

Block_3_IA North Central_2020_D20 Lidar 2020 Final Report

Report Produced for U.S. Geological Survey

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Overview

This task order is for a spring/summer 2020 leaf-off lidar survey to be collected over a primary Defined Project Area (DPA) in the state of Iowa of approximately 19,737 square miles, including the counties of: Boone, Buena Vista, Butler, Calhoun, Carroll, Cerro Gordo, Clay,, Dallas, Dickinson, Emmet, Floyd, Franklin, Greene, Grundy, Guthrie, Hamilton, Hancock, Hardin, Howard, Humboldt, Jasper, Kossuth, Marshall, Mitchell, Osceola, Palo Alto, Pocahontas, Polk, Sac, Story, Tama, Webster, Winnebago, Worth and Wright. This project will support the National Resources Conservation Service (NRCS) high resolution elevation enterprise program, the Iowa Department of Agriculture and Land Stewardship (IDALS) Iowa Flood Plain program, and the 3DEP mission. Block 3 of North Central Iowa was planned for the acquisition, processing, and derivative products of lidar data to be collected at an QL2 aggregate nominal pules spacing (ANPS) of ≤ 0.71 meters. Approximately 6862 square miles of Block 3 referred to as Block_3_IA North Central_2020_D20 Lidar 2019 was acquired in the spring of 2020 with one mission flown in the December of 2020. Block 3 Iowa North Central project area consists of 12 Iowa counties; Buena Vista, Sac, Pocahontas, Calhoun, Humboldt, Webster, Wright, Hamilton, Franklin, Hardin, Butler, and Grundy. The condition of the ground was good during the collection of the survey.

Acquisition of the IA North Central DPA was broken out to three subcontractors in the following manner.

Contractor	Number of Flight Days	Square Miles Flown
Aerial Surveys, International	15	~12,411
SurvTech Solutions	4	~2,889
TAC	13	~4,437

Table 1: Subcontractor Days of Flight and Square Miles Flown

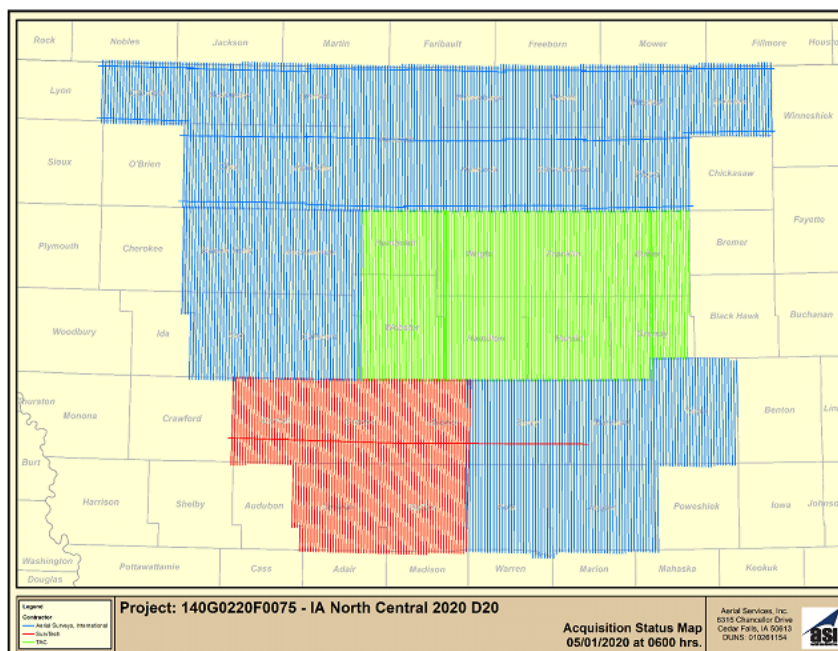


Figure 1: Iowa North Central DPA Subcontractor Breakout

The LiDAR data for Block 3 Iowa North Central was processed and classified according to project specifications. Detailed breaklines, bare earth Digital Elevation Models (DEMs), and Intensity Images were produced for the Block 3 Project area. Data was formatted into tiles with each tile covering an area of 1000 meters by 1000 meters. A total of 17,868 LAS files, 17,868 DEMs, and 17,868 Intensity Images were produced for the project, encompassing the Block 3 project area of approximately 6862 square miles and formatted into 17,868 total tiles.

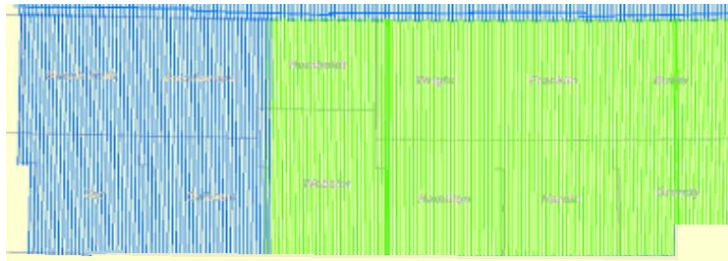


Figure 2: Block 3 Iowa North Central Breakout

Project team

Aerial Services, Inc. (ASI) served as the prime contractor for the project. In addition to project management, ASI was responsible for LAS filtration of the entire Block 3 project area. ASI also preformed bare earth cleanup of the Block 3 project area. ASI produced the LiDAR products; Digital Elevation Model (DEM) production, Intensity Image production, and quality assurance for the entire Block 3 project area. Subcontractor: Aerial Surveys International, LLC (ASU) was responsible for LiDAR acquisition and calibration of approximately 2146 square mile area of the Block 3 project area. Subcontractor: Technical Applications & Consulting, LLC (TAC) was responsible for LiDAR acquisition and calibration of approximately 4715 square mile area of the Block 3 project area. Subcontractor: SurvTech Solutions was responsible for LiDAR acquisition and calibration of less than 1 square mile area of the Block 3 Project area. SurvTech also preformed ground edit and hydro collection for that small area. All follow-on processing was completed by the prime contractor. Subcontractor: Michael Backer International collected hydro for the majority of the Block 3 project area. All follow-on processing was completed by the prime contractor.

Prairie Engineers completed ground surveying for the project and delivered surveyed checkpoints. Prairie Engineers was to acquire surveyed checkpoints for the project to use in independent testing of the vertical accuracy of the LiDAR-derived surface model. Please see SURVEY REPORT to view the separate Survey Report that was provided for this portion of the project.

Survey area

The project area addressed by this report falls within the Block 3 Iowa North Central project area consists of 12 Iowa counties; Buena Vista, Sac, Pocahontas, Calhoun, Humboldt, Webster, Wright, Hamilton, Franklin, Hardin, Butler, and Grundy.

Date of survey

LiDAR acquisition for Block 3 Iowa North Central was conducted between the dates of April 4, 2020 to April 30, 2020, then on December 4, 2020 and December 5, 2020.

Coordinate reference system

Data produced for the project was 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: Universal Transverse Mercator (UTM) Zone 15 North.

Units: Horizontal units are in meters, Vertical units are in meters.

Geoid Model: Geoid12B

Lidar vertical accuracy

For the Block 3 IA North Central project, the tested RMSEz of the classified LiDAR data for checkpoints in non-vegetated terrain equaled 0.035 meters compared with the 10 cm specification: The 95% confidence value of NVA of the classified LiDAR data computed using $RMSEz \times 1.96$ and was found to equal 0.068 meters compared with the 0.196 meter specification.

For the Block 3 IA North Central project, the tested VVA of the classified LiDAR data computed using the 95th percentile was equal to 0.110 meters, compared with the 0.294 meter specification.

This project must meet Non-vegetated Vertical Accuracy (NVA) ≤ 0.0196 meters (19.6 cm) at the 95% confidence level based on $RMSEz \leq 0.100$ meters (10 cm) $\times 1.9600$.

100 % of Totals	# of Points	RMSEz NVA (m)	NVA-Non-vegetated Vertical Accuracy ((RMSEz x 1.9600) m)	Mean (m)	Median (m)	Skew	Std Dev (m)	Min (m)	Max (m)	Kurtosis
NVA	113	0.035	0.068	0.004	0.010	-0.301	0.034	-0.090	0.090	0.152

Table 2: Block 3 IA North Central Non-vegetated Vertical Accuracy (NVA) results.

NVA was run on the unclassified point cloud which met the Non-Vegetated Accuracy (NVA) of ≤ 19.6 cm at the 95% confidence level based on $RMSEz \leq 10$ cm $\times 1.9600$.

100 % of Totals	# of Points	RMSEz NVA (m)	NVA-Non-vegetated Vertical Accuracy ((RMSEz x 1.9600) m)	Mean (m)	Median (m)	Skew	Std Dev (m)	Min (m)	Max (m)	Kurtosis
NVA	112	0.035	0.069	0.005	0.010	-0.400	0.035	-0.90	0.090	0.102

Table 3: Block 3 IA North Central unclassified Calibrated Vertical Accuracy NVA results.

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

Project deliverables

The deliverables for the project are listed below.

- Classified Point Cloud Data (Tiled)
- Bare Earth Surface (Raster DEM – IMG format)
- Intensity Images (8-bit gray scale, tiled, GeoTIFF format)
- Breakline Data (File GDB)
- Independent Survey Checkpoint Data (File GDB)
- Calibration Points (File GDB)
- Metadata
- Maximum surface height raster
- Swath separation Images
- Project Report (Acquisition, Processing, QC)
- Project Extent (Included in breakline GDB)
- Swaths Extents (File GDB)
- Tile Index (included in breakline GDB)

Project tiling footprint

17,868 tiles, 17,868 LAS files, 17,868 DEM tiles, 17,868 Intensity Image tiles were delivered for the project. Each tile's extent is 1000 meter by 1000 meter. (See Appendix A for a complete listing of delivered tiles.)

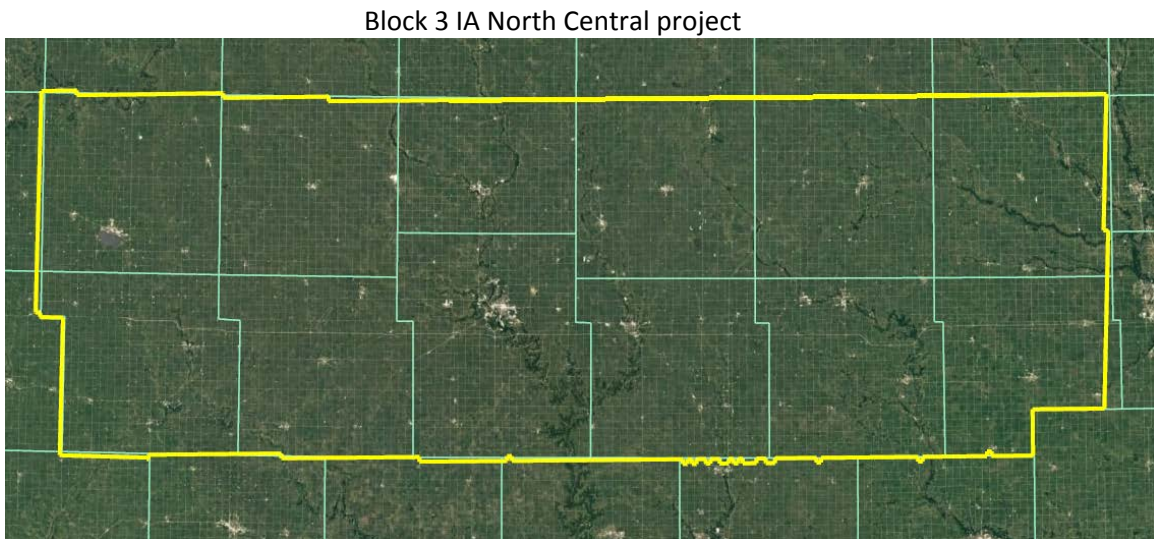


Figure 3: Block 3 IA North Central project Area of Interest

Project Area Elevation Model

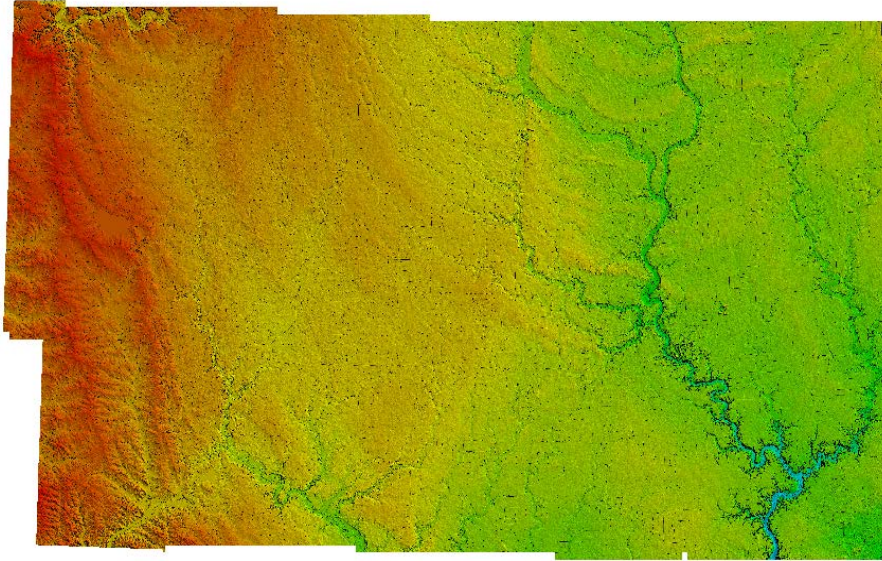


Figure 4: Western section of Block 3 IA North Central project Elevation DEM

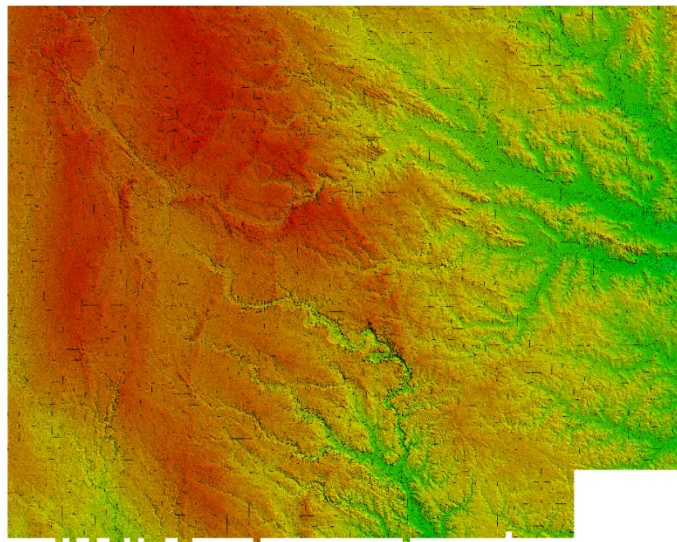


Figure 5: Eastern section of Block 3 IA North Central project Elevation DEM

Aerial Surveys International, LLC LiDAR Acquisition Details and System parameters

Sub Contractor Aerial Services, Inc. (ASU) served as sub contractor for the Block 3 IA North Central project and preformed the LiDAR Acquisition and Calibration for Iowa counties; Buena Vista, Sac, and the western portion of Pocahontas, and Calhoun.

The following image is of the Planned Flight Line Overview for the 12 counties of Block 3 IA North Central project area.



Figure 6: ASU Block 3 IA North Central planned flight line overview

Aerial Surveys International, LLC planned 380 passes for the entire IA North Central project area as well as a series of cross flightlines for quality control during processing and are not included in delivery. Of the 380 passes Aerial Surveys International, LLC collected 84 passes for the Block 3 IA North Central project area. In order to reduce any margin for error in the flight plan, Aerial Surveys International, LLC followed FEMA’s Appendix A guidelines for flight planning and, at a minimum, includes the following criteria:

- A digital flight line layout using FMC Flight Management Suite flight design software for direct integration into the aircraft flight navigation system.
- Planned flight lines; flight line numbers; and coverage area.
- Lidar coverage extended beyond all project borders to ensure necessary over-edge coverage appropriate for specific task order deliverables. A buffered AOI was provided by ASI.
- All airspace was coordinated and any controlled or restricted areas were pre coordinated and approval granted from the airspace owner.

Lidar System parameters

Aerial Surveys International, LLC operated a Cessna 310 (Registration N7516Q) and a Cessna 402 (Registration N2JJ), both equipped with an Optech Galaxy Prime LiDAR system during the collection of this task order. Data was acquired between April 4, 2020 to April 30, 2020, then on December 4, 2020 and December 5, 2020.

Item	Parameter
System	Optech Prime
Maximum Number of Returns per Pulse	7
Nominal Pulse Spacing (single swath), (m)	0.67
Nominal Pulse Density (single swath) (ppsm), (m)	2.21
Aggregate NPS (m) (if ANPS was designed to be met through single coverage, ANPS and NPS will be equal)	0.67
Aggregate NPD (m) (if ANPD was designed to be met through single coverage, ANPD and NPD will be equal)	2.21
Altitude (AGL meters)	2300
Approx. Flight Speed (knots)	160
Total Sensor Scan Angle (degrees)	46
Scan Rate (hz)	63
Scanner Pulse Rate (kHz)	400
Did the Sensor Operate with Multiple Pulses in The Air? (MPiA) (yes/no)	Yes
Beam Divergence (mRADs)	0.25 (1/e)
Nominal Swath Width on the Ground (m)	1953
Swath Overlap (%)	30
Computed Down Track spacing (m) per beam	0.69
Computed Cross Track Spacing (m) per beam	0.69
Maximum Number of Returns per Pulse	Optech Prime

Table 4: ASU Lidar System Parameters

Calibration Report

Acquisition Control

Aerial Surveys International, LLC (ASU) conducted the survey using Applanix PPRTX for processing the GPS/IMU data. Trimble CenterPoint® RTX™ is a proprietary GPS, GLONASS, BeiDou, and QZSS enabled technology that provides high-accuracy GNSS positioning worldwide without the use of traditional local base stations or a VRS network. By combining real-time data from a global reference station infrastructure with innovative positioning and compression algorithms, Trimble RTX technology computes centimeter-level positions based on satellite orbit and clock information.

Airborne GPS Kinematic

Airborne GPS data was processed using POSpac MMS 8.4 GNSS-aided inertial post-processing 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.

For all flights, the GPS data can be classified as excellent, with GPS residuals of 3 cm average or better but no larger than 10 cm being recorded. GPS processing reports for each mission 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 LMS Pro, initially with default values from LMS Pro 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 point 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.

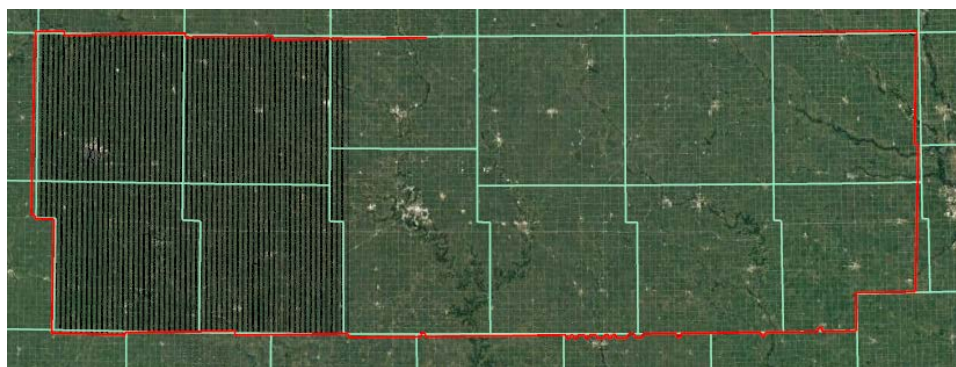


Figure 7: ASU Block 3 IA North Central project Lidar swath coverage.

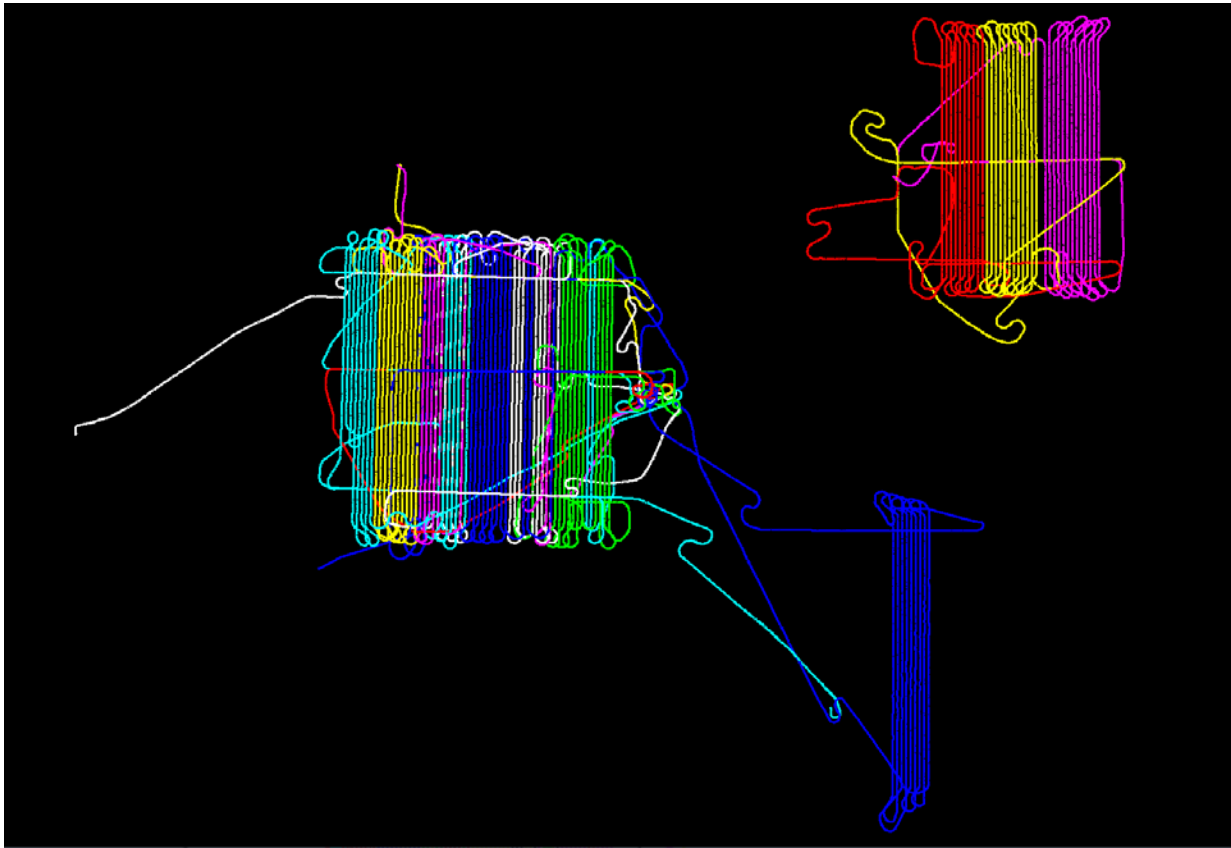


Figure 8: ASU Block 3 IA North Central project Combined project SBET

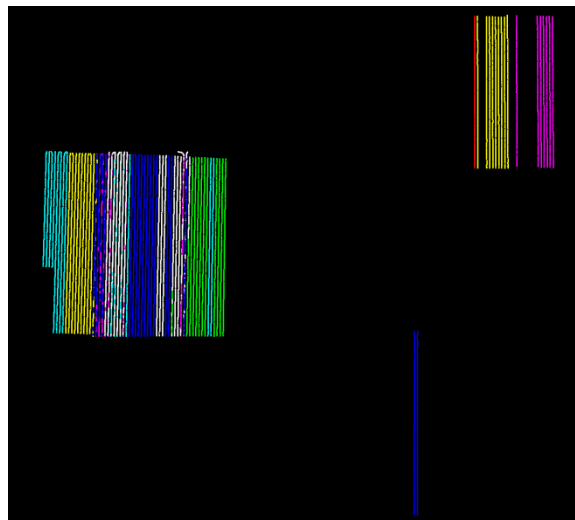


Figure 9: shows ASU's combined trajectory of the flightlines by mission over Block 3 IA North Central project area.

The table below is a listing of Flightlines and corresponding, Lift_ID, Date, Point Source ID, Swath Type, Scanner, and adjusted GPS Start and End times.

Name	Lift_ID	Date	PT Source ID	Swath Type	Scanner	Start Time	End Time
20200404_222809	20200404_F1_SN386	4/4/2020	1010	Fill In	Optech	270074489.000	270075352.000
20200405_005248	20200405_F1_SN386	4/5/2020	1011	Fill In	Optech	270083168.000	270084035.000
20200405_014702	20200405_F1_SN386	4/5/2020	1014	Fill In	Optech	270086422.000	270087302.000
20200405_020508	20200405_F1_SN386	4/5/2020	1015	Fill In	Optech	270087508.000	270088354.000
20200405_022252	20200405_F1_SN386	4/5/2020	1016	Fill In	Optech	270088572.000	270089439.000
20200405_024031	20200405_F1_SN386	4/5/2020	1017	Fill In	Optech	270089631.000	270090477.000
20200405_025824	20200405_F1_SN386	4/5/2020	1018	Fill In	Optech	270090704.000	270091552.000
20200405_031603	20200405_F1_SN386	4/5/2020	1019	Fill In	Optech	270091763.000	270092612.000
20200405_033402	20200405_F1_SN386	4/5/2020	1020	Fill In	Optech	270092842.000	270093685.000
20200405_035836	20200405_F1_SN386	4/5/2020	1022	Fill In	Optech	270094316.000	270095179.000
20200405_041636	20200405_F1_SN386	4/5/2020	1023	Fill In	Optech	270095396.000	270096245.960
20200421_113852	20200421_F1_SN386	4/21/2020	1136	Fill In	Optech	271504332.000	271505377.000
20200421_120314	20200421_F1_SN386	4/21/2020	1137	Fill In	Optech	271505794.000	271507115.000
20200423_120207	20200423_F1_SN386	4/23/2020	1168	Project	Optech	271678527.144	271679556.638
20200423_122232	20200423_F1_SN386	4/23/2020	1169	Project	Optech	271679752.258	271680791.660
20200423_124213	20200423_F1_SN386	4/23/2020	1170	Project	Optech	271680933.233	271681958.226
20200423_130249	20200423_F1_SN386	4/23/2020	1171	Project	Optech	271682169.096	271683193.201
20200423_132154	20200423_F1_SN386	4/23/2020	1172	Project	Optech	271683313.720	271684325.278
20200423_134205	20200423_F1_SN386	4/23/2020	1173	Project	Optech	271684525.315	271685537.987
20200423_141510	20200423_F1_SN386	4/23/2020	1174	Project	Optech	271686509.981	271687533.453
20200423_143547	20200423_F1_SN386	4/23/2020	1175	Project	Optech	271687746.623	271688776.535
20200423_145560	20200423_F1_SN386	4/23/2020	1176	Project	Optech	271688959.903	271689978.628
20200425_134815	20200425_F1_SN386	4/25/2020	1190	Project	Optech	271857695.447	271858734.738
20200425_141159	20200425_F1_SN386	4/25/2020	1191	Fill In	Optech	271859119.000	271859503.000

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20200425_144647	20200425_F1_SN386	4/25/2020	1192	Project	Optech	271861207.247	271862214.806
20200425_150640	20200425_F1_SN386	4/25/2020	1193	Project	Optech	271862400.350	271863430.311
20200426_132912	20200426_F1_SN386	4/26/2020	1194	Project	Optech	271942951.893	271943994.120
20200426_134935	20200426_F1_SN386	4/26/2020	1195	Project	Optech	271944175.293	271945221.558
20200426_140958	20200426_F1_SN386	4/26/2020	1196	Project	Optech	271945398.000	271946434.000
20200426_142926	20200426_F1_SN386	4/26/2020	1197	Project	Optech	271946565.859	271947601.747
20200426_144935	20200426_F1_SN386	4/26/2020	1198	Project	Optech	271947774.628	271948796.624
20200426_150936	20200426_F1_SN386	4/26/2020	1199	Project	Optech	271948975.996	271950025.993
20200426_153048	20200426_F1_SN386	4/26/2020	1200	Project	Optech	271950248.115	271950728.508
20200426_235011	20200426_F2_SN386	4/26/2020	1201	Project	Optech	271980211.006	271981257.757
20200427_001031	20200427_F2_SN386	4/27/2020	1202	Project	Optech	271981431.422	271982495.593
20200427_003128	20200427_F2_SN386	4/27/2020	1203	Project	Optech	271982687.952	271983728.635
20200427_005146	20200427_F2_SN386	4/27/2020	1204	Project	Optech	271983905.541	271984945.906
20200427_011158	20200427_F2_SN386	4/27/2020	1205	Project	Optech	271985117.706	271986170.960
20200427_013240	20200427_F2_SN386	4/27/2020	1206	Project	Optech	271986359.530	271987409.964
20200427_015313	20200427_F2_SN386	4/27/2020	1207	Project	Optech	271987593.127	271988648.307
20200427_021354	20200427_F2_SN386	4/27/2020	1208	Project	Optech	271988834.236	271989887.416
20200427_023430	20200427_F2_SN386	4/27/2020	1209	Project	Optech	271990069.739	271991107.901
20200427_025414	20200427_F2_SN386	4/27/2020	1210	Project	Optech	271991253.906	271992292.457
20200427_031430	20200427_F2_SN386	4/27/2020	1211	Project	Optech	271992469.679	271993518.993
20200427_143450	20200427_F1_SN386	4/27/2020	1213	Project	Optech	272033289.632	272033921.469
20200427_144905	20200427_F1_SN386	4/27/2020	1214	Project	Optech	272034145.322	272035173.446
20200427_150921	20200427_F1_SN386	4/27/2020	1215	Project	Optech	272035360.645	272036388.889
20200427_153013	20200427_F1_SN386	4/27/2020	1216	Project	Optech	272036613.121	272037635.528
20200427_155108	20200427_F1_SN386	4/27/2020	1217	Project	Optech	272037868.477	272038896.771
20200427_161157	20200427_F1_SN386	4/27/2020	1218	Project	Optech	272039117.032	272040142.775
20200427_163233	20200427_F1_SN386	4/27/2020	1219	Project	Optech	272040353.254	272041376.927
20200427_165917	20200427_F1_SN386	4/27/2020	1220	Project	Optech	272041956.857	272042992.614

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20200427_172705	20200427_F1_SN386	4/27/2020	1221	Project	Optech	272043624.543	272044630.040
20200427_174739	20200427_F1_SN386	4/27/2020	1222	Project	Optech	272044859.419	272045899.393
20200427_180814	20200427_F1_SN386	4/27/2020	1223	Project	Optech	272046094.308	272047115.657
20200427_183545	20200427_F1_SN386	4/27/2020	1224	Fill In	Optech	272047745.000	272048015.000
20200405_145117	20200405_F2_SN442	4/5/2020	2030	Fill In	Optech	270133477.000	270134332.000
20200405_151005	20200405_F2_SN442	4/5/2020	2031	Fill In	Optech	270134605.000	270135472.000
20200405_152825	20200405_F2_SN442	4/5/2020	2032	Fill In	Optech	270135705.000	270136556.000
20200405_154701	20200405_F2_SN442	4/5/2020	2033	Fill In	Optech	270136821.000	270137696.000
20200405_160617	20200405_F2_SN442	4/5/2020	2034	Fill In	Optech	270137977.000	270138832.000
20200405_162451	20200405_F2_SN442	4/5/2020	2035	Fill In	Optech	270139091.000	270139960.000
20200405_183937_T1	20200405_F2_SN442	4/5/2020	2043	Fill In	Optech	270147177.000	270148043.000
20200422_154803	20200422_F1_SN442	4/22/2020	2177	Project	Optech	271605682.563	271606353.890
20200422_160203	20200422_F1_SN442	4/22/2020	2178	Project	Optech	271606522.638	271607176.875
20200422_161709	20200422_F1_SN442	4/22/2020	2179	Project	Optech	271607428.796	271608093.971
20200422_164208	20200422_F1_SN442	4/22/2020	2180	Project	Optech	271608927.693	271609594.189
20200422_170347	20200422_F1_SN442	4/22/2020	2181	Project	Optech	271610226.586	271611281.264
20200422_172443	20200422_F1_SN442	4/22/2020	2182	Project	Optech	271611482.609	271612521.368
20200422_174617	20200422_F1_SN442	4/22/2020	2183	Project	Optech	271612777.351	271613822.757
20200422_180648	20200422_F1_SN442	4/22/2020	2184	Project	Optech	271614008.324	271615061.517
20201204_174024	20201204_F1_SN448	12/04/2020	2502	Project	Optech	291138824.624	291139880.873
20201204_180114	20201204_F1_SN448	12/04/2020	2503	Project	Optech	291140074.919	291141246.196
20201204_183043	20201204_F1_SN448	12/04/2020	2504	Project	Optech	291141843.337	291142869.101
20201204_185052	20201204_F1_SN448	12/04/2020	2505	Project	Optech	291143052.624	291144194.895
20201204_191221	20201204_F1_SN448	12/04/2020	2506	Project	Optech	291144340.930	291145380.927
20201204_193234	20201204_F1_SN448	12/04/2020	2507	Project	Optech	291145554.218	291146693.489
20201204_195322	20201204_F1_SN448	12/04/2020	2508	Project	Optech	291146802.515	291147859.521
20201204_201344	20201204_F1_SN448	12/04/2020	2509	Project	Optech	291148024.806	291149180.080
20201204_203433	20201204_F1_SN448	12/04/2020	2510	Project	Optech	291149273.438	291150320.351

20201204_233415	20201204_F1_SN448	12/04/2020	2511	Project	Optech	291160055.585	291161192.356
20201204_235616	20201204_F1_SN448	12/04/2020	2512	Project	Optech	291161376.900	291162413.147
20201205_001846	20201205_F1_SN448	12/05/2020	2513	Project	Optech	291162726.221	291163842.726
20201205_004010	20201205_F1_SN448	12/05/2020	2514	Project	Optech	291164010.280	291165045.525

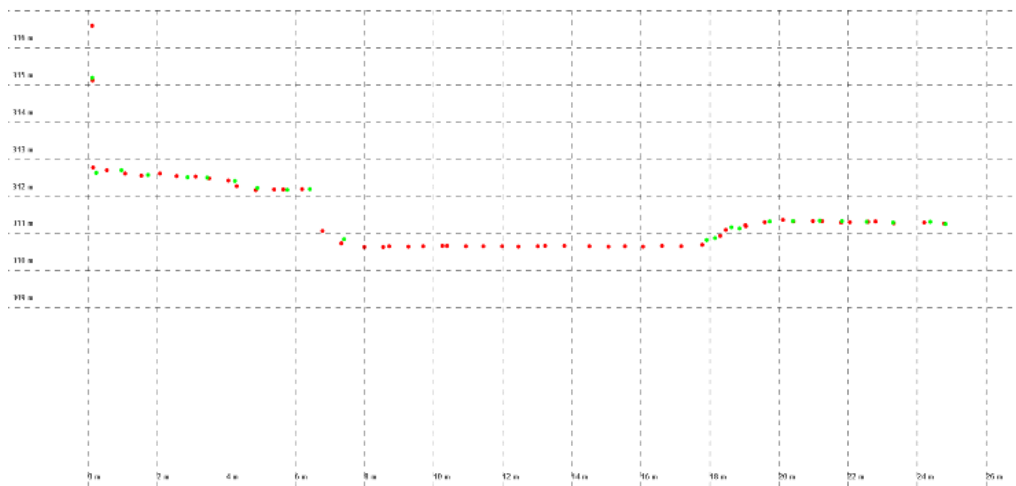
Table 5: Block 3 IA North Central ASU Project flightline by Mission

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 using at least 3 regularly spaced QC blocks in which points from all lines are loaded and inspected. Vertical differences between ground surfaces of each line are displayed. Color scale is adjusted so that errors greater than the specifications are flagged. Cross sections are visually inspected across each block to validate point to point, flight line to flight line and mission to mission agreement.

For this project, the specifications used are as follows (derived from LIDAR base specification 2.1, QL2): Relative accuracy (smooth surface repeatability) ≤ 6 cm maximum differences within individual swaths and ≤ 8 cm RMSDz between adjacent and overlapping swaths.



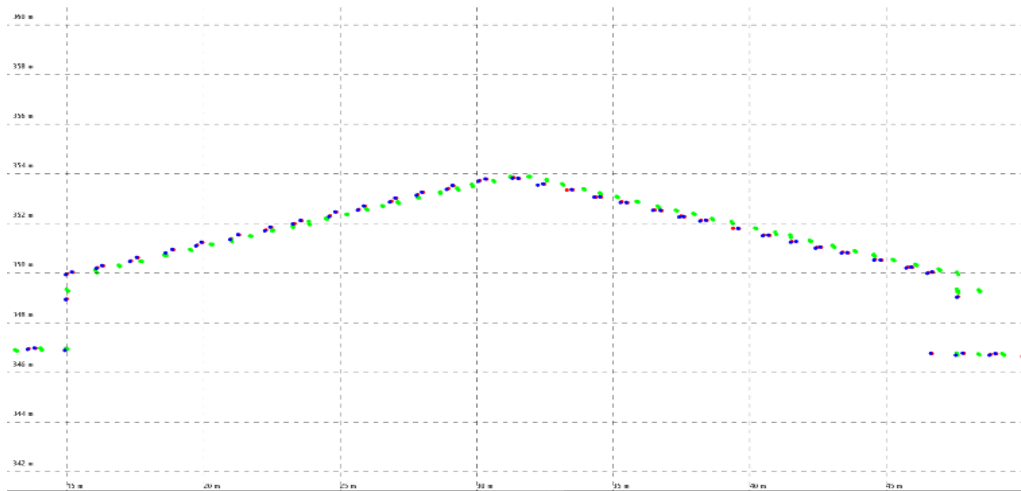


Figure 10: Profile views showing correct roll and pitch adjustments

Final Calibration Verification

Prairie Engineers conducted the survey throughout the area of interest. 30 Ground control points (GCPs) were used to test the accuracy of the calibrated swath data. These 30 GCPs were available to use as control in case the swath data exhibited any biases which would need to be adjusted or removed. The coordinates of all GCPs are provided in the figure below. Surveyed ground control points (GCPs) and the accuracy results from testing the calibrated swath data against the GCPs is provided in the Tables below. Ground control points (GCPs) vertical accuracy results no further adjustments to the swath data were required based on the accuracy results of the GCPs.

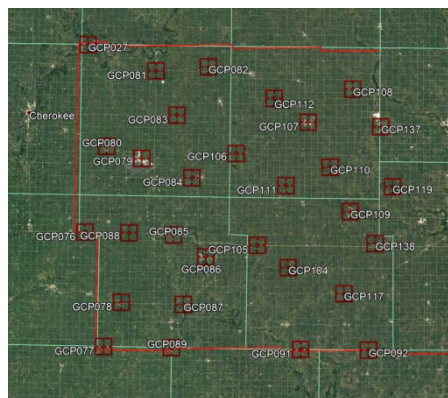


Figure 11: surveyed Ground Control Point Locations

Point ID	NAD83 (2011 adj) UTM Zone 15 N		NAVD88 (Geoid 12B)		
	Easting X (M)	Northing Y (M)	Z-Survey (M)	Z-LiDAR (M)	Dz (M)
GCP092	378230.030	4674057.700	346.070	346.120	0.050

GCP079	320328.160	4724015.350	438.550	438.590	0.040
GCP081	324239.050	4746505.490	398.870	398.910	0.040
GCP076	305345.020	4705238.760	417.230	417.270	0.040
GCP083	329547.860	4735028.570	392.500	392.530	0.030
GCP104	357785.590	4695489.190	375.340	375.370	0.030
GCP027	306709.210	4753518.450	431.900	431.920	0.020
GCP086	336556.180	4698505.530	365.960	365.970	0.010
GCP138	380294.830	4701425.450	358.460	358.470	0.010
GCP077	309797.230	4675758.140	417.980	417.990	0.010
GCP078	314580.960	4687087.560	413.130	413.140	0.010
GCP080	311216.110	4727241.210	462.880	462.890	0.010
GCP085	328258.110	4704241.320	400.500	400.510	0.010
GCP088	316801.150	4704919.430	419.130	419.140	0.010
GCP089	327408.230	4675274.520	415.930	415.940	0.010
GCP110	368920.040	4721178.170	378.010	378.020	0.010
GCP087	330610.440	4686331.030	390.520	390.520	0.000
GCP109	373984.140	4709687.520	379.450	379.450	0.000
GCP117	372078.880	4688656.360	353.890	353.890	0.000
GCP119	384936.290	4715963.100	362.160	362.160	0.000
GCP082	337792.480	4747364.330	424.600	424.590	-0.010
GCP111	357483.680	4716575.480	383.940	383.930	-0.010
GCP091	360747.270	4674441.940	356.920	356.900	-0.020
GCP108	375015.690	4741152.680	361.840	361.820	-0.020
GCP112	354696.140	4739043.950	391.410	391.390	-0.020

GCP137	382152.290	4731414.950	374.730	374.700	-0.030
GCP106	344727.220	4724965.510	386.380	386.340	-0.040
GCP084	333206.260	4718897.390	385.950	385.890	-0.060
GCP105	349905.290	4701322.980	371.790	371.720	-0.070
GCP107	363397.680	4732795.390	375.390	375.320	-0.070

Table 6: Block 3 IA North Central surveyed ground control points (GCPs).

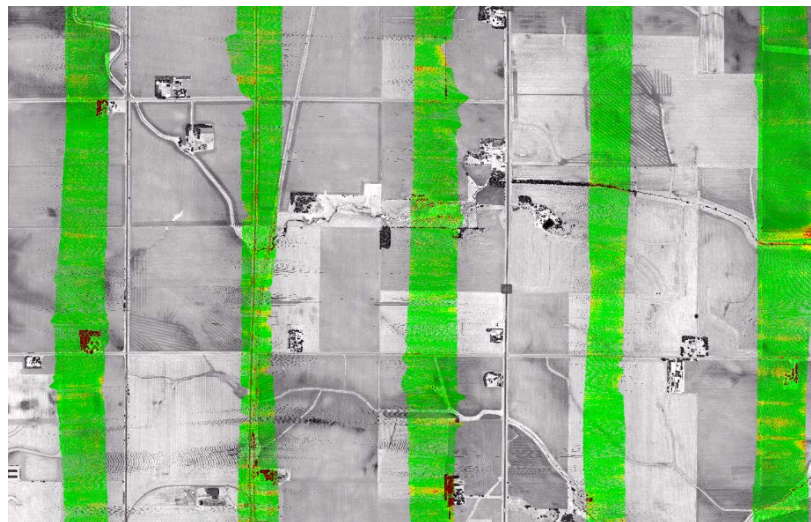
This project meets Ground Control Vertical Accuracy ≤ 19.6 cm at the 95% confidence level based on $RMSEz \leq 10$ cm $\times 1.9600$.

100 % of Totals	# of Points	RMSEz GCP (m)	GCP-Vertical Accuracy ((RMSEz $\times 1.9600$) m)	Mean (m)	Median (m)	Skew	Std Dev (m)	Min (m)	Max (m)	Kurtosis
GCP	30	0.30	0.060	0.000	0.010	-0.755	0.031	-0.070	0.050	0.375

Table 7: Block 3 IA North Central Ground Control Vertical Accuracy (GCP) results.

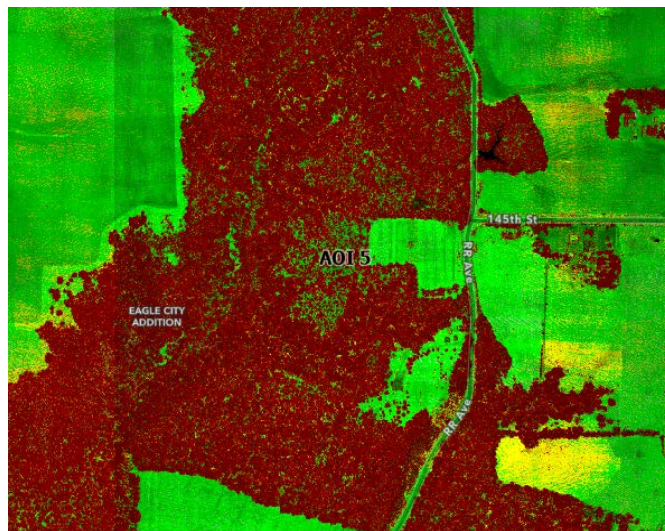
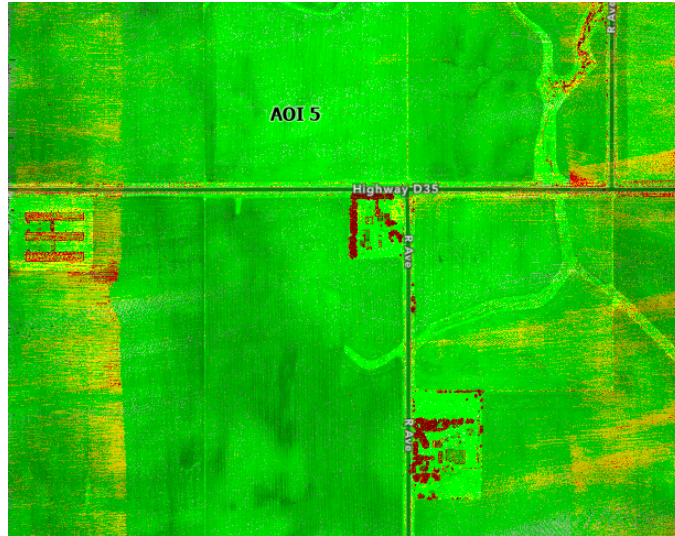
Between Swath Relative Accuracy (DZ Orthos)

Inter-swath relative accuracy passes specification. All pixels colored green are areas where overlapping flight lines are within 8 cm of each other. Areas colored red are where differences greater than 16 cm exist (this is expected in vegetated and sloped areas).



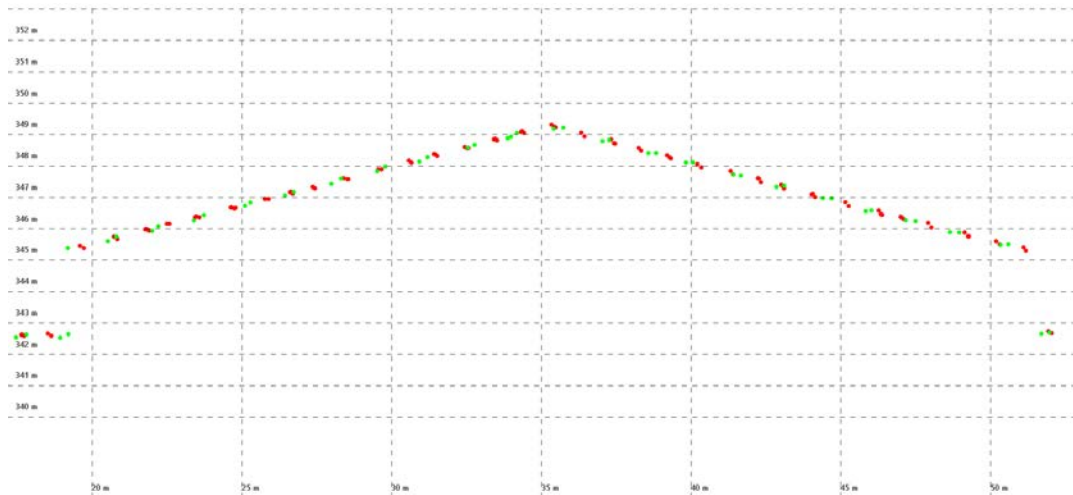
Within Swath Relative Accuracy (Intraswath)

Intra-swath relative accuracy was reviewed and passes specification. All flight lines were reviewed to confirm intra-swath within 6 cm (green) of each on flat plainer surfaces. Areas colored red are where differences greater than 6 cm exist. Red areas are expected in vegetated and sloped areas as this is an assessment only of hard surface repeatability.



Horizontal Alignment/Calibration Check (Rooftops/Planar Surface Profiles)

The profiles show lidar points colored by flight line. The overlapping flight lines match and there is no horizontal (or vertical) offset between the flight lines.

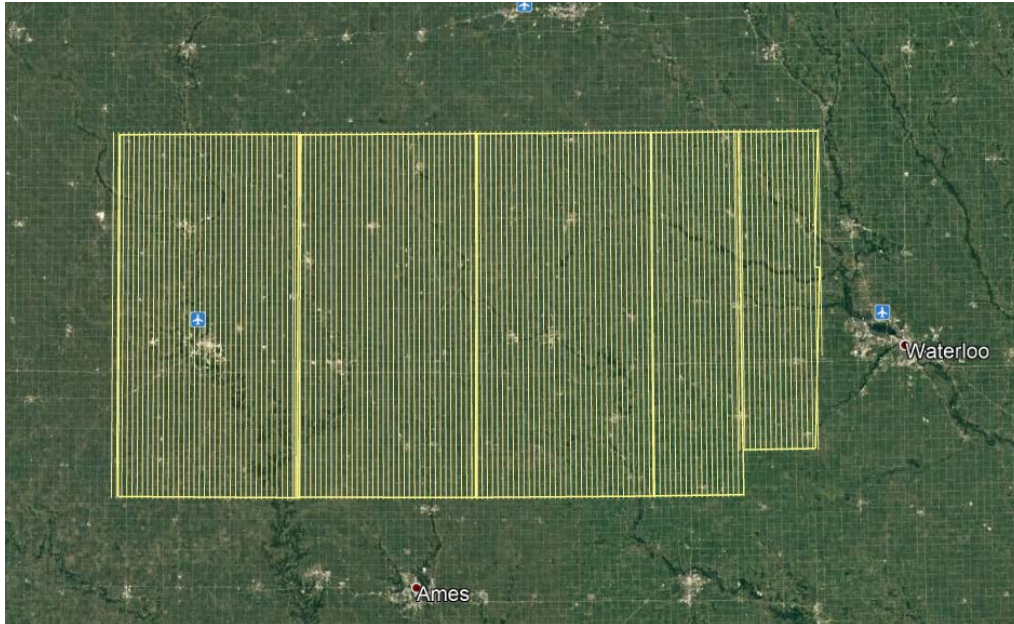


See Appendix B: For Aerial Surveys International, LLC GPS and IMU Processing Reports

Technical Applications & Consulting, LLC (TAC) LiDAR Acquisition Details and System Parameters

Sub Contractor Technical Applications & Consulting, LLC (TAC) served as sub contractor for the Block 3 IA North Central project and preformed the LiDAR Acquisition and Calibration for Iowa counties; Humboldt, Webster, Wright, Hamilton, Franklin, Hardin, Butler, Grundy, and the eastern sections of Pocahontas and Calhoun.

The following image is of the Planned Flight Line Overview for the 8 and 2 partial counties of Block 3 IA North Central project area.



Technical Applications & Consulting, LLC (TAC) planned 222 passes for the project area as well as a series of cross flightlines for quality control. 155 of the 222 planned passes were collected and used for the Block 3 IA North Central project area. In order to reduce any margin for error in the flight plan, TAC followed FEMA's Appendix A guidelines for flight planning and, at a minimum, includes the following criteria:

- A digital flight line layout using Optech AMM Software flight design software for direct integration into the aircraft flight navigation system.
- Planned flight lines; flight line numbers; and coverage area.
- Lidar coverage extended beyond all project borders to ensure necessary over-edge coverage appropriate for specific task order deliverables. A buffered AOI was provided by ASI.
- All airspace was coordinated and any controlled or restricted areas were pre coordinated and approval granted from the airspace owner.

Lidar System parameters

TAC operated a Cessna Turbo Utility 206 (Registration N8647Q) equipped with an Optech Galaxy T500 LiDAR system during the collection of this task order. Data was acquired between 05 April 2020 and 30 April 2020.

Item	Parameter
System	Optech Galaxy T500
Maximum Number of Returns per Pulse	4
Nominal Pulse Spacing (single swath), (m)	0.53
Nominal Pulse Density (single swath) (ppsm), (m)	3.5
Aggregate NPS (m) (if ANPS was designed to be met through single coverage, ANPS and NPS will be equal)	0.53
Aggregate NPD (m) (if ANPD was designed to be met through single coverage, ANPD and NPD will be equal)	3.5
Altitude (AGL meters)	1864
Approx. Flight Speed (knots)	140
Total Sensor Scan Angle (degrees)	50
Scan Rate (hz)	60.47
Scanner Pulse Rate (kHz)	300
Did the Sensor Operate with Multiple Pulses in The Air? (MPIA) (yes/no)	Yes
Beam Divergence (mRADs)	0.25 (1/e)
Nominal Swath Width on the Ground (m)	1385
Swath Overlap (%)	20
Computed Down Track spacing (m) per beam	0.51
Computed Cross Track Spacing (m) per beam	0.62

Table 8: TAC LiDAR system parameters

Calibration Report

Airborne GPS Kinematic

Airborne GPS data was processed using POSpac MMS 8.4 GNSS-aided inertial post-processing 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 40 km.

For all flights, the GPS data can be classified as excellent, with GPS residuals of 3 cm average or better but no larger than 10 cm being recorded. GPS processing reports for each mission are included in Appendix A.

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 LMS Pro, initially with default values from LMS Pro 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 point 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.

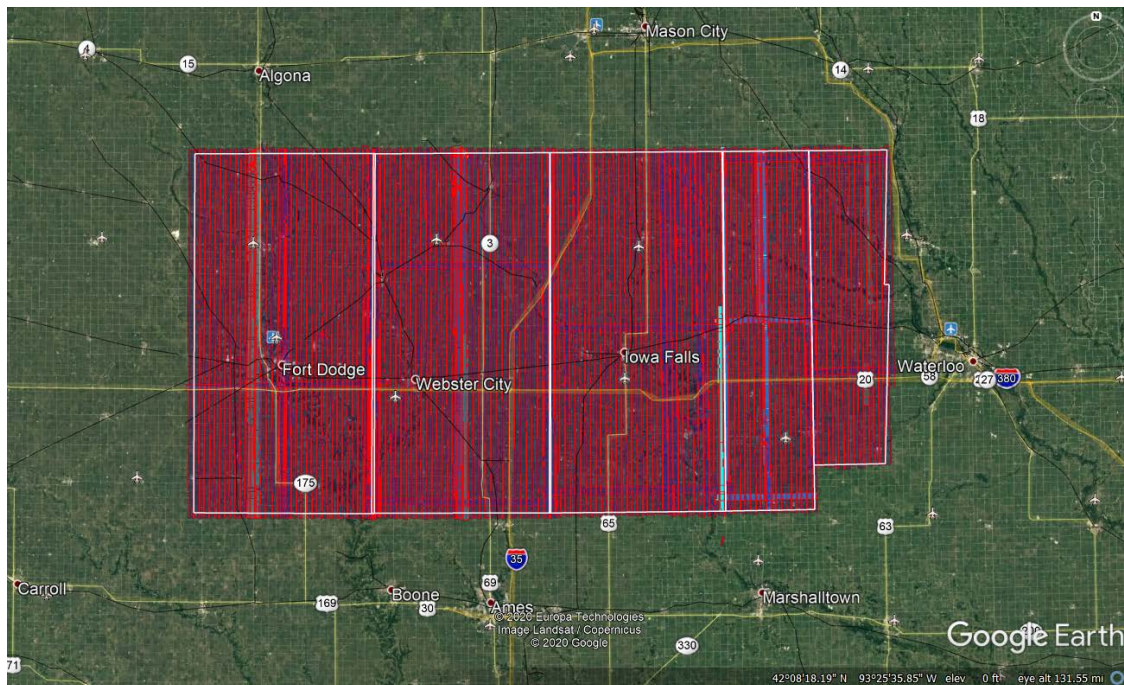


Figure 12: TAC LiDAR swath output showing complete coverage

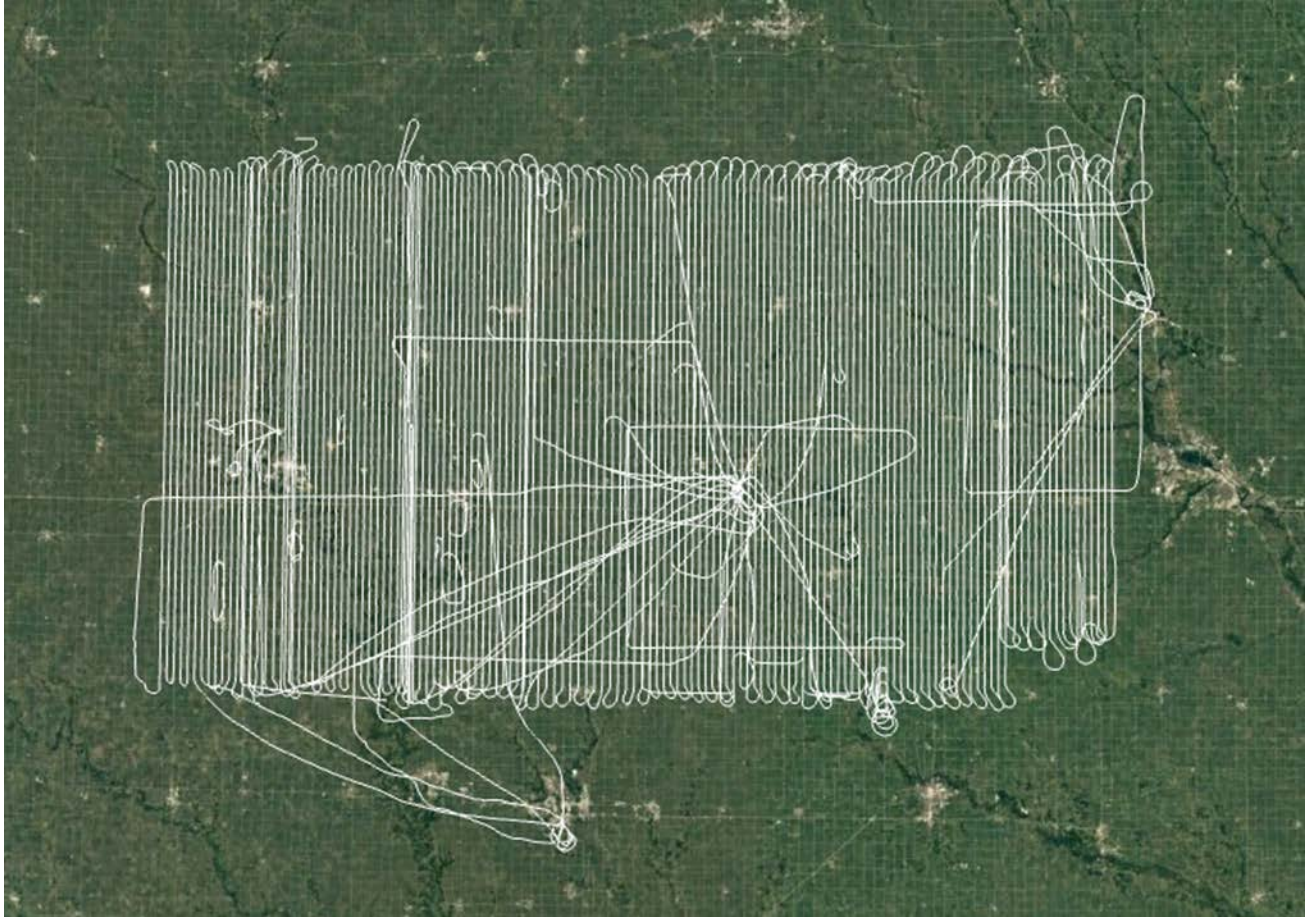


Figure 13: TAC Block 3 IA North Central project Combined project SBET



Figure 14: TAC combined trajectory of the flightlines by mission over Block 3 IA North Central project area.

The following table is a listing of Flightlines and corresponding, Lift_ID, Date, Point Source ID, Scanner, and adjusted GPS Start and End times.

Name	Lift_ID	Date	PT Source ID	Swath Type	Scanner	Start Time	End Time
20200428_045424	20200428_F4_SN5060384	4/28/2020	3001	Project	Optech	272084864.846	272086147.168
20200428_051808	20200428_F4_SN5060384	4/28/2020	3002	Project	Optech	272086288.721	272087682.050
20200428_054260	20200428_F4_SN5060384	4/28/2020	3003	Project	Optech	272087780.073	272089041.372
20200428_060630	20200428_F4_SN5060384	4/28/2020	3004	Project	Optech	272089190.782	272090599.742
20200427_170560	20200427_F4_SN5060384	4/27/2020	3005	Project	Optech	272042360.024	272043706.121
20200427_173004	20200427_F4_SN5060384	4/27/2020	3006	Project	Optech	272043804.730	272045111.042
20200427_175329	20200427_F4_SN5060384	4/27/2020	3007	Project	Optech	272045209.725	272046549.905
20200427_182103	20200427_F4_SN5060384	4/27/2020	3008	Project	Optech	272046863.640	272048201.058
20200427_184503	20200427_F4_SN5060384	4/27/2020	3009	Project	Optech	272048303.628	272049655.060
20200427_190903	20200427_F4_SN5060384	4/27/2020	3010	Project	Optech	272049743.861	272051056.303
20200427_193244	20200427_F4_SN5060384	4/27/2020	3011	Project	Optech	272051164.084	272052485.199
20200427_195629	20200427_F4_SN5060384	4/27/2020	3012	Project	Optech	272052589.604	272053926.963
20200427_214331	20200427_F4_SN5060384	4/27/2020	3013	Project	Optech	272059011.525	272060358.367
20200427_220721	20200427_F4_SN5060384	4/27/2020	3014	Project	Optech	272060441.517	272061753.728
20200427_223033	20200427_F4_SN5060384	4/27/2020	3015	Project	Optech	272061833.132	272063171.594
20200427_225408	20200427_F4_SN5060384	4/27/2020	3016	Project	Optech	272063248.152	272063928.475
20200427_232033	20200427_F4_SN5060384	4/27/2020	3017	Project	Optech	272064833.546	272066167.010
20200427_234357	20200427_F4_SN5060384	4/27/2020	3018	Project	Optech	272066237.531	272067553.515
20200428_000726	20200428_F4_SN5060384	4/28/2020	3019	Project	Optech	272067646.618	272068939.671
20200428_003022	20200428_F4_SN5060384	4/28/2020	3020	Project	Optech	272069022.691	272070363.010
20200428_031407	20200428_F4_SN5060384	4/28/2020	3021	Project	Optech	272078847.621	272079852.861
20200428_033332	20200428_F4_SN5060384	4/28/2020	3022	Project	Optech	272080012.899	272081503.254
20200428_040052	20200428_F4_SN5060384	4/28/2020	3023	Project	Optech	272081653.289	272082956.019
20200430_040416	20200430_F4_SN5060384	4/30/2020	3024	Project	Optech	272254656.567	272255909.317
20200430_033450	20200430_F4_SN5060384	4/30/2020	3025	Project	Optech	272252891.149	272254520.534

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20200430_031139	20200430_F4_SN5060384	4/30/2020	3026	Project	Optech	272251499.285	272252735.112
20200430_024319	20200430_F4_SN5060384	4/30/2020	3027	Project	Optech	272249799.112	272251402.797
20200430_011511	20200430_F4_SN5060384	4/30/2020	3028	Project	Optech	272244511.508	272245228.065
20200430_004634	20200430_F4_SN5060384	4/30/2020	3029	Project	Optech	272242794.107	272244444.682
20200430_002402	20200430_F4_SN5060384	4/30/2020	3030	Project	Optech	272241442.041	272242684.617
20200429_235509	20200429_F4_SN5060384	4/29/2020	3031	Project	Optech	272239709.042	272241377.486
20200429_214446	20200429_F4_SN5060384	4/29/2020	3032	Project	Optech	272231885.691	272233109.799
20200429_211527	20200429_F4_SN5060384	4/29/2020	3033	Project	Optech	272230127.619	272231774.125
20200429_205325	20200429_F4_SN5060384	4/29/2020	3034	Project	Optech	272228805.640	272230042.534
20200429_202334	20200429_F4_SN5060384	4/29/2020	3035	Project	Optech	272227014.531	272228708.767
20200427_230802	20200427_F4_SN5060384	4/27/2020	3039	Project	Optech	272064082.077	272064747.976
20200428_030137	20200428_F4_SN5060384	4/28/2020	3040	Project	Optech	272078097.177	272078475.938
20200430_022411	20200430_F4_SN5060384	4/30/2020	3041	Fill In	Optech	272248651.000	272249032.000
20200430_023557	20200430_F4_SN5060384	4/30/2020	3042	Project	Optech	272249357.832	272249649.066
20200430_135442	20200430_F4_SN5060384	4/30/2020	4001	Project	Optech	272290083.041	272291659.412
20200430_133517	20200430_F4_SN5060384	4/30/2020	4002	Project	Optech	272288917.767	272289953.011
20200430_130730	20200430_F4_SN5060384	4/30/2020	4003	Project	Optech	272287251.375	272288799.739
20200430_124805	20200430_F4_SN5060384	4/30/2020	4004	Project	Optech	272286086.102	272287129.347
20200430_121937	20200430_F4_SN5060384	4/30/2020	4005	Project	Optech	272284377.701	272285956.071
20200430_115936	20200430_F4_SN5060384	4/30/2020	4006	Project	Optech	272283176.419	272284219.664
20200430_102305	20200430_F3_SN5060384	4/30/2020	4007	Project	Optech	272277385.535	272278317.218
20200430_100314	20200430_F3_SN5060384	4/30/2020	4008	Project	Optech	272276194.126	272277216.961
20200430_093202	20200430_F3_SN5060384	4/30/2020	4009	Project	Optech	272274322.284	272276089.697
20200430_091207	20200430_F3_SN5060384	4/30/2020	4010	Project	Optech	272273127.005	272274177.250
20200430_084103	20200430_F3_SN5060384	4/30/2020	4011	Project	Optech	272271263.570	272273008.978
20200430_082038	20200430_F3_SN5060384	4/30/2020	4012	Project	Optech	272270039.285	272271104.203
20200430_074916	20200430_F3_SN5060384	4/30/2020	4013	Project	Optech	272268156.845	272269912.255
20200430_072839	20200430_F3_SN5060384	4/30/2020	4014	Project	Optech	272266919.556	272267992.297

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20200430_065214	20200430_F3_SN5060384	4/30/2020	4015	Project	Optech	272264734.566	272266550.470
20200430_063100	20200430_F3_SN5060384	4/30/2020	4016	Project	Optech	272263460.749	272264544.002
20200430_114315	20200430_F4_SN5060384	4/30/2020	4017	Project	Optech	272282196.190	272283037.387
20200422_010339	20200422_F2_SN5060384	4/22/2020	4018	Project	Optech	271552619.560	271553981.357
20200422_003827	20200422_F2_SN5060384	4/22/2020	4019	Project	Optech	271551107.676	271552510.529
20200422_001416	20200422_F2_SN5060384	4/22/2020	4020	Project	Optech	271549657.333	271551005.652
20200421_234910	20200421_F2_SN5060384	4/21/2020	4021	Project	Optech	271548150.977	271549548.797
20200421_232431	20200421_F2_SN5060384	4/21/2020	4022	Project	Optech	271546671.067	271548018.945
20200421_225905	20200421_F2_SN5060384	4/21/2020	4023	Project	Optech	271545145.266	271546551.774
20200421_220618	20200421_F2_SN5060384	4/21/2020	4024	Project	Optech	271541978.517	271543324.285
20200421_214933	20200421_F2_SN5060384	4/21/2020	4025	Project	Optech	271540973.109	271541849.486
20200421_211243	20200421_F2_SN5060384	4/21/2020	4026	Project	Optech	271538763.105	271540059.558
20200421_204636	20200421_F2_SN5060384	4/21/2020	4027	Project	Optech	271537196.381	271538630.723
20200421_165259	20200421_F1_SN5060384	4/21/2020	4028	Project	Optech	271523179.528	271523566.894
20200421_153845	20200421_F1_SN5060384	4/21/2020	4029	Project	Optech	271518725.000	271519784.000
20200421_150615	20200421_F1_SN5060384	4/21/2020	4030	Project	Optech	271516776.302	271518614.187
20200421_144534	20200421_F1_SN5060384	4/21/2020	4031	Project	Optech	271515535.013	271516617.265
20200421_141312	20200421_F1_SN5060384	4/21/2020	4032	Project	Optech	271513592.560	271515416.550
20200430_072529	20200430_F3_SN5060384	4/30/2020	4033	Fill In	Optech	272266729.000	272266809.000
20200421_213647	20200421_F2_SN5060384	4/21/2020	4034	Project	Optech	271540207.098	271540788.585
20200421_161124	20200421_F1_SN5060384	4/21/2020	4035	Project	Optech	271520684.023	271522087.547
20200430_164714	20200430_F5_SN5060384	4/30/2020	4036	Fill In	Optech	272300435.000	272300780.000
20200430_172659	20200430_F5_SN5060384	4/30/2020	4037	Project	Optech	272302819.140	272304074.705
20200430_170701	20200430_F5_SN5060384	4/30/2020	4038	Project	Optech	272301621.633	272302687.884
20200430_165536	20200430_F5_SN5060384	4/30/2020	4039	Project	Optech	272300936.640	272301226.024
20200415_134260	20200415_F1_SN5060384	4/15/2020	5001	Project	Optech	270993380.495	270994793.823
20200415_140900	20200415_F1_SN5060384	4/15/2020	5002	Project	Optech	270994940.857	270995932.087
20200415_142808	20200415_F1_SN5060384	4/15/2020	5003	Project	Optech	270996089.123	270997471.944

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20200415_145345	20200415_F1_SN5060384	4/15/2020	5004	Project	Optech	270997626.480	270998640.716
20200416_141859	20200416_F2_SN5060384	4/16/2020	5005	Project	Optech	271081939.828	271083203.121
20200416_194537	20200416_F3_SN5060384	4/16/2020	5006	Project	Optech	271101537.077	271102625.613
20200416_200547	20200416_F3_SN5060384	4/16/2020	5007	Project	Optech	271102747.516	271103922.200
20200416_202739	20200416_F3_SN5060384	4/16/2020	5008	Project	Optech	271104059.231	271105187.490
20200416_204831	20200416_F3_SN5060384	4/16/2020	5009	Project	Optech	271105311.519	271106470.285
20200416_210947	20200416_F3_SN5060384	4/16/2020	5010	Project	Optech	271106587.817	271107736.443
20200416_213051	20200416_F3_SN5060384	4/16/2020	5011	Project	Optech	271107851.115	271109000.263
20200416_215151	20200416_F3_SN5060384	4/16/2020	5012	Project	Optech	271109111.069	271110264.687
20200416_221258	20200416_F3_SN5060384	4/16/2020	5013	Project	Optech	271110378.714	271111533.988
20200416_223427	20200416_F3_SN5060384	4/16/2020	5014	Project	Optech	271111668.020	271112830.296
20200418_132524	20200418_F4_SN5060384	4/18/2020	5015	Project	Optech	271251524.236	271252678.513
20200418_134724	20200418_F4_SN5060384	4/18/2020	5016	Project	Optech	271252844.553	271254104.857
20200418_141026	20200418_F4_SN5060384	4/18/2020	5017	Project	Optech	271254226.887	271255407.171
20200418_143254	20200418_F4_SN5060384	4/18/2020	5018	Project	Optech	271255574.806	271256838.512
20200418_145557	20200418_F4_SN5060384	4/18/2020	5019	Project	Optech	271256957.540	271258140.821
20200418_151807	20200418_F4_SN5060384	4/18/2020	5020	Project	Optech	271258287.856	271259528.726
20200418_154048	20200418_F4_SN5060384	4/18/2020	5021	Project	Optech	271259648.764	271260827.459
20200418_160248	20200418_F4_SN5060384	4/18/2020	5022	Project	Optech	271260969.000	271262210.000
20200418_162519	20200418_F4_SN5060384	4/18/2020	5023	Project	Optech	271262319.815	271263484.092
20200418_164650	20200418_F4_SN5060384	4/18/2020	5024	Project	Optech	271263610.867	271264568.350
20200418_223249	20200418_F5_SN5060384	4/18/2020	5025	Project	Optech	271284369.657	271285606.453
20200418_225534	20200418_F5_SN5060384	4/18/2020	5026	Project	Optech	271285734.053	271286987.795
20200410_190926	20200410_F1_SN5060384	4/10/2020	5027	Project	Optech	270580966.869	270582091.510
20200410_193037	20200410_F1_SN5060384	4/10/2020	5028	Project	Optech	270582237.058	270583371.059
20200410_195236	20200410_F1_SN5060384	4/10/2020	5029	Project	Optech	270583556.617	270584739.368
20200410_201503	20200410_F1_SN5060384	4/10/2020	5030	Project	Optech	270584903.521	270586013.415
20200410_203659	20200410_F1_SN5060384	4/10/2020	5031	Project	Optech	270586219.659	270587405.156

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20200410_205913	20200410_F1_SN5060384	4/10/2020	5032	Project	Optech	270587553.591	270588640.041
20200410_212026	20200410_F1_SN5060384	4/10/2020	5033	Project	Optech	270588827.086	270590020.373
20200410_214241	20200410_F1_SN5060384	4/10/2020	5034	Project	Optech	270590161.406	270591245.664
20200410_220436	20200410_F1_SN5060384	4/10/2020	5035	Project	Optech	270591476.074	270592692.498
20200411_015828	20200411_F2_SN5060384	4/11/2020	5036	Project	Optech	270605508.700	270606699.977
20200411_022055	20200411_F2_SN5060384	4/11/2020	5037	Project	Optech	270606855.518	270607973.272
20200411_024237	20200411_F2_SN5060384	4/11/2020	5038	Project	Optech	270608158.314	270609402.601
20200411_030613	20200411_F2_SN5060384	4/11/2020	5039	Project	Optech	270609573.640	270610706.903
20200411_032830	20200411_F2_SN5060384	4/11/2020	5040	Project	Optech	270610910.950	270612086.222
20200411_035030	20200411_F2_SN5060384	4/11/2020	5041	Project	Optech	270612230.750	270613388.524
20200411_041212	20200411_F2_SN5060384	4/11/2020	5042	Project	Optech	270613532.557	270614689.344
20200405_183937	20200405_F1_SN5060384	4/5/2020	5043	Project	Optech	270147177.026	270147984.240
20200405_190153	20200405_F1_SN5060384	4/5/2020	5044	Project	Optech	270148513.574	270149461.285
20200405_192026	20200405_F1_SN5060384	4/5/2020	5045	Project	Optech	270149626.389	270150692.508
20200405_194032	20200405_F1_SN5060384	4/5/2020	5046	Project	Optech	270150833.116	270151791.340
20200405_195947	20200405_F1_SN5060384	4/5/2020	5047	Project	Optech	270151988.387	270152233.214
20200405_202116	20200405_F1_SN5060384	4/5/2020	5048	Project	Optech	270153276.690	270153481.468
20200405_211814	20200405_F1_SN5060384	4/5/2020	5049	Project	Optech	270156694.860	270157784.751
20200405_205952	20200405_F1_SN5060384	4/5/2020	5050	Project	Optech	270155592.060	270156526.646
20200405_213900	20200405_F1_SN5060384	4/5/2020	5051	Project	Optech	270157940.563	270158872.930
20200406_001434	20200405_F2_SN5060384	4/5/2020	5052	Project	Optech	270167274.259	270168365.516
20200406_003711	20200406_F2_SN5060384	4/6/2020	5053	Project	Optech	270168631.083	270169591.802
20200406_005542	20200406_F2_SN5060384	4/6/2020	5054	Project	Optech	270169742.837	270170824.590
20200406_011629	20200406_F2_SN5060384	4/6/2020	5055	Project	Optech	270170990.128	270171948.353
20200406_013606	20200406_F2_SN5060384	4/6/2020	5056	Project	Optech	270172166.954	270173264.663
20200406_015714	20200406_F2_SN5060384	4/6/2020	5057	Project	Optech	270173434.198	270174373.139
20200406_021557	20200406_F2_SN5060384	4/6/2020	5058	Project	Optech	270174557.967	270175652.863
20200405_200707	20200405_F1_SN5060384	4/5/2020	5059	Project	Optech	270152427.200	270153041.635

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20200405_202504	20200405_F1_SN5060384	4/5/2020	5060	Project	Optech	270153504.248	270154224.913
20200416_162710	20200416_F2_SN5060384	4/16/2020	5061	Project	Optech	271089630.617	271090849.641
20200416_165237	20200416_F2_SN5060384	4/16/2020	5062	Project	Optech	271091157.718	271091972.163
20200416_154435	20200416_F2_SN5060384	4/16/2020	5063	Project	Optech	271087075.021	271088269.790
20200416_160707	20200416_F2_SN5060384	4/16/2020	5064	Project	Optech	271088426.806	271089515.085
20200416_133523	20200416_F2_SN5060384	4/16/2020	5065	Project	Optech	271079323.556	271080572.507
20200416_135837	20200416_F2_SN5060384	4/16/2020	5066	Project	Optech	271080717.052	271081797.320
20200419_003112	20200419_F5_SN5060384	4/19/2020	5068	Project	Optech	271291472.540	271292673.383
20200416_192240	20200416_F3_SN5060384	4/16/2020	5069	Project	Optech	271100161.017	271101401.976
20200419_000559	20200419_F5_SN5060384	4/19/2020	5071	Fill In	Optech	271289960.000	271290001.000
20200418_234039	20200418_F5_SN5060384	4/18/2020	5072	Fill In	Optech	271288439.000	271288763.000
20200418_221751	20200418_F5_SN5060384	4/18/2020	5073	Project	Optech	271283471.540	271284254.079
20200411_013643	20200411_F2_SN5060384	4/11/2020	5074	Project	Optech	270604204.394	270605346.662
20200411_170658	20200411_F3_SN5060384	4/11/2020	5075	Project	Optech	270660018.617	270660691.776
20200405_203958	20200405_F1_SN5060384	4/5/2020	5076	Project	Optech	270154398.529	270154927.079
20200405_205202	20200405_F1_SN5060384	4/5/2020	5077	Fill In	Optech	270155123.000	270155261.000
20200406_025442	20200406_F2_SN5060384	4/6/2020	5078	Project	Optech	270176882.510	270176916.518
20200416_191059	20200416_F3_SN5060384	4/16/2020	5079	Project	Optech	271099459.538	271099994.598
20200411_164731	20200411_F3_SN5060384	4/11/2020	5081	Project	Optech	270658852.343	270659865.581

Table 8: TAC Block 3 IA North Central ASInt Project flightline by Mission

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 using at least 3 regularly spaced QC blocks in which points from all lines are loaded and inspected. Vertical differences between ground surfaces of each line are displayed. Color scale is adjusted so that errors greater than the specifications are flagged. Cross sections are visually inspected across each block to validate point to point, flight line to flight line and mission to mission agreement.

