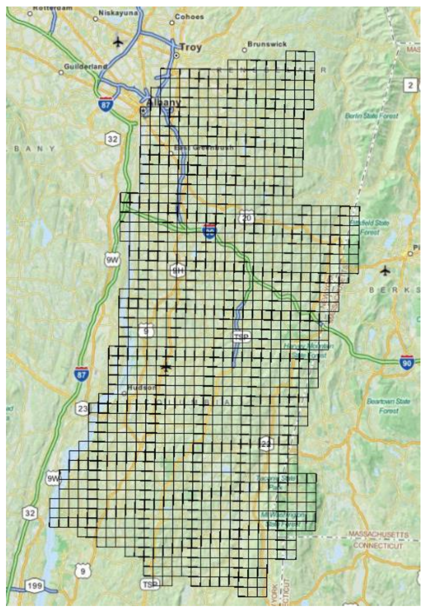
New York State
Airborne LiDAR Acquisition Report

for

New York State Office of Information Technology Services
50 Wolf Road, 3-3
Albany, New York 12232



Project Number 15002-4

Columbia-Rensselaer (AGA Acquisition)

by

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Section 1: Table of Contents

Section 2: Introduction

The New York State Office of Information Technology Services requested delivery of three dimensional classified point cloud and terrain data derived from LiDAR (Light Detection and Ranging) technology for the New York State LiDAR project area covering portions of Columbia and Rensselaer Counties. The data must meet Quality B standards as defined by the State. See Table 1 NYSOOITS LiDAR Quality Specification.

NYSDHSES LiDAR Quality Specification		
Parameter	**Quality A**	**Quality B**
Nominal Point Spacing (m)	1.5	0.7
Vertical Accuracy (cm)	18.5	9.25
Final DEM Spacing (m)	2.0	1.0

Table 1 NYSOOITS LiDAR Quality Specification

The point cloud is to include all returns from the sensor. Points are to be classified to differentiate between bare earth and other return sources using the following classes:

- 1 Processed, but unclassified
- 2 Bare-earth ground
- 7 Noise (low noise)
- 9 Water
- 11 Withheld (if the Withheld bit is not implemented in processing software)
- 12 Overlap
- 17 Bridges
- 18 High Noise

The project area is located in Eastern New York State, to the south and east of Albany, and covers approximately 1,003 square miles. The project area includes portions of the Cities of Albany and Hudson. (See Figure 1 Location of Project Area) The project area measures approximately 25 miles from the eastern boundary to the western boundary and approximately 54 miles from the northern boundary to the southern boundary. (See Figure 2 Project Area)

The acquisition planning task took into account the various terrain changes and land surface configurations within the project area and created an overall plan that was efficient and complete.

Data is to be stored in a non-proprietary format such as LAS and meet the requirements of "U.S. Geological Survey National Geospatial Program LiDAR Guidelines and Base Specifications, Techniques and Methods 11-B4 Version 1.2-Novermber 2014" except as specified by the governing contract.

LiDAR data was processed and projected to UTM Zone 18 North, referenced to the North American Datum 1983 (NAD83) (2011), in units of meters. The vertical datum used for the project is the North American Vertical Datum 1988 (NAVD88) in meters. Orthometric heights are to be determined using Geoid 12A.

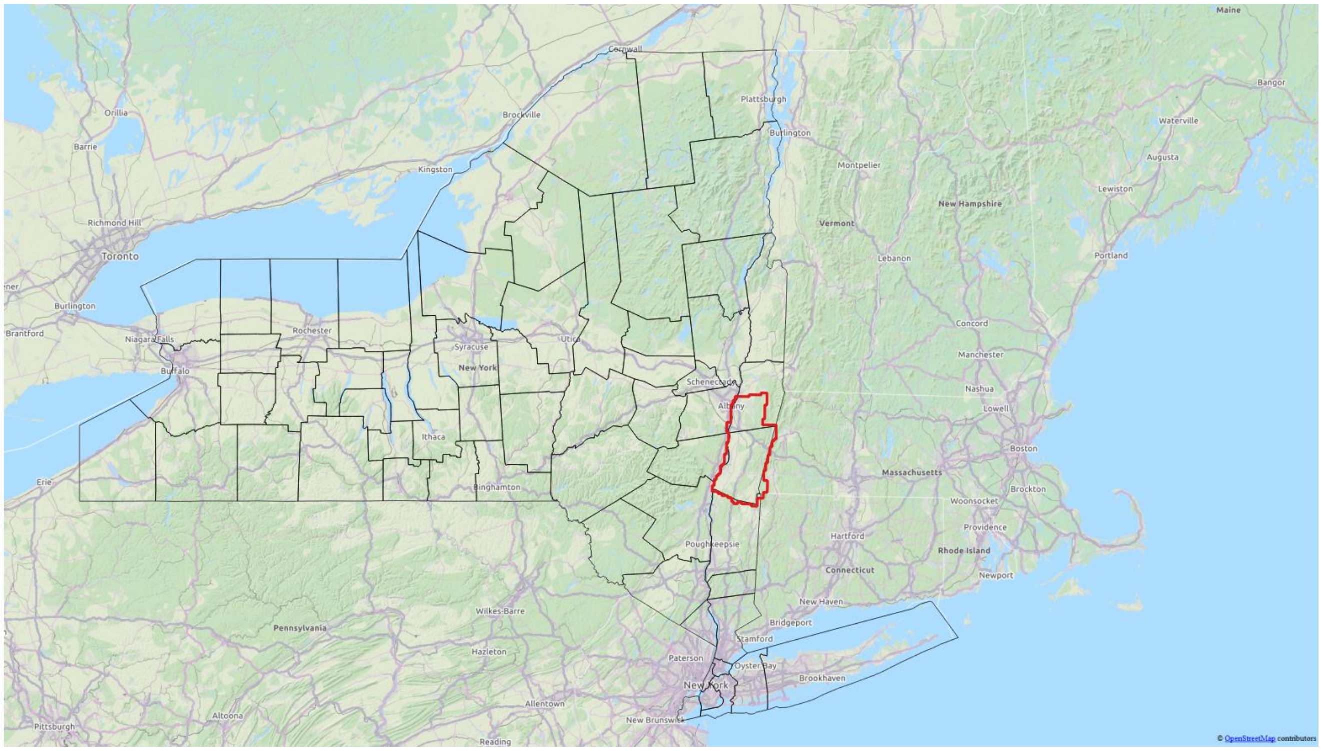


Figure 1: Location of Project Area

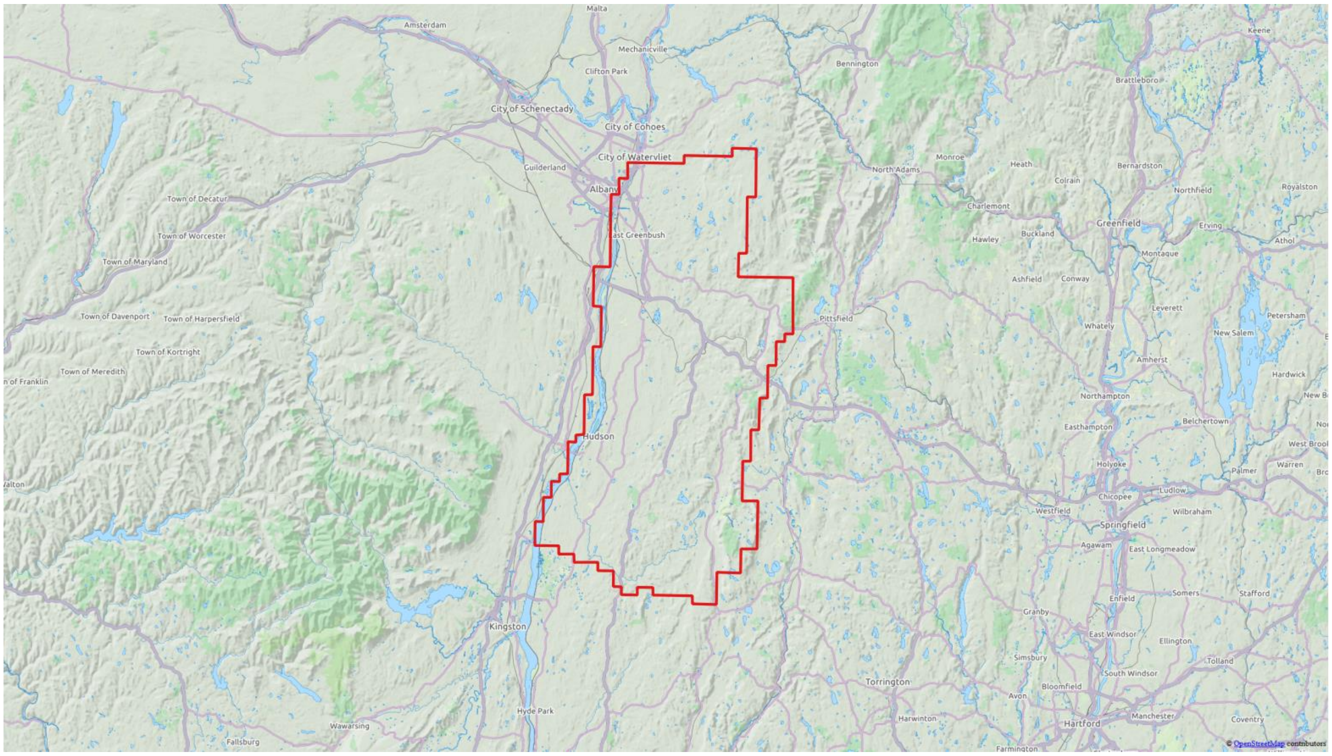


Figure 2: Project Area

Section 3: LiDAR Acquisition

3.1 Acquisition

Airborne LiDAR was acquired with seven flight missions, four other missions were flown, but the data collected was not processed due to issues. The LiDAR coverage is approximately 1,600 square miles or 4,145 square kilometers. A Cessna 206 (N223TC) outfitted with a Riegl Q1560 LiDAR system, owned and operated by Axis GeoAviation, Inc., was deployed to acquire the LiDAR data.

Table 2 represents a list of the features and characteristics for the Riegl Q1560 LiDAR system:

Minimum Range [11)]	50 m
Accuracy [12) 13)]	20 mm
Precision [12) 14)]	20 mm
Laser Pulse Repetition Rate	up to 800 kHz
Effective Measurement Rate	up to 532 kHz @ 60° scan angle
Laser Wavelength	near infrared
Laser Beam Divergence [15)]	≤ 0.25 mrad
Number of Targets per Pulse	digitized waveform processing: unlimited [16)] monitoring data output: first pulse
Scanner Performance	
Scanning Mechanism	rotating polygon mirror
Scan Pattern	parallel scan lines per channel, crossed scan lines between channels
Tilt Angle of Scan Lines	± 14° = 28°
Forward/ Backward Look in Non-Nadir Direction	± 8° at the edges
Scan Angle Range	60° total per channel, resulting in an effective FOV of 58°
Scan Speed	28 - 400 lines/sec[17)] @ laser power level ≥ 50% 20 - 400 lines/sec[18)] @ laser power level < 50%
Angular Step Width Δϑ [19)]	Δϑ ≥ 0.012° @ laser power level ≥ 50% Δϑ ≥ 0.006° @ laser power level < 50%
Angle Measurement Resolution	0.001°

Table 2: Riegl Q1560 Sensor Characteristics

3.2 Acquisition Details

Fifty one (51) passes were completed before snow accumulation in the north east portion of the project resulted in a halt of flying operations until the spring. See Figure 3 for Flight line Orientation and completed lines. The flight plan included cross strip and calibration flight line collection to compensate and correct for the inherent IMU drift associated with all IMU systems. This produced results for standard deviation values of position and height in the 1-2 cm range for each flight mission. Additionally, LiDAR data was only acquired when GPS PDOP was ≤4 and at least 6 satellites were in view.

Weather and atmospheric conditions were monitored and LiDAR missions conducted only when conditions existed that would not degrade sensor ability in the collection of data.

3.3 LiDAR Flightline Orientation

The following graphic represents the alignment of the flight-lines executed to provide coverage.

