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LA Sabine River Lidar Project

Report Produced for U.S. Geological Survey

USGS Contract: G16PC00020

Task Order: 140G1018F0025

Report Date: 09/08/2020

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Executive Summary

The primary purpose of this project was to develop a consistent and accurate surface elevation dataset derived from high-accuracy Light Detection and Ranging (lidar) technology for the USGS LA Sabine Project Area.

The lidar data were processed and classified according to project specifications. Detailed breaklines and bare-earth Digital Elevation Models (DEMs) were produced for the project area. Data was formatted according to tiles with each tile covering an area of 1000m by 1000m. A total of 28119 tiles were produced for the project encompassing an area of approximately 10,535 sq. miles.

THE PROJECT TEAM

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

Dewberry's Gary D. Simpson completed ground surveying for the project and delivered surveyed checkpoints. His task was to acquire surveyed checkpoints for the project to use in independent testing of the vertical accuracy of the lidar-derived surface model. He also verified the GPS base station coordinates used during lidar data acquisition to ensure that the base station coordinates were accurate. Please see Appendix A to view the separate Survey Report that was created for this portion of the project.

Airborne Imaging Inc. and Leading Edge Geomatics, Inc. completed lidar data acquisition and data calibration for the project area.

SURVEY AREA

The project area addressed by this report falls within the Louisiana parishes of Rapides, Natchitoches, Grant, Red Rover, Caddo, Bossier, Calcasieu, Beauregard, Vernon, Sabine, and De Soto.

DATE OF SURVEY

The ground survey was conducted from February 15, 2018 to March 2, 2018.

COORDINATE REFERENCE SYSTEM

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

Horizontal Datum: The horizontal datum for the project is North American Datum of 1983 with the 2011 Adjustment (NAD 83 (2011))
Vertical Datum: The Vertical datum for the project is North American Vertical Datum of 1988 (NAVD88)
Coordinate System: UTM Zone 15
Units: Horizontal units are in meters; Vertical units are in meters.
Geiod Model: Geoid12B (Geoid 12B was used to convert ellipsoid heights to orthometric heights).

LIDAR VERTICAL ACCURACY

For the LA Sabine Lidar Project, the tested $RMSE_z$ of the classified lidar data for checkpoints in non-vegetated terrain equaled **5 cm** compared with the 10 cm specification; and the NVA of the classified lidar data computed using $RMSE_z$ x 1.9600 was equal to **9.4 cm**, compared with the 19.6 cm specification.

For the LA Sabine Lidar Project, the tested VVA of the classified lidar data computed using the 95^{th} percentile was equal to **14.4 cm,** compared with the 29.4 cm specification.

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

PROJECT DELIVERABLES

The deliverables for the project are listed below.

1. Classified Point Cloud Data (Tiled)
2. Bare Earth Surface (Raster DEM – IMG Format)
3. Intensity Images (8-bit gray scale, tiled, GeoTIFF format)
4. Breakline Data (File GDB)
5. Independent Survey Checkpoint Data (Report, Photos, & Points)
6. Calibration Points
7. Metadata
8. Project Report (Acquisition, Processing, QC)
9. Project Extents, including a shapefile derived from the lidar deliverable
10. DZ Orthos (Swath Separation Images), (GeoTiff format)

PROJECT TILING FOOTPRINT

Twenty-eight thousand and one hundred nineteen (28119) tiles were delivered for the project. Each tile's extent is 1,000 meters by 1,000 meters.

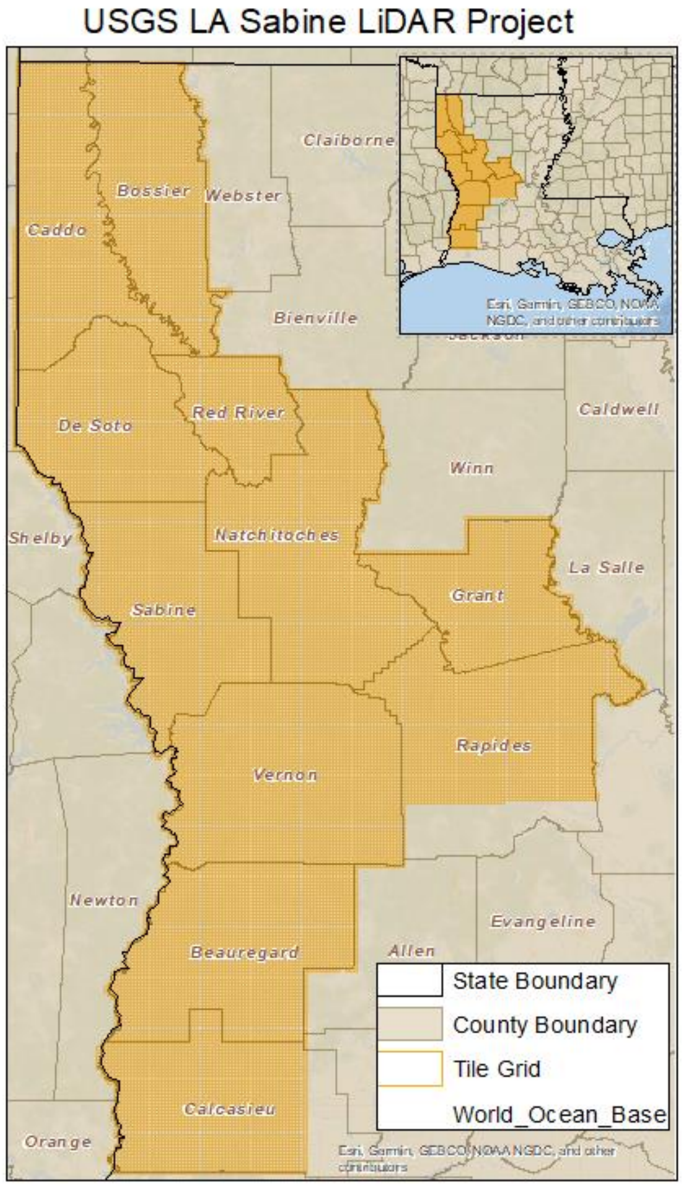

Figure 1 - Project Map

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Lidar Acquisition Report

Dewberry elected to subcontract the lidar acquisition and calibration activities to Airborne Imaging Inc. and Leading Edge Geomatics, Inc. Airborne Imaging Inc. and Leading Edge Geomatics, Inc. was responsible for providing lidar acquisition, calibration and delivery of lidar data files to Dewberry.

The lidar survey was conducted by Airborne Imagine Inc between January 12th, 2018 and June 9th, 2018. The lidar survey was conducted by Leading Edge Geomatics between November 2, 2018 to December 1, 2018. Some data was flown before November 2, 2018 but had to be reflown due to flooding of the study area.

LIDAR ACQUISITION DETAILS

Airborne Imaging Inc. planned 227 passes for the project area as a series of parallel flight lines with cross flightlines for the purposes of quality control. The flight plan included zigzag flight line collection as a result of the inherent IMU drift associated with all IMU systems. In order to reduce any margin for error in the flight plan, Airborne Imaging Inc. followed USGS's Appendix A "guidelines" for flight planning and, at a minimum, includes the following criteria:

- A digital flight line layout using Track Air flight design software for direct integration into the aircraft flight navigation system.
- Planned flight lines; flight line numbers; and coverage area.
- Lidar coverage extended by a predetermined margin beyond all project borders to ensure necessary over-edge coverage appropriate for specific task order deliverables.
- Local restrictions related to air space and any controlled areas have been investigated so that required permissions can be obtained in a timely manner with respect to schedule. Additionally, Airborne Imaging Inc. will file our flight plans as required by local Air Traffic Control (ATC) prior to each mission.

Airborne Imaging Inc. monitored weather and atmospheric conditions and conducted lidar missions only when no conditions exist below the sensor that will affect the collection of data. These conditions include leaf-off for hardwoods, no snow, rain, fog, smoke, mist and low clouds. Lidar systems are active sensors, not requiring light, thus missions may be conducted during night hours when weather restrictions do not prevent collection. Airborne Imaging Inc. accesses reliable weather sites and indicators (webcams) to establish the highest probability for successful collection in order to position our sensor to maximize successful data acquisition.

Within 72-hours prior to the planned day(s) of acquisition, Airborne Imaging Inc. closely monitored the weather, checking all sources for forecasts at least twice daily. As soon as weather conditions were conducive to acquisition, our aircraft mobilized to the project site to begin data collection. Once on site, the acquisition team took responsibility for weather analysis.

Airborne Imaging LiDAR sensors are calibrated at a designated site located at Red Deer, Alberta, Canada or St. Hubert, Quebec, Canada and are periodically checked and adjusted to minimize corrections at project sites.

Leading Edge Geomatics, Inc. planned 387 passes for the project area as a series of parallel flight lines with cross flightlines for the purposes of quality control. The flight plan included zigzag flight line collection as a result of the inherent IMU drift associated with all IMU systems. In order to reduce any margin for error in the flight plan, Leading Edge Geomatics followed USGS's Appendix A "guidelines" for flight planning and, at a minimum, includes the following criteria:

- A digital flight line layout using Track Air flight design software for direct integration into the aircraft flight navigation system.
- Planned flight lines; flight line numbers; and coverage area.
- Lidar coverage extended by a predetermined margin beyond all project borders to ensure necessary over-edge coverage appropriate for specific task order deliverables.
- Local restrictions related to air space and any controlled areas have been investigated so that required permissions can be obtained in a timely manner with respect to schedule. Additionally, Leading Edge Geomatics will file our flight plans as required by local Air Traffic Control (ATC) prior to each mission.

Leading Edge Geomatics monitored weather and atmospheric conditions and conducted lidar missions only when no conditions exist below the sensor that will affect the collection of data. These conditions include leaf-off for hardwoods, no snow, rain, fog, smoke, mist and low clouds. Lidar systems are active sensors, not requiring light, thus missions may be conducted during night hours when weather restrictions do not prevent collection. Leading Edge Geomatics accesses reliable weather sites and indicators (webcams) to establish the highest probability for successful collection in order to position our sensor to maximize successful data acquisition.

Within 72-hours prior to the planned day(s) of acquisition, Leading Edge Geomatics closely monitored the weather, checking all sources for forecasts at least twice daily. As soon as weather conditions were conducive to acquisition, our aircraft mobilized to the project site to begin data collection. Once on site, the acquisition team took responsibility for weather analysis.

Leading Edge Geomatics lidar sensors were calibrated at a designated site located at the Lawrence County Airport in Courtland, Alabama and are periodically checked and adjusted to minimize corrections at project sites.

LIDAR SYSTEM PARAMETERS

Airborne Imaging

Airborne Imaging operated a Piper PA-31 Navajo (Tail # C-FFRY, and #N-44RL) outfitted with a Riegl Q-1560 LiDAR system during the collection of the study area. Table 1 illustrates Airborne Imaging Inc. system parameters for lidar acquisition on this project.

Item	Parameter
System	Riegl VQ-1560i
Altitude (AGL meters)	1260m to 1416m
Approx. Flight Speed (knots)	160
Scanner Pulse Rate (kHz)	2000kHZ True (1333kHz effective)

Item	Parameter
Scan Frequency (hz)	361 scanlines/s
Pulse Duration of the Scanner (nanoseconds)	3
Pulse Width of the Scanner (m)	0.9
Swath width (m)	1617
Central Wavelength of the Sensor Laser (nanometers)	1064
Did the Sensor Operate with Multiple Pulses in The Air? (yes/no)	Yes
Beam Divergence (milliradians)	0.25
Nominal Swath Width on the Ground (m)	1569
Swath Overlap (%)	30
Total Sensor Scan Angle (degree)	60
Computed Down Track spacing (m) per beam	0.44
Computed Cross Track Spacing (m) per beam	0.44
Nominal Pulse Spacing (single swath), (m)	0.32
Nominal Pulse Density (single swath) (ppsm), (m)	9.9
Aggregate NPS (m) (if ANPS was designed to be met through single coverage, ANPS and NPS will be equal)	0.32
Aggregate NPD (m) (if ANPD was designed to be met through single coverage, ANPD and NPD will be equal)	9.9
Maximum Number of Returns per Pulse	7

Table 1: Airborne Imaging Inc.lidar system parameters

Leading Edge Geomatics

Leading Edge Geomatics operated Cessna 206 (Tail # CPTG) and Piper PA-23-250 (Tail # N762SU) aircraft. Each aircraft was outfitted with a Riegl VQ-1560i lidar system. Table 2 illustrates Leading Edge Geomatics system parameters for lidar acquisition on this project.

Item	Parameter
System	Riegl VQ1560i
Altitude (AGL meters)	1200
Approx. Flight Speed (knots)	130
Scanner Pulse Rate (kHz)	2000
Scan Frequency (hz)	175
Pulse Duration of the Scanner (nanoseconds)	3
Pulse Width of the Scanner (m)	0.8994
Swath width (m)	1330
Central Wavelength of the Sensor Laser (nanometers)	1064
Did the Sensor Operate with Multiple Pulses in The Air? (yes/no)	Yes
Beam Divergence (milliradians)	0.25
Nominal Swath Width on the Ground (m)	1330
Swath Overlap (%)	17

Item	Parameter
Total Sensor Scan Angle (degree)	58
Computed Down Track spacing (m) per beam	0.38
Computed Cross Track Spacing (m) per beam	0.37
Nominal Pulse Spacing (single swath), (m)	0.27
Nominal Pulse Density (single swath) (ppsm), (m)	13.7
Aggregate NPS (m) (if ANPS was designed to be met through single coverage, ANPS and NPS will be equal)	0.27
Aggregate NPD (m) (if ANPD was designed to be met through single coverage, ANPD and NPD will be equal)	13.7
Maximum Number of Returns per Pulse	Infinite

Table 2: Leading Edge Geomatics lidar system parameters

ACQUISITION STATUS REPORT AND FLIGHTLINES

Upon notification to proceed, the flight crew loaded the flight plans and validated the flight parameters. The Acquisition Manager contacted air traffic control and coordinated flight pattern requirements. Lidar acquisition began immediately upon notification that control base stations were in place. During flight operations, the flight crew monitored weather and atmospheric conditions. Lidar missions were flown only when no condition existed below the sensor that would affect the collection of data. The pilot constantly monitored the aircraft course, position, pitch, roll, and yaw of the aircraft. The sensor operator monitored the sensor, the status of PDOPs, and performed the first Q/C review during acquisition. The flight crew constantly reviewed weather and cloud locations. Any flight lines impacted by unfavorable conditions were marked as invalid and re-flown immediately or at an optimal time.

Figure 2 shows the combined trajectory of the flightlines.

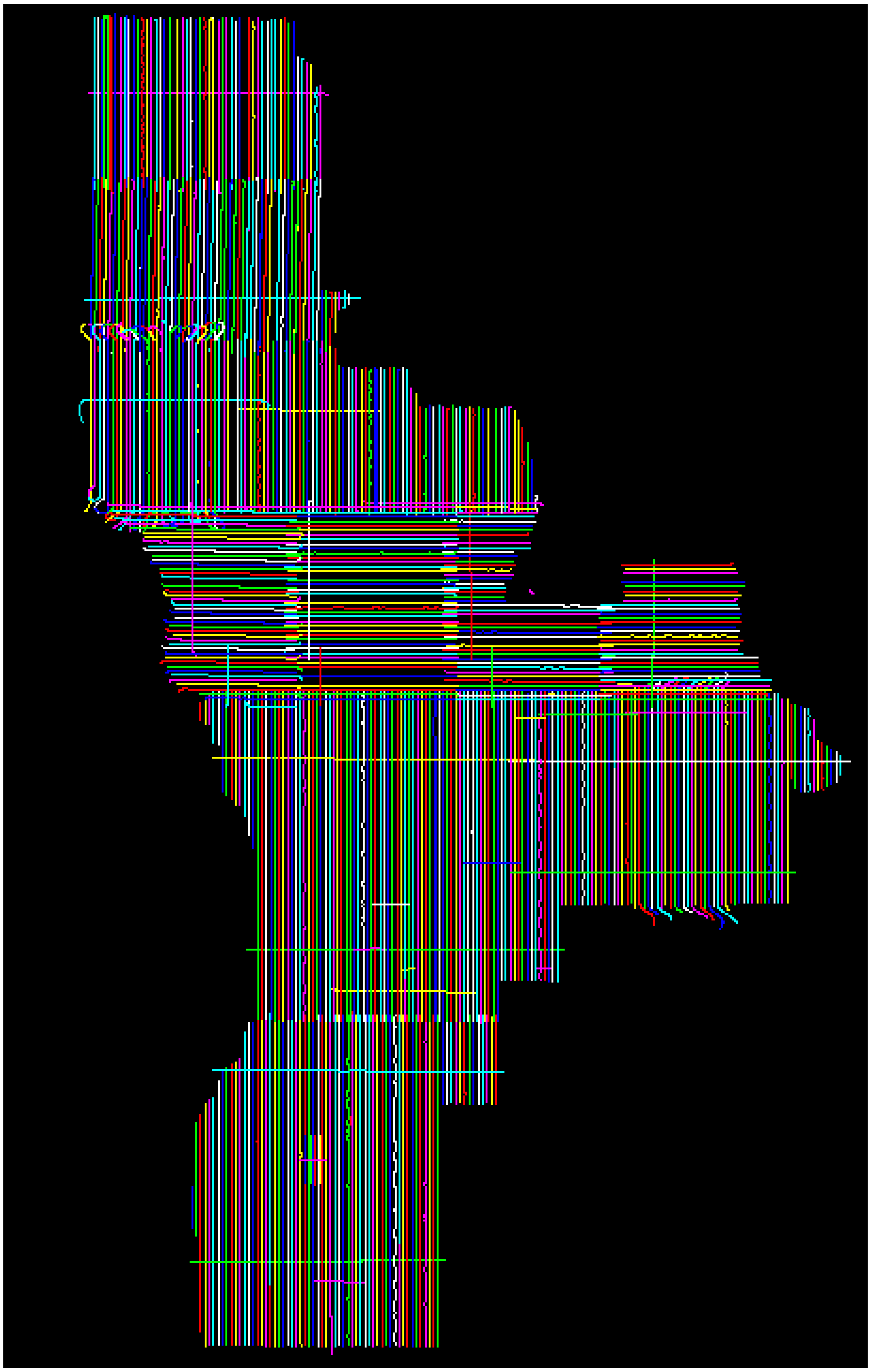


Figure 2: Trajectories as flown by Airborne Imaging Inc., and Leading Edge Geomatics, Inc.

LIDAR CONTROL

Airborne Imagine

Three existing NGS monuments, seven Continuous Operating Reference Stations (CORS), and eight newly established base stations (B178-B184, B190) were used to control the LiDAR acquisition for the Sabine LiDAR project area. An additional eight temporary points (GT01-GT03, TPN1-TPN5) were set for ground control validation points. The coordinates of all used base stations are provided in the table below.

Name	NAD83(2011) UTM 15		Ellipsoid Ht (NAD83(2011), m)
	Easting X (m)	Northing Y (m)	
1NSU	490756.749	3512817.901	29.325
B178	459316.856	3470842.852	76.725
B179	509686.566	3454710.352	41.895
B180	473145.318	3429886.15	72.791
B181	491096.583	3398473.941	1.868
B182	459451.369	3379589.648	-0.891
B183	458876.831	3345624.807	-23.504
B184	478670.85	3332708.032	-23.533
B190	543799.5	3465271.674	-0.26
GT01	436627.634	3353791.639	-16.497
GT02	452341.418	3364916.508	-6.636
GT03	470603.646	3373274.672	-3.765
LESV	474362	3445422.04	76.973
LSUA	555999.462	3449563.288	6.029
LYON	516735.133	3345821.828	-21.648
MCNE	479038.134	3338813.366	-8.705
NORMAN	467937.396	3411423.371	33.473
OAKH	532810.404	3409205.498	21.528
Q239	552532.546	3463322.751	-2.498
TPN1	573199.602	3473069.745	-2.424
TPN2	529503.37	3459850.312	21.807
TPN3	487917.524	3448619.9	66.9
TPN4	467316.336	3447354.819	52.163
TPN5	452729.105	3436994.178	13.745
TPN3	417719.893	3466925.17	67.392
TPN4	420972.211	3332942.175	-19.52
1NSU	490756.749	3512817.901	29.325
B178	459316.856	3470842.852	76.725
B179	509686.566	3454710.352	41.895
B180	473145.318	3429886.15	72.791
B181	491096.583	3398473.941	1.868
B182	459451.369	3379589.648	-0.891
B183	458876.831	3345624.807	-23.504

Table 3 – Base stations used to control lidar acquisition

Leading Edge Geomatics

Leading Edge Geomatics used a combination of National Geodetic Survey and Smartnet GNSS ground stations during the acquisition of the data. Only ground stations which collected data at a rate of 1Hz were used, in order to ensure the highest quality post processed trajectory. Data from these stations was incorporated during the kinematic post-processing of aircraft position. The coordinates of all used base stations are provided in the table below.

Name	NAD83(2011) UTM 15		Ellipsoid Ht (NAD83(2011), m)
	Easting X (m)	Northing Y (m)	
1NSU	490756.756	3512817.893	29.342
ARCM	510887.977	3711426.106	26.713
ARED	530881.834	3674299.979	58.500
ARHP	444343.949	3728617.221	85.686
DHLC	460210.125	3535707.758	33.636
LABK	577310.259	3425307.143	-0.295
LACO	587293.291	3552483.348	10.495
LADR	472429.534	3412501.844	43.547
LAFD	637969.032	3501239.951	1.469
LALG	405119.783	3537892.490	46.059
LAMO	590595.629	3599401.419	3.176
LANA	490268.986	3515412.332	33.251
LAOG	649134.348	3636983.374	10.681
LAOK	532520.371	3409183.609	15.528
LARU	537017.713	3602973.229	59.291
LASH	456478.792	3652064.575	64.314
LASV	429484.881	3597330.479	53.383
LESV	474362.005	3445422.042	76.965
LPS1	473125.491	3576858.068	62.421
LSUA	555999.464	3449563.287	6.029
LTEC	532566.850	3597764.154	73.864
OAKH	532810.405	3409205.499	21.541
SHPT	422650.271	3591579.199	54.699
SHRV	433754.120	3588060.958	38.008
TXC1	390183.510	3520370.670	70.729
TXCR	307787.576	3720941.366	106.248
TXHP	417719.888	3466925.160	67.402
TXLF	336561.663	3470370.568	78.739
TXLG	333657.199	3601048.299	88.652
TXMA	378989.780	3600505.512	80.372
TXMV	292874.542	3671424.368	133.722
TXNC	341778.482	3504822.335	105.712
TXRU	298684.342	3518561.664	147.256

Table 4 – Base stations used to control lidar acquisition

AIRBORNE GPS KINEMATIC

Airborne Imaging

Airborne GNSS data was processed using the Applanix POSPac MMS software suite and Novatel's GrafNav software. Flights were flown with a minimum of 6 satellites in view (13° above the horizon) and with a PDOP of better than 4. Distances from at least one base station to aircraft were kept to a maximum of 40km. For all flights, the GNSS data can be classified as excellent, with GNSS residuals of 3cm average or better but no larger than 10cm being recorded.

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

Leading Edge Geomatics

Airborne GPS data was processed using the POSPac kinematic On-The-Fly (OTF) software suite. Flights were flown with a minimum of 6 satellites in view (13° above the horizon) and with a PDOP of better than 4. Distances from base station to aircraft were kept to a maximum of 70 km.

For all flights, the GPS data can be classified as excellent, meaning GPS residuals have an average of 3cm or better and no GPS residuals larger than 10cm are recorded.

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

GENERATION AND CALIBRATION OF LASER POINTS (RAW DATA)

The initial step of calibration is to verify availability and status of all needed GPS and Laser data against field notes and compile any data if not complete.

Subsequently the mission points are output using Riegl's RiProcess, initially with default values from Riegl or the last mission calibrated for the system. The initial point generation for each mission calibration is verified within Microstation/Terrascan for calibration errors. If a calibration error greater than specification is observed within the mission, the roll, pitch and scanner scale corrections that need to be applied are calculated. The missions with the new calibration values are regenerated and validated internally once again to ensure quality.

Data collected by the lidar unit is reviewed for completeness, acceptable density and to make sure all data is captured without errors or corrupted values. In addition, all GPS, aircraft trajectory, mission information, and ground control files are reviewed and logged into a database.

On a project level, a supplementary coverage check is carried out to ensure no data voids unreported by Field Operations are present.

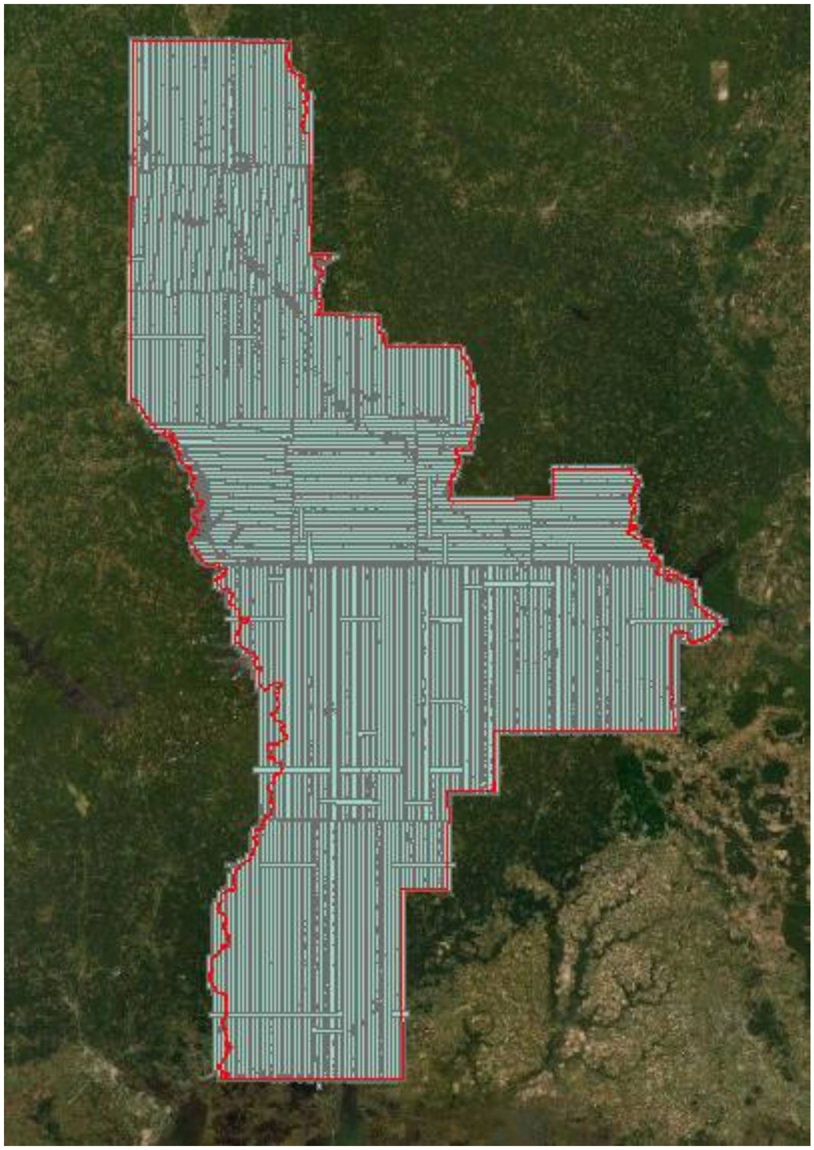


Figure 3 – Lidar swath output showing complete coverage.

BORESIGHT AND RELATIVE ACCURACY

The initial points for each mission calibration are inspected for flight line errors, flight line overlap, slivers or gaps in the data, point data minimums, or issues with the lidar unit or GPS. Roll, pitch and scanner scale are optimized during the calibration process until the relative accuracy is met.

Relative accuracy and internal quality are checked throughout the project area by rasterizing points from all lines. Vertical differences between ground surfaces of each line are displayed. Color scale is adjusted so that errors greater than the specifications are flagged. Cross sections are visually inspected across each block to validate point to point, flight line to flight line and mission to mission agreement.

For this project the specifications used are as follow:

Relative accuracy <= 6 cm maximum difference within individual swaths and <=8 cm RMSDz between adjacent and overlapping swaths.

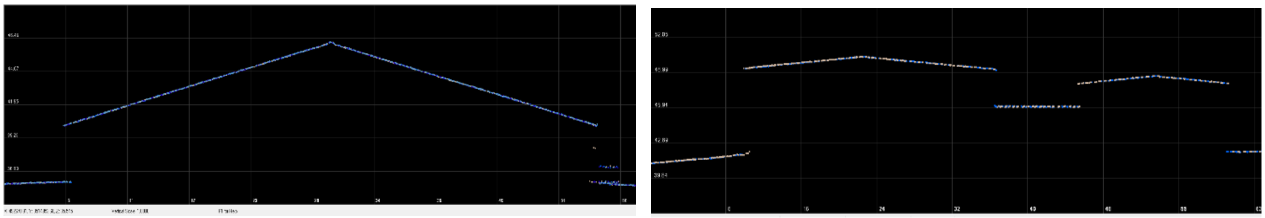


Figure 4 – Profile views showing correct roll and pitch adjustments.

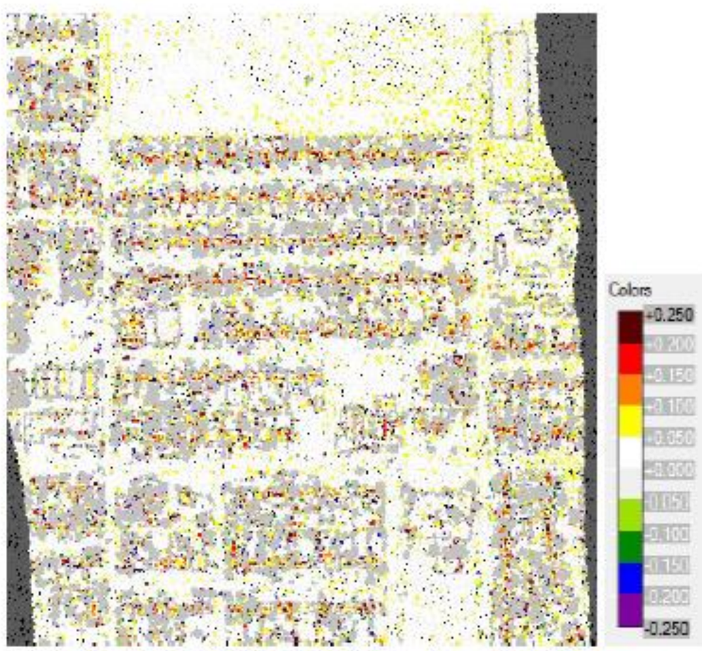


Figure 5 – QC block colored by distance to ensure accuracy at swath edges.

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

PRELIMINARY VERTICAL ACCURACY ASSESSMENT

A preliminary $RMSE_z$ error check is performed by Airborne Imagery and Leading Edge Geomatics at this stage of the project life cycle in the raw lidar dataset against GPS static and kinematic data and compared to $RMSE_z$ project specifications. The lidar data is examined in non-vegetated, flat areas away from breaks. Lidar ground points for each flight line generated by an automatic classification routine are used.

Prior to delivery to Dewberry, the elevation data was verified internally to ensure it met Non-vegetated Vertical Accuracy (NVA) requirements ($RMSE_z \leq$ 10 cm and $Accuracy_z$ at the 95% confidence level ≤ 19.6 cm) when compared to static and kinematic GPS checkpoints. Below is a summary for the test:

Airborne Imagery calibrated Sabine lidar dataset was tested to 0.08 m vertical accuracy at 95% confidence level based on $RMSE_z$ (0.041 m x 1.9600) when compared 8754 GNSS kinematic check points collected. Leading Edge Geomatics calibrated Sabine lidar dataset was tested to 0.09 m vertical accuracy at 95% confidence level based on $RMSE_z$ (0.047 m x 1.9600) when compared to 1152 GNSS kinematic check points collected.

The following are the final statistics for the GNSS kinematic check points used by Airborne Imagery and Leading Edge Geomatics to internally verify vertical accuracy.

100 % of Totals	# of Points	RMSEz (m) NVA Spec=0.1 m	NVA at 95% Spec=0.196 m	Mean (m)	Std Dev (m)	Min (m)	Max (m)
Non-Vegetated Terrain	8754	0.041	0.080	0.000	0.041	-0.156	0.184

Table 5 – Airborne Imagery GNSS Kinematic Check Points Vertical Accuracy Results

100 % of Totals	# of Points	RMSEz (m) NVA Spec=0.1 m	NVA at 95% Spec=0.196 m	Mean (m)	Std Dev (m)	Min (m)	Max (m)
Non-Vegetated Terrain	1152	0.046	0.091	0.0202	0.042	-0.329	0.119

Table 6 – Leading Edge Geomatics GNSS Kinematic Check Points Vertical Accuracy Results

Overall the calibrated lidar data products collected by Airborne Imagery and Leading Edge Geomatics meet or exceed the requirements set out in the Statement of Work. The quality control requirements of Airborne Imagery and Leading Edge Geomatics quality management program were adhered to throughout the acquisition stage for this project to ensure product quality.

Lidar Processing & Qualitative Assessment

INITIAL PROCESSING

Once Dewberry receives the calibrated swath data from the acquisition provider, Dewberry performs several validations on the dataset prior to starting full-scale production on the project. These validations include vertical accuracy of the swath data, inter-swath (between swath) relative accuracy validation, intra-swath (within a single swath) relative accuracy validation, verification of horizontal alignment between swaths, and confirmation of point density and spatial distribution. This initial assessment allows Dewberry to determine if the data are suitable for full-scale production. Addressing issues at this stage allows the data to be corrected while imposing the least disruption possible on the overall production workflow and overall schedule.

Final Swath Vertical Accuracy Assessment

Once Dewberry received the calibrated swath data from Airborne Imaging Inc.and Leading Edge Geomatics, Dewberry tested the vertical accuracy of the non-vegetated terrain swath data prior to additional processing. Dewberry tested the vertical accuracy of the swath data using the two hundred and nine vegetated (open terrain and urban) independent survey check points. The vertical accuracy is tested by comparing survey checkpoints in non-vegetated terrain to a triangulated irregular network (TIN) that is created from the raw swath points. Only checkpoints in non-vegetated terrain can be tested against raw swath data because the data has not undergone classification techniques to remove vegetation, buildings, and other artifacts from the ground surface. Checkpoints are always compared to interpolated surfaces from the lidar point cloud because it is unlikely that a survey checkpoint will be located at the location of a discrete lidar point. Dewberry typically uses LP360 software to test the swath lidar vertical accuracy, Terrascan software to test the classified lidar vertical accuracy, and Esri ArcMap to test the DEM vertical accuracy so that three different software programs are used to validate the vertical accuracy for each project. Project specifications require an NVA of 19.6 cm based on the $RMSE_z$ (10 cm) x 1.96. The dataset for the Sabine Lidar Project satisfies this criterion. This raw lidar swath data set was tested to meet ASPRS Positional Accuracy Standards for Digital Geospatial Data (2014) for a 10 cm $RMSE_z$ Vertical Accuracy Class. Actual NVA accuracy was found to be $RMSE_z$ = 4.8 cm, equating to +/- 9.3 cm at 95% confidence level. The table below shows all calculated statistics for the raw swath data.

100 % of Totals	# of Points	$RMSE_z$ NVA Spec=0.10 m	NVA –Non-vegetated Vertical Accuracy ($RMSE_z$ x 1.9600) Spec=0.196 m	Mean (m)	Median (m)	Skew	Std Dev (m)	Min (m)	Max (m)	Kurtosis
Non-Vegetated Terrain	209	0.048	0.093	-0.003	-0.001	-0.374	0.048	-0.142	0.107	0.032

Table 7: NVA at 95% Confidence Level for Raw Swaths

Inter-Swath (Between Swath) Relative Accuracy

Dewberry verified inter-swath or between swath relative accuracy of the dataset by creating Delta-Z (DZ) orthos. According to the SOW, USGS Lidar Base Specifications v1.2, and ASPRS Positional Accuracy Standards for Digital Geospatial Data, 10 cm Vertical Accuracy Class or QL2 data must meet inter-swath relative accuracy of 8 cm RMSDz or less with maximum differences less than 16 cm. These measurements are to be taken in non-vegetated and flat open terrain using single or only returns from all classes. Measurements are calculated in the DZ orthos on 1-meter pixels or cell sizes. Areas in the dataset where overlapping flight lines are within 8 cm of each other within each pixel are colored green, areas in the dataset where overlapping flight lines have elevation differences in each pixel between 8 cm to 16 cm are colored yellow, and areas in the dataset where overlapping flight lines have elevation differences in each pixel greater than 16 cm are colored red. Pixels that do not contain points from overlapping flight lines are colored according to their intensity values. Areas of vegetation and steep slopes (slopes with 16 cm or more of valid elevation change across 1 linear meter) are expected to appear yellow or red in the DZ orthos. If the project area is heavily vegetated, Dewberry may also create DZ Orthos from the initial ground classification only, while keeping all other parameters consistent. This allows Dewberry to review the ground classification relative accuracy beneath vegetation and to ensure flight line ridges or other issues do not exist in the final classified data.

Flat, open areas are expected to be green in the DZ orthos. Large or continuous sections of yellow or red pixels can indicate the data was not calibrated correctly or that there were issues during acquisition that could affect the usability of the data, especially when these yellow/red sections follow the flight lines and not the terrain or areas of vegetation. The DZ orthos for Sabine are shown in the figure below; this project meets inter-swath relative accuracy specifications.

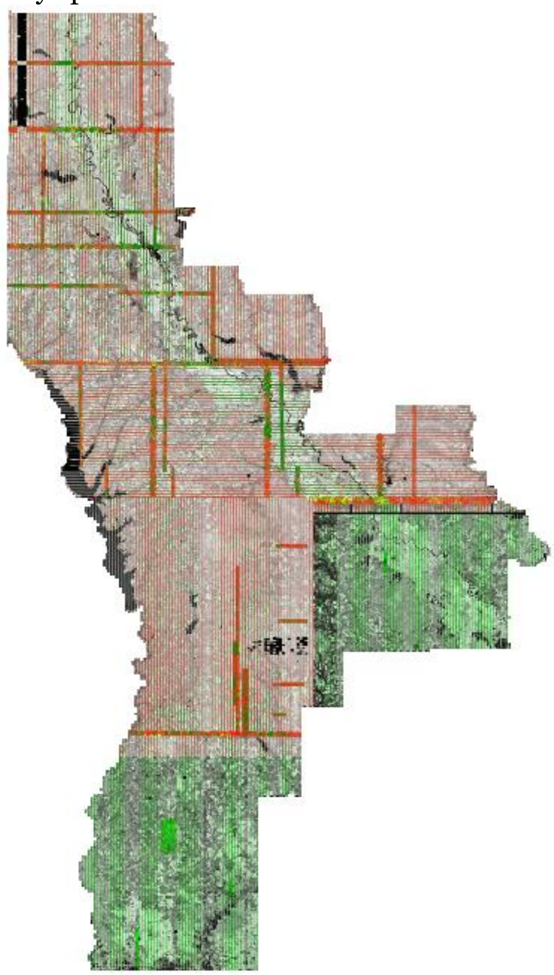


Figure 6– Single return DZ Orthos for the LA Sabine. Inter-swath relative accuracy passes specifications.

Intra-Swath (Within a Single Swath) Relative Accuracy

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

Figure 7–Intra-swath relative accuracy. Image a) shows the full project area; areas where the maximum difference is ≤6 cm per pixel within each swath are colored green and areas exceeding 6 cm are colored red. Image b) shows a large portion of the dataset; flat, open areas are colored green as they are within 6 cm whereas sloped terrain is colored red because it exceeds 6 cm maximum difference, as expected, due to actual slope/terrain change. Image c) is a close-up of a flat area. With the exception of a few trees (shown in red as the elevation/height difference in vegetated areas will exceed 6 cm) this open flat area is acceptable for repeatability testing. Intra-swath relative accuracy passes specifications.

Horizontal Alignment

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

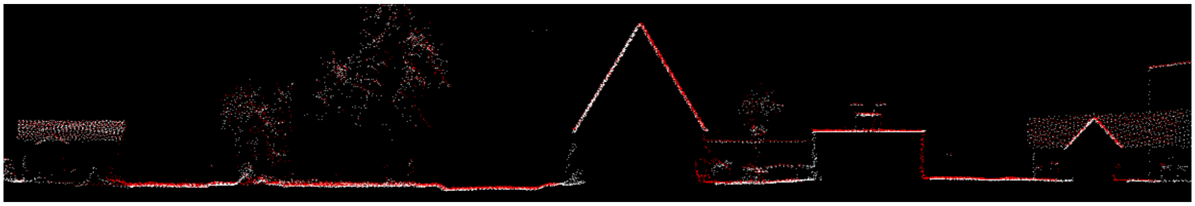


Figure 8– Horizontal Alignment. Two separate flight lines differentiated by color (Red/White) are shown in this profile. There is no visible offset between these two flight lines. No horizontal alignment issues were identified.

Point Density and Spatial Distribution

The required Nonaggregate Nominal Point Spacing (NPS) for this project is no greater than 0.71 meters, which equates to an nonaggregate Nominal Point Density (NPD) of 2 points per square meter or greater. Density calculations were performed using first return data only located in the geometrically usable center portion (typically ~90%) of each swath. By utilizing statistics, the project area was determined to have an NPS of 0.17 meters or an NPD of 7.29 points per square meter which satisfies the project requirements. A visual review of a 1-square meter density grid (figure below) shows that there are some 1-meter cells that do not contain 2 points per square meter (red areas) due to the irregular spacing of lidar point cloud data. Most 1-sqaure meter cells contain at least 2 points per square meter (green areas) and when density is viewed/analyzed by representative 1-square kilometer areas (to account for the irregular spacing of lidar point clouds), density passes with no issues.

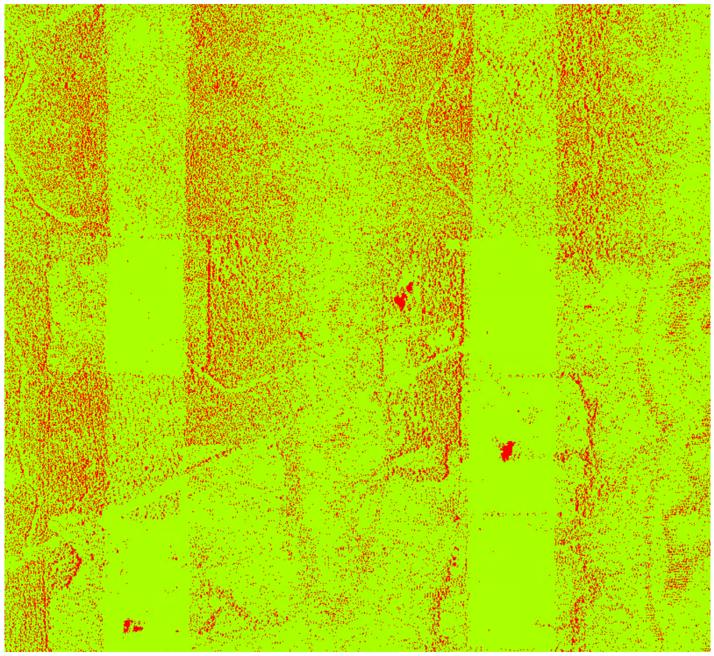


Figure 9– 1-square meter density grid. There are some 1-meter cells that do not contain 2 points per square meter (red areas) due to the irregular spacing of lidar point cloud data. Most 1-sqaure meter cells contain at least 2 points per square meter (green areas) showing there are no systematic density issues. When density is viewed/analyzed by representative 1-square kilometer areas, density passes with no issues.

The spatial distribution of points must be uniform and free of clustering. This specification is tested by creating a grid with cell sizes equal to the design NPS*2. ArcGIS tools are then used to calculate the number of first return points of each swath within each grid cell. At least 90% of the cells must contain 1 lidar point, excluding acceptable void areas such as water or low NIR reflectivity features, i.e. some asphalt and roof composition materials. This project passes spatial distribution requirements, as shown in the image below.

Figure 10– Spatial Distribution. All cells (2*NPS cellsize) containing at least one lidar point are colored green. Cells that do not contain a lidar point, including water bodies which are acceptable NoData area, are colored red. Without removing acceptable NoData areas due to water, 96.3% of cells contain at least one lidar point.

DATA CLASSIFICATION AND EDITING

Once the calibration, absolute swath vertical accuracy, and relative accuracy of the data was confirmed, Dewberry utilized a variety of software suites for data processing. The data was processed using GeoCue and TerraScan software. The initial step is the setup of the GeoCue project, which is done by importing a project defined tile boundary index encompassing the entire project area. The acquired 3D laser point clouds, in LAS binary format, were imported into the GeoCue project and tiled according to the project tile grid. Once tiled, the laser points were classified using a proprietary routine in TerraScan. This routine classifies any obvious low outliers in the dataset to class 7 and high outliers in the dataset to class 18. Points along flight line edges that are geometrically unusable are identified as withheld and classified to a separate class so that they will not be used in the initial ground algorithm. After points that could negatively affect the ground are removed from class 1, the ground layer is extracted from this remaining point cloud. The ground extraction process encompassed in this routine takes place by building an iterative surface model.

This surface model is generated using three main parameters: building size, iteration angle and iteration distance. The initial model is based on low points being selected by a "roaming window" with the assumption that these are the ground points. The size of this roaming window is determined by the building size parameter. The low points are triangulated, and the remaining points are evaluated and subsequently added to the model if they meet the iteration angle and distance constraints. This process is repeated until no additional points are added within iterations. A second critical parameter is the maximum terrain angle constraint, which determines the maximum terrain angle allowed within the classification model.

Each tile was then imported into Terrascan and a surface model was created to examine the ground classification. Dewberry analysts visually reviewed the ground surface model and corrected errors in the ground classification such as vegetation, buildings, and bridges that were present following the initial processing conducted by Dewberry. Dewberry analysts employ 3D visualization techniques to view the point cloud at multiple angles and in profile to ensure that non-ground points are removed from the ground classification. Bridge decks are classified to class 17 using bridge breaklines compiled by Dewberry. After the ground classification corrections were completed, the dataset was processed through a water classification routine that utilizes breaklines compiled by Dewberry to automatically classify hydro features. The water classification routine selects ground points within the breakline polygons and automatically classifies them as class 9, water. During this water classification routine, points that are within 1x NPS or less of the hydrographic features are moved to class 10, an ignored ground due to breakline proximity. Overage points are then identified in Terrascan and GeoCue is used to set the overlap bit for the overage points and the withheld bit is set on the withheld points previously identified in Terrascan before the ground classification routine was performed.

The lidar tiles were classified to the following classification schema:

- Class 1 = Unclassified, used for all other features that do not fit into the Classes 2, 7, 9, 10, 17, or 18, including vegetation, buildings, etc.
- Class 2 = Bare-Earth Ground
- Class 7 = Low Noise
- Class 9 = Water, points located within collected breaklines
- Class 10 = Ignored Ground due to breakline proximity
- Class 17 = Bridge Decks
- Class 18 = High Noise
- Class 22 = Temporal

After manual classification, the LAS tiles were peer reviewed and then underwent a final QA/QC. After the final QA/QC and corrections, all headers, appropriate point data records, and variable length records, including spatial reference information, are updated in GeoCue software and then verified using proprietary Dewberry tools.

Lidar Qualitative Assessment

Dewberry's qualitative assessment utilizes a combination of statistical analysis and interpretative methodology or visualization to assess the quality of the data for a bare-earth digital terrain model (DTM). This includes creating pseudo image products such as lidar orthos produced from the intensity returns, Triangular Irregular Network (TIN)'s, Digital Elevation Models (DEM) and 3-dimensional models as well as reviewing the actual point cloud data. This process looks for anomalies in the data, areas where man-made structures or vegetation points may not have been classified properly to produce a bare-earth model, and other classification errors. This report will present representative examples where the lidar and post processing had issues as well as examples of where the lidar performed well.

VISUAL REVIEW

The following sections describe common types of issues identified in lidar data and the results of the visual review for Sabine.

Data Voids

The LAS files are used to produce density grids using ArcMap . Grid spacing is based on the project density deliverable requirement for un-obscured areas. Acceptable voids (areas with no lidar returns in the LAS files) that are present in the majority of lidar projects include voids caused by bodies of water. No unacceptable voids are present in the Sabine lidar project.

Artifacts

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

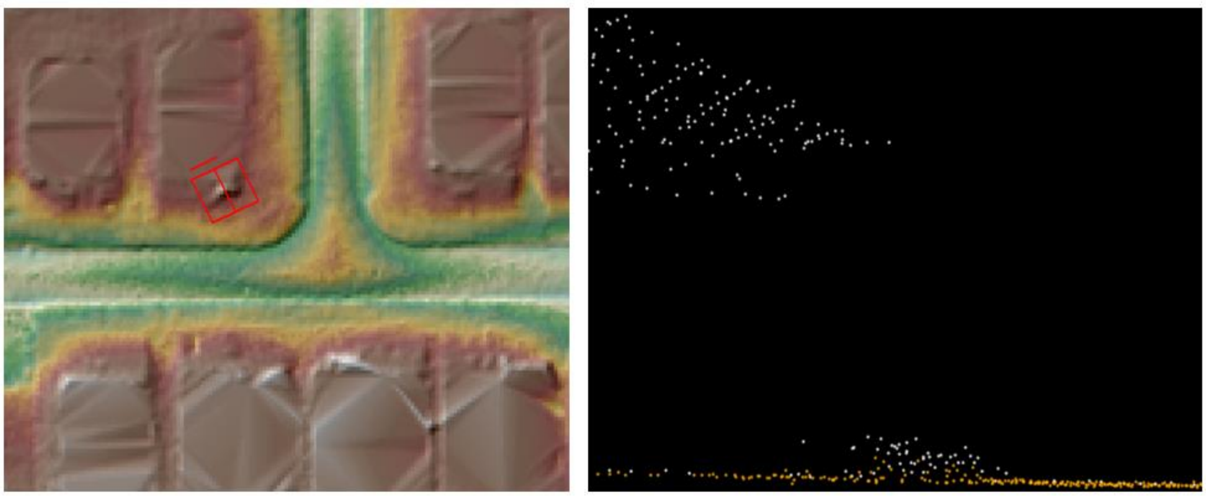


Figure 11 – Tile number 15RVP8438. Profile with points colored by class (class 1=white, class 2=orange) is shown in the right view and a DEM of the surface is shown in the left view. A limited number of these small features are still classified as ground but do not impact the usability of the dataset.

Bridge Removal Artifacts

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

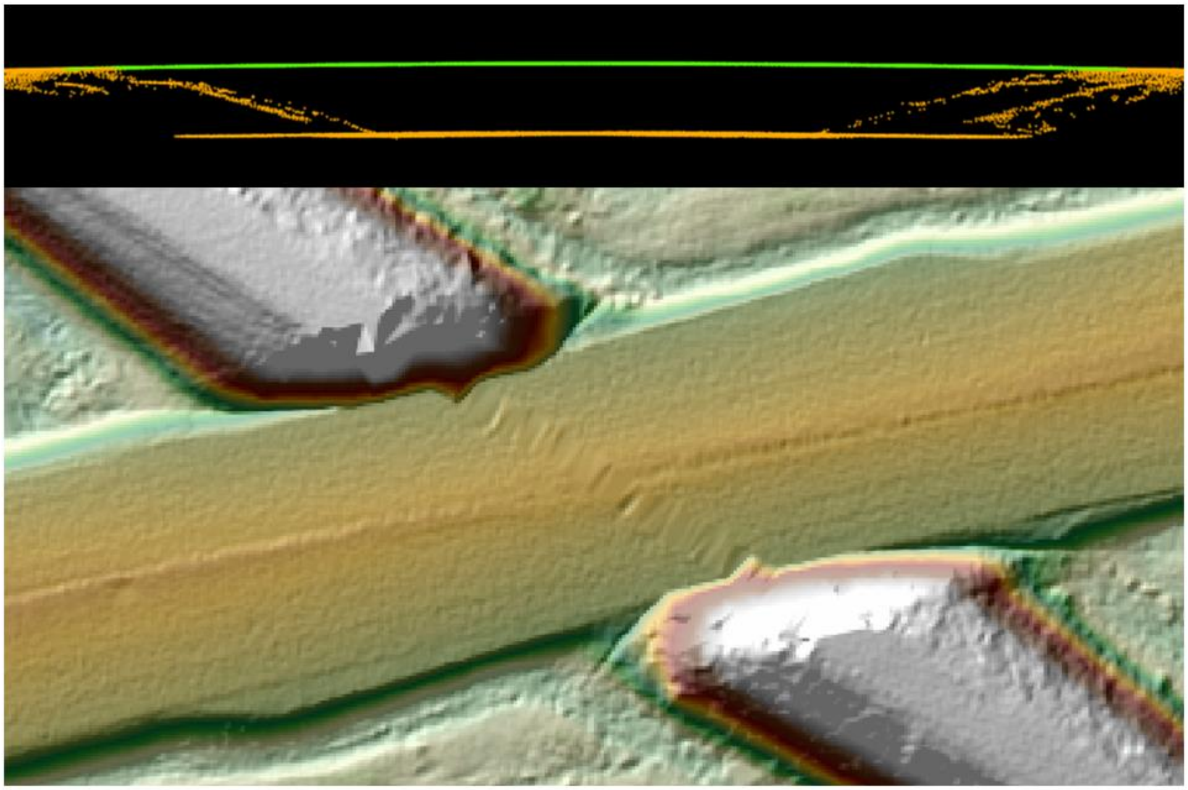


Figure 12 – Tile number 15RVP5140. The DEM in the bottom view shows an area where a bridge has been removed from ground. The surface model must make a continuous model and in order to do so, points are connected through interpolation. This results in less detail where the surface must be interpolated. The profile in the top view shows the lidar points of this particular feature colored by class. All bridge points(green) have been removed from ground (orange).

Culverts and Bridges

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

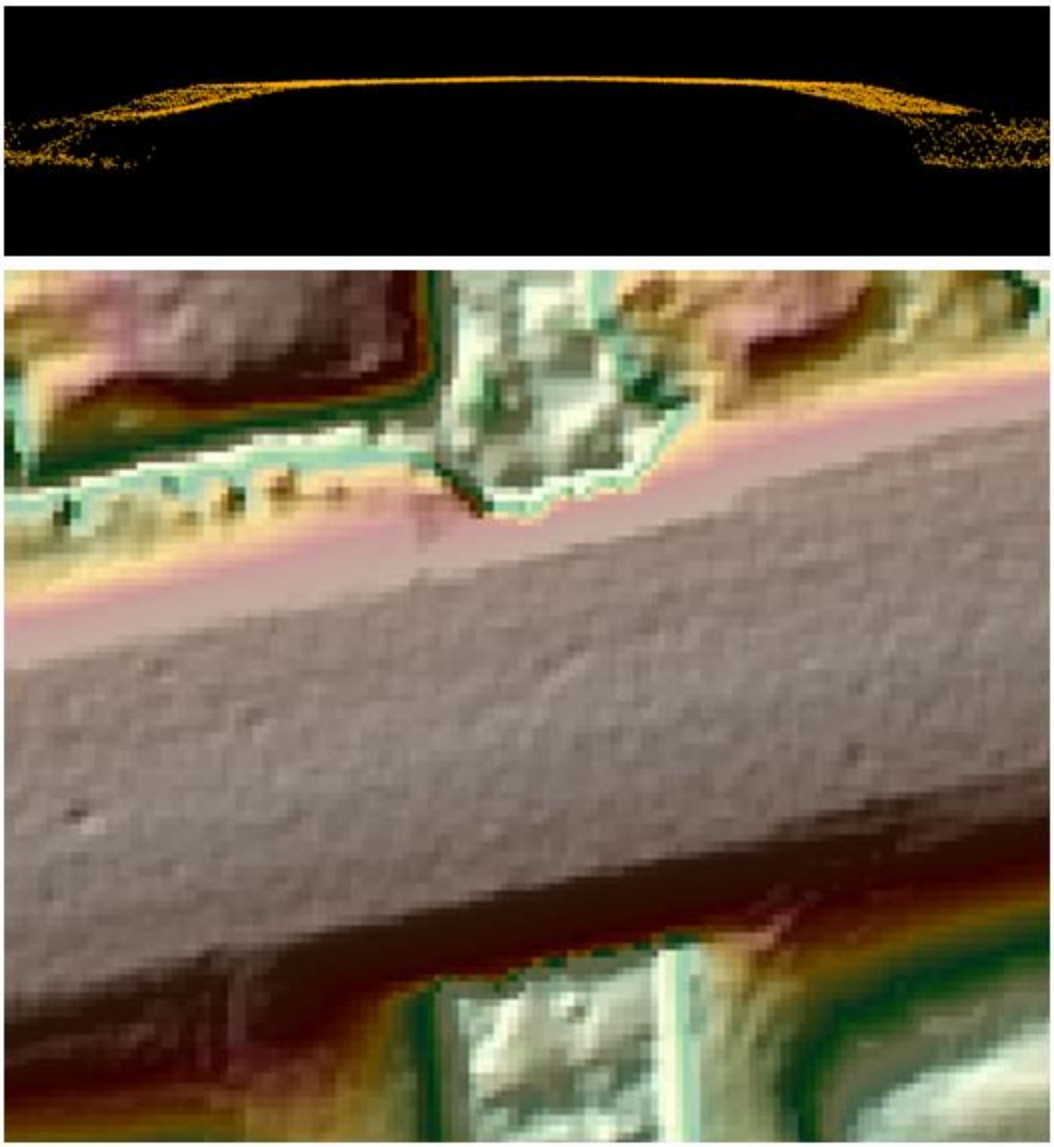


Figure 13– Tile number 15RVP4840. Profile with points colored by class (class 2=orange) is shown in the top view and the DEM is shown in the bottom view. This culvert remains in the bare earth surface. Bridges have been removed from the bare earth surface and classified to class 17.

In Ground Structures

In ground structures exist within the project area. These types of structures occur mainly on military bases and in facilities designed for munitions testing and storage. These features are correctly included in the ground classification.

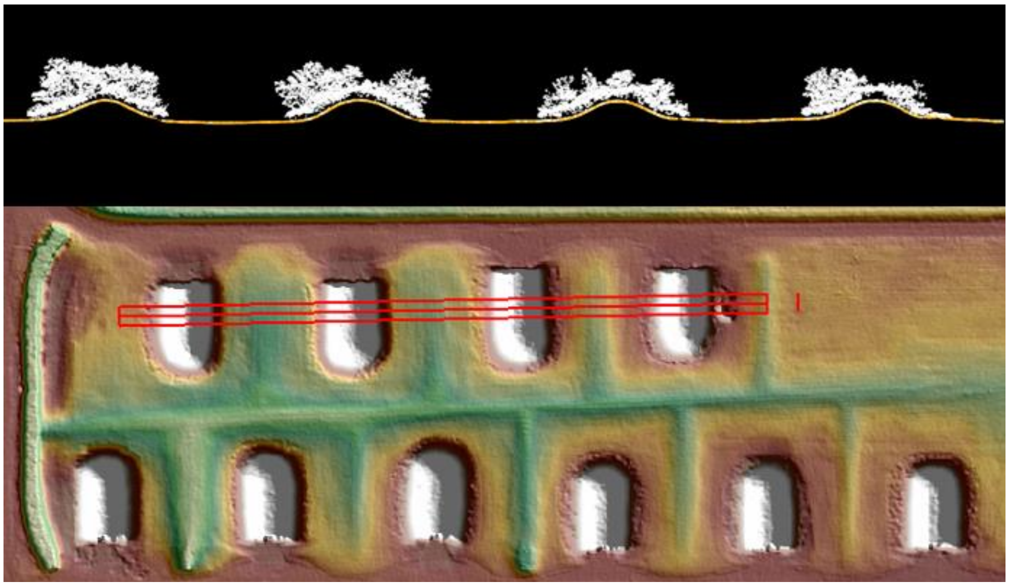


Figure 14 – Tiles 15RVP8539. Profile with the points colored by class (class 1=white, class 2=orange) is shown in the top view and a DEM of the surface is shown in the bottom view. These features are correctly included in the ground classification.

Dirt Mounds

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

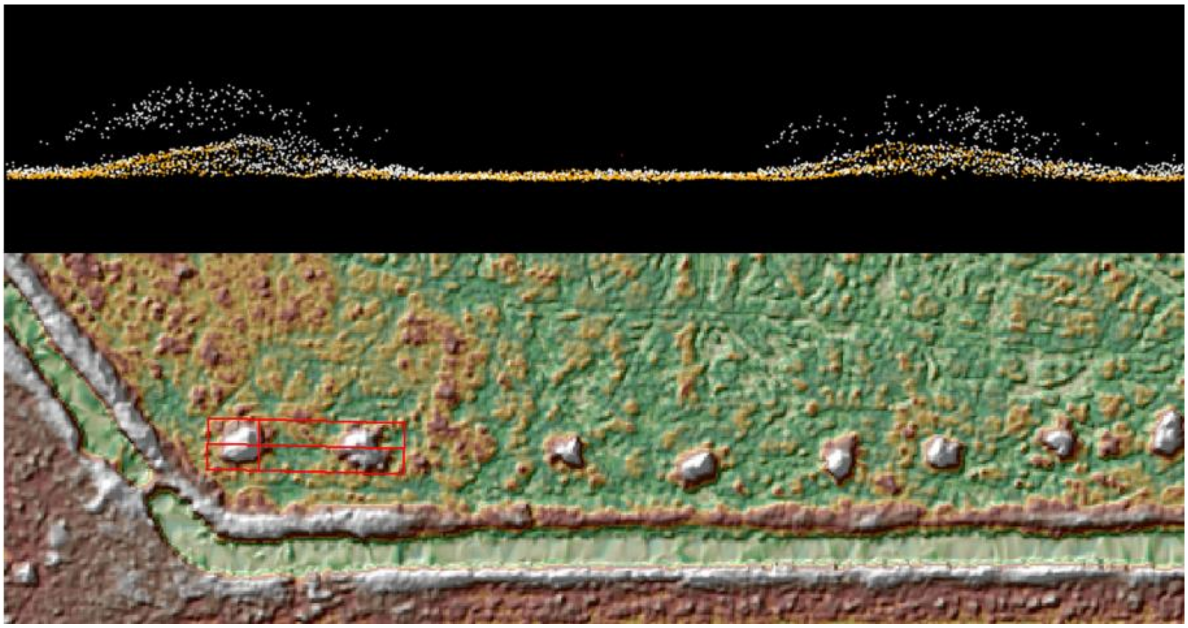


Figure 15 - Tile 15RVP8639. Profile with the points colored by class (class 1=white, class 2=orange) is shown in the top view and a DEM of the surface is shown in the bottom view. These features are correctly included in the ground classification.

Elevation Change Within Breaklines

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

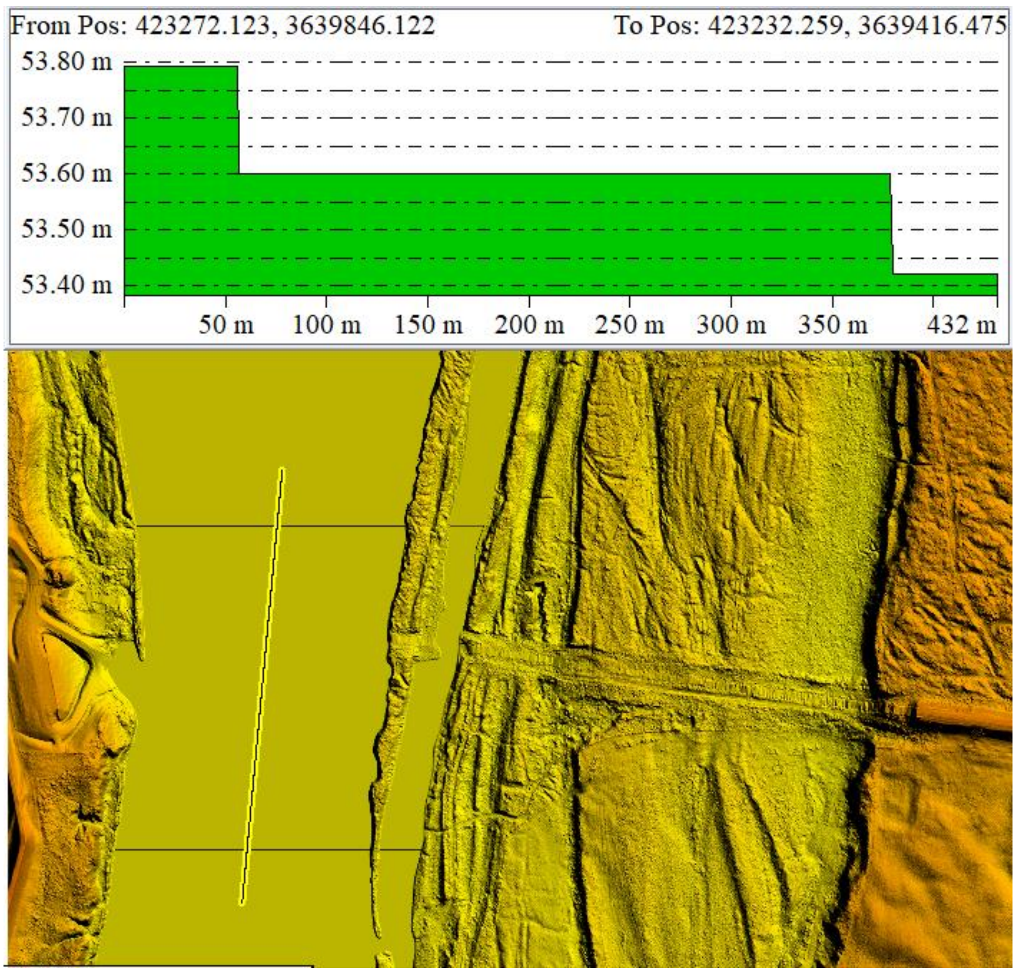


Figure 16 – Tile number 15SVS 2339. Elevation change has been stair stepped. The steps are flat from bank to bank and flow consistently downhill.

Tree Farms and Irrigated Agricultural Areas

The LA Sabine region is a highly productive timber and agricultural area. This is apparent throughout the project area due to the numerous small areas of standing water present at the time the lidar was acquired. Dewberry collected all areas of standing water greater than or equal to 2 acres. Areas of standing water that did not meet the 2-acre size criteria were not collected. Examples are shown below. Timber areas form structured areas with numerous small berms where trees are planted in rows.

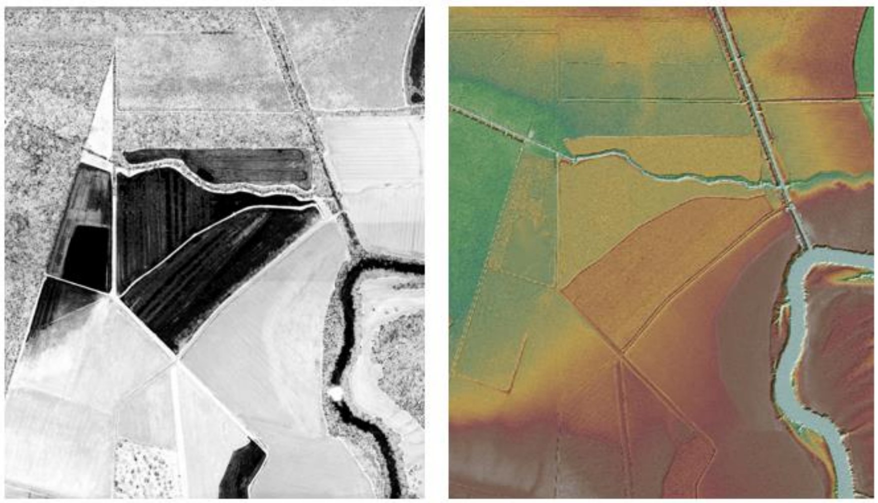


Figure 17 – Tiles15RWQ0994 and 15RWQ0995. All lakes, ponds, irrigated agricultural fields, aquaculture areas and other areas of standing water greater than or equal to 2 acres are included in the delivered breaklines.

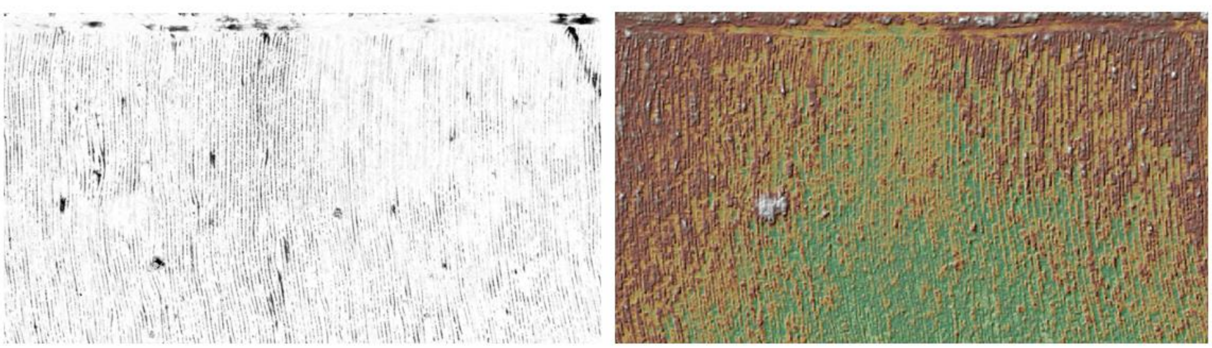


Figure 18 – Tiles15RWR5716. Tree farms form over large areas with small tiny berms where trees are planted in rows.

Bayous and Marsh Areas

It is sometimes difficult to determine true ground in low wet areas; the lowest points available are used to represent ground. Bayous and marsh areas are present within the project area and were not collected with breaklines as they are not open bodies of water. As these areas are not included in the collected breaklines, bayous and marsh areas were not flattened in the final DEMs. While low points are used to determine ground in marsh areas, there is often greater variation within the low points due to wet soils that cause greater interpolation between points and undulating or uneven ground. An example is shown below.

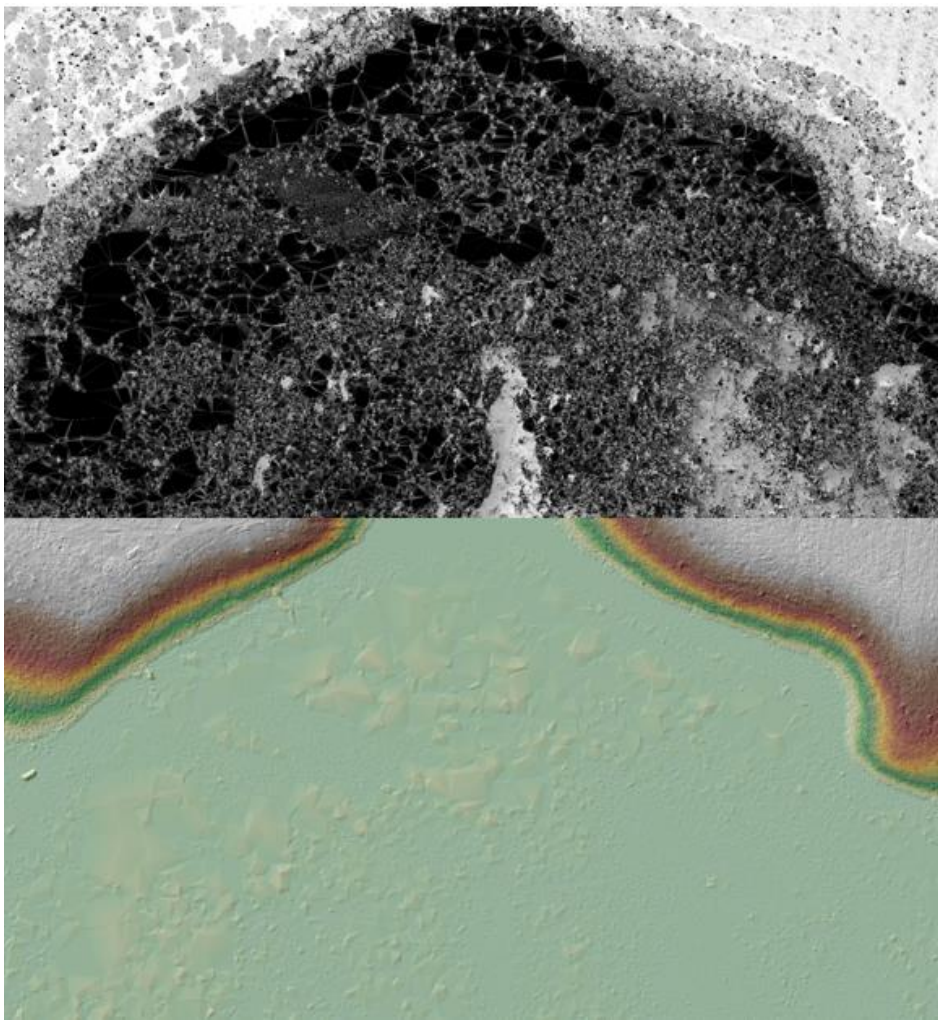


Figure 19 - Tiles 15RWR0829. The intensity on the top shows a marsh area that was not included in the collected breaklines. The same area is shown in the DEM on the bottom. Due to wet soils and broken terrain, the point density in marsh areas is sparser than surrounding areas and there is more variation in the low points representing ground.

Temporal Line Ridges

Ridges occur when there is a difference between the elevations of adjoining flight lines or swaths over hydrographic features such as bayous and marshes due to the tidal influences on the water and little to no elevation changes throughout the dataset. An example of a visible ridge that is within tolerance is shown below. A polygon shapefile, named "Temporal," has been delivered with the project data. This shapefile identifies locations where temporal changes occur.

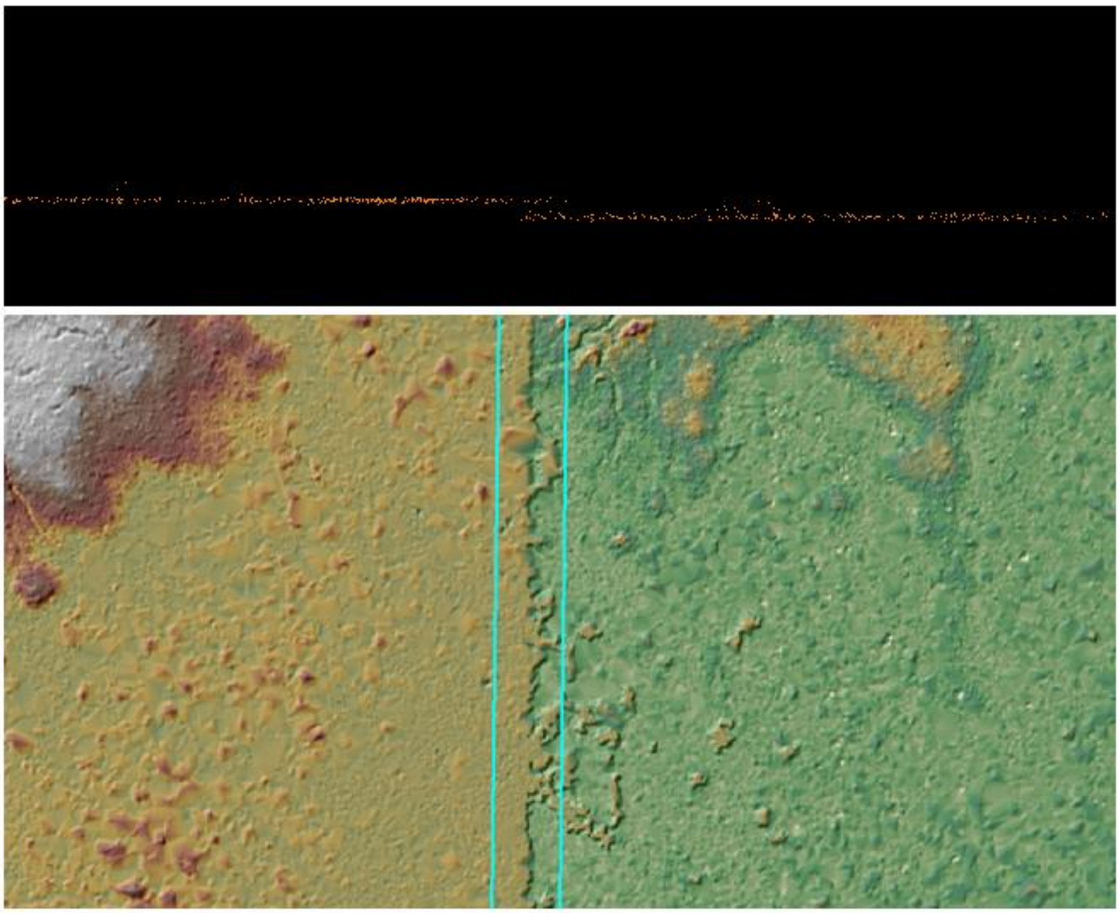


Figure 20– Tile 15RWR0839. An example of a temporal ridge identified by the blue polygon temporal shapefile. Profile with the points colored by class (class 2=orange) is shown in the top view and a DEM is shown in the bottom view.

FORMATTING

After the final QA/QC is performed and all corrections have been applied to the dataset, all lidar files are updated to the final format requirements and the final formatting, header information, point data records, and variable length records are verified using Dewberry proprietary tools. The table below lists some of the main lidar header fields that are updated and verified.

Classified Lidar Formatting		
Parameter	**Requirement**	**Pass/Fail**
LAS Version	1.4	Pass
Point Data Format	Format 6, 7, 8,9, or 10	Pass
Coordinate Reference System	NAD83 (2011) UTM Zone 15, meters and NAVD88 (Geoid 12B), meters in WKT Format	Pass
Global Encoder Bit	Should be set to 17 for Adjusted GPS Time	Pass
Time Stamp	Adjusted GPS Time (unique timestamps)	Pass
System ID	Should be set to the processing system/software and is set to NIIRS10 for GeoCue software	Pass
Multiple Returns	The sensor shall be able to collect multiple returns per pulse and the return numbers are recorded	Pass
Intensity	16 bit intensity values are recorded for each pulse	Pass
Classification	Required Classes include: Class 1: Unclassified Class 2: Ground Class 7: Low Noise Class 9: Water Class 10: Ignored Ground Class 17: Bridge Decks Class 18: High Noise	Pass
Overlap and Withheld Points	Overlap (Overage) and Withheld points are set to the Overlap and Withheld bits	Pass
Scan Angle	Recorded for each pulse	Pass
XYZ Coordinates	Unique Easting, Northing, and Elevation coordinates are recorded for each pulse	Pass

Derivative Lidar Products

USGS required several derivative lidar products to be created. Each type of derived product is described below.

Lidar Positional Accuracy

BACKGROUND

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

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

SURVEY VERTICAL ACCURACY CHECKPOINTS

For the vertical accuracy assessment, three hundred and fifty-nine (359) check points were surveyed for the project and are located within bare earth/open terrain, grass/weeds/crops, and forested/fully grown land cover categories. Please see appendix A to view the survey report which details and validates how the survey was completed for this project.

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

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

Point ID	NAD83(2011) UTM Zone 15		NAVD88 (Geoid 12B)
	Easting X (m)	**Northing Y (m)**	**Elevation (m)**
NVA-1	414917.227	3651314.612	87.557
NVA-2	424662.824	3649304.181	60.852
NVA-3	435815.505	3648510.155	101.208
NVA-4	446169.513	3648741.832	74.392
NVA-5	449736.432	3641079.451	71.25
NVA-6	436410.117	3641016.838	107.789
NVA-7	425971.151	3641187.522	75.732
NVA-8	415660.107	3638428.464	66.332
NVA-9	407869.564	3637628.098	76.644

NVA-10	403290.679	3628138.816	69.23
NVA-11	416944.772	3631073.179	83.598
NVA-12	427532.149	3631510.895	70.032
NVA-13	441095.452	3630910.306	124.054
NVA-14	450922.232	3631090.993	70.346
NVA-15	451602.151	3619769.196	61.036
NVA-16	444391.555	3619805.419	72.304
NVA-17	431137.052	3621567.37	65.146
NVA-18	420908.672	3620240.458	56.098
NVA-19	410341.037	3620505.866	66.178
NVA-20	403509.178	3611861.415	67.363
NVA-21	417127.231	3611264.254	70.696
NVA-22	430310.537	3609942.012	54.337
NVA-23	444273.608	3607283.292	67.992
NVA-24	451703.116	3612068.592	72.711
NVA-25	455849.198	3599782.492	61.187
NVA-26	441023.789	3601385.783	50.205
NVA-27	432094.96	3599701.239	52.951
NVA-28	415572.136	3601948.135	62.946
NVA-29	405347.82	3603100.308	77.577
NVA-30	404913.207	3591109.517	80.642
NVA-31	418577.142	3591468.904	71.051
NVA-32	429709.535	3591365.618	66.527
NVA-33	442408.838	3589582.261	48.115
NVA-34	452092.155	3592652.093	63.735
NVA-35	456269.614	3583985.186	58.41
NVA-36	444090.31	3583568.841	46.853
NVA-37	433048.981	3581597.638	61.431
NVA-38	418686.285	3581431.116	57.076
NVA-39	405871.764	3580396.545	77.538
NVA-40	407283.447	3570671.16	122.066
NVA-41	422901.393	3571974.011	68.18
NVA-42	434980.254	3571896.024	68.667
NVA-43	446801.404	3573370.032	45.723
NVA-44	456489.567	3572070.064	44.537
NVA-45	473832.976	3560967.777	76.902
NVA-46	463262.106	3560833.977	71.604
NVA-47	447700.594	3561936.341	40.194
NVA-48	440443.911	3560752.742	54.002
NVA-49	427705.921	3560260.604	87.287
NVA-50	420706.885	3561249.774	93.826
NVA-51	406275.661	3559336.141	103.596
NVA-52	405521.736	3551300.918	89.048
NVA-53	418146.634	3549587.45	97.144
NVA-54	433094.959	3544667.238	101.408
NVA-55	444670.973	3551450.949	70.644
NVA-56	459366.805	3552592.032	42.617
NVA-57	471404.186	3552891.033	56.256
NVA-58	483268.958	3550759.147	52.109
NVA-59	501219.806	3553181.027	70.675
NVA-60	508610.843	3542504.733	50.903
NVA-61	492231.449	3543056.838	60.666
NVA-62	483584.086	3542842.336	46.169
NVA-63	474329.884	3541317.426	51.992
NVA-64	458786.033	3540868.114	42.001
NVA-65	448939.81	3543536.95	73.93
NVA-66	435406.822	3539208.543	97.986
NVA-67	421292.911	3540605.571	91.962

NVA-68	405542.247	3538156.465	62.052
NVA-69	416738.081	3529992.749	80.215
NVA-70	432818.969	3529849.968	83.938
NVA-71	440290.132	3532736.115	79.976
NVA-72	456268.59	3531211.412	63.797
NVA-73	468038.905	3532927.556	38.513
NVA-74	478794.144	3531909.174	48.998
NVA-75	490582.974	3531237.4	54.676
NVA-76	506865.514	3534096.311	58.396
NVA-77	504245.427	3524109.452	33.006
NVA-78	494133.215	3523608.056	35.08
NVA-79	483448.483	3522823.945	37.647
NVA-80	473475.839	3522381.364	38.349
NVA-81	463135.986	3521814.333	52.77
NVA-82	451552.969	3520779.604	83.642
NVA-83	444079.143	3521547.535	103.601
NVA-84	435224.614	3522107.092	71.3
NVA-85	425166.654	3522188.869	77.506
NVA-86	427581.607	3510645.863	62.242
NVA-87	438019.996	3510656.087	79.229
NVA-88	451785.181	3509119.872	108.379
NVA-89	462764.204	3511541.868	77.522
NVA-90	472949.24	3511135.636	45.075
NVA-91	484831.085	3510150.049	64.494
NVA-92	493707.734	3512975.249	34.993
NVA-93	500374.247	3515518.335	34.102
NVA-94	540235.301	3511805.893	56.308
NVA-95	557288.299	3512407.311	23.712
NVA-96	555551.542	3502354.413	54.546
NVA-97	542434.826	3500612.174	77.538
NVA-98	529077.505	3502942.437	34.586
NVA-99	510103.512	3503870.067	45.551
NVA-100	492611.392	3502423.582	48.723
NVA-101	480845.213	3501974.04	52.161
NVA-102	465216.355	3500679.362	83.731
NVA-103	453401.755	3500619.752	104.572
NVA-104	438923.212	3499577.717	59.184
NVA-105	429229.598	3495406.518	66.626
NVA-106	437926.773	3489330.413	62.078
NVA-107	456553.509	3489465.833	94.31
NVA-108	469578.575	3492511.585	87.034
NVA-109	480359.01	3491876.751	65.439
NVA-110	500346.222	3493317.361	31.481
NVA-111	511831.978	3493018.131	30.661
NVA-112	527123.801	3490783.047	34.598
NVA-113	540333.32	3491762.968	69.412
NVA-114	555882.294	3491276.483	55.05
NVA-115	568049.344	3482622.752	25.314
NVA-116	556247.538	3484996.906	54.981
NVA-117	544029.518	3481781.115	52.645
NVA-118	530163.183	3483815.605	29.716
NVA-119	520004.241	3482102.23	55.209
NVA-120	505032.295	3483266.933	34.771
NVA-121	485309.307	3479404.991	109.105
NVA-122	481000.268	3480362.589	108.902
NVA-123	469601.537	3478994.644	116.539
NVA-124	456529.695	3478637.863	77.167
NVA-125	437644.636	3479657.448	80.299

NVA-126	441218.236	3471106.875	71.238
NVA-127	459561.463	3470371.578	87.633
NVA-128	477009.489	3473366.456	116.68
NVA-129	494217.487	3466369.029	81.573
NVA-130	510999.596	3469556.118	79.588
NVA-131	527743.672	3466929.338	28.658
NVA-132	538918.75	3469728.676	25.218
NVA-133	553475.692	3469486.668	46.12
NVA-134	562997.591	3468869.129	53.222
NVA-135	579504.542	3469506.676	22.545
NVA-136	568683.728	3457419.892	31.453
NVA-137	554303.402	3455814.502	24.867
NVA-138	540756.34	3455833.13	48.272
NVA-139	529340.63	3459683.994	54.284
NVA-140	517921.061	3457259.827	70.018
NVA-141	505143.455	3455999.974	80.445
NVA-142	490914.497	3456414.11	96.566
NVA-143	479501.809	3455029.084	108.771
NVA-144	467559.121	3457543.127	102.507
NVA-145	444665.891	3452884.504	60.333
NVA-146	453186.625	3444471.841	87.211
NVA-147	474864.834	3446783.938	75.886
NVA-148	485009.76	3447576.3	108.09
NVA-149	508166.71	3447671.777	77.769
NVA-150	517803.759	3444951.804	57.106
NVA-151	530264.278	3444400.695	60.783
NVA-152	547403.463	3448616.548	33.724
NVA-153	557207.348	3449853.242	22.104
NVA-154	568339.495	3445305.75	18.591
NVA-155	560165.631	3435590.59	21.429
NVA-156	545637.661	3437785.02	57.255
NVA-157	526465.7	3436424.212	46.29
NVA-158	513105.362	3432540.826	70.268
NVA-159	501699.813	3428793.683	62.512
NVA-160	483547.184	3431257.918	94.061
NVA-161	473650.369	3430972.854	83.487
NVA-162	460663.045	3431627.817	82.547
NVA-163	451929.444	3424064.708	30.581
NVA-164	473122.574	3420723.767	68.128
NVA-165	483429.585	3418311.418	61.212
NVA-166	501554.709	3422317.375	56.457
NVA-167	510555.18	3419869.448	44.312
NVA-168	498610.913	3411838.542	53.763
NVA-169	489274.949	3405115.988	37.835
NVA-170	476784.338	3407002.501	47.813
NVA-171	463015.857	3407438.017	57.758
NVA-172	451266.813	3412456.381	31.283
NVA-173	446095.324	3397476.525	26.199
NVA-174	466476.504	3401362.711	43.946
NVA-175	477278.371	3399758.822	47.236
NVA-176	487176.431	3396551.439	40.091
NVA-177	496630.129	3396673.451	26.638
NVA-178	495593.712	3386707.925	33.922
NVA-179	482176.316	3386772.276	37.678
NVA-180	471955.358	3386027.731	40.921
NVA-181	460428.898	3391471.873	44.911
NVA-182	451055.22	3385848.105	40.247
NVA-183	440534.642	3388208.174	23.748

NVA-184	434391.621	3378184.42	27.749
NVA-185	451678.282	3376810.515	30.423
NVA-186	467576.932	3379580.2	32.569
NVA-187	477440.697	3375340.893	25.476
NVA-188	485805.138	3376064.477	16.027
NVA-189	485363.783	3364241.88	7.968
NVA-190	477631.366	3363042.269	8.161
NVA-191	460365.416	3362366.779	17.167
NVA-192	451122.868	3363995.289	22.02
NVA-193	441915.633	3357598.284	12.98
NVA-194	437795.295	3367212.392	15.949
NVA-195	434279.333	3353691.437	7.478
NVA-196	451794.294	3354113.48	6.502
NVA-197	465151.913	3355790.429	6.263
NVA-198	480771.354	3352306.959	6.211
NVA-199	483265.121	3340224.072	3.184
NVA-200	468670.222	3339239.404	4.399
NVA-201	457323.177	3340749.831	3.337
NVA-202	444156.819	3340071.156	4.41
NVA-203	434615.665	3341188.085	2.051
NVA-204	434505.887	3330748.059	2.506
NVA-205	450065.359	3329481.714	1.904
NVA-206	461345.873	3330448.143	0.816
NVA-207	472750.917	3332616.726	2.015
NVA-208	479539.037	3324987.242	2.134
NVA-209	485953.257	3332726.105	2.833
VVA-1	411222.592	3644800.83	69.714
VVA-2	425688.912	3648451.109	60.893
VVA-3	442165.557	3651243.92	74.397
VVA-4	448687.639	3645354.25	71.916
VVA-5	452430.469	3635972.442	66.916
VVA-6	434687.631	3635880.169	74.607
VVA-7	416889.001	3634836.419	55.891
VVA-8	405193.463	3633854.955	68.094
VVA-9	412344.168	3626116.295	52.907
VVA-10	428645.719	3625825.202	71.464
VVA-11	439735.081	3627701.547	73.482
VVA-12	448528.009	3628546.148	69.44
VVA-13	449945.246	3615689.549	81.011
VVA-14	434278.538	3617689.211	64.333
VVA-15	419173.252	3614584.724	52.423
VVA-16	405332.018	3616253.96	64.885
VVA-17	407927.4	3607065.381	85.576
VVA-18	423801.54	3608258.377	50.973
VVA-19	437929.413	3610480.804	49.292
VVA-20	455719.798	3611931.423	64.544
VVA-21	450286.063	3596844.203	70.226
VVA-22	436323.127	3602156.567	50.258
VVA-23	419992.773	3598971.533	59.81
VVA-24	406724.146	3599644.112	64.436
VVA-25	409055.825	3585905.351	90.955
VVA-26	422014.015	3585923.687	63.857
VVA-27	444391.792	3587645.276	47.292
VVA-28	455981.909	3589472.53	63.587
VVA-29	457369.797	3577062.072	57.378
VVA-30	440971.174	3577040.545	46.291
VVA-31	425836.427	3573606.77	69.879
VVA-32	416041.643	3574879.546	73.889

VVA-33	402924.561	3575530.612	108.191
VVA-34	407952.8	3565398.944	104.858
VVA-35	426022.096	3566023.276	76.46
VVA-36	448360.179	3565337.136	42.964
VVA-37	466243.723	3560961.461	60.506
VVA-38	477190.914	3561287.721	52.408
VVA-39	504793.834	3549273.752	79.005
VVA-40	490728.155	3547585.257	55.164
VVA-41	477248.022	3545057.051	68.528
VVA-42	451809.872	3544511.22	59.416
VVA-43	439879.85	3543899.149	99.623
VVA-44	416466.025	3544678.898	90.623
VVA-45	409470.593	3535487.886	58.136
VVA-46	426878.263	3534853.631	100.476
VVA-47	445278.045	3535084.919	112.099
VVA-48	466290.211	3536196.325	39.488
VVA-49	485724.867	3537398.757	41.449
VVA-50	501509.693	3538726.287	77.399
VVA-51	506338.443	3528964.802	44.882
VVA-52	484913.156	3529466.252	45.848
VVA-53	464799.681	3526544.441	65.098
VVA-54	452624.179	3524742.536	106.3
VVA-55	436827.374	3526650.274	74.594
VVA-56	422698.282	3525801.664	63.381
VVA-57	429690.914	3516180.698	99.388
VVA-58	443659.868	3515832.737	67.136
VVA-59	454322.87	3516118.191	104.996
VVA-60	473225.512	3516849.272	46.982
VVA-61	483400.52	3517632.988	55.766
VVA-62	501308.728	3518778.091	35.025
VVA-63	498532.387	3507523.283	34.732
VVA-64	488129.47	3509099.331	41.697
VVA-65	471377.86	3504661.082	69.881
VVA-66	458290.342	3504898.892	90.02
VVA-67	445597.027	3503959.218	88.845
VVA-68	428992.08	3504324.092	69.998
VVA-69	441308.8	3489523.112	60.8
VVA-70	463450.02	3491270.013	127.873
VVA-71	476572.693	3495173.629	77.452
VVA-72	490480.655	3495474.337	40.023
VVA-73	505302.446	3498494.489	31.167
VVA-74	519631.902	3500823.588	61.207
VVA-75	534637.108	3502281.786	29.551
VVA-76	547670.319	3515256.763	32.131
VVA-77	552849.808	3506861.081	52.322
VVA-78	550937.176	3491905.849	59.881
VVA-79	538701.251	3487948.806	52.044
VVA-80	511718.263	3488369.016	30.801
VVA-81	574191.746	3476312.953	26.307
VVA-82	543281.252	3477161.722	33.674
VVA-83	494233.509	3481016.689	87.868
VVA-84	511048.806	3477648.453	95.261
VVA-85	474601.021	3474182.671	112.018
VVA-86	457963.341	3474055.048	67.456
VVA-87	448538.108	3467627.046	61.197
VVA-88	471073.885	3463216.655	92.937
VVA-89	500213.879	3465753.011	73.999
VVA-90	513230.08	3462684.624	73.412

VVA-91	528269.328	3462558.295	46.63
VVA-92	562425.961	3463597.685	51.428
VVA-93	585566.004	3467796.499	13.213
VVA-94	558848.889	3449700.998	21.243
VVA-95	542344.293	3449765.972	58.059
VVA-96	529776.506	3440390.985	64.25
VVA-97	511246.362	3441252.423	70.944
VVA-98	496951.757	3450408.039	95.852
VVA-99	469659.249	3450628.344	76.923
VVA-100	456295.041	3457500.649	122.546
VVA-101	459651.72	3446608.402	96.072
VVA-102	453024.726	3440225.605	52.003
VVA-103	468462.799	3438124.888	68.502
VVA-104	476263.613	3432858.159	92.573
VVA-105	495572.406	3428451.729	78.067
VVA-106	507886.662	3426840.08	58.339
VVA-107	491856.96	3417048.796	62.707
VVA-108	475204.845	3418289.821	64.039
VVA-109	463552.14	3429707.585	77.616
VVA-110	464562.736	3418577.056	47.296
VVA-111	454546.252	3418763.014	46.601
VVA-112	449027.742	3409890.038	26.951
VVA-113	460731.938	3411879.867	53.485
VVA-114	479618.305	3414179.489	47.834
VVA-115	491785.601	3410902.478	58.928
VVA-116	500398.881	3414878.744	51.846
VVA-117	499732.867	3405014.926	31.612
VVA-118	483677.563	3403362.475	38.638
VVA-119	472834.47	3402977.252	51.924
VVA-120	455879.575	3404492.718	55.983
VVA-121	443638.371	3402367.213	20.068
VVA-122	458963.025	3396788.592	47.227
VVA-123	472805.062	3395936.939	48.896
VVA-124	482442.85	3395687.162	43.617
VVA-125	500067.411	3392481.117	29.417
VVA-126	486300.58	3388151.624	41.21
VVA-127	482989.966	3379760.414	27.522
VVA-128	471213.413	3381196.273	32.099
VVA-129	458120.358	3383066.82	32.594
VVA-130	436125.565	3383100.189	30.464
VVA-131	435625.064	3373295.23	27.745
VVA-132	451681.309	3373201.974	28.933
VVA-133	461923.431	3371586.628	26.407
VVA-134	476879.565	3372311.929	22.211
VVA-135	485539.058	3355379.591	7.054
VVA-136	474314.369	3356957.158	7.048
VVA-137	466630.45	3360497.41	8.616
VVA-138	457845.413	3358621.112	13.029
VVA-139	444382.67	3359636.831	15.411
VVA-140	433131.923	3359207.809	9.445
VVA-141	437868.548	3348062.861	7.148
VVA-142	451593.252	3350135.295	5.823
VVA-143	458208.511	3350533.454	4.97
VVA-144	469800.558	3350041.868	5.924
VVA-145	3347301.494	485056.607	3.16
VVA-146	482688.081	3329464.843	1.524
VVA-147	465977.398	3326777.417	0.495
VVA-148	453260.649	3334312.087	2.819

VVA-149	442870.206	3333937.918	2.297
VVA-150	436986.413	3332307.371	1.098

Table 8: USGS – LA Sabine lidar surveyed accuracy checkpoints

Three hundred and fifty-nine checkpoints were surveyed for vertical accuracy testing. While reviewing the final coordinates of the provided survey checkpoints against the field sketches and intensity imagery created from the lidar. The figure below shows the location of the QA/QC checkpoints used to test the positional accuracy of the dataset.