For this project, the specifications used are as follows (derived from LiDAR base specification 2.1, QL2): Relative accuracy (smooth surface repeatability) ≤ 6 cm maximum differences within individual swaths and ≤ 8 cm RMSDz between adjacent and overlapping swaths.

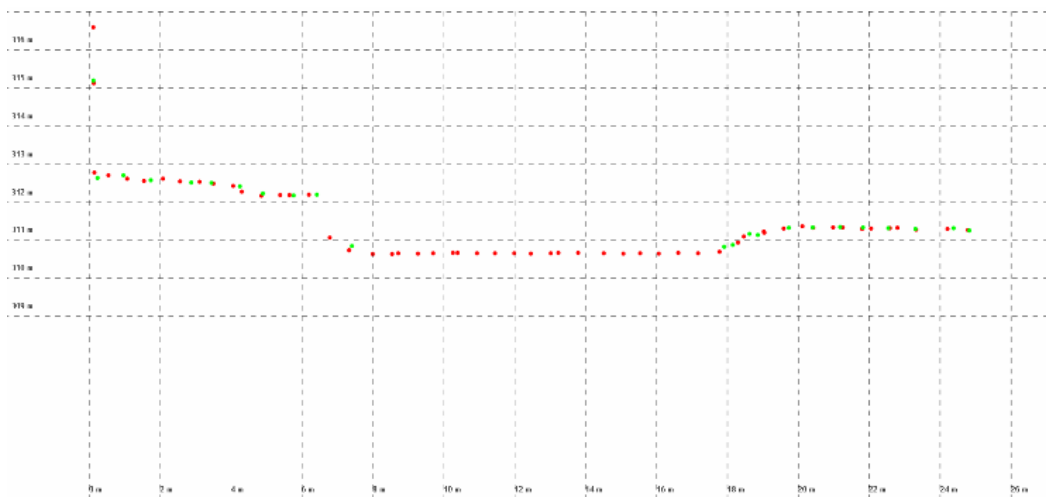


Figure 15: Profile views showing correct roll and pitch adjustments



Final Calibration Verification

Prairie Engineers conducted the survey throughout the area of interest. 57 Ground control points (GCPs) were used to test the accuracy of the calibrated swath data. These 57 GCPs were available to use as control in case the swath data exhibited any biases which would need to be adjusted or removed. The coordinates of all GCPs are provided in the figure below. Surveyed ground control points (GCPs) and the accuracy results from testing the calibrated swath data against the GCPs is provided in the following Tables which include the Ground control points (GCPs) vertical accuracy results (vegetated and non-vegetated); no further adjustments to the swath data were required based on the accuracy results of the GCPs.

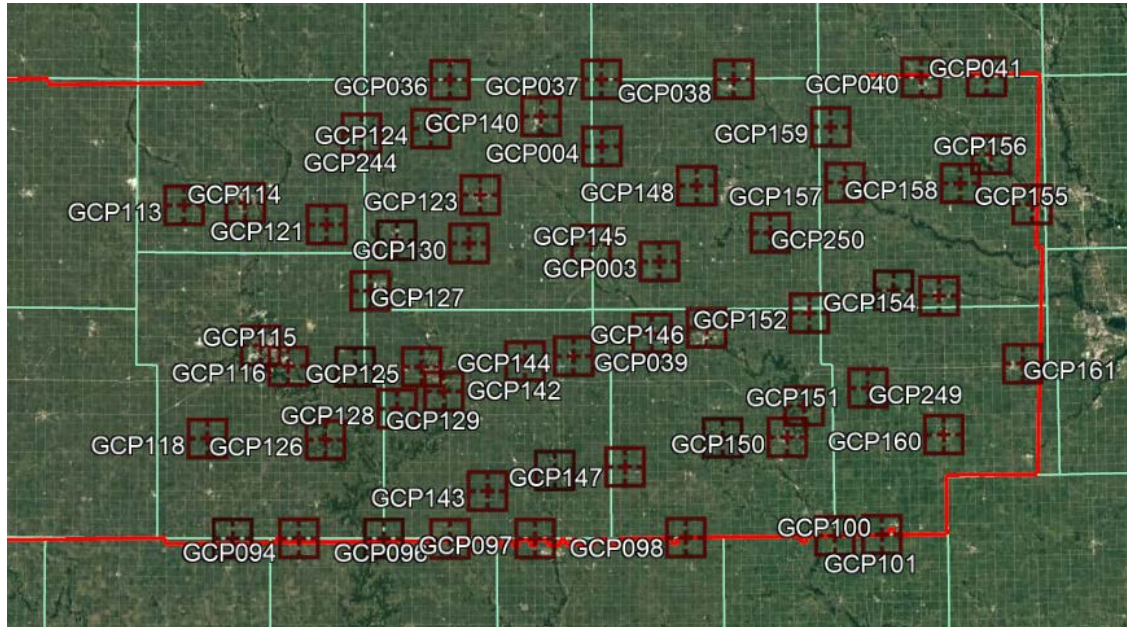


Figure 16: surveyed Ground Control Point Locations

Point ID	NAD83 (2011 adj) UTM Zone 15 N		NAVD88 (Geoid 12B)		Dz (M)
	Easting X (M)	Northing Y (M)	Z-Survey (M)	Z-LiDAR (M)	
GCP153	510305.290	4714507.240	294.890	294.960	0.070
GCP155	534217.020	4728785.580	276.610	276.680	0.070
GCP101	507877.600	4673103.600	315.320	315.380	0.060
GCP124	431911.480	4742739.040	345.520	345.580	0.060
GCP157	502223.430	4732832.840	297.720	297.780	0.060
GCP036	435248.410	4750985.370	362.850	362.900	0.050
GCP121	414006.360	4726715.420	348.170	348.220	0.050

GCP145	458858.500	4722803.620	350.640	350.680	0.040
GCP152	495899.320	4710789.580	326.740	326.780	0.040
GCP122	425861.160	4723915.760	339.870	339.900	0.030
GCP160	518623.160	4689923.250	313.780	313.810	0.030
GCP093	397447.160	4673807.670	341.110	341.140	0.030
GCP244	420115.320	4742060.350	353.100	353.130	0.030
GCP094	408689.400	4673682.950	349.630	349.650	0.020
GCP120	418566.890	4702578.050	337.900	337.920	0.020
GCP130	438132.630	4723244.300	350.520	350.540	0.020
GCP147	464215.030	4685124.470	361.590	361.610	0.020
GCP149	480882.990	4689840.430	320.710	320.730	0.020
GCP156	527299.490	4737342.100	285.590	285.610	0.020
GCP158	521950.950	4732489.850	315.280	315.300	0.020
GCP127	421279.250	4715406.500	345.310	345.330	0.020
GCP140	450635.680	4744589.180	362.440	362.460	0.020
GCP144	455686.310	4703961.750	366.110	366.130	0.020
GCP154	518090.370	4713446.340	300.300	300.320	0.020
GCP161	532273.840	4701792.810	306.990	307.010	0.020
GCP115	402550.290	4706384.890	333.150	333.160	0.010
GCP004	460902.620	4739391.030	383.660	383.670	0.010
GCP038	483500.300	4750536.580	336.440	336.450	0.010
GCP098	474436.310	4673024.850	343.510	343.520	0.010
GCP114	400244.340	4730560.110	330.510	330.520	0.010
GCP139	452267.240	4684661.610	329.730	329.740	0.010

GCP250	489379.730	4724439.410	337.310	337.320	0.010
GCP040	515509.110	4750534.370	306.840	306.840	0.000
GCP118	393352.800	4690753.790	350.590	350.590	0.000
GCP037	460966.26	4750737.6	387.92	387.92	0.000
GCP096	434342.81	4673314.22	313.81	313.81	0.000
GCP128	425598.99	4695425.69	338	338	0.000
GCP150	491898.18	4689789.55	331.42	331.42	0.000
GCP249	505758.03	4697987.78	325.58	325.58	0.000
GCP003	470469.97	4719812.24	361.54	361.53	-0.010
GCP095	423105.67	4673487.39	341.59	341.58	-0.010
GCP097	448806.91	4673186.82	315.53	315.52	-0.010
GCP123	440123.82	4731424.53	359.35	359.34	-0.010
GCP126	413385.79	4690293.89	290.52	290.51	-0.010
GCP148	476953.55	4732579.54	363.1	363.09	-0.010
GCP041	526699.78	4750566.01	307.42	307.4	-0.020
GCP100	499859.45	4673000.55	284.93	284.91	-0.020
GCP146	478345.32	4708493.87	335.42	335.4	-0.020
GCP113	389853.22	4730260.44	351.23	351.21	-0.020
GCP125	429857.14	4702456.72	333.79	333.77	-0.020
GCP116	407198.24	4702832.78	340.96	340.93	-0.030
GCP129	433581.41	4698281.16	315.02	314.99	-0.030
GCP039	469038.71	4707673.02	338.91	338.88	-0.030
GCP143	440794.08	4681327.75	339.54	339.51	-0.030
GCP151	494788.89	4695081.06	308.49	308.46	-0.030

GCP159	499899.82	4742297.85	313.99	313.96	-0.030
GCP142	447416.19	4703214.83	374.31	374.22	-0.090

Table 9: Block 3 IA North Central surveyed ground control points (GCPs).

This project meets Non-vegetated Vertical Accuracy (NVA) ≤ 19.6 cm at the 95% confidence level based on $RMSEz \leq 10$ cm x 1.9600.

100 % of Totals	# of Points	RMSEz (m) GCP Spec=0.1 m	GCP Vertical Accuracy ((RMSEz x 1.9600) Spec = .196m	Mean (m)	Median (m)	Skew	Std Dev (m)	Min (m)	Max (m)	Kurtosis
GCP	57	0.031	0.060	0.009	0.010	-0.251	0.030	-0.090	0.070	1.147

Table 10: Ground control points (GCPs) vertical accuracy results

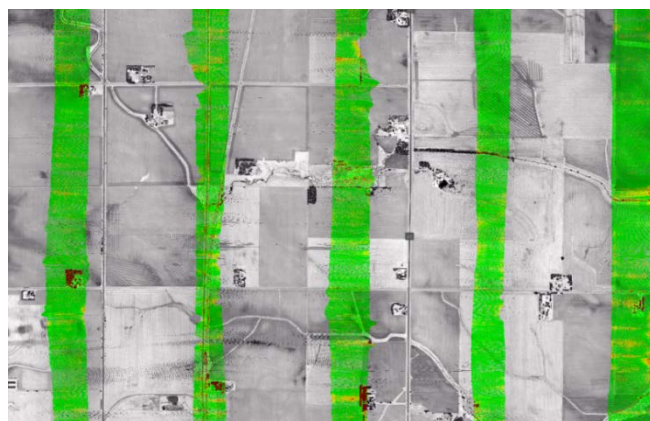
LiDAR Quality Control Reporting

Overview

Technical Applications & Consulting, LLC (TAC) conducted the evaluation of calibrated data for Iowa North Central 2020 D20 to ensure that the swath lidar has been calibrated and produced to meet the required specifications in the Scope of Work (SOW). This review includes verifying the calibration and final formatting of the swath data. Between swath relative accuracy, horizontal alignment, and LAS statistics were reviewed.

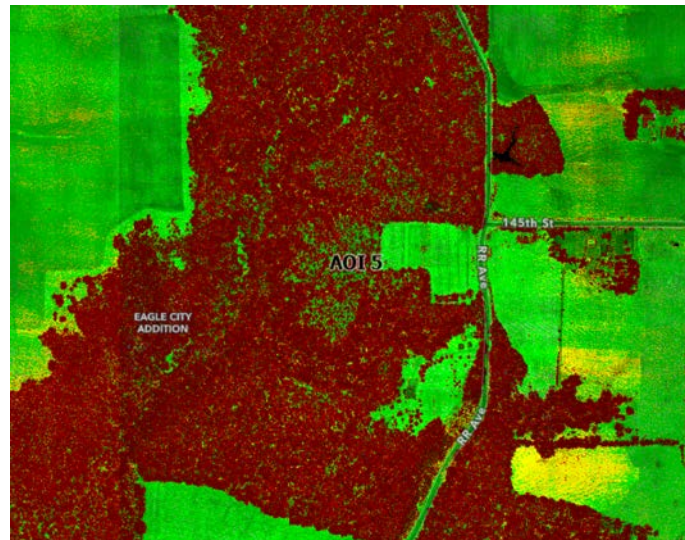
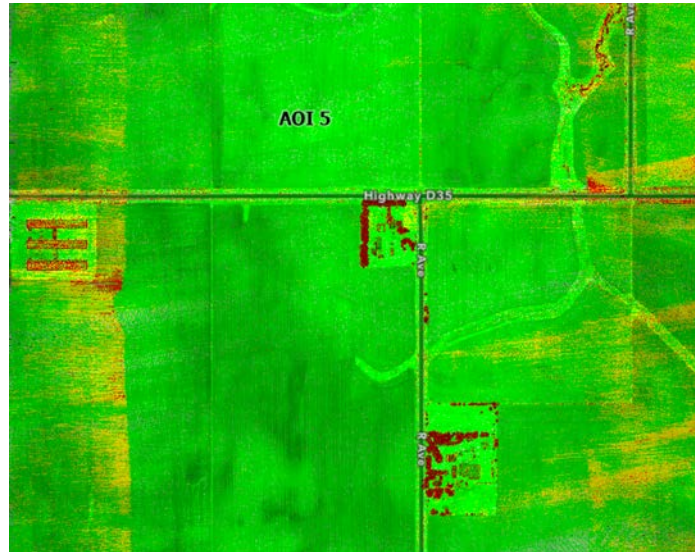
Between Swath Relative Accuracy (DZ Orthos):

Inter-swath relative accuracy passes specification. All pixels colored green are areas where overlapping flight lines are within 8 cm of each other. Areas colored red are where differences greater than 16 cm exist (this is expected in vegetated and sloped areas).



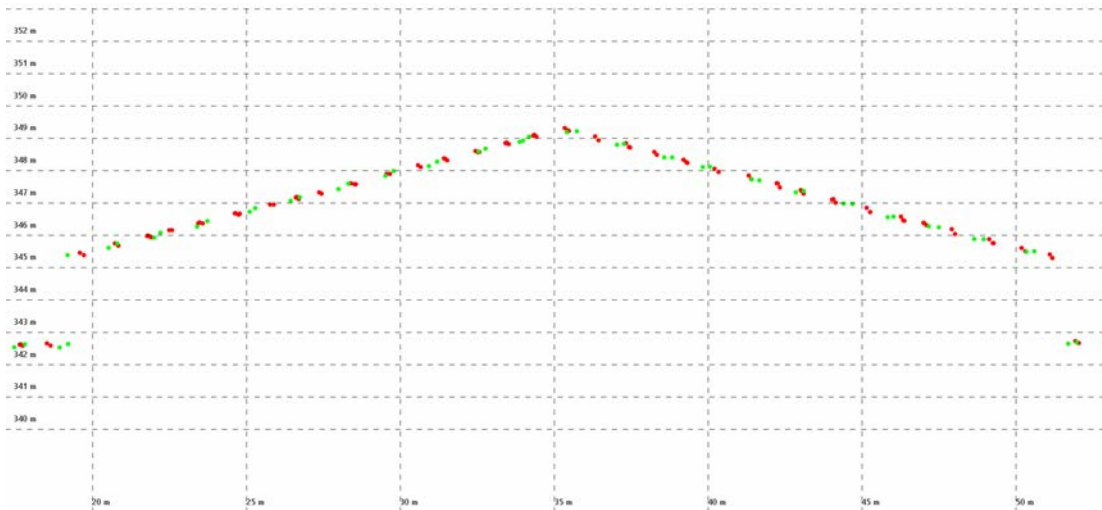
Within Swath Relative Accuracy (Intraswath):

Intra-swath relative accuracy was reviewed and passes specification. All flight lines were reviewed to confirm intra-swath within 6 cm (green) of each to its self on flat plainer surfaces. Areas colored red are where differences greater than 6 cm exist. Red areas are expected in vegetated and sloped areas as this is an assessment only of hard surface repeatability.



Horizontal Alignment/Calibration Check (Rooftops/Planar Surface Profiles):

The profiles show lidar points colored by flight line. The overlapping flight lines match and there is no horizontal (or vertical) offset between the flight lines.

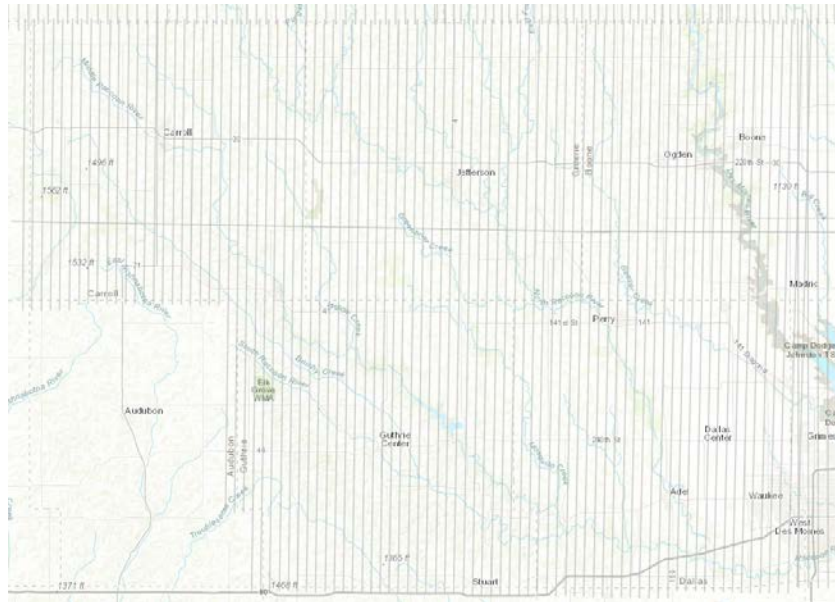


See Appendix B: For Technical Applications & Consulting, LLC (TAC) GPS and IMU Processing Reports

SurvTech Solutions LiDAR Acquisition Details and System Parameters for Iowa North Central

SurvTech Solutions served as Sub Contractor for the Block 3 IA North Central project area and preformed the LiDAR Acquisition and Calibration for less than 1 square mile portion of Webster County.

The following image is of the Planned Flight Line Overview IA North Central project area.



SurvTech Solutions planned 2 passes for the project area. In order to reduce any margin for error in the flight plan, SurvTech Solutions followed FEMA's Appendix A guidelines for flight planning and, at a minimum, includes the following criteria:

- A digital flight line layout using Optech AMM Software flight design software for direct integration into the aircraft flight navigation system.
- Planned flight lines; flight line numbers; and coverage area.
- Lidar coverage extended beyond all project borders to ensure necessary over-edge coverage appropriate for specific task order deliverables. A buffered AOI was provided by ASI.
- All airspace was coordinated and any controlled or restricted areas were pre coordinated and approval granted from the airspace owner.

Lidar System parameters

SurvTech Solutions operated a Cessna 401 (Registration N41GD) equipped with an Optech Galaxy Prime Lidar system during the collection of this task order. Data was acquired April 21, 2020.

Item	Parameter
System	Optech Galaxy Prime
Altitude (AGL meters)	2286
Approx. Ground Speed (kts)	150
Laser Firing Rate (kHz)	400
Swath width (m)	1894
Swath Overlap (%)	30%
Line Spacing (m)	1300
Pass heading °	North-South
Field of View °	45
Computed Down Track spacing (m) per beam	0.61
Computed Cross Track Spacing (m) per beam	0.67
Average point spacing (m)	0.64
Point density at Nadir	2.42
Points per meter ² (m)	2.74
Scan Pattern	Sawtooth

Table #: SurvTech Solutions LiDAR system parameters

Calibration Report

Point clouds are output using Optech's LMS. The initial point generation for each mission calibration is verified within LMS for calibration errors. If significant calibration errors are observed within the mission; the internal sensor misalignments are calculated. The data is then regenerated with the new solution and is validated internally once again to ensure quality.

Relative accuracy and internal quality are checked using Terramatch, as well as, BayesMap-StripAlign, in which points from all lines are observed and compared. Vertical differences between ground surfaces of each line are displayed. Rasters are generated on filtered tiles to model Dz between adjacent lines. Inter-swath accuracy is tested to the <.08m standard specified in the base spec. Data are visually inspected across each block to validate point to point, flight line to flight line and mission to mission agreement.

Acquisition Control

SurvTech Solutions conducted the survey which provided the established base stations used to control the lidar acquisition for USGS Iowa North Central area. The coordinates of the base stations are provided in the table below. These stations are continuously running by the state of IOWA which is the IARTN.

Name	NAD83(2011) Deg Min Sec		Ellipsoid Ht
	Latitude	Longitude	(GRS80, m)
IACA	42-04-40.01012	-94-54-40.40128	366.0066
IAJE	42-01-16.06223	-94-22-55.43946	303.9157
AIDM	41-39-27.16598	-93-35-48.11477	255.7855

Table 11: Base stations used to control lidar acquisition for the Project.

Airborne GPS Kinematic

Airborne GPS data was processed using PosPac MMS 8.4. Flights were flown with a minimum of 8 satellites in view (10° above the horizon) and with a PDOP of better than 4. Distances from base station to aircraft were kept to a maximum of 80km.

For all flights the GPS data can be classified as good with GPS residuals of 3cm average or better but no larger than 10cm being 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.

The initial points for each mission are inspected for flight line errors, flight line overlap, slivers or data holidays, point data minimums or issues with the LiDAR unit or GPS. Data collected by the LiDAR unit is reviewed for completeness, acceptable density and errors or corrupted values. Intra-swath repeatability is tested to meet the <.06m standard specified in the base spec. In addition, all GPS data, aircraft trajectories, mission information and ground control files are reviewed. On a project level, a supplementary coverage check is carried out to ensure data voids unreported by Field Operations are not present.

Data collected by the lidar unit is reviewed for completeness, acceptable point 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 17: SURVTECH Block 3 LiDAR swath output showing complete coverage

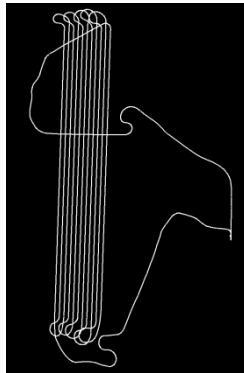


Figure 18: SURVTECH Block 3 IA North Central project Combined project SBET

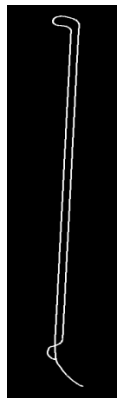


Figure 19: SURVTECH combined trajectory of the flightlines by mission over Block 3 IA North Central project area.

The following table is a listing of Flightlines and corresponding, Lift_ID, Date, Point Source ID, Scanner, and adjusted GPS Start and End times.

Name	Lift_ID	Date	PT Source ID	Swath Type	Scanner	Start Time	End Time
20200421_181730	20200421_F2_SN5060413	4/21/2020	16101	Fill In	Optech	271528250.000	271529685.000
20200421_184125	20200421_F2_SN5060413	4/21/2020	16201	Fill In	Optech	271529685.000	271530863.000

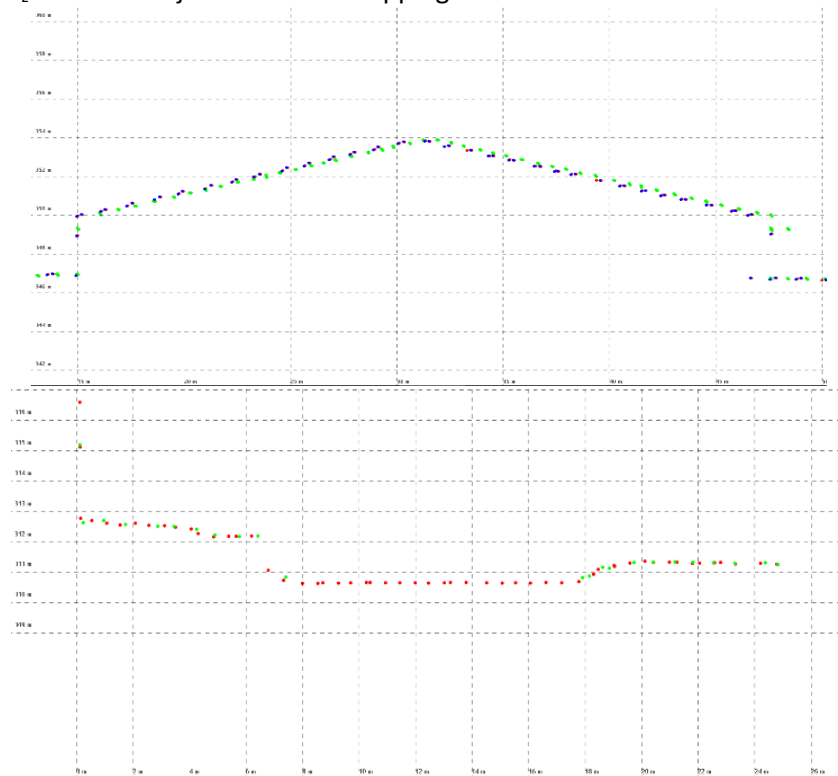
Table 12: TAC Block 3 IA North Central ASInt Project flightline by Mission

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 using at least 3 regularly spaced QC blocks in which points from all lines are loaded and inspected. Vertical differences between ground surfaces of each line are displayed. Color scale is adjusted so that errors greater than the specifications are flagged. Cross sections are visually inspected across each block to validate point to point, flight line to flight line and mission to mission agreement.

For this project, the specifications used are as follows (derived from LiDAR base specification 2.1, QL2): Relative accuracy (smooth surface repeatability) ≤ 6 cm maximum differences within individual swaths and ≤ 8 cm RMSD_z between adjacent and overlapping swaths.



Final Calibration Verification

Please refer back to the Technical Applications & Consulting, LLC (TAC) Final Calibration Verification section of this report (pages 34 – 37) for ground control listings and results.

LiDAR Quality Control Reporting

Overview

SurvTech Solutions conducted the evaluation of calibrated data for USGS Iowa South Central to ensure that the swath lidar has been calibrated and produced to meet the required specifications in the Scope of Work (SOW). This review includes verifying the calibration and final formatting of the swath data. Between swath relative accuracy, horizontal alignment, and LAS statistics were reviewed. Results of this review are provided below.

LiDAR Calibration Review			
Requirement	Description of Check	Yes / No	Additional Comments
Review Adjustment Parameters	Examine magnitude and types of corrections applied (POSPac) for outliers or issues.	Yes	
Review against control	Calculate offset between control and lidar points. These statistics include RMSE, standard deviation, mean, min/max. Report magnitude of bias shift made, or report if no shift applied.	Yes	
Run DZ Orthos	Create difference rasters (DZ orthos) and review for any artifacts.	Yes	
Run intraswath Check	Create intraswath difference rasters and review for artifacts	Yes	
Run and review quantitative interswath check	Create statistics showing the alignment swath-swath (e.g. Measure Match report)	Yes	
Spot check cross sections	Draw cross sections on roofs and open areas throughout the project to check horizontal and vertical alignment. Include example cross sections in this report	Yes	

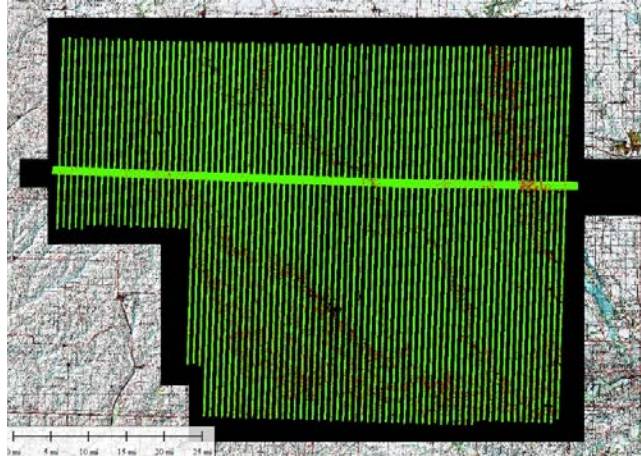
Formatting Checks			
Requirement	Description of Check	Pass/Fail	Additional Comments
Swaths are in v1.4 formatting	Swaths are in LAS v1.4 as required by the project.	Pass	
Classification set to 0	All classes should be set to class 0. If any classes are set, or flags are set (withheld, synthetic, etc) please describe what these classes/flags are denoting.	Pass	
All swaths must have File Source IDs assigned (these should equal the Point Source ID or the flight line number)	File Source IDs are correctly assigned	Pass	
GPS timestamps must be in Adjusted GPS time format and Global Encoding field must also indicate Adjusted GPS	GPS timestamps are Adjusted GPS time and Global Encoding field is correctly set to 17	Pass	

timestamps			
Intensity values must be 16-bit, with values ranging between 0-65,535	Intensity values are 16-bit	Pass	
Point Source IDs must be populated and should match the File Source IDs	Point Source IDs are assigned and match the File Source IDs	Pass	
Scan angle values must be within expected range	Verify scan angle statistics for angles that are significantly above or below expected ranges	Pass	
Channels are merged and channel bit set	If the processing software outputs multiple LAS per swath for a single sensor, these should be merged into a single LAS file. Additionally, the scanner bit and user byte should be set to the scanner numbers. (e.g. 1 for channel 1)		None Applicable.
Scan Direction and Edge of Flightline Flags Set Correctly	The scan direction flag should be set to 0 for rotating mirror systems, and 0/1 for oscillating mirror systems. The edge of flightline flag should be set for all systems.	Pass	

Lidar Calibration Deliverables			
Requirement	Description of Deliverable	Included?	Additional Comments
Calibrated LAS Swaths	Examine magnitude and types of corrections applied (either Bayesmap or TerraMatch TMS) for outliers or issues.	Yes	
Terrascan TRJ Files	.trj files for each swath delivered. These trajectory files need to match the LAS swath spatially, temporally (correct time system), and have identical flightline numbering	Yes	
Calibration Adjustment Reports	Files that contain information on the adjustments applied. This at a bare minimum must include what parameters are being solved for. Ideally these include all the values being applied to the data. An example from the TerraMatch workflow would be to include all .TMS files applied.	Yes	
Calibration Control Reports	Calculate offset between control and lidar points. These statistics include RMSE, standard deviation, mean, min/max. Report magnitude of bias shift made, or report if no shift applied.	Yes	
Calibration Control Shapefile	Provide shapefile of calibration control points	Yes	
Relative Accuracy Statistics	Quantitative statistics showing relative alignment of swath-swath	Yes	
DZ Ortho Rasters	DZ raster's showing alignment between swaths (interswath)	Yes	

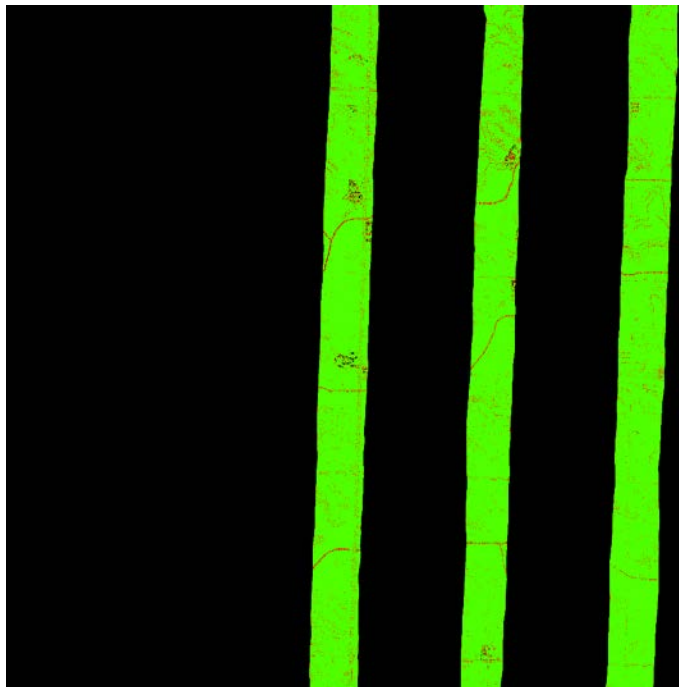
Between Swath Relative Accuracy (DZ Orthos):

Inter-swath relative accuracy passes specification. All pixels colored green are areas where overlapping flight lines are within 8 cm of each other. Areas colored red are where differences greater than 8 cm exist (this is expected in vegetated and sloped areas).



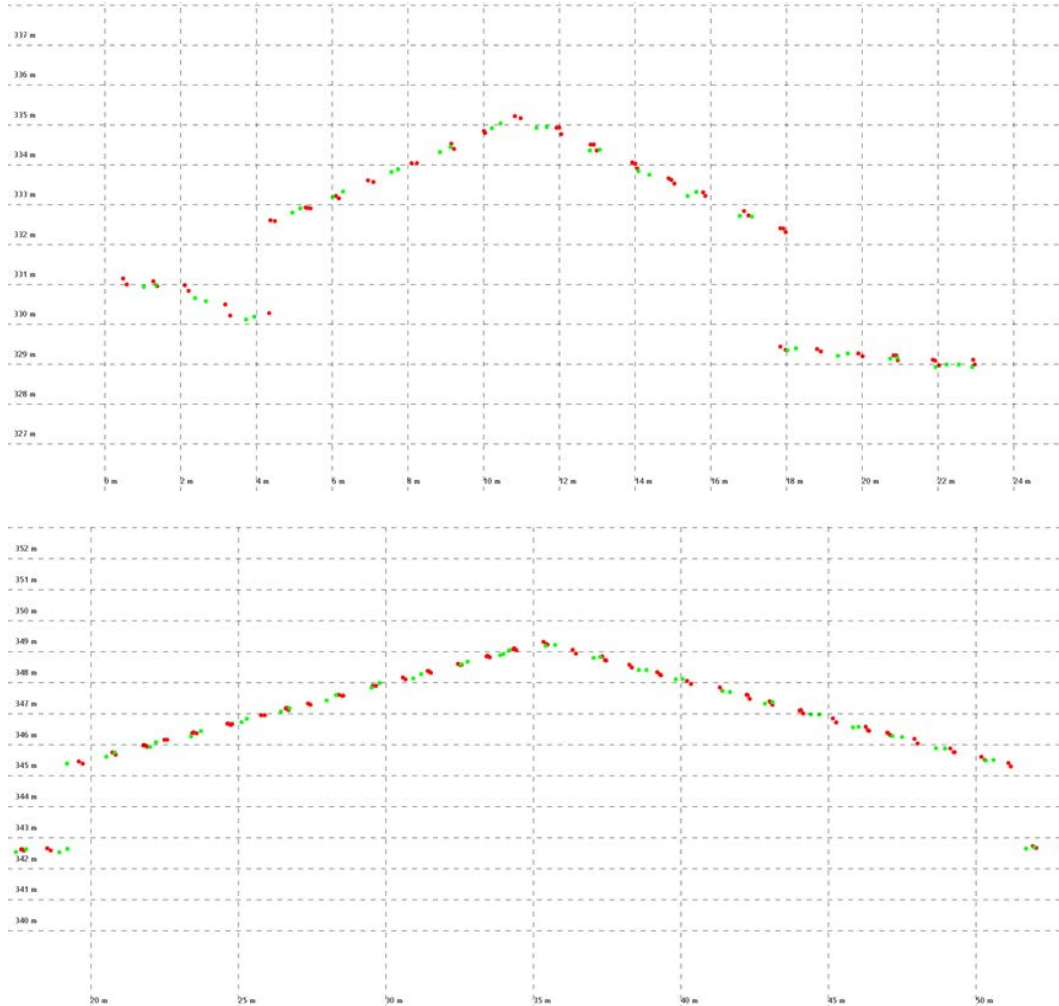
Within Swath Relative Accuracy (Intraswath):

Intra-swath relative accuracy was reviewed and passes specification. All flight lines were reviewed to confirm intra-swath within 8 cm (green) of each other on flat plainer surfaces. Areas colored red are where differences greater than 8 cm exist. Red areas are expected in vegetated and sloped areas as this is an assessment only of hard surface repeatability.



Horizontal Alignment/Calibration Check (Rooftops/Planar Surface Profiles):

The profiles show lidar points colored by flight line. The overlapping flight lines match and there is no horizontal (or vertical) offset between the flight lines.



See Appendix B: For SurvTech Solutions GPS and IMU Processing Reports

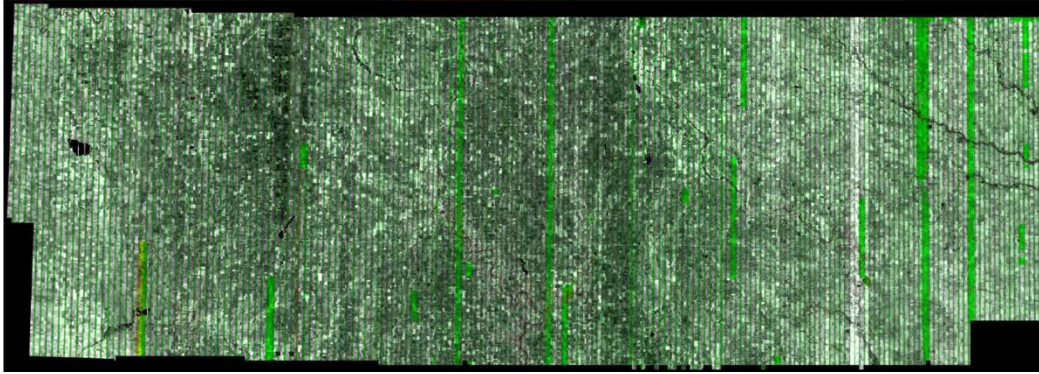


Figure 20: Block 3 IA North Central Project Delta-z raster image.

DATA CLASSIFICATION AND EDITING

Once the calibration, absolute swath vertical accuracy, and relative accuracy of the data were confirmed, ASI utilized TerraScan software for data processing. The acquired 3D laser point clouds, in LAS binary format, were imported into the 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. In areas of very dense noise class code 18 was bitset to withheld. 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.

In TerraScan surface models for each tile was created to examine the ground classification. ASI analysts visually reviewed the ground surface model for artifacts left in the ground classification. These artifacts consist of vegetation, buildings, and bridges that were still present in the ground after initial processing. ASI analysts employ 3D visualization techniques to view the point cloud at multiple angles and in profile to ensure that errant points are removed from the ground classification. Bridge decks are manually classified to class 17. After the ground classification had been completed, the dataset was processed through a water classification routine that utilized breaklines compiled by the Prime and Subcontractor 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, ground points that are within 2x NPS or less of the hydrographic features are moved to class 20 ignored ground, due to breakline proximity. Overage points are then identified in TerraScan and used to set the overlap bit for those points. The withheld points identified during the classification routine are used to set the withheld bit. The LiDAR tiles were classified to the following classification schema:

- o Class 1 – Default, Processed, but unclassified
- o Class 2 – Ground, Bare-earth
- o Class 7 – Low Noise (low and manually identified)
- o Class 9 – Water
- o Class 17 – Bridge Decks
- o Class 18 – High Noise (high, manually identified)
- o Class 20 – Ignored Ground (Breakline Proximity)

After manual classification, the LAS tiles were peer reviewed and then underwent a final QA/QC. After the final QA/QC and corrections, the LAS files were then converted from LAS v1.2 to LAS v1.4 using TerraScan software to flag the overlap bit and withheld bit. An LP360 64 bit was used to deduce the Well Known Text (WKT) and ASI proprietary software was used to format the LAS to the final LAS v1.4 Format 6 version. LAStools by rapidlasso GmbH, open source, lasInfo (open source LGPL) and ASI proprietary software was used to perform final analysis to checks on LAS header information, LAS point classes, and LAS timestamps.

This project consists of 71,829,457,873 lidar points the table below shows the total number of points for every class.

Project Count by Class		
Class 1	Processed, unclassified	14549657204
Class 2	Bare-earth ground	36185412878
Class 7	Low Noise	40272873
Class 9	Water	69738547
Class 17	Bridge Decks	2068196
Class 18	High Noise	222608381
Class 20	Ignored_Ground	2822470
Class Overlap 1	Overlap Processed, unclassified	10382313582
Class Overlap 2	Overlap Bare-earth ground	9021357554
Class Overlap 7	Overlap Low Noise	732981

Class Overlap 9	Overlap Water	2618636
Class Overlap 17	Overlap Bridge Decks	807175
Class Overlap 18	Overlap High Noise	21799717
Class Overlap 20	Overlap Ignored_Ground	660019
Class Withheld 1	Withheld Processed, unclassified	193185114
Class Withheld 2	Withheld Bare-earth ground	178990141
Class Withheld 7	Withheld Low Noise	347752
Class Withheld 9	Withheld Water	113162
Class Withheld 17	Withheld Bridge Decks	29478
Class Withheld 18	Withheld High Noise	154558864
Class Withheld 20	Withheld Ignored_Ground	7152
Class Overlap Withheld 1	Overlap Withheld Processed, unclassified	660019
Class Overlap Withheld 2	Overlap Withheld Ground	375177515
Class Overlap Withheld 7	Overlap Withheld Low Noise	207573893
Class Overlap Withheld 9	Overlap Withheld Water	250570
Class Overlap Withheld 17	Overlap Withheld Bridge Decks	109643
Class Overlap Withheld 18	Overlap Withheld High Noise	51642
Class Overlap Withheld 20	Overlap Withheld Ignored_Ground	216179465
Project Total Count		71829457873

Table 13: By Class Point Count.

LiDAR Qualitative Assessment

ASI'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 Block 3 IA North Central project.

Data Voids

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 Block 3 IA North Central project.

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. 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 have been removed from ground (orange) and are bridge deck (blue).

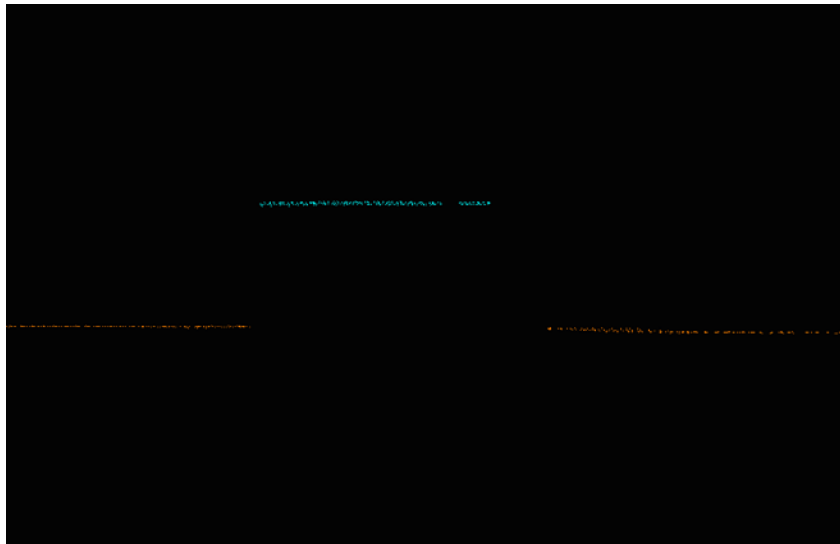


Figure 21: Profile view of a classified bridge deck (blue) and ground (orange).

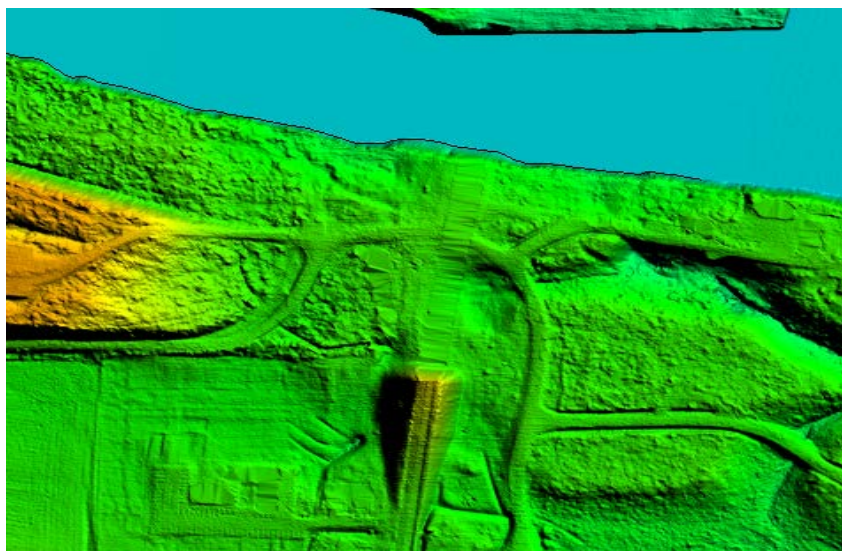


Figure 22: DEM with bridge removed from surface model.

Culverts

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, ASI 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.

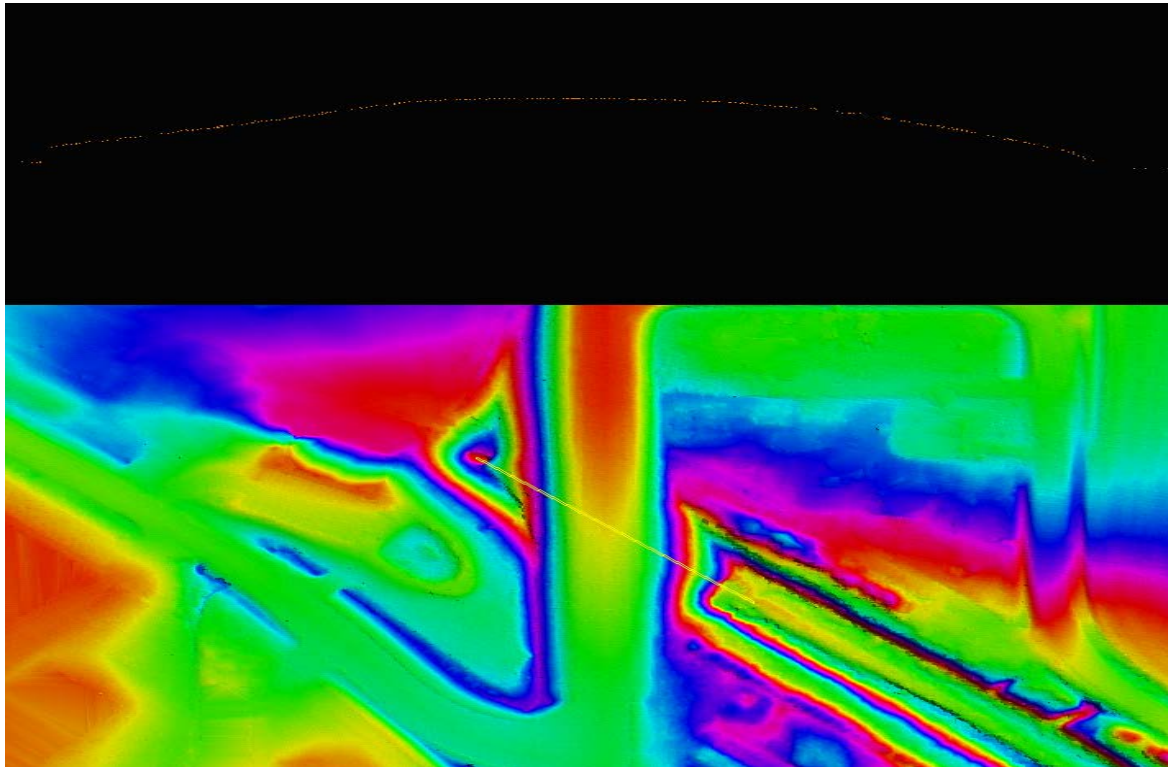


Figure 23: Profile with points colored by class (class 1=white, class 2=orange) is shown in the top view and the DEM is shown in the bottom view. This culvert remains in the bare earth surface. Bridges have been removed from the bare earth surface and classified to class 17.

Dirt Mounds

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

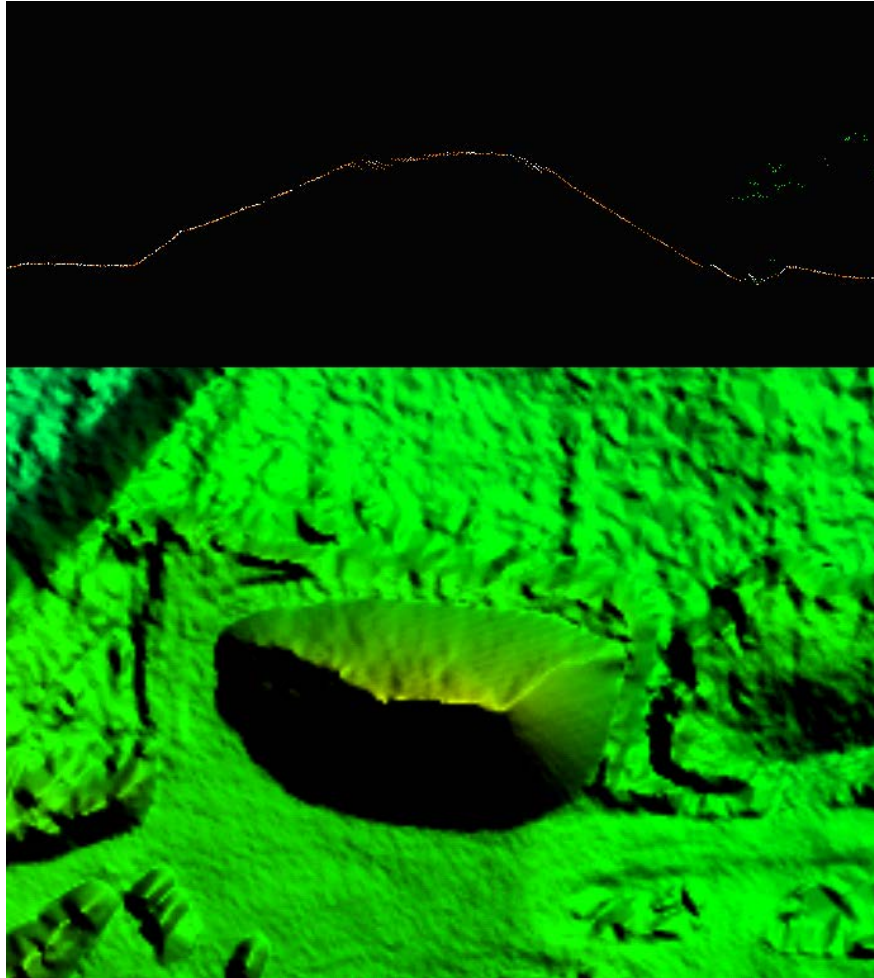


Figure 24: Profile with the points colored by class (unclassified points are white, ground points are orange) is shown on the right and a DEM of the surface is shown to the left. These features are correctly included in the ground classification.

Flightline Ridges

Ridges occur when there is a difference between the elevations of adjoining flight lines or swaths. Some flightline ridges are visible in the final DEMs but they do not exceed the project specifications and the overall relative accuracy requirements for the project area have been met. An example of a visible flightline ridge that is within tolerance is shown below.

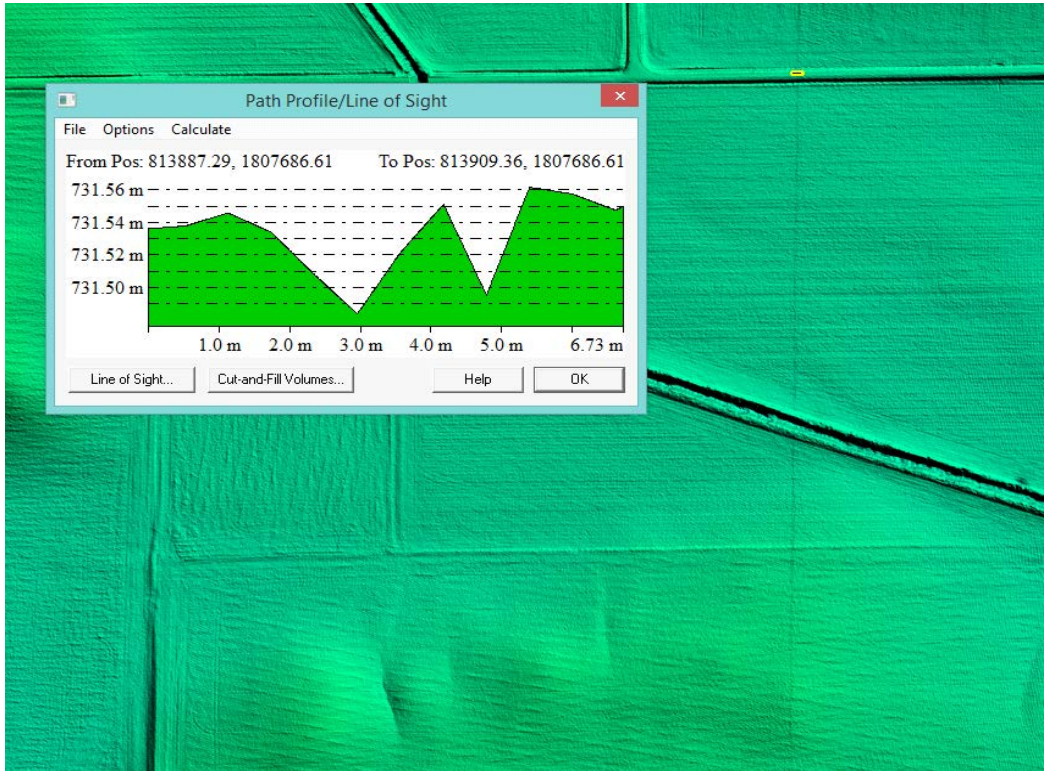


Figure 25: The flight line ridge is less than 8 cm. Overall; the Block 3 IA North Central project data meets the project specifications for 8 cm RMSDz relative accuracy requirement.

Dam and Lock system

Irregularities in the natural water flow exist in sections of river affected by Lock and Dam systems. Series of locks enable vessels to “step” up or down a river or canal from one water level to another. There are no Lock systems in the Block 3 IA North Central Lidar project area.

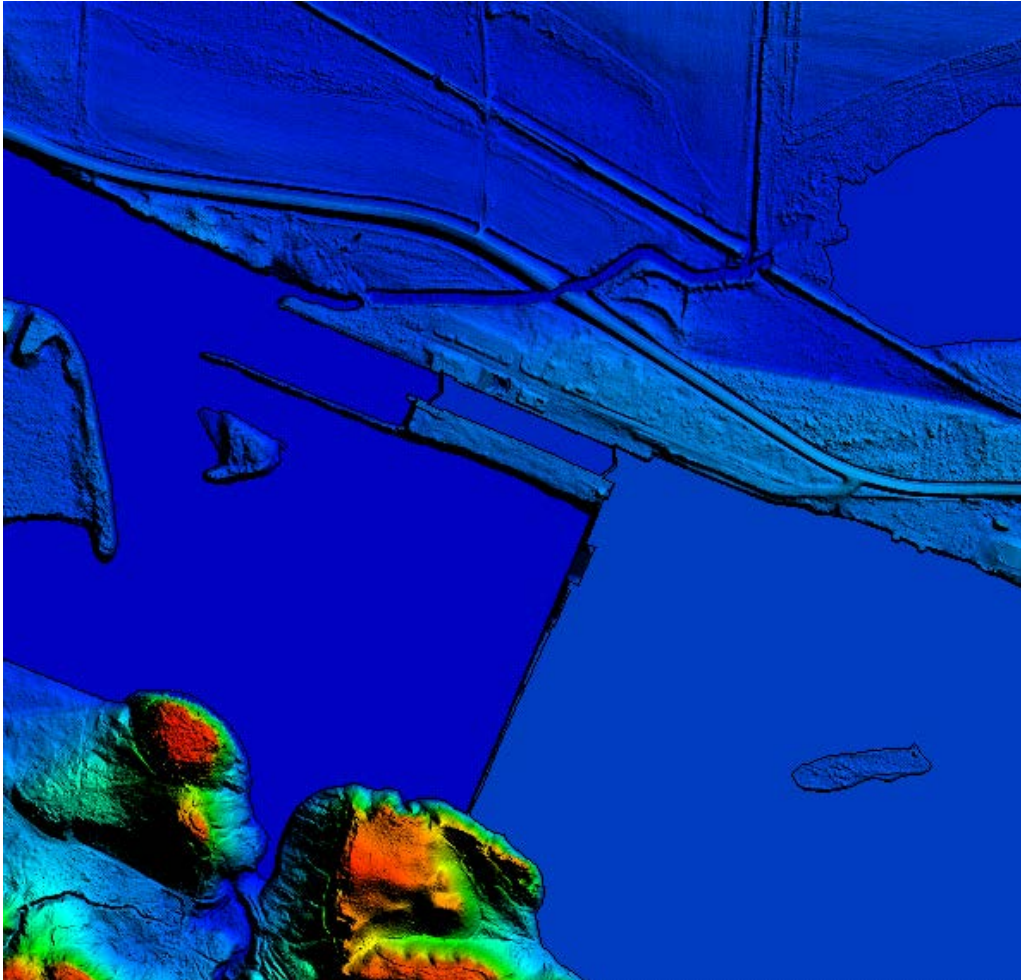


Figure 26: DEM shows Large Dam structure that disrupts natural monotonic river flow, coupled with a lock system.

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 ASI proprietary tools. ASI routinely reviews for: proper LAS versions, Coordinate Reference System, Global Encoder Bit, Time Stamp, System ID, Multiple Returns, Intensity, Classification, Overlap and Withheld Points, Scan angle, XYZ Coordinates.

LiDAR Positional Accuracy

BACKGROUND

ASI quantitatively tested the dataset by testing the vertical accuracy of the LiDAR. The vertical accuracy is tested by comparing the discrete 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. The nature of lidar data makes it difficult to assess absolute horizontal accuracy as one would with imagery or compiled planimetric data. Guidance on how absolute horizontal accuracy can be estimated and reported based on the error budget of the instrumentation and operational parameters can be found in ASPRS (2014). The horizontal accuracy of each lidar project shall be reported using the form specified by the ASPRS (2014).

SURVEY VERTICAL ACCURACY CHECKPOINTS

For the vertical accuracy assessment of Block 3 IA North Central project, one hundred thirteen checkpoints were surveyed. All of those checkpoints are located within bare earth/open terrain (113 NVA points). Please see provided 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 North	NAD83 (2011) UTM Zone 15 North	NAVD88 (Geoid12B)
	Easting (M)	Northing (M)	Elevation (M)
NVA078	365572.5	4695012.32	375.41
NVA079	357106.24	4681011.19	378.57
NVA080	370443.65	4680649.53	352.85
NVA081	380259.95	4700472.31	356.35
NVA082	346907.19	4686786.33	377.4
NVA083	389694.93	4715753.79	366.4
NVA084	403011.43	4711757.12	350.76
NVA085	406582.81	4718783.67	346.14

NVA086	416271.67	4716188.31	346.85
NVA087	393536.11	4681719.38	348.42
NVA152	324477.33	4751188.94	385.9
NVA153	311164.95	4726155	456.31
NVA154	320065.91	4732060.9	420.47
NVA155	304822.61	4743795.39	435.37
NVA156	337741.54	4747382.54	424.33
NVA157	340563	4738399.85	402.88
NVA158	320937.41	4722486.36	428.52
NVA159	334849.63	4719347.41	386.33
NVA160	312073.03	4714592.82	435.74
NVA161	348694.69	4745446.17	398.81
NVA162	362765.49	4743028.44	371.42
NVA163	364644.53	4734032.41	372.99
NVA164	377345.91	4748330.76	360.34
NVA165	381851.57	4731834.54	376.3
NVA166	344931.73	4734241.57	395.88
NVA167	357638.66	4724506.28	385.85
NVA168	368926.34	4721177.44	378.02
NVA169	348533.53	4716068.84	374.49
NVA170	387380.26	4749704.13	353
NVA171	394839.69	4747004.19	351.58
NVA172	400538.24	4730447.77	331.86
NVA173	403212.76	4746854.02	348.81

NVA174	414112.1	4736374.63	347.16
NVA174	403213.76	4746855.02	349.81
NVA175	419828.99	4742297.32	351.23
NVA176	414057.79	4731537.57	344.03
NVA177	418768.65	4723442.06	345.75
NVA178	384987.47	4723966.57	364.02
NVA179	391668.64	4739930.8	350.91
NVA180	431987.73	4745856.68	348.78
NVA181	450121.25	4743889.53	359.56
NVA182	439719.19	4731300.94	355.79
NVA183	447862.41	4731148.09	371.81
NVA184	424654.02	4731814.13	344.17
NVA185	439912.1	4738517.53	361.64
NVA187	425643.44	4724188.92	339.92
NVA188	425145.67	4713738.92	340.49
NVA189	454996.09	4713768.83	367.94
NVA190	441273.98	4711923.19	361.86
NVA191	482435.76	4748990.3	328.34
NVA192	471268.27	4748835.61	373.44
NVA193	482206	4732215.37	348.17
NVA194	469864.8	4734685.32	378.36
NVA195	459019.75	4722801.97	350.33
NVA196	479921.17	4720037.61	383.34
NVA197	495522.29	4742282.91	313.51

NVA198	489381.94	4724777.83	335.7
NVA199	497867.74	4732508.26	310.65
NVA200	501988.69	4742292.73	315.43
NVA201	516301.76	4749218.92	291.1
NVA202	526716.45	4747109.56	309.98
NVA203	527098.17	4736887.26	286.17
NVA204	534195.81	4728801.68	276.95
NVA205	530130.09	4712552.48	273.99
NVA206	517575.79	4713291.65	306.81
NVA207	516858.42	4733543.43	321.04
NVA208	509461.67	4714638.99	296.47
NVA209	495282.57	4711555.45	330.04
NVA210	509111.12	4722768.26	307.5
NVA211	305450.38	4705235.51	419.74
NVA212	310171.98	4687798.44	409.81
NVA213	311394.24	4675707	420.65
NVA214	336237.14	4698657.93	371.27
NVA215	330849.47	4685890.46	381.76
NVA216	323366.62	4704612.78	421.32
NVA217	336275.63	4709189.49	386.37
NVA218	311982.12	4707640.99	430.87
NVA219	323027.2	4689828.83	392.73
NVA220	347601.76	4708905.63	370.44
NVA221	361743.22	4712296.29	377.72

NVA222	373999.36	4709702.51	379.53
NVA223	362710.36	4700953.98	372.7
NVA224	407206.51	4702884.23	341.17
NVA225	394225.91	4701001.78	351.96
NVA226	411774.33	4679391.69	344.14
NVA227	428523.77	4699025.55	337.78
NVA228	413390.26	4690289.92	290.6
NVA229	384250.48	4681963.74	348.03
NVA230	402519	4691396.41	349.48
NVA231	447395.91	4703131.42	373.66
NVA232	454945.75	4702455.37	365.46
NVA233	431215.02	4692709.32	336.11
NVA235	447275.6	4684024.32	322.36
NVA236	423531.3	4680182.73	339.3
NVA237	434397.25	4682169.96	340.98
NVA238	439953.05	4693541.02	341.45
NVA239	464202.28	4684877.04	360.43
NVA240	468748.77	4706994.24	355.04
NVA241	478286.37	4701987.29	344.28
NVA242	495767.53	4700787.28	335.91
NVA243	478452.94	4709244.16	342.69
NVA244	491775.02	4689827.24	330.32
NVA245	492629.77	4676985.15	304.11
NVA246	474481.72	4689104.62	344.89

NVA247	467369.32	4677108.38	366.21
NVA248	432900.34	4702239.03	316.99
NVA249	505733.13	4697960.7	325.34
NVA250	518887.39	4708409.89	308.8
NVA251	530673.25	4701470.93	287.05
NVA252	519144.93	4690004.76	311.52
NVA253	533026.97	4685883.97	289.64
NVA254	510014.79	4675294.72	308.78
NVA255	499836.4	4684271.94	311.82
VVA100	509460.09	4714194	305.74
VVA101	531338.35	4713165.93	271.94
VVA102	517705.15	4713546.8	305.02
VVA103	522005.97	4722593.39	281.3
VVA104	530597.27	4701624.84	288.8
VVA105	523605.5	4708284.76	311.89
VVA106	518940.95	4702008.84	316.62
VVA107	506309.93	4701070.09	307.74
VVA108	488972.43	4703024.53	303.71
VVA109	483115.7	4697602.95	340.21
VVA110	459075.21	4722749.77	348.93
VVA111	452036.15	4684877.01	331.46
VVA112	393771.86	4681655.35	345.5
VVA113	411733.19	4679642.87	342.48

VVA114	424536.22	4685762.99	289.69
VVA115	533314.18	4685209.84	298.33
VVA116	518060.7	4690146.5	307.82
VVA118	492634.14	4681985.09	288.94
VVA174	356108.69	4681346.15	370.15
VVA175	347821.1	4686515.98	374.79
VVA176	330374.11	4686368.71	396.7
VVA177	314690.84	4686764	412.56
VVA178	314692.11	4677967	393.59
VVA179	327140.34	4682100.46	392.46
VVA184	434362.62	4675063.87	308.69
VVA185	382804.97	4749825.09	349.52
VVA195	420006.09	4742115.84	352.96
VVA198	382111.82	4692561.81	350.92
VVA203	476021.9	4683384.56	341.93
VVA204	479902.8	4720151.54	380.86
VVA205	505152.62	4722729.47	317.37
VVA206	450401.87	4743759.76	361.08
VVA210	386006.87	4723319.96	360.7
VVA211	383601.1	4740052.67	341.95
VVA212	407122.05	4739291.82	333.12
VVA222	405496.21	4697494.69	340.32
VVA223	447340.84	4703241.73	373.49
VVA224	344348.69	4724338.6	381.78

VVA228	362234.31	4711788.99	375.46
VVA229	368857.31	4721043.53	377.93
VVA230	416322.61	4715968.35	347.53
VVA231	431001.76	4712883.22	338.05
VVA232	491923.78	4689948.42	329.93
VVA233	493995.51	4695043.64	297.36
VVA234	469335.04	4696324.75	351.18
VVA235	454865.38	4732230.03	368.91
VVA236	481874.6	4742383.9	352.81
VVA244	374684.39	4741489.37	359.62
VVA249	455694.26	4703864.18	364.82
VVA250	413503.96	4690362.55	286.83
VVA60	325190.45	4751032.45	411.49
VVA66	349729.83	4745036.81	391.54
VVA67	340333.82	4738776.62	400.61
VVA68	321735.47	4721302.98	427.85
VVA69	311349.95	4726541.29	459.1
VVA70	321274.66	4732817.52	417.23
VVA71	373750.93	4710699.74	375.57
VVA72	362957.07	4732070.27	378.59
VVA73	399362.09	4730050.06	348.43
VVA74	403658.4	4746920.83	348.43
VVA78	440285.74	4731612.24	357.05
VVA83	516093.97	4749034.29	291.03

VVA84	499984.36	4742514.67	314.92
VVA85	527294.57	4737175.47	285.75
VVA86	516710.1	4733697.57	322.42
VVA87	483759.7	4732309.7	346.13
VVA88	460841.18	4739270.68	381.19
VVA89	427060.54	4724113.32	339.33
VVA90	403757.33	4707867.32	337.72
VVA91	348487.03	4715749.52	374.49
VVA92	311306.5	4707551.55	437.89
VVA93	322683.15	4703440.37	410.68
VVA94	337086.59	4698231.18	363.91
VVA95	365469.94	4694987.89	376.38
VVA96	431566.33	4701484.03	328.54
VVA97	478221.88	4707622.93	339.67
VVA98	468768.86	4707489.16	350.92
VVA99	495805.26	4710461.9	326.46

Table 14: Block 3 IA North Central project LiDAR Validation Checkpoints.

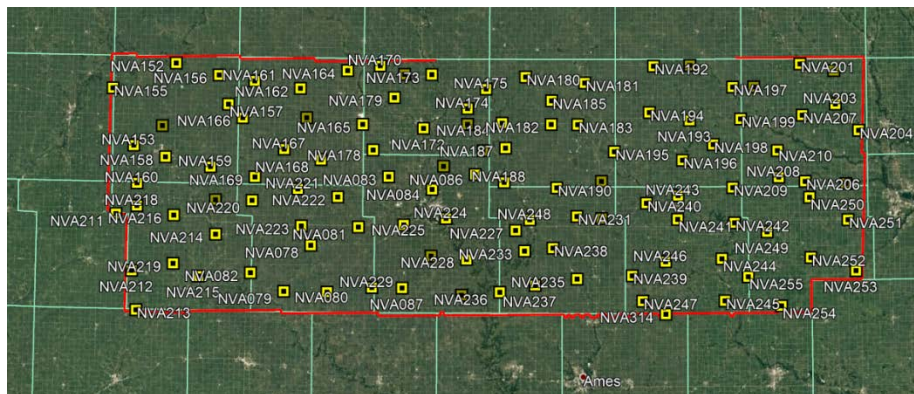


Figure 27: Location of Block 3 IA North Central LiDAR NVA Checkpoints

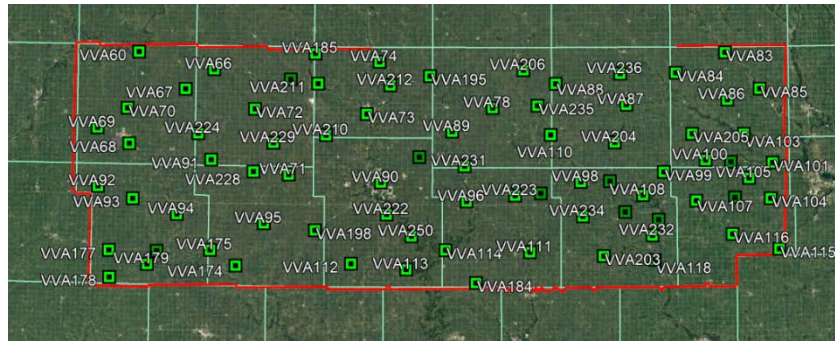


Figure 28: VVA Checkpoints were located in Block 3 IA North Central

VERTICAL ACCURACY TEST PROCEDURES

NVA (Non-vegetated Vertical Accuracy) is determined with check points located only in nonvegetated 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 (RMSEz) of the checkpoints x 1.9600. For the Block 3 IA North Central project, vertical accuracy must be 19.6 cm (0.64 ft) or less based on an RMSEz of 10 cm (0.33 ft) 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 Block 3 IA North Central Lidar project VVA standard is 29.4 cm (0.96 ft) based on the 95th percentile.

Quantitative Criteria	Measure of Acceptability
Non-Vegetated Vertical Accuracy (NVA) in open terrain and urban land cover categories using RMSEz *1.96	19.6 cm (based on RMSEz (10 cm)*1.96)
Vegetated Vertical Accuracy (VVA) in all vegetated land cover categories combined and at the 95 th Percentile error	29.4 cm (based on combined 95th percentile)

Table 15: Acceptance Criteria.

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

1. Prairie Engineers surveyed QA/QC vertical checkpoints in accordance with the project’s specifications.
2. Next, ASI interpolated the bare-earth LiDAR DTM to provide the z-value for every checkpoint.
3. ASI 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 ASI 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 (95% confidence)Spec = 0.196 m	VVA – Vegetated Vertical Accuracy (95 th Percentile) spec = 0.294 m
NVA	113	0.068	
VVA	78		0.110

Table 16: Tested NVA and VVA.

HORIZONTAL ACCURACY TEST PROCEDURES

The Optech Galaxy Prime data set was produced to meet ASPRS “Positional Accuracy Standards for Digital Geospatial Data” (2014) for a 32.72 (cm) RMSE_x / RMSE_y Horizontal Accuracy Class which equates to Positional Horizontal Accuracy = +/- 64.13 cm at a 95% confidence level.

Breakline Production methodology

MicroStation, in conjunction with TerraSolid's TerraScan and TerraModeler was utilized for the collection of hydrologic breaklines, which occurred independently of manual edit. Collection was done using 2D information in the LAS format, intensity format, and ground surface. Breaklines are developed to the limit of the defined project boundary. Breaklines are in the same coordinate reference system and unit of measure as the LiDAR point delivery. Hydrologic water-surface edges are set at or just below the immediately surrounding terrain. Breaklines are developed to the limit of the project boundary.

Breakline Qualitative Assessment

Completeness and horizontal placement is verified through visual review against LiDAR intensity imagery, and bare earth surface. Breakline features are checked for connectivity of features, enforced monotonicity on linear hydrographic breaklines, and flatness on water bodies.

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

Feature Definition

Inland Streams and Rivers

Streams and Rivers with a nominal width of 30 meters (100 feet), were collected to best fit the shoreline by using information in the LAS format; intensity format, ground surface TIN, and sometimes "quick guide" contours. Streams and rivers do not break at bridges, but they are closed ended breaks at culvert locations. Streams and Rivers breaklines have been delivered in PolylineZ format in the final GDB.

Inland Ponds and Lakes

Inland ponds and lakes of 2 acres (86,111 square feet/ ~350'/~106 meter diameter for a round pond) or greater were collected. Inland pond and Lakes were collected to best fit the shoreline by using information in the LAS format; intensity format, ground surface TIN, and sometimes "quick guide" contours. Inland pond and Lakes Breaklines have been delivered in PolygonZ format in the final GDB.

Islands

Permanent island 4046m² (1 acre) or larger were delineated within all water bodies. Breaklines have been delivered in PolygonZ format in the final GDB.

Bridge Breaklines

Breaklines were placed across the bottom of the bridge embankment when triangulation occurred due to bridge deck classification. Breaklines have been delivered in PolylineZ format in the final GDB.

Intensity Imagery Production & Qualitative Assessment

INTENSITY PRODUCTION METHODOLOGY

ASI utilized MicroStation in conjunction with TerraSolid's TerraScan for Intensity production. Global Mapper was used to QC the products. ArcGIS was used to finalize the Intensity's projection.

Intensity Images are created for each tile in the tiling schema. The Intensities are reviewed for any issues requiring corrections. Tiles are verified for final formatting and loaded into Global Mapper to ensure there are no missing, or corrupt tiles, and to check for seamlessness across tile boundaries.

INTENSITY QUALITATIVE ASSESSMENT

ASI performed a qualitative assessment of the Intensity deliverables to ensure that all tiled Intensity products were delivered with the proper extents, and contained proper referencing information. Intensity bounding values were manually set in RiProcess to utilize the full range of values available. Subcontractor intensities were linearly scaled to match the intensity of ASI's collection. During some reprocessing to improve the calibration, some points received maximum value intensity; however these were corrected to the original output values prior to delivery.



Figure 29: Intensity Image example.

DEM Production & Qualitative Assessment

DEM PRODUCTION METHODOLOGY

ASI utilized MicroStation Connect in conjunction with TerraSolid's TerraScan and TerraModeler for DEM production. Global Mapper version 21.0 was used to format and QC the products. GDAL version 2.4.0 was used to finalize the DEMs projection.

The final bare earth LiDAR points are used to create a terrain. The final 3D breaklines collected for the project are enforced in the terrain. The terrain is then converted to raster format using linear interpolation. DEMs are created for each tile in the tiling schema. The DEMs are reviewed for any issues requiring corrections, including remaining LiDAR ground misclassification, erroneous breakline elevations, poor hydro flattening, and processing artifacts. Tiles are verified for final formatting and loaded into Global Mapper to ensure there are no missing, or corrupt tiles, and to check for seamlessness across tile boundaries.

DEM QUALITATIVE ASSESSMENT

ASI performed a 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 proper referencing information.

The image below shows an example of a bare earth DEM.

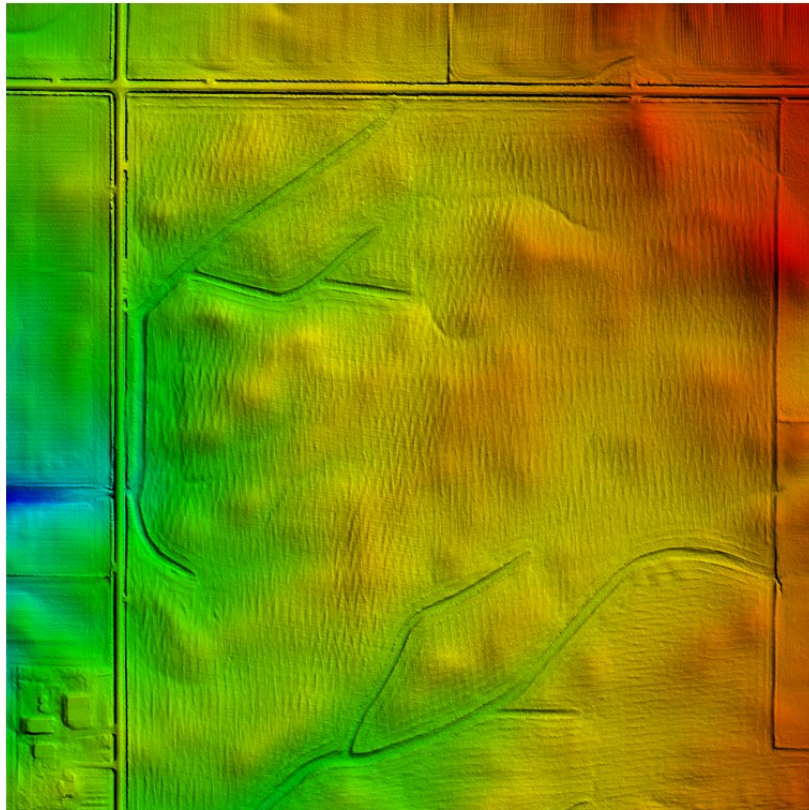


Figure 30: Block 3 IA North Central project bare earth DEM

DEM VERTICAL ACCURACY RESULTS

The same 113 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. The DEM pixel does not average several LiDAR point's together, it interpolates (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 survey elevations.

