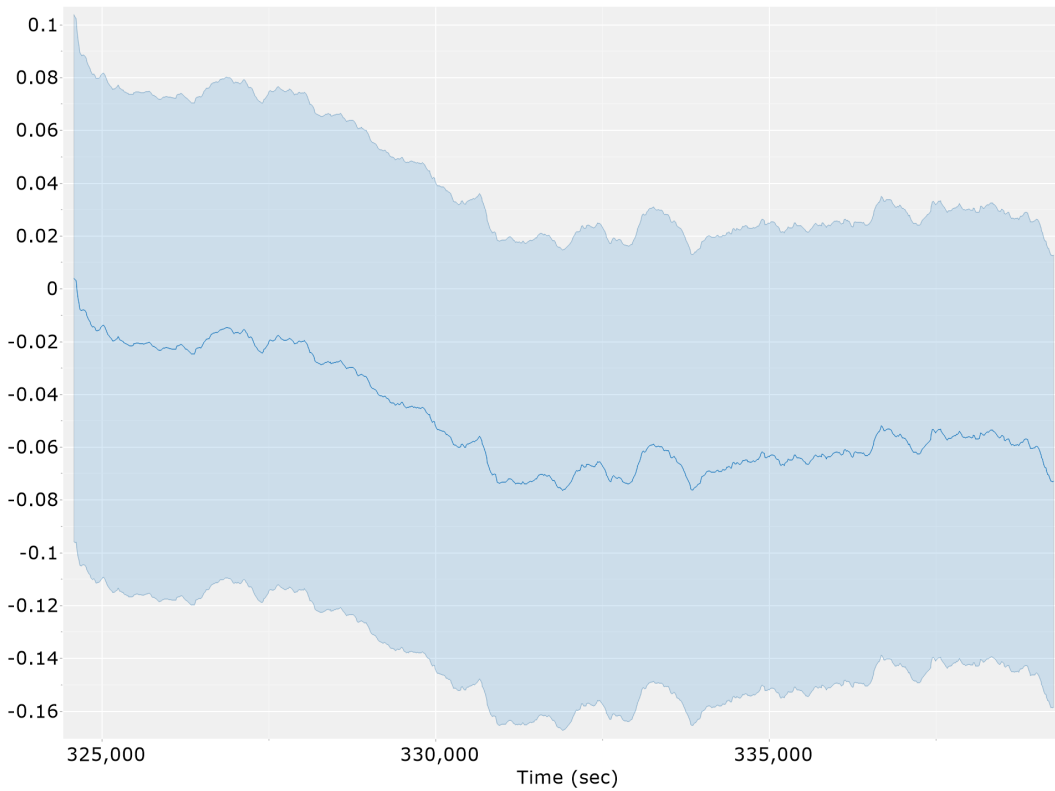
Z Accelerometer Scale Error (ppm)



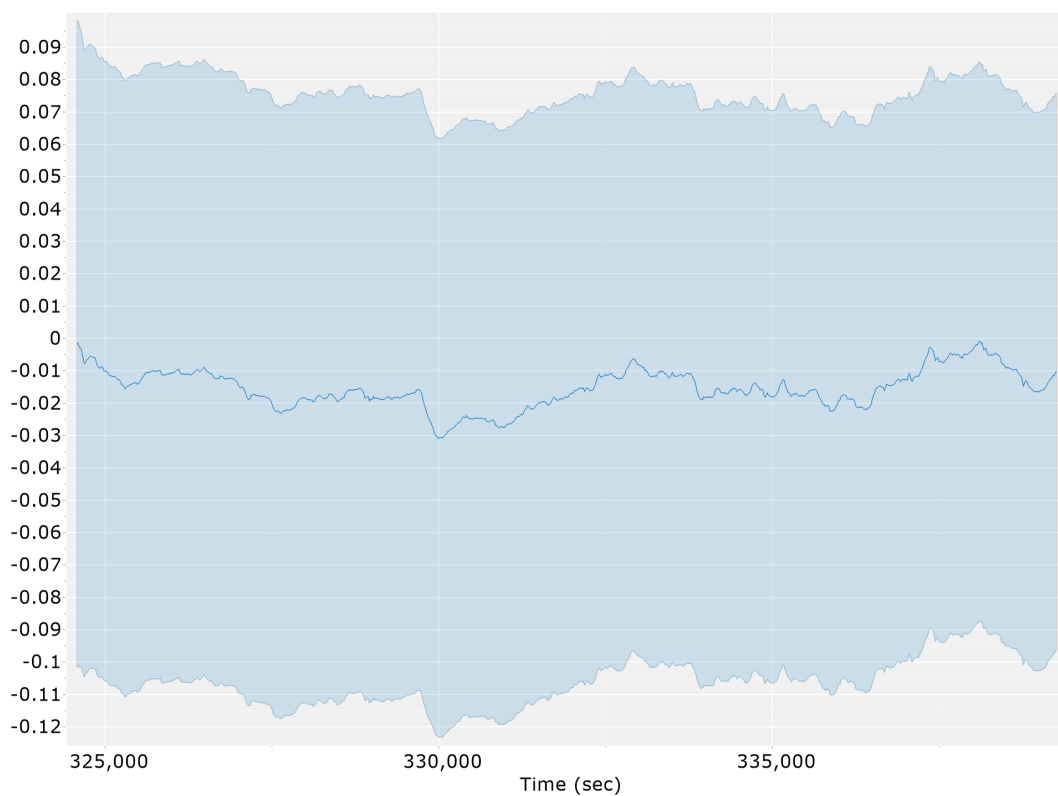
Gyro Bias (deg/h)