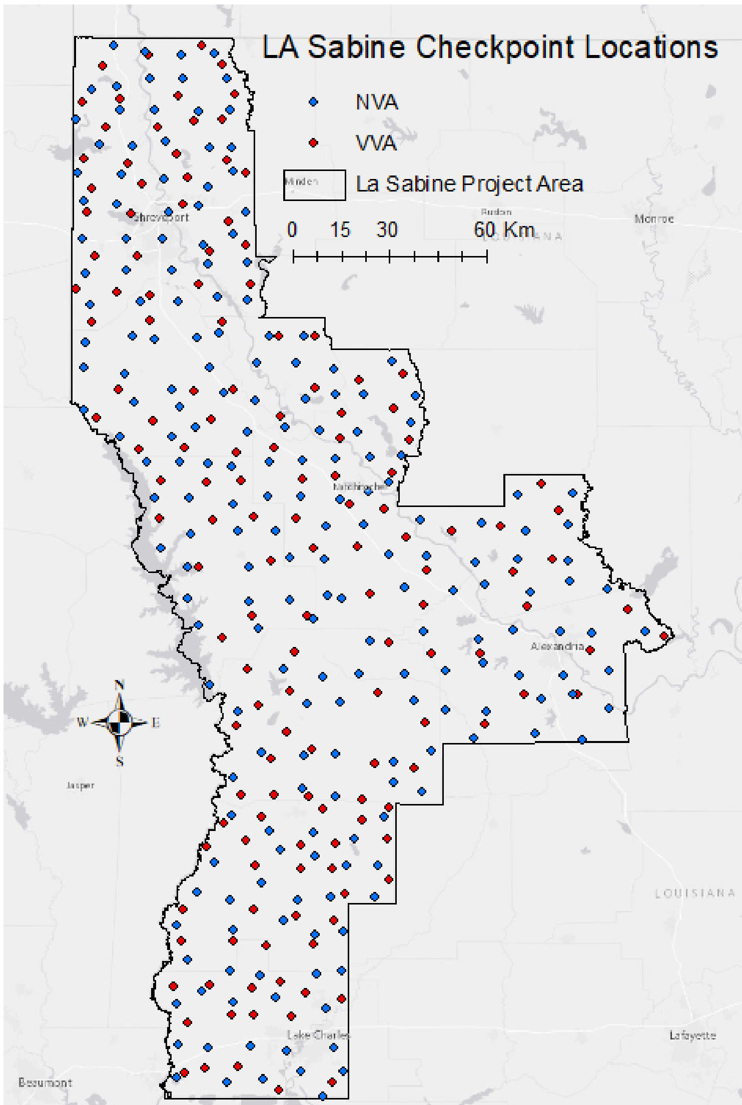


Figure 21 – Location of QA/QC Checkpoints

VERTICAL ACCURACY TEST PROCEDURES

NVA (Non-vegetated Vertical Accuracy) is determined with check points located only in non-vegetated terrain, including open terrain (grass, dirt, sand, and/or rocks) and urban areas, where there is a very high probability that the lidar sensor will have detected the bare-earth ground surface and where random errors are expected to follow a normal error distribution. The NVA determines how well the calibrated lidar sensor performed. With a normal error distribution, the vertical accuracy at the 95% confidence level is computed as the vertical root mean square error ($RMSE_z$) of the checkpoints x 1.9600. For the La Sabine project, vertical accuracy must be 19.6 cm or less based on an $RMSE_z$ of 10 cm x 1.9600.

VVA (Vegetated Vertical Accuracy) is determined with all checkpoints in vegetated land cover categories, including tall grass, weeds, crops, brush and low trees, and fully forested areas, where there is a possibility that the lidar sensor and post-processing may yield elevation errors that do not follow a normal error distribution. VVA at the 95% confidence level equals the 95th percentile error for all checkpoints in all vegetated land cover categories combined. The La Sabine Lidar Project VVA standard is 29.4 cm based on the 95th percentile. The VVA is accompanied by a listing of the 5% outliers that are larger than the 95th percentile used to compute the VVA; these are always the largest outliers that may depart from a normal error distribution. Here, $Accuracy_z$ differs from VVA because $Accuracy_z$ assumes elevation errors follow a normal error distribution where RMSE procedures are valid, whereas VVA assumes lidar errors may not follow a normal error distribution in vegetated categories, making the RMSE process invalid.

The relevant testing criteria are summarized in Table 9.

Quantitative Criteria	Measure of Acceptability
Non-Vegetated Vertical Accuracy (NVA) in open terrain and urban land cover categories using $RMSE_z$ *1.9600	19.6 cm (based on $RMSE_z$ (10 cm) * 1.9600)
Vegetated Vertical Accuracy (VVA) in all vegetated land cover categories combined at the 95% confidence level	29.4 cm (based on combined 95th percentile)

Table 9 — Acceptance Criteria

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

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

VERTICAL ACCURACY RESULTS

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

Land Cover Category	# of Points	NVA — Non-vegetated Vertical Accuracy ($RMSE_z$ x 1.9600) Spec=19.6 cm	VVA — Vegetated Vertical Accuracy (95th Percentile) Spec=29.4 cm
NVA	209	0.094	
VVA	150		0.144

Table 10 — Tested NVA and VVA

This lidar dataset was tested to meet ASPRS Positional Accuracy Standards for Digital Geospatial Data (2014) for a 10 cm RMSEz Vertical Accuracy Class. Actual NVA accuracy was found to be $RMSE_z$ =4.8 cm, equating to +/- 9.4 cm at 95% confidence level. Actual VVA accuracy was found to be +/- 14.4 cm at the 95th percentile.

The figure below illustrates the magnitude of the differences between the QA/QC checkpoints and lidar data. This shows that the majority of lidar elevations were within +/- 20 cm of the checkpoints elevations, but there were some outliers where lidar and checkpoint elevations differed by up to +27 cm.

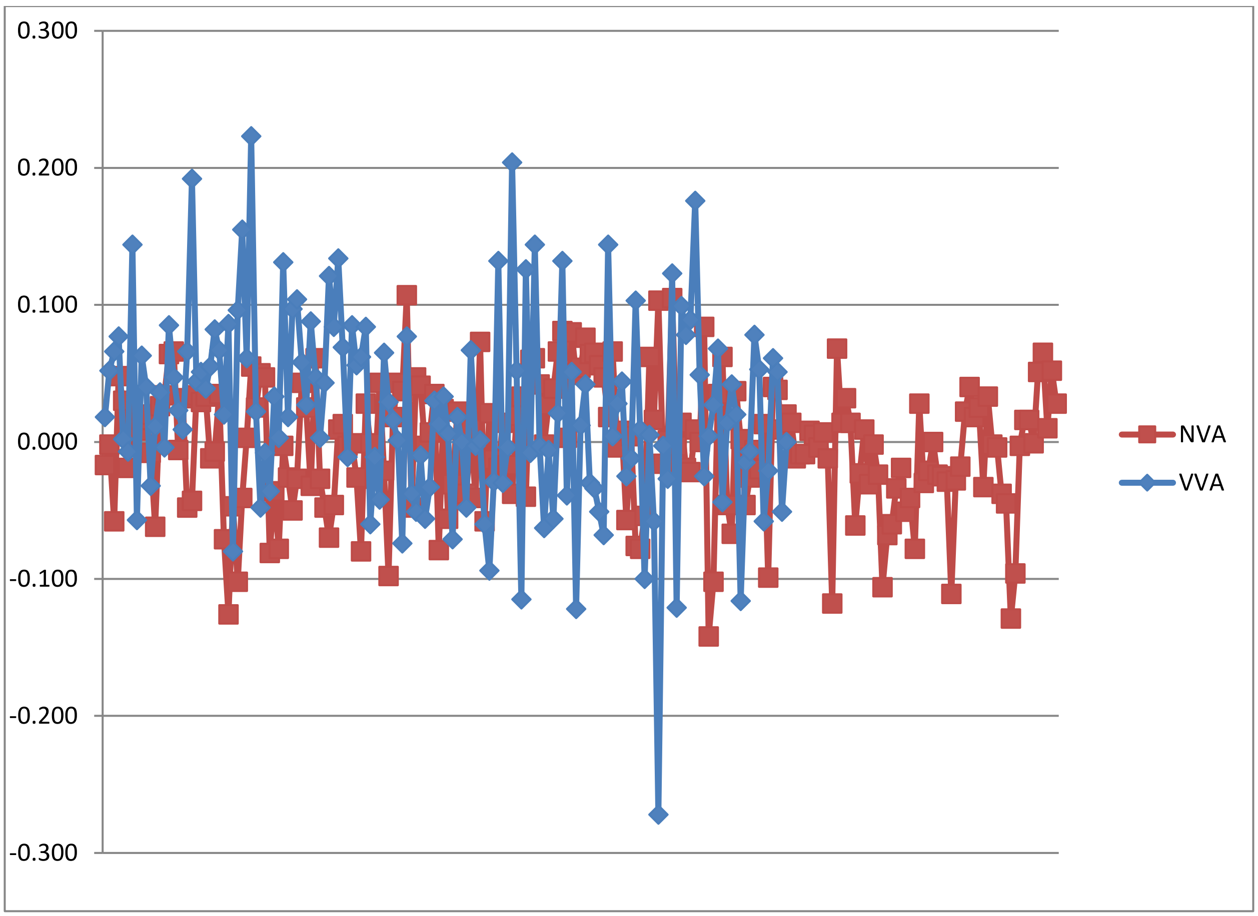


Figure 22 – Magnitude of elevation discrepancies per land cover category

Table 11 lists the 5% outliers that are larger than the VVA 95th percentile.

Point ID	NAD83(2011) UTM Zone 15		NAVD88 (Geoid 12B)	Lidar Z (m)	Delta Z	AbsDeltaZ
	Easting X (m)	Northing Y (m)	Survey Z (m)			
NVA-149	508166.710	3447671.777	77.769	77.640	-0.129	0.129
VVA-123	472805.062	3395936.939	48.896	49.040	0.144	0.144
VVA-136	474314.369	3356957.158	7.048	7.240	0.192	0.192
VVA-147	465977.398	3326777.417	0.495	0.650	0.155	0.155
VVA-149	442870.206	3333937.918	2.297	2.520	0.223	0.223

Table 11 — 5% Outliers

Table 12 provides overall descriptive statistics.

100 % of Totals	# of Points	RMSEz (m) NVA Spec=0.1 m	Mean (m)	Median (m)	Skew	Std Dev (m)	Kurtosis	Min (m)	Max (m)
NVA	209	0.048	-0.003	-0.001	-0.362	0.048	0.012	-0.142	0.107
VVA	150	N/A	0.022	0.019	-0.155	0.071	1.601	-0.272	0.223

Table 12 — Overall Descriptive Statistics

The figure below illustrates a histogram of the associated elevation discrepancies between the QA/QC checkpoints and elevations interpolated from the lidar triangulated irregular network (TIN). The frequency shows the number of discrepancies within each band of elevation differences. Although the discrepancies vary between a low of -0.003 meters and a high of +0.223 meters, the histogram shows that the majority of the discrepancies are skewed on the positive side. The vast majority of points are within the ranges of -0.1 meters to +0.1 meters.

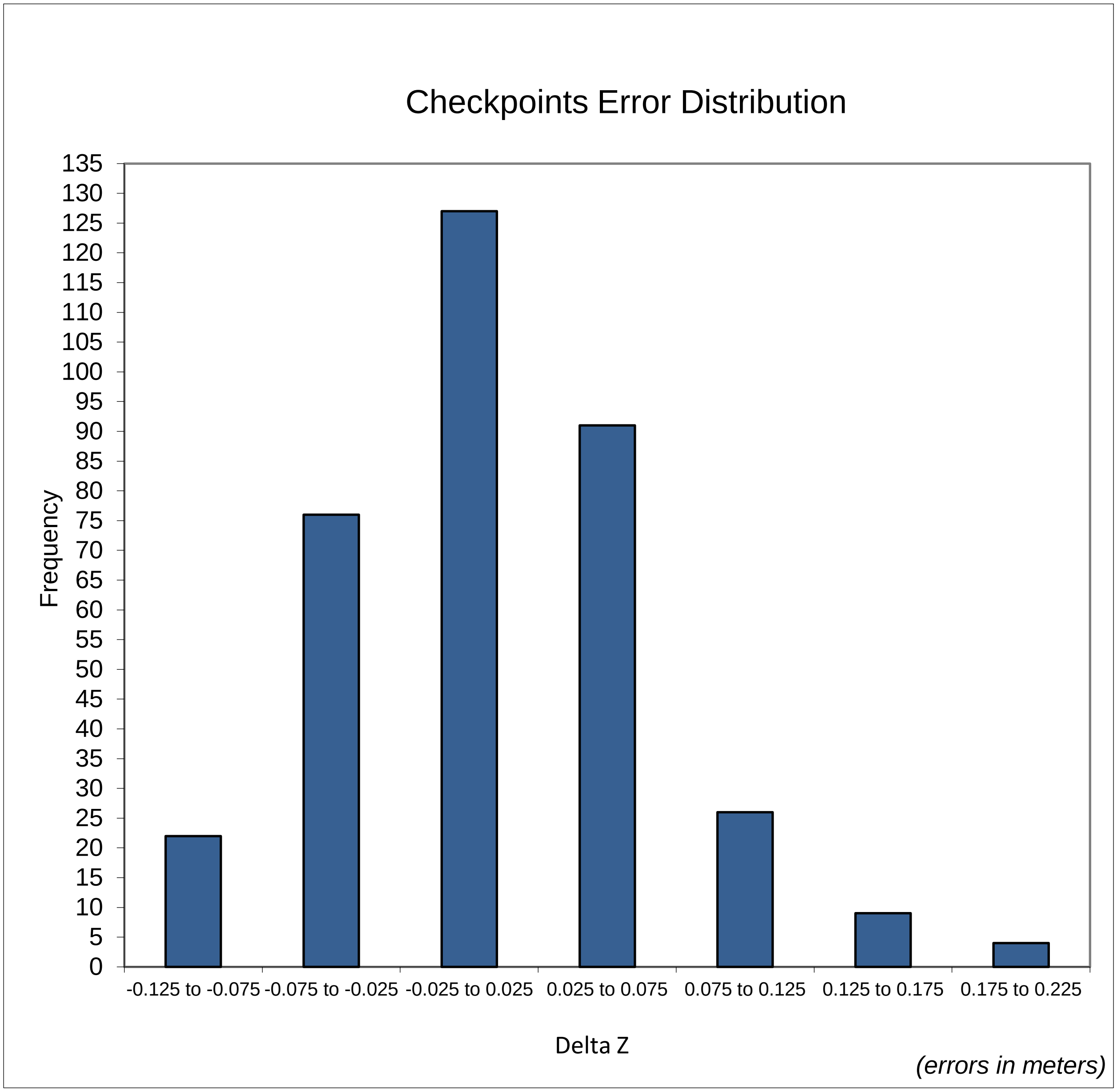


Figure 23 — Histogram of Elevation Discrepancies with errors in meters

Based on the vertical accuracy testing conducted by Dewberry, the lidar dataset for the Sabine satisfies the project's pre-defined vertical accuracy criteria.

HORIZONTAL ACCURACY TEST PROCEDURES

Horizontal accuracy testing requires well-defined checkpoints that can be identified in the dataset. Elevation datasets, including lidar datasets, do not always contain well-defined checkpoints suitable for horizontal accuracy assessment. However, the ASPRS Positional Accuracy Standards for Digital Geospatial Data (2014) recommends at least half of the NVA vertical check points should be located at the ends of paint stripes or other point features visible on the lidar intensity image, allowing them to double as horizontal check points.

Dewberry reviews all NVA checkpoints to determine which, if any, of these checkpoints are located on photo-identifiable features in the intensity imagery. This subset of checkpoints was then used for horizontal accuracy testing.

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

1. Dewberry's team surveyed QA/QC vertical checkpoints in accordance with the project's specifications and tried to locate half of the NVA checkpoints on features photo-identifiable in the intensity imagery.
2. Next, Dewberry identified the well-defined features in the intensity imagery.
3. Dewberry then computed the associated xy-value differences between the coordinates of the well-defined feature in the lidar intensity imagery and the ground truth survey checkpoints.
4. The data were analyzed by Dewberry to assess the accuracy of the data. Horizontal accuracy was assessed using NSSDA methodology where horizontal accuracy is calculated at the 95% confidence level. This report provides the results of the horizontal accuracy testing.

HORIZONTAL ACCURACY RESULTS

Thirteen checkpoints were determined to be photo-identifiable in the intensity imagery and were used to test the horizontal accuracy of the lidar dataset.

Using NSSDA methodology (endorsed by the ASPRS Positional Accuracy Standards for Digital Geospatial Data (2014)), horizontal accuracy at the 95% confidence level (called ACCURACYr) is computed by the formula RMSEr * 1.7308 or RMSExy * 2.448.

No horizontal accuracy requirements or thresholds were provided for this project. However, lidar datasets are generally calibrated by methods designed to ensure a horizontal accuracy of 1 meter or less at the 95% confidence level.

# of Points	$RMSE_x$ (Spec=0.409 m)	$RMSE_y$ (Spec=0.409 m)	$RMSE_r$ (Spec=0.578 m)	$ACCURACY_r$ ($RMSE_r$ x 1.7308) Spec=1 m
24	0.229	0.217	0.315	0.545

Table 13 -Tested horizontal accuracy at the 95% confidence level

This data set was produced to meet ASPRS Positional Accuracy Standards for Digital Geospatial Data (2014) for a 41 cm RMSEx/RMSEy Horizontal Accuracy Class which equates to Positional Horizontal Accuracy = +/- 1 meter at a 95% confidence level. Using this small sample set of photo-identifiable checkpoints, positional accuracy of this dataset was found to be RMSEx = 22.9 cm and RMSEy = 21.7 cm which equates to +/- 54.5 cm at 95% confidence level. While not statistically significant, the results of the small sample set of checkpoints are within the produced to meet horizontal accuracy.

Breakline Production & Qualitative Assessment Report

Dewberry produced full point cloud intensity imagery, bare earth ground models, density models, and slope models. These files were ingested into eCognition software, segmented into polygons, and training samples were created to identify water. eCognition used the training samples and defined parameters to identify water segments throughout the project area. Water segments were then reviewed for completeness. Segments identified as each type of required breakline type, i.e. lakes and ponds, streams and rivers, or tidal waters, were merged and smoothed. 3D elevations were then applied to the breakline features.

All drainage breaklines are monotonically enforced to show downhill flow. Water bodies are at a constant elevation where the lowest elevation of the water body has been applied to the entire water body.

BREAKLINE QUALITATIVE ASSESSMENT

Dewberry completed breakline qualitative assessments according to a defined workflow. The following workflow diagram represents the steps taken by Dewberry to provide a thorough qualitative assessment of the breakline data.

Completeness and horizontal placement is verified through visual reviews against lidar intensity imagery. Automated checks are applied on all breakline features to validate topology, including the 3D connectivity of features, enforced monotonicity on linear hydrographic breaklines, and flatness on water bodies.

The next step is to compare the elevation of the breakline vertices against the ground elevation extracted from the ESRI Terrain built from the lidar ground points, keeping in mind that a discrepancy is expected because of the hydro-enforcement applied to the breaklines and because of the interpolated imagery used to acquire the breaklines. A given tolerance is used to validate if the elevations differ too much from the lidar.

After all corrections and edits to the breakline features, the breaklines are imported into the final GDB and verified for correct formatting.

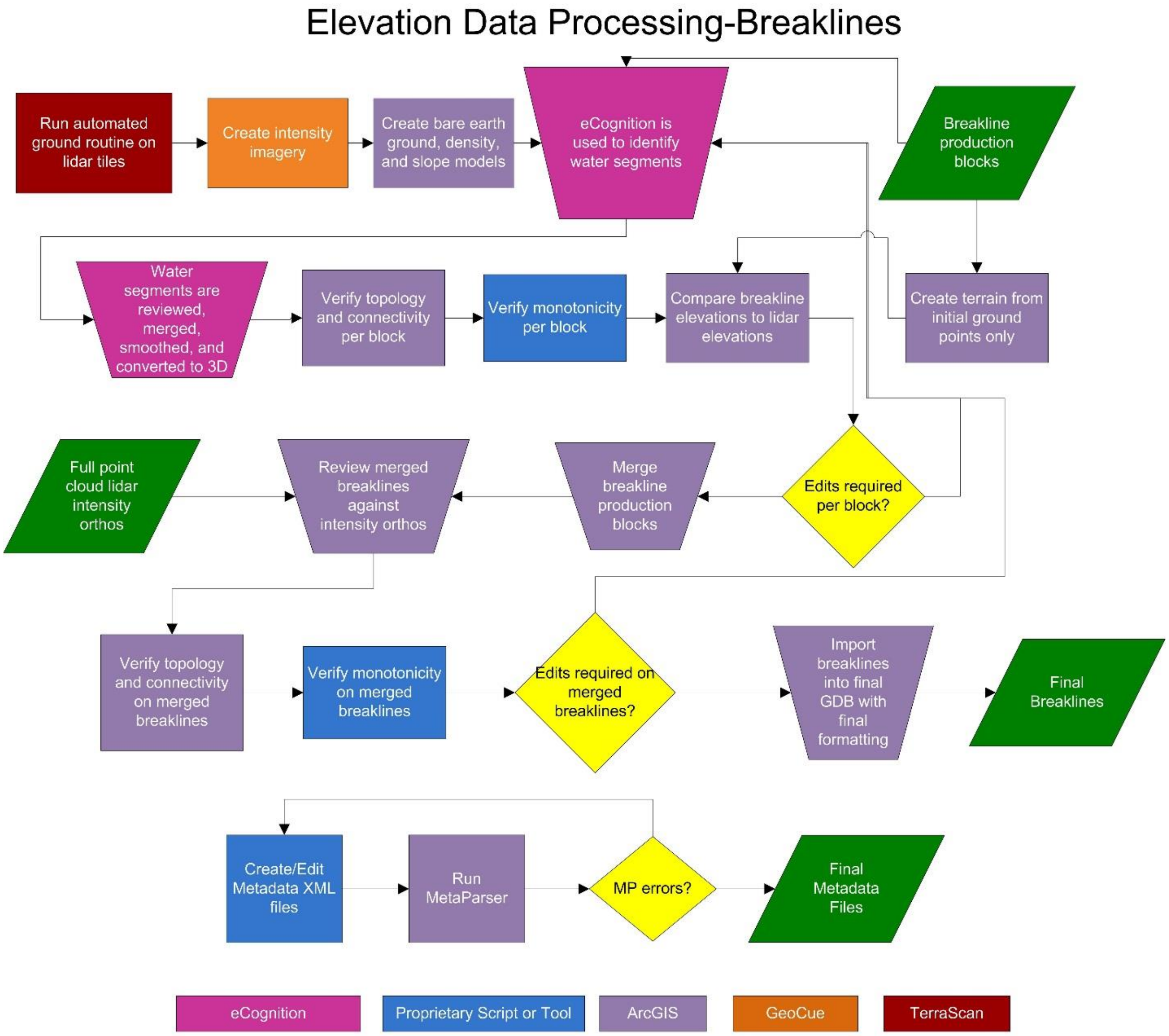


Figure 24-Breakline QA/QC workflow

BREAKLINE CHECKLIST

The following table represents a portion of the high-level steps in Dewberry's Production and QA/QC checklist that were performed for this project.

Pass/Fail	Validation Step
Pass	Use lidar-derived data, which may include intensity imagery, stereo pairs, bare earth ground models, density models, slope models, and terrains, to collect breaklines according to project specifications.
Pass	In areas of heavy vegetation or where the exact shoreline is hard to delineate, it is better to err on placing the breakline *slightly* inside or seaward of the shoreline (breakline can be inside shoreline by 1x-2x NPS).
Pass	After each producer finishes breakline collection for a block, each producer must perform a completeness check, breakline variance check, and all automated checks on their block before calling that block complete and ready for the final merge and QC
Pass	After breaklines are completed for production blocks, all production blocks should be merged together, and completeness and automated checks should be performed on the final, merged GDB. Ensure correct snapping-horizontal (x,y) and vertical (z)-between all production blocks.
Pass	Check entire dataset for missing features that were not captured but should be to meet baseline specifications or for consistency. Features should be collected consistently across tile bounds. Check that the horizontal placement of breaklines is correct. Breaklines should be compared to full point cloud intensity imagery and terrains
Pass	Breaklines are correctly edge-matched to adjoining datasets in completion, coding, and horizontal placement.
Pass	Using a terrain created from lidar ground (all ground including 2, 8, and 10) and water points (class 9), compare breakline Z values to interpolated lidar elevations.
Pass	Perform all Topology and Data Integrity Checks
Pass	Perform hydro-flattening and hydro-enforcement checks including monotonicity and flatness from bank to bank on linear hydrographic features and flatness of water bodies. Tidal waters should preserve as much ground as possible and can include variations or be non-monotonic.

Table 14-A subset of the high-level steps from Dewberry's Production and QA/QC checklist performed for this project.

DATA DICTIONARY

The following data dictionary was used for this project.

Horizontal and Vertical Datum

The horizontal datum shall be North American Datum of 1983(2011), Units in Meters. The vertical datum shall be referenced to the North American Vertical Datum of 1988 (NAVD 88), Units in Meters. Geoid12B shall be used to convert ellipsoidal heights to orthometric heights.

Coordinate System and Projection

All data shall be projected to UTM Zone 15, Horizontal Units in Meters and Vertical Units in Meters.

Inland Streams and Rivers

Feature Dataset: BREAKLINES
Feature Type: Polygon
Contains Z Values: Yes
XY Resolution: Accept Default Setting
Feature Class: STREAMS_AND_RIVERS
Contains M Values: No
Annotation Subclass: None
Z Resolution: Accept Default Setting

XY Tolerance: 0.003 **Z Tolerance:** 0.001

Description

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

Table Definition

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

Feature Definition

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

		Every effort should be made to avoid breaking a stream or river into segments. Dual line features shall break at road crossings (culverts). In areas where a bridge is present the dual line feature shall continue through the bridge. Islands: The double line stream shall be captured around an island if the island is greater than 1 acre. In this case a segmented polygon shall be used around the island in order to allow for the island feature to remain as a "hole" in the feature.

Inland Ponds and Lakes

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

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

Description

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

Table Definition

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

Feature Definition

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

		falls, beneath the dock or pier, then the edge of water will be collected at the elevation of the water where it can be directly measured. If there is a clearly-indicated headwall or bulkhead adjacent to the dock or pier and it is evident that the waterline is most probably adjacent to the headwall or bulkhead, then the water line will follow the headwall or bulkhead at the elevation of the water where it can be directly measured. If there is no clear indication of the location of the water's edge beneath the dock or pier, then the edge of water will follow the outer edge of the dock or pier as it is adjacent to the water, at the measured elevation of the water.

Tidal Waters

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

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

Description

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

Table Definition

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

Feature Definition

Description	Definition	Capture Rules
TIDAL_WATERS	The coastal breakline will delineate the land water interface using lidar data as reference. In flight line boundary areas with tidal variation the coastal shoreline may show stair stepping as no feathering is allowed. Stair stepping is allowed to show as much ground as the collected data permits.	The feature shall be extracted at the apparent land/water interface, as determined by the lidar intensity data, to the extent of the tile boundaries. Differences caused by tidal variation are acceptable and breaklines delineated should reflect that change with no feathering. Breaklines must be captured at or just below the elevations of the immediately surrounding terrain. Under no circumstances should a feature be elevated above the surrounding lidar points. Acceptable variance in the negative direction will be defined for each project individually. If it can be reasonably determined where the edge of water most probably falls, beneath the dock or pier, then the edge of water will be collected at the elevation of the water where it can be directly measured. If there is a clearly-indicated headwall or bulkhead adjacent to the dock or pier and it is evident that the waterline is

		most probably adjacent to the headwall or bulkhead, then the water line will follow the headwall or bulkhead at the elevation of the water where it can be directly measured. If there is no clear indication of the location of the water's edge beneath the dock or pier, then the edge of water will follow the outer edge of the dock or pier as it is adjacent to the water, at the measured elevation of the water. Breaklines shall snap and merge seamlessly with linear hydrographic features.

Bridge Saddle Breaklines

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

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

Description

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

Table Definition

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

Feature Definition

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

DEM Production & Qualitative Assessment

DEM PRODUCTION METHODOLOGY

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

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

Figure 25-DEM Production Workflow

DEM QUALITATIVE ASSESSMENT

Dewberry performed a comprehensive qualitative assessment of the bare earth DEM deliverables to ensure that all tiled DEM products were delivered with the proper extents, were free of processing artifacts, and contained the proper referencing information. This process was performed in ArcGIS software with the use of a tool set Dewberry has developed to verify that the raster extents match those of the tile grid and contain the correct projection information. The DEM data was reviewed at a scale of 1:5000 to review for artifacts caused by the DEM generation process and to review the hydro-flattened features. To perform this review Dewberry creates HillShade models and overlays a partially transparent colorized elevation model to review for these issues. All corrections are completed using Dewberry's proprietary correction workflow. Upon completion of the corrections, the DEM data is loaded into Global Mapper for its second review and to verify corrections. Once the DEMs are tiled out, the final tiles are again loaded into Global Mapper to ensure coverage, extents, and that the final tiles are seamless.

The images below show an example of a bare earth DEM.

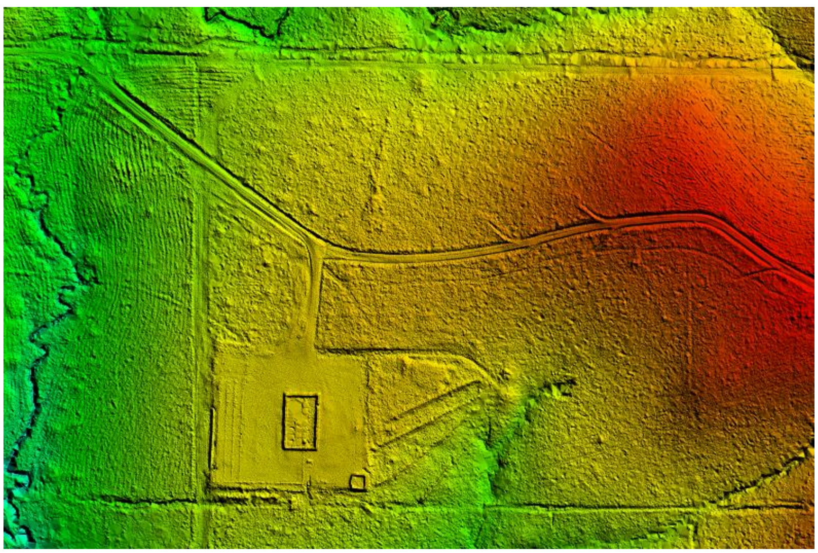


Figure 26-Tile 15RWQ0529. The bare earth DEM is shown above.

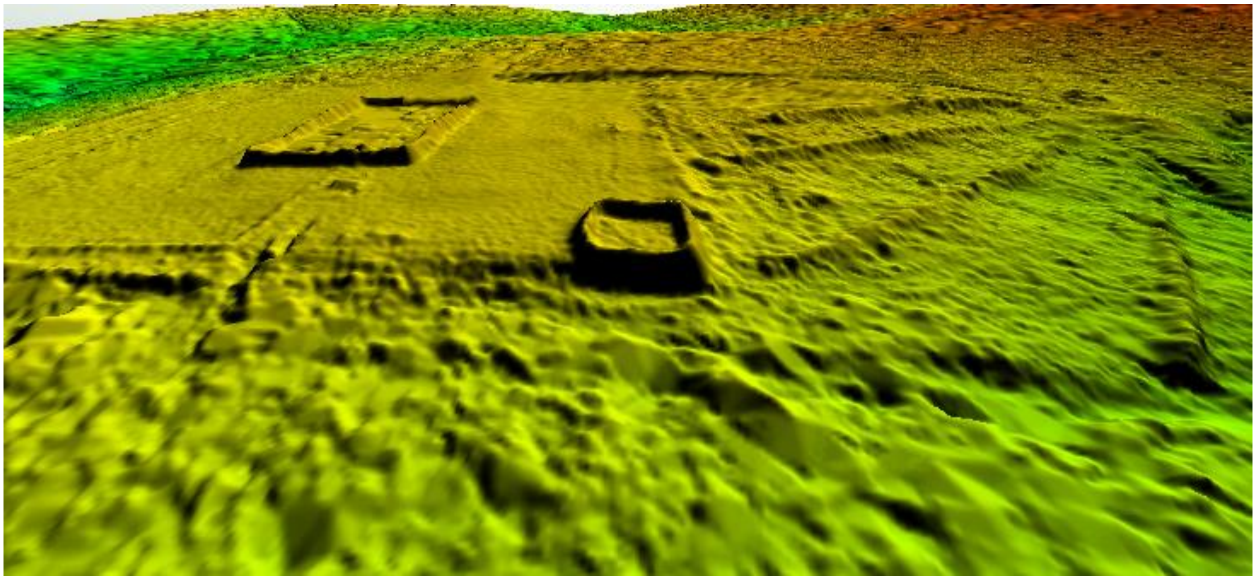


Figure 27-15RWQ0529. 3D Profile view of the bare earth DEM

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

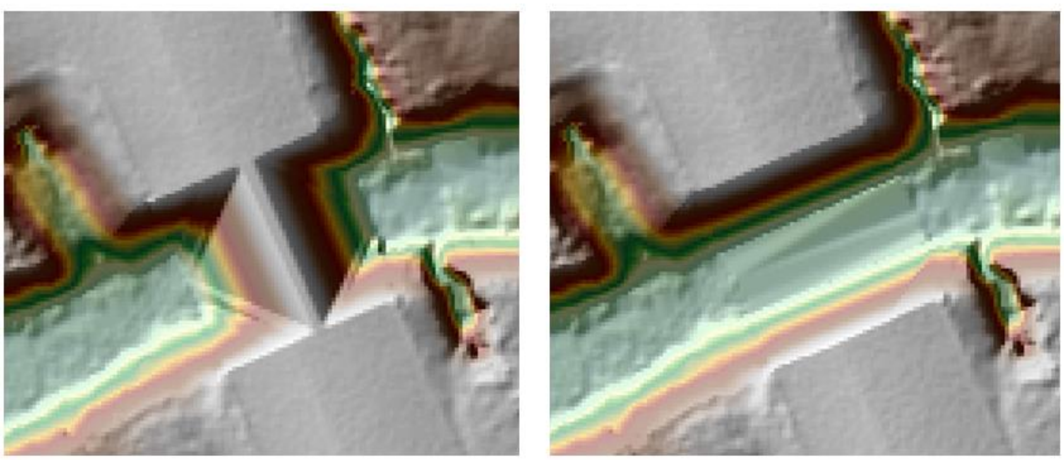


Figure 28-15SVS3602. The DEM on the left shows a bridge saddle artifact while the DEM on the right shows the same location after bridge breaklines have been enforced.

DEM VERTICAL ACCURACY RESULTS

The same 359 checkpoints that were used to test the vertical accuracy of the lidar were used to validate the vertical accuracy of the final DEM products as well. Accuracy results may vary between the source lidar and final DEM deliverable. DEMs are created by averaging several lidar points within each pixel which may result in slightly different elevation values at each survey checkpoint when compared to the source LAS, which does not average several lidar points together but may interpolate (linearly) between two or three points to derive an elevation value. The vertical accuracy of the DEM is tested by extracting the elevation of the pixel that contains the x/y coordinates of the checkpoint and comparing these DEM elevations to the surveyed elevations. Dewberry typically uses LP360 software to test the swath lidar vertical accuracy, Terrascan software to test the classified lidar vertical accuracy, and Esri ArcMap to test the DEM vertical accuracy so that three different software programs are used to validate the vertical accuracy for each project.

Table 15 summarizes the tested vertical accuracy results from a comparison of the surveyed checkpoints to the elevation values present within the final DEM dataset.

Land Cover Category	# of Points	NVA — Non-vegetated Vertical Accuracy ($RMSE_z$ x 1.9600) Spec=19.6 cm	VVA — Vegetated Vertical Accuracy (95th Percentile) Spec=29.4 cm
NVA	209	0.130	
VVA	150		0.189

Table 15 — DEM tested NVA and VVA

This DEM dataset was tested to meet ASPRS Positional Accuracy Standards for Digital Geospatial Data (2014) for a 10 cm RMSEz Vertical Accuracy Class. Actual NVA accuracy was found to be $RMSE_z$ =6.6 cm, equating to +/- 13.0 cm at 95% confidence level. Actual VVA accuracy was found to be +/- 18.9 cm at the 95th percentile.

Table 16 lists the 5% outliers that are larger than the VVA 95th percentile.

Point ID	NAD83(2011) UTM Zone 15		NAVD88 (Geoid 12B)	DEM Z (m)	Delta Z	AbsDeltaZ
	Easting X (m)	Northing Y (m)	Survey Z (m)			
VVA-37	466243.723	3560961.461	60.506	60.707	0.201	0.201
VVA-71	476572.693	3495173.629	77.452	77.194	-0.258	0.258
VVA-131	435625.064	3373295.230	27.745	28.000	0.255	0.255
VVA-133	461923.431	3371586.628	26.407	26.000	-0.407	0.407
VVA-134	476879.565	3372311.929	22.211	22.000	-0.211	0.211
VVA-136	474314.369	3356957.158	7.048	7.244	0.196	0.196
VVA-137	466630.450	3360497.410	8.616	9.000	0.384	0.384
VVA-149	442870.206	3333937.918	2.297	2.519	0.222	0.222

Table 16 — 5% Outliers

Table 17 provides overall descriptive statistics.

100 % of Totals	# of Points	RMSEz (m) NVA Spec=0.1 m	Mean (m)	Median (m)	Skew	Std Dev (m)	Kurtosis	Min (m)	Max (m)
NVA	209	0.066	-0.009	-0.002	-3.048	0.069	18.330	-0.476	0.114
VVA	150	N/A	0.025	0.024	-0.387	0.089	4.994	-0.407	0.384

Table 17 – Overall Descriptive Statistics

Based on the vertical accuracy testing conducted by Dewberry, the DEM dataset for the Sabine satisfies the project's pre-defined vertical accuracy criteria.

DEM CHECKLIST

The following table represents a portion of the high-level steps in Dewberry's bare earth DEM Production and QA/QC checklist that were performed for this project.

Pass/Fail	Validation Step
Pass	Masspoints (LAS to multipoint) are created from ground points only (class 2 and class 8 if model key points created, but no class 10 ignored ground points or class 9 water points
Pass	Create a terrain for each production block using the final bare earth lidar points and final breaklines.
Pass	Convert terrains to rasters using project specifications for grid type, formatting, and cell size
Pass	Create hillshades for all DEMs
Pass	Manually review bare-earth DEMs in ArcMap with hillshades to check for issues
Pass	DEMs should be hydro-flattened or hydro-enforced as required by project specifications
Pass	DEMs should be seamless across tile boundaries
Pass	Water should be flowing downhill without excessive water artifacts present
Pass	Water features should NOT be floating above surrounding
Pass	Bridges should NOT be present in bare-earth DEMs.
Pass	Any remaining bridge saddles where below bridge breaklines were not used need to be fixed by adding below bridge breaklines and re-processing.
Pass	All qualitative issues present in the DEMs as a result of lidar processing and editing issues must be marked for corrections in the lidar These DEMs will need to be recreated after the lidar has been corrected.
Pass	Calculate DEM Vertical Accuracy including NVA, VVA, and other statistics
Pass	Split the DEMs into tiles according to the project tiling scheme
Pass	Verify all properties of the tiled DEMs, including coordinate reference system information, cell size, cell extents, and that compression has not been applied to the tiled DEMs
Pass	Load all tiled DEMs into Global Mapper to verify complete coverage to the (buffered) project boundary and that no tiles are corrupt.

Table 18-A subset of the high-level steps from Dewberry's bare earth DEM Production and QA/QC checklist performed for this project.

Appendix A: Survey Report

Check Point Survey Report

Louisiana Sabine River, QL1 LiDAR Project USGS Contract: G16PC00020

Task Order Number: 140G1018F0025

Prepared for:

United States Geological Survey (USGS)

Prepared By:

Dewberry Engineers Inc.
4601 Forbes Boulevard, Suite 300
Lanham, Maryland, 20706
Phone (301)364-1855 Fax (301)731-0188

TABLE OF CONTENTS

1. INTRODUCTION

1.1 Project Summary

Dewberry Engineers Inc. is under contract to the United States Geological Survey to provide 359 Check Points in the state of Louisiana. Under the above referenced USGS Task Order, Dewberry is tasked to complete the quality assurance of LiDAR products. As part of this work Dewberry staff will complete Check Point surveys that will be used to evaluate vertical and horizontal accuracy. The ground survey was conducted February 15, 2018 thru March 2, 2018.

Existing NGS Control Points were located and surveyed to check the accuracy of the RTK/GPS survey equipment with the results shown in Section 2.4 of this Report.

As an internal QA/QC procedure and to verify that the Ground Control Points meet the 95% confidence level approximately 50% of the points were re-observed and are shown in Section 5 of this report.

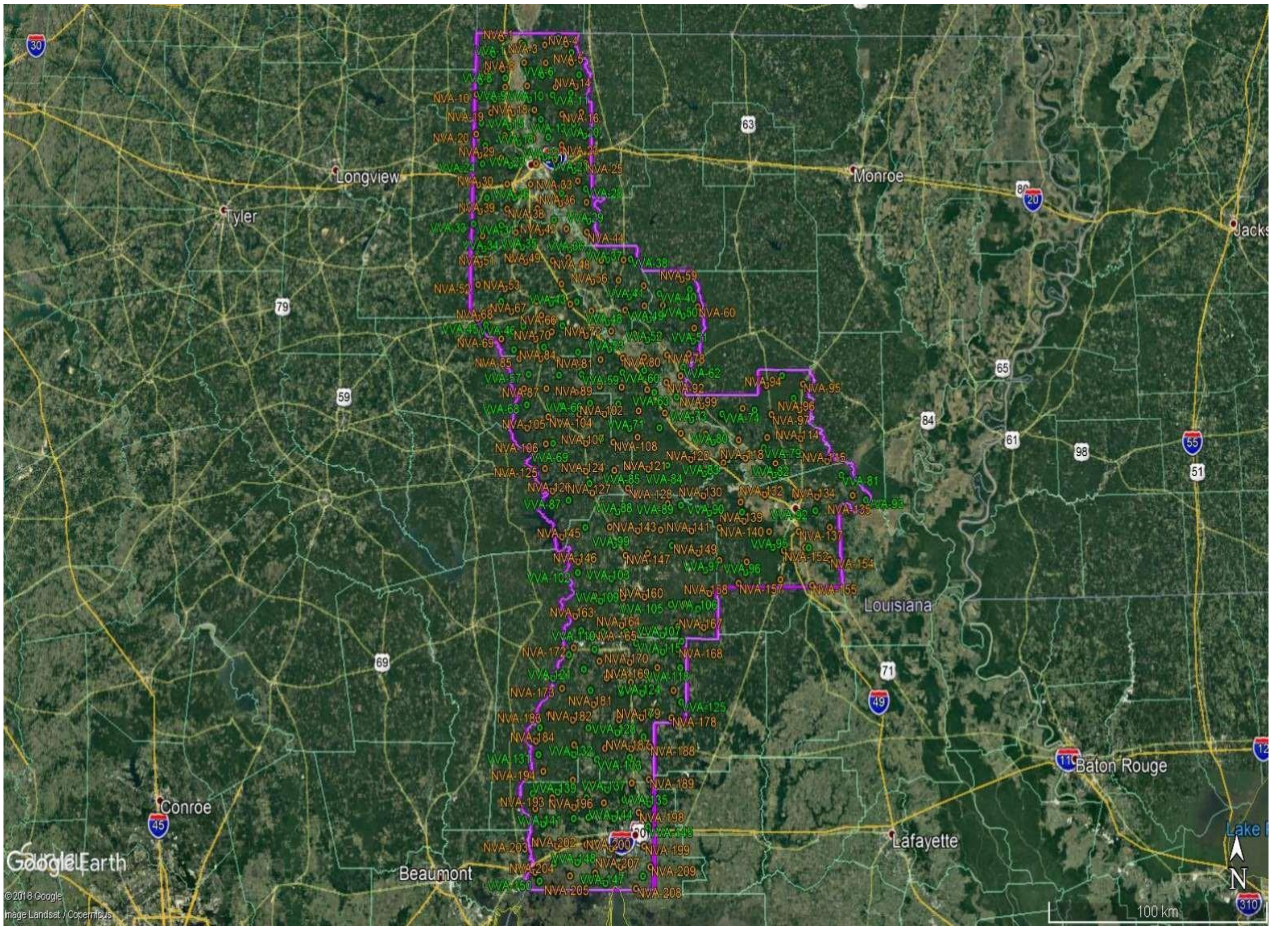
Final horizontal coordinates are referenced to UTM Zone 15, NAD83 (2011) in meters. Final Vertical elevations are referenced to NAVD88 in meters using Geoid model 2012B (Geoid12B).

1.2 Points of Contact

Questions regarding the technical aspects of this report should be addressed to:
Dewberry Engineers Inc.

Gary D. Simpson, L.S.
Senior Associate
4601 Forbes Boulevard
Suite 300
Lanham, Maryland 20706
(301) 364-1855 direct
(301) 731-0188 fax

1.3 PROJECT AREA


Longview
Tyler
Monroe
Louisiana
Conroe
Beaumont
Lafayette
Baton Rouge
Google Earth
100 km
N

PROJECT DETAILS

2.1 SURVEY EQUIPMENT

In performing the GPS observations Trimble R-10 GNSS receiver/antenna attached to a two meter fixed height pole with a Trimble TSC3 Data Collector to collect GPS raw data were used to perform the field surveys.

2.2 SURVEY POINT DETAIL

The 359 Check Points were well distributed throughout the project area.
A sketch was made for each location and a nail was set at the point where possible or at an identifiable point. The Check Point locations are detailed on the "Control Point Documentation Report" sheets attached to this report.

2.3 NETWORK DESIGN

The GPS survey performed by Dewberry Engineers Inc. office located in Lanham, MD was tied to a Real Time Network operated by Louisiana State University (LSU). The network is a series of "real-time" continuously operating, high precision GPS reference stations. All of the reference stations have been linked together using Trimble GPSNet software, creating a Virtual Reference Station System (VRS).

The Trimble NetR5 Reference Station is a multi-channel, multi-frequency GNSS (Global Navigation Satellite System) receiver designed for use as a stand-alone reference station or as part of a GNSS infrastructure solution. Trimble R-Track technology in the NetR5 receiver supports the modernized GPS L2C and L5 signals as well as GLONASS L1/L2 signals.

2.4 FIELD SURVEY PROCEDURES AND ANALYSIS

Dewberry field surveyors used Trimble R-10 GNSS receivers, which is a geodetic quality dual frequency GPS receiver, to collect data at each surveyed location.

All locations were occupied once with approximately 50% of the locations being reobserved. All re-observations matched the initially derived station positions within the allowable tolerance of ± 5cm or within the 95% confidence level. Each occupation which utilized the VRS network was occupied for approximately three (3) minutes in duration and measured to 180 epochs.

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

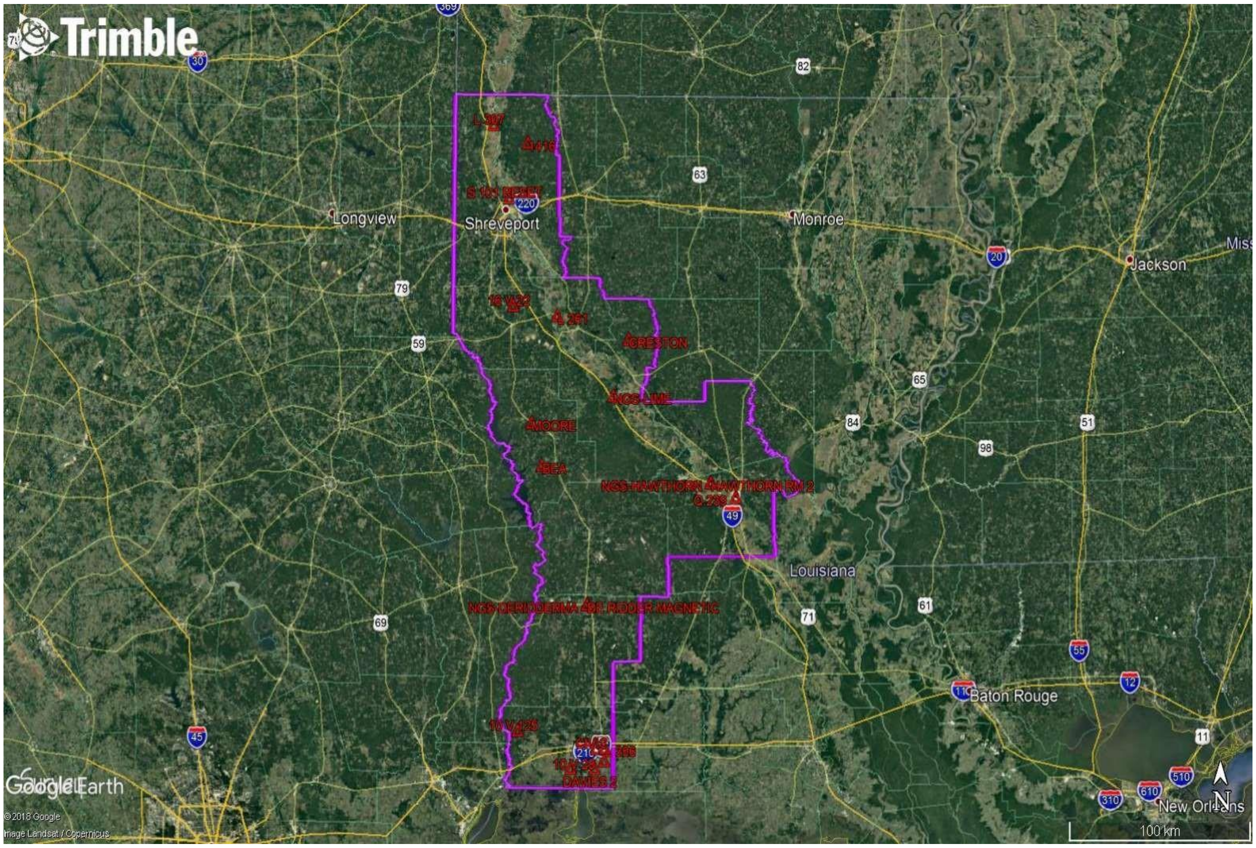
Field GPS observations are detailed on the "Control Point Documentation Reports" submitted as part of this report.

Thirteen (13) existing NGS monument listed in the NSRS database were located for the Louisiana area as an additional QA/QC method to check the horizontal and vertical accuracy of the VRS network as well as being the primary project control monuments designated as BK1612, BK2488, CQ2059, BK3291, BK2787, BK1646,BK1265, BX1108, CQ1500, CQ2174, BK2248, BX2833, and BX0916. The results are as follows:

	Observed Values			Data Sheet Values					
PT. #	NORTHING	EASTING	ELEVS.	NORTHING	EASTING	ELEVS.	Δ X	Δ Y	Δ Z
NGS-10V28	3337932.281	482709.362	4.581	3337932.291	482709.371	N/A	-0.010	-0.009	N/A
NGS-10V125	3352288.981	436548.564	9.463	3352288.984	436548.589	N/A	-0.003	-0.025	N/A
NGS-1416	3630983.609	441275.721	121.988	3630983.584	441275.712	121.983	0.025	0.009	0.005
NGS-CIVIC	3343870.342	478499.013	1.717	3343870.334	478499.013	N/A	0.008	0.000	N/A
NGS-CRESTON	3537743.785	495318.640	49.681	3537743.832	495318.657	N/A	-0.047	-0.017	N/A
NGS-DAVIES2	3334303.751	477620.261	3.681	3334303.769	477620.240	N/A	-0.018	0.021	N/A
NGS-DERIDDERMA	3412246.631	473481.813	55.900	3412246.642	473481.873	55.906	-0.011	-0.06	-0.006
NGS-HAWTHORN	3470074.484	539313.458	25.637	N/A	N/A	25.613	N/A	N/A	0.024
NGS-L261	3548987.453	457291.992	42.200	3548987.443	457292.016	42.192	0.010	-0.024	0.008
NGS-L307	3639740.893	422968.989	64.116	3639740.877	422969.008	64.132	0.016	-0.019	-0.016
NGS-L356	3344009.037	483175.716	3.004	3344009.026	483175.697	N/A	0.011	0.019	N/A
NGS-LIME	3511118.286	487246.305	62.401	3511118.329	487246.313	N/A	-0.043	-0.008	N/A
NGS-Q239	3463322.78	552532.56	23.931	3463322.765	552532.546	23.918	0.015	0.014	0.013

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

NGS Monuments



2.5 ADJUSTMENT

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

The system is designed to provide a true Network RTK performance, the RTKNet software enables high-accuracy positioning in real time across a geographic region. The RTKNet software package uses real-time data streams from the Louisiana State University (LSU) network user and generates correction models for high-accuracy RTK GPS corrections throughout the network. Therefore, corrections were applied to the points as they were being collected, thus negating the need for a post process adjustment.

2.6 DATA PROCESSING PROCEDURES

After field data is collected the information is downloaded from the data collectors into the office software. The Software program used is called Trimble Business Center.

Downloaded data is run through the TBC program to obtain the following reports; points report, point comparison report and a point detail report. The reports are reviewed for point accuracy and precision.

After review of the point data an "ASCII" or "txt" file which is the industry standard is created. Point files are loaded into our CADD program (Carlson Survey 2017) to make a visual check of the point data (Pt. #, Coordinates, Elev. and Description). The data can now be imported into the final product.

3. FINAL COORDINATES/ELEVATIONS

POINT ID	NORTHING (m)	EASTING (m)	ELEV. (m)
UTM Zone 15 North NAD83 (2011), Meters			
Check Points - NVA's			
NVA-1	3651314.612	414917.227	87.557
NVA-2	3649304.181	424662.824	60.852
NVA-3	3648510.155	435815.505	101.208
NVA-4	3648741.832	446169.513	74.392
NVA-5	3641079.451	449736.432	71.250
NVA-6	3641016.838	436410.117	107.789

NVA-7	3641187.522	425971.151	75.732
NVA-8	3638428.464	415660.107	66.332
NVA-9	3637628.098	407869.564	76.644
NVA-10	3628138.816	403290.679	69.230
NVA-11	3631073.179	416944.772	83.598
NVA-12	3631510.895	427532.149	70.032
NVA-13	3630910.306	441095.452	124.054
NVA-14	3631090.993	450922.232	70.346
NVA-15	3619769.196	451602.151	61.036
NVA-16	3619805.419	444391.555	72.304
NVA-17	3621567.370	431137.052	65.146
NVA-18	3620240.458	420908.672	56.098
NVA-19	3620505.866	410341.037	66.178
NVA-20	3611861.415	403509.178	67.363
NVA-21	3611264.254	417127.231	70.696
NVA-22	3609942.012	430310.537	54.337
NVA-23	3607283.292	444273.608	67.992
NVA-24	3612068.592	451703.116	72.711
NVA-25	3599782.492	455849.198	61.187
NVA-26	3601385.783	441023.789	50.205
NVA-27	3599701.239	432094.960	52.951
NVA-28	3601948.135	415572.136	62.946
NVA-29	3603100.308	405347.820	77.577
NVA-30	3591109.517	404913.207	80.642
NVA-31	3591468.904	418577.142	71.051
NVA-32	3591365.618	429709.535	66.527
NVA-33	3589582.261	442408.838	48.115

NVA-34	3592652.093	452092.155	63.735
NVA-35	3583985.186	456269.614	58.410
NVA-36	3583568.841	444090.310	46.853
NVA-37	3581597.638	433048.981	61.431
NVA-38	3581431.116	418686.285	57.076
NVA-39	3580396.545	405871.764	77.538
NVA-40	3570671.160	407283.447	122.066
NVA-41	3571974.011	422901.393	68.180
NVA-42	3571896.024	434980.254	68.667
NVA-43	3573370.032	446801.404	45.723
NVA-44	3572070.064	456489.567	44.537
NVA-45	3560967.777	473832.976	76.902
NVA-46	3560833.977	463262.106	71.604
NVA-47	3561936.341	447700.594	40.194
NVA-48	3560752.742	440443.911	54.002
NVA-49	3560260.604	427705.921	87.287
NVA-50	3561249.774	420706.885	93.826
NVA-51	3559336.141	406275.661	103.596
NVA-52	3551300.918	405521.736	89.048
NVA-53	3549587.450	418146.634	97.144
NVA-54	3544667.238	433094.959	101.408
NVA-55	3551450.949	444670.973	70.644
NVA-56	3552592.032	459366.805	42.617
NVA-57	3552891.033	471404.186	56.256
NVA-58	3550759.147	483268.958	52.109
NVA-59	3553181.027	501219.806	70.675
NVA-60	3542504.733	508610.843	50.903
NVA-61	3543056.838	492231.449	60.666
NVA-62	3542842.336	483584.086	46.169
NVA-63	3541317.426	474329.884	51.992

NVA-64	3540868.114	458786.033	42.001
NVA-65	3543536.950	448939.810	73.930
NVA-66	3539208.543	435406.822	97.986
NVA-67	3540605.571	421292.911	91.962
NVA-68	3538156.465	405542.247	62.052
NVA-69	3529992.749	416738.081	80.215
NVA-70	3529849.968	432818.969	83.938
NVA-71	3532736.115	440290.132	79.976
NVA-72	3531211.412	456268.590	63.797
NVA-73	3532927.556	468038.905	38.513
NVA-74	3531909.174	478794.144	48.998
NVA-75	3531237.400	490582.974	54.676
NVA-76	3534096.311	506865.514	58.396
NVA-77	3524109.452	504245.427	33.006
NVA-78	3523608.056	494133.215	35.080
NVA-79	3522823.945	483448.483	37.647
NVA-80	3522381.364	473475.839	38.349
NVA-81	3521814.333	463135.986	52.770
NVA-82	3520779.604	451552.969	83.642
NVA-83	3521547.535	444079.143	103.601
NVA-84	3522107.092	435224.614	71.300
NVA-85	3522188.869	425166.654	77.506
NVA-86	3510645.863	427581.607	62.242
NVA-87	3510656.087	438019.996	79.229
NVA-88	3509119.872	451785.181	108.379
NVA-89	3511541.868	462764.204	77.522
NVA-90	3511135.636	472949.240	45.075
NVA-91	3510150.049	484831.085	64.494
NVA-92	3512975.249	493707.734	34.993
NVA-93	3515518.335	500374.247	34.102

NVA-94	3511805.893	540235.301	56.308
NVA-95	3512407.311	557288.299	23.712
NVA-96	3502354.413	555551.542	54.546
NVA-97	3500612.174	542434.826	77.538
NVA-98	3502942.437	529077.505	34.586
NVA-99	3503870.067	510103.512	45.551
NVA-100	3502423.582	492611.392	48.723
NVA-101	3501974.040	480845.213	52.161
NVA-102	3500679.362	465216.355	83.731
NVA-103	3500619.752	453401.755	104.572
NVA-104	3499577.717	438923.212	59.184
NVA-105	3495406.518	429229.598	66.626
NVA-106	3489330.413	437926.773	62.078
NVA-107	3489465.833	456553.509	94.310
NVA-108	3492511.585	469578.575	87.034
NVA-109	3491876.751	480359.010	65.439
NVA-110	3493317.361	500346.222	31.481
NVA-111	3493018.131	511831.978	30.661
NVA-112	3490783.047	527123.801	34.598
NVA-113	3491762.968	540333.320	69.412
NVA-114	3491276.483	555882.294	55.050
NVA-115	3482622.752	568049.344	25.314
NVA-116	3484996.906	556247.538	54.981
NVA-117	3481781.115	544029.518	52.645
NVA-118	3483815.605	530163.183	29.716
NVA-119	3482102.230	520004.241	55.209
NVA-120	3483266.933	505032.295	34.771
NVA-121	3479404.991	485309.307	109.105
NVA-122	3480362.589	481000.268	108.902

NVA-123	3478994.644	469601.537	116.539
NVA-124	3478637.863	456529.695	77.167
NVA-125	3479657.448	437644.636	80.299
NVA-126	3471106.875	441218.236	71.238
NVA-127	3470371.578	459561.463	87.633
NVA-128	3473366.456	477009.489	116.680
NVA-129	3466369.029	494217.487	81.573
NVA-130	3469556.118	510999.596	79.588
NVA-131	3466929.338	527743.672	28.658
NVA-132	3469728.676	538918.750	25.218
NVA-133	3469486.668	553475.692	46.120
NVA-134	3468869.129	562997.591	53.222
NVA-135	3469506.676	579504.542	22.545
NVA-136	3457419.892	568683.728	31.453
NVA-137	3455814.502	554303.402	24.867
NVA-138	3455833.130	540756.340	48.272
NVA-139	3459683.994	529340.630	54.284
NVA-140	3457259.827	517921.061	70.018
NVA-141	3455999.974	505143.455	80.445
NVA-142	3456414.110	490914.497	96.566
NVA-143	3455029.084	479501.809	108.771
NVA-144	3457543.127	467559.121	102.507
NVA-145	3452884.504	444665.891	60.333
NVA-146	3444471.841	453186.625	87.211
NVA-147	3446783.938	474864.834	75.886
NVA-148	3447576.300	485009.760	108.090
NVA-149	3447671.777	508166.710	77.769
NVA-150	3444951.804	517803.759	57.106
NVA-151	3444400.695	530264.278	60.783

NVA-152	3448616.548	547403.463	33.724
NVA-153	3449853.242	557207.348	22.104
NVA-154	3445305.750	568339.495	18.591
NVA-155	3435590.590	560165.631	21.429
NVA-156	3437785.020	545637.661	57.255
NVA-157	3436424.212	526465.700	46.290
NVA-158	3432540.826	513105.362	70.268
NVA-159	3428793.683	501699.813	62.512
NVA-160	3431257.918	483547.184	94.061
NVA-161	3430972.854	473650.369	83.487
NVA-162	3431627.817	460663.045	82.547
NVA-163	3424064.708	451929.444	30.581
NVA-164	3420723.767	473122.574	68.128
NVA-165	3418311.418	483429.585	61.212
NVA-166	3422317.375	501554.709	56.457
NVA-167	3419869.448	510555.180	44.312
NVA-168	3411838.542	498610.913	53.763
NVA-169	3405115.988	489274.949	37.835
NVA-170	3407002.501	476784.338	47.813
NVA-171	3407438.017	463015.857	57.758
NVA-172	3412456.381	451266.813	31.283
NVA-173	3397476.525	446095.324	26.199
NVA-174	3401362.711	466476.504	43.946
NVA-175	3399758.822	477278.371	47.236
NVA-176	3396551.439	487176.431	40.091
NVA-177	3396673.451	496630.129	26.638
NVA-178	3386707.925	495593.712	33.922
NVA-179	3386772.276	482176.316	37.678
NVA-180	3386027.731	471955.358	40.921
NVA-181	3391471.873	460428.898	44.911

NVA-182	3385848.105	451055.220	40.247
NVA-183	3388208.174	440534.642	23.748
NVA-184	3378184.420	434391.621	27.749
NVA-185	3376810.515	451678.282	30.423
NVA-186	3379580.200	467576.932	32.569
NVA-187	3375340.893	477440.697	25.476
NVA-188	3376064.477	485805.138	16.027
NVA-189	3364241.880	485363.783	7.968
NVA-190	3363042.269	477631.366	8.161
NVA-191	3362366.779	460365.416	17.167
NVA-192	3363995.289	451122.868	22.020
NVA-193	3357598.284	441915.633	12.980
NVA-194	3367212.392	437795.295	15.949
NVA-195	3353691.437	434279.333	7.478
NVA-196	3354113.480	451794.294	6.502
NVA-197	3355790.429	465151.913	6.263
NVA-198	3352306.959	480771.354	6.211
NVA-199	3340224.072	483265.121	3.184
NVA-200	3339239.404	468670.222	4.399
NVA-201	3340749.831	457323.177	3.337
NVA-202	3340071.156	444156.819	4.410
NVA-203	3341188.085	434615.665	2.051
NVA-204	3330748.059	434505.887	2.506
NVA-205	3329481.714	450065.359	1.904
NVA-206	3330448.143	461345.873	0.816
NVA-207	3332616.726	472750.917	2.015
NVA-208	3324987.242	479539.037	2.134
NVA-209	3332726.105	485953.257	2.833
Check Points - VVA's			
VVA-1	3644800.830	411222.592	69.714

VVA-2	3648451.109	425688.912	60.893
VVA-3	3651243.920	442165.557	74.397
VVA-4	3645354.250	448687.639	71.916
VVA-5	3635972.442	452430.469	66.916
VVA-6	3635880.169	434687.631	74.607
VVA-7	3634836.419	416889.001	55.891
VVA-8	3633854.955	405193.463	68.094
VVA-9	3626116.295	412344.168	52.907
VVA-10	3625825.202	428645.719	71.464
VVA-11	3627701.547	439735.081	73.482
VVA-12	3628546.148	448528.009	69.440
VVA-13	3615689.549	449945.246	81.011
VVA-14	3617689.211	434278.538	64.333
VVA-15	3614584.724	419173.252	52.423
VVA-16	3616253.960	405332.018	64.885
VVA-17	3607065.381	407927.400	85.576
VVA-18	3608258.377	423801.540	50.973
VVA-19	3610480.804	437929.413	49.292
VVA-20	3611931.423	455719.798	64.544
VVA-21	3596844.203	450286.063	70.226
VVA-22	3602156.567	436323.127	50.258
VVA-23	3598971.533	419992.773	59.810
VVA-24	3599644.112	406724.146	64.436
VVA-25	3585905.351	409055.825	90.955
VVA-26	3585923.687	422014.015	63.857
VVA-27	3587645.276	444391.792	47.292
VVA-28	3589472.530	455981.909	63.587
VVA-29	3577062.072	457369.797	57.378
VVA-30	3577040.545	440971.174	46.291
VVA-31	3573606.770	425836.427	69.879

VVA-32	3574879.546	416041.643	73.889
VVA-33	3575530.612	402924.561	108.191
VVA-34	3565398.944	407952.800	104.858
VVA-35	3566023.276	426022.096	76.460
VVA-36	3565337.136	448360.179	42.964
VVA-37	3560961.461	466243.723	60.506
VVA-38	3561287.721	477190.914	52.408
VVA-39	3549273.752	504793.834	79.005
VVA-40	3547585.257	490728.155	55.164
VVA-41	3545057.051	477248.022	68.528
VVA-42	3544511.220	451809.872	59.416
VVA-43	3543899.149	439879.850	99.623
VVA-44	3544678.898	416466.025	90.623
VVA-45	3535487.886	409470.593	58.136
VVA-46	3534853.631	426878.263	100.476
VVA-47	3535084.919	445278.045	112.099
VVA-48	3536196.325	466290.211	39.488
VVA-49	3537398.757	485724.867	41.449
VVA-50	3538726.287	501509.693	77.399
VVA-51	3528964.802	506338.443	44.882
VVA-52	3529466.252	484913.156	45.848
VVA-53	3526544.441	464799.681	65.098
VVA-54	3524742.536	452624.179	106.300
VVA-55	3526650.274	436827.374	74.594
VVA-56	3525801.664	422698.282	63.381
VVA-57	3516180.698	429690.914	99.388
VVA-58	3515832.737	443659.868	67.136
VVA-59	3516118.191	454322.870	104.996
VVA-60	3516849.272	473225.512	46.982
VVA-61	3517632.988	483400.520	55.766

VVA-62	3518778.091	501308.728	35.025
VVA-63	3507523.283	498532.387	34.732
VVA-64	3509099.331	488129.470	41.697
VVA-65	3504661.082	471377.860	69.881
VVA-66	3504898.892	458290.342	90.020
VVA-67	3503959.218	445597.027	88.845
VVA-68	3504324.092	428992.080	69.998
VVA-69	3489523.112	441308.800	60.800
VVA-70	3491270.013	463450.020	127.873
VVA-71	3495173.629	476572.693	77.452
VVA-72	3495474.337	490480.655	40.023
VVA-73	3498494.489	505302.446	31.167
VVA-74	3500823.588	519631.902	61.207
VVA-75	3502281.786	534637.108	29.551
VVA-76	3515256.763	547670.319	32.131
VVA-77	3506861.081	552849.808	52.322
VVA-78	3491905.849	550937.176	59.881
VVA-79	3487948.806	538701.251	52.044
VVA-80	3488369.016	511718.263	30.801
VVA-81	3476312.953	574191.746	26.307
VVA-82	3477161.722	543281.252	33.674
VVA-83	3481016.689	494233.509	87.868
VVA-84	3477648.453	511048.806	95.261
VVA-85	3474182.671	474601.021	112.018
VVA-86	3474055.048	457963.341	67.456
VVA-87	3467627.046	448538.108	61.197
VVA-88	3463216.655	471073.885	92.937
VVA-89	3465753.011	500213.879	73.999
VVA-90	3462684.624	513230.080	73.412
VVA-91	3462558.295	528269.328	46.630

VVA-92	3463597.685	562425.961	51.428
VVA-93	3467796.499	585566.004	13.213
VVA-94	3449700.998	558848.889	21.243
VVA-95	3449765.972	542344.293	58.059
VVA-96	3440390.985	529776.506	64.250
VVA-97	3441252.423	511246.362	70.944
VVA-98	3450408.039	496951.757	95.852
VVA-99	3450628.344	469659.249	76.923
VVA-100	3457500.649	456295.041	122.546
VVA-101	3446608.402	459651.720	96.072
VVA-102	3440225.605	453024.726	52.003
VVA-103	3438124.888	468462.799	68.502
VVA-104	3432858.159	476263.613	92.573
VVA-105	3428451.729	495572.406	78.067
VVA-106	3426840.080	507886.662	58.339
VVA-107	3417048.796	491856.960	62.707
VVA-108	3418289.821	475204.845	64.039
VVA-109	3429707.585	463552.140	77.616
VVA-110	3418577.056	464562.736	47.296
VVA-111	3418763.014	454546.252	46.601
VVA-112	3409890.038	449027.742	26.951
VVA-113	3411879.867	460731.938	53.485
VVA-114	3414179.489	479618.305	47.834
VVA-115	3410902.478	491785.601	58.928
VVA-116	3414878.744	500398.881	51.846
VVA-117	3405014.926	499732.867	31.612
VVA-118	3403362.475	483677.563	38.638
VVA-119	3402977.252	472834.470	51.924
VVA-120	3404492.718	455879.575	55.983
VVA-121	3402367.213	443638.371	20.068

VVA-122	3396788.592	458963.025	47.227
VVA-123	3395936.939	472805.062	48.896
VVA-124	3395687.162	482442.850	43.617
VVA-125	3392481.117	500067.411	29.417
VVA-126	3388151.624	486300.580	41.210
VVA-127	3379760.414	482989.966	27.522
VVA-128	3381196.273	471213.413	32.099
VVA-129	3383066.820	458120.358	32.594
VVA-130	3383100.189	436125.565	30.464
VVA-131	3373295.230	435625.064	27.745
VVA-132	3373201.974	451681.309	28.933
VVA-133	3371586.628	461923.431	26.407
VVA-134	3372311.929	476879.565	22.211
VVA-135	3355379.591	485539.058	7.054
VVA-136	3356957.158	474314.369	7.048
VVA-137	3360497.410	466630.450	8.616
VVA-138	3358621.112	457845.413	13.029
VVA-139	3359636.831	444382.670	15.411
VVA-140	3359207.809	433131.923	9.445
VVA-141	3348062.861	437868.548	7.148
VVA-142	3350135.295	451593.252	5.823
VVA-143	3350533.454	458208.511	4.970
VVA-144	3350041.868	469800.558	5.924
VVA-145	485056.607	3347301.494	3.160
VVA-146	3329464.843	482688.081	1.524
VVA-147	3326777.417	465977.398	0.495
VVA-148	3334312.087	453260.649	2.819
VVA-149	3333937.918	442870.206	2.297
VVA-150	3332307.371	436986.413	1.098

4. GPS OBSERVATIONS

POINT ID	OBSERV. DATE	JULIAN DATE	TIME OF DAY (AST)	RE-OBSERV. DATE	RE-OBSERV. TIME
NVA-1	3/2/2018	61	16:21	3/2/2018	16:24
NVA-2	4/14/2018	73	13:44	4/14/2018	14:47
NVA-3	4/14/2018	73	14:11	N/A	N/A
NVA-4	4/14/2018	73	15:22	4/14/2018	16:26
NVA-5	4/14/2018	73	16:21	4/14/2018	17:24
NVA-6	4/14/2018	73	12:25	4/14/2018	13:28
NVA-7	4/14/2018	73	12:57	4/15/2018	18:18
NVA-8	4/13/2018	72	15:24	4/15/2018	11:23
NVA-9	4/13/2018	72	14:57	4/15/2018	11:40
NVA-10	4/13/2018	72	13:59	4/15/2018	12:23
NVA-11	4/13/2018	72	16:14	4/15/2018	17:30
NVA-12	4/14/2018	73	11:07	N/A	N/A
NVA-13	4/14/2018	73	17:40	4/14/2018	18:43
NVA-14	4/14/2018	73	17:03	4/15/2018	10:08
NVA-15	4/14/2018	73	19:47	4/14/2018	19:50
NVA-16	4/14/2018	73	18:19	N/A	N/A
NVA-17	4/14/2018	73	10:18	4/15/2018	16:51
NVA-18	4/13/2018	72	16:37	4/15/2018	10:27
NVA-19	4/13/2018	72	12:17	4/15/2018	13:31
NVA-20	4/13/2018	72	10:50	4/15/2018	13:09
NVA-21	4/13/2018	72	17:20	4/15/2018	9:53
NVA-22	4/14/2018	73	8:48	4/15/2018	14:01
NVA-23	4/10/2018	69	14:59	N/A	N/A
NVA-24	4/14/2018	73	19:35	4/14/2018	N/A

NVA-25	4/10/2018	69	15:43	N/A	N/A
NVA-26	4/10/2018	69	14:29	4/13/2018	11:34
NVA-27	4/10/2018	69	13:35	4/13/2018	10:56
NVA-28	4/13/2018	72	18:32	N/A	N/A
NVA-29	4/13/2018	72	10:00	N/A	N/A
NVA-30	4/10/2018	69	18:11	N/A	N/A
NVA-31	4/10/2018	69	17:45	N/A	N/A
NVA-32	4/9/2018	68	18:54	4/9/2018	18:57
NVA-33	4/13/2018	72	16:00	N/A	N/A
NVA-34	4/13/2018	72	13:27	4/13/2018	13:30
NVA-35	4/13/2018	72	14:38	N/A	N/A
NVA-36	4/13/2018	72	16:34	N/A	N/A
NVA-37	4/9/2018	68	13:19	4/9/2018	13:22
NVA-38	4/12/2018	71	11:19	N/A	N/A
NVA-39	4/11/2018	70	12:18	4/11/2018	12:21
NVA-40	4/11/2018	70	13:13	N/A	N/A
NVA-41	4/9/2018	68	18:00	N/A	N/A
NVA-42	4/9/2018	68	15:52	4/9/2018	15:55
NVA-43	4/9/2018	68	14:18	4/9/2018	14:21
NVA-44	4/13/2018	72	17:00	N/A	N/A
NVA-45	4/14/2018	73	15:26	N/A	N/A
NVA-46	4/13/2018	72	17:33	4/15/2018	15:10
NVA-47	4/9/2018	68	15:04	N/A	N/A
NVA-48	4/9/2018	68	16:38	4/12/2018	13:40
NVA-49	4/9/2018	68	17:01	4/12/2018	13:20
NVA-50	4/9/2018	68	17:22	N/A	N/A
NVA-51	4/11/2018	70	14:06	4/11/2018	14:09
NVA-52	4/11/2018	70	14:31	N/A	N/A
NVA-53	4/11/2018	70	15:02	N/A	N/A
NVA-54	4/11/2018	70	18:41	4/11/2018	18:44

NVA-55	4/11/2018	70	19:17	4/11/2018	19:20
NVA-56	4/13/2018	72	18:17	N/A	N/A
NVA-57	4/14/2018	73	14:55	N/A	N/A
NVA-58	4/14/2018	73	16:03	N/A	N/A
NVA-59	4/14/2018	73	18:09	4/15/2018	13:23
NVA-60	4/15/2018	74	12:57	N/A	N/A
NVA-61	4/14/2018	73	16:43	4/14/2018	16:46
NVA-62	4/14/2018	73	13:24	N/A	N/A
NVA-63	4/13/2018	72	19:01	N/A	N/A
NVA-64	4/12/2018	71	14:59	4/12/2018	15:02
NVA-65	4/12/2018	71	18:17	4/12/2018	18:20
NVA-66	4/12/2018	71	17:30	4/12/2018	17:33
NVA-67	4/11/2018	70	16:03	4/11/2018	16:06
NVA-68	4/11/2018	70	18:05	4/11/2018	18:08
NVA-69	3/2/2018	61	15:41	3/2/2018	15:45
NVA-70	3/2/2018	61	16:32	3/2/2018	16:36
NVA-71	4/12/2018	71	17:11	N/A	N/A
NVA-72	4/12/2018	71	16:11	N/A	N/A
NVA-73	4/12/2018	71	15:40	4/12/2018	15:43
NVA-74	4/14/2018	73	12:24	N/A	N/A
NVA-75	4/14/2018	73	11:46	N/A	N/A
NVA-76	4/15/2018	74	12:34	N/A	N/A
NVA-77	3/1/2018	60	9:55	3/1/2018	9:58
NVA-78	3/1/2018	60	10:23	3/1/2018	10:26
NVA-79	3/1/2018	60	12:09	3/1/2018	12:12
NVA-80	2/28/2018	59	16:07	N/A	N/A
NVA-81	3/1/2018	60	13:52	N/A	N/A
NVA-82	2/27/2018	58	16:06	2/28/2018	13:49
NVA-83	3/1/2018	60	16:26	N/A	N/A
NVA-84	3/1/2018	60	17:04	3/1/2018	17:07

NVA-85	3/1/2018	60	17:32	3/1/2018	17:35
NVA-86	2/27/2018	58	13:16	2/27/2018	13:19
NVA-87	2/27/2018	58	14:31	N/A	N/A
NVA-88	2/26/2018	57	16:10	N/A	N/A
NVA-89	2/27/2018	58	17:38	N/A	N/A
NVA-90	2/28/2018	59	15:20	N/A	N/A
NVA-91	2/28/2018	59	10:00	3/1/2018	7:03
NVA-92	2/28/2018	59	8:18	3/1/2018	8:29
NVA-93	2/28/2018	59	8:52	3/1/2018	9:28
NVA-94	2/26/2018	57	15:15	N/A	N/A
NVA-95	2/26/2018	57	13:41	2/26/2018	13:45
NVA-96	2/26/2018	57	12:47	2/26/2018	12:51
NVA-97	2/26/2018	57	15:40	3/1/2018	16:33
NVA-98	2/28/2018	59	10:28	3/1/2018	17:15
NVA-99	2/28/2018	59	9:20	N/A	N/A
NVA-100	3/1/2018	60	9:23	3/1/2018	9:27
NVA-101	2/28/2017	59	18:12	2/28/2018	18:16
NVA-102	2/26/2018	57	14:23	N/A	N/A
NVA-103	2/26/2018	57	18:28	2/27/2018	18:19
NVA-104	2/26/2018	57	17:30	6/27/2018	10:53
NVA-105	2/27/2018	58	11:23	N/A	N/A
NVA-106	2/27/2018	58	9:56	N/A	N/A
NVA-107	2/27/2018	58	8:09	N/A	N/A
NVA-108	2/26/2018	57	12:37	N/A	N/A
NVA-109	2/26/2018	57	10:48	N/A	N/A
NVA-110	2/28/2018	59	15:49	N/A	N/A
NVA-111	2/28/2017	59	15:18	N/A	N/A
NVA-112	2/27/2018	58	18:14	N/A	N/A
NVA-113	2/28/2018	59	11:55	N/A	N/A
NVA-114	2/26/2018	57	12:29	2/26/2018	17:15

NVA-115	2/26/2018	57	10:51	N/A	N/A
NVA-116	2/26/2018	57	10:40	2/26/2018	17:28
NVA-117	2/27/2018	58	17:13	N/A	N/A
NVA-118	2/27/2018	58	16:23	N/A	N/A
NVA-119	2/27/2018	58	15:34	N/A	N/A
NVA-120	2/27/2018	58	15:00	N/A	N/A
NVA-121	2/26/2018	57	9:40	N/A	N/A
NVA-122	2/26/2018	57	10:20	2/26/2018	10:24
NVA-123	2/24/2018	55	16:48	2/25/2018	12:14
NVA-124	2/24/2018	55	16:01	N/A	N/A
NVA-125	2/27/2018	58	9:33	N/A	N/A
NVA-126	2/24/2018	55	14:47	N/A	N/A
NVA-127	2/25/2018	56	10:45	N/A	N/A
NVA-128	2/24/2018	55	18:12	N/A	N/A
NVA-129	2/25/2018	56	14:05	2/26/2018	8:58
NVA-130	2/27/2018	58	12:02	N/A	N/A
NVA-131	2/27/2018	58	9:54	N/A	N/A
NVA-132	2/27/2018	58	8:32	N/A	N/A
NVA-133	2/25/2018	56	16:01	N/A	N/A
NVA-134	2/26/2018	57	8:06	2/26/2018	18:24
NVA-135	2/26/2018	57	8:31	2/26/2018	8:35
NVA-136	2/25/2018	56	13:47	2/25/2018	13:51
NVA-137	2/24/2018	55	17:33	2/25/2017	7:59
NVA-138	2/24/2018	55	16:03	N/A	N/A
NVA-139	2/27/2018	58	10:41	3/1/2018	13:30
NVA-140	2/27/2018	58	11:06	2/27/2018	11:10
NVA-141	2/25/2018	56	16:07	N/A	N/A
NVA-142	2/25/2018	56	16:36	N/A	N/A
NVA-143	2/26/2018	57	7:07	N/A	N/A
NVA-144	2/25/2018	56	8:45	2/25/2018	5:57

NVA-145	2/24/2018	55	13:13	2/24/2018	13:16
NVA-146	2/24/2018	55	10:23	N/A	N/A
NVA-147	2/23/2018	54	17:34	2/24/2018	7:37
NVA-148	2/23/2018	54	16:56	2/24/2018	9:27
NVA-149	2/23/2018	54	15:45	N/A	N/A
NVA-150	2/23/2018	54	15:25	2/24/2018	10:48
NVA-151	2/24/2018	55	10:41	N/A	N/A
NVA-152	2/24/2018	55	15:12	N/A	N/A
NVA-153	2/25/2018	56	8:17	2/25/2018	15:09
NVA-154	2/25/2018	56	9:10	N/A	N/A
NVA-155	2/25/2018	56	9:46	N/A	N/A
NVA-156	2/24/2018	55	14:28	N/A	N/A
NVA-157	2/24/2018	55	13:39	2/24/2018	13:43
NVA-158	2/22/2018	53	16:31	N/A	N/A
NVA-159	2/22/2018	53	17:07	2/23/2018	13:59
NVA-160	2/24/2018	55	8:32	N/A	N/A
NVA-161	2/20/2018	51	18:49	N/A	N/A
NVA-162	2/23/2018	54	9:08	N/A	N/A
NVA-163	2/23/2018	54	10:32	N/A	N/A
NVA-164	2/20/2018	51	18:13	N/A	N/A
NVA-165	2/22/2018	53	11:10	N/A	N/A
NVA-166	2/22/2018	53	15:30	N/A	N/A
NVA-167	2/22/2018	53	14:59	N/A	N/A
NVA-168	2/22/2018	53	14:04	N/A	N/A
NVA-169	2/22/2018	53	13:12	N/A	N/A
NVA-170	2/19/2018	50	16:03	2/20/2018	17:24
NVA-171	2/19/2018	50	14:52	N/A	N/A
NVA-172	2/19/2018	50	14:08	2/19/2018	14:11
NVA-173	2/19/2018	50	11:26	N/A	N/A
NVA-174	2/19/2018	50	15:17	N/A	N/A