The table below; summarizes the tested vertical accuracy result from a comparison of surveyed checkpoint to the elevation values present within the final DEM dataset.

Land Cover Category	# of Points	NVA – Non-vegetated Vertical Accuracy (RMSEz x 1.960)	VVA – Vegetated Vertical Accuracy (95 th percentile)
NVA	113	0.066	
VVA	78		0.061

Table 17: DEM vertical accuracy summary

DEM datasets were 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 RMSEz = 0.033 meters with a 0.066 meters accuracy at 95 % confidence level. Actual VVA accuracy tested **0.061** meters using checkpoints located in forested land cover categories at the 95th percentile, derived according to ASPRS guidelines, tested against the DEM. Based on the vertical accuracy testing conducted by ASI, the DEM dataset for the Block 3 IA North Central project satisfies the project's pre-defined vertical accuracy criteria.

Appendix A: List of Delivered LAS File

w3020n4706	w3030n4742	w3040n4750
w3020n4707	w3030n4743	w3040n4751
w3020n4708	w3030n4744	w3040n4752
w3020n4709	w3030n4745	w3040n4753
w3020n4710	w3040n4704	w3050n4704
w3020n4711	w3040n4705	w3050n4705
w3020n4712	w3040n4706	w3050n4706
w3020n4713	w3040n4707	w3050n4707
w3020n4714	w3040n4708	w3050n4708
w3020n4715	w3040n4709	w3050n4709
w3020n4716	w3040n4710	w3050n4710
w3020n4717	w3040n4711	w3050n4711
w3030n4704	w3040n4712	w3050n4712
w3030n4705	w3040n4713	w3050n4713
w3030n4706	w3040n4714	w3050n4714
w3030n4707	w3040n4715	w3050n4715
w3030n4708	w3040n4716	w3050n4716
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w3030n4710	w3040n4718	w3050n4718
w3030n4711	w3040n4719	w3050n4719
w3030n4712	w3040n4720	w3050n4720
w3030n4713	w3040n4721	w3050n4721
w3030n4714	w3040n4722	w3050n4722
w3030n4715	w3040n4723	w3050n4723
w3030n4716	w3040n4724	w3050n4724
w3030n4717	w3040n4725	w3050n4725
w3030n4718	w3040n4726	w3050n4726
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w3080n4717	w3090n4688	w3090n4739
w3080n4718	w3090n4689	w3090n4740
w3080n4719	w3090n4690	w3090n4741
w3080n4720	w3090n4691	w3090n4742
w3080n4721	w3090n4692	w3090n4743
w3080n4722	w3090n4693	w3090n4744
w3080n4723	w3090n4694	w3090n4745
w3080n4724	w3090n4695	w3090n4746
w3080n4725	w3090n4696	w3090n4747
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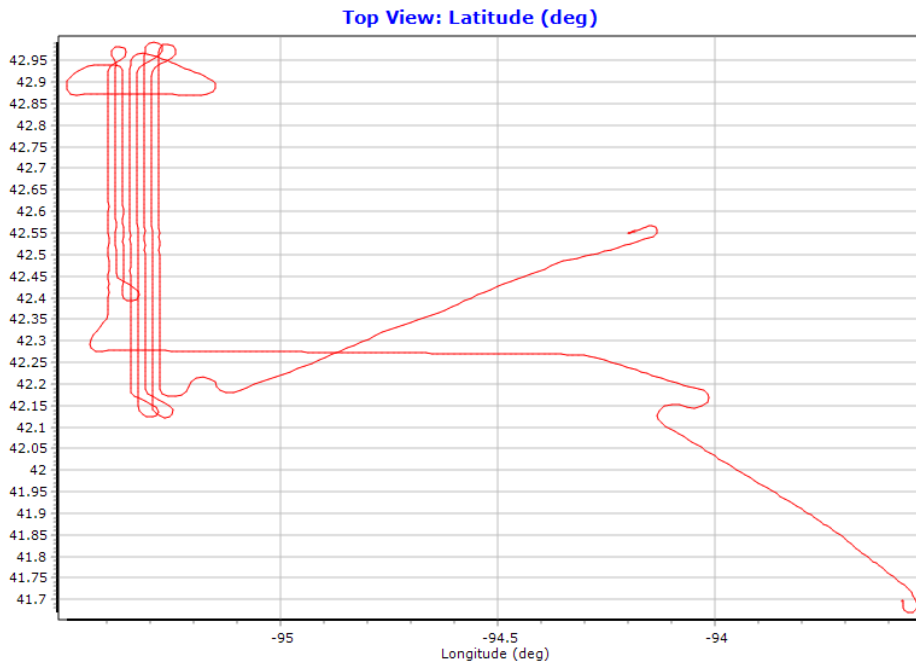
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Appendix B: Aerial Surveys International, LLC Mission GPS and IMU Processing Report

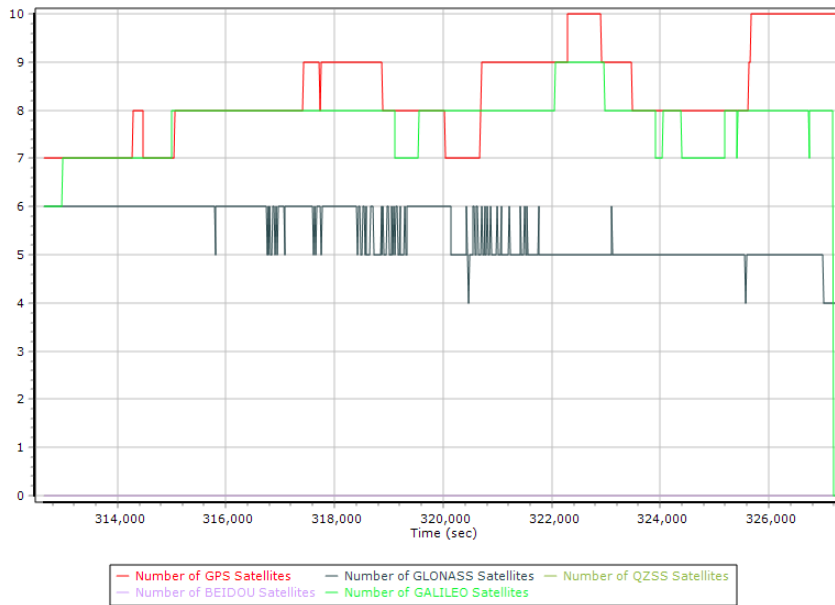
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Smoothed Trajectory Information

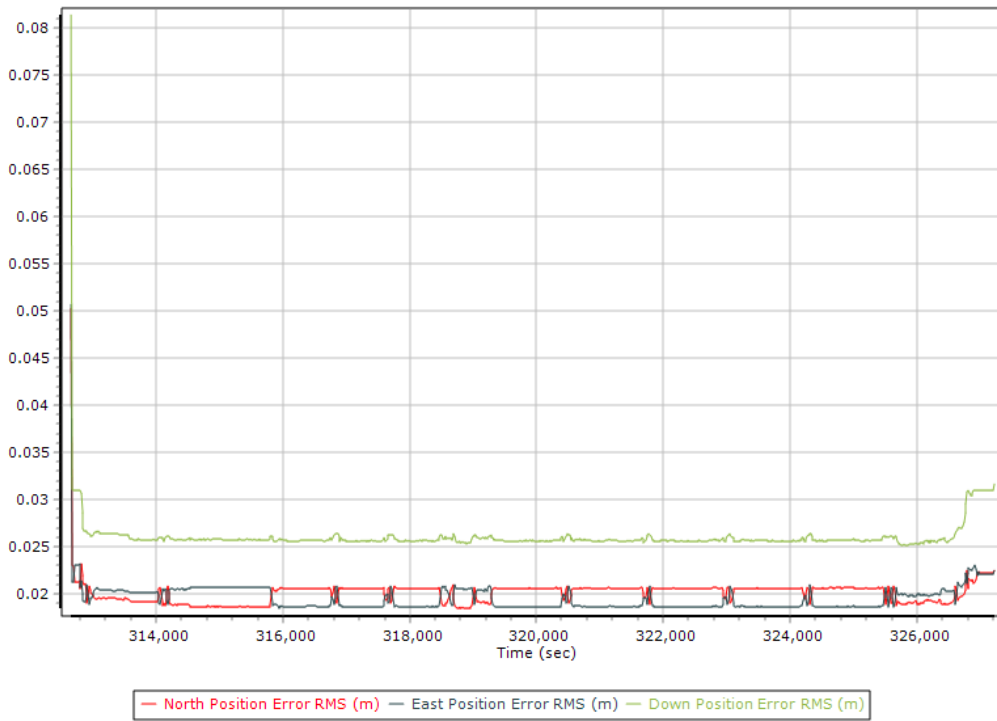
Top View



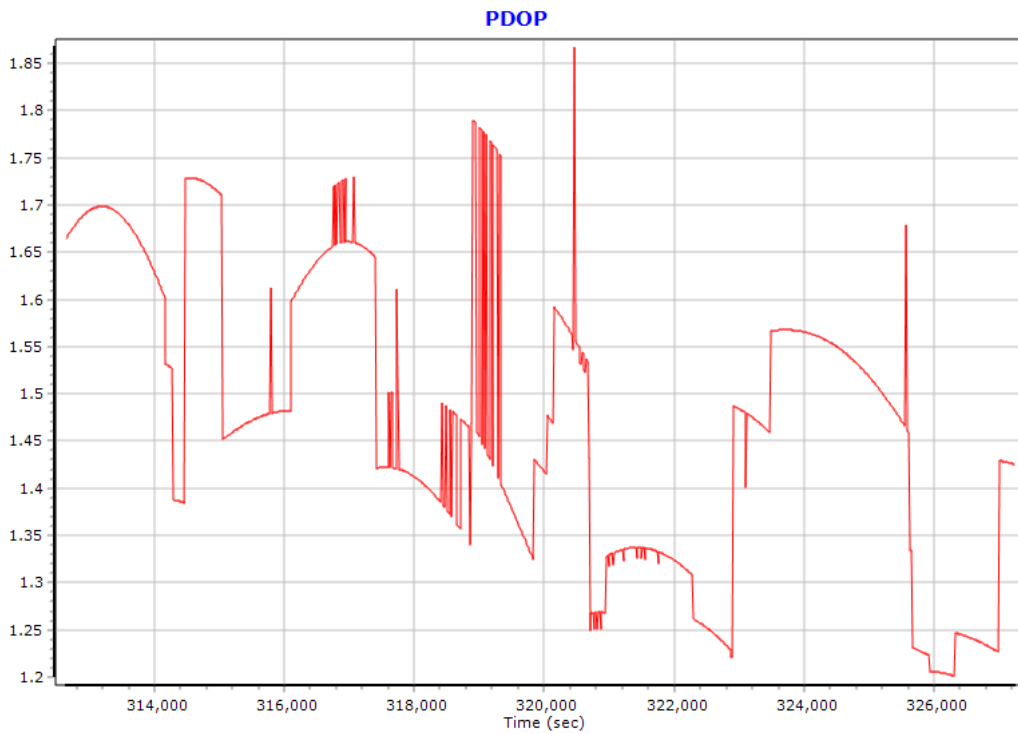
Number of Satellites



Forward/Reverse Separation



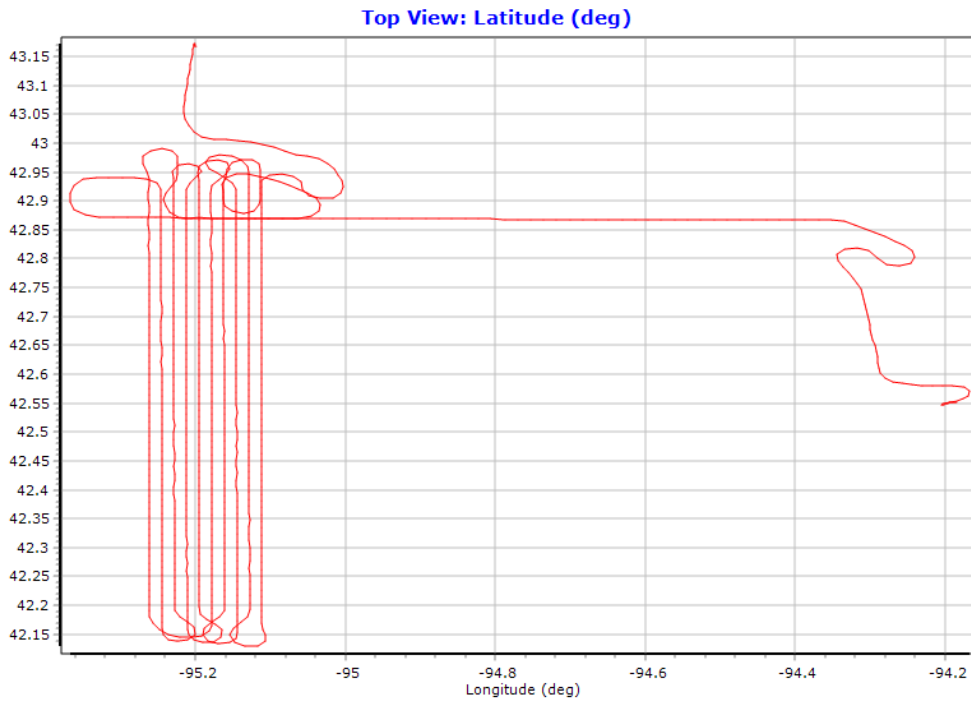
PDOP



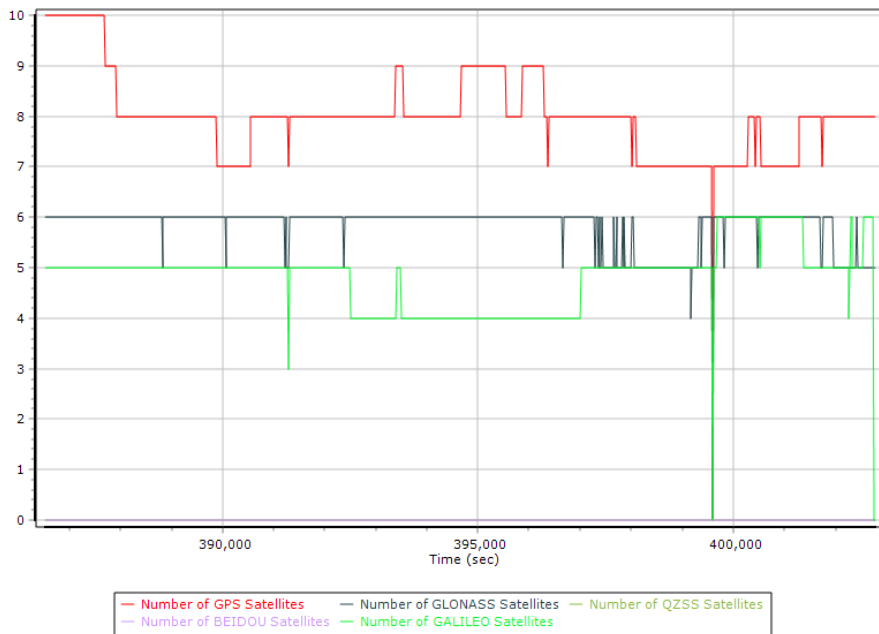
Central_042320A_18-386.docx- 4/07/2021 13:05:13

Smoothed Trajectory Information

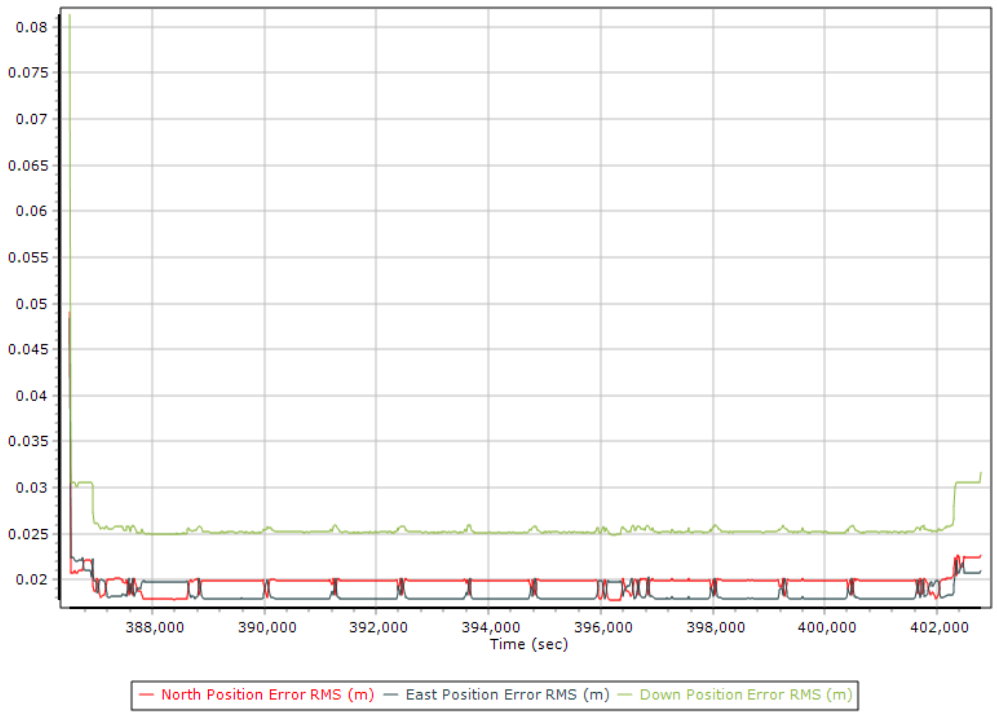
Top View



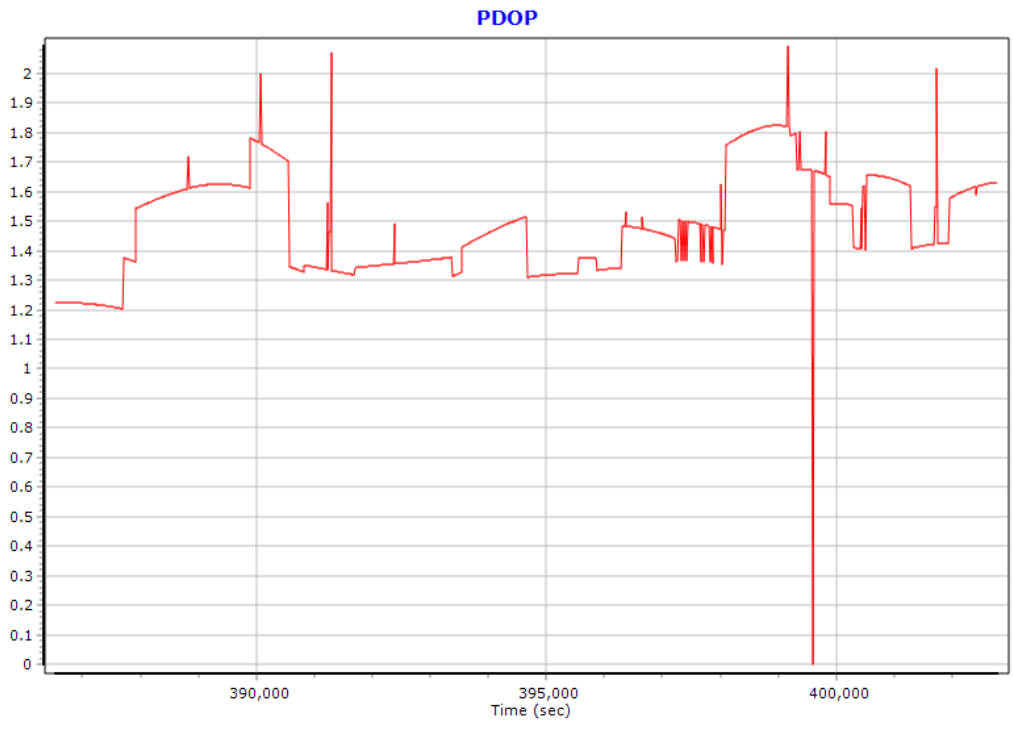
Number of Satellites



Forward/Reverse Separation



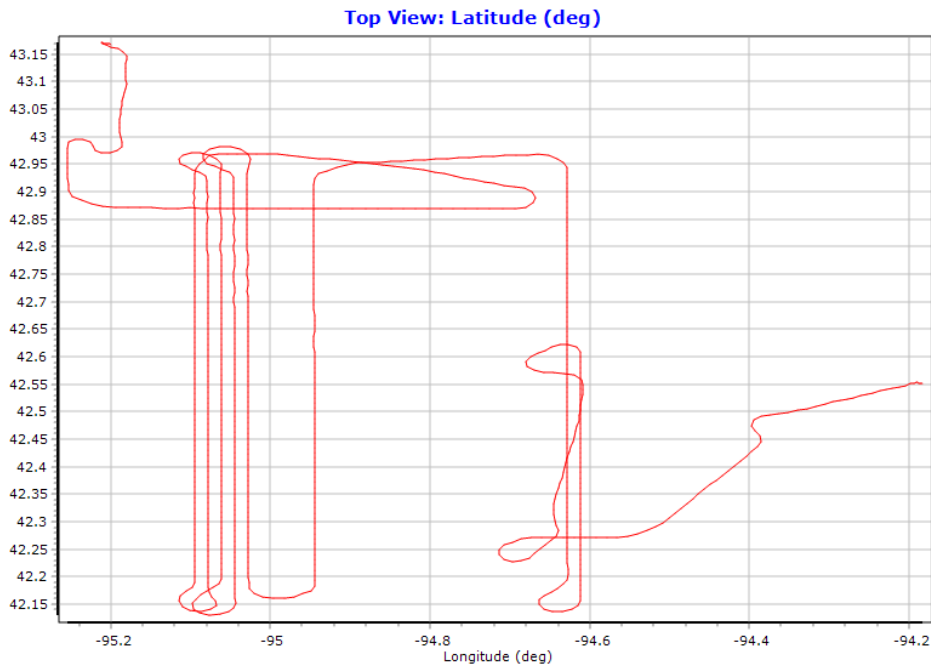
PDOP



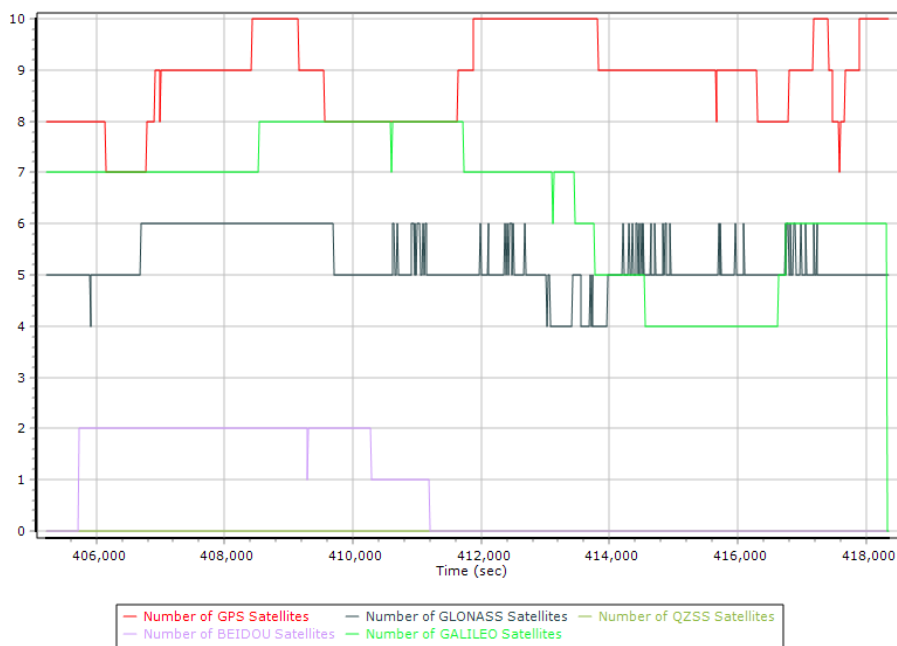
Central_042320B_19-386.docx- 4/07/2021 13:08:19

Smoothed Trajectory Information

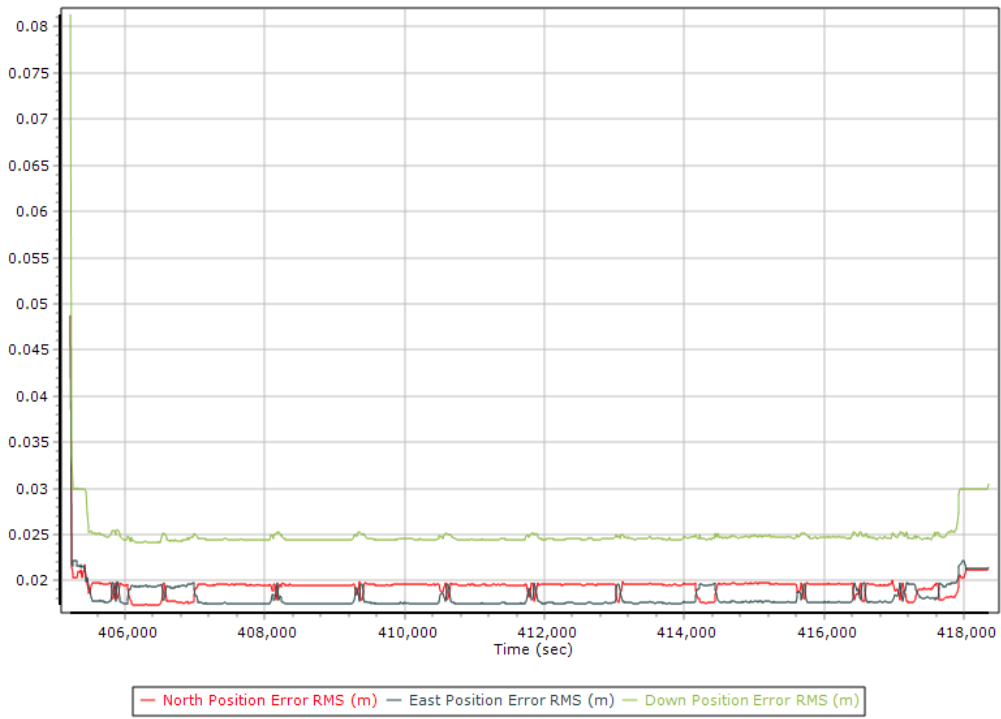
Top View



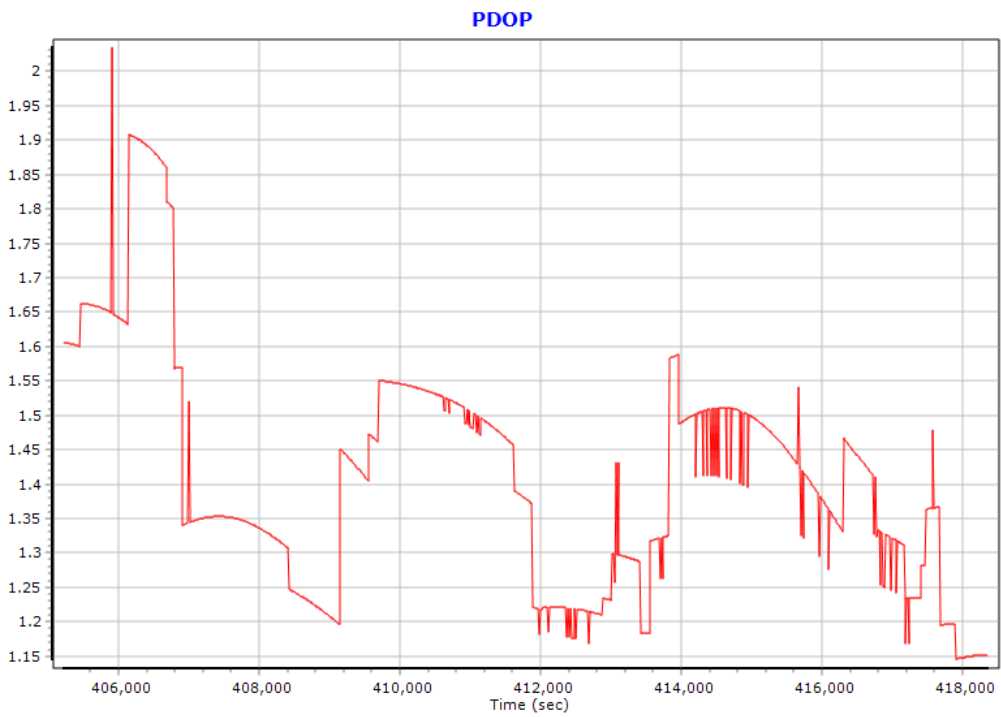
Number of Satellites



Forward/Reverse Separation

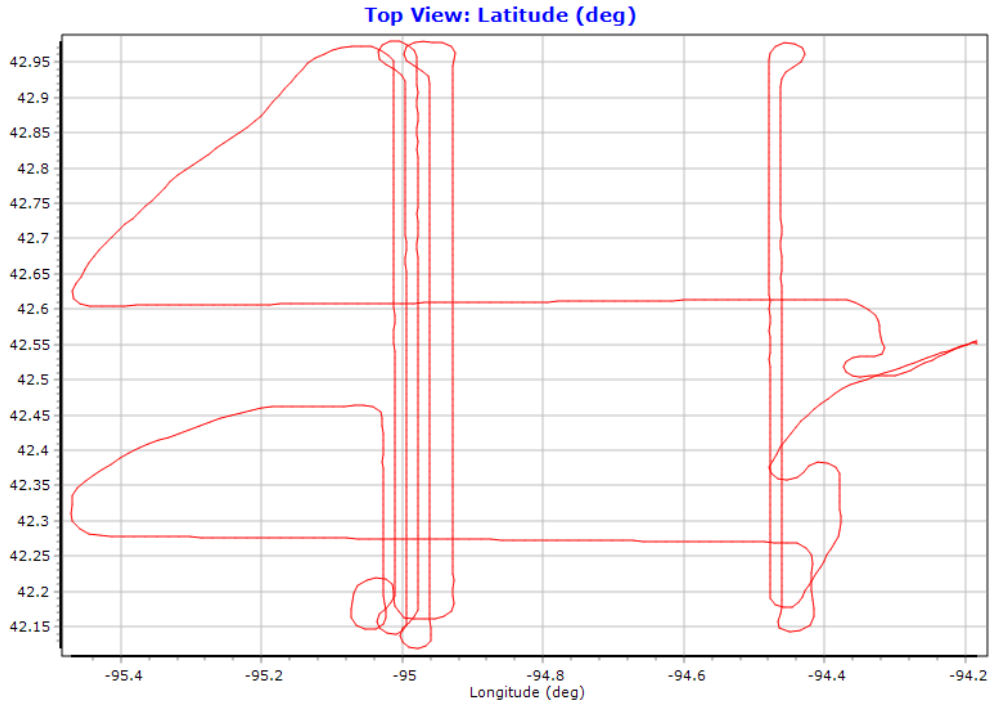


PDOP

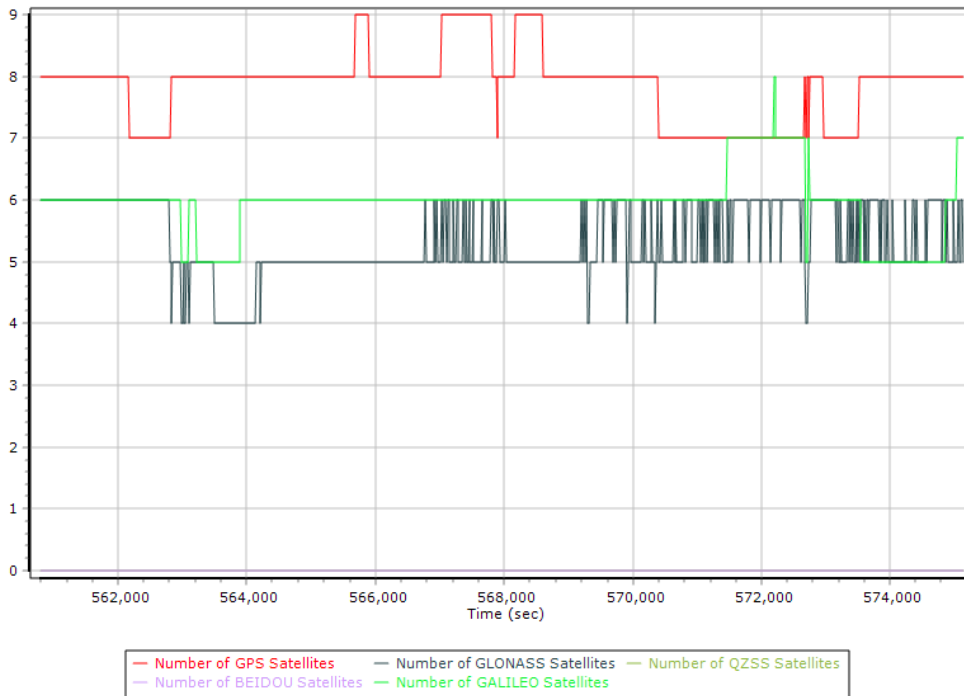


Smoothed Trajectory Information

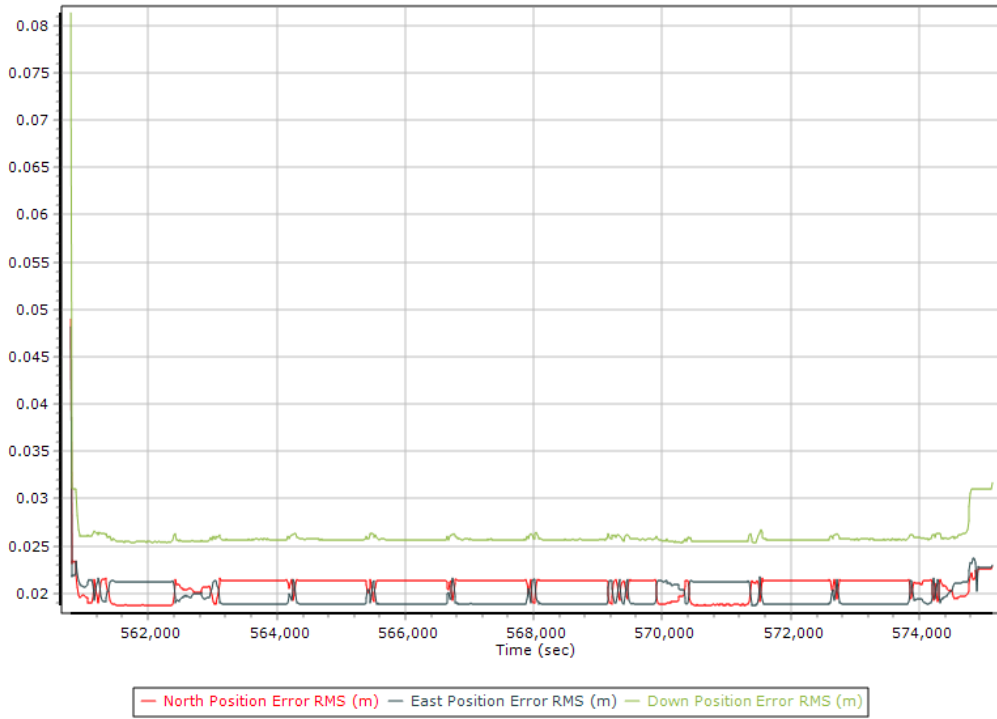
Top View



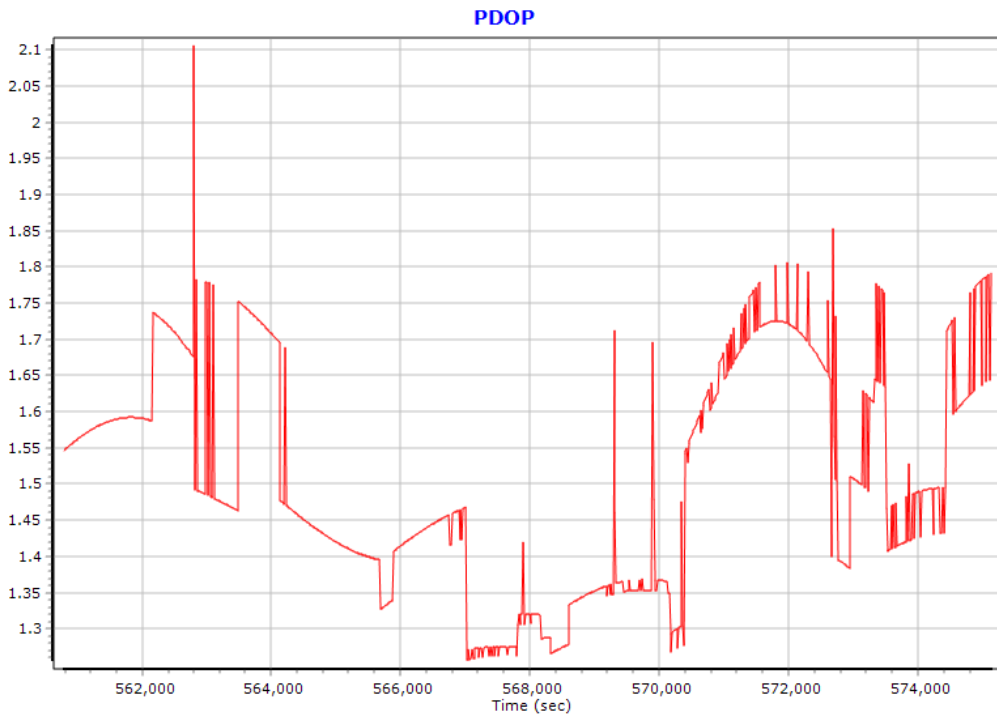
Number of Satellites



Forward/Reverse Separation

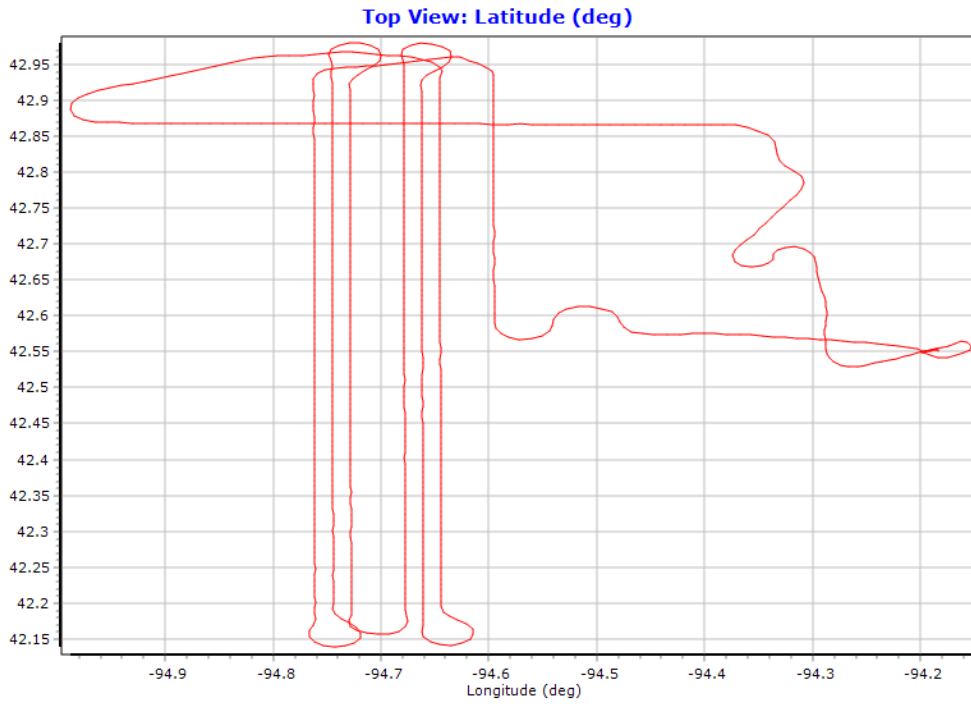


PDOP

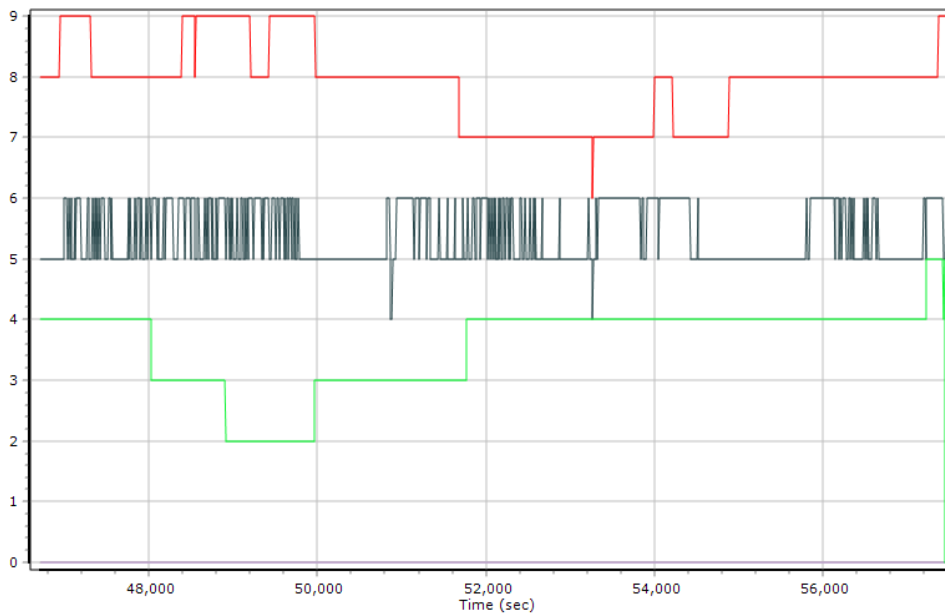


Smoothed Trajectory Information

Top View

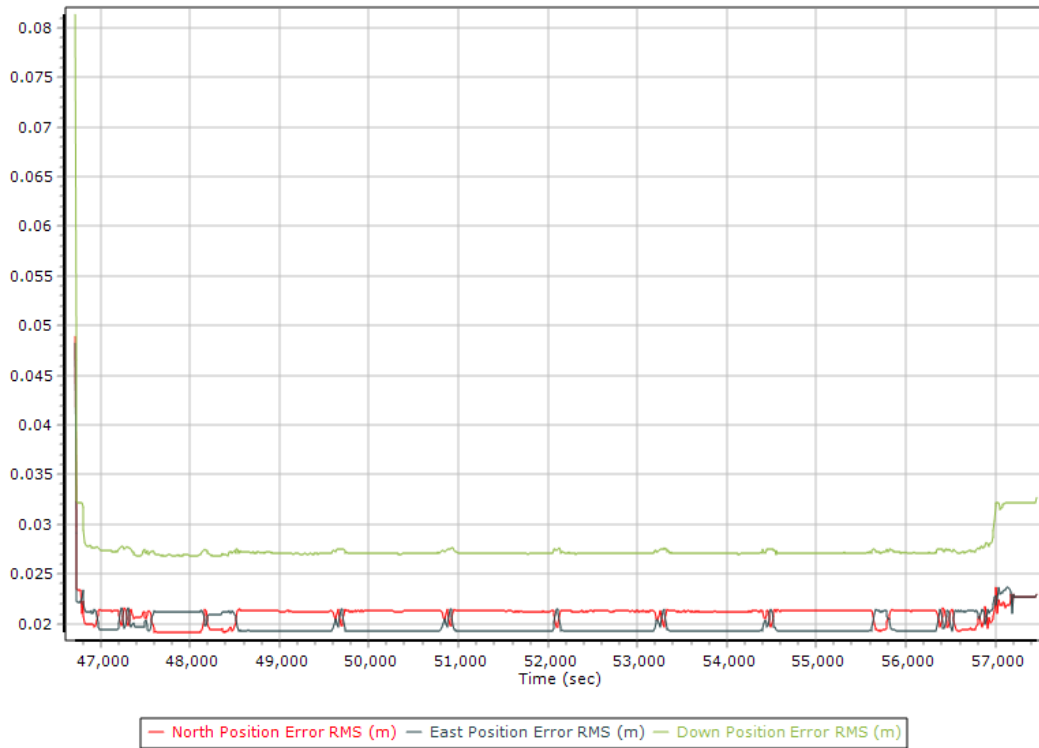


Number of Satellites

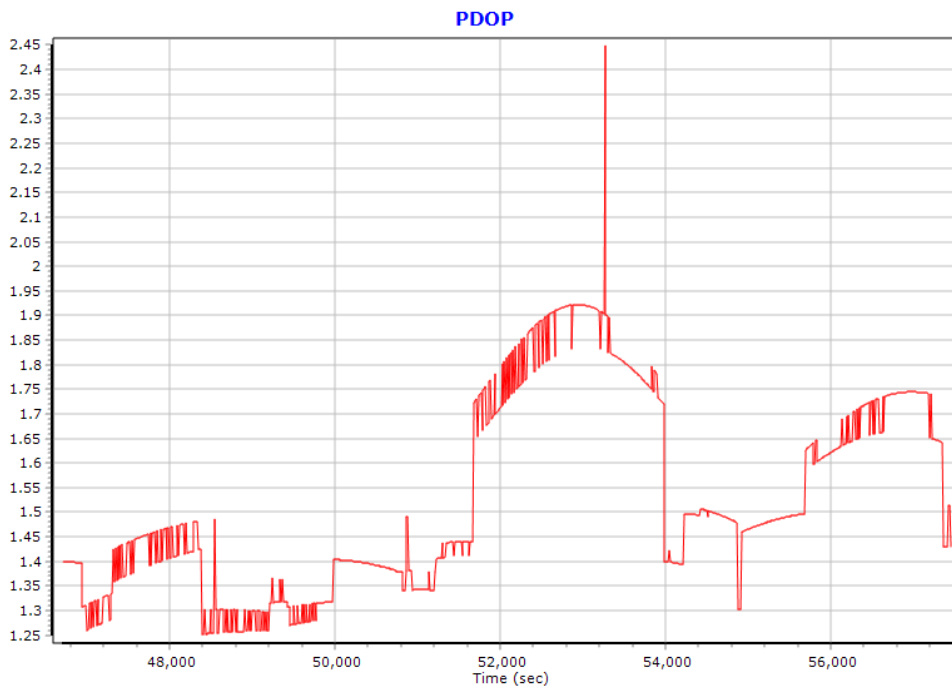


— Number of GPS Satellites — Number of GLONASS Satellites — Number of QZSS Satellites
— Number of BEIDOU Satellites — Number of GALILEO Satellites

Forward/Reverse Separation

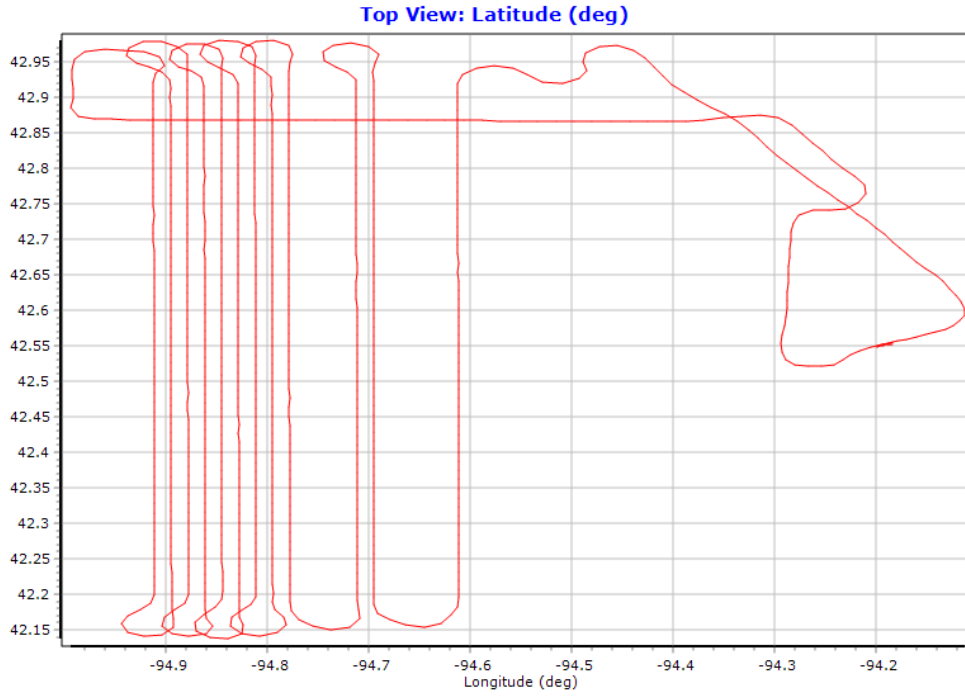


PDOP

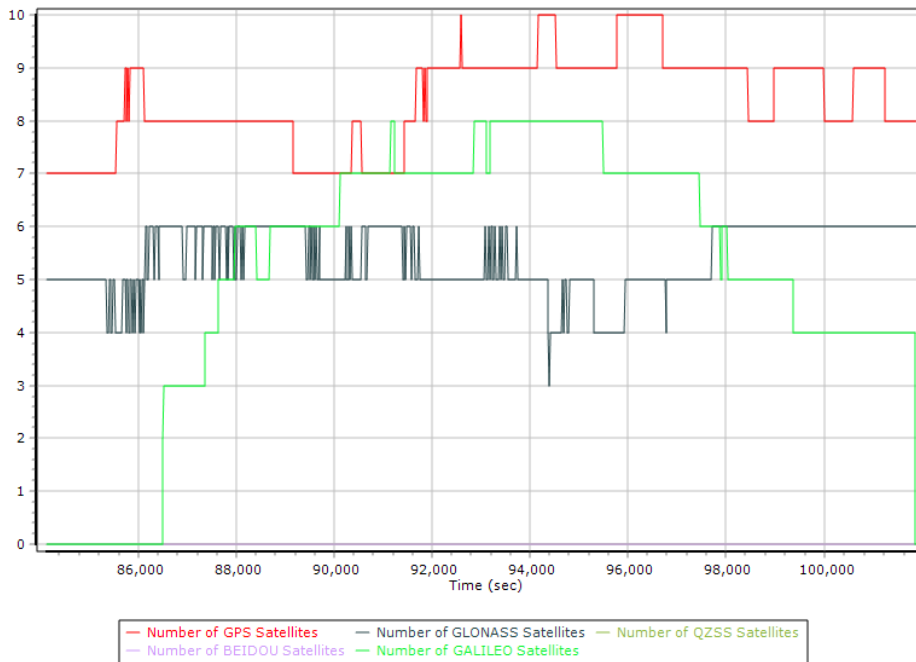


Smoothed Trajectory Information

Top View



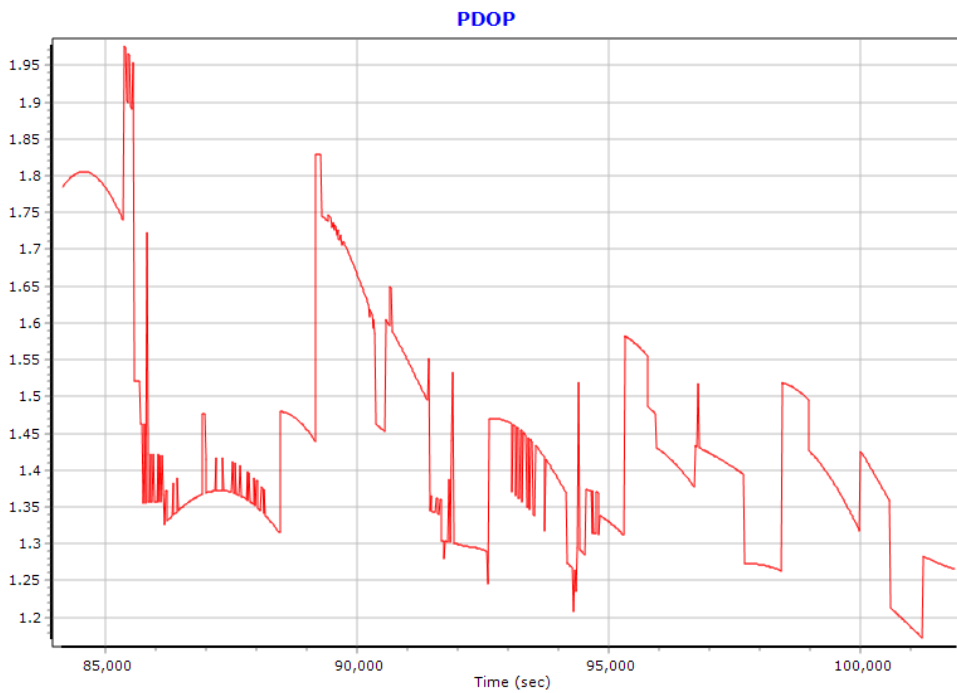
Number of Satellites



Forward/Reverse Separation

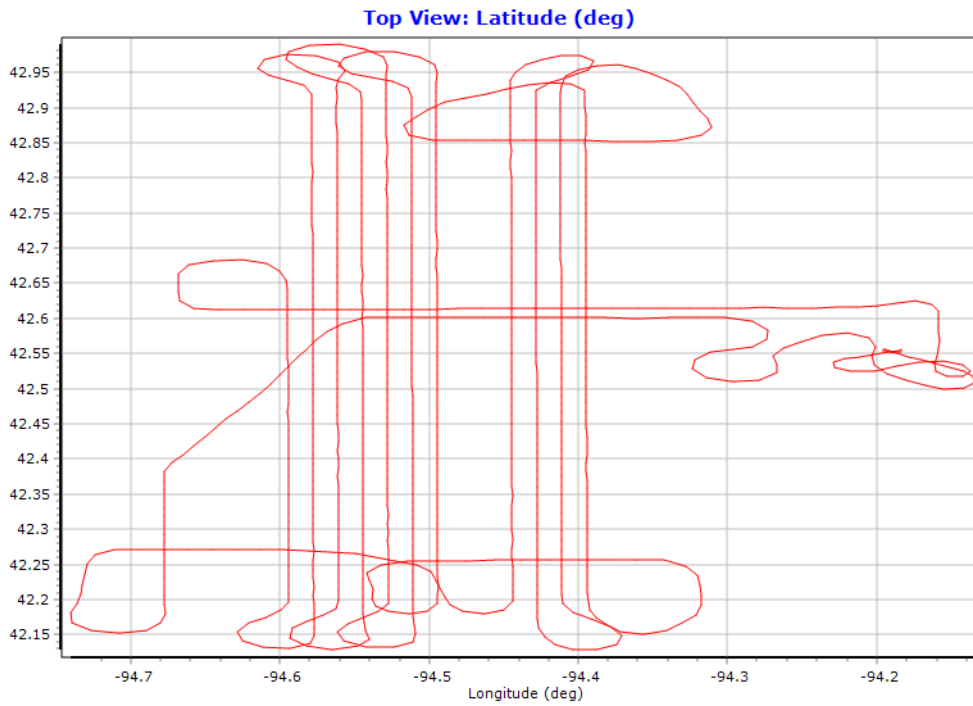


PDOP

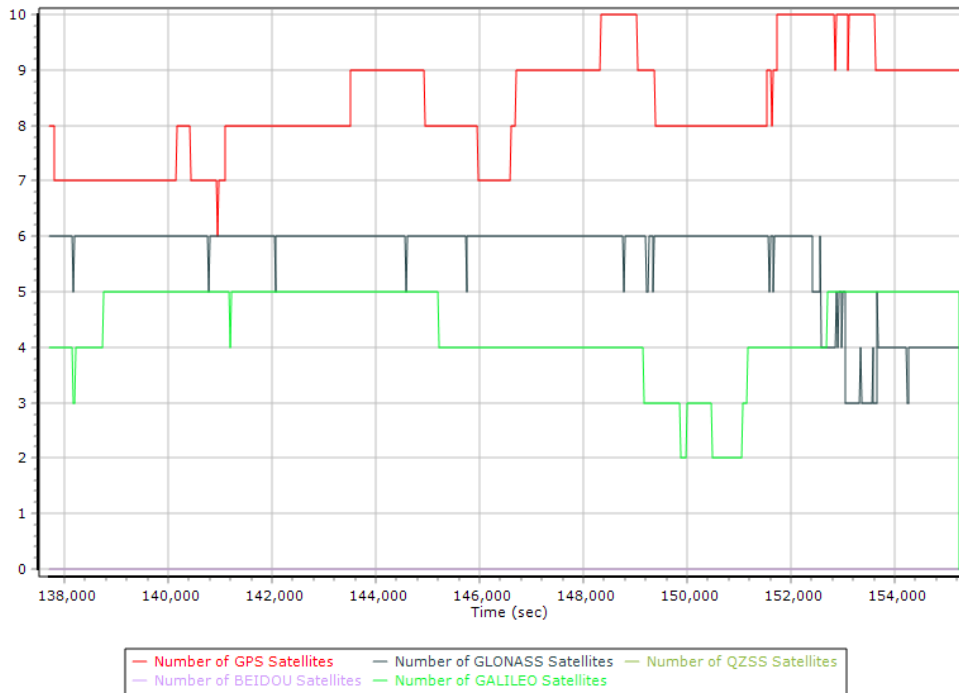


Smoothed Trajectory Information

Top View



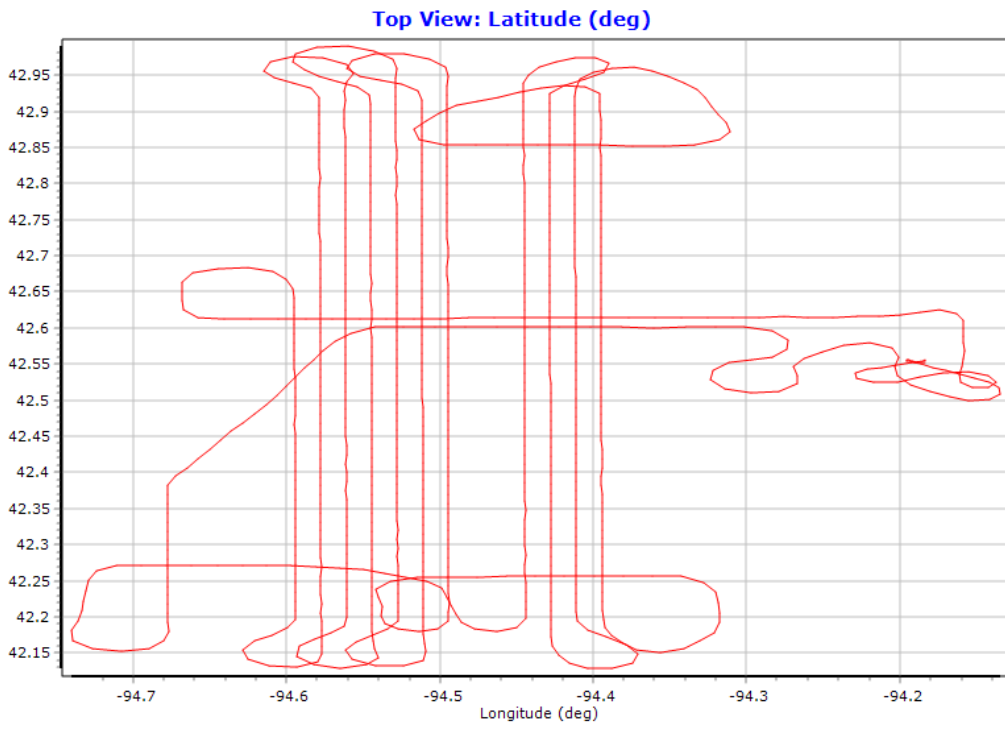
Number of Satellites



Forward/Reverse Separation

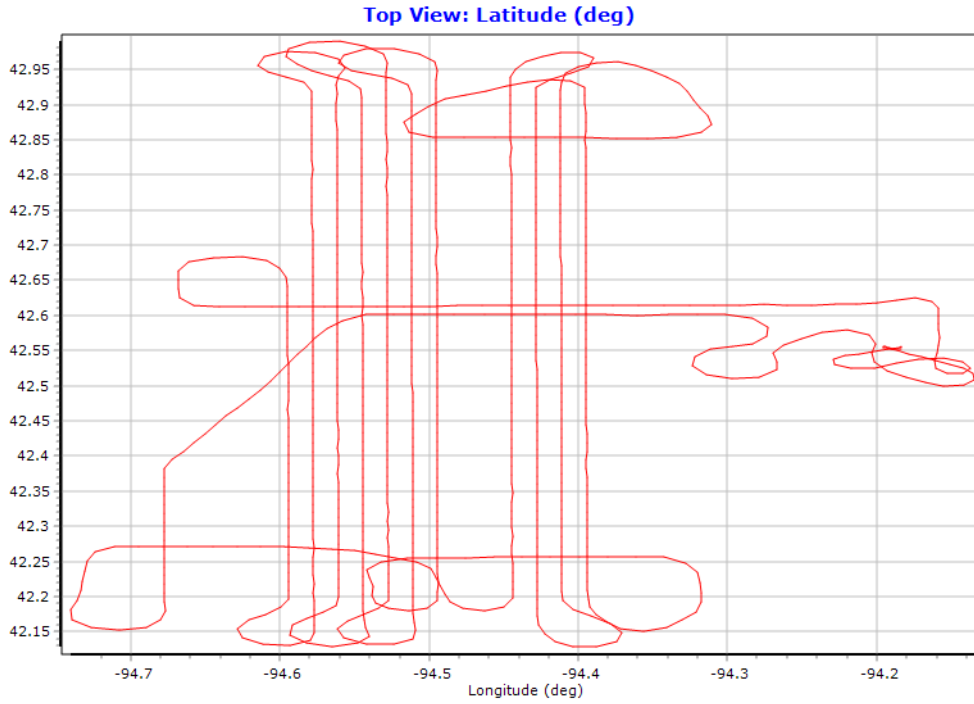


PDOP

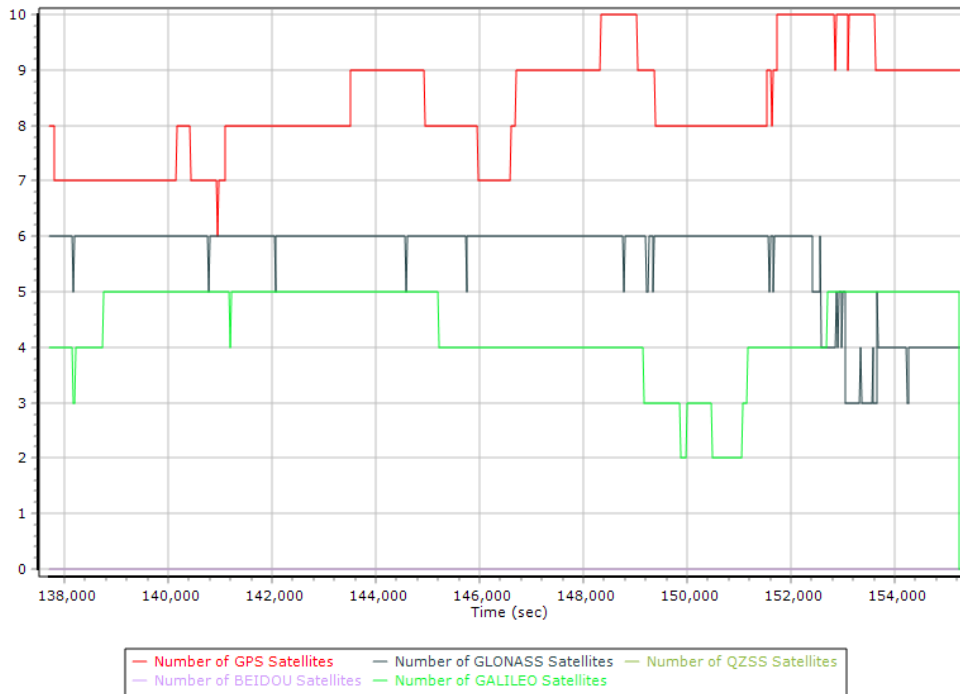


Smoothed Trajectory Information

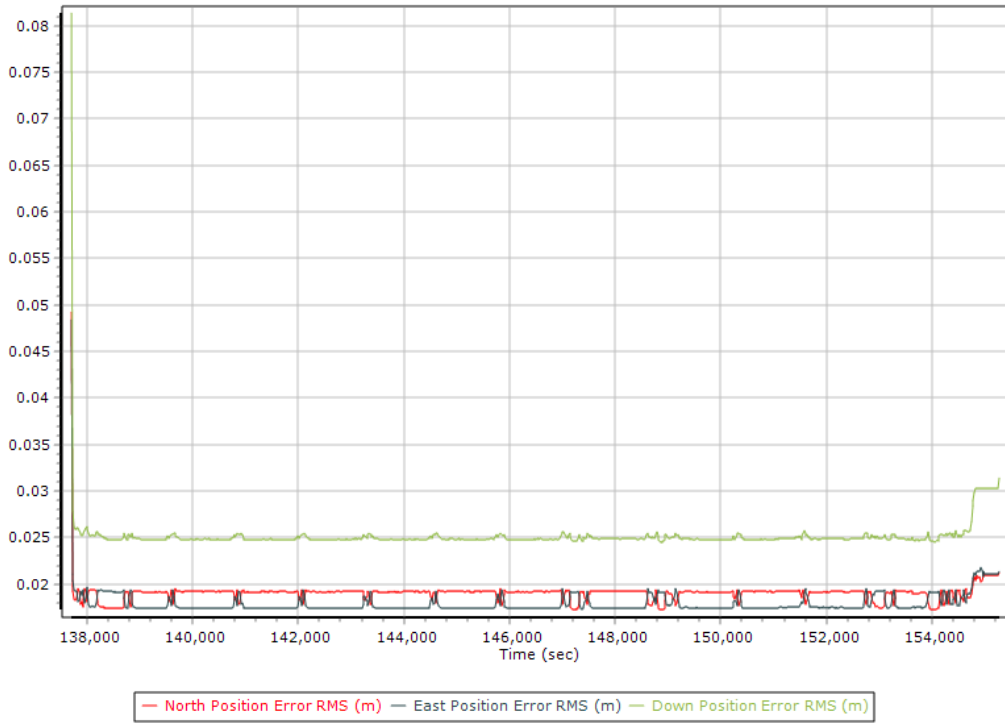
Top View



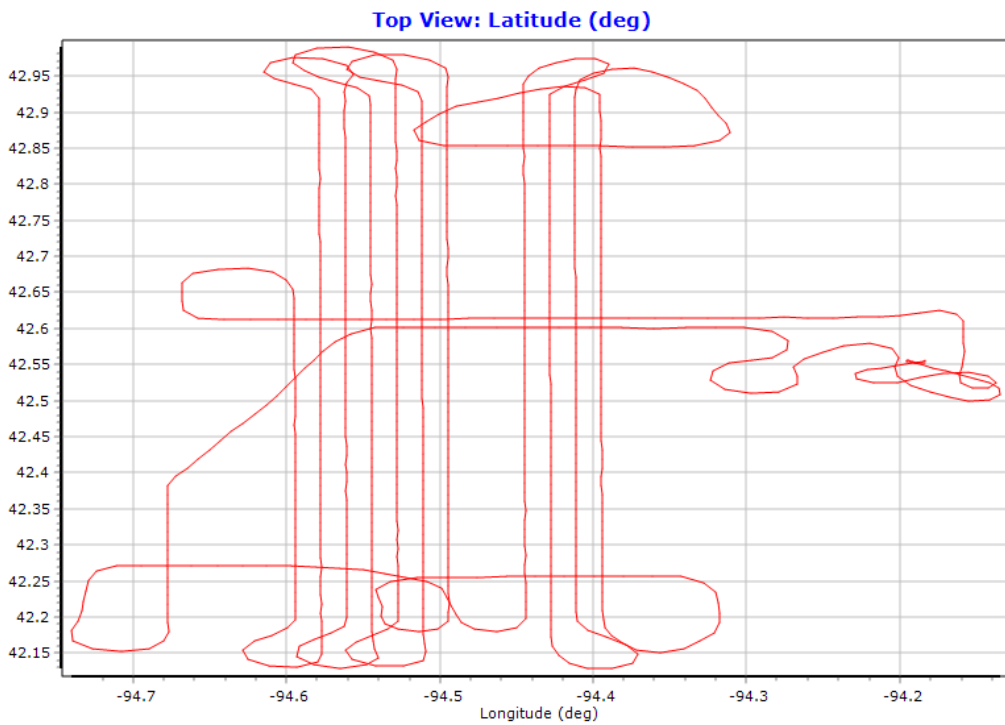
Number of Satellites



Forward/Reverse Separation



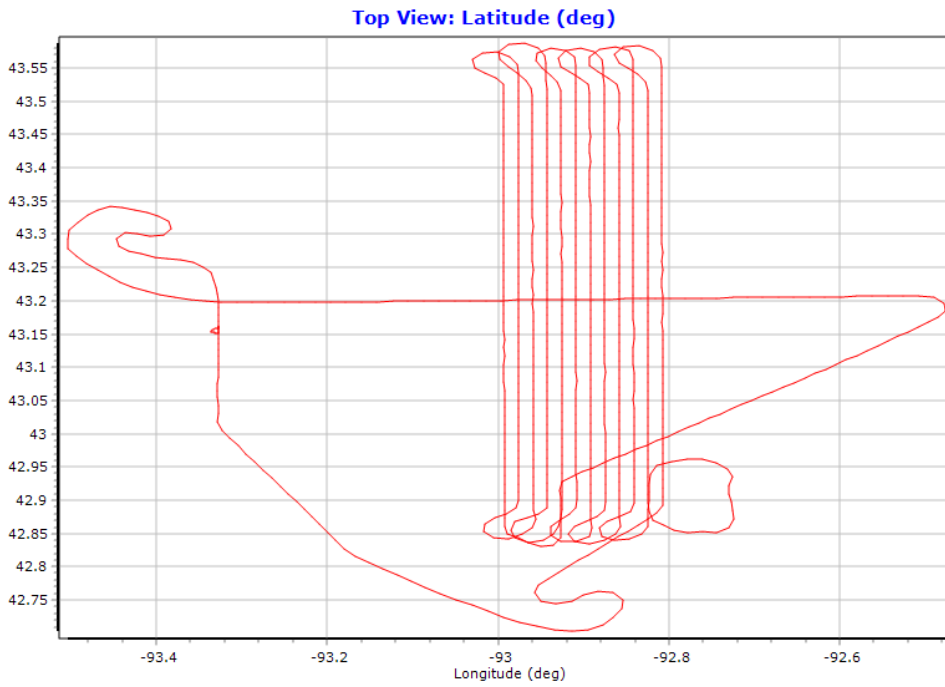
PDOP



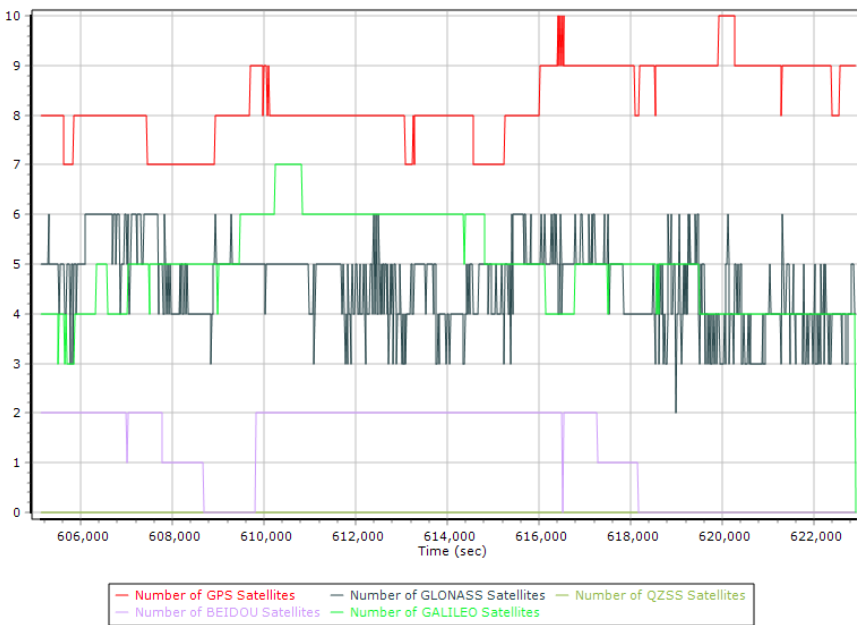
North_040420B_2-386.docx QC Report - 4/07/2021 09:13:25

