



Compte-rendu de mission. Acquisition de données Lidar par drone. Mission du 22/11/2021 – Le Riols (81)

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<https://hal.science/hal-04270067>

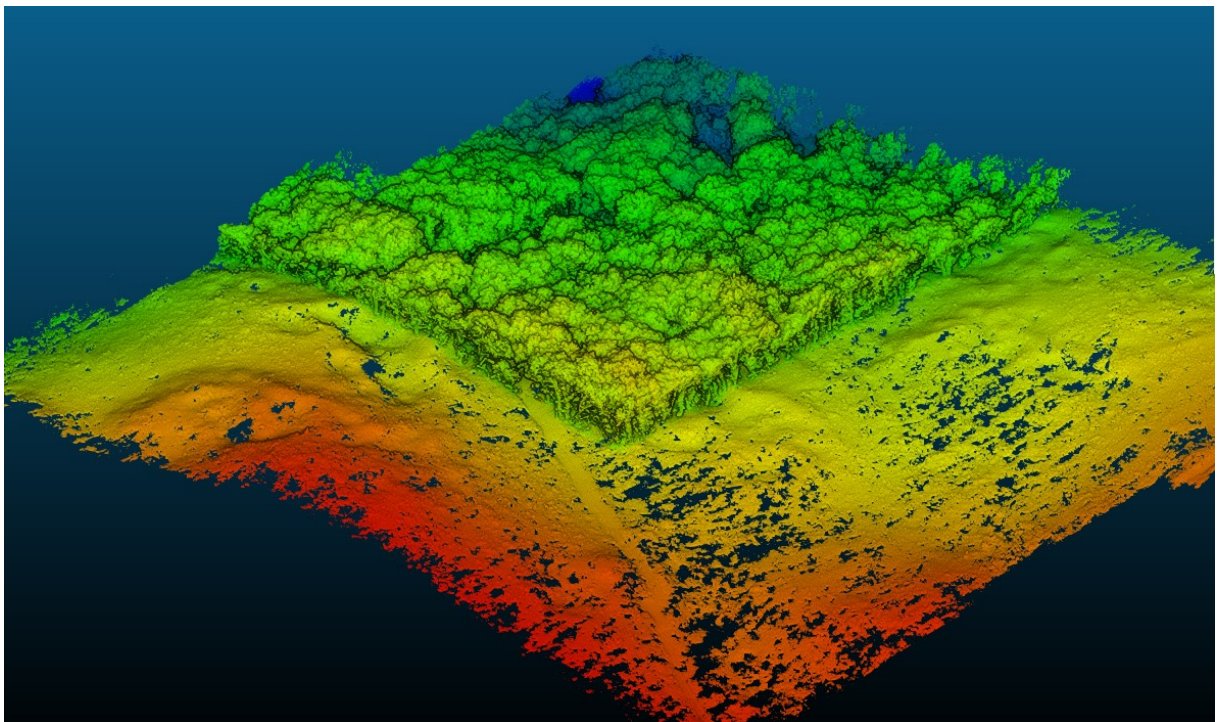
Submitted on 3 Nov 2023

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Commune du Riols (81), La Marèze Acquisition de données Lidar par drone

Mission du 22/11/2021



Compte-rendu de mission Acquisition de données Lidar par drone

Mission du 22/11/2021 – Le Riols (81)

N. Poirier, C. Calastrenc

1. Objectif et contexte

La mission d'acquisition de données Lidar par drone du 22/11/2021 a été réalisée sur la commune du Riols (81), sur un massif forestier dénommé la Marèze.

L'objectif était de réaliser le relevé tridimensionnel du sous-bois dans le but de rechercher des anomalies d'intérêt archéologique, en particulier des carrières de meules déjà repérées par Messieurs Christian Garcia (Association J.P.G.F Villiers-le-Bel) et Pierre Caussade (doctorant Université Bordeaux Montaigne et laboratoire Ausonius).

L'acquisition et le traitement des données Lidar a été financé par le Service Régional de l'Archéologie de la DRAC Occitanie.

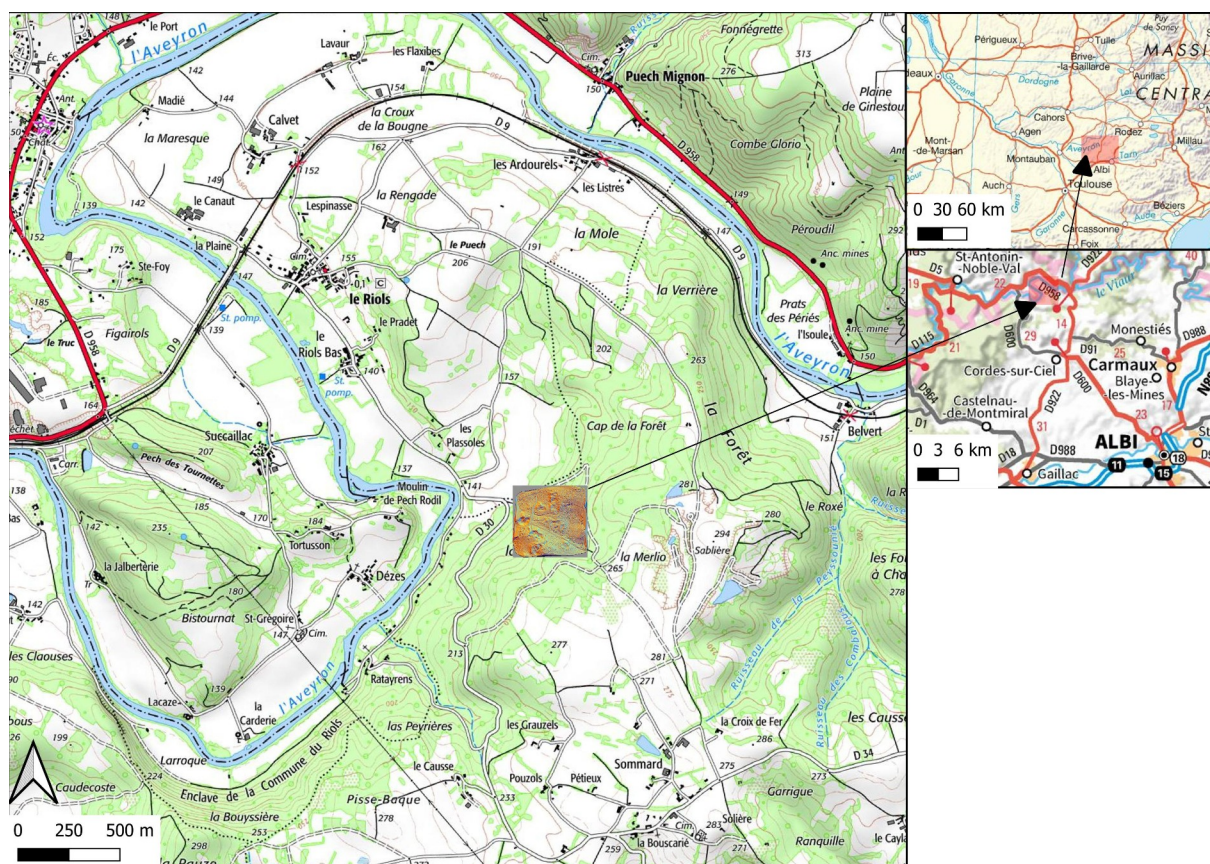


Figure 1- Le Riols (81), la Marèze – mission du 22/11/2021 - Localisation de la zone couverte par le vol Lidar par drone (Fond – IGN)

2. Conditions de vol

Compte-tenu des contraintes de maintien du drone à vue, de l'état du couvert végétal encore marqué par la présence de feuilles sur les arbres, et en accord avec les responsables thématiques du projet, il a été convenu de réaliser 2 vols identiques sur la même emprise, de manière à obtenir le plus de points-sols possible. Ces 2 vols ont été réalisés à 50m de hauteur au-dessus du sol à une vitesse moyenne de 4m/s.

La couverture obtenue est le meilleur compromis entre la surface à couvrir dans le respect des règles d'usage du drone et la densité minimale des points sols permettant une détection archéologique.



Figure 2- Le Riols (81), la Marèze – mission du 22/11/2021 - Emprise des 2 vols cumulés

3. Traitement des nuages de points

3.1. Évaluation des nuages de points bruts

Les 2 vols ont été assemblés en un seul nuage de points comprenant un peu plus de 27,6 M de points pour une surface documentée de 12 ha, soit une densité d'échos (végétation comprise) d'environ 237 points/m².

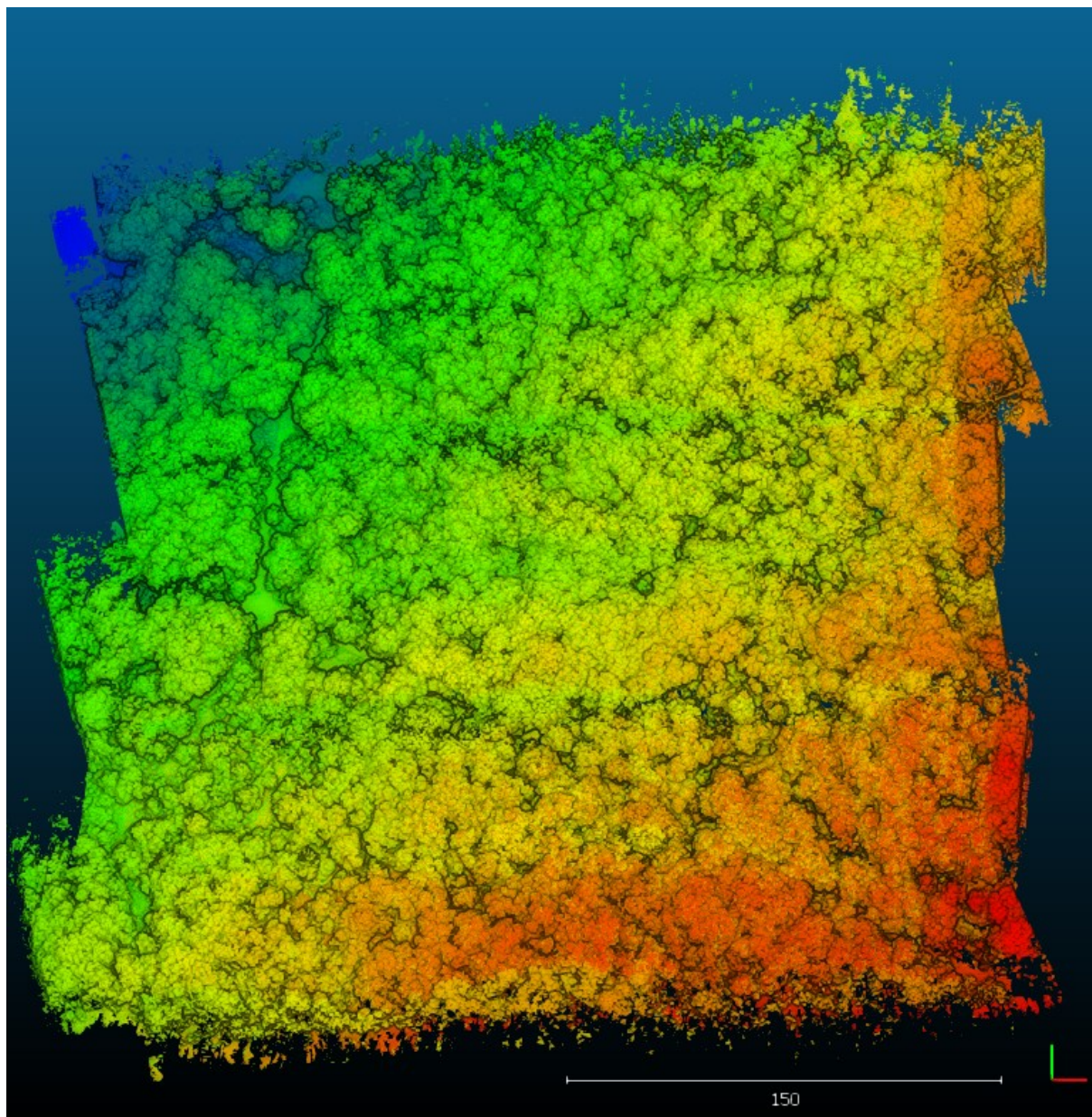


Figure 3- Le Riols (81), la Marèze – mission du 22/11/2021 - Nuage de points total

3.2. Correction des imprécisions GPS

Les données issues de ces vols ont été corrigées des imprécisions GPS en utilisant les données fournies par les bornes du Réseau Géodésique Permanent de l'IGN (disponibles gratuitement sur le site www.rgp.ign.fr) et au logiciel PosPac de Applanix¹ (cf. rapports de correction en annexe).

3.3. Extraction des points sols

Après plusieurs tests réalisés en utilisant différents algorithmes et logiciels, c'est finalement le filtrage obtenu avec l'extension CSF de Cloudcompare² qui s'est révélé le plus satisfaisant.

¹<https://www.applanix.com/>

²<https://www.danielgm.net/cc/>

Les paramètres utilisés sont les suivants :

- Cloth resolution = 0,4
- Classification threshold = 0,2

Ce filtrage permet de retenir un peu plus de 5,8M de points, soit environ 50/m².

Les densités sont variables en fonction de la distance par rapport au capteur et les variations de végétation.

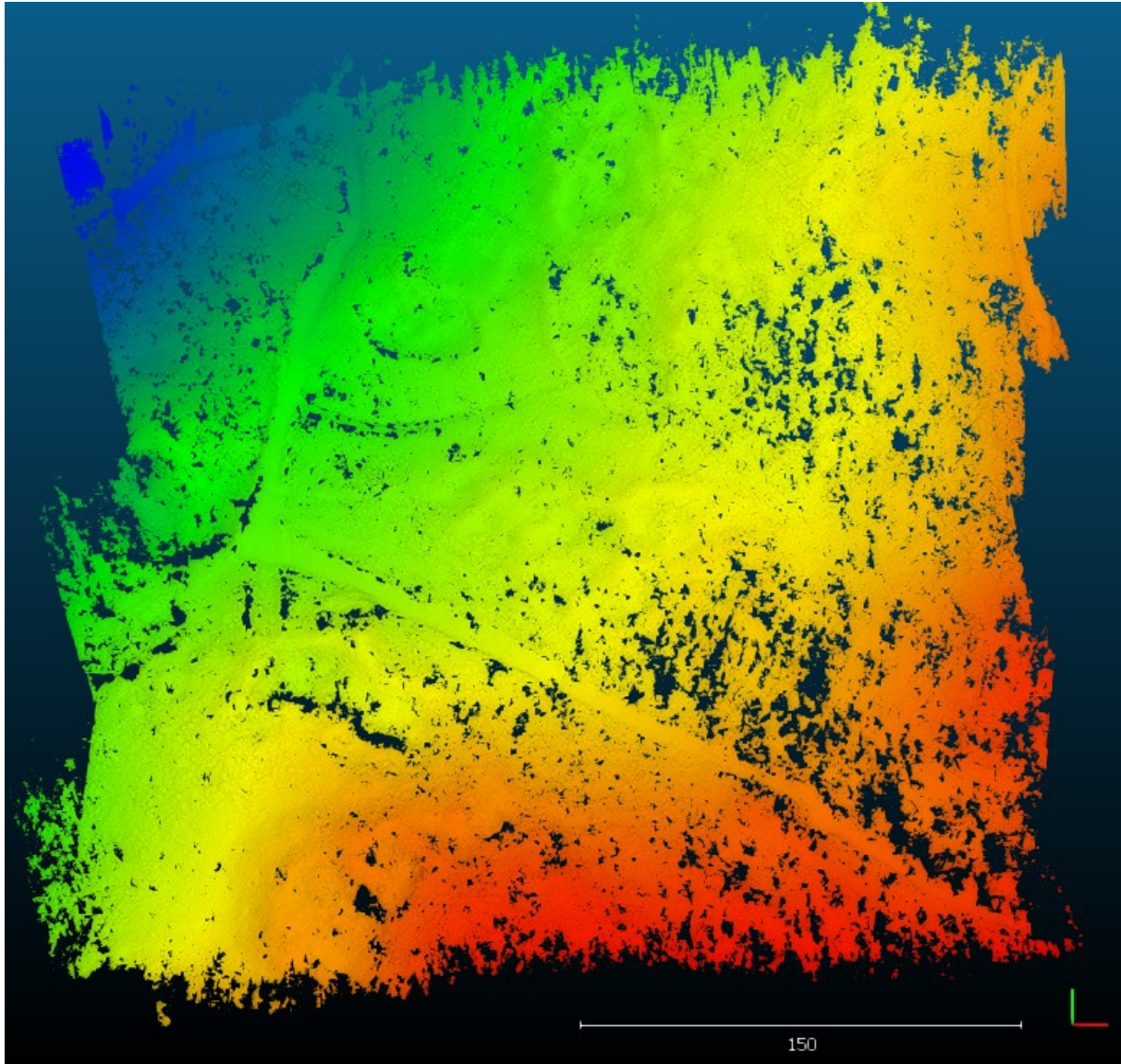


Figure 4- Le Riols (81), la Marèze – mission du 22/11/2021 - Nuage de points-sol

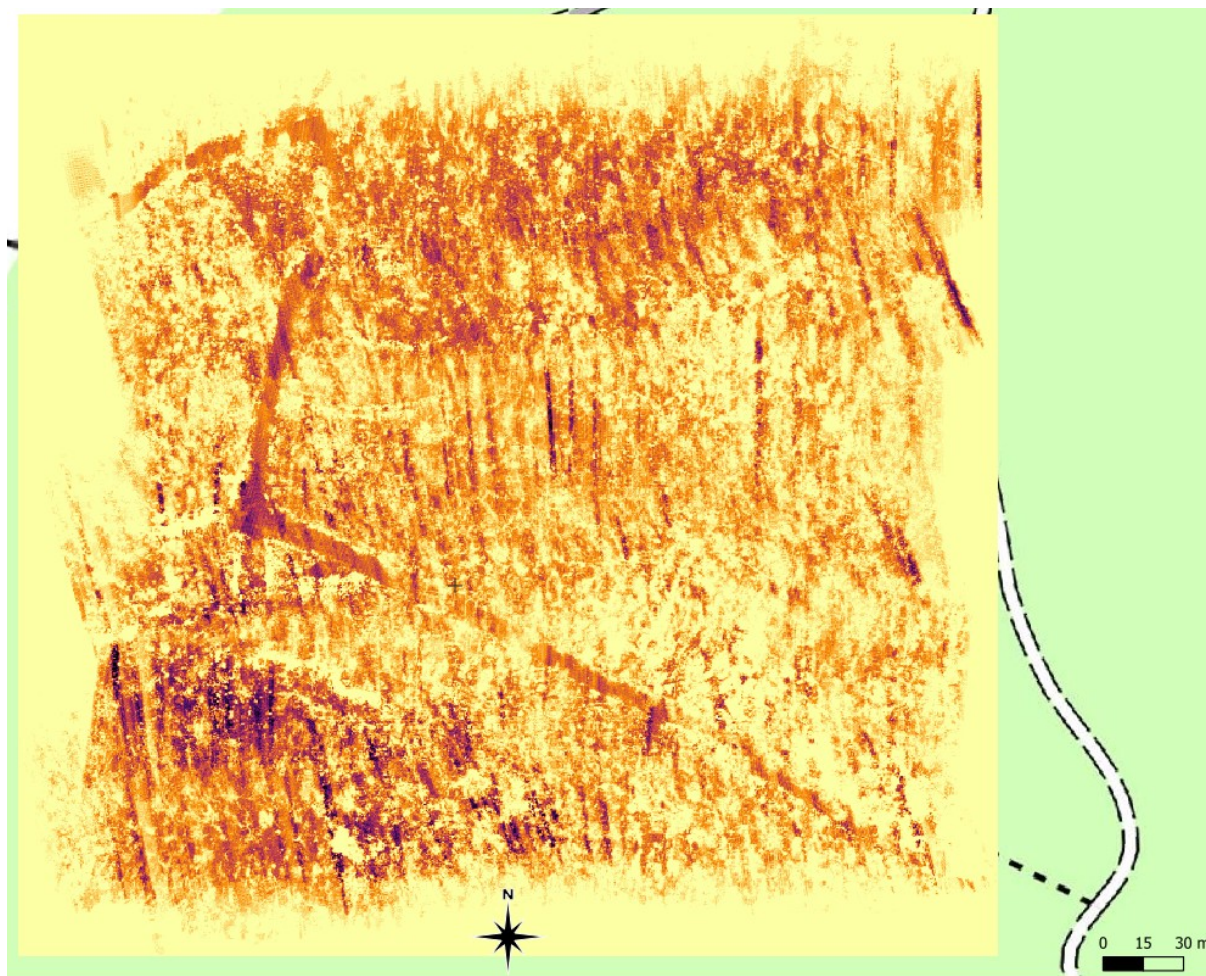


Figure 5- Le Riols (81), la Marèze – mission du 22/11/2021 – Densité des points-sols

4. Génération des visualisations des MNT

Dans CloudCompare, avec l'outil Raster, un Modèle Numérique de Terrain (MNT) d'une résolution de 50 cm a été généré en ne prenant en compte que les points sols.

Avec le logiciel RVT (Relief Visualization Toolbox³) développé par l'Institute of Anthropological and Spatial Studies du ZRC-SAZU (Slovénie), il est possible d'appliquer plusieurs traitements aux MNT ainsi produits :

- Ombrage : simulation d'un éclairage et des ombrages correspondants selon une direction et un azimuth défini par l'opérateur
- Ombrages cumulés depuis des directions différentes
- Gradient de pente
- Modèle de relief local (SLRM) : suppression des grandes tendances de la topographie du terrain au profit de l'accentuation des micro-reliefs (locaux)
- Sky-view factor : mesure du pourcentage de ciel visible depuis chaque pixel du modèle

³ <https://iaps.zrc-sazu.si/en/rvt#v>

Ces différents traitements permettent de multiplier les visions du même espace et de mieux identifier les indicateurs archéologiques. Nous livrons ci-après les visualisations les plus efficaces, mais l'ensemble des données sont fournies par lien de téléchargement. Toutes sont géoréférencées et immédiatement intégrables dans un projet SIG.



Figure 6 - Le Riols (81), la Marèze – mission du 22/11/2021 - Hillshade - Azimuth 315° - Hauteur 35° (RVT)

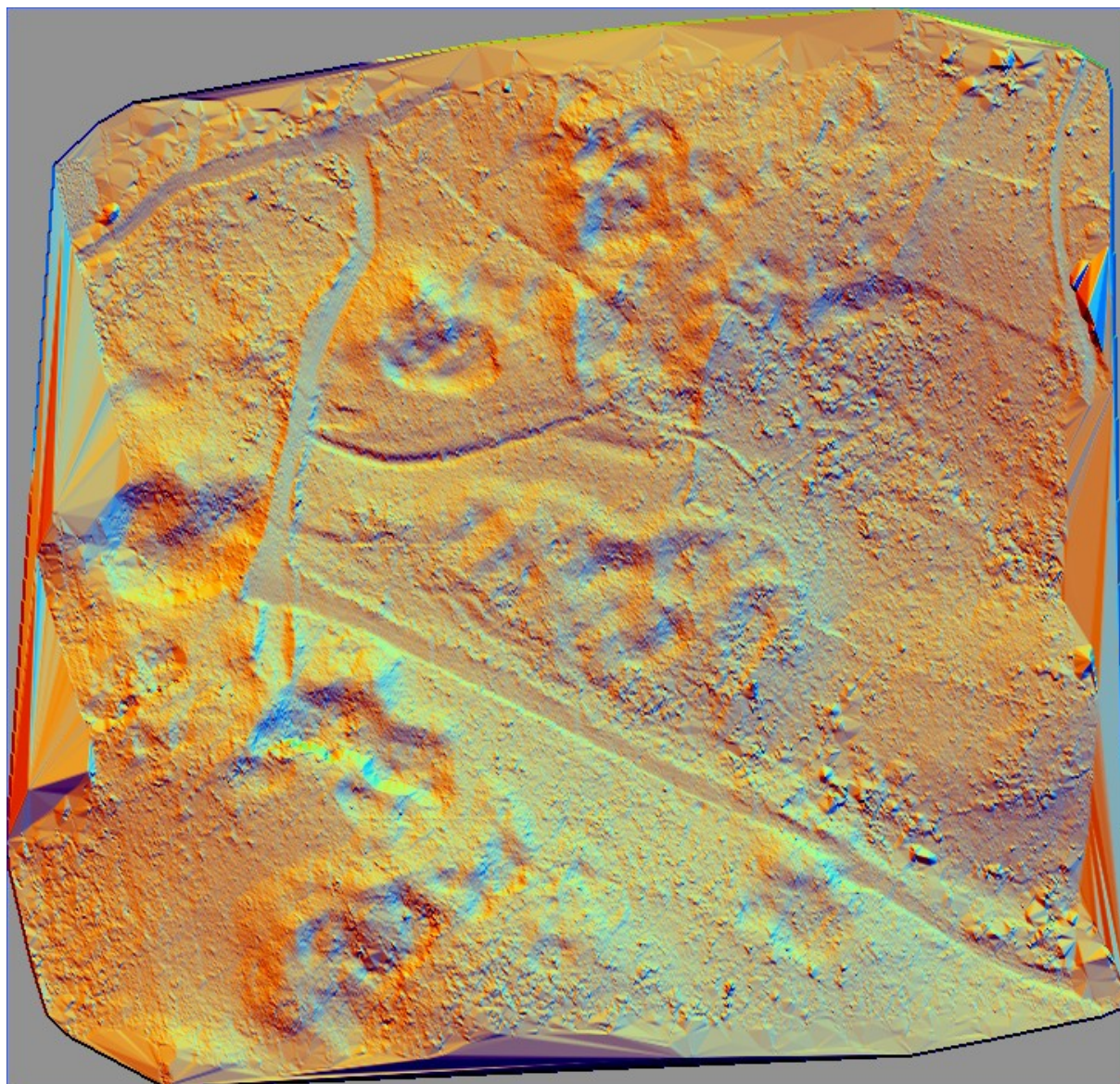


Figure 7 - Le Riols (81), la Marèze – mission du 22/11/2021 - Multi-hillshade - 16 directions - 35 degrés (RVT)

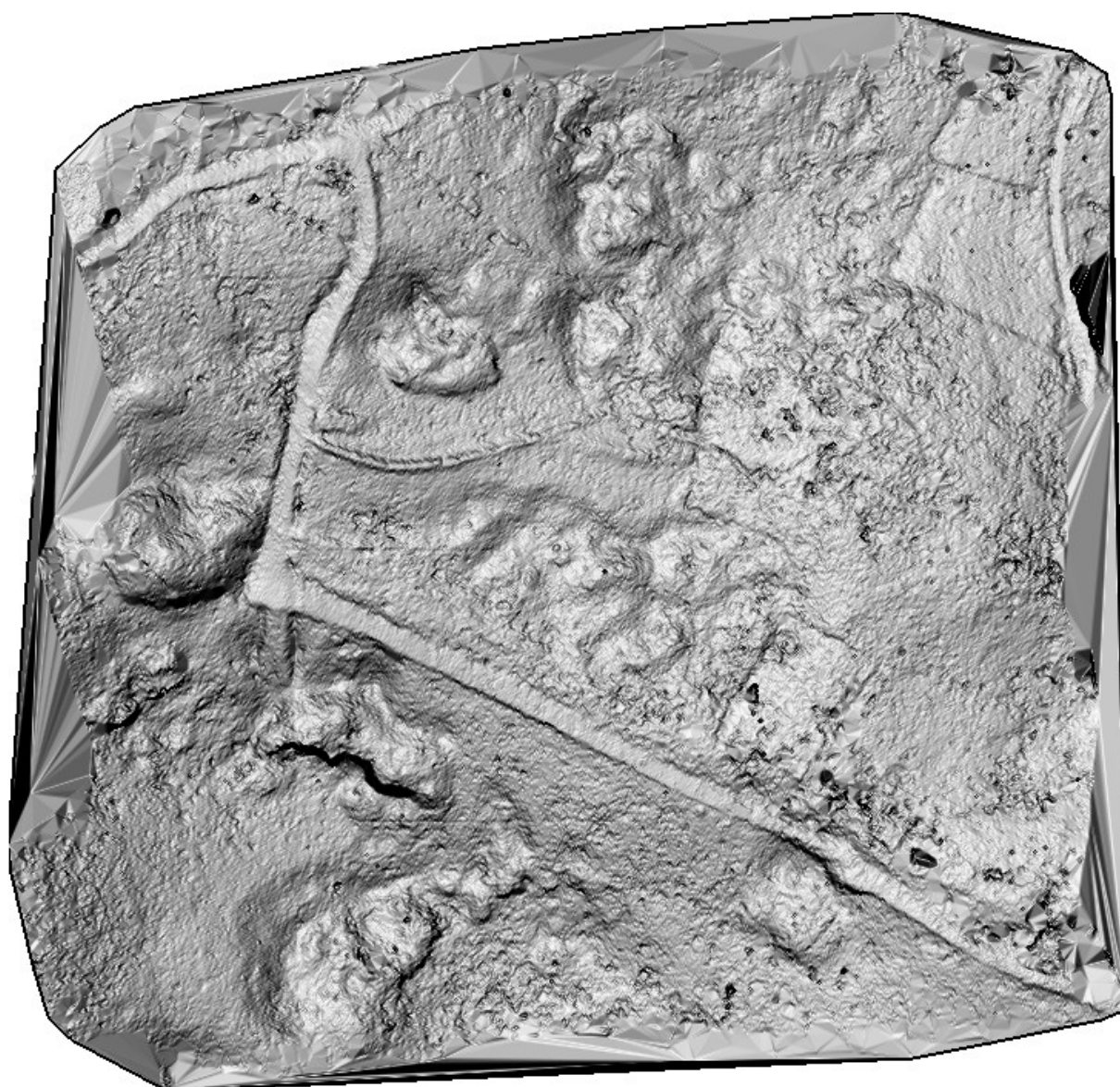


Figure 8 - Le Riols (81), la Marèze – mission du 22/11/2021 - Slope gradient (RVT)



Figure 9 - Le Riols (81), la Marèze – mission du 22/11/2021 - Sky View Factor – Rayon 20 px - 16 directions (RVT)



Figure 10 - Le Riols (81), la Marèze – mission du 22/11/2021 - Vizualisation for Archaeological Topography (VAT) (RVT)

Nous laissons le soin aux responsables thématiques du projets, meilleurs connaisseurs de leur sujet et de leur terrain, le soin d'interpréter finement ces résultats.

Données livrées avec le présent rapport :

- Nuage de points total au format *.las : Riols_2vols_PosPac_merge.las
- Nuage de points sols filtrés avec le plugin CSF de Cloudcompare au format *.las : Riols_2vols_PosPac_merge_ground.las
- Modèle Numérique de Terrain à la résolution de 50 cm issus du nuage de points-sols : Riols_merge_CSF_0402_50cm.tif
- Ensemble des visualisations de ce MNT au format *.tif et géoréférencées pour intégration SIG.

General Information

Mission Information

Project name	riols
Processing date	2021-12-10 13:08:03
Mission date	2021-11-22 10:15:46
Mission duration	00:14:59.993
Processing mode	IN-Fusion Single Base
GPS Station	TLMF

Rover Hardware Information

Product	APX 15 AVX 210 VER0 174
Serial number	S/N001
IMU type	59
Receiver type	APX-15v3
Antenna type	AV14

Project File List

Rover Data Files

File name	File type
YS-20211122-101522.T04	T04 Rover Data

Input Files

File Name	File type
tlmf326z.21o	GNSS SingleBase

Output Files

Filename	File type
sbet_Mission 1.out	SBET Trajectory File
export_Mission 1.txt	ASCII Export Output

Rover Data Summary

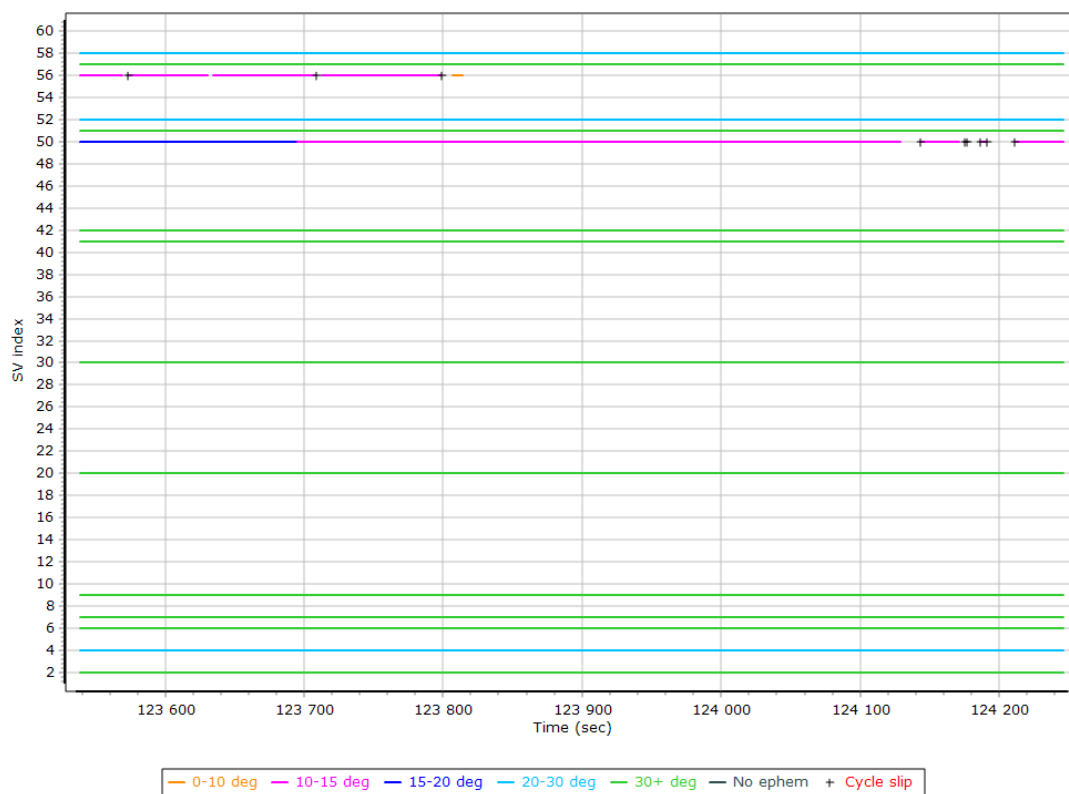
First raw data file	YS-20211122-101522.T04		
Last raw data file	YS-20211122-101522.T04		
Start GPS week	2185		
Start time	123346.000 (11/22/2021 10:15:46 AM)		
End time	124246.000 (11/22/2021 10:30:46 AM)		
Start of fine alignment	123478.800 (11/22/2021 10:17:58 AM)		
Available subsystems	Primary GNSS, IMU		
POS Event Input	None		
Correction data	None		
IMU Installation Lever Arms & Mounting Angles			
Reference to IMU lever arm [m]	-0.013	0.108	-0.007
Reference to IMU mounting angles [deg]	0.000	0.000	0.000
Reference to Primary GNSS lever arm [m]	0.006	0.218	-0.435
Reference to Primary GNSS lever arm std dev [m]	0.020		
Aircraft to Reference mounting angles [deg]	0.000	0.000	0.000

Raw Data QC

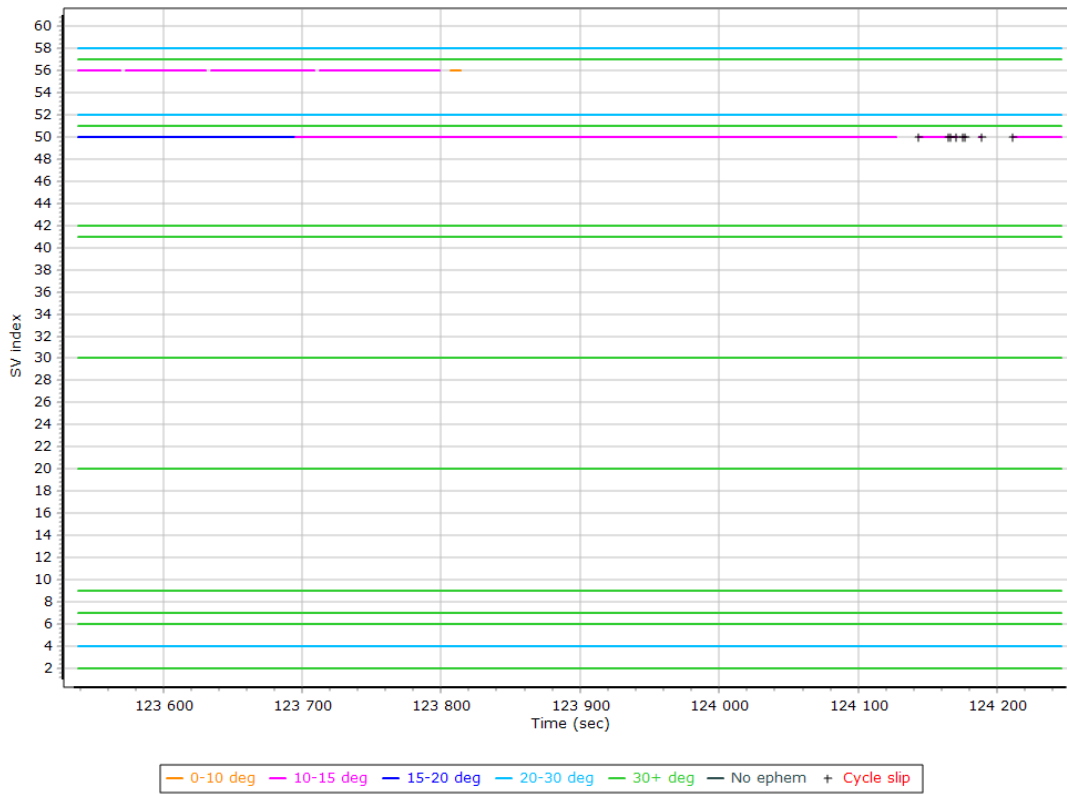
Raw IMU Import QC Summary

IMU data input file	imu_Mission 1.dat
IMU data check log file	imudt_Mission 1.log
IMU Records Processed	180100
Termination Status	Normal
IMU Anomalies	0