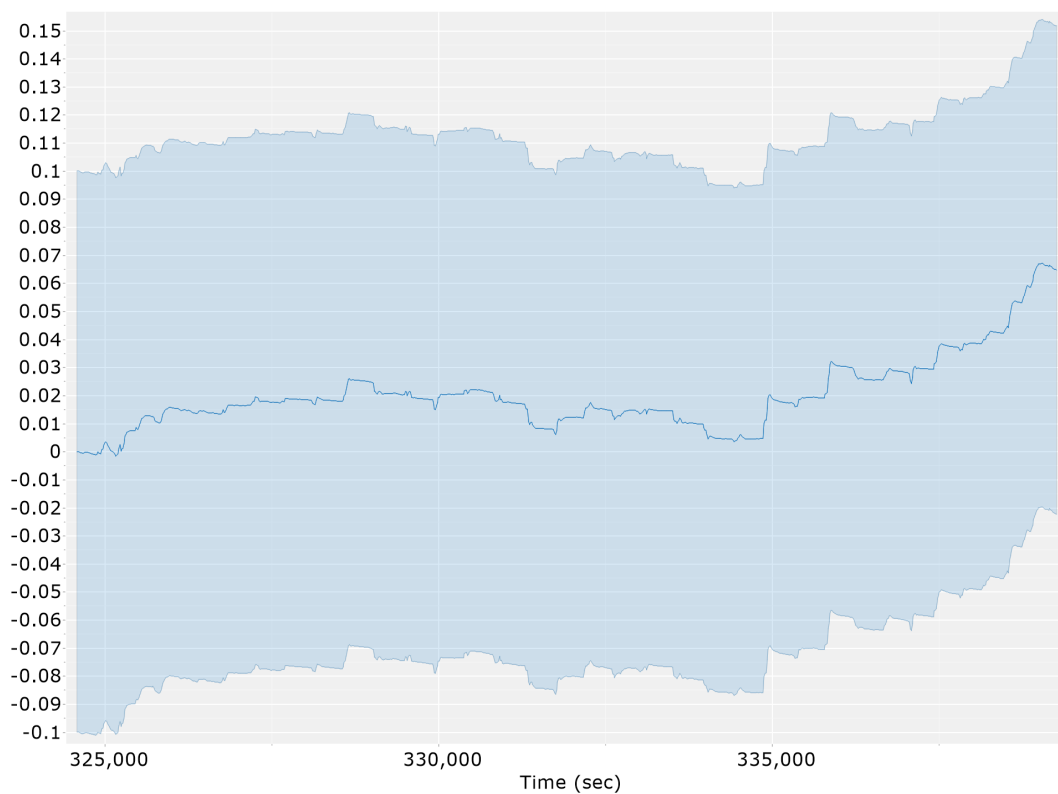
X Gyro Bias (deg/h)



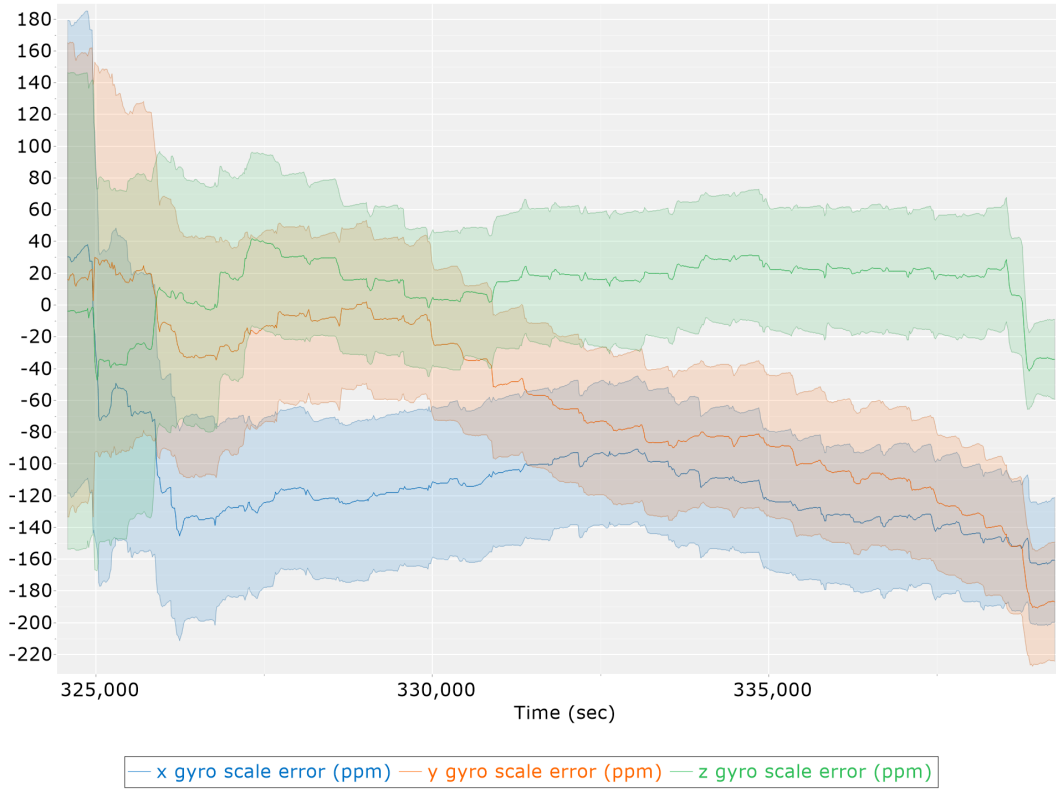
Y Gyro Bias (deg/h)