Smoothed Trajectory Information

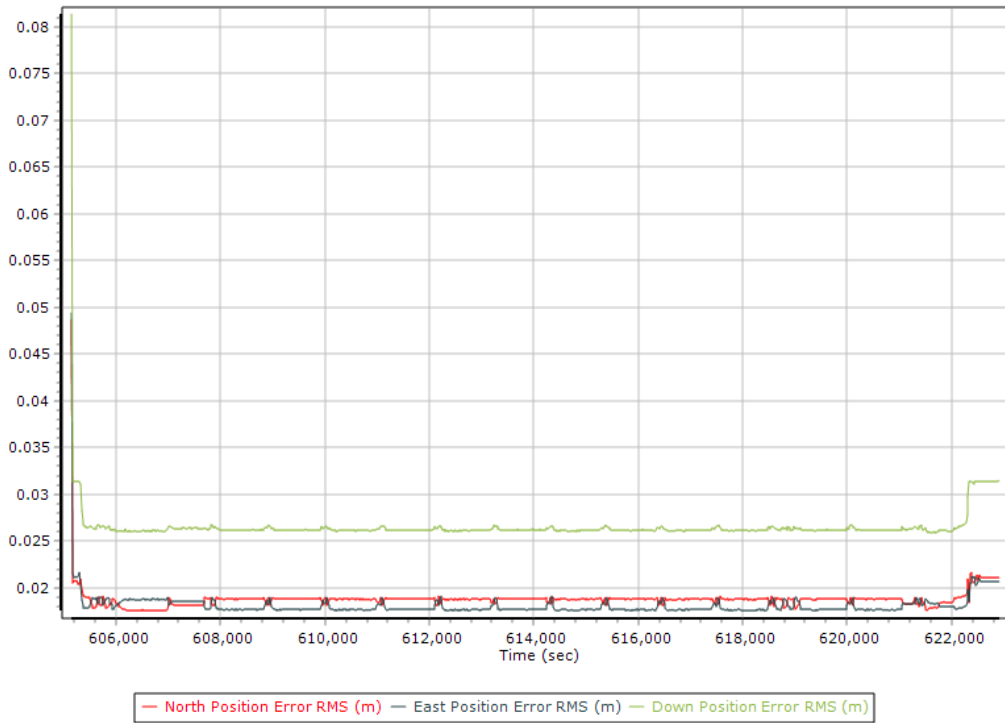
Top View



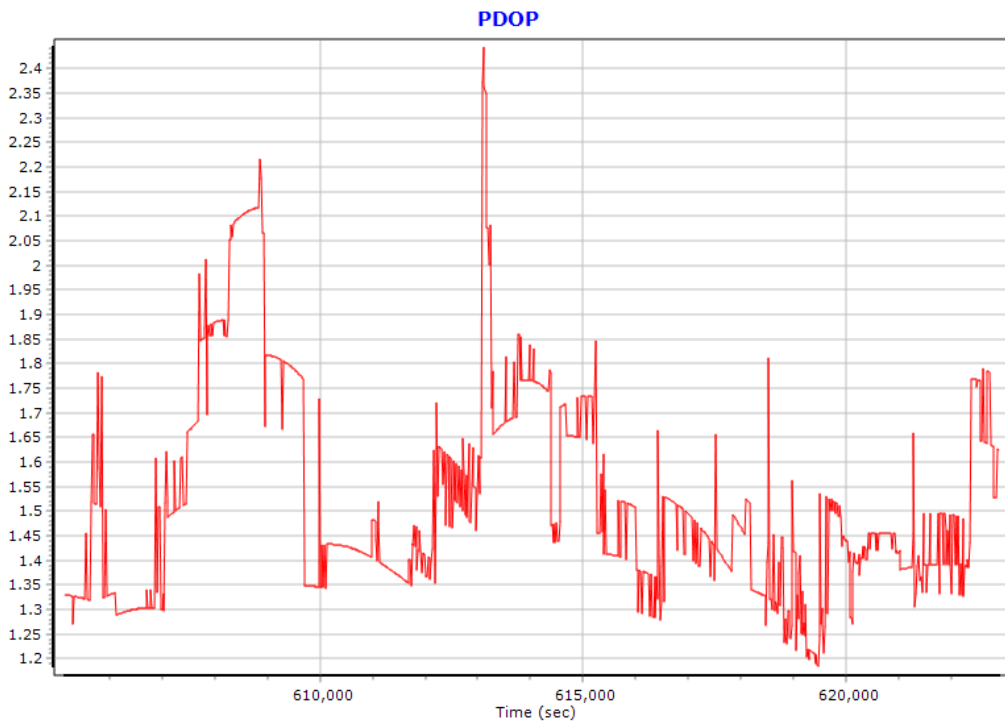
Number of Satellites



Forward/Reverse Separation

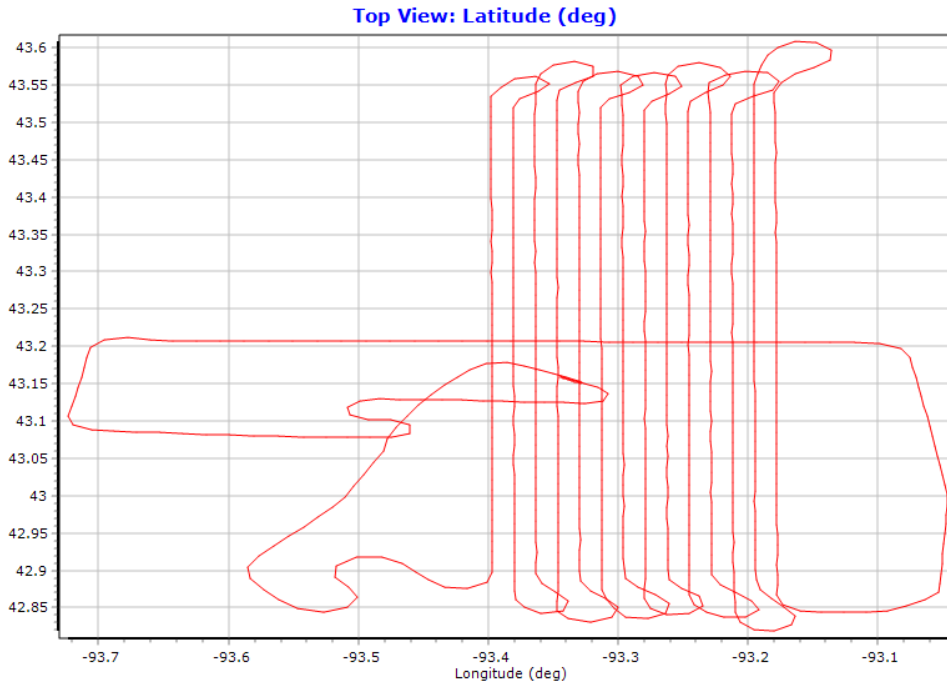


PDOP

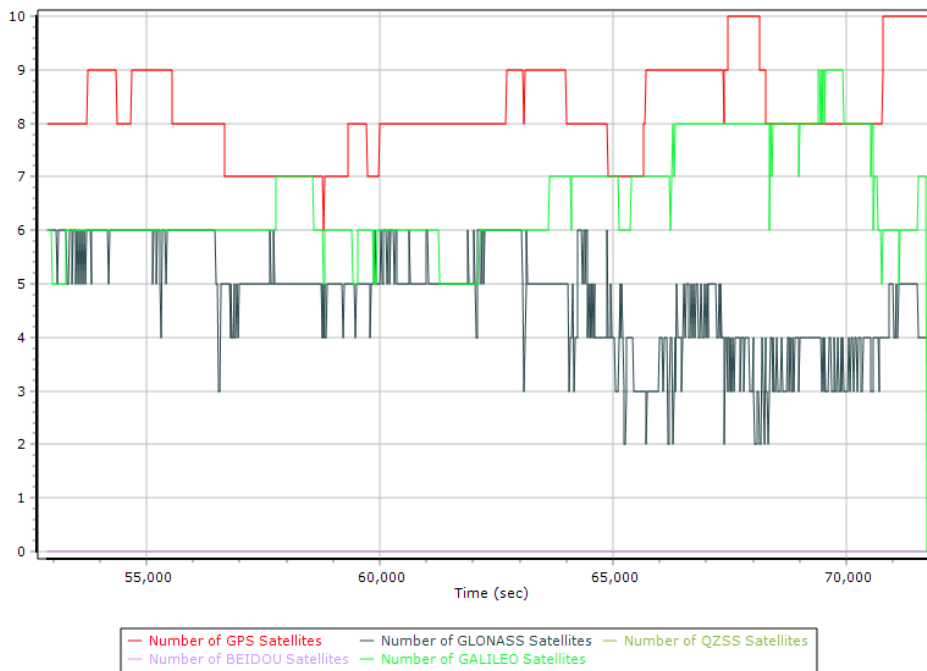


Smoothed Trajectory Information

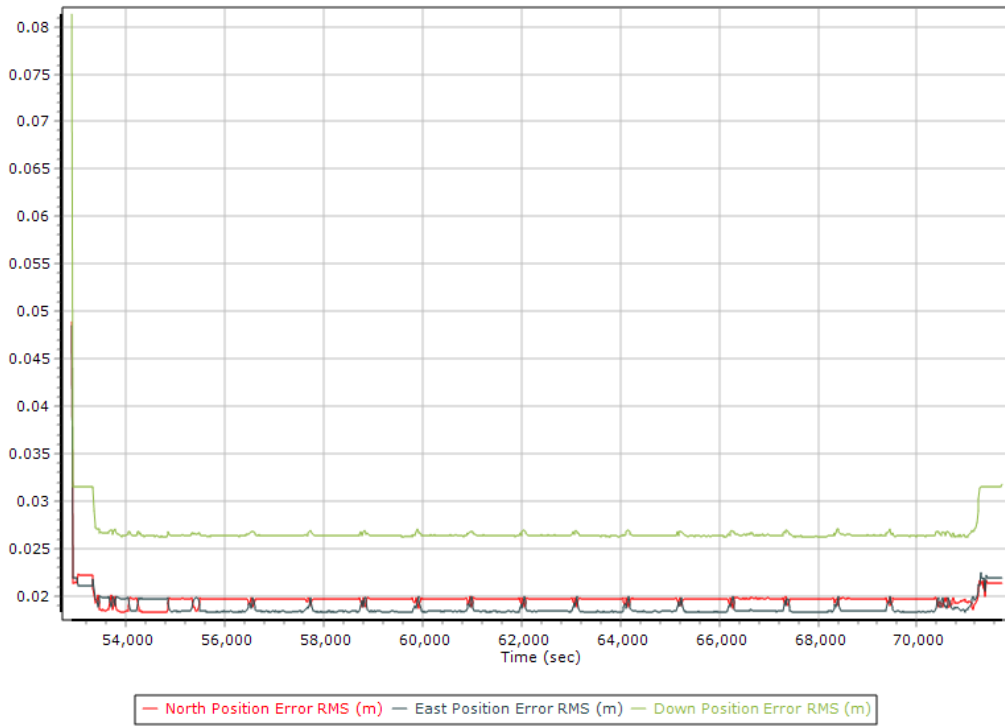
Top View



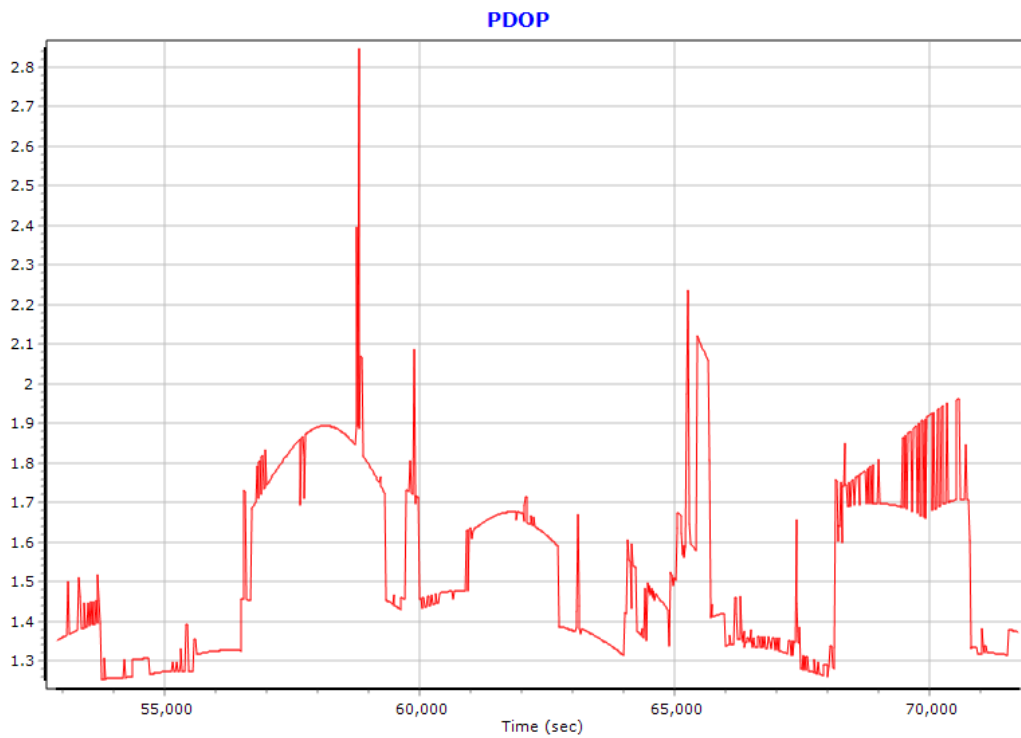
Number of Satellites



Forward/Reverse Separation

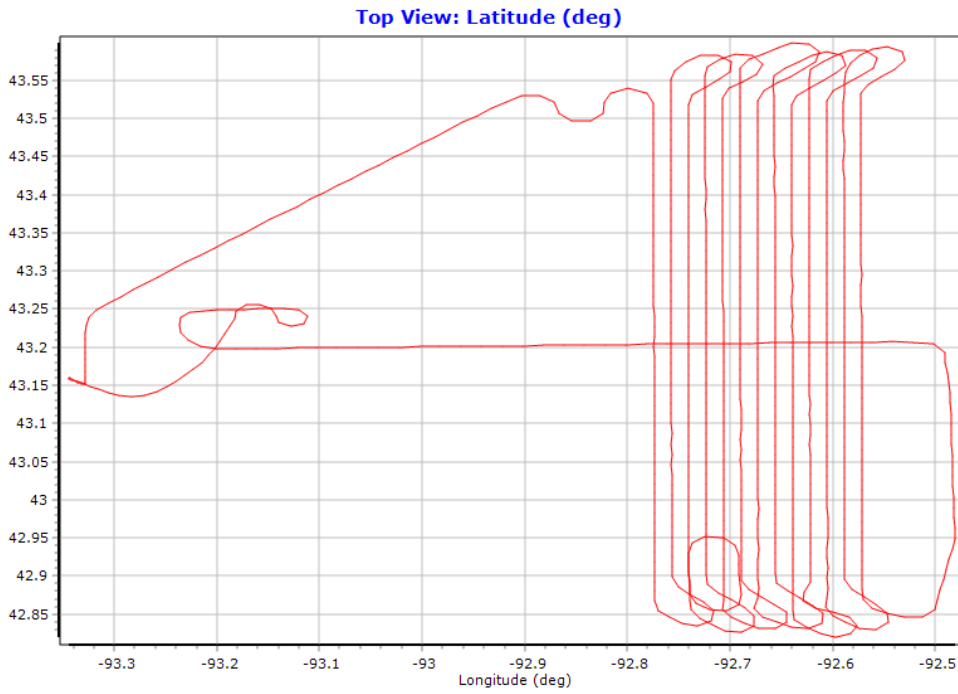


PDOP

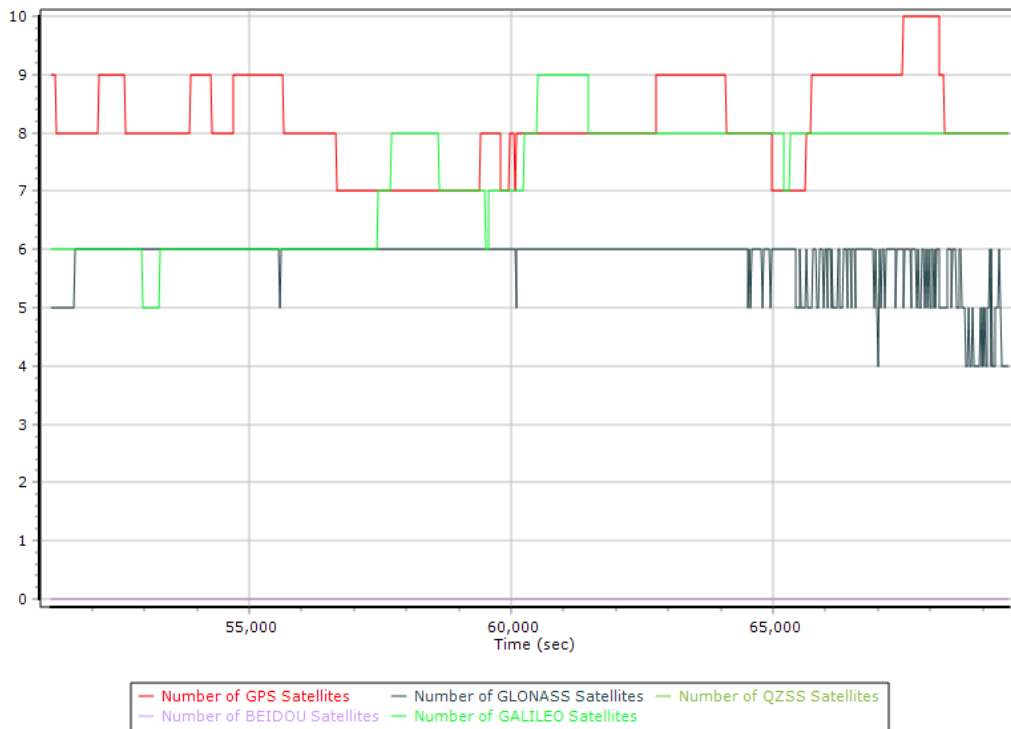


Smoothed Trajectory Information

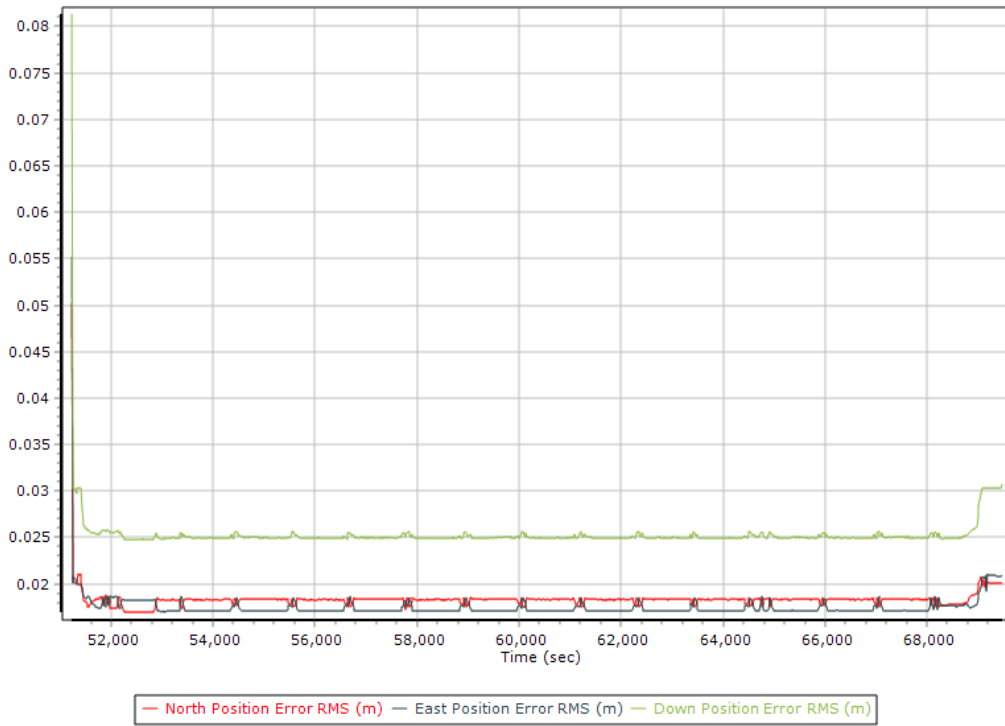
Top View



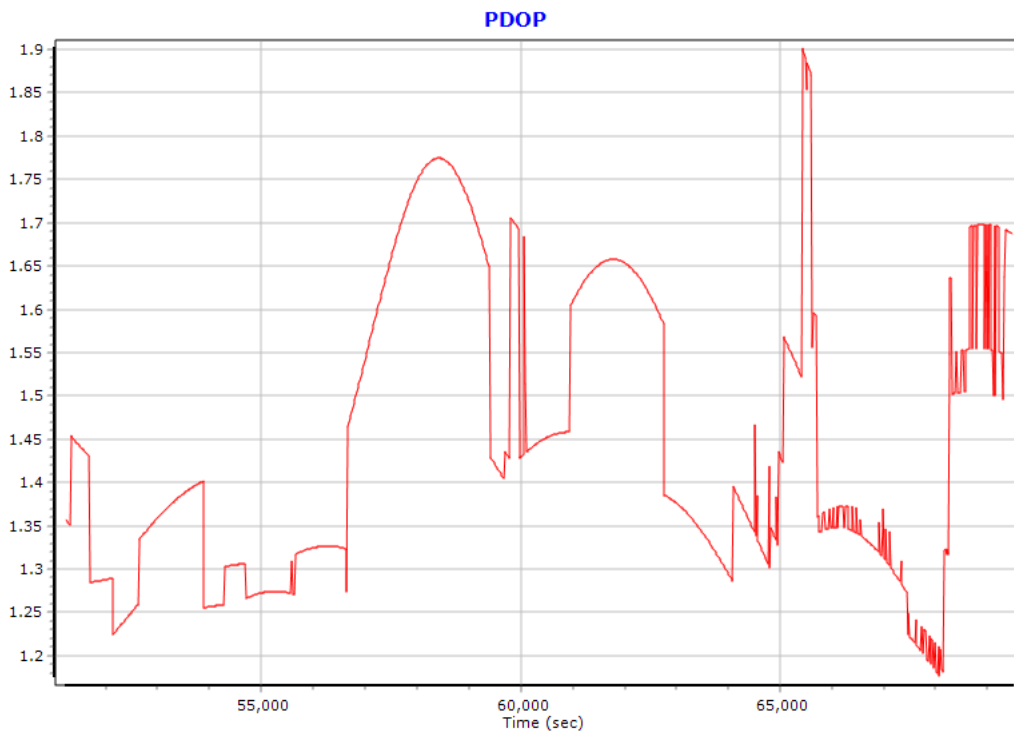
Number of Satellites



Forward/Reverse Separation

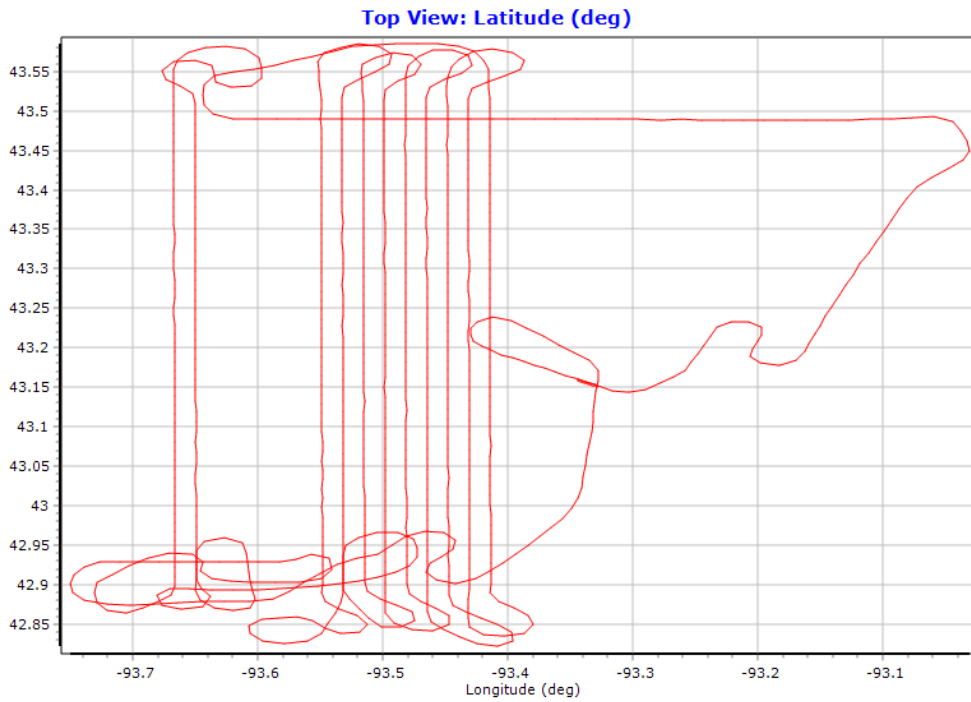


PDOP

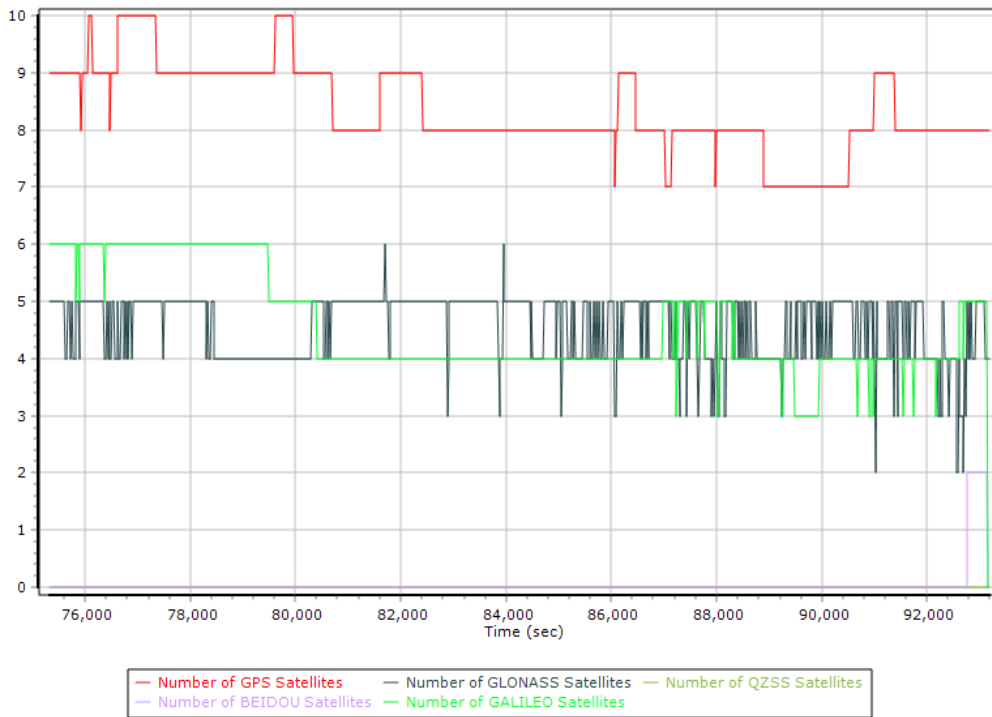


Smoothed Trajectory Information

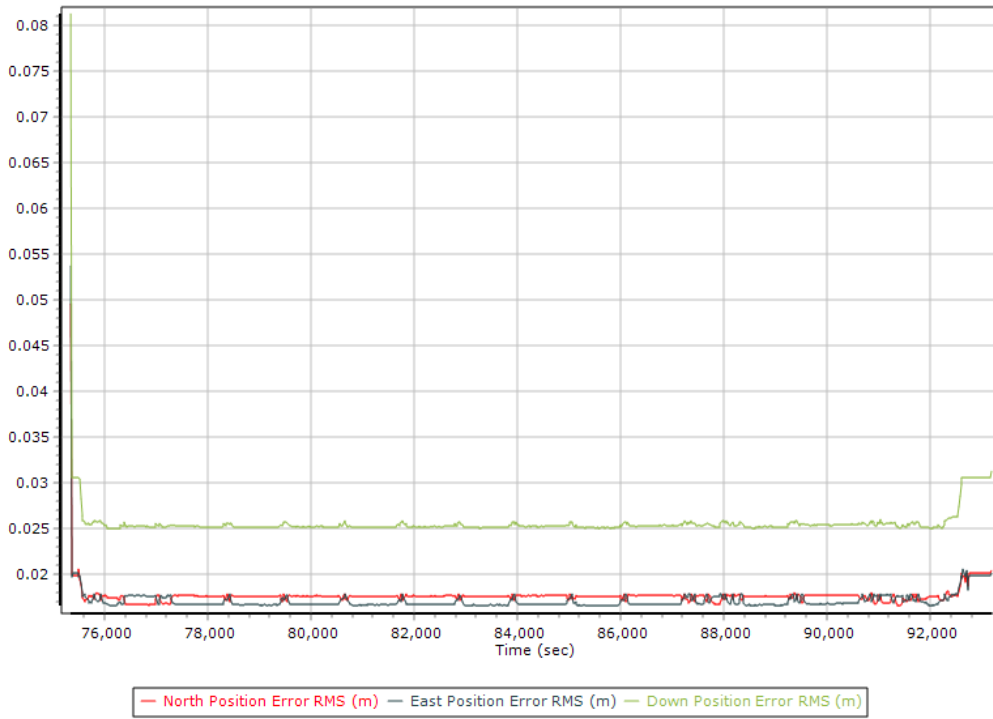
Top View



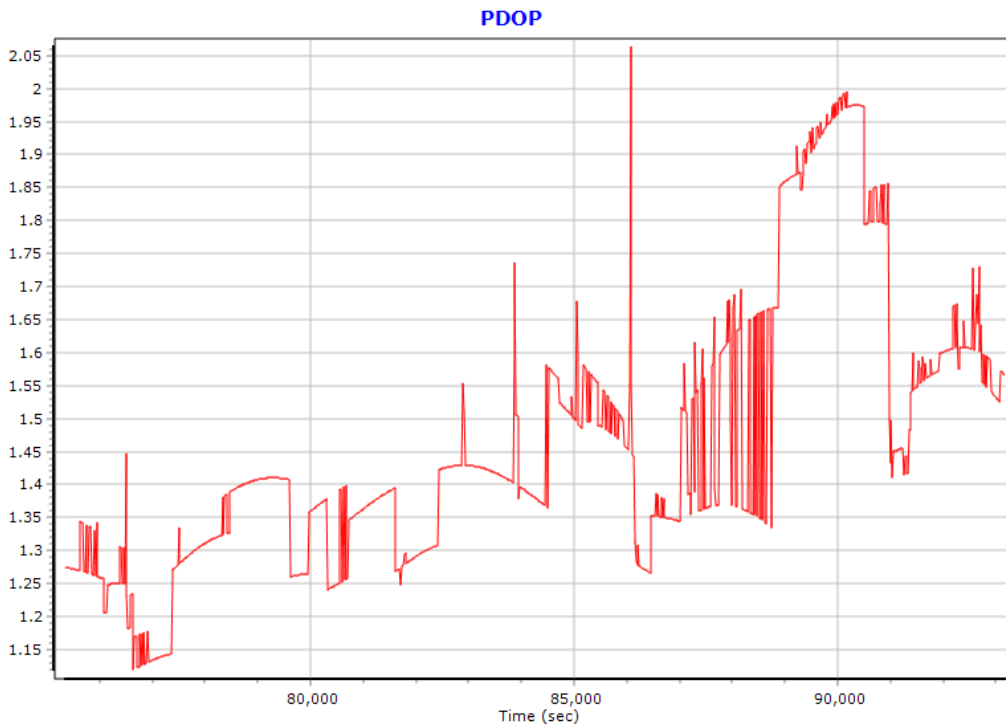
Number of Satellites



Forward/Reverse Separation

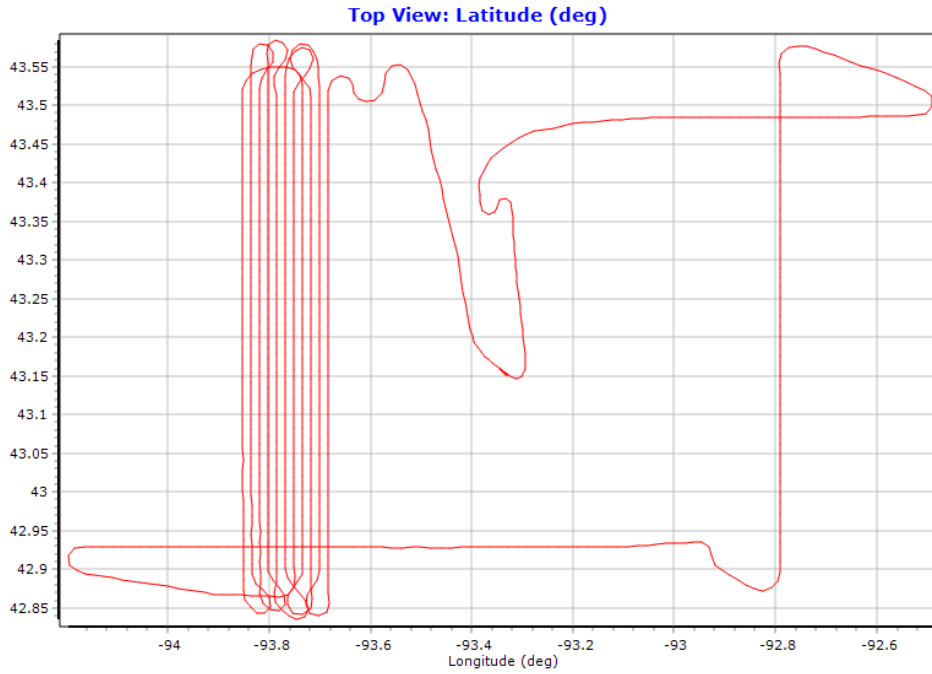


PDOP

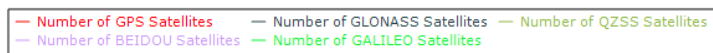
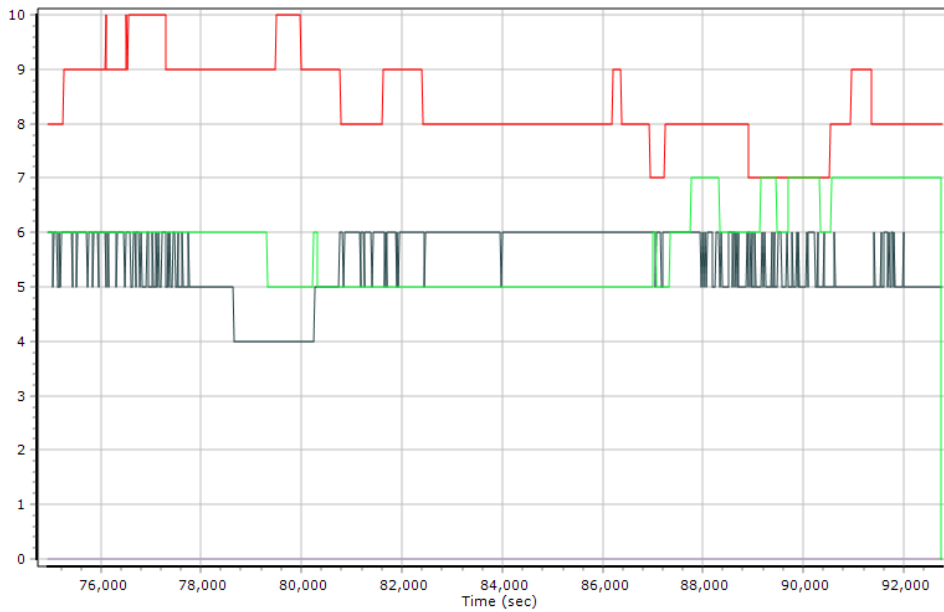


Smoothed Trajectory Information

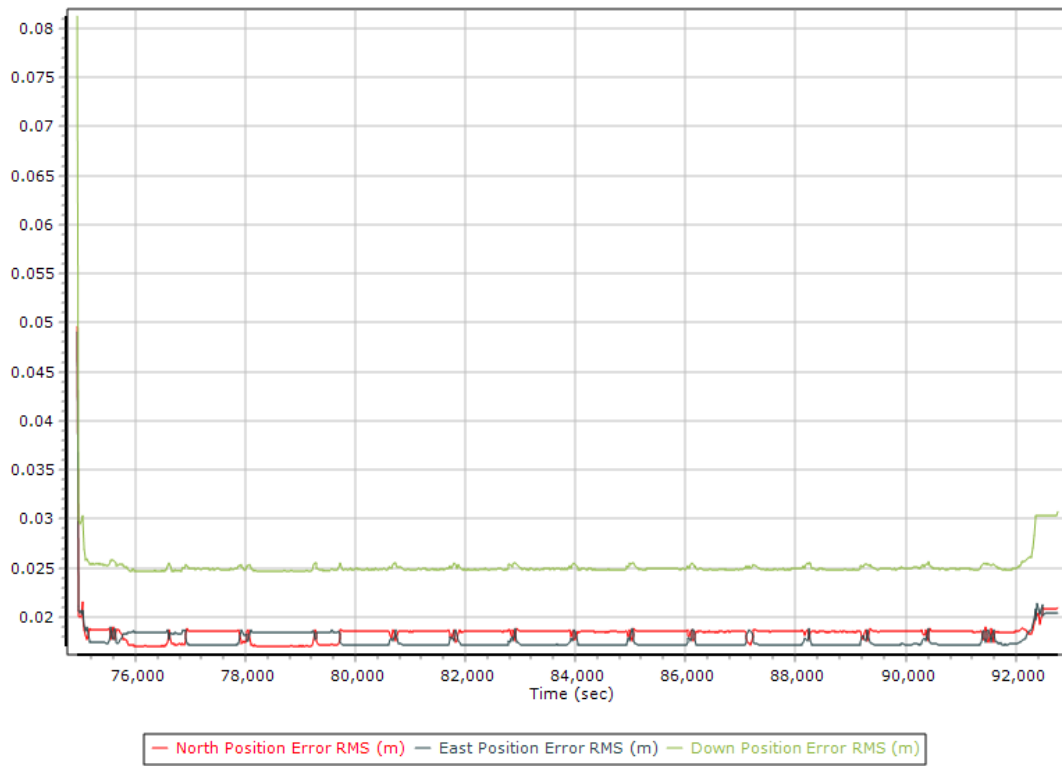
Top View



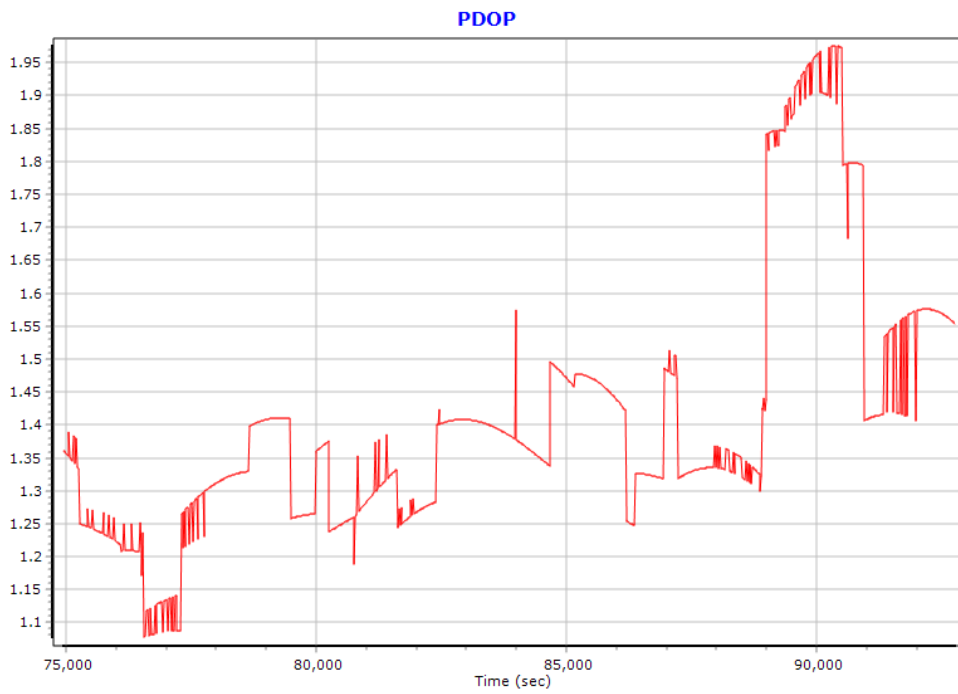
Number of Satellites



Forward/Reverse Separation

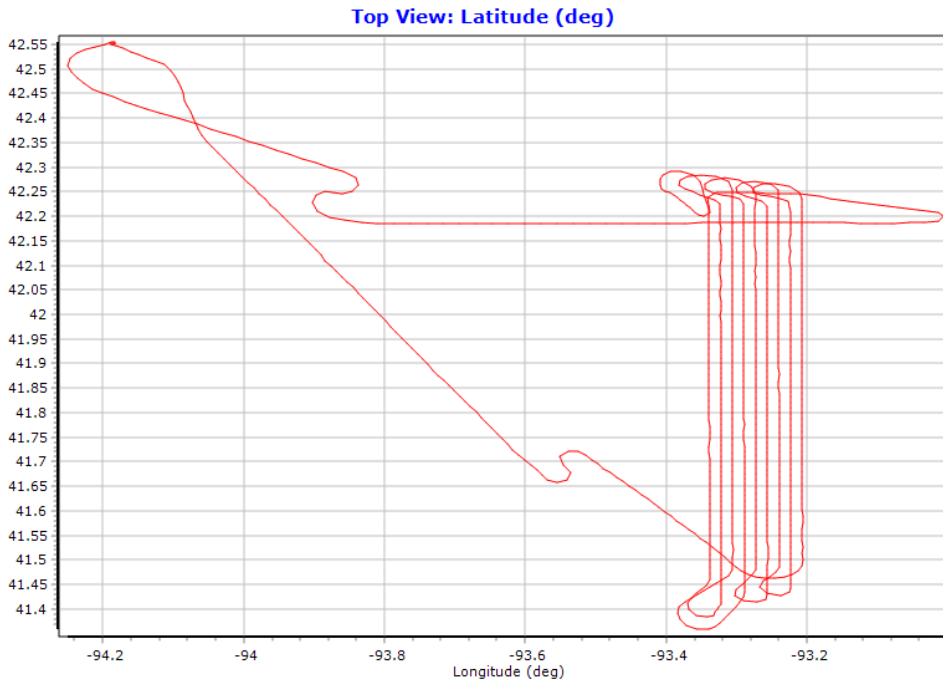


PDOP

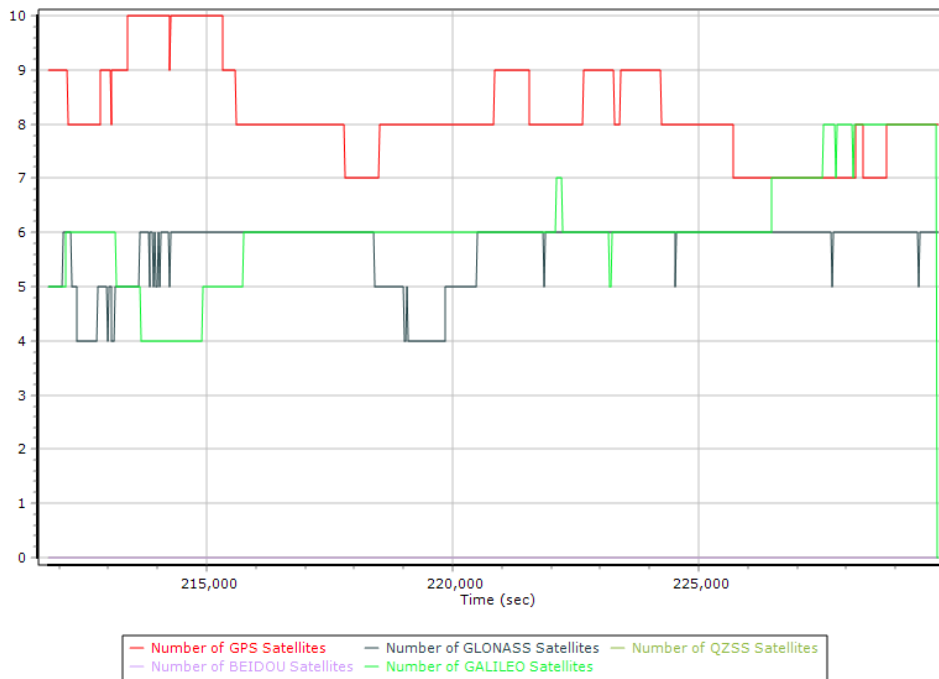


Smoothed Trajectory Information

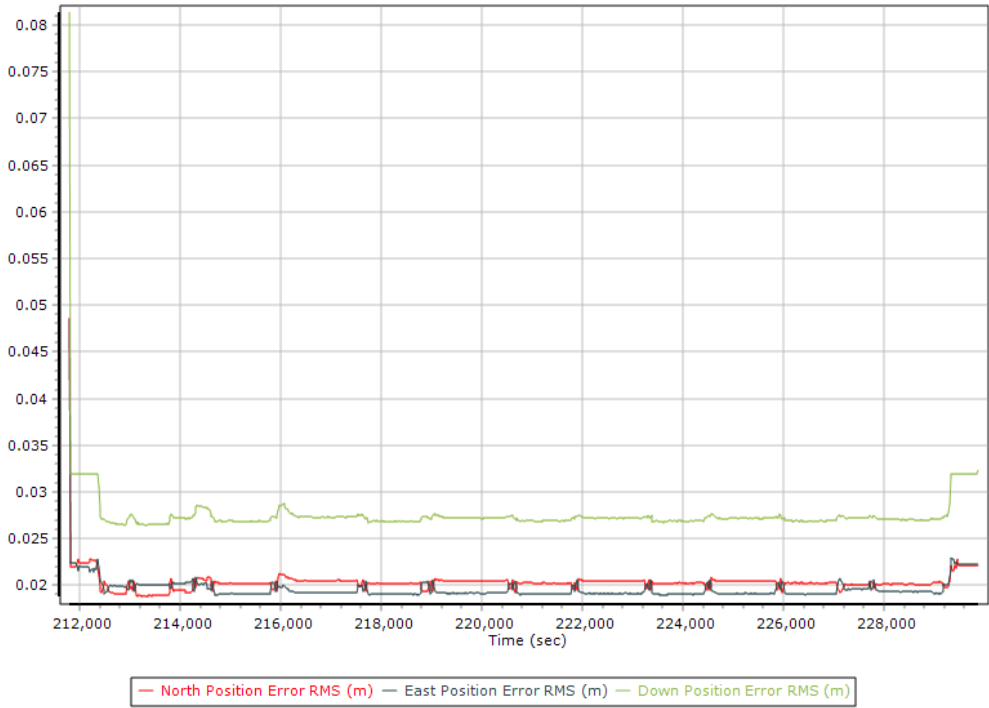
Top View



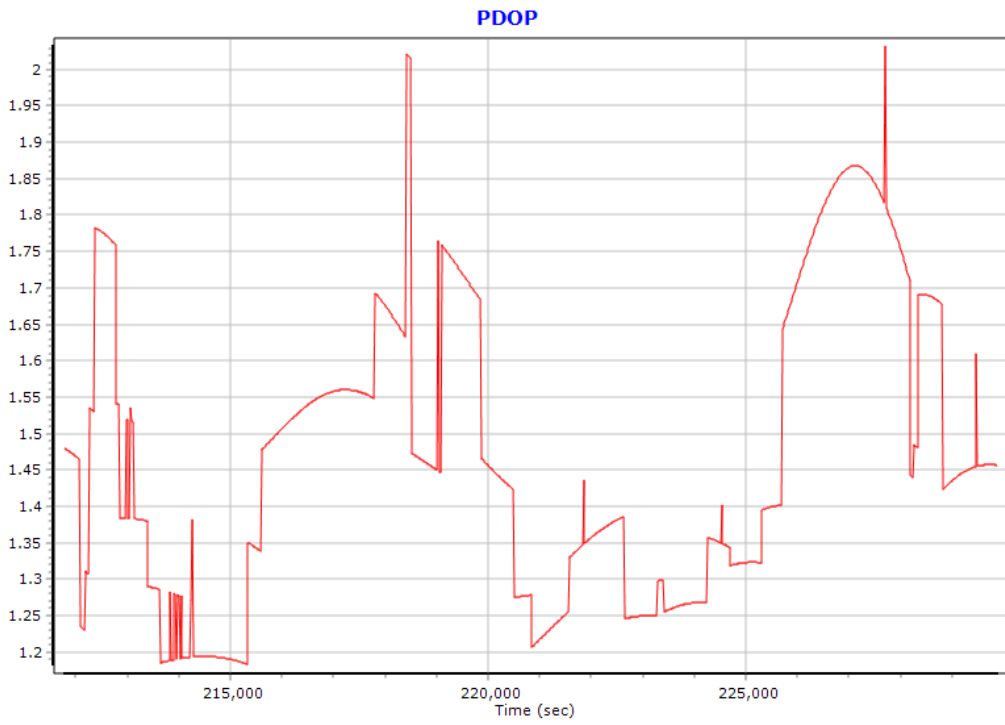
Number of Satellites



Forward/Reverse Separation

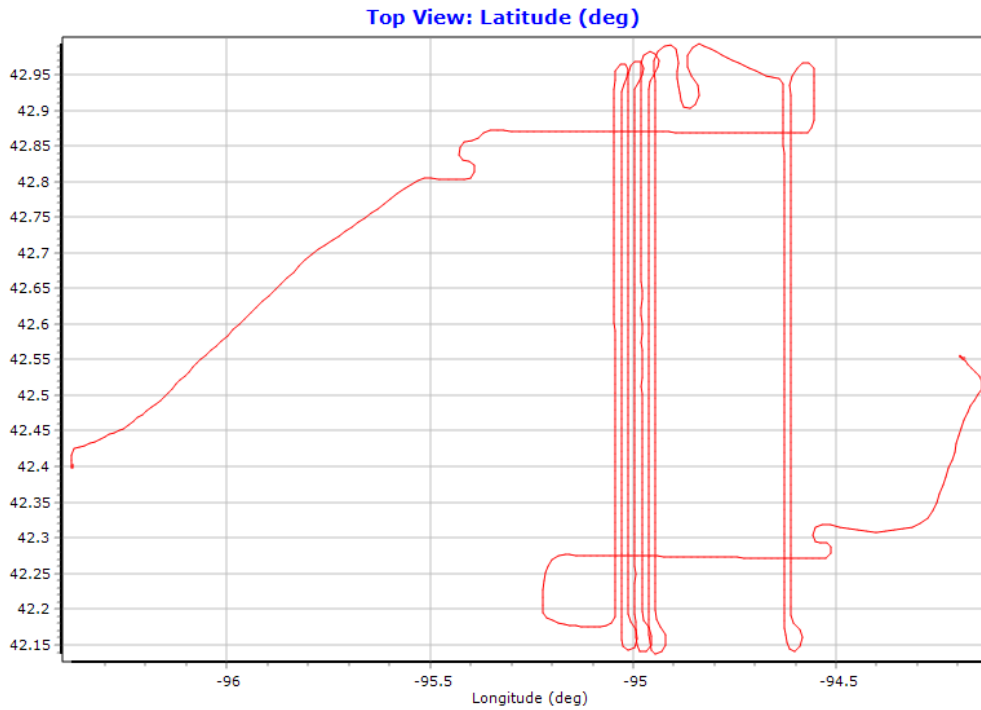


PDOP

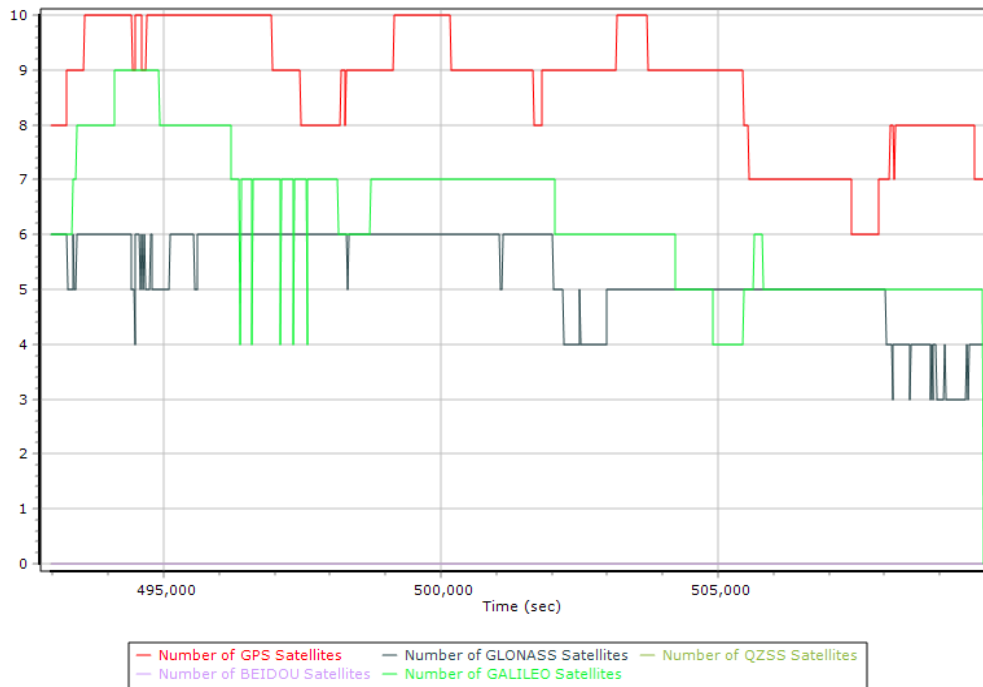


Smoothed Trajectory Information

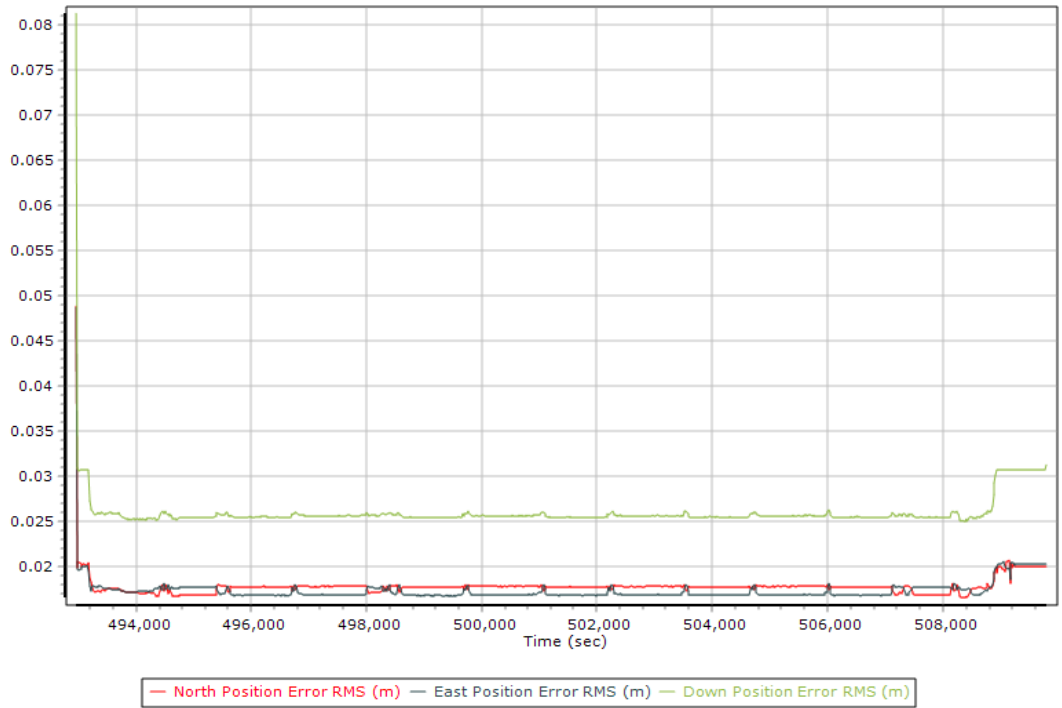
Top View



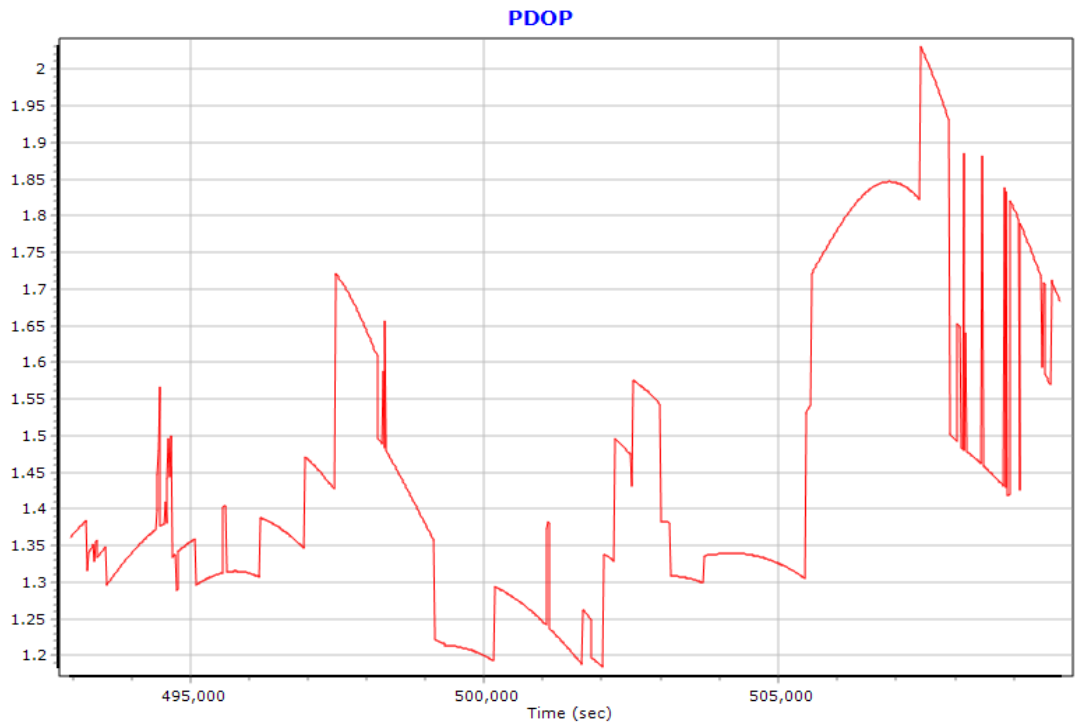
Number of Satellites



Forward/Reverse Separation

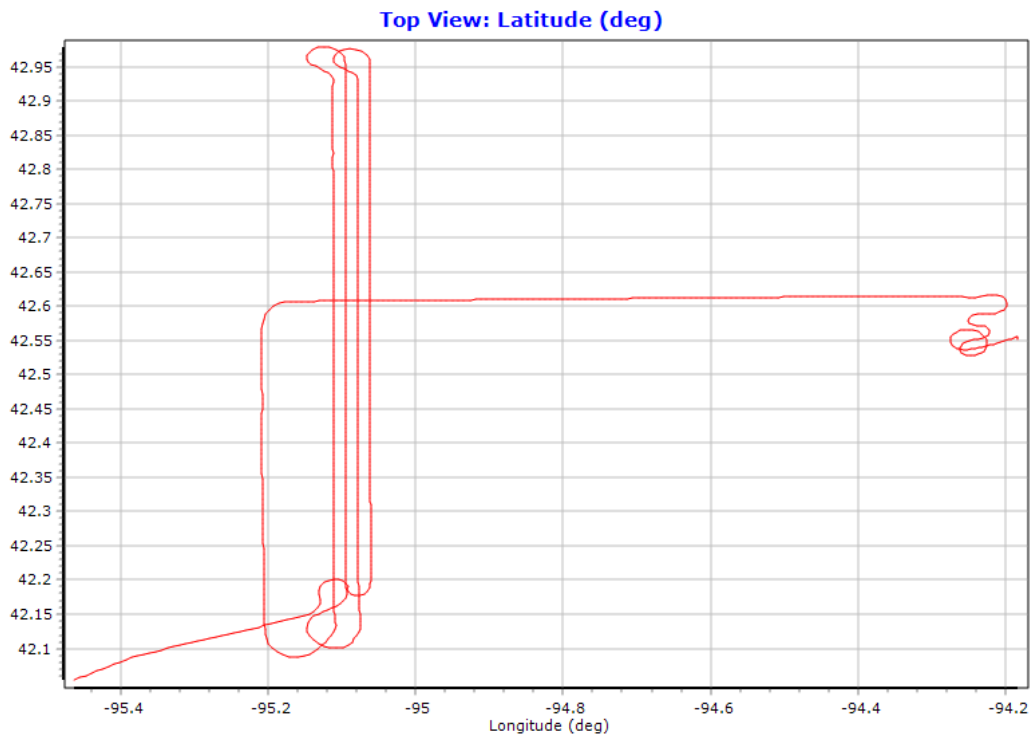


PDOP

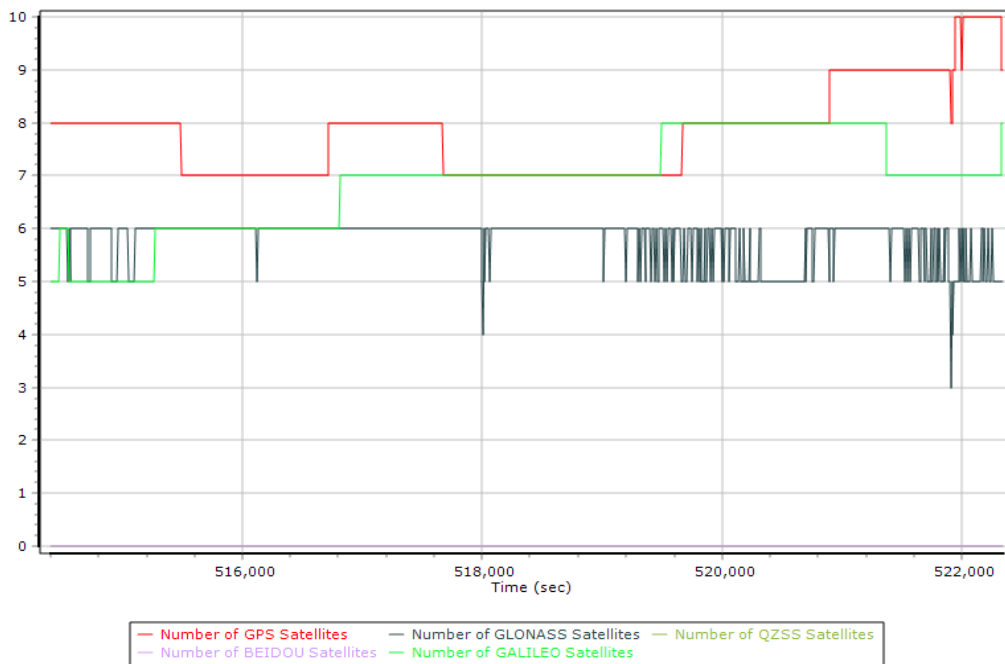


Smoothed Trajectory Information

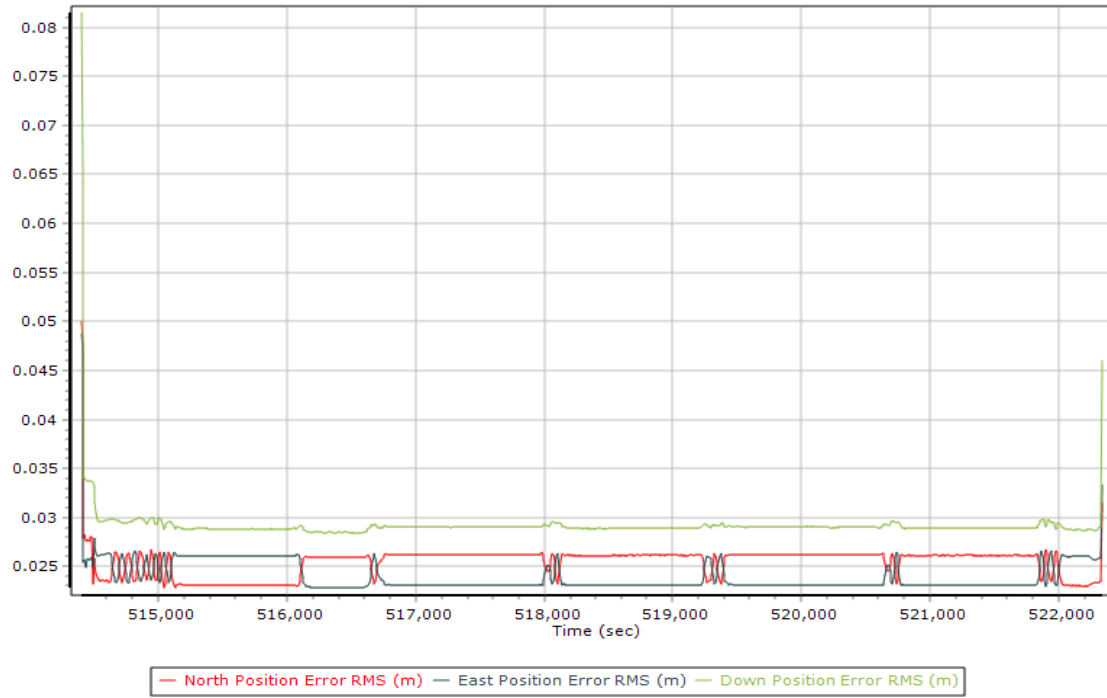
Top View



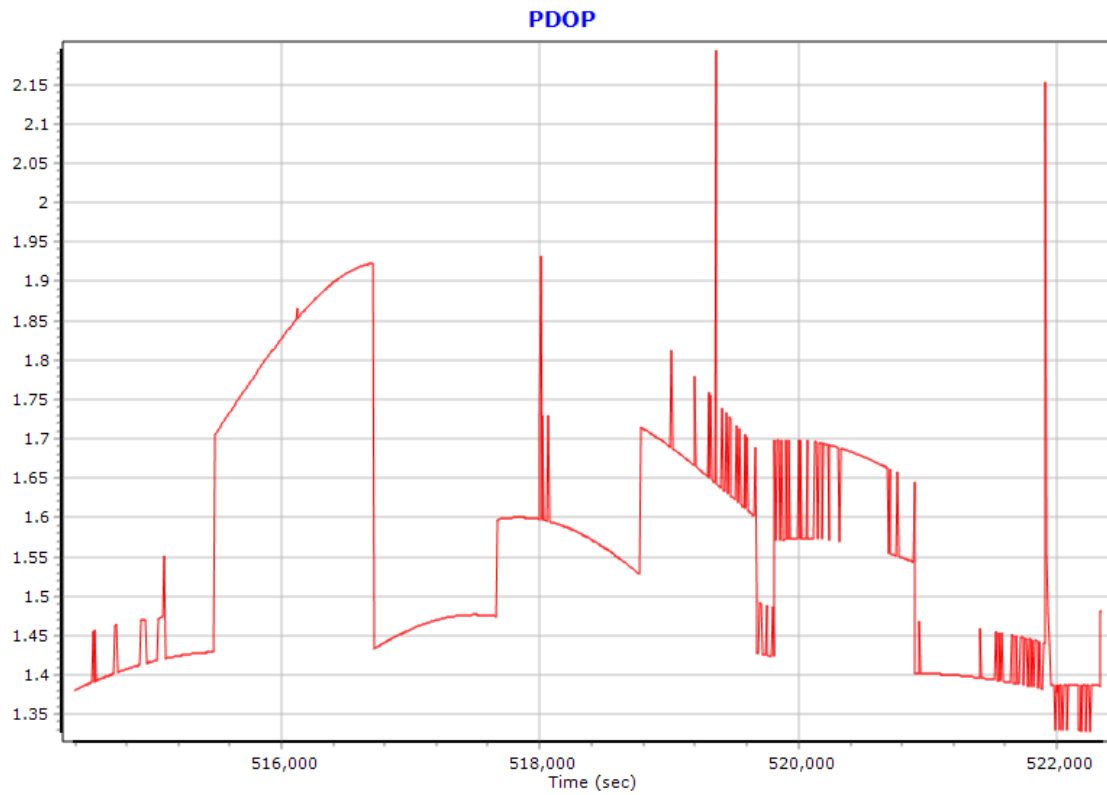
Number of Satellites



Forward/Reverse Separation



PDOP

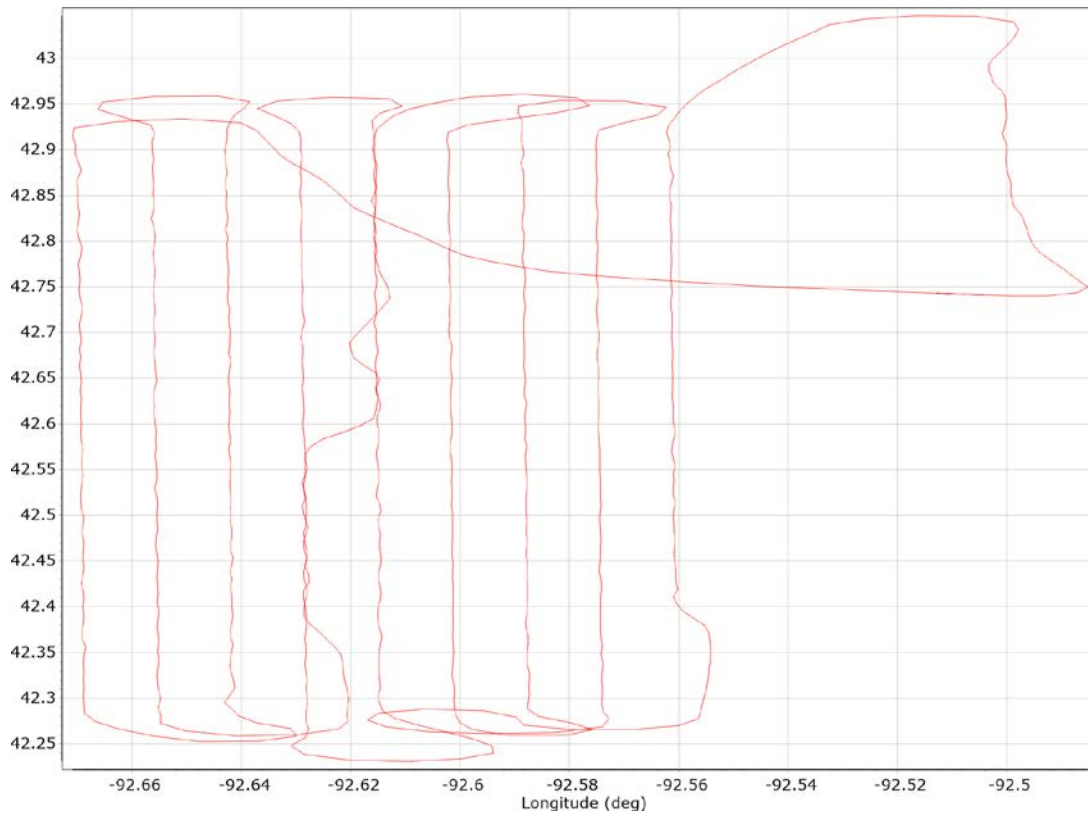


Technical Applications & Consulting, LLC (TAC) Mission GPS and IMU Processing Report

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Smoothed Trajectory Information

Top View

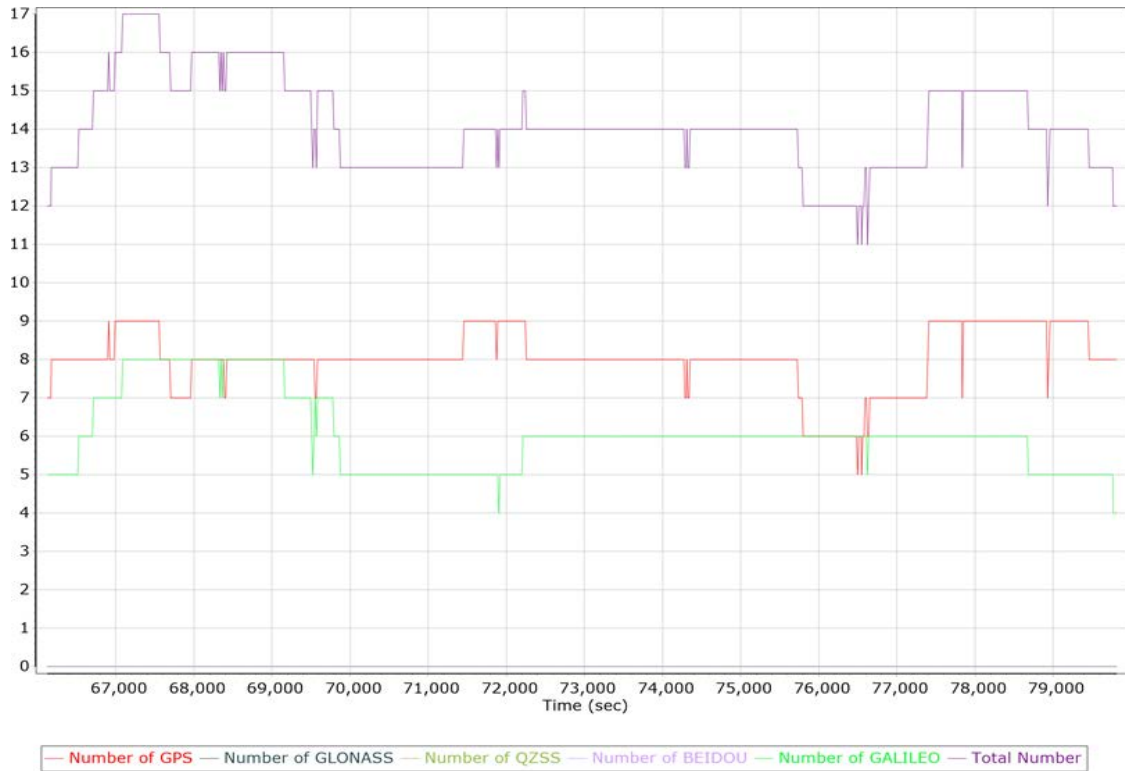


GNSS QC

GNSS QC Statistics

Statistics	Min	Max	Mean
Baseline length (km)	0.00	0.00	
Number of GPS SV	5	9	8
Number of GLONASS SV	0	0	0
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Number of GALILEO SV	4	8	6
Total number of SV	11	17	14
PDOP	1.22	2.05	1.52
QC Solution Gaps	0.00	0.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	14103.00	0.00	0.00
Percentage	100.00	0.00	0.00

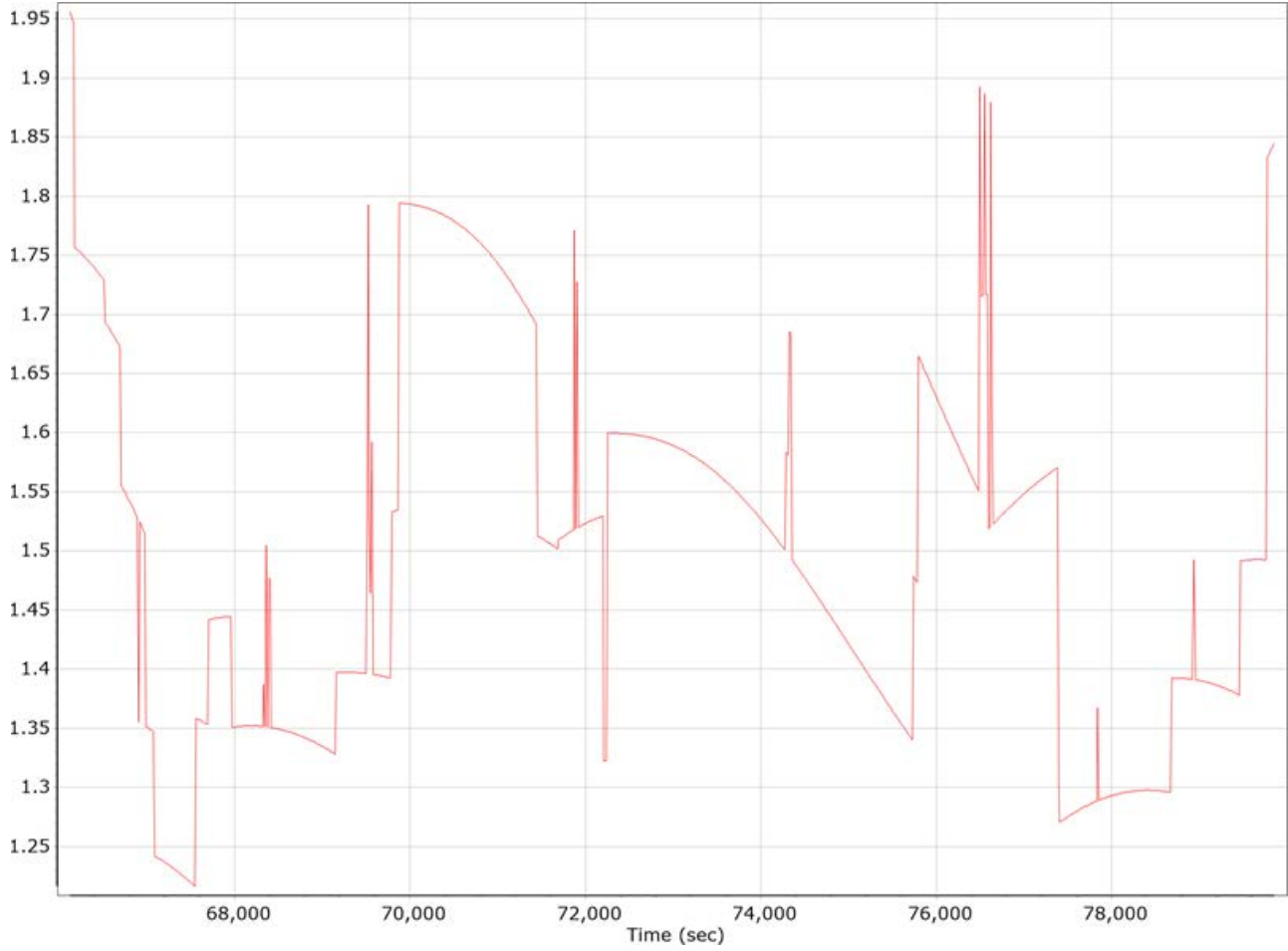
Number of Satellites



Forward/Reverse Separation



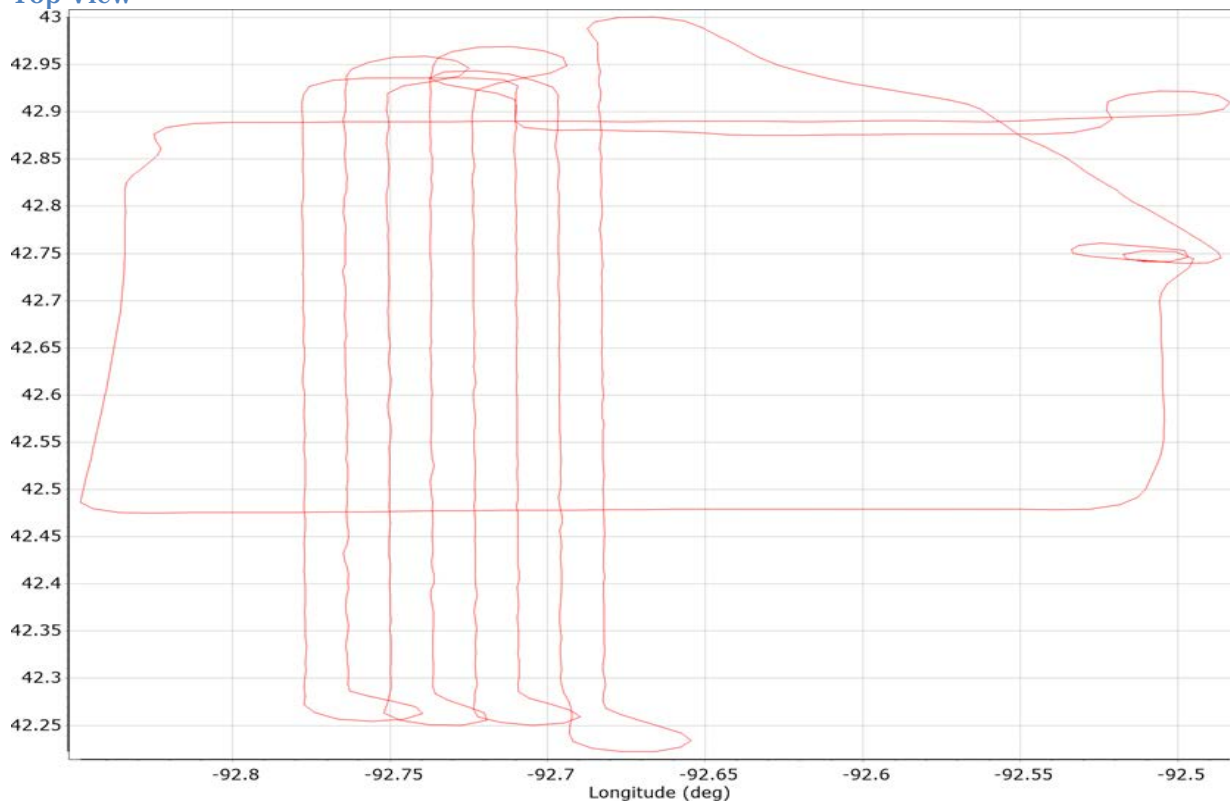
PDOP



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Smoothed Trajectory Information