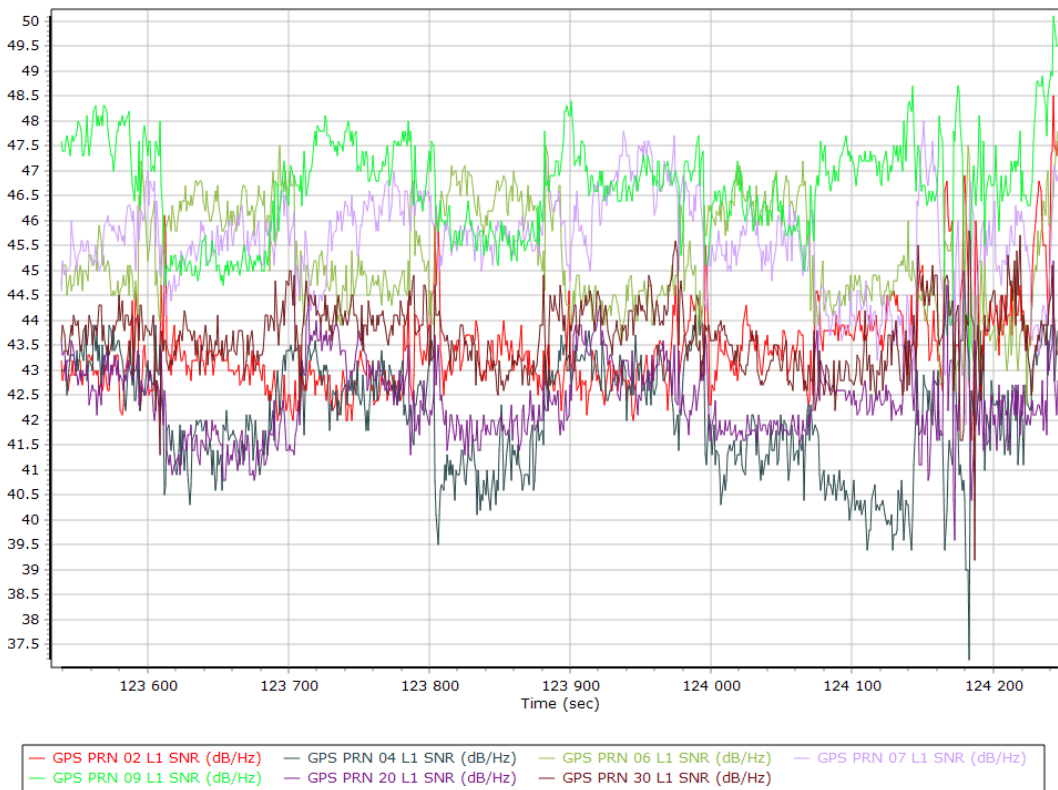
L1 Satellite Lock/Elevation



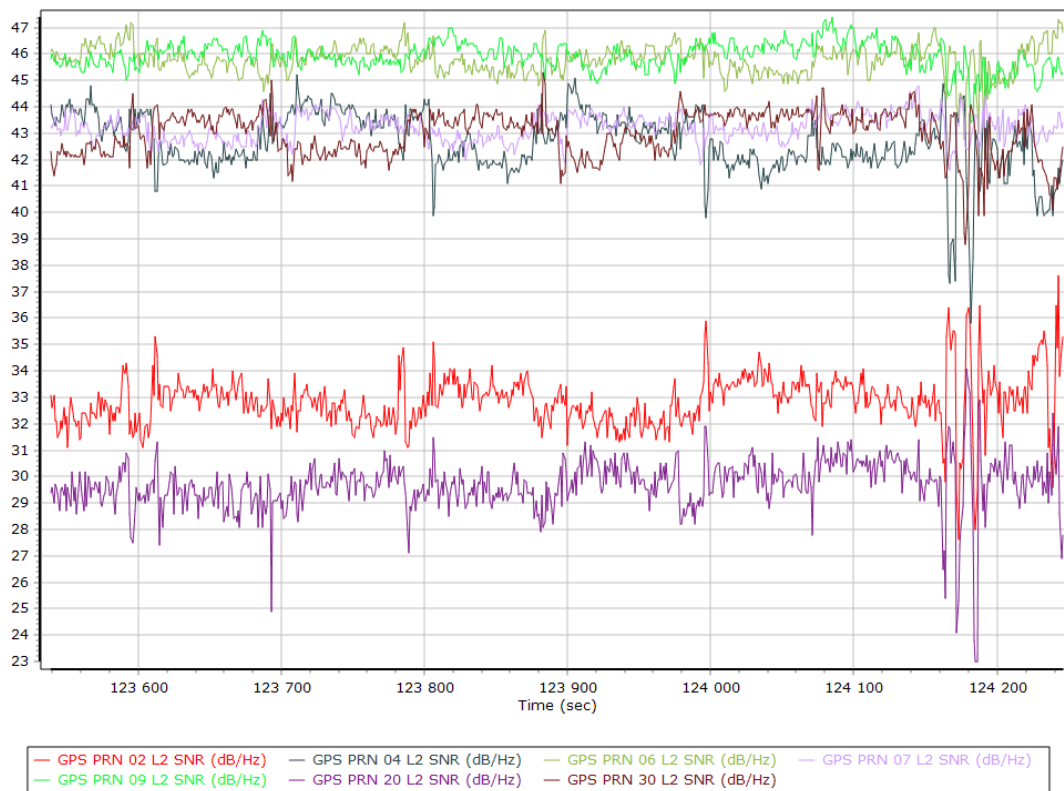
L2 Satellite Lock/Elevation



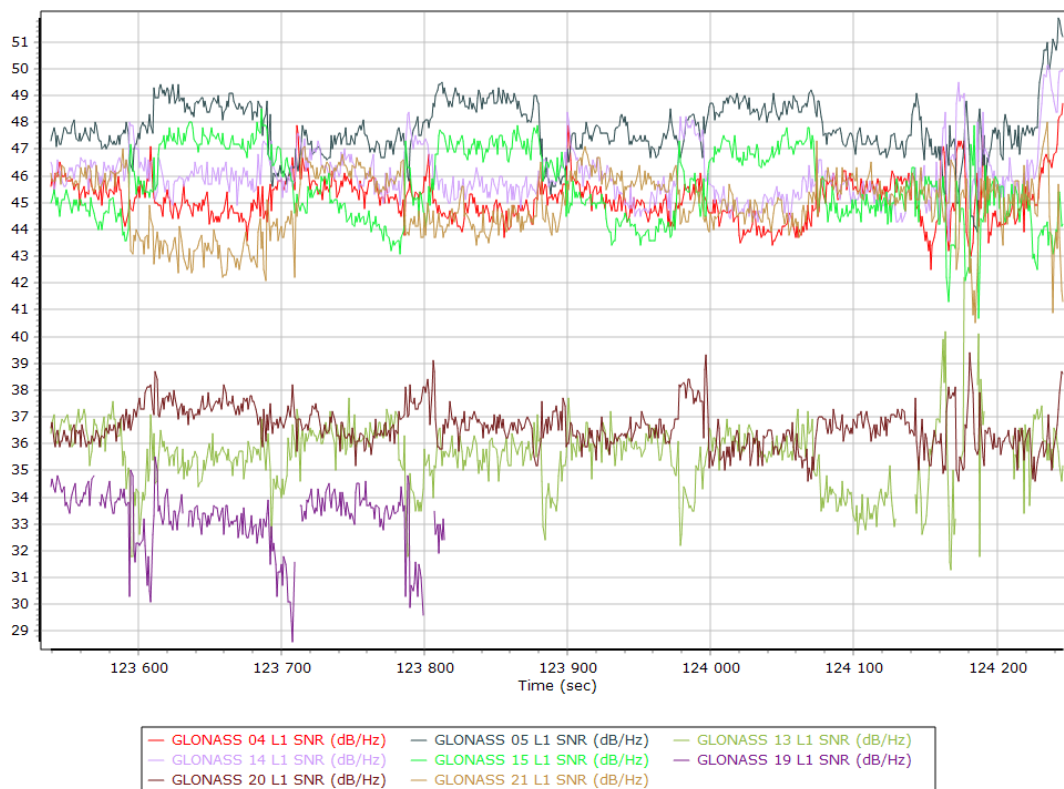
GPS L1 SNR



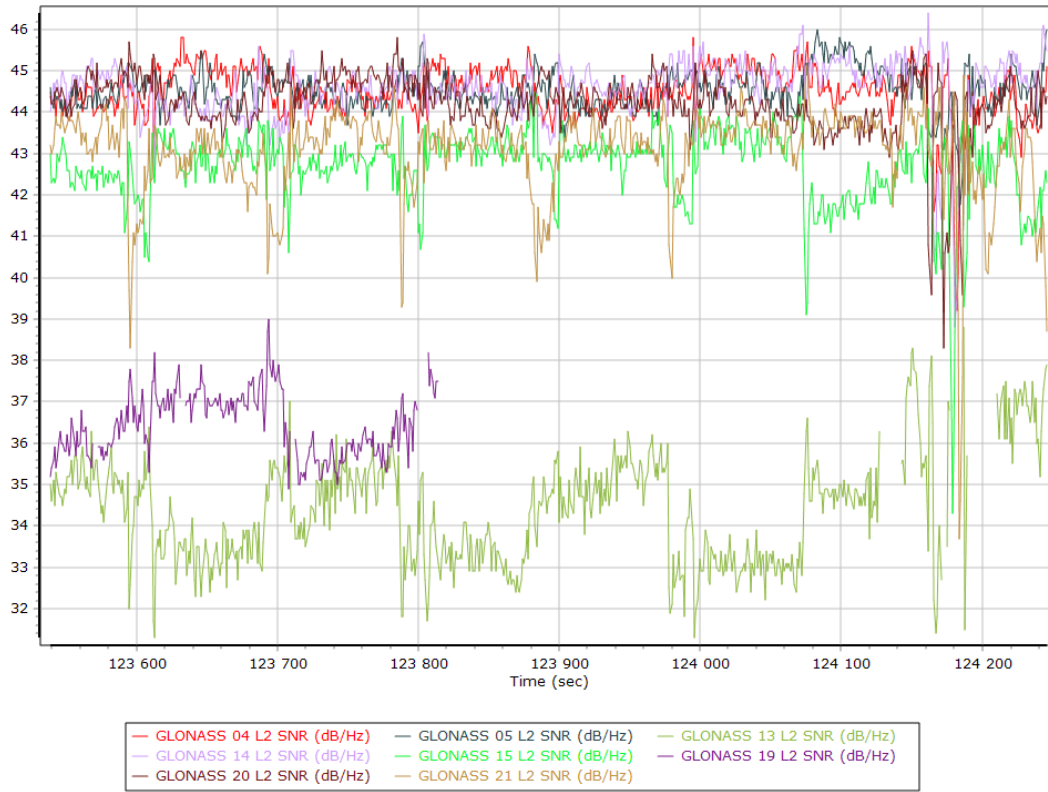
GPS L2 SNR



GLONASS L1 SNR

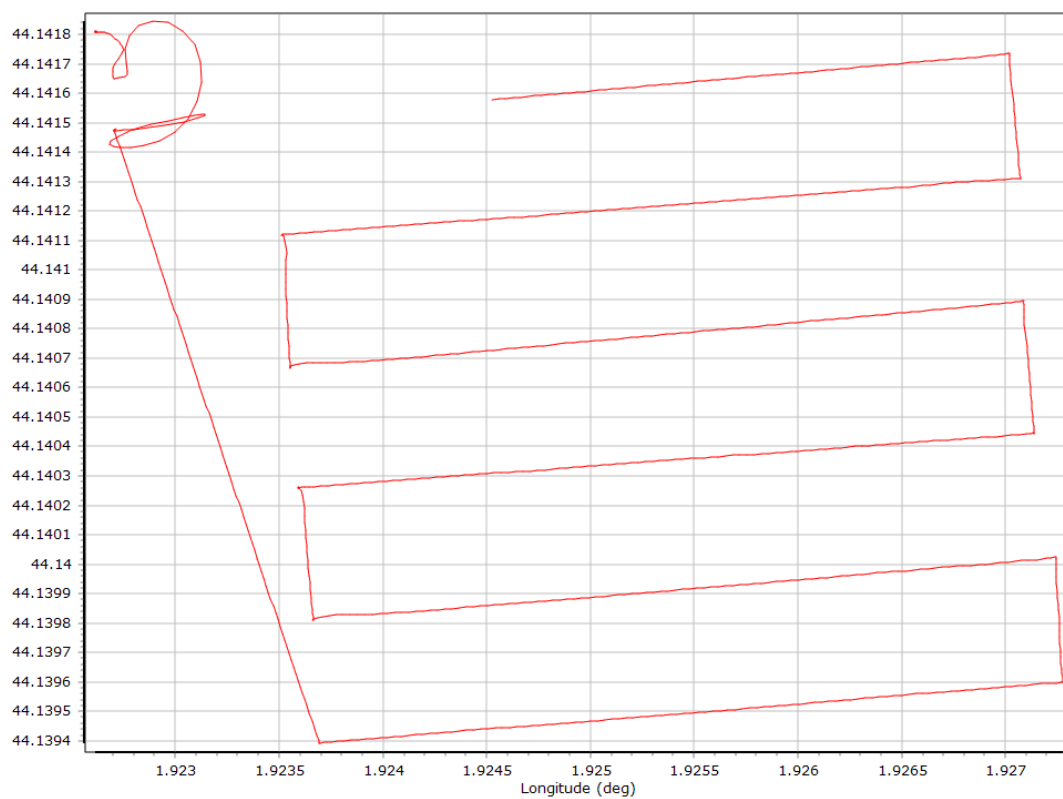


GLONASS L2 SNR

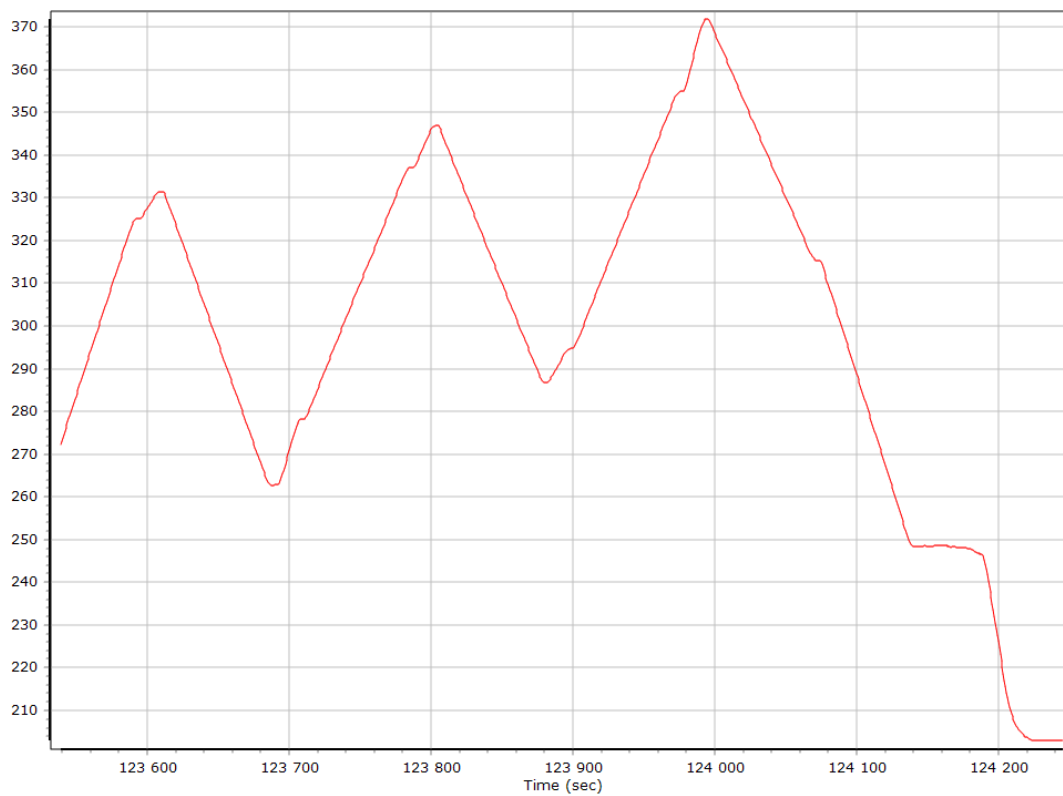


Trajectory Information

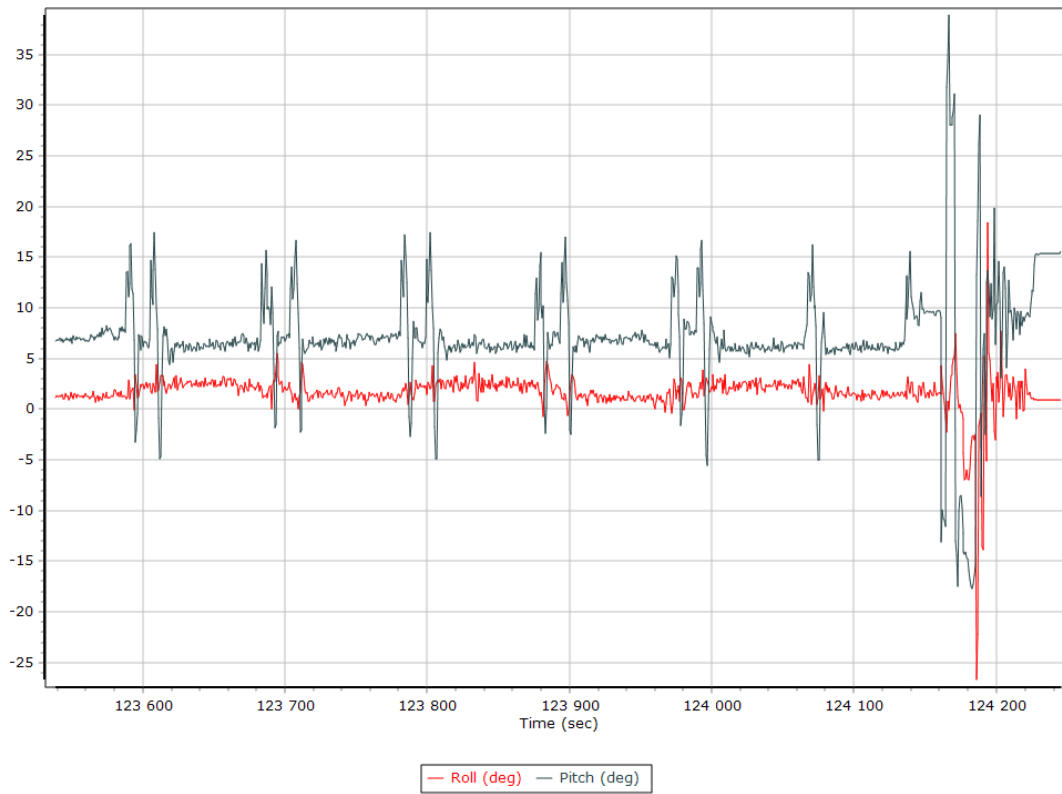
Top View



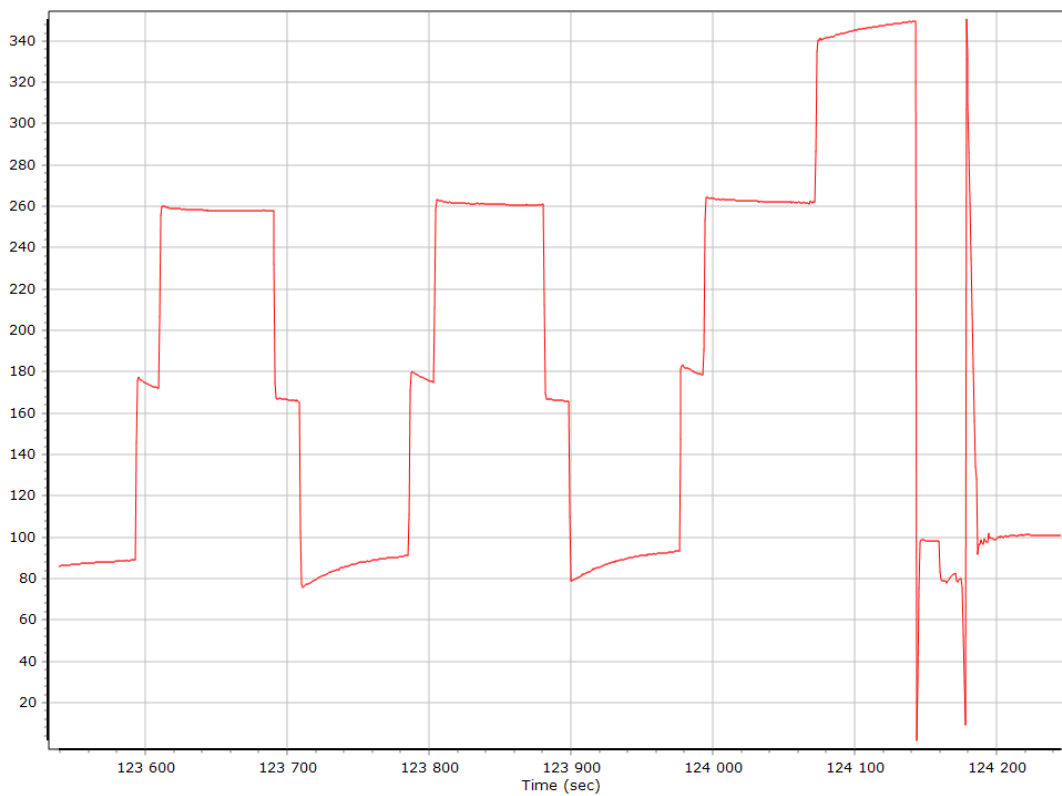
Altitude



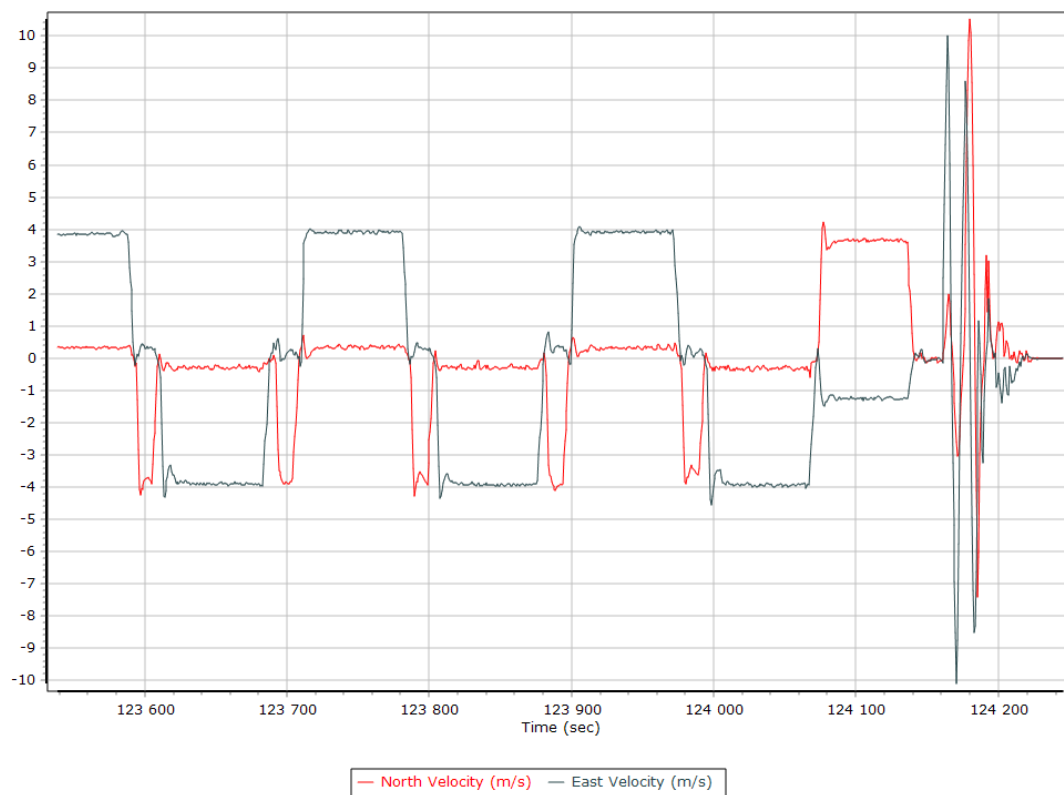
Roll/Pitch



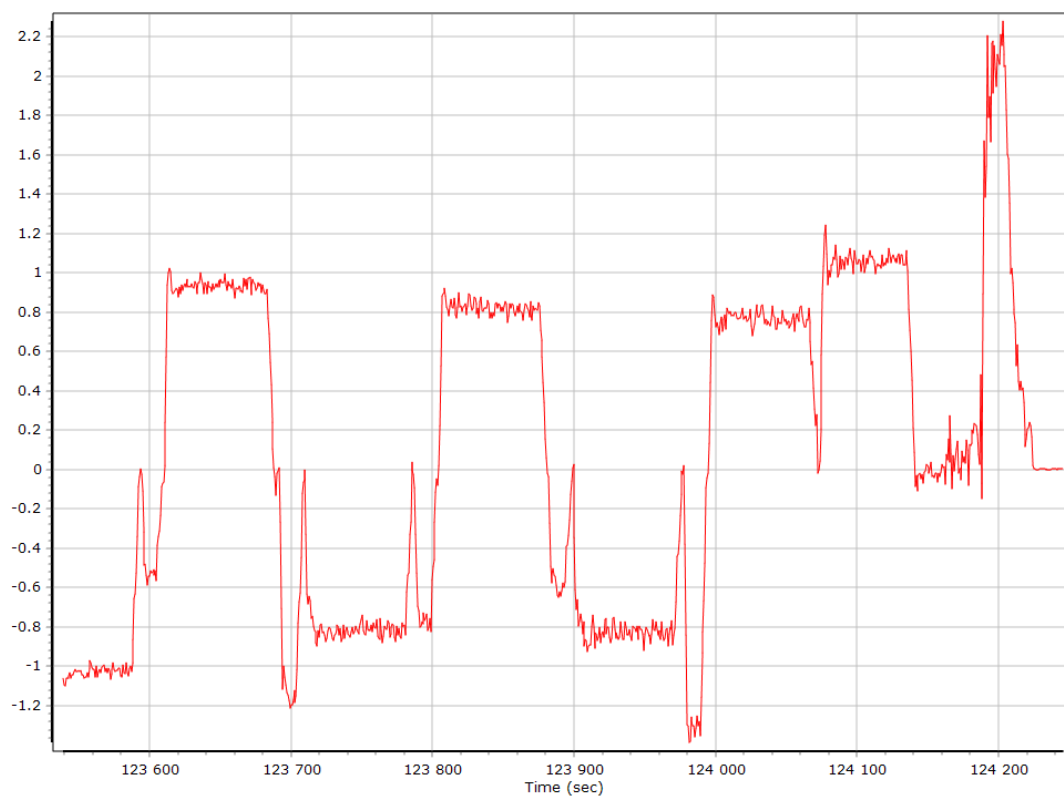
Heading



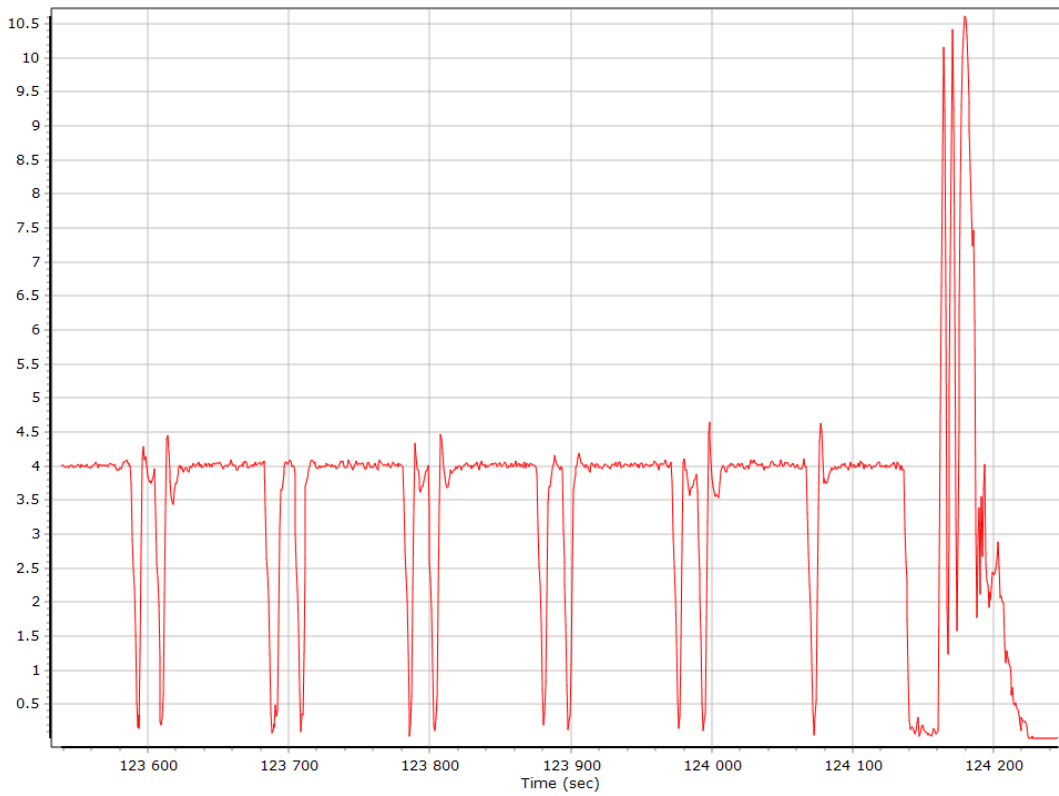
North/East Velocity



Down Velocity



Total Speed



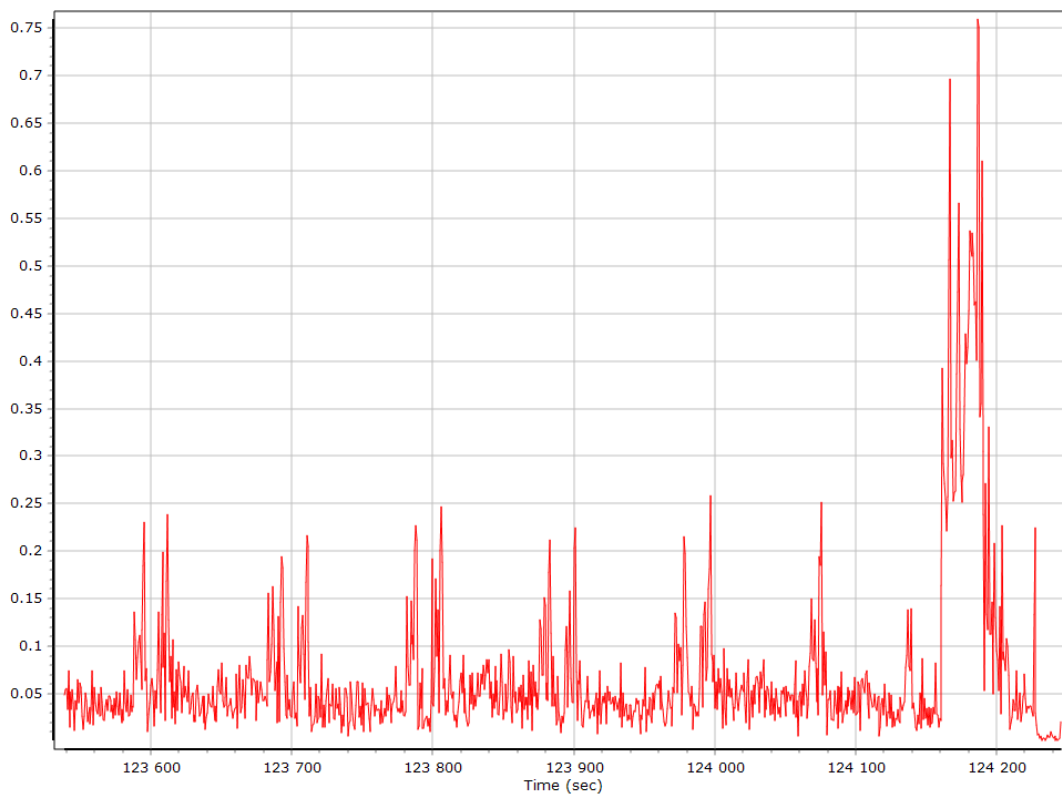
Ground Speed



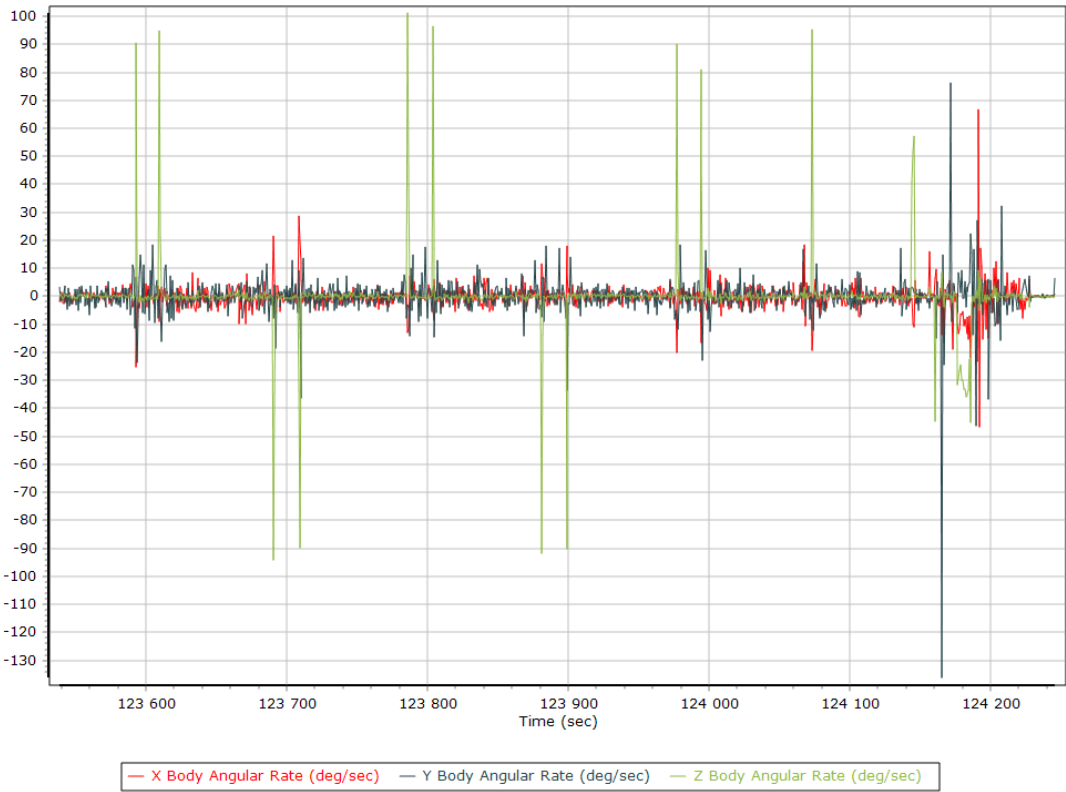
Body Acceleration



Total Body Acceleration



Body Angular Rate



Base Station Information

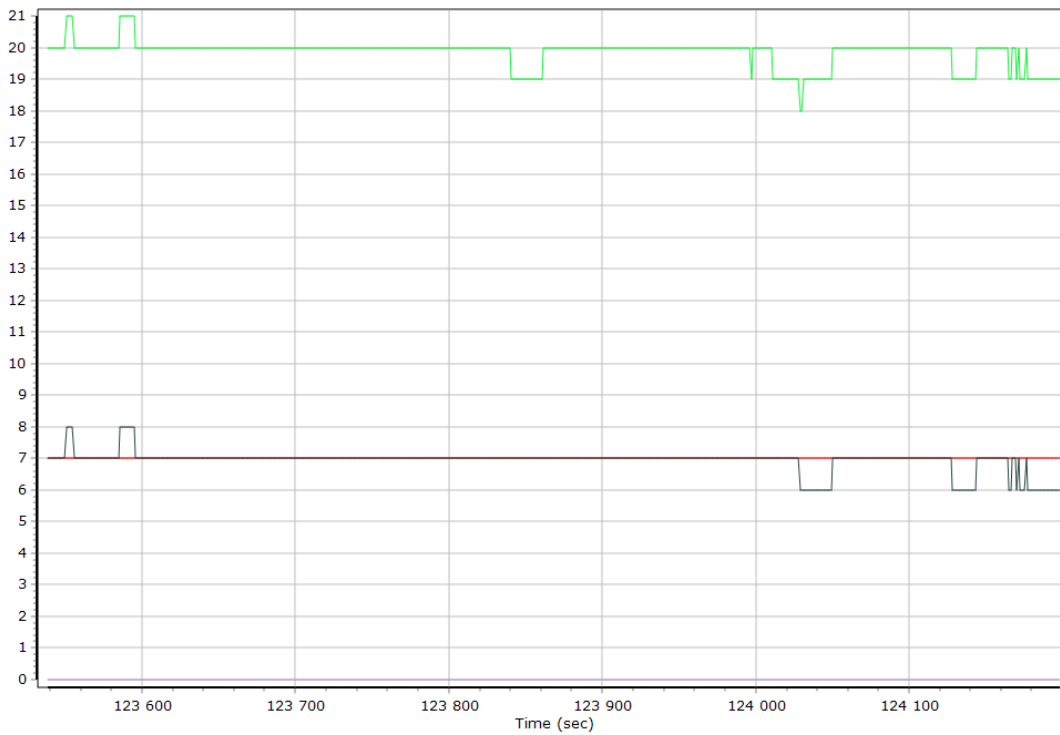
Station ID	TLMF		
Filename	t1mf326z.21o		
Start date	11/22/2021 10:00:00 AM		
End date	11/22/2021 1:59:59 PM		
Duration	03:59:59.000		
Data type	GNSS		
Receiver manufacturer, model, serial no.	Leica	GR25	1830399
Antenna manufacturer, model	Trimble		Zephyr Geodetic 2 RoHS
Antenna height [m]	0.000		
Antenna measurement method	Bottom of antenna mount		
Offset from measured point to APC [m]	0.08546		
Latitude	N43°34'28.57480"		
Longitude	E1°22'30.33938"		
Ellipsoidal height [m]	221.02170		
Frame	ITRF00		
Epoch	1997		
Ellipsoid	WGS84		
Velocity North [mm/y]	0		
Velocity East [mm/y]	0		
Velocity Up [mm/y]	0		