NVA-175	2/19/2018	50	18:02	2/20/2018	17:10
NVA-176	2/20/2018	51	15:15	N/A	N/A
NVA-177	2/20/2018	51	14:21	2/20/2018	14:24
NVA-178	2/20/2018	51	13:18	2/20/2018	13:21
NVA-179	2/20/2018	51	12:23	N/A	N/A
NVA-180	2/20/2018	51	12:02	2/20/2018	12:05
NVA-181	2/19/2018	50	10:22	N/A	N/A
NVA-182	2/18/2018	49	14:38	N/A	N/A
NVA-183	2/18/2018	49	13:34	2/18/2018	13:37
NVA-184	2/18/2018	49	13:00	N/A	N/A
NVA-185	2/18/2018	49	15:27	1/19/2018	9:24
NVA-186	2/17/2018	48	14:09	N/A	N/A
NVA-187	2/17/2018	48	12:38	2/20/2018	10:31
NVA-188	2/17/2018	48	12:57	2/20/2018	10:50
NVA-189	2/17/2018	48	11:37	2/17/2018	11:40
NVA-190	2/17/2018	48	10:50	N/A	N/A
NVA-191	2/16/2018	47	16:20	2/17/2018	15:13
NVA-192	2/16/2018	47	15:28	2/18/2018	17:29
NVA-193	2/16/2018	47	15:08	2/18/2018	16:53
NVA-194	2/18/2018	49	12:15	N/A	N/A
NVA-195	2/16/2018	47	13:50	2/18/2018	11:32
NVA-196	2/17/2018	48	15:51	N/A	N/A
NVA-197	2/16/2018	47	17:17	N/A	N/A
NVA-198	2/17/2018	48	9:38	2/17/2018	9:41
NVA-199	2/14/2018	45	16:10	2/15/2018	12:55
NVA-200	2/15/2018	46	15:21	2/16/2018	9:29
NVA-201	2/15/2018	46	14:32	2/16/2018	10:03
NVA-202	2/15/2018	46	18:02	2/15/2018	18:05
NVA-203	2/16/2018	47	12:43	N/A	N/A
NVA-204	2/16/2018	47	12:07	2/16/2018	12:10

NVA-205	2/15/2018	46	16:50	2/16/2018	10:45
NVA-206	2/15/2018	46	15:53	2/15/2018	15:56
NVA-207	2/15/2018	46	9:34	2/15/2018	9:37
NVA-208	2/14/2018	45	17:50	N/A	N/A
NVA-209	2/14/2018	45	17:04	2/15/2018	12:03

VVA's					
VVA-1	3/2/2018	61	15:52	3/2/2018	15:55
VVA-2	4/14/2018	73	13:25	N/A	N/A
VVA-3	4/14/2018	73	14:44	N/A	N/A
VVA-4	4/14/2018	73	15:46	4/14/2018	16:46
VVA-5	4/14/2018	73	16:43	4/14/2018	17:43
VVA-6	4/14/2018	73	0:00	4/15/2018	17:55
VVA-7	4/13/2018	72	15:49	N/A	N/A
VVA-8	4/13/2018	72	14:35	N/A	N/A
VVA-9	4/13/2018	72	13:32	N/A	N/A
VVA-10	4/14/2018	73	10:44	N/A	N/A
VVA-11	4/14/2018	73	17:55	4/14/2018	18:59
VVA-12	4/14/2018	73	17:20	4/14/2018	18:23
VVA-13	4/14/2018	73	19:08	N/A	N/A
VVA-14	4/14/2018	73	9:46	4/15/2018	16:36
VVA-15	4/13/2018	72	17:00	N/A	N/A
VVA-16	4/13/2018	72	11:47	N/A	N/A
VVA-17	4/13/2018	72	10:28	4/15/2018	14:15
VVA-18	4/13/2018	72	17:49	4/15/2018	9:29
VVA-19	4/14/2018	73	9:10	4/15/2018	16:17
VVA-20	4/14/2018	73	19:55	4/14/2018	20:59
VVA-21	4/13/2018	72	12:54	4/13/2018	12:57
VVA-22	4/10/2018	69	13:58	4/13/2018	11:15
VVA-23	4/14/2018	73	8:07	4/14/2018	21:18
VVA-24	4/13/2018	72	9:32	4/15/2018	15:58

VVA-25	4/11/2018	70	12:00	4/11/2018	12:03
VVA-26	4/12/2018	71	11:00	4/12/2018	11:03
VVA-27	4/13/2018	72	16:15	4/15/2018	16:26
VVA-28	4/13/2018	72	14:09	4/13/2018	14:12
VVA-29	4/13/2018	72	15:01	N/A	N/A
VVA-30	4/9/2018	68	13:44	4/9/2018	13:47
VVA-31	4/9/2018	68	18:23	4/12/2018	12:16
VVA-32	4/12/2018	71	11:39	4/12/2018	11:42
VVA-33	4/11/2018	70	12:45	4/11/2018	12:48
VVA-34	4/11/2018	70	13:38	N/A	N/A
VVA-35	4/9/2018	68	17:39	N/A	N/A
VVA-36	4/9/2018	68	14:44	4/9/2018	14:47
VVA-37	4/13/2018	72	17:52	N/A	N/A
VVA-38	4/14/2018	73	15:40	4/14/2018	15:43
VVA-39	4/14/2018	73	18:43	N/A	N/A
VVA-40	4/14/2018	73	16:26	4/15/2018	13:51
VVA-41	4/14/2018	73	13:52	N/A	N/A
VVA-42	4/12/2018	71	14:39	4/12/2018	14:42
VVA-43	4/12/2018	71	17:55	4/12/2018	17:58
VVA-44	4/11/2018	70	15:26	4/11/2018	15:29
VVA-45	4/11/2018	70	17:46	N/A	N/A
VVA-46	4/11/2018	70	16:25	4/11/2018	16:28
VVA-47	4/12/2018	71	16:36	4/12/2018	16:39
VVA-48	4/12/2018	71	15:22	4/12/2018	15:25
VVA-49	4/14/2018	73	12:54	N/A	N/A
VVA-50	4/14/2018	73	17:21	4/14/2018	17:24
VVA-51	4/15/2018	74	12:11	N/A	N/A
VVA-52	4/14/2018	73	12:07	4/14/2018	12:10
VVA-53	3/1/2018	60	13:19	N/A	N/A
VVA-54	3/1/2018	60	14:28	N/A	N/A

VVA-55	3/1/2018	60	15:27	N/A	N/A
VVA-56	3/2/2018	61	16:02	3/2/2018	16:06
VVA-57	2/27/2018	58	13:35	N/A	N/A
VVA-58	2/27/2018	58	15:10	N/A	N/A
VVA-59	2/27/2018	58	16:32	2/27/2018	17:35
VVA-60	2/28/2018	59	15:46	2/28/2018	15:49
VVA-61	2/28/2018	59	16:38	3/1/2018	11:34
VVA-62	3/1/2018	60	9:07	3/1/2018	9:10
VVA-63	2/28/2018	59	17:17	2/28/2018	17:20
VVA-64	2/28/1959	59	9:37	2/28/2018	18:32
VVA-65	2/26/2018	57	13:38	N/A	N/A
VVA-66	2/26/2018	57	15:03	N/A	N/A
VVA-67	2/26/2018	57	16:30	N/A	N/A
VVA-68	2/27/2018	58	12:18	N/A	N/A
VVA-69	2/27/2018	58	10:24	2/27/2018	10:27
VVA-70	2/27/2018	58	7:22	2/27/2018	7:25
VVA-71	2/26/2018	57	11:19	N/A	N/A
VVA-72	2/26/2018	57	17:37	N/A	N/A
VVA-73	3/1/2018	60	10:33	3/1/2018	10:37
VVA-74	2/28/2019	59	13:39	2/28/2018	13:43
VVA-75	2/28/2018	59	10:48	N/A	N/A
VVA-76	2/26/2018	57	14:32	2/26/2018	14:36
VVA-77	2/26/2018	57	13:11	2/26/2018	13:15
VVA-78	2/26/2018	57	16:32	N/A	N/A
VVA-79	2/27/2018	58	17:44	3/1/2018	15:55
VVA-80	2/28/2018	59	15:00	3/1/2018	11:37
VVA-81	2/26/2018	57	10:05	N/A	N/A
VVA-82	2/25/2018	56	16:31	N/A	N/A
VVA-83	2/27/2018	58	13:00	N/A	N/A
VVA-84	2/28/2018	59	16:45	N/A	N/A

VVA-85	2/24/2018	55	17:22	N/A	N/A
VVA-86	2/25/2018	56	11:08	N/A	N/A
VVA-87	2/24/2018	55	13:56	N/A	N/A
VVA-88	2/25/2018	56	9:18	2/25/2018	9:21
VVA-89	2/25/2018	56	14:43	2/25/2018	14:46
VVA-90	2/27/2018	58	11:32	2/27/2018	11:36
VVA-91	2/27/2018	58	10:17	N/A	N/A
VVA-92	2/25/2018	56	13:03	N/A	N/A
VVA-93	2/26/2018	57	9:05	2/26/2018	9:09
VVA-94	3/1/2018	60	14:25	3/1/2018	14:29
VVA-95	2/24/2018	55	15:34	N/A	N/A
VVA-96	2/24/2018	55	12:41	N/A	N/A
VVA-97	2/23/2018	54	14:58	N/A	N/A
VVA-98	2/23/2018	54	16:34	N/A	N/A
VVA-99	2/24/2018	55	8:03	2/24/2018	8:06
VVA-100	2/24/2018	55	12:00	N/A	N/A
VVA-101	2/24/2018	55	8:57	N/A	N/A
VVA-102	2/24/2018	55	9:40	N/A	N/A
VVA-103	2/23/2018	54	8:27	2/23/2018	8:31
VVA-104	2/21/2018	52	15:30	N/A	N/A
VVA-105	2/22/2018	53	18:01	N/A	N/A
VVA-106	2/22/2018	53	16:07	2/23/2018	14:30
VVA-107	2/22/2018	53	11:47	N/A	N/A
VVA-108	2/22/2018	53	10:38	N/A	N/A
VVA-109	2/23/2018	54	9:30	N/A	N/A
VVA-110	2/23/2018	54	11:33	N/A	N/A
VVA-111	2/23/2018	54	10:53	N/A	N/A
VVA-112	2/19/2018	50	13:54	N/A	N/A
VVA-113	2/19/2018	50	14:30	N/A	N/A
VVA-114	2/19/2018	50	17:15	N/A	N/A

VVA-115	2/22/2018	53	12:30	N/A	N/A
VVA-116	2/22/2018	53	14:31	2/22/2018	14:35
VVA-117	2/22/2018	53	13:44	2/22/2018	13:48
VVA-118	2/19/2018	50	17:42	N/A	N/A
VVA-119	2/19/2018	50	15:40	N/A	N/A
VVA-120	2/19/2018	50	13:20	2/19/2018	13:23
VVA-121	2/19/2018	50	12:03	N/A	N/A
VVA-122	2/19/2018	50	10:50	N/A	N/A
VVA-123	2/20/2018	51	16:40	N/A	N/A
VVA-124	2/20/2018	51	16:06	N/A	N/A
VVA-125	2/20/2018	51	13:39	2/20/2018	13:42
VVA-126	2/20/2018	51	12:40	N/A	N/A
VVA-127	2/17/2018	48	13:14	N/A	N/A
VVA-128	2/17/2018	48	13:46	N/A	N/A
VVA-129	2/18/2018	49	15:06	2/19/2018	10:05
VVA-130	2/18/2018	49	13:16	2/18/2018	13:19
VVA-131	2/18/2018	49	12:41	2/18/2018	12:44
VVA-132	2/18/2018	49	15:43	2/19/2018	9:16
VVA-133	2/17/2018	48	14:40	2/19/2018	8:52
VVA-134	2/17/2018	48	12:20	N/A	N/A
VVA-135	2/17/2018	48	9:58	2/17/2018	10:01
VVA-136	2/17/2018	48	10:28	2/17/2018	10:31
VVA-137	2/16/2018	47	16:40	2/16/2018	16:43
VVA-138	2/17/2018	48	15:29	2/17/2018	15:32
VVA-139	2/16/2018	47	14:50	2/18/2018	17:04
VVA-140	2/16/2018	47	14:22	2/18/2018	11:48
VVA-141	2/16/2018	47	13:17	2/18/2018	11:02
VVA-142	2/17/2018	48	16:06	N/A	N/A
VVA-143	2/17/2018	48	16:24	2/17/2018	16:27
VVA-144	2/16/2018	48	18:00	N/A	N/A

VVA-145	2/14/2018	45	15:21	N/A	N/A
VVA-146	2/14/2018	45	17:21	2/15/2018	10:04
VVA-147	2/15/2018	46	16:22	N/A	N/A
VVA-148	2/15/2018	46	17:06	2/16/2018	10:22
VVA-149	2/15/2018	46	17:45	2/16/2018	11:11
VVA-150	2/16/2018	47	11:49	N/A	N/A

5. POINT COMPARISON

Point ID	Point CK	Delta North (M)	Delta East (M)	Vertical Difference (M)
NVA-1	NVA-1CK	0.002	-0.004	-0.007
NVA-2	NVA-2CK	-0.005	0.001	0.001
NVA-4	NVA-4CK	-0.001	0.001	0.007
NVA-5	NVA-5CK	0.001	0.000	-0.001
NVA-6	NVA-6CK	0.003	0.006	0.031
NVA-7	NVA-7CK	0.007	0.002	-0.002
NVA-8	NVA-8CK	-0.006	0.004	0.019
NVA-9	NVA-9CK	0.008	-0.004	-0.010
NVA-11	NVA-11CK	0.001	0.002	-0.005
NVA-13	NVA-13CK	0.000	0.000	-0.004
NVA-14	NVA-14CK	-0.010	0.007	-0.018
NVA-15	NVA-15CK	0.007	0.011	0.006
NVA-17	NVA-17CK	-0.004	-0.005	0.000
NVA-18	NVA-18CK	0.003	0.001	0.002
NVA-19	NVA-19CK	0.008	-0.022	0.005
NVA-20	NVA-20CK	0.010	0.001	-0.004
NVA-21	NVA-21CK	-0.012	0.008	-0.025
NVA-22	NVA-22CK	0.003	0.009	-0.019
NVA-24	NVA-24CK	0.004	-0.003	0.004
NVA-26	NVA-26CK	0.000	0.000	0.003
NVA-27	NVA-27CK	0.000	-0.003	0.009

NVA-32	NVA-32CK	-0.003	0.004	-0.008
NVA-34	NVA-34CK	-0.010	0.003	-0.012
NVA-37	NVA-37CK	0.001	0.000	0.008
NVA-39	NVA-39CK	0.001	0.004	0.001
NVA-42	NVA-42CK	0.003	0.002	0.001
NVA-43	NVA-43CK	-0.003	-0.003	-0.002
NVA-46	NVA-46CK	0.006	-0.004	-0.001
NVA-48	NVA-48CK	0.000	0.000	0.009
NVA-49	NVA-49CK	0.005	0.004	0.009
NVA-51	NVA-51CK	0.008	-0.003	0.005
NVA-54	NVA-54CK	0.001	0.002	0.000
NVA-55	NVA-55CK	-0.002	0.002	0.007
NVA-59	NVA-59CK	0.004	-0.011	0.002
NVA-61	NVA-61CK	0.004	-0.002	0.008
NVA-64	NVA-64CK	0.001	0.002	0.003
NVA-65	NVA-65CK	-0.004	0.003	-0.002
NVA-66	NVA-66CK	-0.003	0.004	-0.003
NVA-67	NVA-67CK	0.002	0.002	-0.002
NVA-68	NVA-68CK	0.001	0.008	-0.009
NVA-69	NVA-69CK	0.010	-0.003	0.003
NVA-70	NVA-70CK	0.006	0.005	0.000
NVA-73	NVA-73CK	0.001	-0.008	-0.006
NVA-77	NVA-77CK	-0.002	-0.002	-0.004
NVA-78	NVA-78CK	0.003	0.000	-0.007
NVA-79	NVA-79CK	0.003	-0.002	0.008
NVA-82	NVA-82CK	-0.002	-0.003	-0.005
NVA-84	NVA-84CK	-0.003	-0.006	0.001
NVA-85	NVA-85CK	0.001	0.006	0.005
NVA-86	NVA-86CK	-0.001	-0.009	-0.003
NVA-91	NVA-91CK	-0.004	0.001	-0.007
NVA-92	NVA-92CK	0.003	0.001	0.003
NVA-93	NVA-93CK	-0.004	-0.006	-0.004

NVA-95	NVA-95CK	0.000	0.001	0.009
NVA-96	NVA-96CK	0.013	0.008	0.007
NVA-97	NVA-97CK	-0.004	-0.002	0.007
NVA-98	NVA-98CK	0.005	0.004	0.000
NVA-100	NVA-100CK	0.000	0.002	0.006
NVA-101	NVA-101CK	-0.001	-0.002	0.002
NVA-103	NVA-103CK	0.005	-0.002	0.006
NVA-104	NVA-104CK	0.007	-0.003	0.002
NVA-114	NVA-114CK	0.003	-0.002	-0.006
NVA-116	NVA-116CK	0.003	-0.004	0.006
NVA-122	NVA-122CK	-0.002	-0.009	0.004
NVA-123	NVA-123CK	0.009	0.004	0.012
NVA-129	NVA-129CK	-0.010	-0.004	-0.018
NVA-134	NVA-134CK	0.004	-0.006	-0.001
NVA-135	NVA-135CK	-0.002	0.007	0.006
NVA-136	NVA-136CK	-0.003	-0.001	0.005
NVA-137	NVA-137CK	0.004	-0.003	0.004
NVA-139	NVA-139CK	-0.004	-0.001	-0.005
NVA-140	NVA-140CK	0.004	0.004	-0.005
NVA-144	NVA-144CK	0.000	-0.003	0.002
NVA-145	NVA-145CK	-0.011	-0.004	-0.008
NVA-147	NVA-147CK	0.006	-0.003	-0.008
NVA-148	NVA-148CK	0.000	0.009	0.001
NVA-150	NVA-150CK	-0.011	0.004	-0.003
NVA-153	NVA-153CK	-0.002	0.000	-0.004
NVA-157	NVA-157CK	-0.007	-0.002	0.012
NVA-159	NVA-159CK	0.002	-0.005	0.002
NVA-170	NVA-170CK	-0.008	0.005	-0.031
NVA-172	NVA-172CK	-0.031	0.001	0.009
NVA-175	NVA-175CK	0.003	0.005	0.013

NVA-177	NVA-177CK	0.003	0.002	0.005
NVA-178	NVA-178CK	0.011	-0.002	-0.002
NVA-180	NVA-180CK	-0.010	0.000	-0.002
NVA-183	NVA-183CK	-0.005	0.009	0.007
NVA-185	NVA-185CK	-0.001	0.001	-0.010
NVA-187	NVA-187CK	0.004	-0.010	0.004
NVA-188	NVA-188CK	-0.003	-0.008	0.001
NVA-189	NVA-189CK	-0.005	-0.010	-0.005
NVA-191	NVA-191CK	0.002	0.003	-0.004
NVA-192	NVA-192CK	-0.009	-0.001	0.002
NVA-193	NVA-193CK	-0.002	0.000	-0.007
NVA-195	NVA-195CK	0.003	0.008	0.003
NVA-198	NVA-198CK	0.004	0.001	-0.002
NVA-199	NVA-199CK	0.002	0.001	0.008
NVA-200	NVA-200CK	-0.004	0.002	0.000
NVA-201	NVA-201CK	0.013	0.001	-0.010
NVA-202	NVA-202CK	0.002	0.005	-0.003
NVA-204	NVA-204CK	-0.007	-0.003	0.012
NVA-205	NVA-205CK	0.003	0.005	0.002
NVA-206	NVA-206CK	0.003	-0.001	0.010
NVA-207	NVA-207CK	0.003	0.000	0.004
NVA-209	NVA-209CK	-0.001	-0.002	0.012
VVA’s				
VVA-1	VVA-1CK	0.010	0.007	0.005
VVA-4	VVA-4CK	-0.003	-0.007	0.011

VVA-5	VVA-5CK	-0.006	0.007	0.010
VVA-6	VVA-6CK	0.000	-0.018	-0.021
VVA-11	VVA-11CK	-0.002	0.000	-0.017
VVA-12	VVA-12CK	-0.001	0.011	0.016
VVA-14	VVA-14CK	0.008	0.003	0.019
VVA-17	VVA-17CK	0.007	-0.005	-0.009
VVA-18	VVA-18CK	-0.001	-0.001	-0.011
VVA-19	VVA-19CK	0.003	0.017	0.021
VVA-20	VVA-20CK	0.003	0.009	0.015
VVA-21	VVA-21CK	0.015	-0.026	0.026
VVA-22	VVA-22CK	-0.001	-0.002	-0.005
VVA-23	VVA-23CK	0.010	0.002	-0.004
VVA-24	VVA-24CK	0.002	-0.001	0.031
VVA-25	VVA-25CK	0.005	0.003	0.007
VVA-26	VVA-26CK	-0.004	0.001	0.022
VVA-27	VVA-27CK	0.006	-0.007	-0.008
VVA-28	VVA-28CK	-0.004	0.000	-0.002
VVA-30	VVA-30CK	-0.007	0.002	-0.002
VVA-31	VVA-31CK	0.001	-0.001	0.005
VVA-32	VVA-32CK	0.002	0.004	-0.004
VVA-33	VVA-33CK	0.014	-0.013	-0.016
VVA-36	VVA-36CK	0.000	0.000	0.006
VVA-38	VVA-38CK	-0.002	-0.005	-0.007
VVA-40	VVA-40CK	-0.003	-0.003	-0.020
VVA-42	VVA-42CK	-0.009	-0.004	-0.019
VVA-43	VVA-43CK	0.003	-0.007	-0.017
VVA-44	VVA-44CK	0.000	-0.010	0.013
VVA-46	VVA-46CK	-0.002	0.001	-0.006
VVA-47	VVA-47CK	-0.004	-0.004	-0.003
VVA-48	VVA-48CK	0.004	-0.022	0.006
VVA-50	VVA-50CK	-0.015	0.026	0.011
VVA-52	VVA-52CK	-0.007	-0.001	-0.006

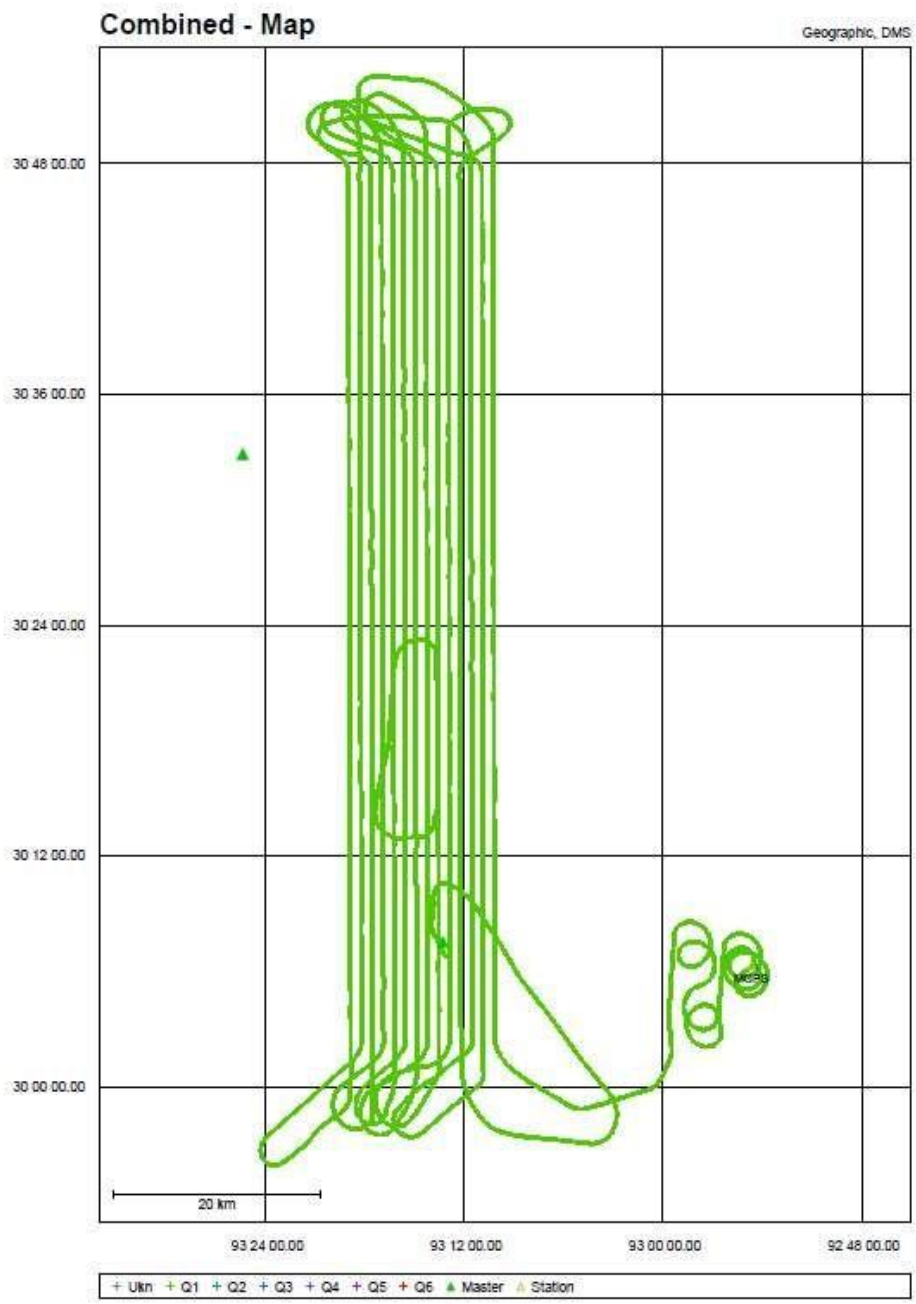
VVA-56	VVA-56CK	0.009	-0.002	0.015
VVA-59	VVA-59CK	0.012	0.012	0.016
VVA-60	VVA-60CK	0.003	0.018	-0.032
VVA-61	VVA-61CK	0.009	0.005	-0.012
VVA-62	VVA-62CK	0.002	-0.007	-0.003
VVA-63	VVA-63CK	0.000	0.003	0.015
VVA-64	VVA-64CK	0.002	-0.003	0.007
VVA-69	VVA-69CK	-0.007	0.004	-0.001
VVA-70	VVA-70CK	0.004	-0.008	-0.003
VVA-73	VVA-73CK	-0.007	-0.019	0.005
VVA-77	VVA-77CK	0.004	0.008	-0.015
VVA-79	VVA-79CK	-0.012	-0.009	-0.019
VVA-80	VVA-80CK	-0.012	-0.002	0.000
VVA-88	VVA-88CK	0.006	0.004	-0.032
VVA-89	VVA-89CK	0.009	0.004	0.006
VVA-90	VVA-90CK	0.012	0.007	-0.007
VVA-93	VVA-93CK	0.019	-0.002	0.014
VVA-94	VVA-94CK	-0.002	0.002	-0.004
VVA-99	VVA-99CK	-0.01	0.007	-0.014
VVA-103	VVA-103CK	0.012	-0.015	0.007
VVA-106	VVA-106CK	-0.005	-0.013	-0.010
VVA-116	VVA-116CK	-0.005	0.003	0.014
VVA-117	VVA-117CK	0.001	0.007	-0.008
VVA-120	VVA-120CK	-0.004	-0.001	0.021
VVA-125	VVA-125CK	0.008	-0.009	0.003
VVA-129	VVA-129CK	0.006	-0.005	-0.002
VVA-130	VVA-130CK	0.007	0.002	0.003
VVA-131	VVA-131CK	-0.019	-0.004	0.003
VVA-132	VVA-132CK	0.014	0.002	-0.008
VVA-133	VVA-133CK	0.000	-0.003	0.005
VVA-135	VVA-135CK	0.001	-0.005	0.002
VVA-136	VVA-136CK	0.009	-0.016	0.014
VVA-137	VVA-137CK	0.005	0.001	0.002

VVA-138	VVA-138CK	-0.016	-0.027	-0.018
VVA-139	VVA-139CK	-0.004	0.017	-0.001
VVA-140	VVA-140CK	0.002	0.009	0.017
VVA-141	VVA-141CK	-0.013	0.003	-0.008
VVA-143	VVA-143CK	-0.018	0.017	0.013
VVA-146	VVA-146CK	-0.004	0.003	0.008
VVA-148	VVA-148CK	-0.001	-0.001	-0.009
VVA-149	VVA-149CK	-0.005	0.005	-0.002

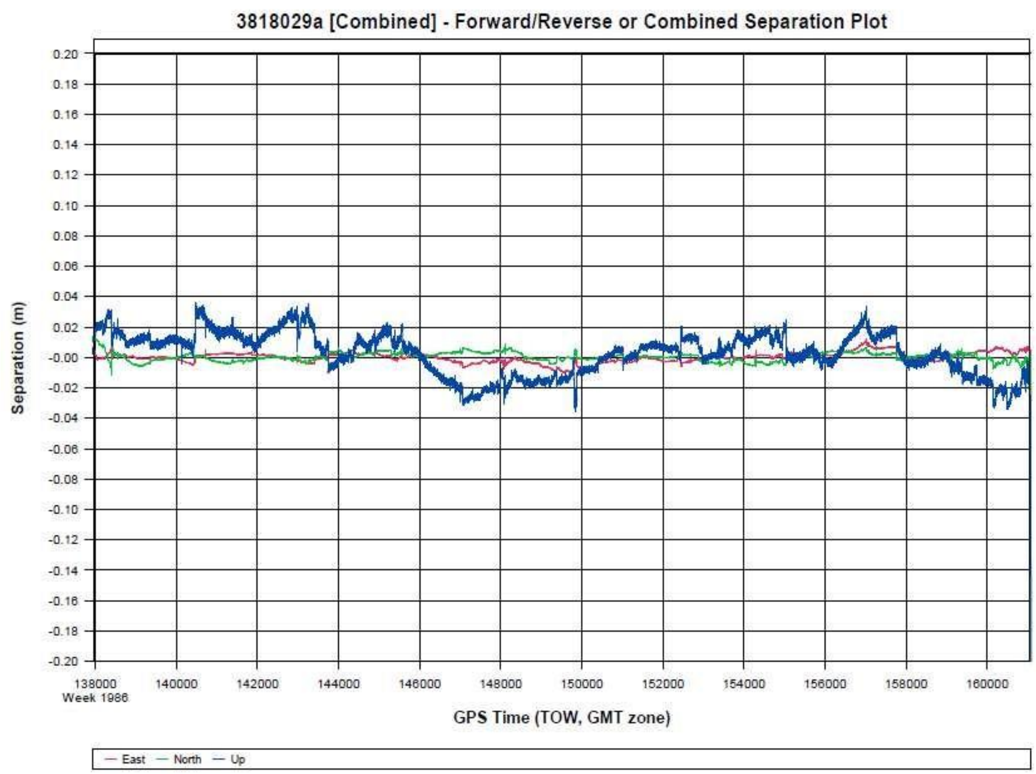
Appendix B: GPS Processing

Airborne Imaging Inc.

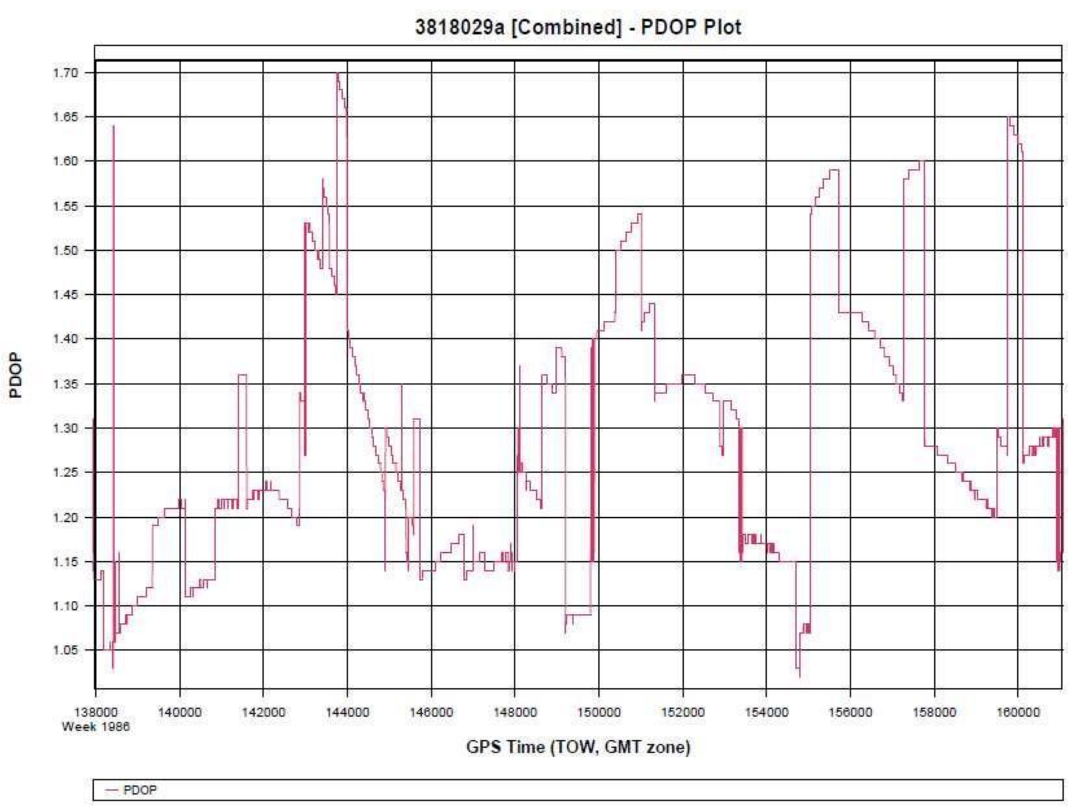
Mission 1 – 3818029a GNSS Processing



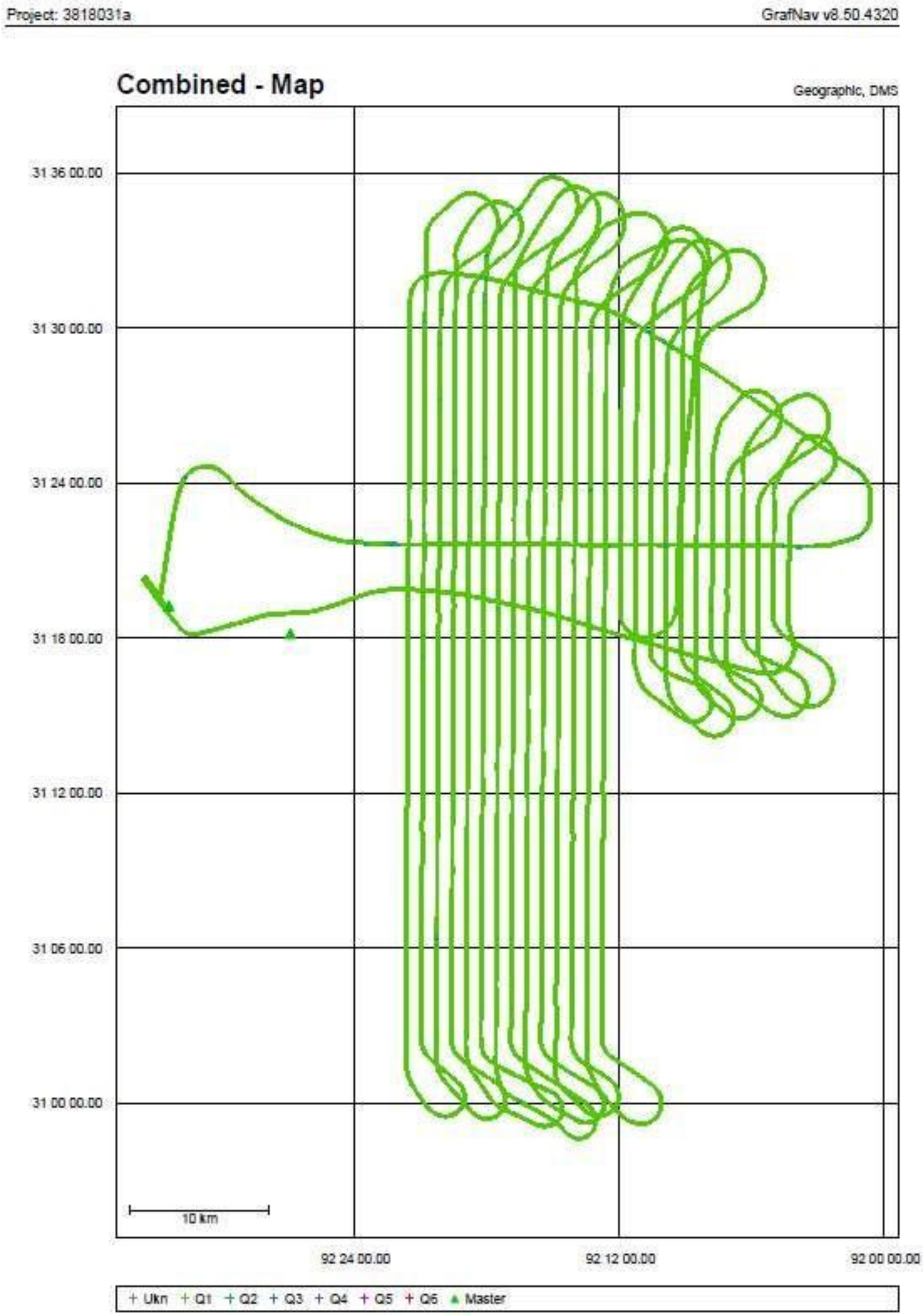
Project: 3818029a GrafNav v8.50.4320



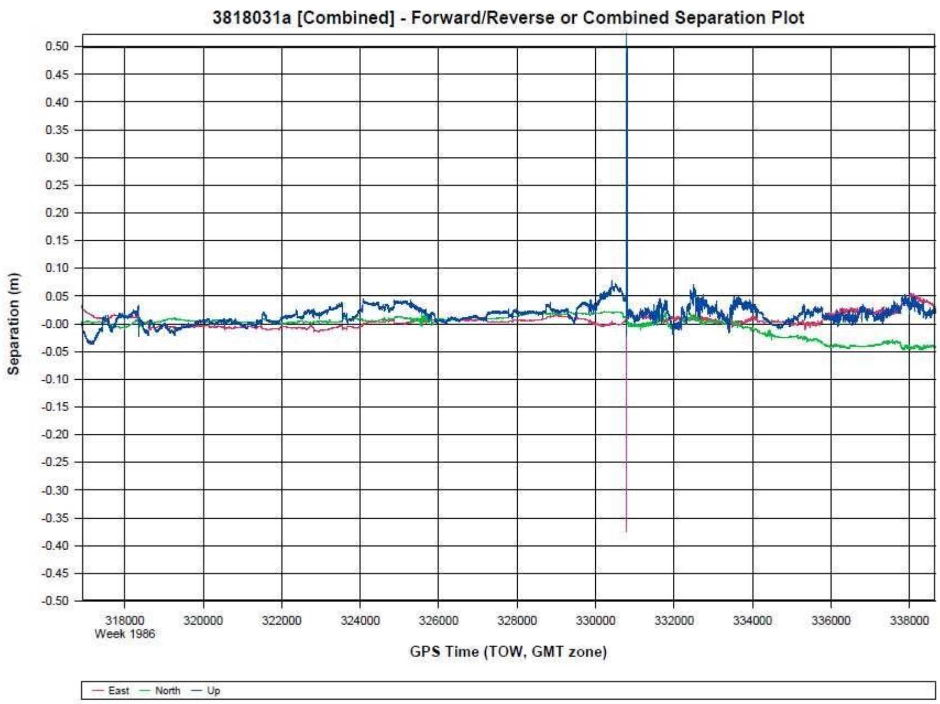
Project: 3818029a GrafNav v8.50.4320



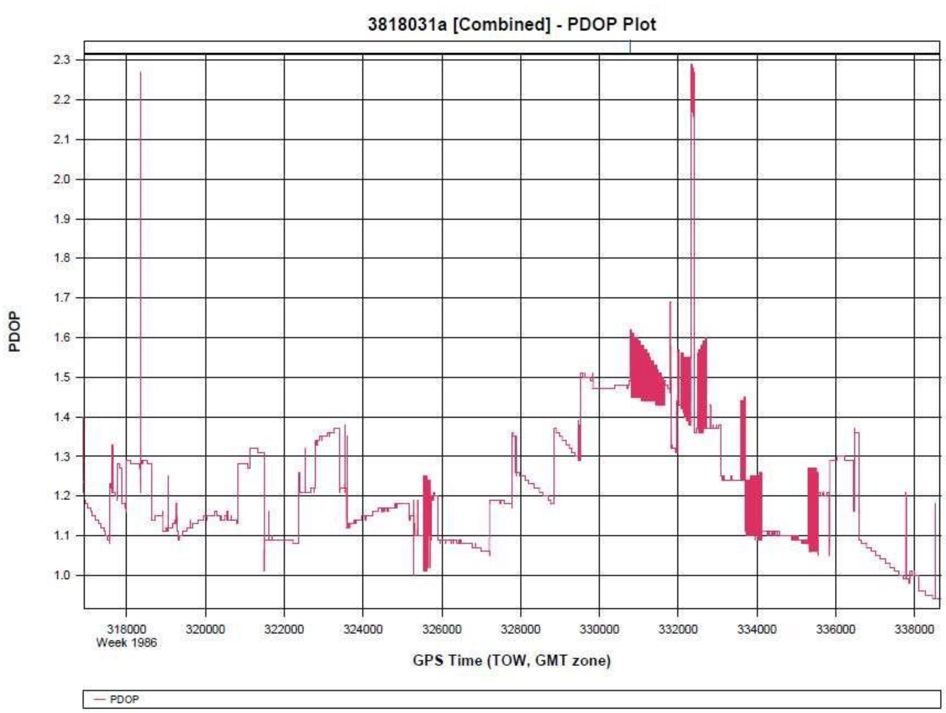
Mission 2 – 3818031a GNSS Processing



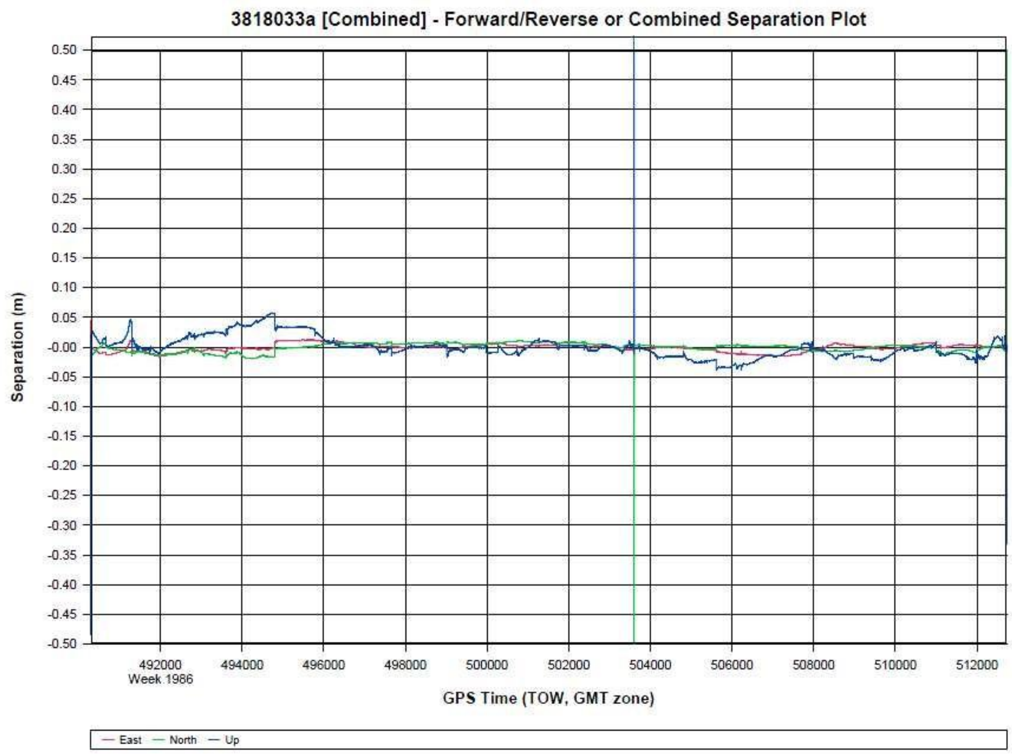
Project: 3818031a GrafNav v8.50.4320

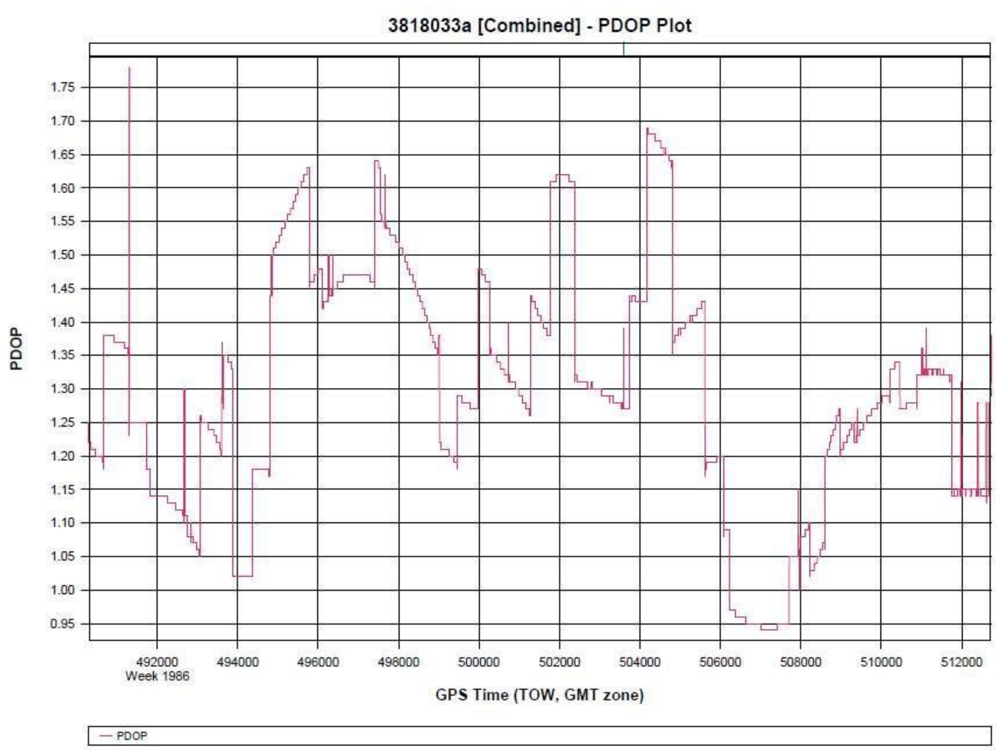


Project: 3818031a GrafNav v8.50.4320

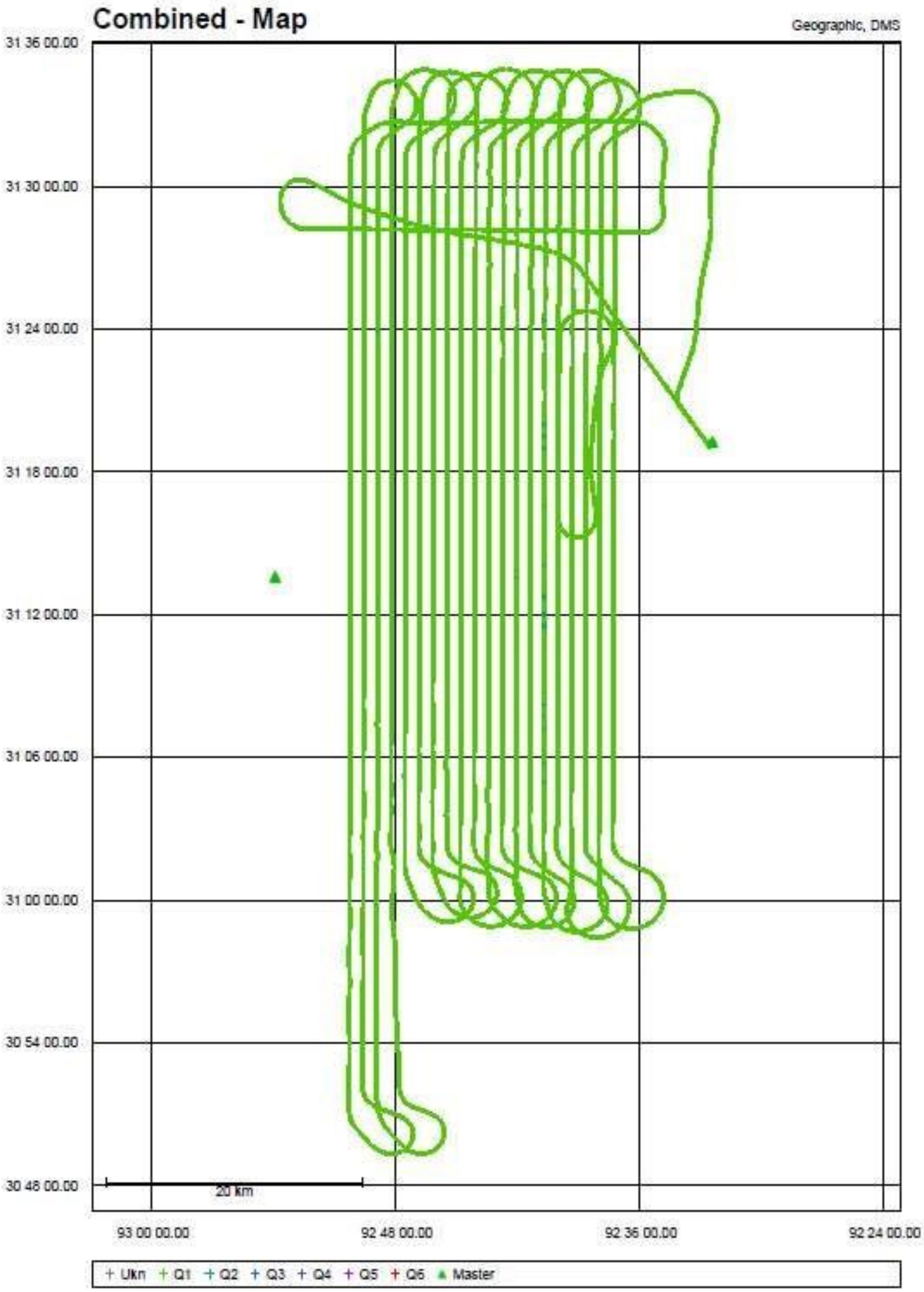


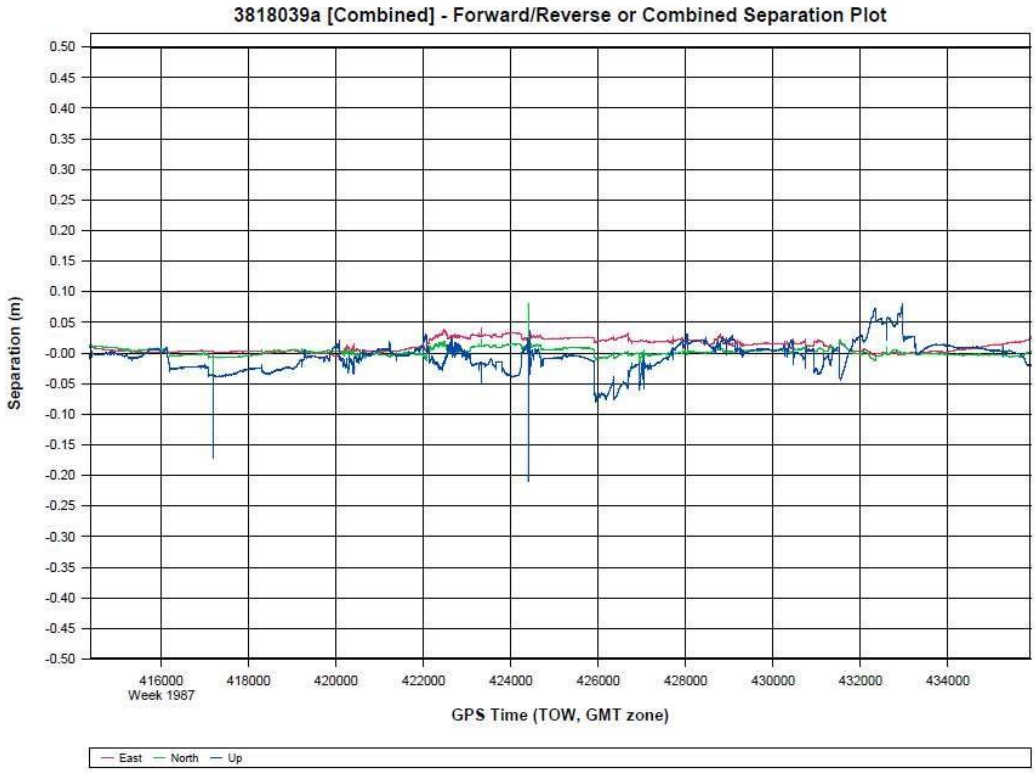
Mission 3 – 3818033a GNSS Processing

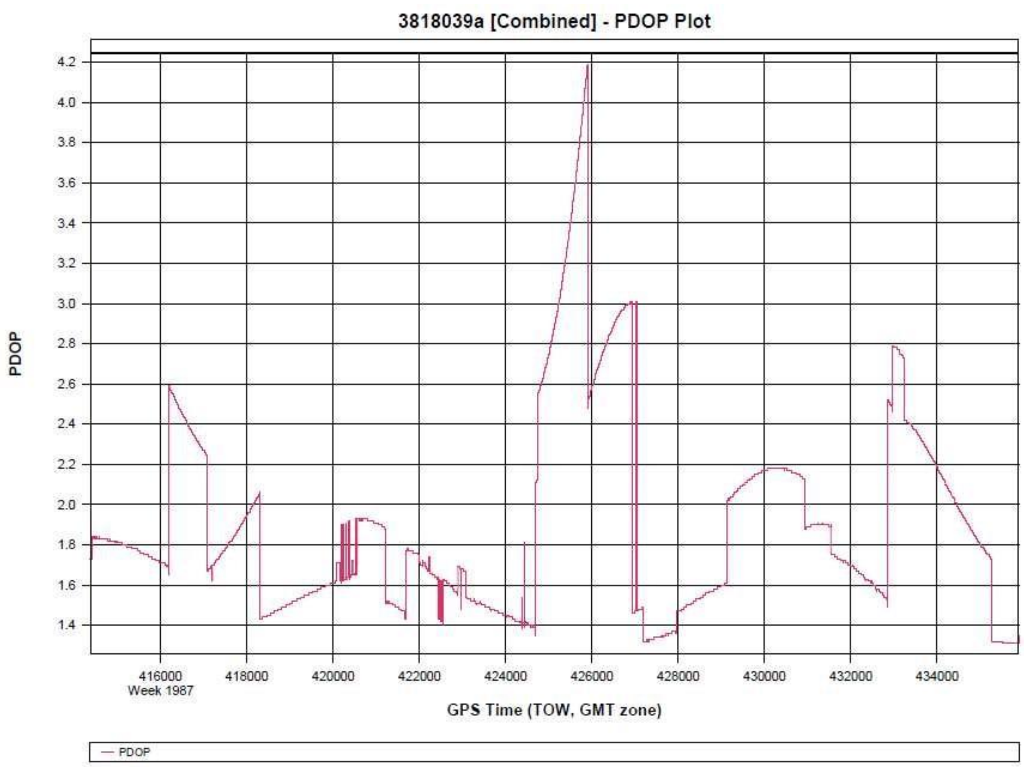




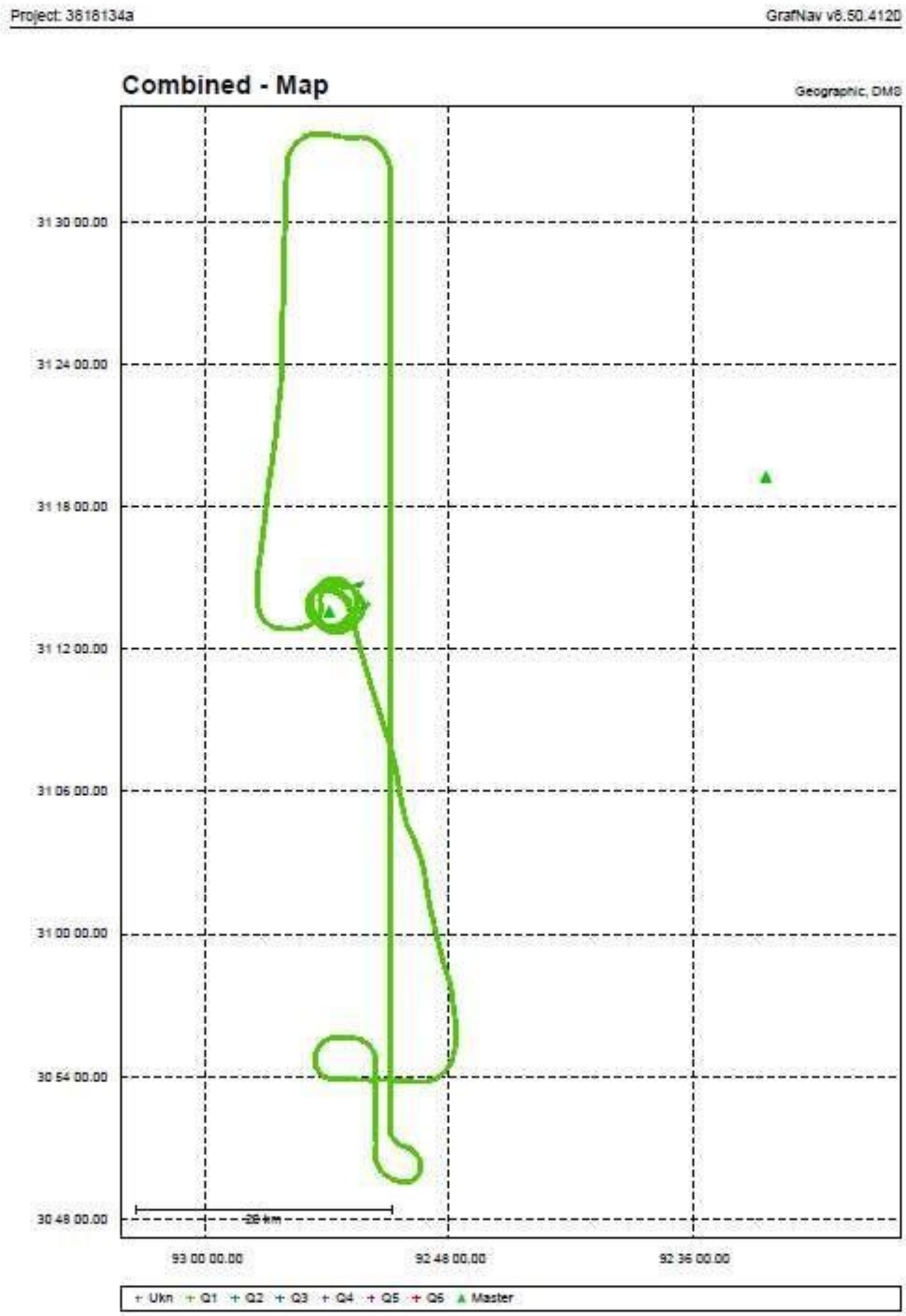
Mission 4 – 3818039a GNSS Processing

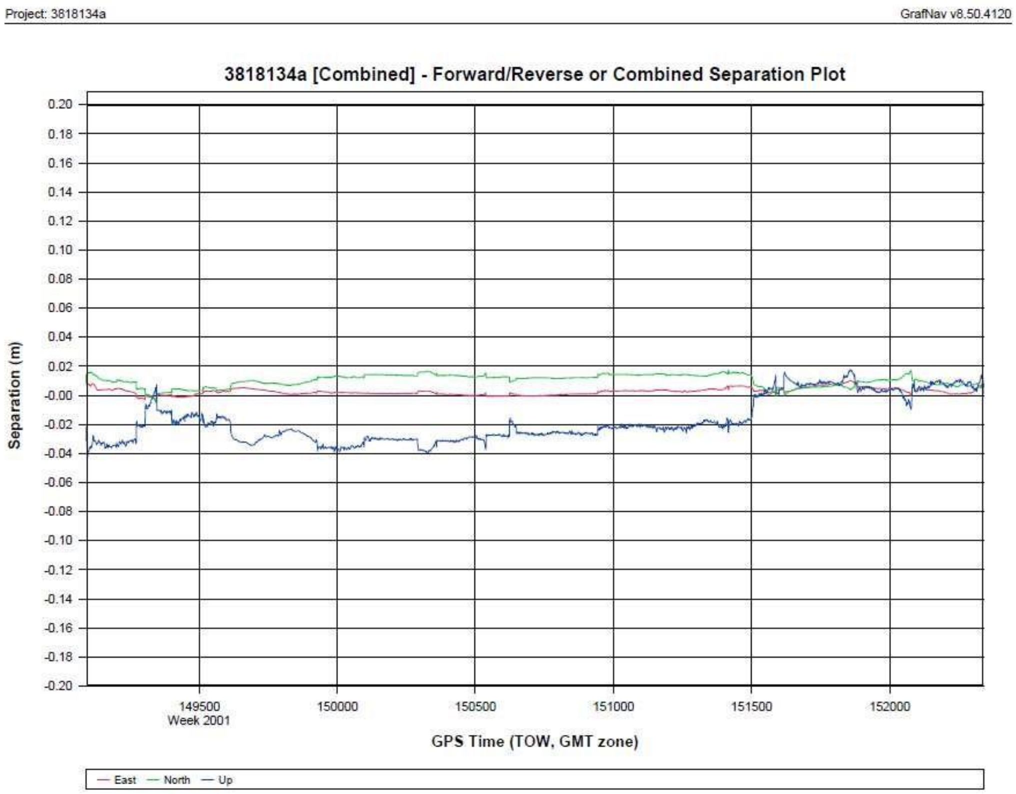

Combined - Map
Geographic, DMS
31 36 00.00
31 30 00.00
31 24 00.00
31 18 00.00
31 12 00.00
31 06 00.00
31 00 00.00
30 54 00.00
30 48 00.00
20 km
93 00 00.00
92 48 00.00
92 36 00.00
92 24 00.00
+ Ukn + Q1 + Q2 + Q3 + Q4 + Q5 + Q6 ▲ Master

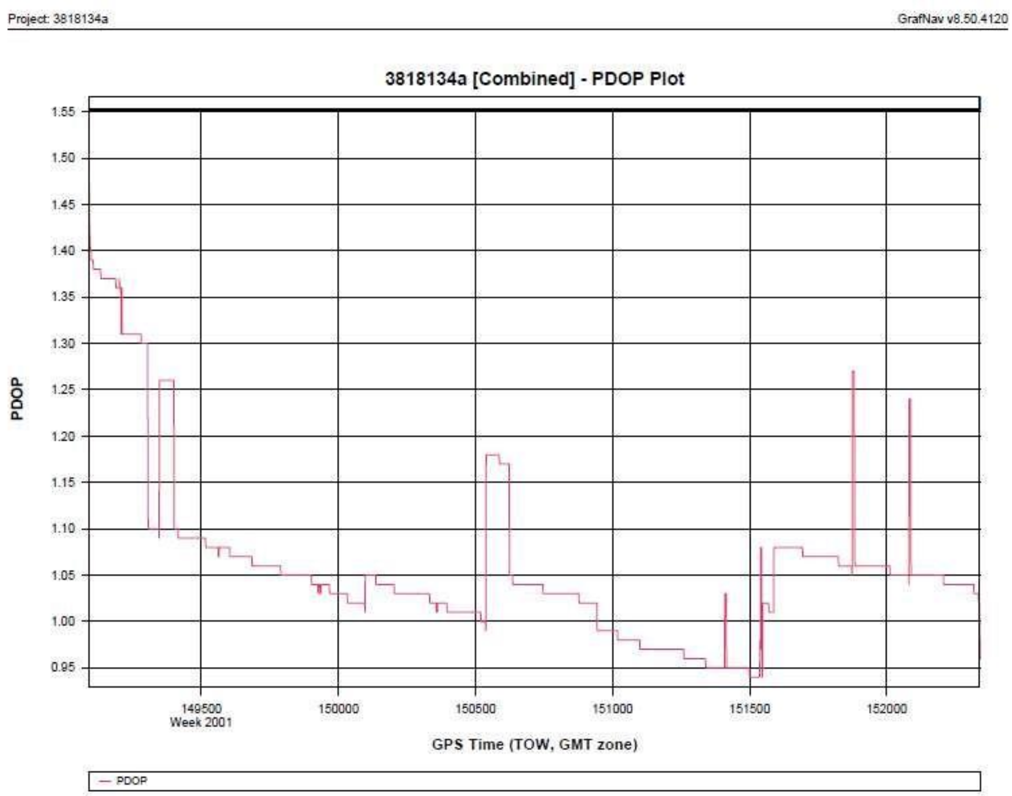

3818039a [Combined] - Forward/Reverse or Combined Separation Plot
Separation (m)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
-0.05
-0.10
-0.15
-0.20
-0.25
-0.30
-0.35
-0.40
-0.45
-0.50
416000
Week 1987
418000
420000
422000
424000
426000
428000
430000
432000
434000
GPS Time (TOW, GMT zone)
East
North
Up


3818039a [Combined] - PDOP Plot
PDOP
4.2
4.0
3.8
3.6
3.4
3.2
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
416000
Week 1987
418000
420000
422000
424000
426000
428000
430000
432000
434000
GPS Time (TOW, GMT zone)
PDOP

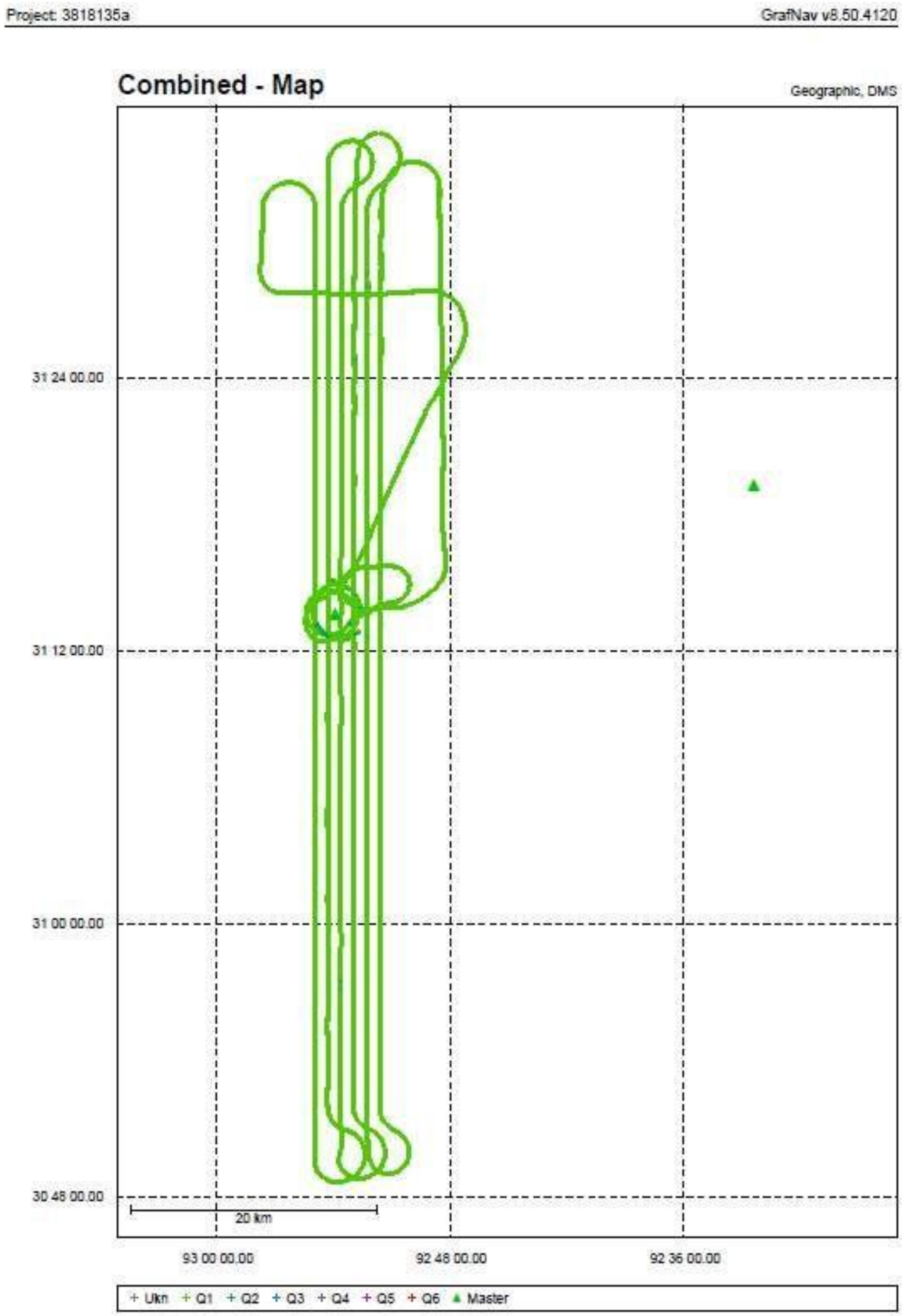
Mission 5 – 3818134a GNSS Processing

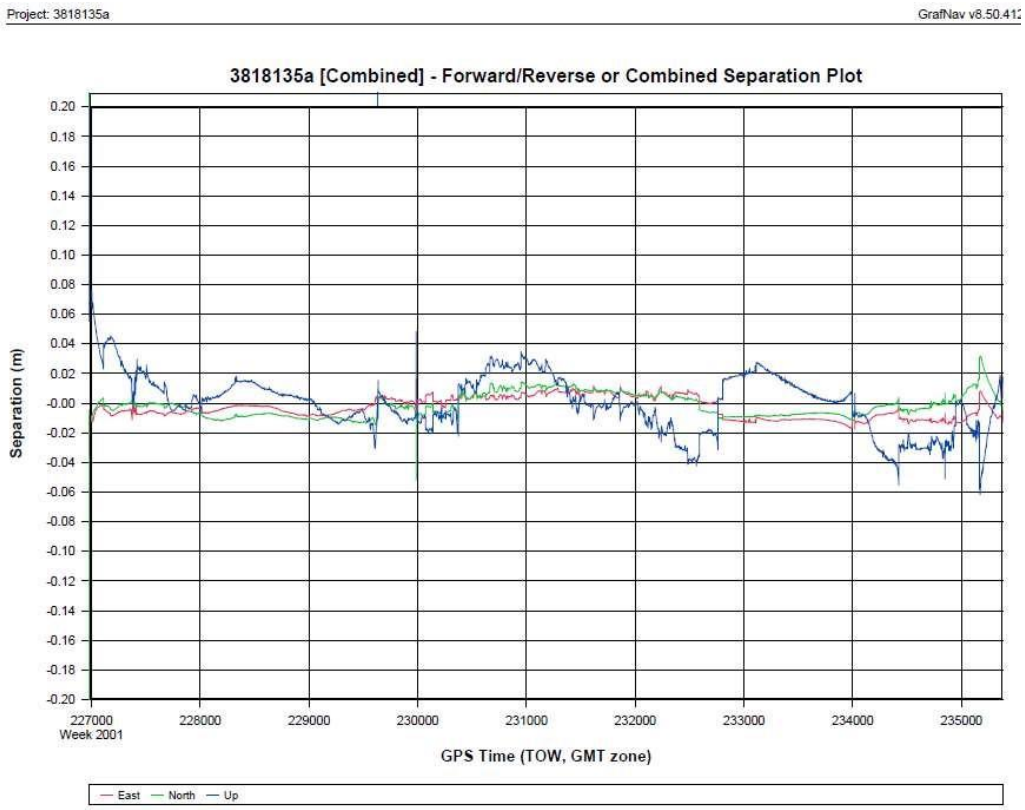


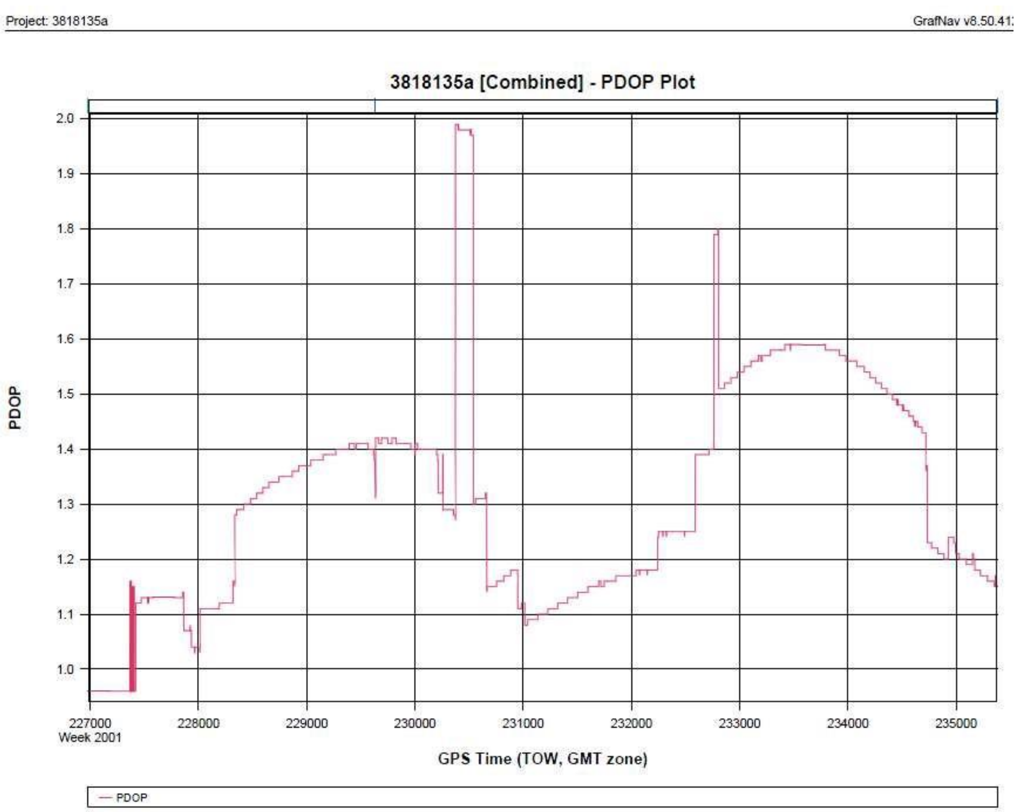

Project: 3818134a
GrafNav v8.50.4120
3818134a [Combined] - Forward/Reverse or Combined Separation Plot
Separation (m)
GPS Time (TOW, GMT zone)
149500
Week 2001
150000
150500
151000
151500
152000
East
North
Up


Project: 3818134a
GrafNav v8.50.4120
3818134a [Combined] - PDOP Plot
PDOP
GPS Time (TOW, GMT zone)
149500
Week 2001
150000
150500
151000
151500
152000
PDOP

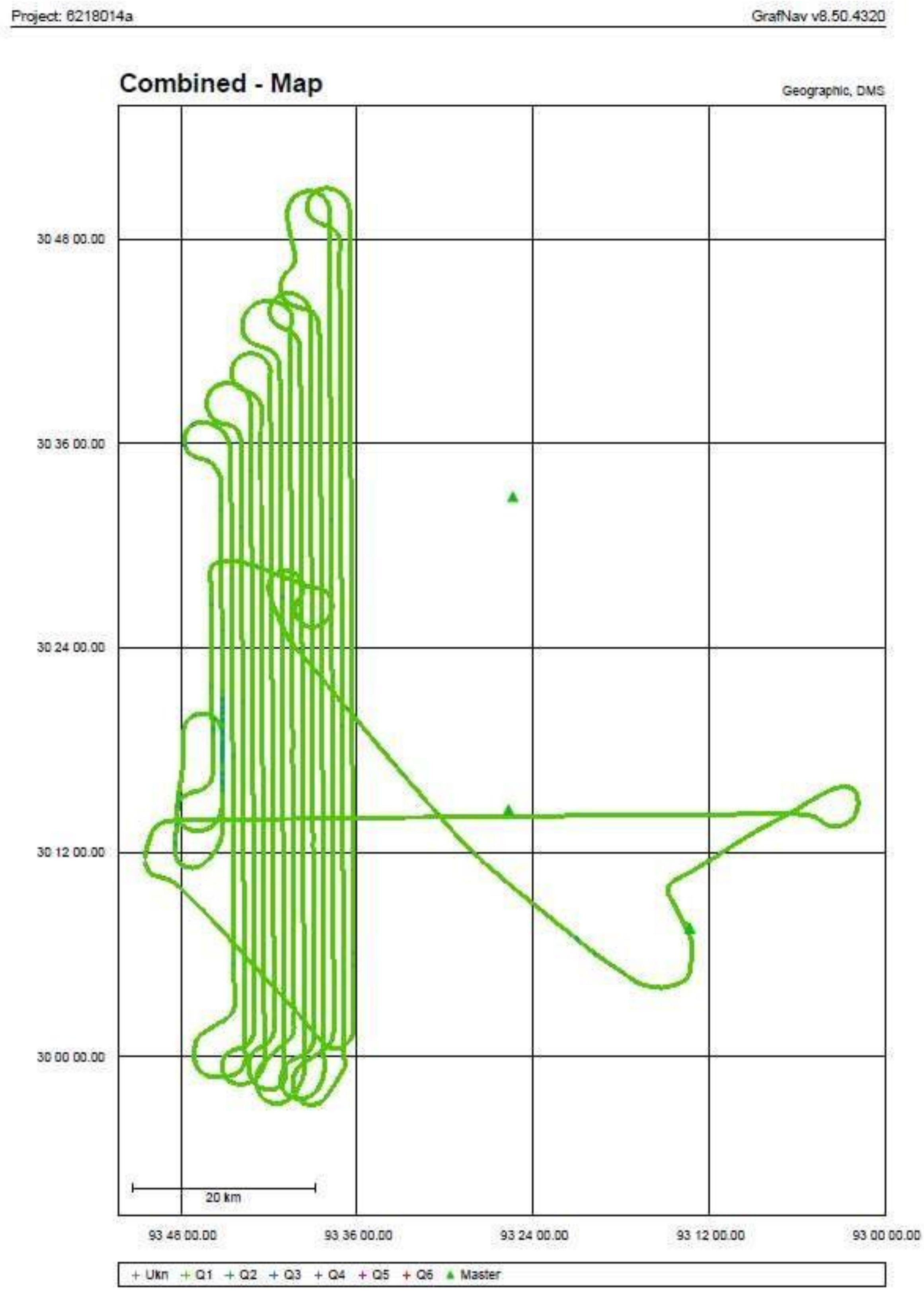
Mission 6 – 3818135a GNSS Processing

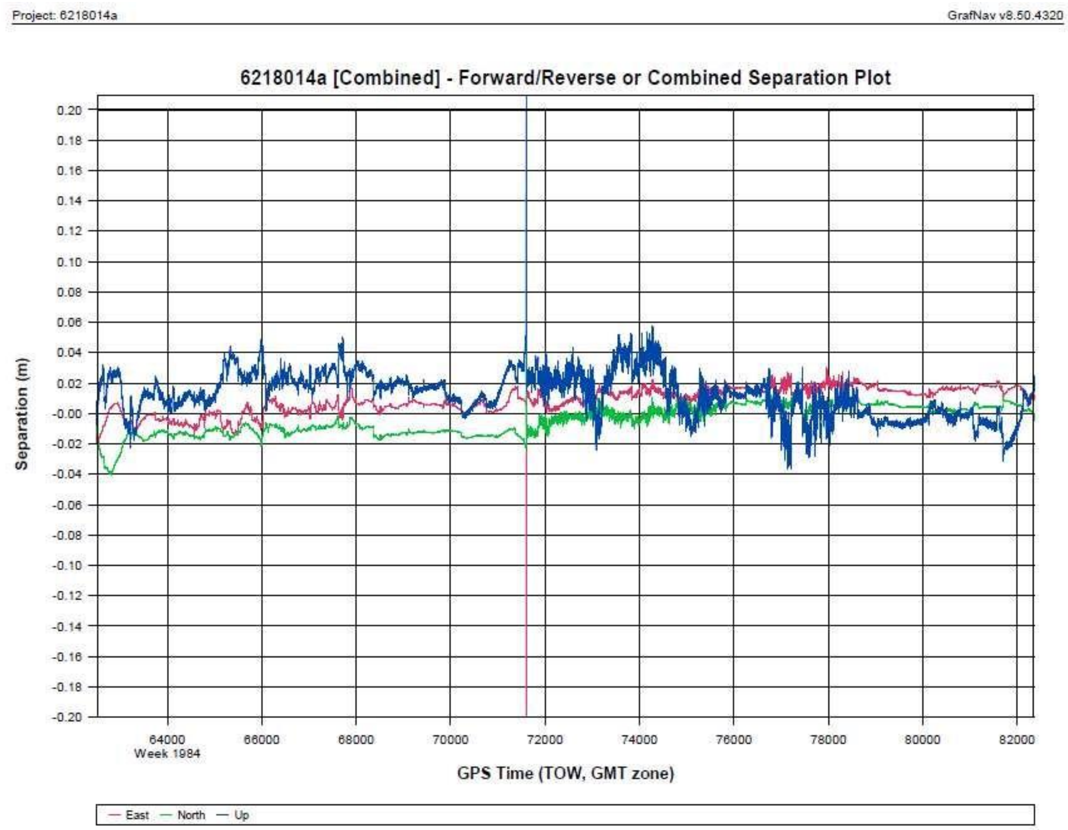


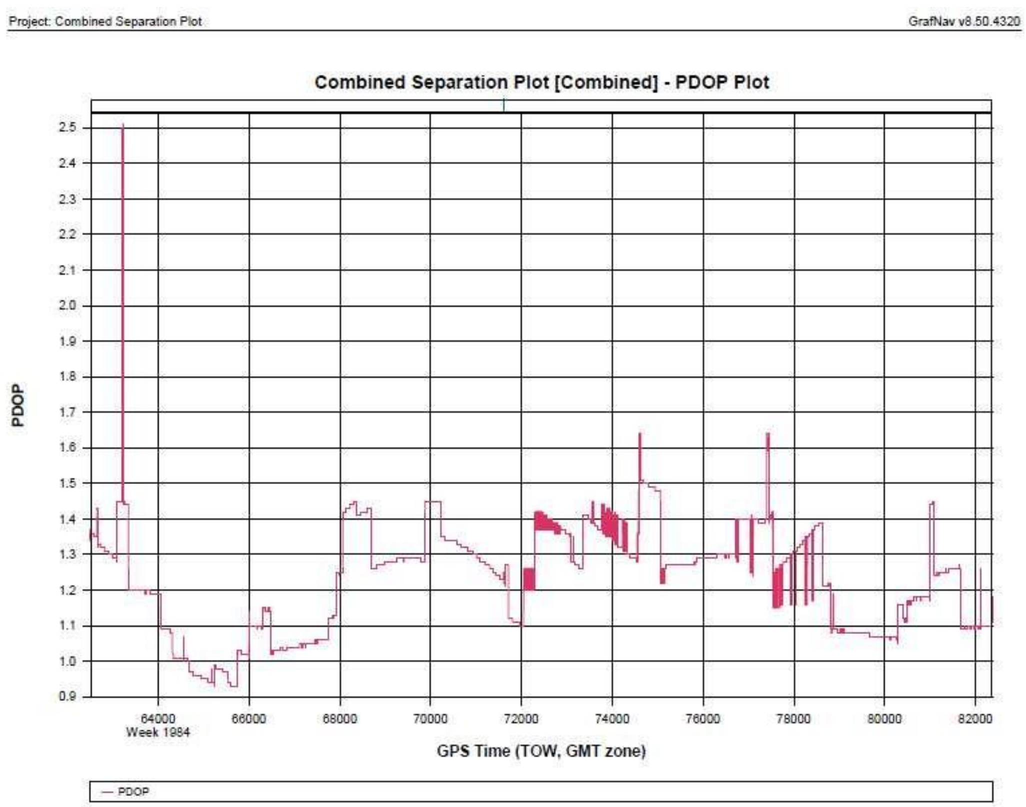

Project: 3818135a
GrafNav v8.50.412
3818135a [Combined] - Forward/Reverse or Combined Separation Plot
Separation (m)
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
-0.00
-0.02
-0.04
-0.06
-0.08
-0.10
-0.12
-0.14
-0.16
-0.18
-0.20
227000
Week 2001
228000
229000
230000
231000
232000
233000
234000
235000
GPS Time (TOW, GMT zone)
East
North
Up


Project: 3818135a
GrafNav v8.50.412
3818135a [Combined] - PDOP Plot
PDOP
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
227000
Week 2001
228000
229000
230000
231000
232000
233000
234000
235000
GPS Time (TOW, GMT zone)
PDOP

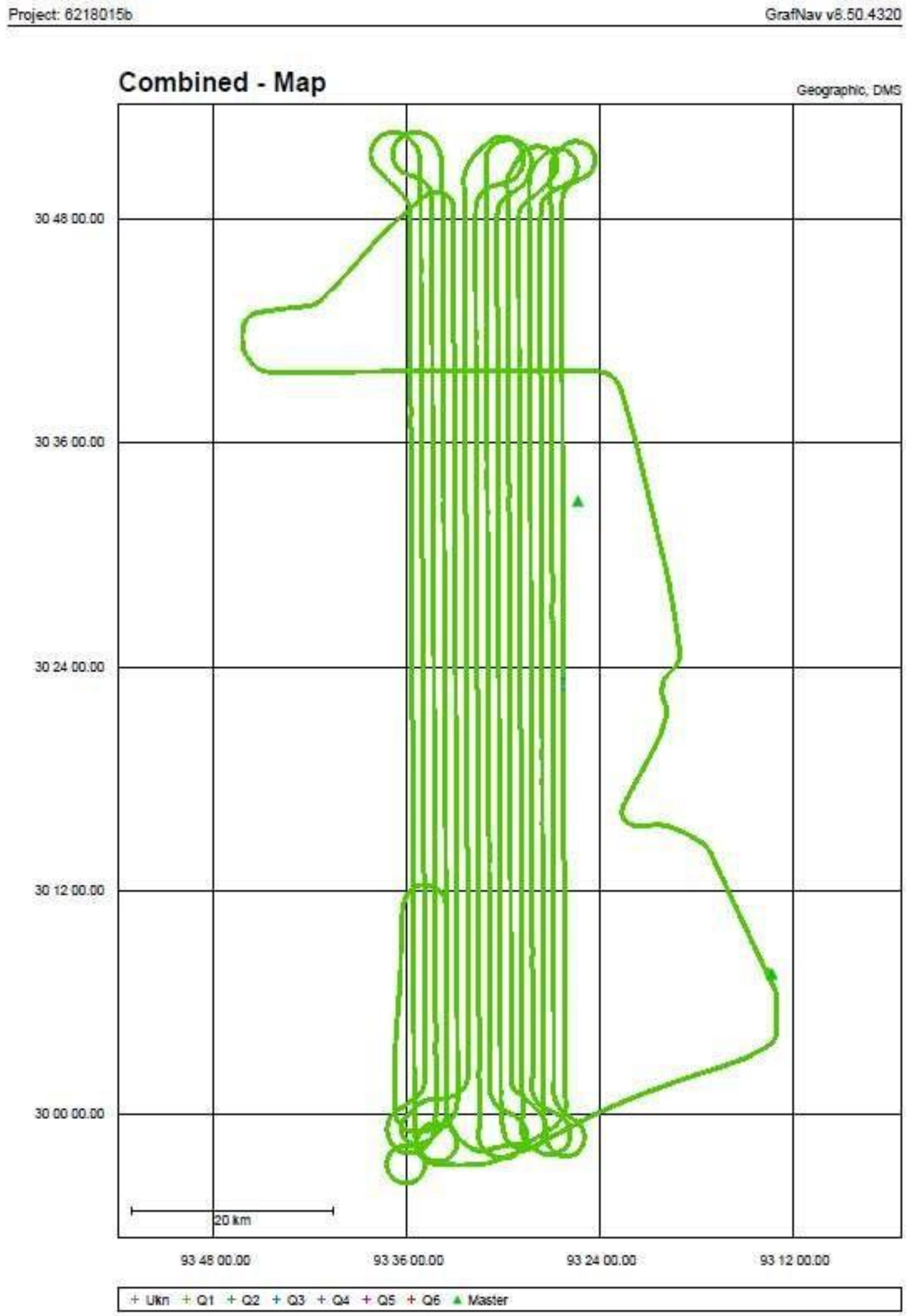
Mission 7 – 62180014a GNSS Processing

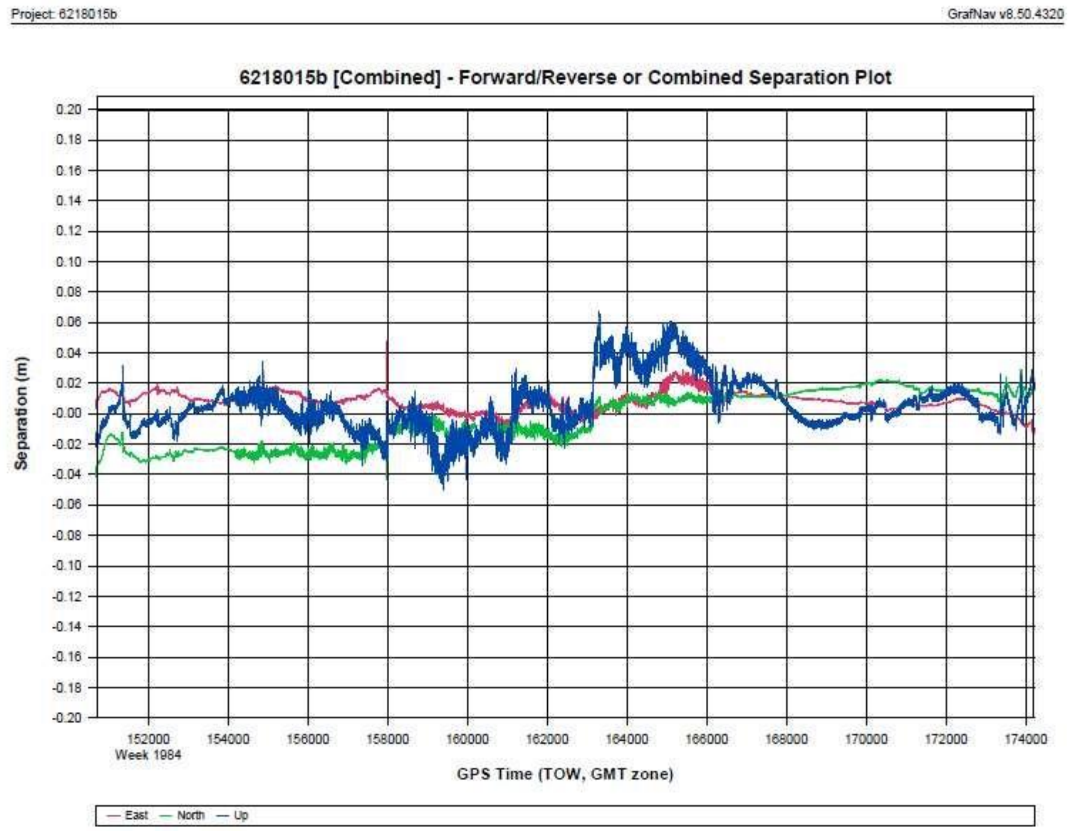


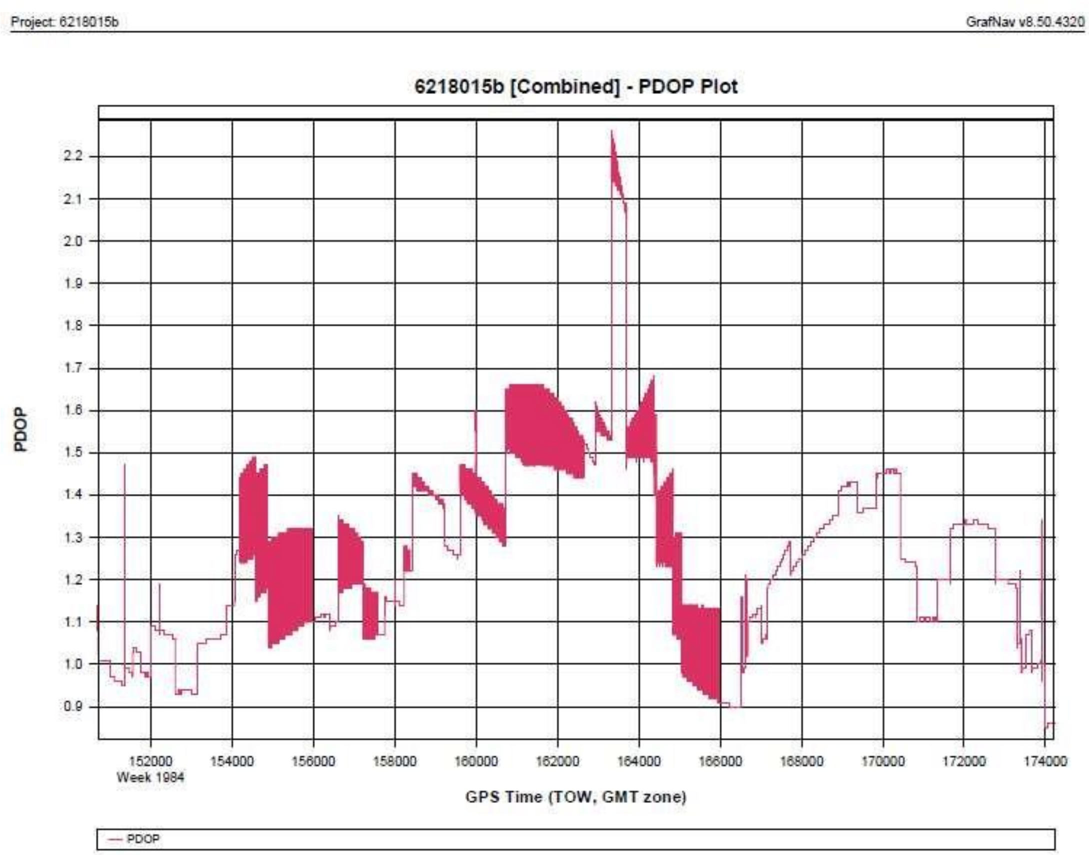

Project: 6218014a
GrafNav v8.50.4320
6218014a [Combined] - Forward/Reverse or Combined Separation Plot
Separation (m)
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
-0.00
-0.02
-0.04
-0.06
-0.08
-0.10
-0.12
-0.14
-0.16
-0.18
-0.20
64000
Week 1984
66000
68000
70000
72000
74000
76000
78000
80000
82000
GPS Time (TOW, GMT zone)
East
North
Up