Top View

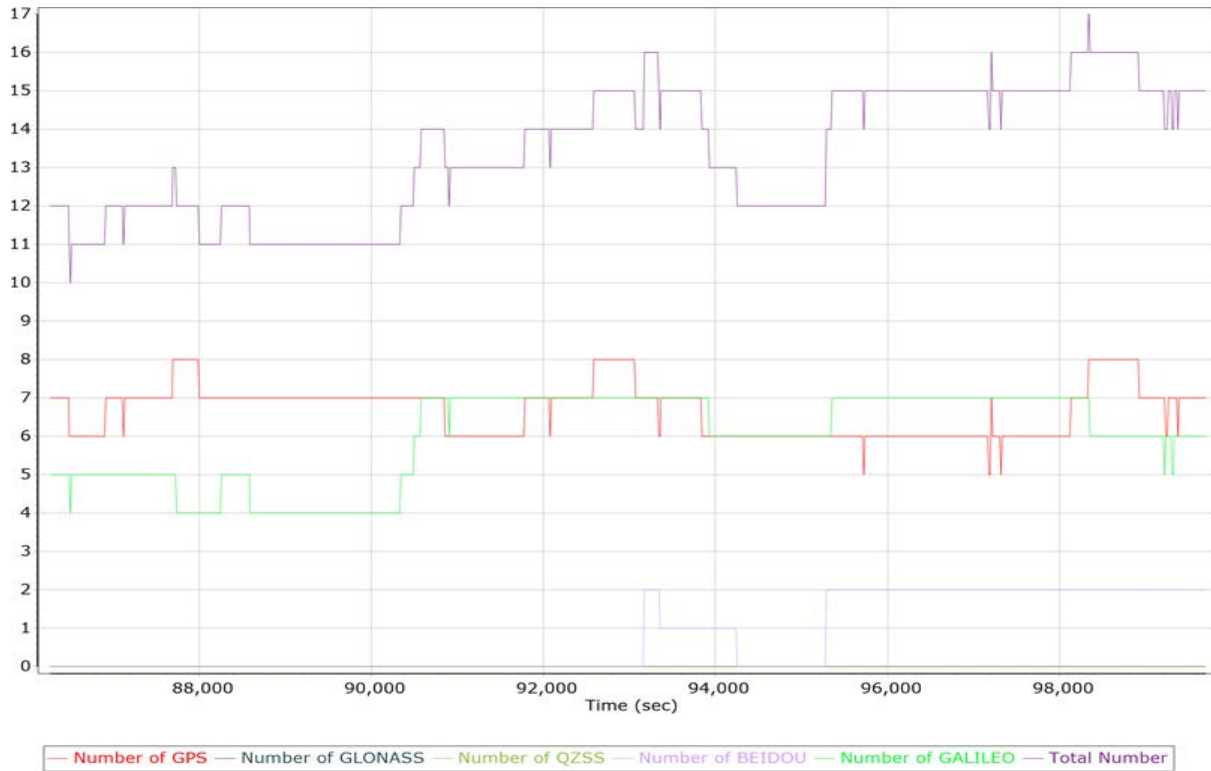


GNSS QC

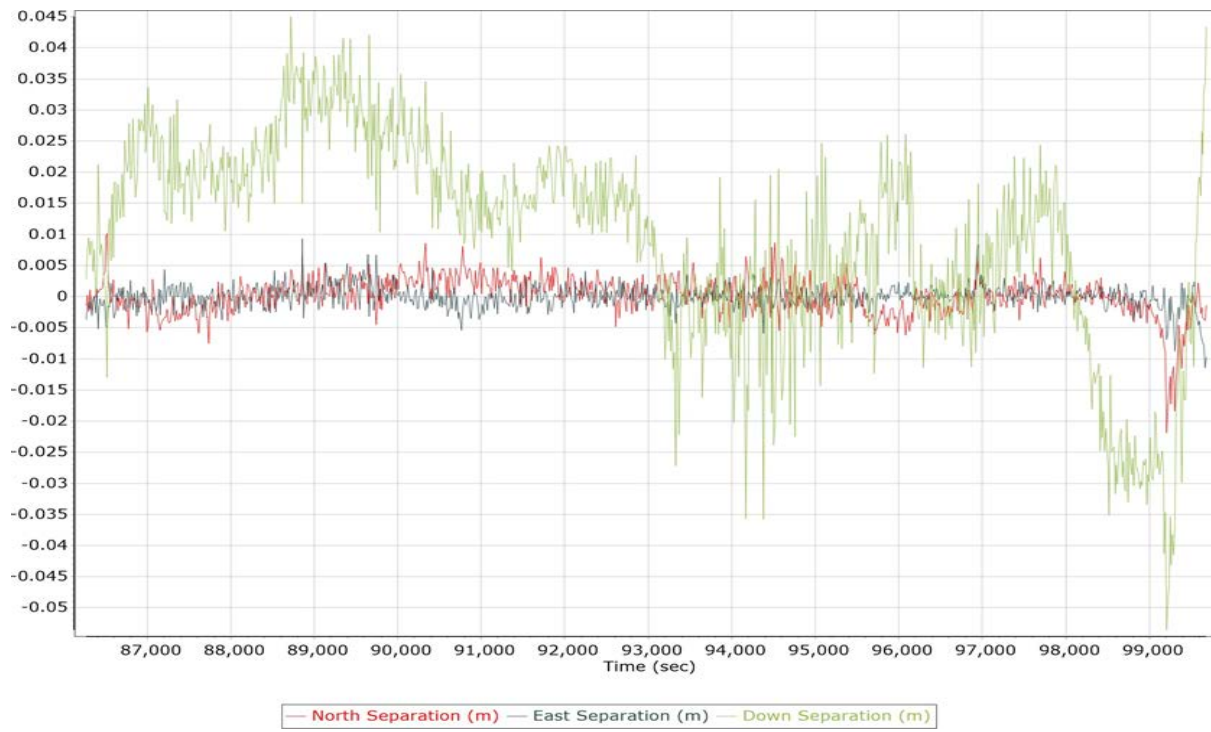
GNSS QC Statistics

Statistics	Min	Max	Mean
Baseline length (km)	0.00	0.00	
Number of GPS SV	5	8	7
Number of GLONASS SV	0	0	0
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	2	1
Number of GALILEO SV	4	7	6
Total number of SV	10	17	13
PDOP	1.33	3.01	1.79
QC Solution Gaps	0.00	0.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	13932.00	0.00	0.00
Percentage	100.00	0.00	0.00

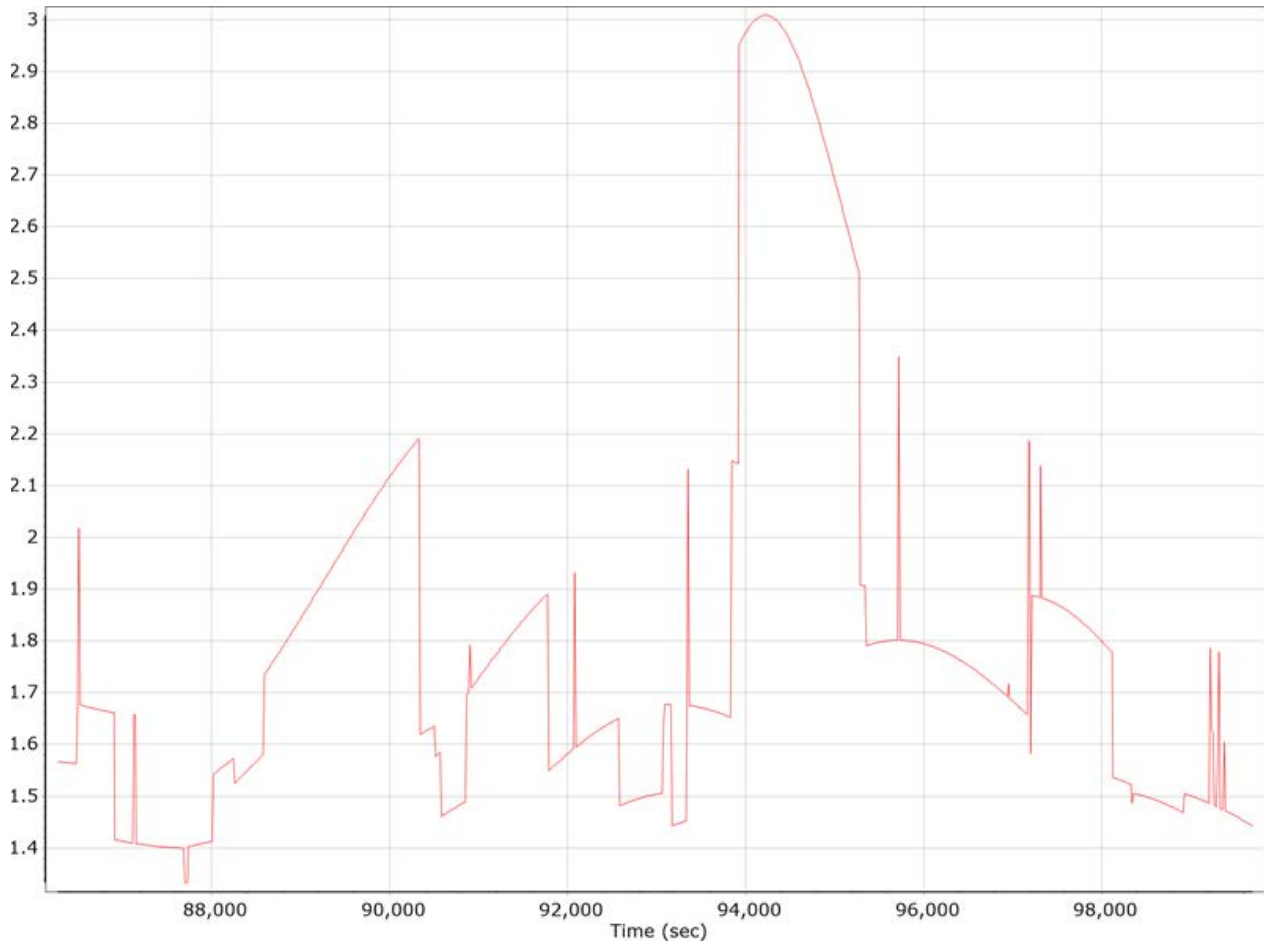
Number of Satellites



Forward/Reverse Separation



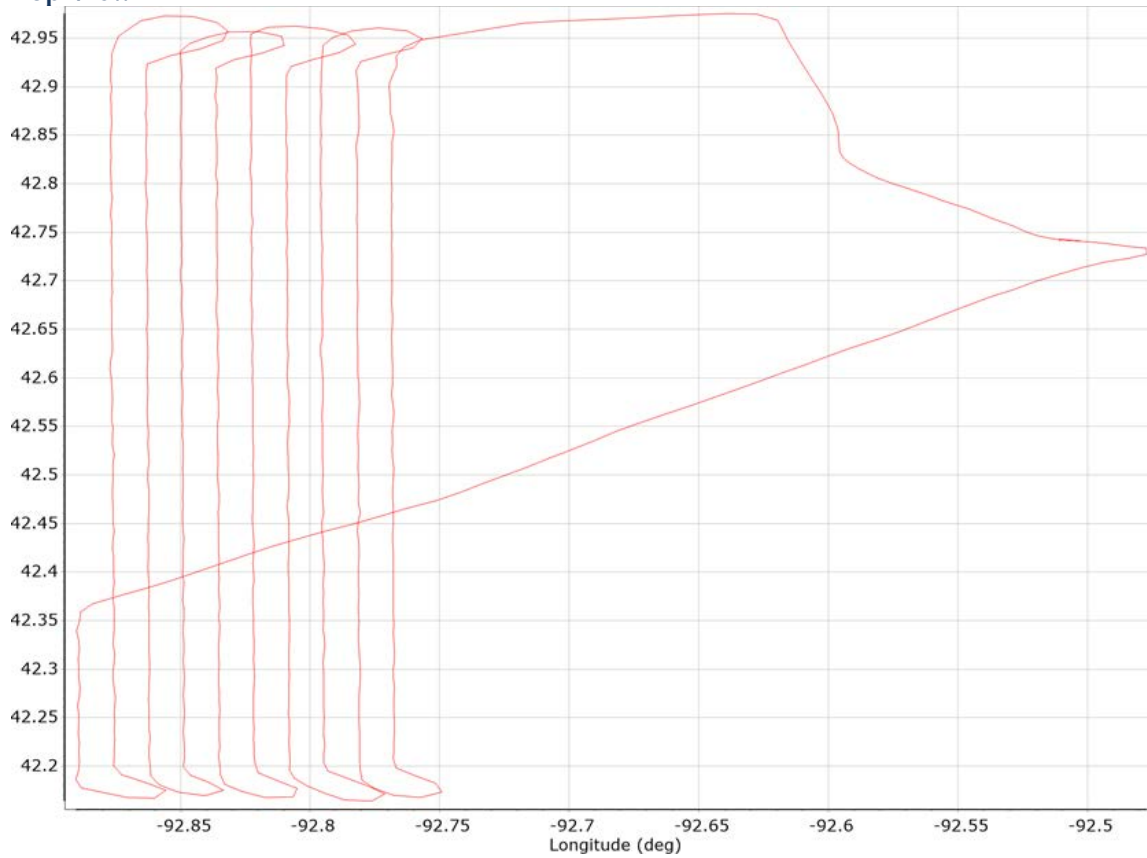
PDOP



Lift 3 Report.docx QC Report – 06/18/2020

Smoothed Trajectory Information

Top View



GNSS QC

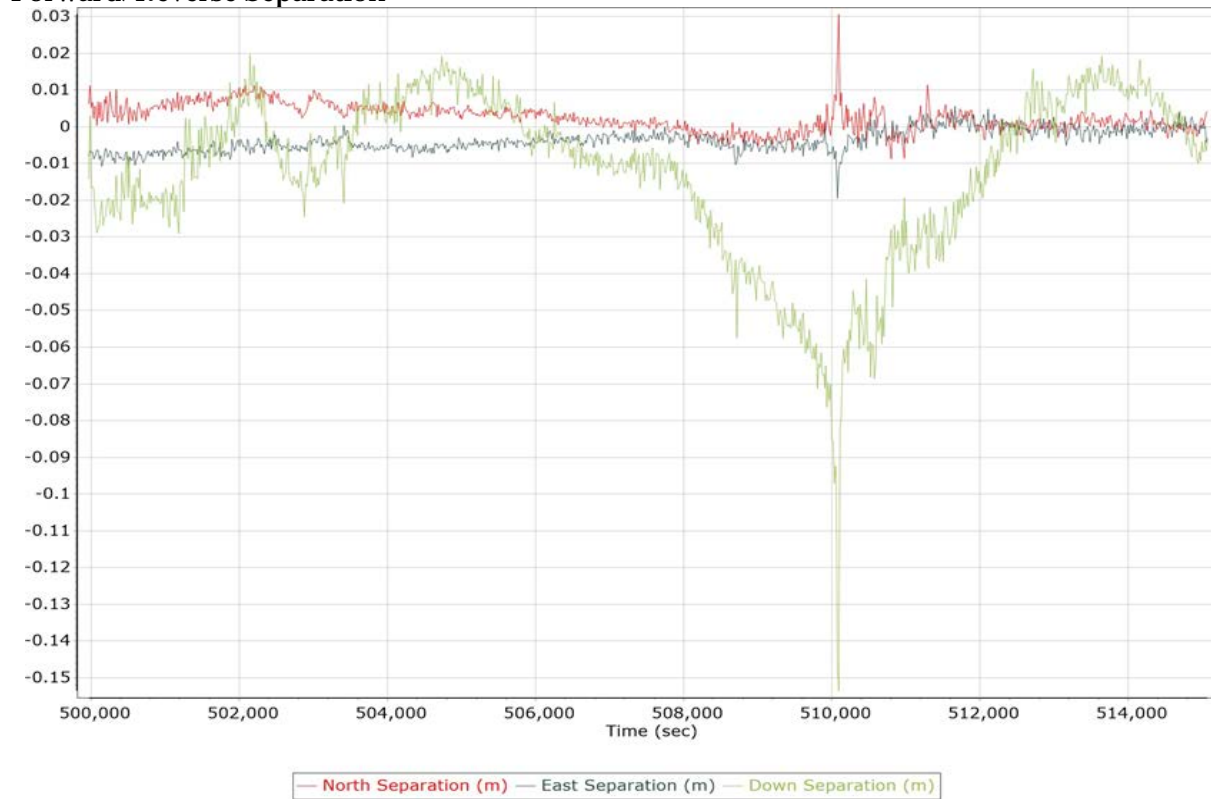
GNSS QC Statistics

Statistics	Min	Max	Mean
Baseline length (km)	0.00	0.00	
Number of GPS SV	5	9	8
Number of GLONASS SV	0	0	0
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	2	1
Number of GALILEO SV	4	6	5
Total number of SV	9	16	14
PDOP	1.28	2.66	1.57
QC Solution Gaps	0.00	0.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	15468.00	0.00	0.00
Percentage	100.00	0.00	0.00

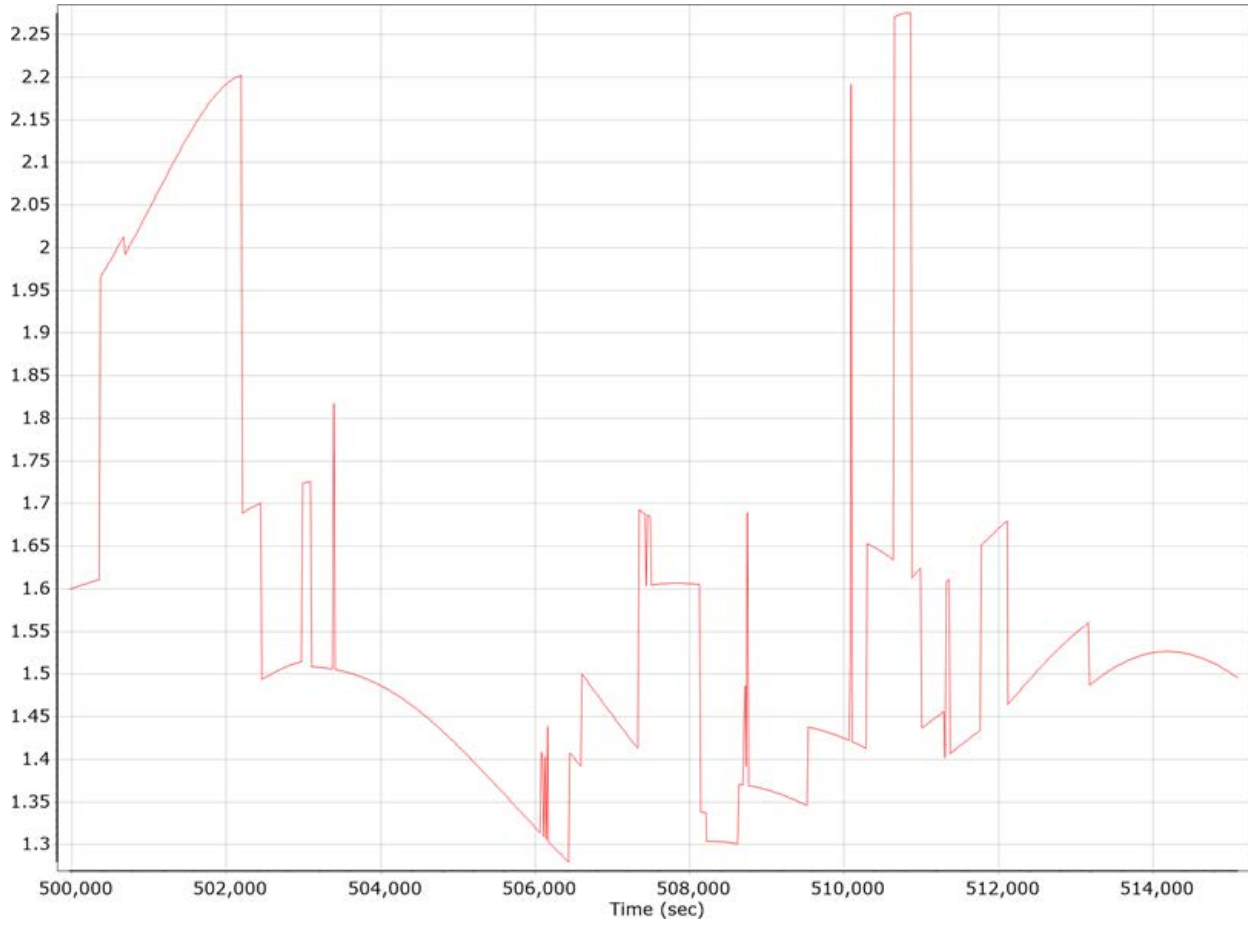
Number of Satellites



Forward/Reverse Separation



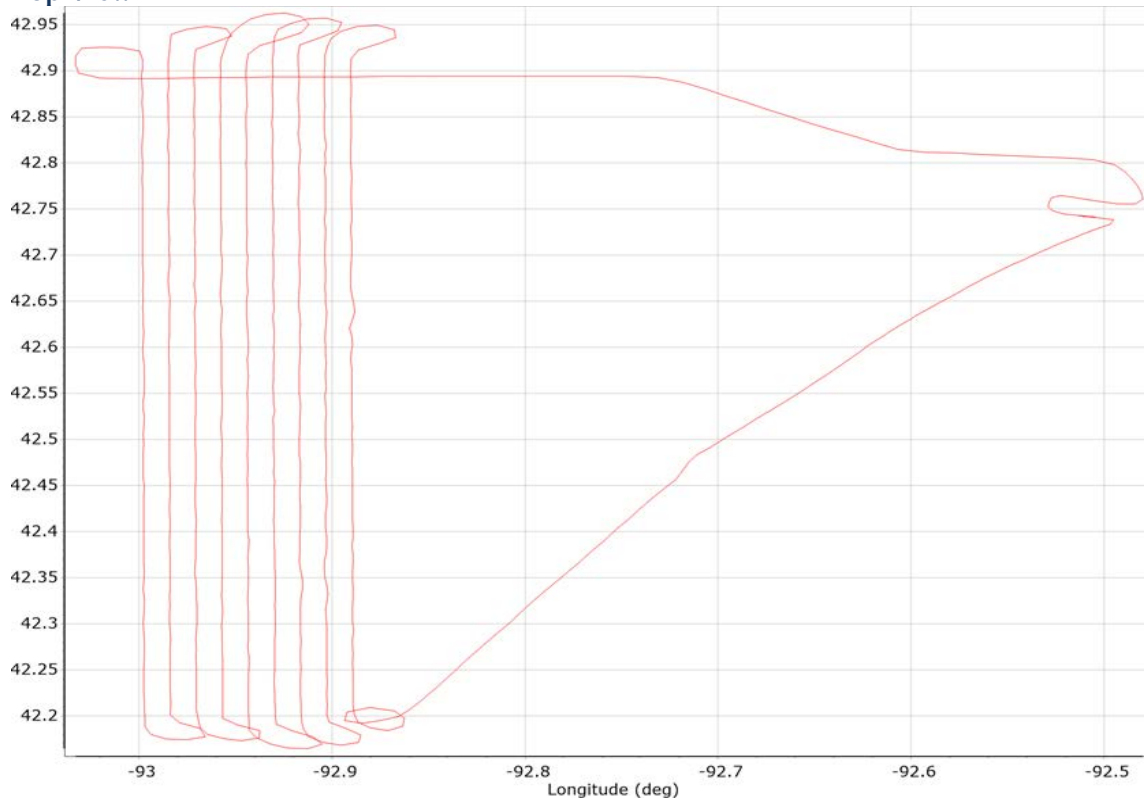
PDOP



Lift 4 Report.docx QC Report – 06/18/2020

Smoothed Trajectory Information

Top View



GNSS QC

GNSS QC Statistics

Statistics	Min	Max	Mean
Baseline length (km)	0.00	0.00	
Number of GPS SV	5	8	6
Number of GLONASS SV	0	0	0
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Number of GALILEO SV	3	7	5
Total number of SV	8	15	12
PDOP	1.37	3.22	1.83
QC Solution Gaps	0.00	0.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	15468.00	0.00	0.00
Percentage	100.00	0.00	0.00

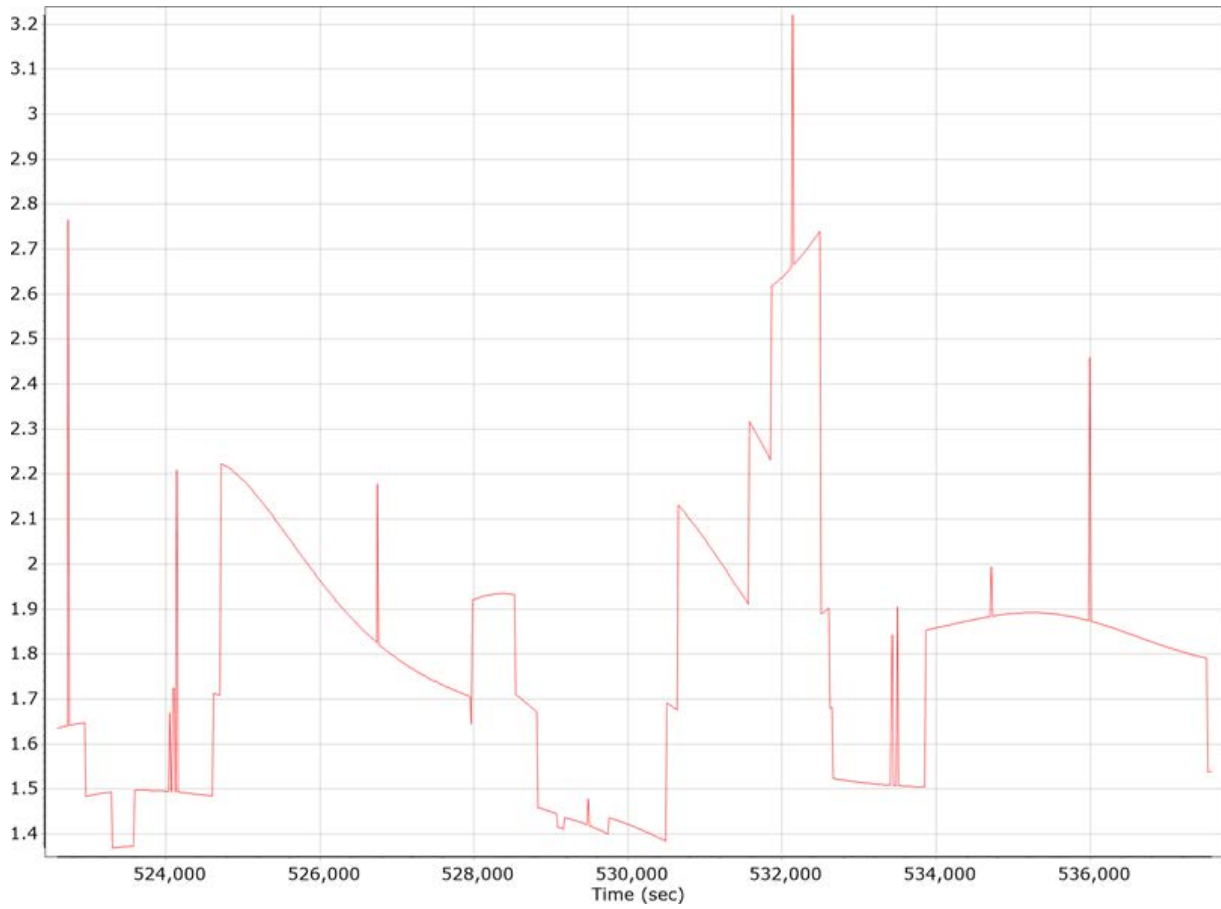
Number of Satellites



Forward/Reverse Separation



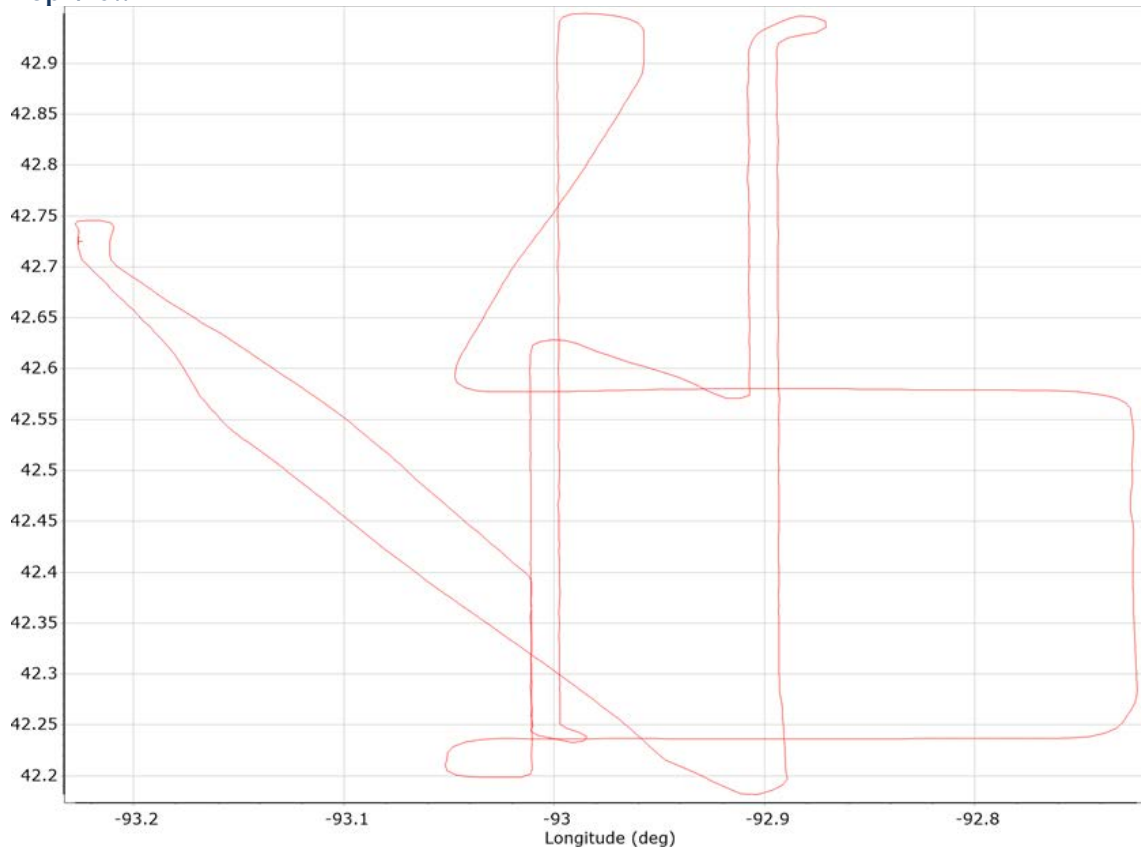
PDOP



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Smoothed Trajectory Information

Top View

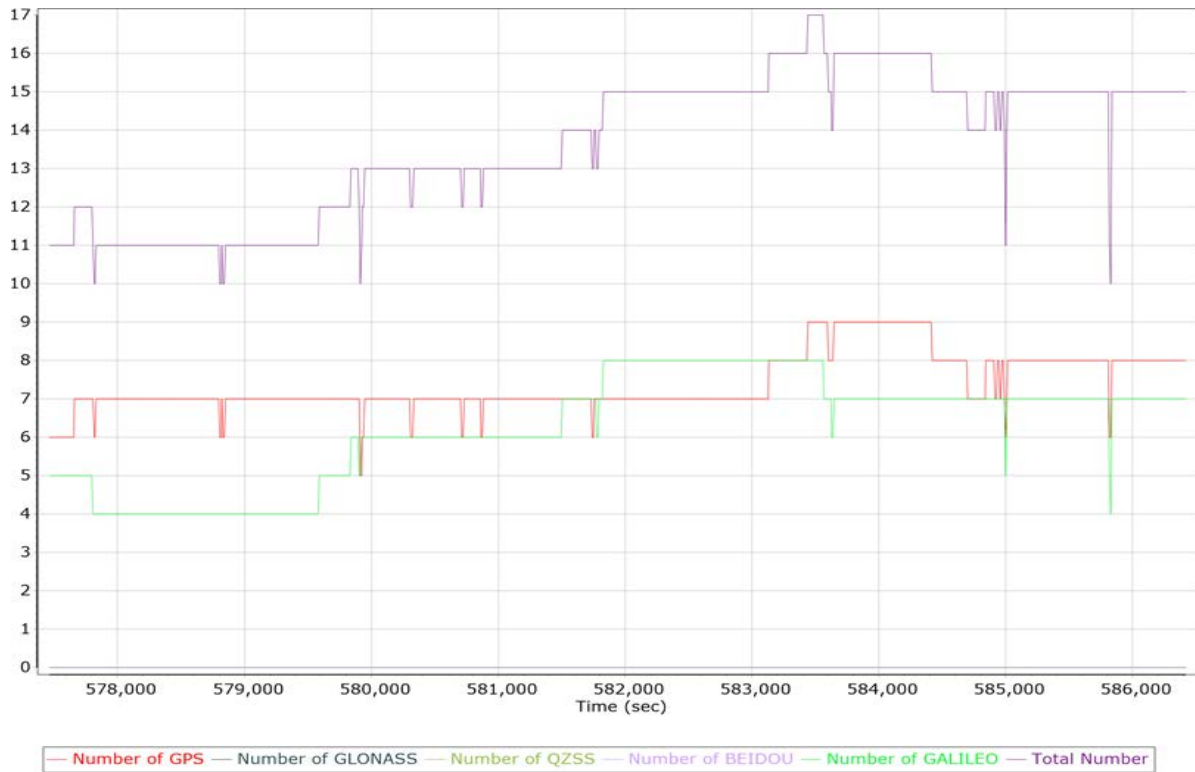


GNSS QC

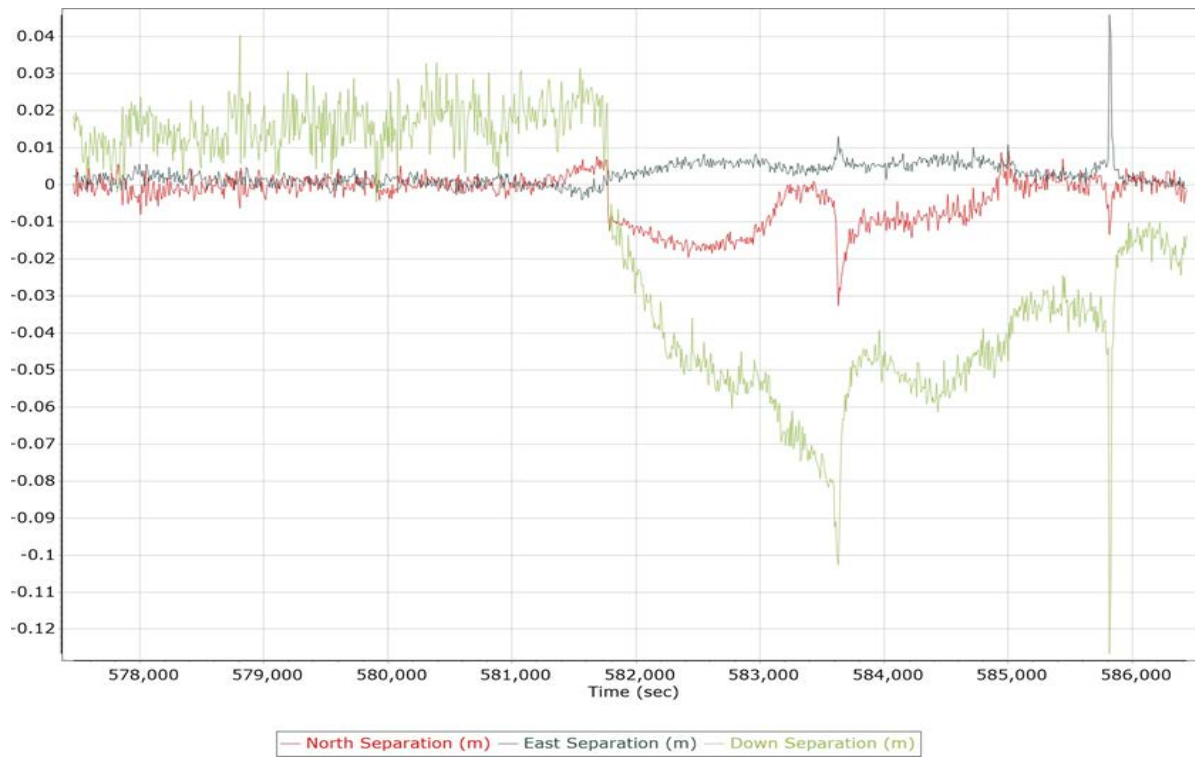
GNSS QC Statistics

Statistics	Min	Max	Mean
Baseline length (km)	0.00	0.00	
Number of GPS SV	5	9	7
Number of GLONASS SV	0	0	0
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Number of GALILEO SV	4	8	6
Total number of SV	9	17	14
PDOP	1.25	2.63	1.66
QC Solution Gaps	0.00	0.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	9438.00	0.00	0.00
Percentage	100.00	0.00	0.00

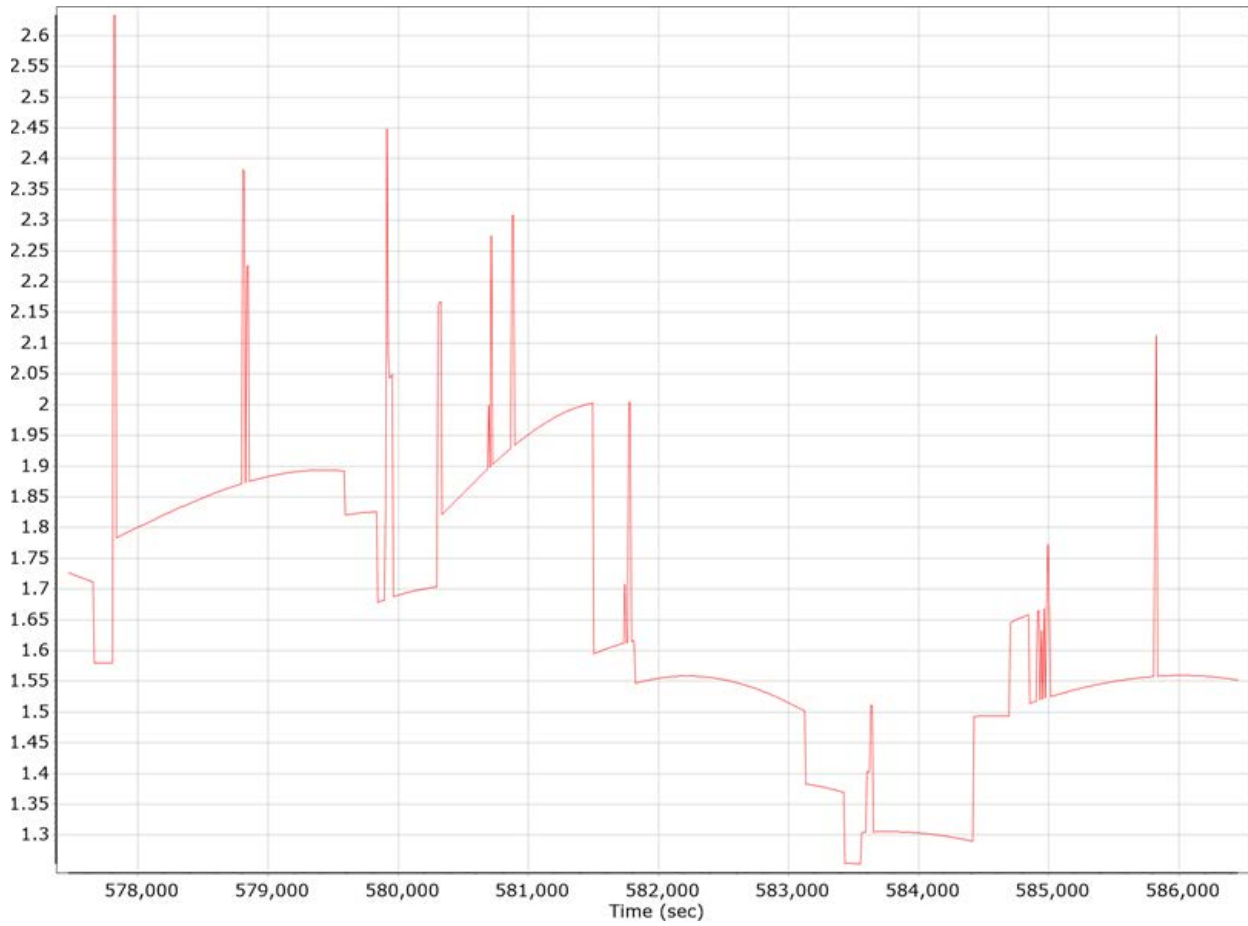
Number of Satellites



Forward/Reverse Separation



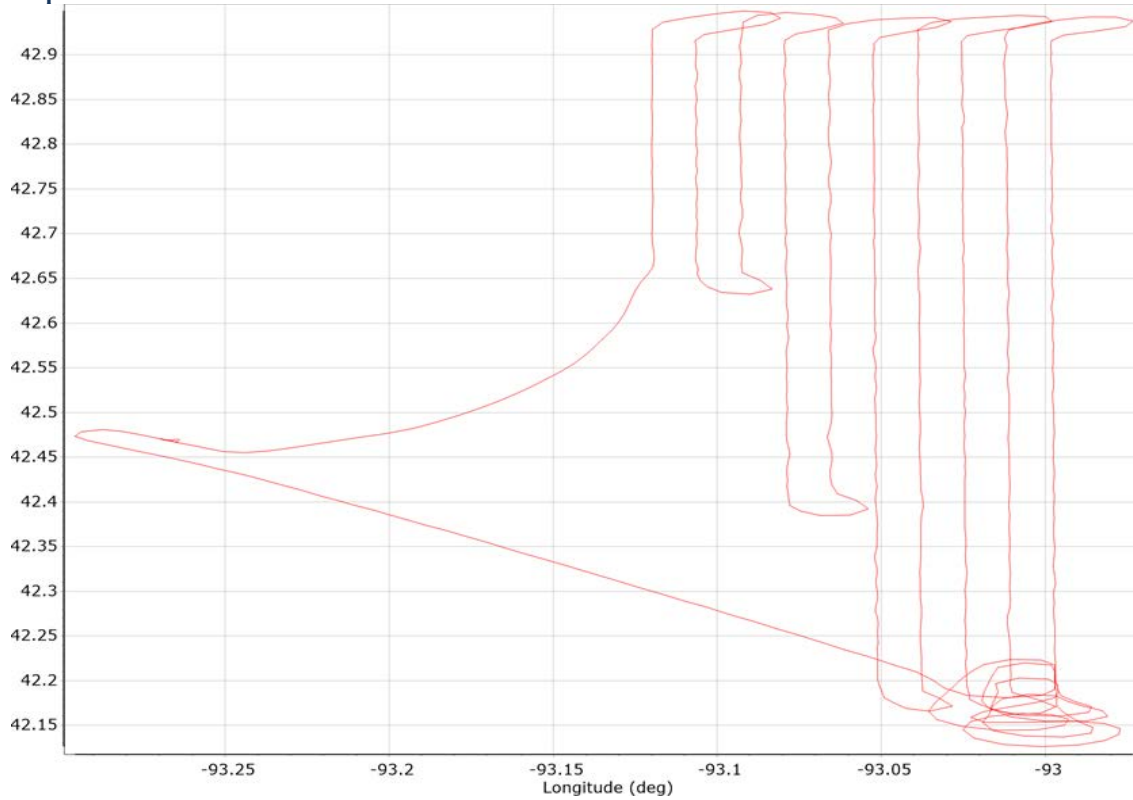
PDOP



Lift 6 Report.docx QC Report – 06/18/2020

Smoothed Trajectory Information

Top View

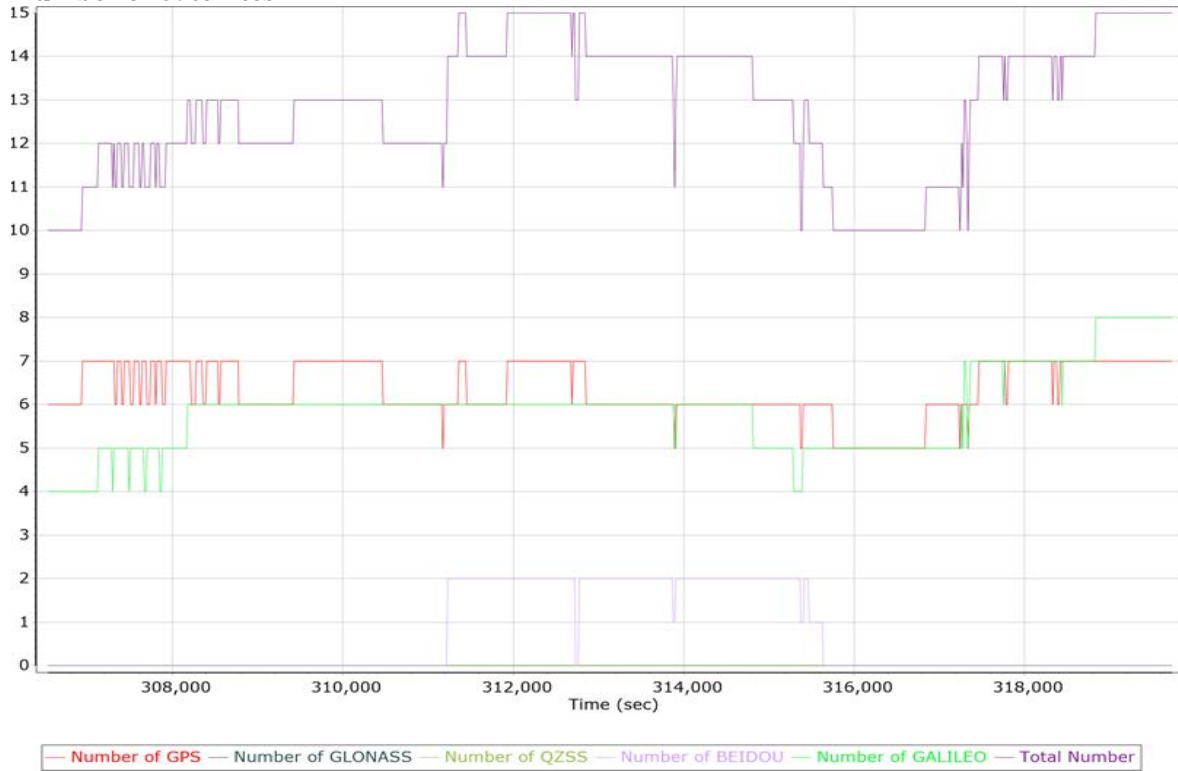


GNSS QC

GNSS QC Statistics

Statistics	Min	Max	Mean
Baseline length (km)	0.00	0.00	
Number of GPS SV	4	7	6
Number of GLONASS SV	0	0	0
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	2	1
Number of GALILEO SV	3	8	6
Total number of SV	9	15	13
PDOP	1.32	4.00	1.78
QC Solution Gaps	0.00	0.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	13534.00	0.00	0.00
Percentage	100.00	0.00	0.00

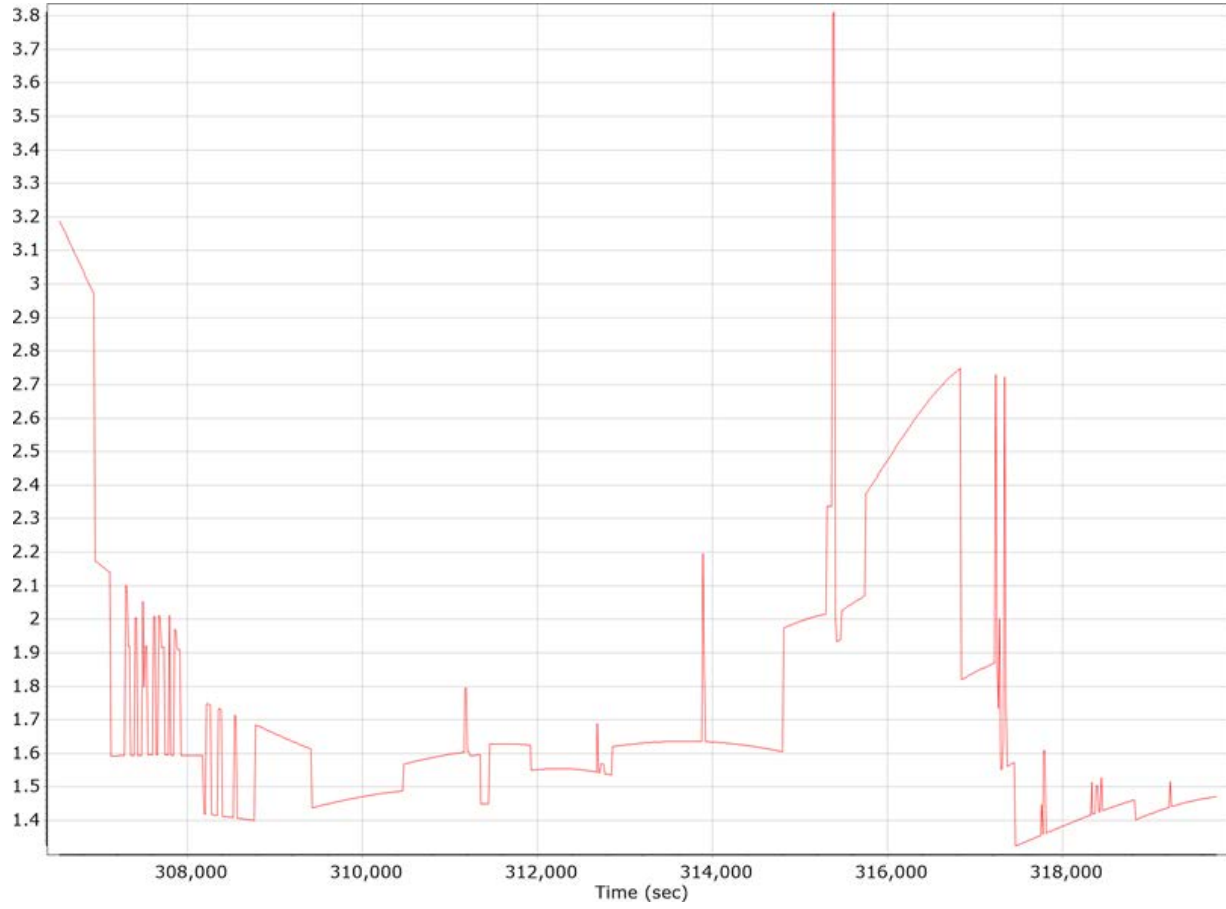
Number of Satellites



Forward/Reverse Separation



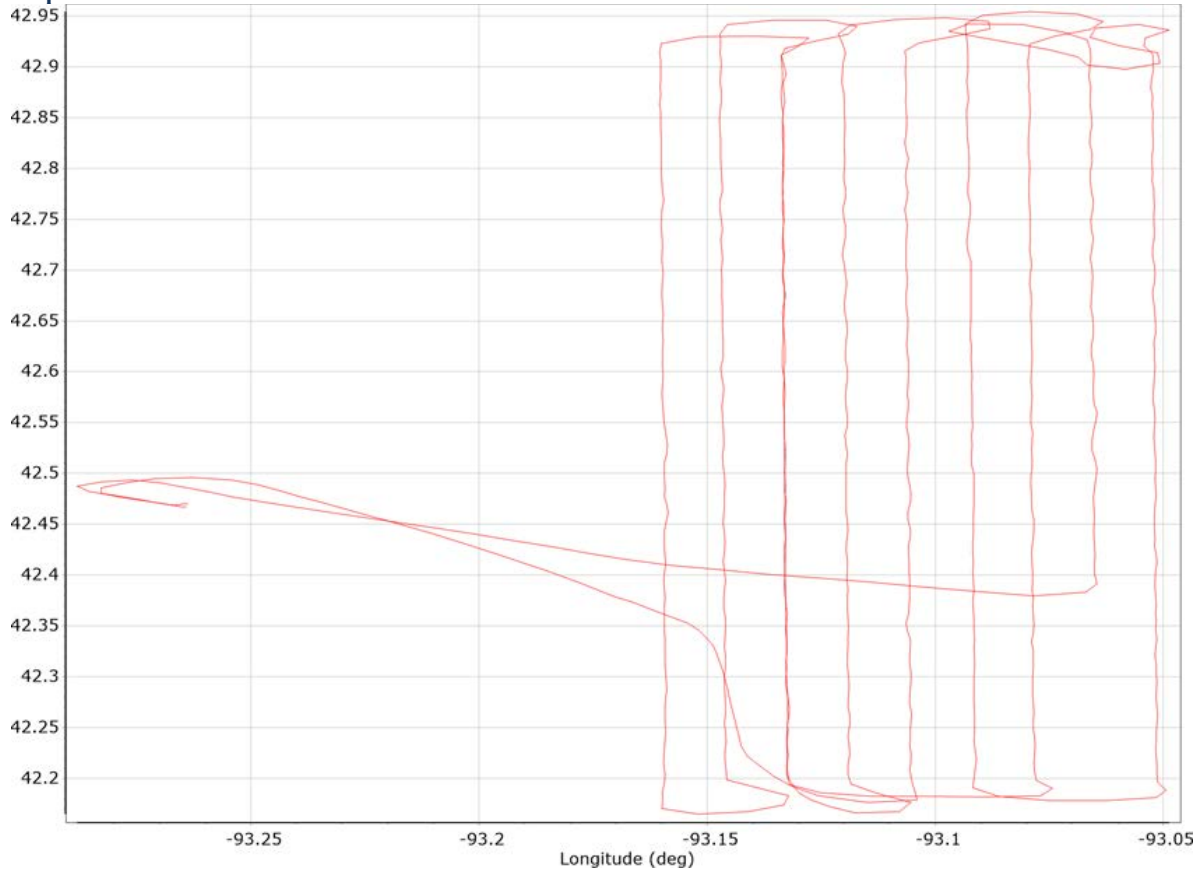
PDOP



Lift 7 Report.docx QC Report – 06/18/2020

Smoothed Trajectory Information

Top View

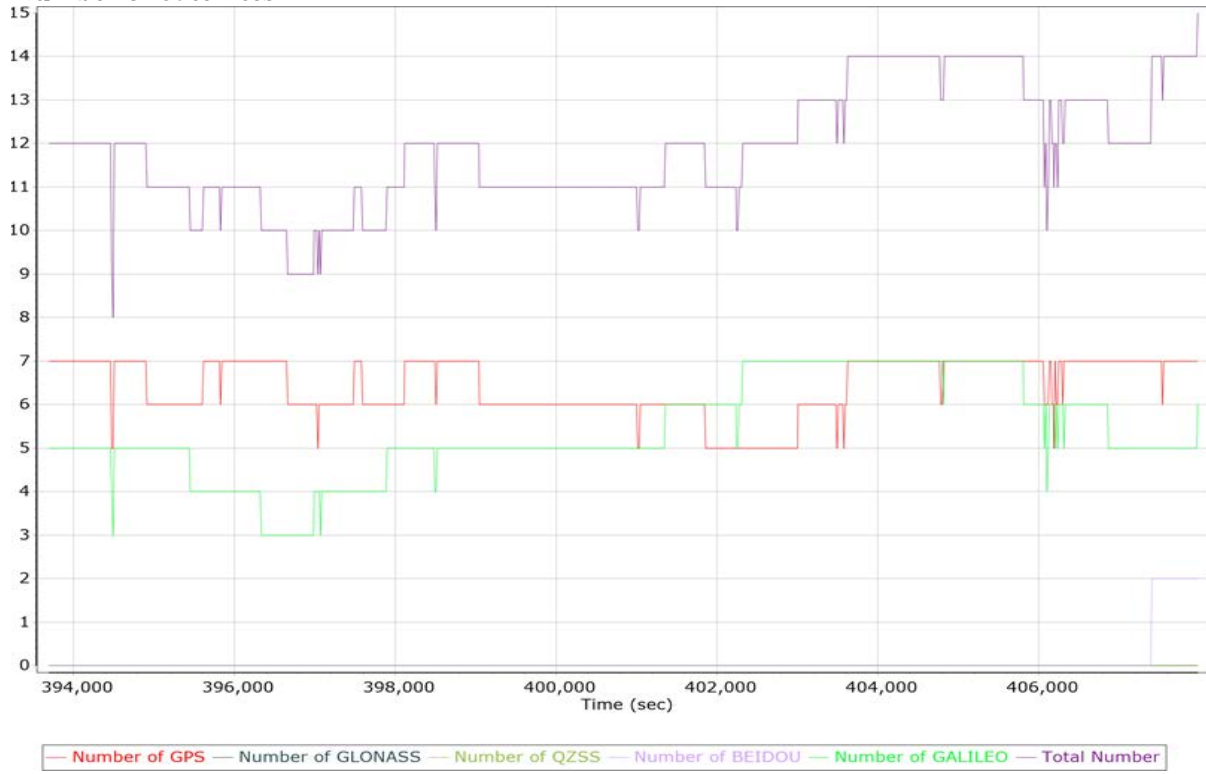


GNSS QC

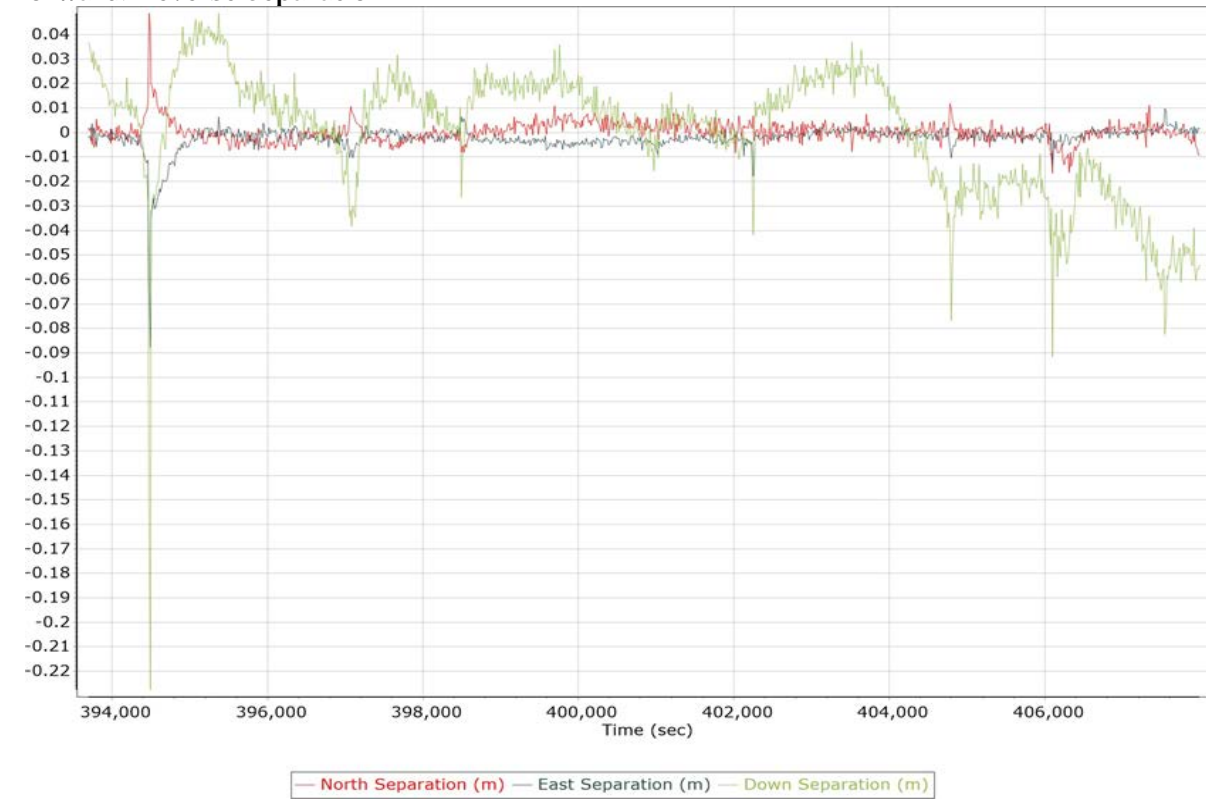
GNSS QC Statistics

Statistics	Min	Max	Mean
Baseline length (km)	0.00	0.00	
Number of GPS SV	4	7	6
Number of GLONASS SV	0	0	0
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	2	0
Number of GALILEO SV	3	7	5
Total number of SV	8	15	12
PDOP	1.45	4.36	1.77
QC Solution Gaps	0.00	0.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	14672.00	0.00	0.00
Percentage	100.00	0.00	0.00

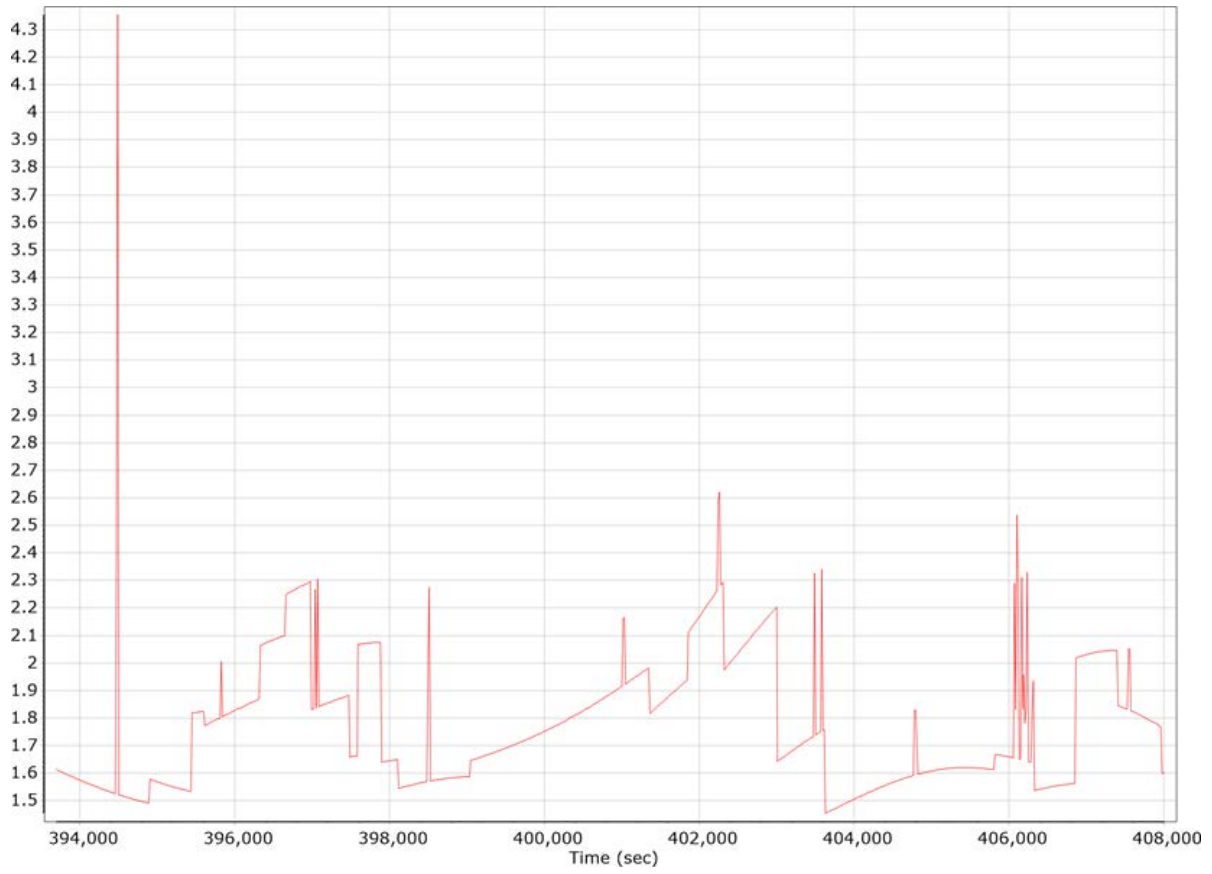
Number of Satellites



Forward/Reverse Separation



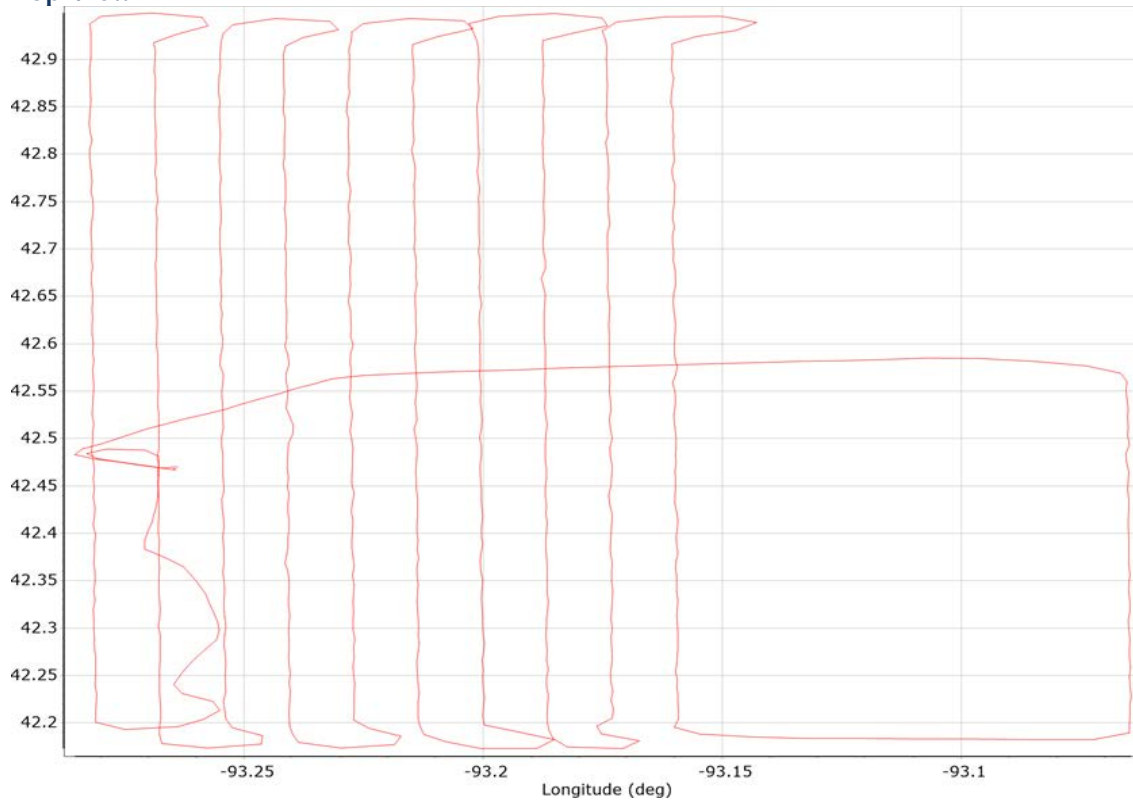
PDOP



Lift 8 Report.docx QC Report – 06/18/2020

Smoothed Trajectory Information

Top View

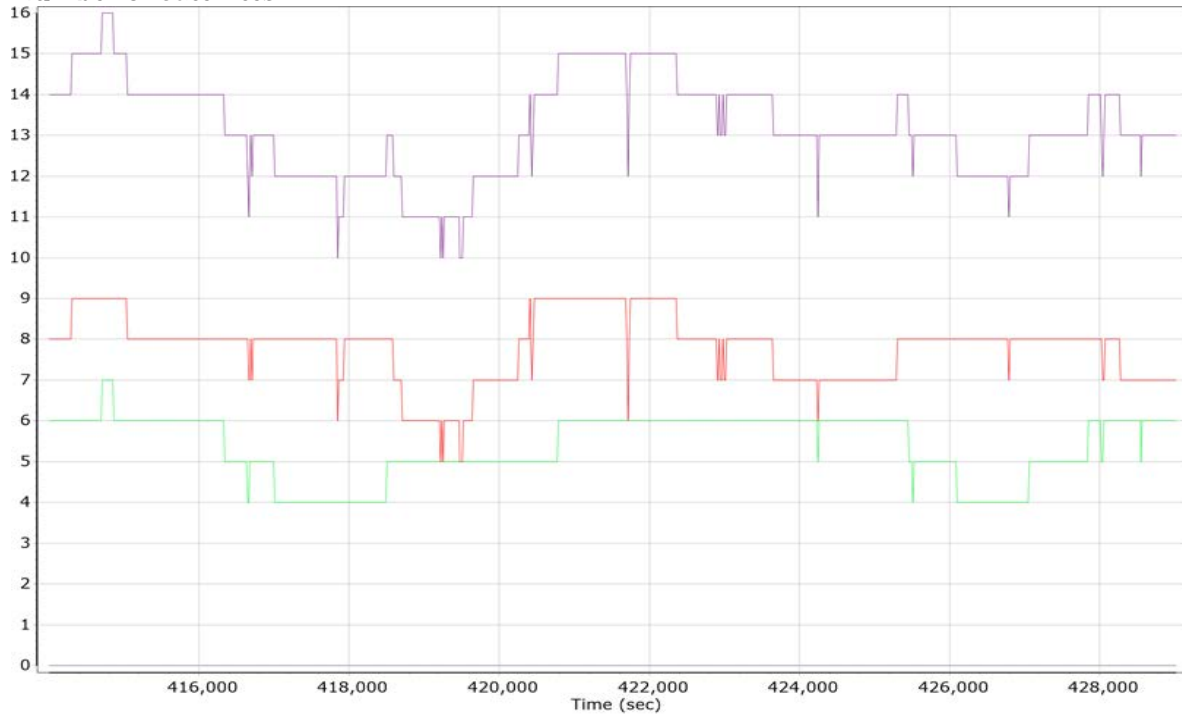


GNSS QC

GNSS QC Statistics

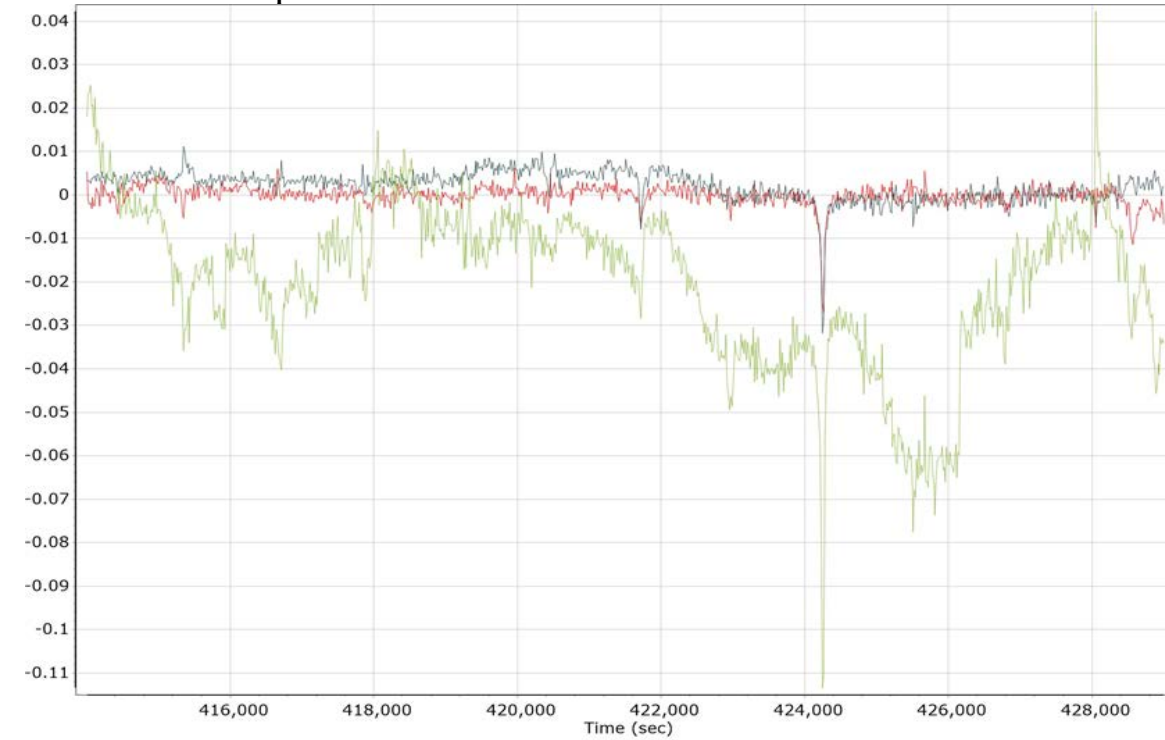
Statistics	Min	Max	Mean
Baseline length (km)	0.00	0.00	
Number of GPS SV	5	9	8
Number of GLONASS SV	0	0	0
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Number of GALILEO SV	4	7	5
Total number of SV	10	16	13
PDOP	1.25	2.54	1.54
QC Solution Gaps	0.00	0.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	15298.00	0.00	0.00
Percentage	100.00	0.00	0.00

Number of Satellites



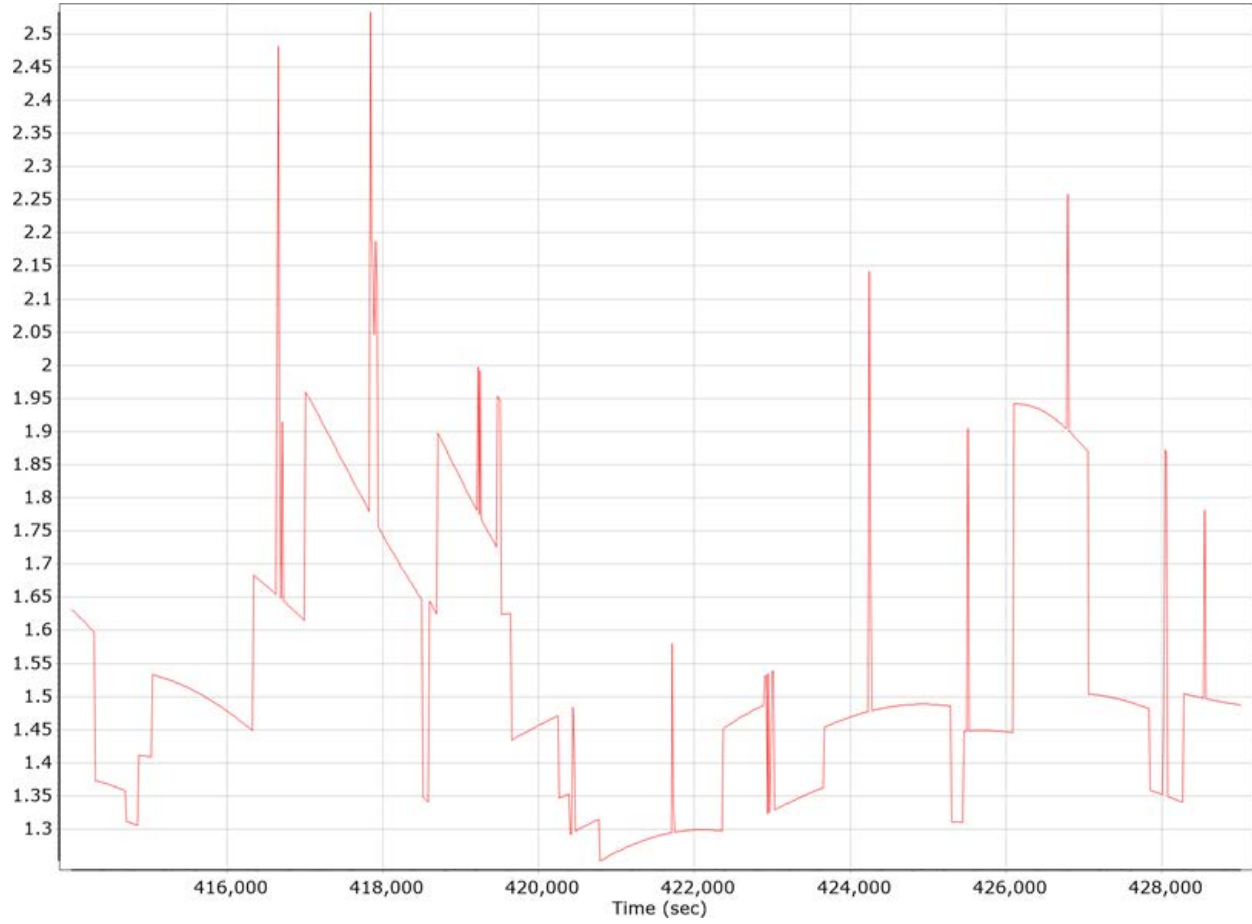
— Number of GPS — Number of GLONASS — Number of QZSS — Number of BEIDOU — Number of GALILEO — Total Number

Forward/Reverse Separation



— North Separation (m) — East Separation (m) — Down Separation (m)