GNSS QC

GNSS QC Statistics

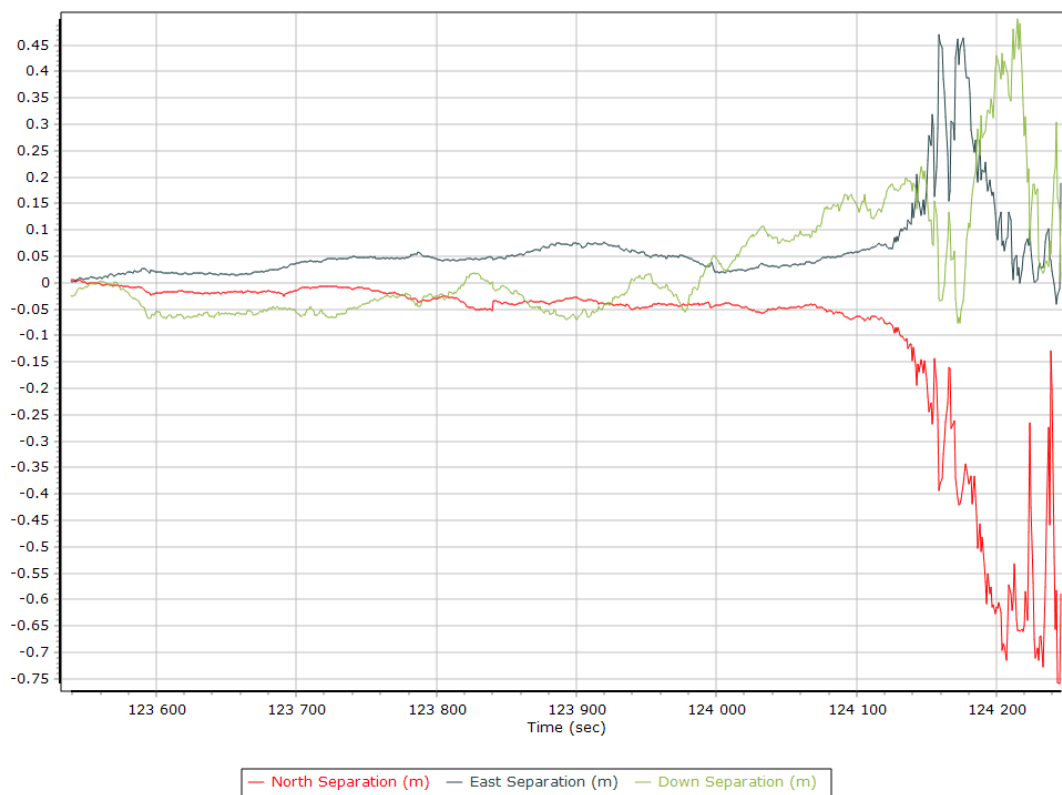
Statistics	Min	Max	Mean
Baseline length [km]	76.71	77.07	
Number of GPS SV	7	7	7
Number of GLONASS SV	6	8	7
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Total number of SV	13	15	14
PDOP	1.26	1.61	1.37
QC Solution Gaps	0.00	0.00	
Solution Type	Fixed	Float	No solution
Epoch (s)	852.00	0.00	0.00
Percentage	100.00	0.00	0.00

Num SVs in solution

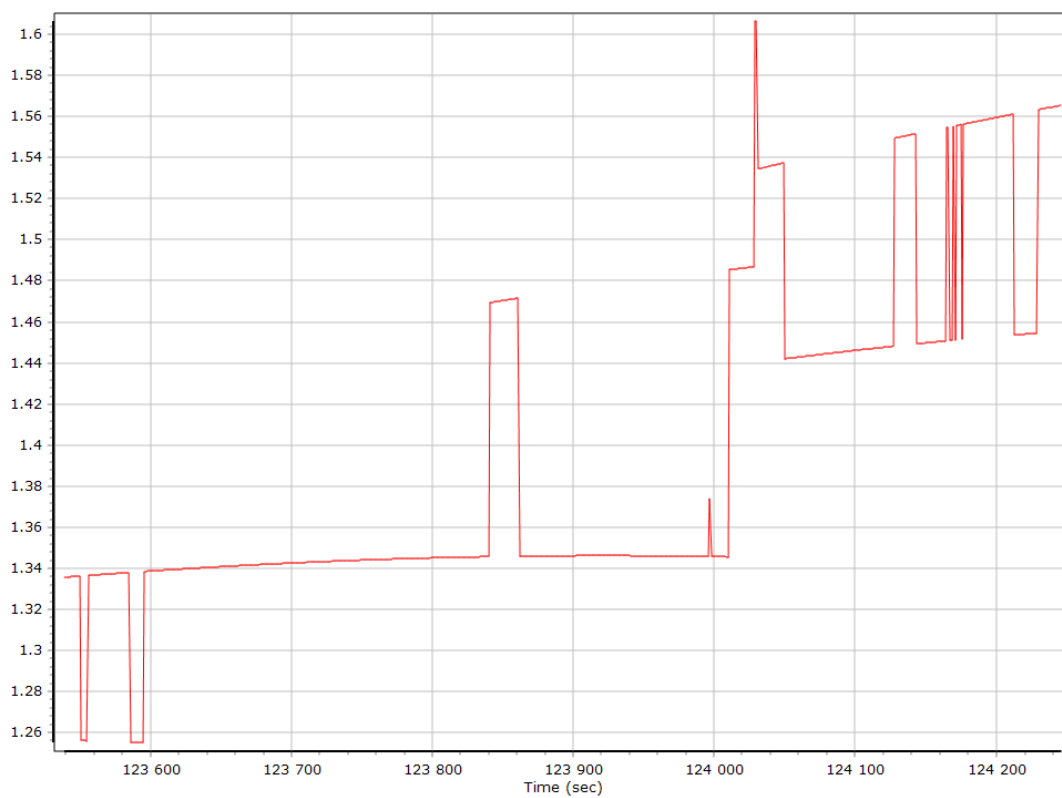


— Number of GPS — Number of GLONASS — Number of QZSS — Number of BEIDOU — Total Number

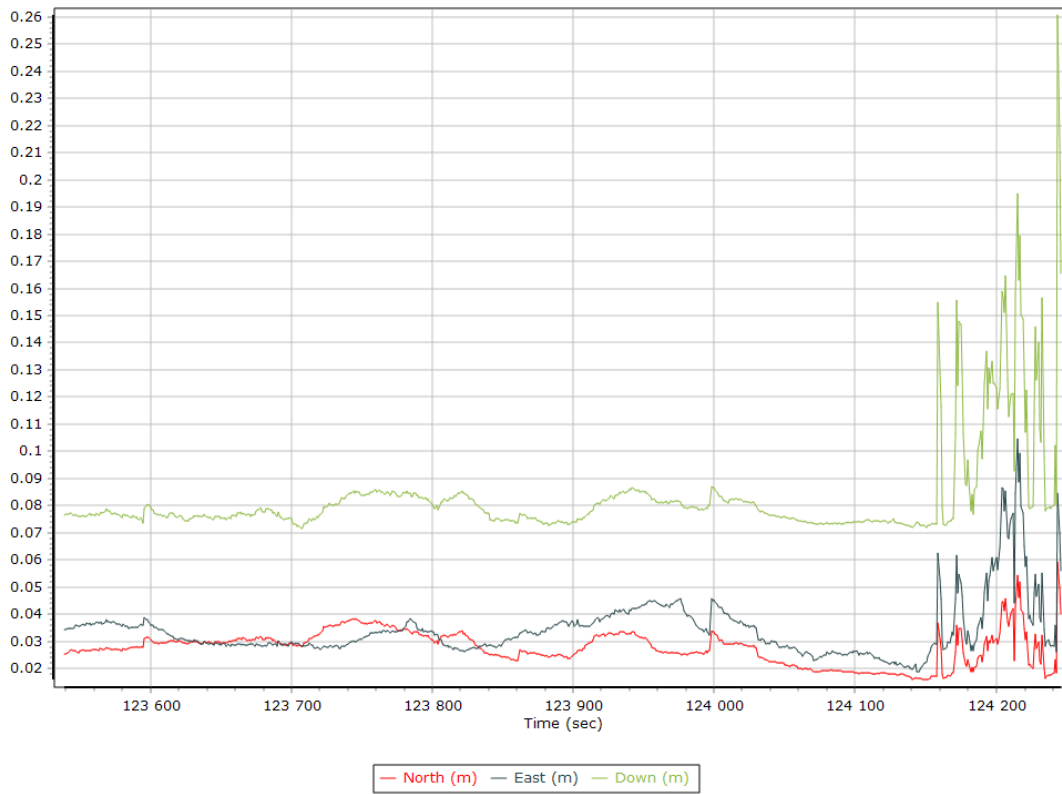
Forward/Reverse Separation



PDOP



Estimated Position Accuracy



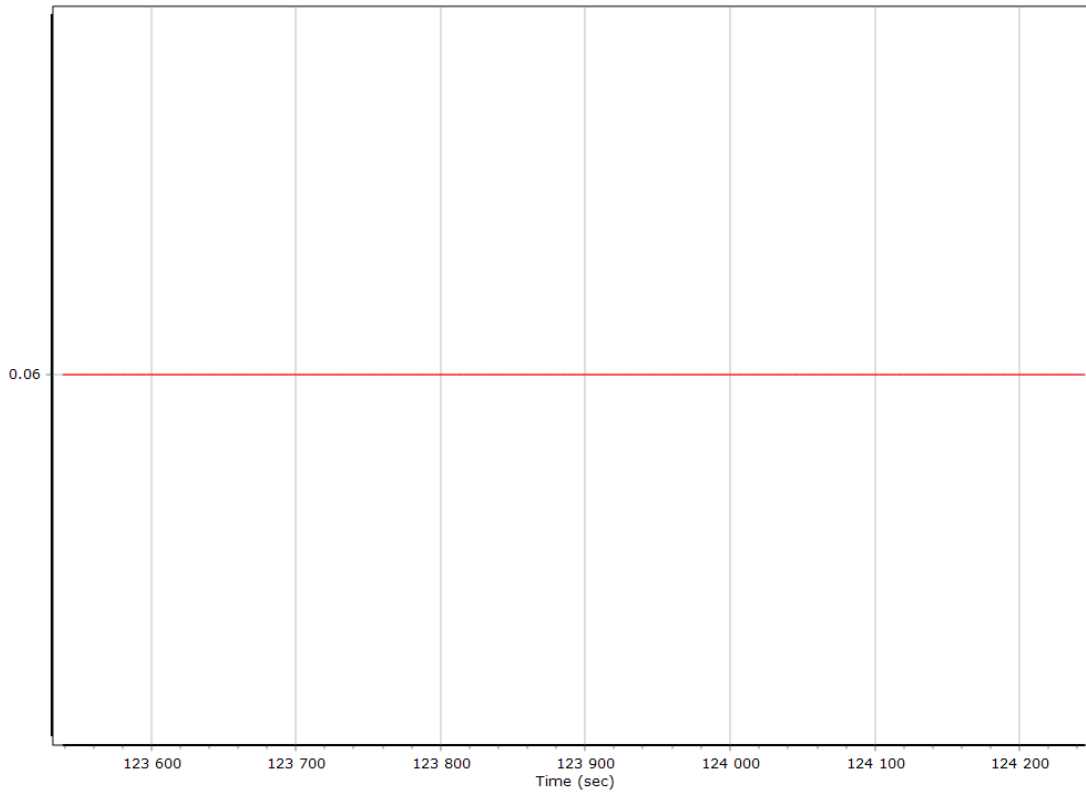
GNSS-Inertial Processor Configuration

Processing mode	IN-Fusion Single Base		
Stabilized mount	False		
Base station	TLMF		
Processing start time	123346.007 (11/22/2021 10:15:46 AM)		
Processing end time	124246.000 (11/22/2021 10:30:46 AM)		
Initial attitude source	Primary GNSS Track		
IMU Sensor Context	Processing with Onboard IMU		
Reference to IMU lever arm [m]	-0.013	0.108	-0.007
Reference to IMU mounting angles [deg]	0.000	0.000	0.000
Reference to Primary GNSS lever arm [m]	0.060	0.190	-0.400
Reference to Primary GNSS lever arm std dev [m]	0.010	0.010	0.010
Aircraft to Reference mounting angles [deg]	0.000	0.000	0.000

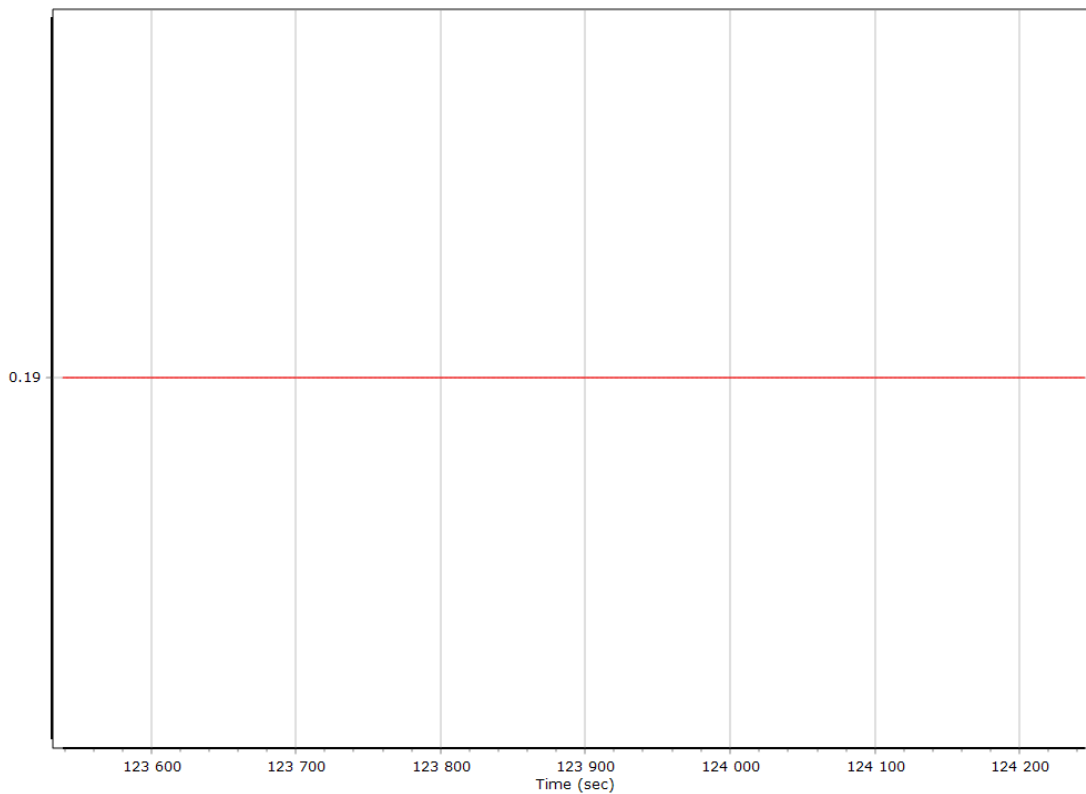
Calibrated Installation Parameters

Reference-Primary GNSS Lever Arm

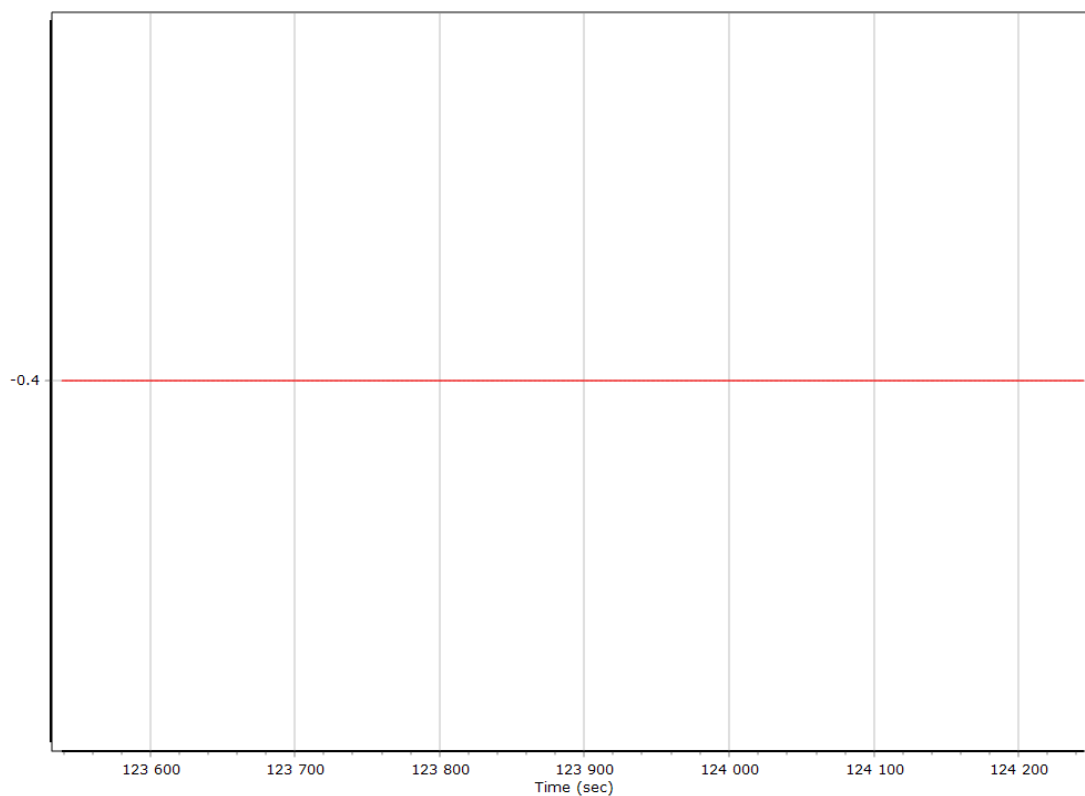
X Reference-Primary GNSS Lever Arm (m)



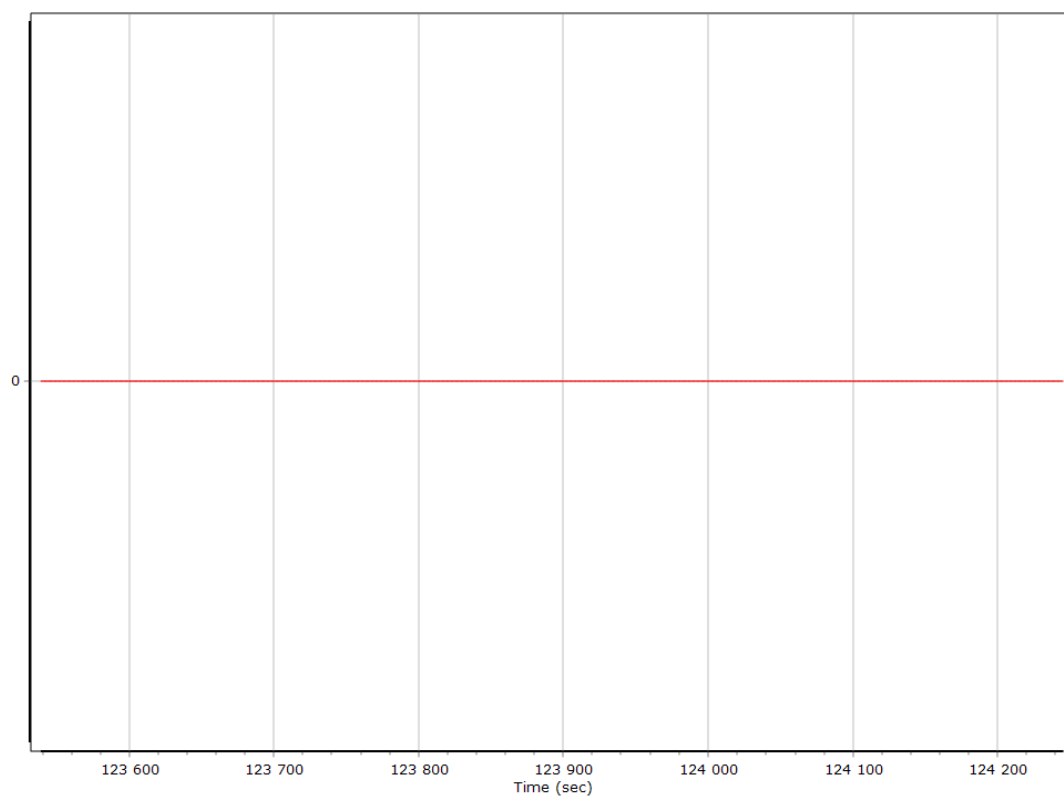
Y Reference-Primary GNSS Lever Arm (m)



Z Reference-Primary GNSS Lever Arm (m)



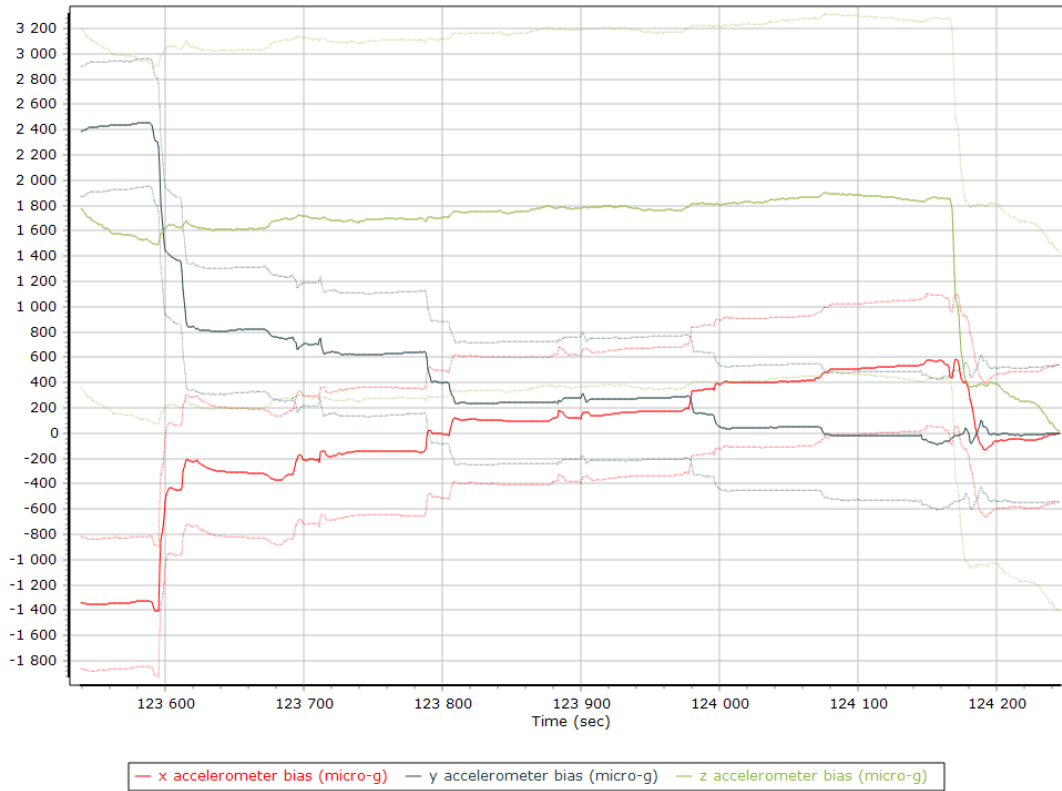
Reference-Primary GNSS Lever Arm Figure of Merit



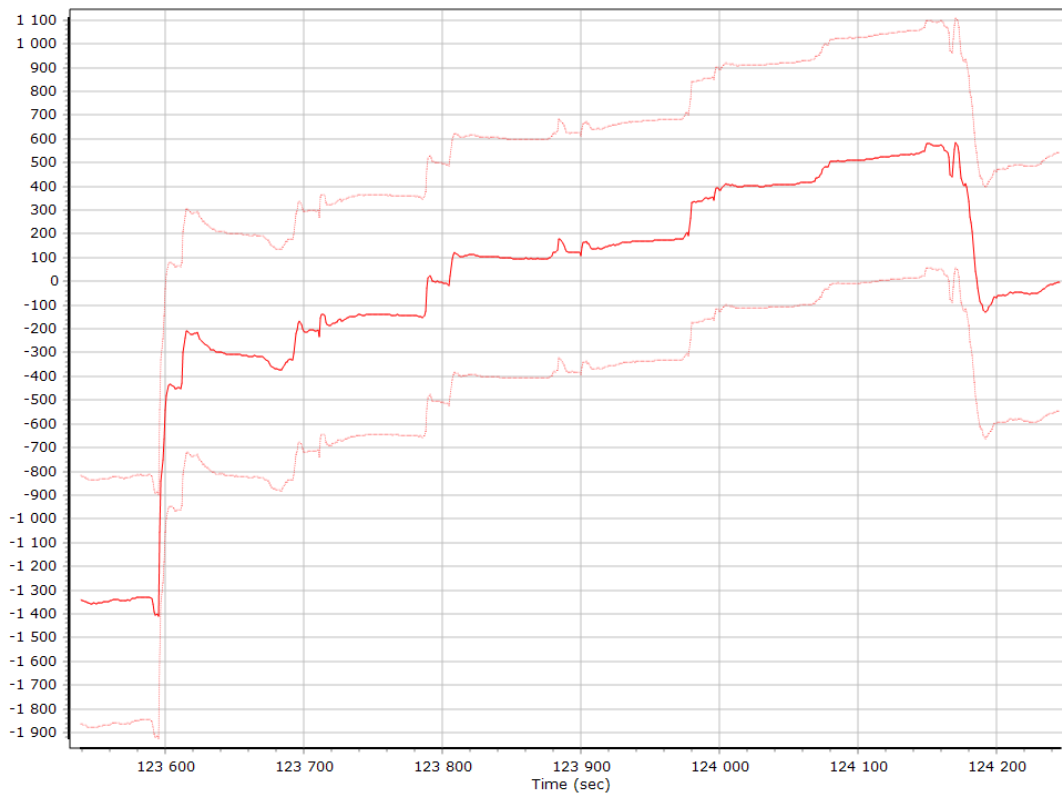
Smoothed IN-Fusion QC

Smoothed Estimated Errors, Reference Frame

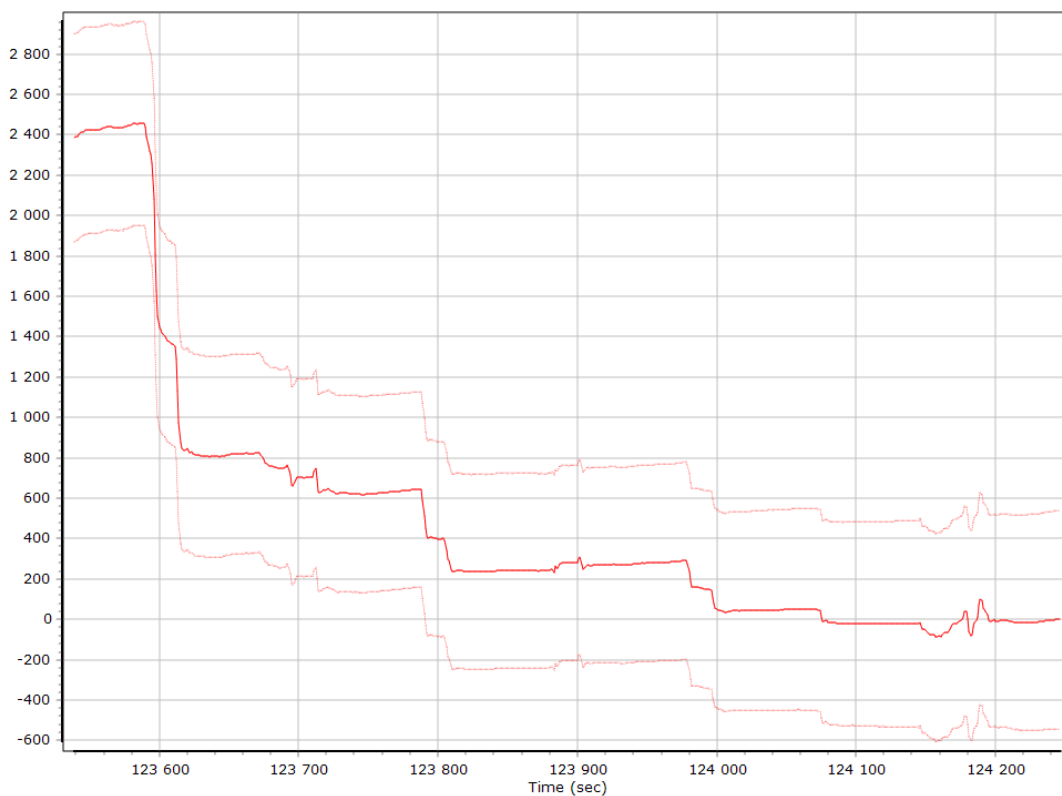
Accelerometer Bias (micro-g)



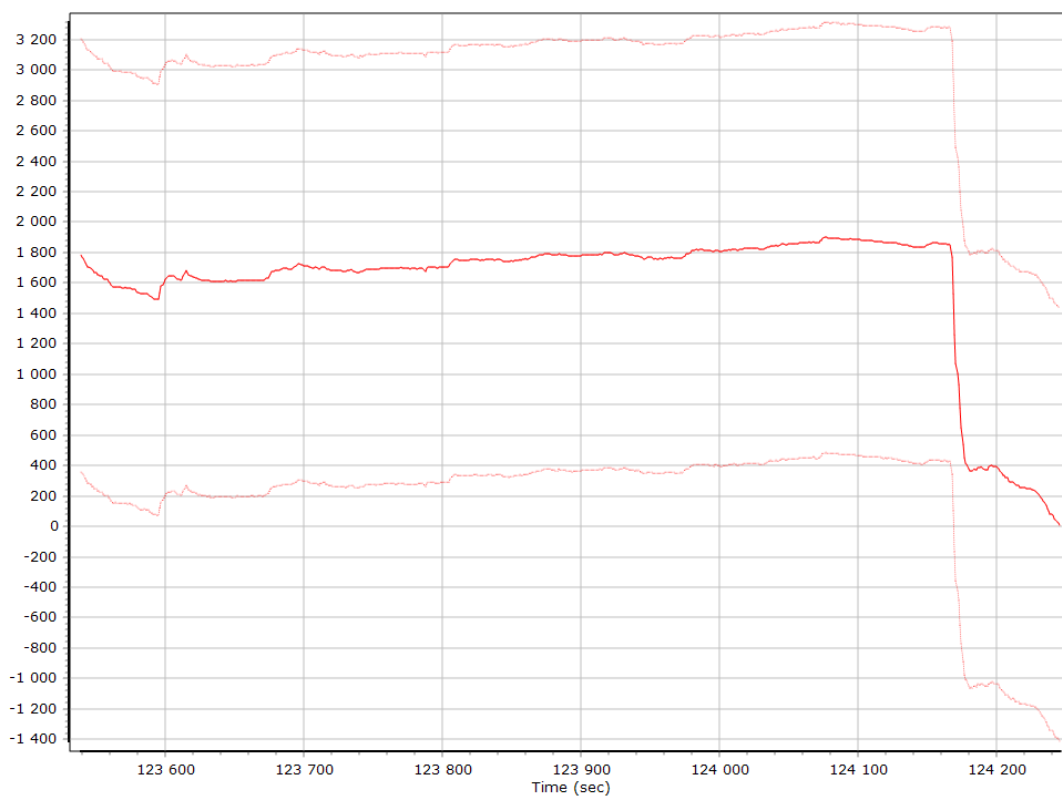
X Accelerometer Bias (micro-g)



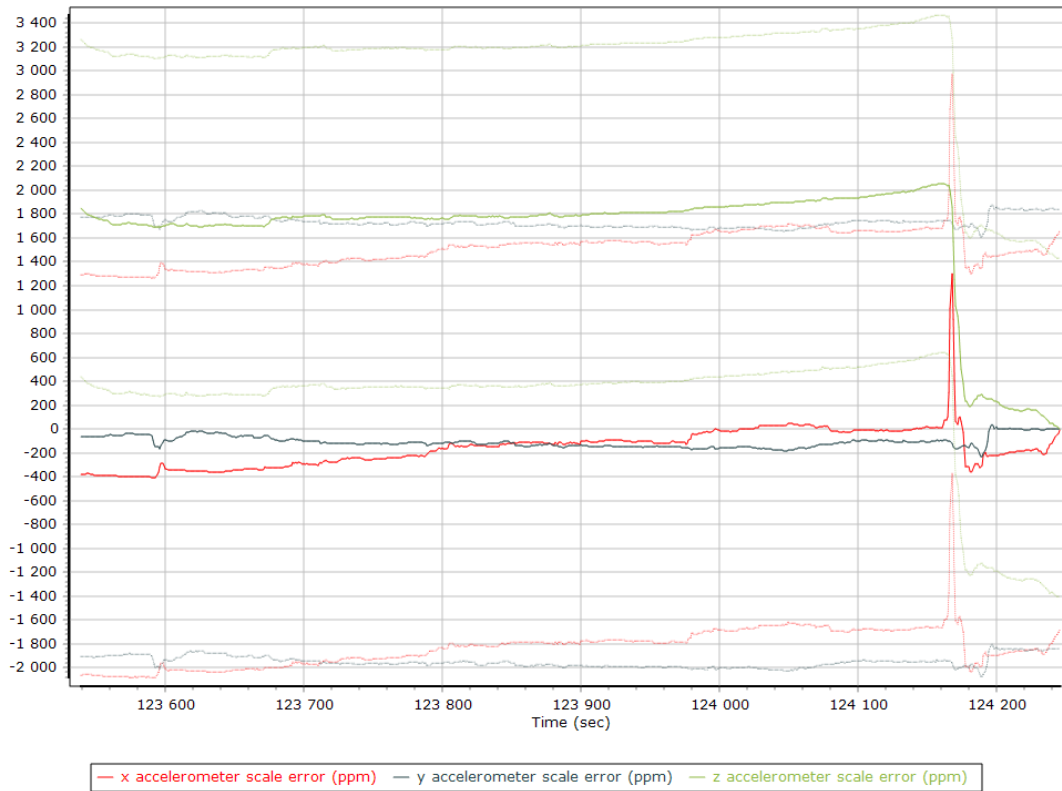
Y Accelerometer Bias (micro-g)