Project: Combined Separation Plot
GrafNav v8.50.4320
Combined Separation Plot [Combined] - PDOP Plot
PDOP
2.5
2.4
2.3
2.2
2.1
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
64000
Week 1984
66000
68000
70000
72000
74000
76000
78000
80000
82000
GPS Time (TOW, GMT zone)
PDOP

Mission 8 – 6218015b GNSS Processing

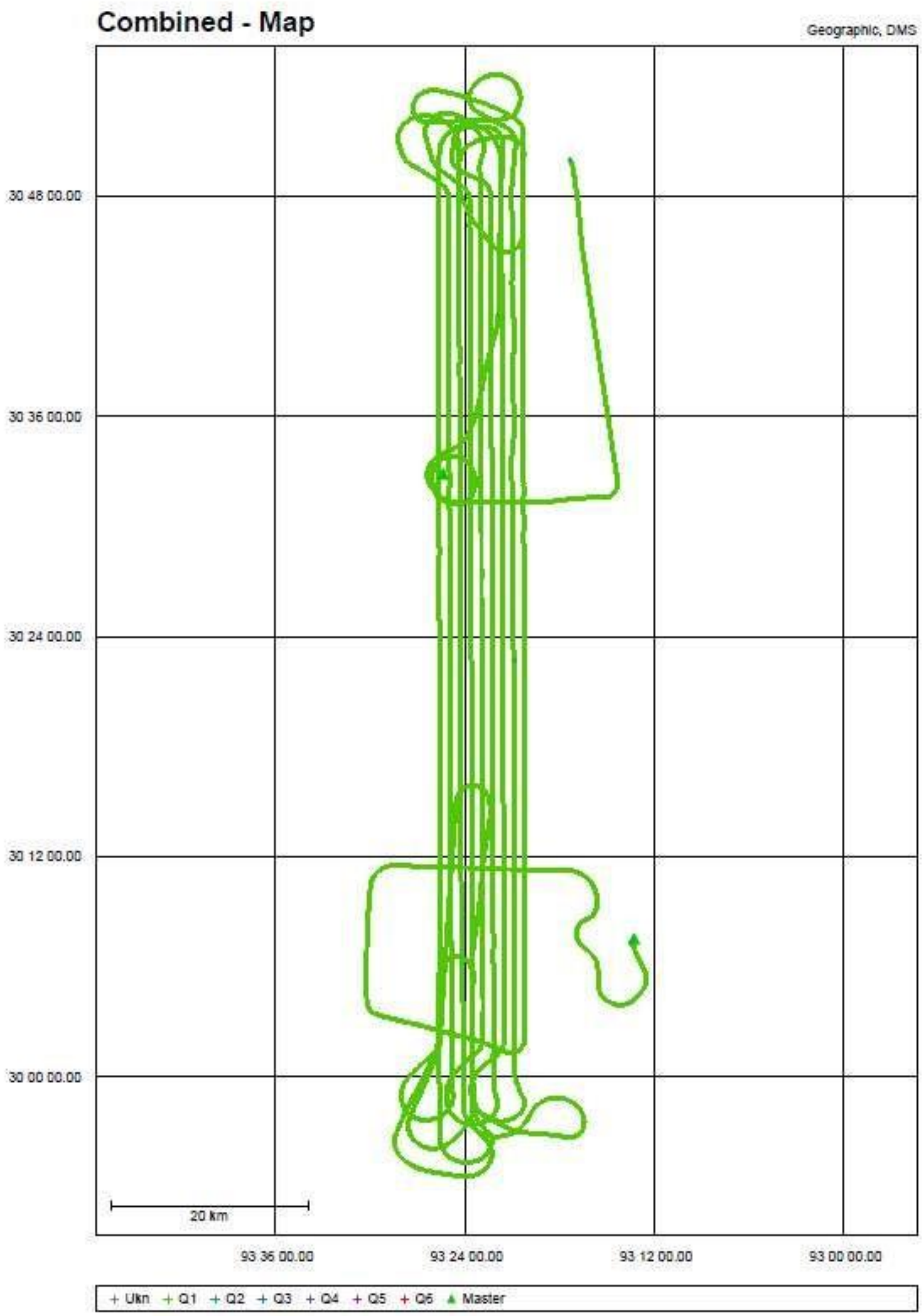


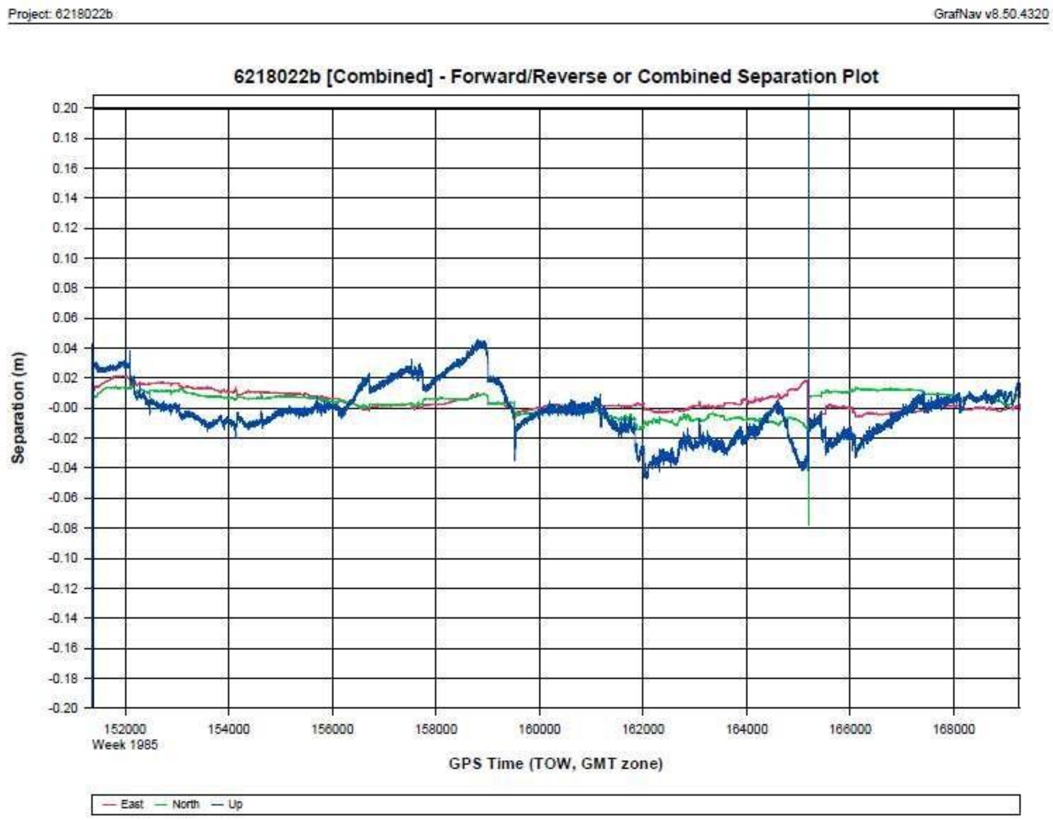

Project: 6218015b
GrafNav v8.50.4320
6218015b [Combined] - Forward/Reverse or Combined Separation Plot
Separation (m)
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
-0.00
-0.02
-0.04
-0.06
-0.08
-0.10
-0.12
-0.14
-0.16
-0.18
-0.20
152000
Week 1984
154000
156000
158000
160000
162000
164000
166000
168000
170000
172000
174000
GPS Time (TOW, GMT zone)
East
North
Up

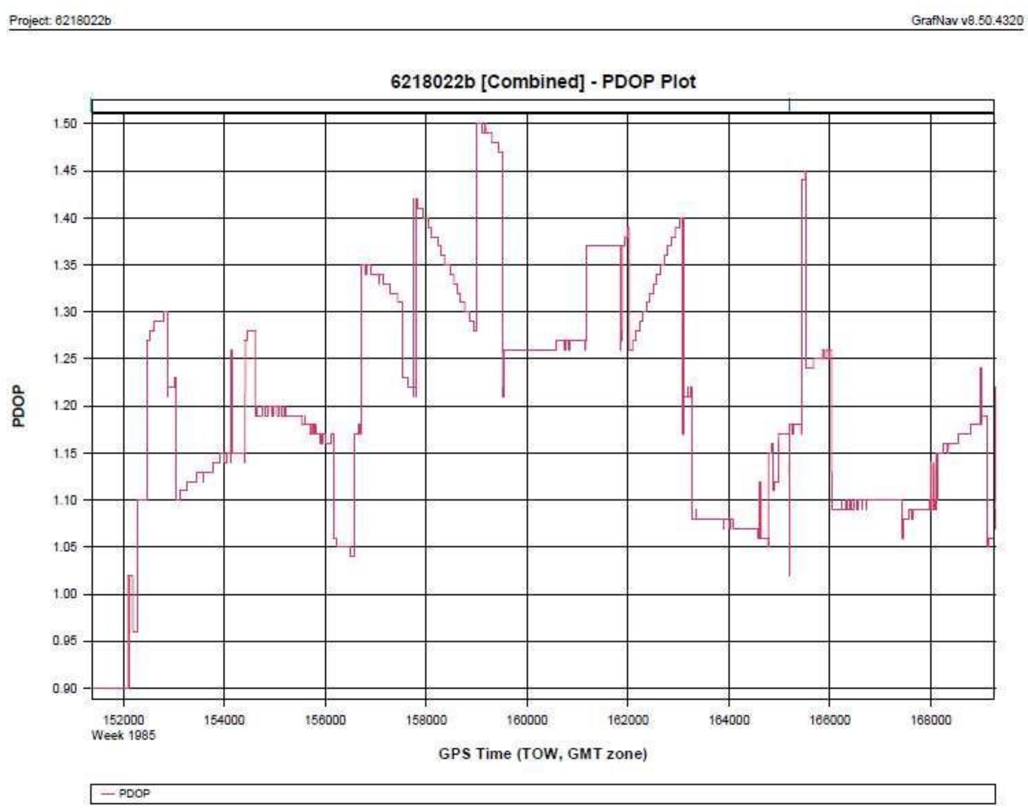

Project: 6218015b
GrafNav v8.50.4320
6218015b [Combined] - PDOP Plot
PDOP
2.2
2.1
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
152000
Week 1984
154000
156000
158000
160000
162000
164000
166000
168000
170000
172000
174000
GPS Time (TOW, GMT zone)
PDOP

Mission 9 – 6218022b GNSS Processing

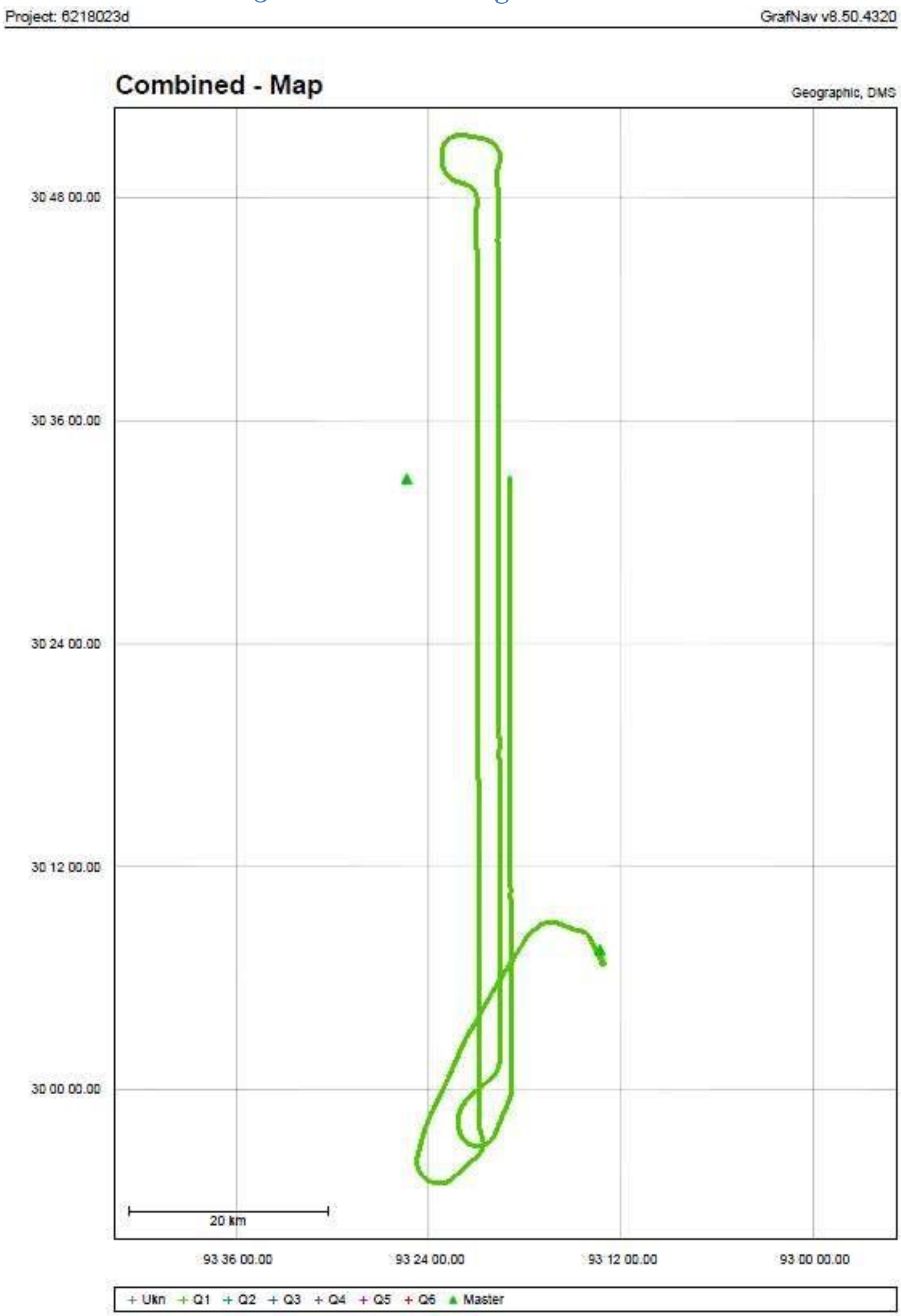
Project: 6218022b GrafNav v8.50.4320



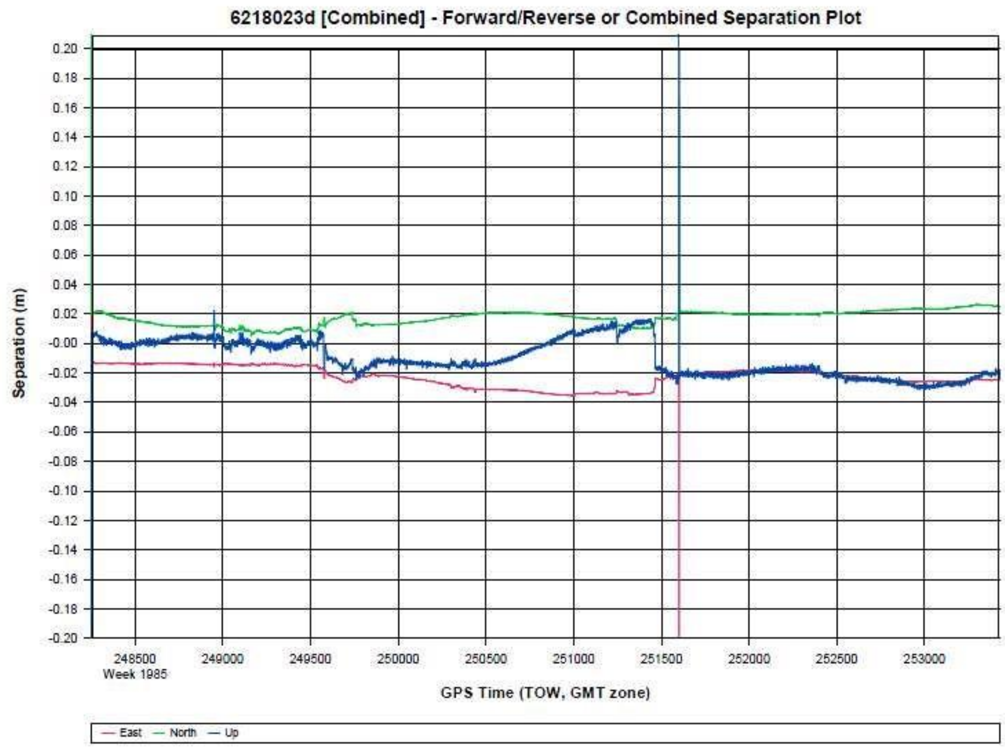

Project: 6218022b
GrafNav v8.50.4320
6218022b [Combined] - Forward/Reverse or Combined Separation Plot
Separation (m)
GPS Time (TOW, GMT zone)
Week 1985
East
North
Up


Project: 6218022b
GrafNav v8.50.4320
6218022b [Combined] - PDOP Plot
PDOP
GPS Time (TOW, GMT zone)
Week 1985
PDOP

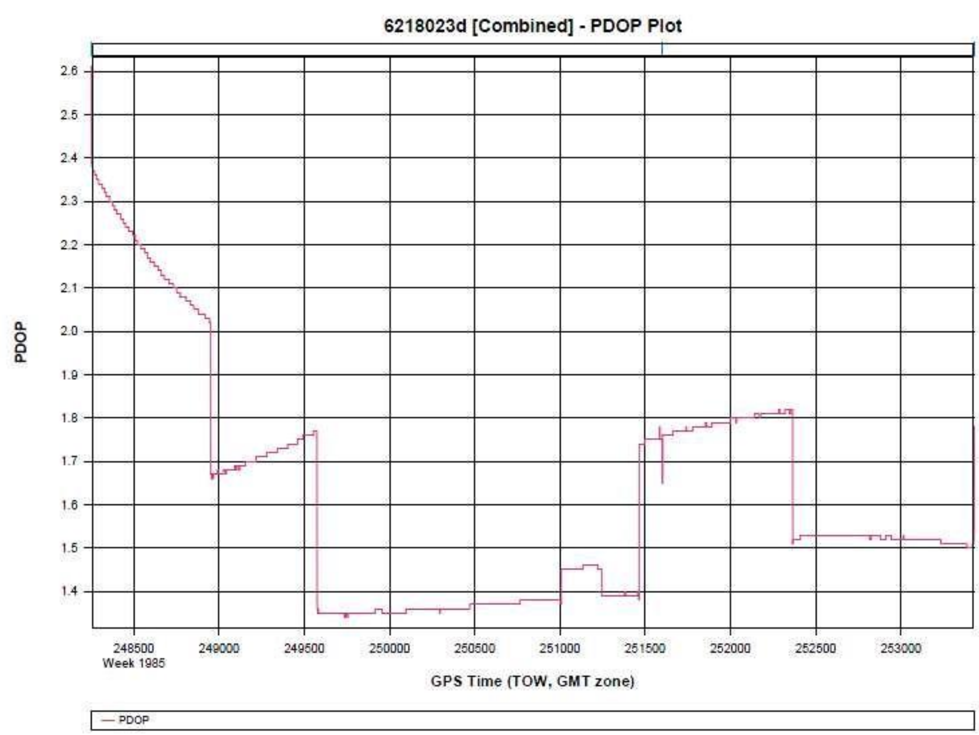
Mission 10 – 6218023d GNSS Processing



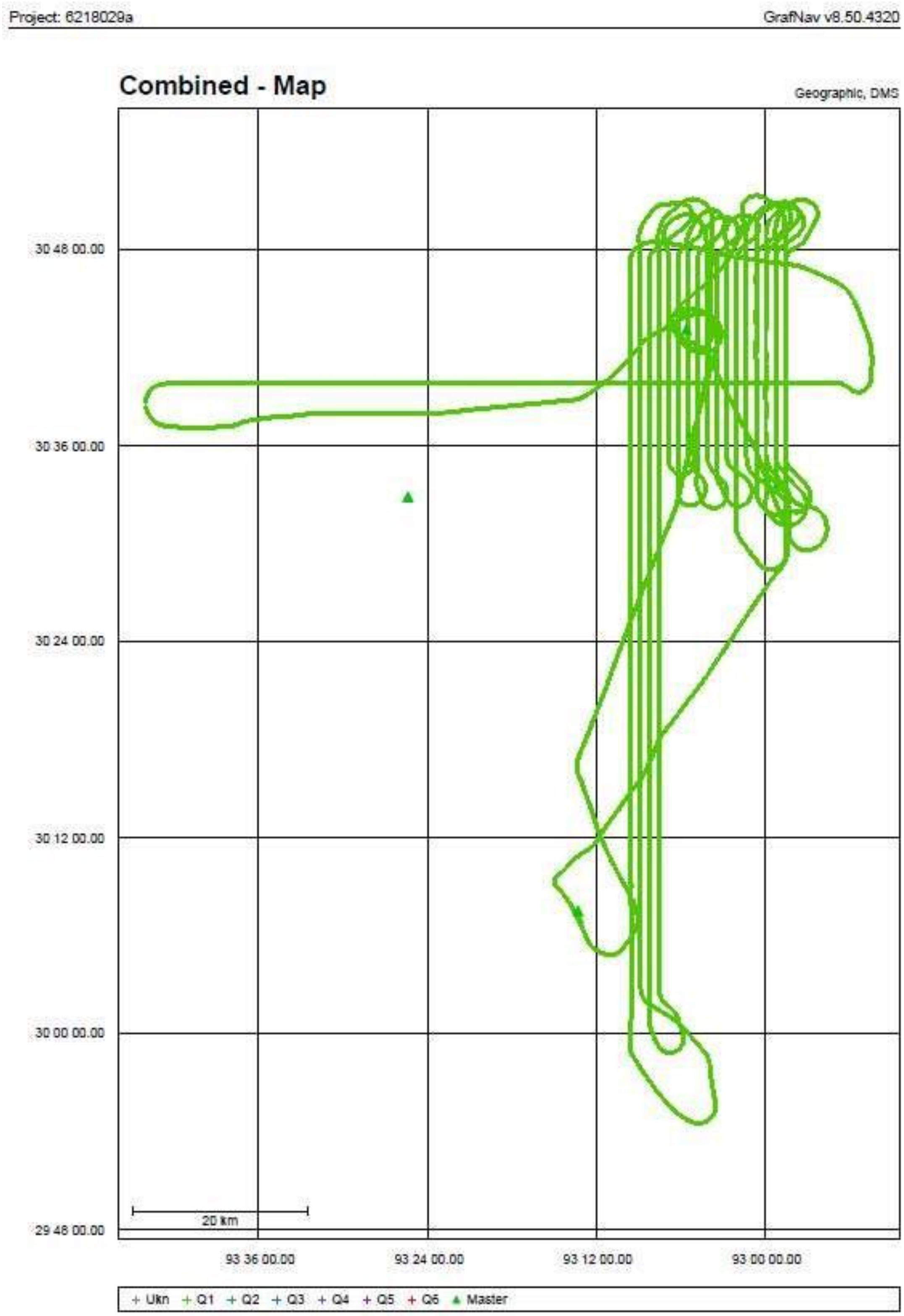
Project: 6218023d GrafNav v8.50.4320

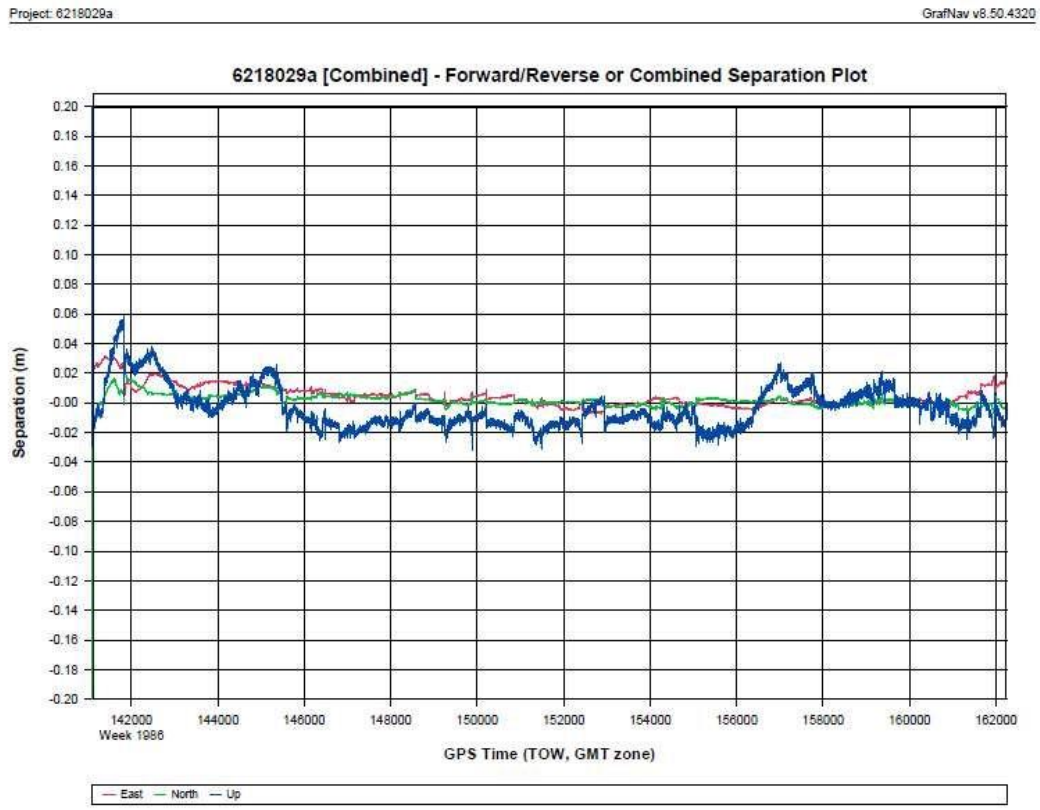


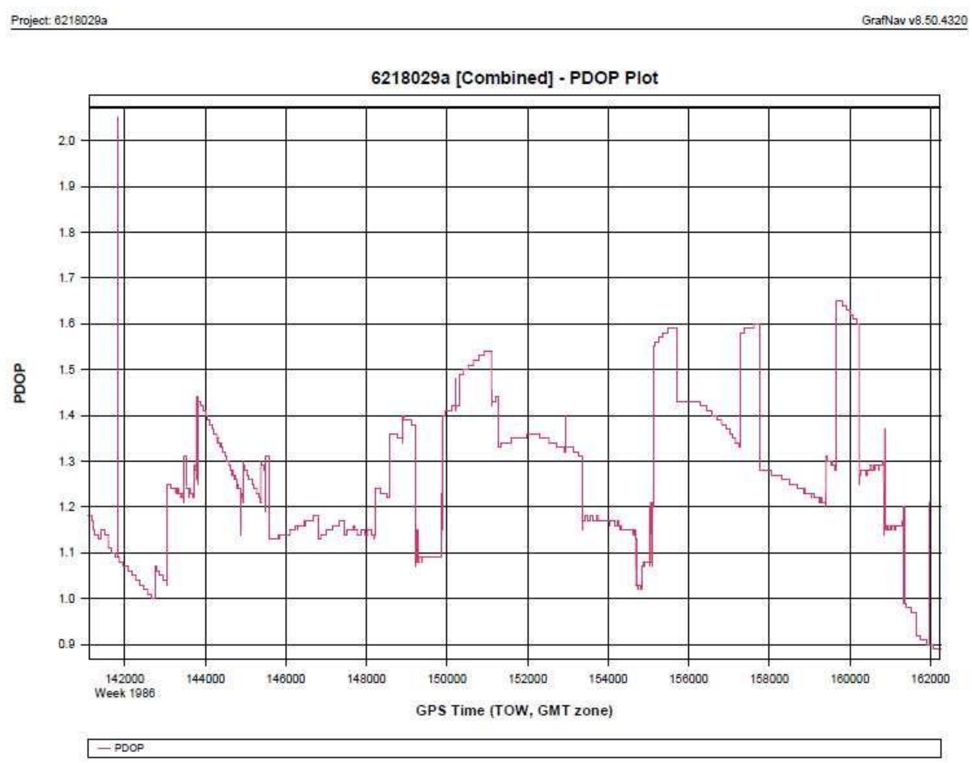
Project: 6218023d GrafNav v8.50.4320



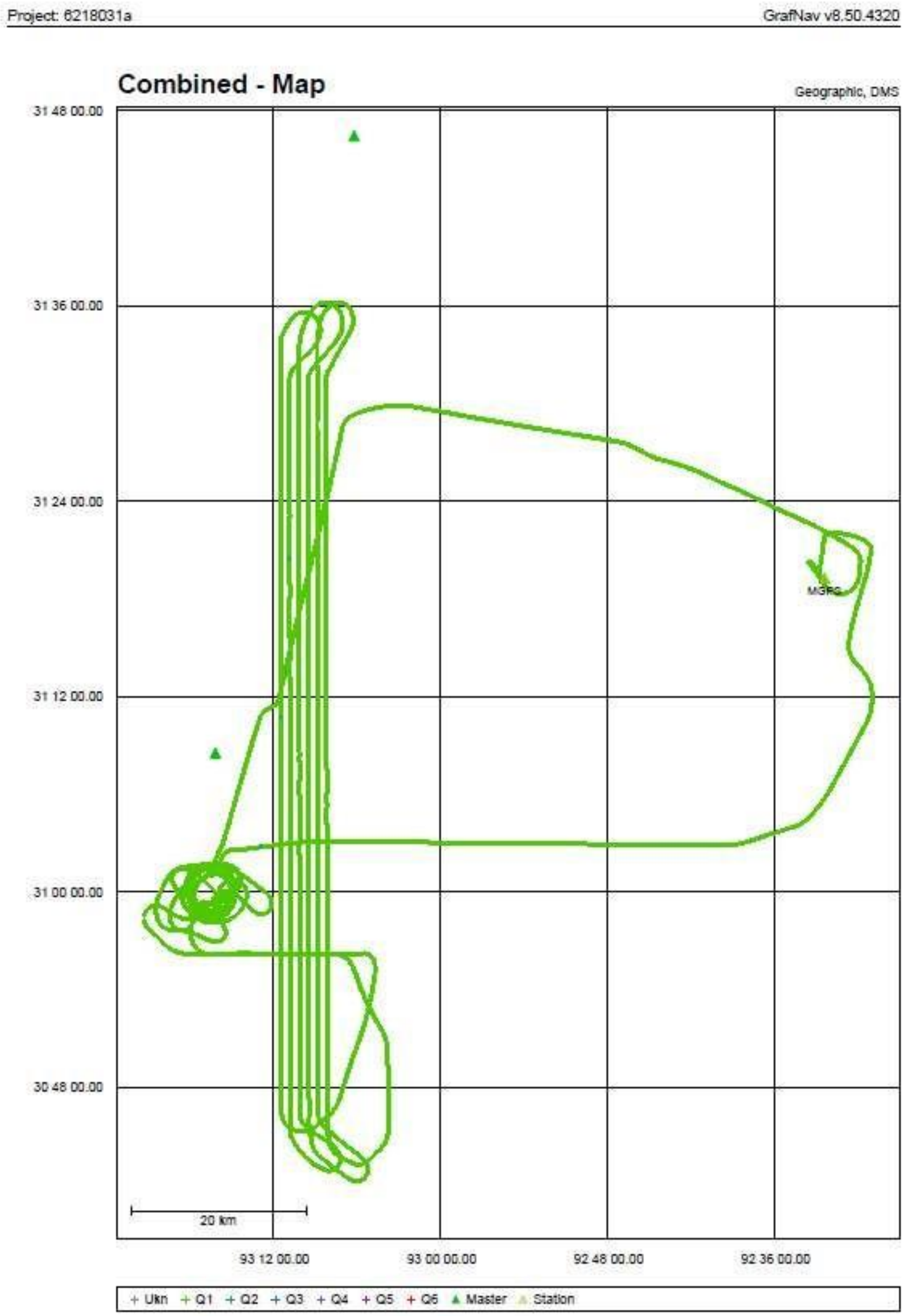
Mission 11 – 6218029a GNSS Processing



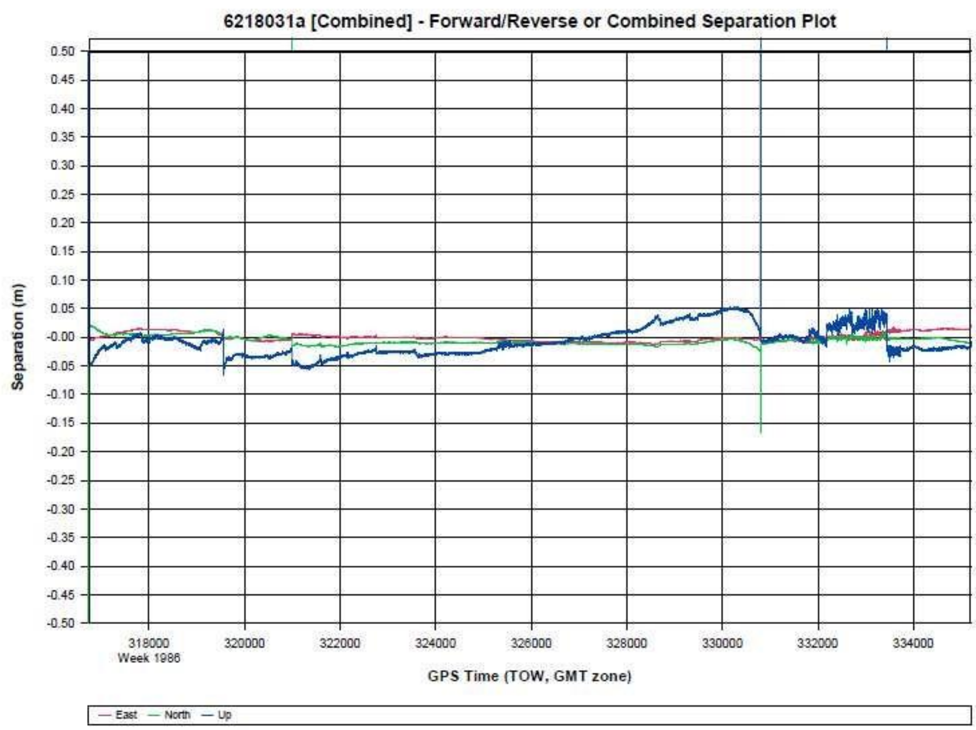

Project: 6218029a
GrafNav v8.50.4320
6218029a [Combined] - Forward/Reverse or Combined Separation Plot
Separation (m)
GPS Time (TOW, GMT zone)
Week 1986
East
North
Up


Project: 6218029a
GrafNav v8.50.4320
6218029a [Combined] - PDOP Plot
PDOP
GPS Time (TOW, GMT zone)
Week 1986
PDOP

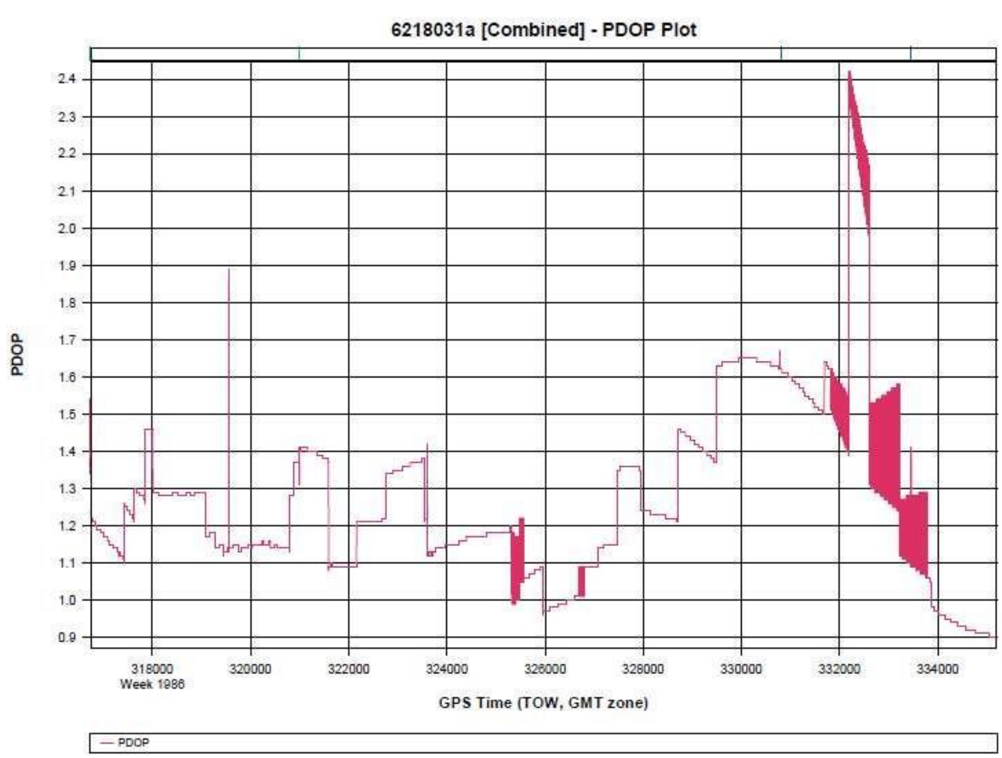
Mission 12 – 6218031a GNSS Processing



Project: 6218031a GrafNav v8.50.4320

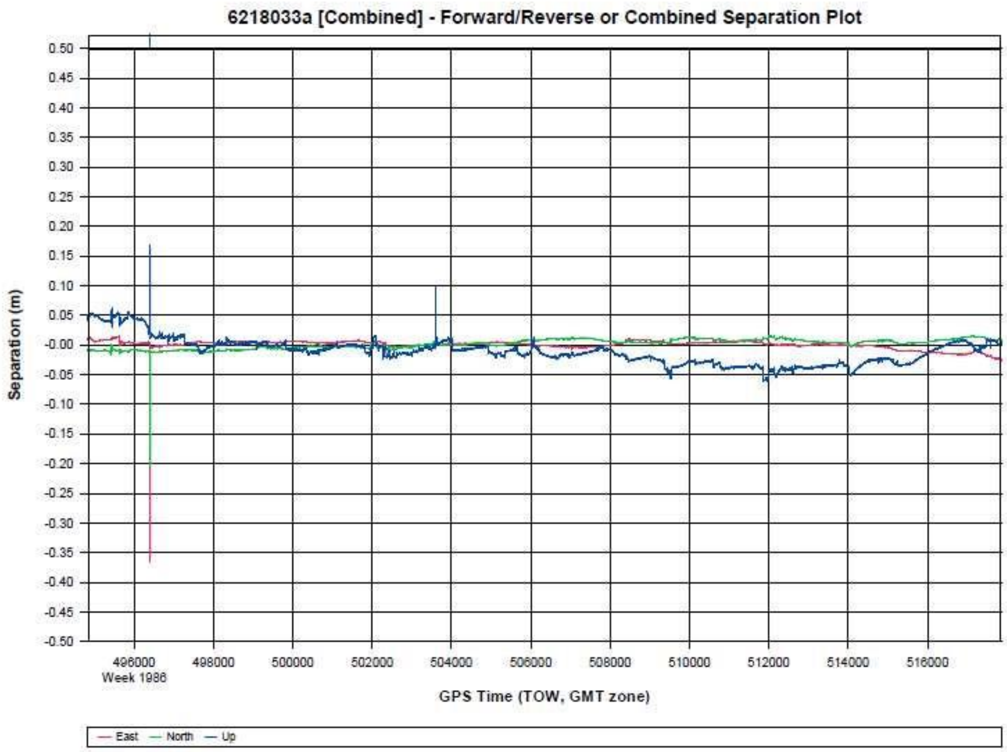


Project: 6218031a GrafNav v8.50.432

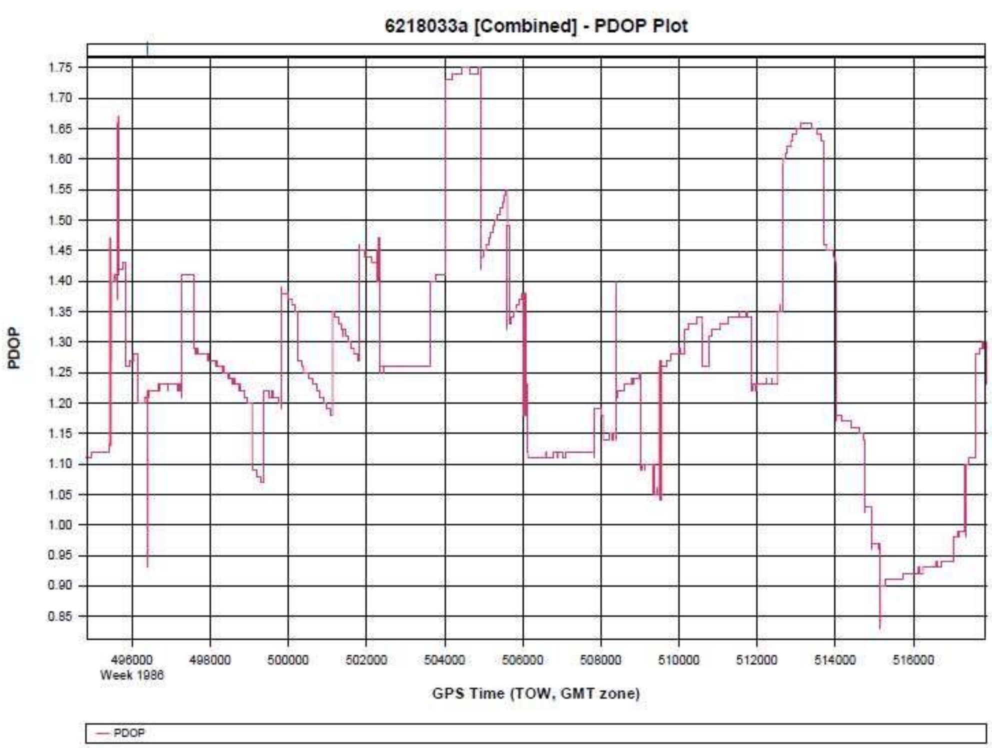


Mission 13 – 6218033a GNSS Processing

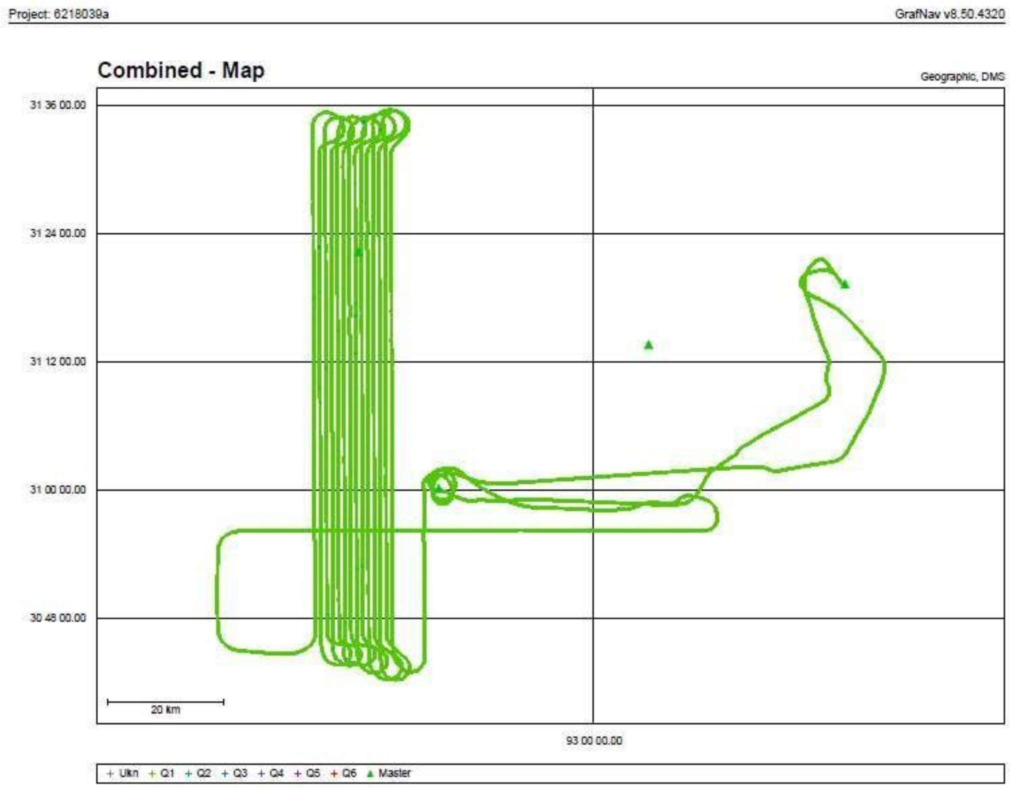
Project: 6218033a GrafNav v8.50.4320

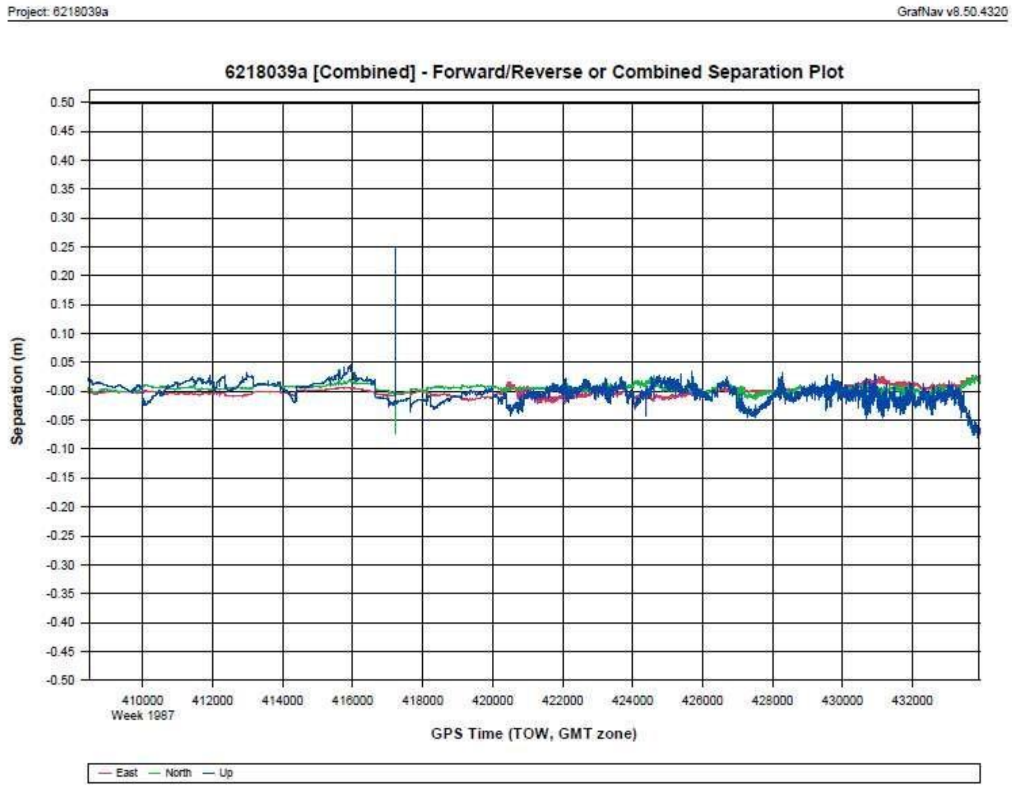


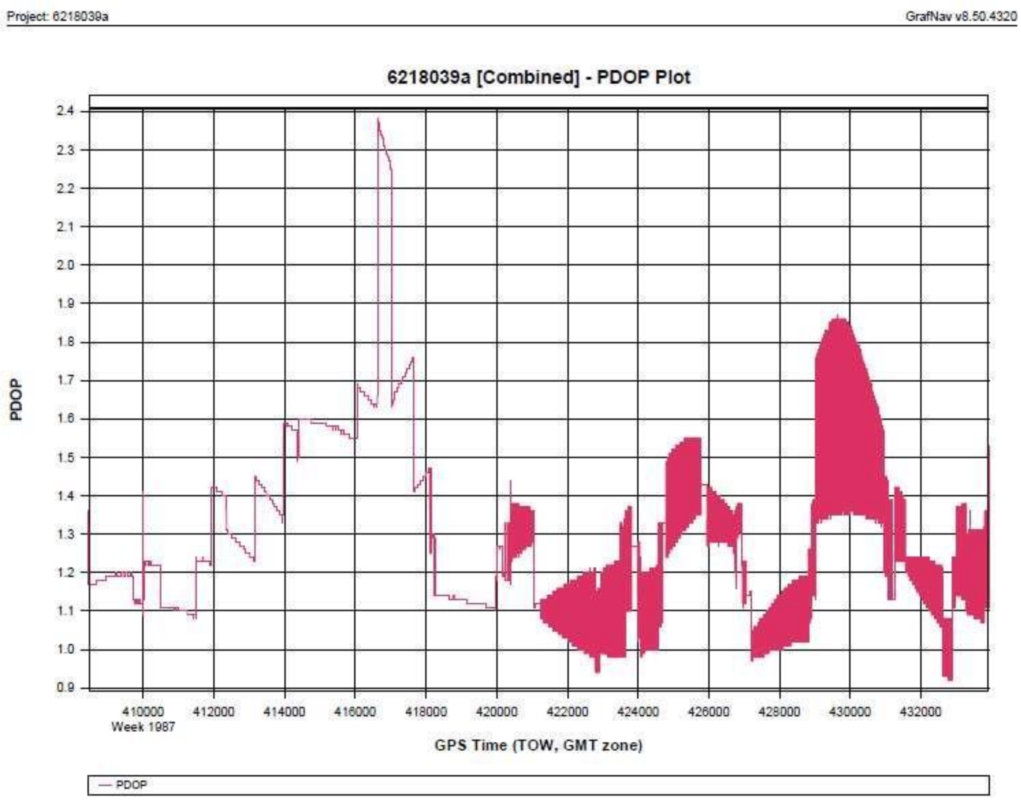
Project: 6218033a GrafNav v8.50.4320



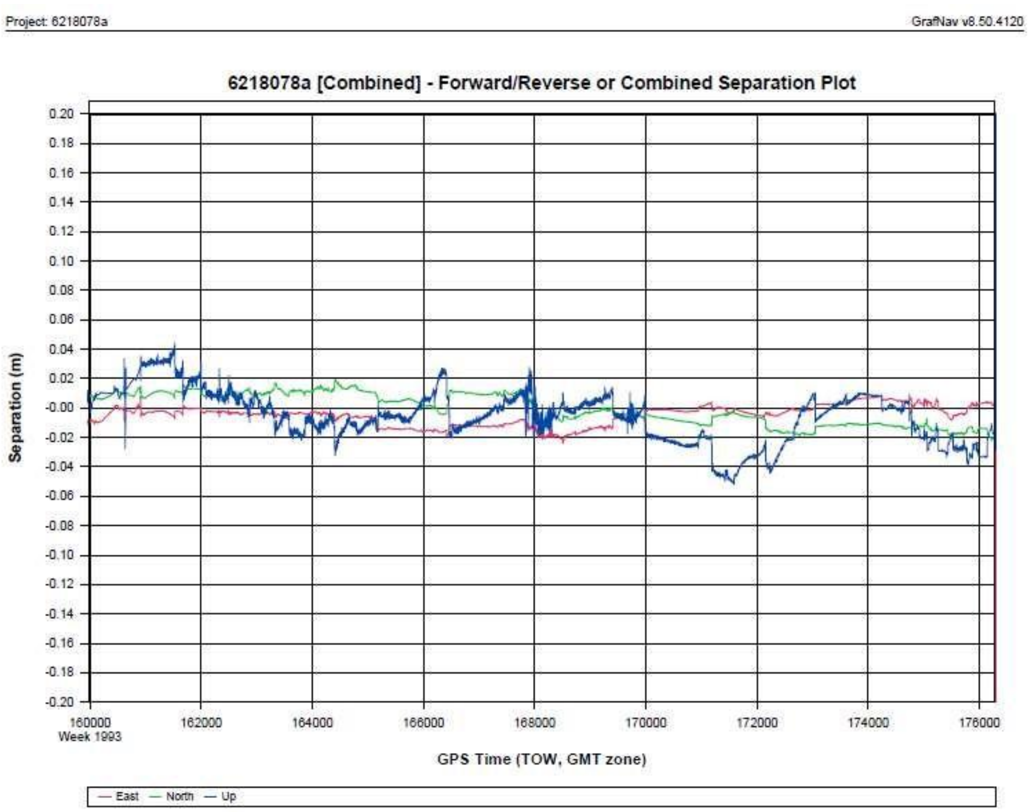
Mission 14 – 6218039a GNSS Processing

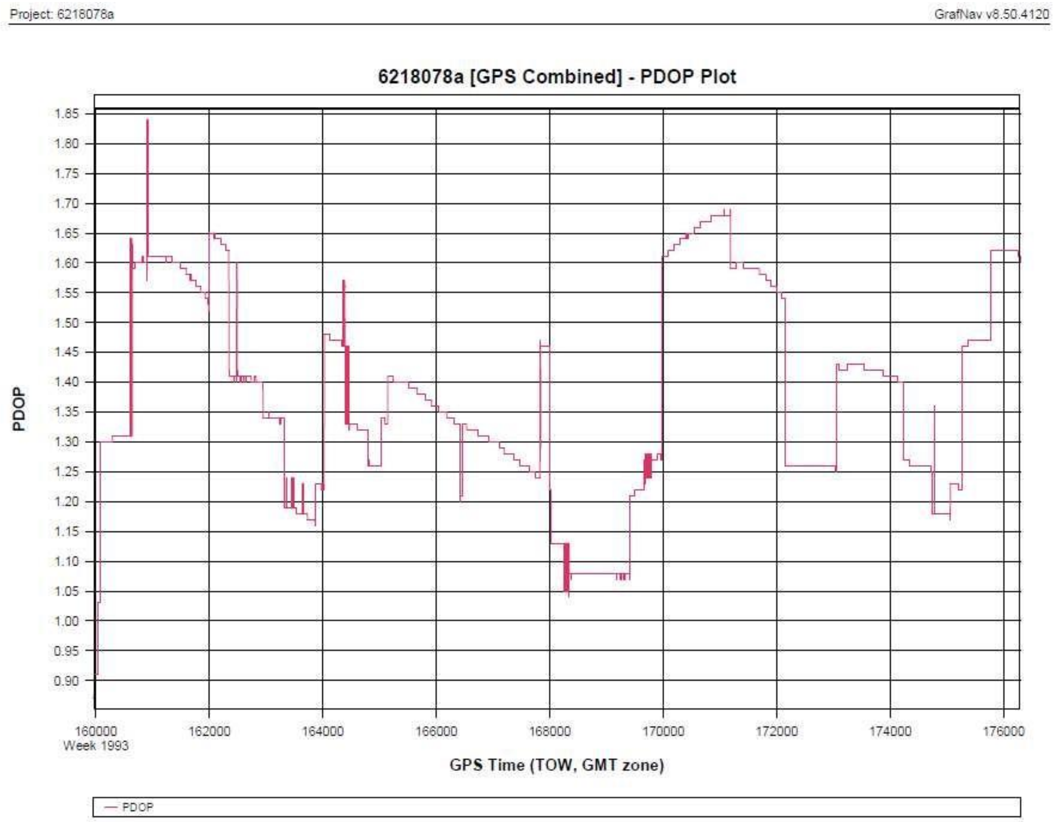



Project: 6218039a
GrafNav v8.50.4320
6218039a [Combined] - Forward/Reverse or Combined Separation Plot
Separation (m)
GPS Time (TOW, GMT zone)
Week 1987
East
North
Up

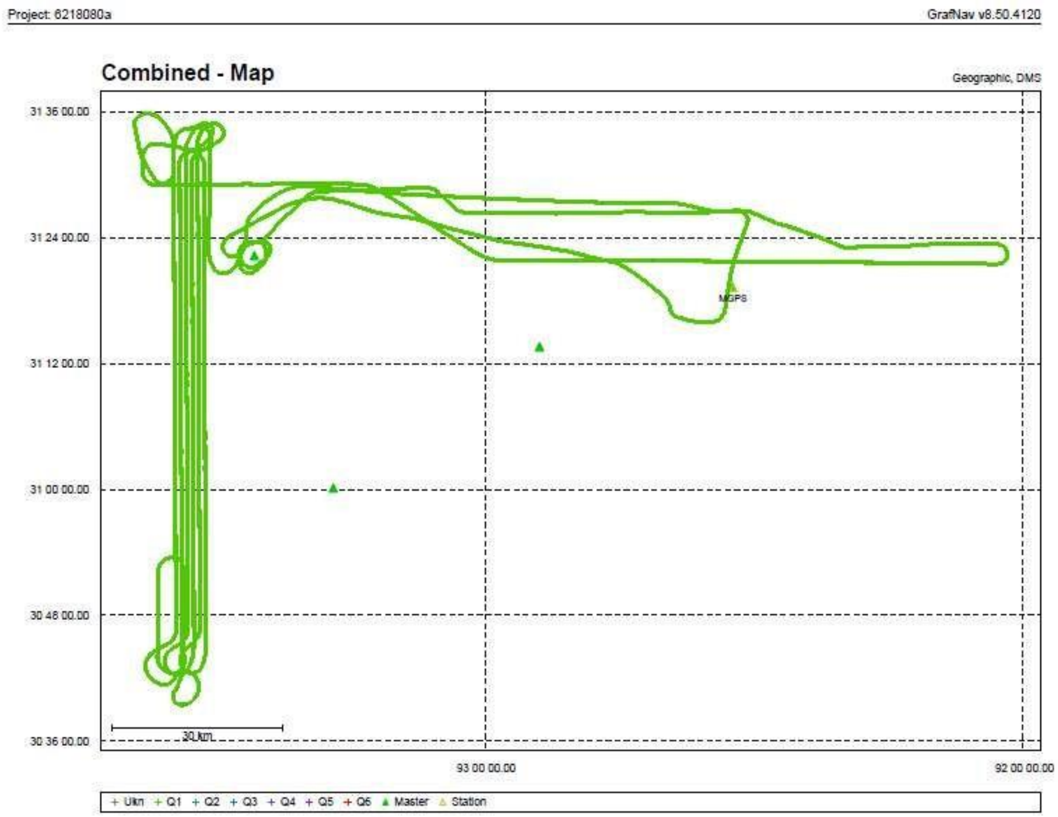

Project: 6218039a
GrafNav v8.50.4320
6218039a [Combined] - PDOP Plot
PDOP
GPS Time (TOW, GMT zone)
Week 1987
PDOP

Mission 15 – 6218078a GNSS Processing

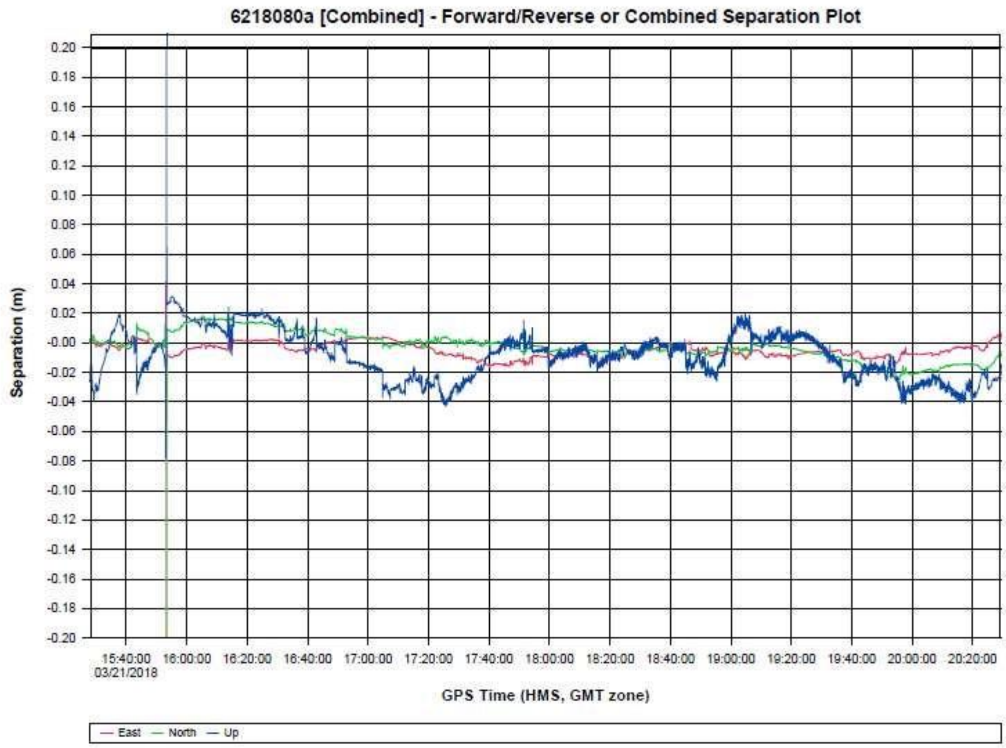



Project: 6218078a
GrafNav v8.50.4120
6218078a [GPS Combined] - PDOP Plot
PDOP
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1.25
1.20
1.15
1.10
1.05
1.00
0.95
0.90
160000
Week 1993
162000
164000
166000
168000
170000
172000
174000
176000
GPS Time (TOW, GMT zone)
PDOP

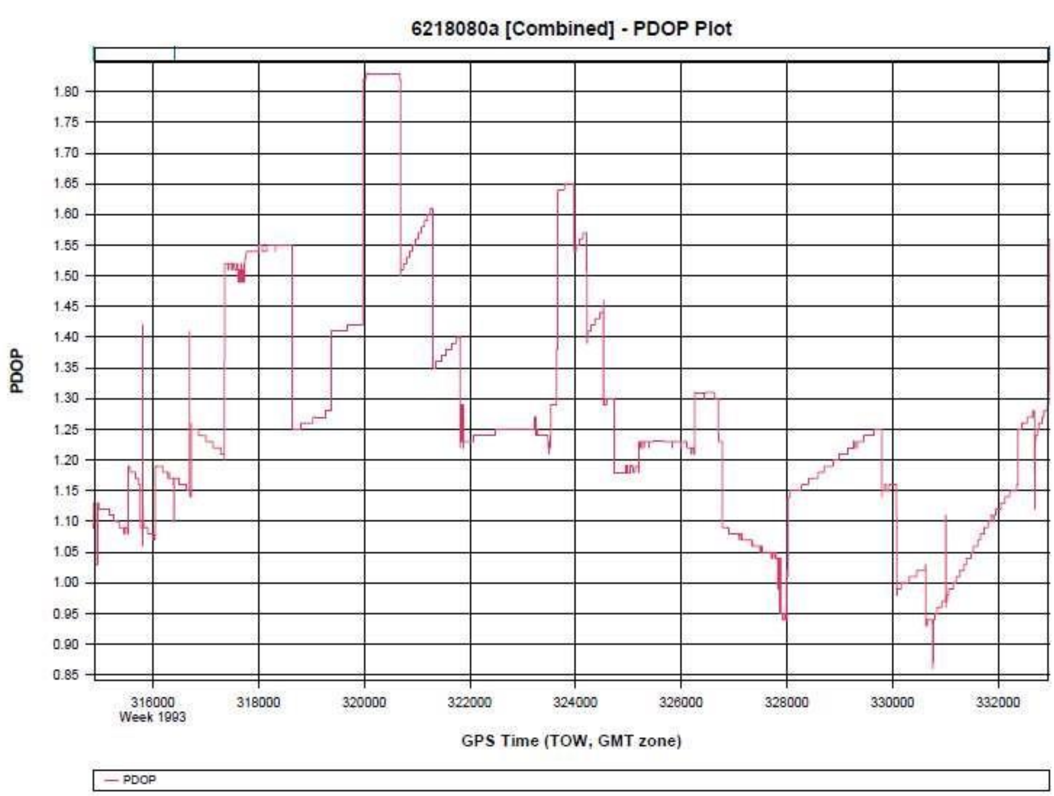
Mission 16 – 6218080a GNSS Processing



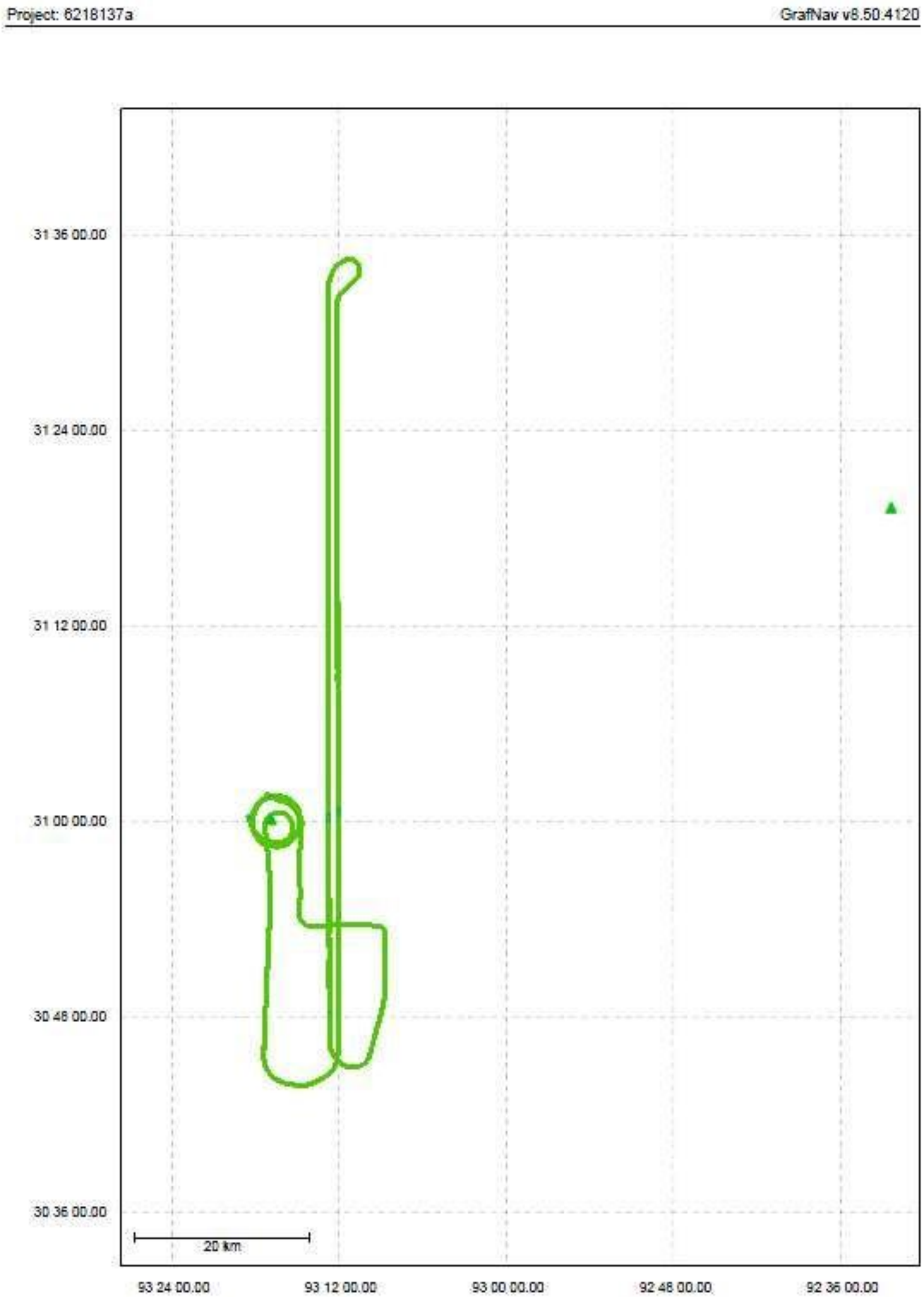
Project: 6218080a GrafNav v8.50.4120



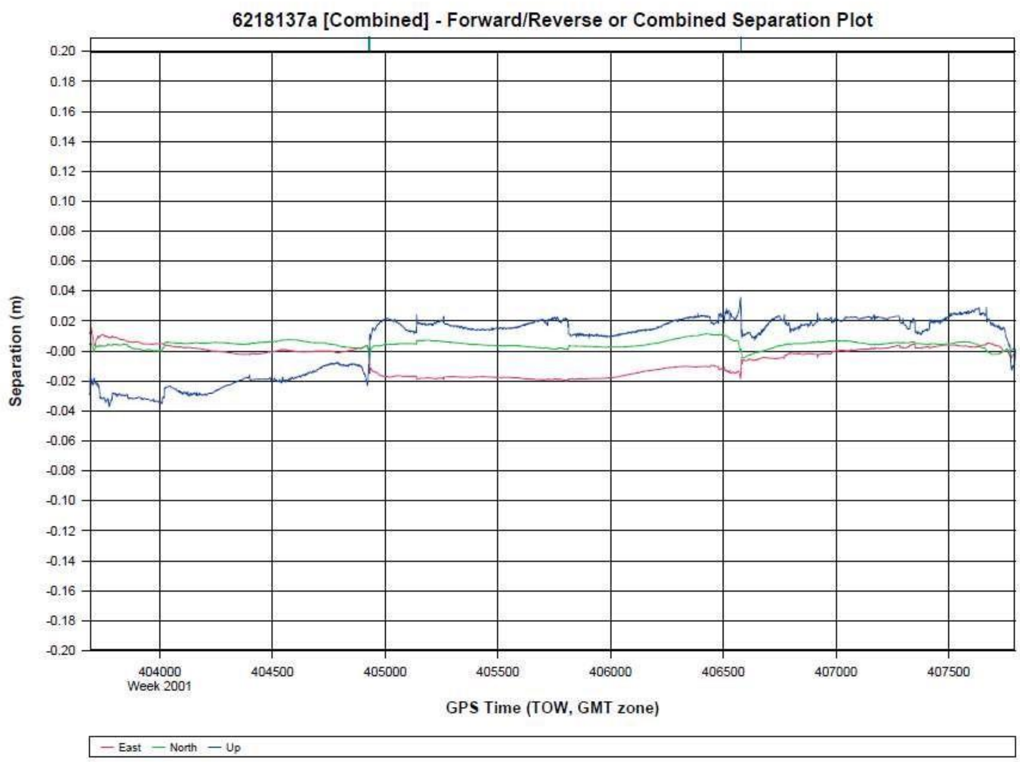
Project: 6218080a GrafNav v8.50.4120



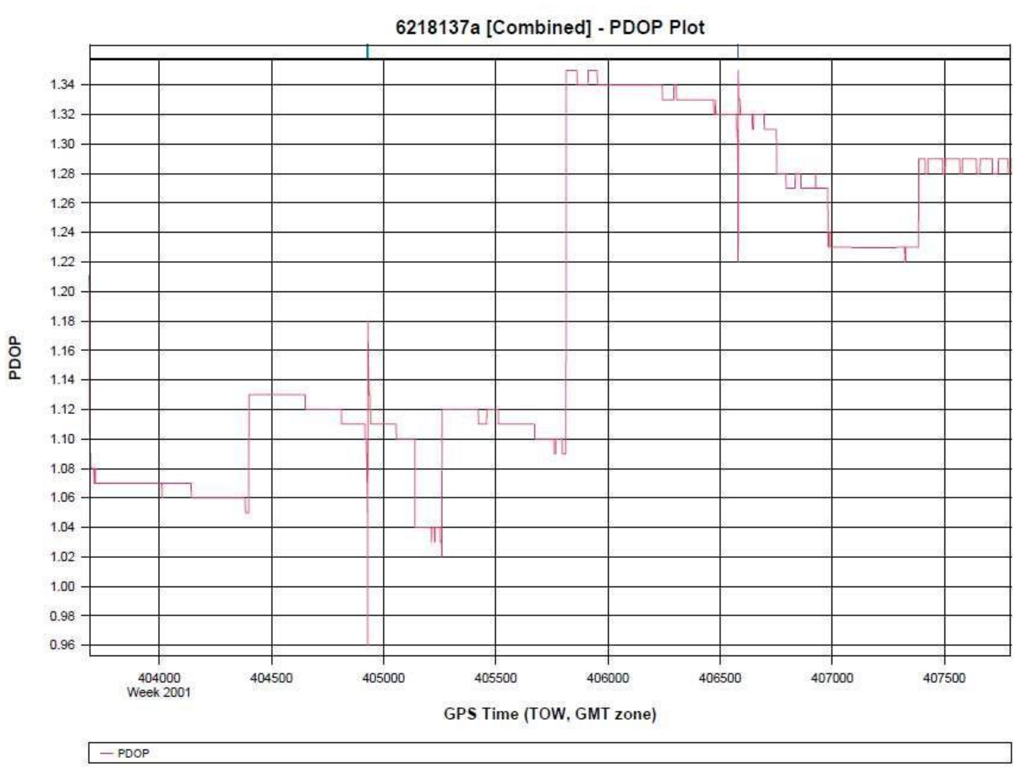
Mission 17 – 6218137a GNSS Processing



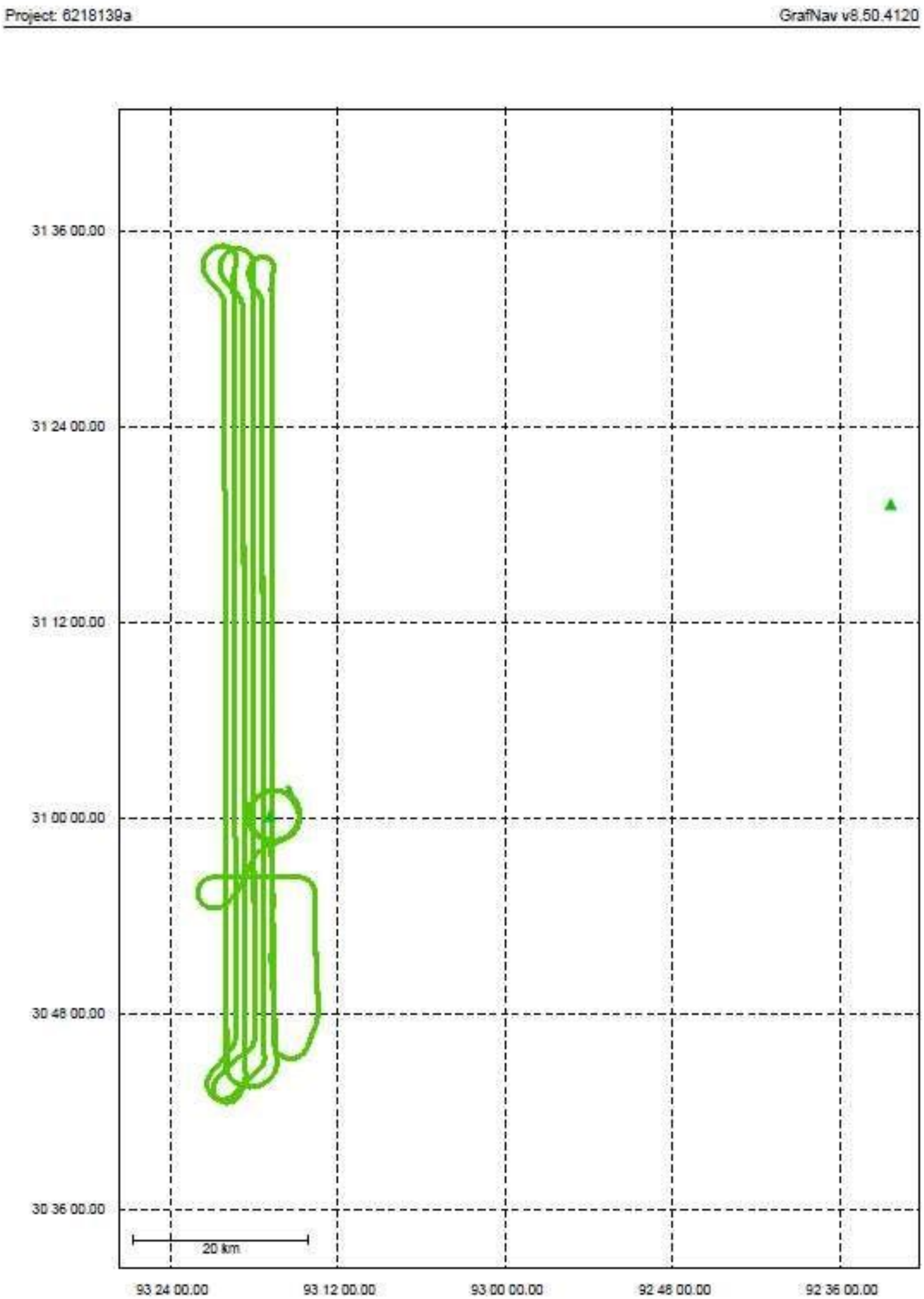
Project: 6218137a GrafNav v8.50.4120



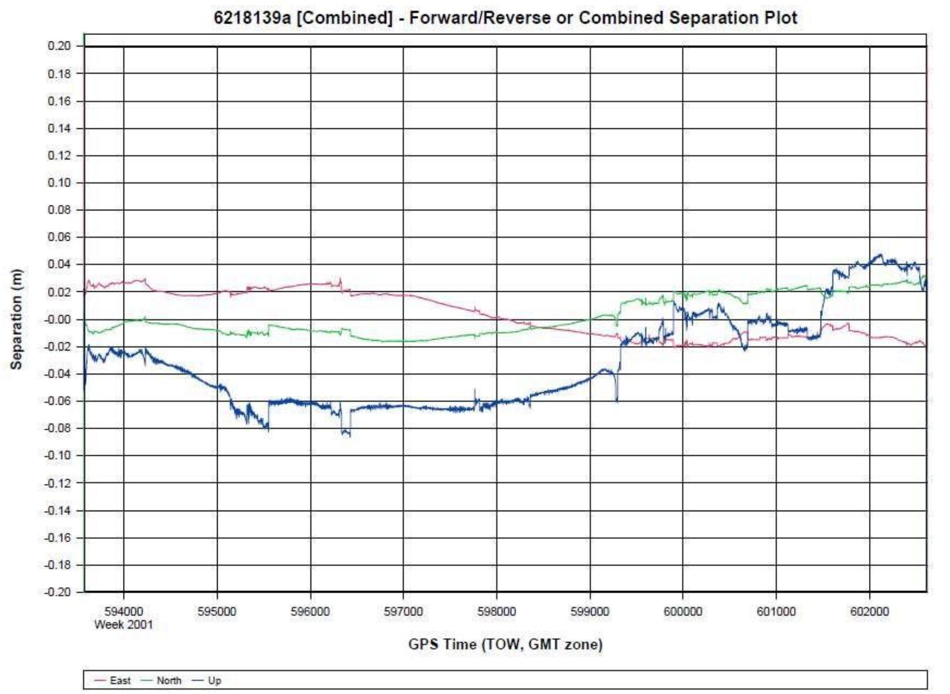
Project: 6218137a GrafNav v8.50.4120



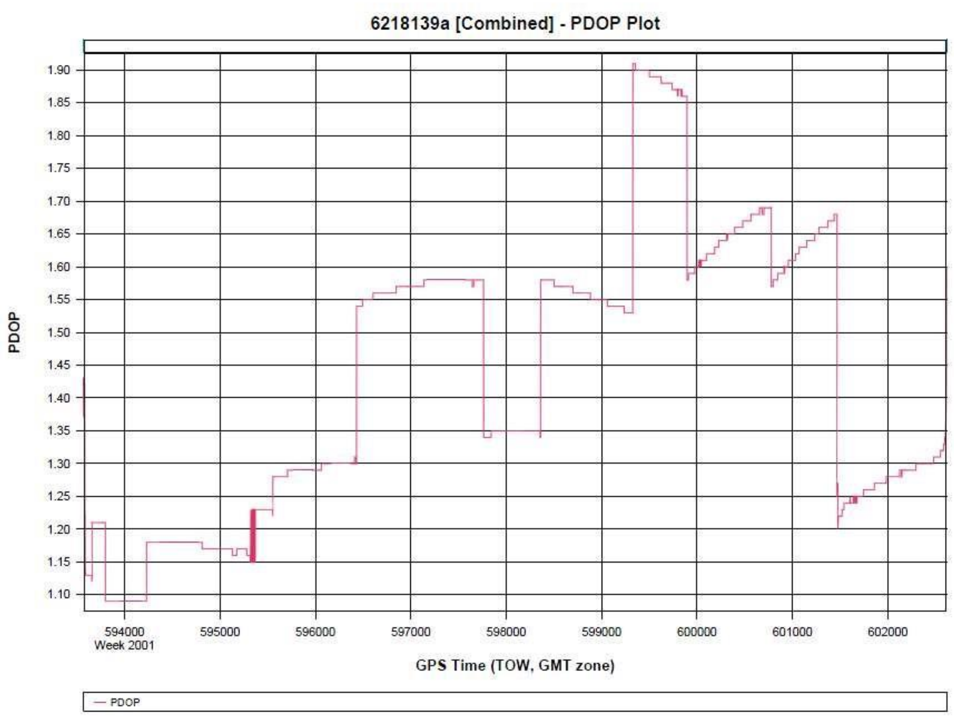
Mission 18 – 6218139a GNSS Processing



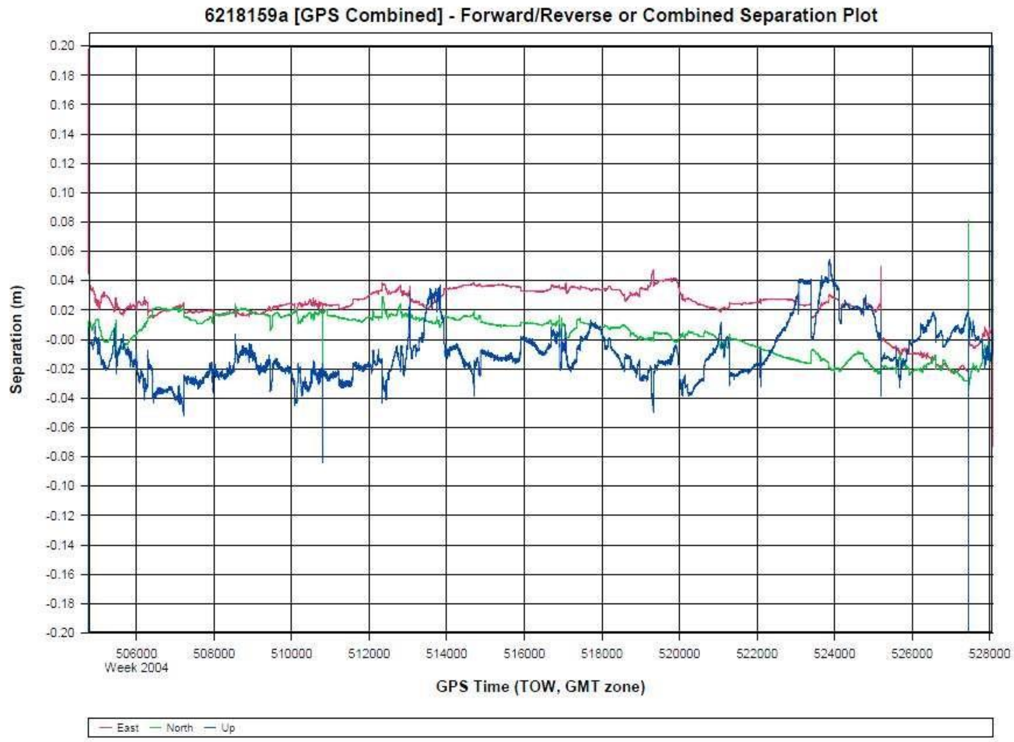
Project: 6218139a GrafNav v8.50.4120

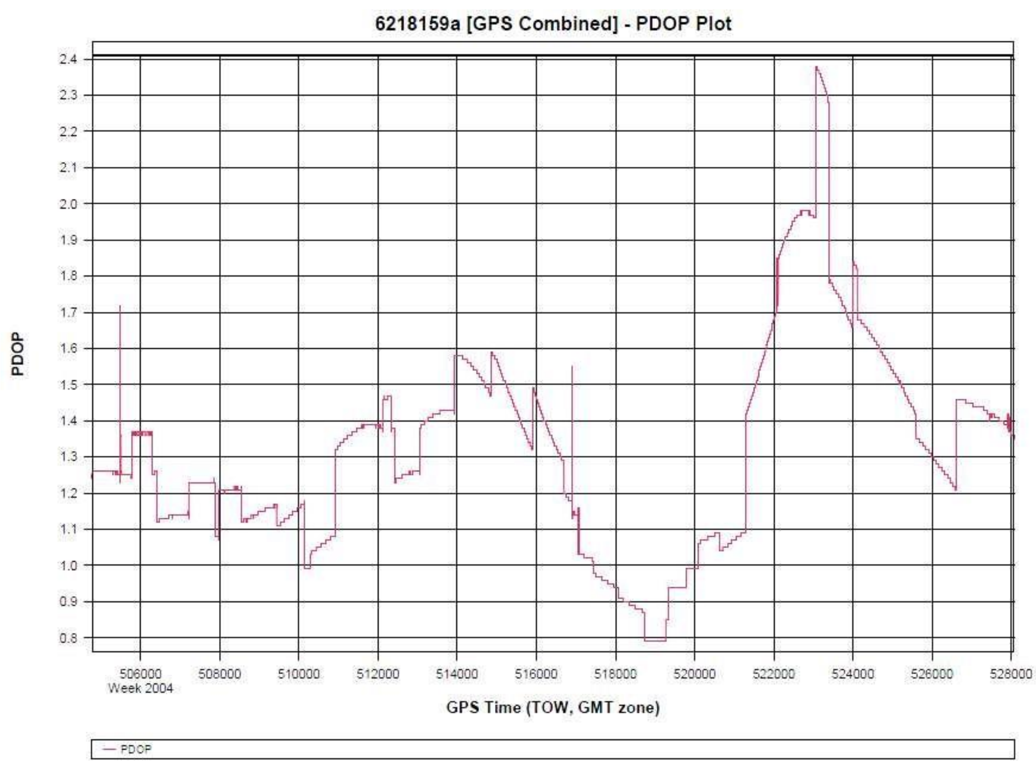


Project: 6218139a GrafNav v8.50.41

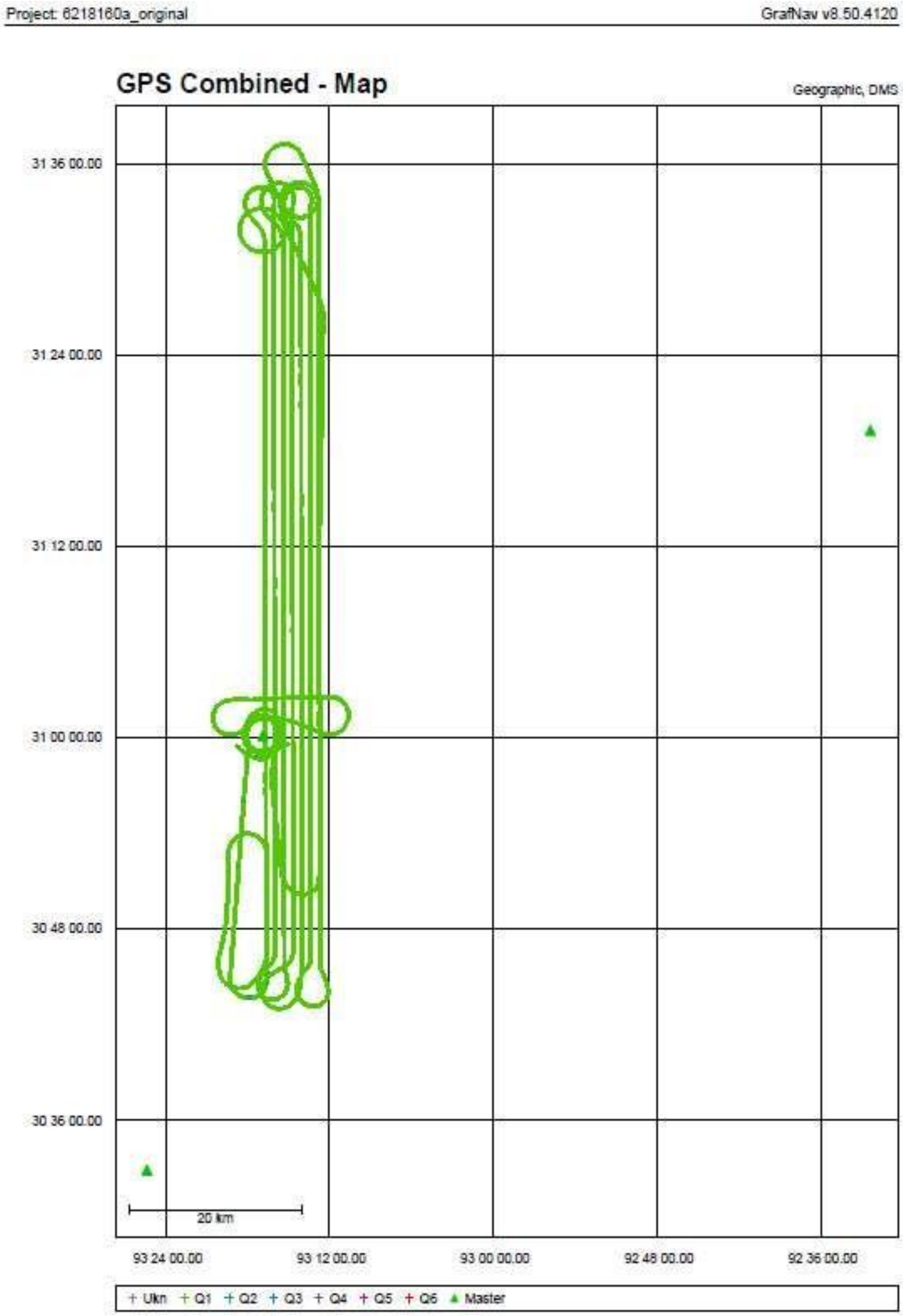


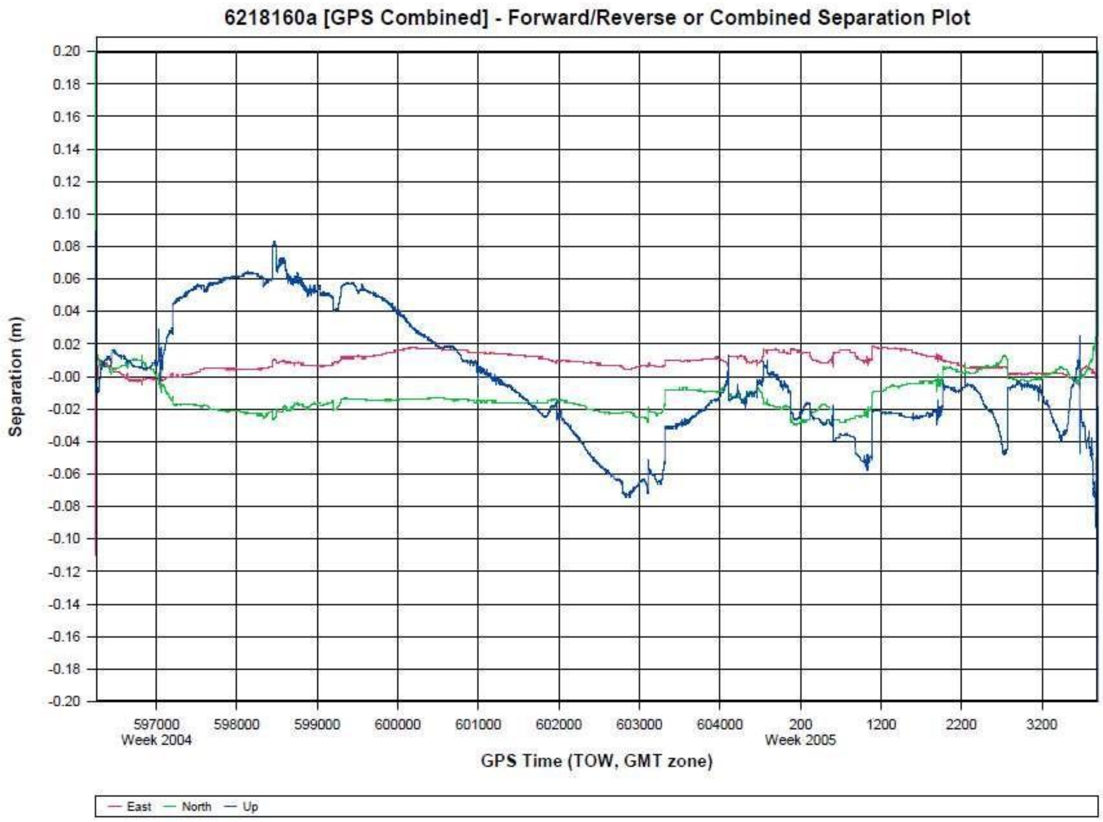
Mission 19 – 6218159a GNSS Processing

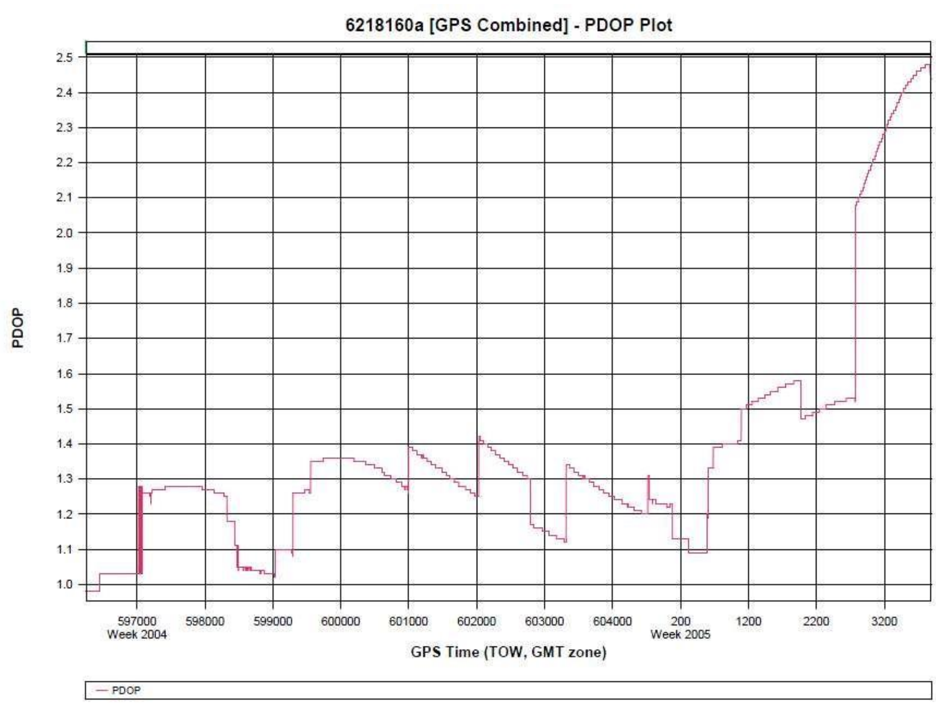

6218159a [GPS Combined] - Forward/Reverse or Combined Separation Plot
Separation (m)
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
-0.02
-0.04
-0.06
-0.08
-0.10
-0.12
-0.14
-0.16
-0.18
-0.20
506000
Week 2004
508000
510000
512000
514000
516000
518000
520000
522000
524000
526000
528000
GPS Time (TOW, GMT zone)
East
North
Up