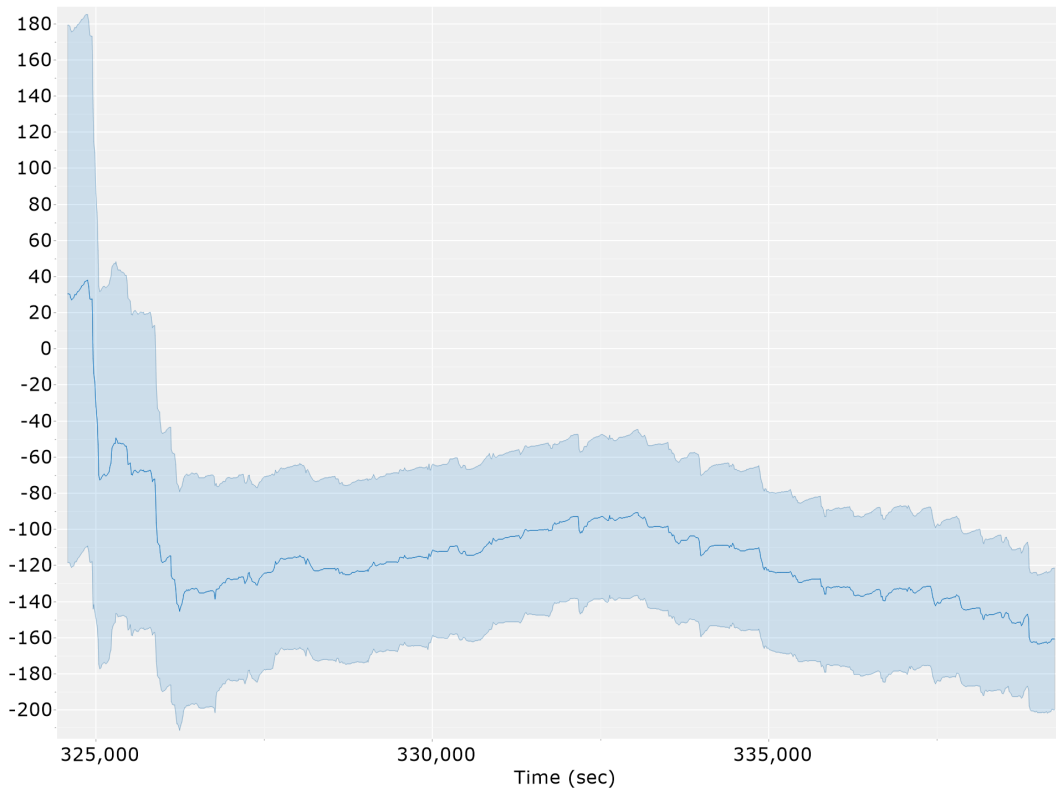
Z Gyro Bias (deg/h)



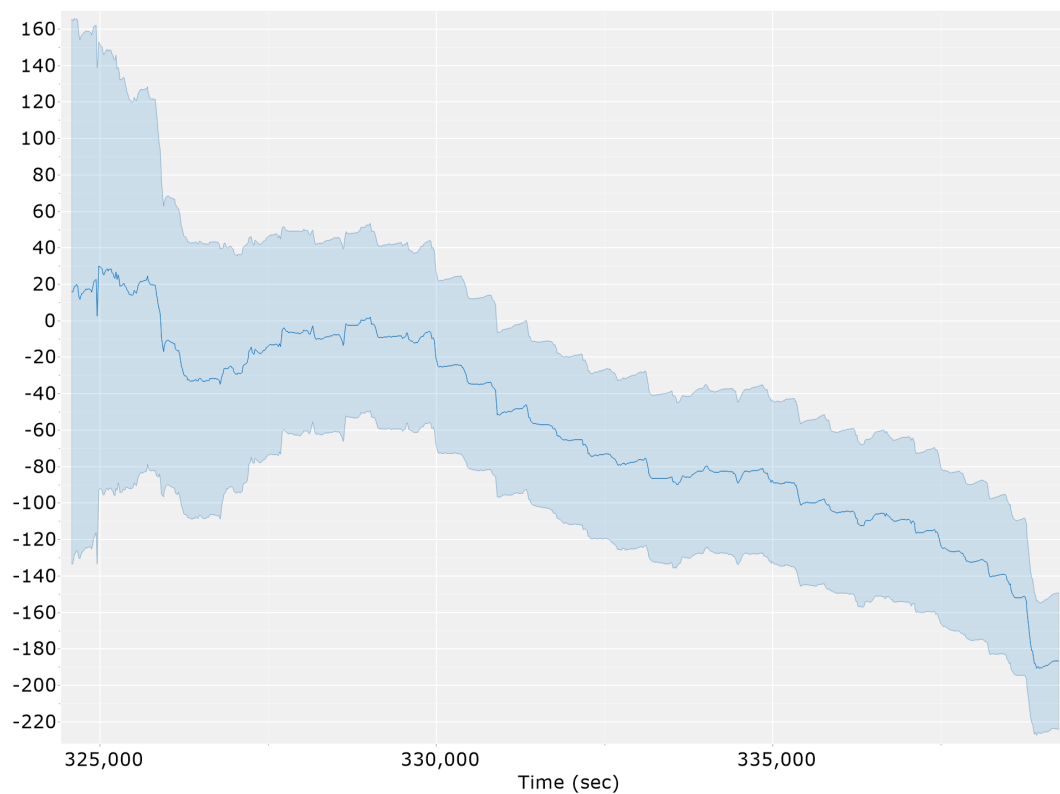
Gyro Scale Error (ppm)