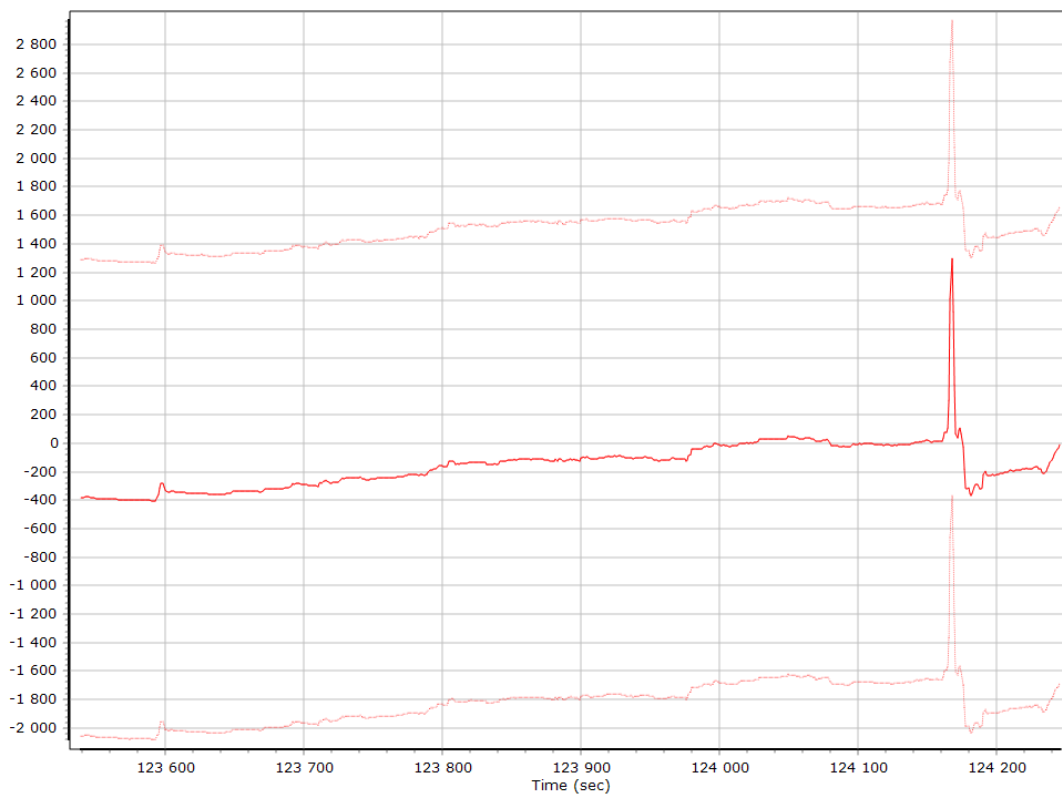
Z Accelerometer Bias (micro-g)



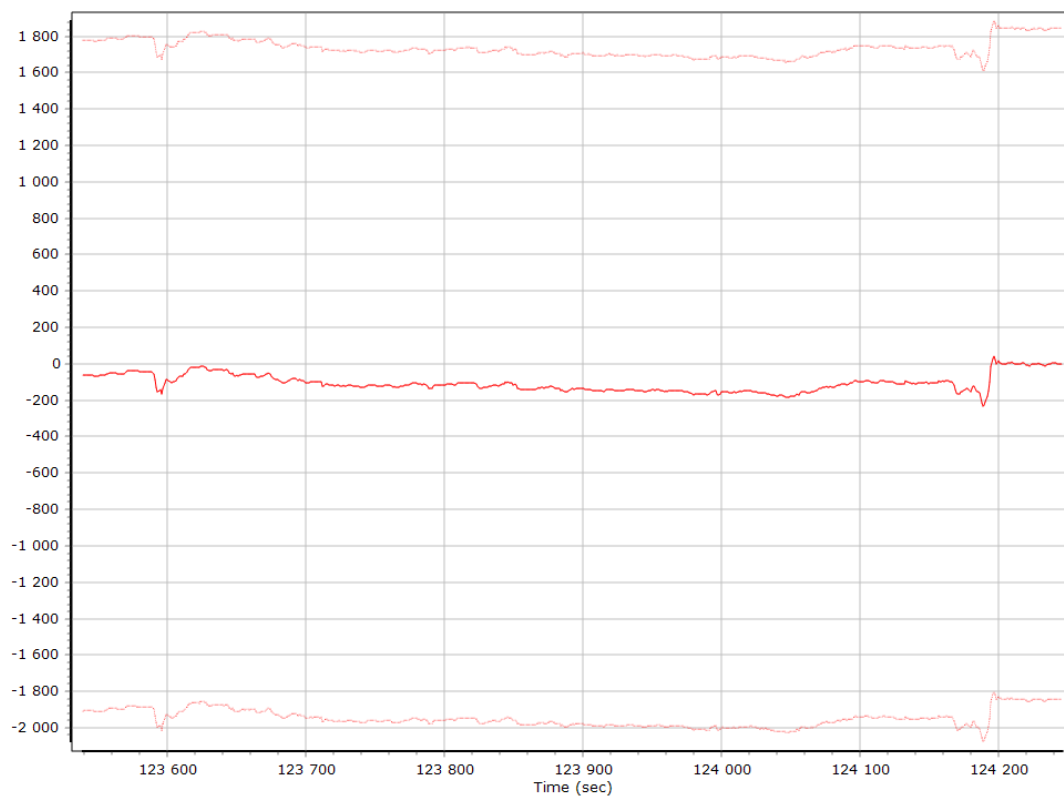
Accelerometer Scale Error (ppm)



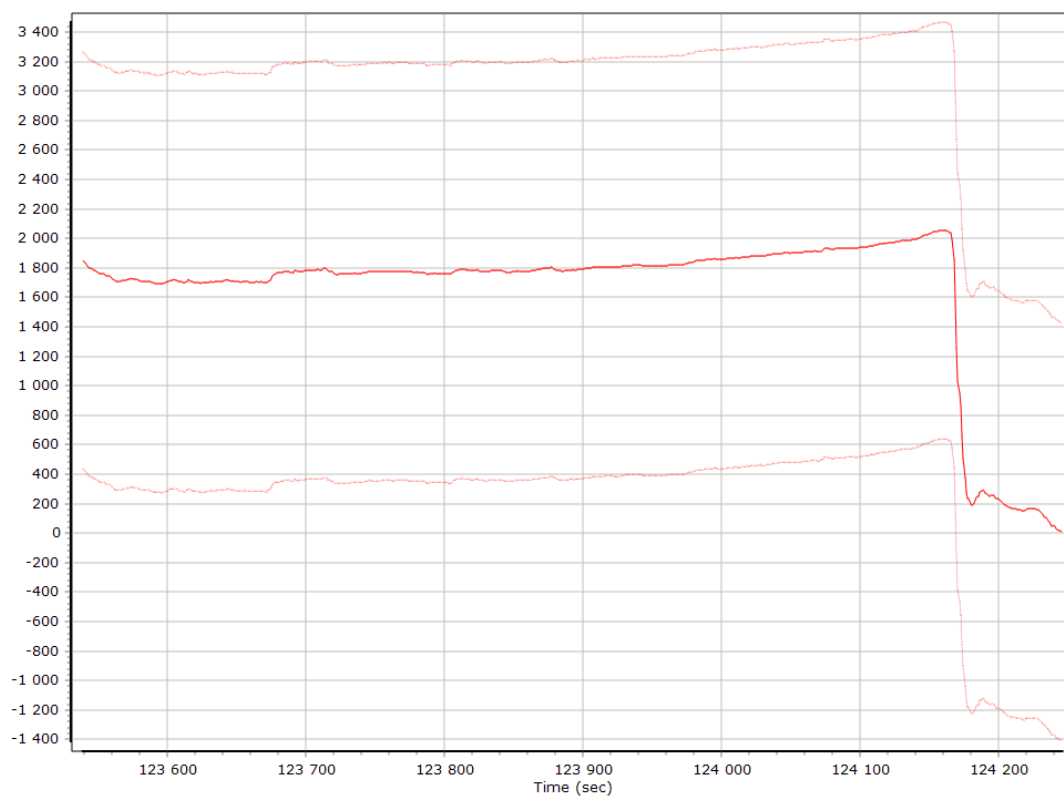
X Accelerometer Scale Error (ppm)



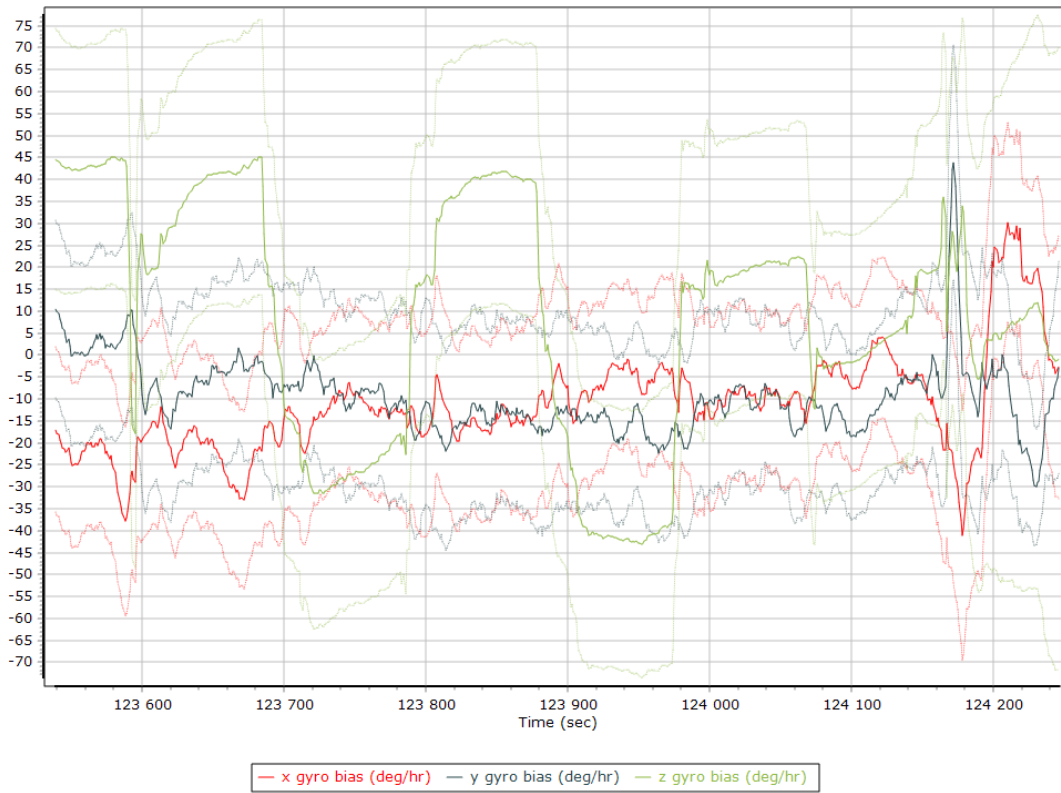
Y Accelerometer Scale Error (ppm)



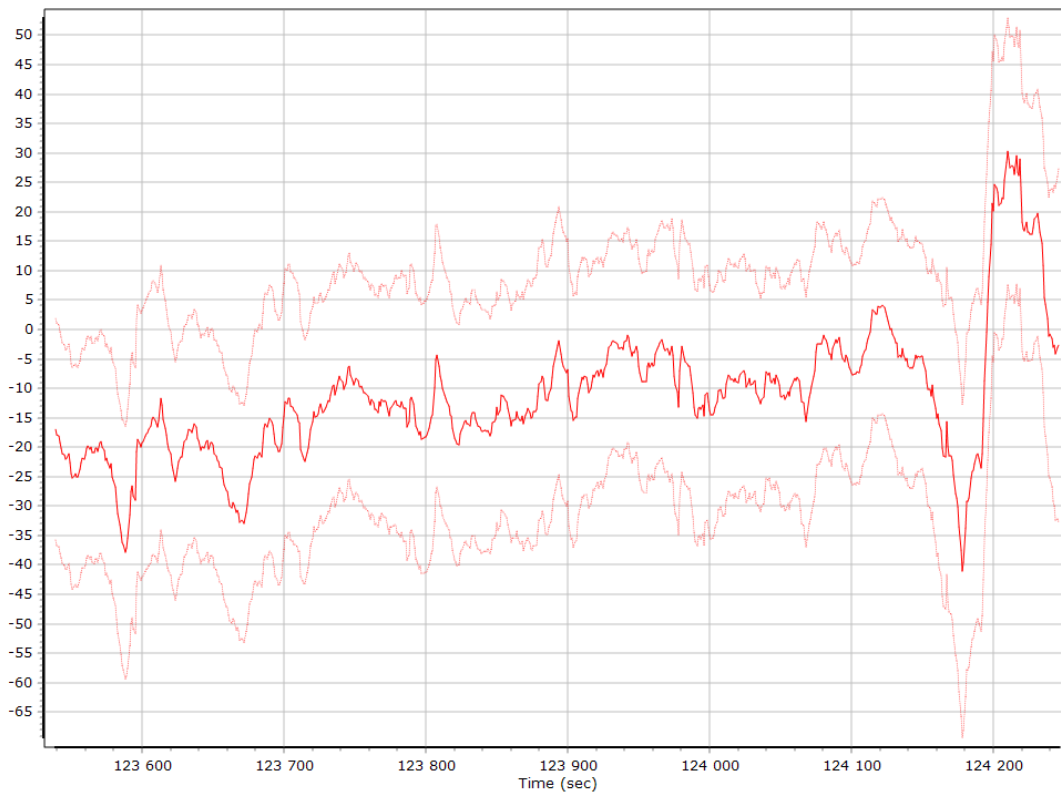
Z Accelerometer Scale Error (ppm)



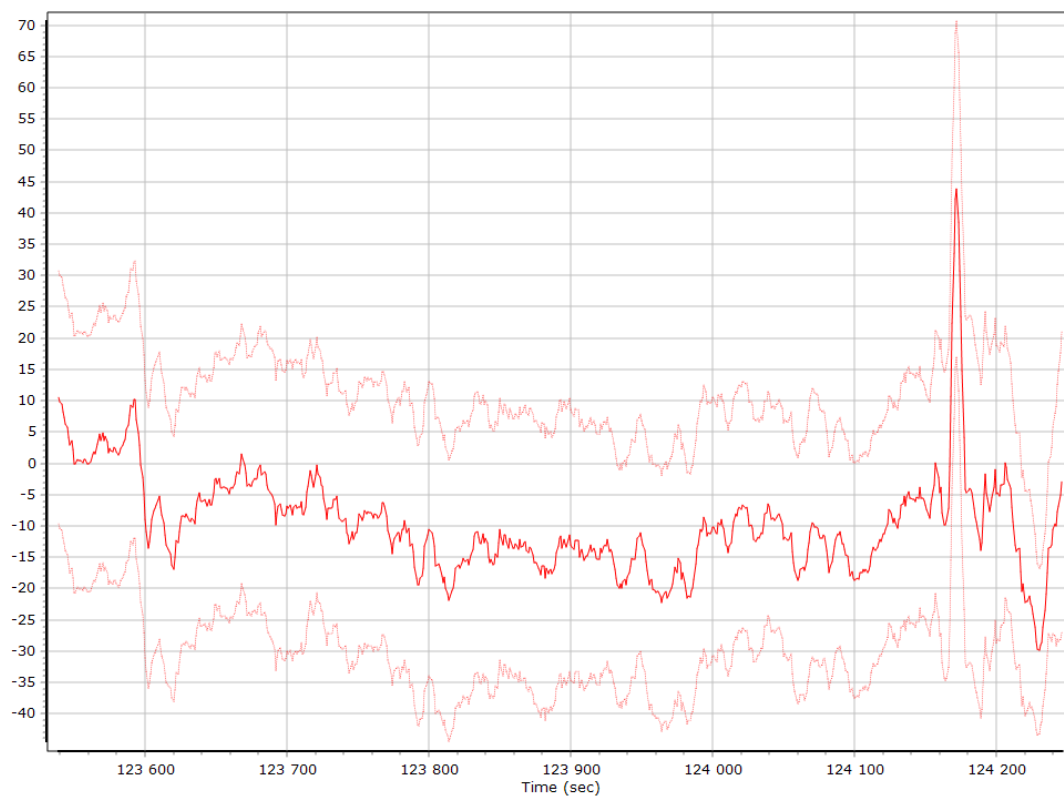
Gyro Bias (deg/h)



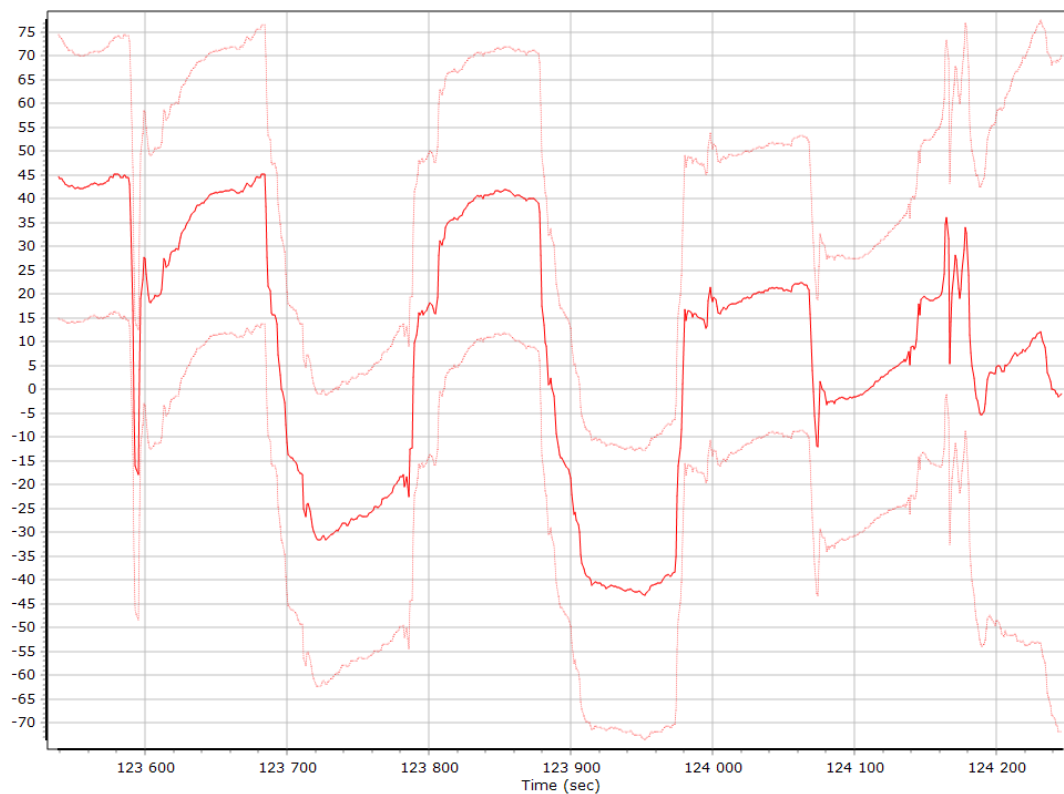
X Gyro Bias (deg/h)



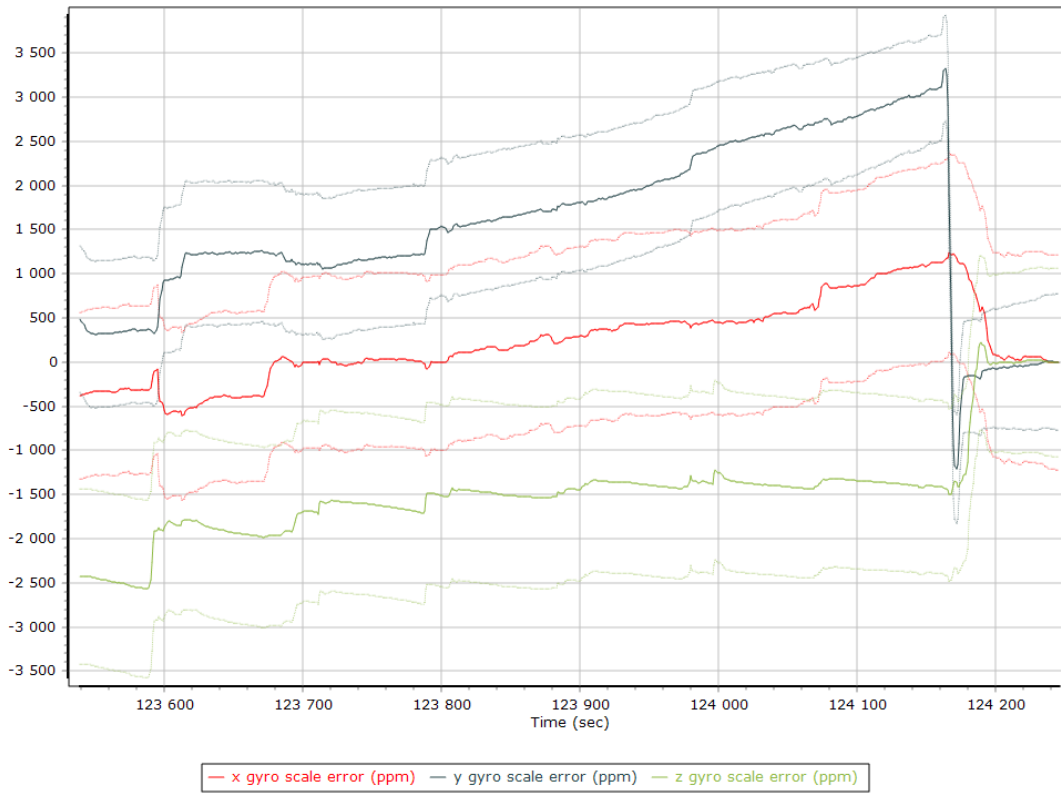
Y Gyro Bias (deg/h)



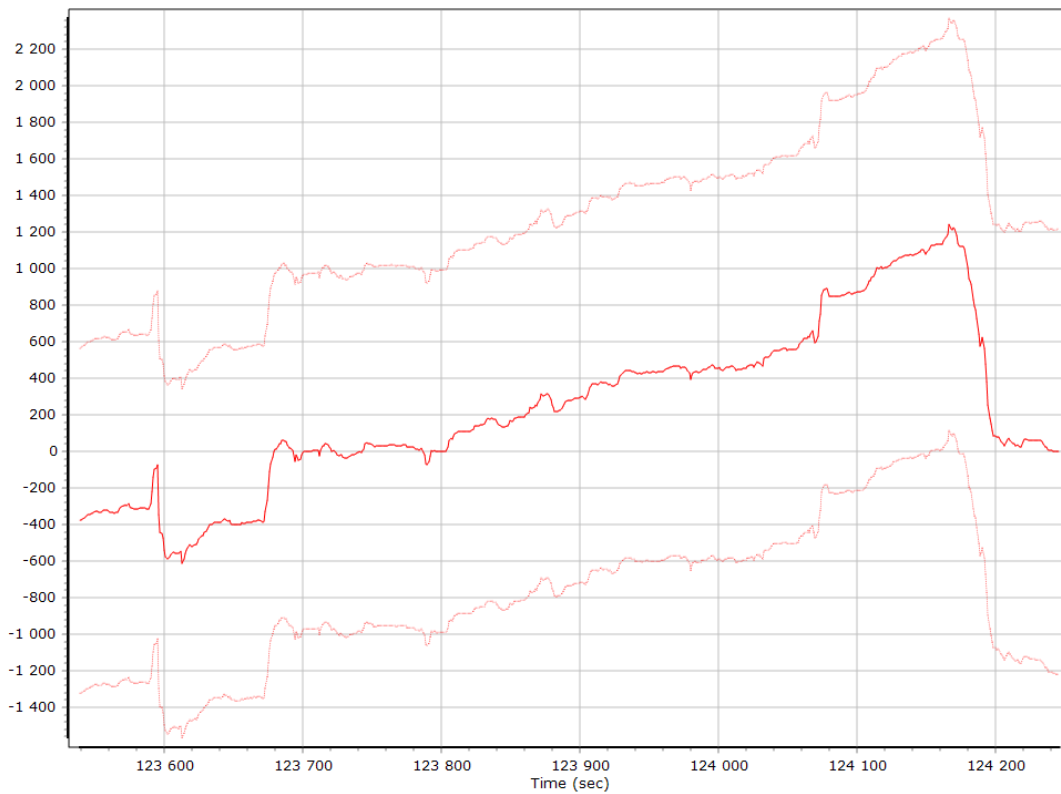
Z Gyro Bias (deg/h)



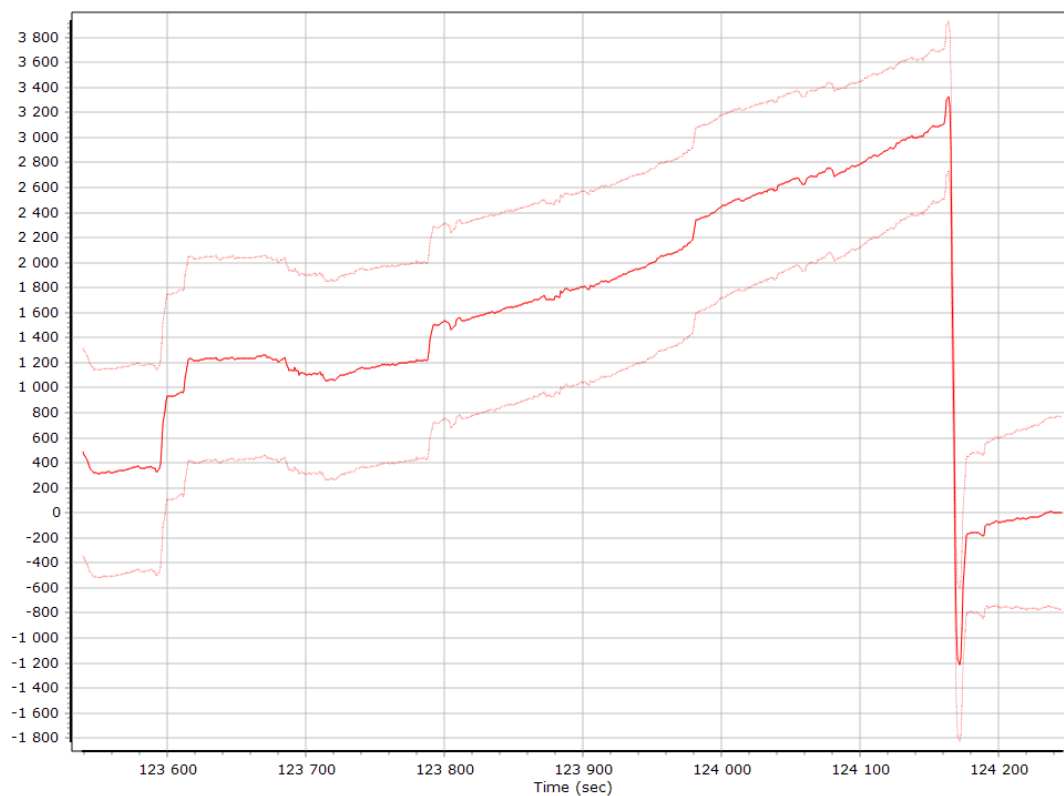
Gyro Scale Error (ppm)



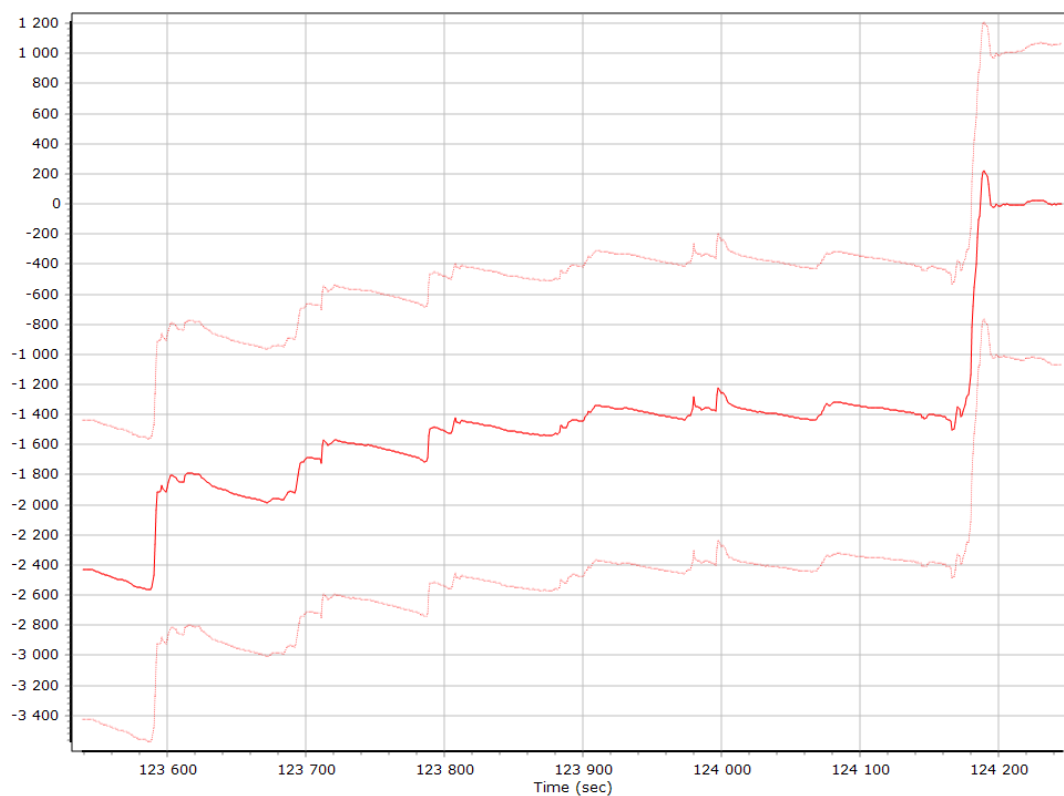
X Gyro Scale Error (ppm)



Y Gyro Scale Error (ppm)

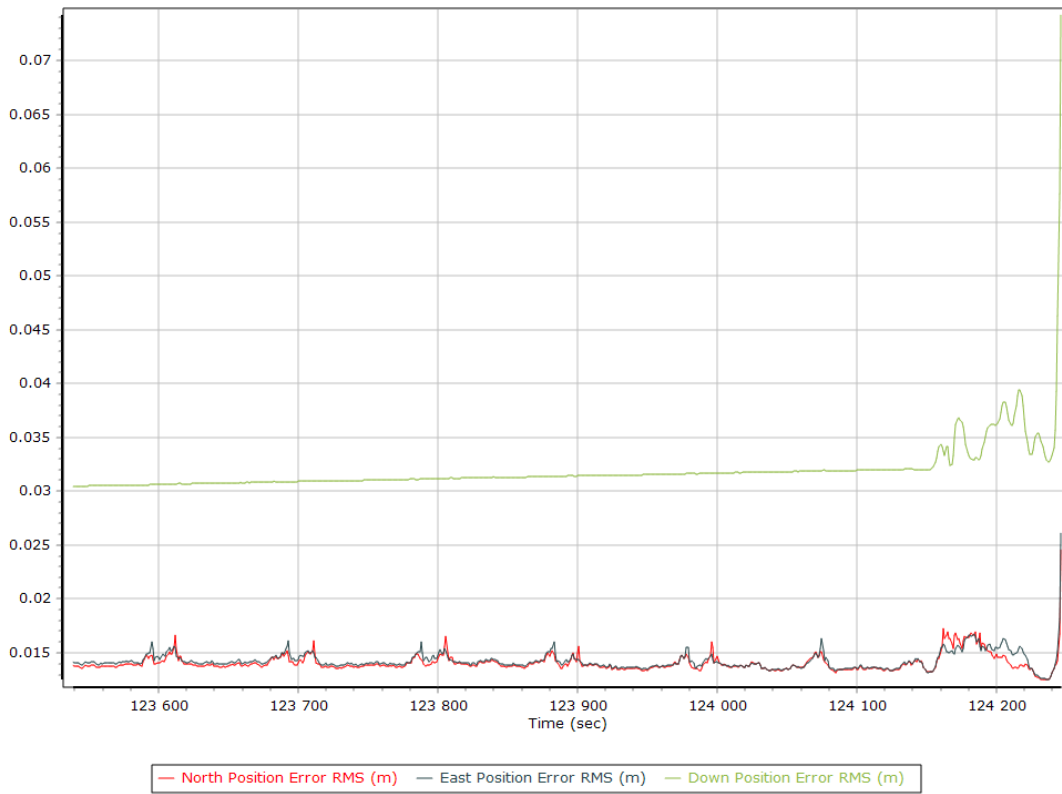


Z Gyro Scale Error (ppm)

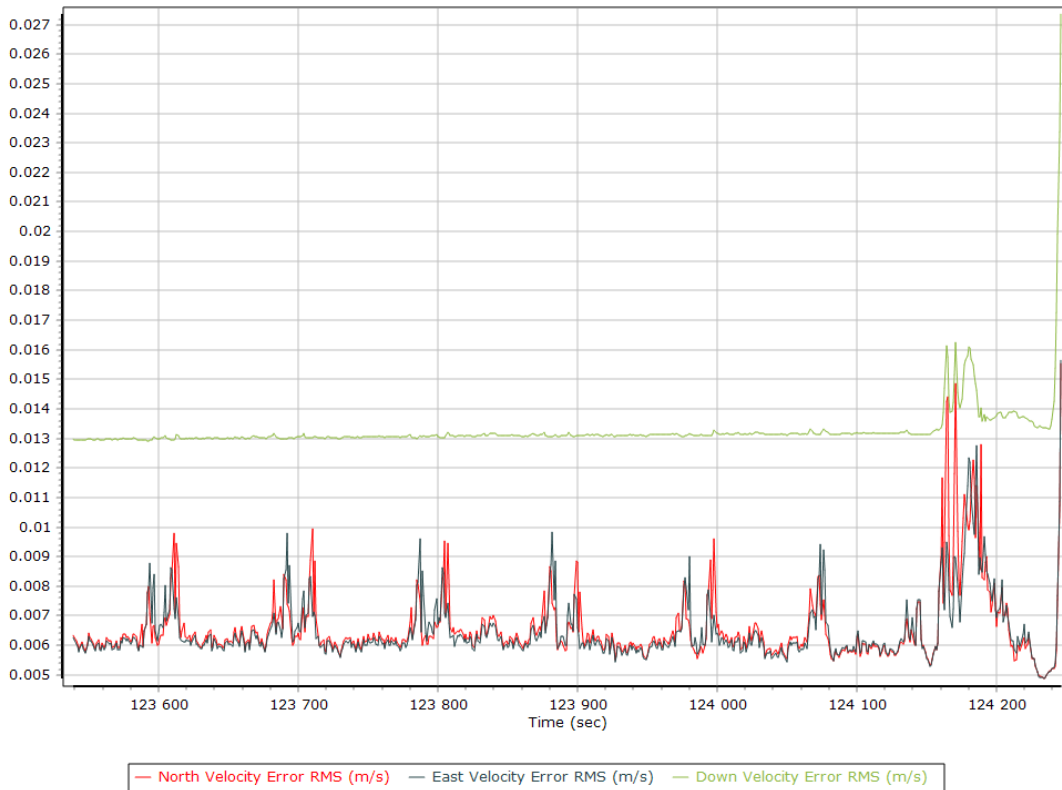


Smoothed Performance Metrics

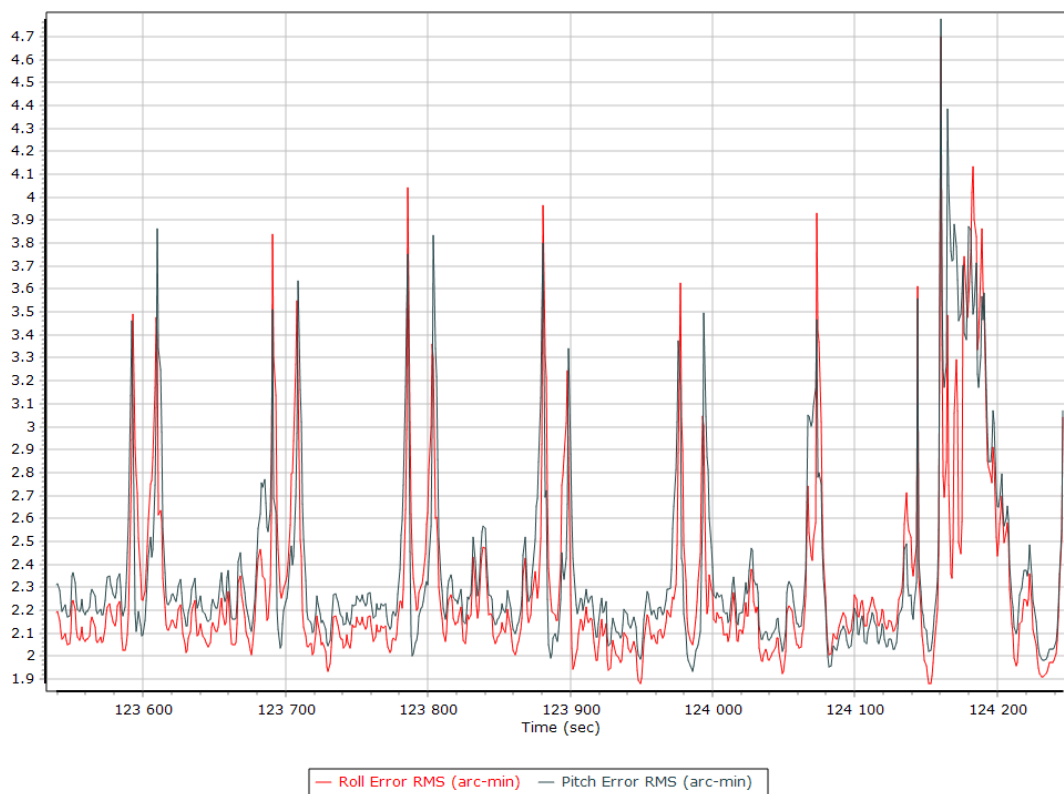
Position Error RMS (m)