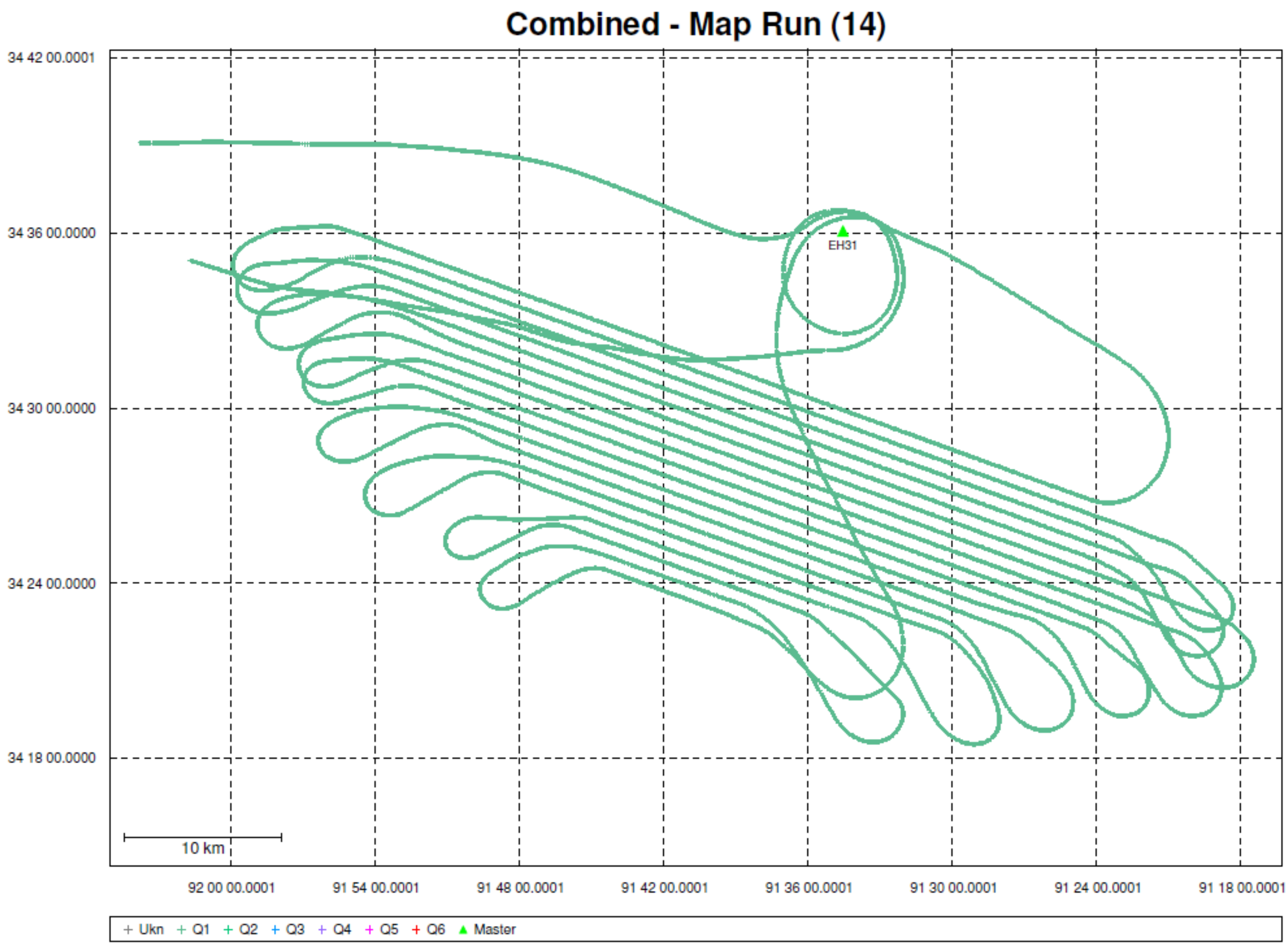

6218159a [GPS Combined] - PDOP Plot
PDOP
2.4
2.3
2.2
2.1
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
506000
Week 2004
508000
510000
512000
514000
516000
518000
520000
522000
524000
526000
528000
GPS Time (TOW, GMT zone)
PDOP

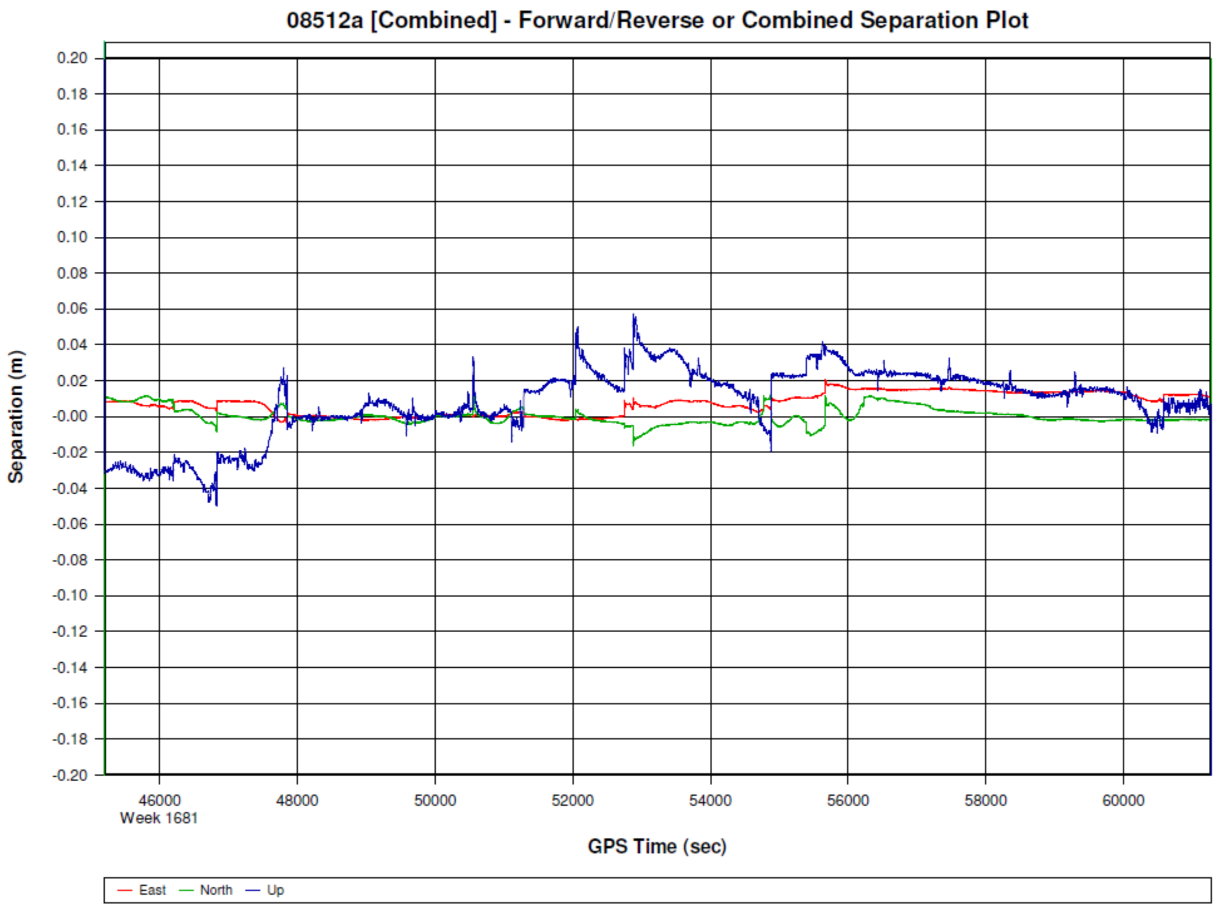
Mission 20 – 6218160a GNSS Processing

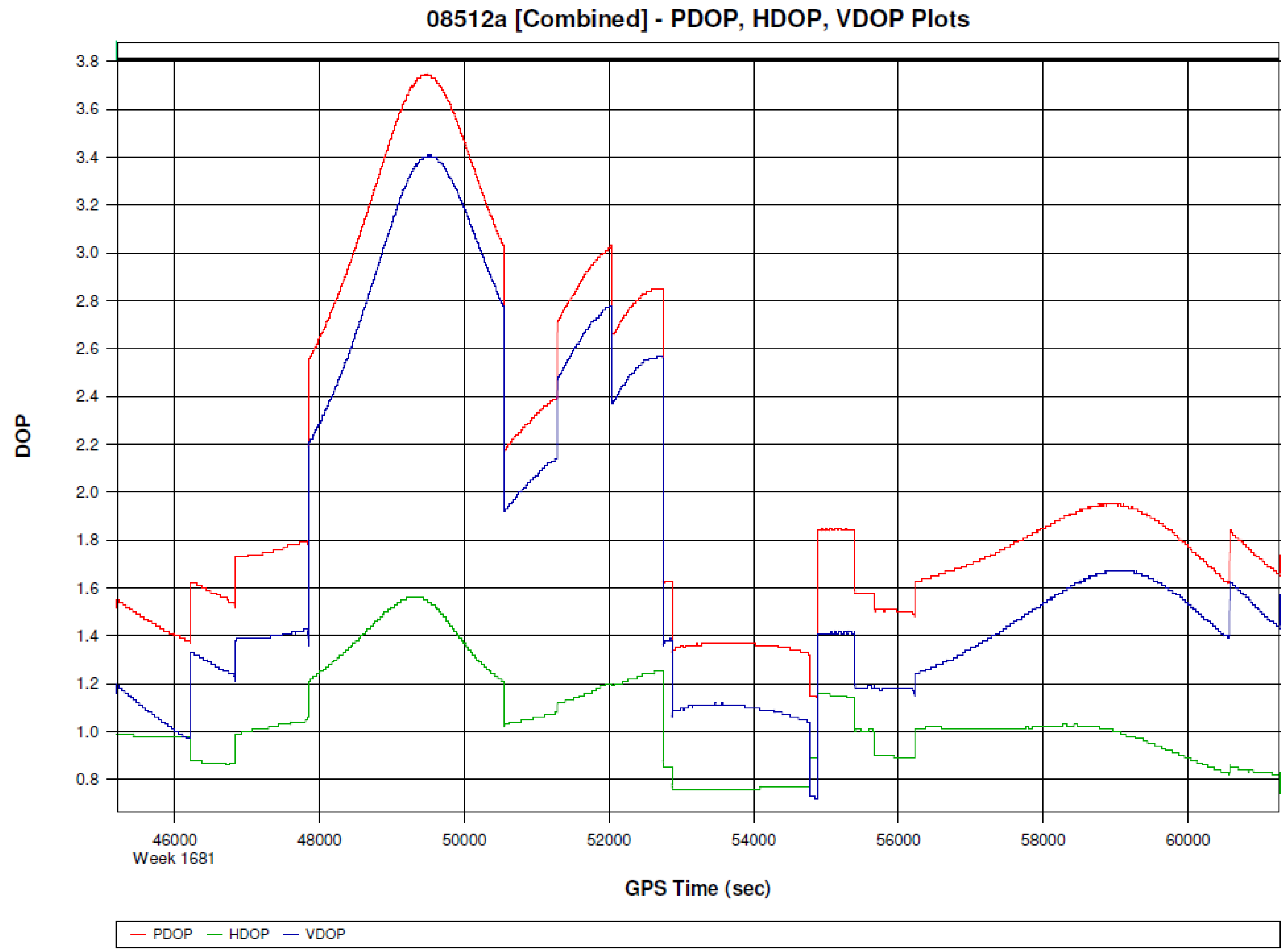



6218160a [GPS Combined] - Forward/Reverse or Combined Separation Plot
Separation (m)
GPS Time (TOW, GMT zone)
597000 Week 2004
598000
599000
600000
601000
602000
603000
604000
200 Week 2005
1200
2200
3200
East
North
Up

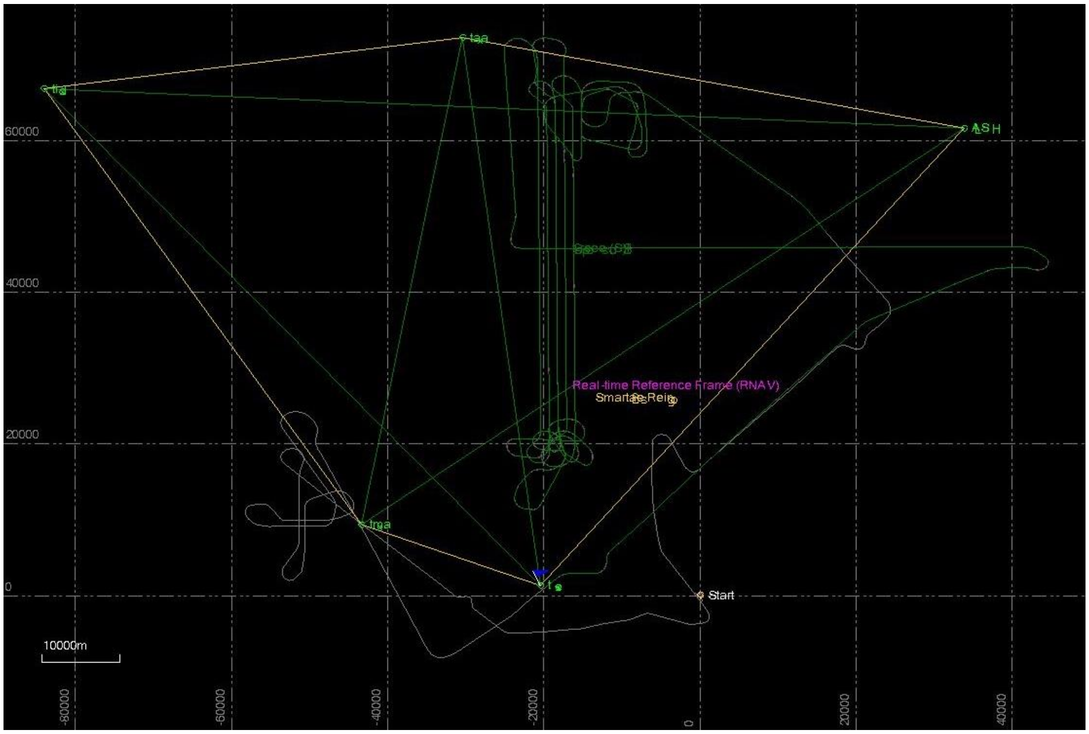

6218160a [GPS Combined] - PDOP Plot
PDOP
GPS Time (TOW, GMT zone)
597000 Week 2004
598000
599000
600000
601000
602000
603000
604000
200 Week 2005
1200
2200
3200
PDOP

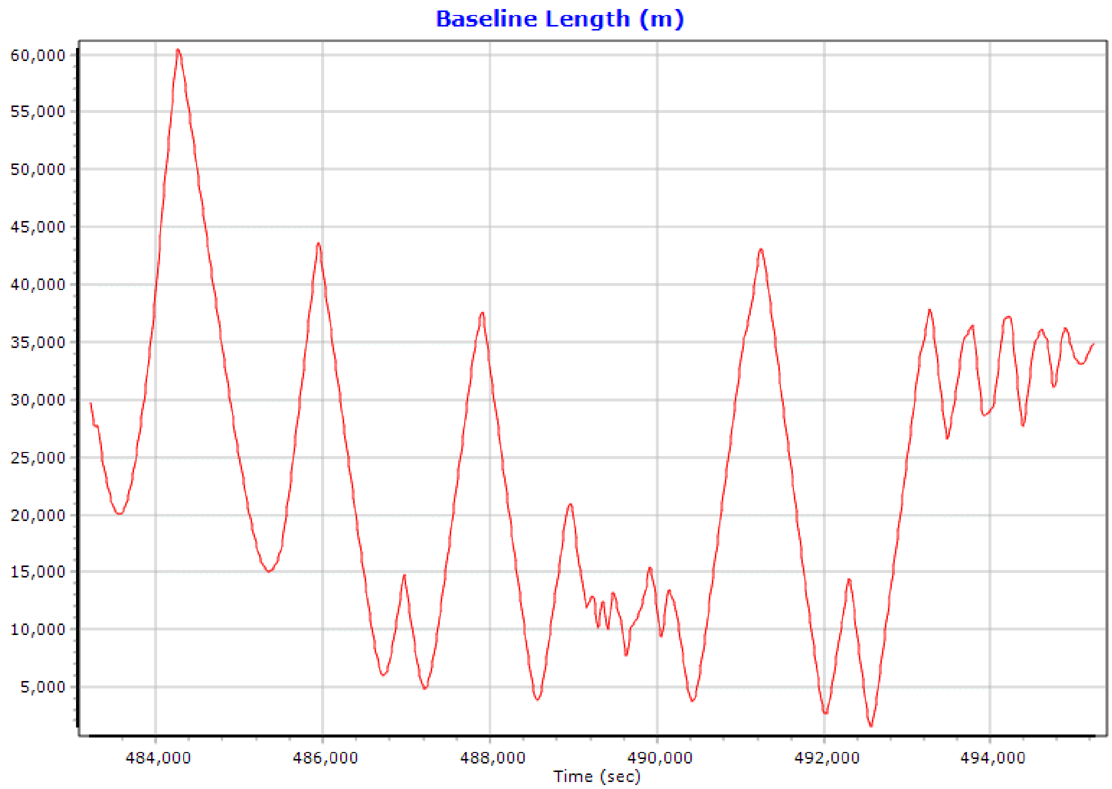

Combined - Map Run (14)
34 42 00.0001
34 36 00.0000
34 30 00.0000
34 24 00.0000
34 18 00.0000
EH31
10 km
92 00 00.0001
91 54 00.0001
91 48 00.0001
91 42 00.0001
91 36 00.0001
91 30 00.0001
91 24 00.0001
91 18 00.0001
+ Ukn + Q1 + Q2 + Q3 + Q4 + Q5 + Q6 ▲ Master

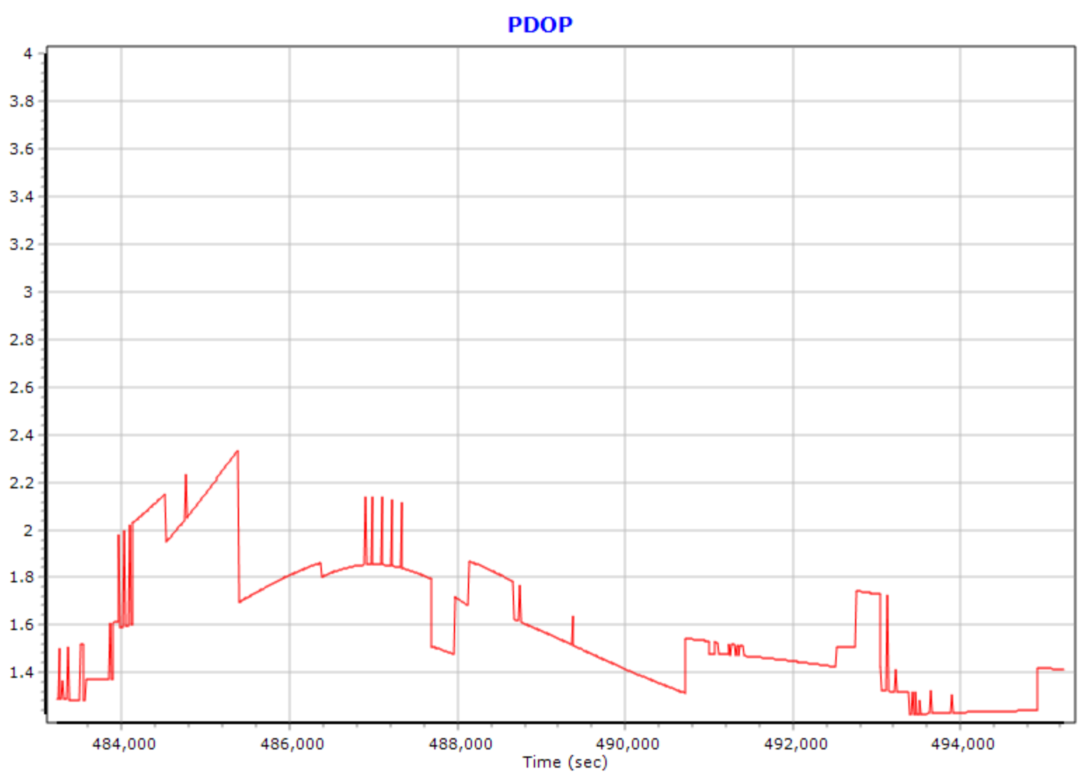

08512a [Combined] - Forward/Reverse or Combined Separation Plot
Separation (m)
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
-0.00
-0.02
-0.04
-0.06
-0.08
-0.10
-0.12
-0.14
-0.16
-0.18
-0.20
46000
Week 1681
48000
50000
52000
54000
56000
58000
60000
GPS Time (sec)
East
North
Up


08512a [Combined] - PDOP, HDOP, VDOP Plots
DOP
3.8
3.6
3.4
3.2
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
46000
Week 1681
48000
50000
52000
54000
56000
58000
60000
GPS Time (sec)
PDOP
HDOP
VDOP

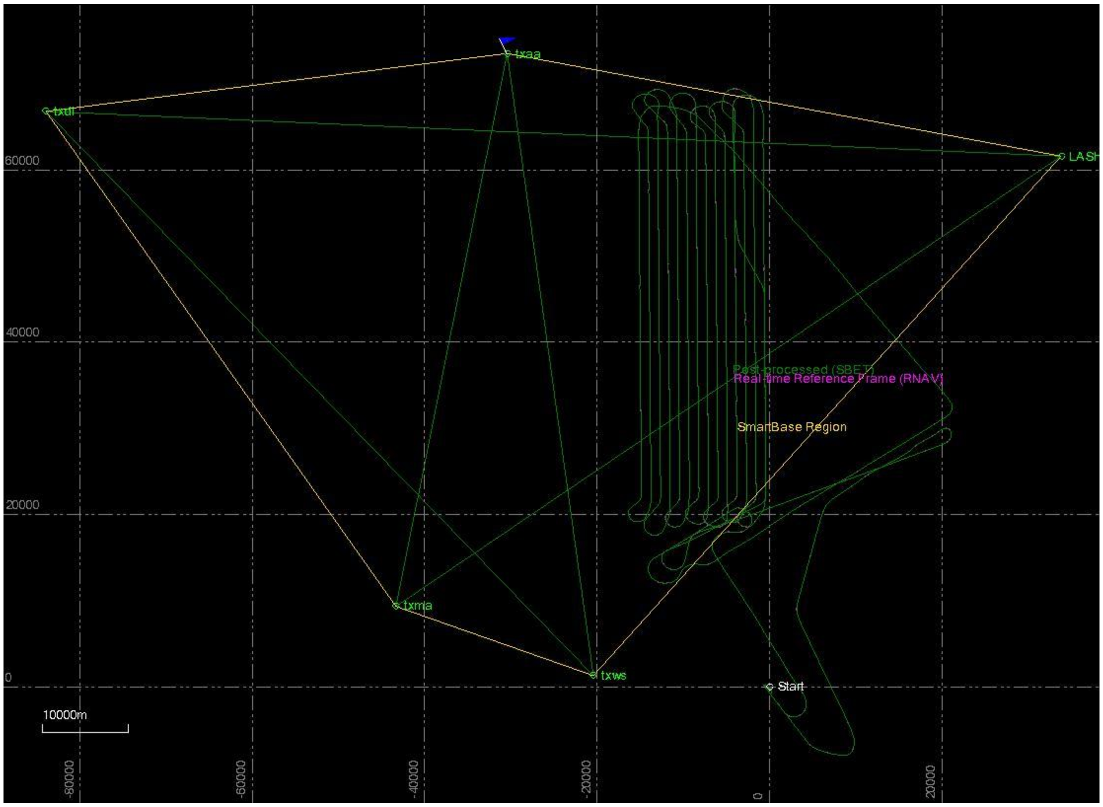
Leading Edge Geomatics
2SU18306A

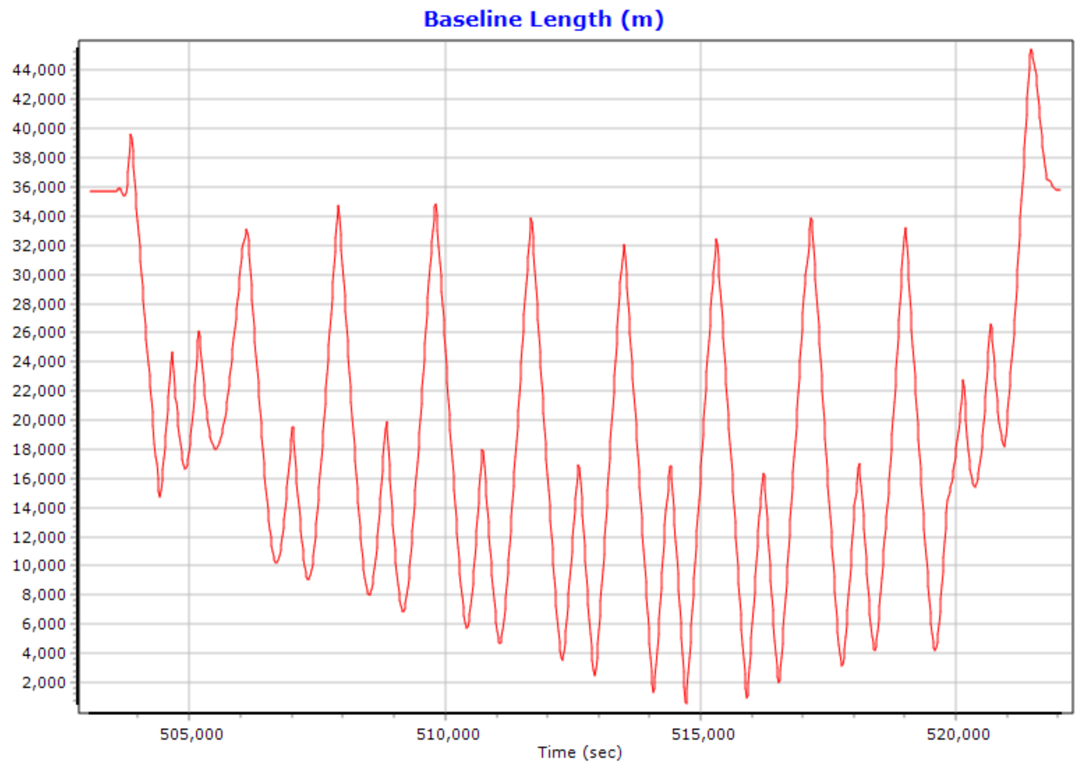



Baseline Length (m)
60,000
55,000
50,000
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
484,000
486,000
488,000
490,000
492,000
494,000
Time (sec)


PDOP
4
3.8
3.6
3.4
3.2
3
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
484,000
486,000
488,000
490,000
492,000
494,000
Time (sec)

2SU18036B


txaa
txul
LASH
60000
40000
20000
0
Post-processed (SBET)
Real-time Reference Frame (RNAV)
SmartBase Region
txma
txws
Start
10000m
-80000
-60000
-40000
-20000
0
20000


Baseline Length (m)
44,000
42,000
40,000
38,000
36,000
34,000
32,000
30,000
28,000
26,000
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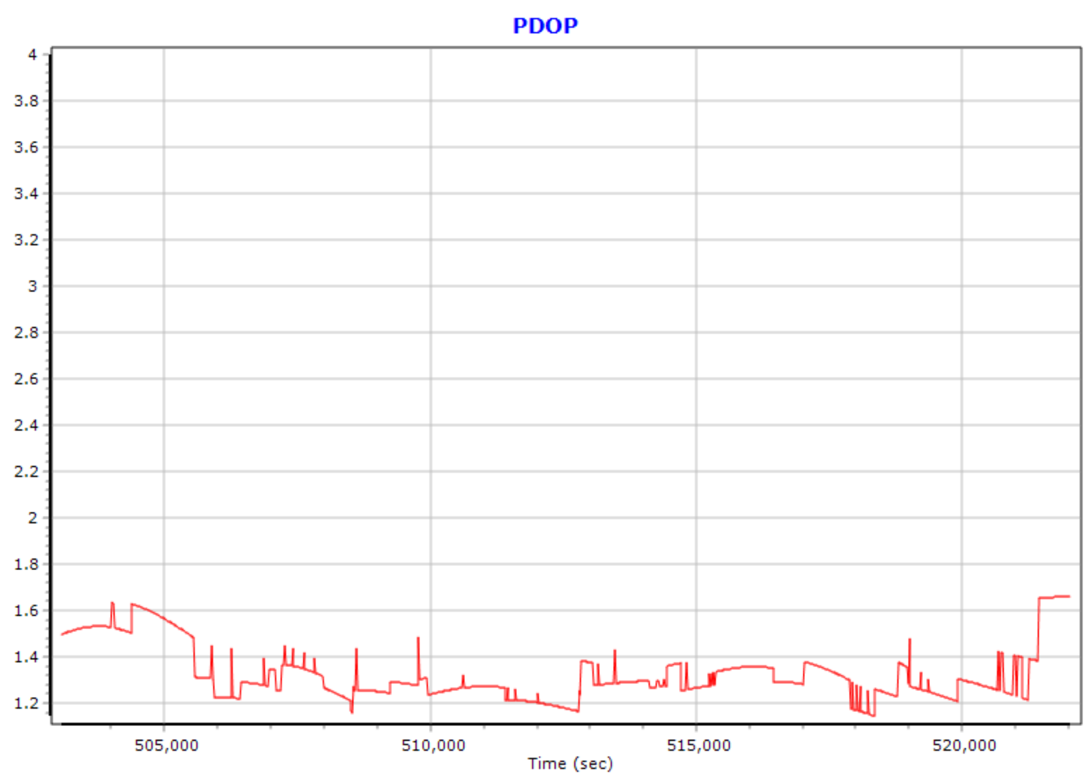
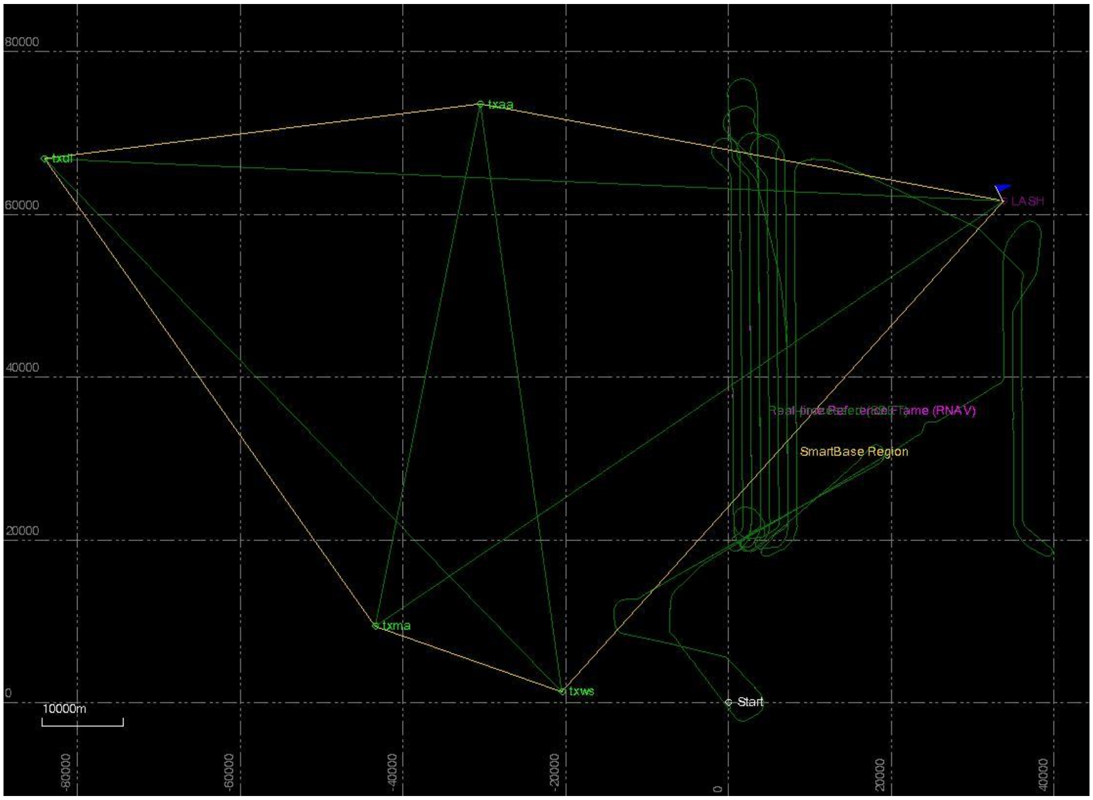
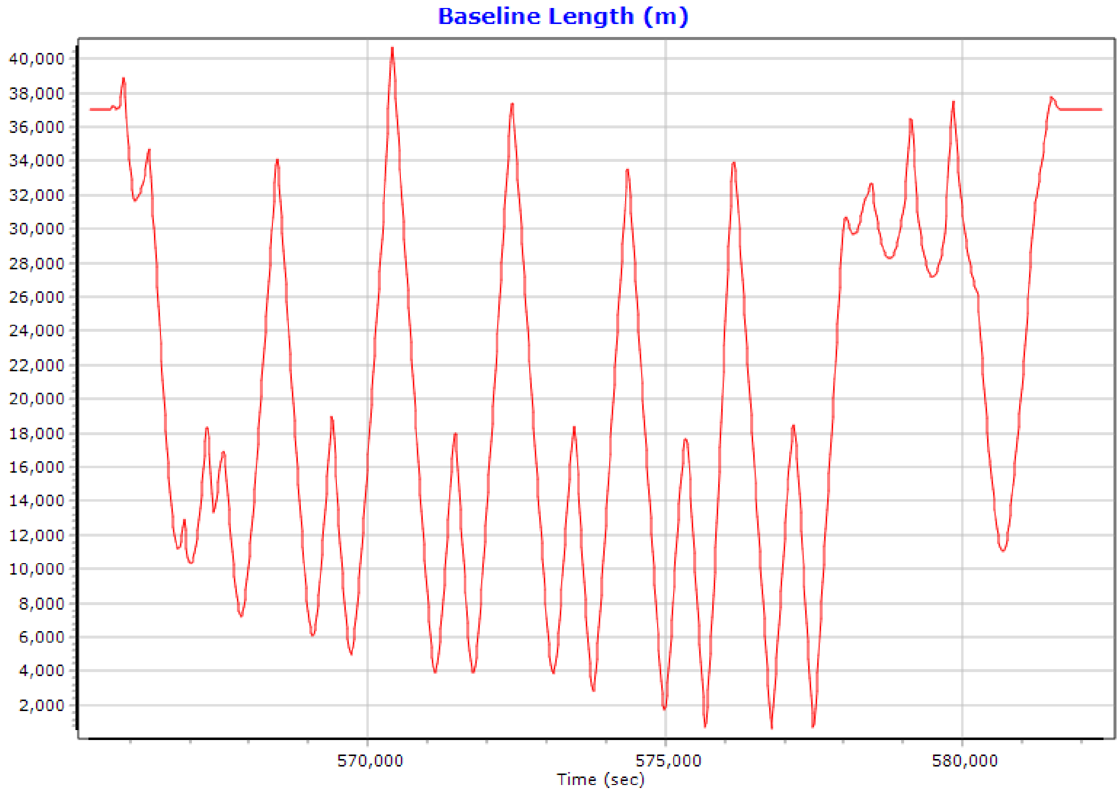
22,000
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
505,000
510,000
515,000
520,000
Time (sec)


PDOP
4
3.8
3.6
3.4
3.2
3
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
505,000
510,000
515,000
520,000
Time (sec)


80000
60000
40000
20000
0
txaa
txdi
LASH
txma
txws
Start
SmartBase Region
10000m
-80000
-60000
-40000
-20000
0
20000
40000


Baseline Length (m)
40,000
38,000
36,000
34,000
32,000
30,000
28,000
26,000
24,000
22,000
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18,000
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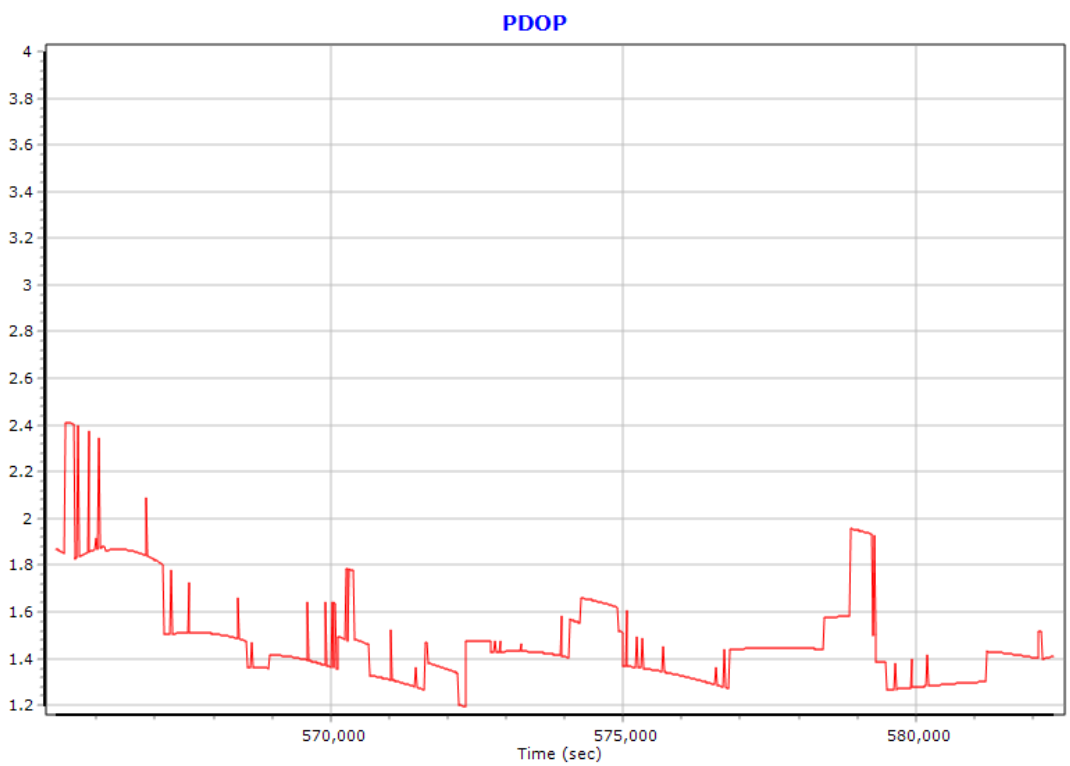
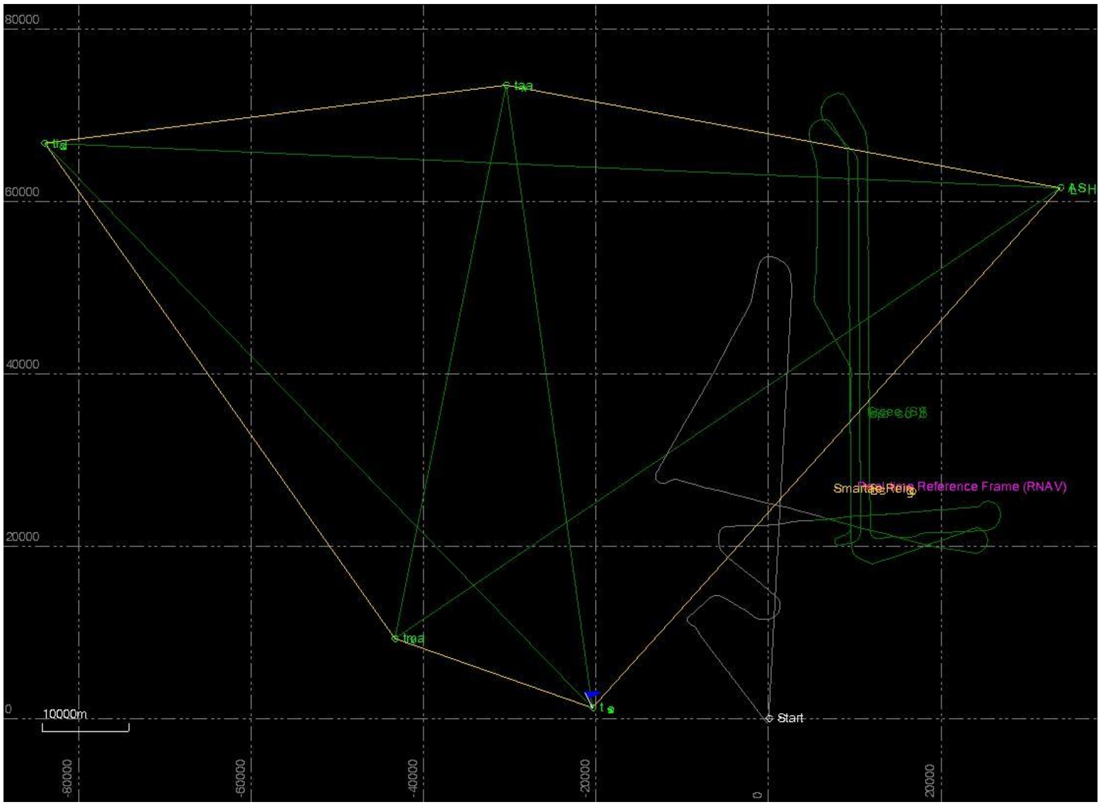
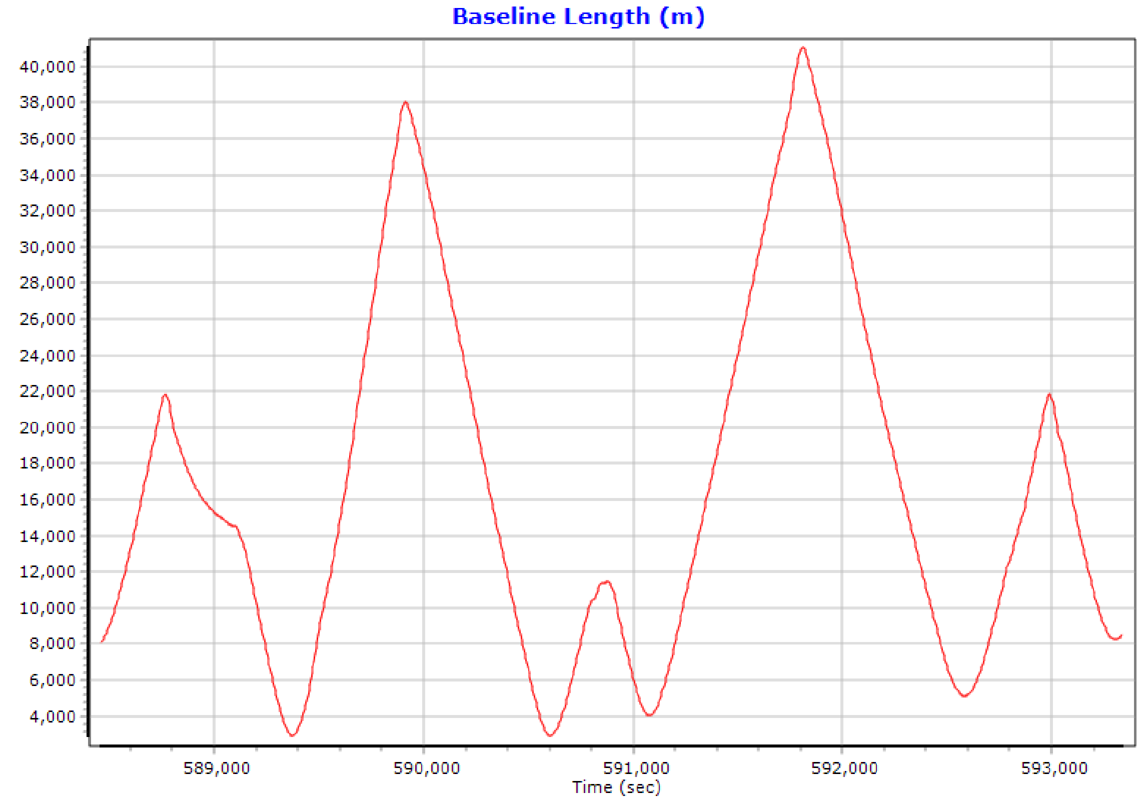
575,000
580,000
Time (sec)


PDOP
4
3.8
3.6
3.4
3.2
3
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
570,000
575,000
580,000
Time (sec)

2SU18037B


80000
60000
40000
20000
0
10000m
-80000
-60000
-40000
-20000
0
20000
Start
Reference Frame (RNAV)


Baseline Length (m)
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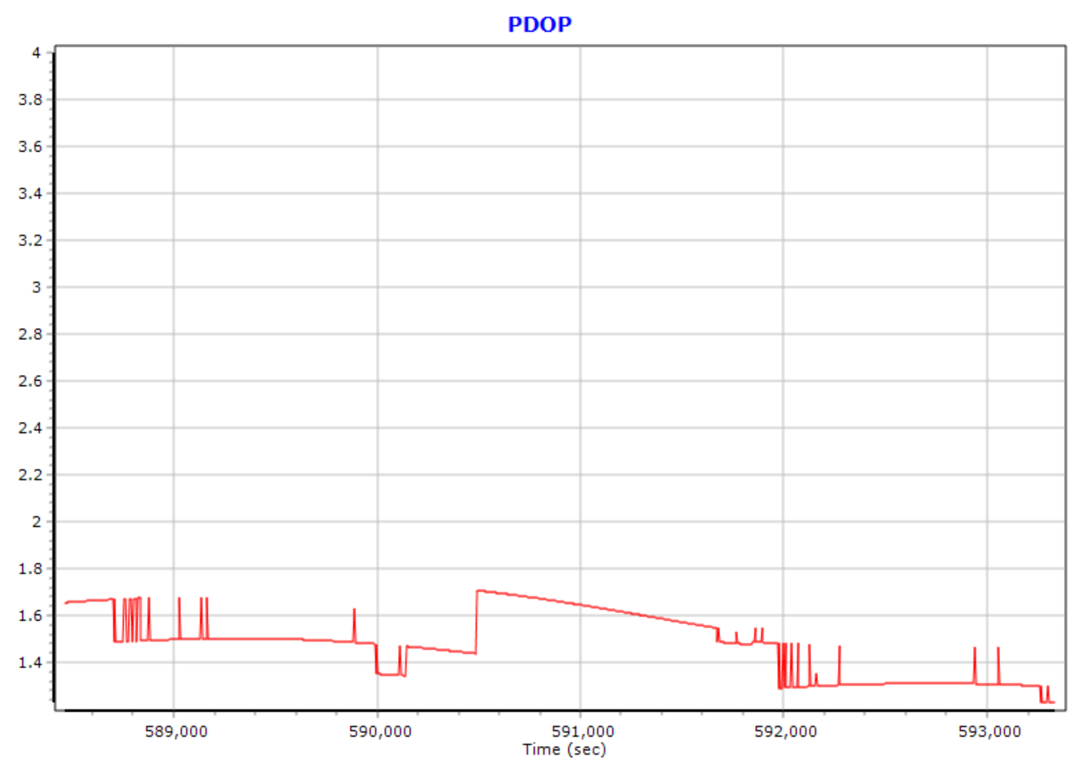
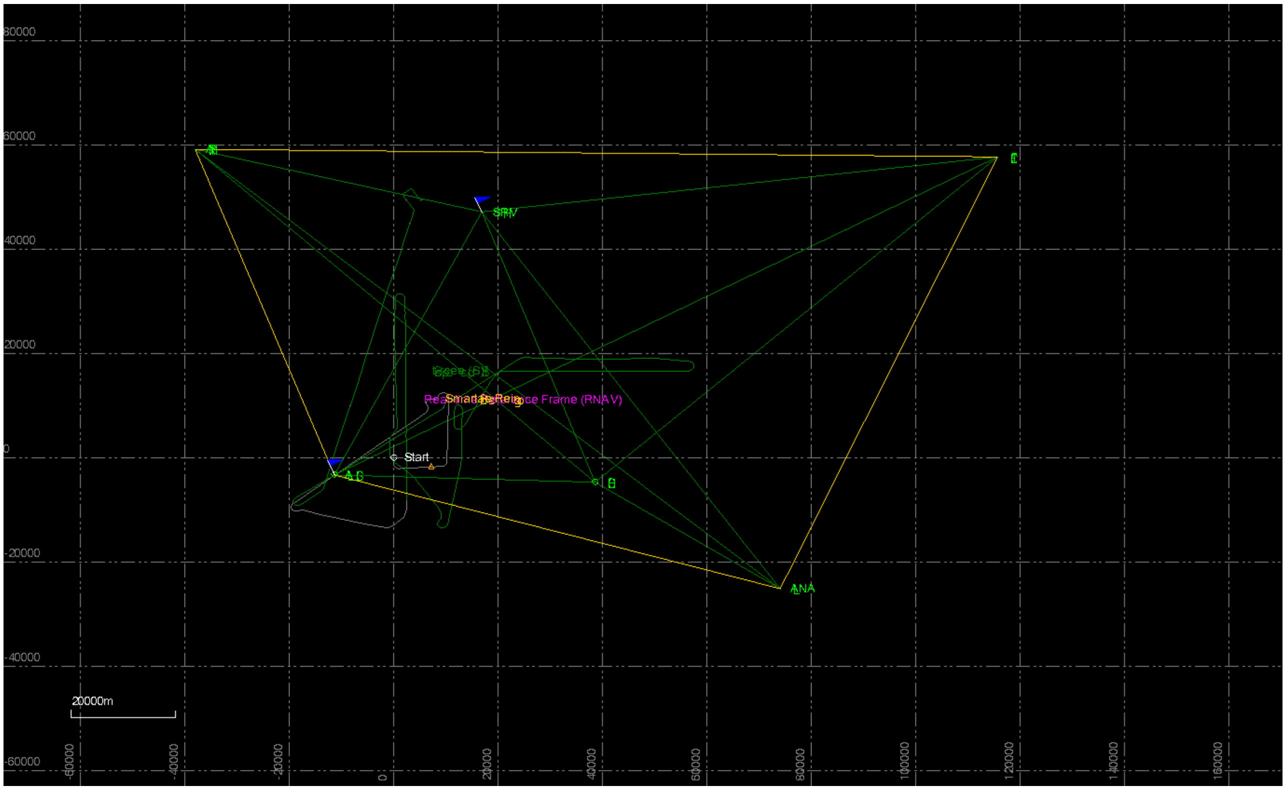
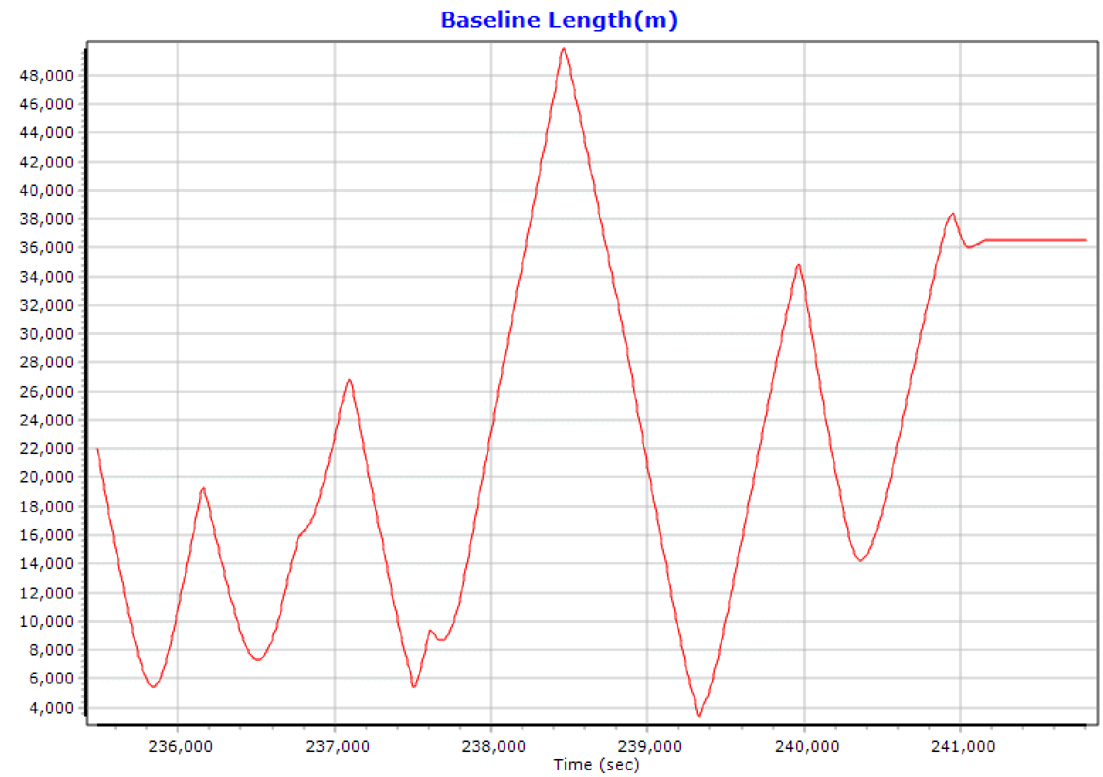
38,000
36,000
34,000
32,000
30,000
28,000
26,000
24,000
22,000
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
589,000
590,000
591,000
592,000
593,000
Time (sec)


PDOP
4
3.8
3.6
3.4
3.2
3
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
589,000
590,000
591,000
592,000
593,000
Time (sec)

2SU18310A




Baseline Length(m)
48,000
46,000
44,000
42,000
40,000
38,000
36,000
34,000
32,000
30,000
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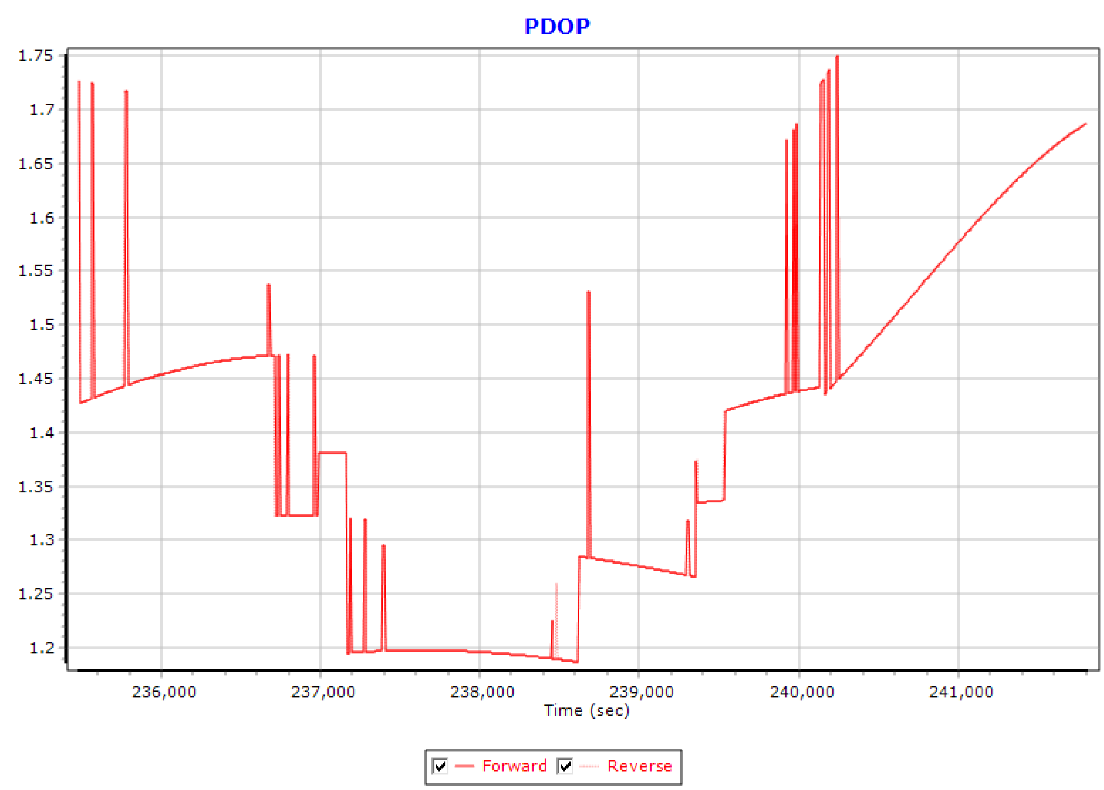
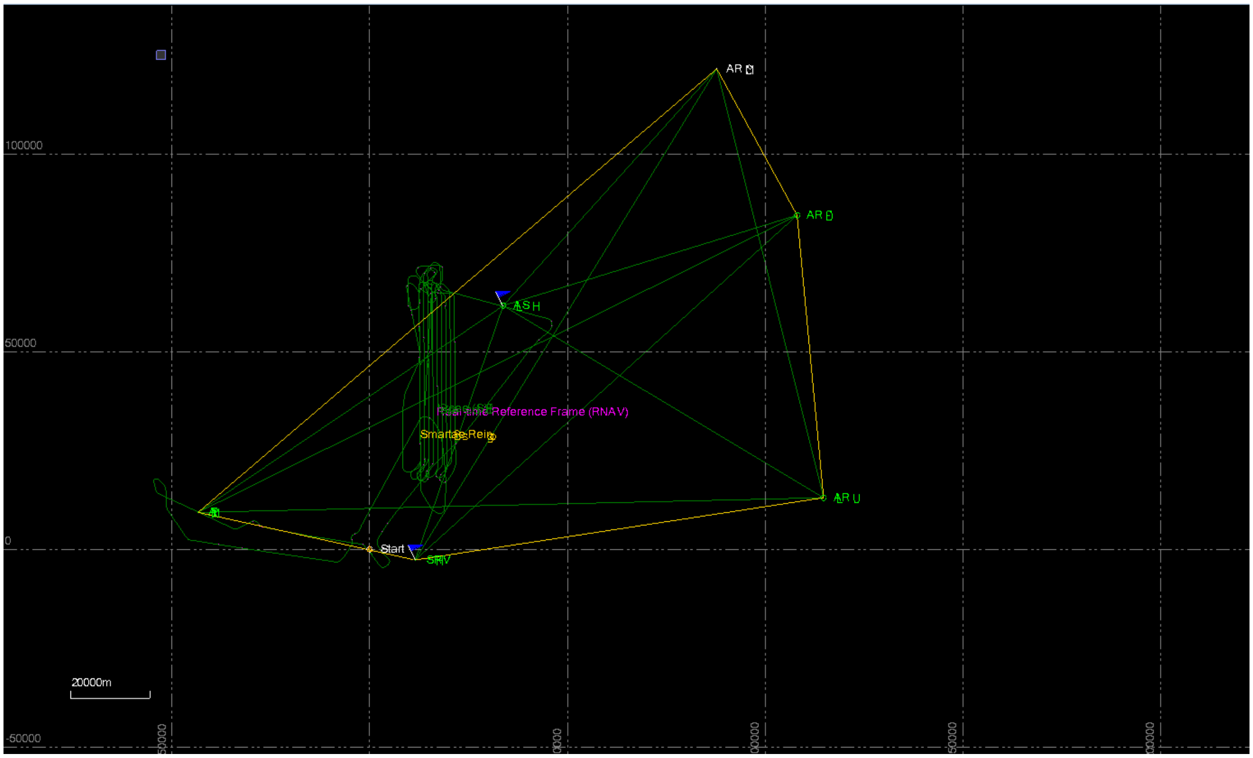
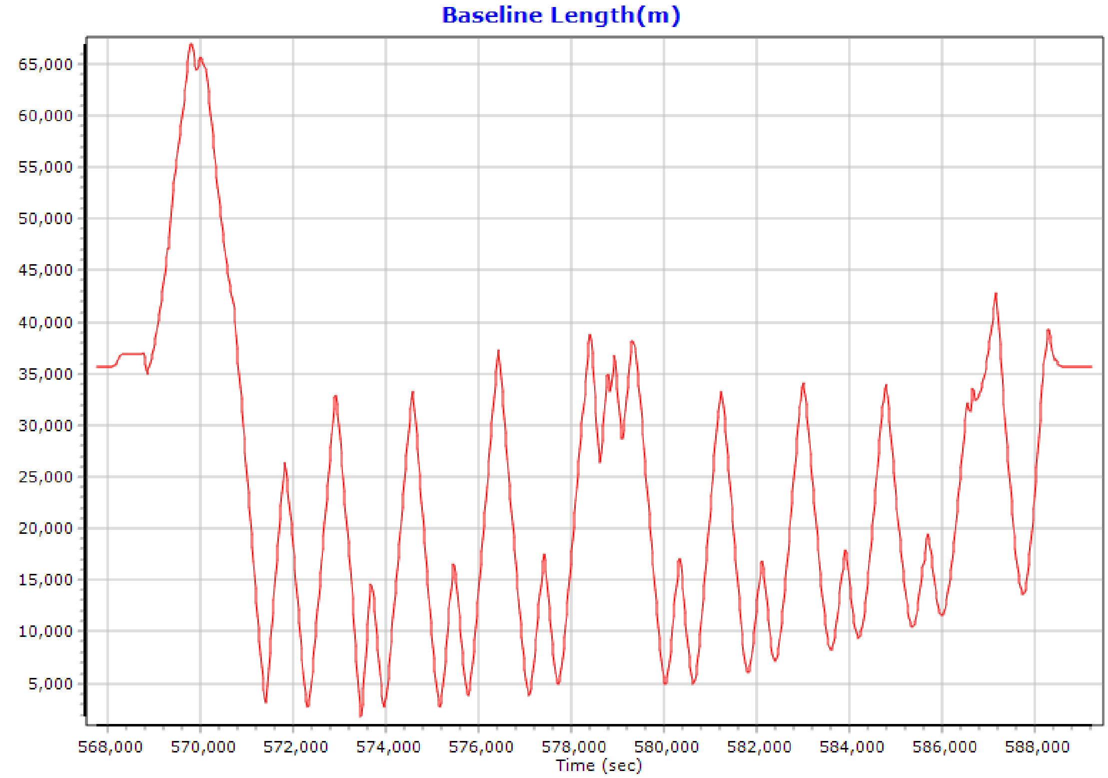
26,000
24,000
22,000
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
236,000
237,000
238,000
239,000
240,000
241,000
Time (sec)


PDOP
1.75
1.7
1.65
1.6
1.55
1.5
1.45
1.4
1.35
1.3
1.25
1.2
236,000
237,000
238,000
239,000
240,000
241,000
Time (sec)
Forward
Reverse

2SU18314A


100000
50000
0
-50000
20000m
AR
AR
ASH
AR U
Start
SRIV
Real-time Reference Frame (RNAV)
SmartBase


Baseline Length(m)
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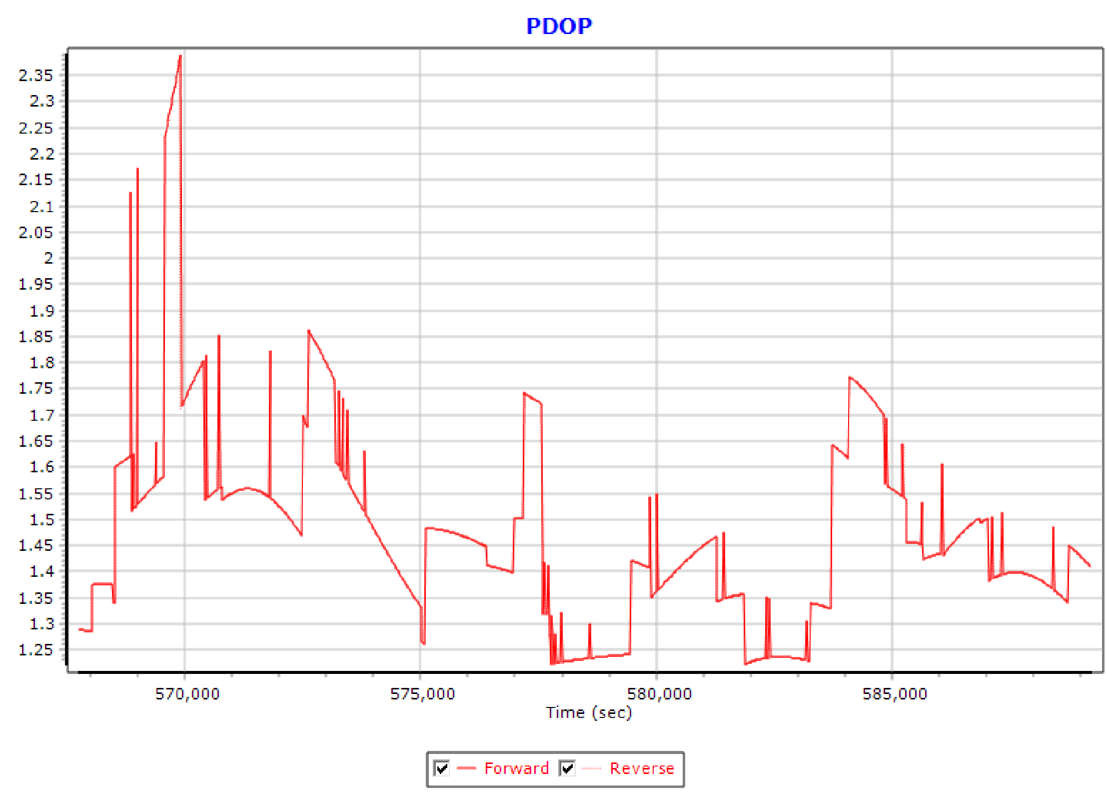
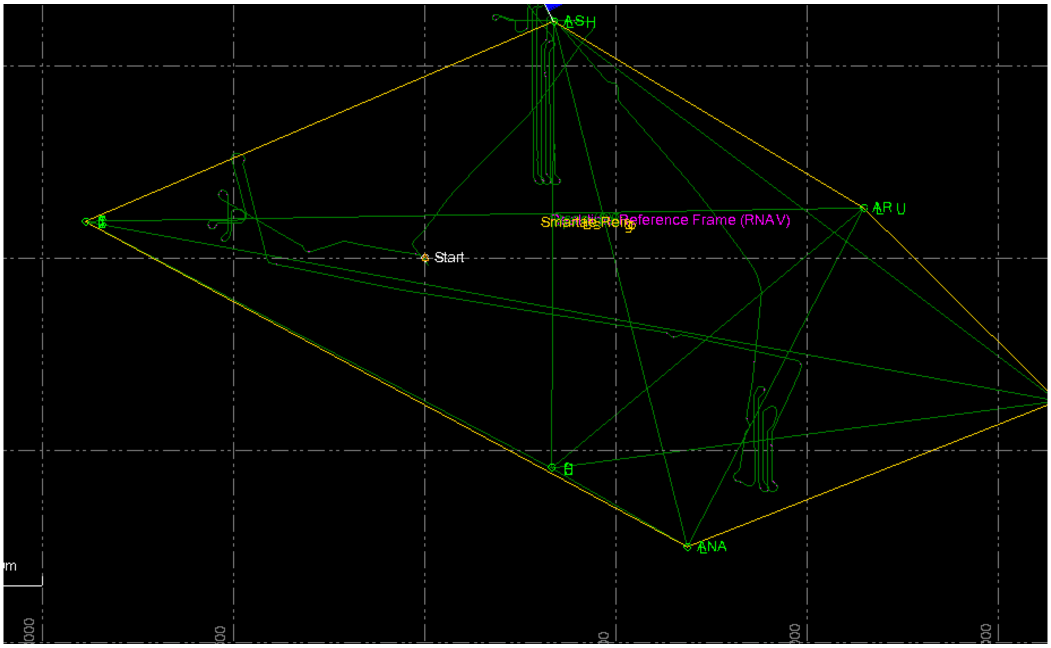
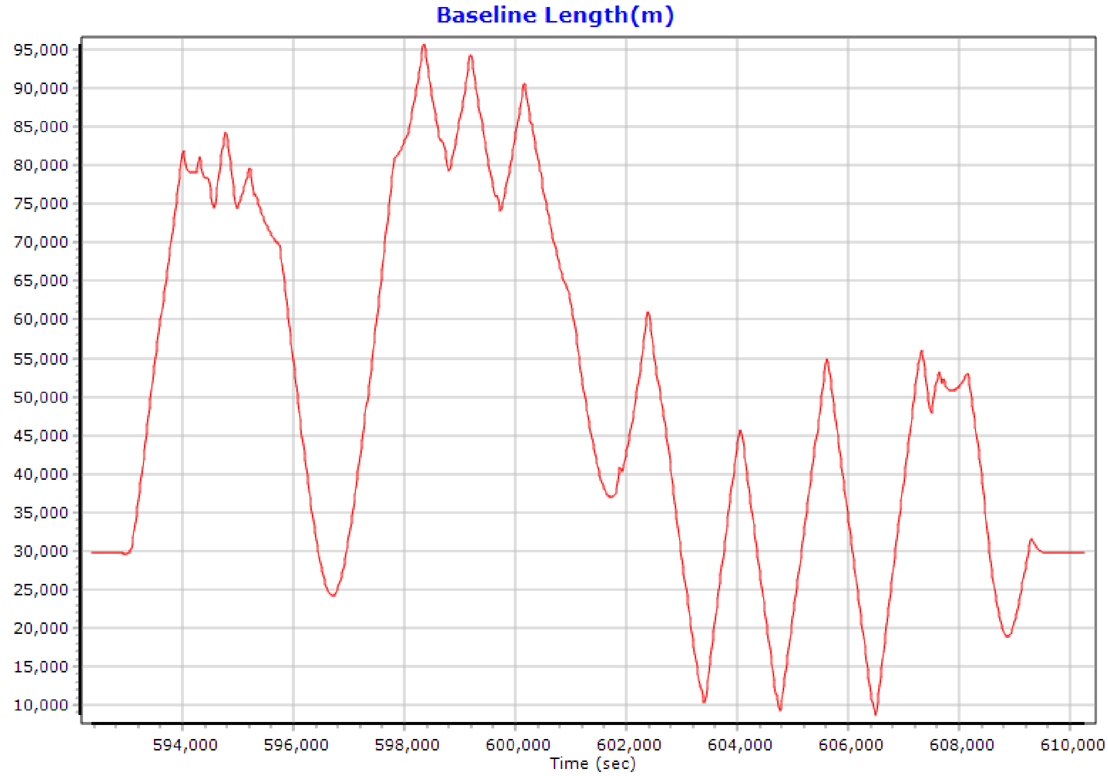
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
568,000
570,000
572,000
574,000
576,000
578,000
580,000
582,000
584,000
586,000
588,000
Time (sec)


PDOP
2.35
2.3
2.25
2.2
2.15
2.1
2.05
2
1.95
1.9
1.85
1.8
1.75
1.7
1.65
1.6
1.55
1.5
1.45
1.4
1.35
1.3
1.25
570,000
575,000
580,000
585,000
Time (sec)
Forward
Reverse

2SU18314B




Baseline Length(m)
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25,000
20,000
15,000
10,000
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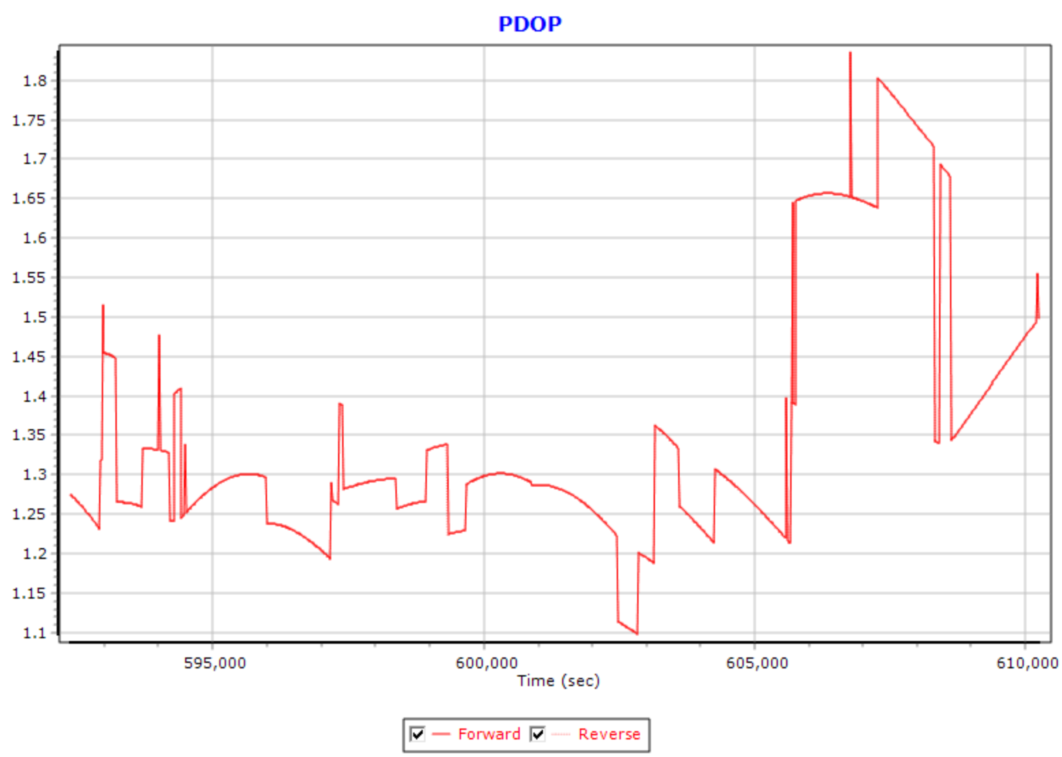
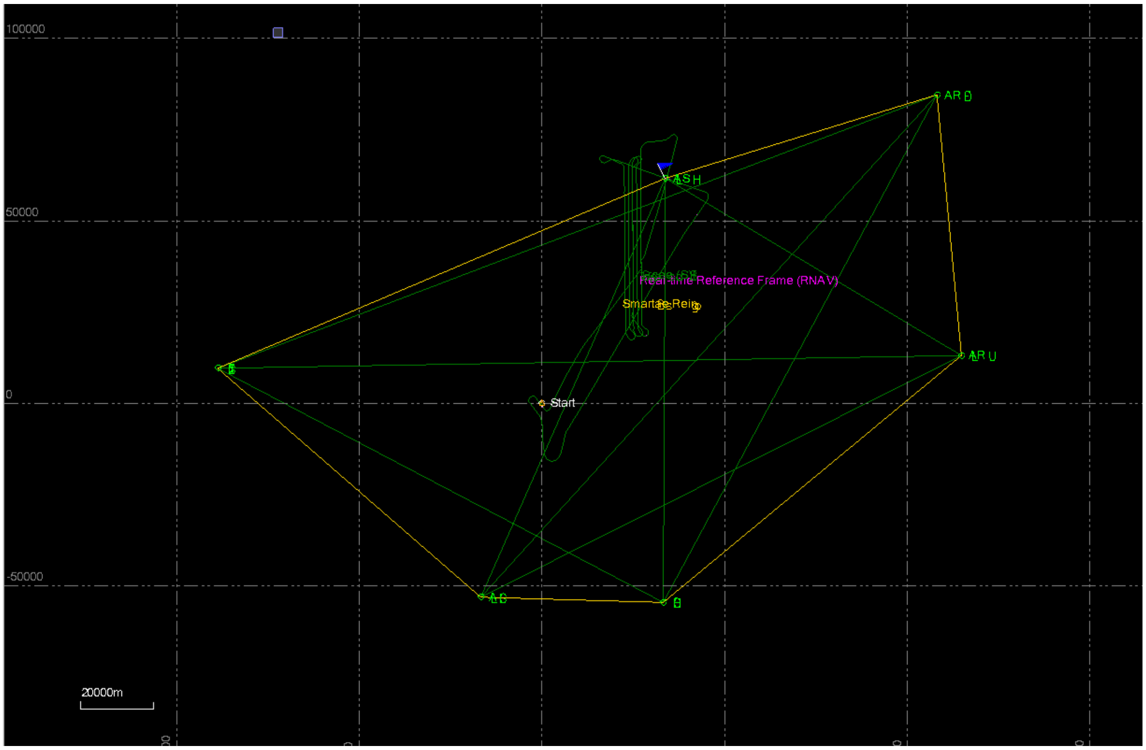
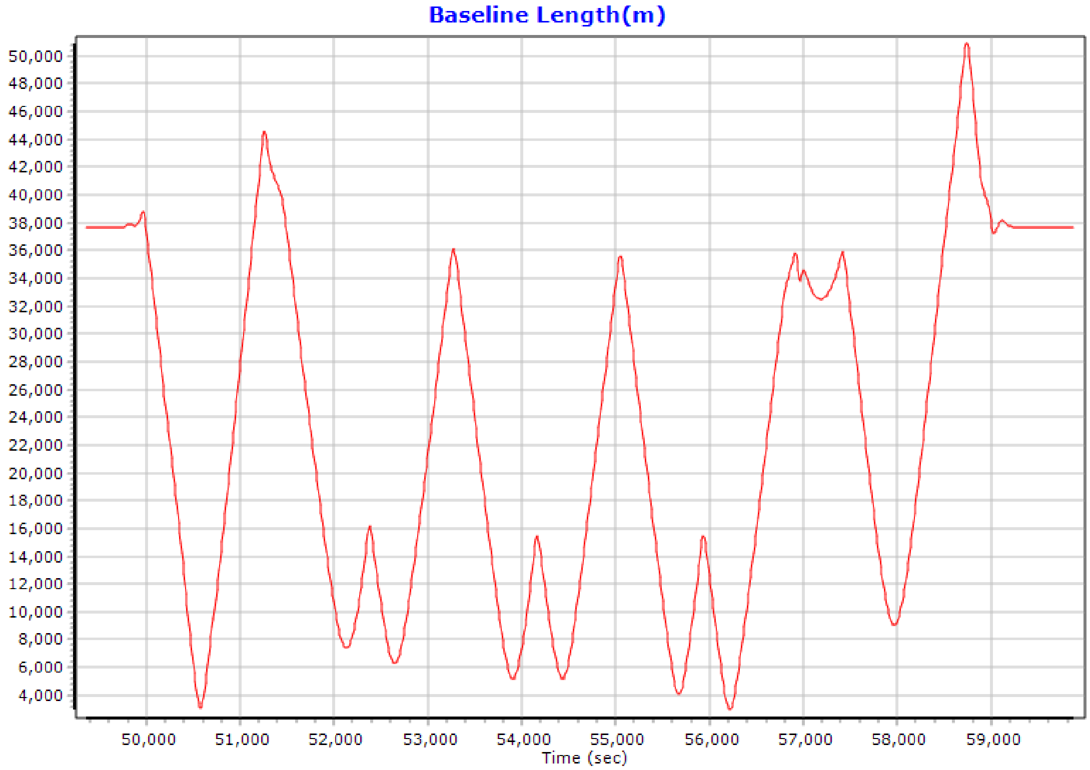
598,000
600,000
602,000
604,000
606,000
608,000
610,000
Time (sec)


PDOP
1.8
1.75
1.7
1.65
1.6
1.55
1.5
1.45
1.4
1.35
1.3
1.25
1.2
1.15
1.1
595,000
600,000
605,000
610,000
Time (sec)
Forward
Reverse