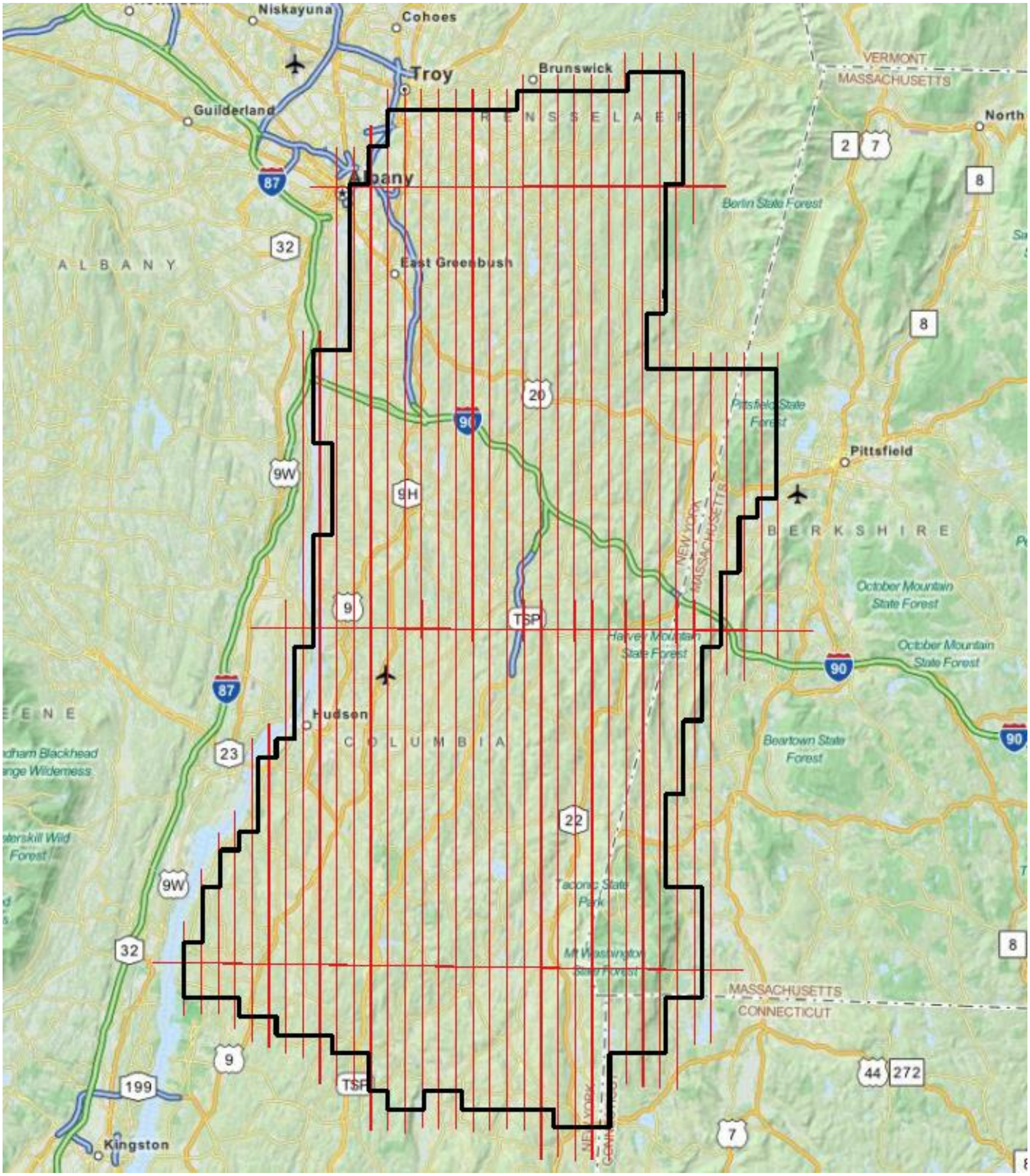


Figure 3: Flight line alignment

3.4 Acquisition Flight Summary

LiDAR acquisition missions were flown between December 20th, 2015 and March 21, 2016. Flights were planned at various flying heights above 1830 m AGL.

Date of Mission(s)	Lift Number	Mission Number	# of Lines Acquired	Mission Time (UTC)	Aircraft Tail Number
Dec. 20, 2015	1	1	6	19:57-20:40	N223TC
Dec. 21, 2015	1	2	9	15:48-18:00	N223TC
Dec. 28, 2015*	1	3	8	18:30-20:35	N223TC
Jan 6, 2016	1	4	9	16:20-18:47	N223TC
Jan 6, 2016*	2	5	6	20:51-22:16	N223TC
Jan 7, 2016	1	6	11	14:22-16:53	N223TC
Jan 7, 2016	2	7	10	19:29-21:42	N223TC
Jan 8, 2016*	1	8	6	15:09-16:07	N223TC
March 5, 2016*	1	9	18	16:08-18:56	N223TC
March 6, 2016*	1	10	9	14:42-16:41	N223TC
March 21, 2016	1	11	3	18:10-18:44	N223TC

Table 3: Acquisition Dates

***Indicates Mission Errors-See Section 3.6 for corrective measures taken**

Flight Logs for each acquisition mission are provided in Section 4 Flight Logs. Calibration lines were run at the beginning or end of the day and a cross strip running east or west was obtained at the end of each successful lift.

3.5 LiDAR System Acquisition Limitations

There are several limiting factors to LiDAR data acquisition which include weather, ground conditions, satellite configuration and equipment malfunctions.

During a LiDAR acquisition mission, there can be no clouds below the aircraft, rain, fog or excessive humidity between the sensor and the ground. Excessive, heavy winds, engaging the aircraft perpendicular to the line of flight, can result in "crab" of the aircraft which results in "gaps" or "slivers' in the data between flight lines. Ground conditions which include pools of standing water and ditches filled with moving water affect the accuracy of LiDAR returns. The number of satellites "visible" to the aircraft during acquisition is an important factor and a poor Global Positioning System (GPS) configuration will contribute to less than desired accuracy. Therefore, satellite configuration, measured by PDOP (Positional Dilution of Precision) is checked each morning to ensure acquisition occurs during the most favorable geometric configuration of the satellites. Finally, despite the best maintenance routines and practices, systems malfunction and fail. Operator awareness is key to identifying the exact moment when a system malfunctions. This enables the crew to stop acquisition and correct the issue before continuing. At times, lines acquired with anomalies will need to be re-acquired.

3.6 Acquisition Issues and Resolutions

Unfortunately, there were missions that experienced unexpected equipment malfunctions and weather delays. The following identifies the missions, the type of issue and the actions taken to overcome the problem. Axis's QC procedure is to manually inspect the data to validate coverage. During this process gaps were identified. These data voids were then ingested into a new flight plan. Once the re-flight plan was generated it was sent out to the field crew for collection. The following identifies the missions, the type of issue and the actions taken to overcome the problem:

- December 28th, 2015, condensation formed on the lens for both channels for the sensor resulting in missing returns near nadir for all swaths flown. This area was reflown on March 6, 2016. No data from the December 28th flight will be used for this project.

- January 8th, 2016, clouds were observed at the mid to end points of the flight lines and the decision was made to fly these lines half length. These lines were reflown at the full length on March 5tgh, 2016 and the data from the 8th was not used.

- March 5th, 2016, a failure of the Q1560 software on the on-board laptop computer resulted in the primary navigation record to no longer be viable. However, the navigation data was also recorded in the Q1560 IMU and was recovered successfully. Lines 11,12,25,26 and 27 were not included with the deliveries to the state as new software resolved the issues with the original lines.

- March 6th, 2016, clouds moved in to the area during the end of the lift and were observed in lines 46 and 47. The mission on March 21st was used to supplement the clouded out areas.

- All flights – MTA zone issues were present at nadir for the majority of the lines flow. New software from Riegl resolved this issue however this required reprocessing of the raw LiDAR data.

3.7 LiDAR System Acquisition Parameters

LiDAR acquisition was planned to meet the following specifications:

Item	Parameter
System	Riegl Q1560
Nominal Pulse Spacing (m)	0.77
Nominal Pulse Density (pls/m²)	2.6
Nominal Flight Height (MSL meters)	1830
Nominal Flight Speed (kts)	135-150
Pass Heading (degree)	180,360
Sensor Scan Angle (degree)	58.52
Scan Frequency (Hz)	84.3
Pulse Rate of Scanner (kHz)	625khz
Line Spacing (m)	.87
Pulse Duration of Scanner (ns)	5
Pulse Width of Scanner (m)	0.60
Central Wavelength of Sensor Laser	1064
Sensor Operated with Multiple Pulses	Yes

Beam Divergence (mrad)	0.25
Nominal Swath Width (m)	2350
Nominal Swath Overlap (%)	30
Scan Pattern	Parallel scan lines per channel, crossed scan lines between channels

Table 4 System Parameters for LiDAR Acquisition

3.8 CORS Reference Stations

The presence of a strong CORS (Continuously Operating Reference Station) and base station configuration allowed for the LiDAR to be acquired with Global Navigation Satellite System (GNSS) techniques and procedures. Table 5 and Figure 4 below contains a listing and graphic of the CORS and base stations that were used during the processing, their calculated latitude, longitude and ellipsoid height. Minor variations in position, due to changes in satellite availability, geometry and varying availability of the CORS stations, were observed, and are of millimeter level magnitude. These variations had no impact on system positioning and are unavoidable.

NAME	LATITUDE (N)	LONGITUDE (W)	ELEVATION (M)
CTBR	41°29'49.89730"	73°25'05.69190"	52.088
CTEG	41°55'24.38063"	72°41'55.89829"	29.060
CTWI	41°53'51.94081"	73°04'10.98639"	190.864
HAMP	42°19'03.90652"	72°38'22.42055"	41.137
HDF5	43°16'14.97538"	73°32'20.84195"	41.842
HDF6	43°16'15.85530"	73°32'20.73715"	42.635
MABN	42°40'12.02528"	72°32'28.66150"	93.682
MASH	42°08'25.78744"	73°21'51.08187"	174.371
NYCS	42°40'02.87006"	74°29'10.96796"	269.475
NYFV	42°56'21.03162"	74°21'12.03405"	103.483
NYHS	42°15'08.39284"	73°45'27.17939"	20.848
NYKT	41°56'12.97153"	74°01'52.21844"	30.345
NYLC	41°28'51.90907"	73°39'05.38715"	200.850
NYNB	41°29'42.83873"	74°01'31.99182"	21.943
NYST	43°03'41.76916"	73°48'15.02975"	68.431
VTBE	42°52'57.06346"	73°11'59.66696"	182.697

Table 5: GPS Reference Station Coordinates

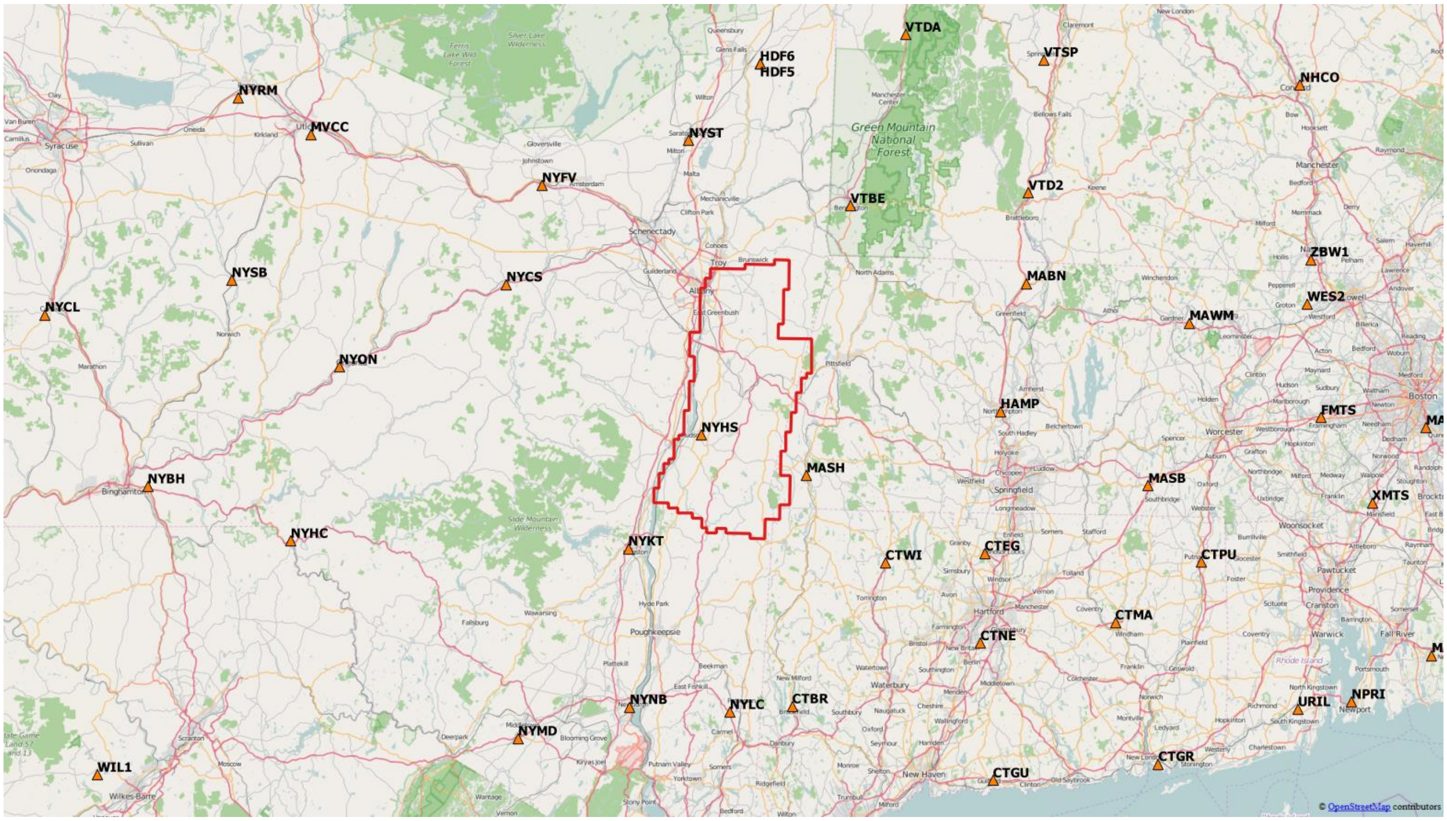


Figure 4: GPS Reference Stations

3.9 Airborne GPS Kinematic and Processing

The Differential GPS unit in the aircraft collected positions at 2Hz. Airborne GPS data was processed using the POS Pac MMS v.7.1 software. Flights were flown with a minimum of 6 satellites in view (10° above the horizon) and with a PDOP of ≤3 when laser online. Distances from base station to aircraft were kept to a maximum of 50km.

For all flights, the GPS data can be classified as good, with GPS residuals of 3cm average or better but none larger than 15cm being recorded when laser online.