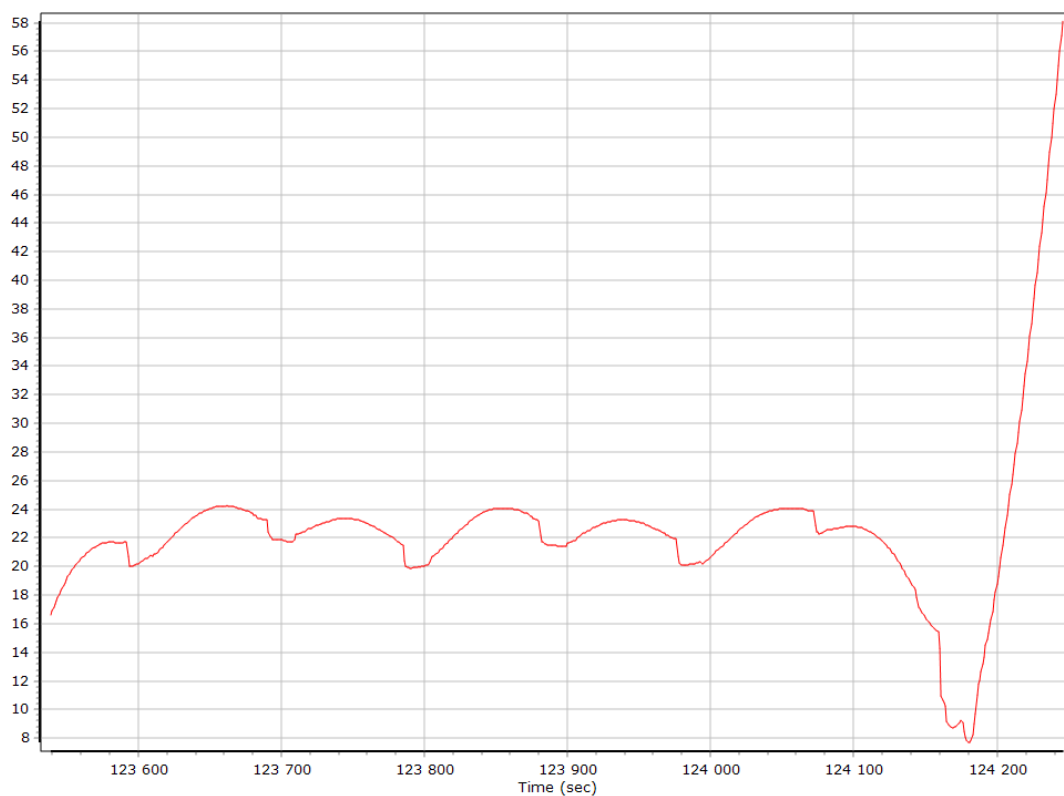
Velocity Error RMS (m/s)



Roll/Pitch Error RMS (arc-min)

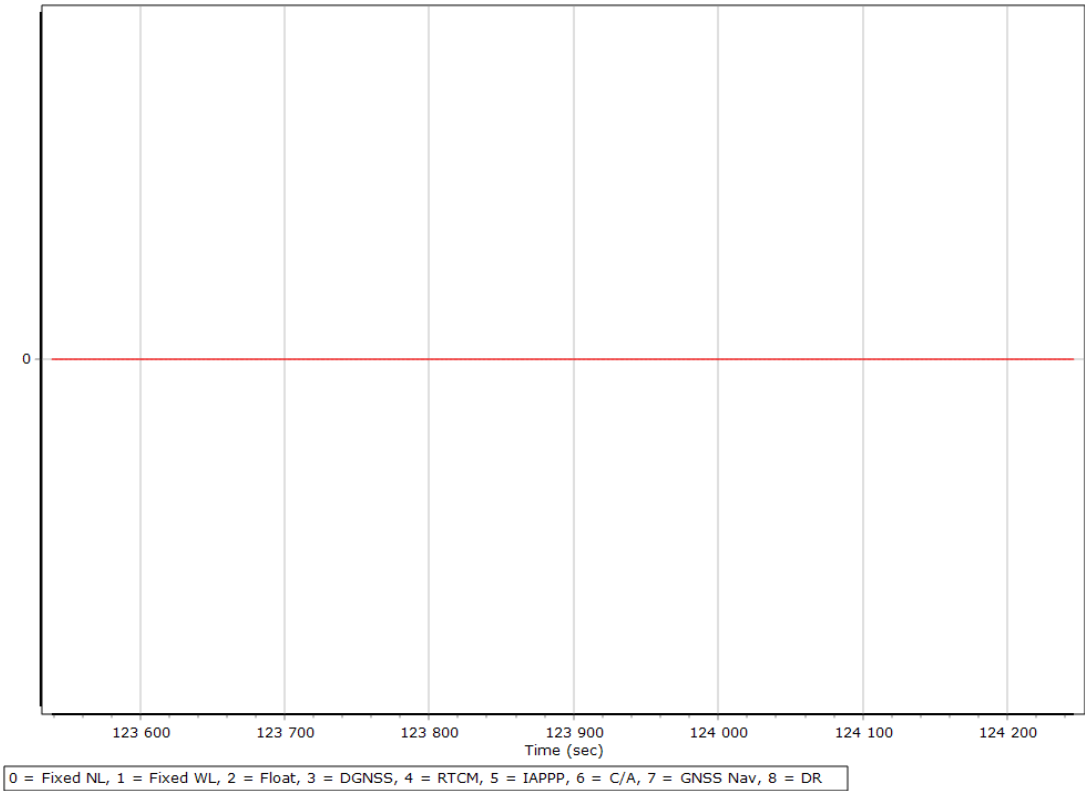


Heading Error RMS (arc-min)

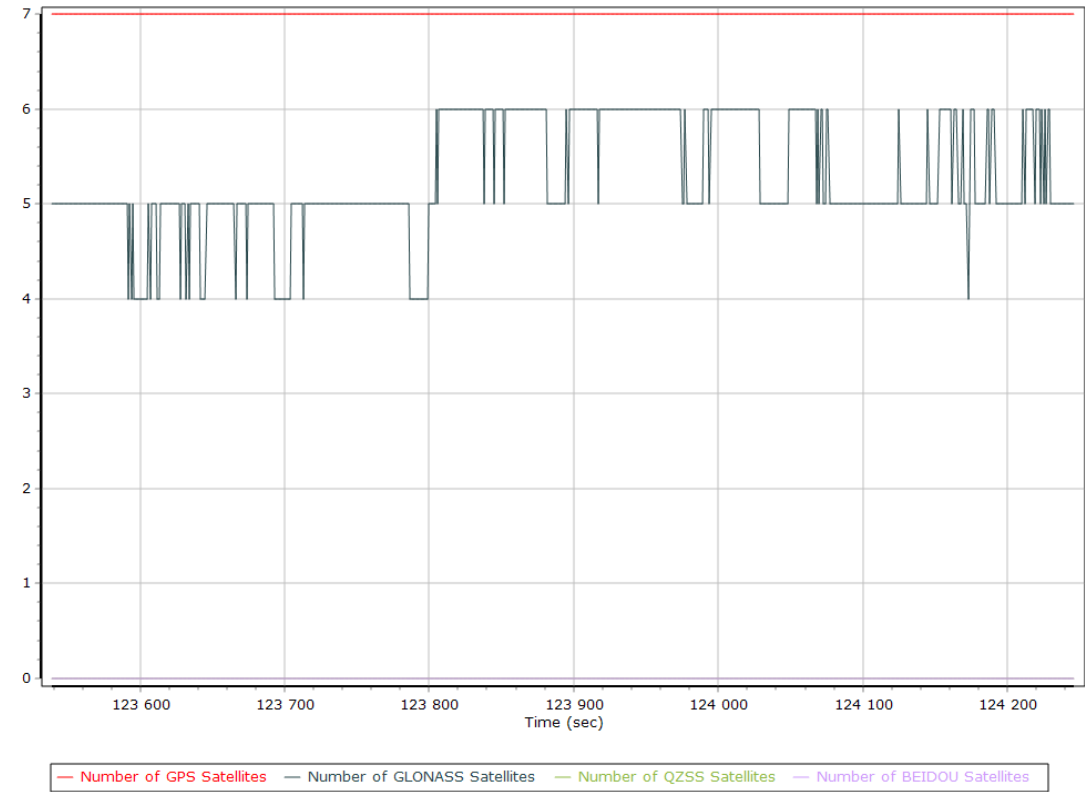


Smoothed Solution Status

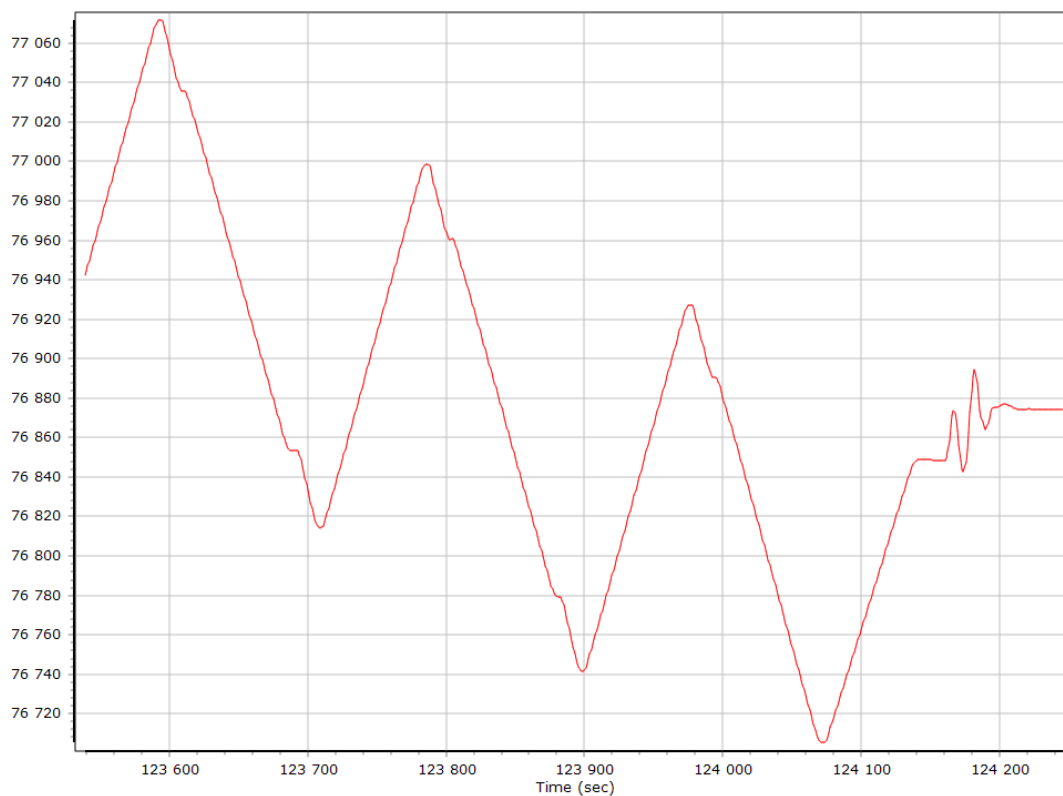
Processing Mode



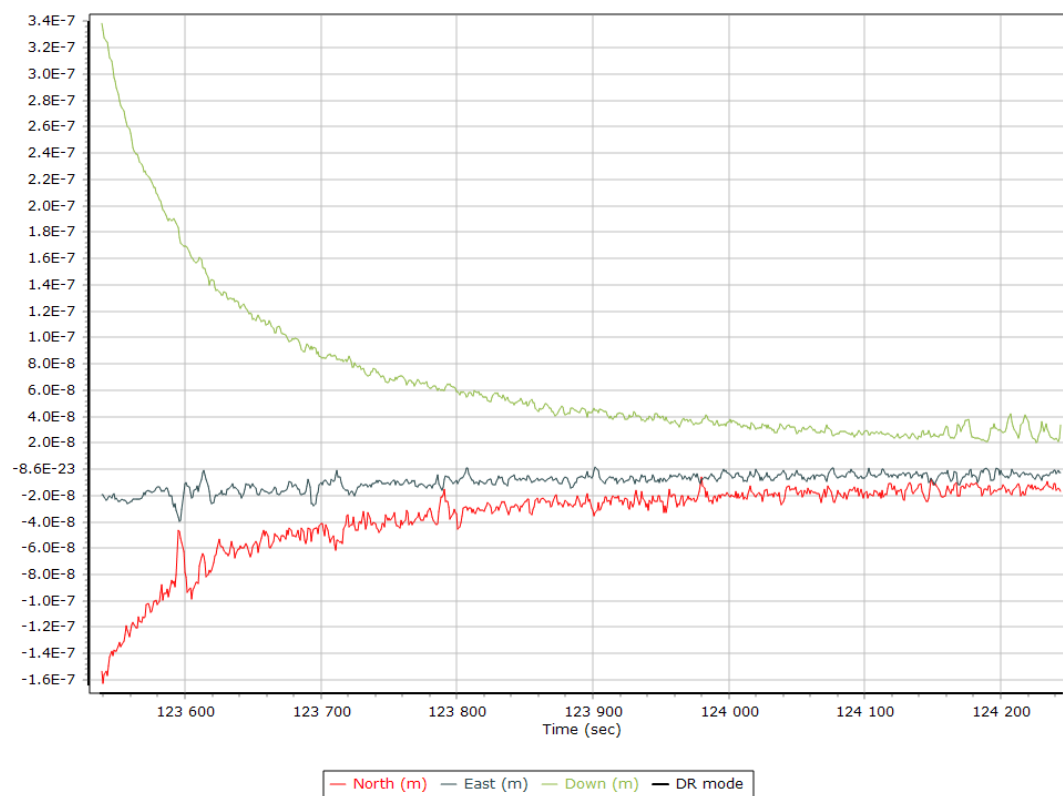
Number of Satellites



Baseline Length



SBET IAKAR Separation



Export Summary

Export file	export_Mission 1.txt		
Export format	ASCII		
Solution in use	Post-processed		
Output rate	All Records		
Reference to Output lever arm [m]	0.000	0.000	0.000
Reference mounting angles [deg]	0.000	0.000	0.000
Output units (Coordinate / Lat & Lon)	Meter		Deg Decimal
Export start time	123475.001 (11/22/2021 10:17:55 AM)		
Export end time	124246.000 (11/22/2021 10:30:46 AM)		
Height option	Ellipsoid Height		
WGS84 height flag	False		
Grid	Universal Transverse Mercator		
Zone	UTM North 31 (0E to 6E)		
Datum	WGS84		
Ellipsoid	WGS84		
Local Transformation	NONE		
Target Epoch	2021.890411		

EO Summary

EO file			
EO format			
Lever arm [m]	0.000	0.000	0.000
Boresight angles [arcmin]	0.000	0.000	0.000
Output rate	All Records		
Rotation sequence	x omega	y phi	z kappa
Local shift [m]	0.000	0.000	0.000
Output units (coordinate / angle / lat & lon)	Meter	Degree	Deg Decimal
Height option	Ellipsoid Height		
WGS84 height flag	False		
Scale height option	False		
Kappa cardinal rotation [deg]	0		
Solution in use	Post-processed		
EO start time	123475.001 (11/22/2021 10:17:55 AM)		
EO end time	124246.000 (11/22/2021 10:30:46 AM)		
Grid	Universal Transverse Mercator		
Zone	UTM North 31 (0E to 6E)		
Datum	WGS84		
Ellipsoid	WGS84		
Local Transformation	NONE		
Target Epoch	2021.890411		

General Information

Mission Information

Project name	riols2
Processing date	2021-12-10 13:20:28
Mission date	2021-11-22 10:57:37
Mission duration	00:15:24.997
Processing mode	IN-Fusion Single Base
GPS Station	TLMF

Rover Hardware Information

Product	APX 15 AVX 210 VER0 174
Serial number	S/N001
IMU type	59
Receiver type	APX-15v3
Antenna type	AV14

Project File List

Rover Data Files

File name	File type
YS-20211122-105713.T04	T04 Rover Data

Input Files

File Name	File type
tlmf326z.21o	GNSS SingleBase

Output Files

Filename	File type
sbet_Mission 1.out	SBET Trajectory File
export_Mission 1.txt	ASCII Export Output

Rover Data Summary

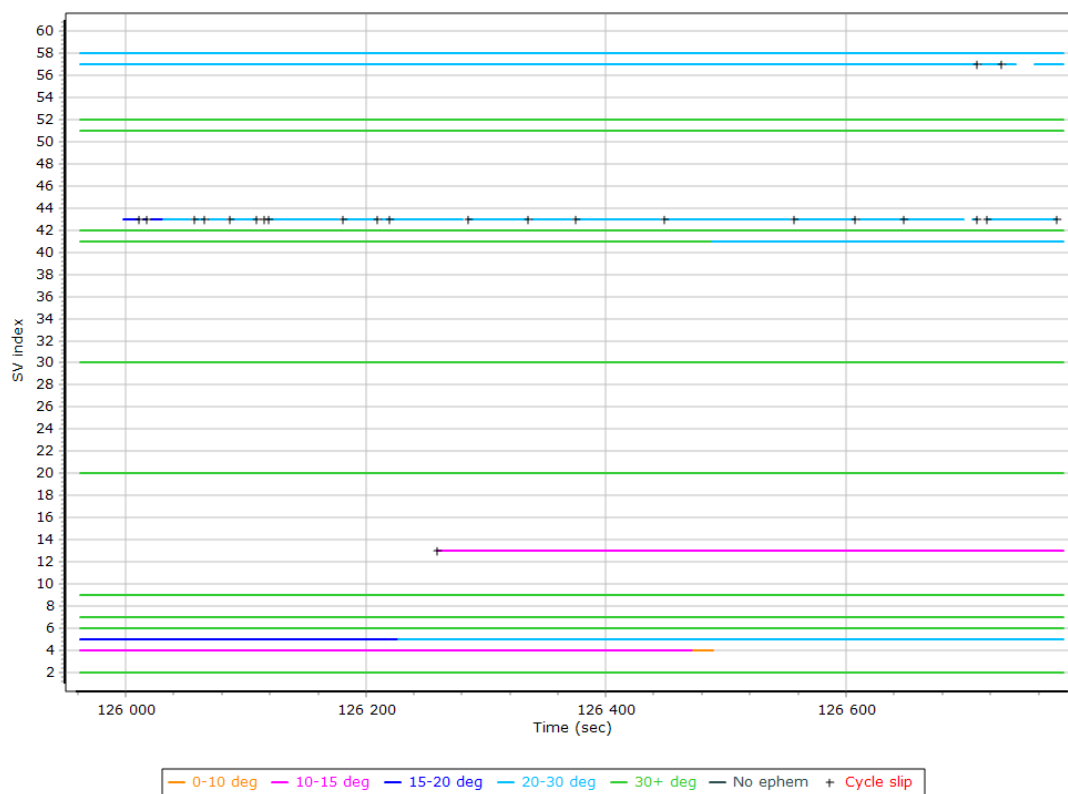
First raw data file	YS-20211122-105713.T04		
Last raw data file	YS-20211122-105713.T04		
Start GPS week	2185		
Start time	125857.000 (11/22/2021 10:57:37 AM)		
End time	126781.860 (11/22/2021 11:13:01 AM)		
Start of fine alignment	125901.200 (11/22/2021 10:58:21 AM)		
Available subsystems	Primary GNSS, IMU		
POS Event Input	None		
Correction data	None		
IMU Installation Lever Arms & Mounting Angles			
Reference to IMU lever arm [m]	-0.013	0.108	-0.007
Reference to IMU mounting angles [deg]	0.000	0.000	0.000
Reference to Primary GNSS lever arm [m]	0.006	0.218	-0.435
Reference to Primary GNSS lever arm std dev [m]	0.020		
Aircraft to Reference mounting angles [deg]	0.000	0.000	0.000

Raw Data QC

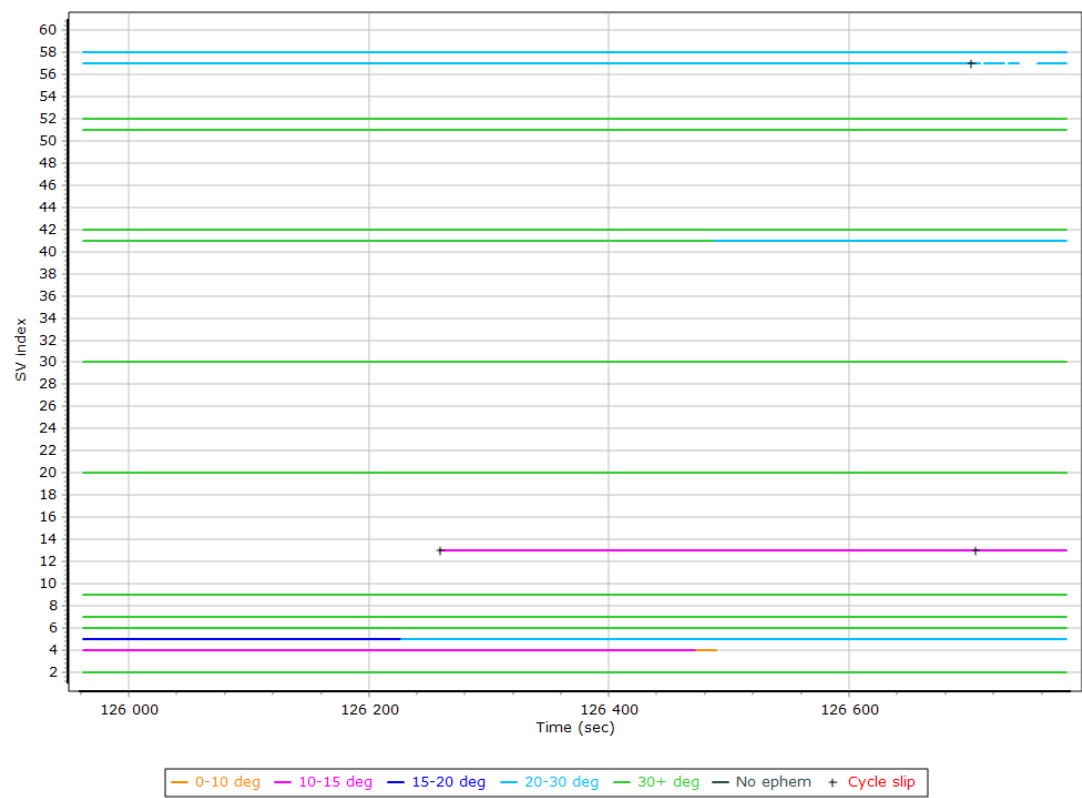
Raw IMU Import QC Summary

IMU data input file	imu_Mission 1.dat
IMU data check log file	imudt_Mission 1.log
IMU Records Processed	185135
Termination Status	Normal
IMU Anomalies	0