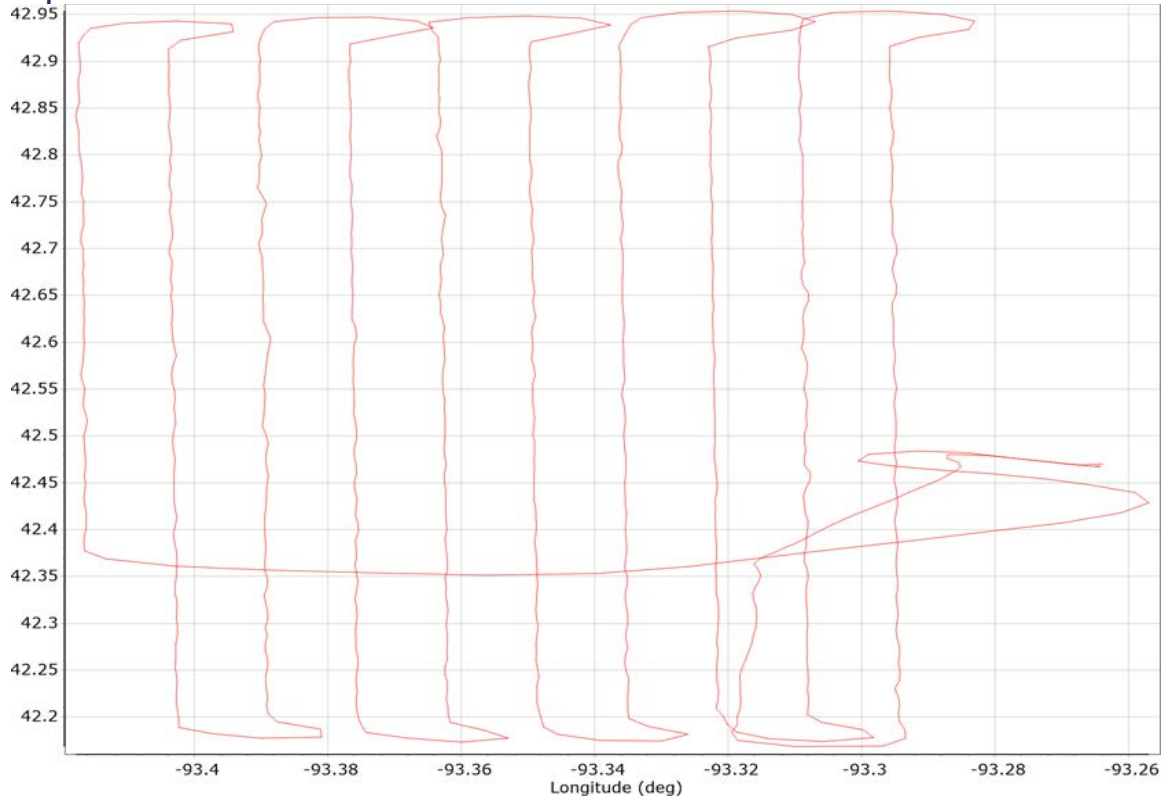
PDOP



Lift 9 Report.docx QC Report – 06/18/2020

Smoothed Trajectory Information

Top View

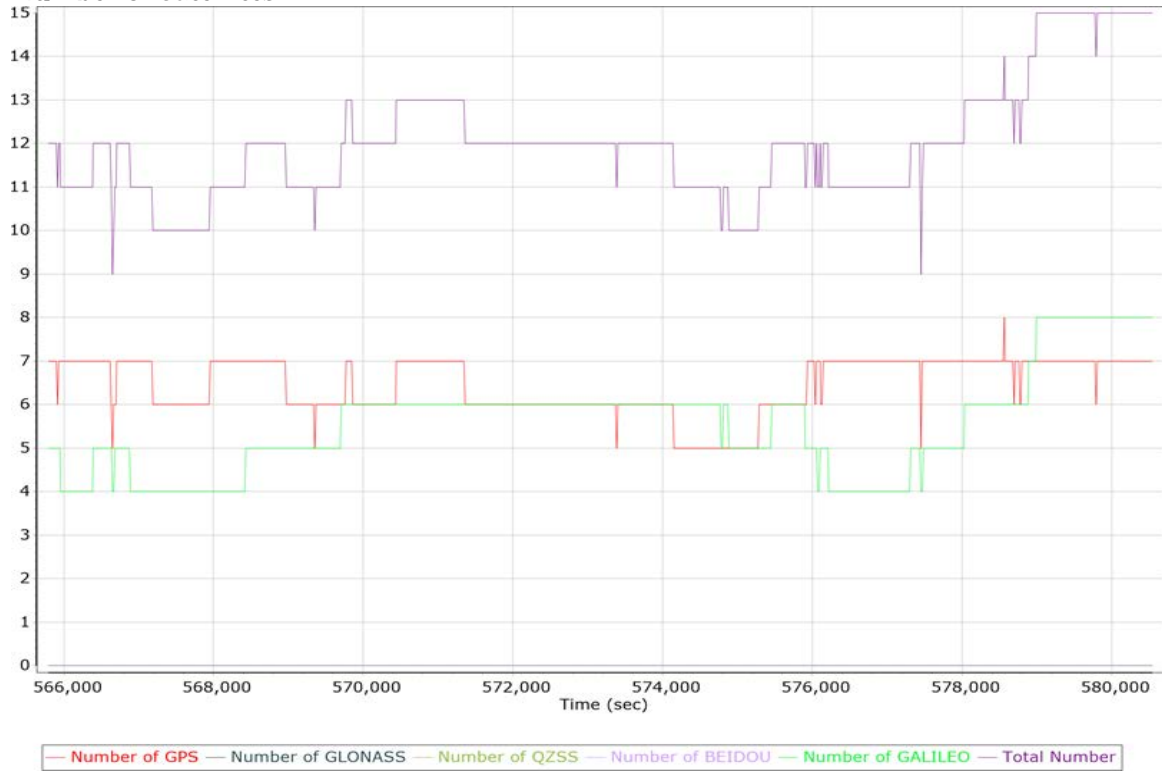


GNSS QC

GNSS QC Statistics

Statistics	Min	Max	Mean
Baseline length (km)	0.00	0.00	
Number of GPS SV	5	8	6
Number of GLONASS SV	0	0	0
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Number of GALILEO SV	4	8	6
Total number of SV	9	15	12
PDOP	1.40	3.69	1.76
QC Solution Gaps	0.00	0.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	15013.00	0.00	0.00
Percentage	100.00	0.00	0.00

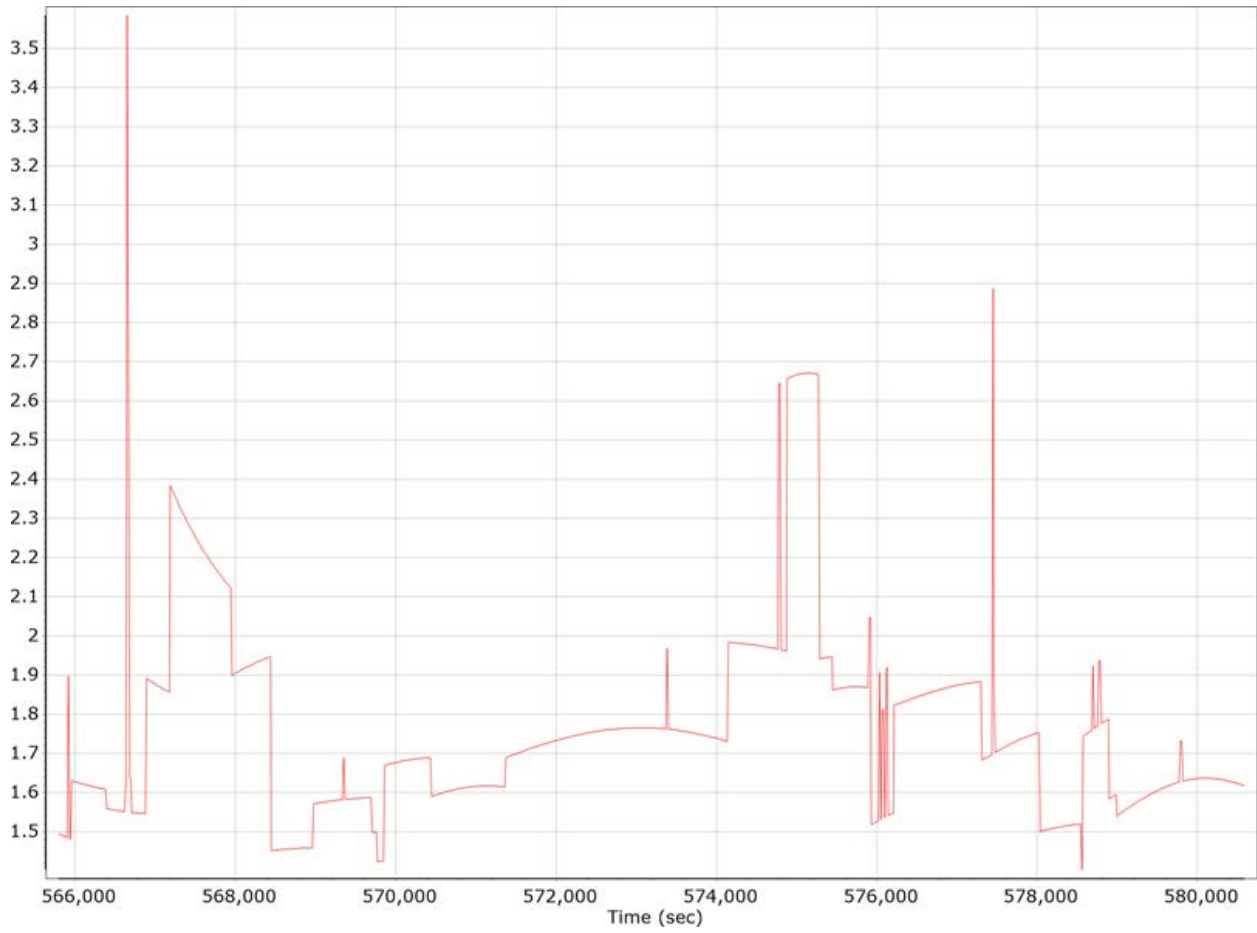
Number of Satellites



Forward/Reverse Separation



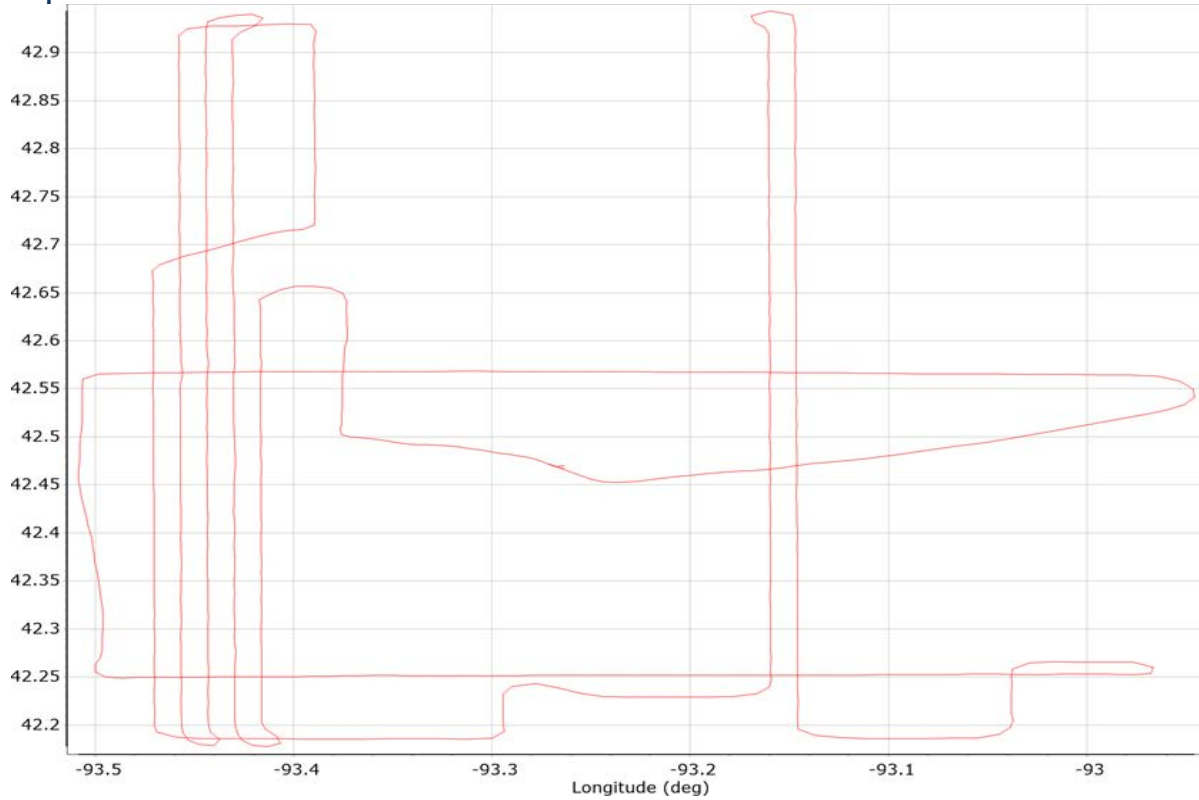
PDOP



Lift 10 Report.docx QC Report – 06/18/2020

Smoothed Trajectory Information

Top View

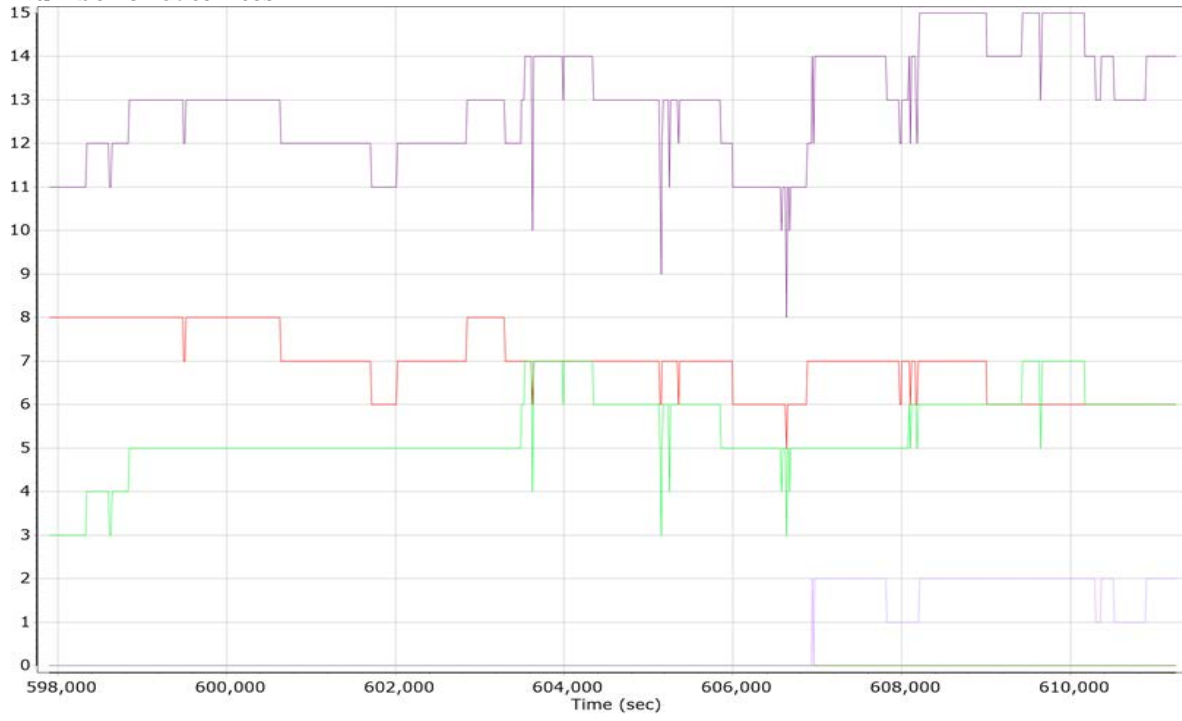


GNSS QC

GNSS QC Statistics

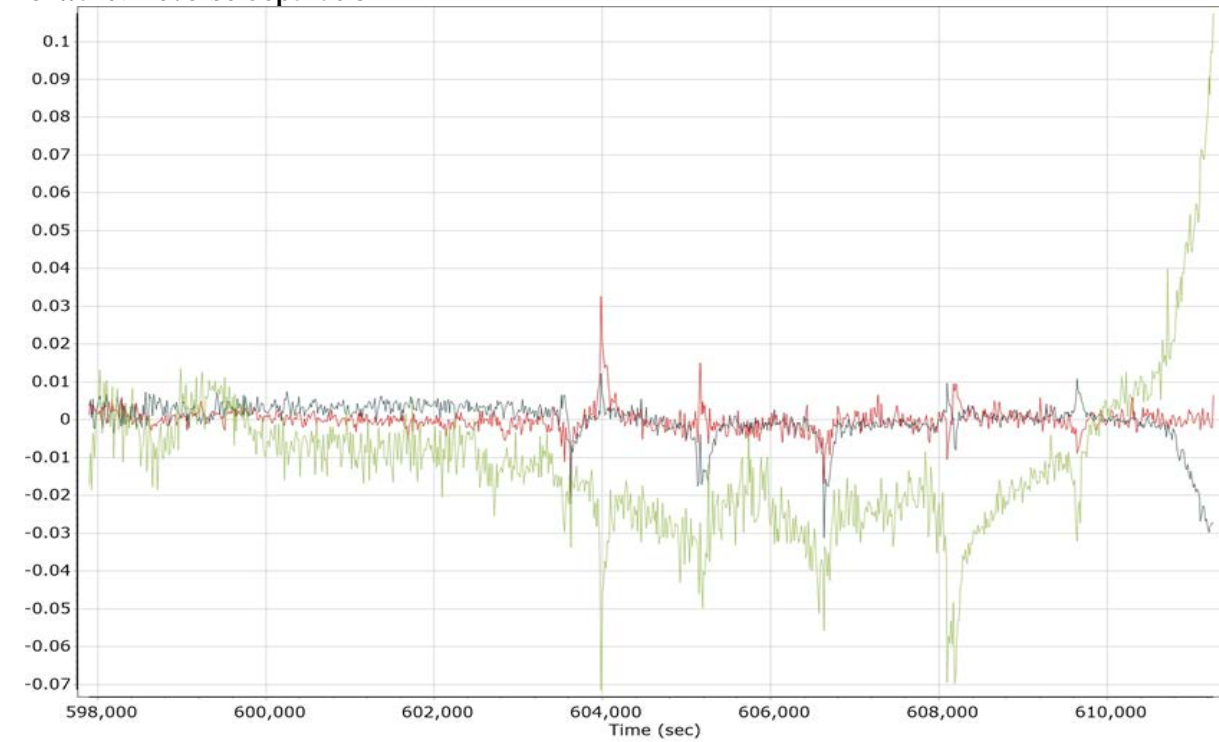
Statistics	Min	Max	Mean
Baseline length (km)	0.00	0.00	
Number of GPS SV	5	8	7
Number of GLONASS SV	0	0	0
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	2	1
Number of GALILEO SV	3	7	5
Total number of SV	8	15	13
PDOP	1.43	3.67	1.76
QC Solution Gaps	0.00	0.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	13648.00	0.00	0.00
Percentage	100.00	0.00	0.00

Number of Satellites



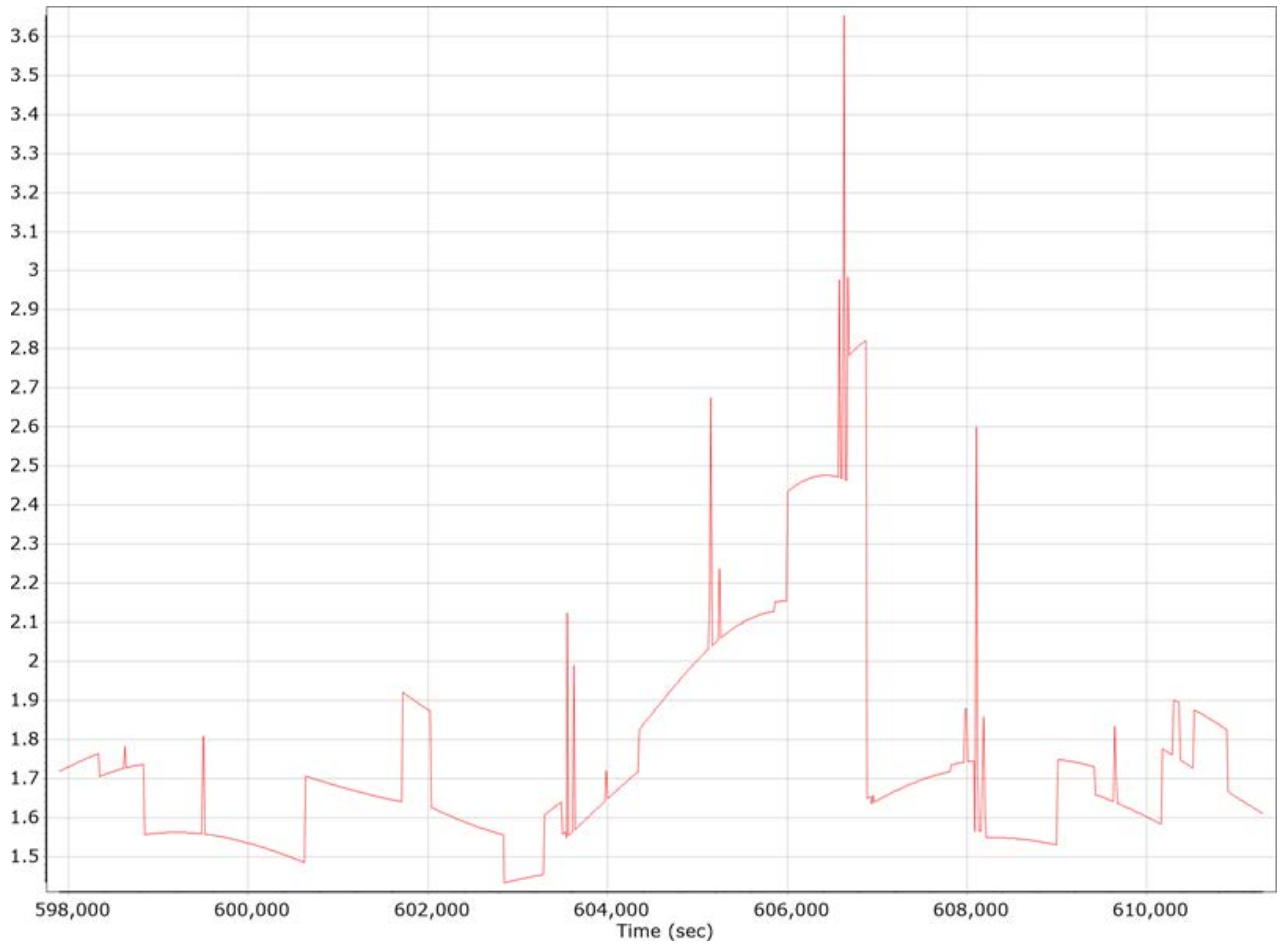
— Number of GPS — Number of GLONASS — Number of QZSS — Number of BEIDOU — Number of GALILEO — Total Number

Forward/Reverse Separation



— North Separation (m) — East Separation (m) — Down Separation (m)

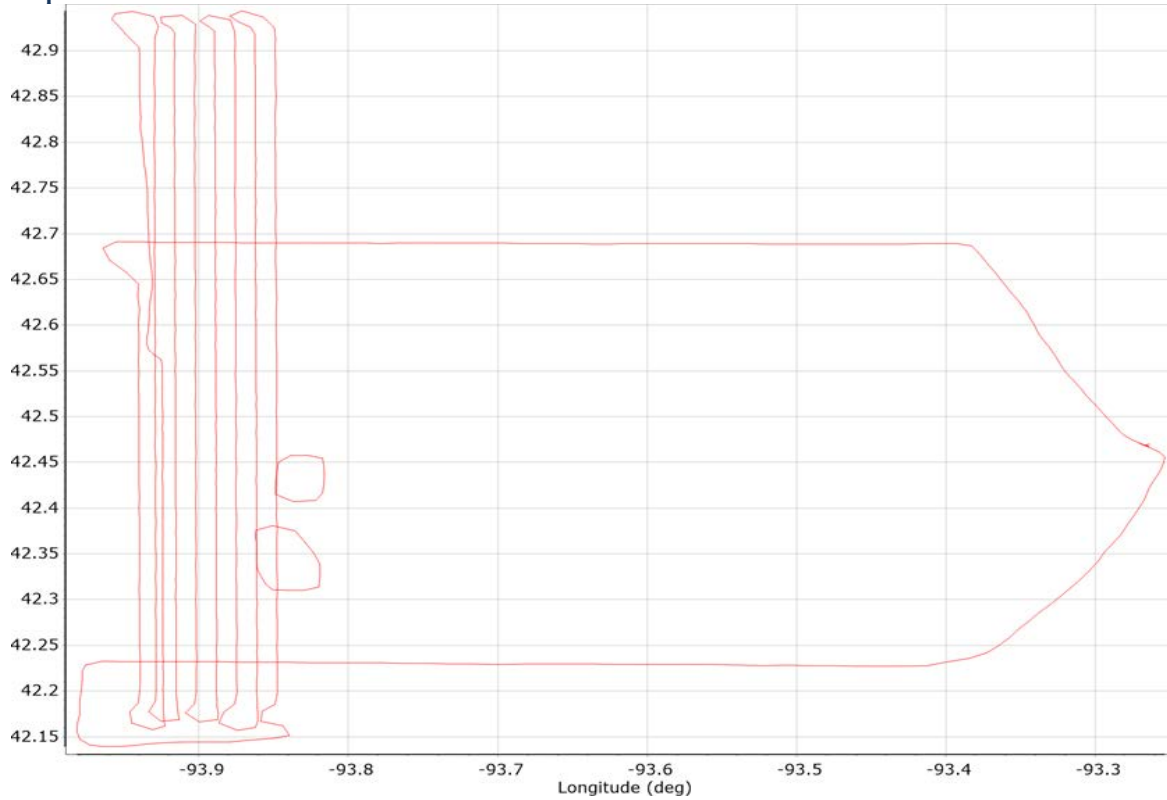
PDOP



Lift 11 Report.docx QC Report – 06/18/2020

Smoothed Trajectory Information

Top View

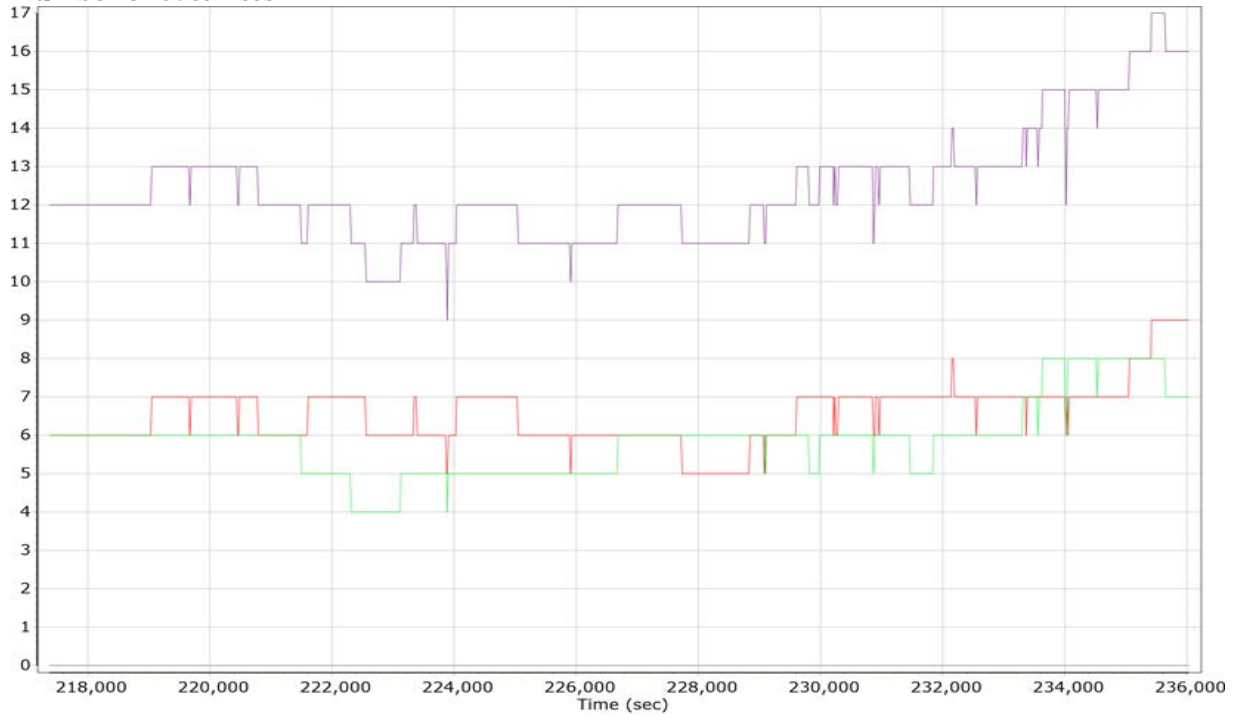


GNSS QC

GNSS QC Statistics

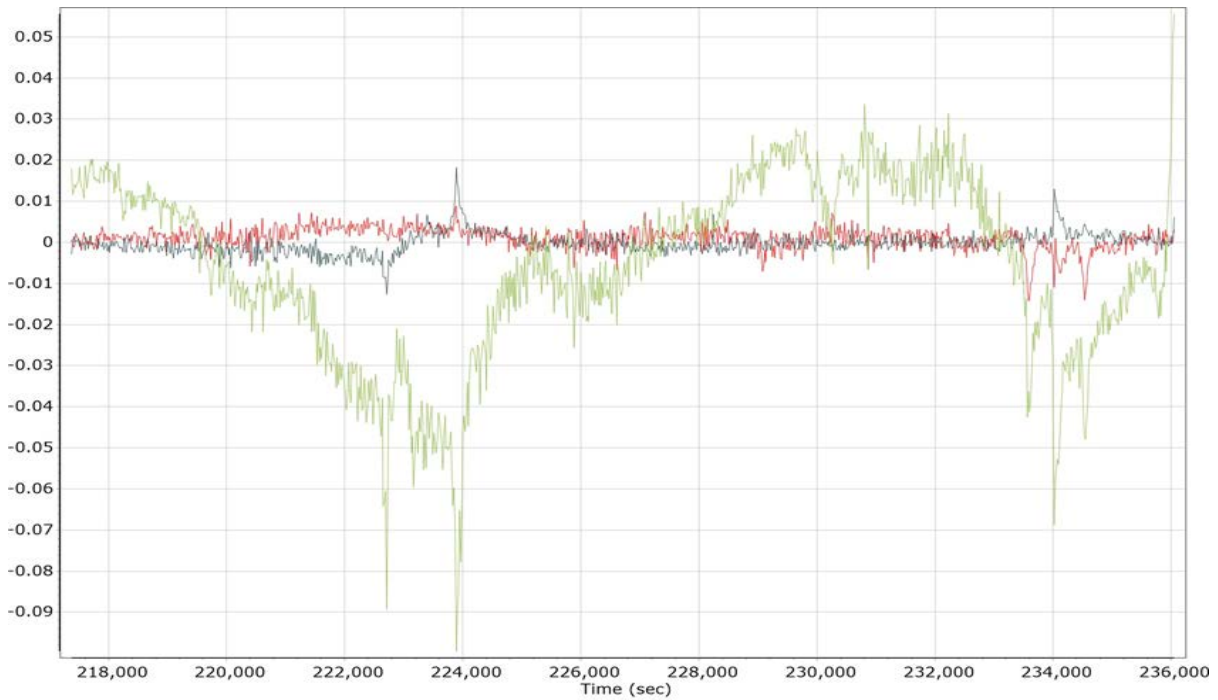
Statistics	Min	Max	Mean
Baseline length (km)	0.00	0.00	
Number of GPS SV	4	9	7
Number of GLONASS SV	0	0	0
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Number of GALILEO SV	4	8	6
Total number of SV	8	17	12
PDOP	1.25	3.48	1.76
QC Solution Gaps	0.00	0.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	19223.00	0.00	0.00
Percentage	100.00	0.00	0.00

Number of Satellites



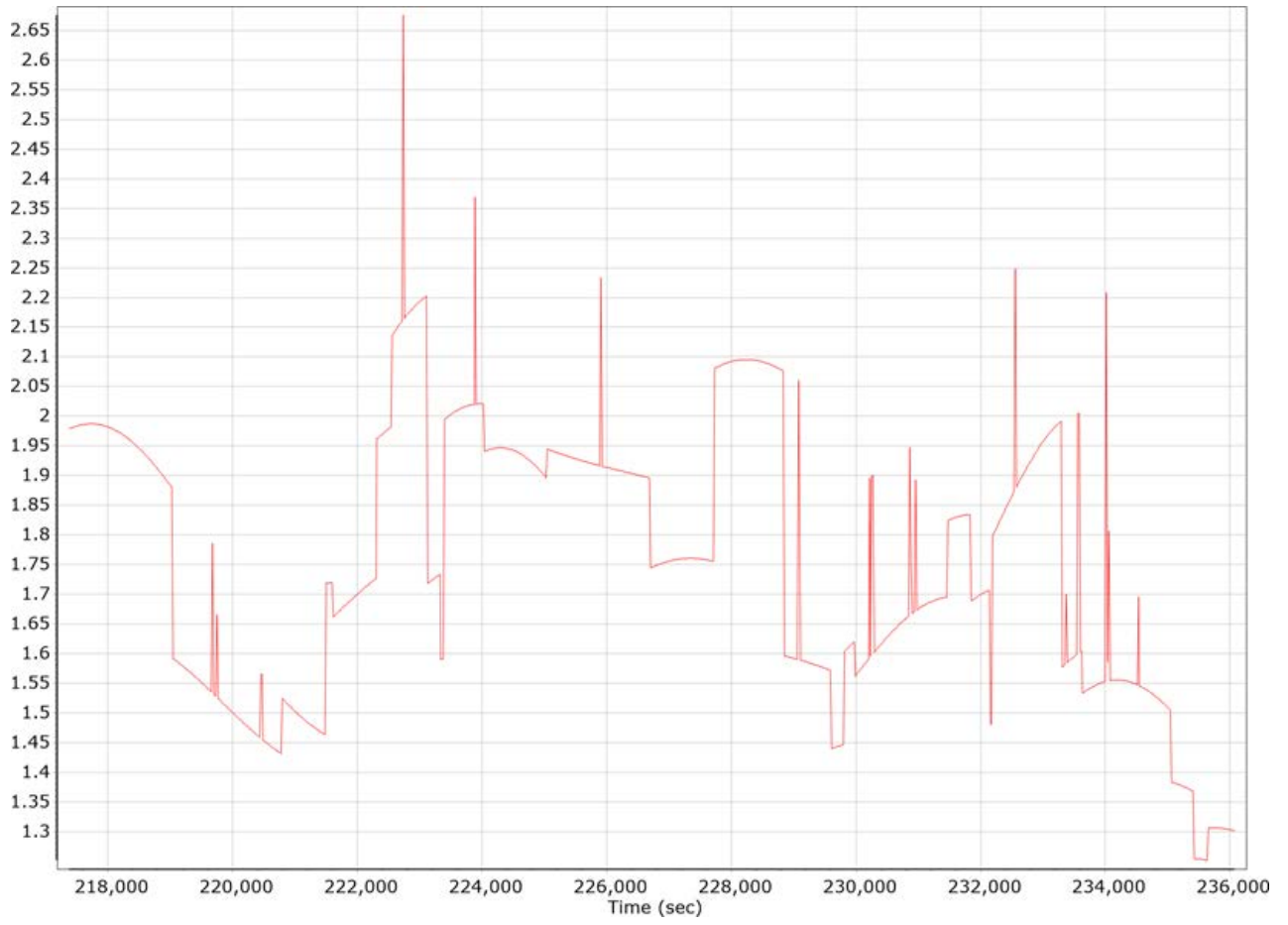
— Number of GPS — Number of GLONASS — Number of QZSS — Number of BEIDOU — Number of GALILEO — Total Number

Forward/Reverse Separation



— North Separation (m) — East Separation (m) — Down Separation (m)

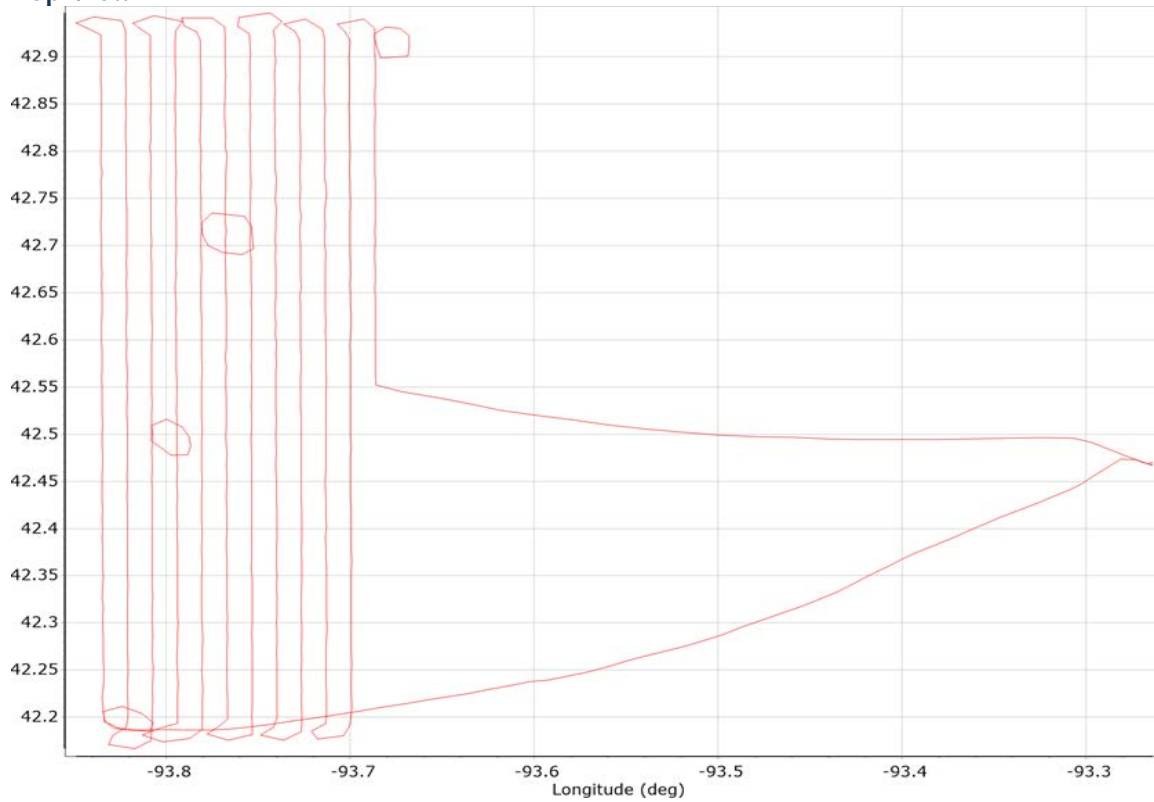
PDOP



Lift 12 Report.docx QC Report – 06/18/2020

Smoothed Trajectory Information

Top View

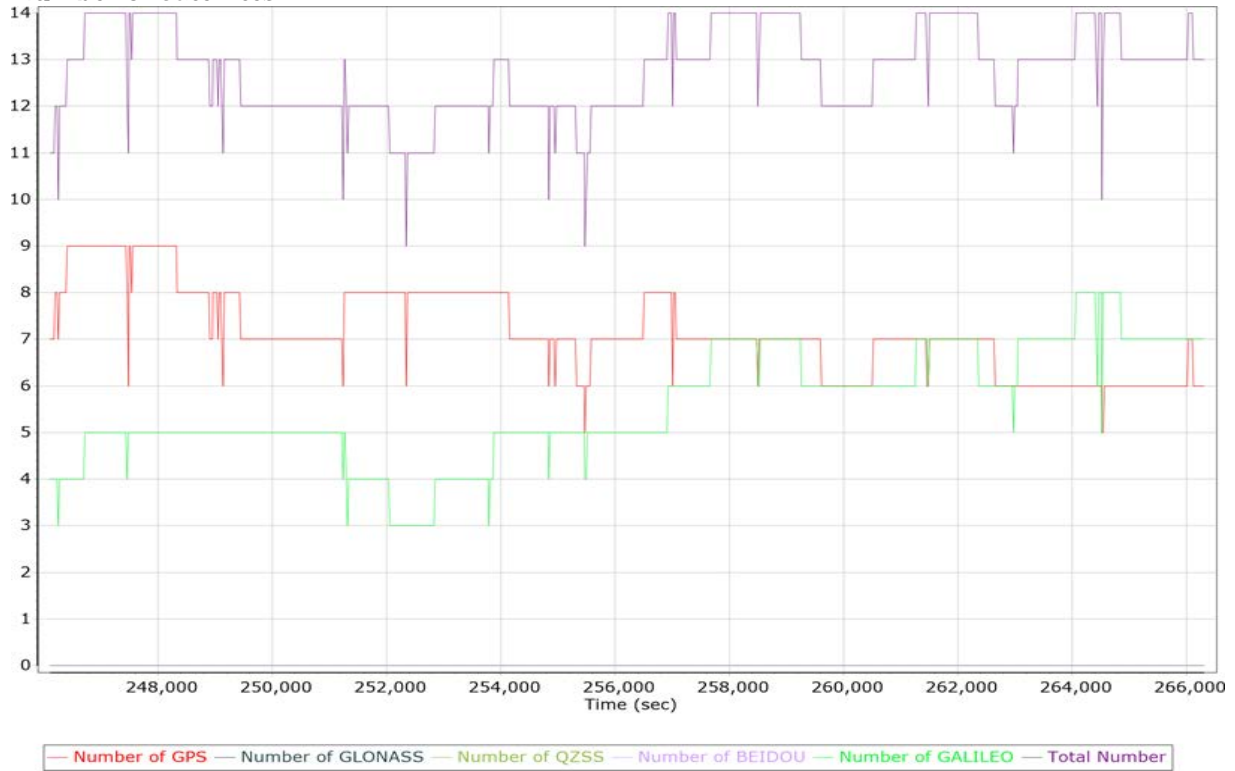


GNSS QC

GNSS QC Statistics

Statistics	Min	Max	Mean
Baseline length (km)	0.00	0.00	
Number of GPS SV	5	9	7
Number of GLONASS SV	0	0	0
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Number of GALILEO SV	3	8	6
Total number of SV	8	14	13
PDOP	1.29	3.40	1.60
QC Solution Gaps	0.00	0.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	20418.00	0.00	0.00
Percentage	100.00	0.00	0.00

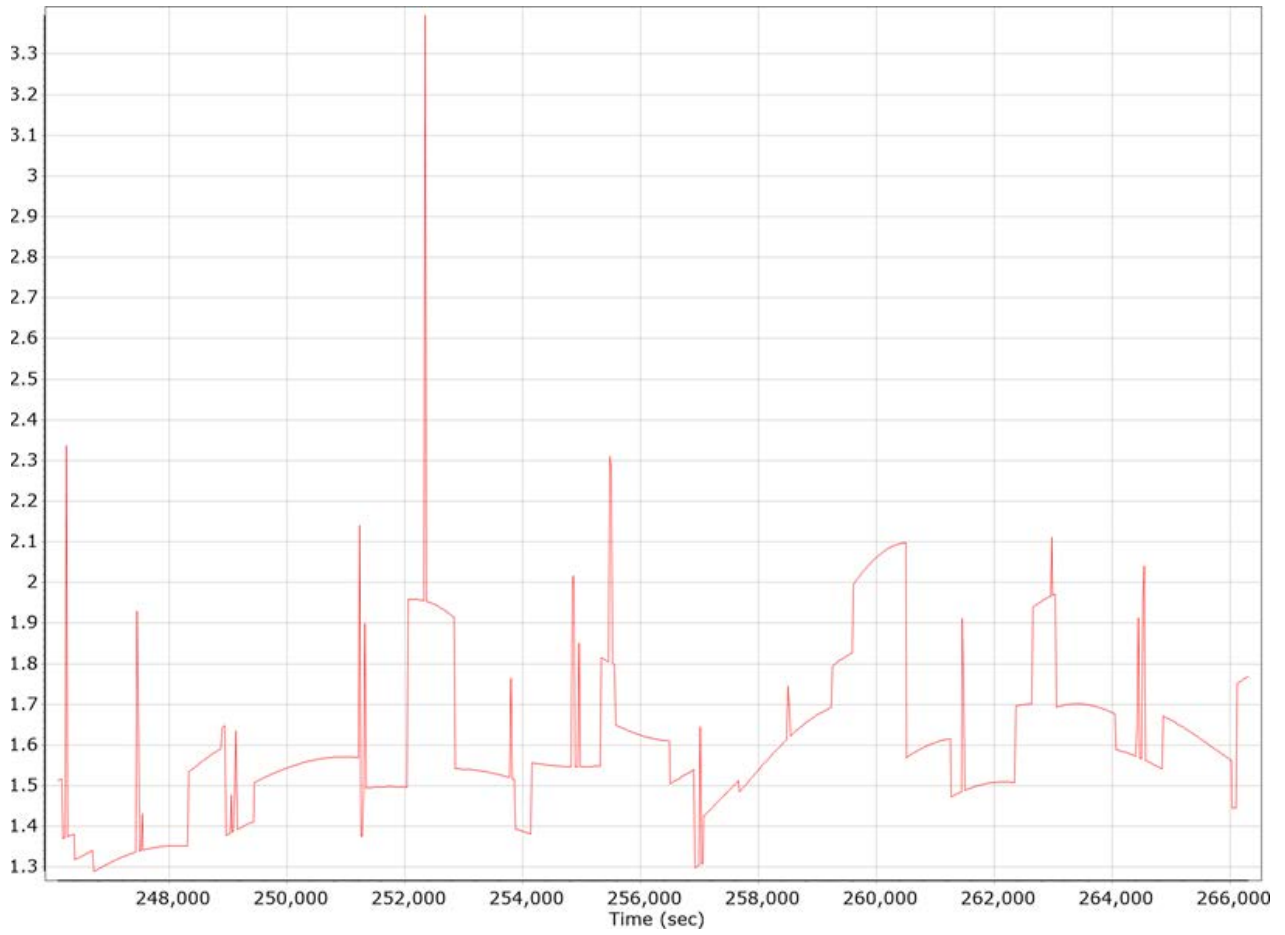
Number of Satellites



Forward/Reverse Separation



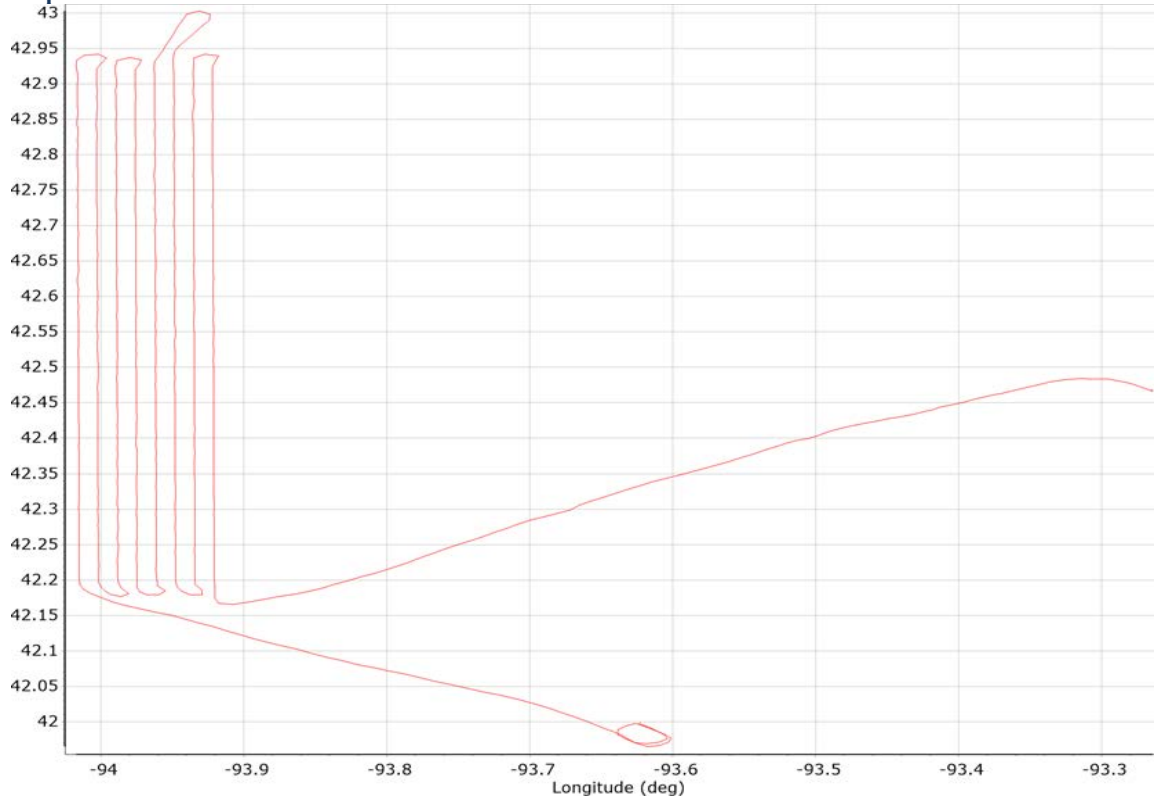
PDOP



Lift 13 Report.docx QC Report – 06/18/2020

Smoothed Trajectory Information

Top View

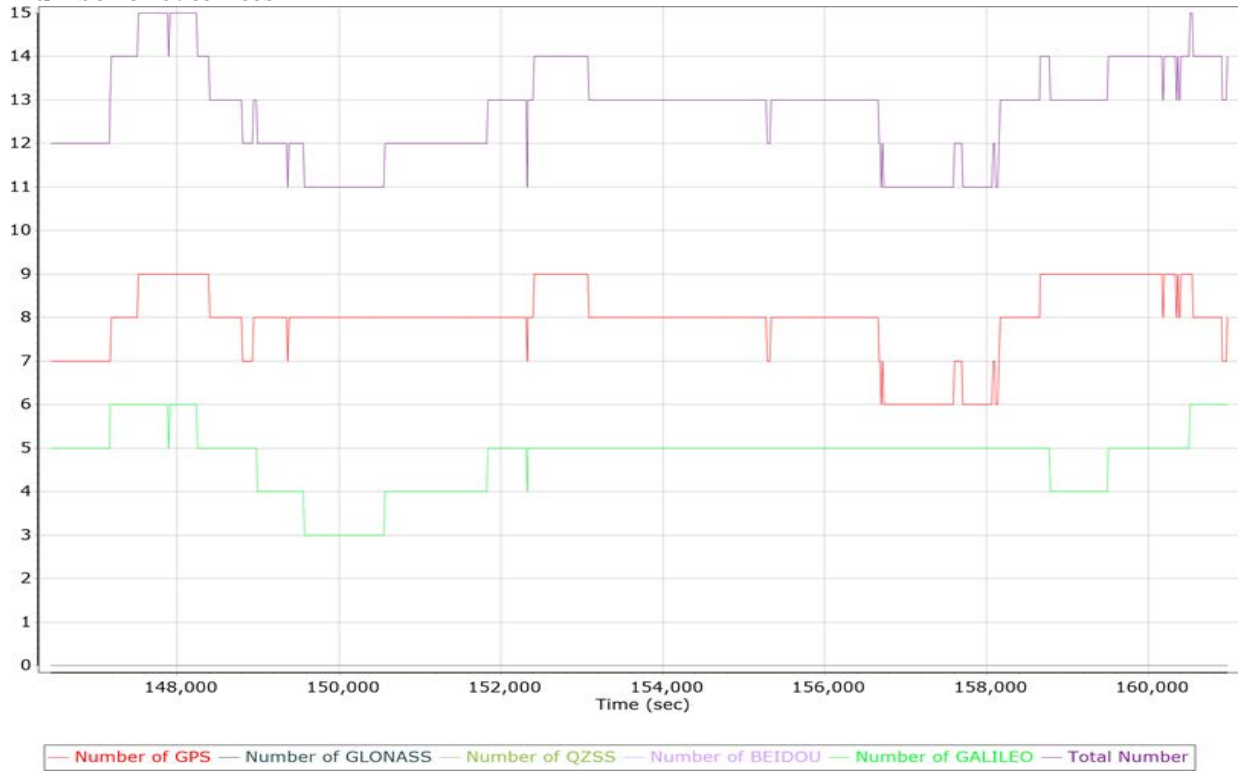


GNSS QC

GNSS QC Statistics

Statistics	Min	Max	Mean
Baseline length (km)	0.00	0.00	
Number of GPS SV	6	9	8
Number of GLONASS SV	0	0	0
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Number of GALILEO SV	3	6	5
Total number of SV	11	15	13
PDOP	1.17	2.20	1.62
QC Solution Gaps	0.00	0.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	15013.00	0.00	0.00
Percentage	100.00	0.00	0.00

Number of Satellites



Forward/Reverse Separation



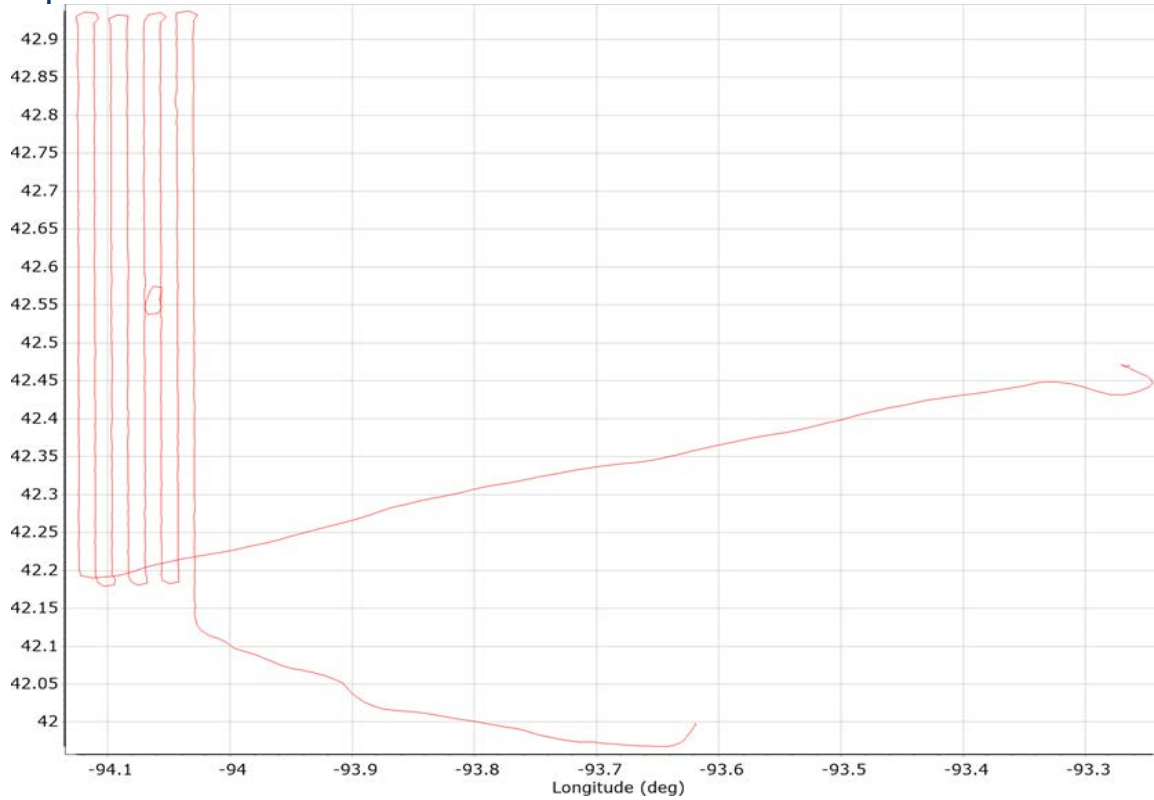
PDOP



Lift 14 Report.docx QC Report – 06/18/2020

Smoothed Trajectory Information

Top View

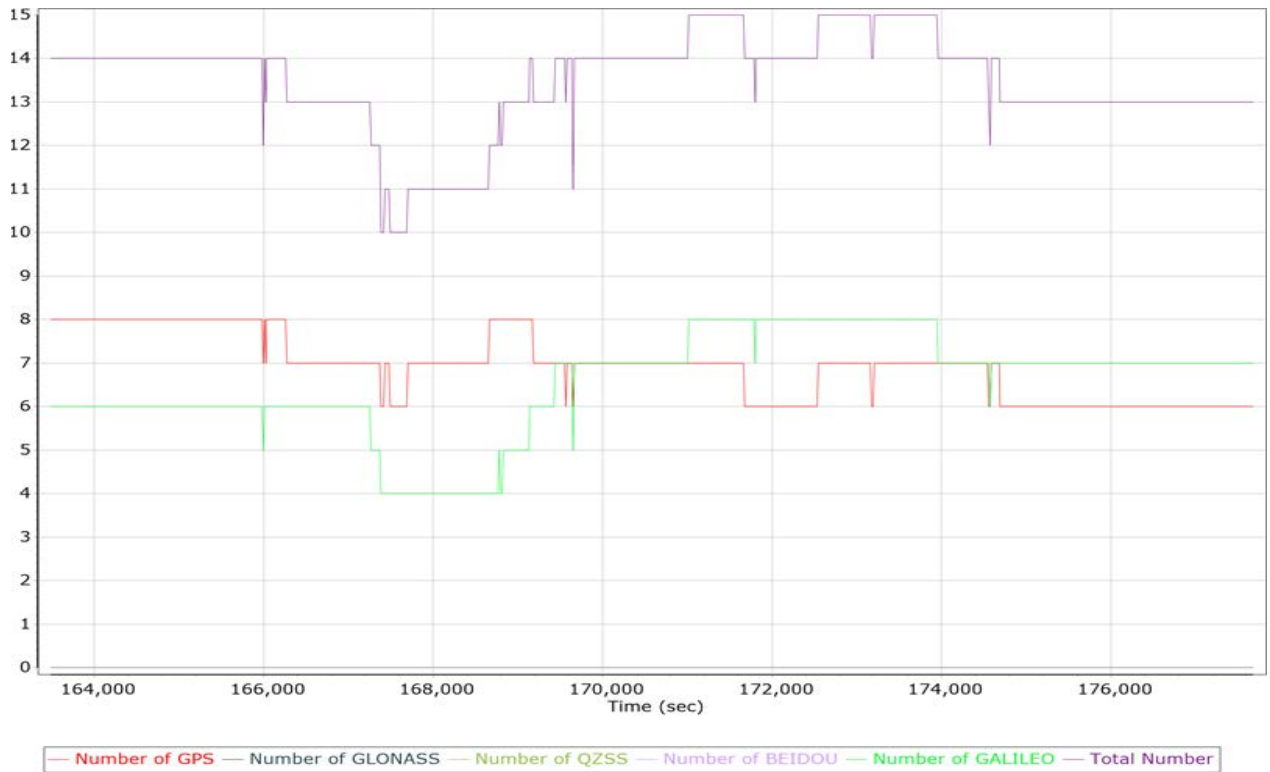


GNSS QC

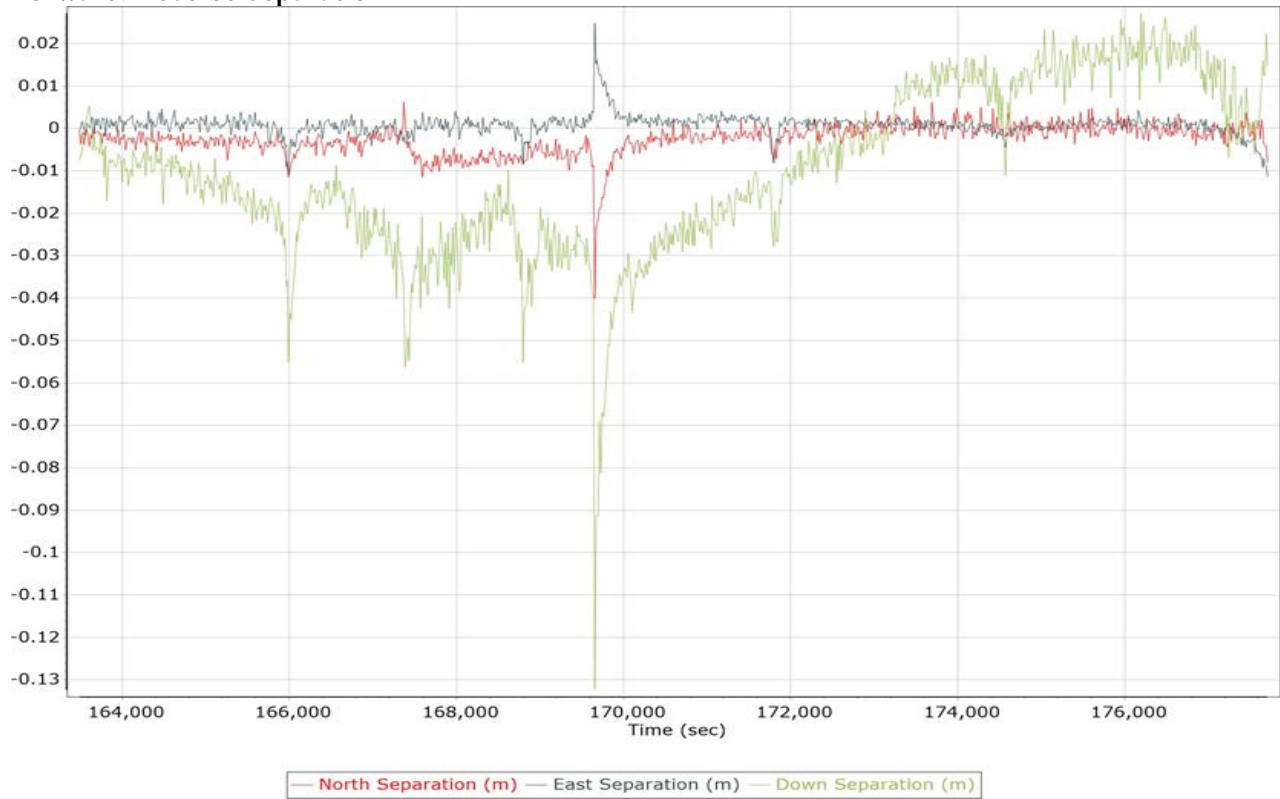
GNSS QC Statistics

Statistics	Min	Max	Mean
Baseline length (km)	0.00	0.00	
Number of GPS SV	6	8	7
Number of GLONASS SV	0	0	0
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Number of GALILEO SV	4	8	7
Total number of SV	10	15	13
PDOP	1.31	3.10	1.62
QC Solution Gaps	0.00	0.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	14615.00	0.00	0.00
Percentage	100.00	0.00	0.00

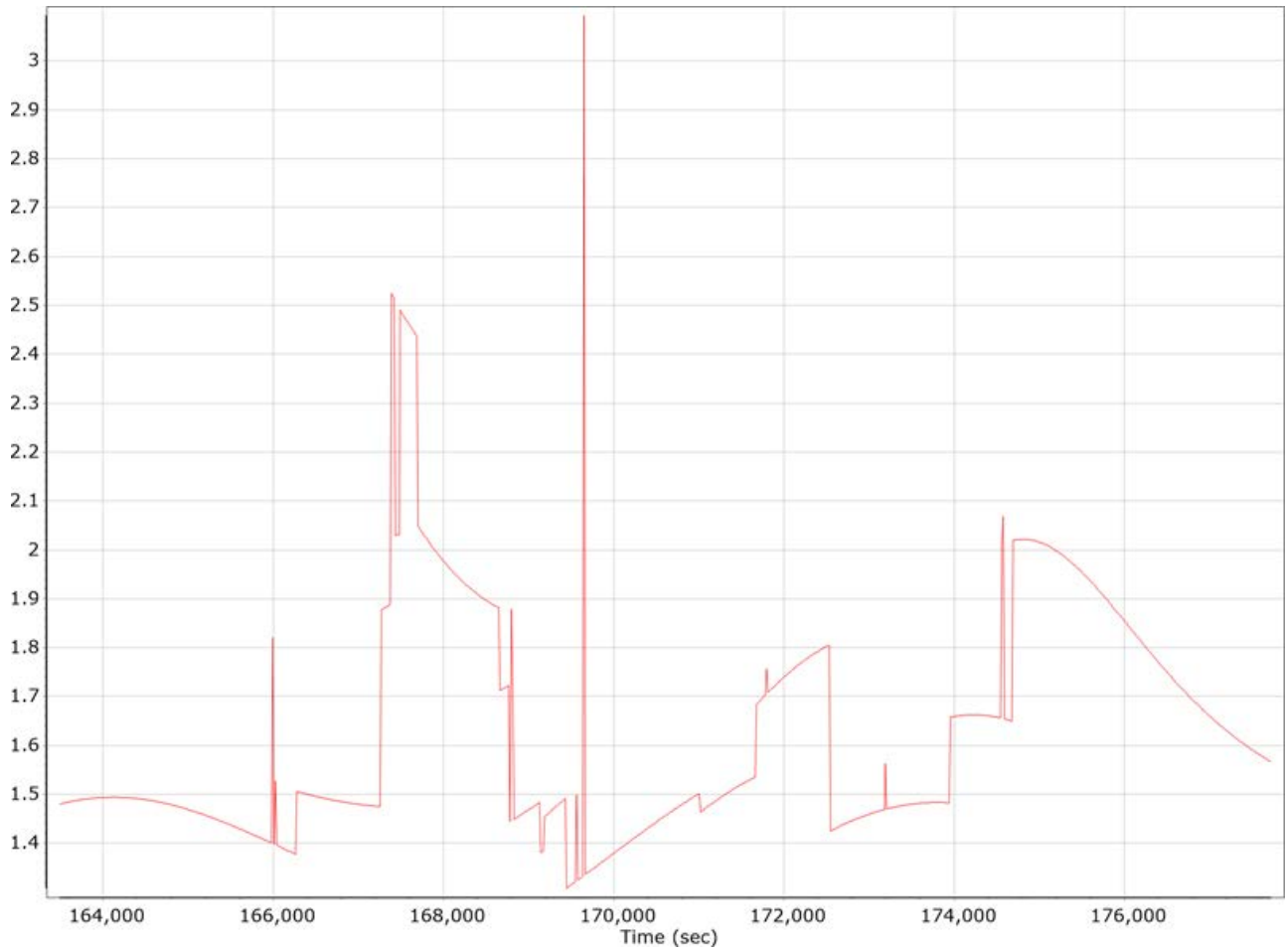
Number of Satellites



Forward/Reverse Separation



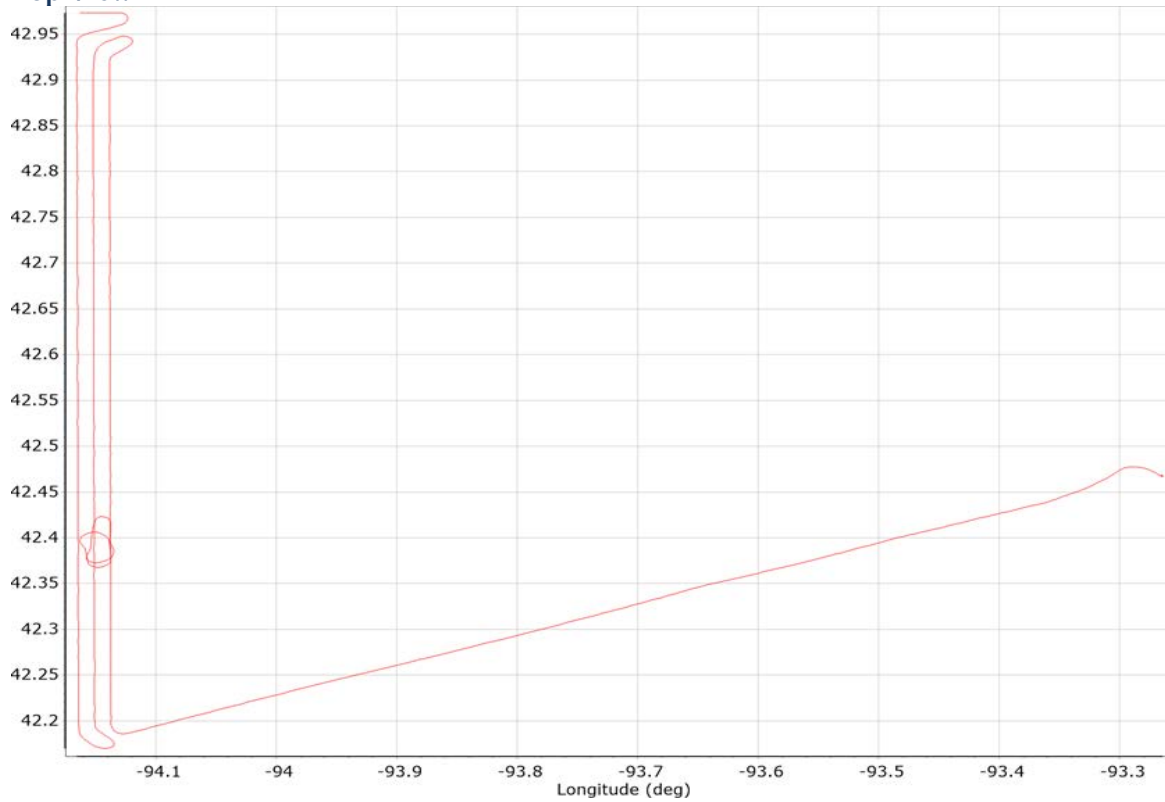
PDOP



Lift 15 Half 1 Report.docx QC Report – 06/18/2020

Smoothed Trajectory Information

Top View

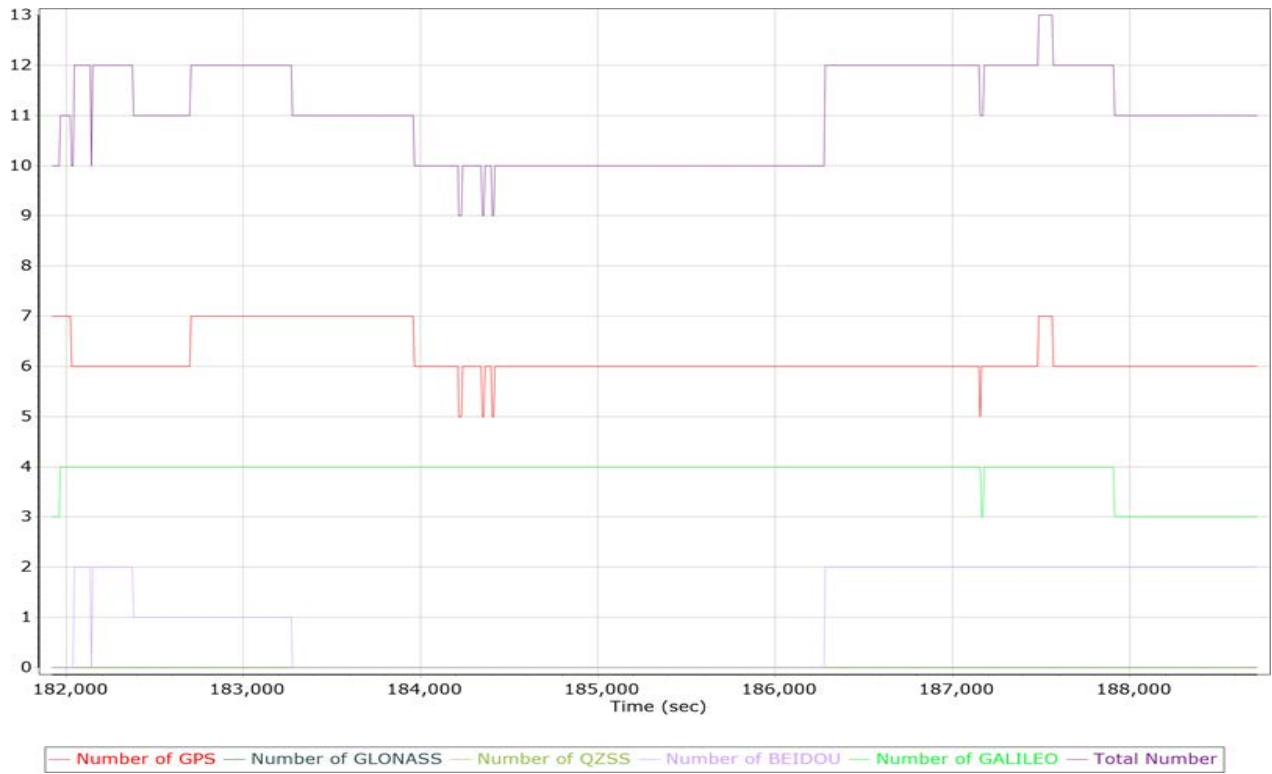


GNSS QC

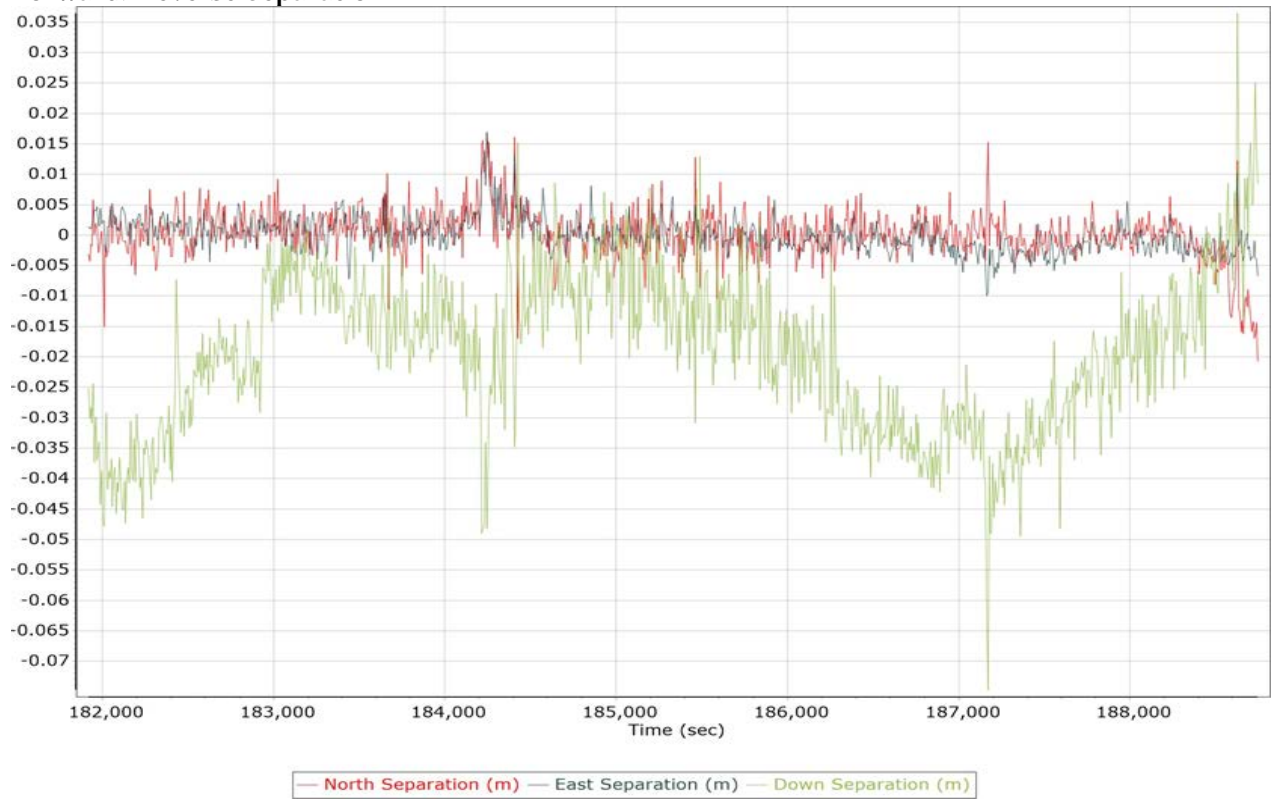
GNSS QC Statistics

Statistics	Min	Max	Mean
Baseline length (km)	0.00	0.00	
Number of GPS SV	3	7	6
Number of GLONASS SV	0	0	0
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	2	1
Number of GALILEO SV	3	4	4
Total number of SV	8	13	11
PDOP	1.43	4.12	1.96
QC Solution Gaps	0.00	0.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	7390.00	0.00	0.00
Percentage	100.00	0.00	0.00