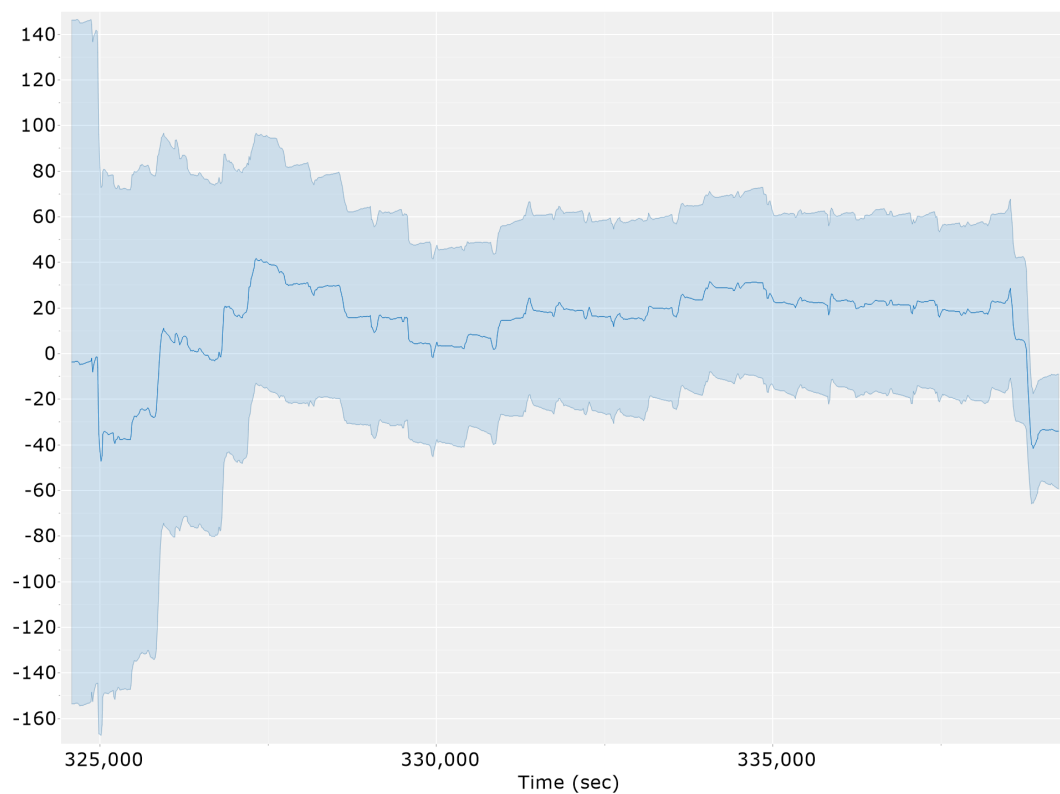
X Gyro Scale Error (ppm)



Y Gyro Scale Error (ppm)

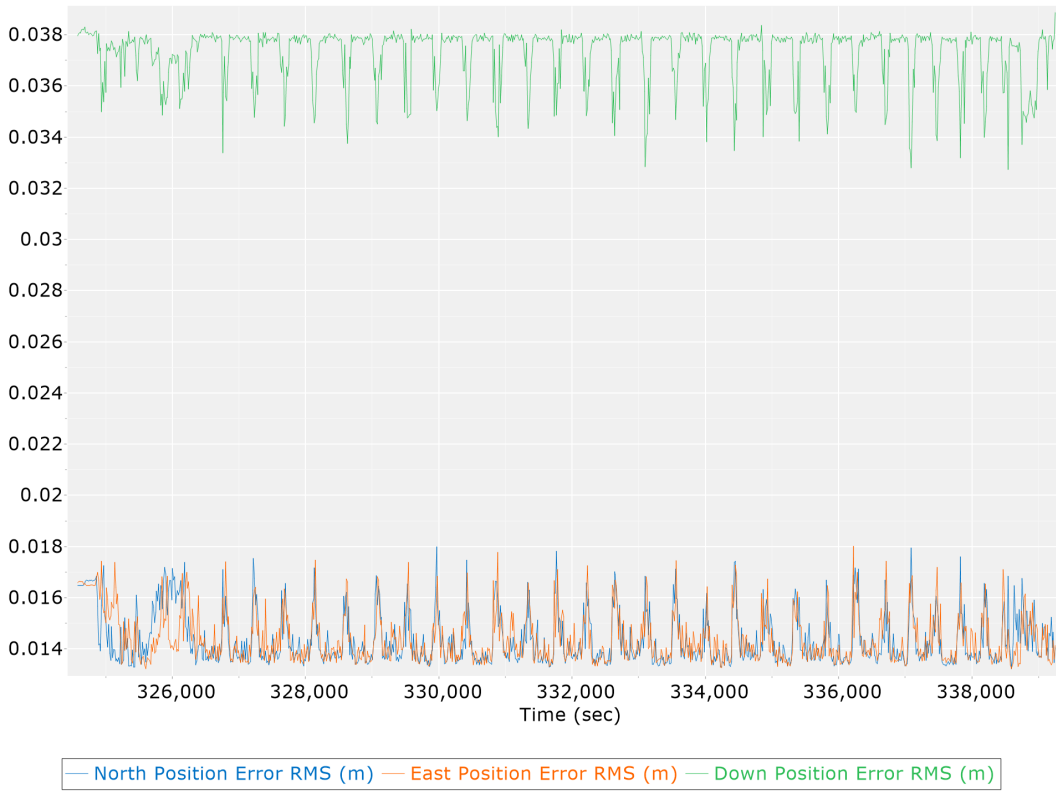


Z Gyro Scale Error (ppm)