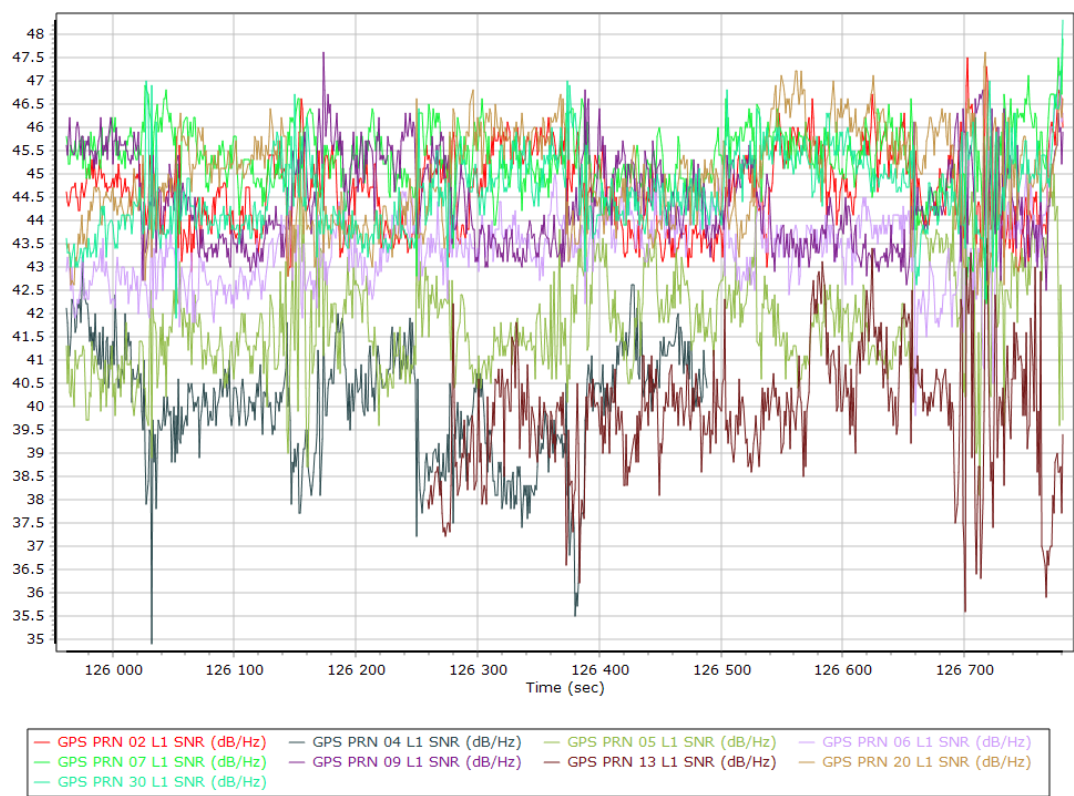
L1 Satellite Lock/Elevation



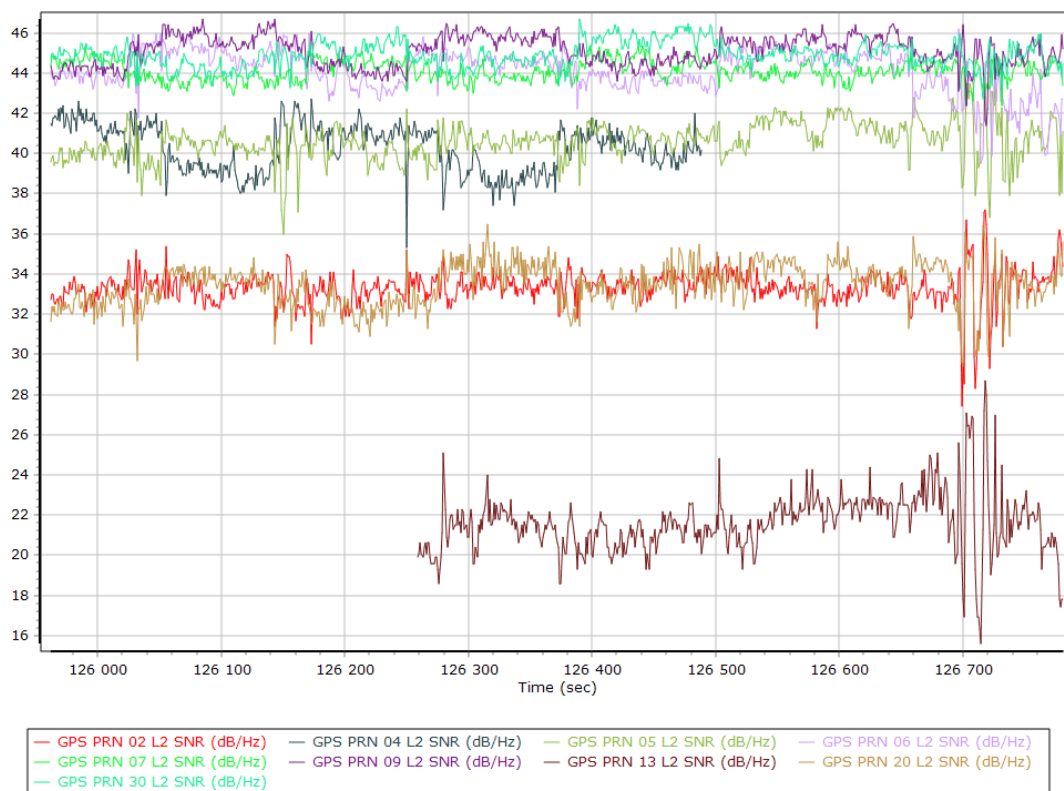
L2 Satellite Lock/Elevation



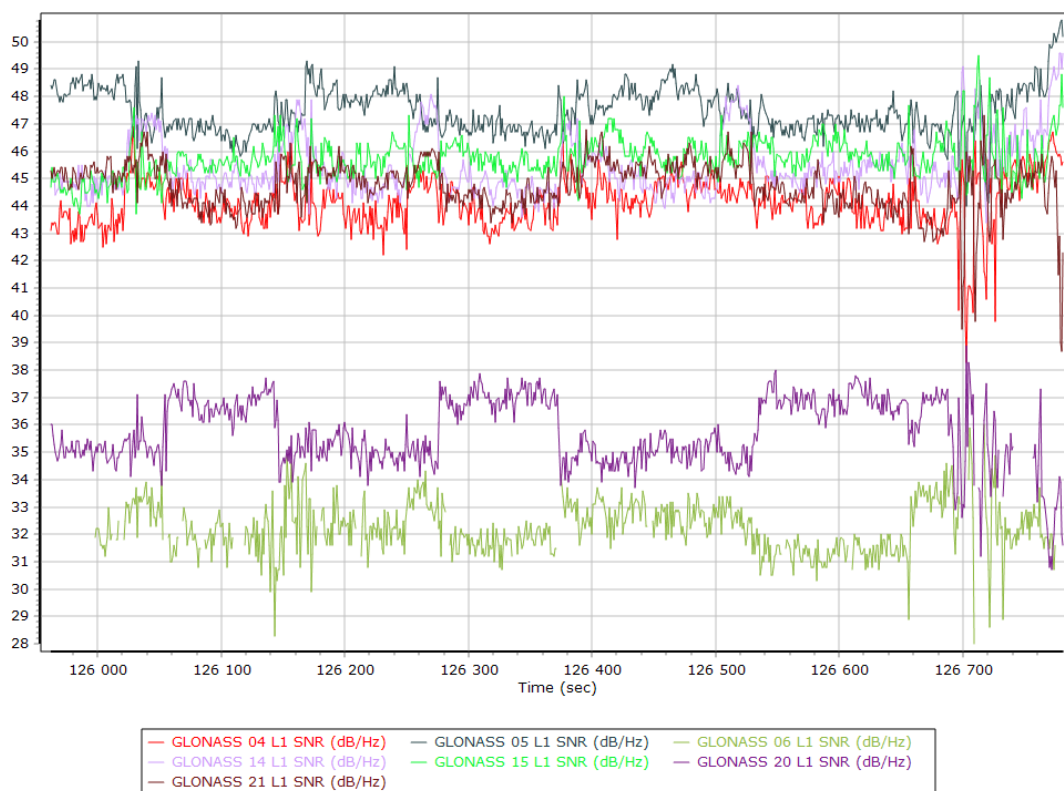
GPS L1 SNR



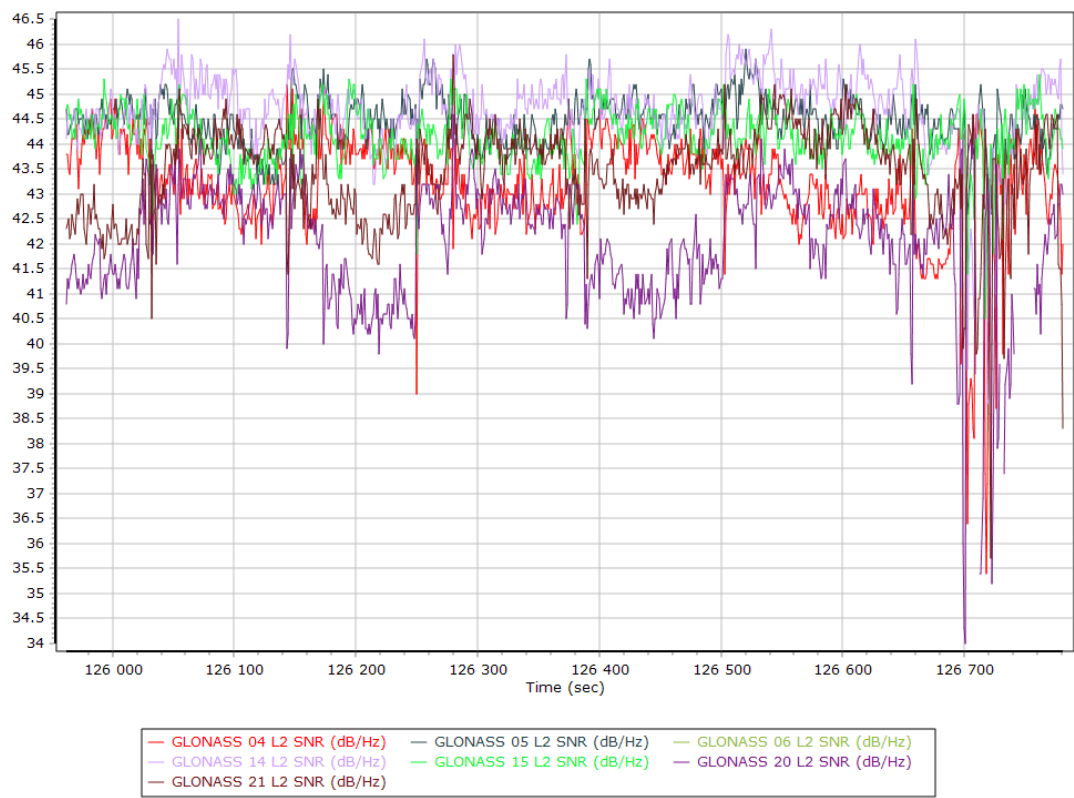
GPS L2 SNR



GLONASS L1 SNR

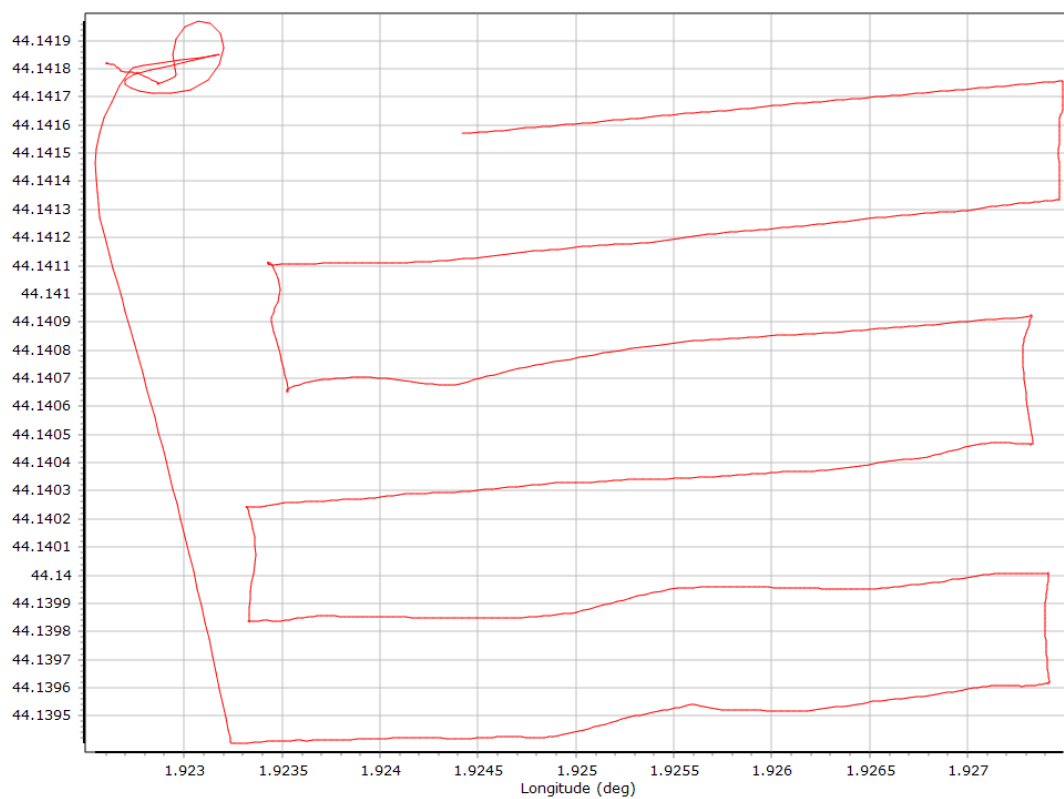


GLONASS L2 SNR

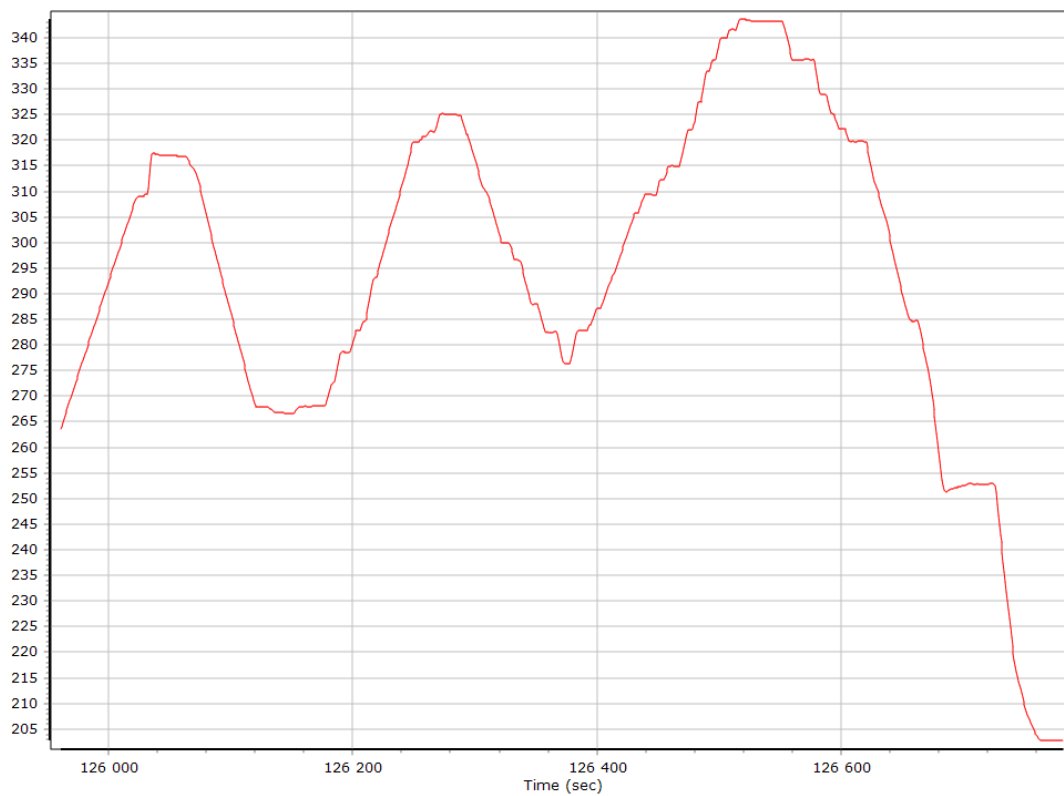


Trajectory Information

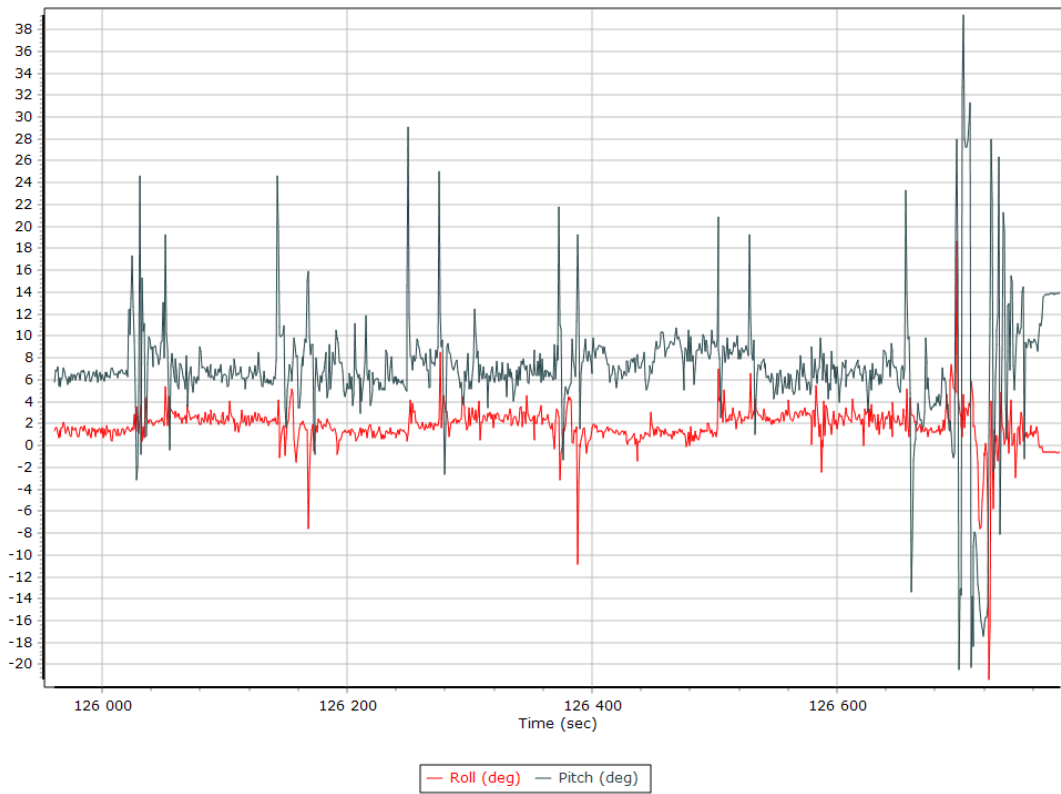
Top View



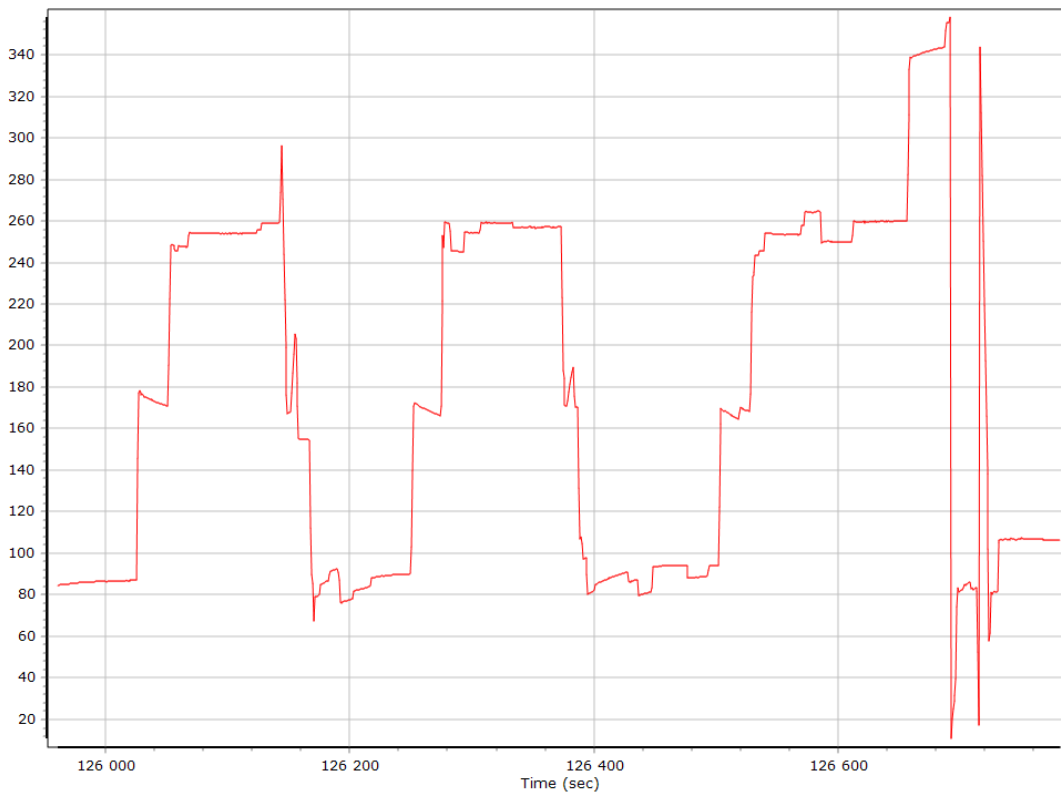
Altitude



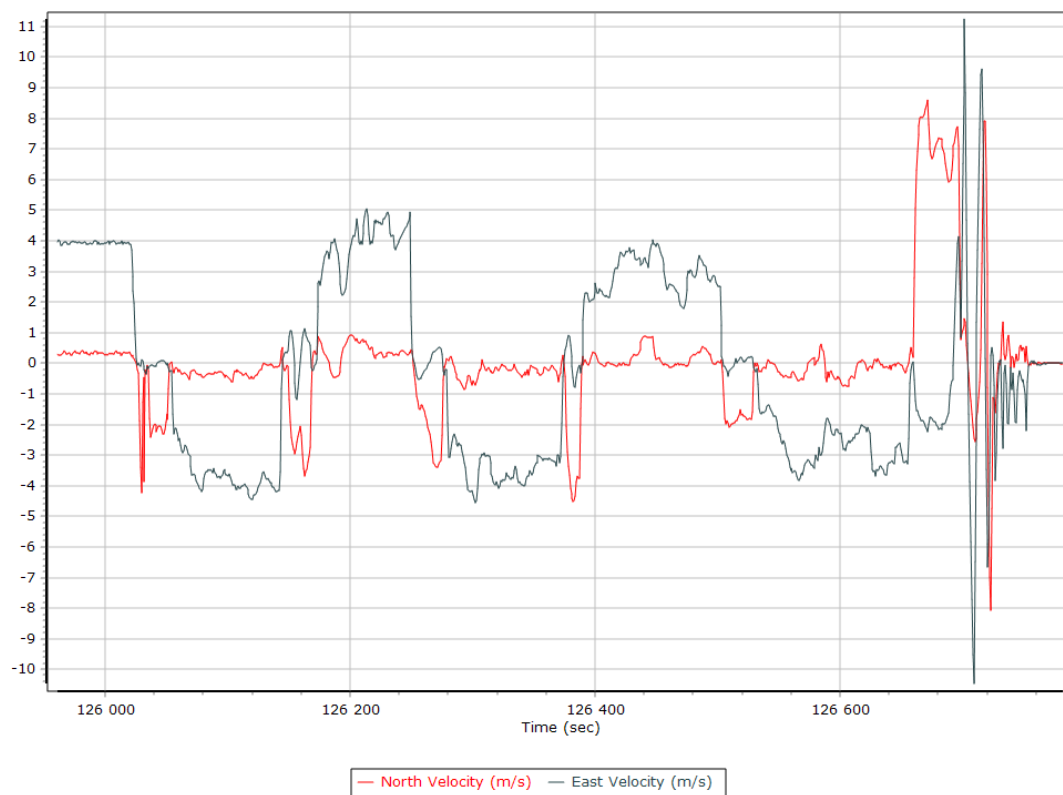
Roll/Pitch



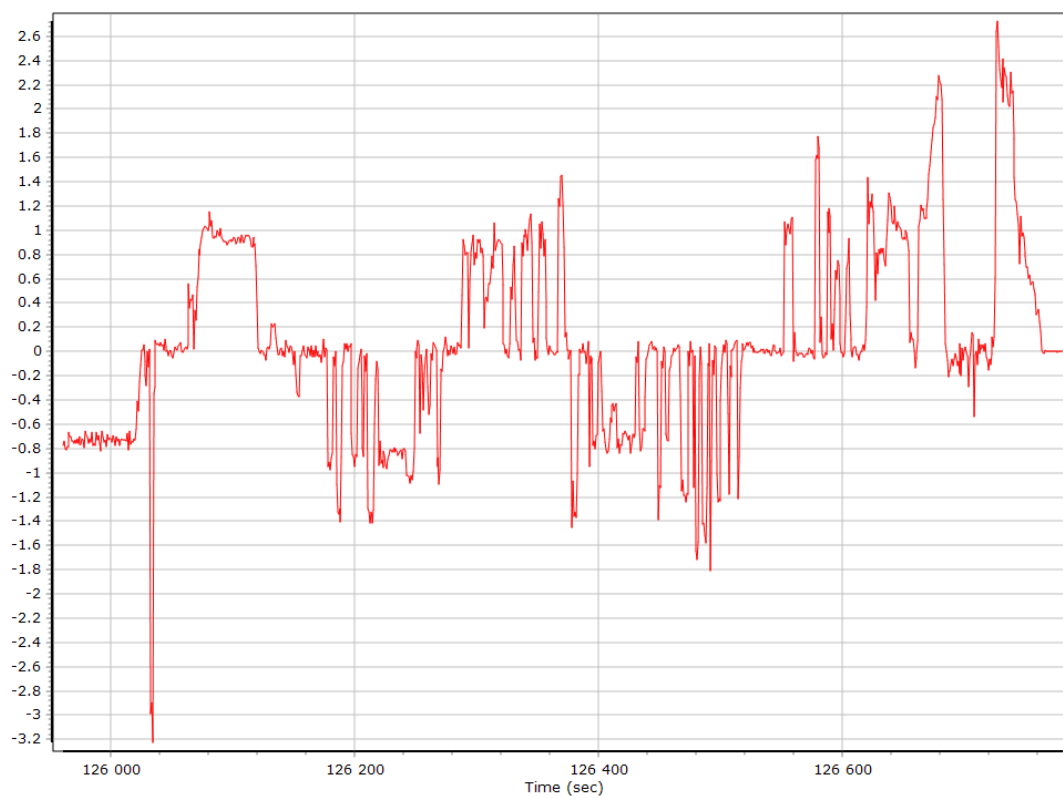
Heading



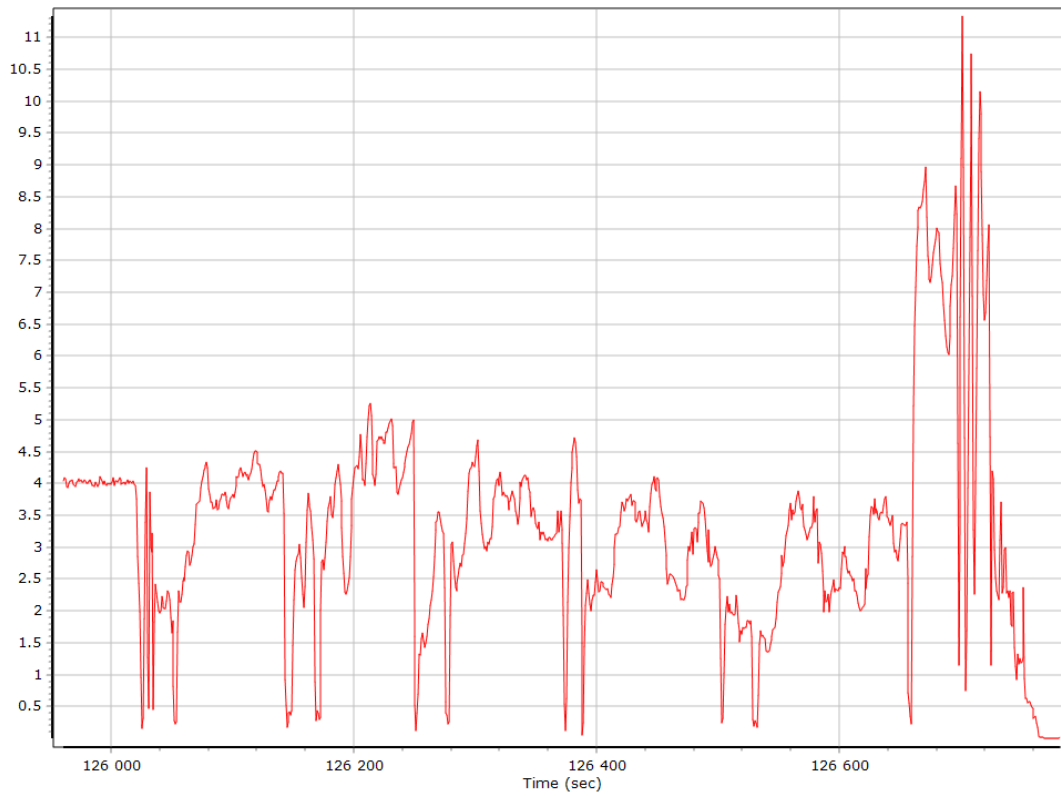
North/East Velocity



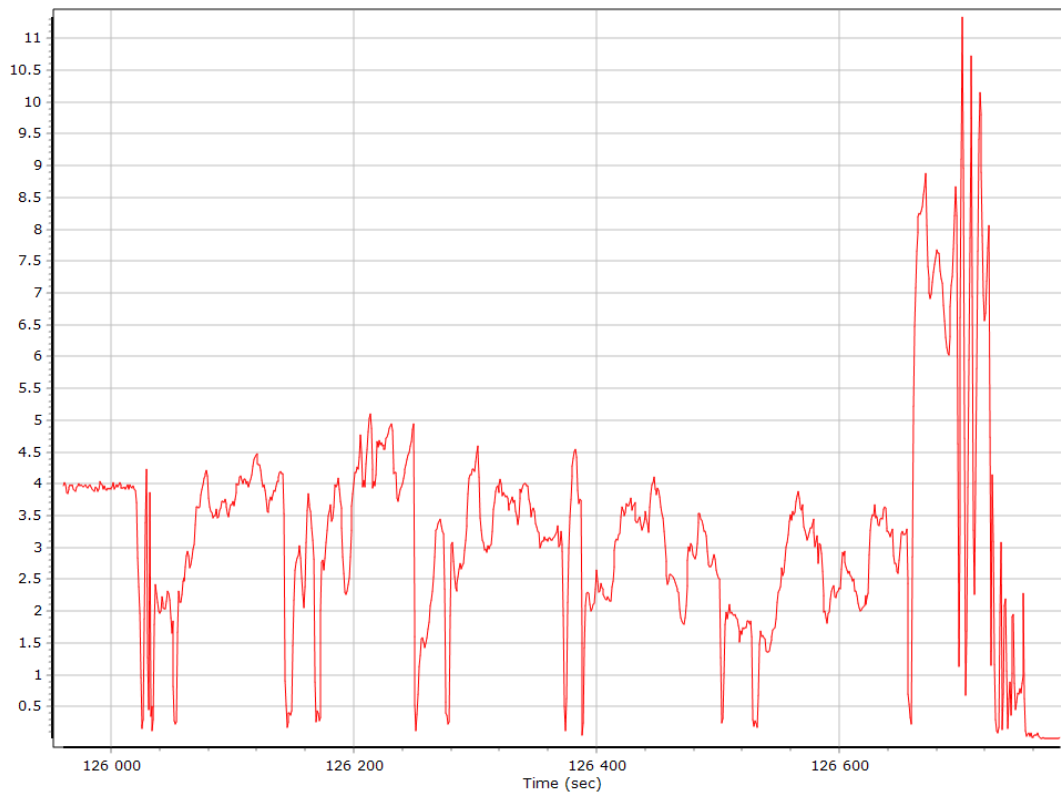
Down Velocity



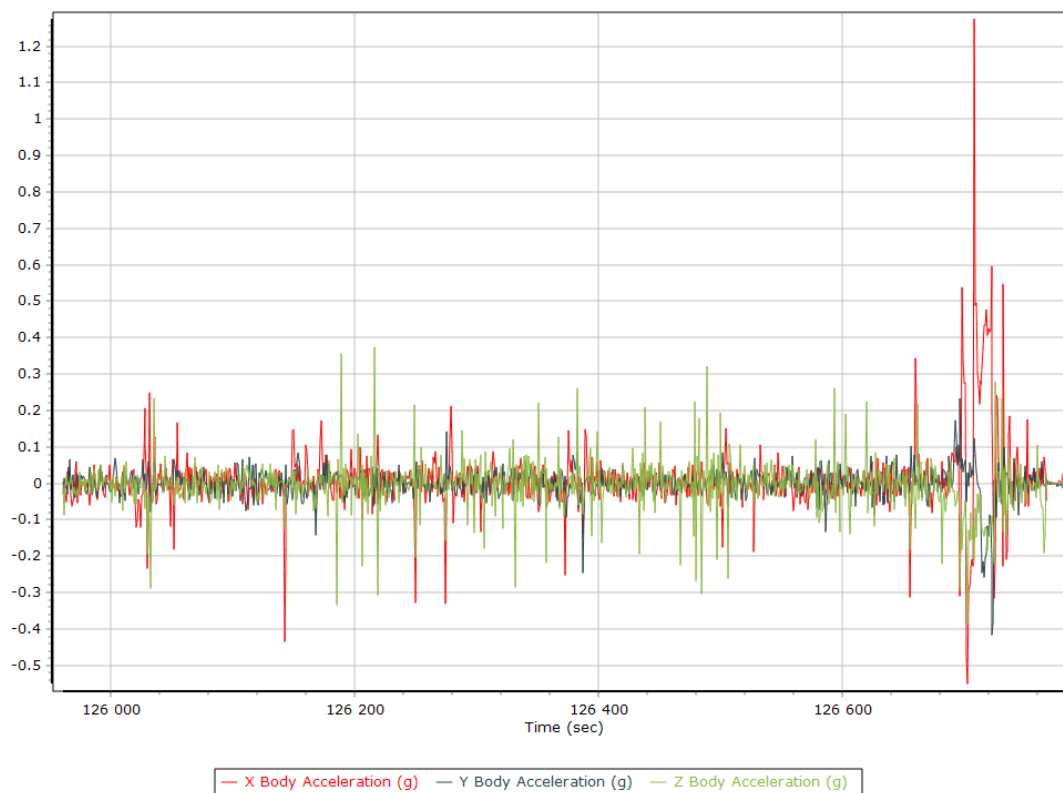
Total Speed



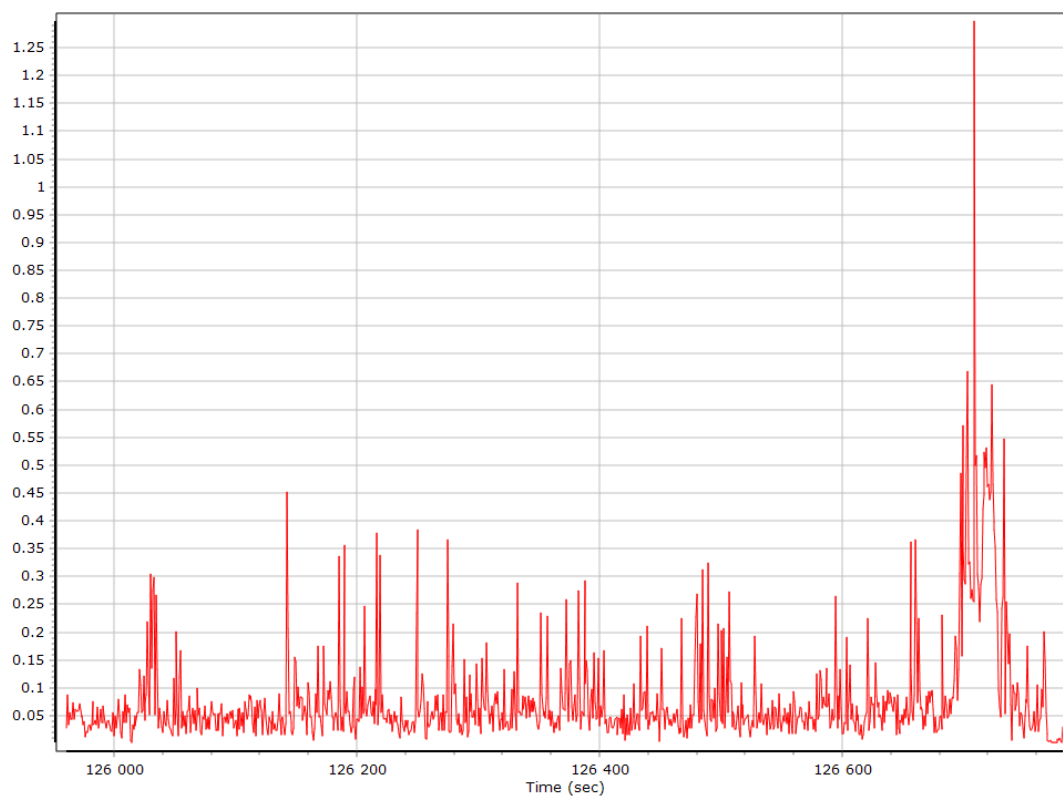
Ground Speed



Body Acceleration



Total Body Acceleration



Body Angular Rate



Base Station Information

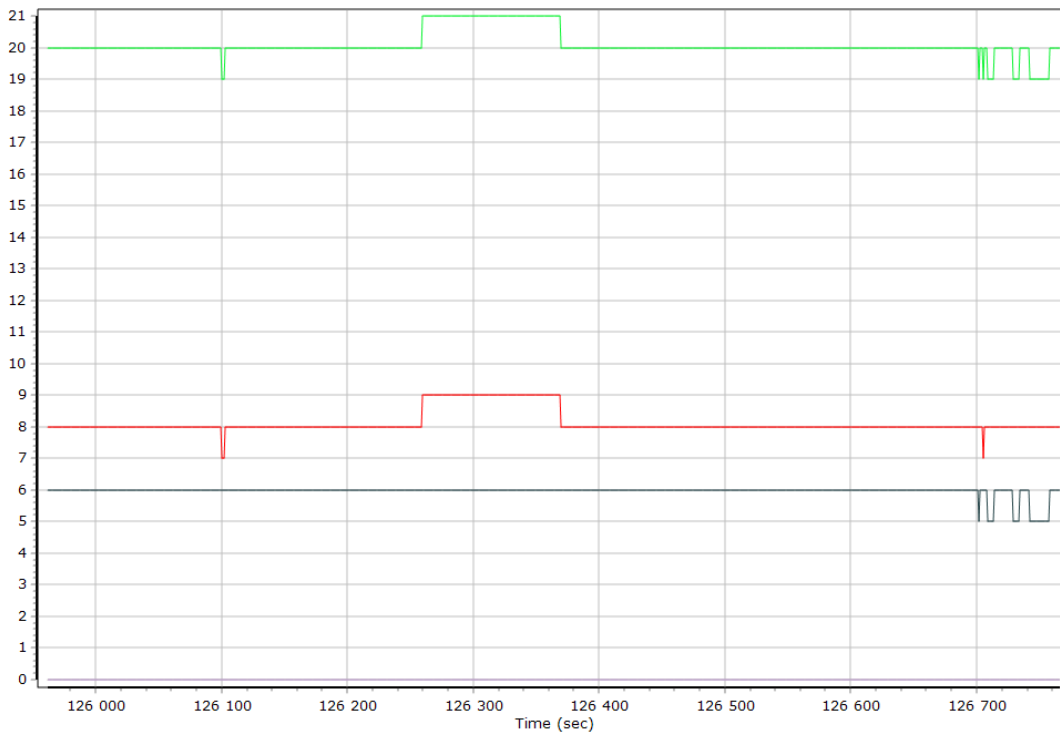
Station ID	TLMF		
Filename	t1mf326z.21o		
Start date	11/22/2021 10:00:00 AM		
End date	11/22/2021 1:59:59 PM		
Duration	03:59:59.000		
Data type	GNSS		
Receiver manufacturer, model, serial no.	Leica	GR25	1830399
Antenna manufacturer, model	Trimble		Zephyr Geodetic 2 RoHS
Antenna height [m]	0.000		
Antenna measurement method	Bottom of antenna mount		
Offset from measured point to APC [m]	0.08546		
Latitude	N43°34'28.57480"		
Longitude	E1°22'30.33938"		
Ellipsoidal height [m]	221.02170		
Frame	ITRF00		
Epoch	1997		
Ellipsoid	WGS84		
Velocity North [mm/y]	0		
Velocity East [mm/y]	0		
Velocity Up [mm/y]	0		

GNSS QC

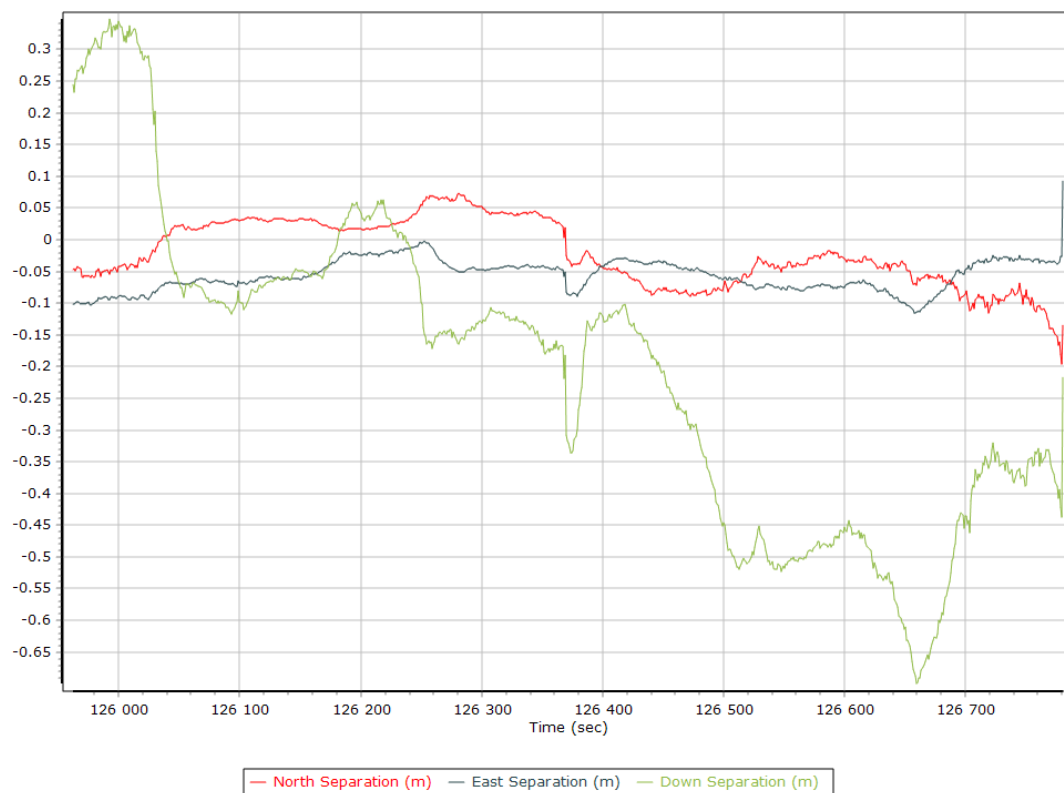
GNSS QC Statistics

Statistics	Min	Max	Mean
Baseline length [km]	76.69	77.10	
Number of GPS SV	7	9	8
Number of GLONASS SV	5	6	6
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Total number of SV	13	15	14
PDOP	1.21	1.53	1.34
QC Solution Gaps	0.00	0.00	
Solution Type	Fixed	Float	No solution
Epoch (s)	909.00	0.00	0.00
Percentage	100.00	0.00	0.00

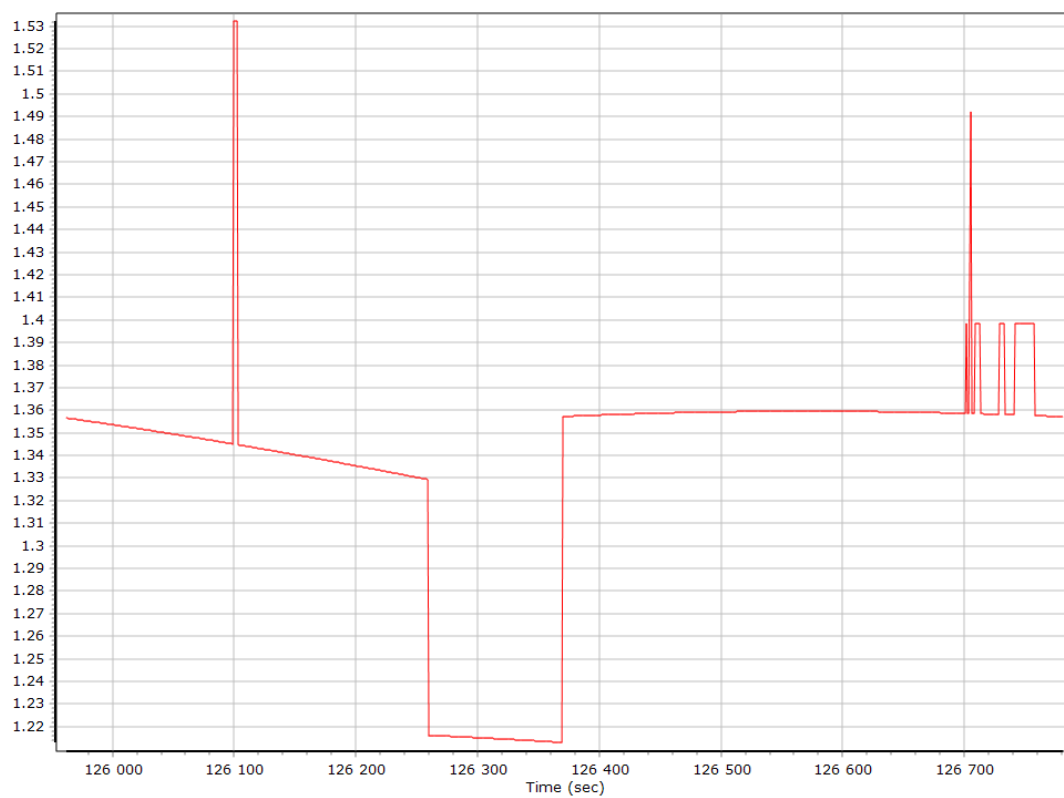
Num SVs in solution



Forward/Reverse Separation



PDOP



Estimated Position Accuracy



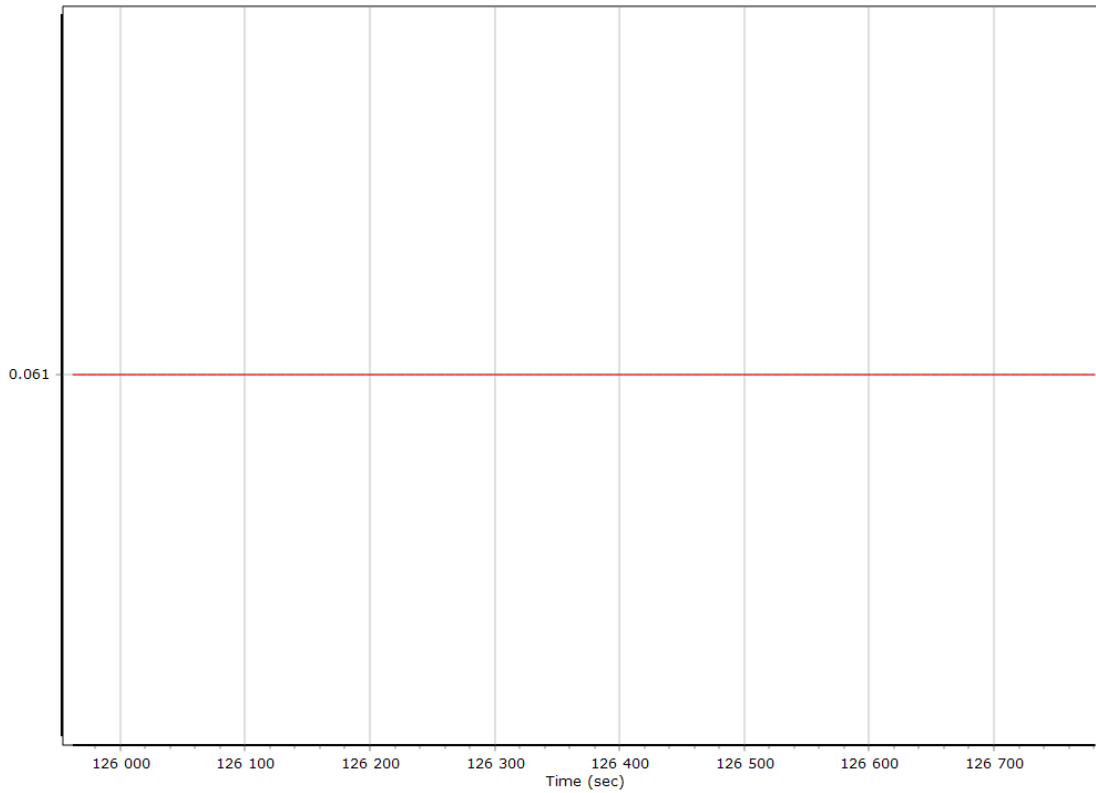
GNSS-Inertial Processor Configuration

Processing mode	IN-Fusion Single Base		
Stabilized mount	False		
Base station	TLMF		
Processing start time	125857.003 (11/22/2021 10:57:37 AM)		
Processing end time	126782.000 (11/22/2021 11:13:02 AM)		
Initial attitude source	Primary GNSS Track		
IMU Sensor Context	Processing with Onboard IMU		
Reference to IMU lever arm [m]	-0.013	0.108	-0.007
Reference to IMU mounting angles [deg]	0.000	0.000	0.000
Reference to Primary GNSS lever arm [m]	0.061	0.188	-0.425
Reference to Primary GNSS lever arm std dev [m]	0.010	0.010	0.010
Aircraft to Reference mounting angles [deg]	0.000	0.000	0.000