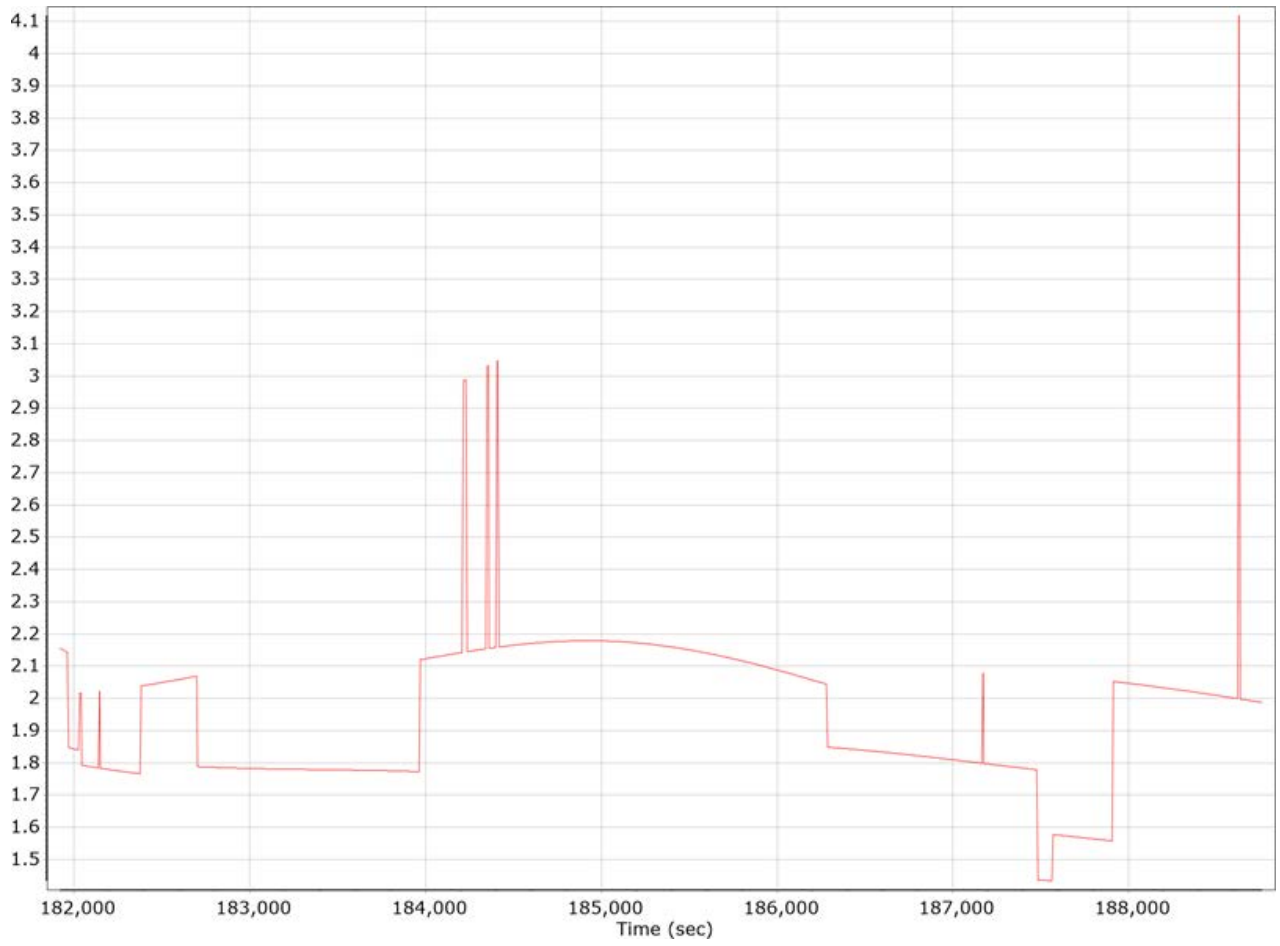
Number of Satellites



Forward/Reverse Separation



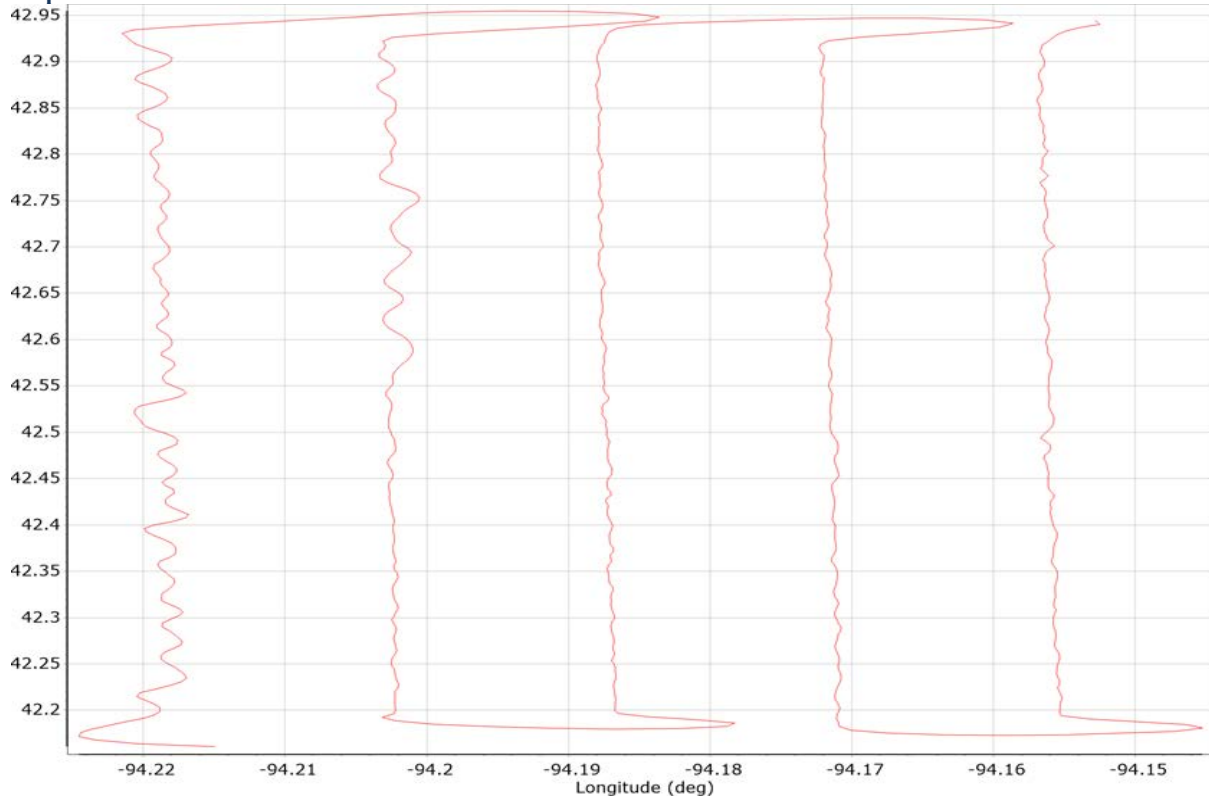
PDOP



Lift 15 Half 2 Report.docx QC Report – 06/18/2020

Smoothed Trajectory Information

Top View

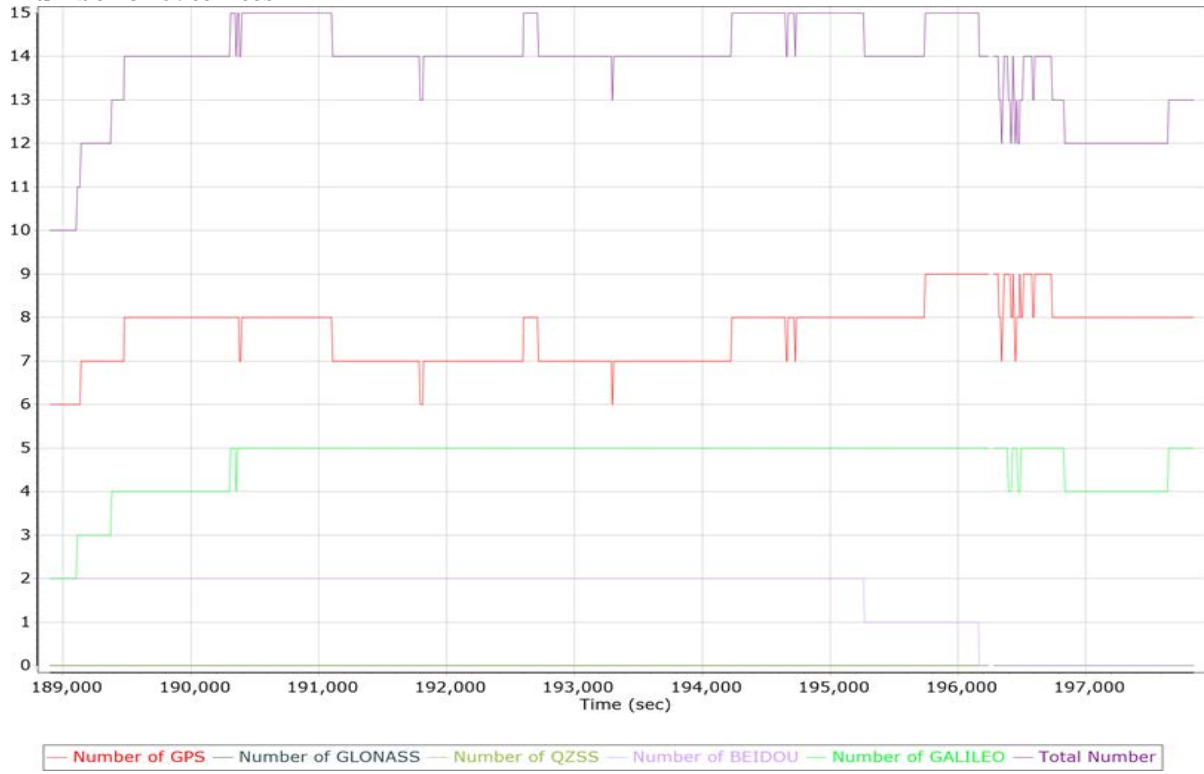


GNSS QC

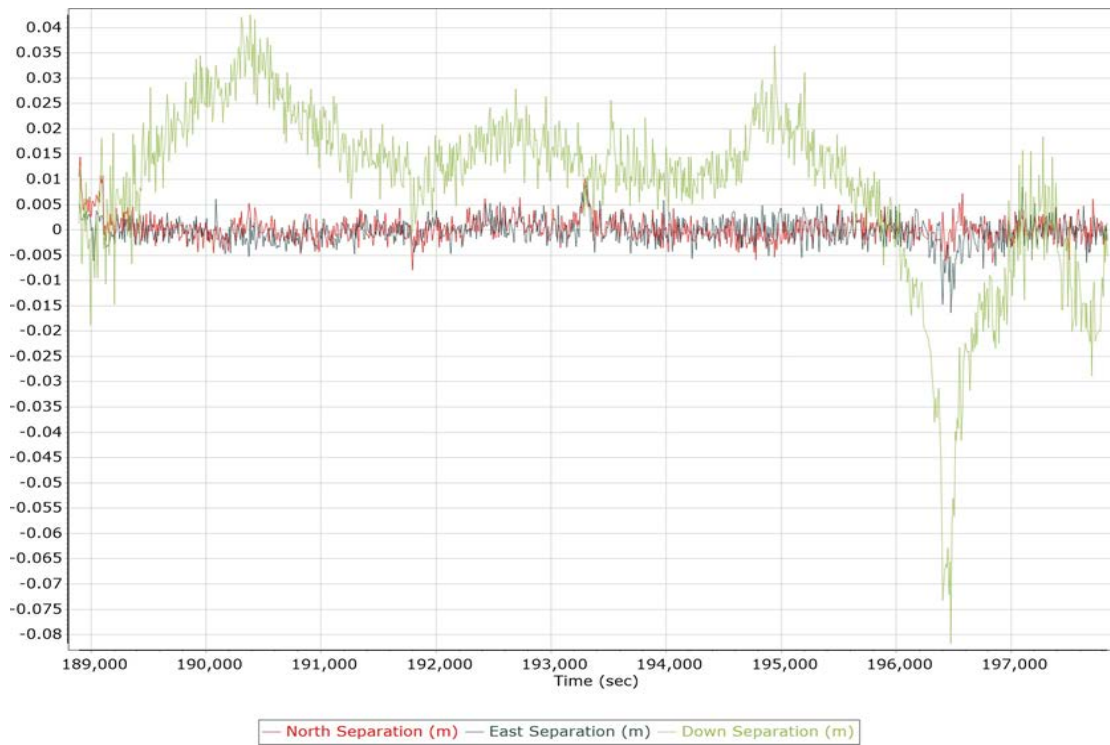
GNSS QC Statistics

Statistics	Min	Max	Mean
Baseline length (km)	0.00	0.00	
Number of GPS SV	6	9	8
Number of GLONASS SV	0	0	0
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	2	2
Number of GALILEO SV	2	5	5
Total number of SV	10	15	14
PDOP	1.32	2.51	1.61
QC Solution Gaps	30.00	30.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	8983.00	0.00	30.00
Percentage	99.67	0.00	0.33

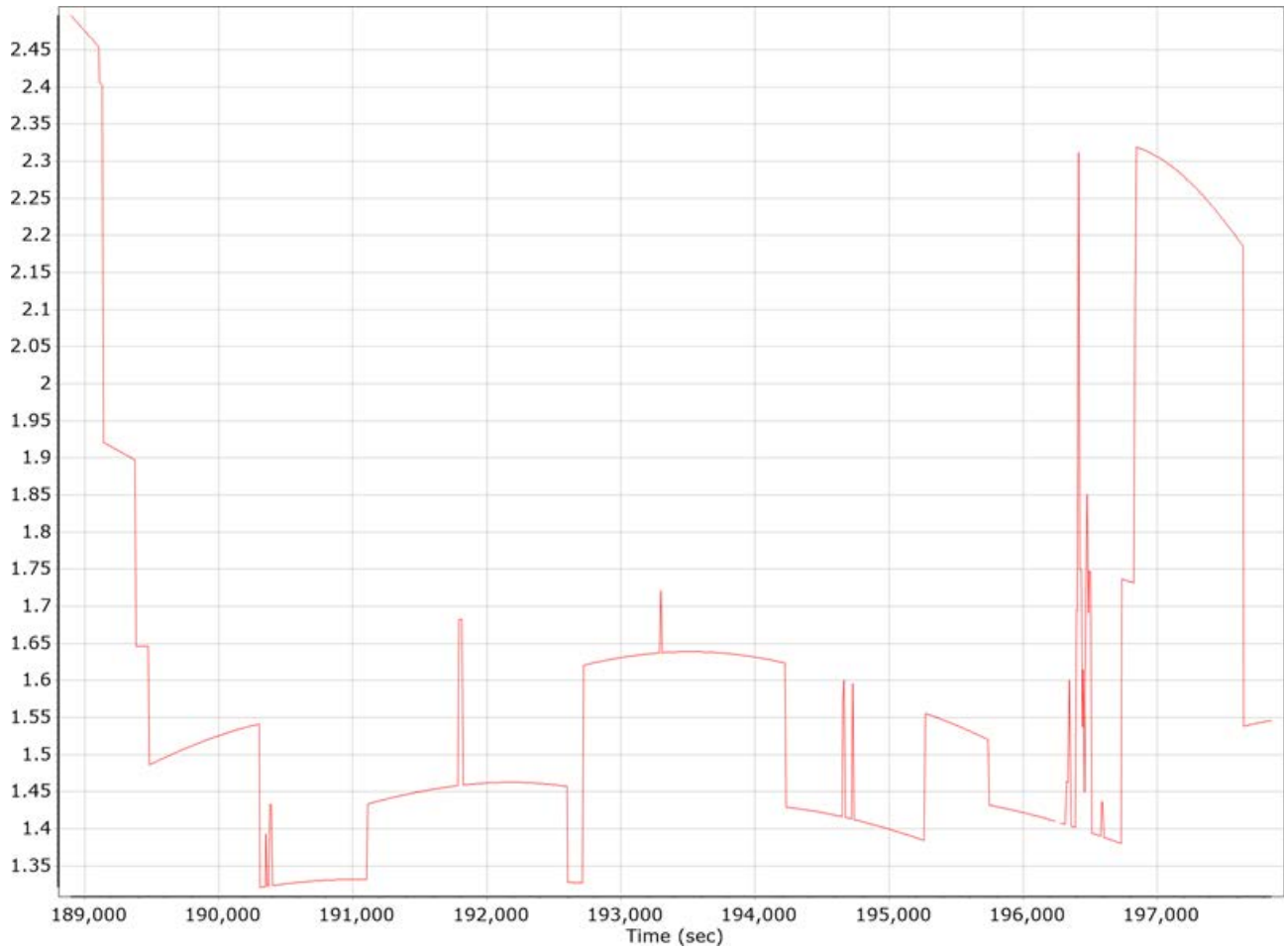
Number of Satellites



Forward/Reverse Separation



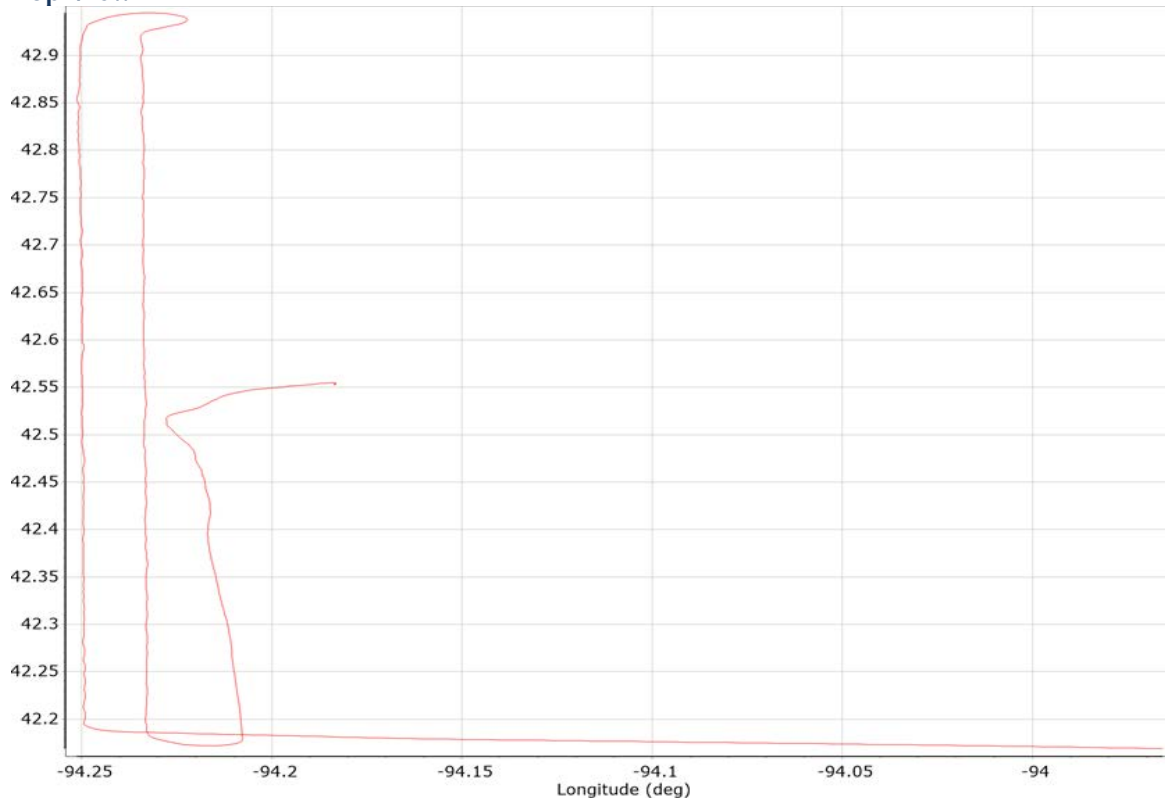
PDOP



Lift 16 Report.docx QC Report – 06/18/2020

Smoothed Trajectory Information

Top View

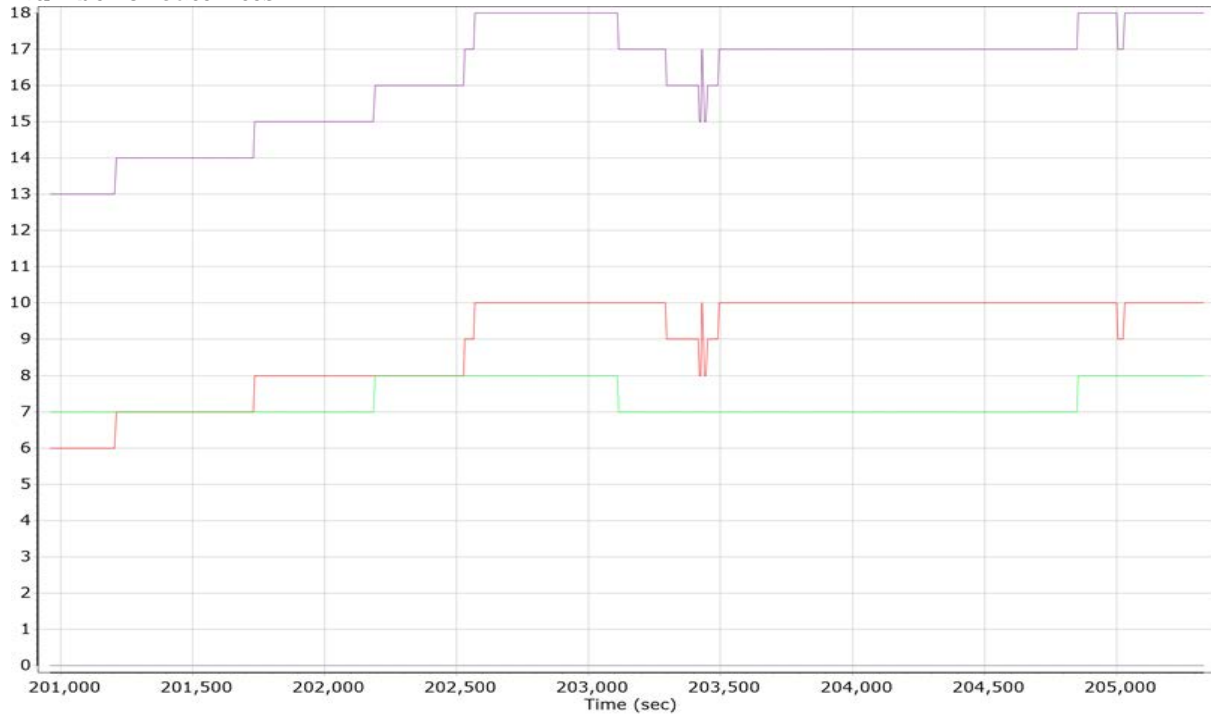


GNSS QC

GNSS QC Statistics

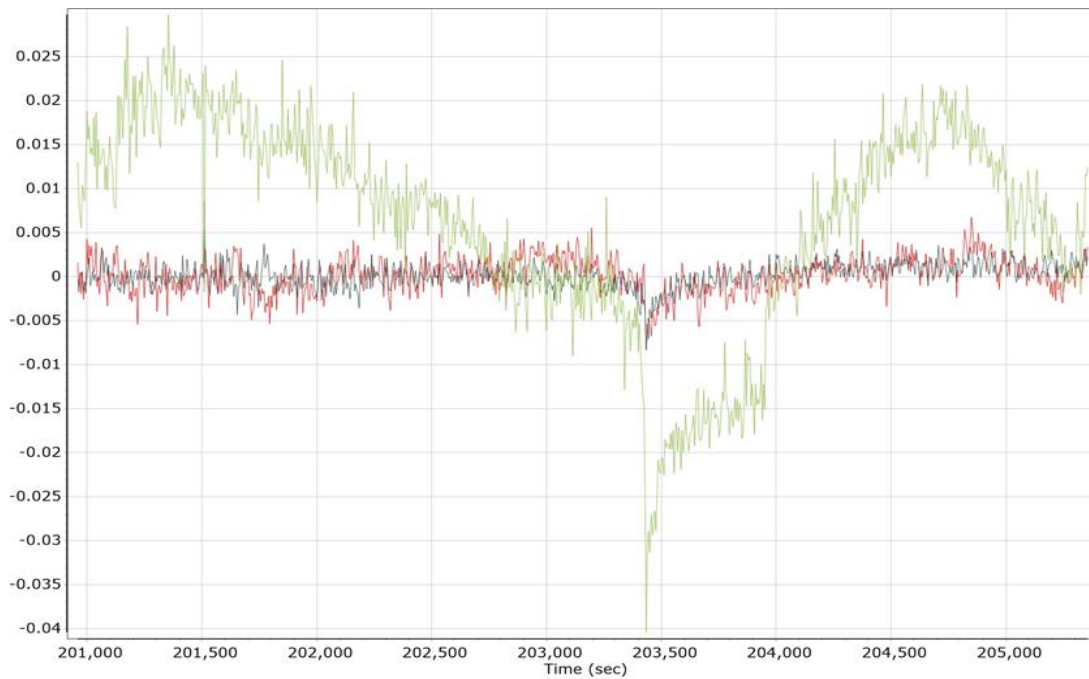
Statistics	Min	Max	Mean
Baseline length (km)	0.00	0.00	
Number of GPS SV	6	10	9
Number of GLONASS SV	0	0	0
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Number of GALILEO SV	6	8	7
Total number of SV	12	18	16
PDOP	1.20	1.69	1.36
QC Solution Gaps	0.00	0.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	4773.00	0.00	0.00
Percentage	100.00	0.00	0.00

Number of Satellites



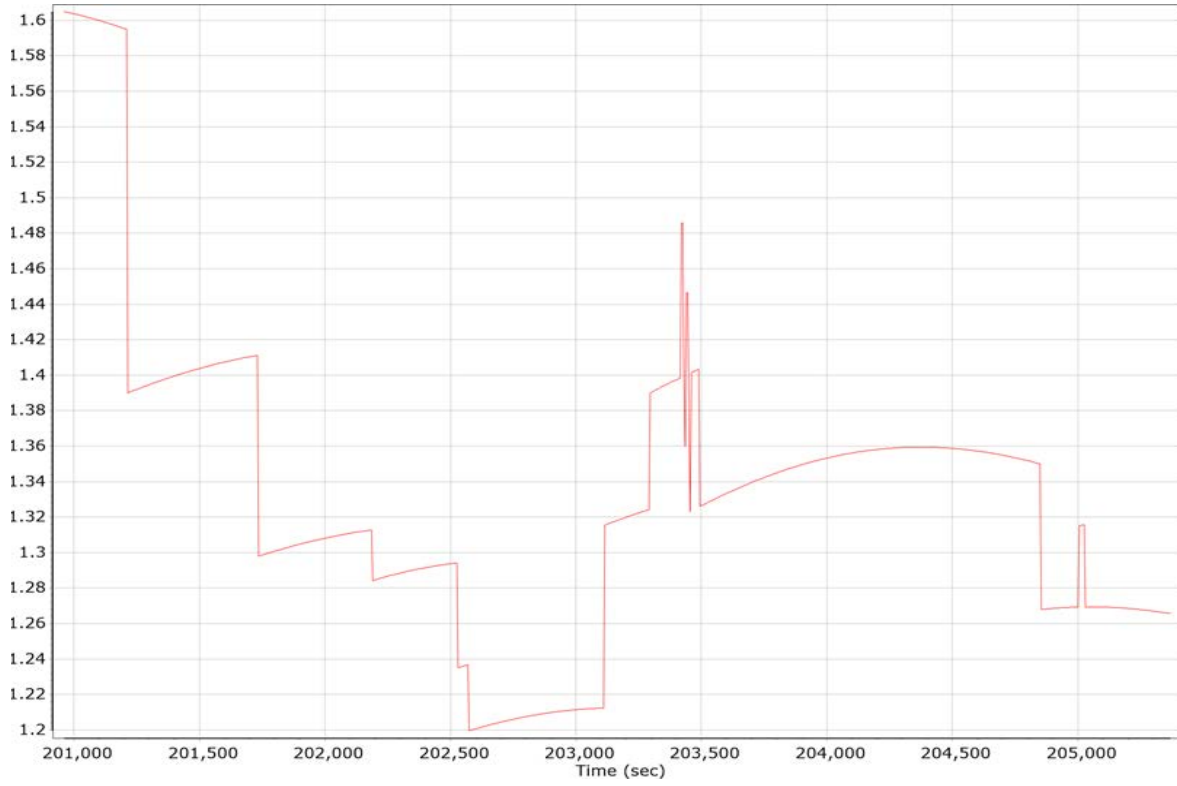
— Number of GPS — Number of GLONASS — Number of QZSS — Number of BEIDOU — Number of GALILEO — Total Number

Forward/Reverse Separation



— North Separation (m) — East Separation (m) — Down Separation (m)

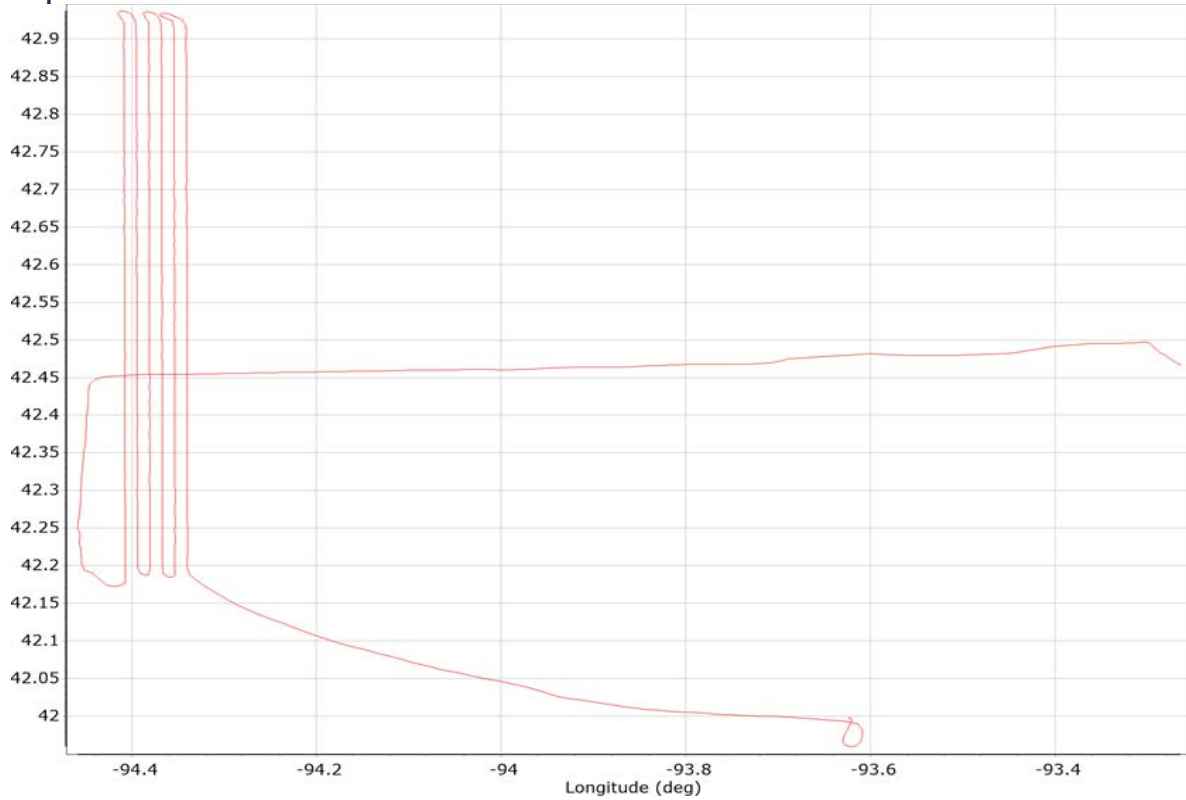
PDOP



Lift 17 Report.docx QC Report – 06/18/2020

Smoothed Trajectory Information

Top View

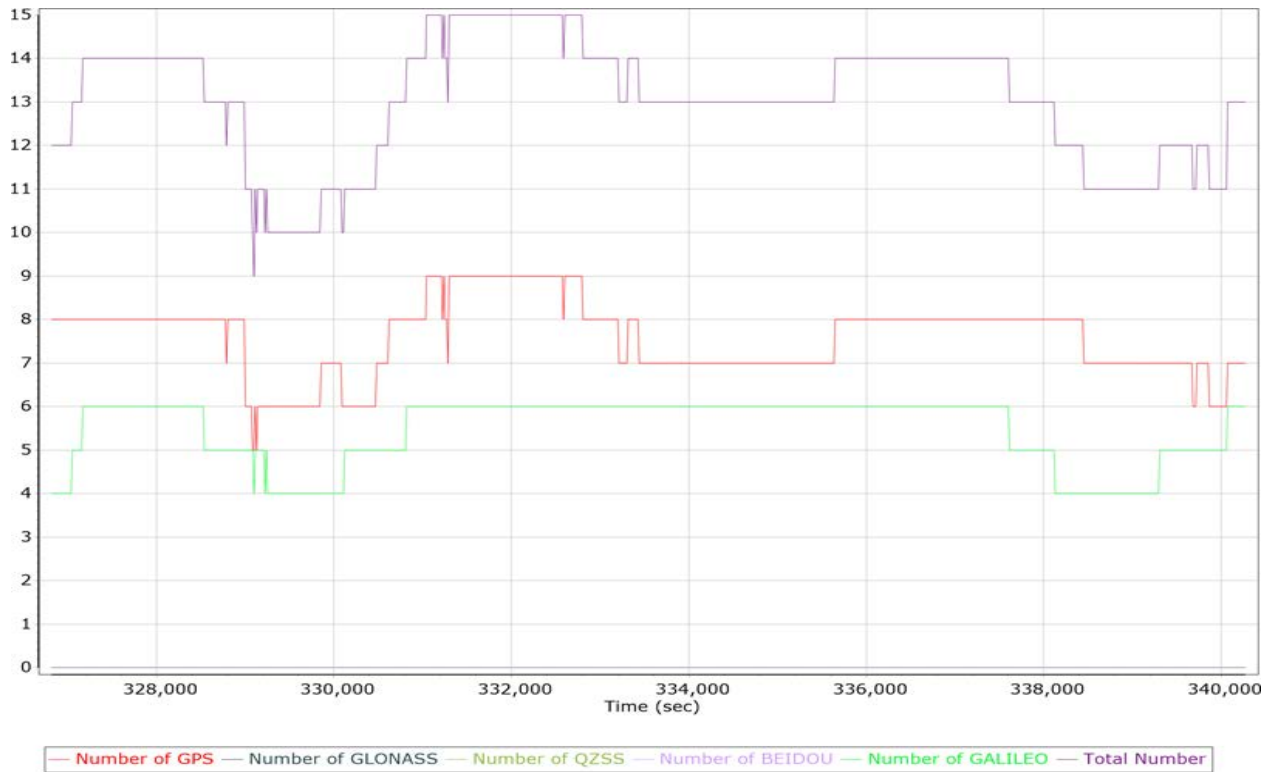


GNSS QC

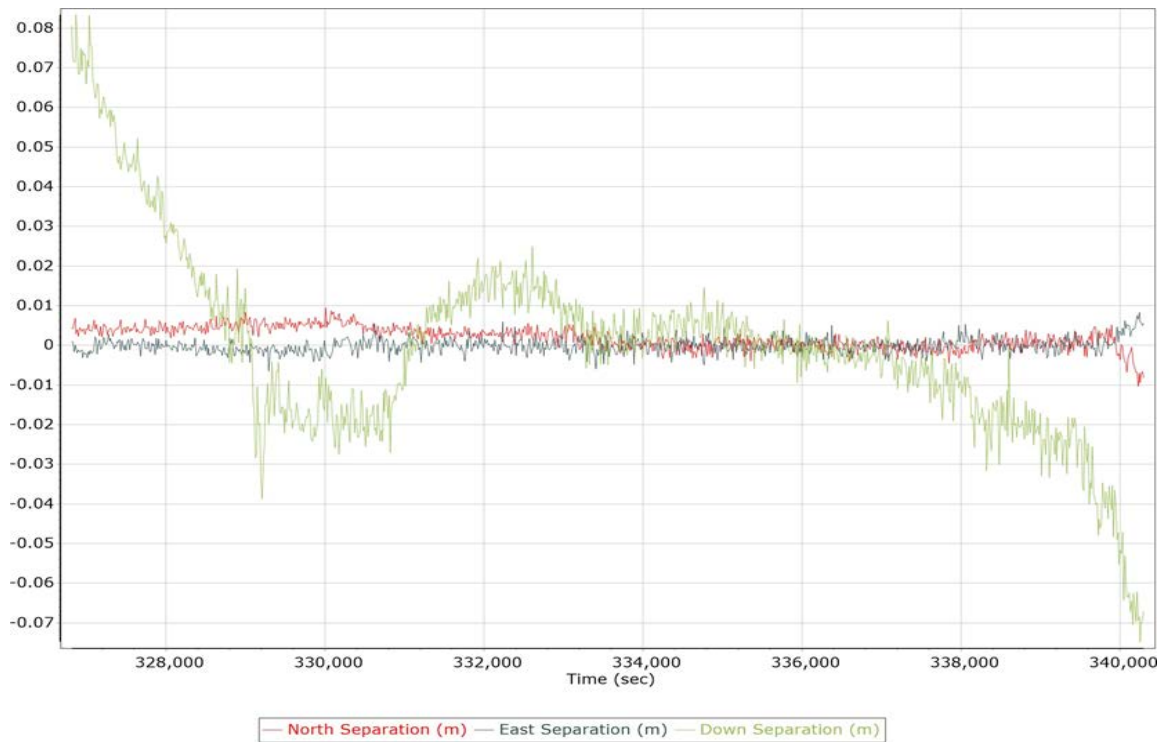
GNSS QC Statistics

Statistics	Min	Max	Mean
Baseline length (km)	0.00	0.00	
Number of GPS SV	5	9	8
Number of GLONASS SV	0	0	0
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Number of GALILEO SV	3	6	5
Total number of SV	9	15	13
PDOP	1.16	3.41	1.57
QC Solution Gaps	0.00	0.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	13534.00	0.00	0.00
Percentage	100.00	0.00	0.00

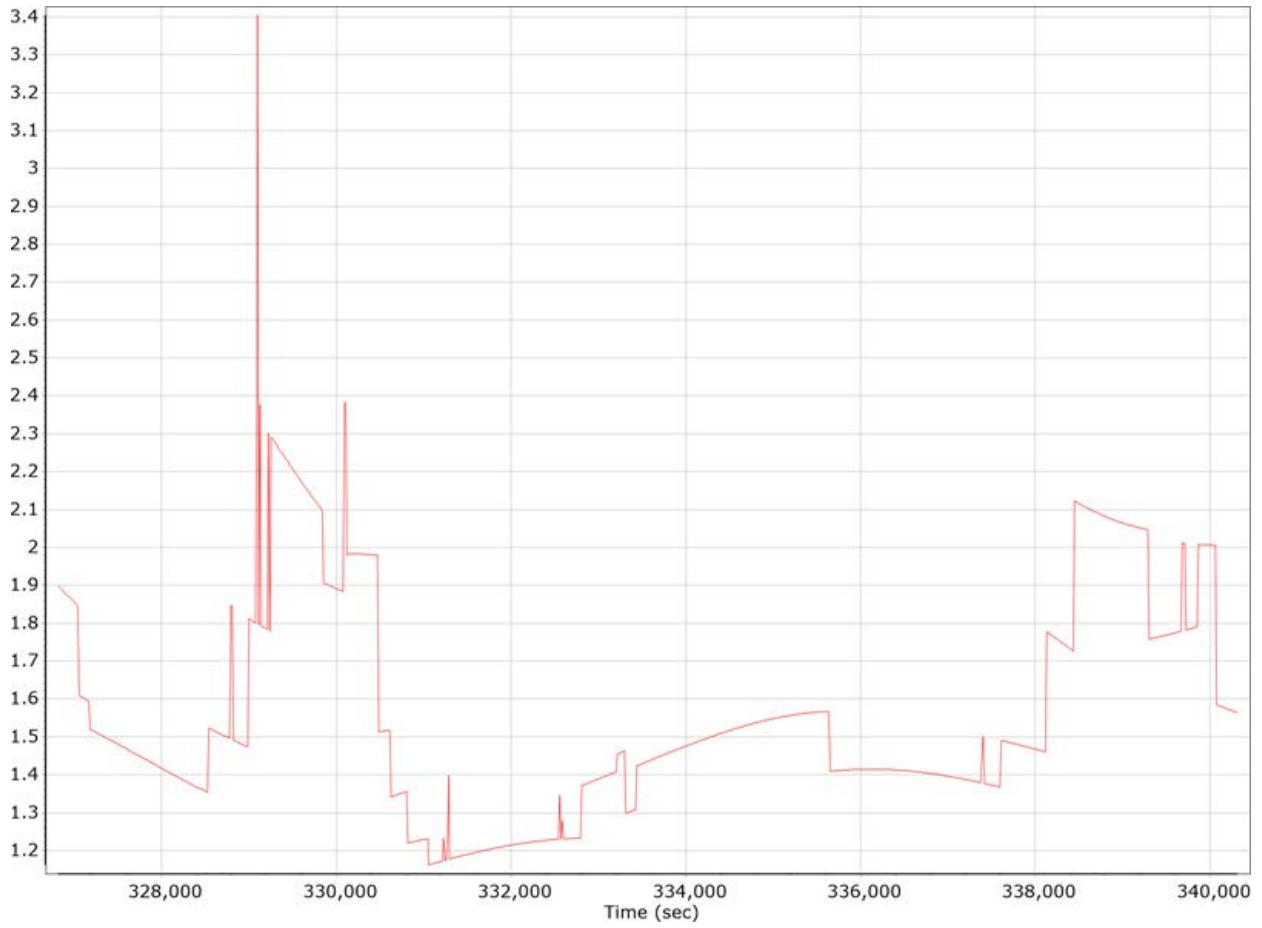
Number of Satellites



Forward/Reverse Separation



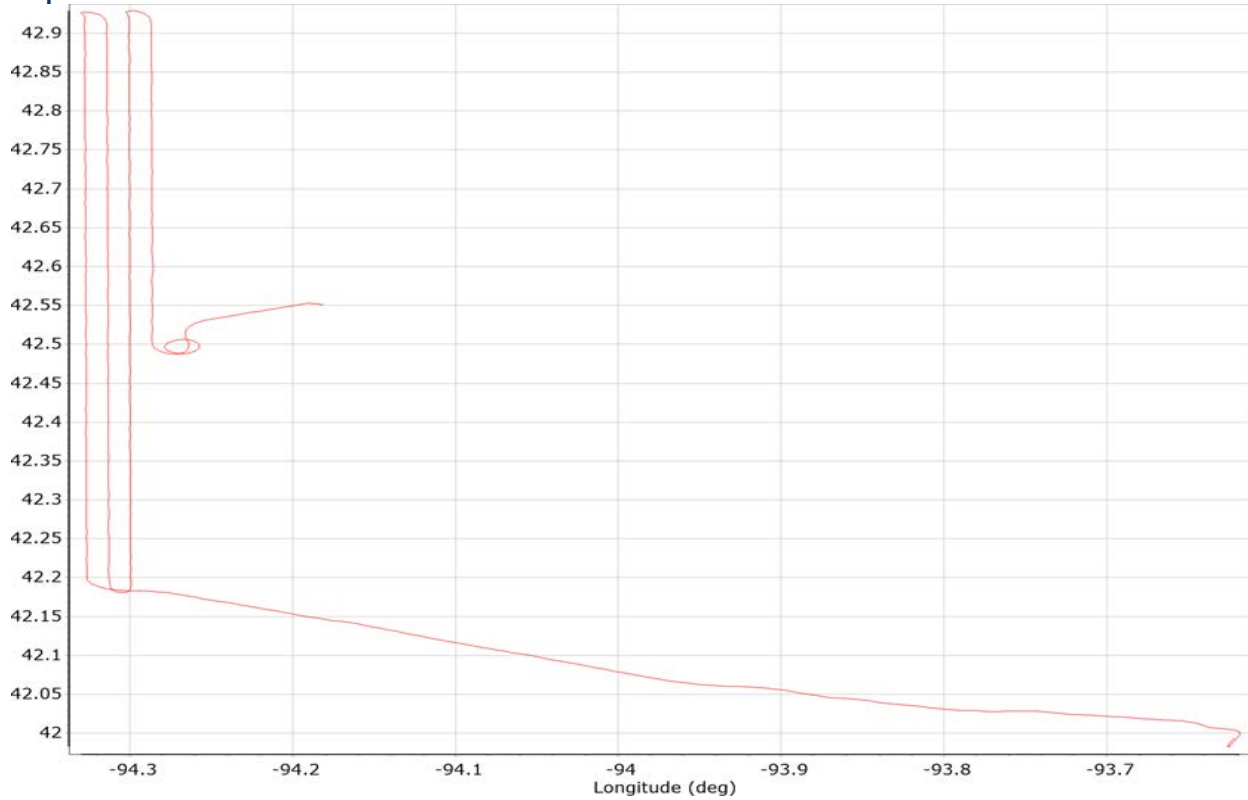
PDOP



Lift 18 Report.docx QC Report – 06/18/2020

Smoothed Trajectory Information

Top View

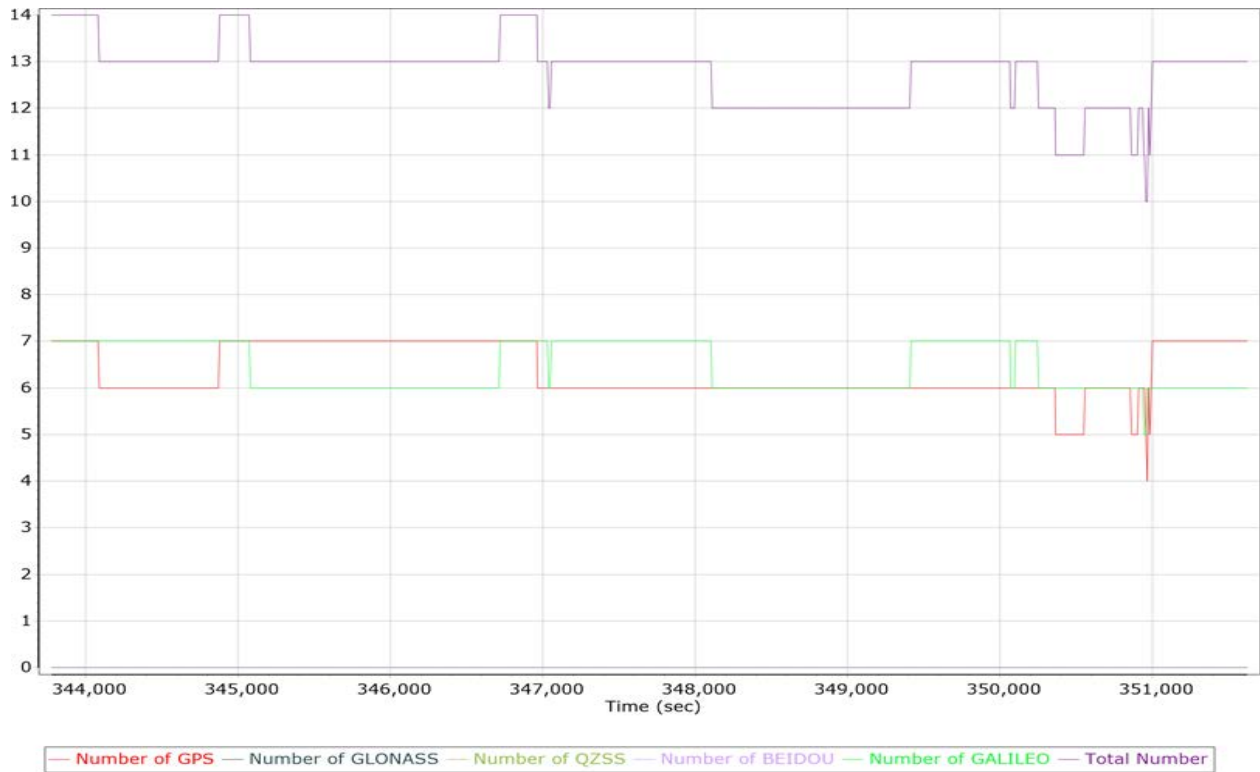


GNSS QC

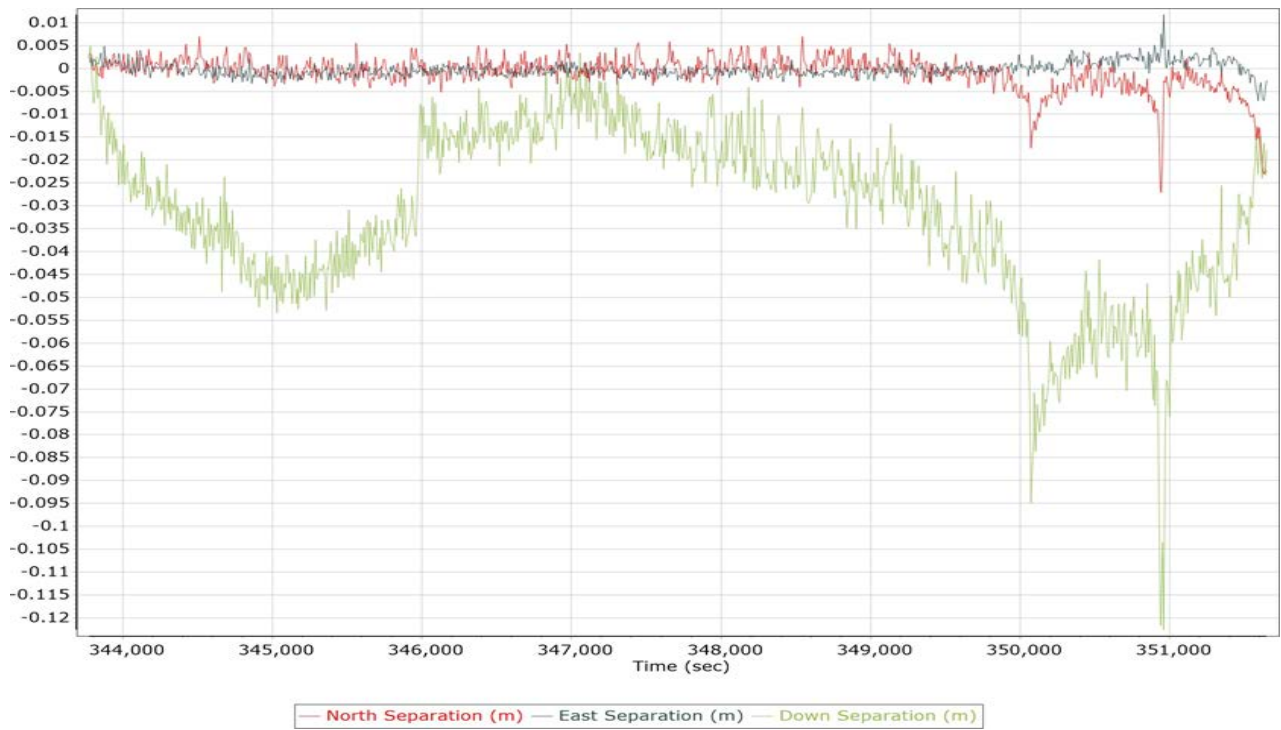
GNSS QC Statistics

Statistics	Min	Max	Mean
Baseline length (km)	0.00	0.00	
Number of GPS SV	4	7	6
Number of GLONASS SV	0	0	0
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Number of GALILEO SV	4	7	6
Total number of SV	10	14	13
PDOP	1.47	3.25	1.76
QC Solution Gaps	0.00	0.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	8130.00	0.00	0.00
Percentage	100.00	0.00	0.00

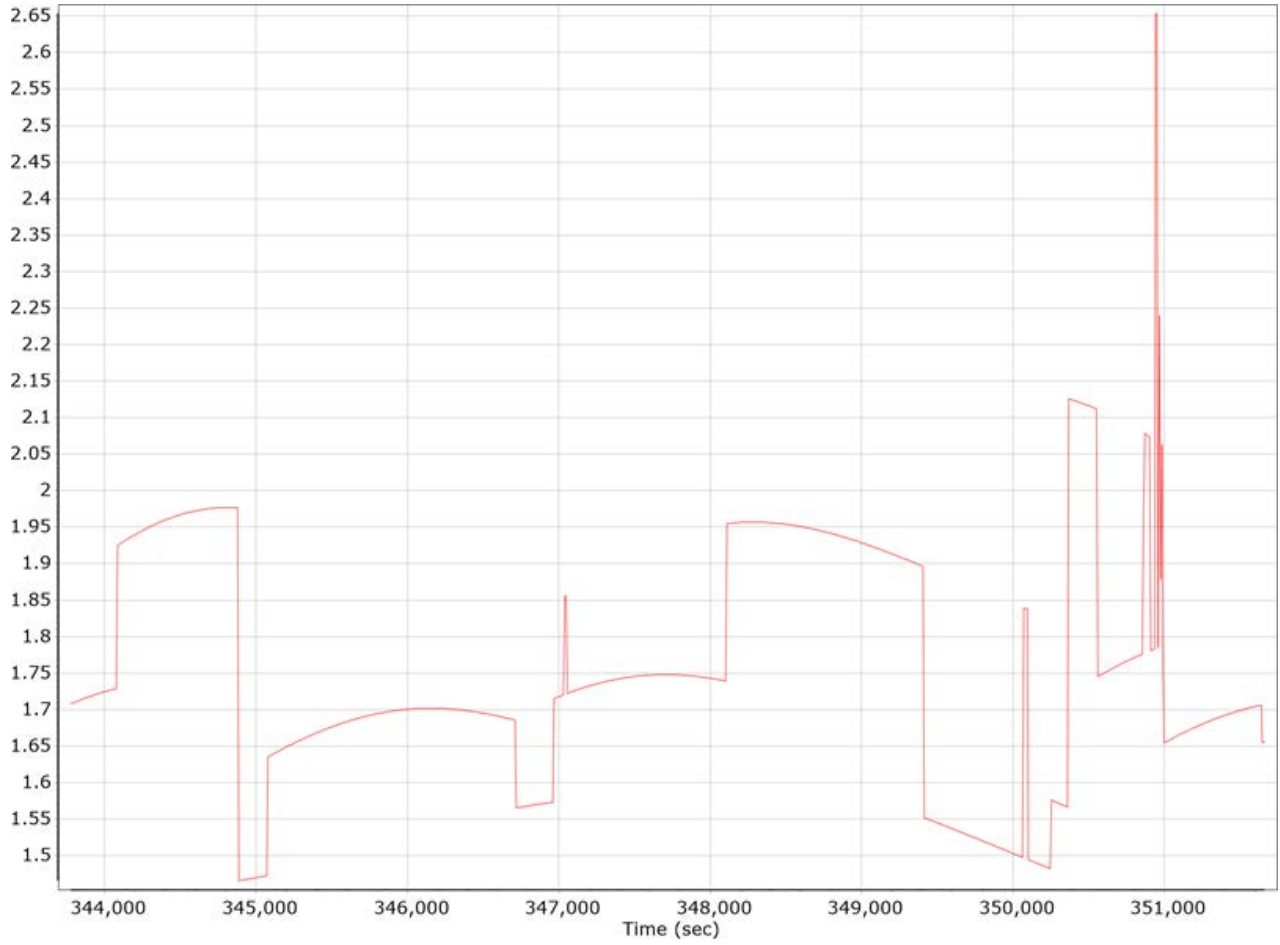
Number of Satellites



Forward/Reverse Separation



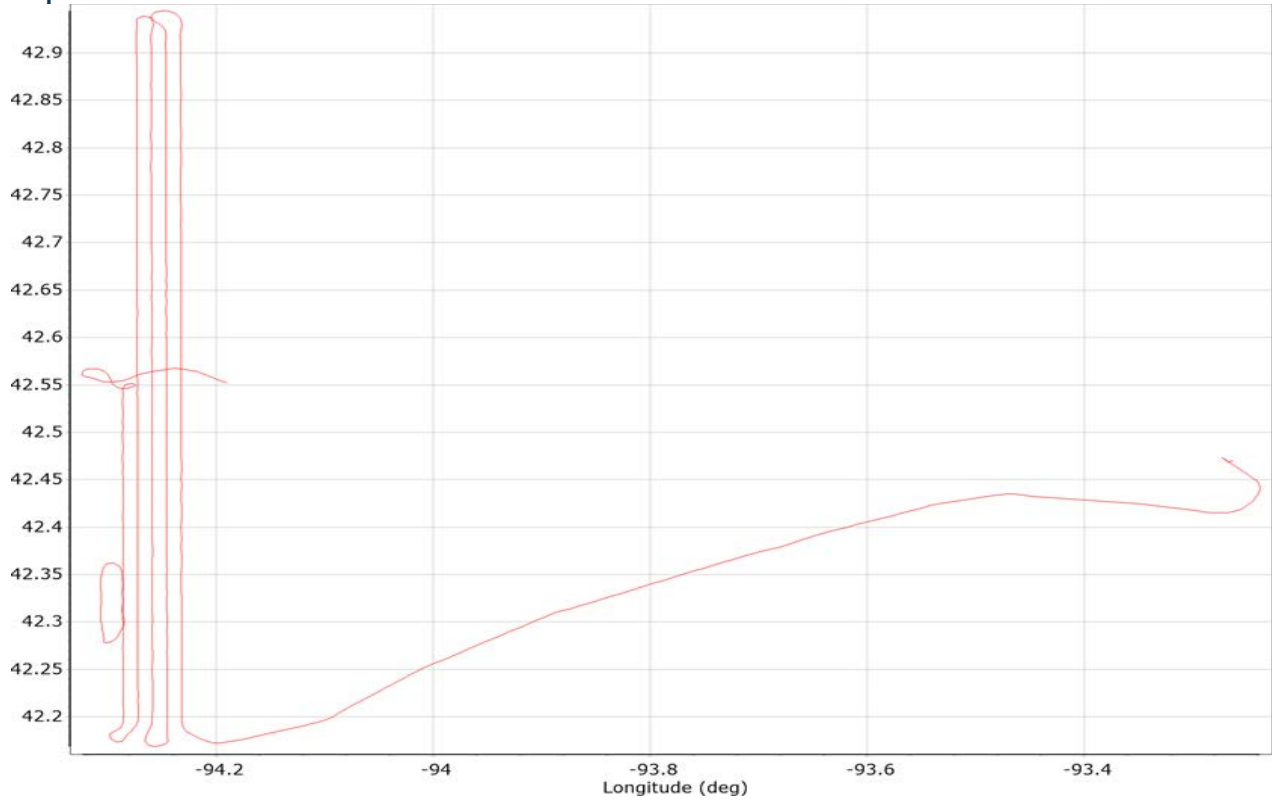
PDOP



Lift 19 Report.docx QC Report – 06/18/2020

Smoothed Trajectory Information

Top View

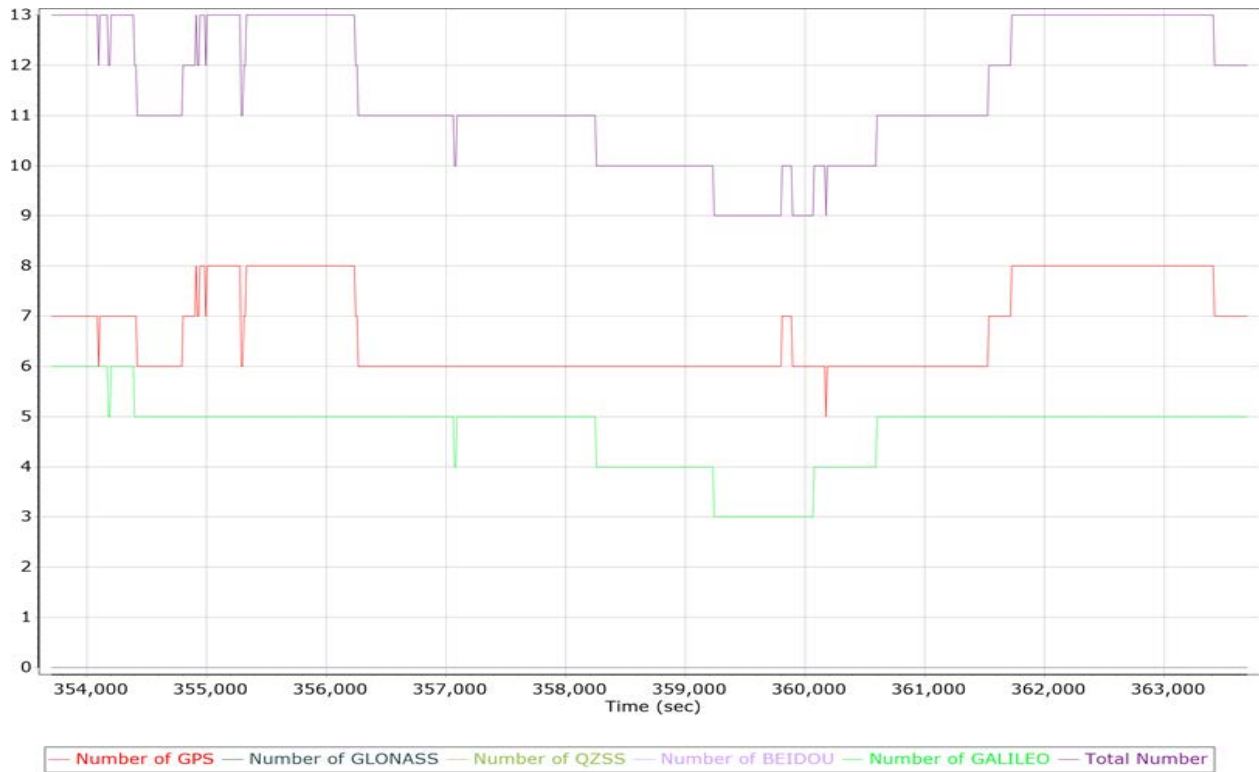


GNSS QC

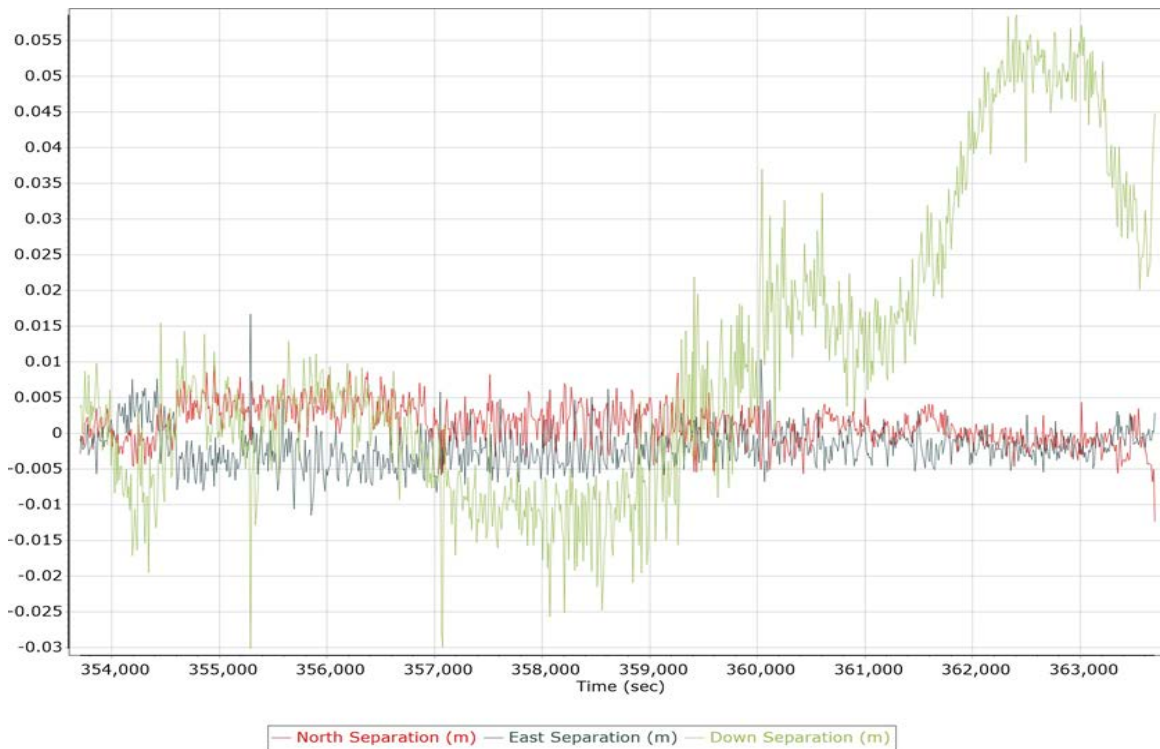
GNSS QC Statistics

Statistics	Min	Max	Mean
Baseline length (km)	0.00	0.00	
Number of GPS SV	3	8	7
Number of GLONASS SV	0	0	0
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Number of GALILEO SV	3	7	5
Total number of SV	7	14	12
PDOP	1.37	2.86	1.76
QC Solution Gaps	0.00	0.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	10405.00	0.00	0.00
Percentage	100.00	0.00	0.00

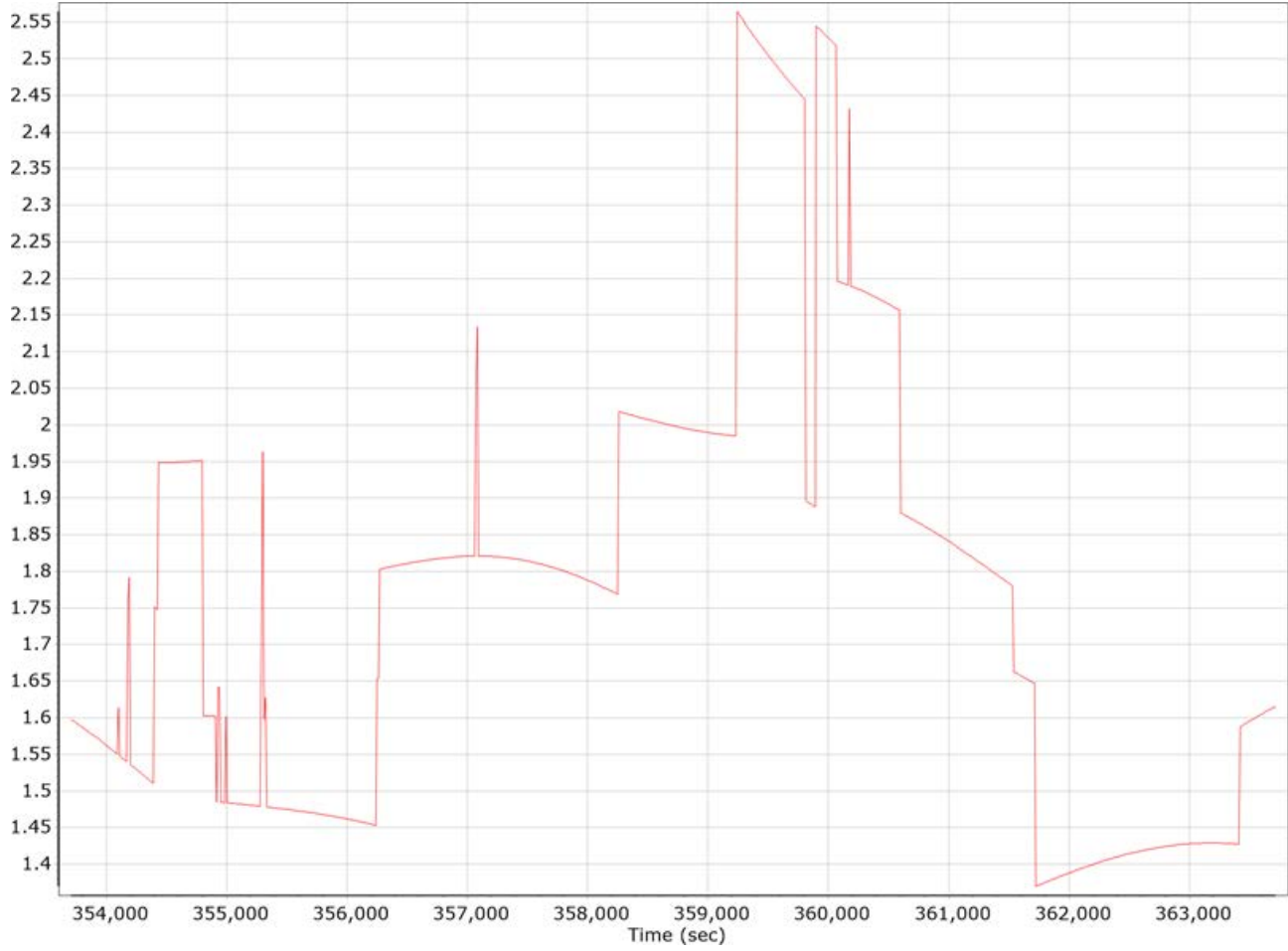
Number of Satellites



Forward/Reverse Separation



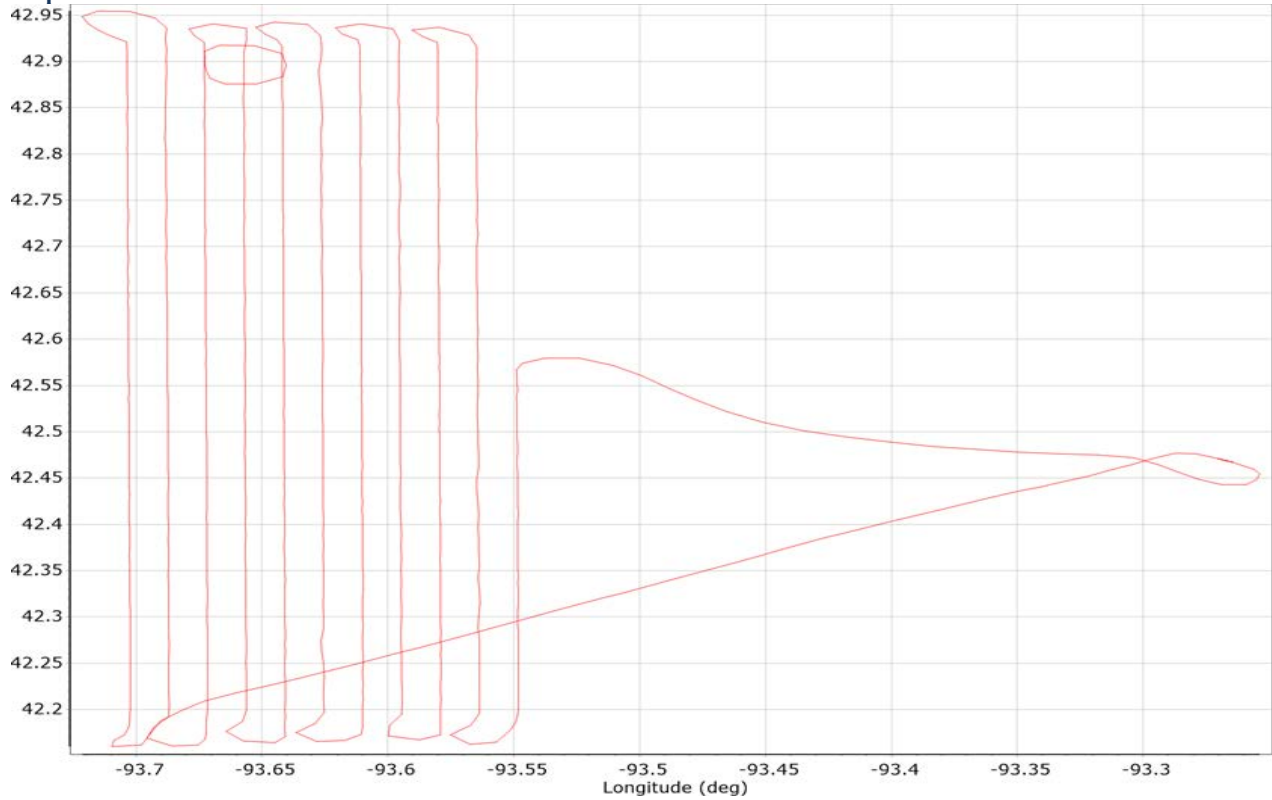
PDOP



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Smoothed Trajectory Information

Top View

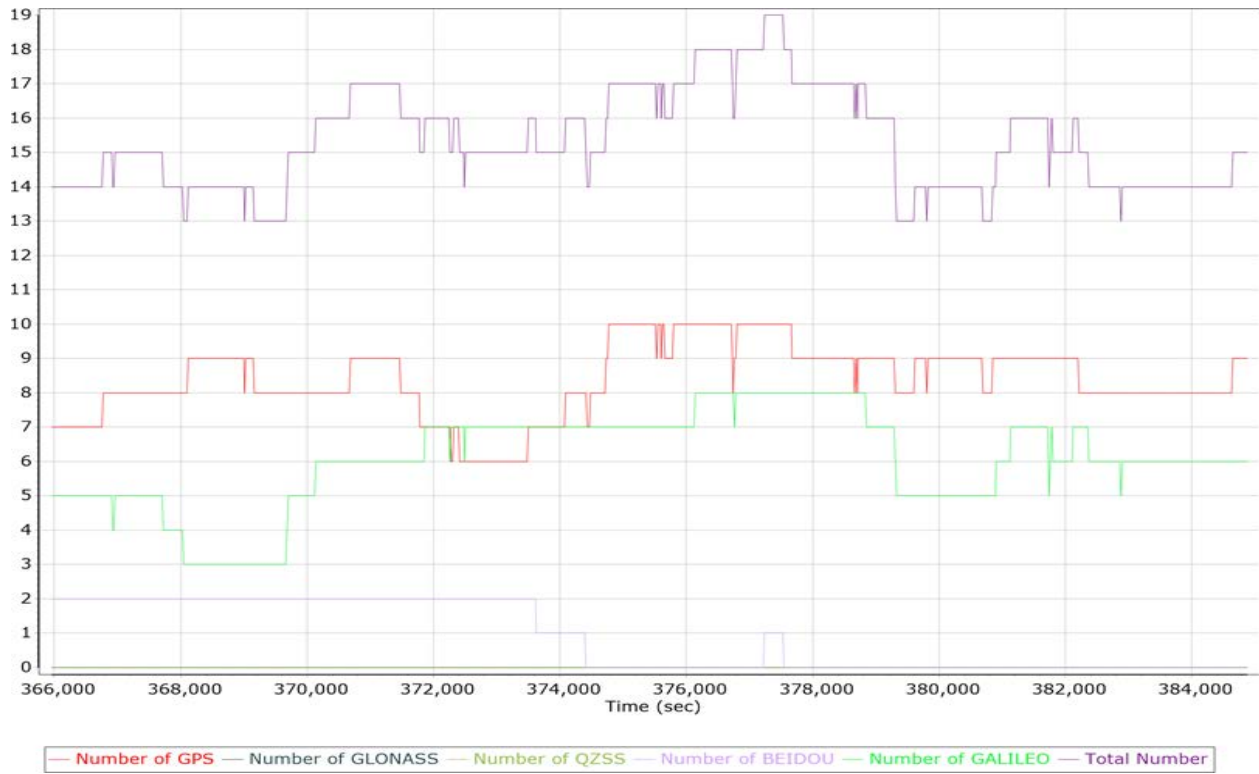


GNSS QC

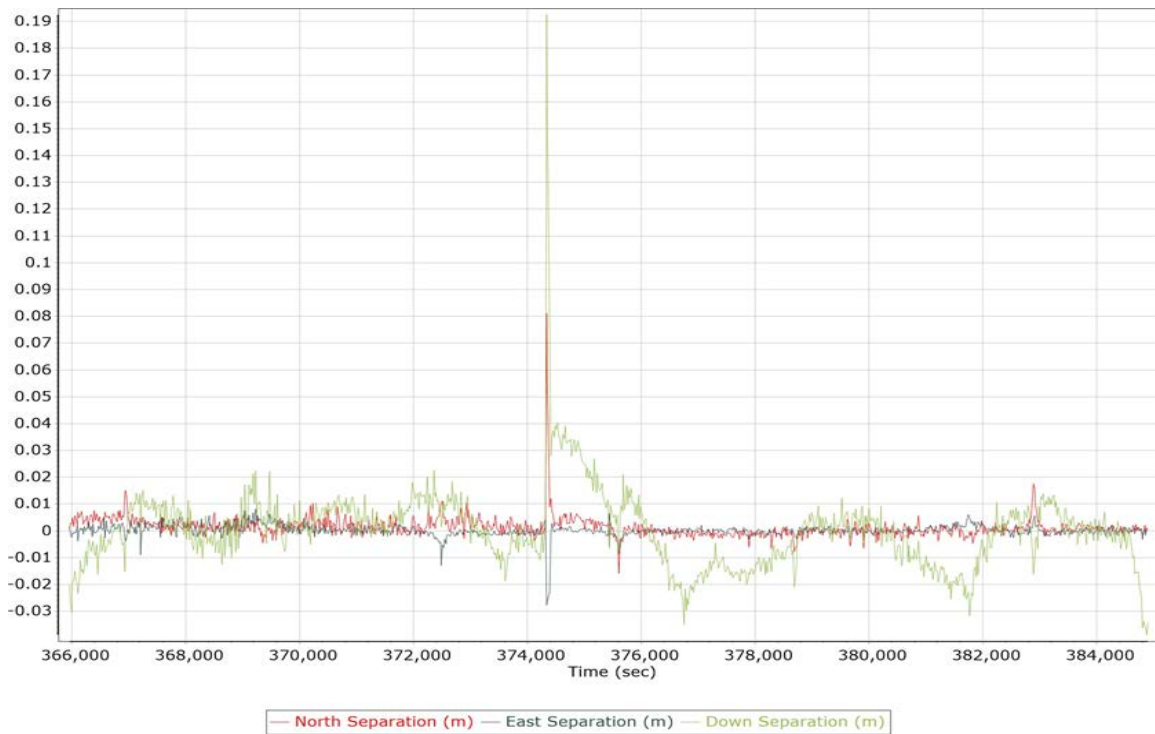
GNSS QC Statistics

Statistics	Min	Max	Mean
Baseline length (km)	0.00	0.00	
Number of GPS SV	5	10	8
Number of GLONASS SV	0	0	0
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	2	1
Number of GALILEO SV	3	8	6
Total number of SV	12	19	15
PDOP	1.23	2.17	1.45
QC Solution Gaps	5.00	5.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	19104.00	0.00	5.00
Percentage	99.97	0.00	0.03