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

AXIS makes use of the latest in Airborne-GPS (AGPS) and Inertial Measurement Unit (IMU) systems to determine the precise three-dimensional trajectory of its aircraft in flight. These state of the art sensor systems use the global navigation satellite system (GNSS), pitch-roll-yaw sensors, accelerometers and gyrocompasses to measure and record every change in the attitude, speed and direction of the aircraft during its data collection mission.

These measurements are linked together according to a precise time baseline that is collected as part of the GNSS message stream, allowing corrections for attitude variations to be known at the exact time the digital sensor records an image.

AGPS/IMU Processing

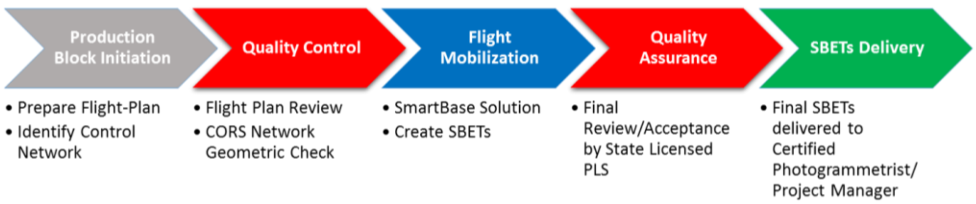
Axis uses Applanix POS Pac MMS v.7.1 to process Airborne GNSS/IMU datasets and compute Smoothed Best Estimated

Trajectory (SBET) files for our LiDAR and Photogrammetry missions. This state-of-the-art GNSS/IMU processing technology uses a combination of GNSS data collected onboard the aerial platform during the mission, twenty-four (24) hours of satellite geometry and ephemeris data from the National CORS network that surrounds the flight mission footprint, and data from the onboard IMU that tracks the heading, acceleration/deceleration, pitch, roll and yaw of the aircraft during the flight.

The processing software uses all of the data inputs to determine the precise three dimensional trajectory of the aircraft during the mission. The process includes operator managed and software driven QA/QC checks, and a professional land surveyor monitors the entire process, focusing on the geometry and spacing of the CORS network control points around the project area, data integrity and software are properly configured to account for the system hardware locations in relation to the IMU reference location.

The workflow for each production block will follow a structured path, modified as needed to make adjustments for buy ups or other optional tasks:

SBET Processing Workflow Chart



First, a flight plan and project are reviewed prior to mobilization to confirm CORS network geometry, station availability and data observation rates. Once approved for flight, the mission is executed by the flight operations team within the parameters of the flight plan, STATE requirements, applicable mapping guidelines, industry standards and our own in-house protocols. These requirements include collection of data on the ground before and after the flight, proper manipulation of the IMU during flight to avoid heading drift and careful navigation of the aircraft to avoid loss of satellite lock during the entire mission such as unduly steep banking turns, flight line deviations, or operation during turbulent conditions. Upon return to the airfield, the IMU and other data are downloaded and posted to our computer network for post processing. Post processing involves assembling flight data from the onboard GNSS and IMU, downloaded CORS vector data for a time balanced observation period centered on the takeoff to touchdown flight window of the data collection mission, published and vetted positional data for the CORS control stations, broadcast and precise ephemeris data documenting the projected and actual positions of the satellites during the mission.

GNSS Base Stations for the SmartBase processing are selected based on conformance with requirements of the software, including distance from the center of the flight mission, network station spacing, observation rates of the network base stations, and availability of both broadcast and precise ephemeris data for the satellites included in the GNSS dataset.

All of these datasets are linked to the project database, checked for accuracy and readied for processing. The software uses a proprietary process to compute GNSS based forward and backward trajectories, IMU based forward and backward trajectories based on accelerometer and gyrocompass data, pitch, roll and yaw sensors, and then combine all of the independent solutions into a precisely computed string of plane and sensor positions during the mission. Due to the speed of travel of the aircraft, positioning is determined at the rate of fifty (50) times per second, based on actual observed data from equipment operating at that recording interval, not from interpolated data from equipment operating at slower data rates. This method yields truer positioning from direct observation rather than estimated positions between true fixes. The IMU system operates at very high speed, typically at two hundred measurements (200) per second, which allows the system to maintain a precise track on changes in aircraft attitude during acquisition. The GNSS data is combined with the IMU data to bridge the separations in position fixes and refine the precision of the planes trajectory down to nearly centimeter level three-dimensional precision.

The software downloads GNSS data from the CORS stations around the project area, and performs a dataset integrity check of the GNSS RINEX files to find errors in the data such as gaps, incompatible collection rates or missing antenna information. The Applanix SmartBase software includes a SmartBase Quality Check module that performs an extremely accurate network analysis and adjustment on all the base-lines and reference stations in the network. The Quality Check module uses 18 to 24 hours of reference station data to accurately compute the base-lines between one station set as the control and the rest of the stations. The long duration of data is used to ensure that all multipath variations due to changes in satellite positions are averaged out as much as possible.

The output of the Quality Check module is a table indicating the estimated error for each set of reference station coordinates. If the estimated error is larger than 5 cm, the coordinates are flagged as unacceptable, indicating the input coordinate cannot be trusted. The user has the option of using the adjusted coordinates instead of the input coordinates, or not using the reference station at all in the Applanix SmartBase computations.

Additional quality checks are made on the individual reference station observation files before the Applanix SmartBase is computed. The final result of this process ensures the integrity of the computed reference station data and coordinates are known and trusted before the airborne data set is even processed.

Once the network framework is approved, the software establishes a Virtual Reference Station in close proximity to the project area. This technology is known as the Applanix SmartBase Solution, and allows the software to minimize vector length from the primary base station to the aircraft, minimizing the effect of atmospheric and other systematic errors. Once the Virtual Reference Station is established, forward and backward processing of the GNSS and IMU datasets is executed to determine the exact path, known as the Smoothed Best Estimated Trajectory (SBET), of the airborne platform and its associated equipment.

ABGPS/IMU QA Review & Analysis

Once the SBET file is created, reports and output files of the data are automatically generated for review by the system operator. The primary analysis tool are the charts showing differences in values for aircraft roll-pitch and yaw values, positional quality information, satellite health and geometry, signal to noise ratios, and variances in direction or velocity vectors between forward and backward processed data that indicate some environmental variable has affected the data. The primary means of mitigating these errors is proper positioning support by the surrounding base station network, management of flight path length to eliminate IMU drift, and flight procedures that avoid interruption of satellite data reception.

ABGPS/IMU Data Finalization and Preparation for LiDAR Production

The SBET QA/QC review is finalized by independent assessment of the output charts and reports showing deviations between processing directions, spikes in aircraft attitude variations and quality of GNSS data and positional fixes. IMU data is put to further use in the next step of the data processing workflow, when Exterior Orientations of the digital sensor systems are determined and corrections are applied to the images based on changes in aircraft orientation at the time of exposure.

GPS processing results for each lift are included in Section5: GPS Processing.

Section 4: Flight Logs

LiDAR and Imagery Flight Report

Project(s): 15002-4 NYS Col-Rens

Pilot: Jerry Lewis	Project Number(s): 15002-4 Col-Rens
Operator: Jameson Harrington	Project Name(s): New York State Col-Rens LiDAR (Counties of Columbia & Rensselaer)
Aircraft: Cessna 206 N223TC	Block Number:

LiDAR Unit: Q1560	Scan Rate: 153	Camera Unit: Phase One 80	Date: 12-20-15
MTA Zones: 5	Ground Speed Start (kts): 149	View Angle (deg): 58.52	Sun Angle: N/A
PRR (kHz): 625	Altitude(feet AMT): 6800	Endlap (%): N/A	Lens:
Laser Power (%): 100	Point Spacing (m): .77	Side-Lap(%): N/A	Point Density (ppms): 2.6 ave

Direction	Line #	From	To	Start Time	Altitude(AMSL)	Remarks	Clouds	Turbulance
s	1			19:57	6100'	Southern Half; West Side	•	
n	2			20:03	6140'		•	
s	3			20:11	6140'		•	
n	4			20:19	6180'		•	
s	5			20:30	6180'		•	
n	6			20:40	6180'		•	

Cloud Cover Codes: ⊕ = High Thin ●= Solid Overcast O = Clear

Remarks:

LiDAR and Imagery Flight Report	Project(s): 15002-4 NYS Col-Rens
Pilot: Jerry Lewis	Project Number(s): 15002-4 Col-Rens
Operator: Jameson Harrington	Project Name(s): New York State Col-Rens LiDAR (Counties of Columbia & Rensselaer)
Aircraft: Cessna 206 N223TC	Block Number:

LiDAR Unit: Q1560	Scan Rate: 153	Camera Unit: Phase One 80	Date: 12-21-15
MTA Zones: 5	Ground Speed Start (kts): 149	View Angle (deg): 58.52	Sun Angle: N/A
PRR (kHz): 625	Altitude(feet AMT): 6800	Endlap (%): N/A	Lens:
Laser Power (%): 100	Point Spacing (m): .77	Side-Lap(%): N/A	Point Density (ppms): 2.6 ave

Direction	Line #	From	To	Start Time	Altitude(AMSL)	Remarks	Clouds	Turbulance
s	7			15:48	6220'		•	
n	8			16:02	6300'		•	
s	9			16:14	6360'		•	
n	10			16:29	6440'		•	
s	11			16:42	6440'		•	
n	12			16:58	6480'		•	
s	13			17:21	6520'		•	
n	14			17:36	6600'		•	
w	64			18:00	6600'		•	

Cloud Cover Codes	⊕ = High Thin	●= Solid Overcast	O = Clear

Remarks:

LiDAR and Imagery Flight Report — Project(s): 15002-4 NYS Col-Rens

Pilot: Jerry Lewis	Project Number(s): 15002-4 Col-Rens
Operator: Jameson Harrington	Project Name(s): New York State Col-Rens LiDAR (Counties of Columbia & Rensselaer)
Aircraft: Cessna 206 N223TC	Block Number:

LiDAR Unit: Q1560	Scan Rate: 153	Camera Unit: Phase One 80	Date: 12-28-15
MTA Zones: 5	Ground Speed Start (kts): 149	View Angle (deg): 58.52	Sun Angle: N/A
PRR (kHz): 625	Altitude(feet AMT): 6800	Endlap (%): N/A	Lens:
Laser Power (%): 100	Point Spacing (m): .77	Side-Lap(%): N/A	Point Density (ppms): 2.6 ave

Direction	Line #	From	To	Start Time	Altitude(AMSL)	Remarks	Clouds	Turbulance
S	43			18:30	6480'		•	
N	41			18:47	6340'		•	
S	42			19:06	6440'		•	
N	44			19:23	6500'		•	
S	45			19:41	6520'		•	
N	46			19:56	6620'		•	
S	47			20:12	6640'		•	
W	NA			20:35	6640'	Cross Strip	•	

Cloud Cover Codes: ⊕ = High Thin ●= Solid Overcast O = Clear

Remarks:

LiDAR and Imagery Flight Report

Project(s): 15002-4 NYS Col-Rens

Pilot: Jerry Lewis	Project Number(s): 15002-4 Col-Rens
Operator: Jameson Harrington	Project Name(s): New York State Col-Rens LiDAR (Counties of Columbia & Rensselaer)
Aircraft: Cessna 206 N223TC	Block Number:

LiDAR Unit: Q1560	Scan Rate: 153	Camera Unit: Phase One 80	Date: 1-6-16 Morning
MTA Zones: 5	Ground Speed Start (kts): 149	View Angle (deg): 58.52	Sun Angle: N/A
PRR (kHz): 625	Altitude(feet AMT): 6800	Endlap (%): N/A	Lens:
Laser Power (%): 100	Point Spacing (m): .77	Side-Lap(%): N/A	Point Density (ppms): 2.6 ave

Direction	Line #	From	To	Start Time	Altitude(AMSL)	Remarks	Clouds	Turbulance
s	15			16:20	6600'		SCT	
n	16			16:41	6600'		SCT	
s	17			16:59	6620'		SCT	
n	18			17:18	6680'		SCT	
s	19			17:34	6680'		SCT	
n	20			17:50	6740'		SCT	
s	21			18:06	6800'		SCT	
n	22			18:25	6860'		SCT	
e	NA			18:41	6860'	Cross Strip	SCT	

Cloud Cover Codes: ⊕ = High Thin ●= Solid Overcast O = Clear

Remarks:

LiDAR and Imagery Flight Report

Project(s): 15002-4 NYS Col-Rens

Pilot: James Mancini		Project Number(s): 15002-4 Col-Rens	
Operator: Jameson Harrington		Project Name(s): New York State Col-Rens LiDAR (Counties of Columbia & Rensselaer)	
Aircraft: Cessna 206 N223TC		Block Number:	
LiDAR Unit: Q1560	Scan Rate: 153	Camera Unit: Phase One 80	Date: 1-6-16 Afternoon
MTA Zones: 5	Ground Speed Start (kts): 149	View Angle (deg): 58.52	Sun Angle: N/A
PRR (kHz): 625	Altitude(feet AMT): 6800	Endlap (%): N/A	Lens:
Laser Power (%): 100	Point Spacing (m): .77	Side-Lap(%): N/A	Point Density (ppms): 2.6 ave

Direction	Line #	From	To	Start Time	Altitude(AMSL)	Remarks	Clouds	Turbulance
S	23			20:51	6900'		SCT	
N	24			21:07	7000'		SCT	
S	25			21:24	6960'		SCT	
N	26			21:41	7280'		SCT	
S	27			21:58	7440'	RiAcquire Crash, Data and NAV Ok	SCT	
W	64			22:16	7440'	Cross Strip	SCT	