2SU18315A


100000
50000
0
-50000
AR
ASH
AR U
Start
Real-time Reference Frame (RNAV)
20000m


Baseline Length(m)
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48,000
46,000
44,000
42,000
40,000
38,000
36,000
34,000
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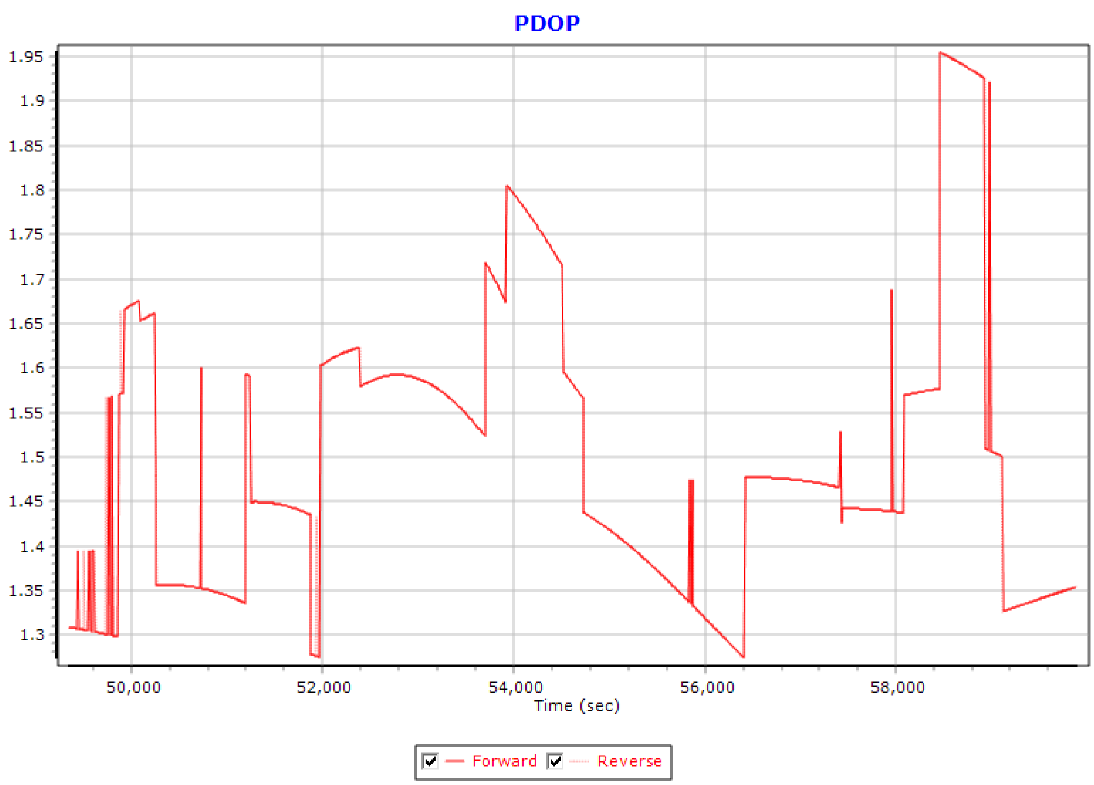
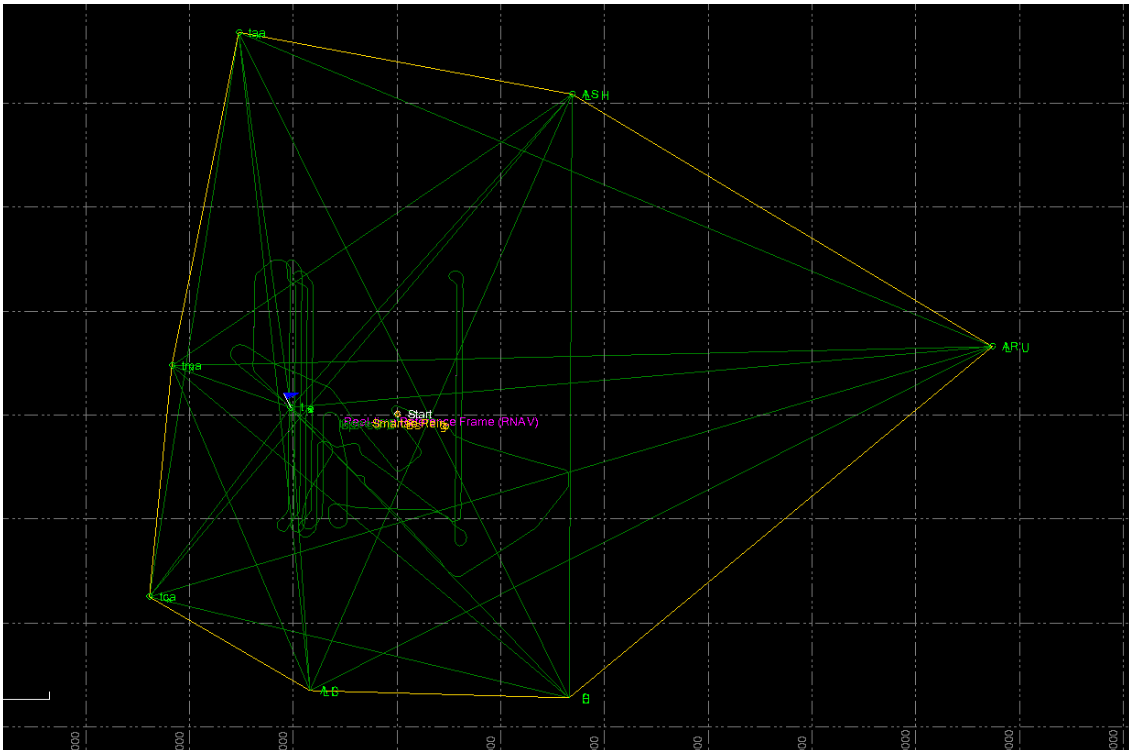
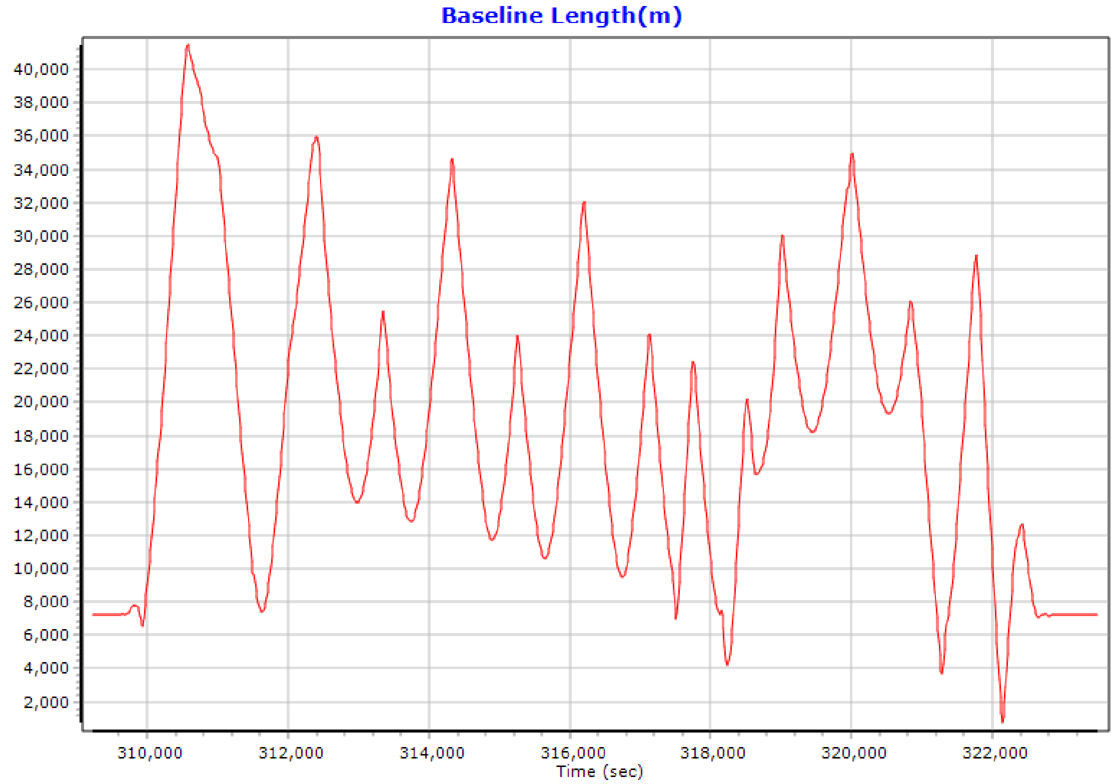
58,000
59,000
Time (sec)


PDOP
1.95
1.9
1.85
1.8
1.75
1.7
1.65
1.6
1.55
1.5
1.45
1.4
1.35
1.3
50,000
52,000
54,000
56,000
58,000
Time (sec)
Forward
Reverse

2SU18318A




Baseline Length(m)
40,000
38,000
36,000
34,000
32,000
30,000
28,000
26,000
24,000
22,000
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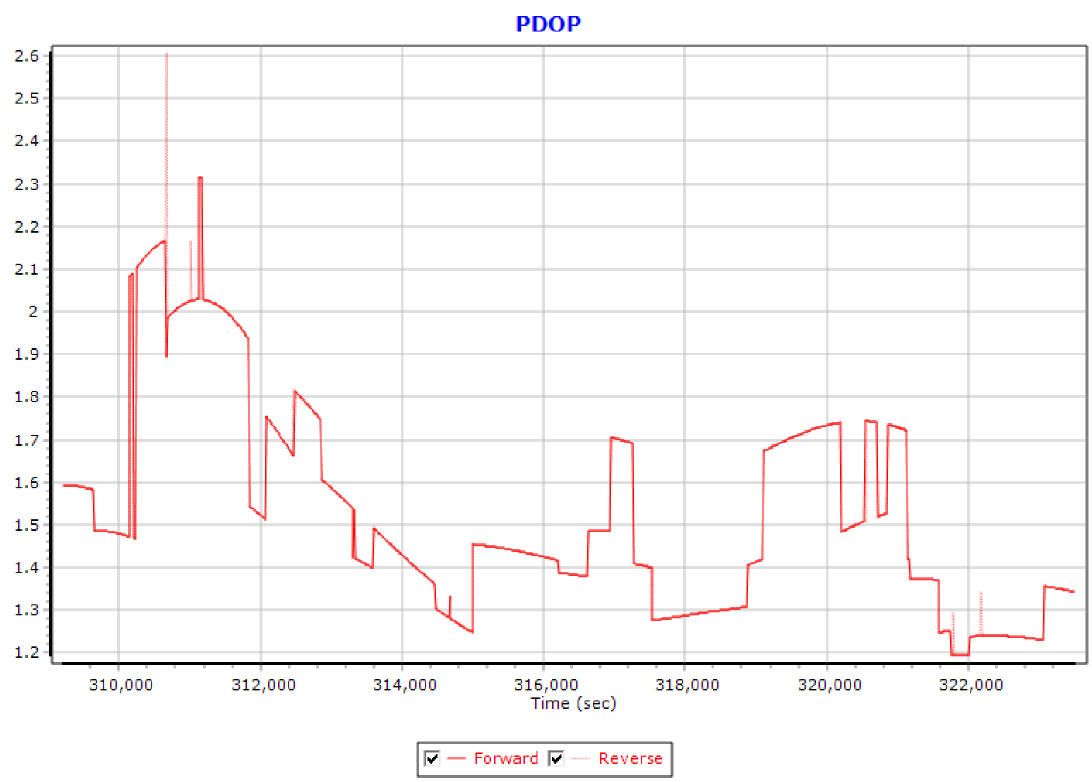
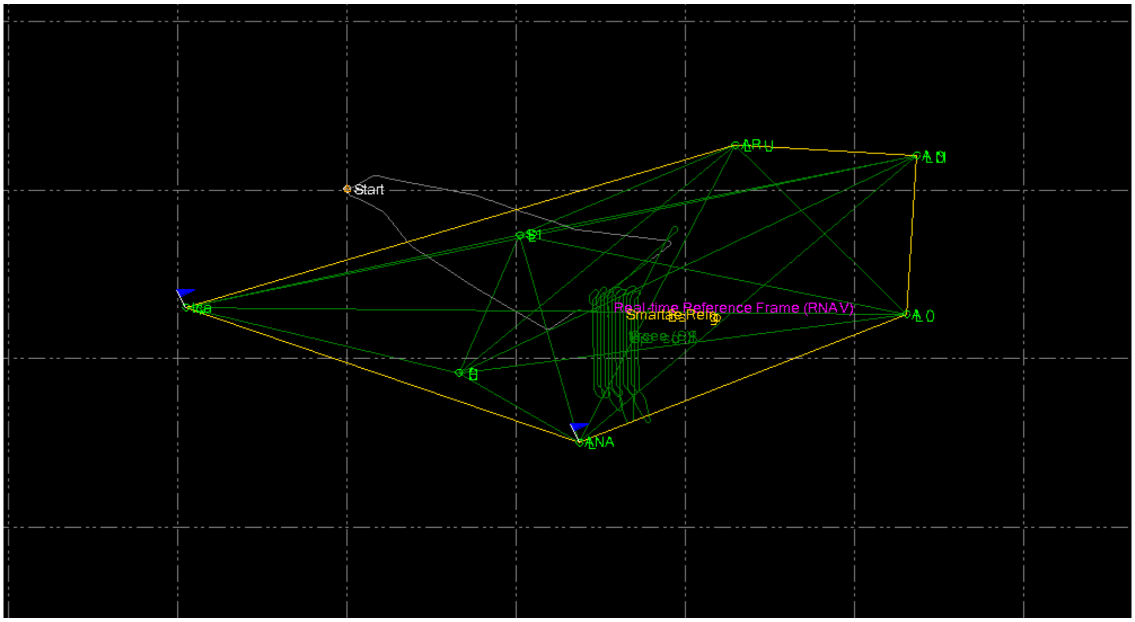
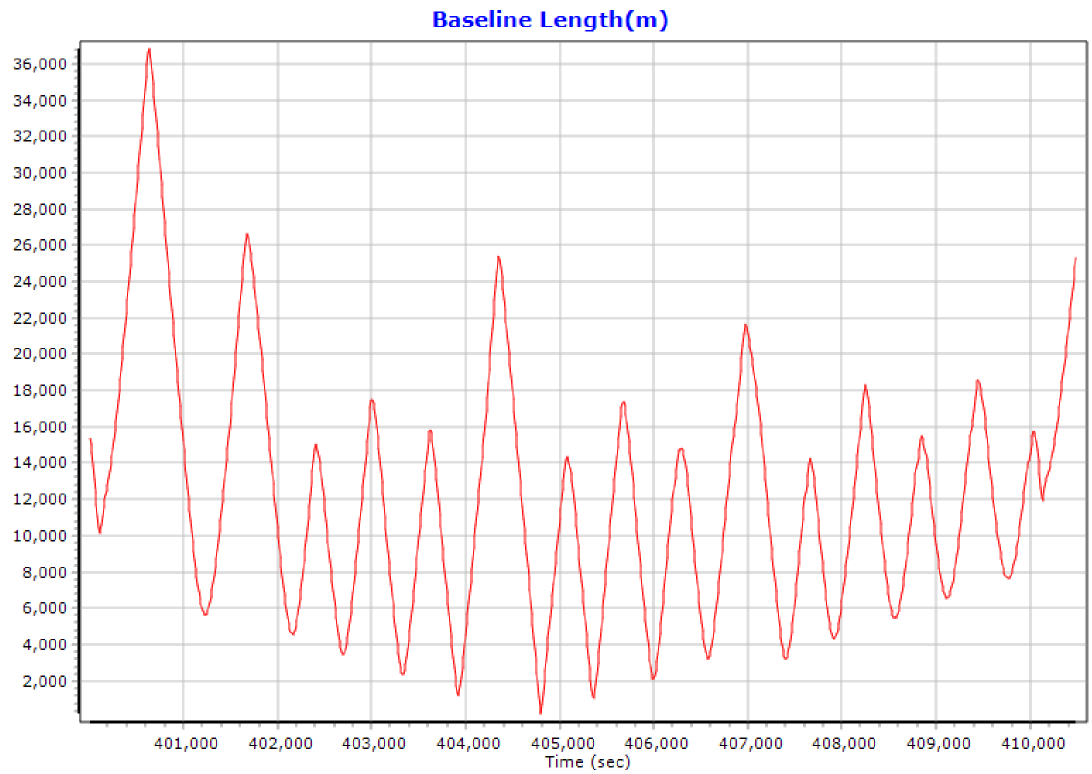
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
310,000
312,000
314,000
316,000
318,000
320,000
322,000
Time (sec)


PDOP
2.6
2.5
2.4
2.3
2.2
2.1
2
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
310,000
312,000
314,000
316,000
318,000
320,000
322,000
Time (sec)
Forward
Reverse

2SU18319A




Baseline Length(m)
36,000
34,000
32,000
30,000
28,000
26,000
24,000
22,000
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6,000
4,000
2,000
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403,000
404,000
405,000
406,000
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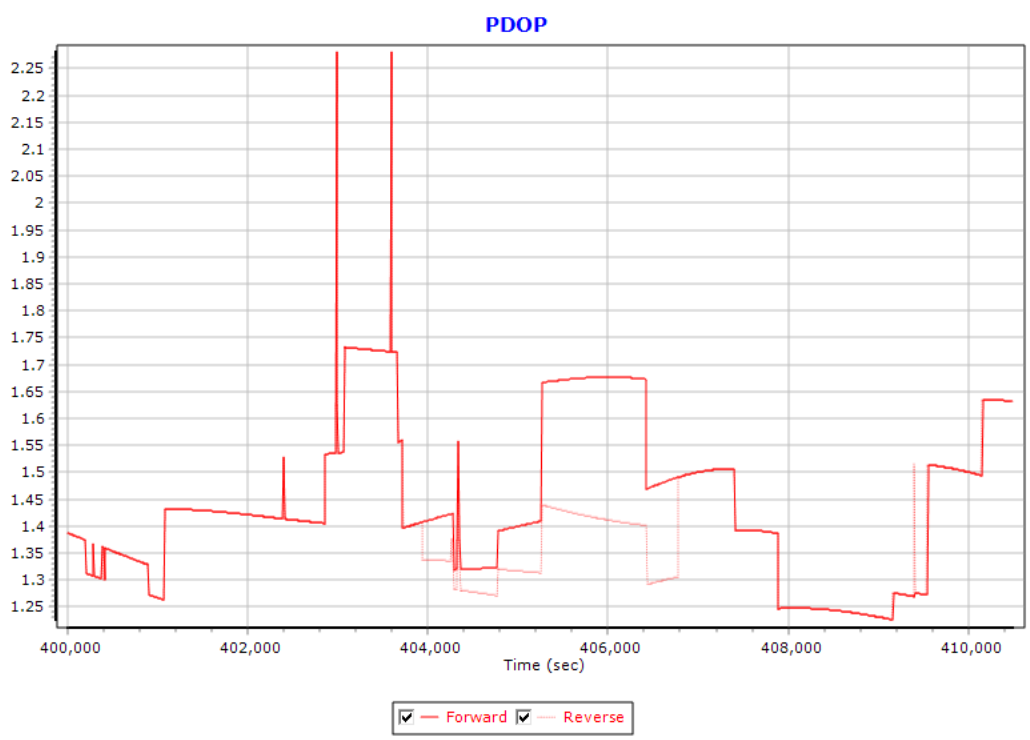
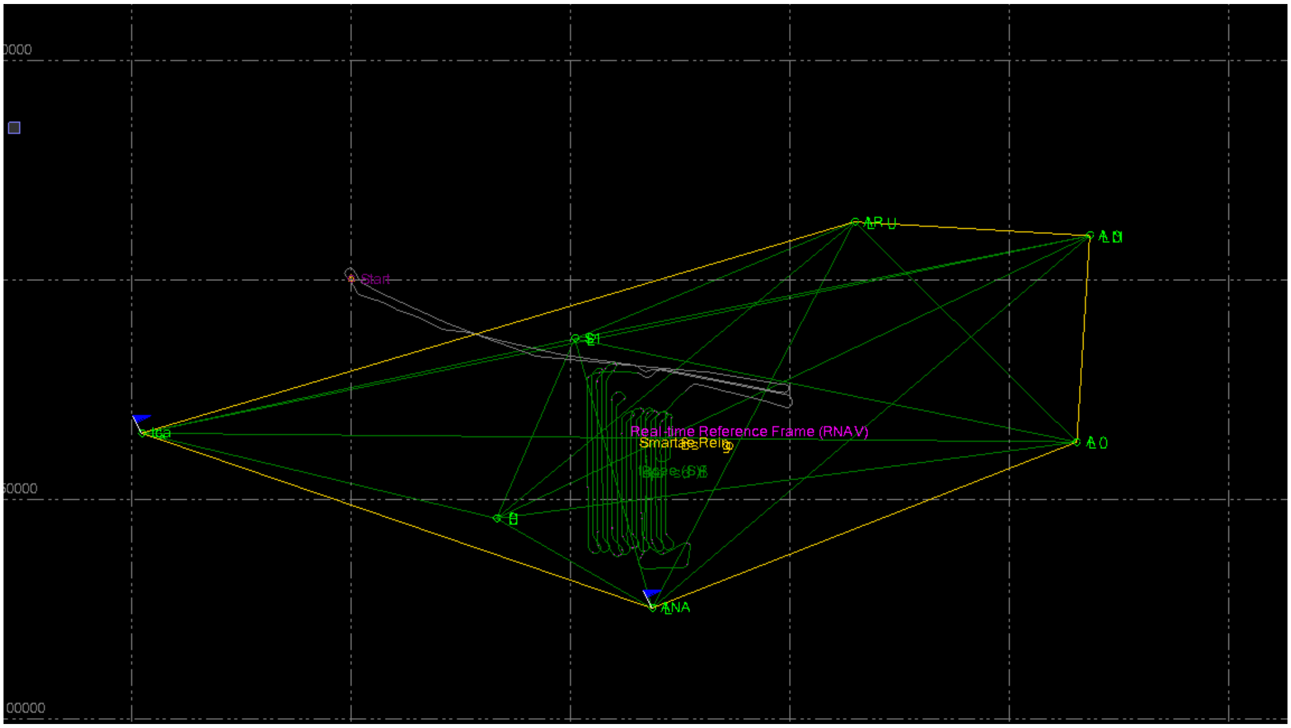
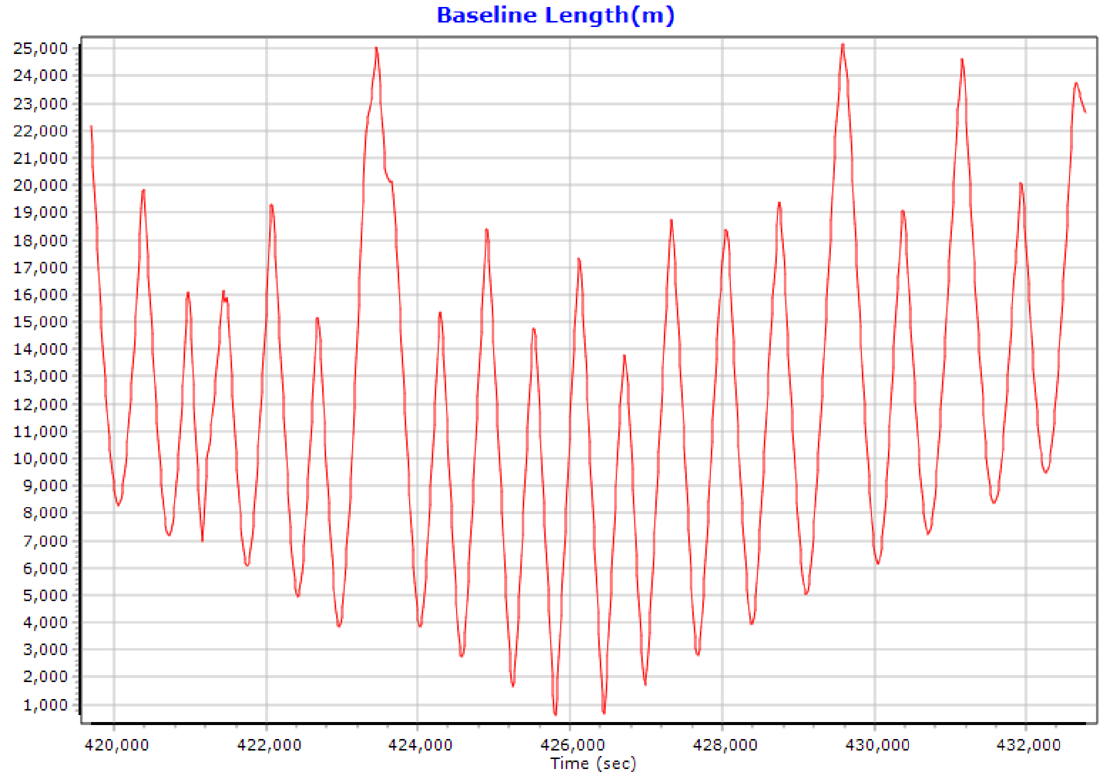
408,000
409,000
410,000
Time (sec)


PDOP
2.25
2.2
2.15
2.1
2.05
2
1.95
1.9
1.85
1.8
1.75
1.7
1.65
1.6
1.55
1.5
1.45
1.4
1.35
1.3
1.25
400,000
402,000
404,000
406,000
408,000
410,000
Time (sec)
Forward
Reverse

2SU18319B


Real-time Reference Frame (RNAV)


Baseline Length(m)
25,000
24,000
23,000
22,000
21,000
20,000
19,000
18,000
17,000
16,000
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14,000
13,000
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10,000
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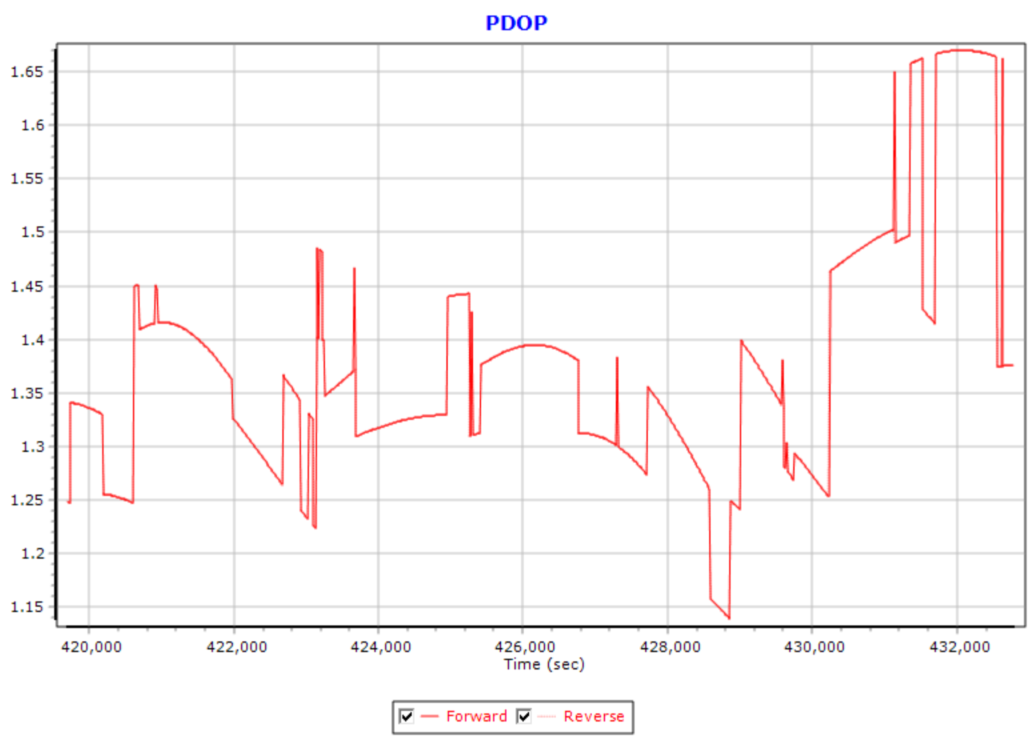
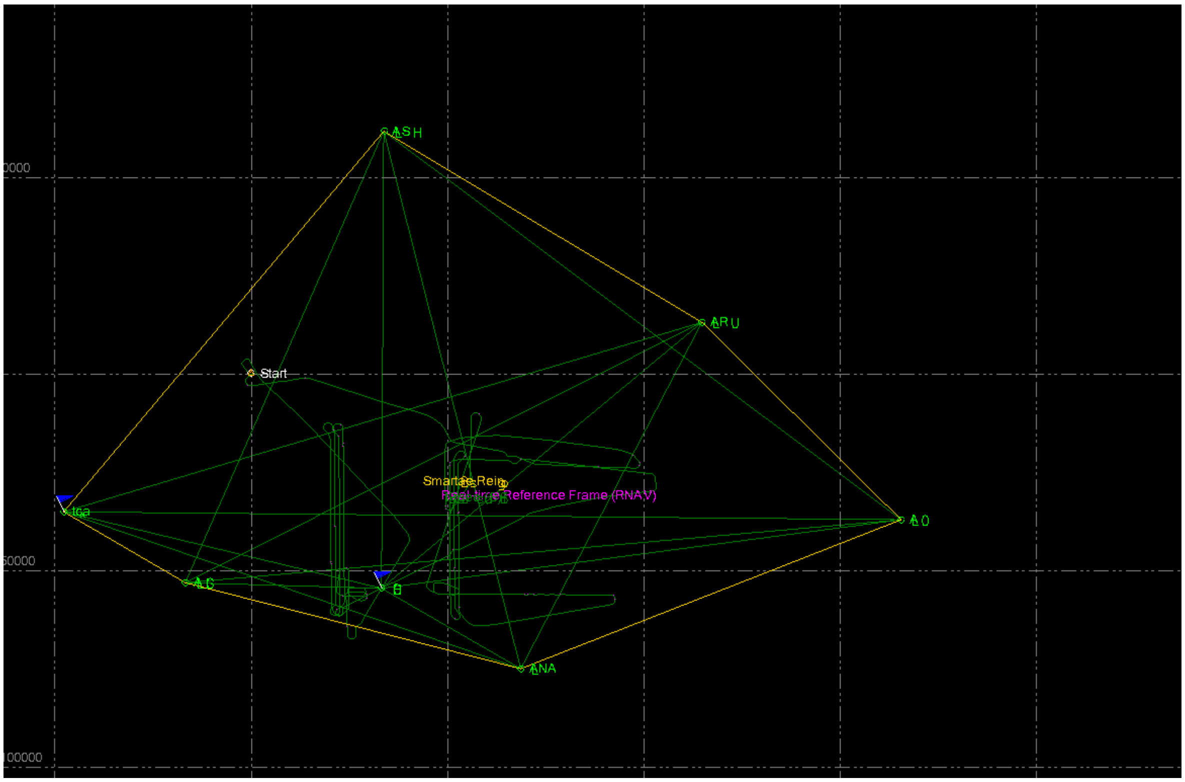
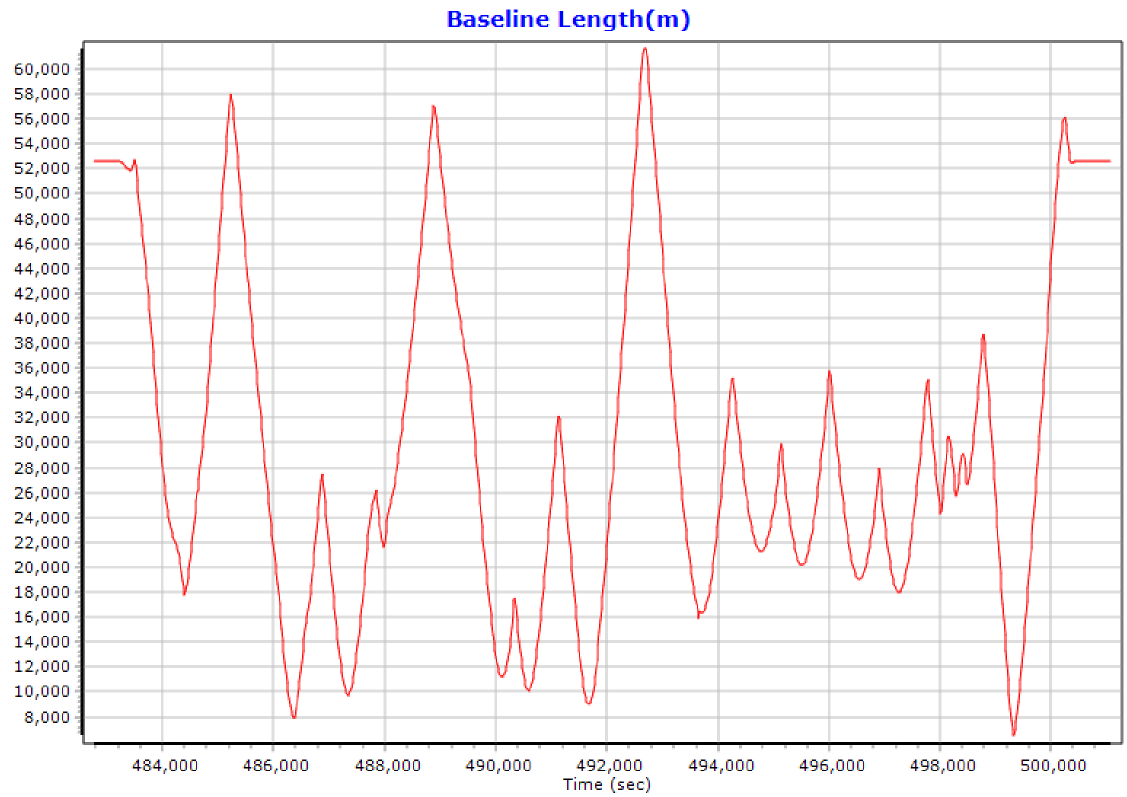
6,000
5,000
4,000
3,000
2,000
1,000
420,000
422,000
424,000
426,000
428,000
430,000
432,000
Time (sec)


PDOP
1.65
1.6
1.55
1.5
1.45
1.4
1.35
1.3
1.25
1.2
1.15
420,000
422,000
424,000
426,000
428,000
430,000
432,000
Time (sec)
Forward
Reverse

2SU18320A


ASH
ARU
Start
Smart Se Rein
Real-time Reference Frame (RNAV)
tca
AO
AC
B
ANA


Baseline Length(m)
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58,000
56,000
54,000
52,000
50,000
48,000
46,000
44,000
42,000
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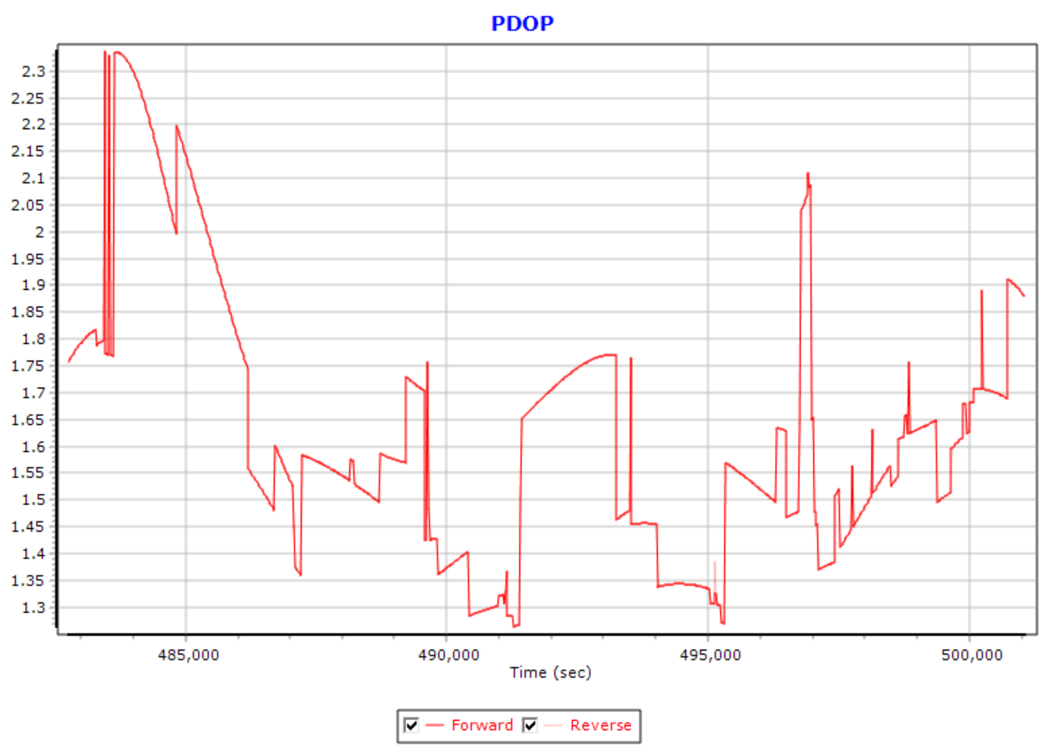
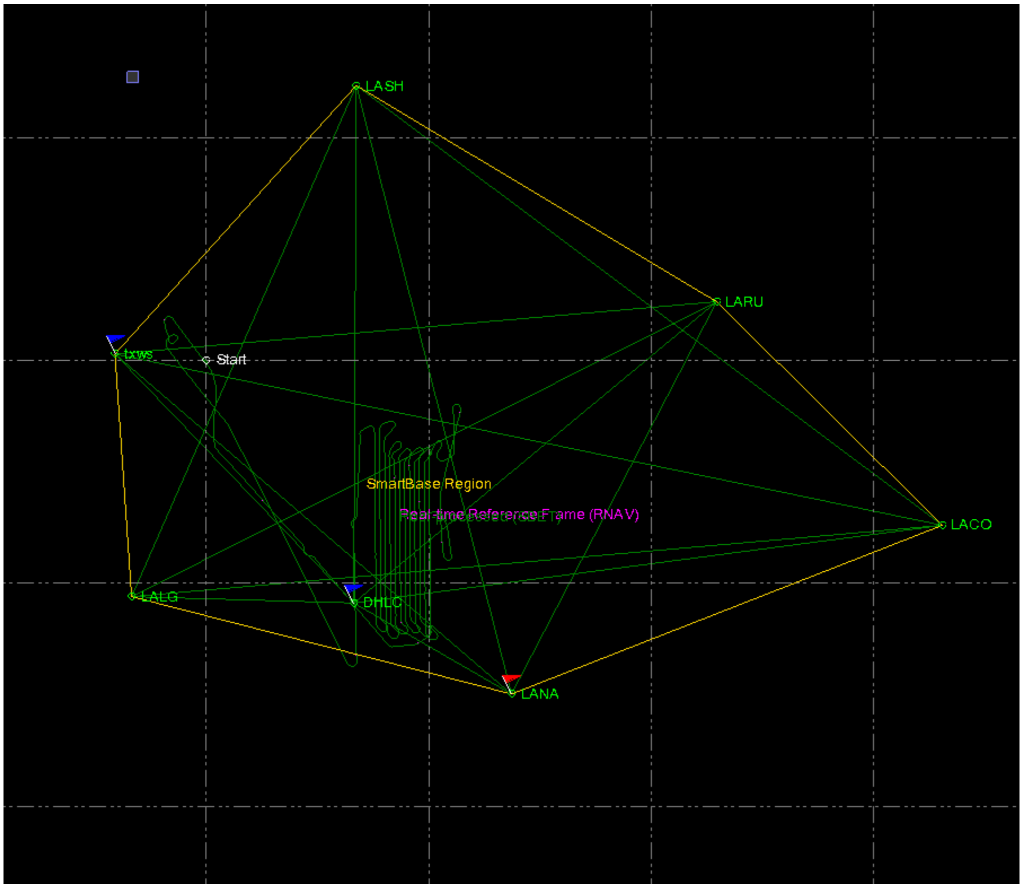
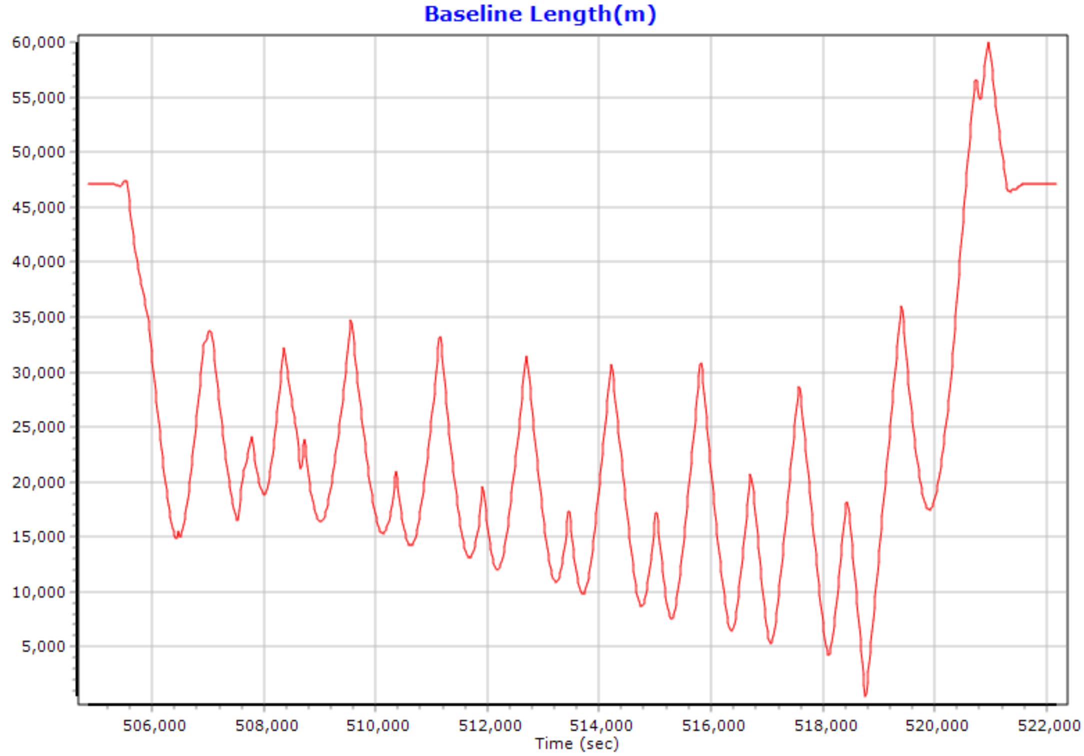
36,000
34,000
32,000
30,000
28,000
26,000
24,000
22,000
20,000
18,000
16,000
14,000
12,000
10,000
8,000
484,000
486,000
488,000
490,000
492,000
494,000
496,000
498,000
500,000
Time (sec)


PDOP
2.3
2.25
2.2
2.15
2.1
2.05
2
1.95
1.9
1.85
1.8
1.75
1.7
1.65
1.6
1.55
1.5
1.45
1.4
1.35
1.3
485,000
490,000
495,000
500,000
Time (sec)
Forward
Reverse


LASH
LARU
txws
Start
SmartBase Region
Real-time Reference Frame (RNAV)
LACO
LALG
DHLC
LANA


Baseline Length(m)
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15,000
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5,000
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508,000
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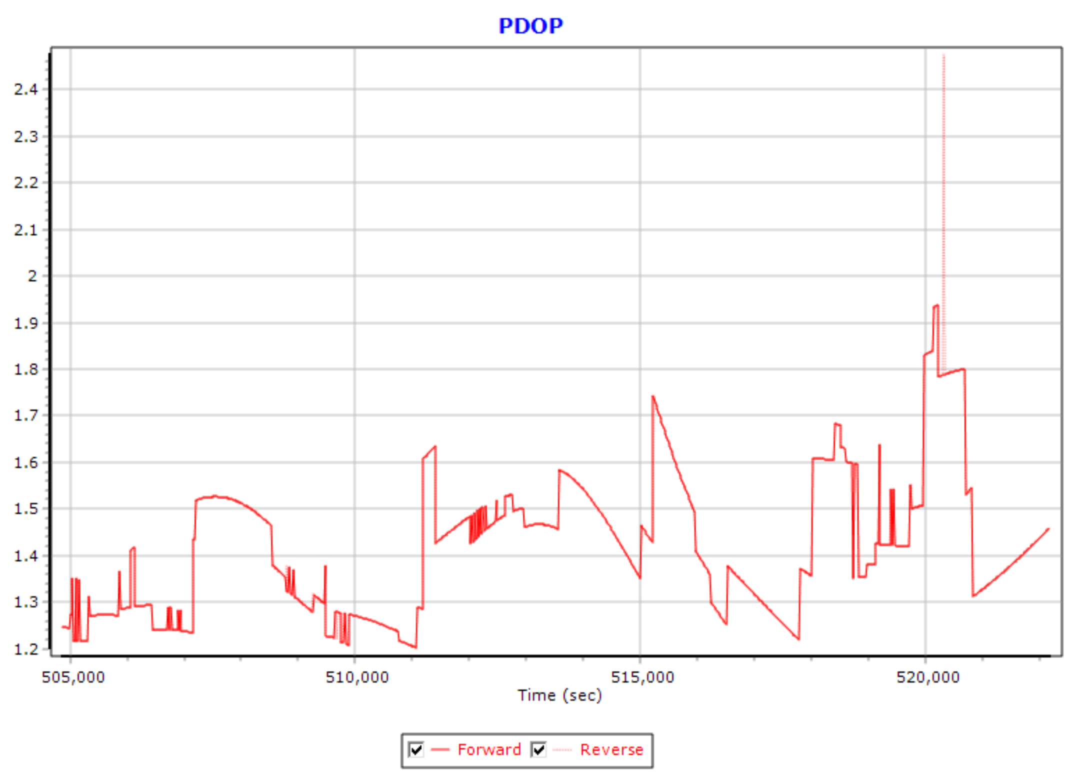
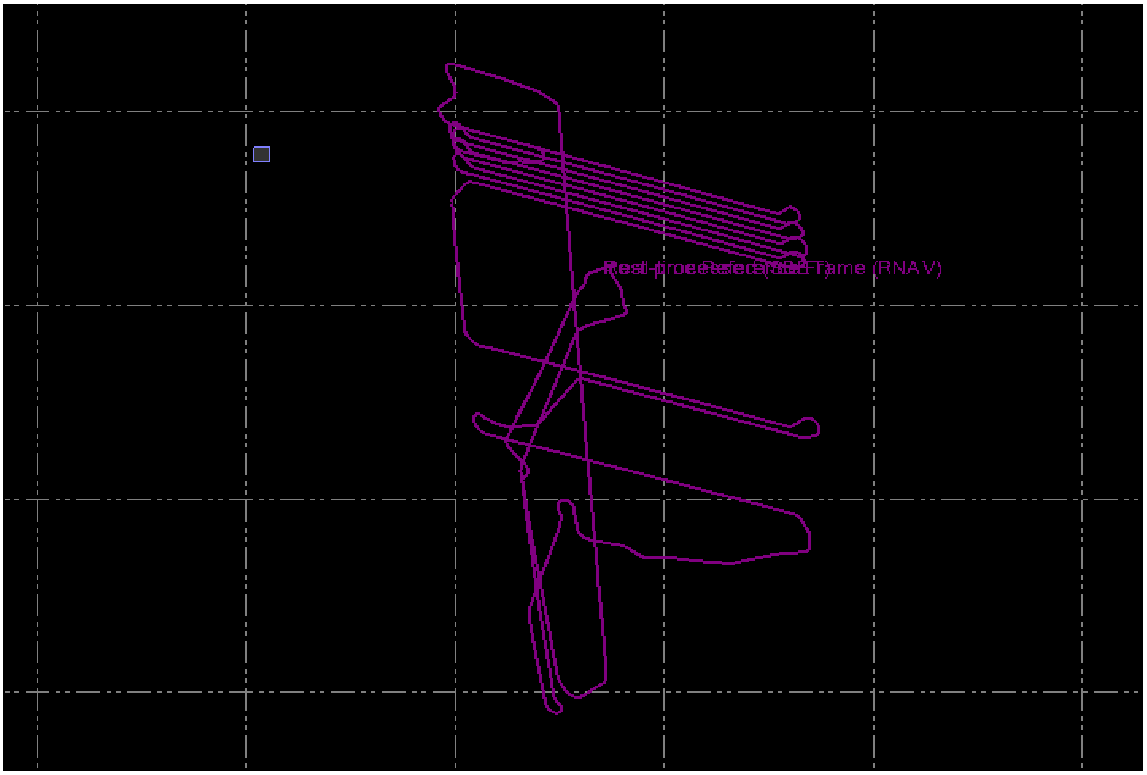
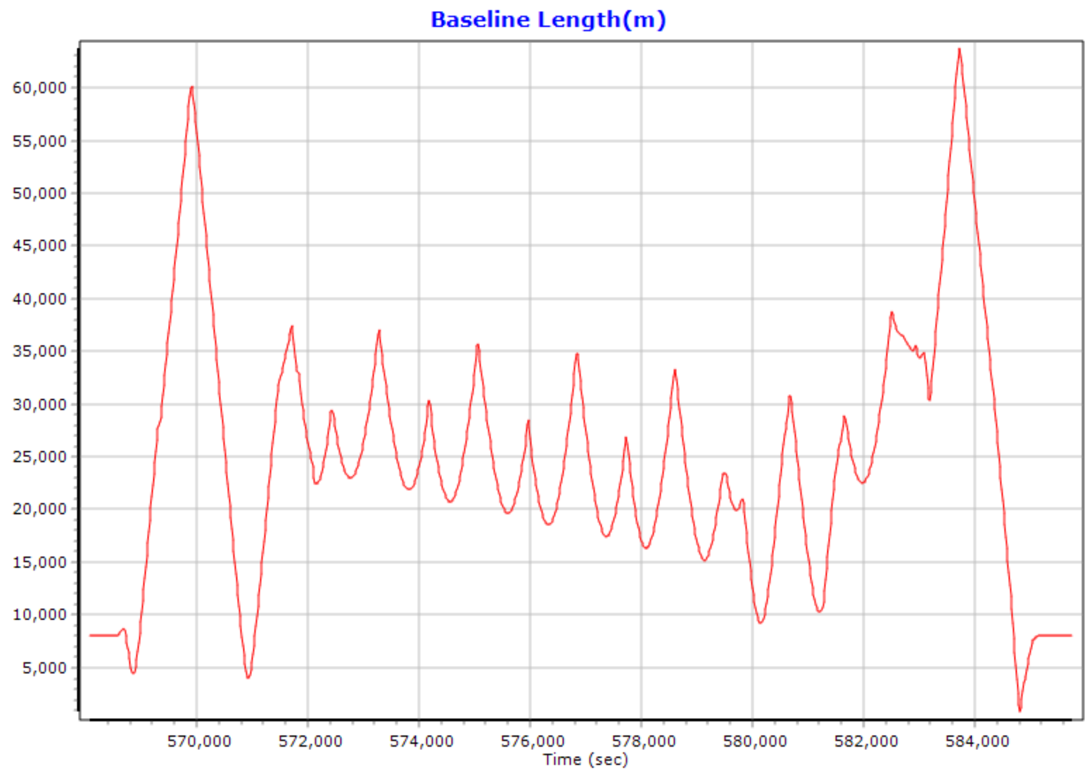
512,000
514,000
516,000
518,000
520,000
522,000
Time (sec)


PDOP
2.4
2.3
2.2
2.1
2
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
505,000
510,000
515,000
520,000
Time (sec)
Forward
Reverse

2SU18321A




Baseline Length(m)
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30,000
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20,000
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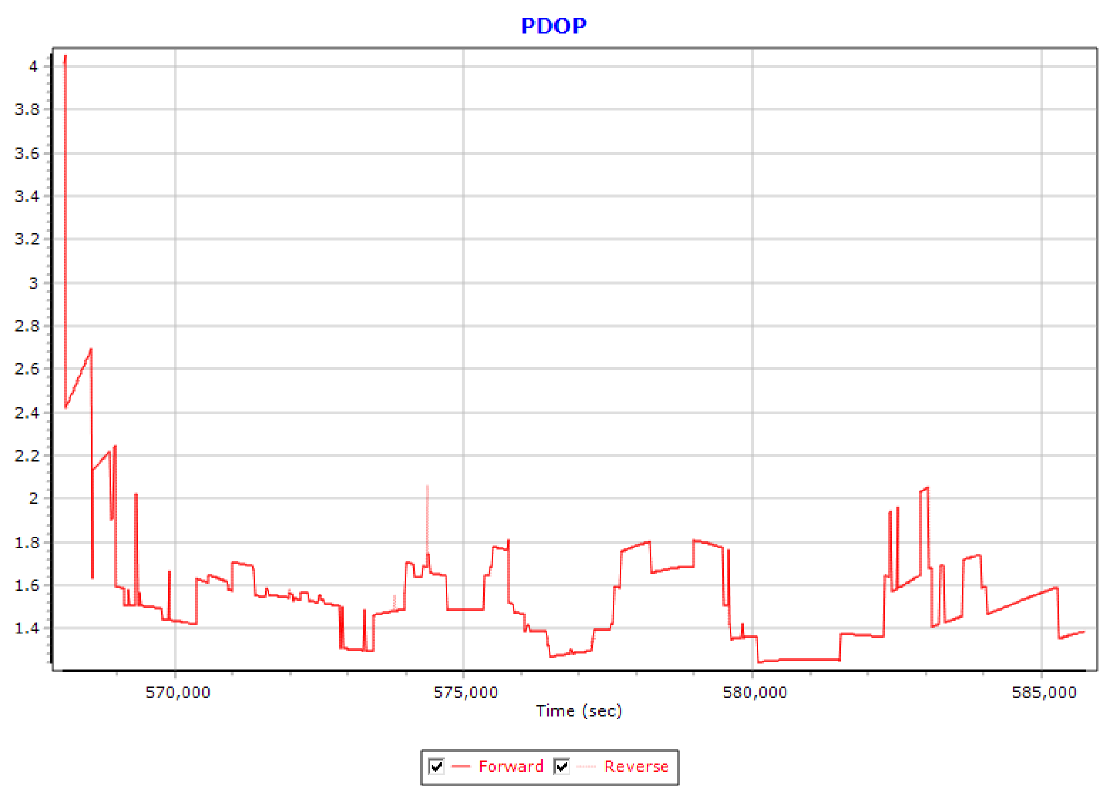
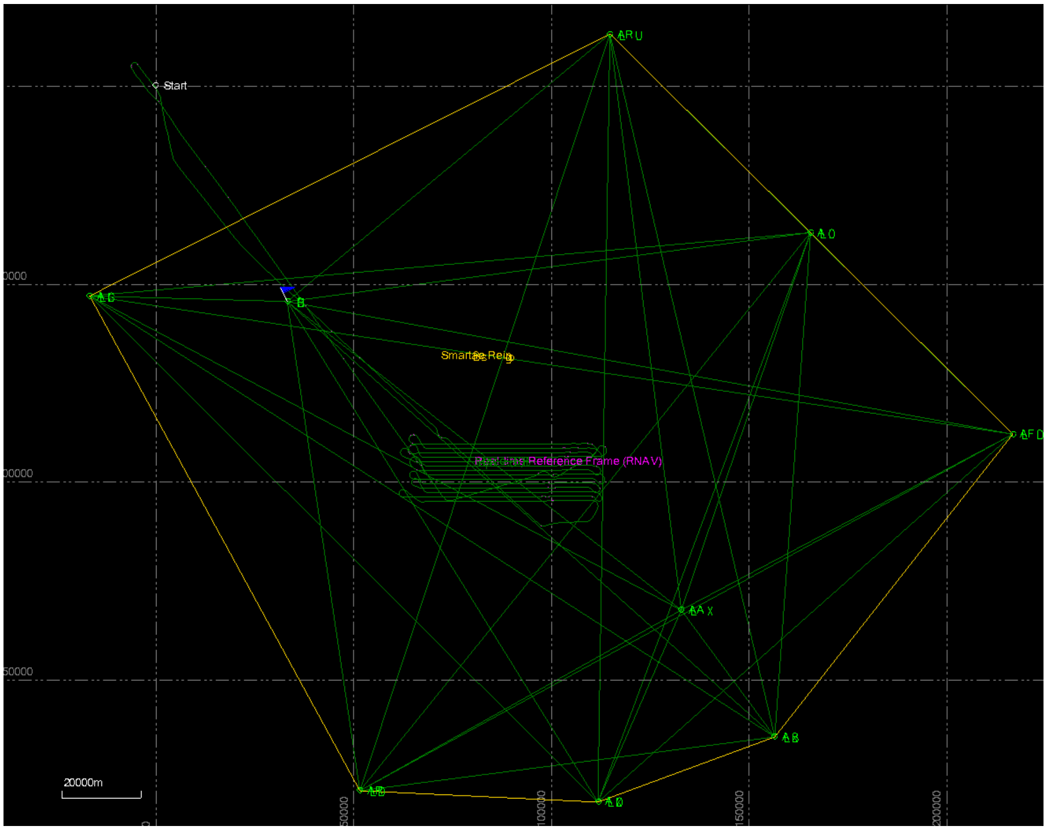
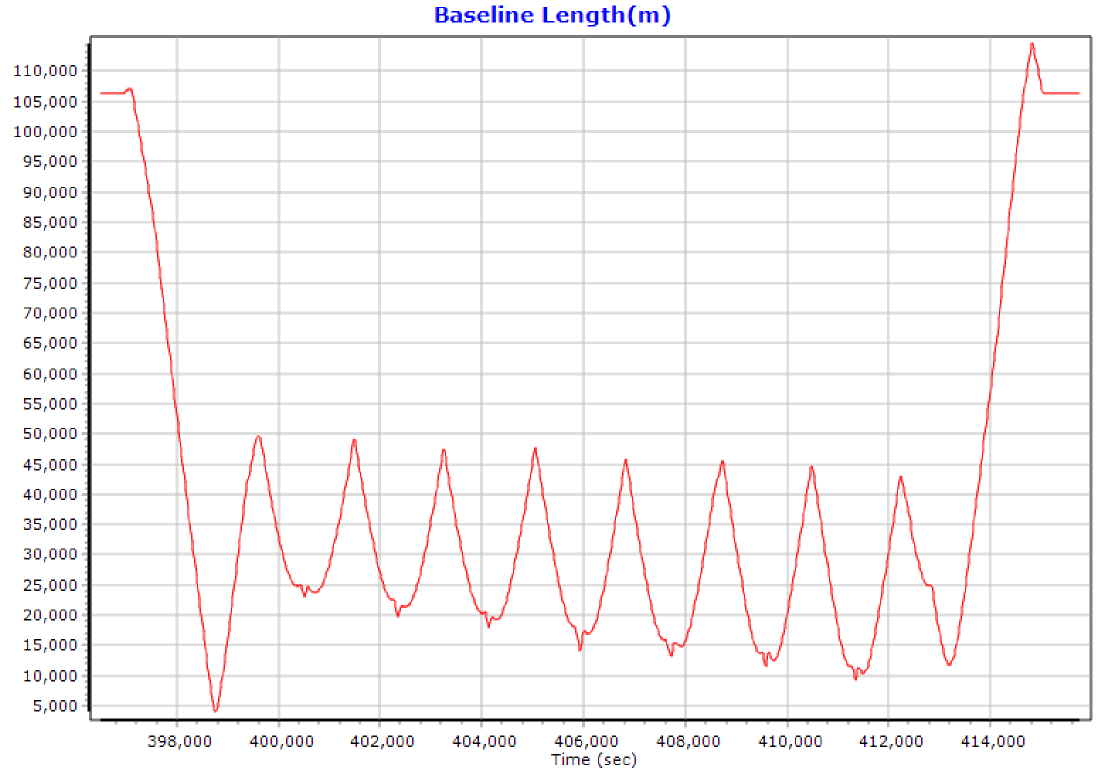
570,000
572,000
574,000
576,000
578,000
580,000
582,000
584,000
Time (sec)


PDOP
4
3.8
3.6
3.4
3.2
3
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
570,000
575,000
580,000
585,000
Time (sec)
Forward
Reverse

2SU18326A


Start
SmartBase Ref
Processing Reference Frame (RNAV)
20000m
50000
100000
150000
200000


Baseline Length(m)
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105,000
100,000
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85,000
80,000
75,000
70,000
65,000
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20,000
15,000
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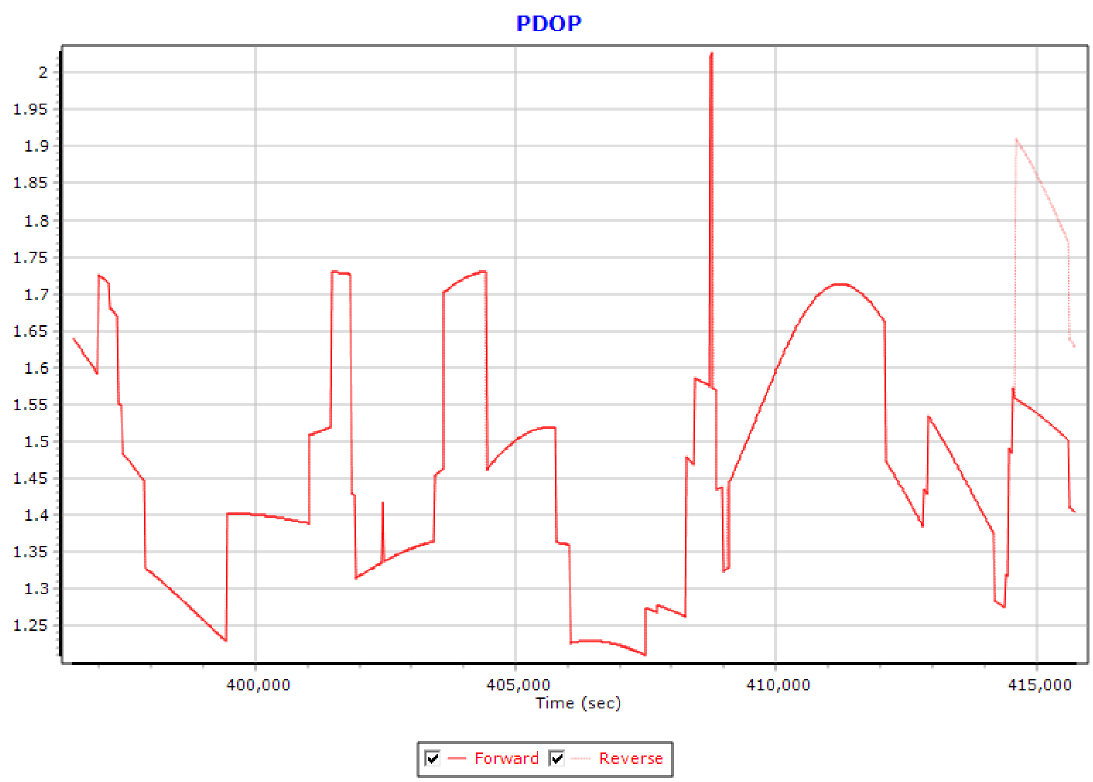
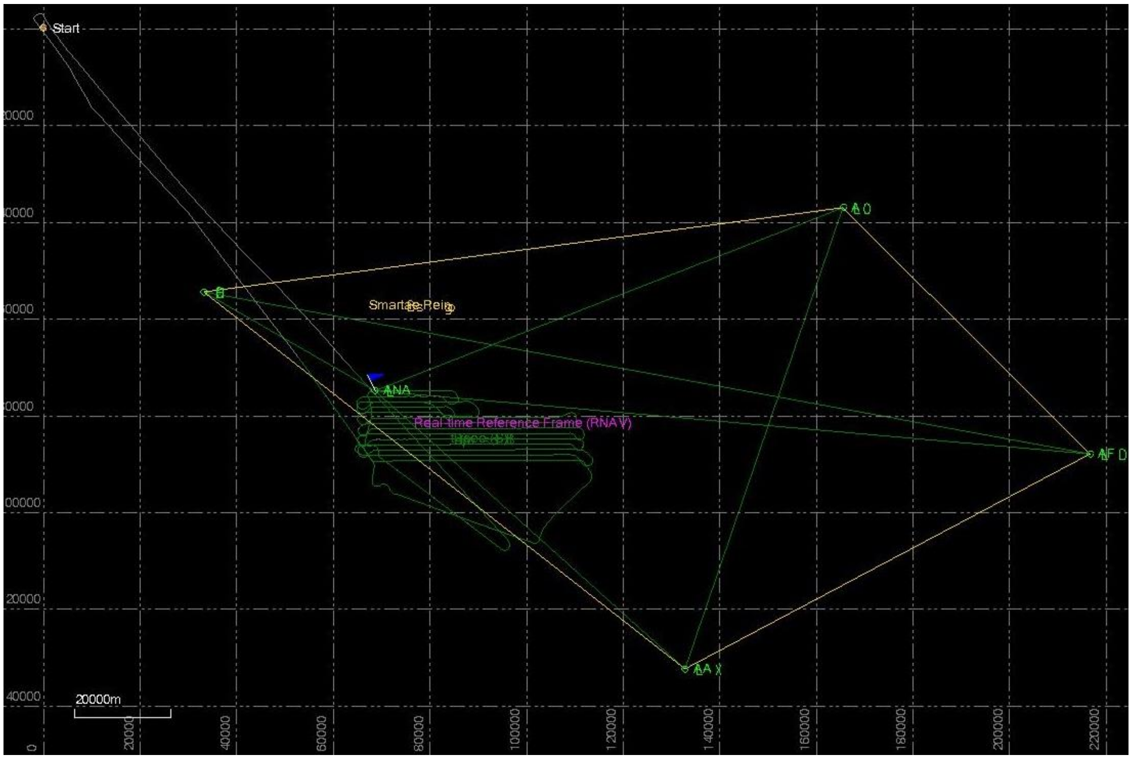
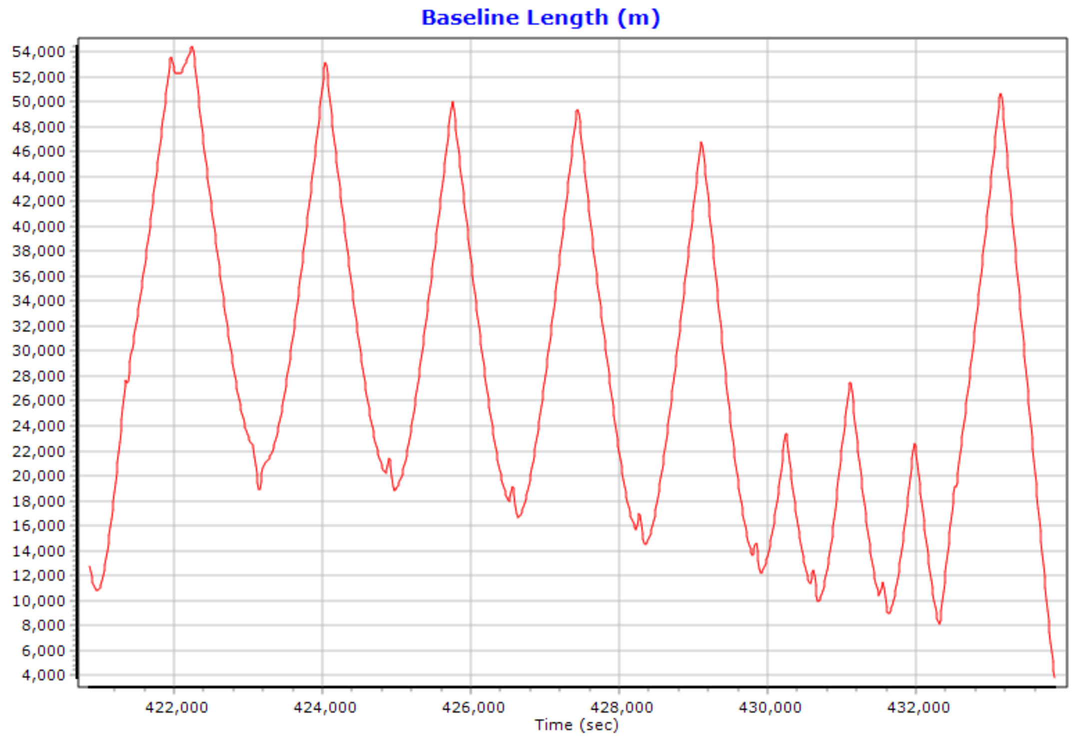
5,000
398,000
400,000
402,000
404,000
406,000
408,000
410,000
412,000
414,000
Time (sec)


PDOP
2
1.95
1.9
1.85
1.8
1.75
1.7
1.65
1.6
1.55
1.5
1.45
1.4
1.35
1.3
1.25
400,000
405,000
410,000
415,000
Time (sec)
Forward
Reverse

2SU18326B


Start
B
A O
Smartbase Ref
ANA
Real-time Reference Frame (RNAV)
AF D
A X
20000m


Baseline Length (m)
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44,000
42,000
40,000
38,000
36,000
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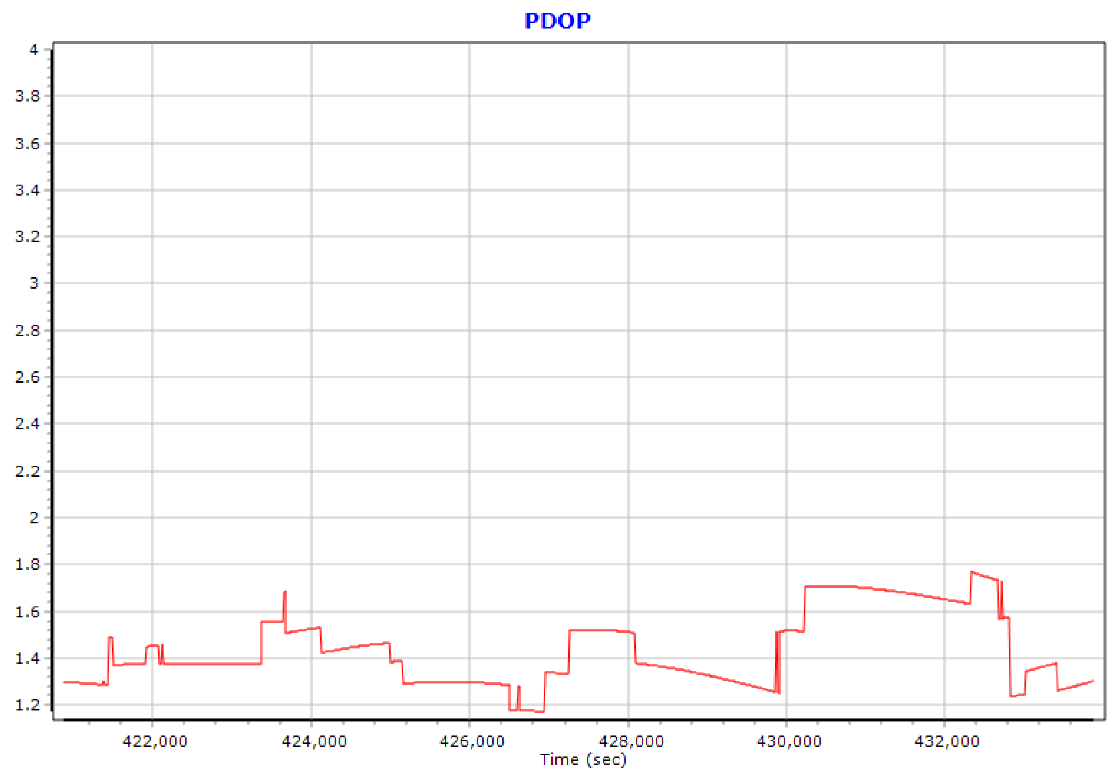
16,000
14,000
12,000
10,000
8,000
6,000
4,000
422,000
424,000
426,000
428,000
430,000
432,000
Time (sec)


PDOP
4
3.8
3.6
3.4
3.2
3
2.8
2.6
2.4
2.2
2
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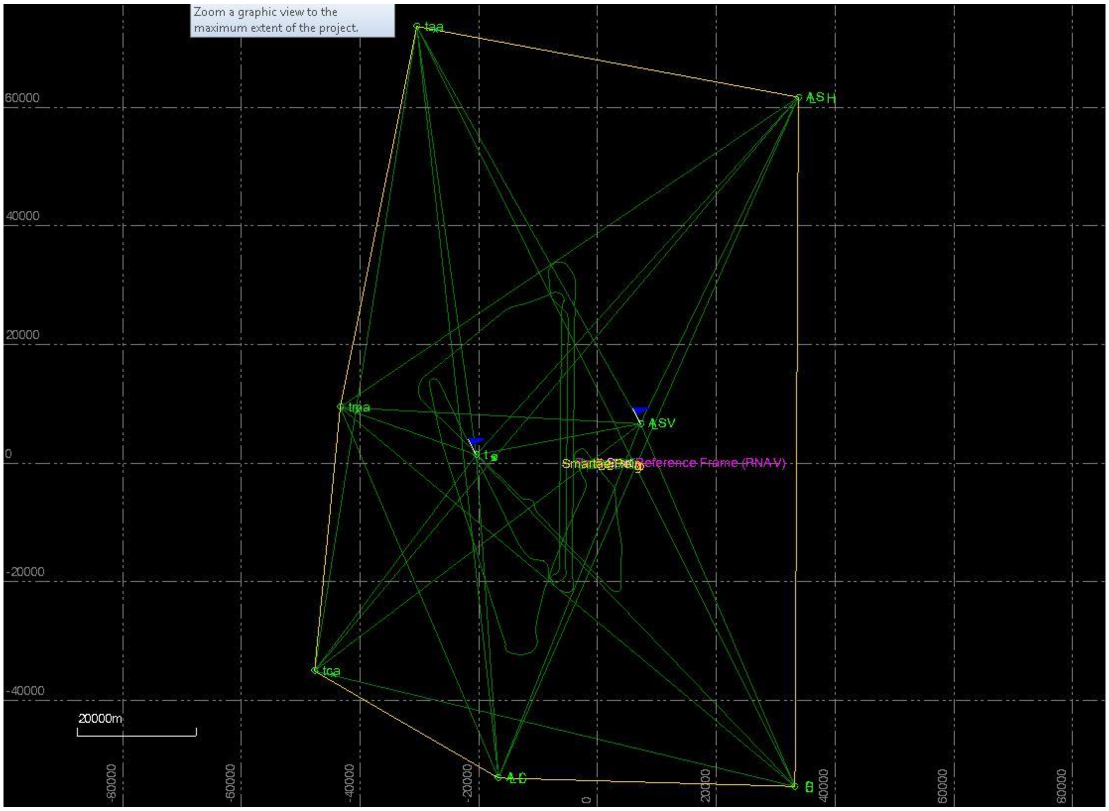
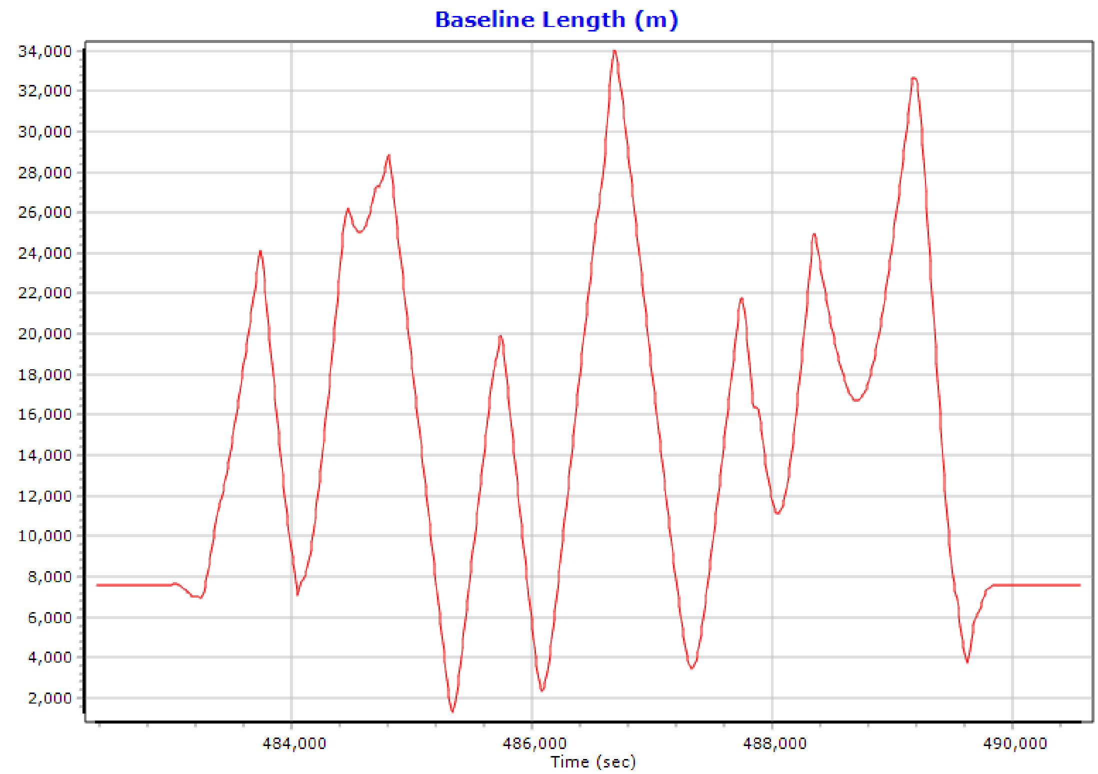
1.6
1.4
1.2
422,000
424,000
426,000
428,000
430,000
432,000
Time (sec)

SU18327A


Zoom a graphic view to the maximum extent of the project.
taa
ASH
tma
ASV
ts
tca
AC
60000
40000
20000
0
-20000
-40000
20000m
-80000
-60000
-40000
-20000
0
20000
40000
60000
80000


Baseline Length (m)
34,000
32,000
30,000
28,000
26,000
24,000
22,000
20,000
18,000
16,000
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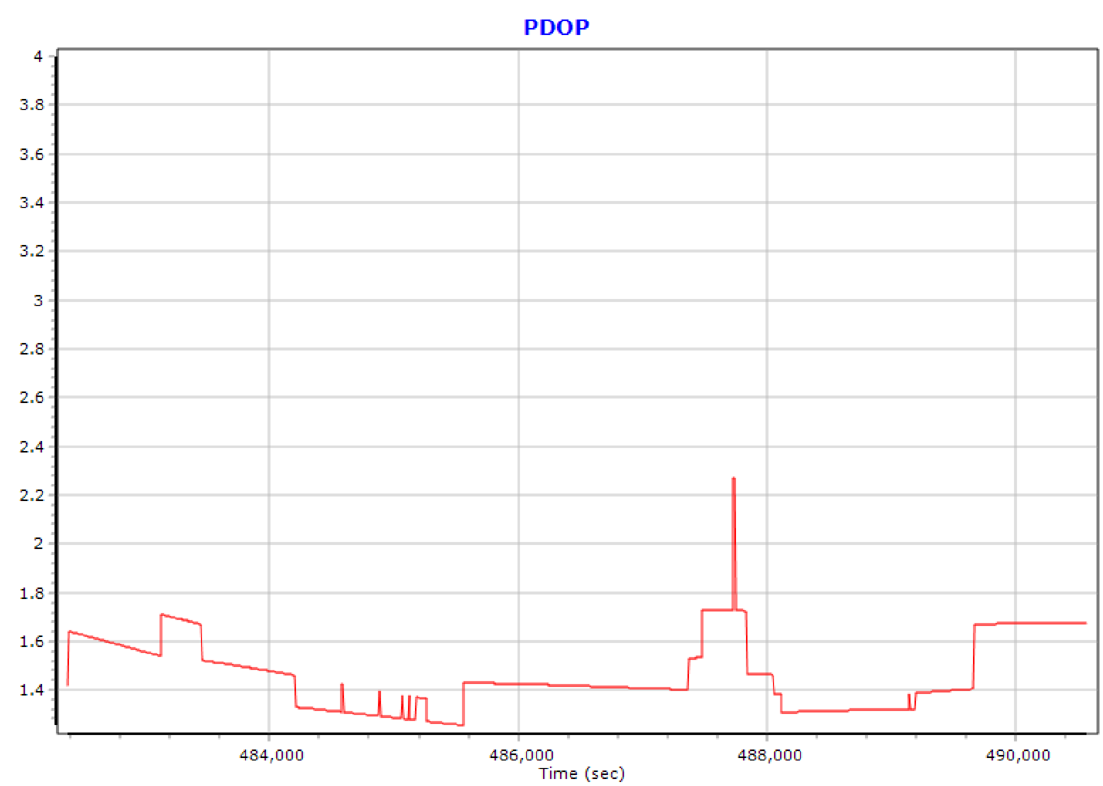
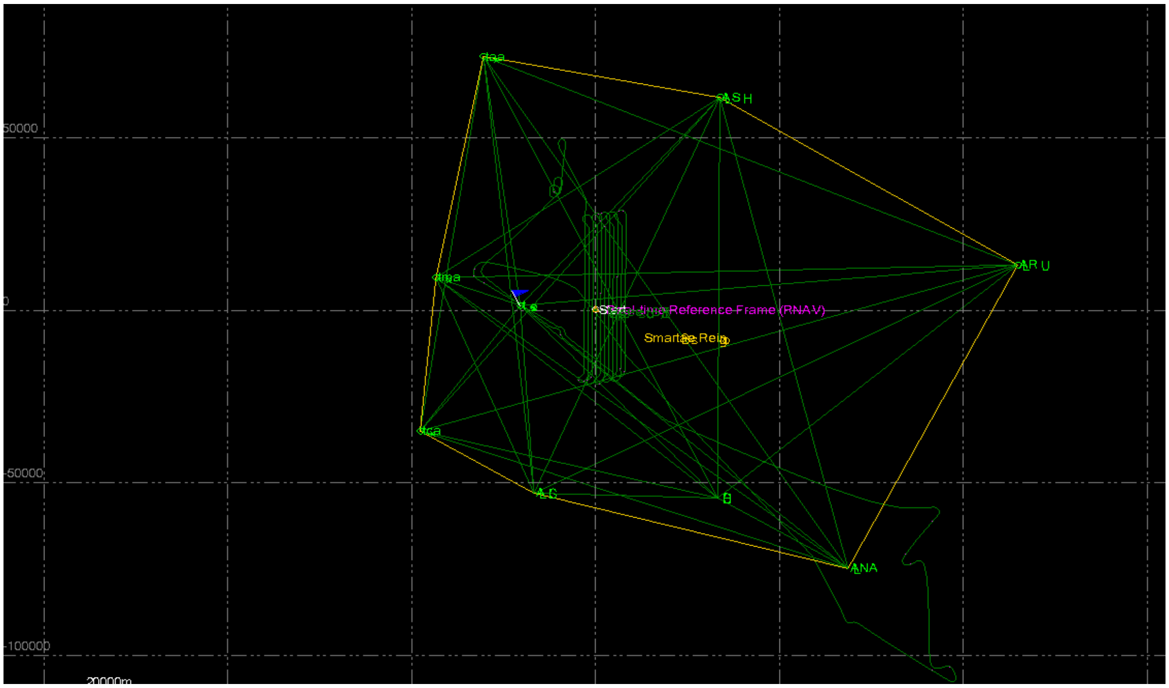
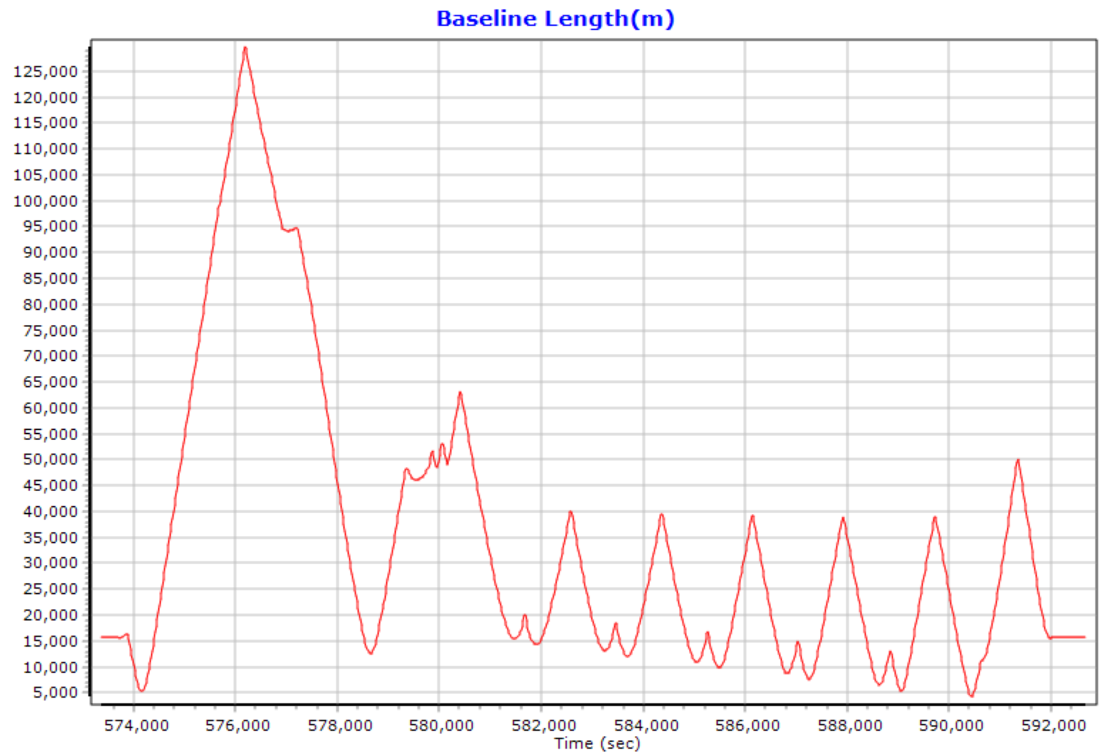
488,000
490,000
Time (sec)


PDOP
4
3.8
3.6
3.4
3.2
3
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
484,000
486,000
488,000
490,000
Time (sec)

2SU18328A


50000
0
-50000
-100000
20000m
ASH
ARU
ANA
Reference Frame (RNAV)
Smart


Baseline Length(m)
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120,000
115,000
110,000
105,000
100,000
95,000
90,000
85,000
80,000
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15,000
10,000
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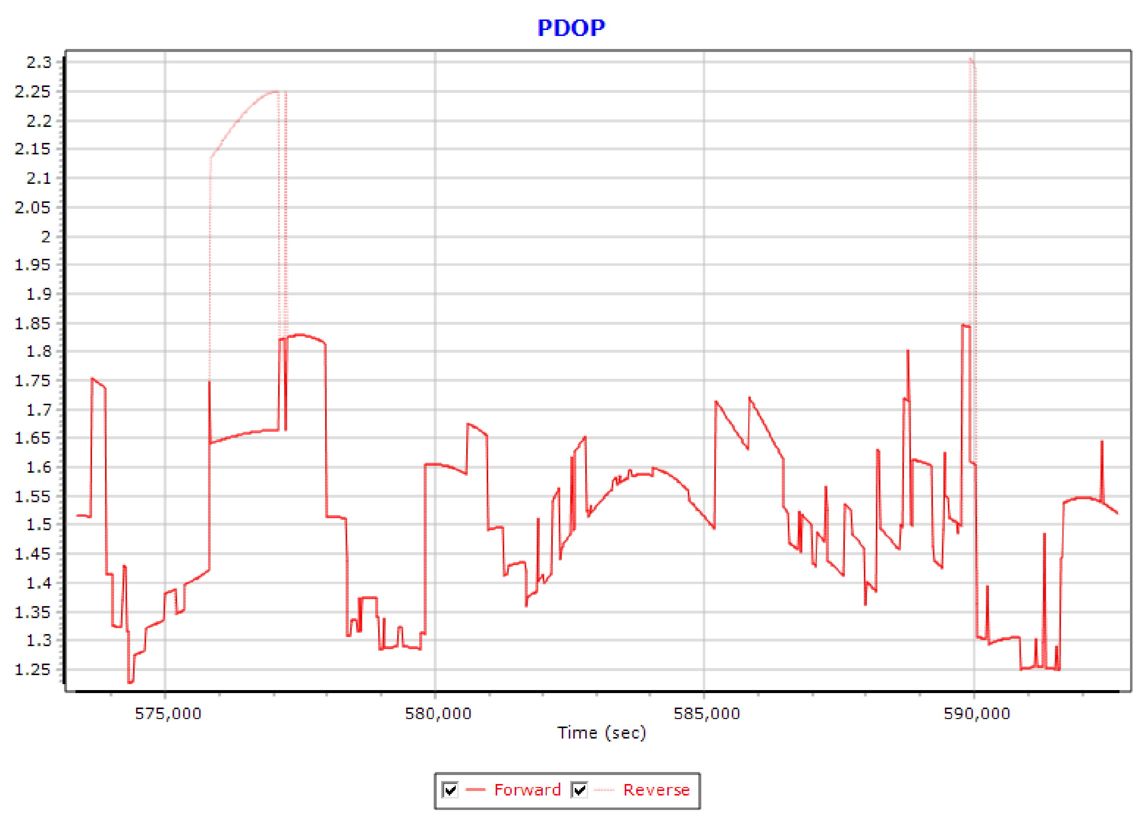
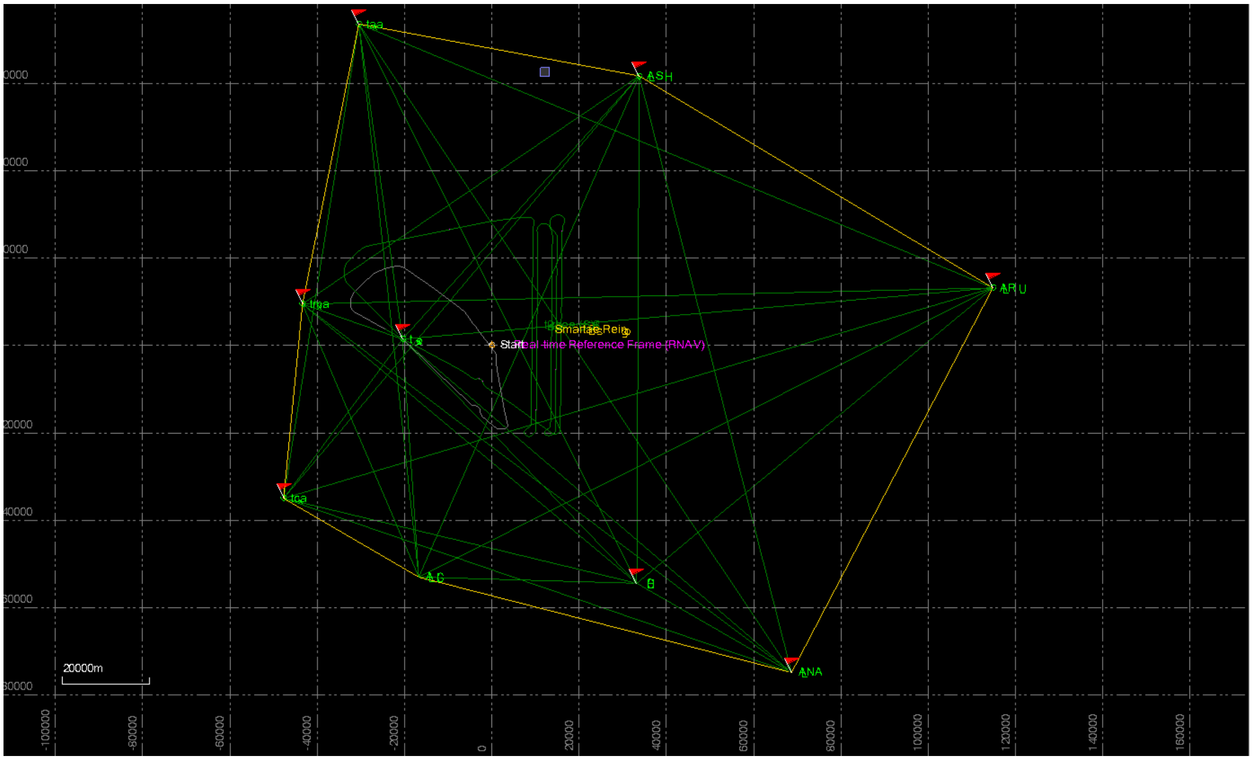
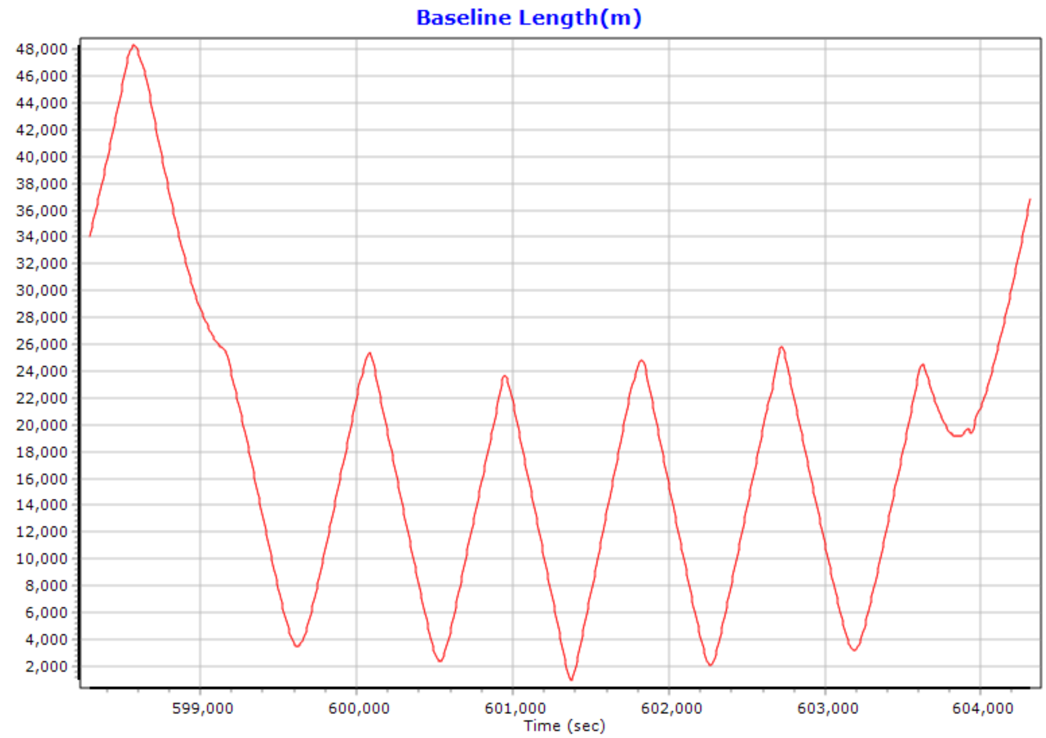
590,000
592,000
Time (sec)