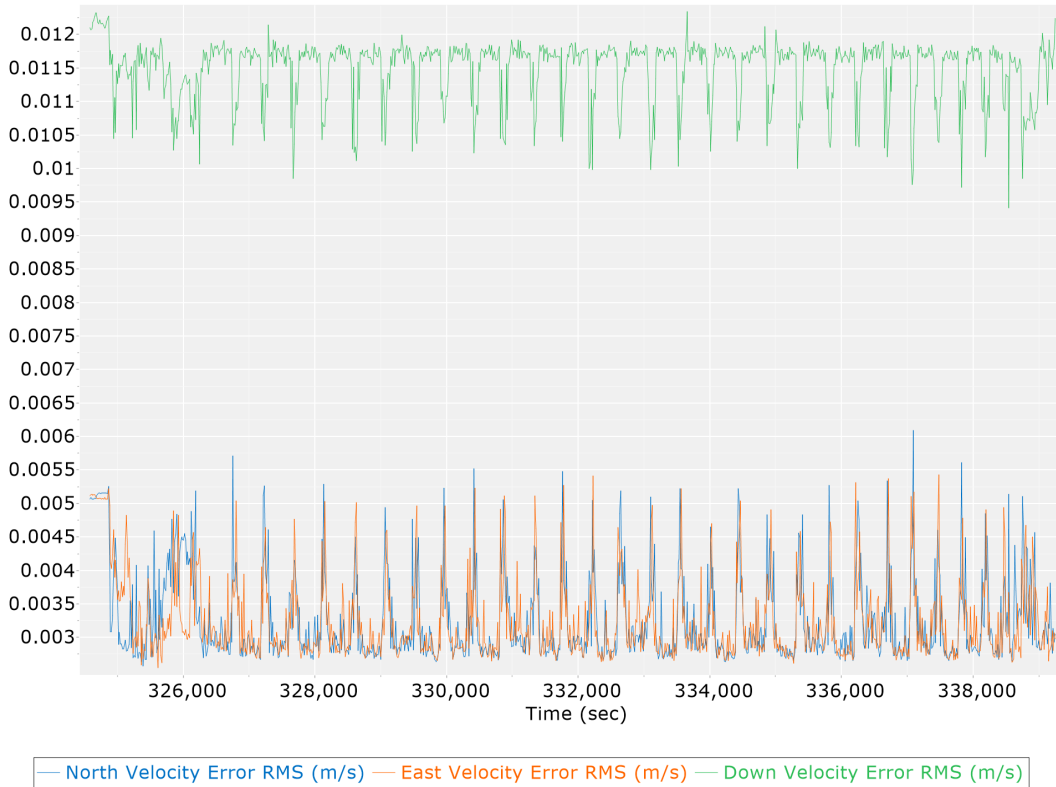


Smoothed Performance Metrics

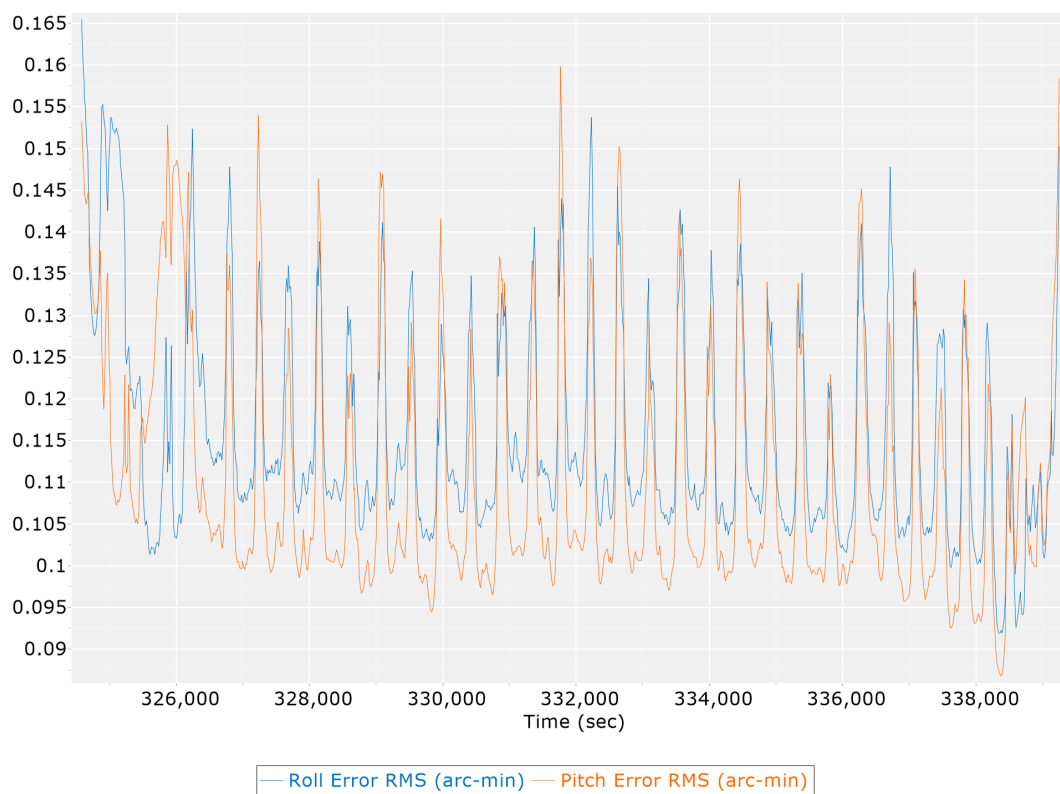
Position Error RMS (m)



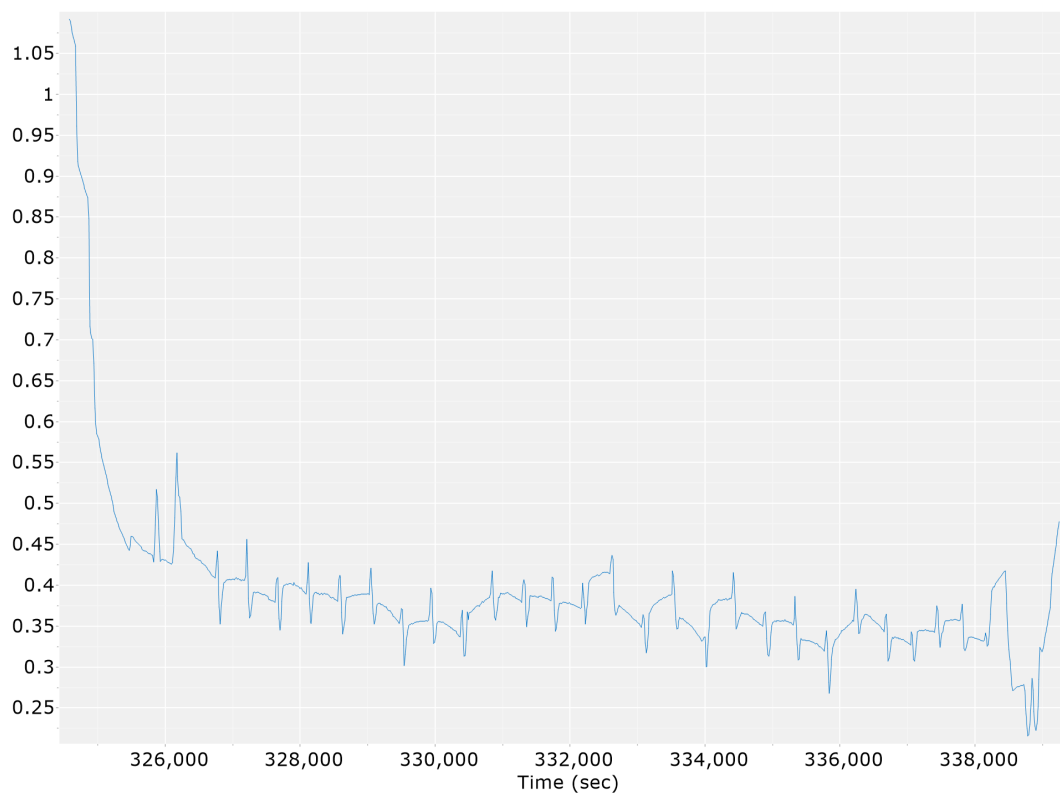
Velocity Error RMS (m/s)