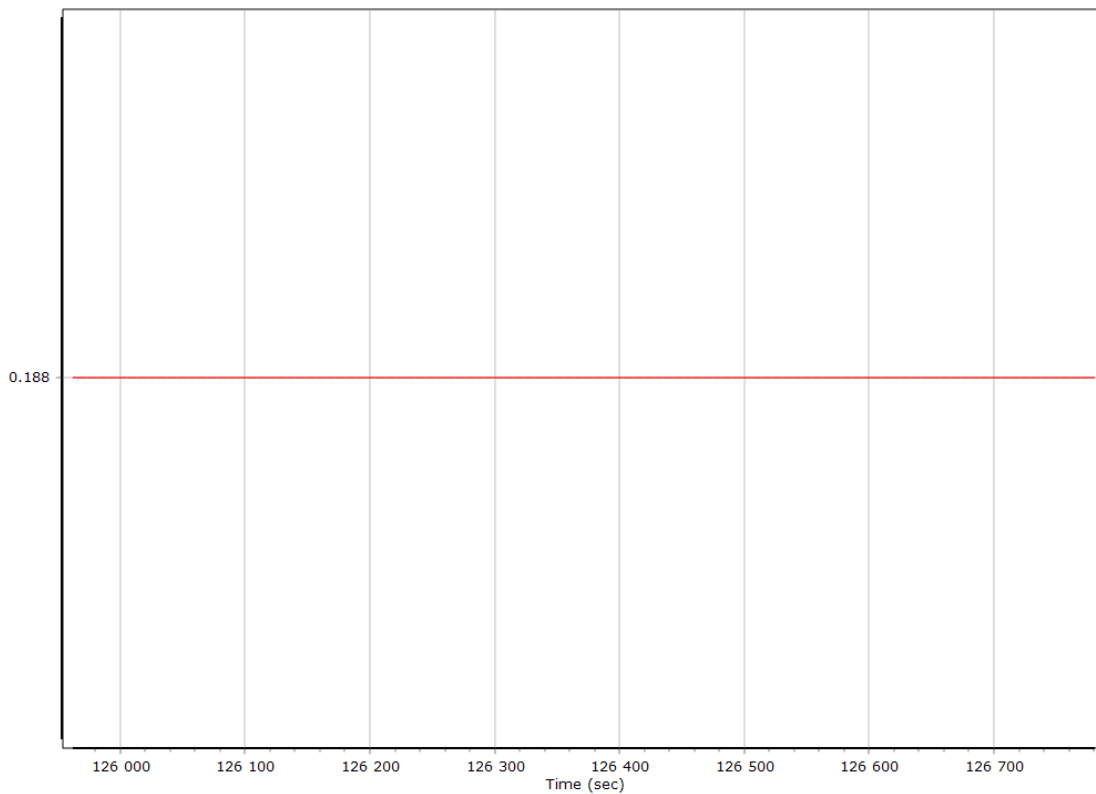
Calibrated Installation Parameters

Reference-Primary GNSS Lever Arm

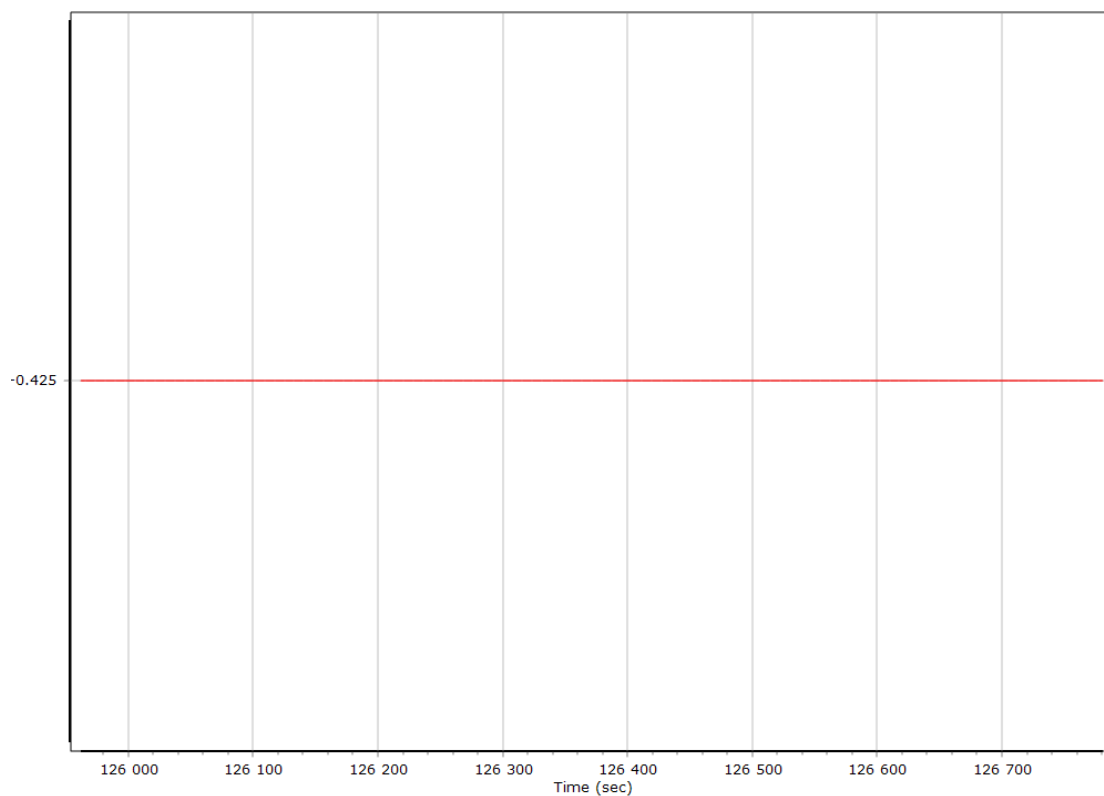
X Reference-Primary GNSS Lever Arm (m)



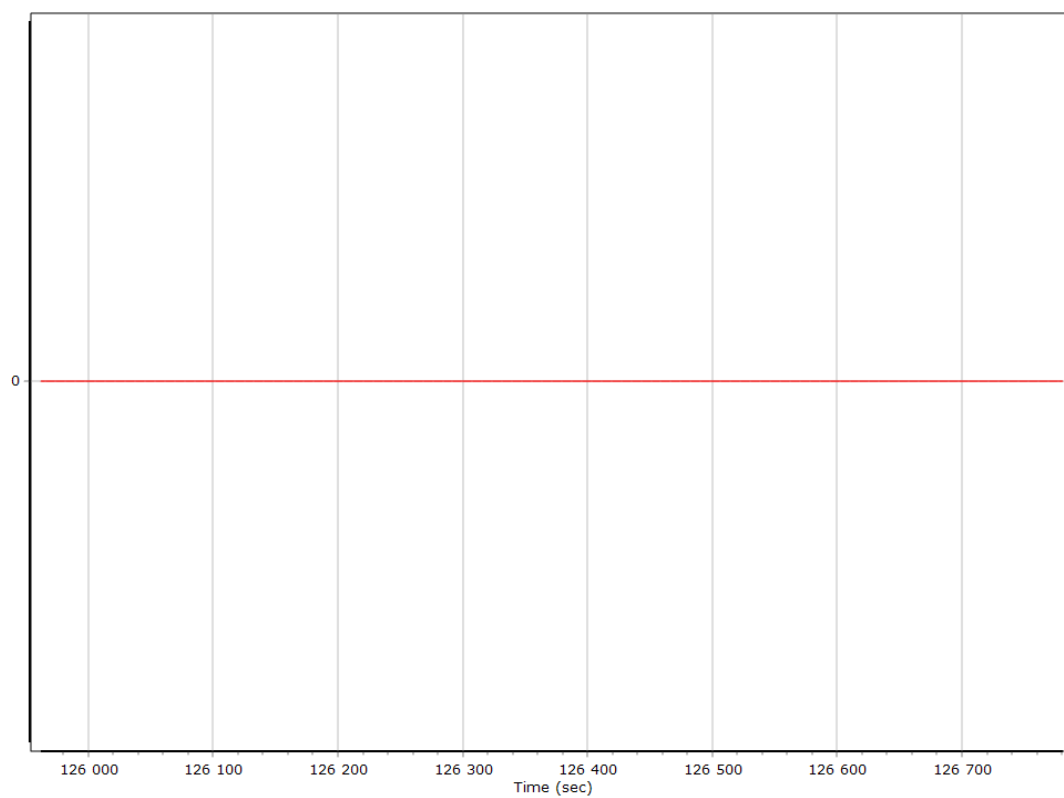
Y Reference-Primary GNSS Lever Arm (m)



Z Reference-Primary GNSS Lever Arm (m)



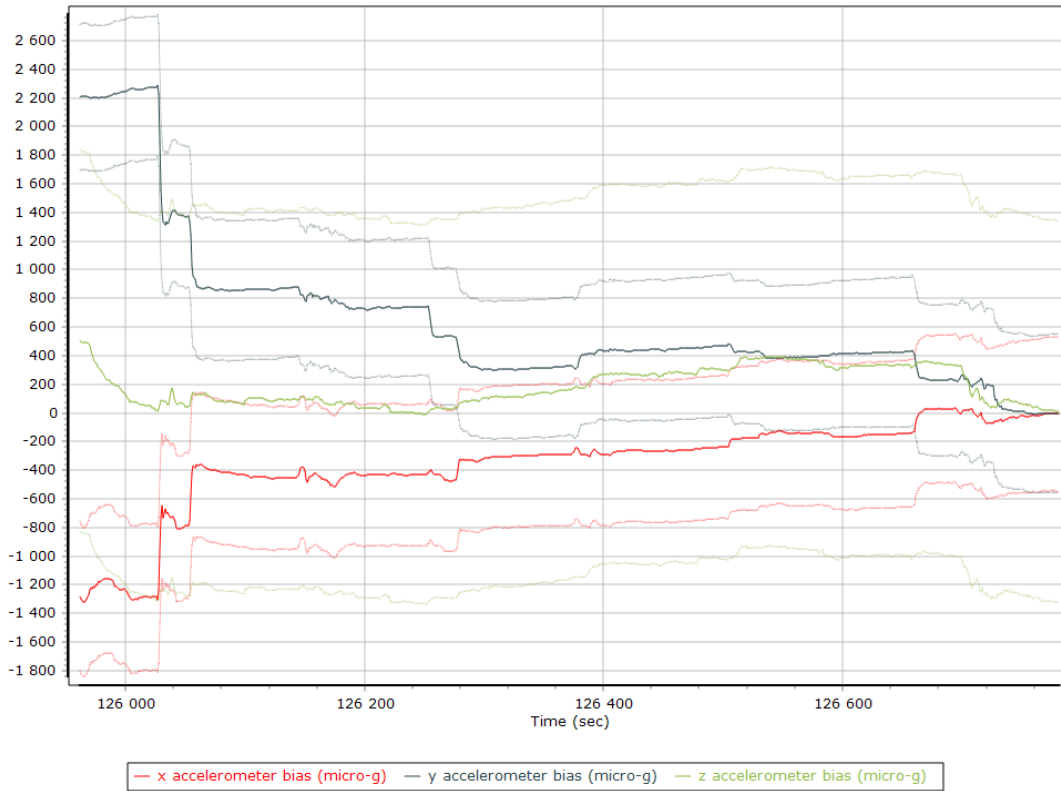
Reference-Primary GNSS Lever Arm Figure of Merit



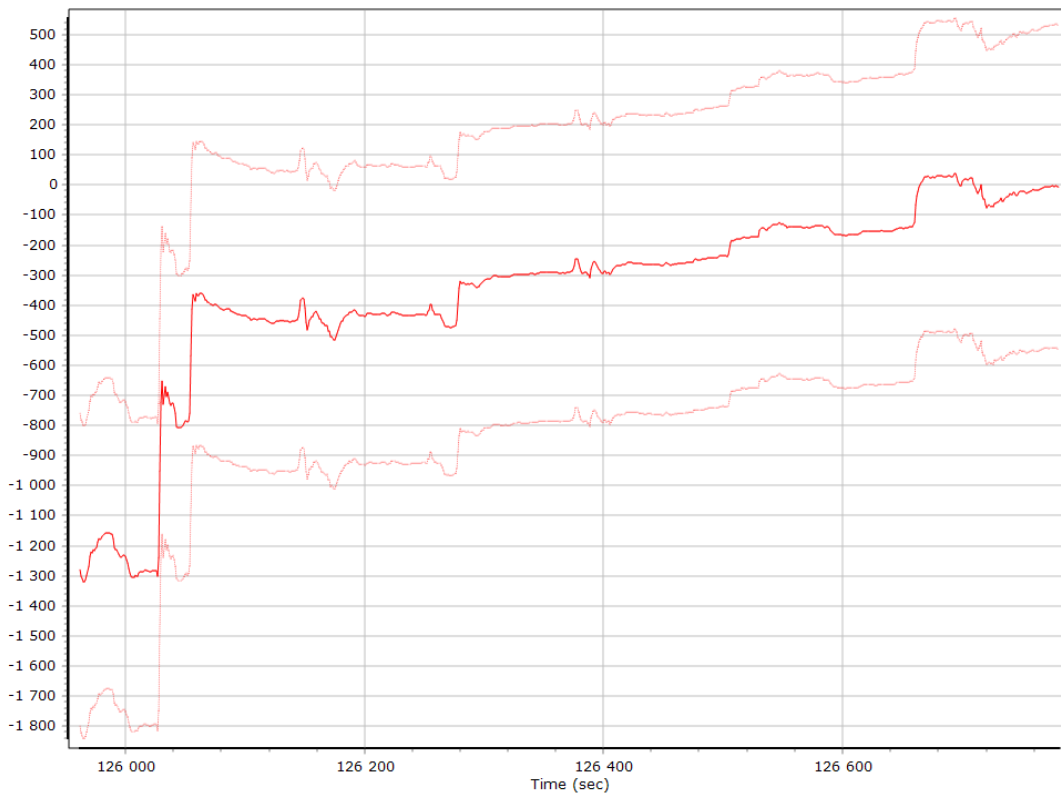
Smoothed IN-Fusion QC

Smoothed Estimated Errors, Reference Frame

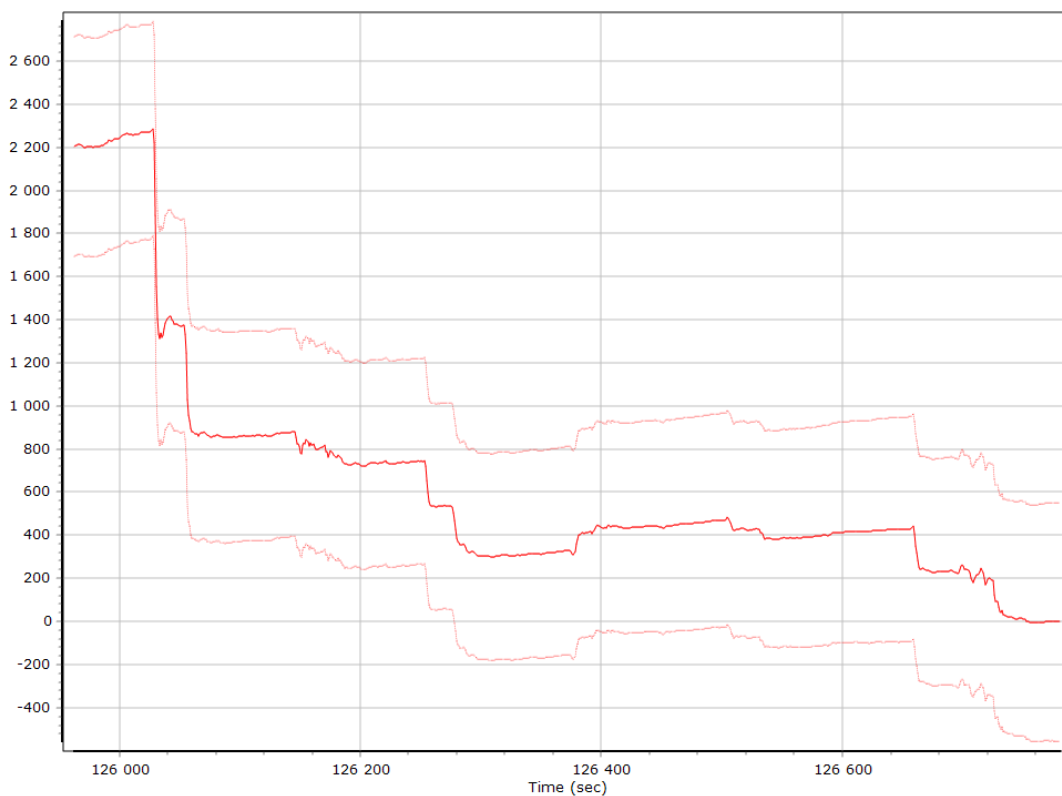
Accelerometer Bias (micro-g)



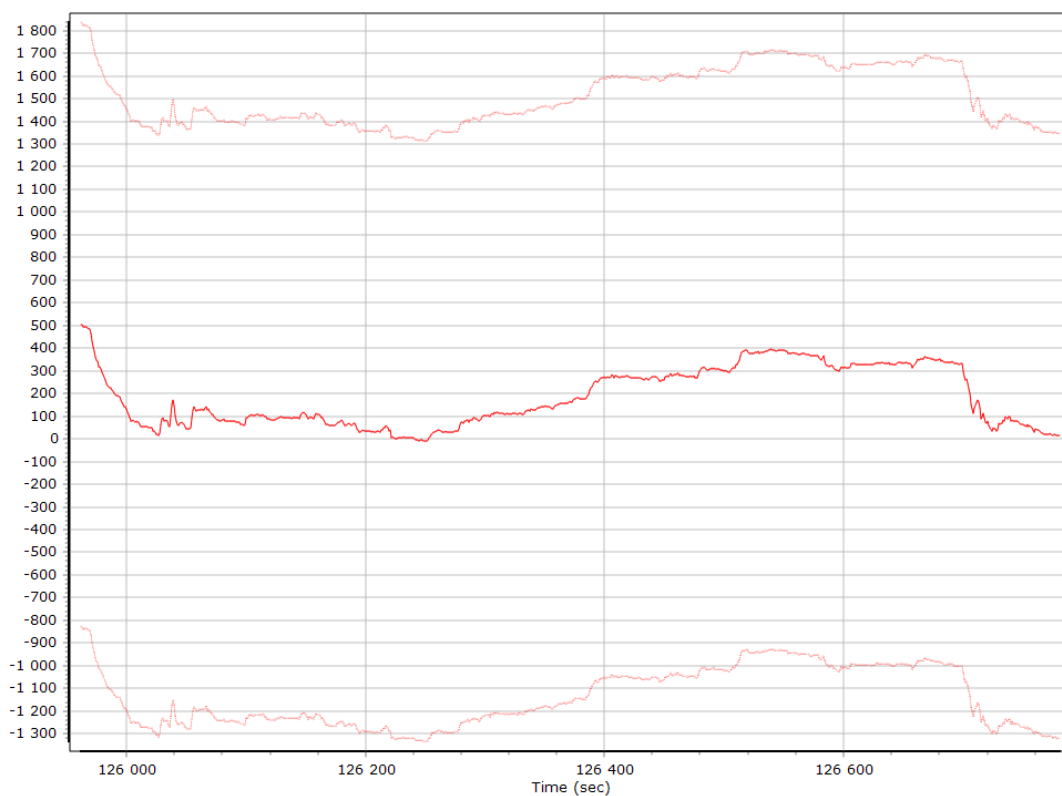
X Accelerometer Bias (micro-g)



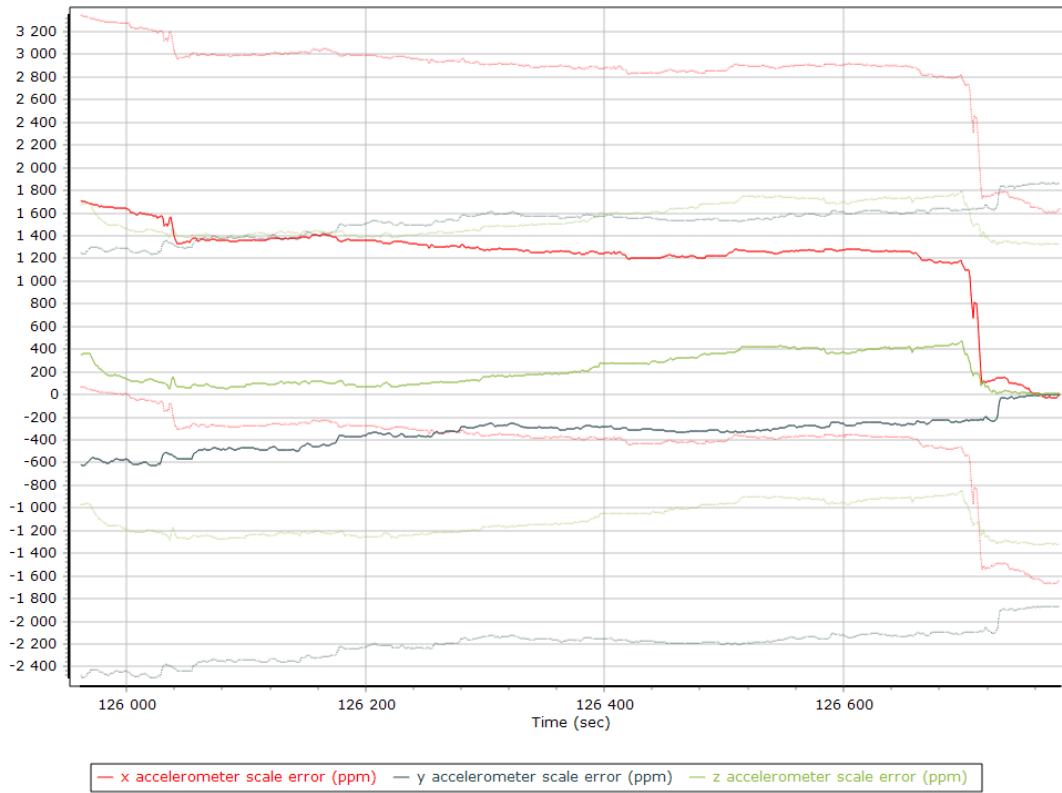
Y Accelerometer Bias (micro-g)



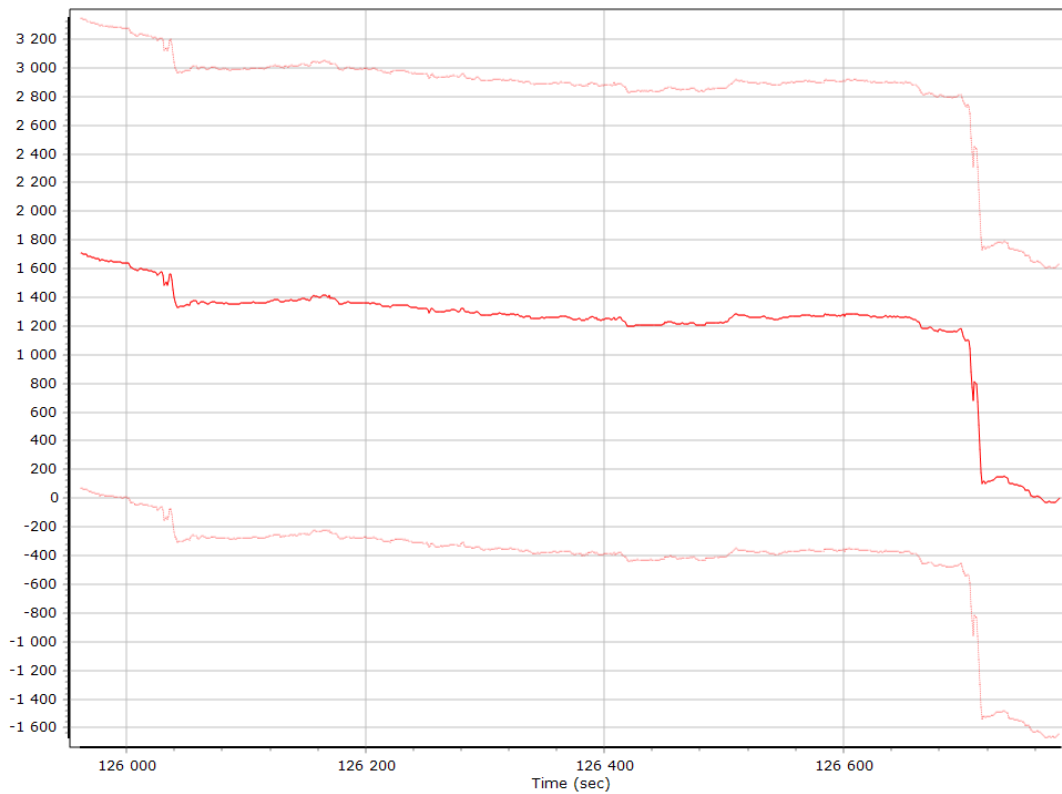
Z Accelerometer Bias (micro-g)



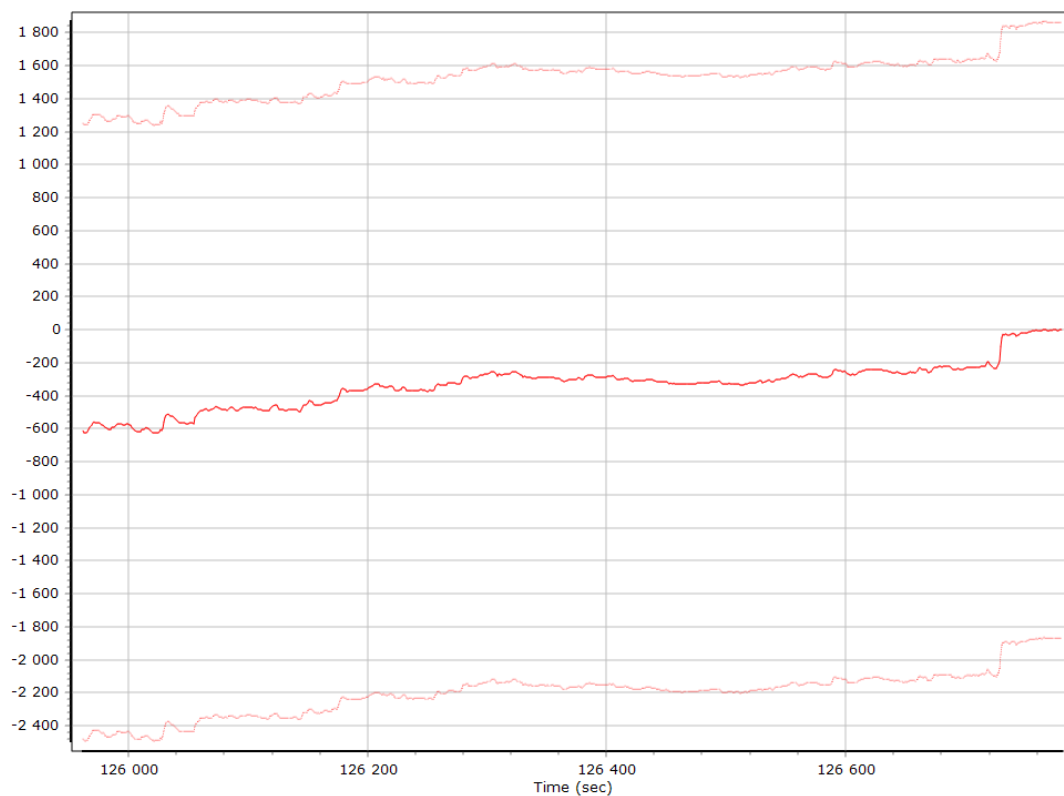
Accelerometer Scale Error (ppm)



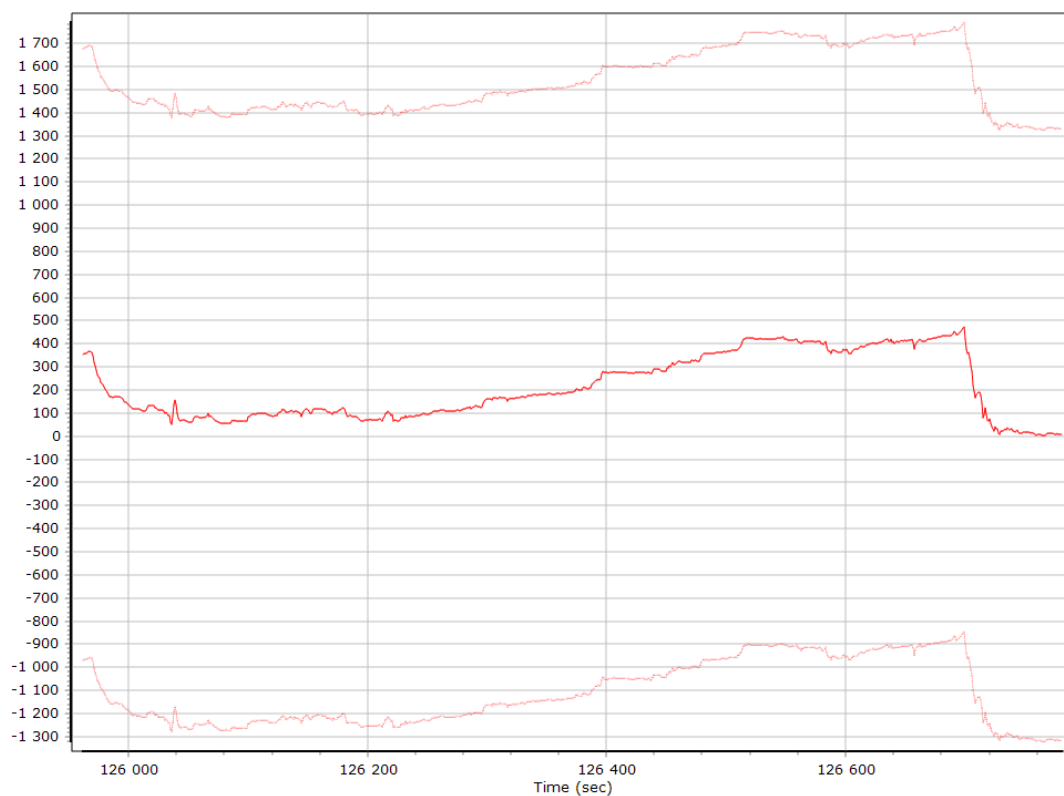
X Accelerometer Scale Error (ppm)



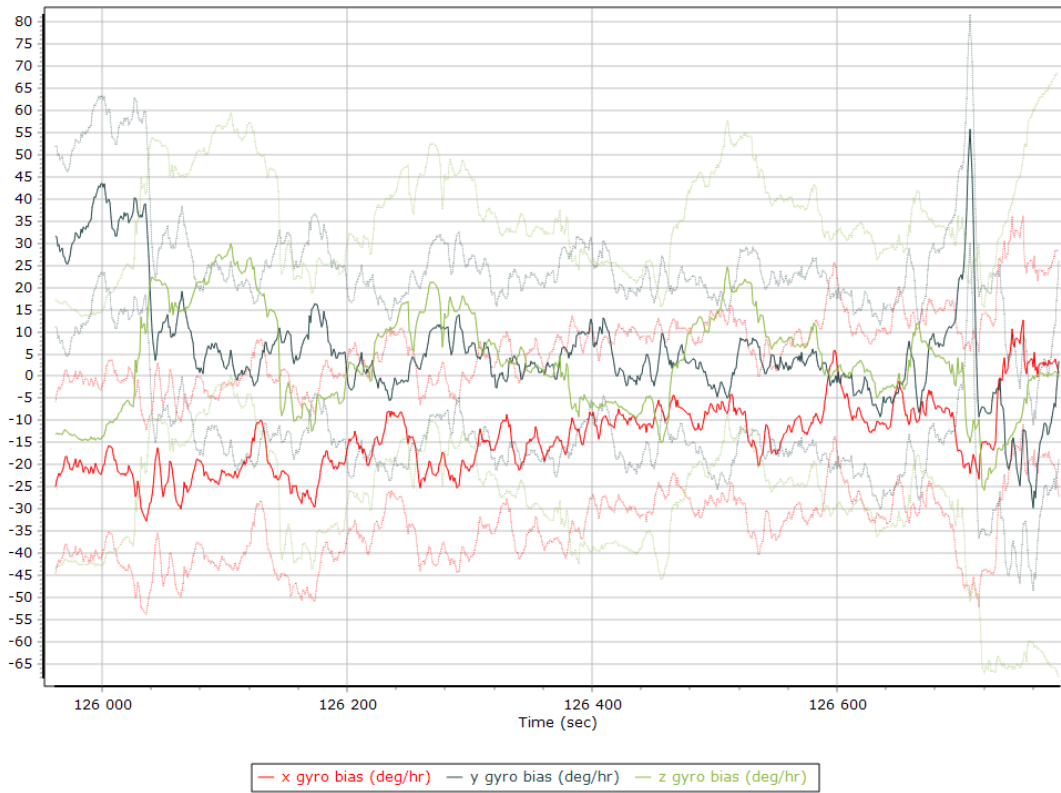
Y Accelerometer Scale Error (ppm)



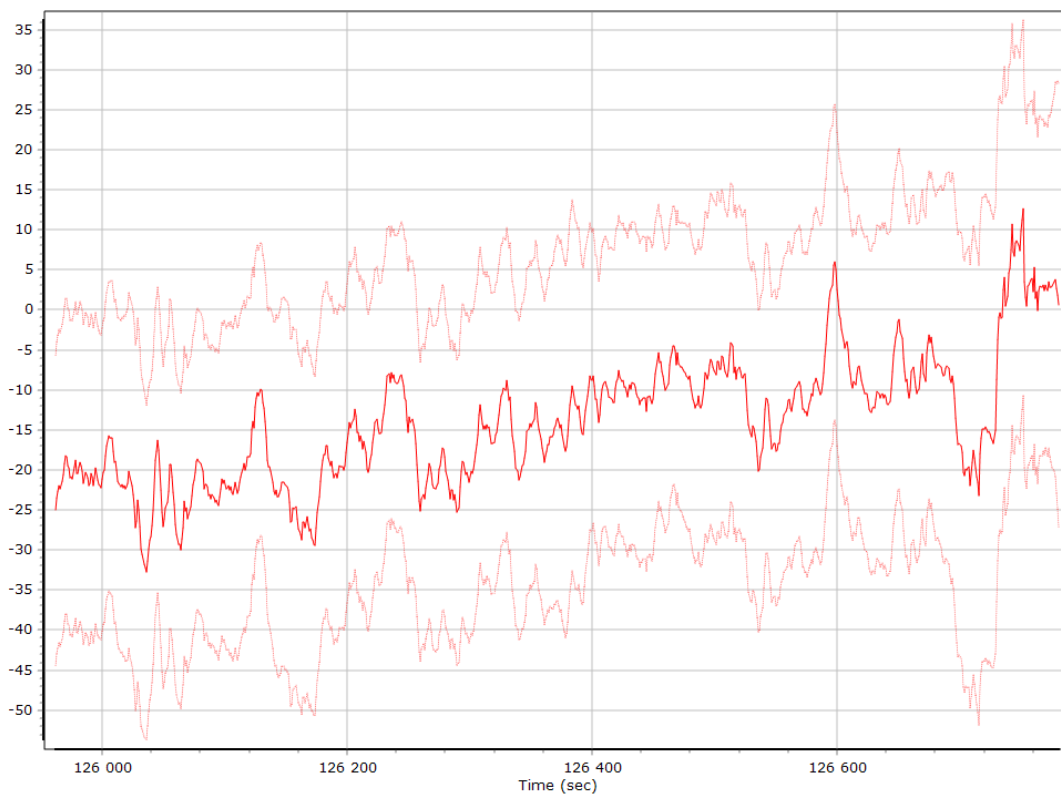
Z Accelerometer Scale Error (ppm)



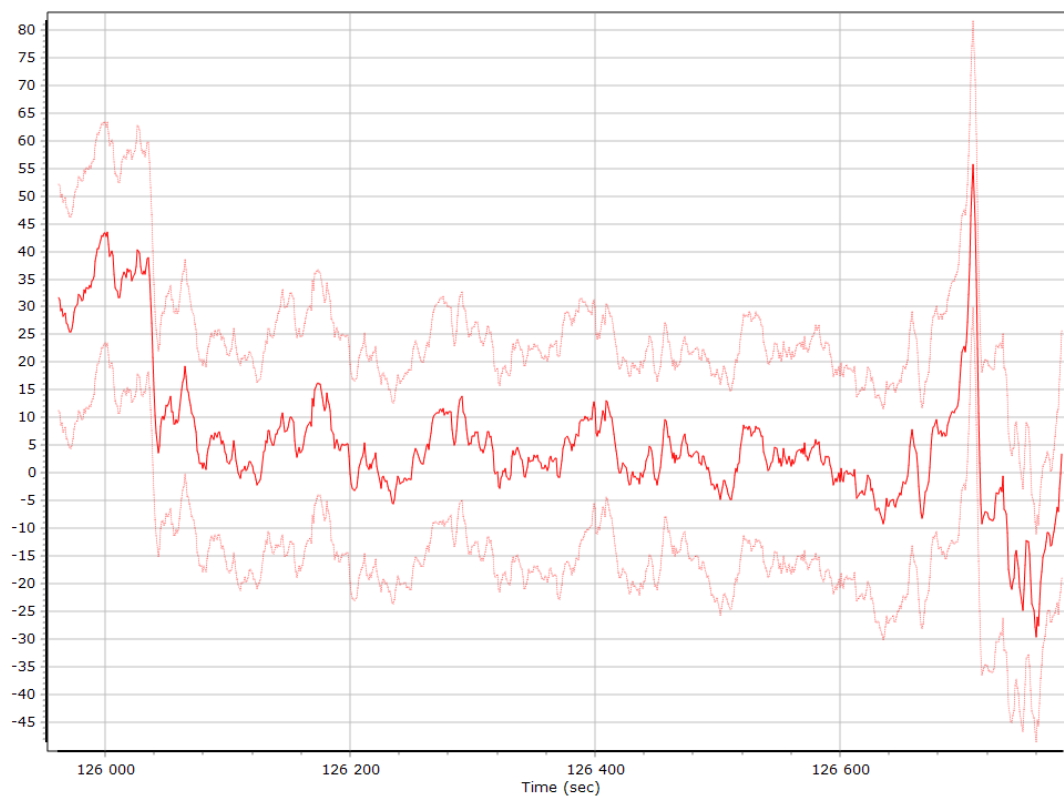
Gyro Bias (deg/h)