Cloud Cover Codes | ⊕ = High Thin | ●= Solid Overcast | O = Clear

Remarks:

LiDAR and Imagery Flight Report | **Project(s): 15002-4 NYS Col-Rens**

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Operator: Jameson Harrington	Project Name(s): New York State Col-Rens LiDAR (Counties of Columbia & Rensselaer)
Aircraft: Cessna 206 N223TC	Block Number:

LiDAR Unit: Q1560	Scan Rate: 153	Camera Unit: Phase One 80	Date: 1-7-Morning
MTA Zones: 5	Ground Speed Start (kts): 149	View Angle (deg): 58.52	Sun Angle: N/A
PRR (kHz): 625	Altitude(feet AMT): 6800	Endlap (%): N/A	Lens:
Laser Power (%): 100	Point Spacing (m): .77	Side-Lap(%): N/A	Point Density (ppms): 2.6 ave

Direction	Line #	From	To	Start Time	Altitude(AMSL)	Remarks	Clouds	Turbulance
S	29			14:22	7580		BKN	
N	28			14:36	7560'		BKN	
S	31			14:53	7640'		BKN	
N	30			15:07	7480'		BKN	
S	32			15:23	7540'		BKN	
N	64			15:37	7540'	Cross Strip	BKN	
S	33			15:52	6260'	Southern Half; East Side	BKN	
N	34			16:10	6160'	Northern Half; West Side	BKN	
S	35			16:20	6140'		BKN	
N	36			16:35	6180'		BKN	
E	66			16:53	6180'	Cross Strip	BKN	

Cloud Cover Codes | ⊕ = High Thin | ●= Solid Overcast | O = Clear

Remarks:

LiDAR and Imagery Flight Report		Project(s): 15002-4 NYS Col-Rens	
Pilot: James Mancini		Project Number(s): 15002-4 Col-Rens	
Operator: Jameson Harrington		Project Name(s): New York State Col-Rens LiDAR (Counties of Columbia & Rensselaer)	
Aircraft: Cessna 206 N223TC		Block Number:	
LiDAR Unit: Q1560	Scan Rate: 153	Camera Unit: Phase One 80	Date: 1-7-16 Afternoon
MTA Zones: 5	Ground Speed Start (kts): 149	View Angle (deg): 58.52	Sun Angle: N/A
PRR (kHz): 625	Altitude(feet AMT): 6800	Endlap (%): N/A	Lens:
Laser Power (%): 100	Point Spacing (m): .77	Side-Lap(%): N/A	Point Density (ppms): 2.6 ave

Direction	Line #	From	To	Start Time	Altitude(AMSL)	Remarks	Clouds	Turbulance
N	37			19:29	6180'		BKN	
S	38			19:46	6200'		BKN	
N	39			20:01	6200'		BKN	
S	40			20:19	6280'		BKN	
N	48			20:34	6840'		BKN	
S	49			20:50	6960'		BKN	
N	50			21:07	6980'		BKN	
S	51			21:22	7100'		BKN	
W	NA			21:38	7100'	Cross Strip	BKN	
W	NA			21:42	7100'	Cross Strip	BKN	

Cloud Cover Codes	⊕ = High Thin	●= Solid Overcast	O = Clear

Remarks:

LiDAR and Imagery Flight Report

Project(s): 15002-4 NYS Col-Rens

Pilot: James Mancini	Project Number(s): 15002-4 Col-Rens
Operator: Jameson Harrington	Project Name(s): New York State Col-Rens LiDAR (Counties of Columbia & Rensselaer)
Aircraft: Cessna 206 N223TC	Block Number:

LiDAR Unit: Q1560	Scan Rate: 153	Camera Unit: Phase One 80	Date: 3-5-16
MTA Zones: 5	Ground Speed Start (kts): 149	View Angle (deg): 58.52	Sun Angle: N/A
PRR (kHz): 625	Altitude(feet AMT): 6800	Endlap (%): N/A	Lens:
Laser Power (%): 100	Point Spacing (m): .77	Side-Lap(%): N/A	Point Density (ppms): 2.6 ave

Direction	Line #	From	To	Start Time	Altitude(AMSL)	Remarks	Clouds	Turbulance
S	51			16:08	7100'			
N	52			16:26	7160'			
S	53			16:44	7220'			
N	54			17:00	7280'			
S	55			17:17	7280'			
N	56			18:47	7700'			
N	57			17:32	7180'			
S	58			17:42	7360'			
N	59			17:52	7340'			
S	60			18:03	7380'			⁇
N	61			18:13	7380'			
S	62			18:22	7500'			
W	66			18:34	6960'	cross flight		
W	N/A			18:56	7700'	cross flight		

Cloud Cover Codes: ⊕ = High Thin ●= Solid Overcast O = Clear

Remarks:

LiDAR and Imagery Flight Report

Project(s): 15002-4 NYS Col-Rens

Pilot: James Mancini	Project Number(s): 15002-4 Col-Rens
Operator: Jameson Harrington	Project Name(s): New York State Col-Rens LiDAR (Counties of Columbia & Rensselaer)
Aircraft: Cessna 206 N223TC	Block Number:

LiDAR Unit: Q1560	Scan Rate: 153	Camera Unit: Phase One 80	Date: 3-6-16
MTA Zones: 5	Ground Speed Start (kts): 149	View Angle (deg): 58.52	Sun Angle: N/A
PRR (kHz): 625	Altitude(feet AMT): 6800	Endlap (%): N/A	Lens:
Laser Power (%): 100	Point Spacing (m): .77	Side-Lap(%): N/A	Point Density (ppms): 2.6 ave

Direction	Line #	From	To	Start Time	Altitude(AMSL)	Remarks	Clouds	Turbulance
S	41			14:42	6480'		O	
N	42			14:56	6340'		FEW	
S	43			15:11	6440'		SCT	
N	44			15:26	6500'		SCT	
S	45			15:41	6520'		SCT	
N	46			15:55	6620'		SCT	
S	47			16:10	6640'	Clouds	SCT	
N	47			16:25	6640'	Clouds	SCT	
W	N/A			16:41		Cross Strip		

Cloud Cover Codes: ⊕ = High Thin ●= Solid Overcast O = Clear

Remarks:

LiDAR and Imagery Flight Report		Project(s): 15002-4 NYS Col-Rens	
Pilot: Jerry Lewis		Project Number(s): 15002-4 Col-Rens	
Operator: Jameson Harrington		Project Name(s): New York State Col-Rens LiDAR (Counties of Columbia & Rensselaer)	
Aircraft: Cessna 206 N223TC		Block Number:	
LiDAR Unit: Q1560	Scan Rate: 153	Camera Unit: Phase One 80	Date: 3-21-16
MTA Zones: 5	Ground Speed Start (kts): 149	View Angle (deg): 58.52	Sun Angle: N/A
PRR (kHz): 625	Altitude(feet AMT): 6800	Endlap (%): N/A	Lens:
Laser Power (%): 100	Point Spacing (m): .77	Side-Lap(%): N/A	Point Density (ppms): 2.6 ave

Direction	Line #	From	To	Start Time	Altitude(AMSL)	Remarks	Clouds	Turbulance
N	46			18:10	6620'		SCT	Light
S	47			18:24	6640'		SCT	Light
W	N/A			18:44	6600'	Cross Strip	SCT	

Cloud Cover ⊕ = High Thin ●= Solid Overcast O = Clear

Remarks:

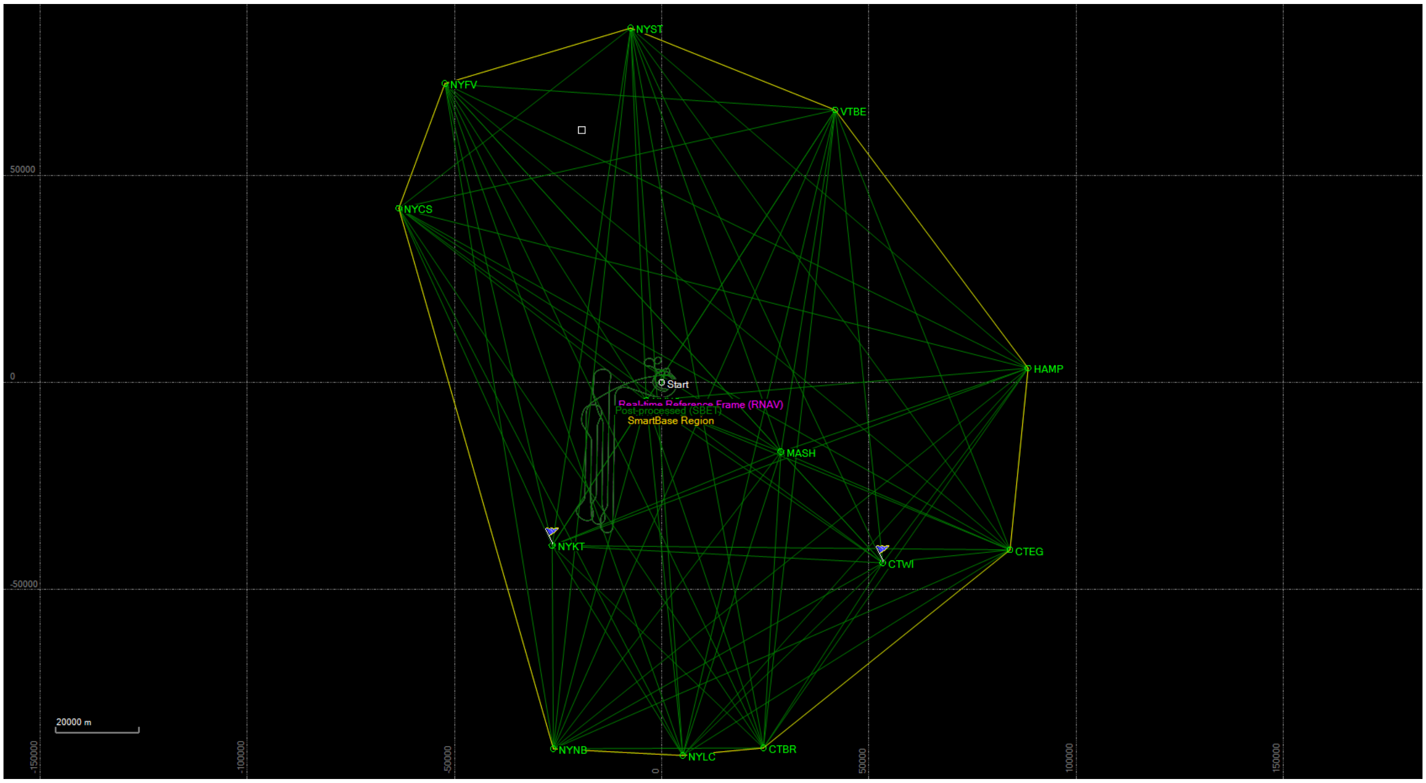
Section 5: GPS Processing Plots

POSPac MMS Version 7.1

Plots by lift of the Coverage Map, Estimated Position Accuracy, Number of Satellites, Combined Separation, and PDOP.

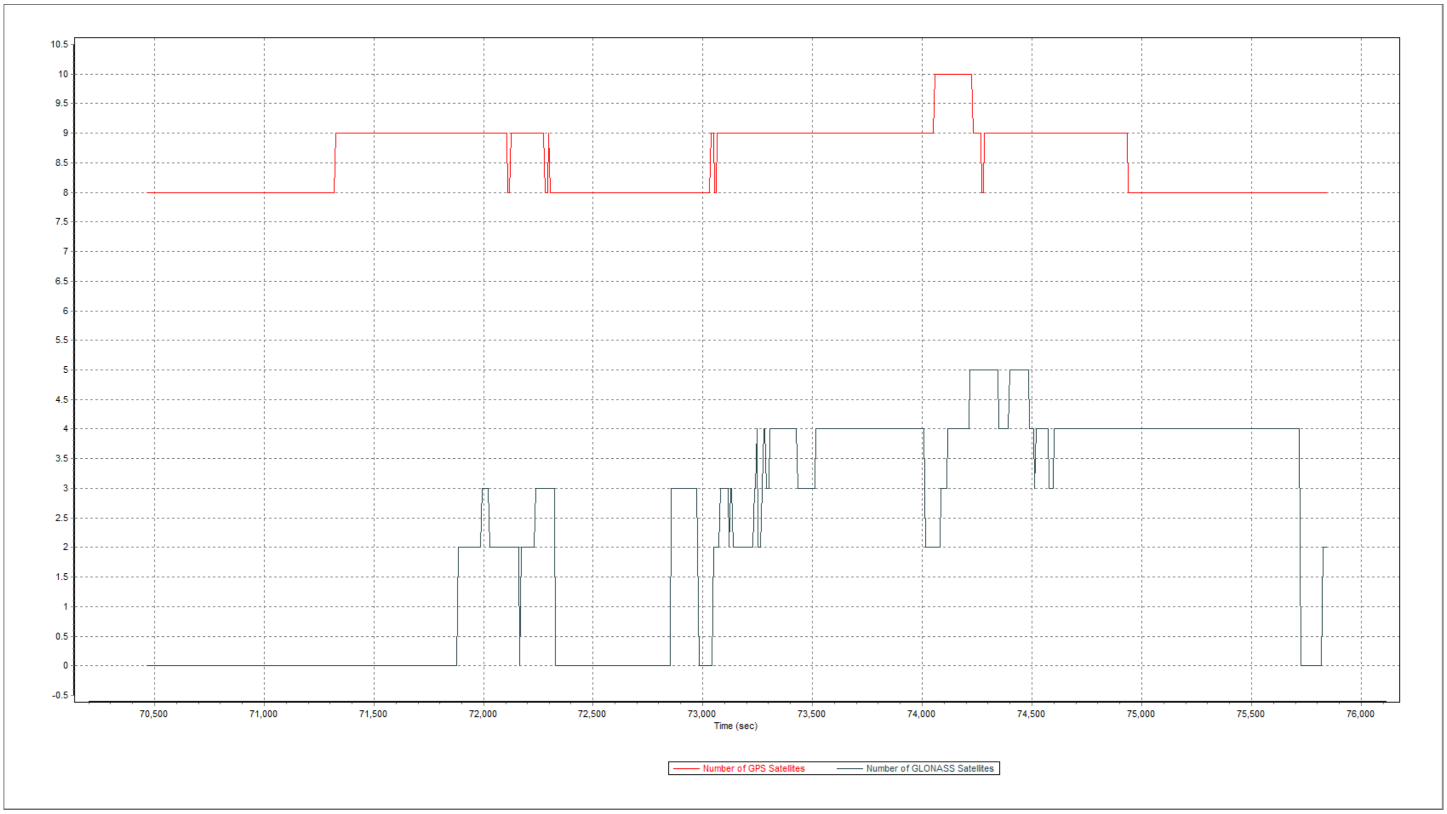
20151220-1

Coverage Map: The Coverage Map plot shows the Aircraft GPS-IMU Trajectory in reference to localized GPS Reference Stations.