Roll/Pitch Error RMS (arc-min)

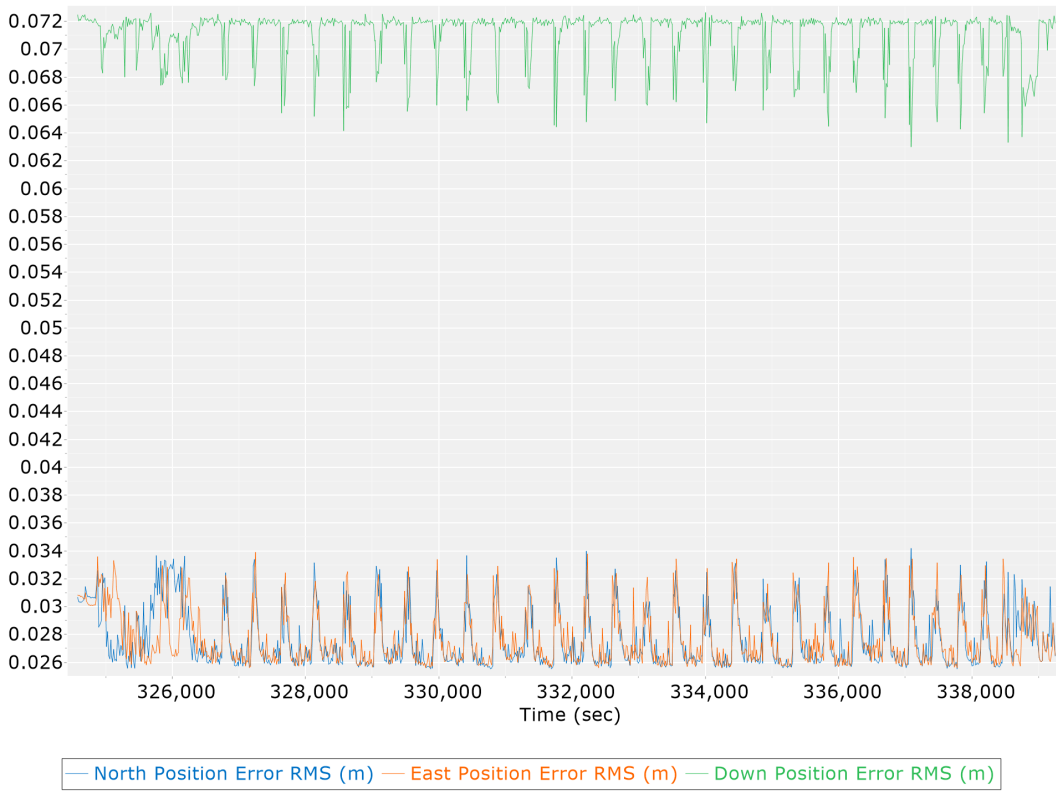


Heading Error RMS (arc-min)