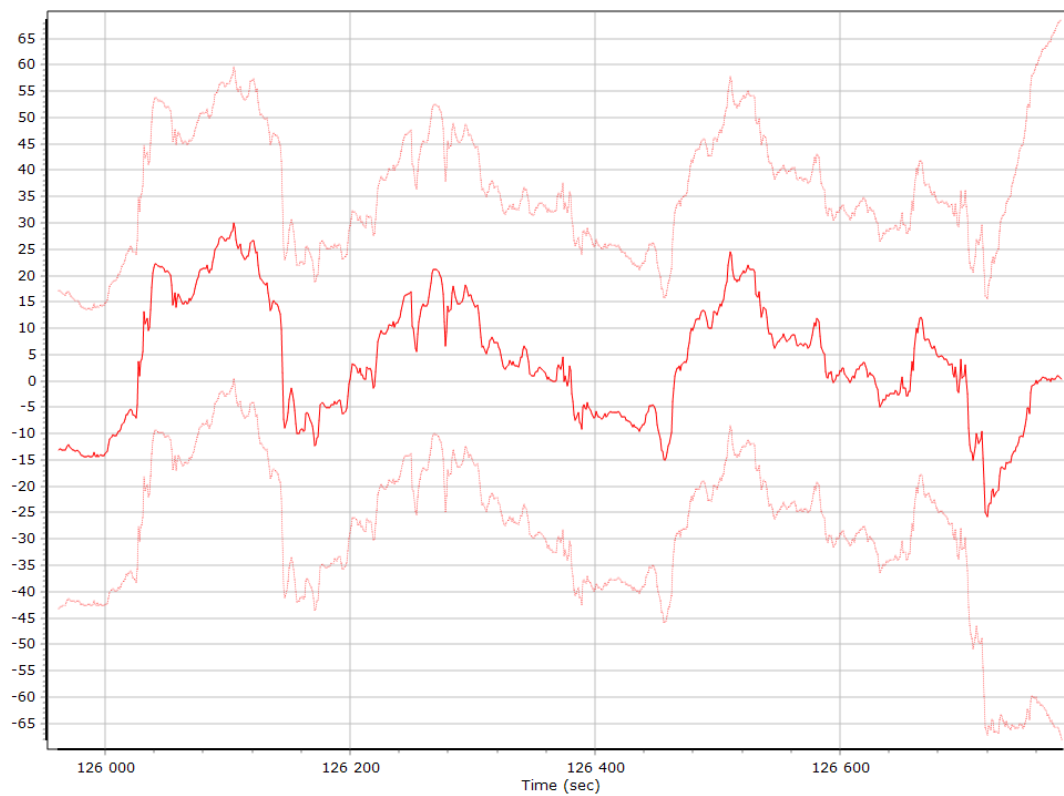
X Gyro Bias (deg/h)



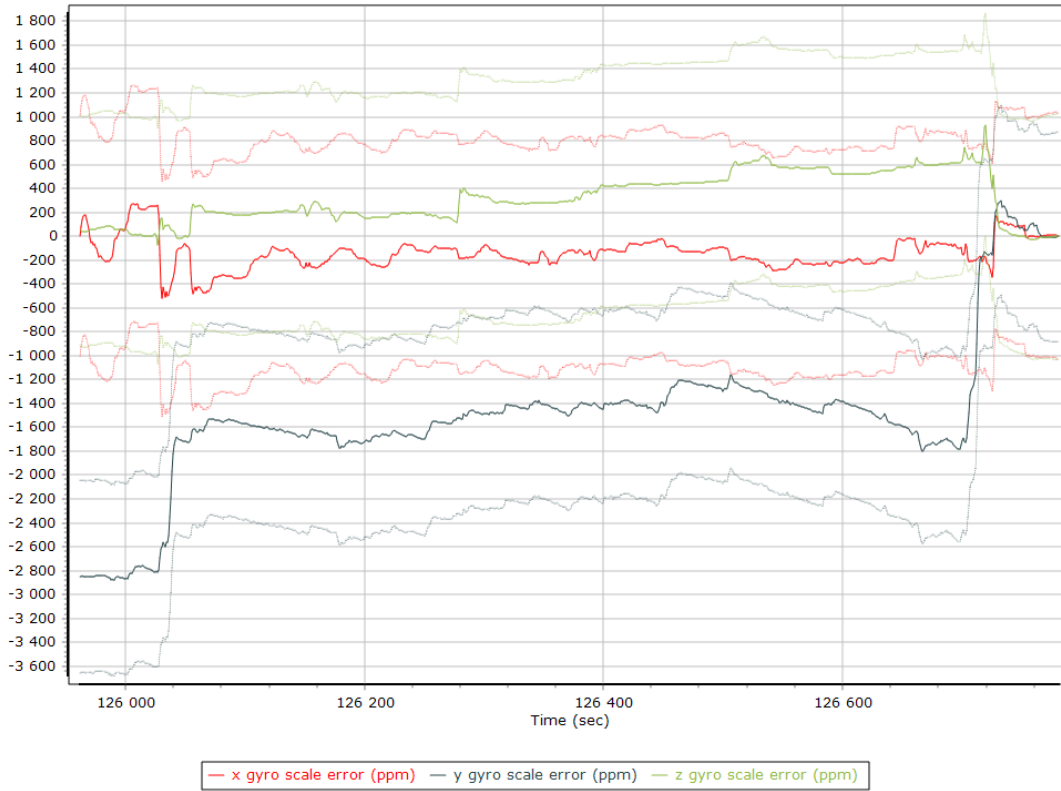
Y Gyro Bias (deg/h)



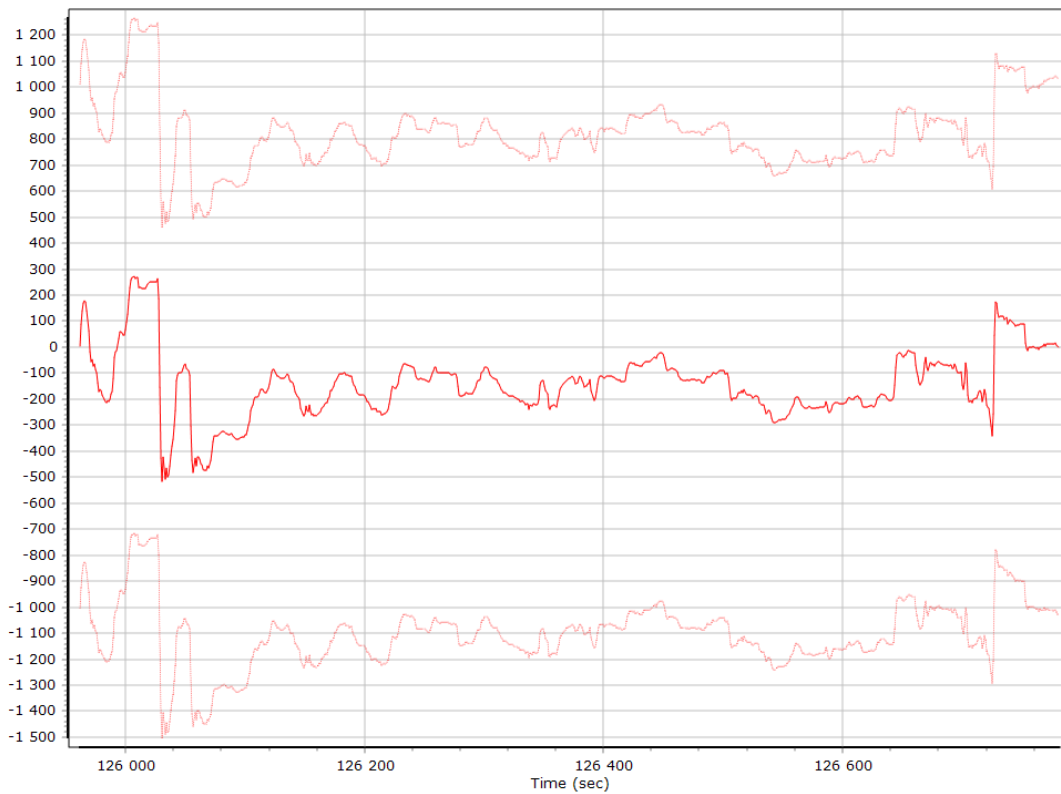
Z Gyro Bias (deg/h)



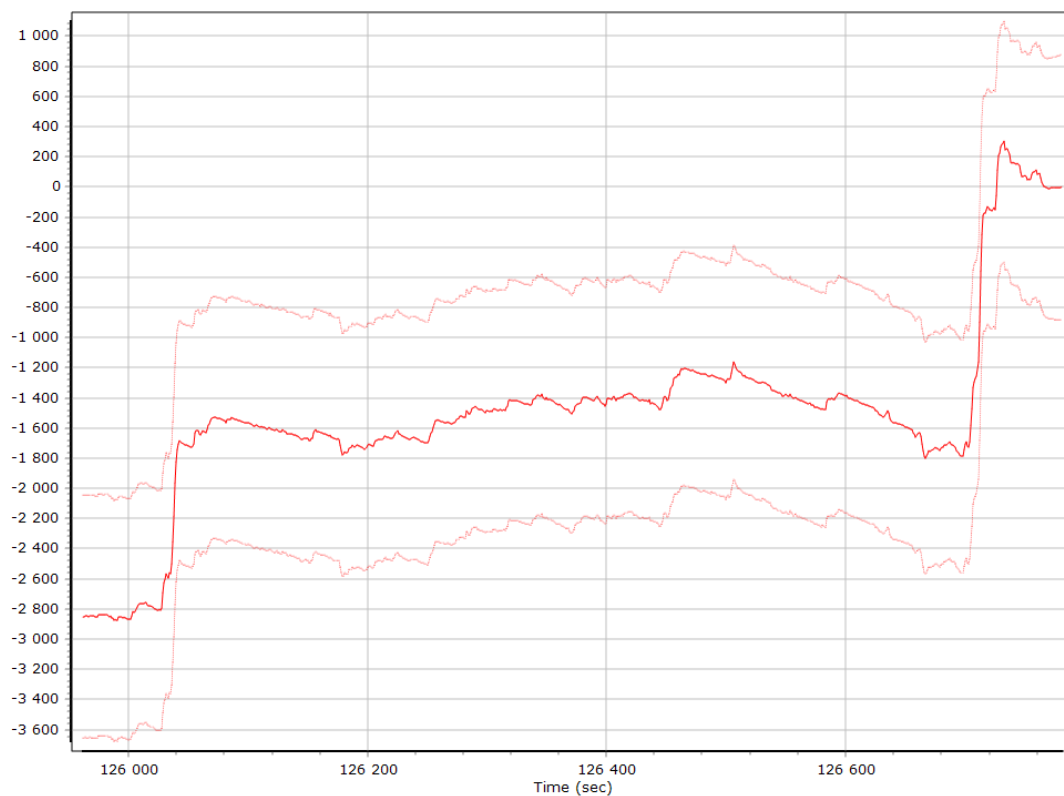
Gyro Scale Error (ppm)



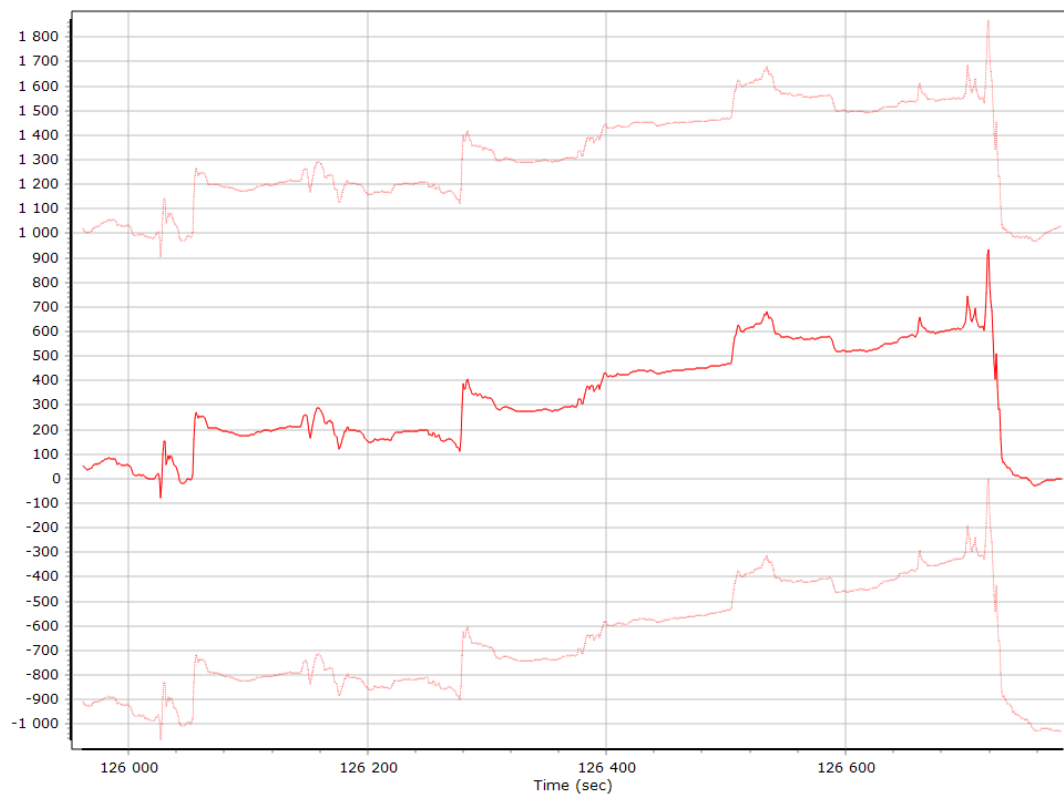
X Gyro Scale Error (ppm)



Y Gyro Scale Error (ppm)

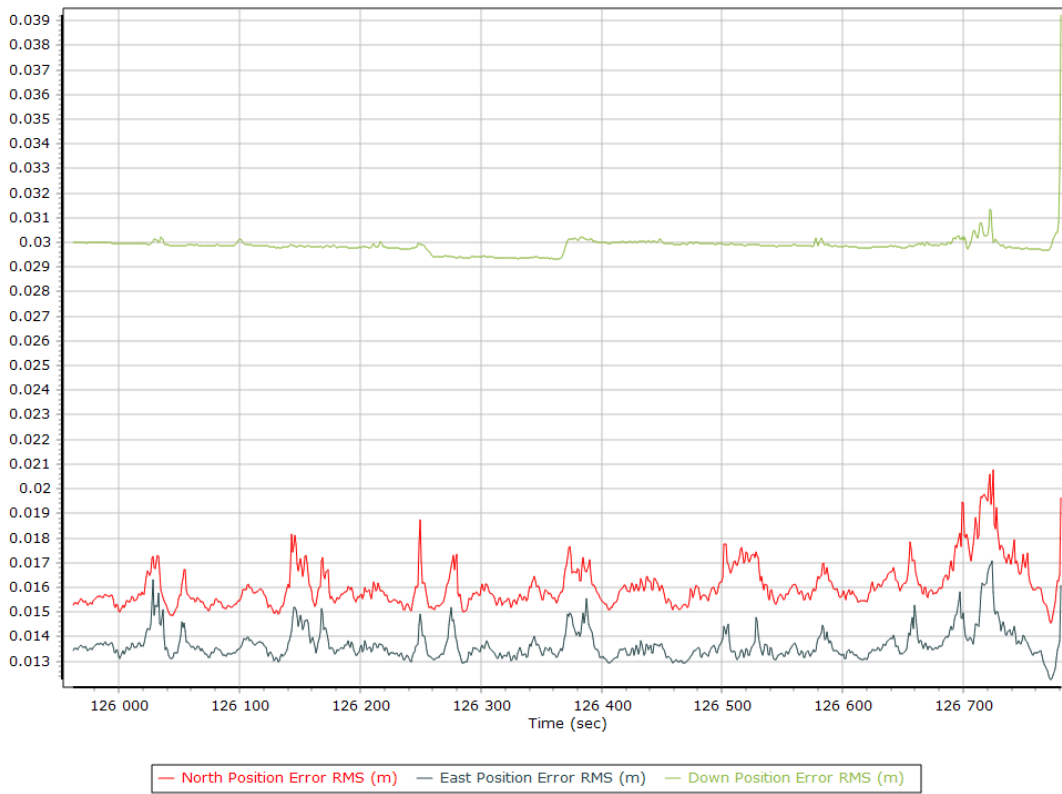


Z Gyro Scale Error (ppm)

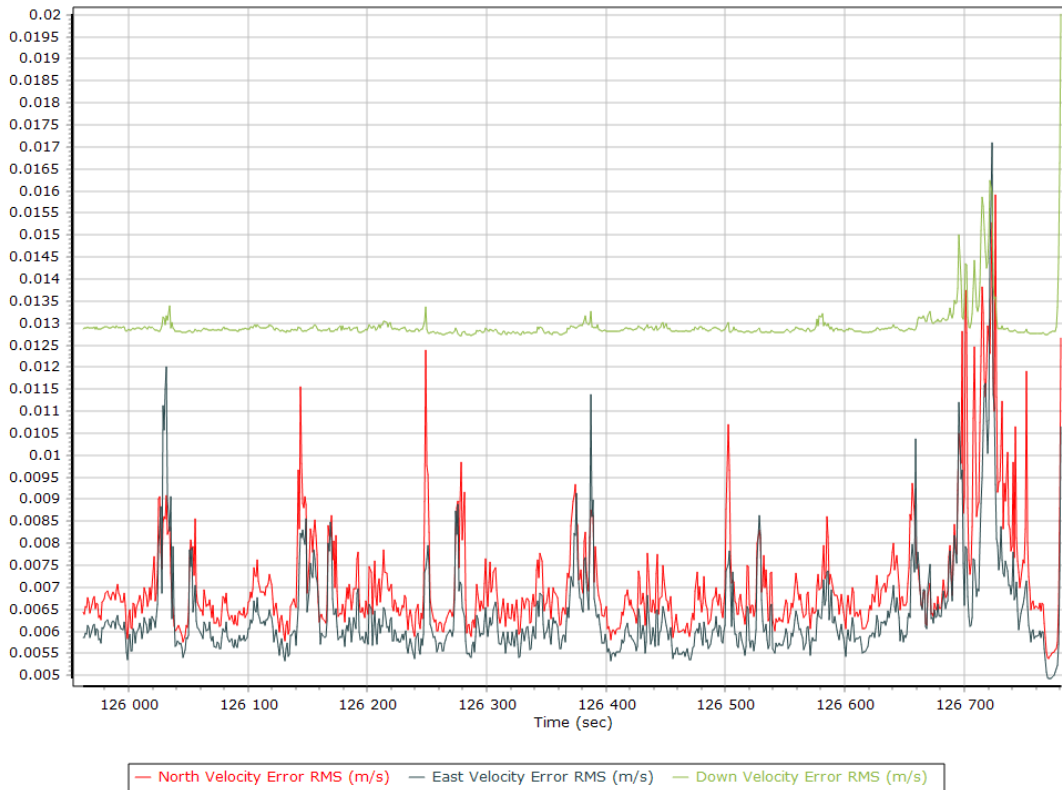


Smoothed Performance Metrics

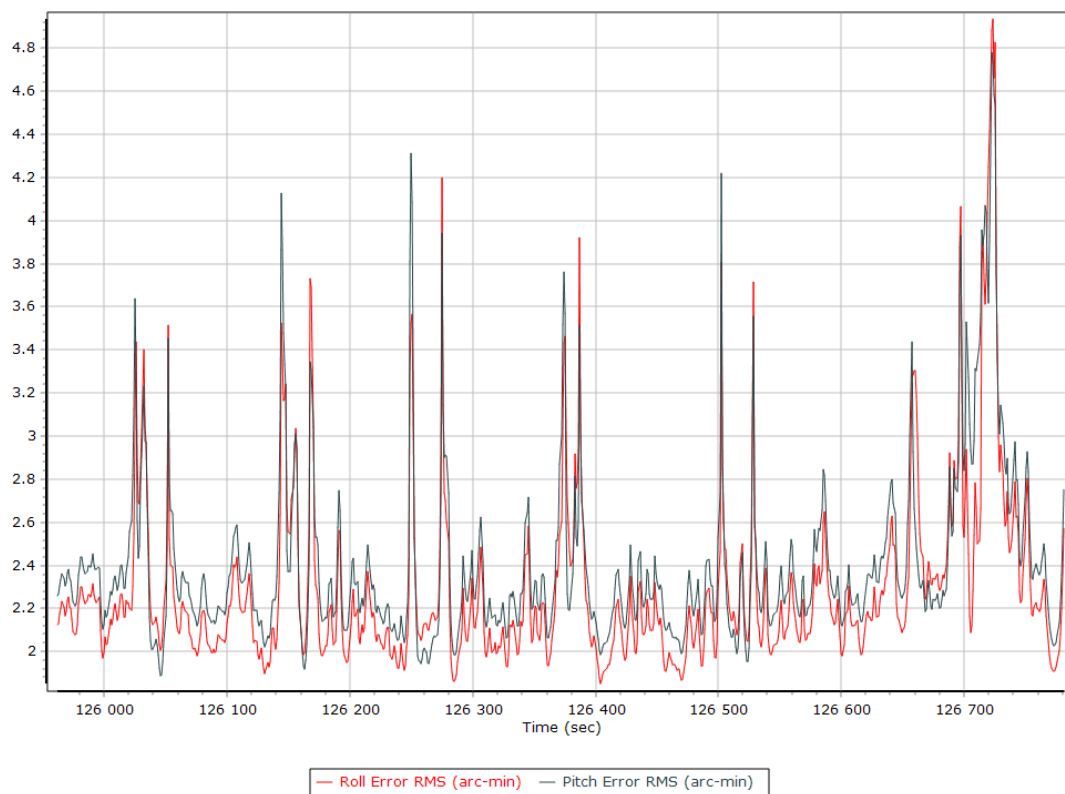
Position Error RMS (m)



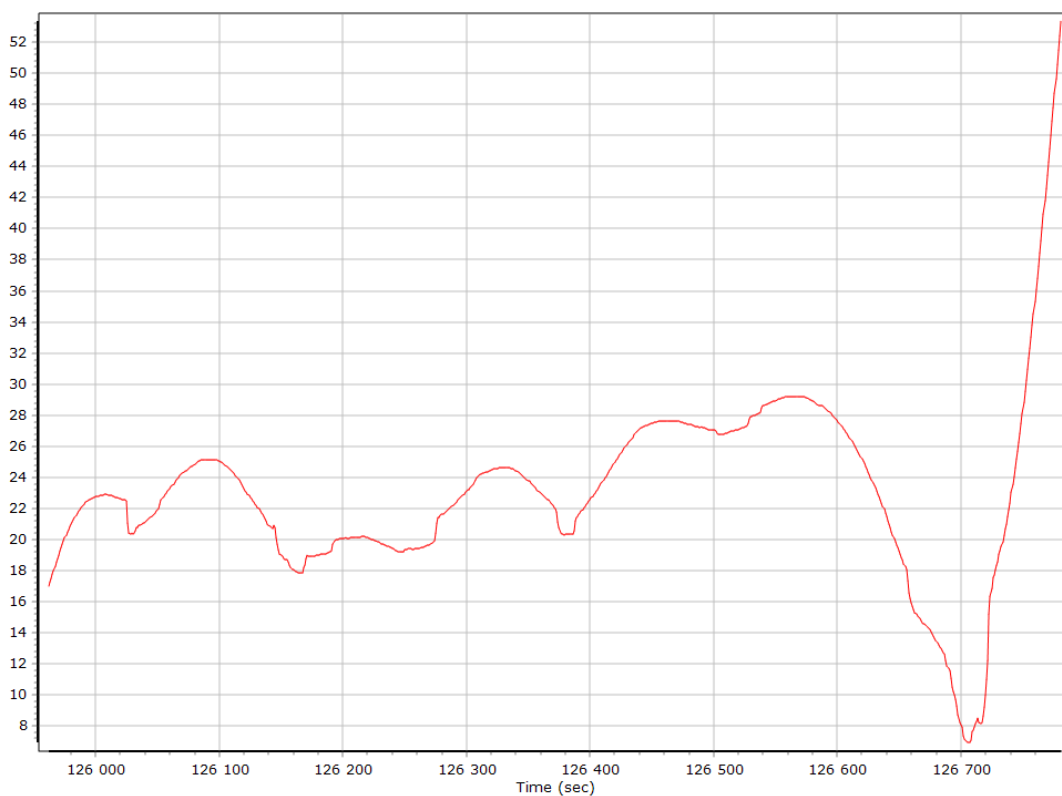
Velocity Error RMS (m/s)



Roll/Pitch Error RMS (arc-min)

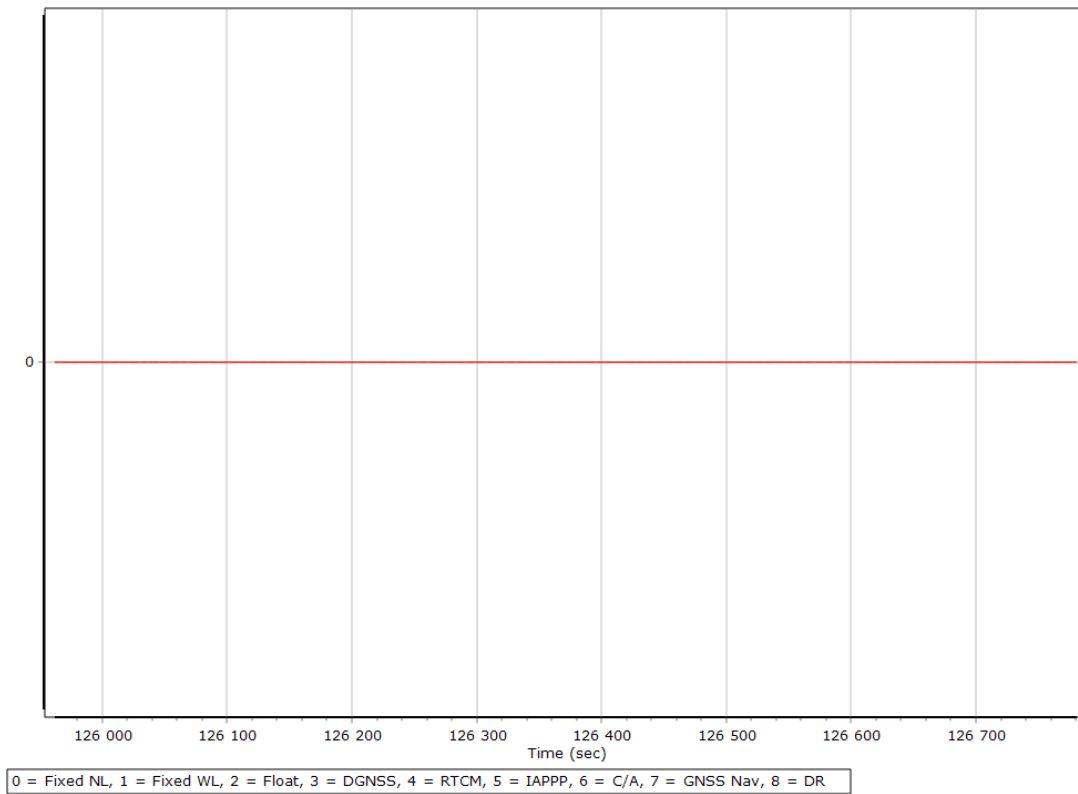


Heading Error RMS (arc-min)

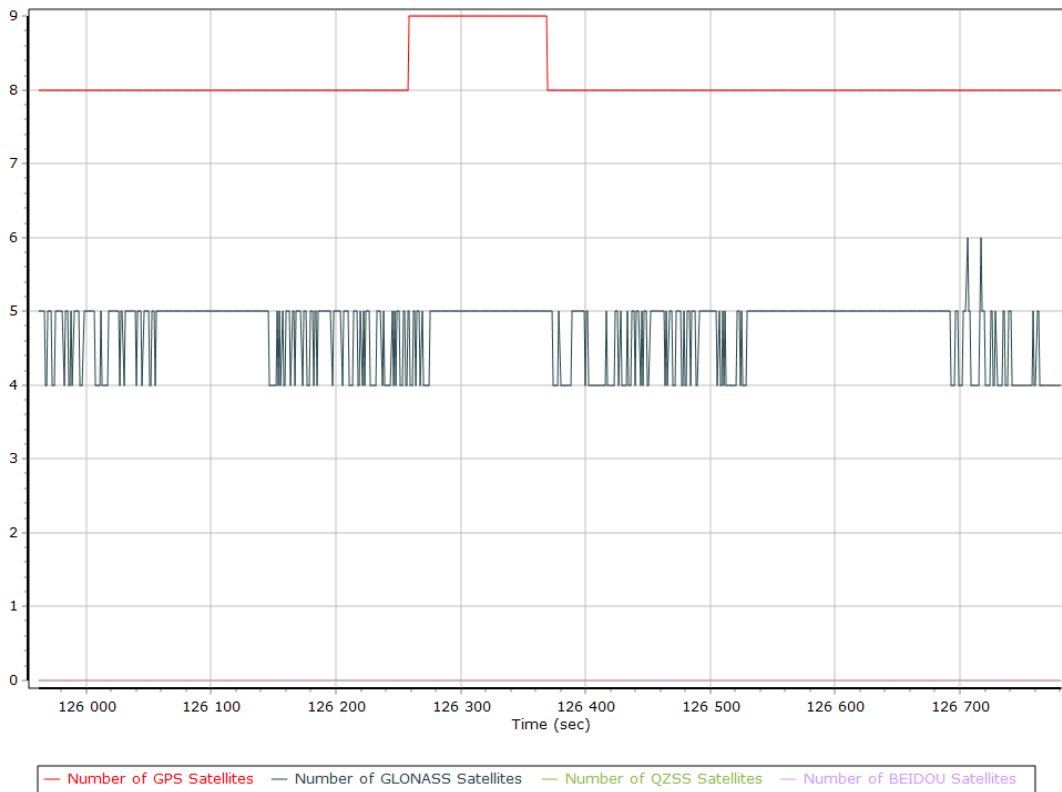


Smoothed Solution Status

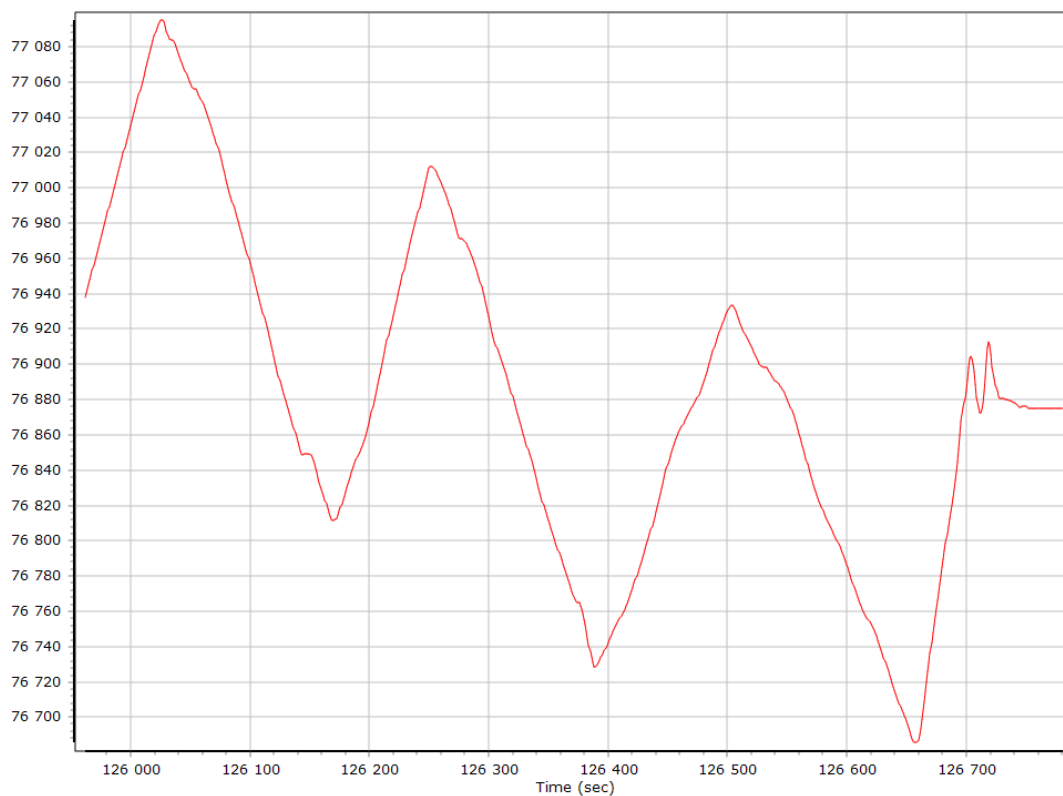
Processing Mode



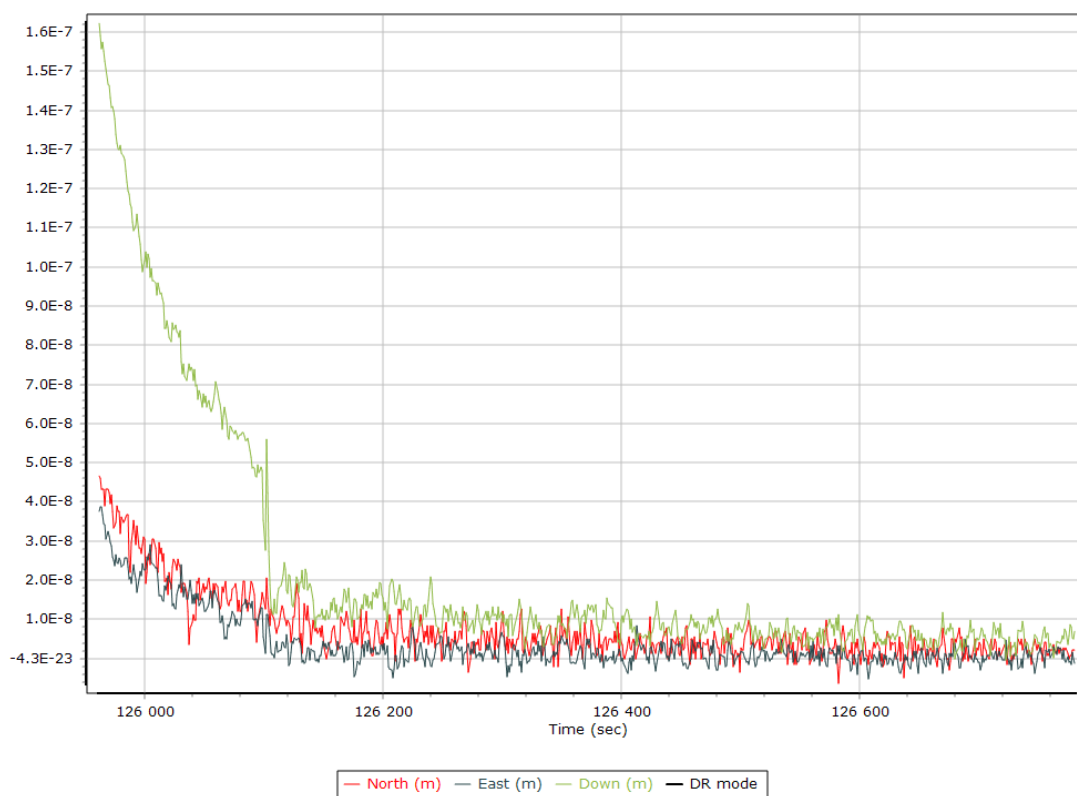
Number of Satellites



Baseline Length



SBET IAKAR Separation



Export Summary

Export file	export_Mission 1.txt		
Export format	ASCII		
Solution in use	Post-processed		
Output rate	All Records		
Reference to Output lever arm [m]	0.000	0.000	0.000
Reference mounting angles [deg]	0.000	0.000	0.000
Output units (Coordinate / Lat & Lon)	Meter		Deg Decimal
Export start time	125898.001 (11/22/2021 10:58:18 AM)		
Export end time	126782.002 (11/22/2021 11:13:02 AM)		
Height option	Ellipsoid Height		
WGS84 height flag	False		
Grid	Universal Transverse Mercator		
Zone	UTM North 31 (0E to 6E)		
Datum	WGS84		
Ellipsoid	WGS84		
Local Transformation	NONE		
Target Epoch	2021.890411		

EO Summary

EO file			
EO format			
Lever arm [m]	0.000	0.000	0.000
Boresight angles [arcmin]	0.000	0.000	0.000
Output rate	All Records		
Rotation sequence	x omega	y phi	z kappa
Local shift [m]	0.000	0.000	0.000
Output units (coordinate / angle / lat & lon)	Meter	Degree	Deg Decimal
Height option	Ellipsoid Height		
WGS84 height flag	False		
Scale height option	False		
Kappa cardinal rotation [deg]	0		
Solution in use	Post-processed		
EO start time	125898.001 (11/22/2021 10:58:18 AM)		
EO end time	126782.002 (11/22/2021 11:13:02 AM)		
Grid	Universal Transverse Mercator		
Zone	UTM North 31 (0E to 6E)		
Datum	WGS84		
Ellipsoid	WGS84		
Local Transformation	NONE		
Target Epoch	2021.890411		