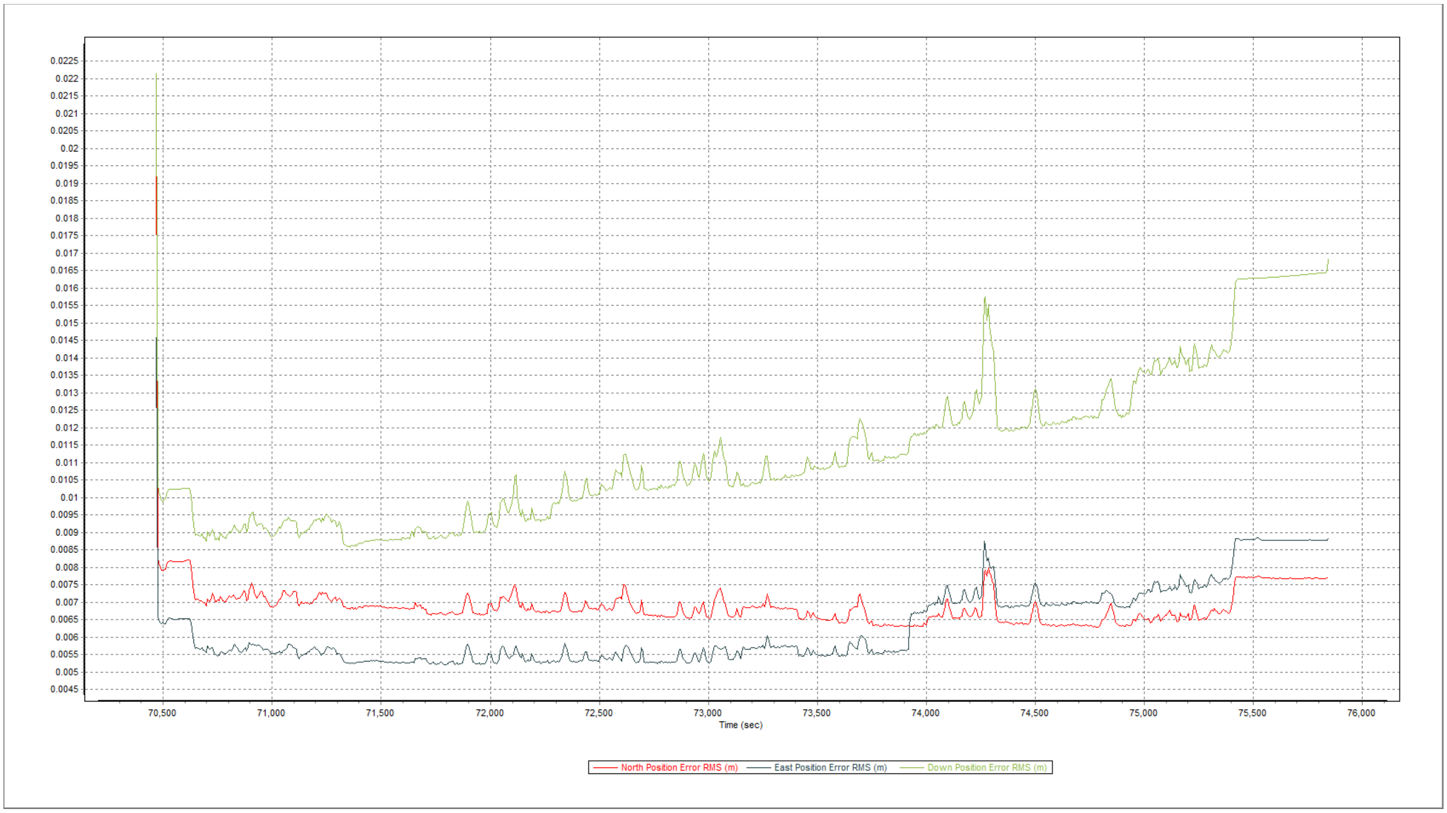


Combined Separation: Plots the north, east, and height position difference between any two solutions loaded into the project. This is most often the forward and reverse processing results, unless other solutions have been loaded from the Combine Solutions dialog. Plotting the difference between forward and reverse solutions can be very helpful in quality checking. When processing both directions, no information is shared between forward and reverse processing. Thus both directions are processed independently of each other. When forward and reverse solutions agree closely, it helps provide confidence in the solution. To a lesser extent, this plot can also help gauge solution accuracy.

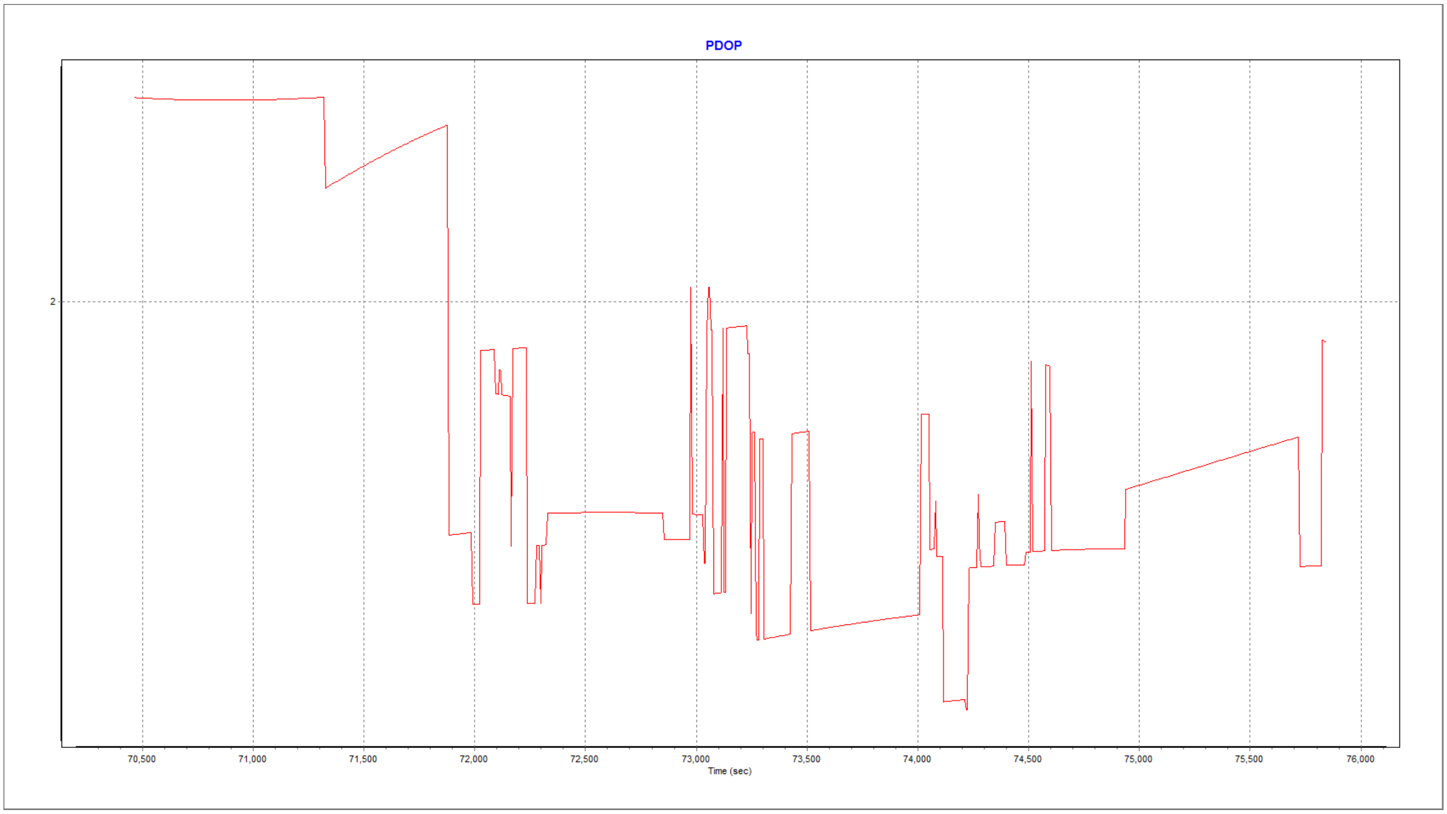
Number of Satellites: Plots the number of satellites used in the solution as a function of time. The number of GPS satellites, GLONASS satellites and the total number of satellites are distinguished with separate lines.


Time (sec)
Number of GPS Satellites
Number of GLONASS Satellites

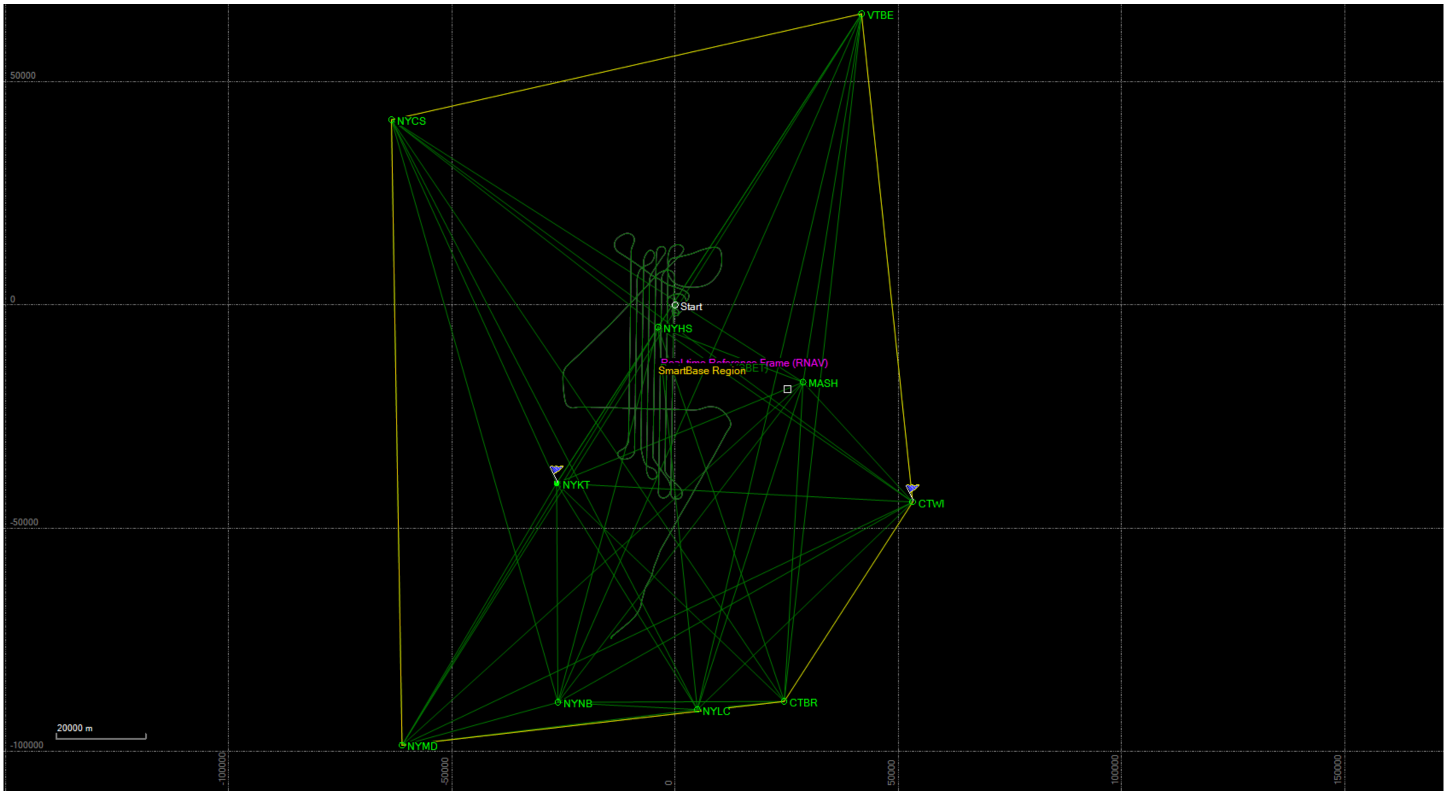
Estimated Position Accuracy: The Estimated Position Accuracy plot shows the standard deviations of the east, north, and up directions versus time for the solution.