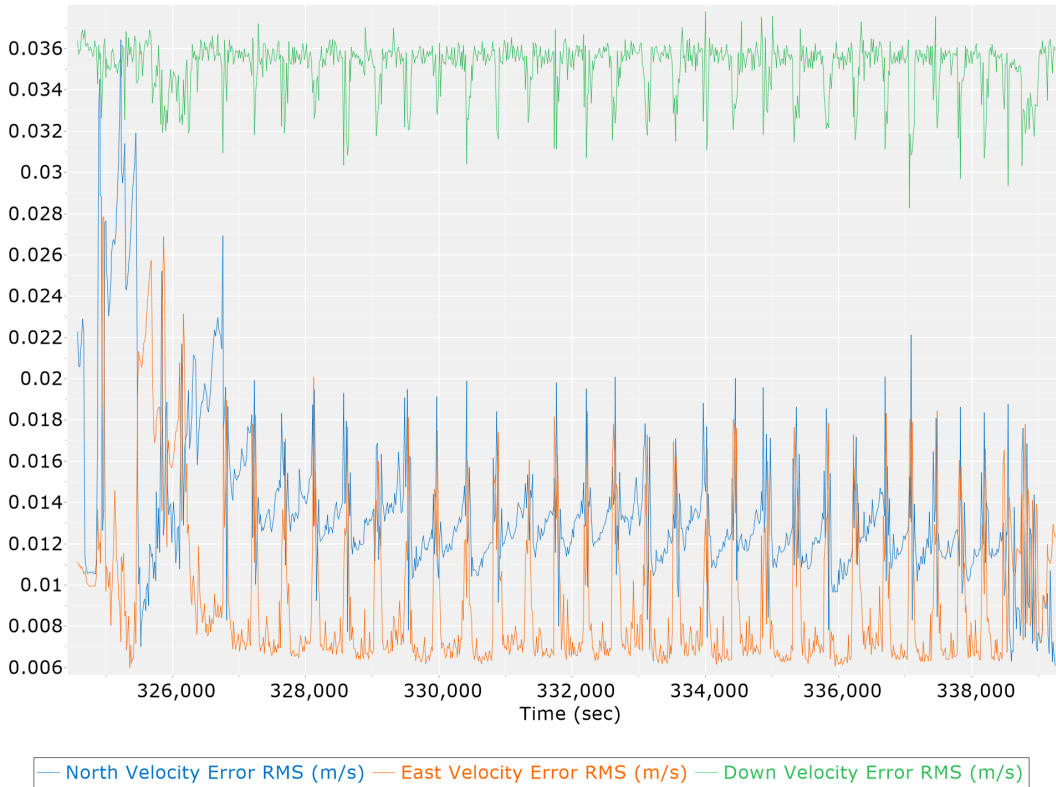


Forward Processed Performance Metrics

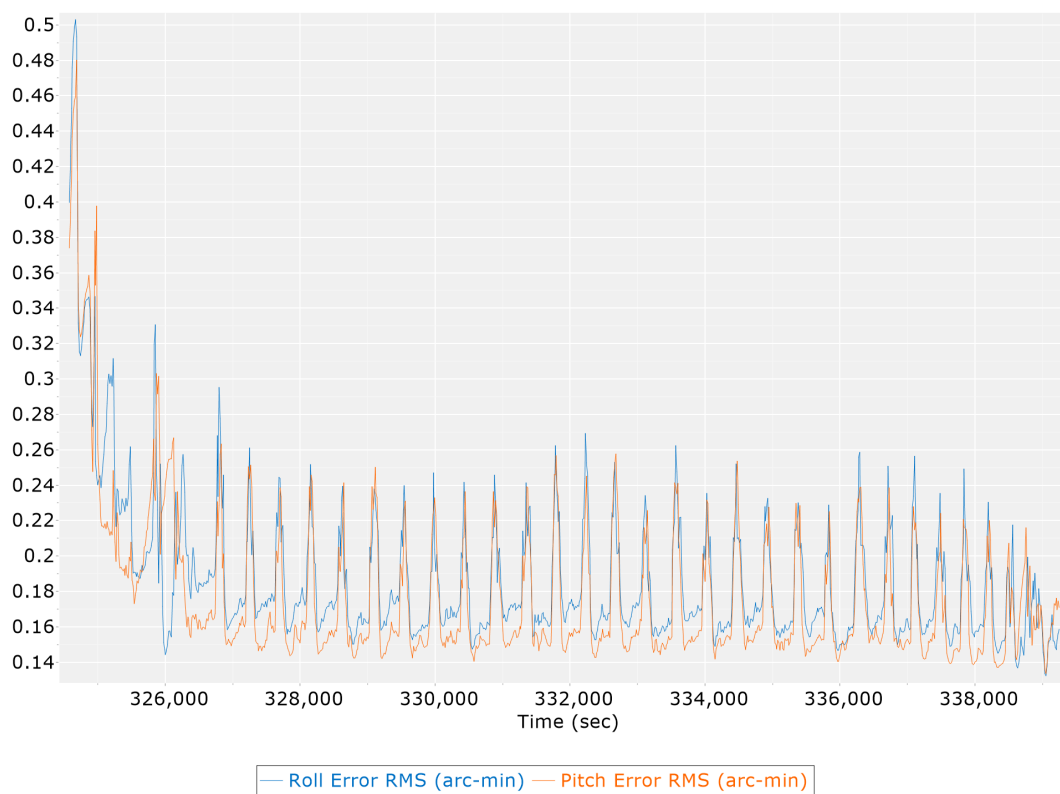
Position Error RMS (m)



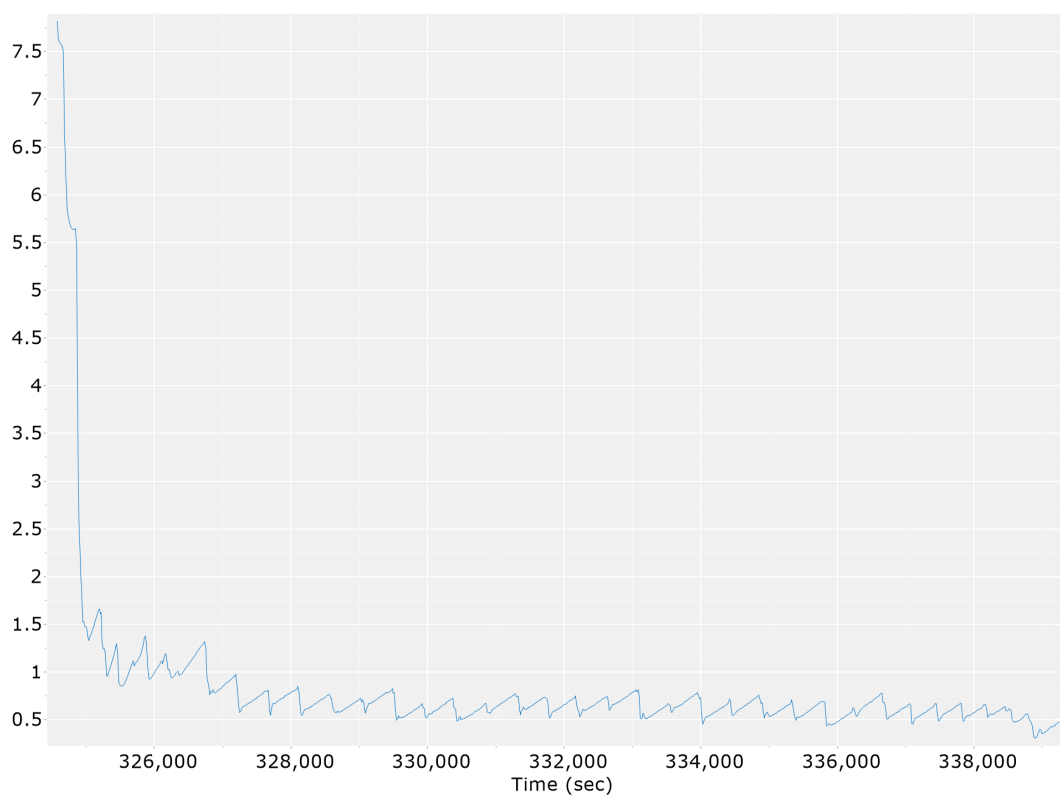
Velocity Error RMS (m/s)