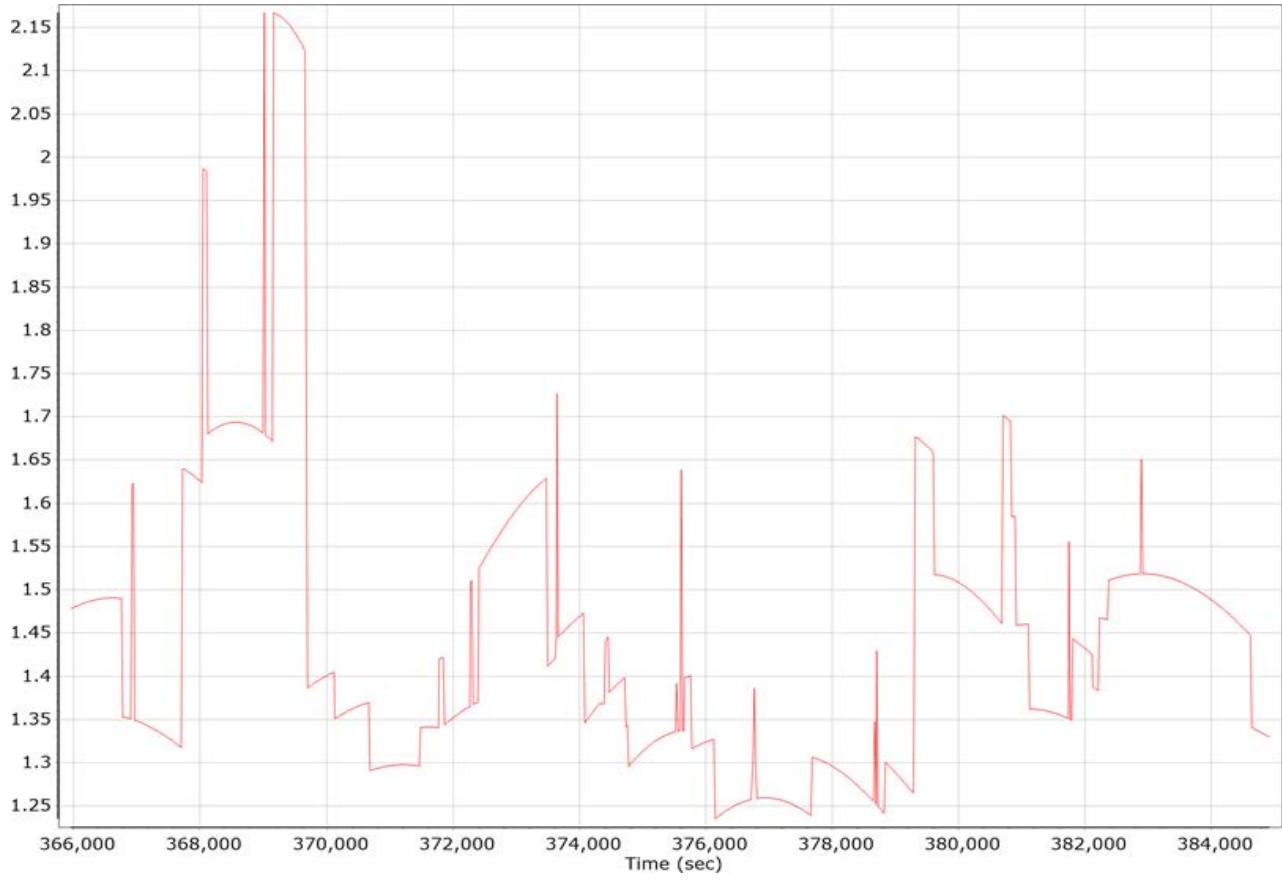
Number of Satellites



Forward/Reverse Separation



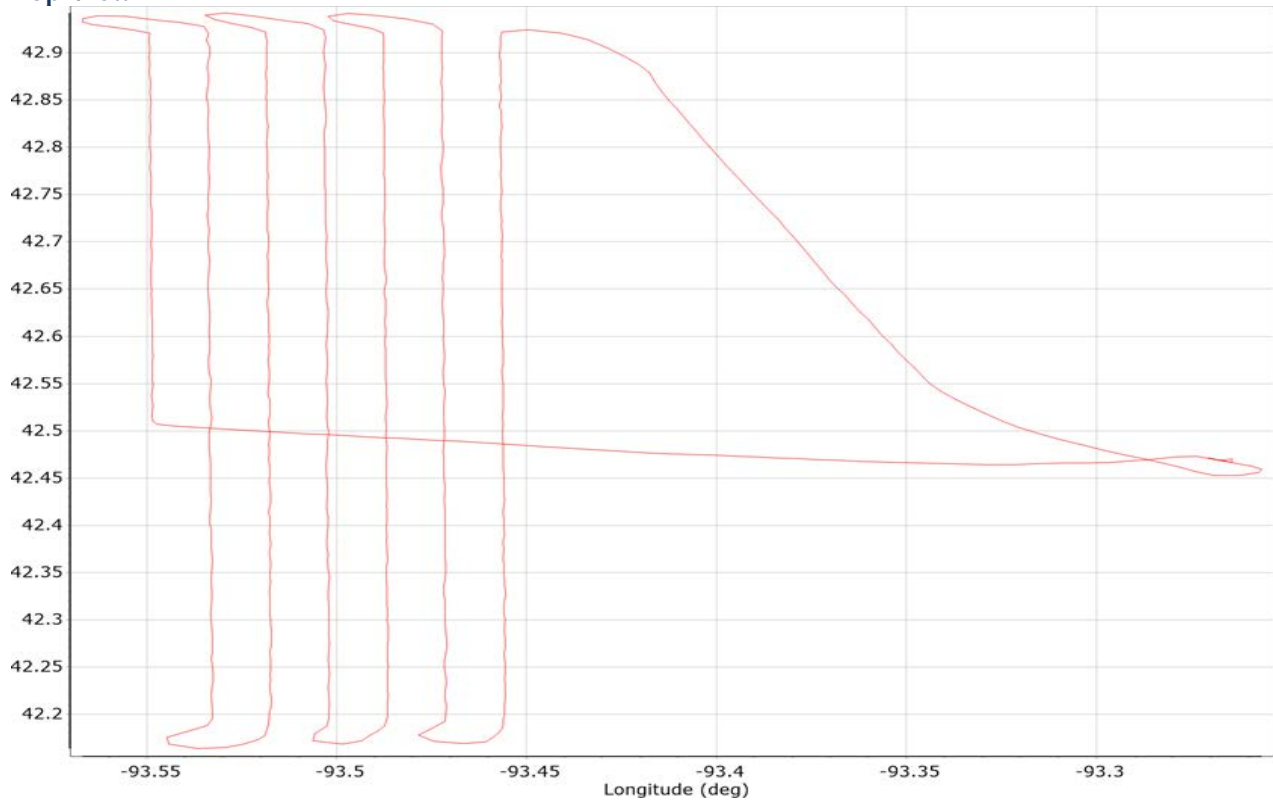
PDOP



Lift 21 Report.docx QC Report – 06/18/2020

Smoothed Trajectory Information

Top View

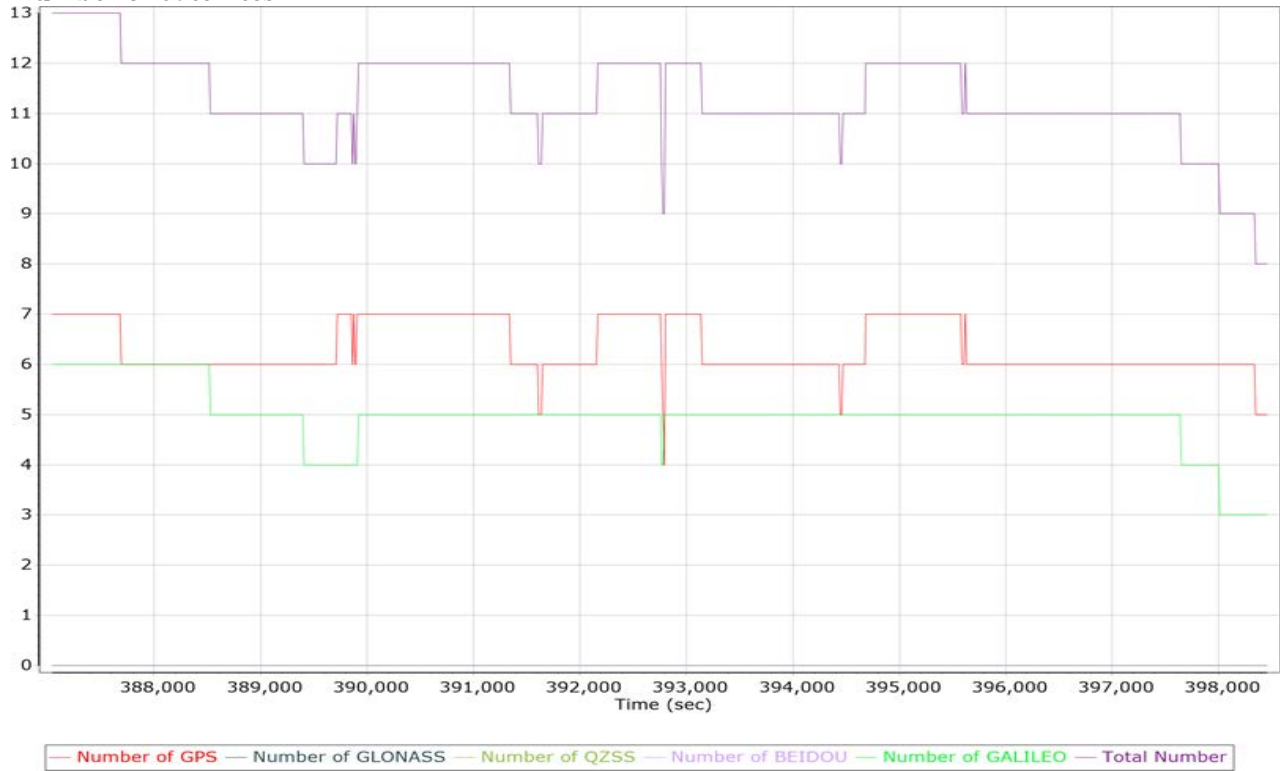


GNSS QC

GNSS QC Statistics

Statistics	Min	Max	Mean
Baseline length (km)	0.00	0.00	
Number of GPS SV	4	7	6
Number of GLONASS SV	0	0	0
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Number of GALILEO SV	3	6	5
Total number of SV	8	13	11
PDOP	1.58	4.19	1.88
QC Solution Gaps	0.00	0.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	11657.00	0.00	0.00
Percentage	100.00	0.00	0.00

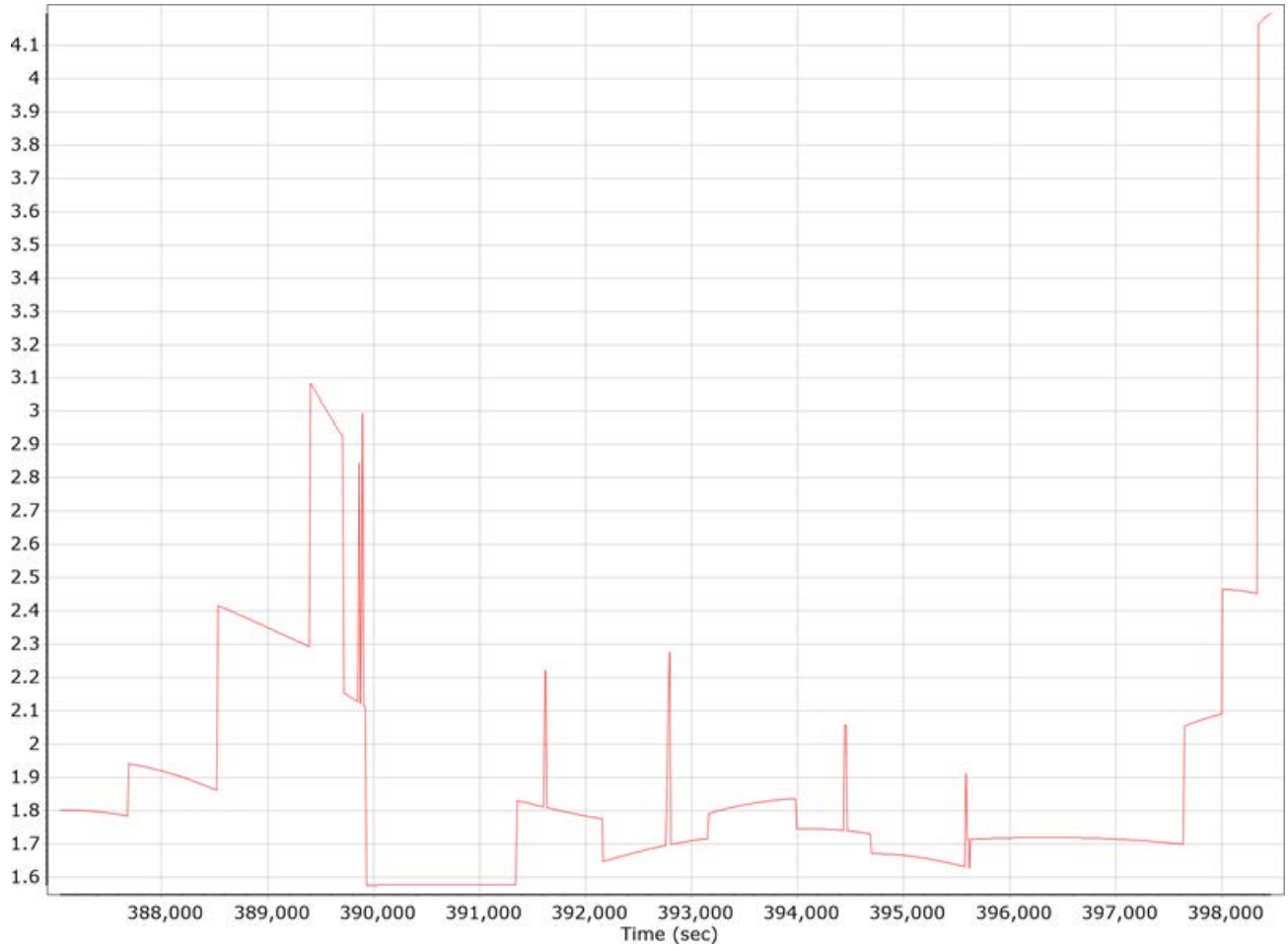
Number of Satellites



Forward/Reverse Separation



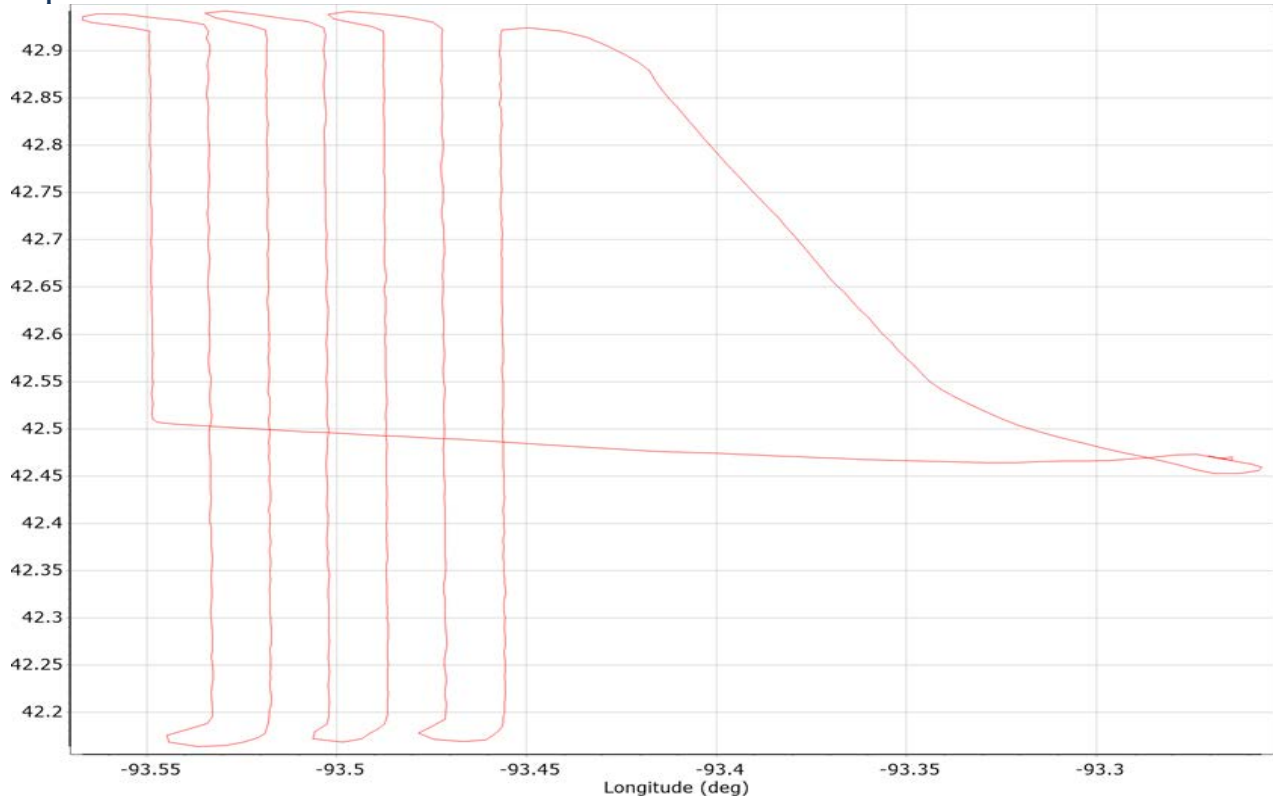
PDOP



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Smoothed Trajectory Information

Top View

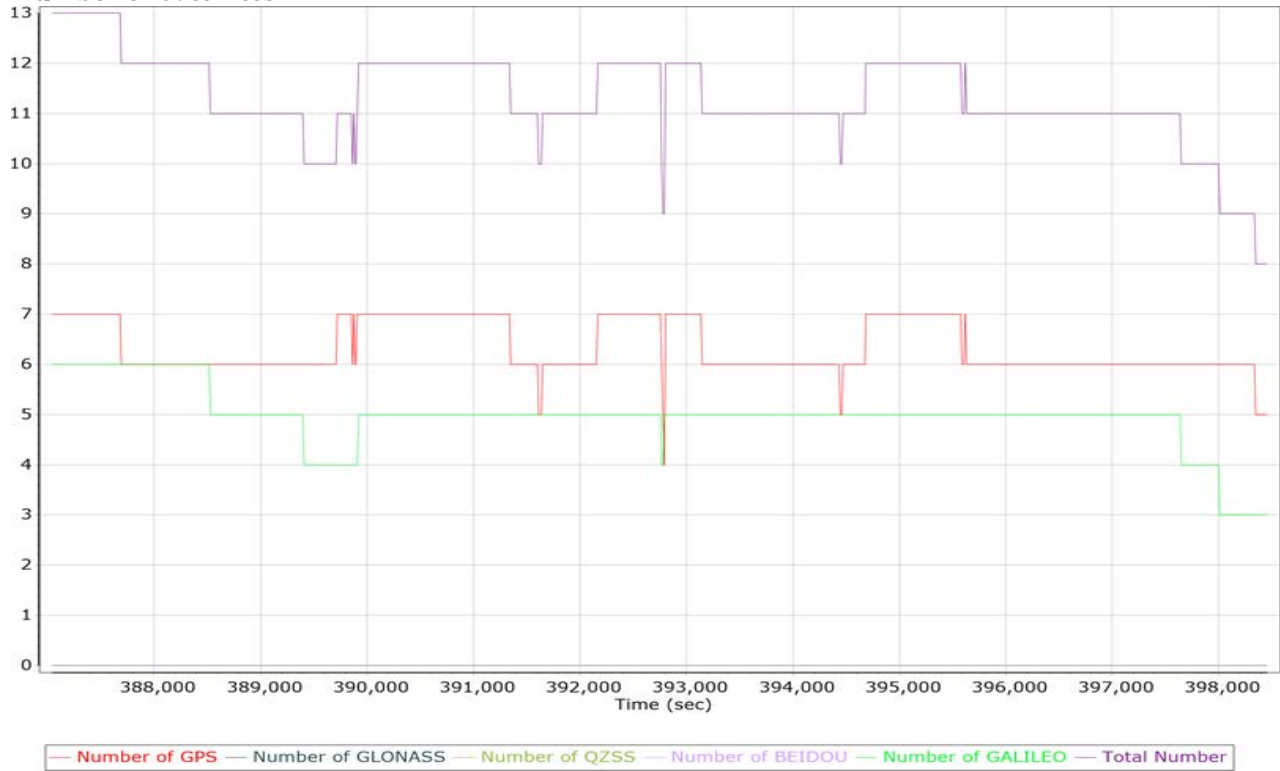


GNSS QC

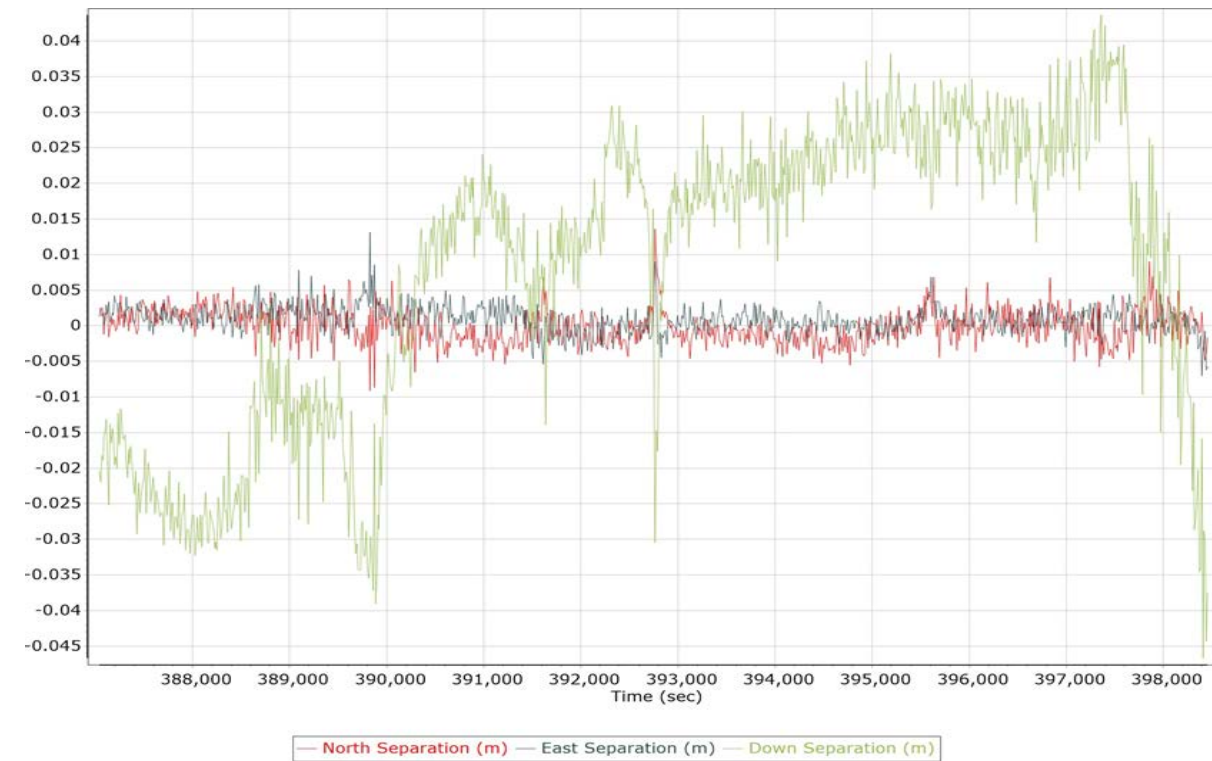
GNSS QC Statistics

Statistics	Min	Max	Mean
Baseline length (km)	0.00	0.00	
Number of GPS SV	4	7	6
Number of GLONASS SV	0	0	0
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Number of GALILEO SV	3	6	5
Total number of SV	8	13	11
PDOP	1.58	4.19	1.88
QC Solution Gaps	0.00	0.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	11657.00	0.00	0.00
Percentage	100.00	0.00	0.00

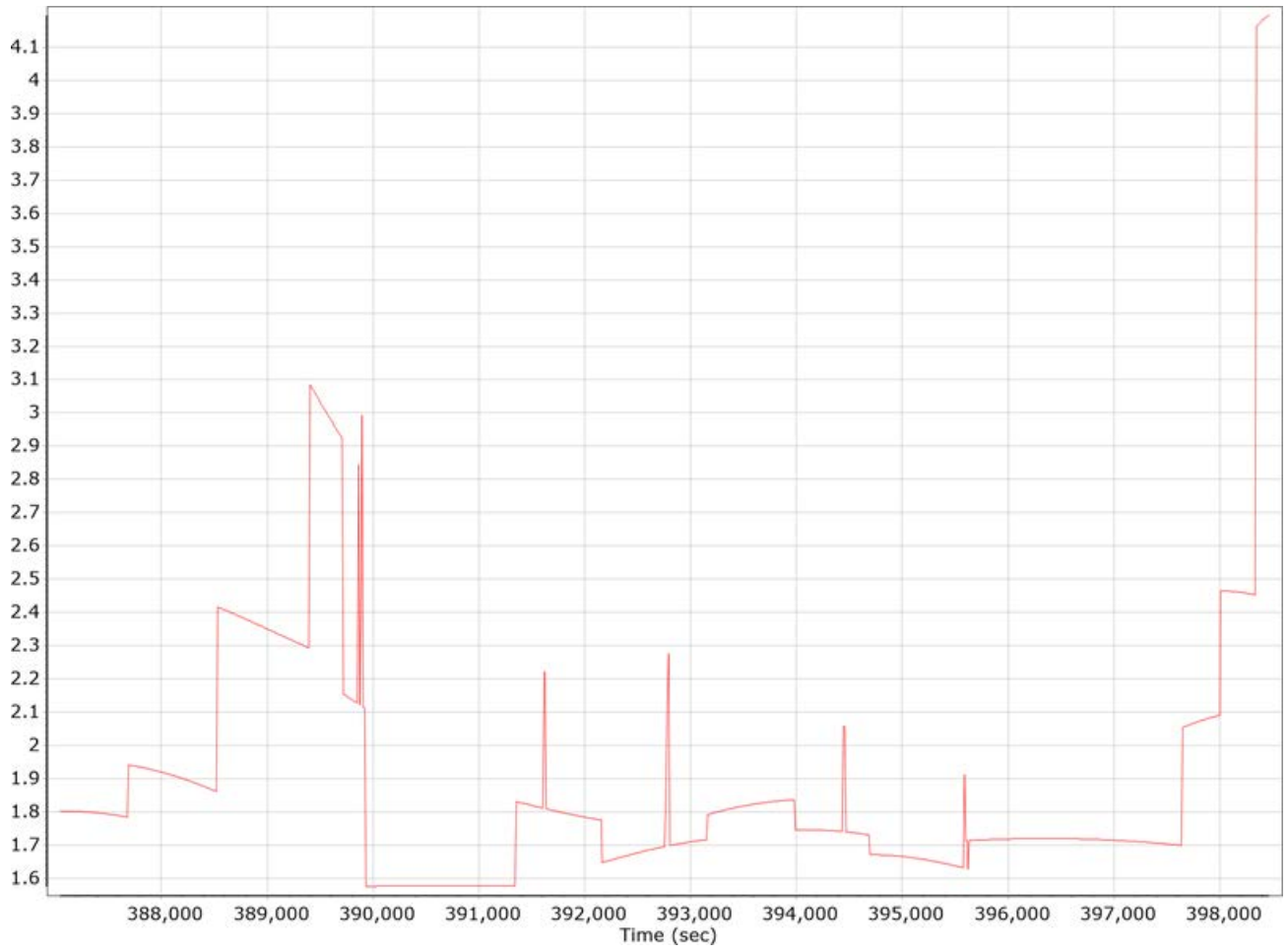
Number of Satellites



Forward/Reverse Separation



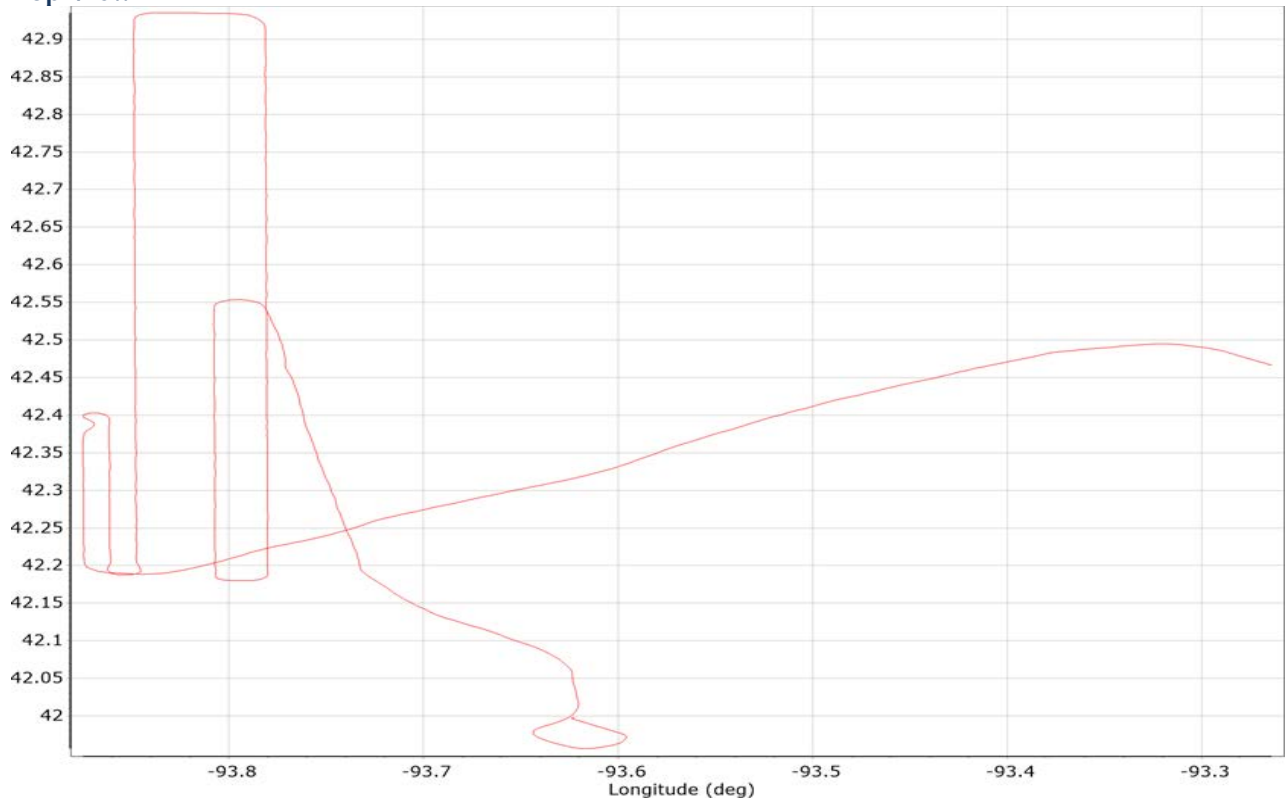
PDOP



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Smoothed Trajectory Information

Top View

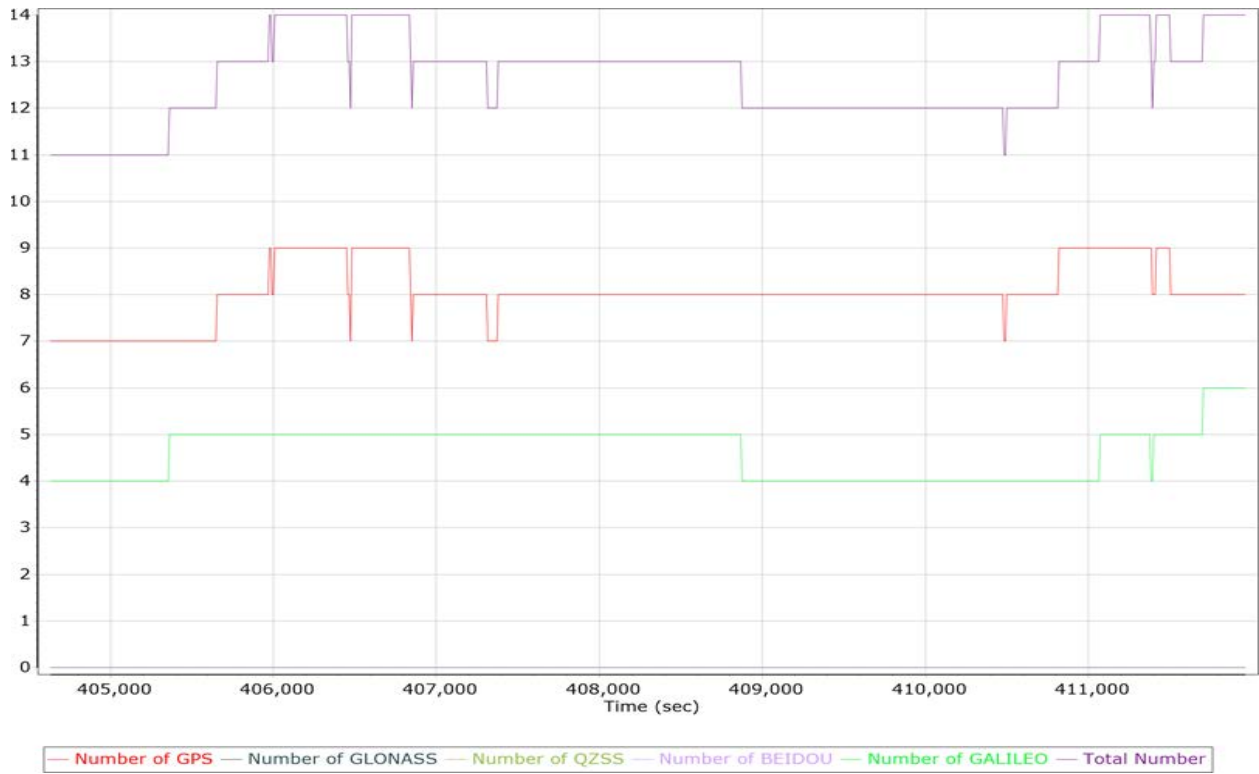


GNSS QC

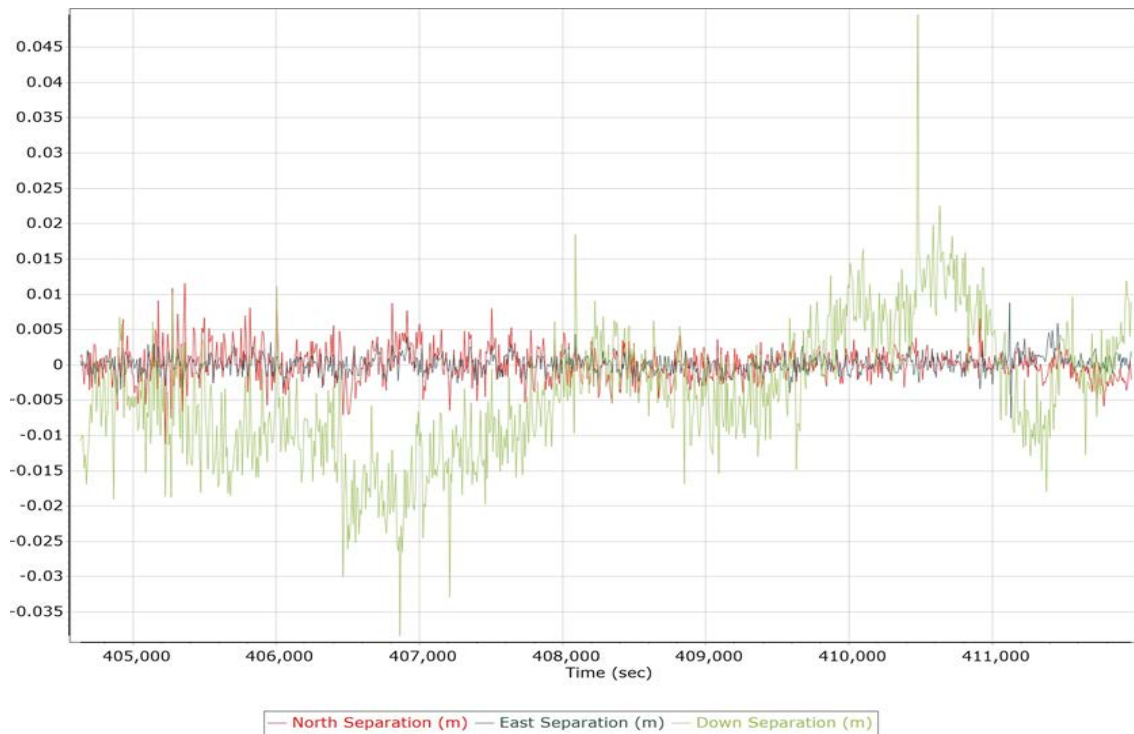
GNSS QC Statistics

Statistics	Min	Max	Mean
Baseline length (km)	0.00	0.00	
Number of GPS SV	7	9	8
Number of GLONASS SV	0	0	0
Number of QZSS SV	0	0	0
Number of BEIDOU SV	0	0	0
Number of GALILEO SV	4	6	5
Total number of SV	11	14	13
PDOP	1.34	2.63	1.73
QC Solution Gaps	0.00	0.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	7390.00	0.00	0.00
Percentage	100.00	0.00	0.00

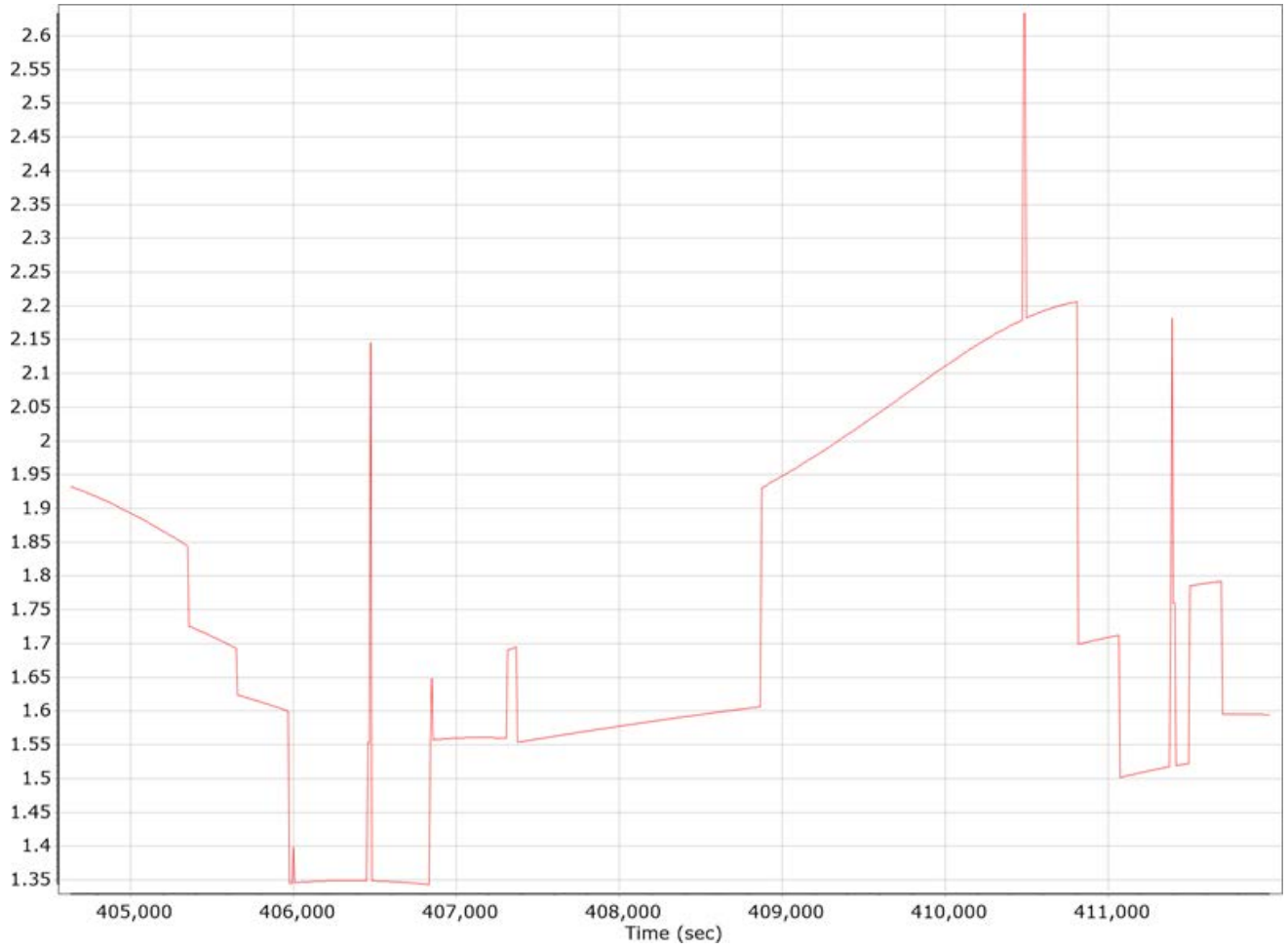
Number of Satellites



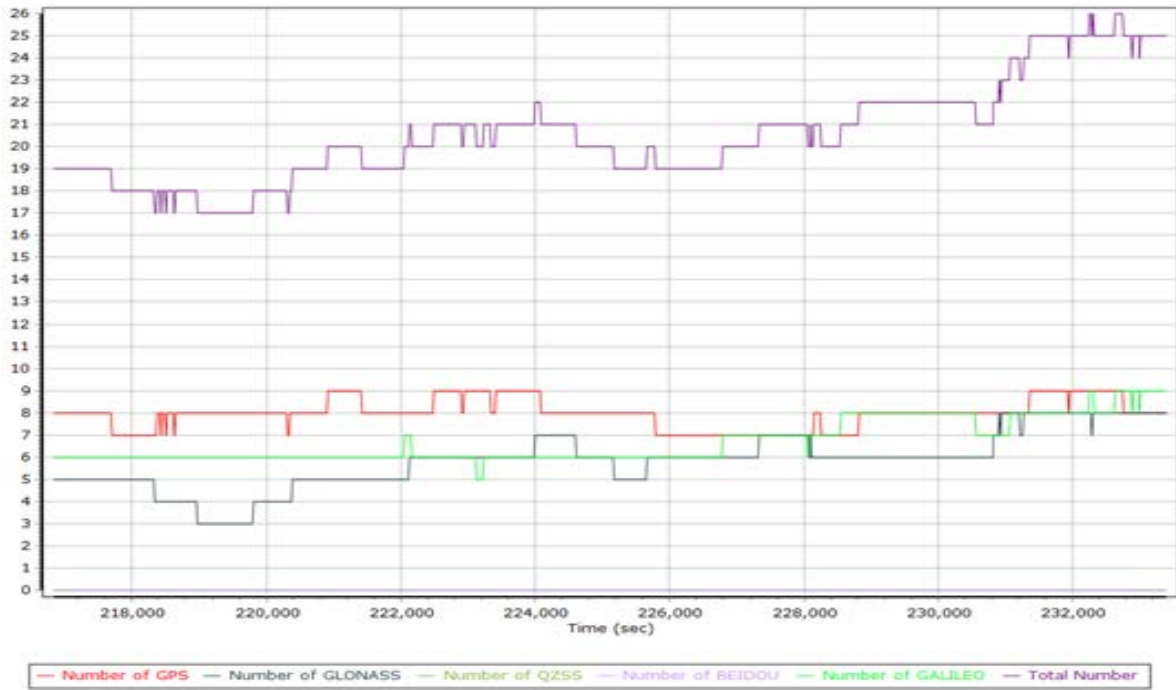
Forward/Reverse Separation



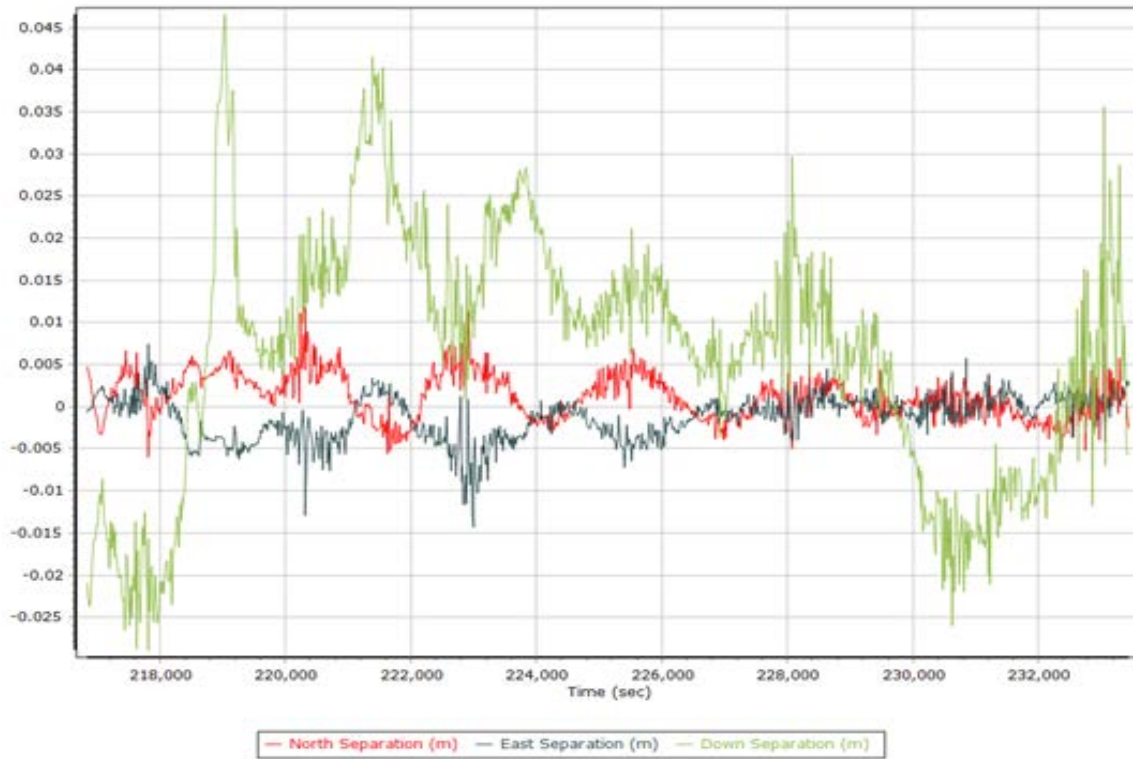
PDOP



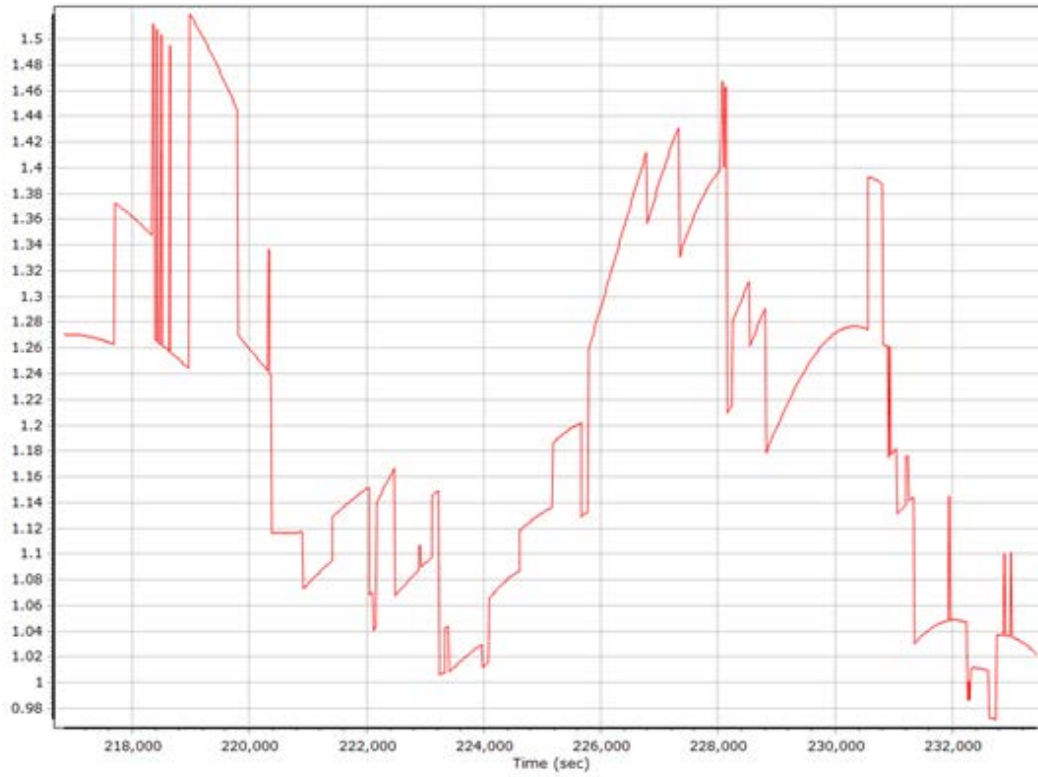
Number of Satellites



Forward/Reverse Separation



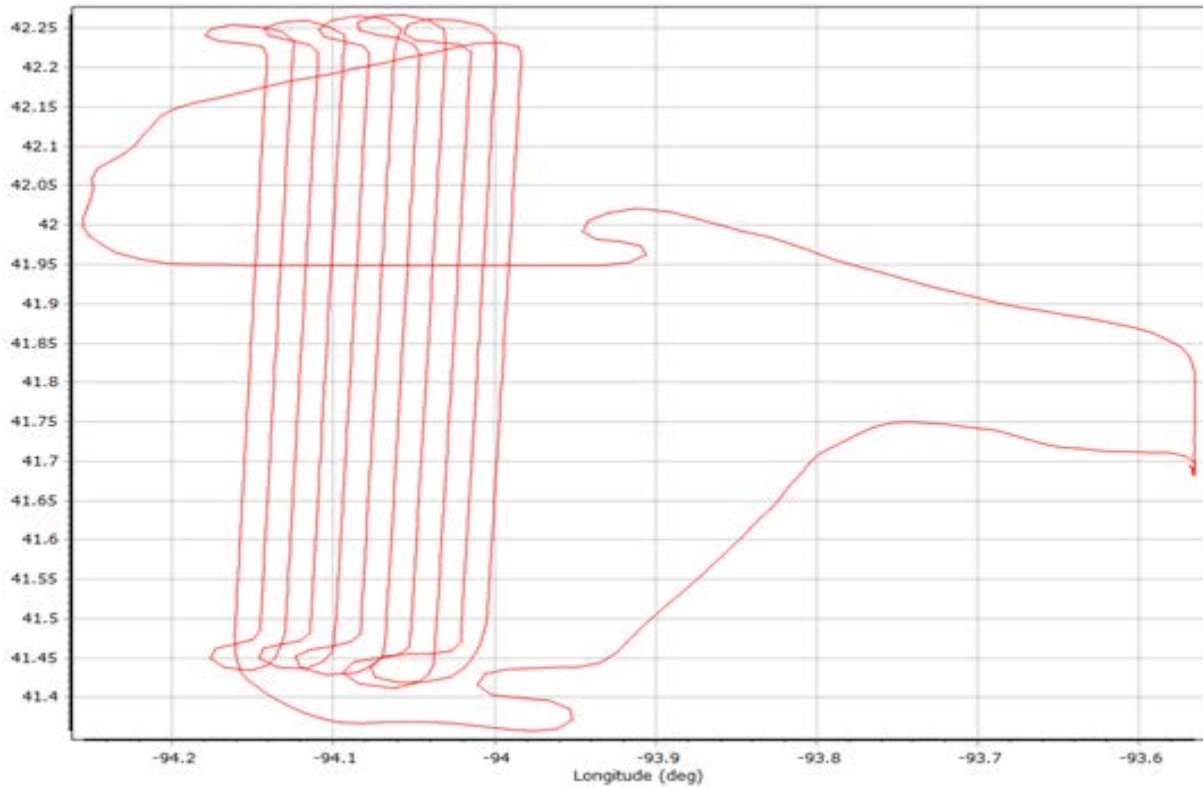
PDOP



200421B.doc QC Report – 04/22/2020

Smoothed Trajectory Information

Top View

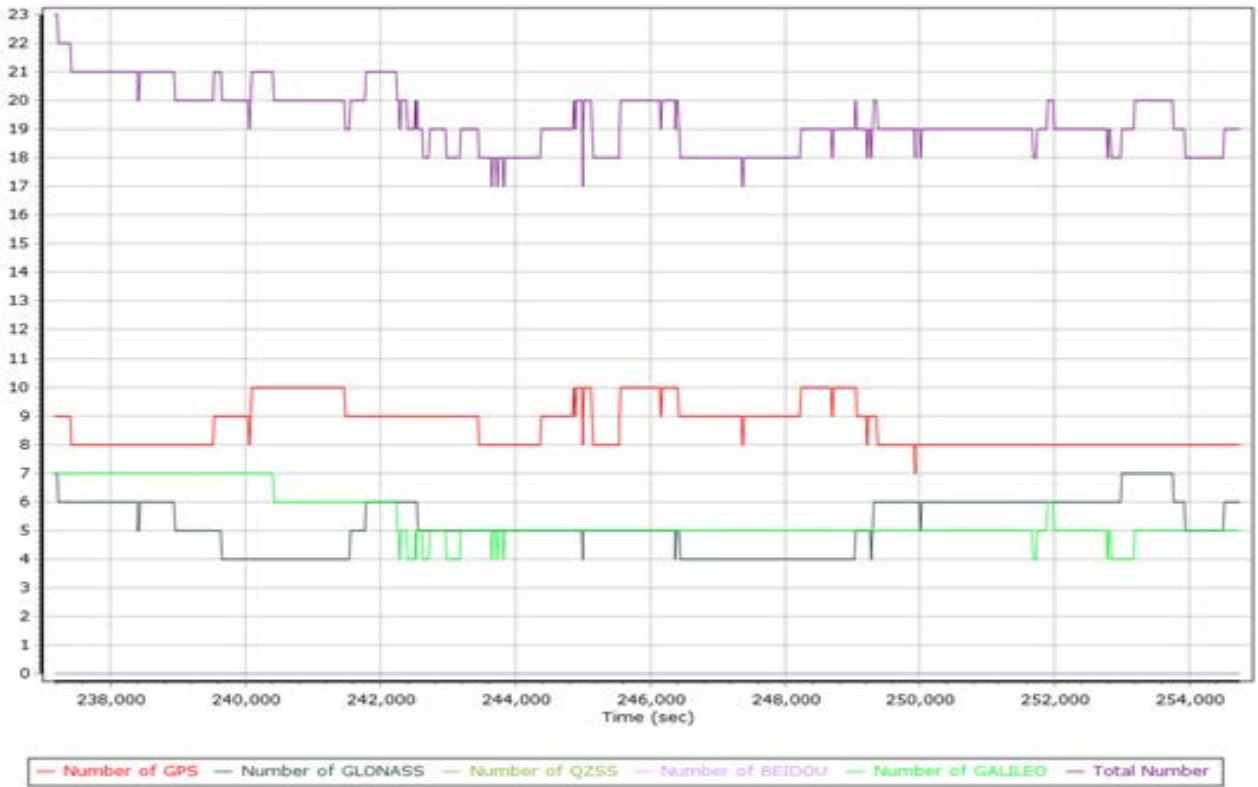


GNSS QC

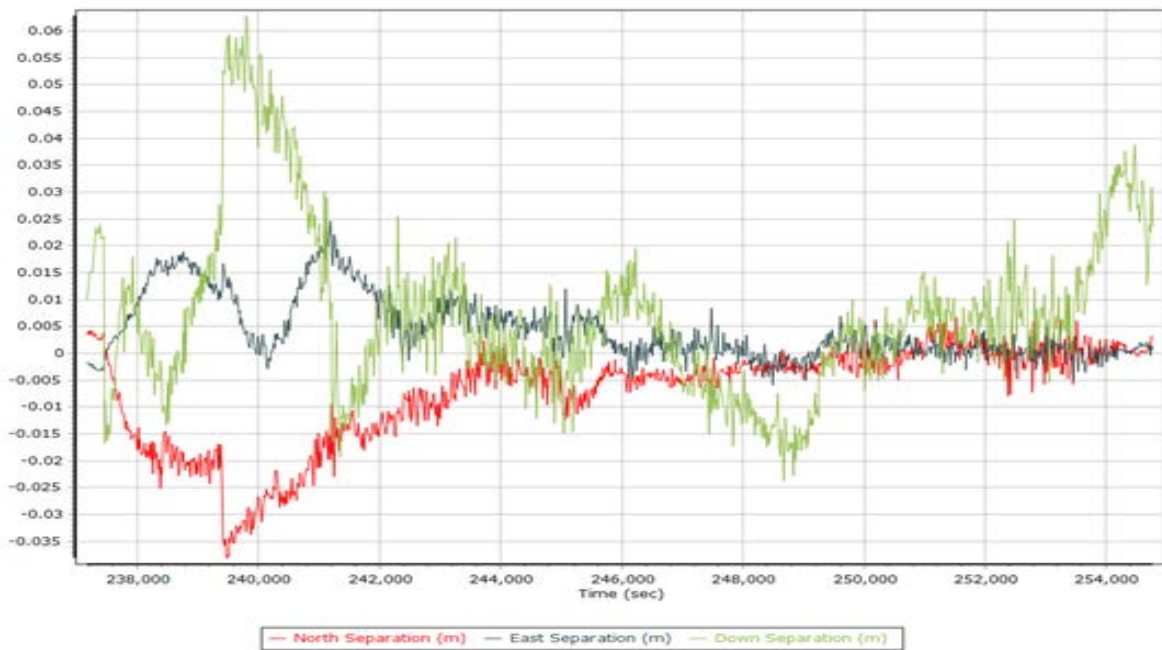
GNSS QC Statistics

Statistics	Min	Max	Mean
Baseline length (km)	3.72	81.56	
Number of GPS SV	7	10	9
Number of GLONASS SV	0	7	5
PDOP	1.00	1.55	1.17
QC Solution Gaps	1.00	1.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	17974.00	0.00	1.00
Percentage	99.99	0.00	0.01

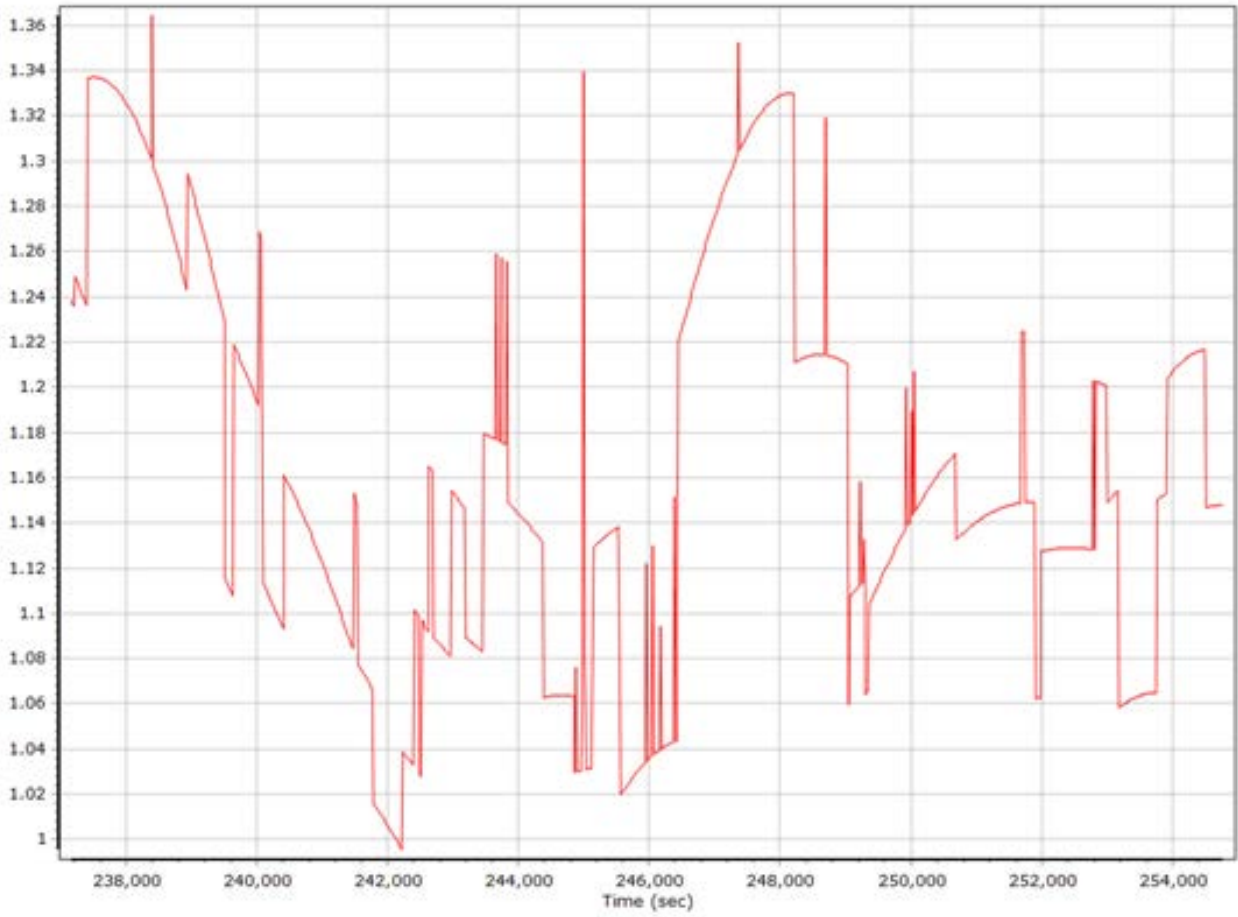
Number of Satellites



Forward/Reverse Separation



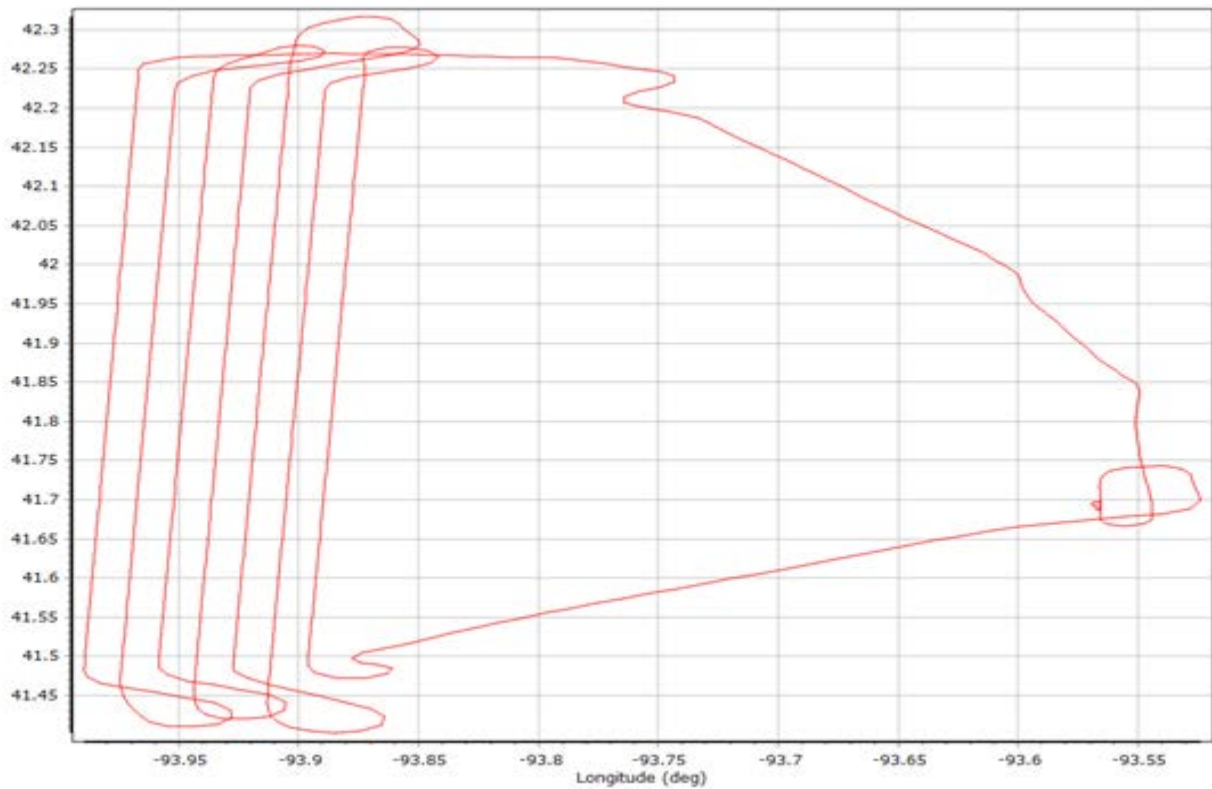
PDOP



200421C.doc QC Report – 04/22/2020

Smoothed Trajectory Information

Top View

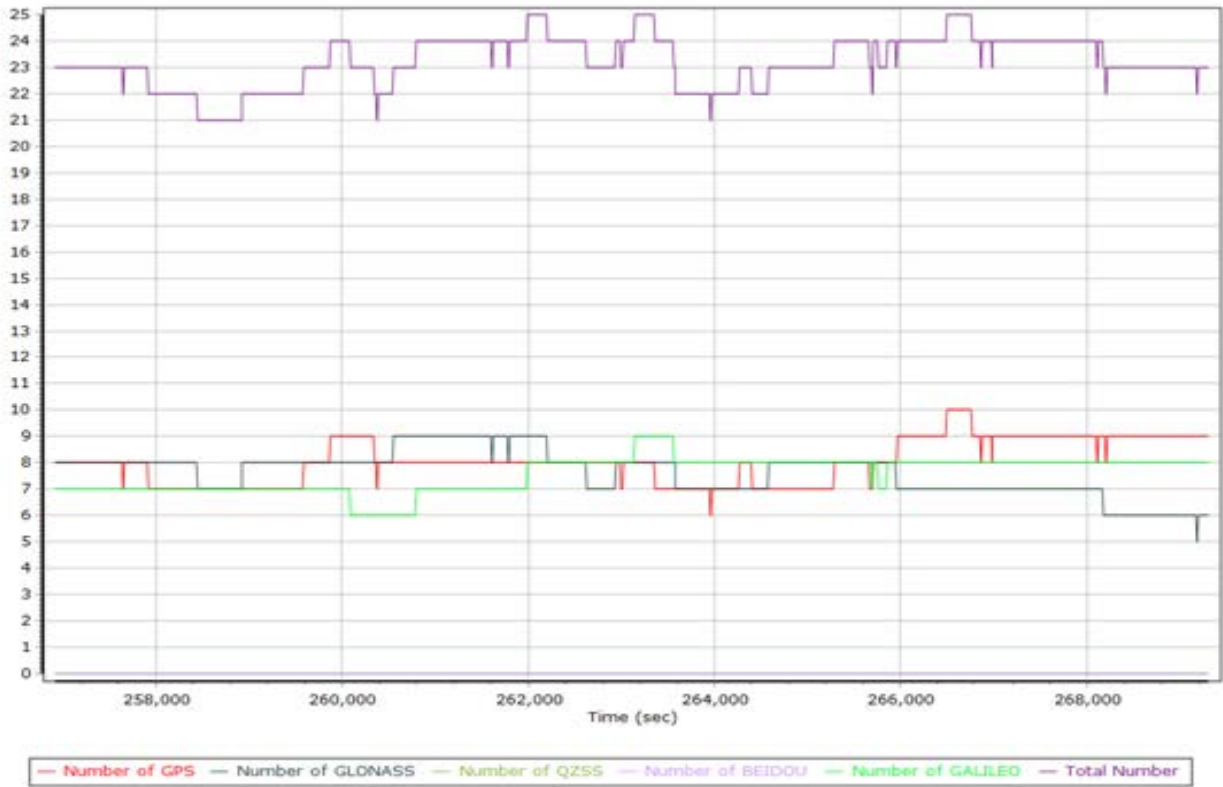


GNSS QC

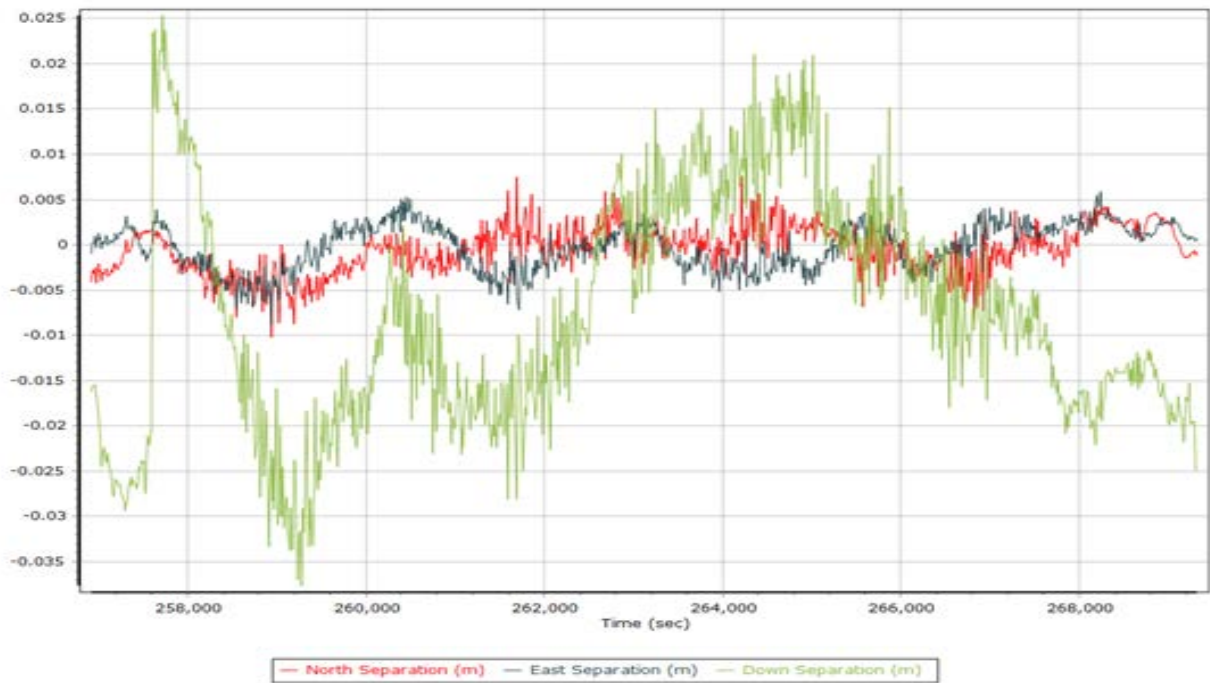
GNSS QC Statistics

Statistics	Min	Max	Mean
Baseline length (km)	1.43	76.79	
Number of GPS SV	6	10	8
Number of GLONASS SV	0	9	8
PDOP	0.99	1.45	1.18
QC Solution Gaps	1.00	1.00	
Solution Type	Fixed	Float	No solution
Epoch (sec)	12570.00	0.00	1.00
Percentage	99.99	0.00	0.01

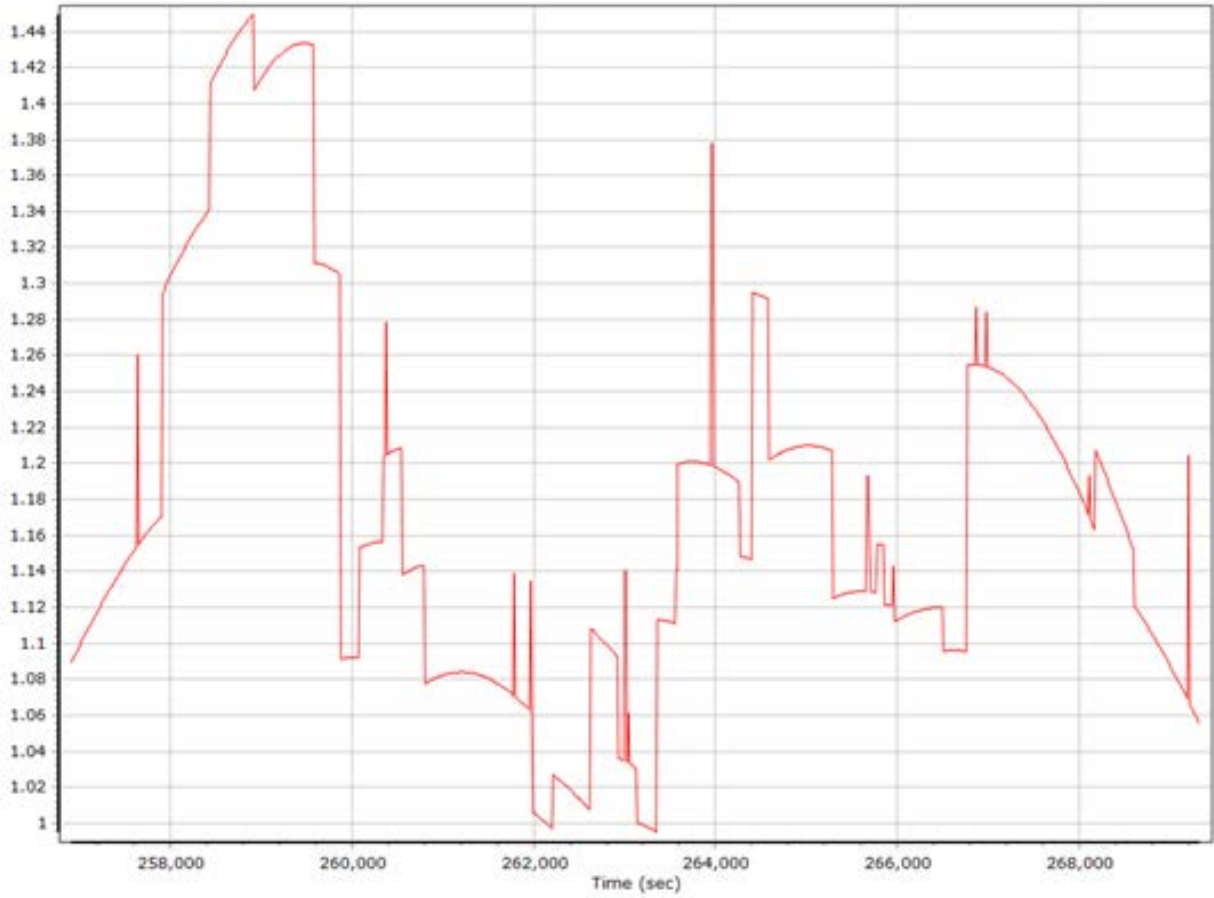
Number of Satellites



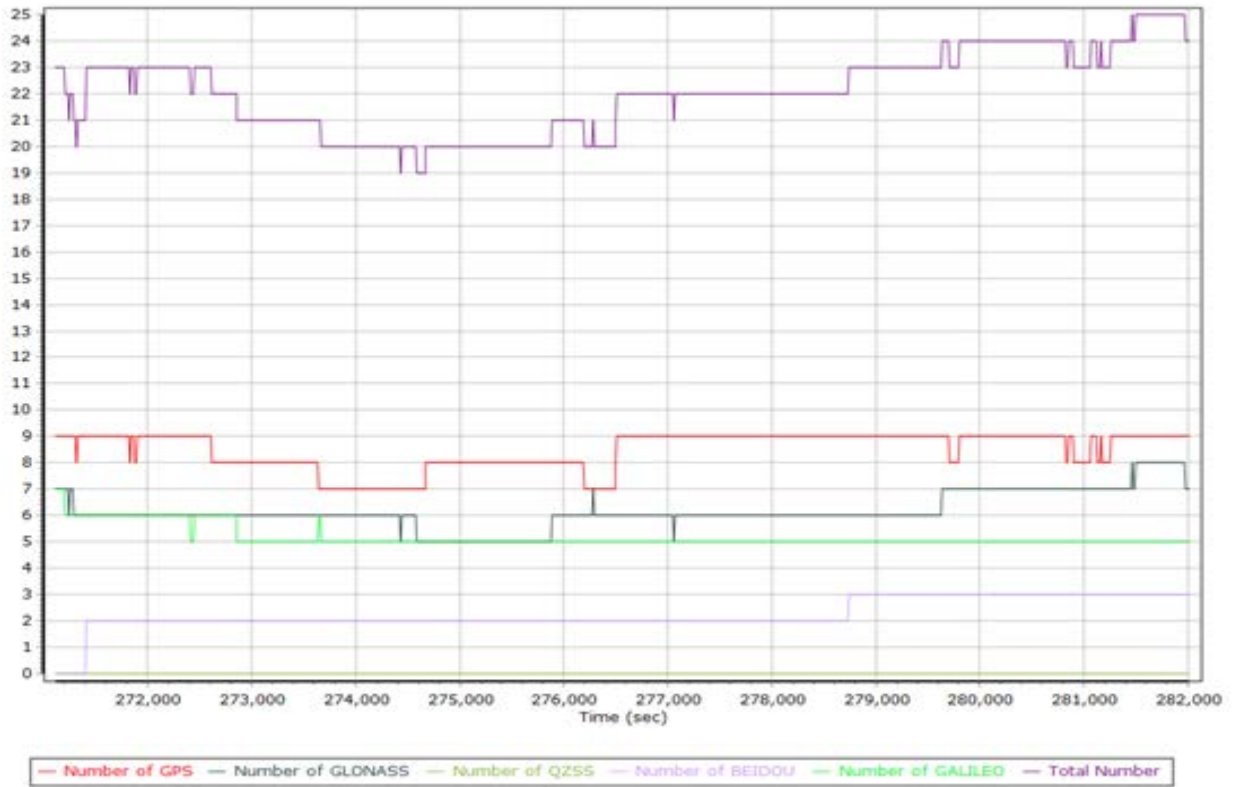
Forward/Reverse Separation



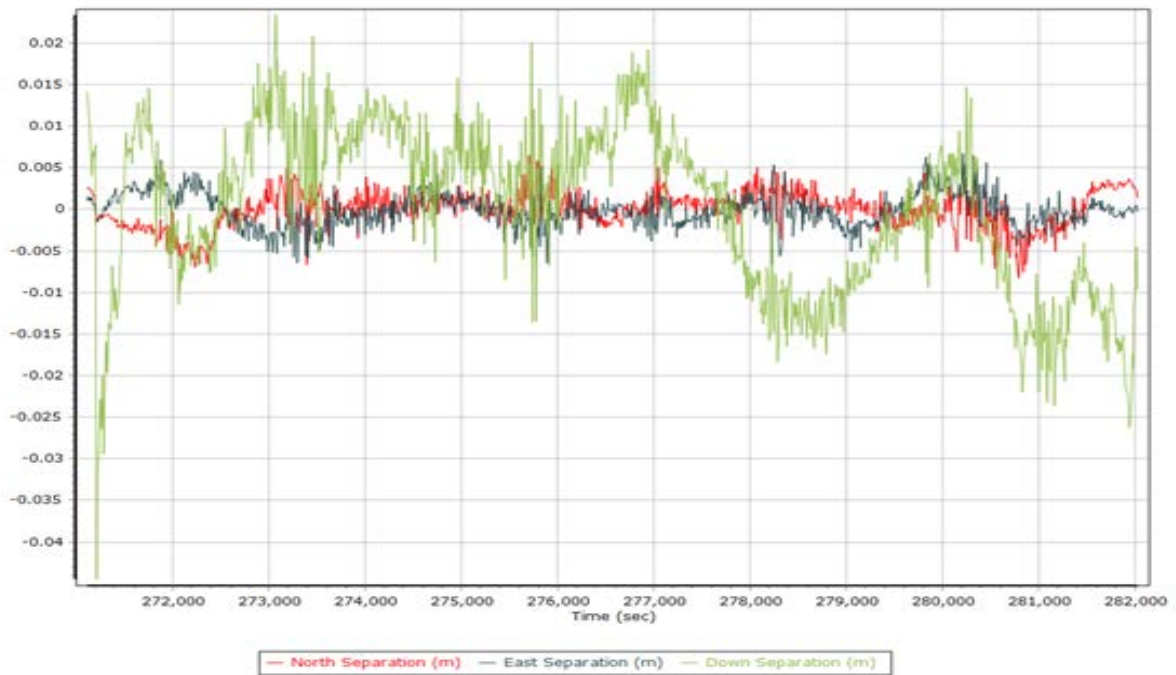
PDOP



Number of Satellites



Forward/Reverse Separation



PDOP