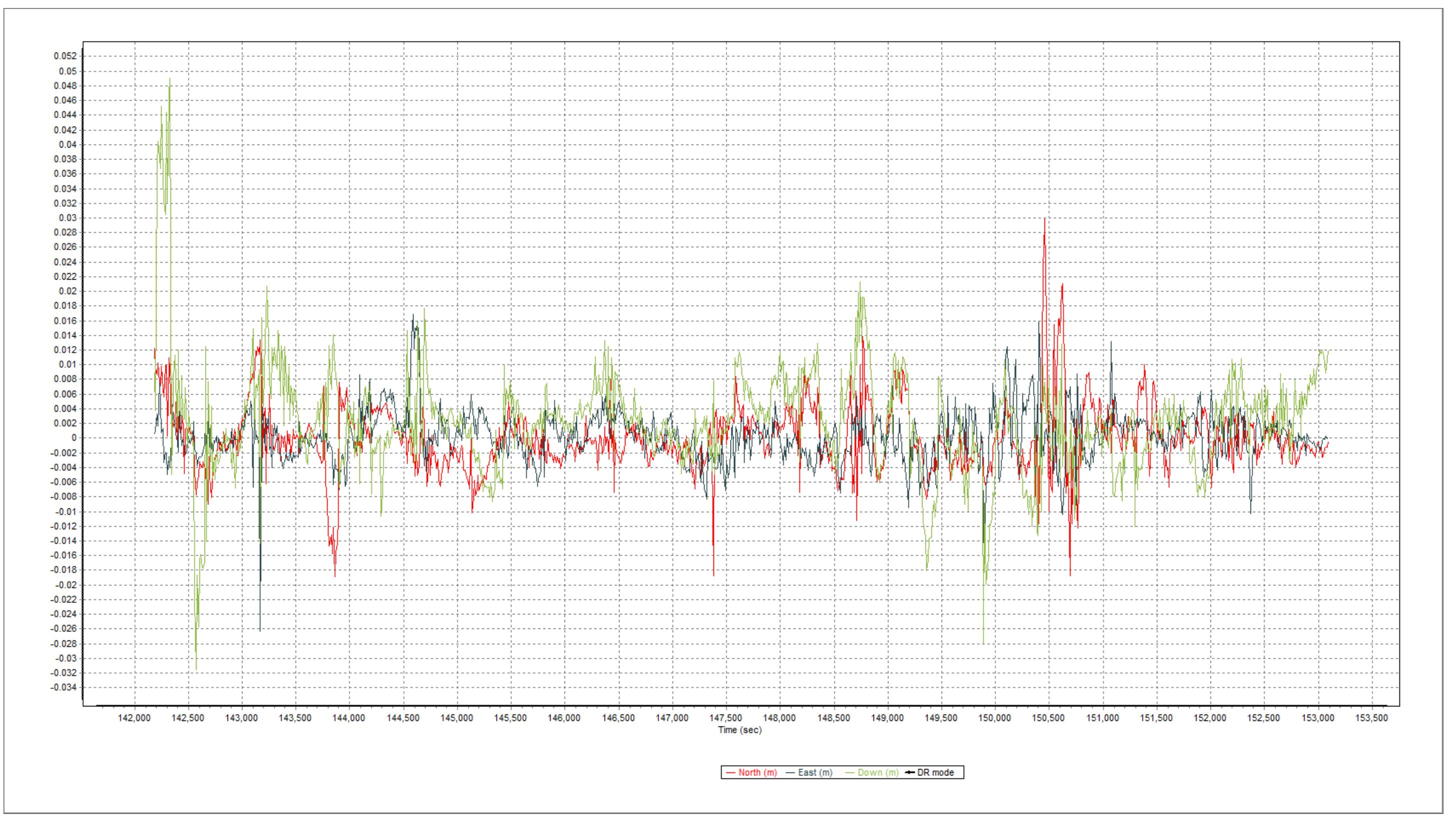


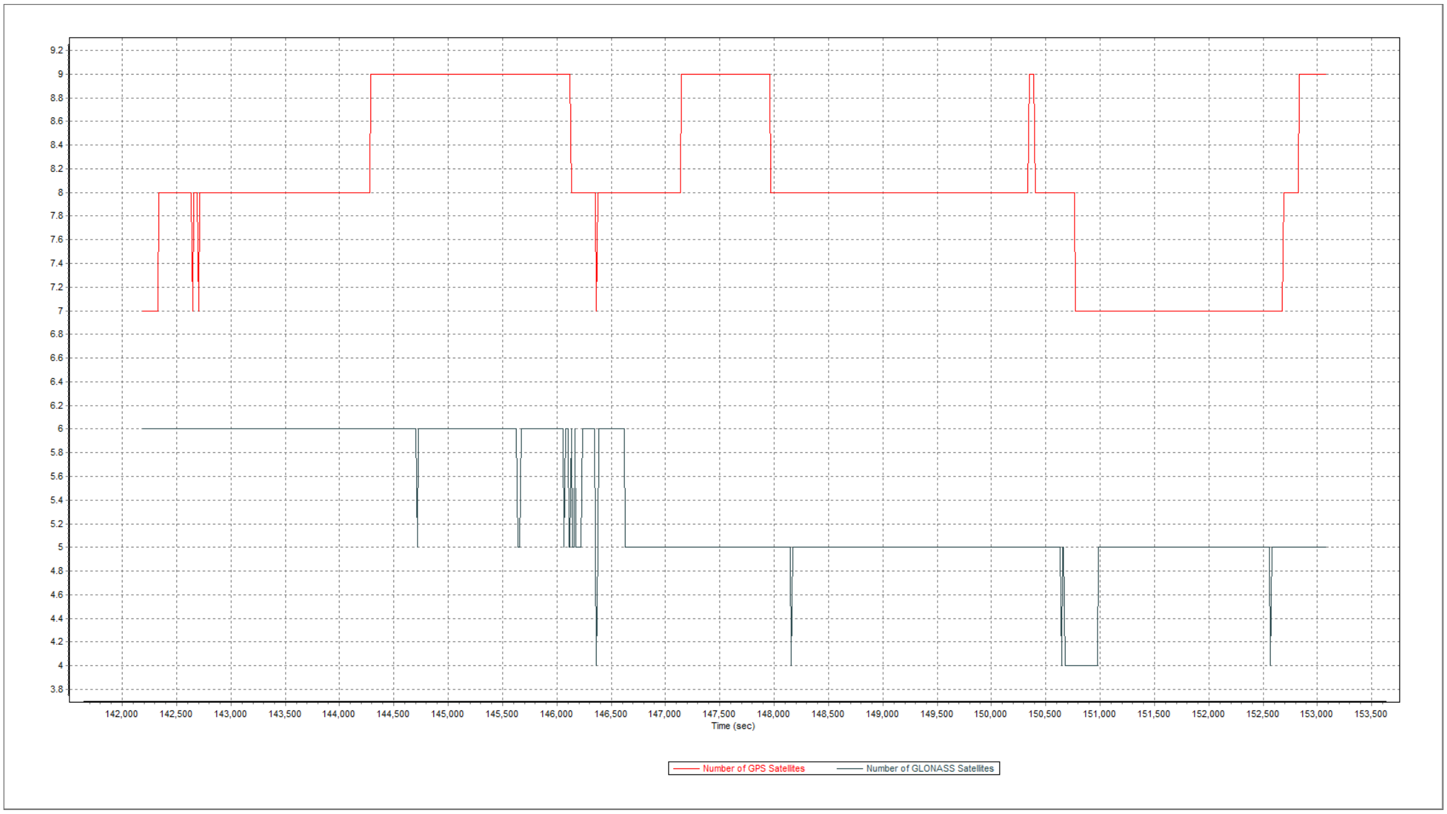
PDOP: PDOP is a unitless number which indicates how favorable the satellite geometry is to 3D positioning accuracy. A strong satellite geometry, where the PDOP is low, occurs when satellites are well distributed in each direction (north, south, east and west) as well as directly overhead. Values in the range of 1-2 indicate very good satellite geometry; 2-3 are adequate in the sense that they do not generally, by themselves, limit positioning accuracy. Values between 3 and 4 are considered marginal, and values approaching or exceeding 5 can be considered poor.