Roll/Pitch Error RMS (arc-min)

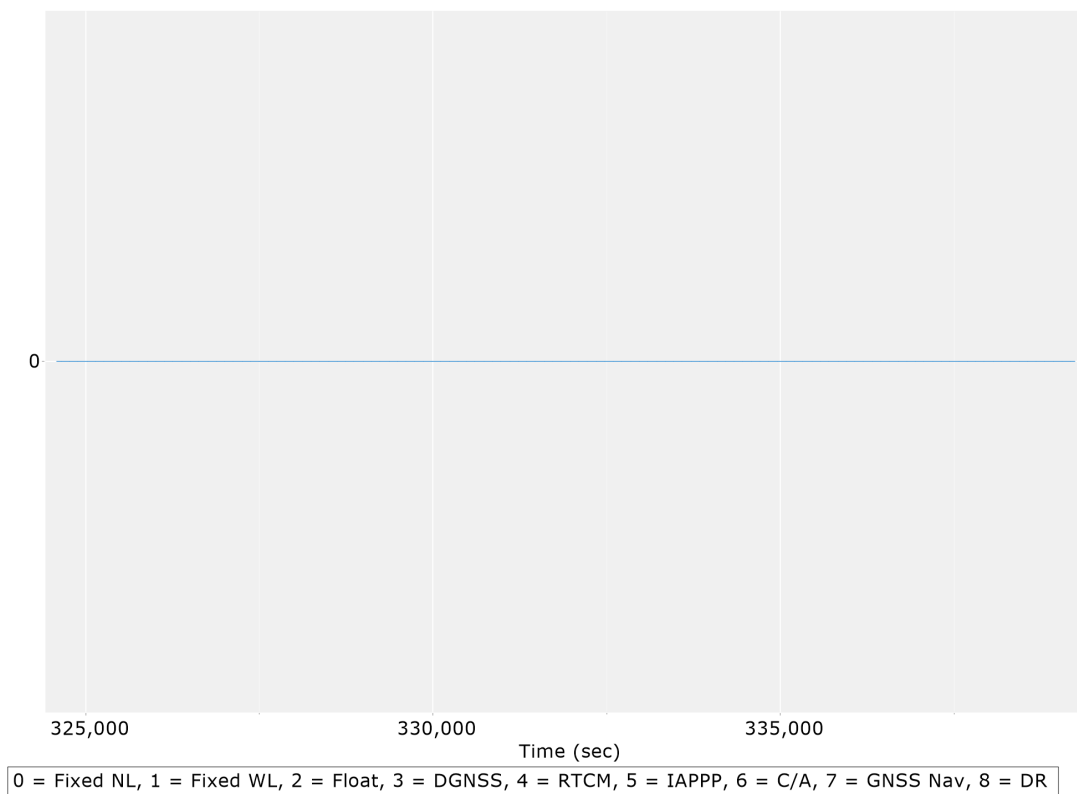


Heading Error RMS (arc-min)

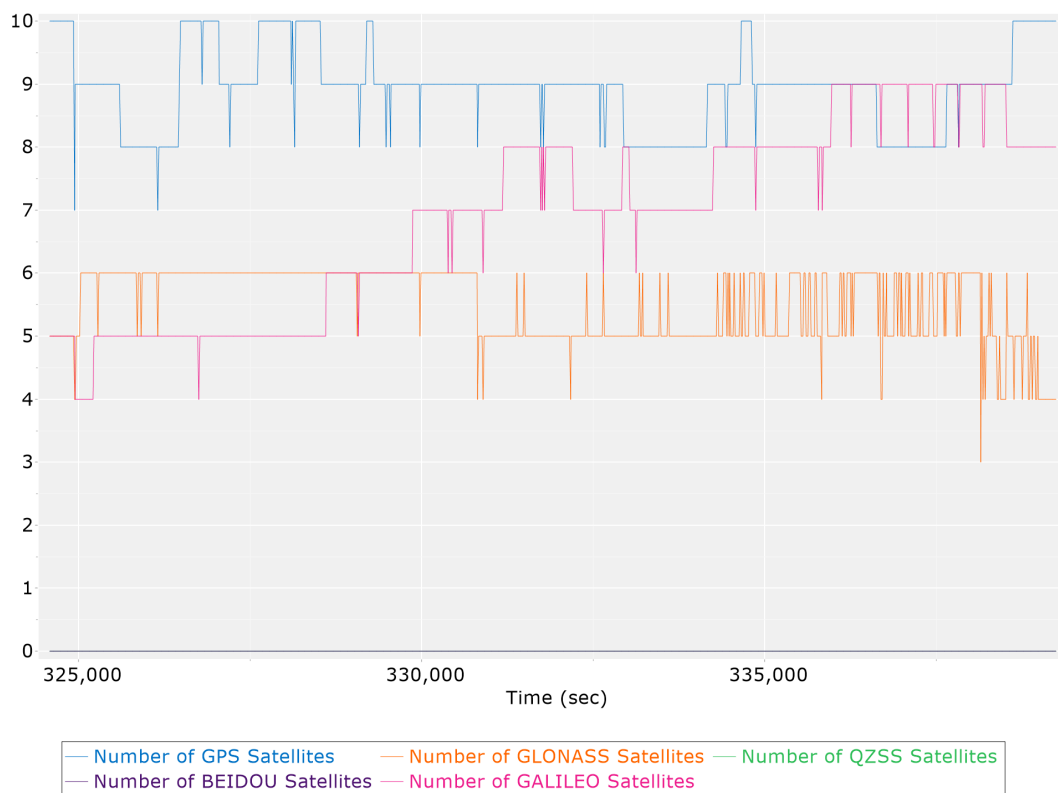


Forward Processed Solution Status

Processing Mode



Number of Satellites



Baseline Length