PDOP
2.3
2.25
2.2
2.15
2.1
2.05
2
1.95
1.9
1.85
1.8
1.75
1.7
1.65
1.6
1.55
1.5
1.45
1.4
1.35
1.3
1.25
575,000
580,000
585,000
590,000
Time (sec)
Forward
Reverse

SU18328B




Baseline Length(m)
48,000
46,000
44,000
42,000
40,000
38,000
36,000
34,000
32,000
30,000
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26,000
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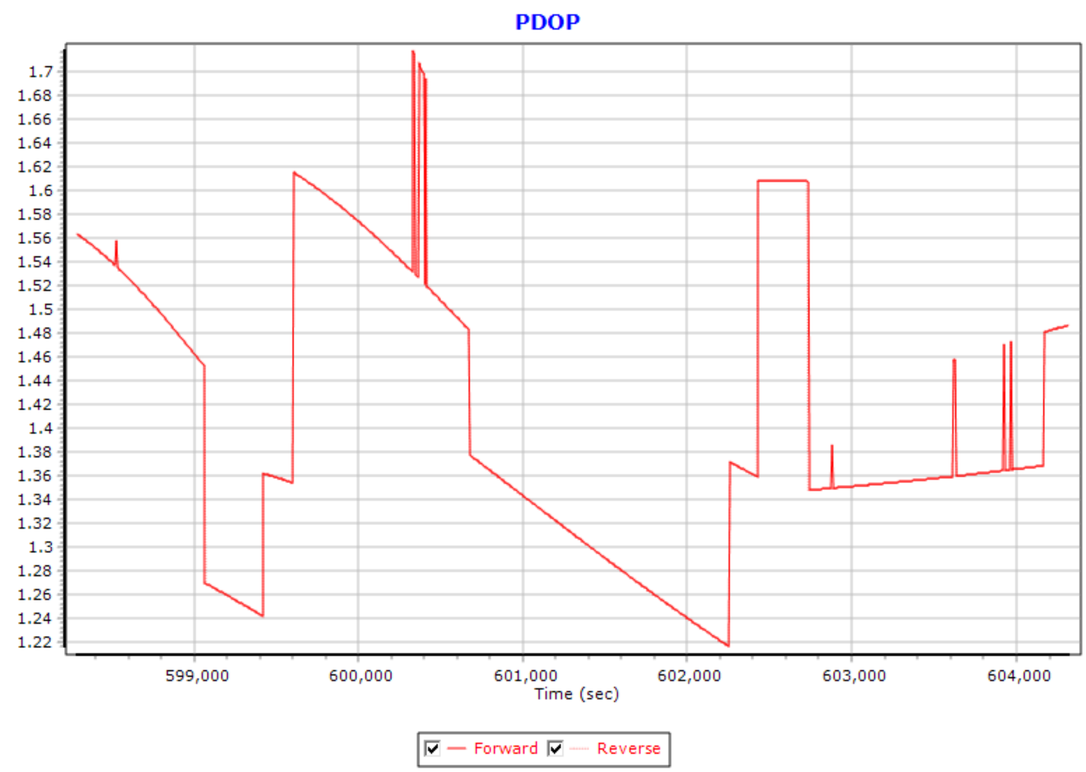
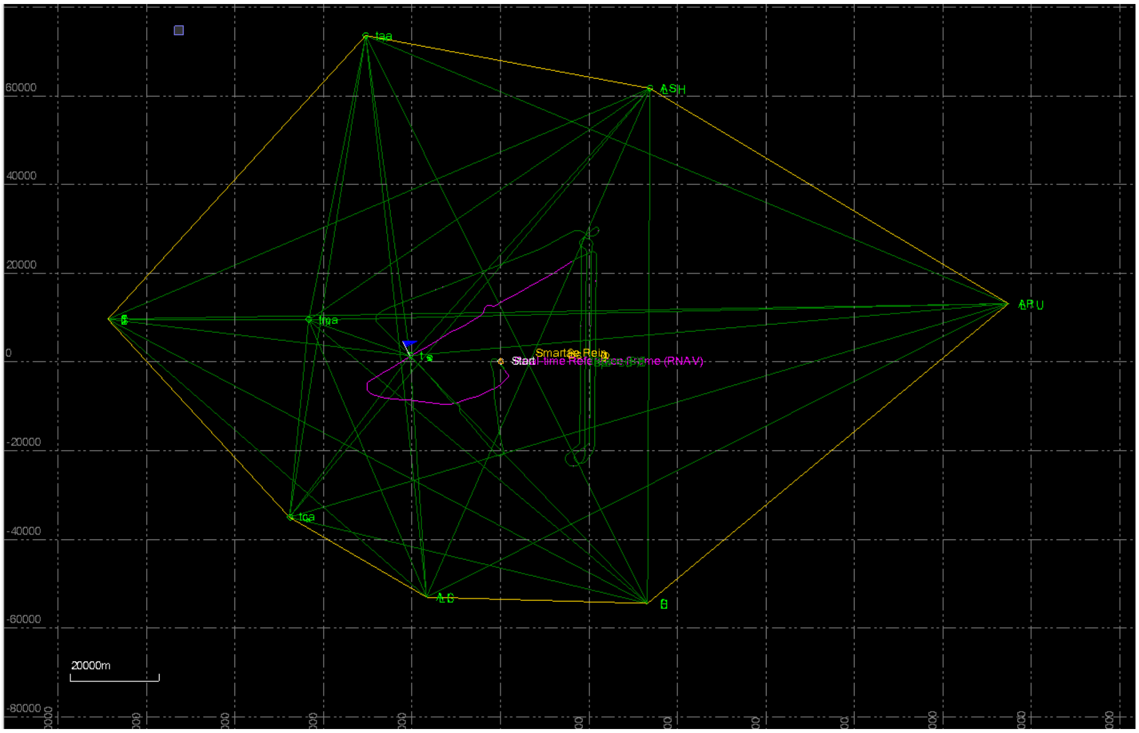
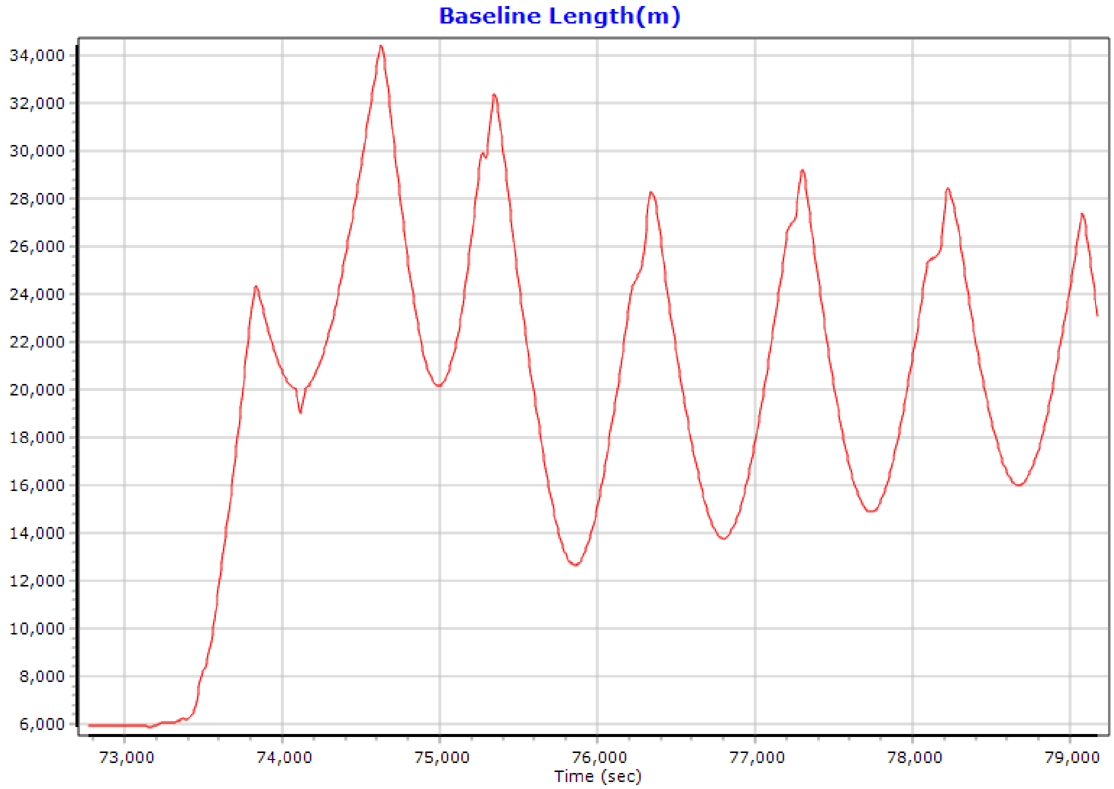
14,000
12,000
10,000
8,000
6,000
4,000
2,000
599,000
600,000
601,000
602,000
603,000
604,000
Time (sec)


PDOP
1.7
1.68
1.66
1.64
1.62
1.6
1.58
1.56
1.54
1.52
1.5
1.48
1.46
1.44
1.42
1.4
1.38
1.36
1.34
1.32
1.3
1.28
1.26
1.24
1.22
599,000
600,000
601,000
602,000
603,000
604,000
Time (sec)
Forward
Reverse




Baseline Length(m)
34,000
32,000
30,000
28,000
26,000
24,000
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16,000
14,000
12,000
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6,000
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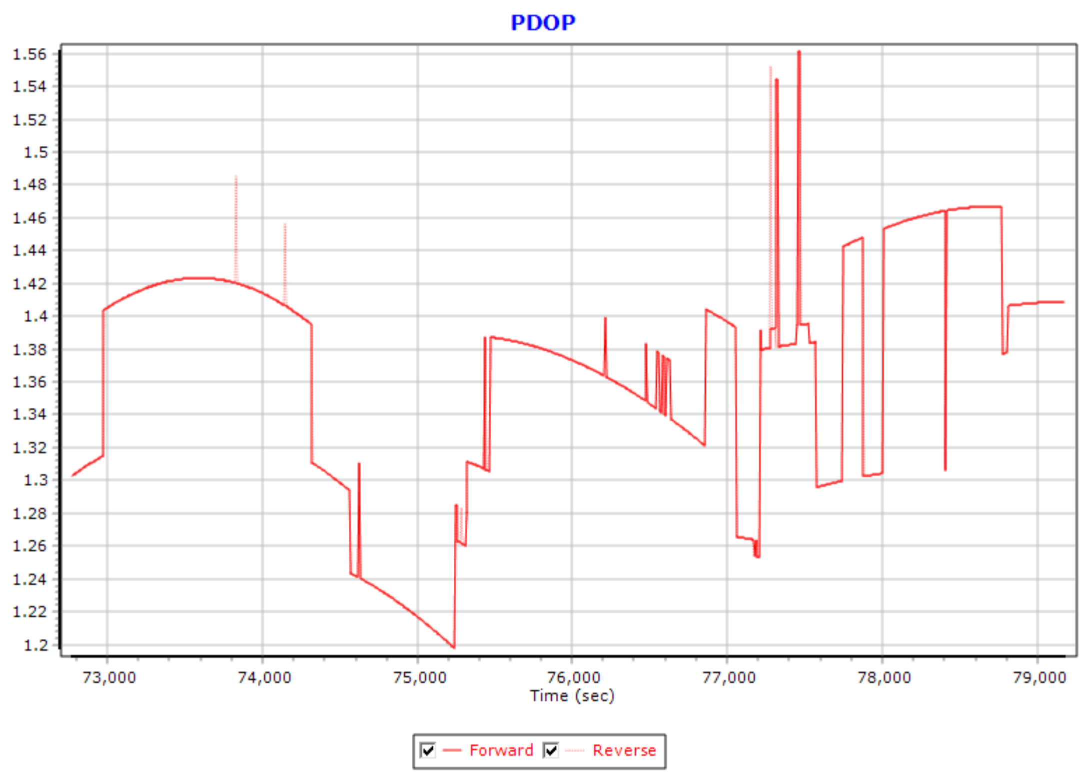
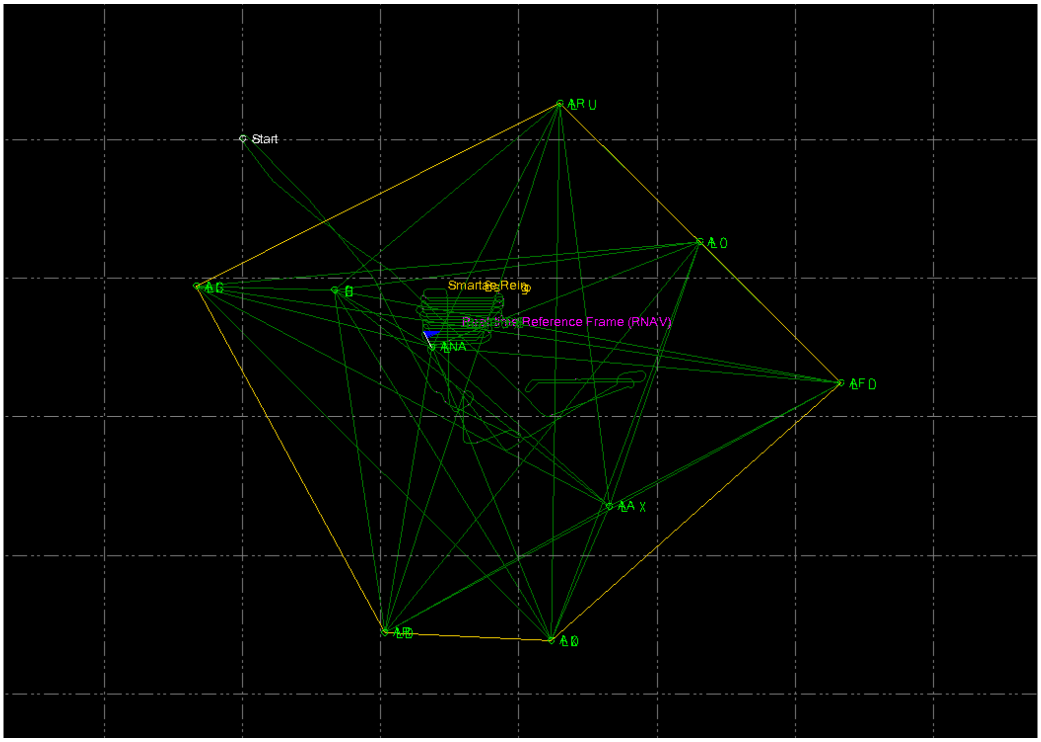
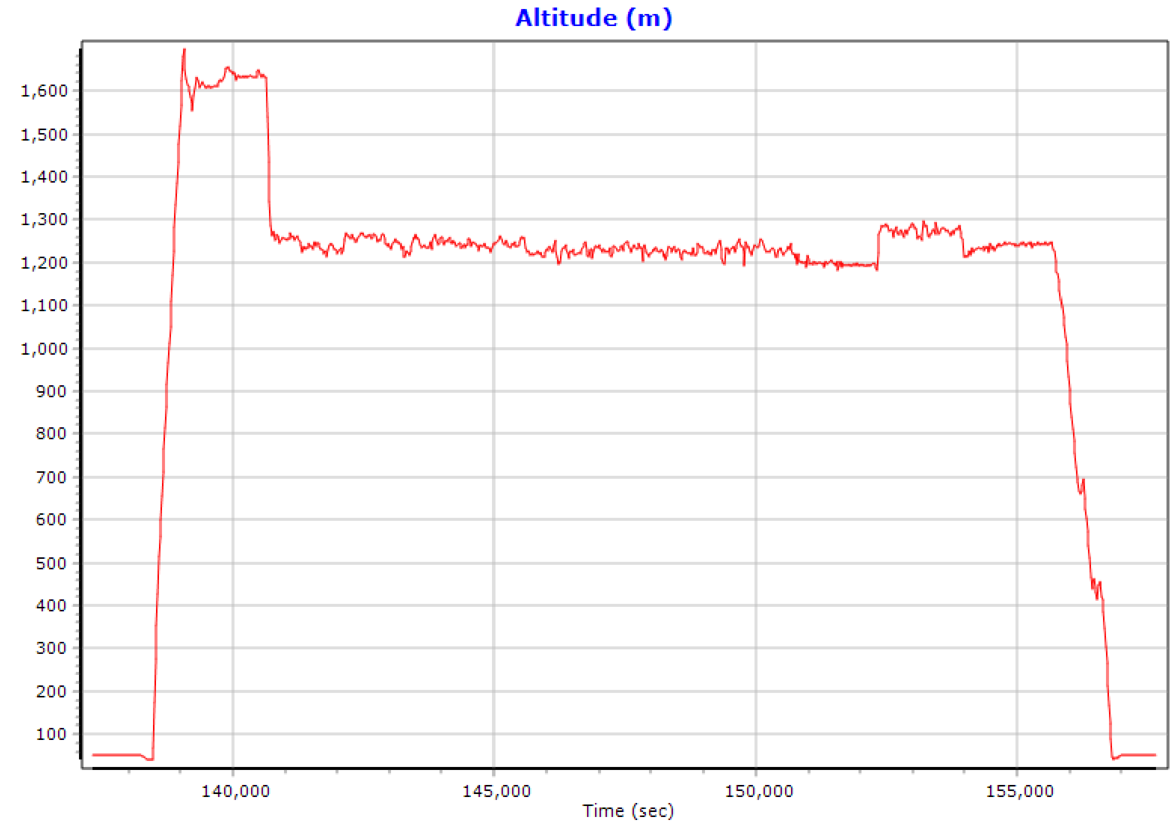
74,000
75,000
76,000
77,000
78,000
79,000
Time (sec)


PDOP
1.56
1.54
1.52
1.5
1.48
1.46
1.44
1.42
1.4
1.38
1.36
1.34
1.32
1.3
1.28
1.26
1.24
1.22
1.2
73,000
74,000
75,000
76,000
77,000
78,000
79,000
Time (sec)
Forward
Reverse

2SU18330A




Altitude (m)
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1,500
1,400
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1,200
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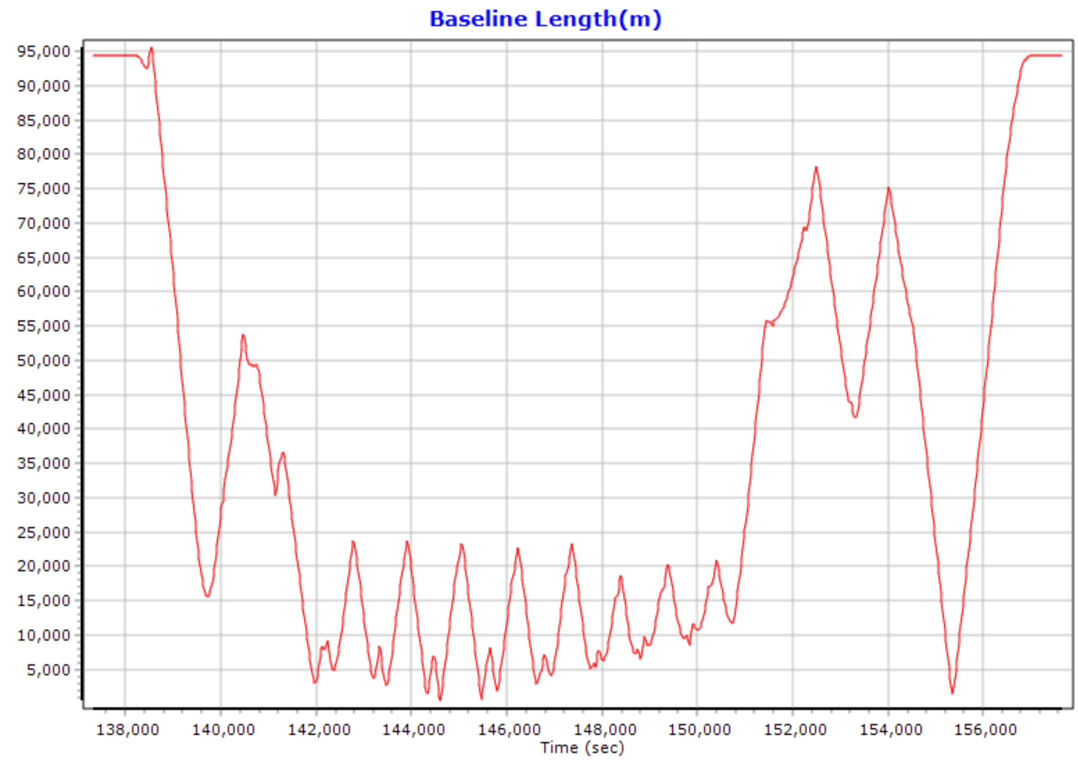
1,000
900
800
700
600
500
400
300
200
100
140,000
145,000
150,000
155,000
Time (sec)


Baseline Length(m)
95,000
90,000
85,000
80,000
75,000
70,000
65,000
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55,000
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15,000
10,000
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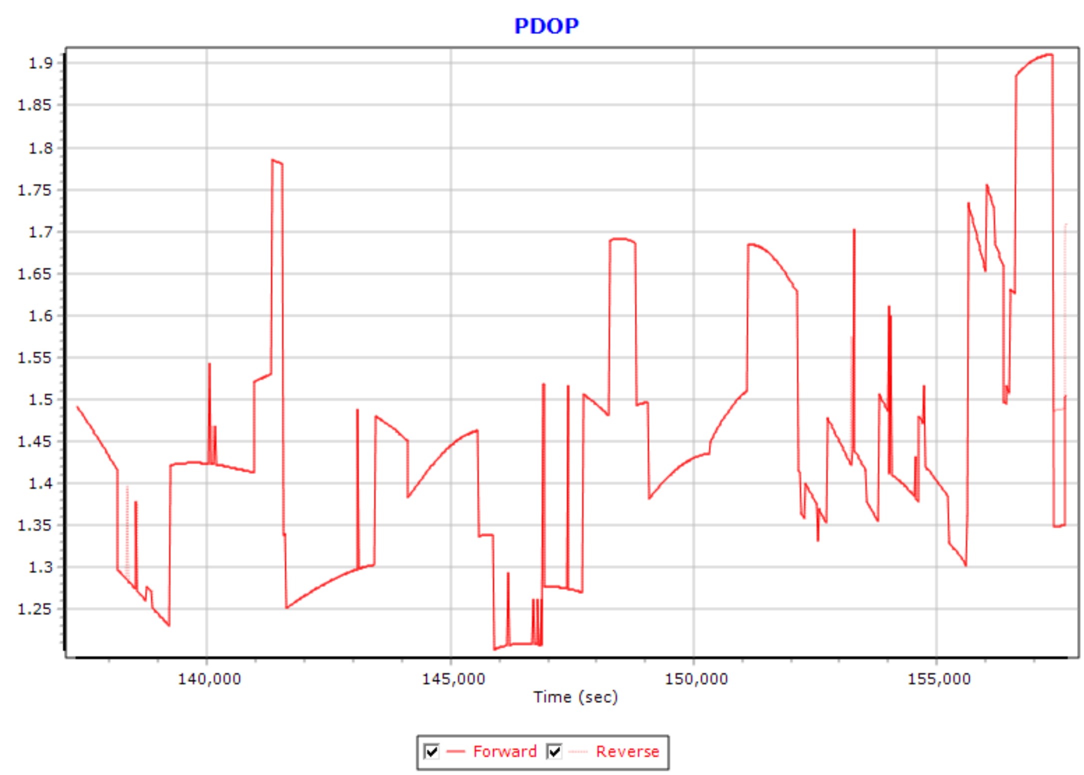
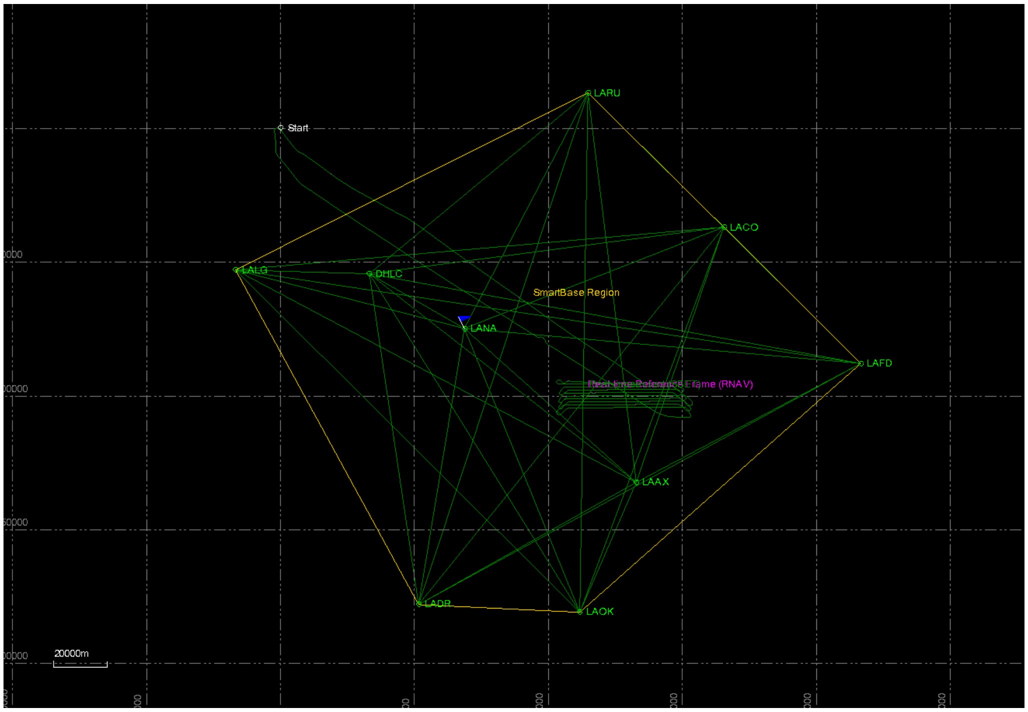
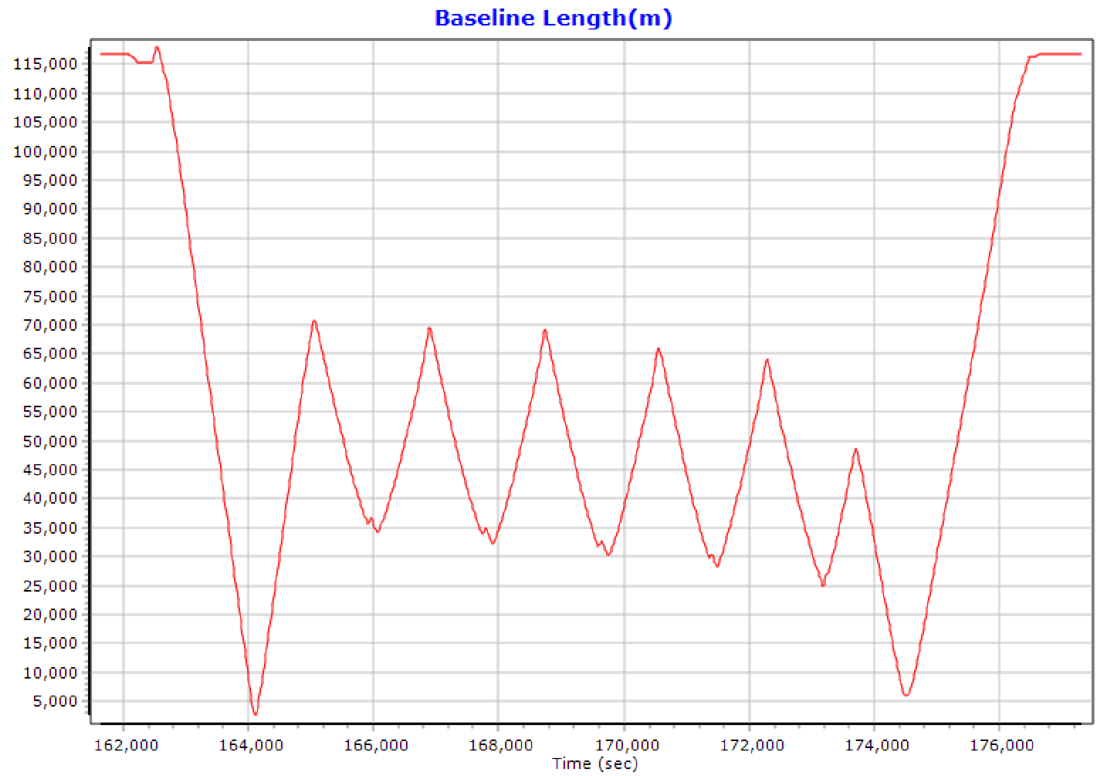
148,000
150,000
152,000
154,000
156,000
Time (sec)


PDOP
1.9
1.85
1.8
1.75
1.7
1.65
1.6
1.55
1.5
1.45
1.4
1.35
1.3
1.25
140,000
145,000
150,000
155,000
Time (sec)
Forward
Reverse

2SU18330B


LARU
Start
LACO
LALG
DHLC
SmartBase Region
LANA
LAFD
LAAX
LADR
LAOK
20000m


Baseline Length(m)
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110,000
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90,000
85,000
80,000
75,000
70,000
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20,000
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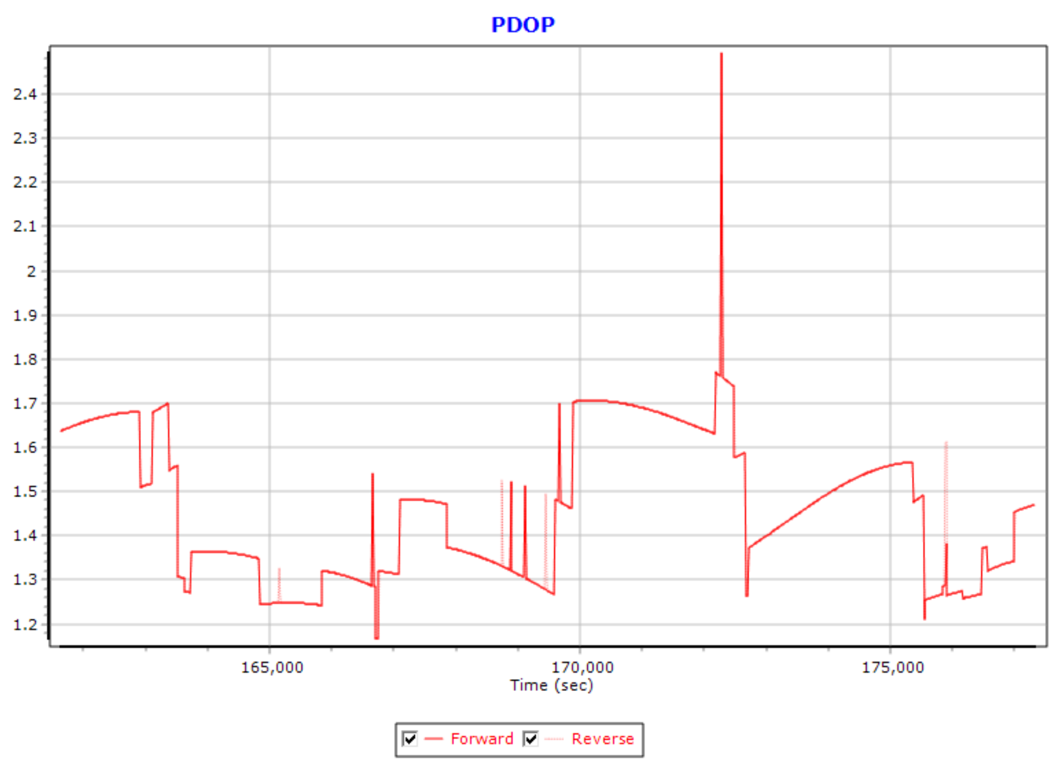
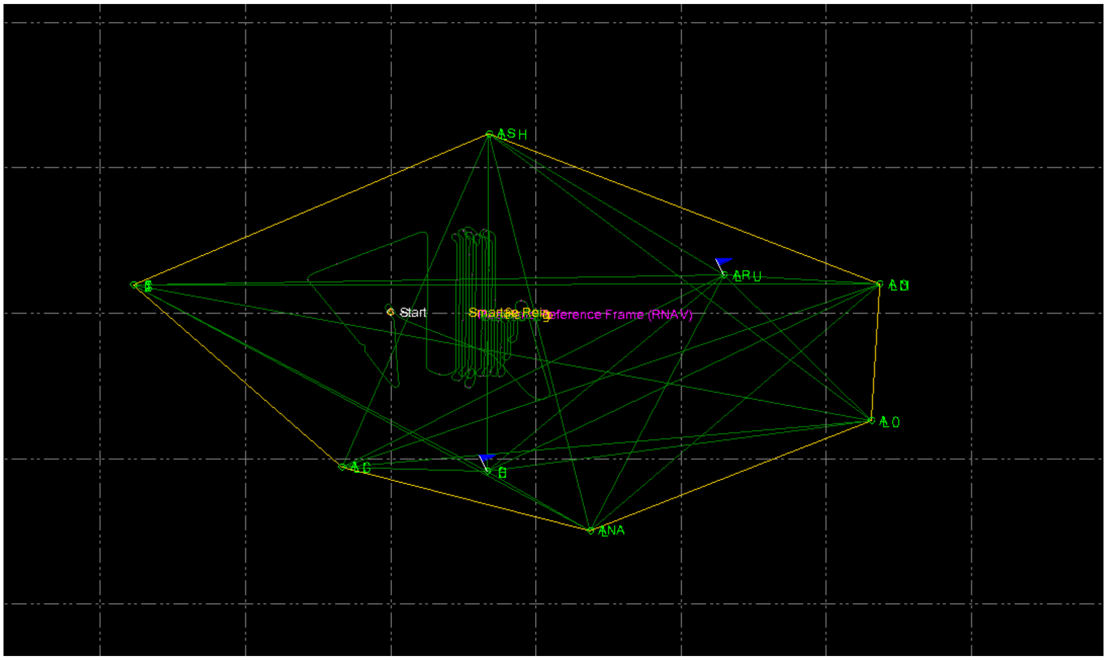
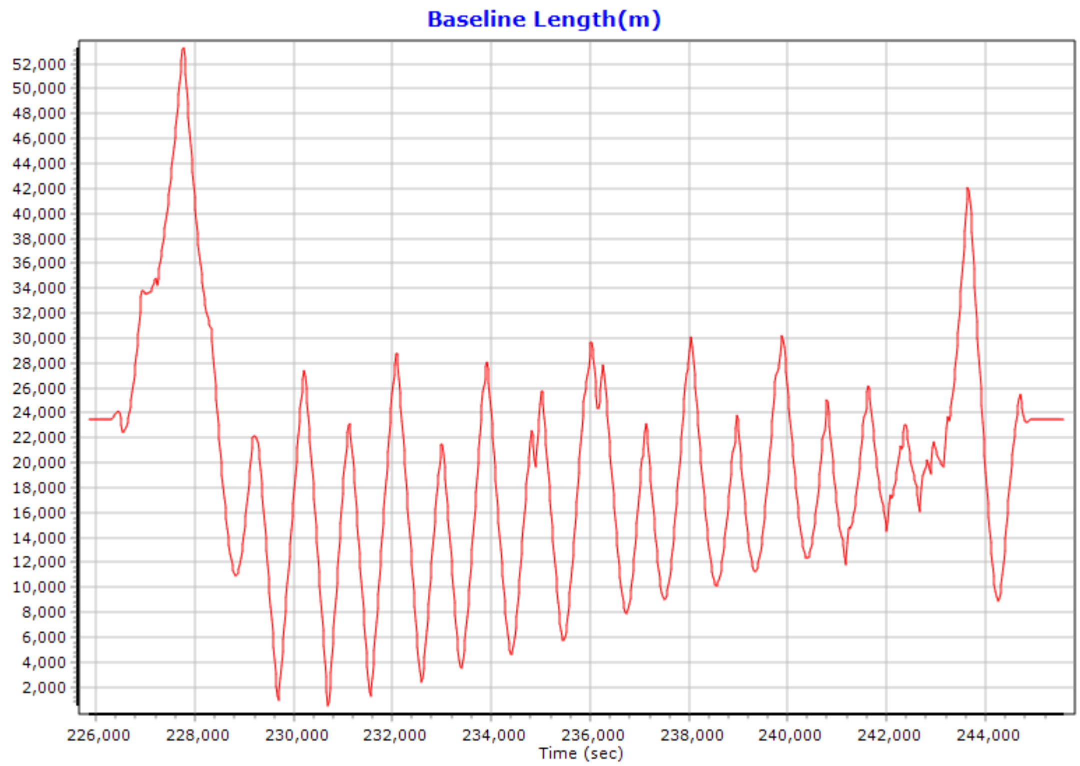
174,000
176,000
Time (sec)


PDOP
2.4
2.3
2.2
2.1
2
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
165,000
170,000
175,000
Time (sec)
Forward
Reverse

2SU18331A




Baseline Length(m)
52,000
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44,000
42,000
40,000
38,000
36,000
34,000
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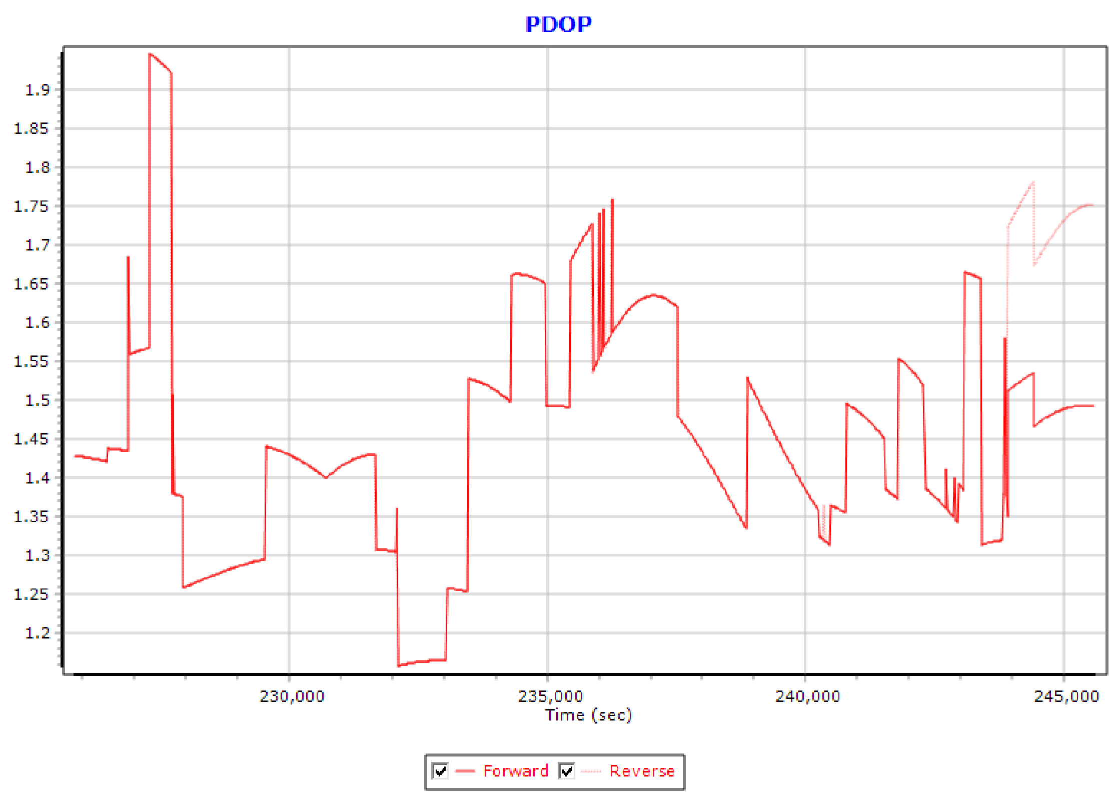
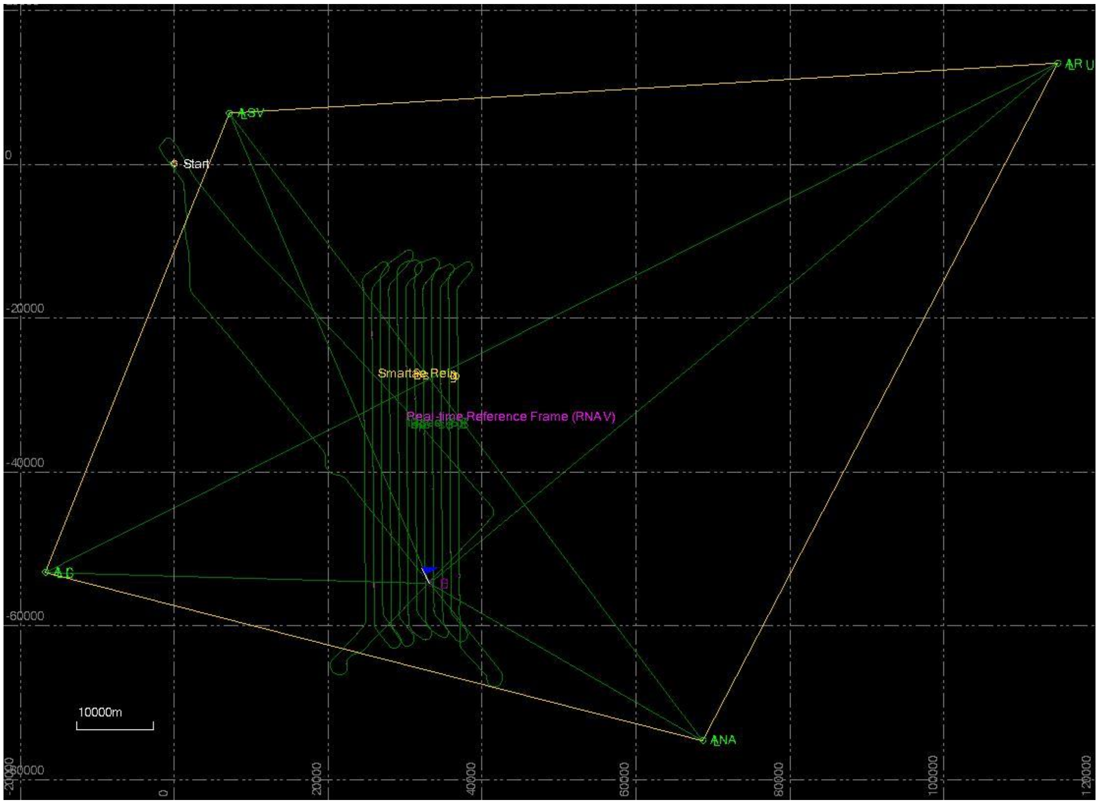
6,000
4,000
2,000
226,000
228,000
230,000
232,000
234,000
236,000
238,000
240,000
242,000
244,000
Time (sec)


PDOP
1.9
1.85
1.8
1.75
1.7
1.65
1.6
1.55
1.5
1.45
1.4
1.35
1.3
1.25
1.2
230,000
235,000
240,000
245,000
Time (sec)
Forward
Reverse

2SU18331B


ASV
ARU
Start
SmartBase Ref
Real-time Reference Frame (RNAV)
ANA
10000m
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-20000
-40000
-60000
-80000
-20000
20000
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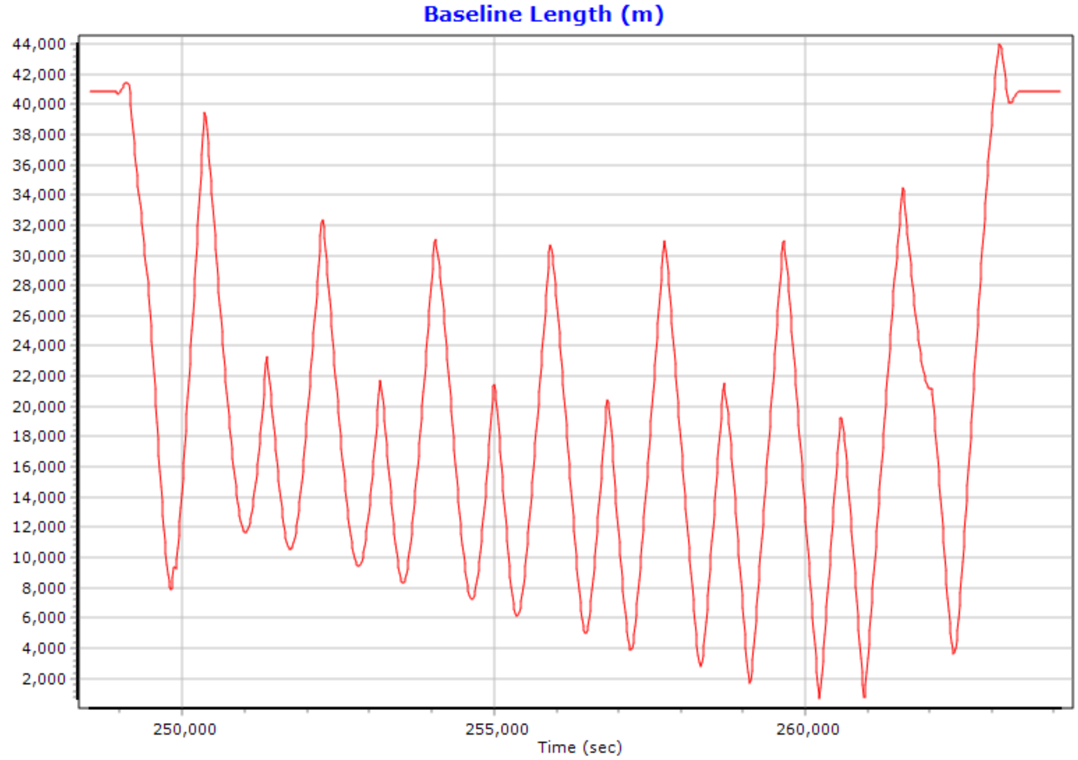
60000
80000
100000
120000


Baseline Length (m)
44,000
42,000
40,000
38,000
36,000
34,000
32,000
30,000
28,000
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20,000
18,000
16,000
14,000
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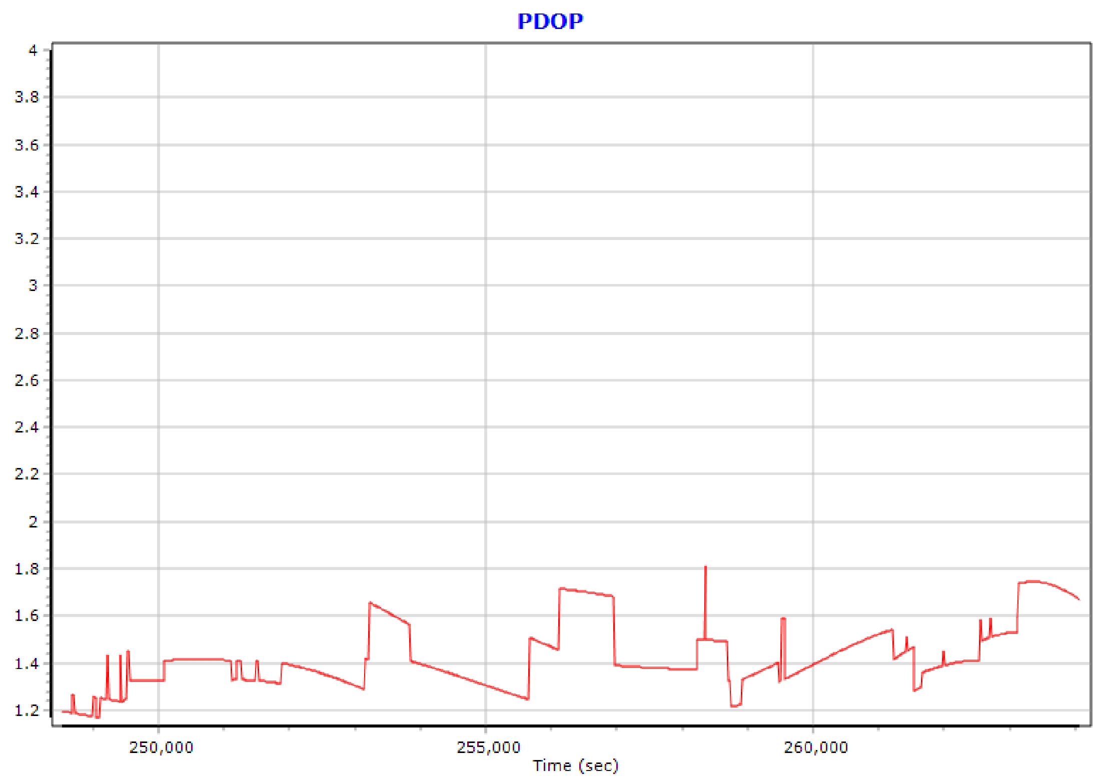
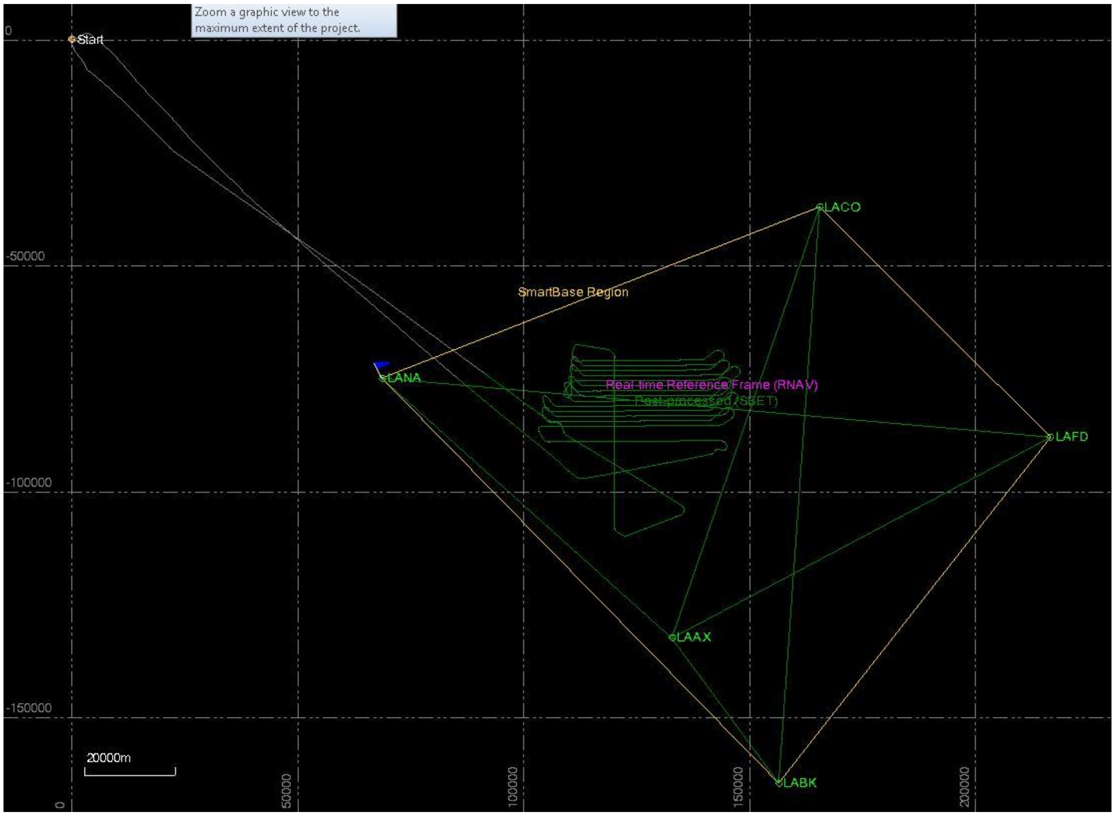
10,000
8,000
6,000
4,000
2,000
250,000
255,000
260,000
Time (sec)


PDOP
4
3.8
3.6
3.4
3.2
3
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
250,000
255,000
260,000
Time (sec)

2SU18332A


Zoom a graphic view to the maximum extent of the project.
Start
LACO
SmartBase Region
LANA
Real-time Reference Frame (RNAV)
Post-processed (SBET)
LAFD
LAAX
LABK
20000m
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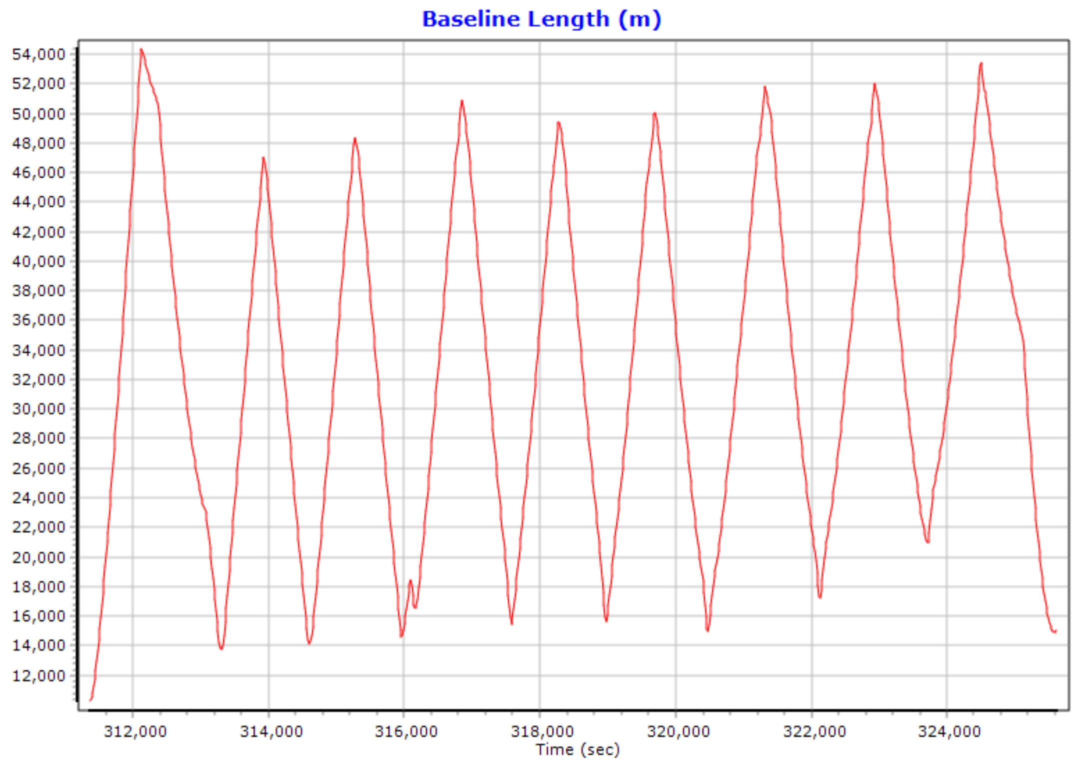
-100000
-150000
50000
100000
150000
200000


Baseline Length (m)
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22,000
20,000
18,000
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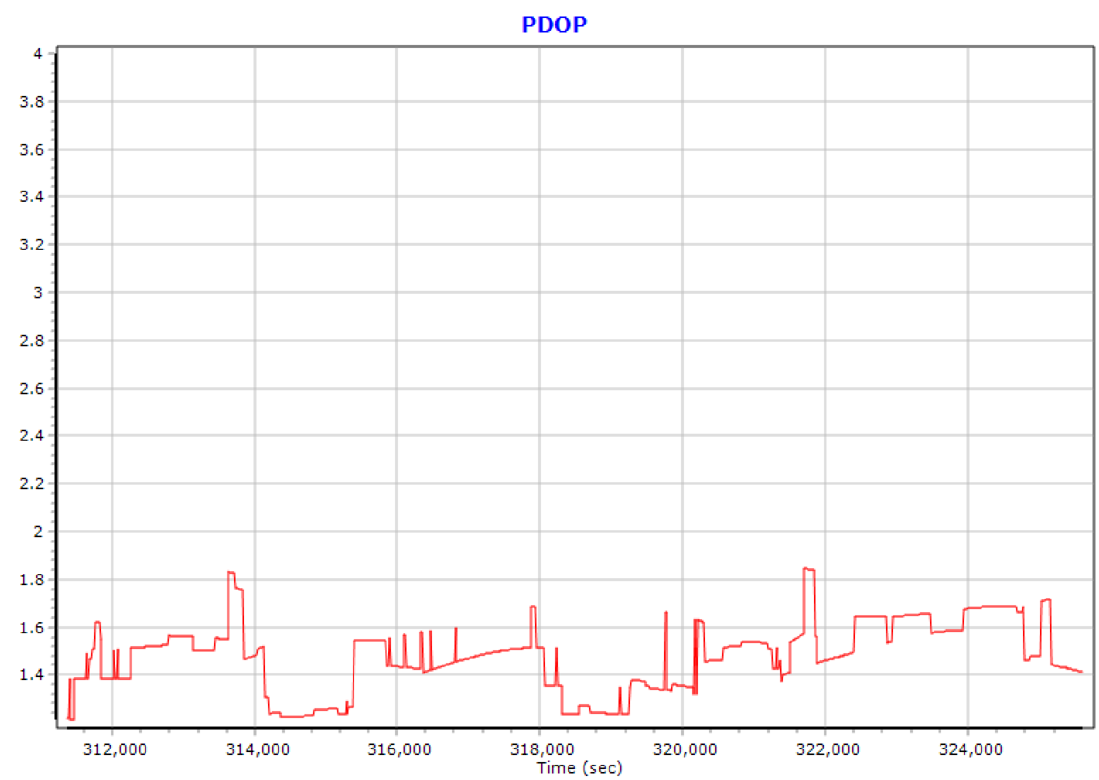
314,000
316,000
318,000
320,000
322,000
324,000
Time (sec)


PDOP
4
3.8
3.6
3.4
3.2
3
2.8
2.6
2.4
2.2
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1.8
1.6
1.4
312,000
314,000
316,000
318,000
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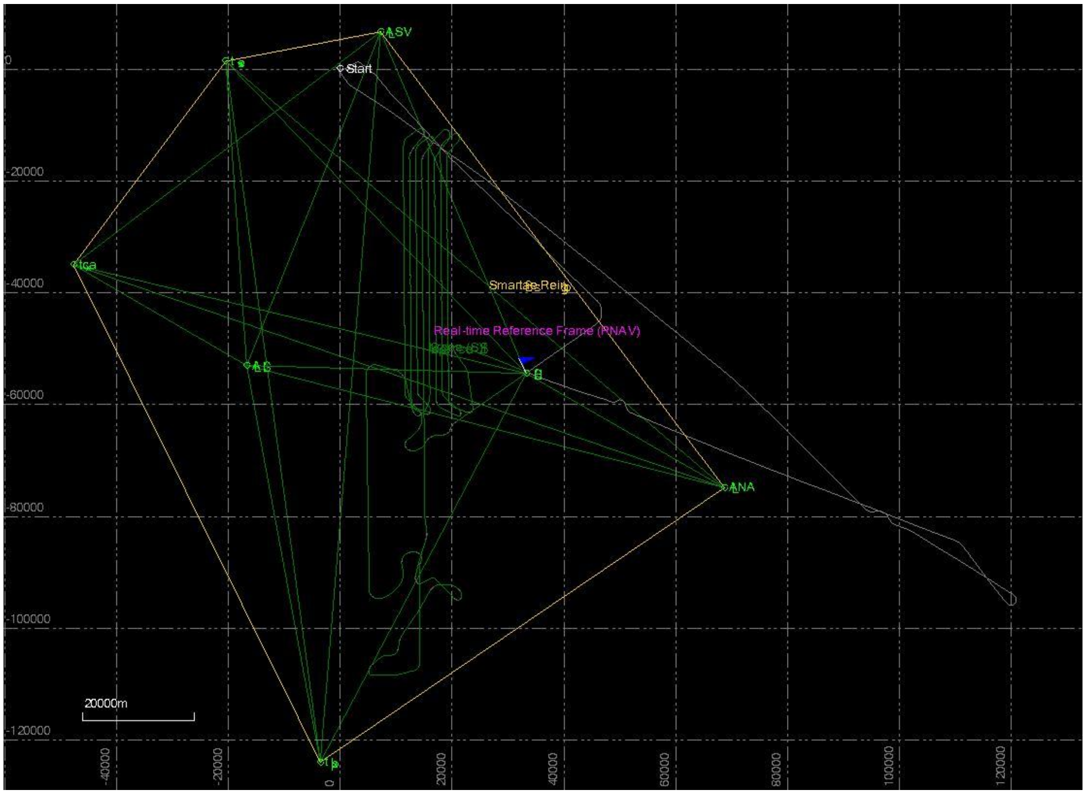
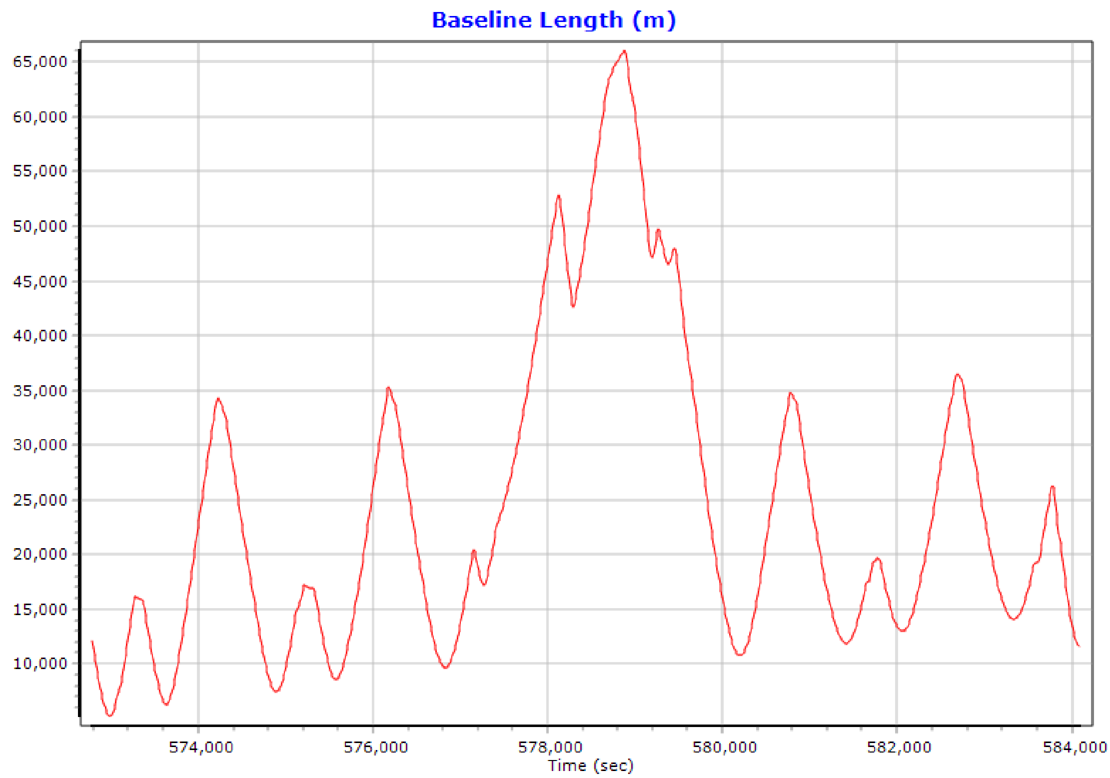
322,000
324,000
Time (sec)

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45,000
40,000
35,000
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576,000
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580,000
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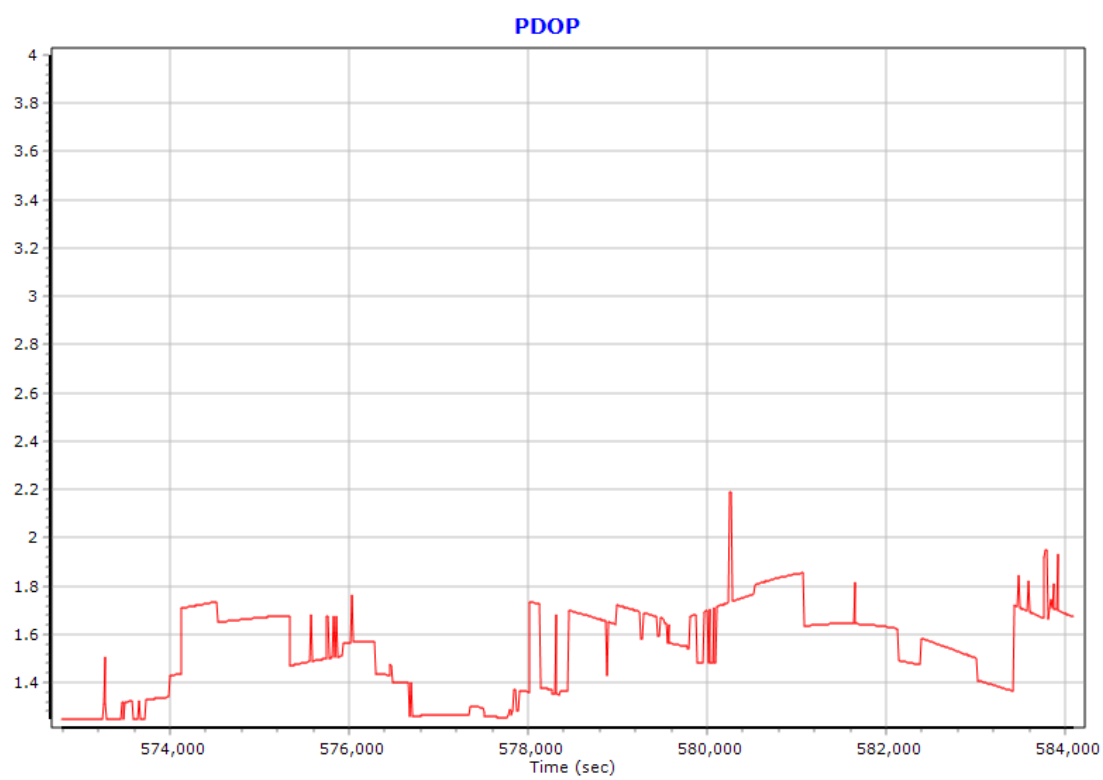
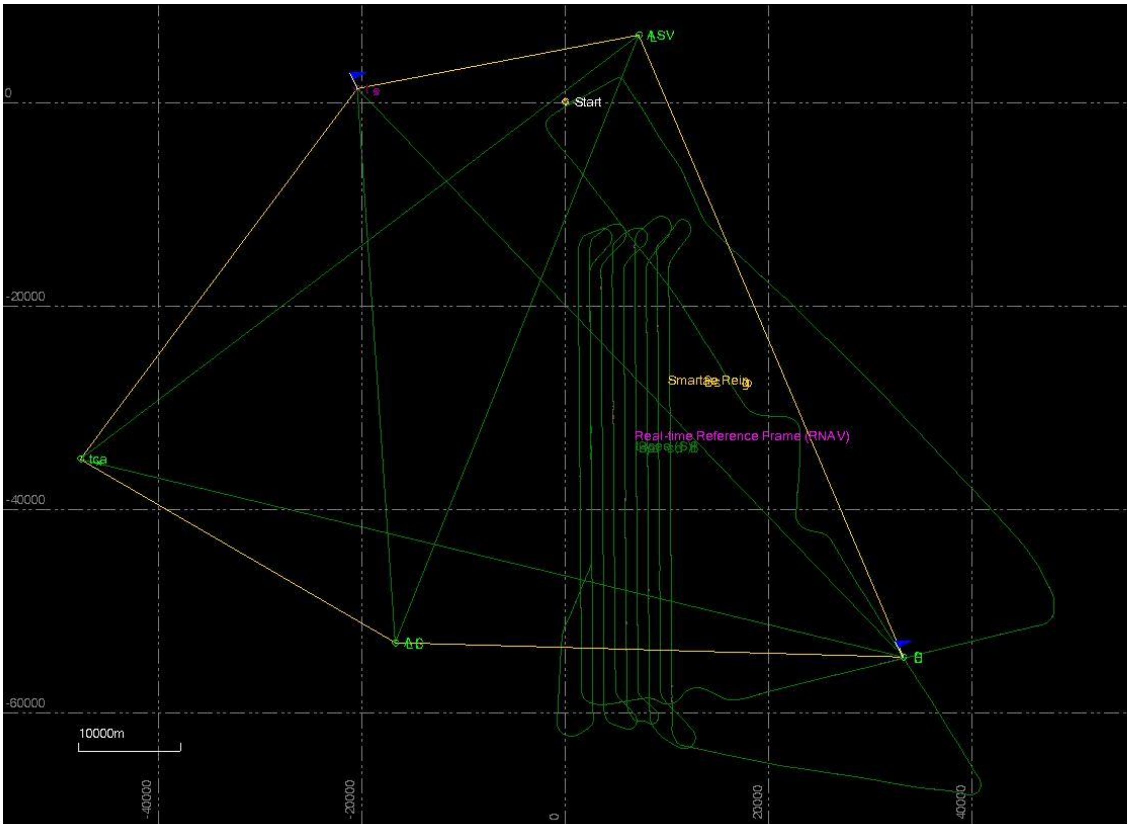
584,000
Time (sec)


PDOP
4
3.8
3.6
3.4
3.2
3
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
574,000
576,000
578,000
580,000
582,000
584,000
Time (sec)

2SU18335B


LSV
Start
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-20000
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-60000
Smart Base Ref
Real-time Reference Frame (RNAV)
tca
LC
B
10000m
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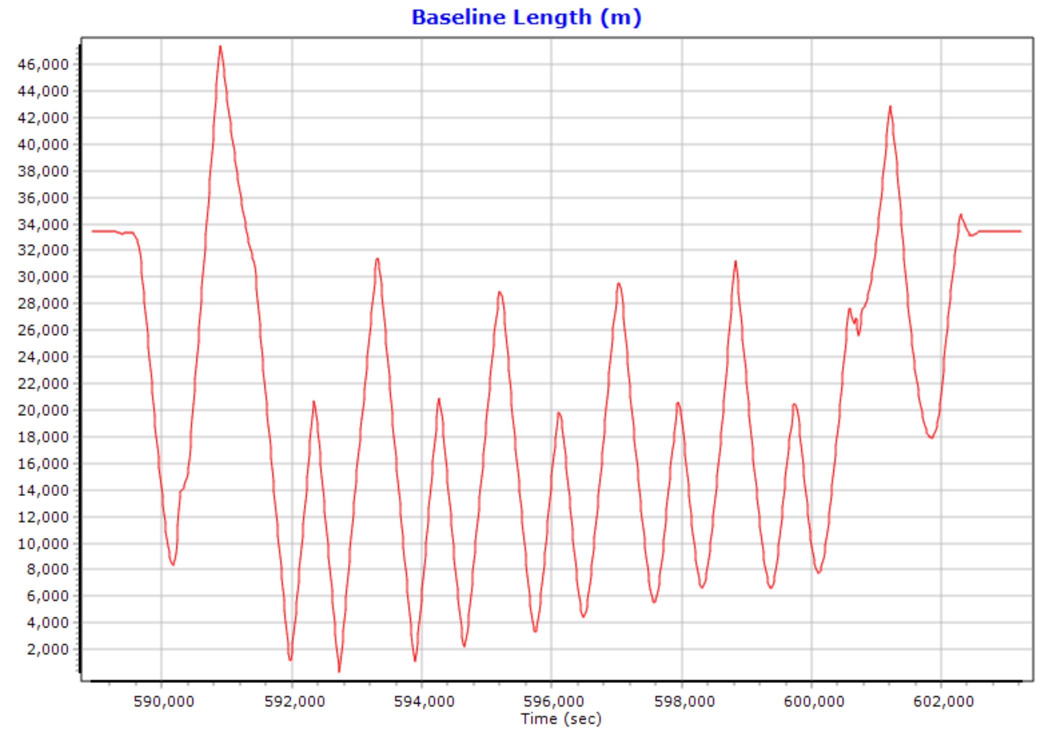
0
20000
40000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20,000
18,000
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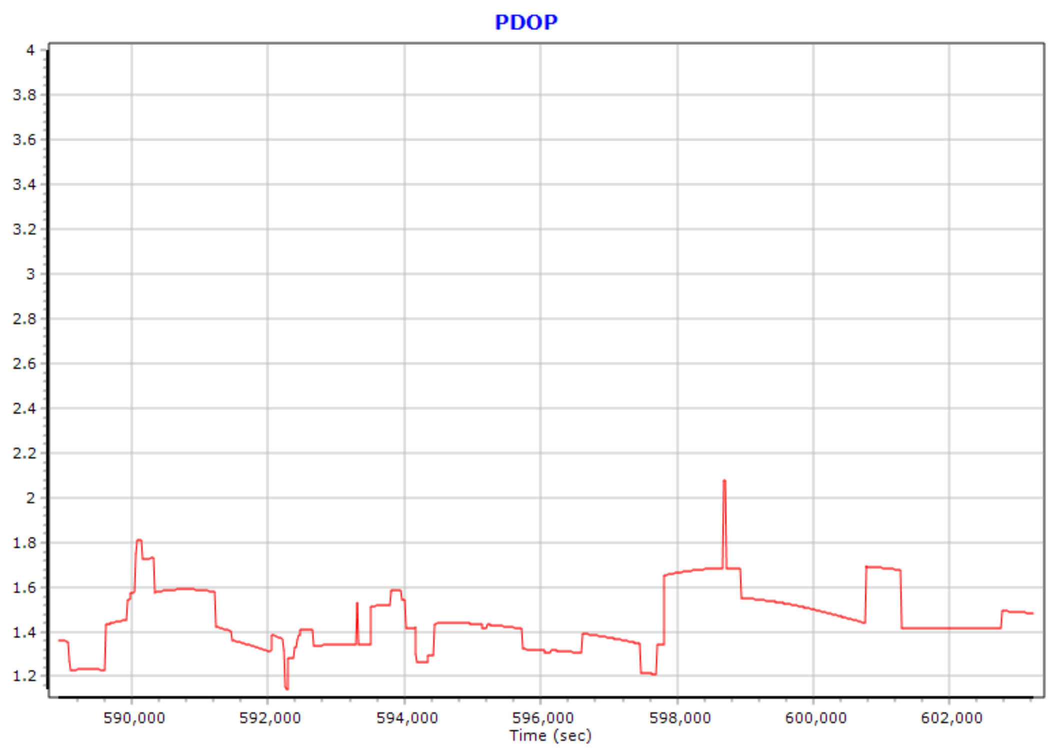
14,000
12,000
10,000
8,000
6,000
4,000
2,000
590,000
592,000
594,000
596,000
598,000
600,000
602,000
Time (sec)


PDOP
4
3.8
3.6
3.4
3.2
3
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
590,000
592,000
594,000
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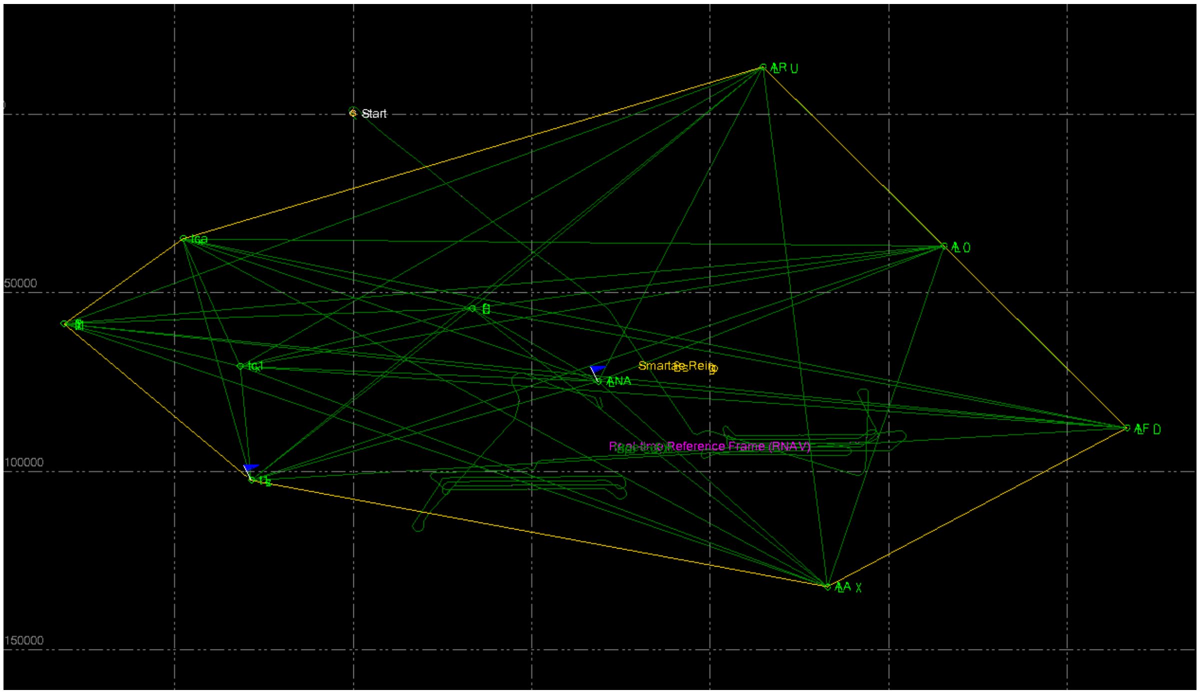
602,000
Time (sec)


Start
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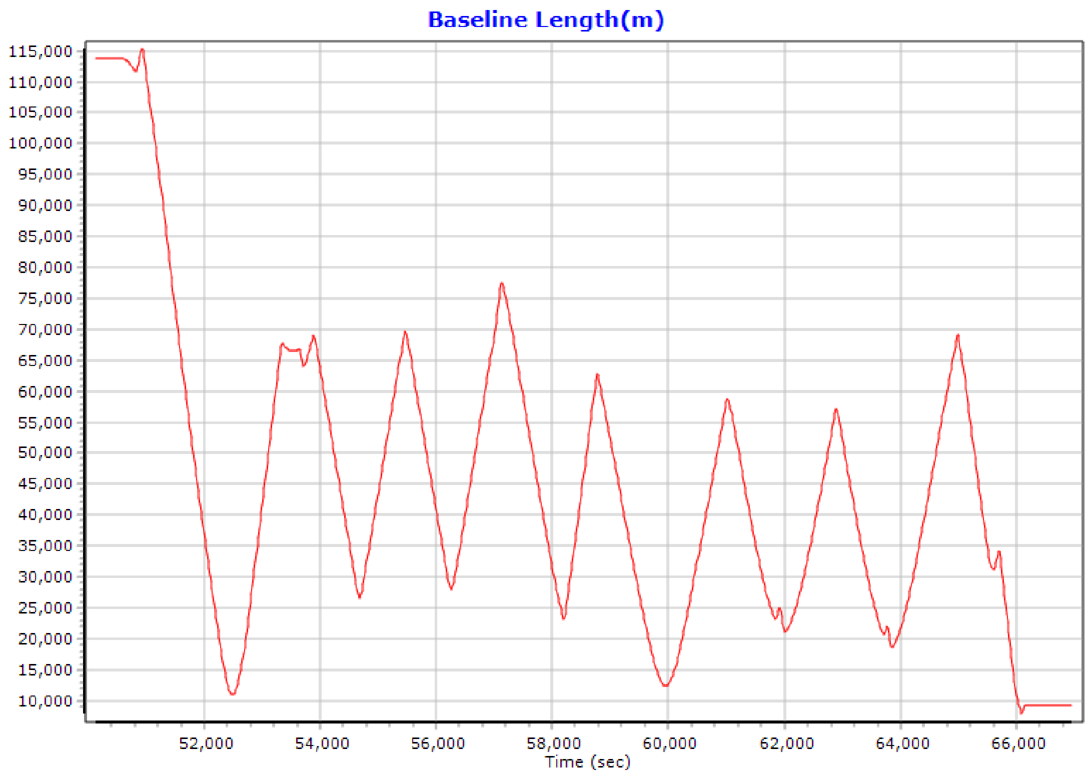
150000
ANA
Smartnet Ref
Real-time Reference Frame (RNAV)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110,000
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75,000
70,000
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35,000
30,000
25,000
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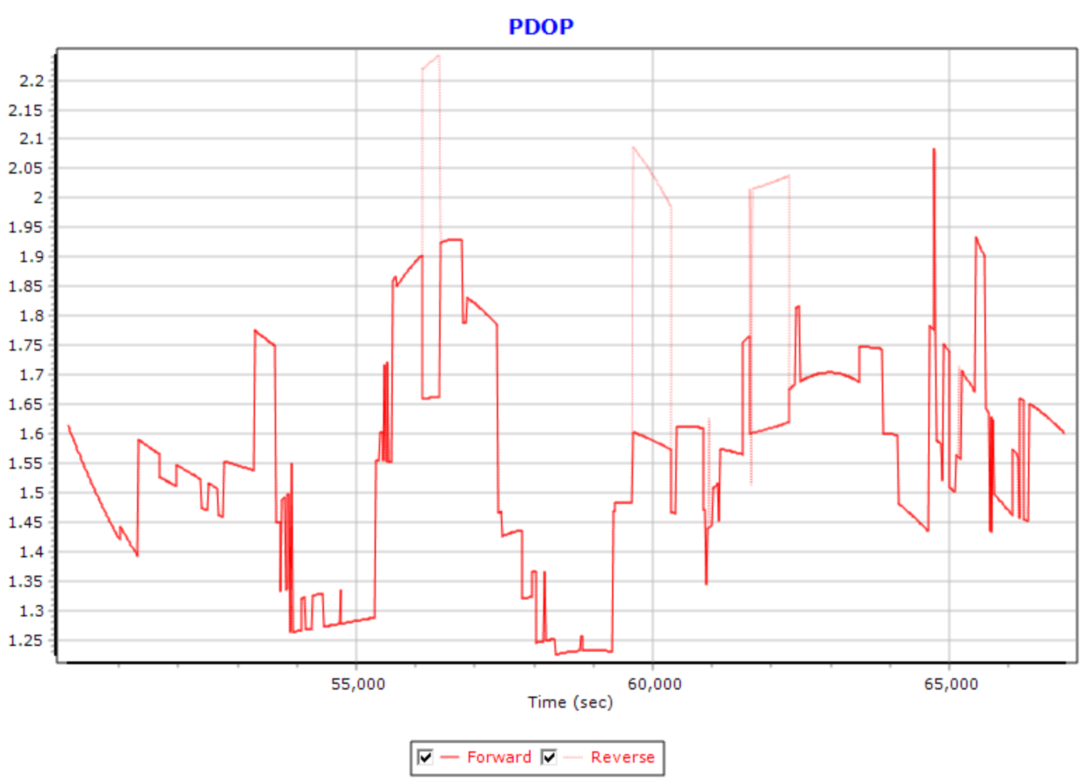
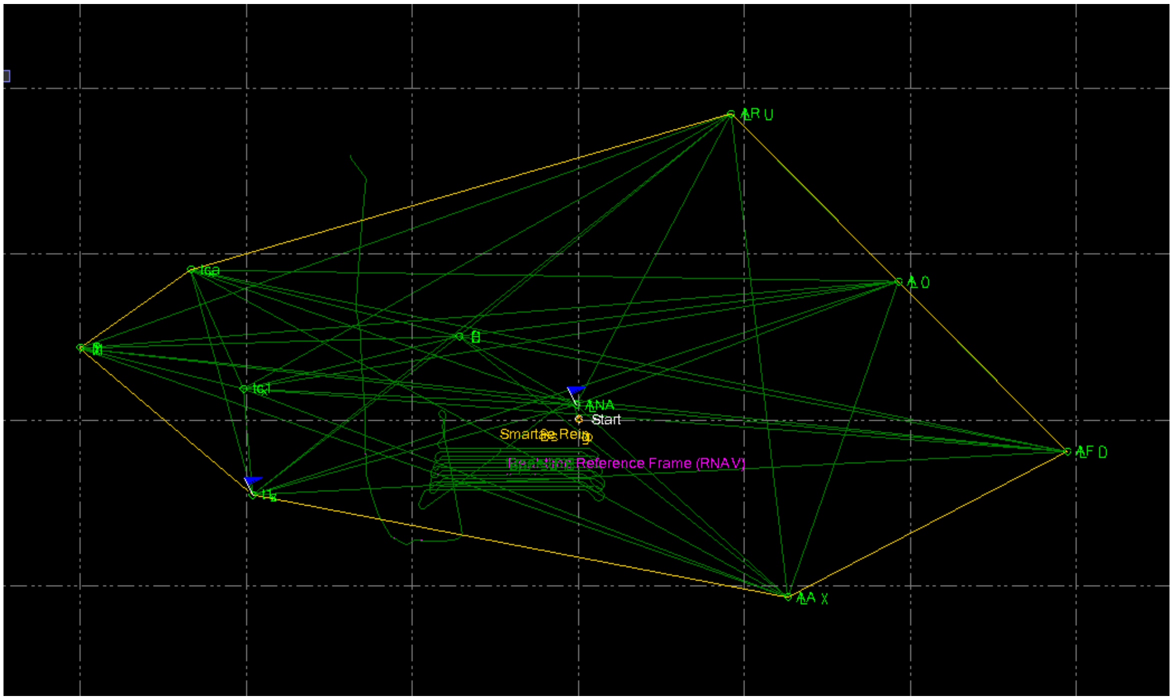
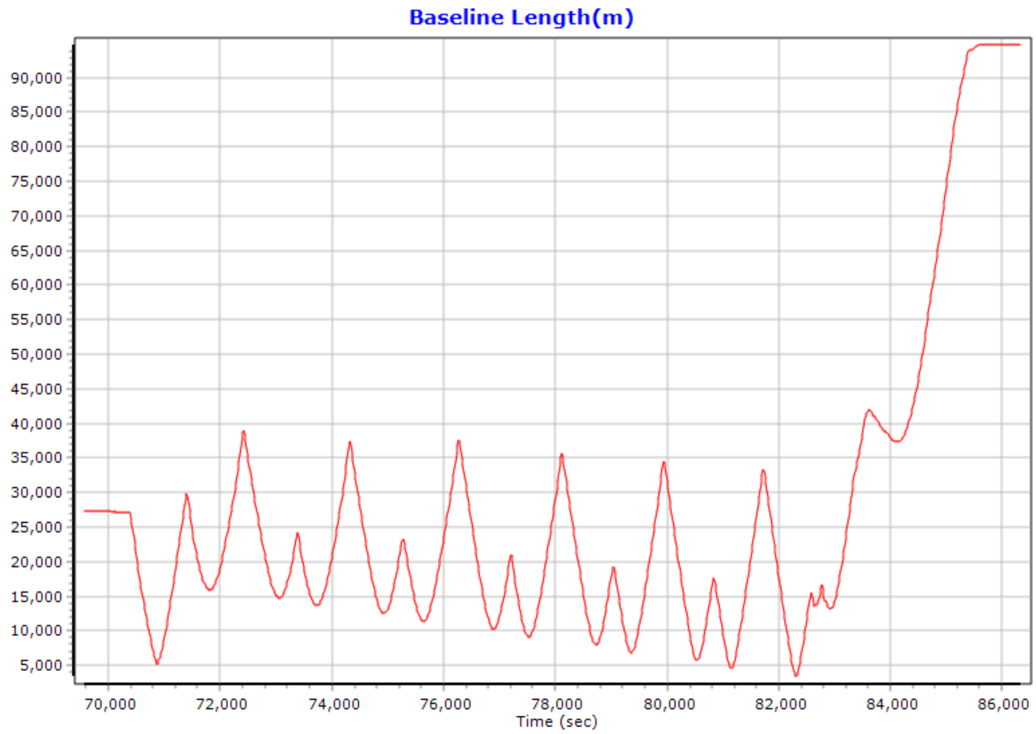
10,000
52,000
54,000
56,000
58,000
60,000
62,000
64,000
66,000
Time (sec)


PDOP
2.2
2.15
2.1
2.05
2
1.95
1.9
1.85
1.8
1.75
1.7
1.65
1.6
1.55
1.5
1.45
1.4
1.35
1.3
1.25
55,000
60,000
65,000
Time (sec)
Forward
Reverse