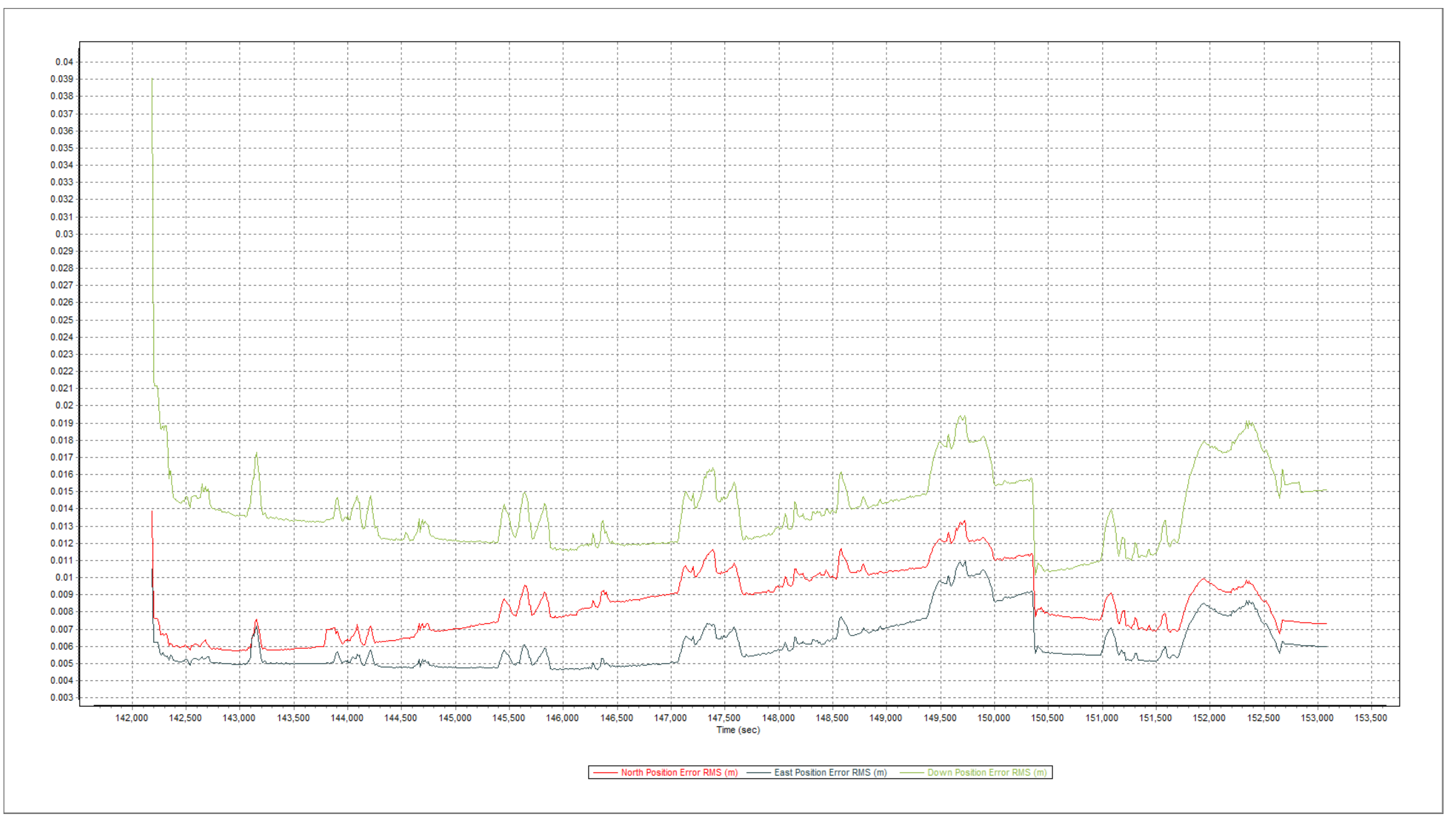


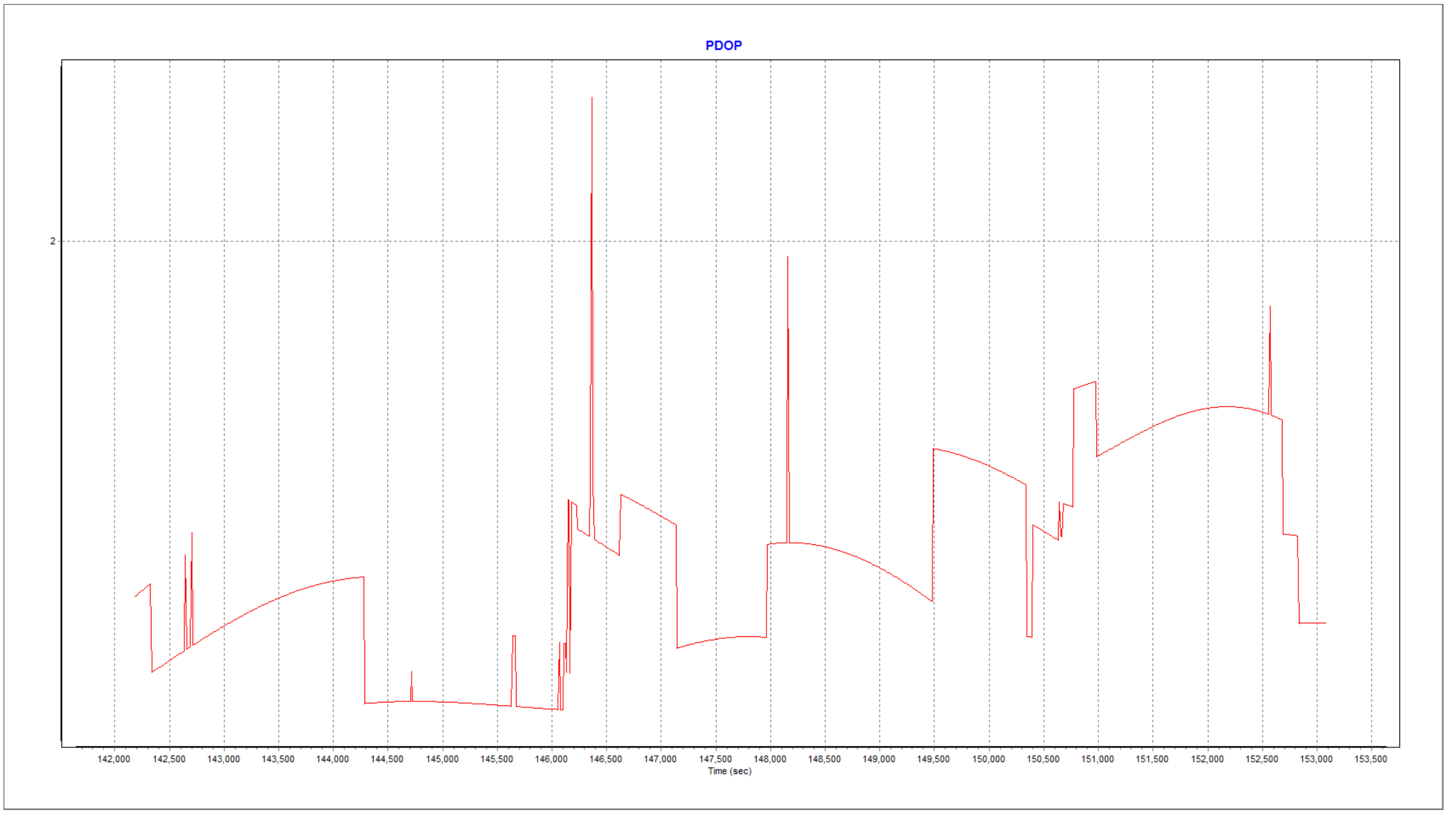
20151221-1


VTBE
NYCS
Start
NYHS
Real-time Reference Frame (RNAV)
SmartBase Region
MASH
NYKT
CTWI
NYNB
NYLC
CTBR
NYMD
20000 m
50000
0
-50000
-100000
-100000
-50000
0
50000
100000
150000


Time (sec)
North (m)
East (m)
Down (m)
DR mode


Time (sec)
Number of GPS Satellites
Number of GLONASS Satellites


Time (sec)
North Position Error RMS (m)
East Position Error RMS (m)
Down Position Error RMS (m)


PDOP
2
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142,500
143,000
143,500
144,000
144,500
145,000
145,500
146,000
146,500
147,000
147,500
148,000
148,500
149,000
149,500
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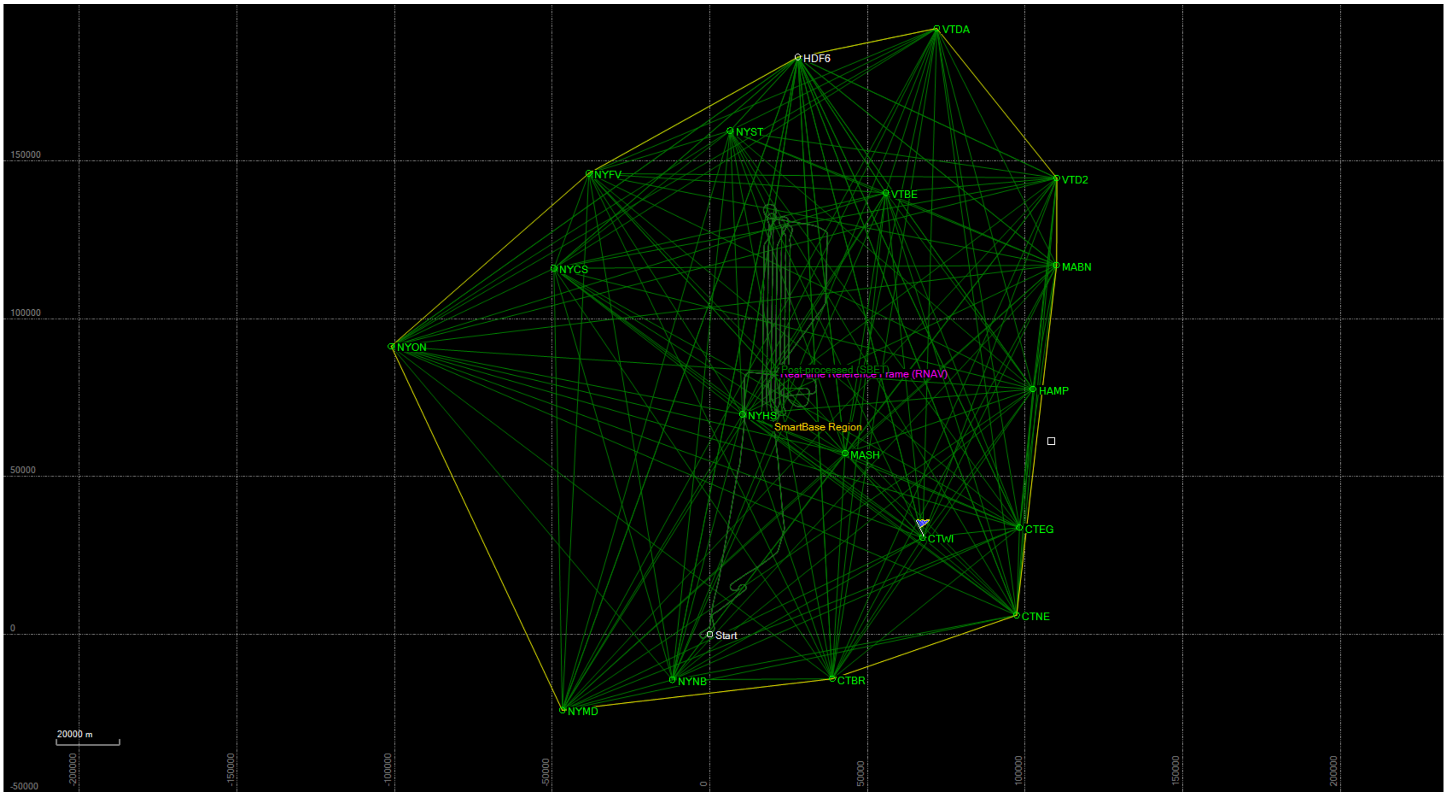
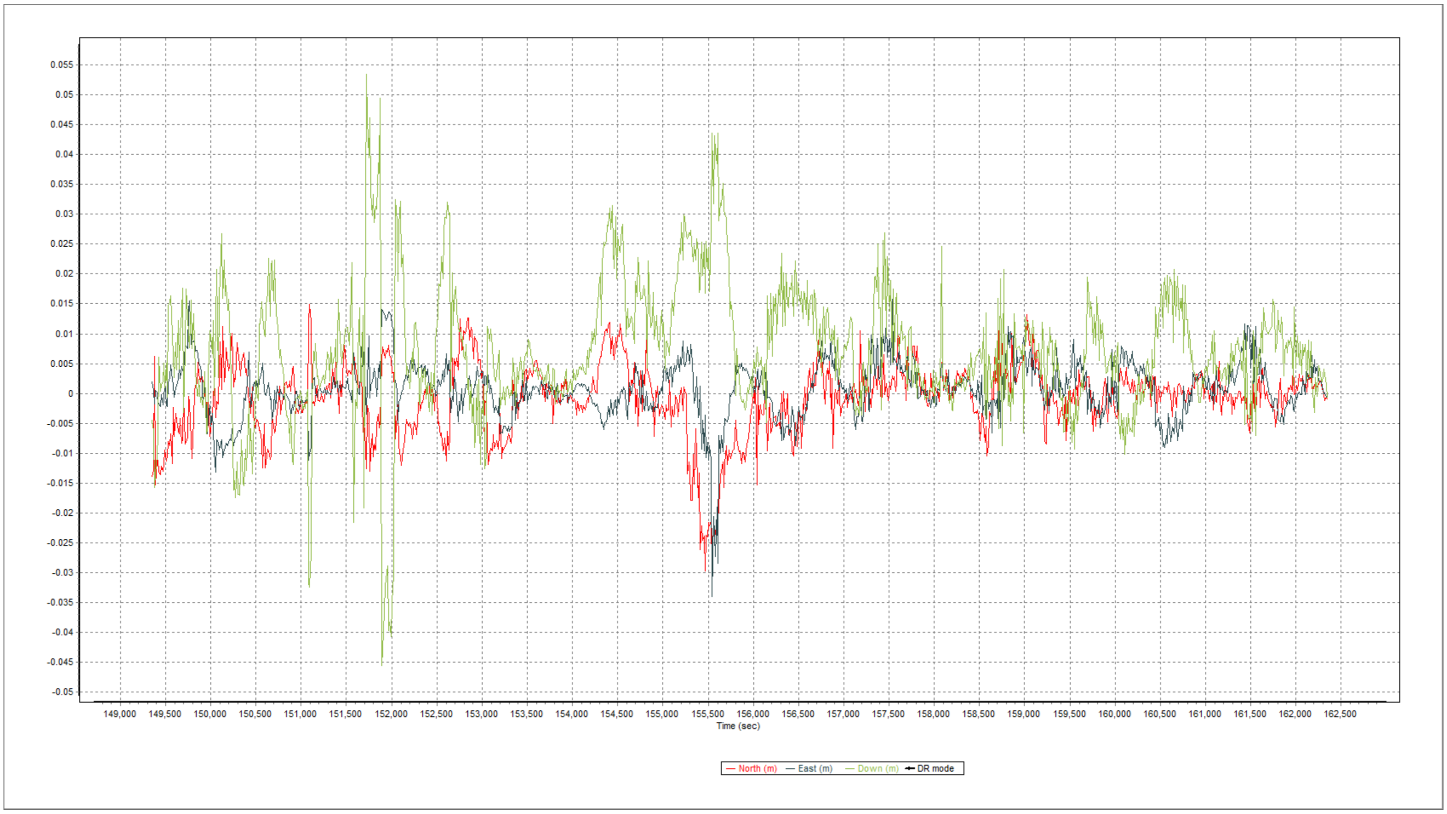
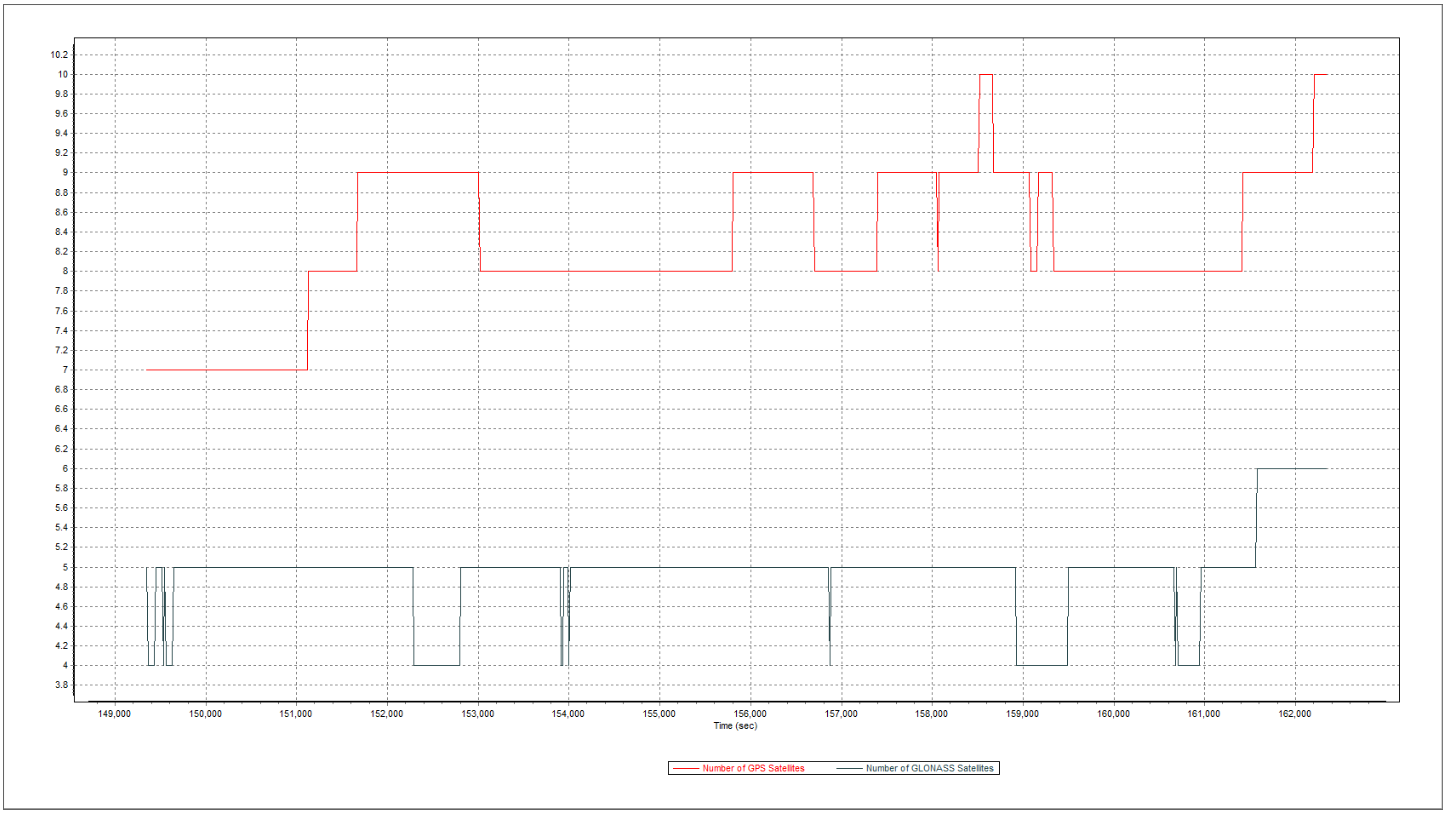
150,500
151,000
151,500
152,000
152,500
153,000
153,500
Time (sec)