2SU18336B




Baseline Length(m)
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85,000
80,000
75,000
70,000
65,000
60,000
55,000
50,000
45,000
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35,000
30,000
25,000
20,000
15,000
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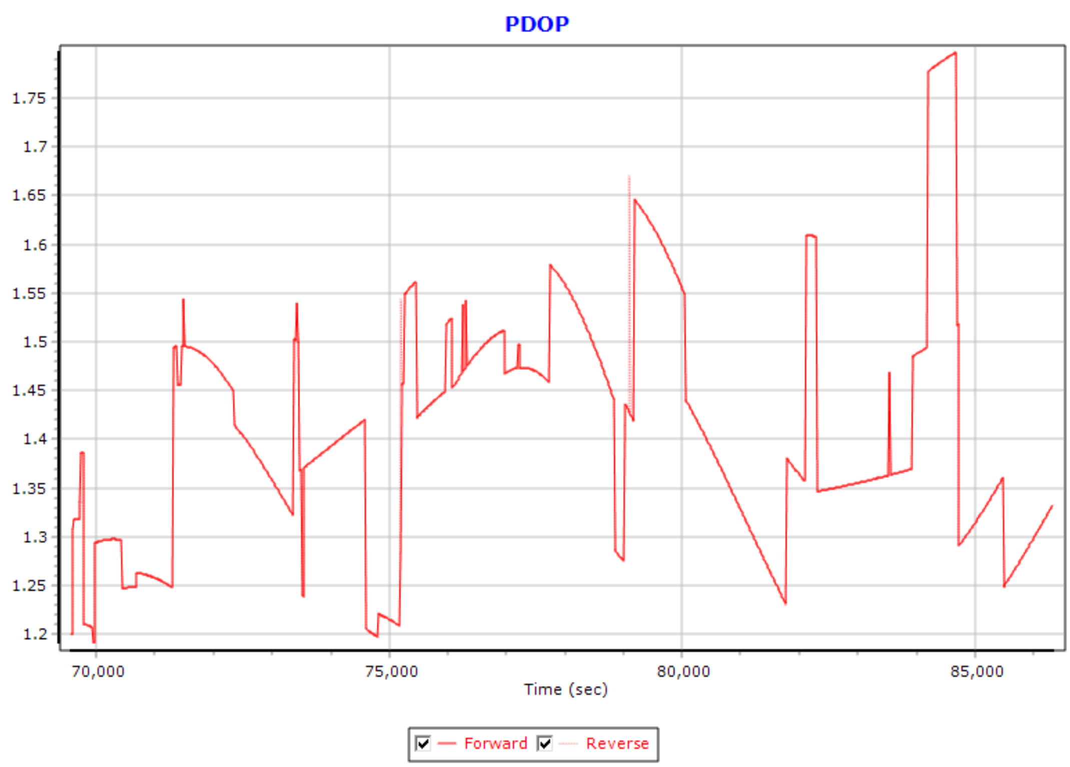
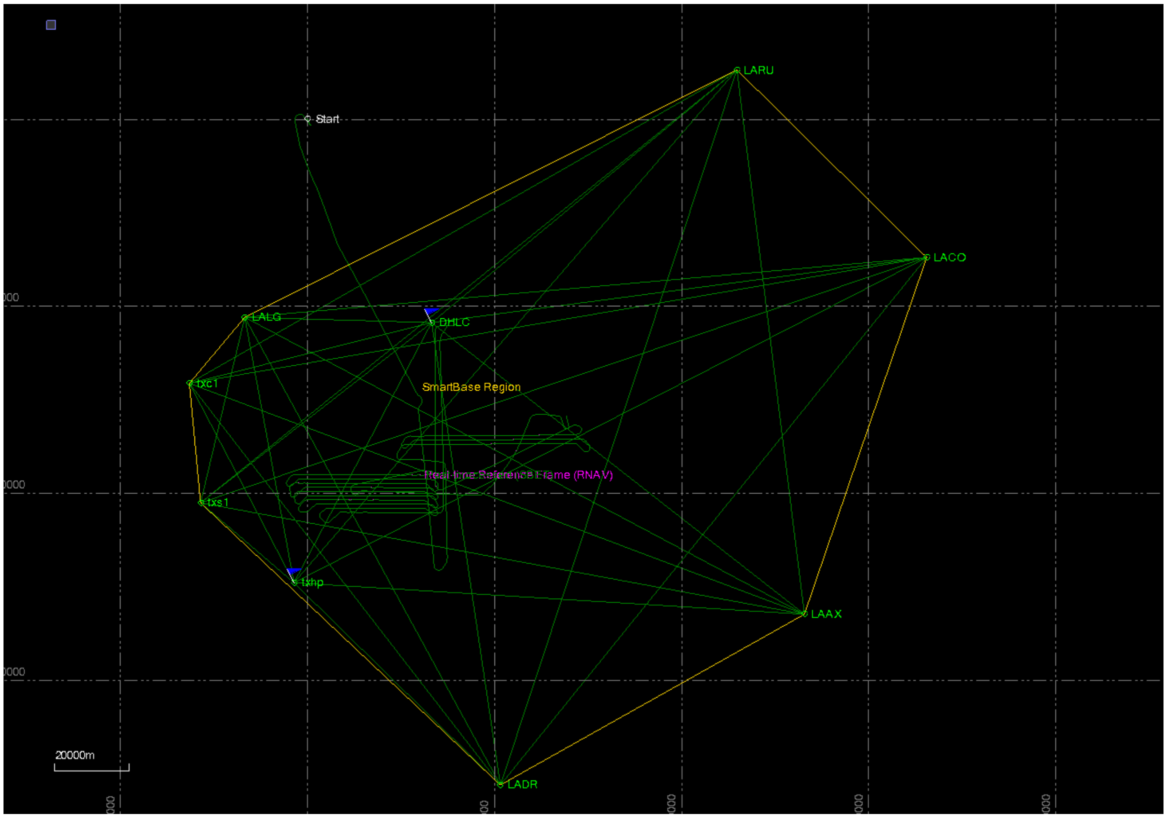
84,000
86,000
Time (sec)


PDOP
1.75
1.7
1.65
1.6
1.55
1.5
1.45
1.4
1.35
1.3
1.25
1.2
70,000
75,000
80,000
85,000
Time (sec)
Forward
Reverse

2SU18337A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LALG
DHLC
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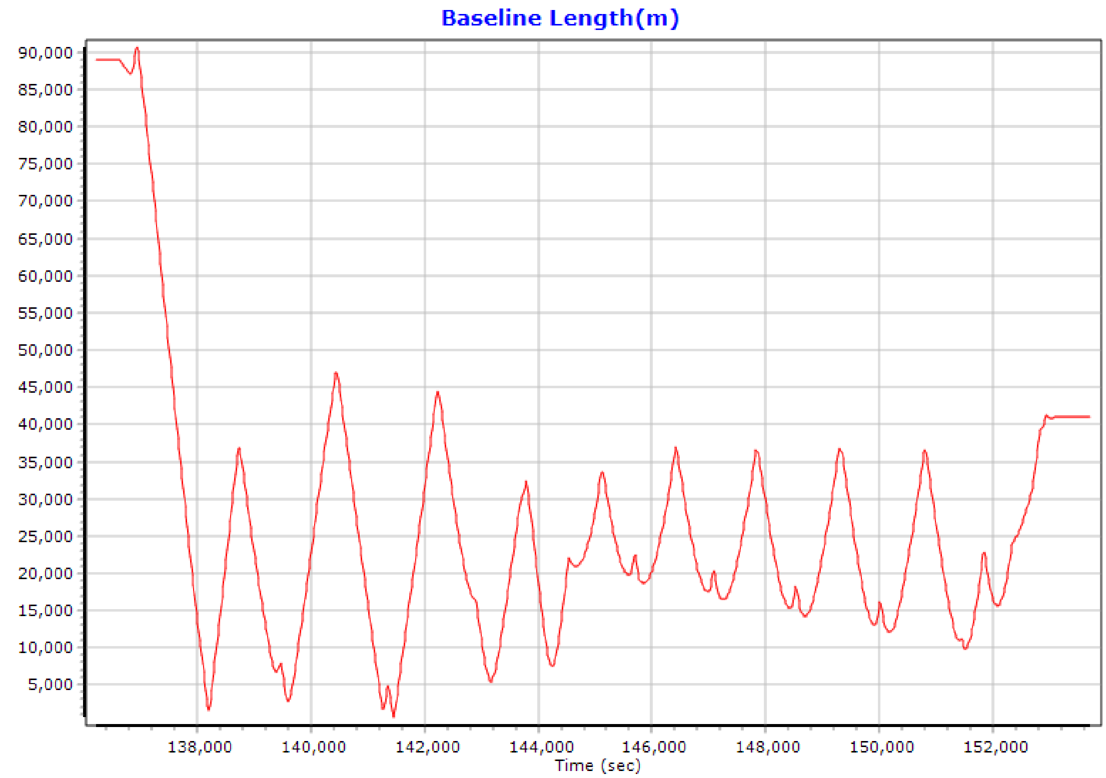
SmartBase Region
txs1
txhp
LAAX
20000m
LADR


Baseline Length(m)
90,000
85,000
80,000
75,000
70,000
65,000
60,000
55,000
50,000
45,000
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35,000
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20,000
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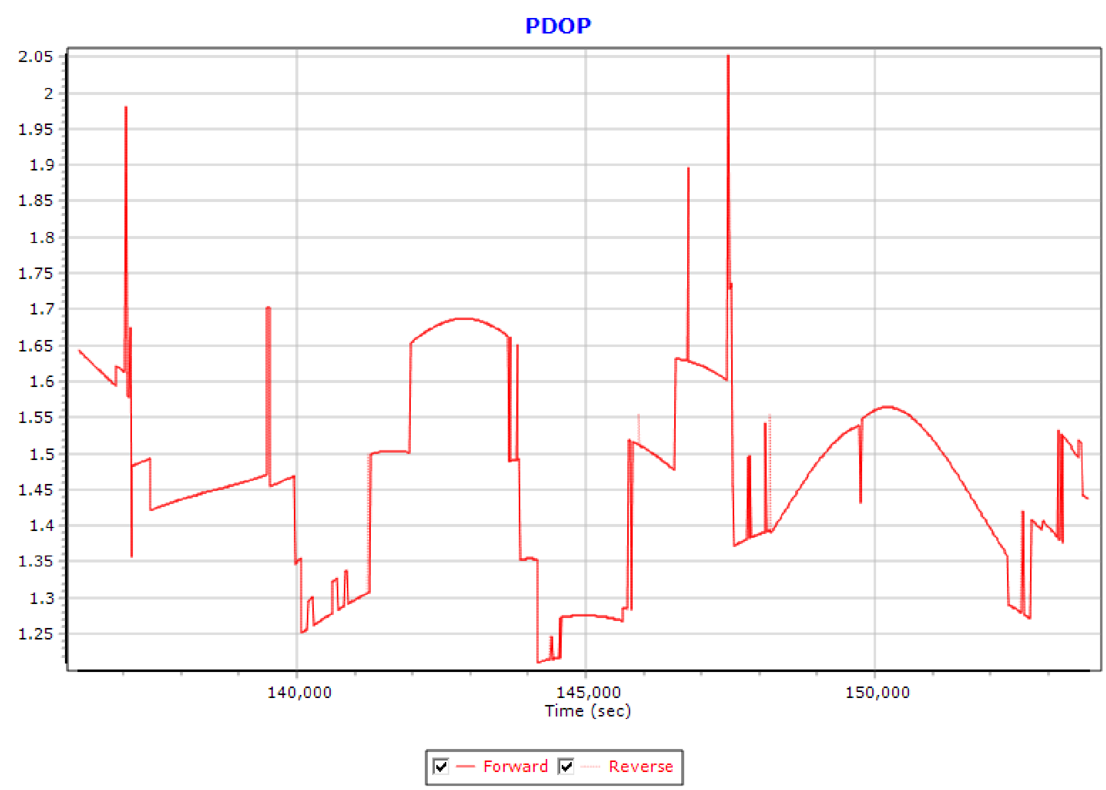
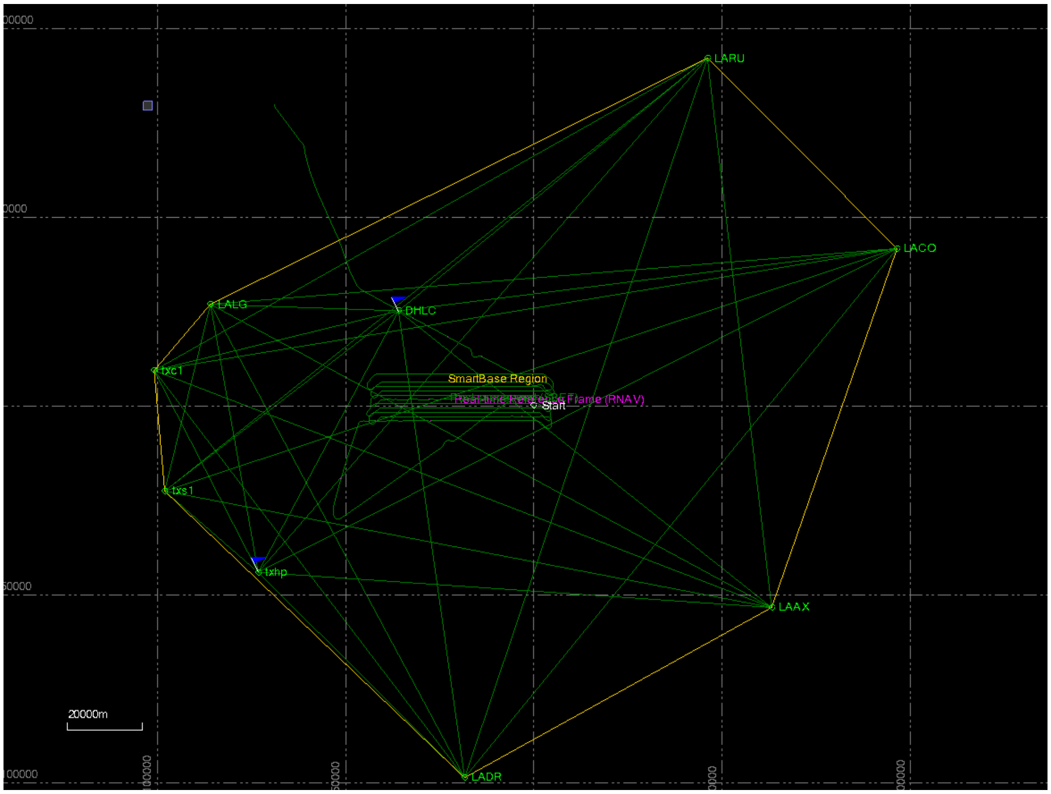
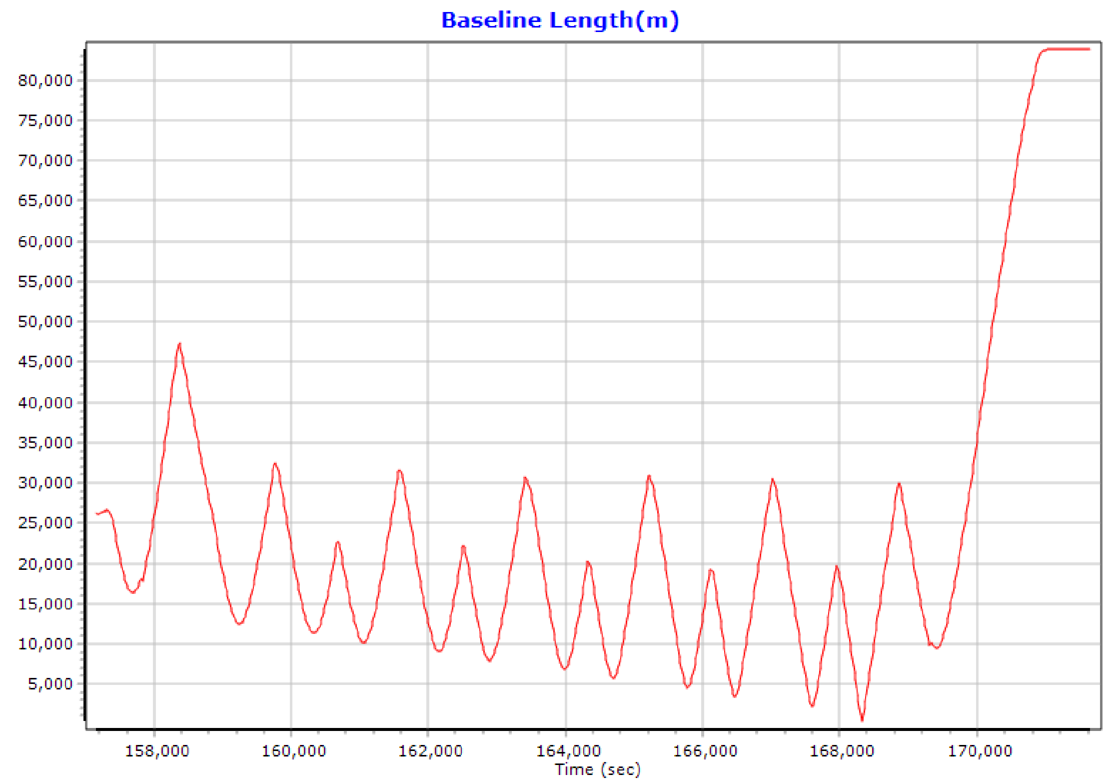
150,000
152,000
Time (sec)


PDOP
2.05
2
1.95
1.9
1.85
1.8
1.75
1.7
1.65
1.6
1.55
1.5
1.45
1.4
1.35
1.3
1.25
140,000
145,000
150,000
Time (sec)
Forward
Reverse

2SU18337B


LARU
LACQ
LALG
DHLC
txc1
SmartBase Region
Real-time Reference Frame (RNAV)
Start
txs1
txhp
LAAX
LADR
20000m


Baseline Length(m)
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75,000
70,000
65,000
60,000
55,000
50,000
45,000
40,000
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30,000
25,000
20,000
15,000
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5,000
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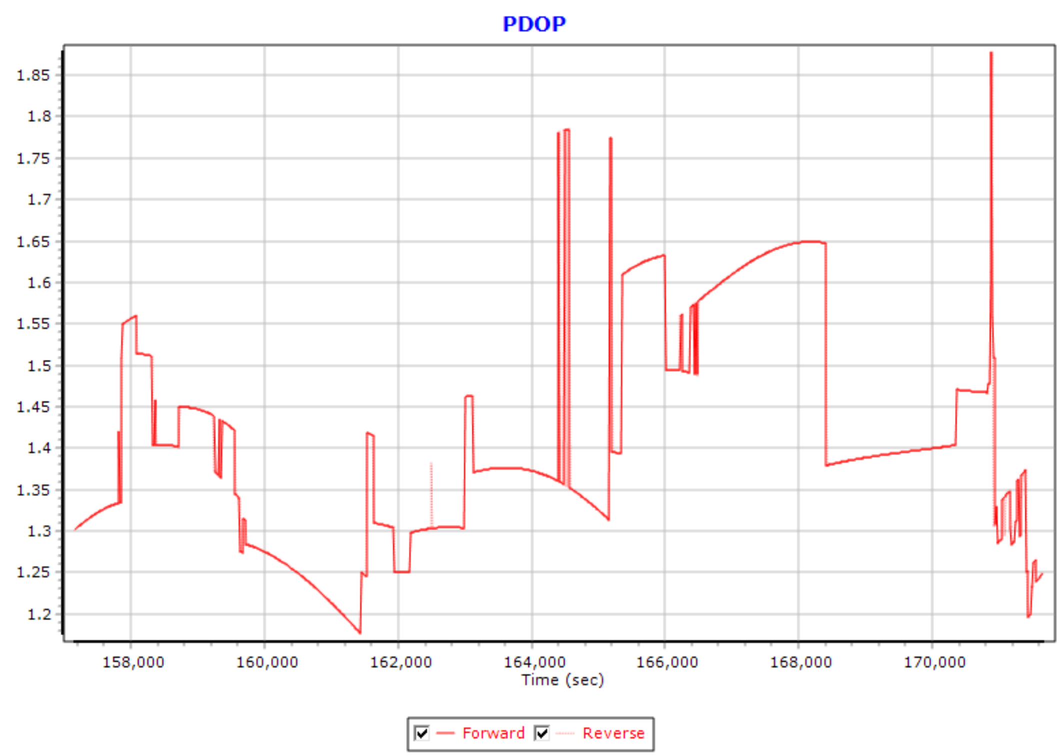
160,000
162,000
164,000
166,000
168,000
170,000
Time (sec)


PDOP
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1.75
1.7
1.65
1.6
1.55
1.5
1.45
1.4
1.35
1.3
1.25
1.2
158,000
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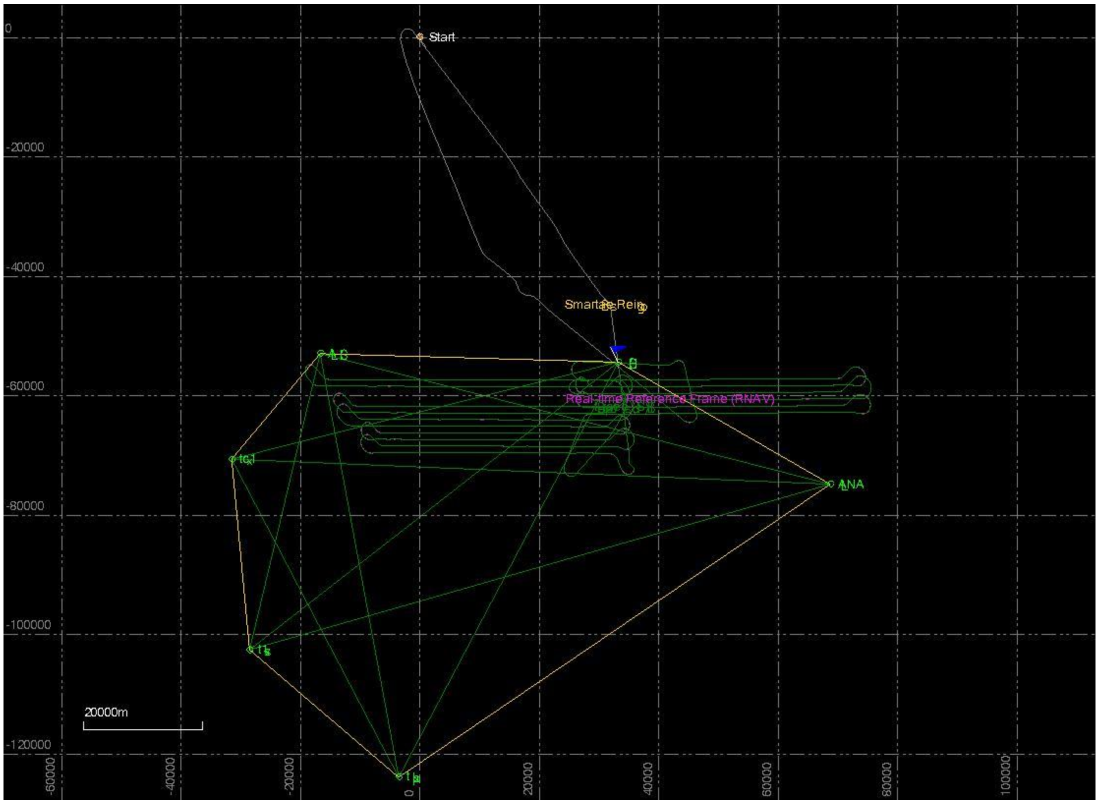
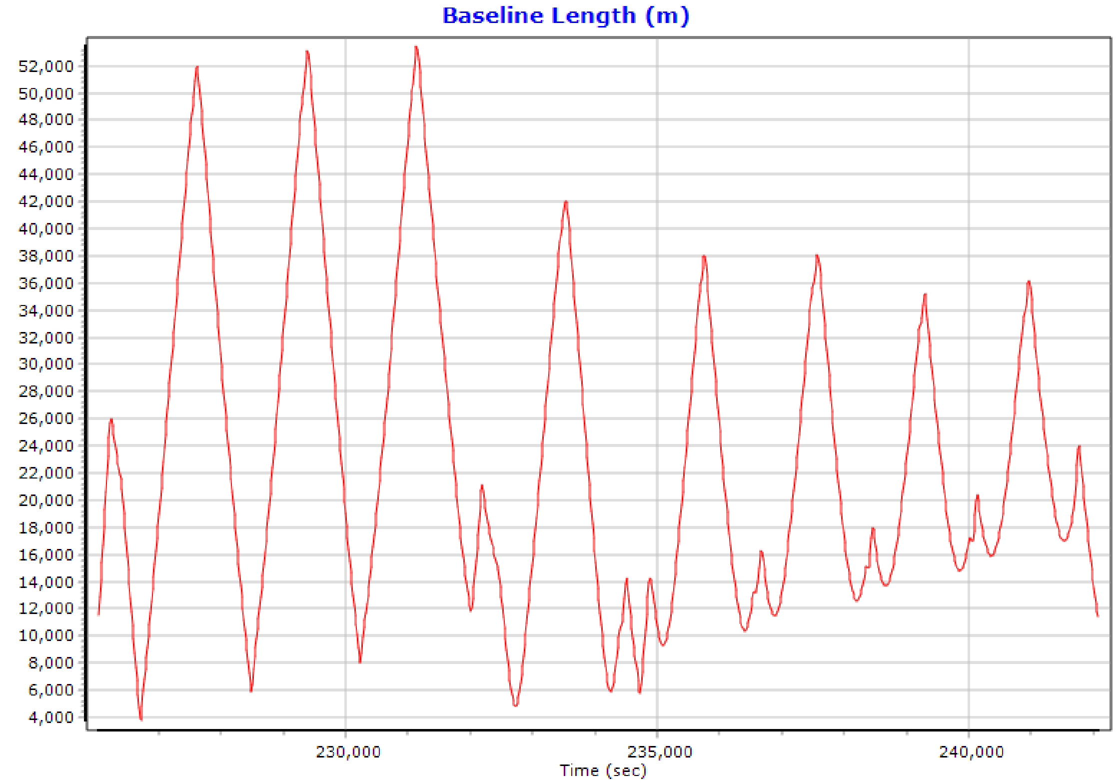
162,000
164,000
166,000
168,000
170,000
Time (sec)
Forward
Reverse

2SU18338A


Start
Smartbase Reie
Real-time Reference Frame (RNAV)
ANA
20000m
0
-20000
-40000
-60000
-80000
-100000
-120000
-60000
-40000
-20000
0
20000
40000
60000
80000
100000


Baseline Length (m)
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48,000
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44,000
42,000
40,000
38,000
36,000
34,000
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22,000
20,000
18,000
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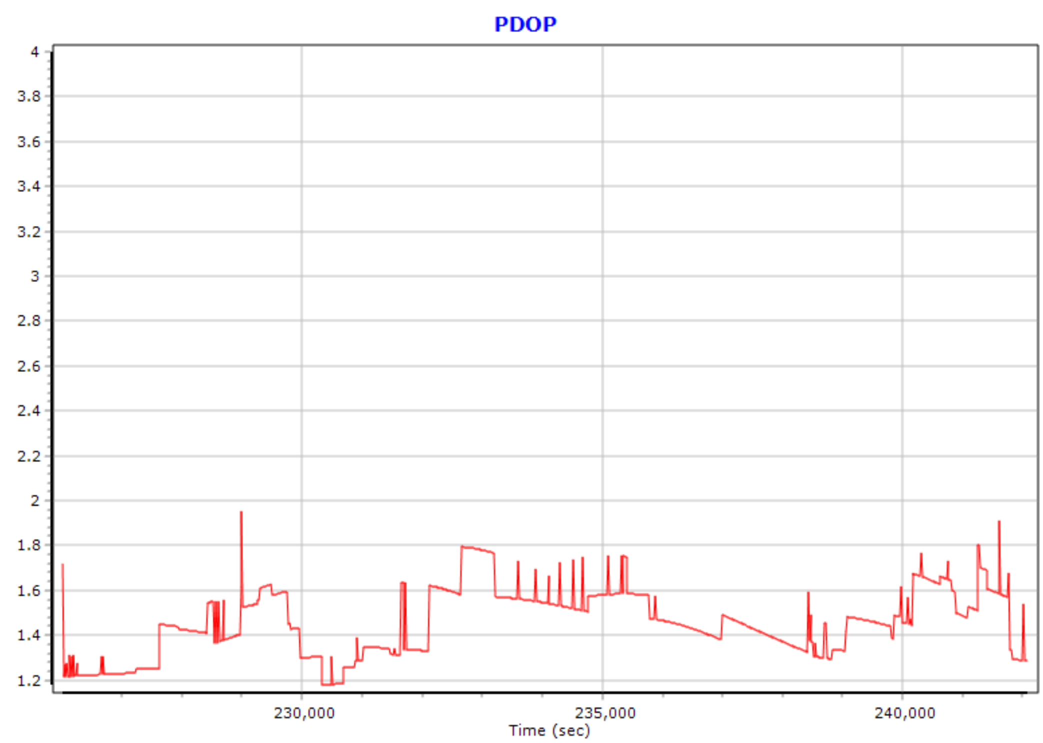
12,000
10,000
8,000
6,000
4,000
230,000
235,000
240,000
Time (sec)


PDOP
4
3.8
3.6
3.4
3.2
3
2.8
2.6
2.4
2.2
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1.8
1.6
1.4
1.2
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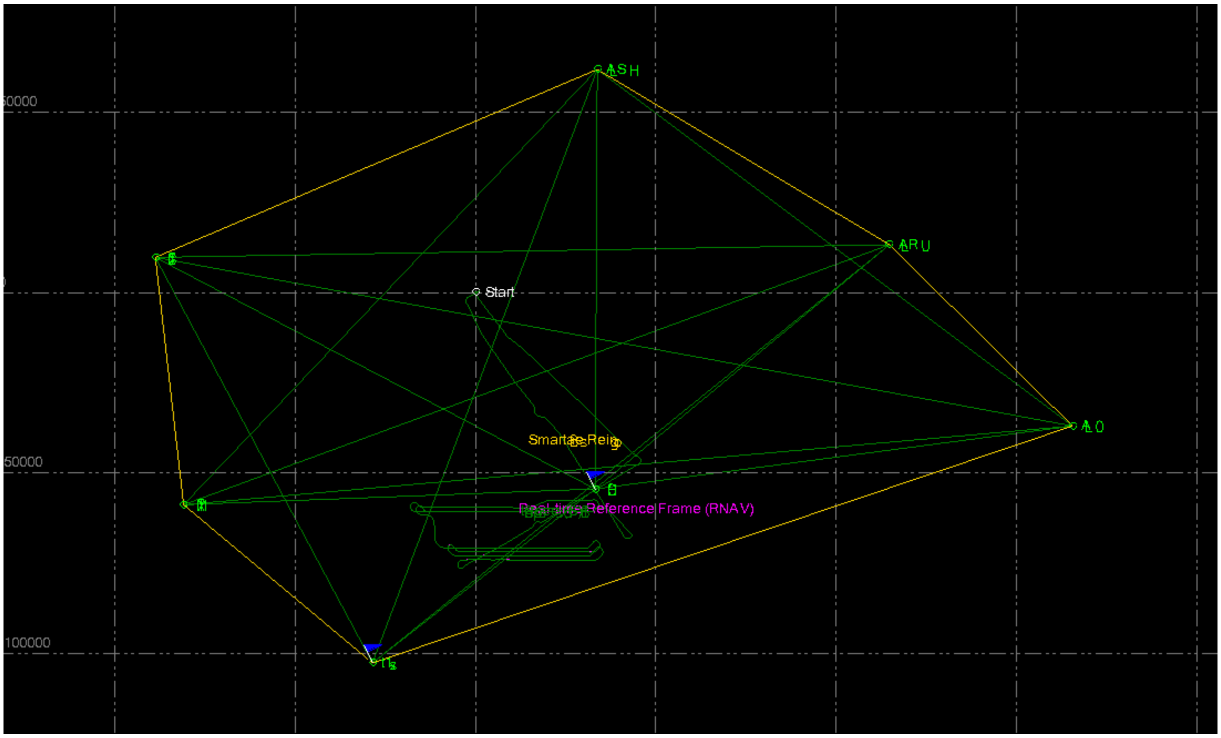
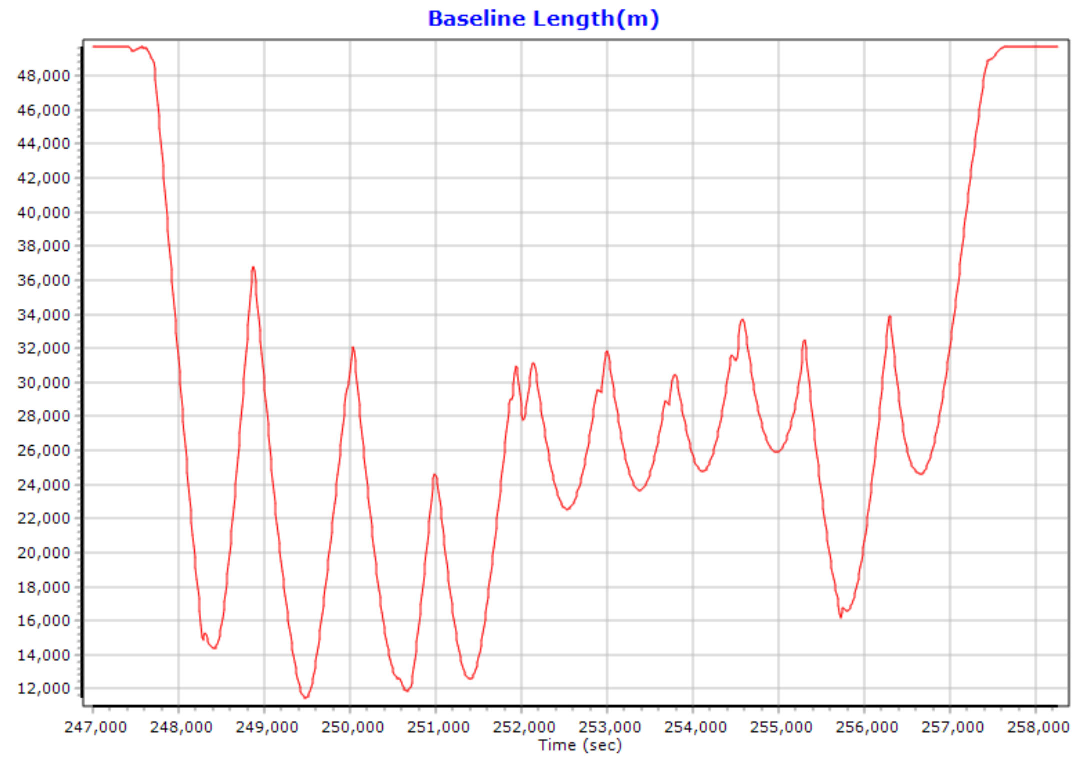
235,000
240,000
Time (sec)

2SU18338B


ASH
ARU
Start
LO
Smartsel Reig
B
Real-time Reference Frame (RNAV)
100000


Baseline Length(m)
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46,000
44,000
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40,000
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32,000
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12,000
247,000
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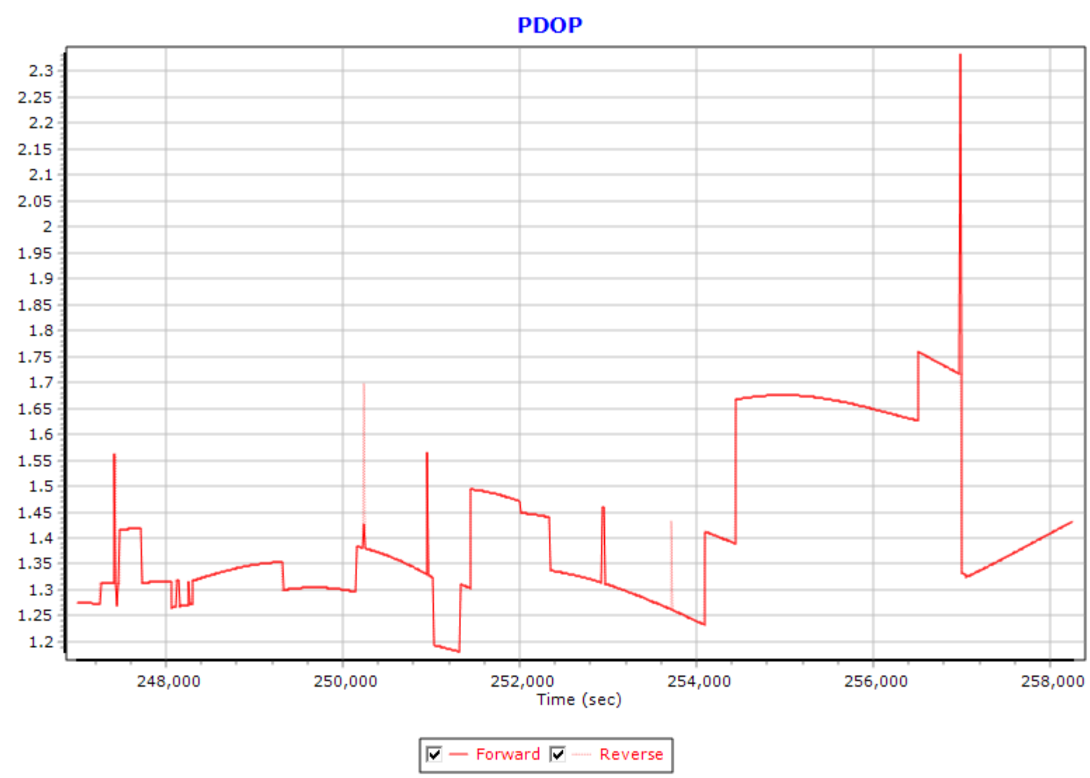
257,000
258,000
Time (sec)


PDOP
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2.25
2.2
2.15
2.1
2.05
2
1.95
1.9
1.85
1.8
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1.7
1.65
1.6
1.55
1.5
1.45
1.4
1.35
1.3
1.25
1.2
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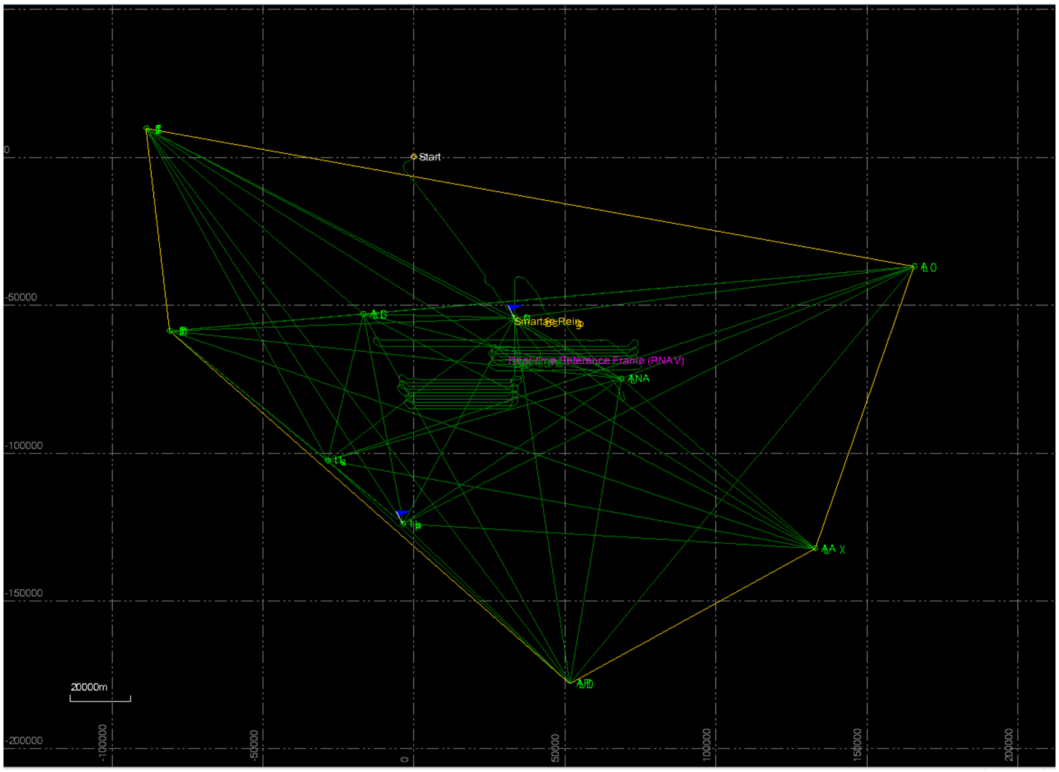
250,000
252,000
254,000
256,000
258,000
Time (sec)
Forward
Reverse

2SU18339A


Start
Real-time Reference Frame (RNAV)
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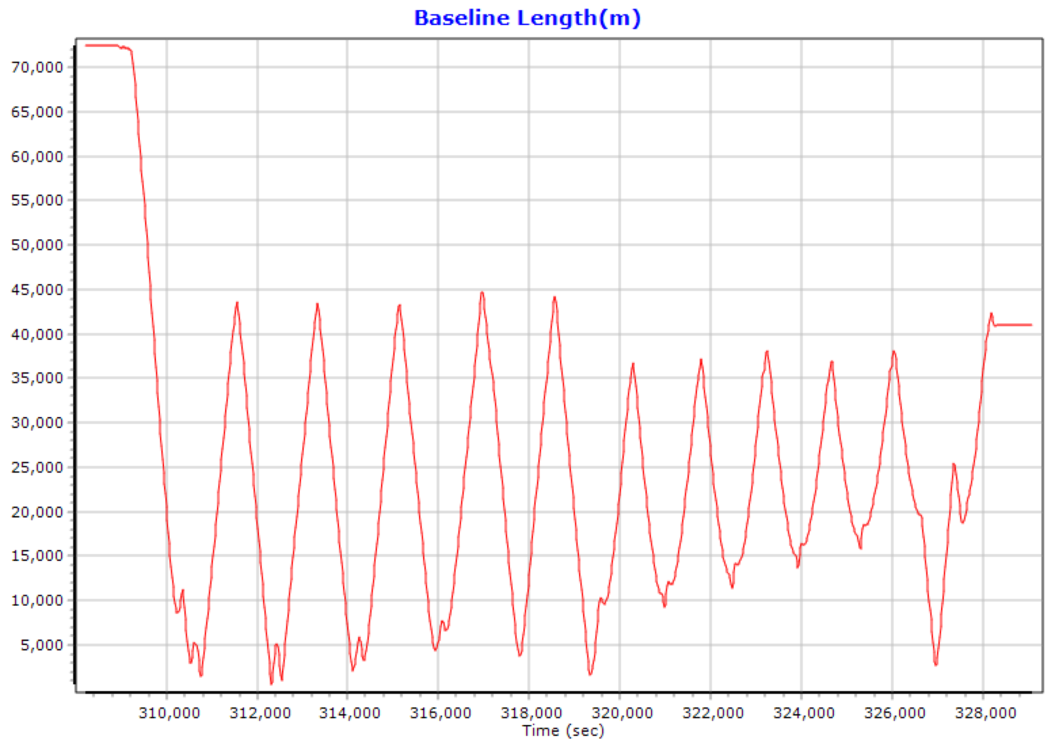
-200000
-100000
-50000
0
50000
100000
150000
200000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50,000
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40,000
35,000
30,000
25,000
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15,000
10,000
5,000
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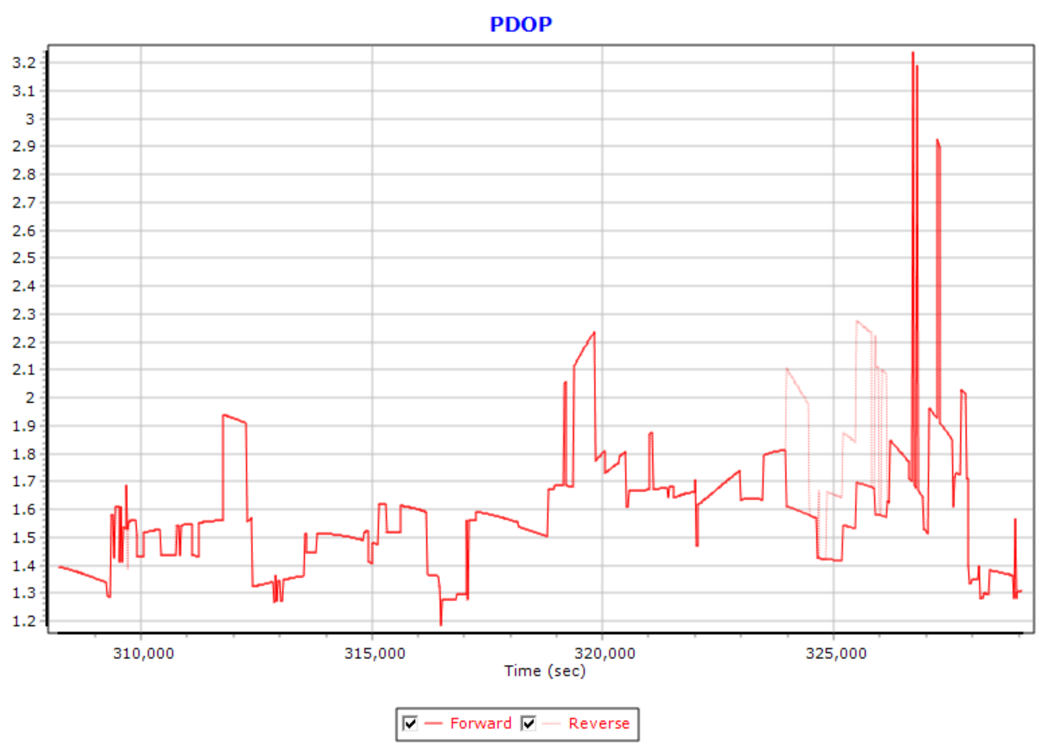
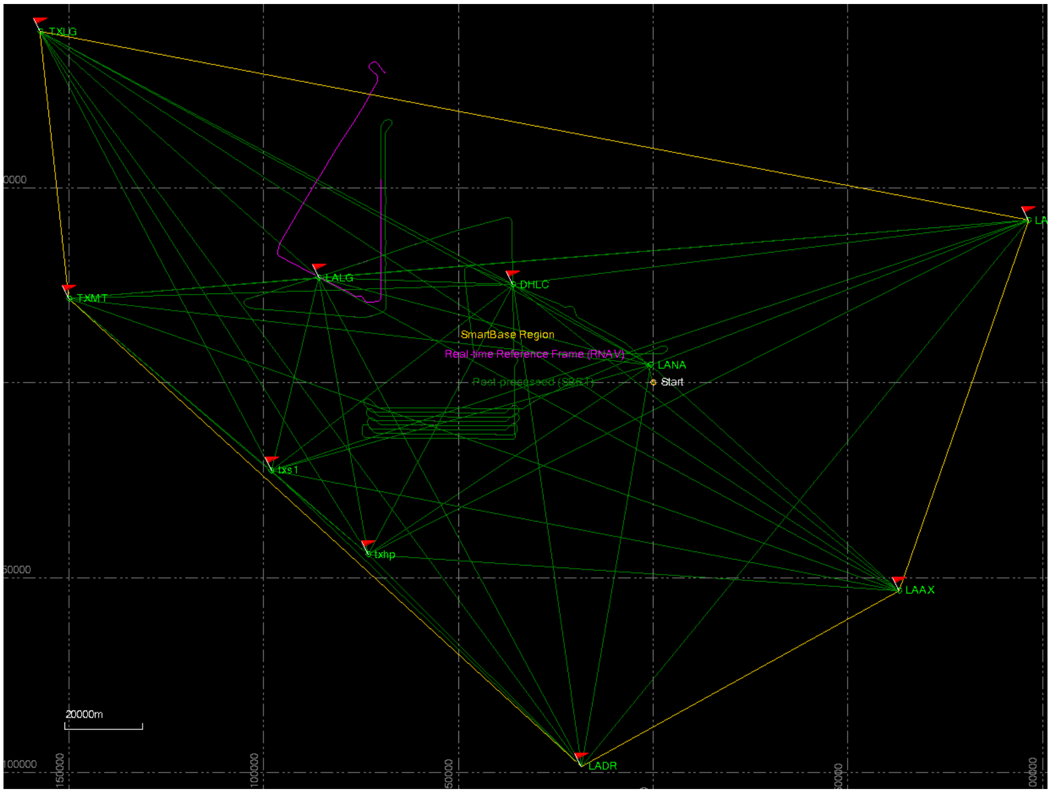
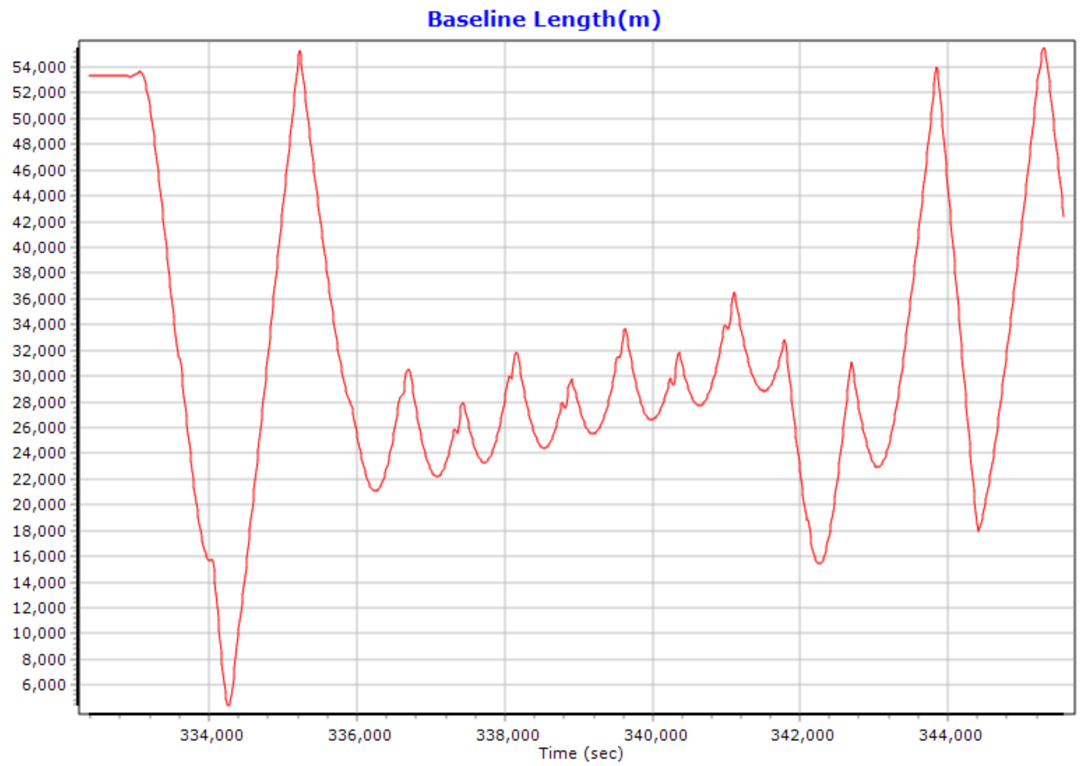
318,000
320,000
322,000
324,000
326,000
328,000
Time (sec)


PDOP
3.2
3.1
3
2.9
2.8
2.7
2.6
2.5
2.4
2.3
2.2
2.1
2
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
310,000
315,000
320,000
325,000
Time (sec)
Forward
Reverse

2SU18339B


TXLG
TXMT
LALG
DHLC
LANA
Start
SmartBase Region
Real-time Reference Frame (RNAV)
Post-processed (SBET)
tx61
Txhp
LAAX
LADR
20000m


Baseline Length(m)
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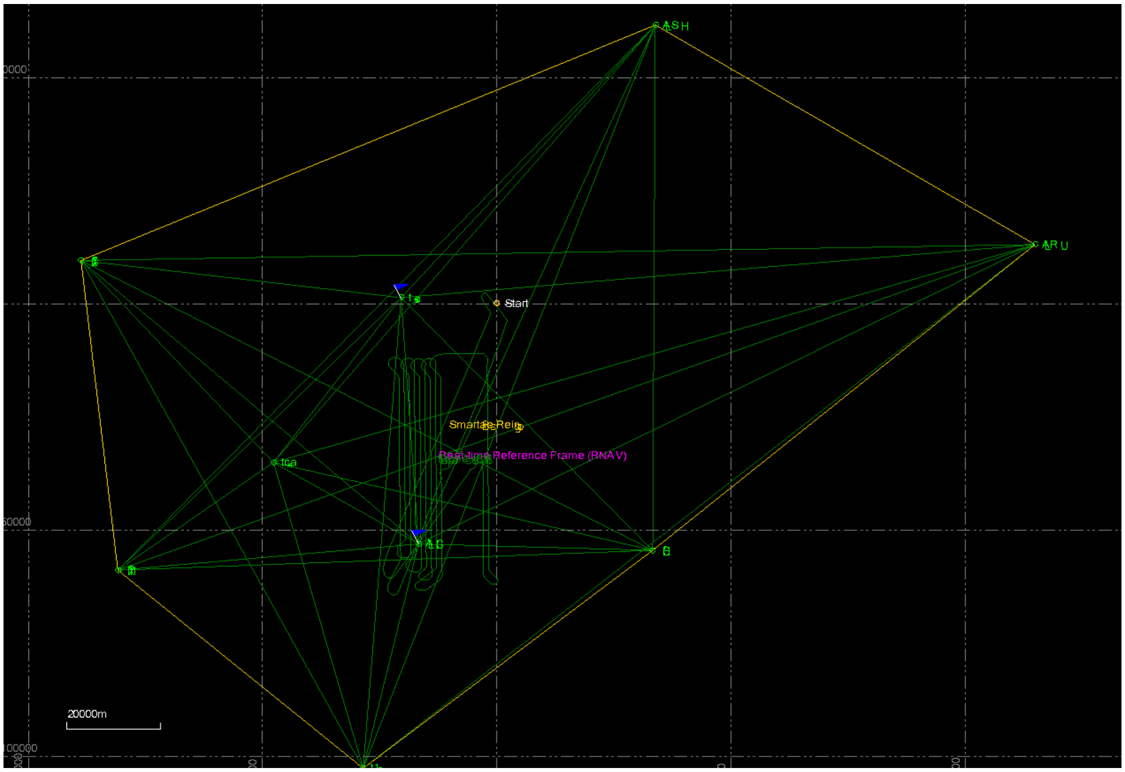
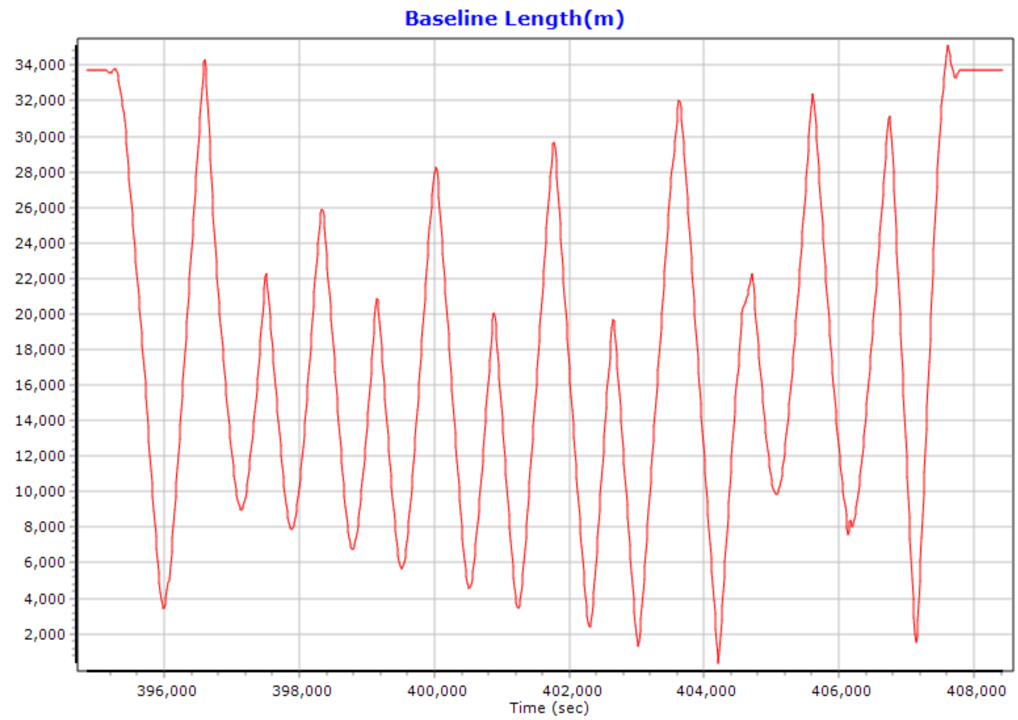
18,000
16,000
14,000
12,000
10,000
8,000
6,000
334,000
336,000
338,000
340,000
342,000
344,000
Time (sec)


PDOP
1.7
1.65
1.6
1.55
1.5
1.45
1.4
1.35
1.3
1.25
1.2
334,000
336,000
338,000
340,000
342,000
344,000
Time (sec)
Forward
Reverse

2SU18340A


ASH
ARU
Start
Smart Base Rein
Real-time Reference Frame (RNAV)
B
20000m


Baseline Length(m)
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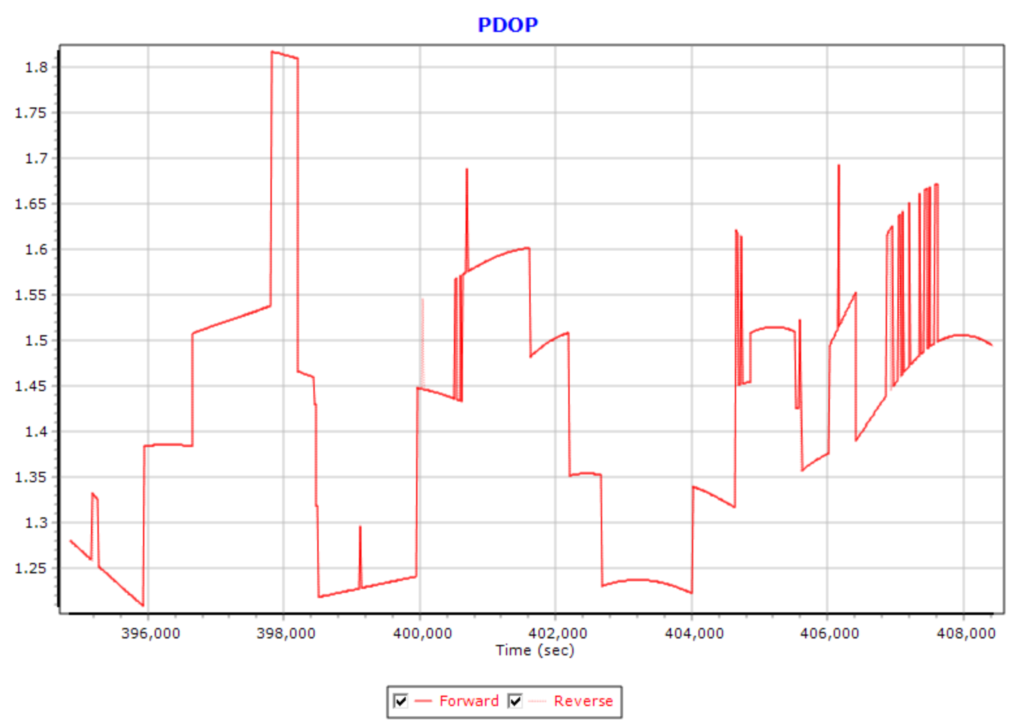
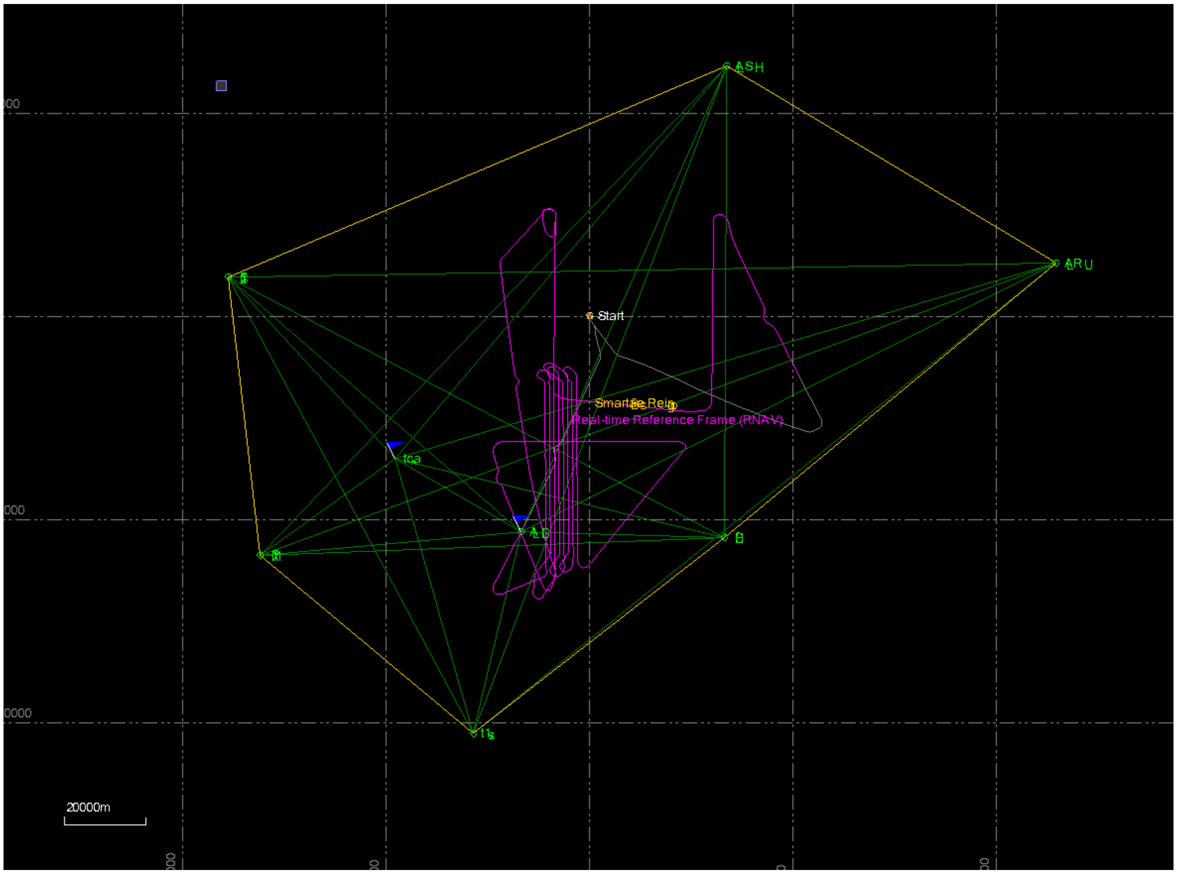
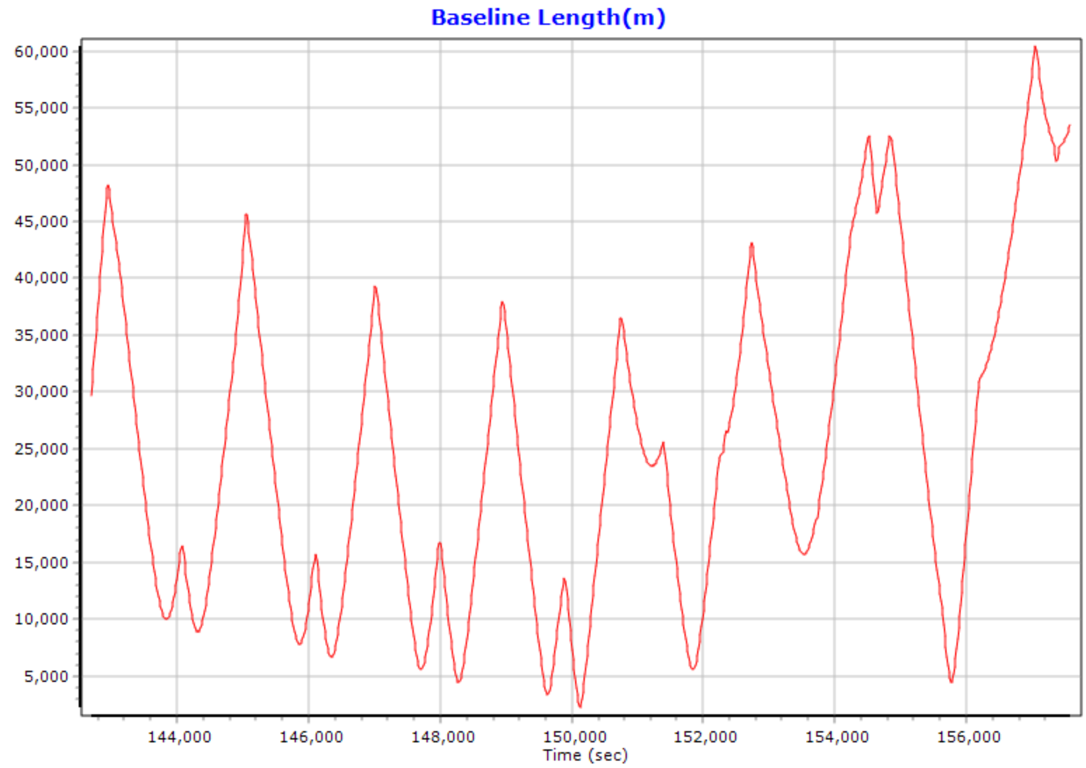
12,000
10,000
8,000
6,000
4,000
2,000
396,000
398,000
400,000
402,000
404,000
406,000
408,000
Time (sec)


PDOP
1.8
1.75
1.7
1.65
1.6
1.55
1.5
1.45
1.4
1.35
1.3
1.25
396,000
398,000
400,000
402,000
404,000
406,000
408,000
Time (sec)
Forward
Reverse

2SU18344A


ASH
ARU
Start
SmartBase Ref
Real-time Reference Frame (RNAV)
tca
B
20000m


Baseline Length(m)
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50,000
45,000
40,000
35,000
30,000
25,000
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15,000
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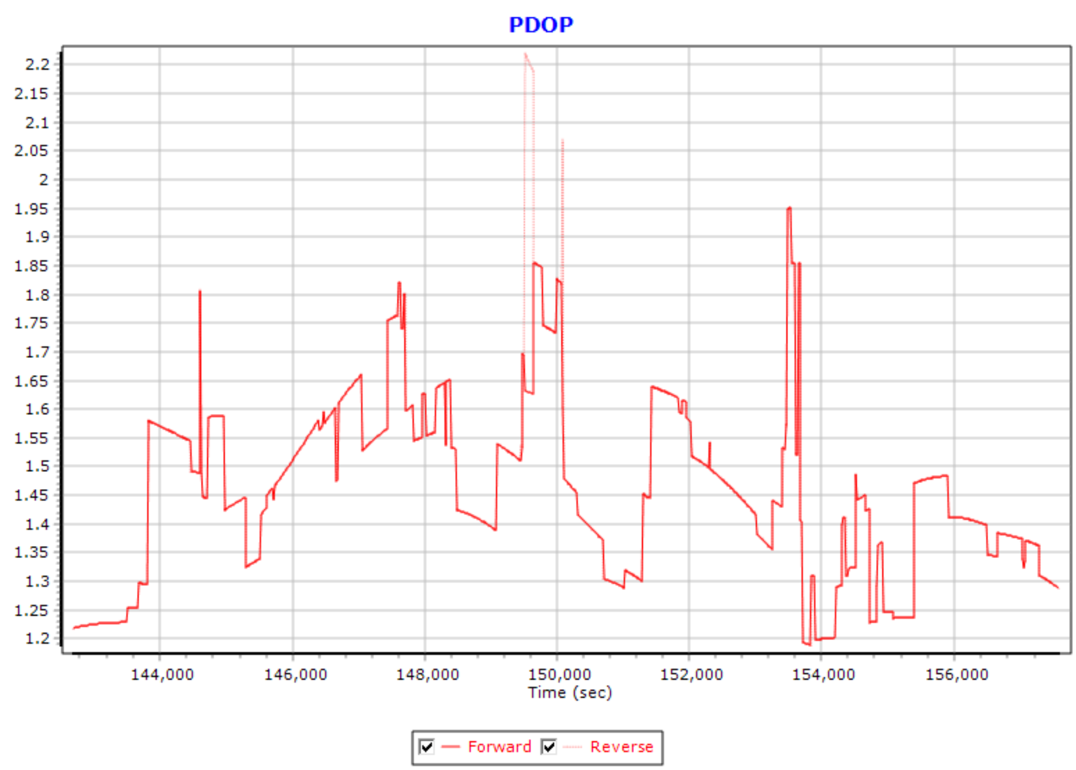
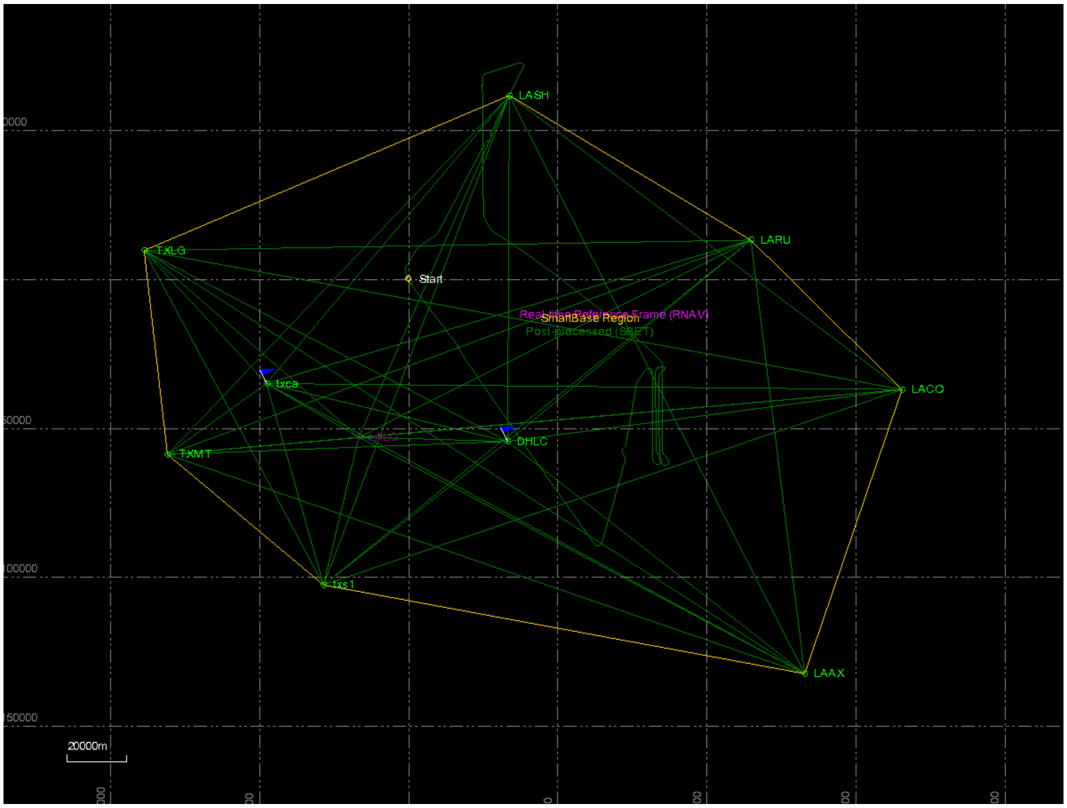
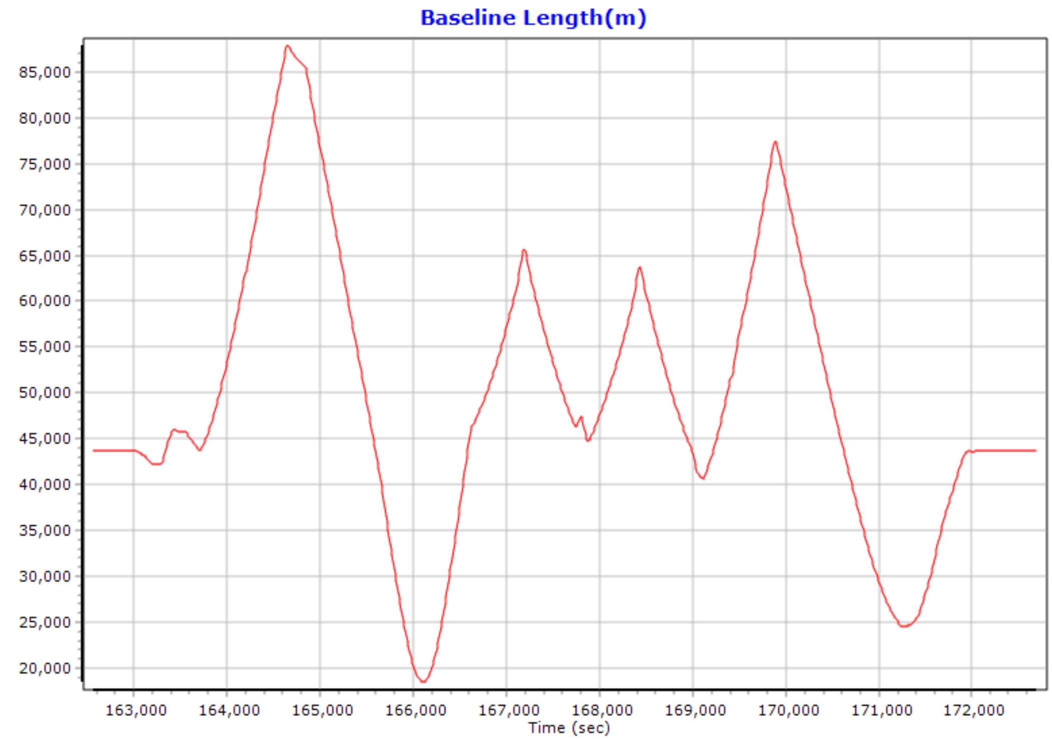
154,000
156,000
Time (sec)


PDOP
2.2
2.15
2.1
2.05
2
1.95
1.9
1.85
1.8
1.75
1.7
1.65
1.6
1.55
1.5
1.45
1.4
1.35
1.3
1.25
1.2
144,000
146,000
148,000
150,000
152,000
154,000
156,000
Time (sec)
Forward
Reverse

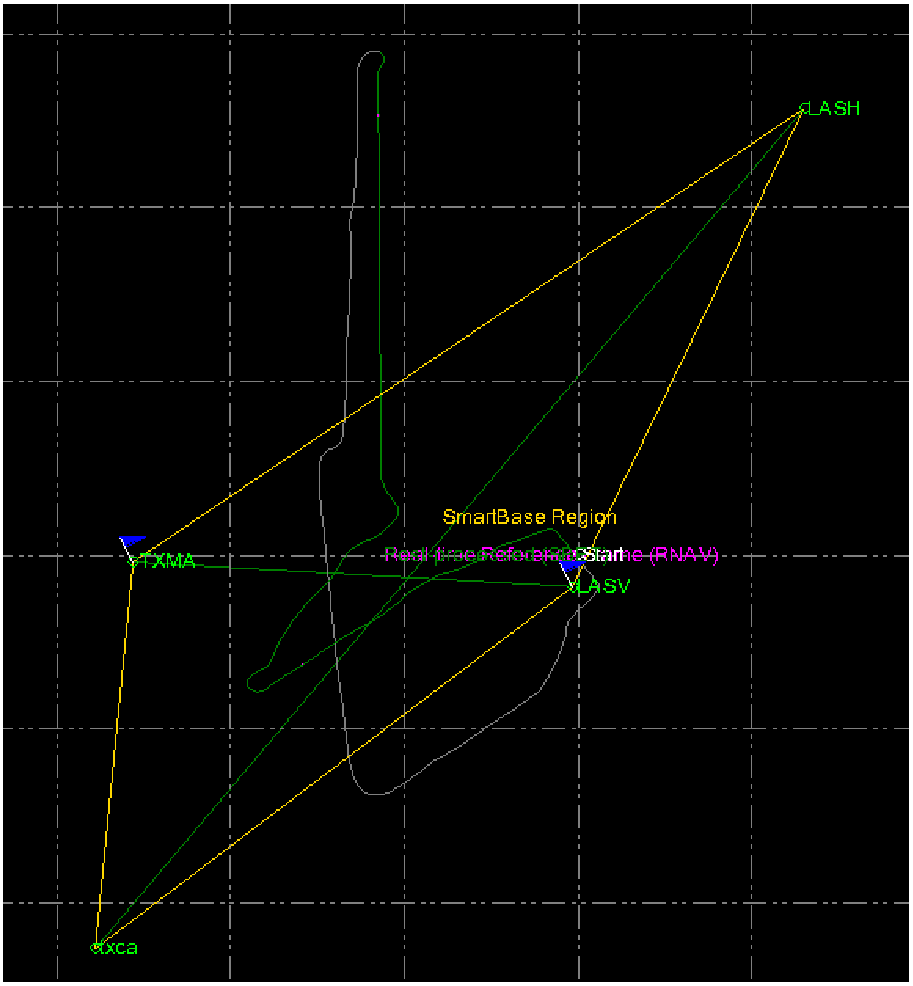
2SU18344B

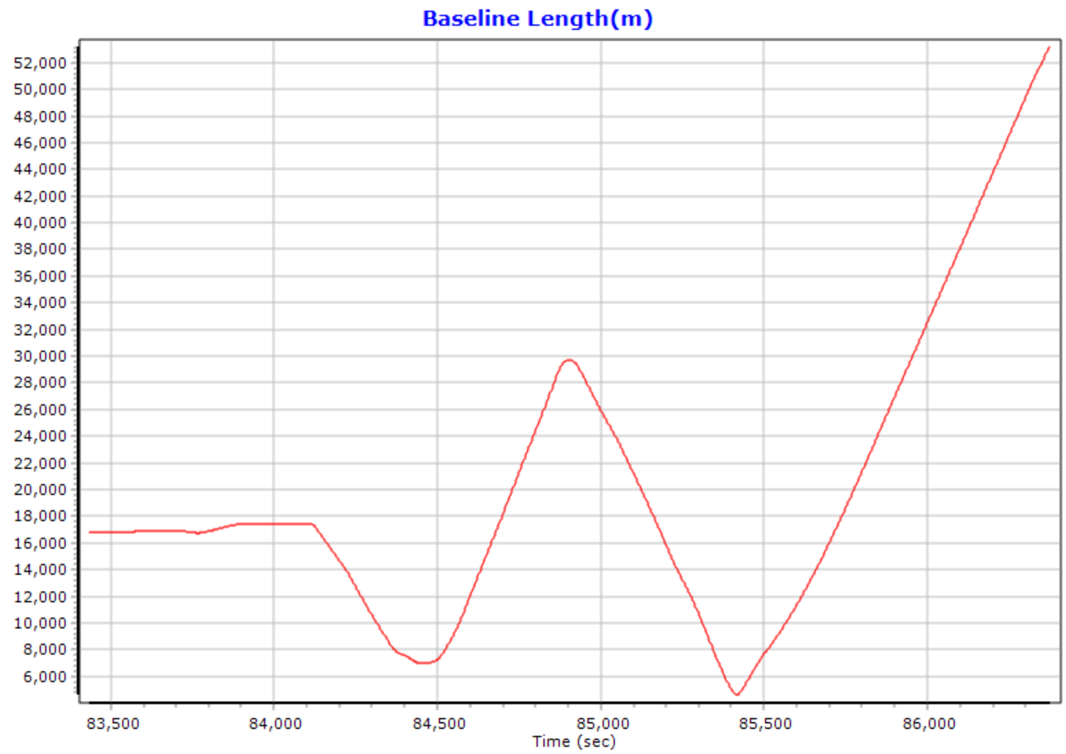

LASH
LARU
TXLG
Start
Real-time Reference Frame (RNAV)
SmartBase Region
Post-processed (SBET)
LACO
txca
DHLC
TXMT
txs1
LAAX
20000m

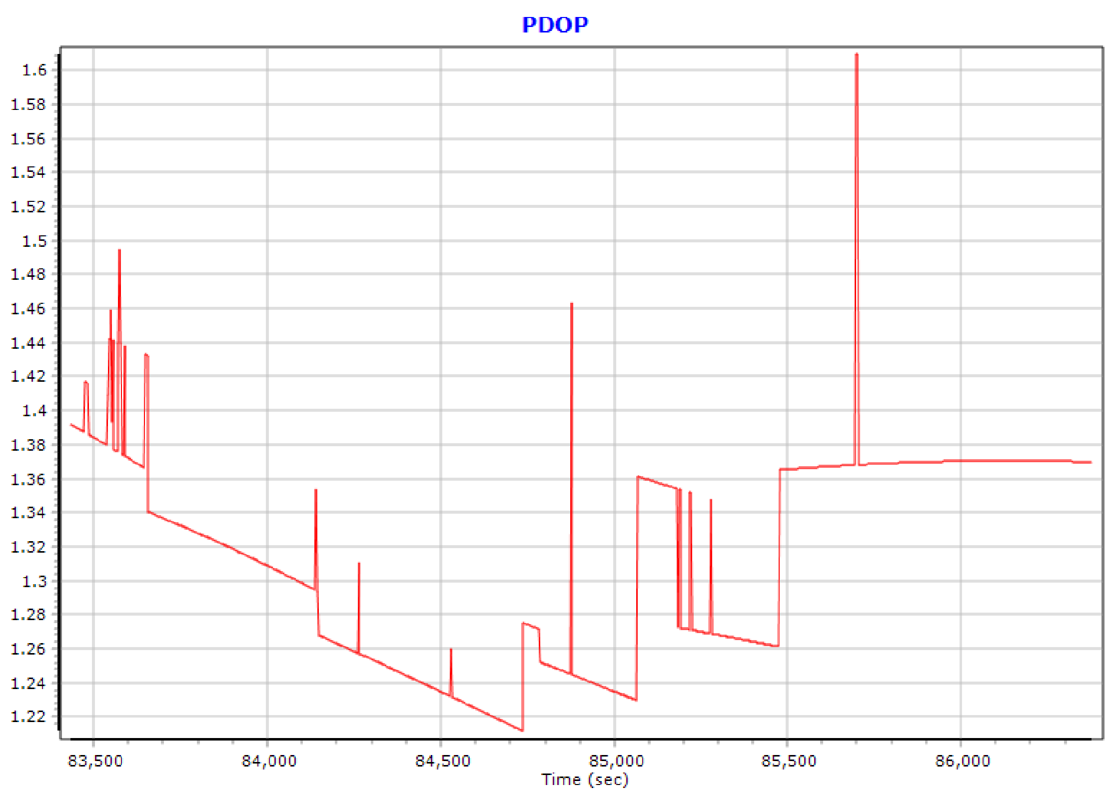


Sensor Errors

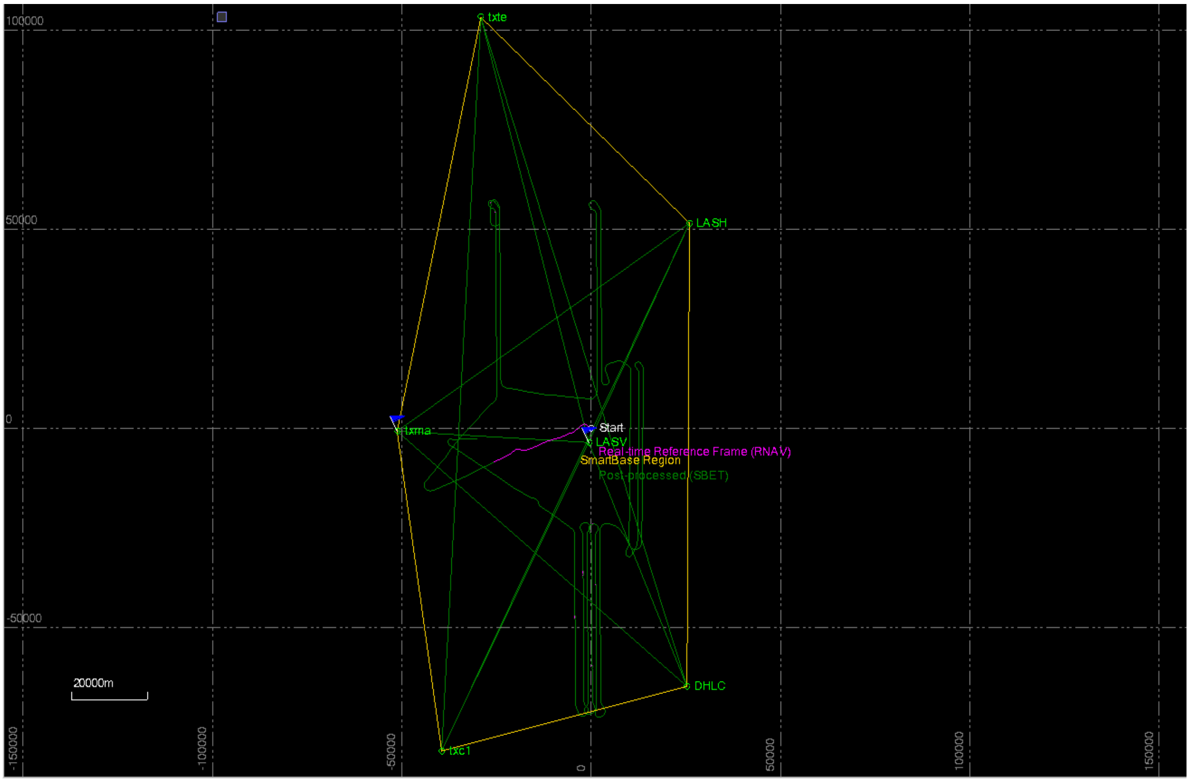
PTG18048A

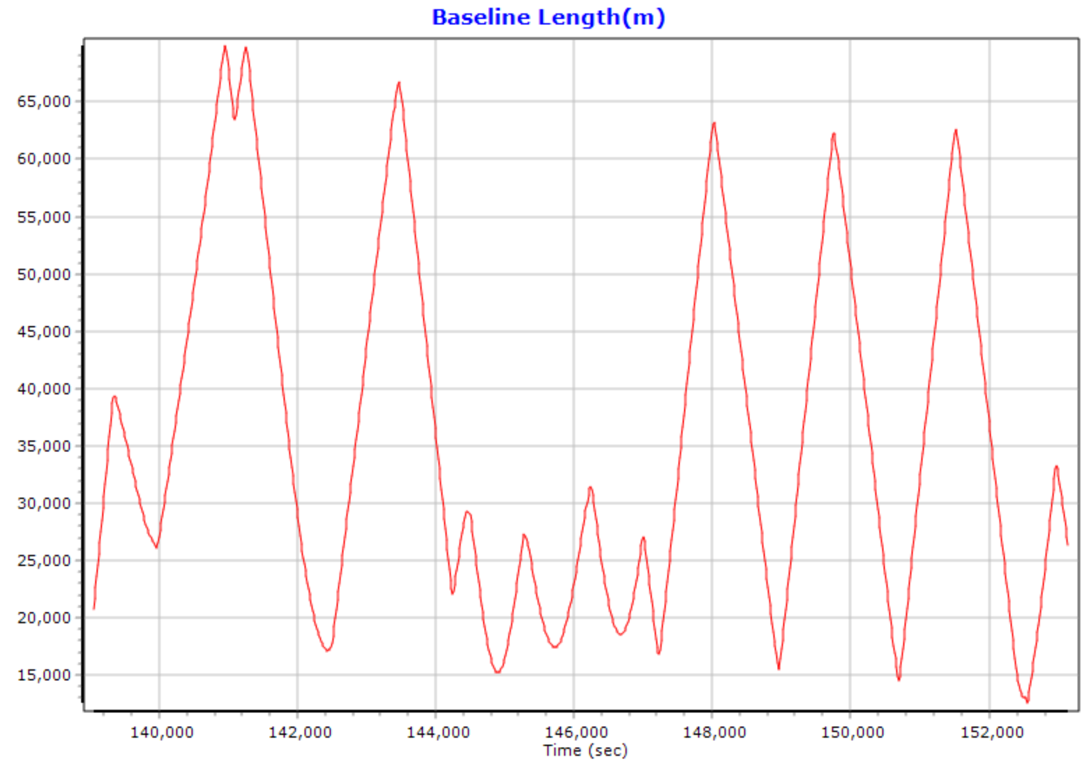


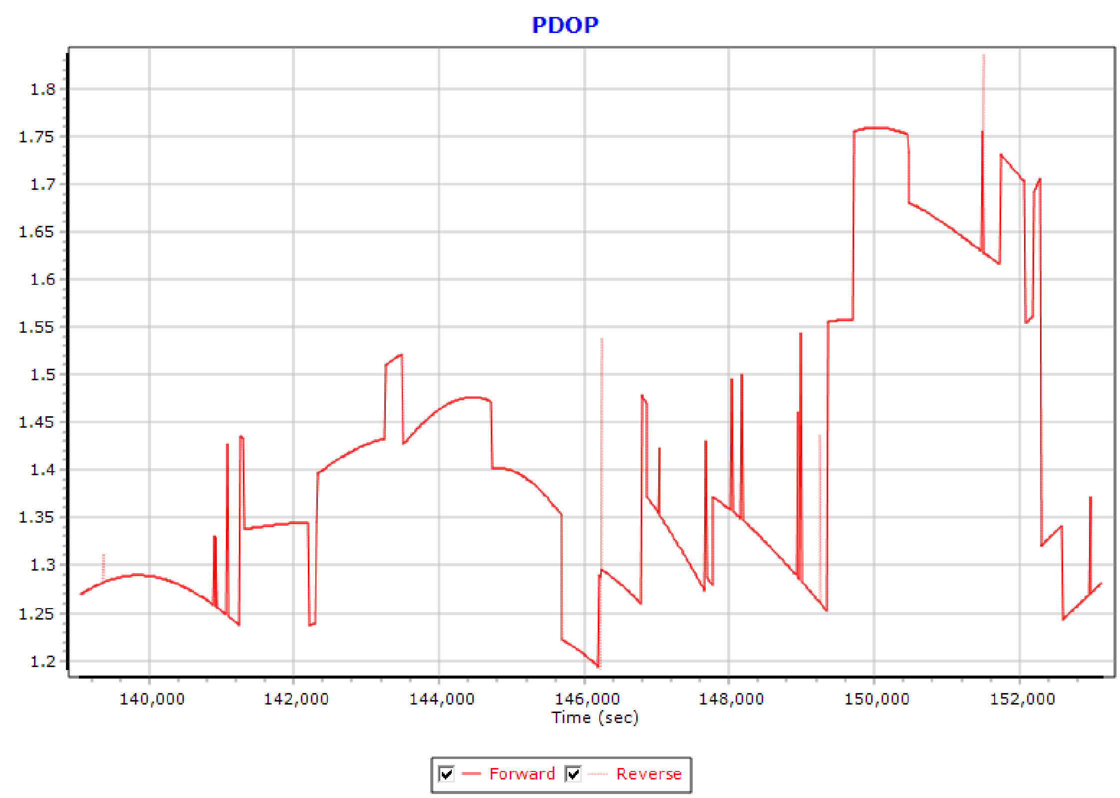

Baseline Length(m)
52,000
50,000
48,000
46,000
44,000
42,000
40,000
38,000
36,000
34,000
32,000
30,000
28,000
26,000
24,000
22,000
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
83,500
84,000
84,500
85,000
85,500
86,000
Time (sec)


PDOP
1.6
1.58
1.56
1.54
1.52
1.5
1.48
1.46
1.44
1.42
1.4
1.38
1.36
1.34
1.32
1.3
1.28
1.26
1.24
1.22
83,500
84,000
84,500
85,000
85,500
86,000
Time (sec)

PTG18049A


100000
50000
0
-50000
20000m
-150000
-100000
-50000
0
50000
100000
150000
txte
LASH
txma
Start
LASV
Real-time Reference Frame (RNAV)
SmartBase Region
Post-processed (SBET)
DHLC
txc1


Baseline Length(m)
65,000
60,000
55,000
50,000
45,000
40,000
35,000
30,000
25,000
20,000
15,000
140,000
142,000
144,000
146,000
148,000
150,000
152,000
Time (sec)


PDOP
1.8
1.75
1.7
1.65
1.6
1.55
1.5
1.45
1.4
1.35
1.3
1.25
1.2
140,000
142,000
144,000
146,000
148,000
150,000
152,000
Time (sec)
Forward
Reverse