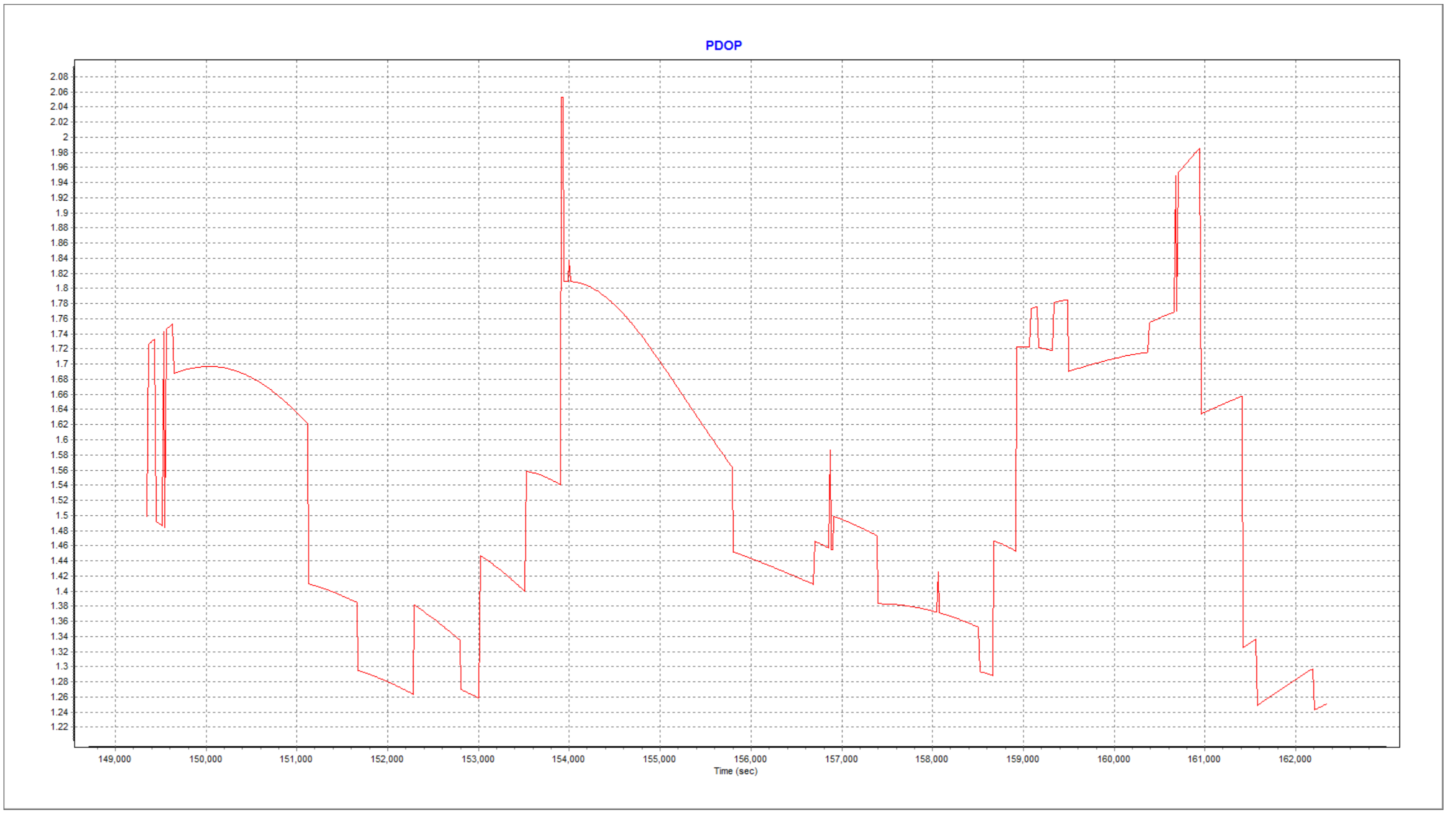
20151228-1


VTDA
HDF6
NYST
NYFV
VTBE
VTD2
MABN
NYCS
NYON
HAMP
NYHS
SmartBase Region
MASH
CTEG
CTWI
CTNE
Start
NYNB
CTBR
NYMD
20000 m


Time (sec)
North (m)
East (m)
Down (m)
DR mode


Time (sec)
North Position Error RMS (m)
East Position Error RMS (m)
Down Position Error RMS (m)


Time (sec)
Number of GPS Satellites
Number of GLONASS Satellites


PDOP
2.08
2.06
2.04
2.02
2
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1.96
1.94
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1.9
1.88
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1.84
1.82
1.8
1.78
1.76
1.74
1.72
1.7
1.68
1.66
1.64
1.62
1.6
1.58
1.56
1.54
1.52
1.5
1.48
1.46
1.44
1.42
1.4
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1.3
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1.26
1.24
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151,000
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161,000
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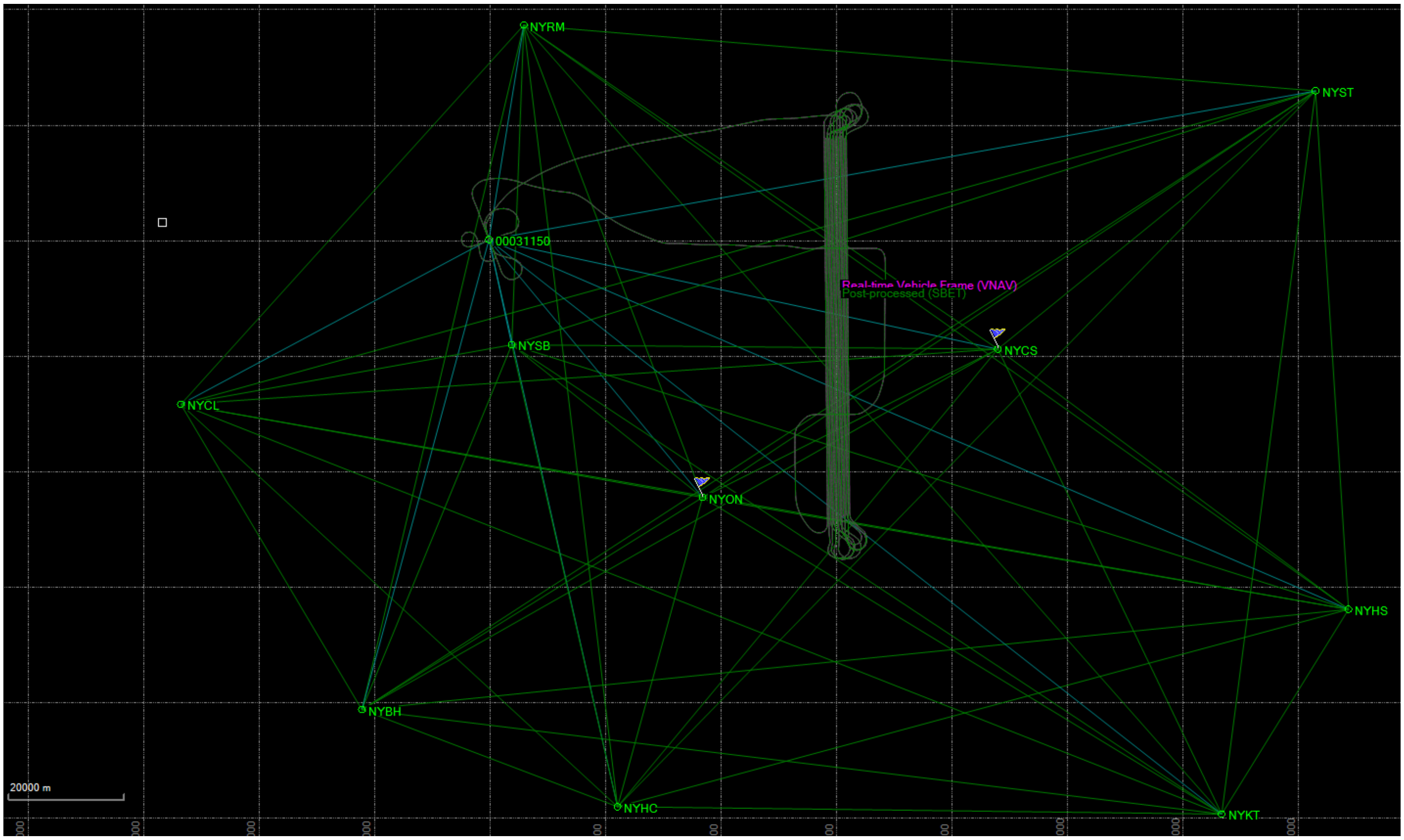
Time (sec)

20160106-1


NYRM
NYST
00031150
Real-time Vehicle Frame (VNAV)
Post-processed (SBET)
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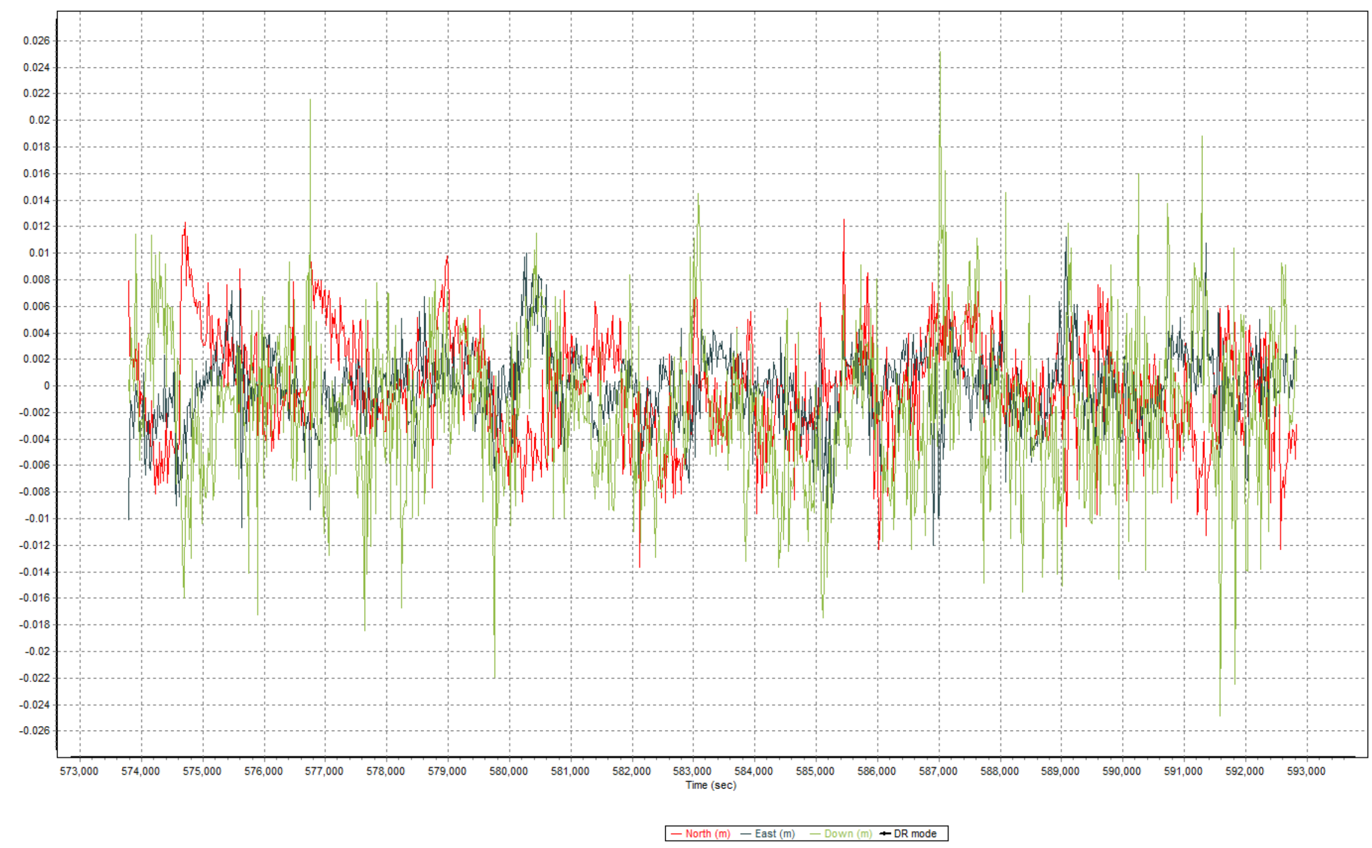
NYCL
NYON
NYHS
NYBH
20000 m
NYHC
NYKT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0.022
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0.018
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0.006
0.004
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0
-0.002
-0.004
-0.006
-0.008
-0.01
-0.012
-0.014
-0.016
-0.018
-0.02
-0.022
-0.024
-0.026
573,000
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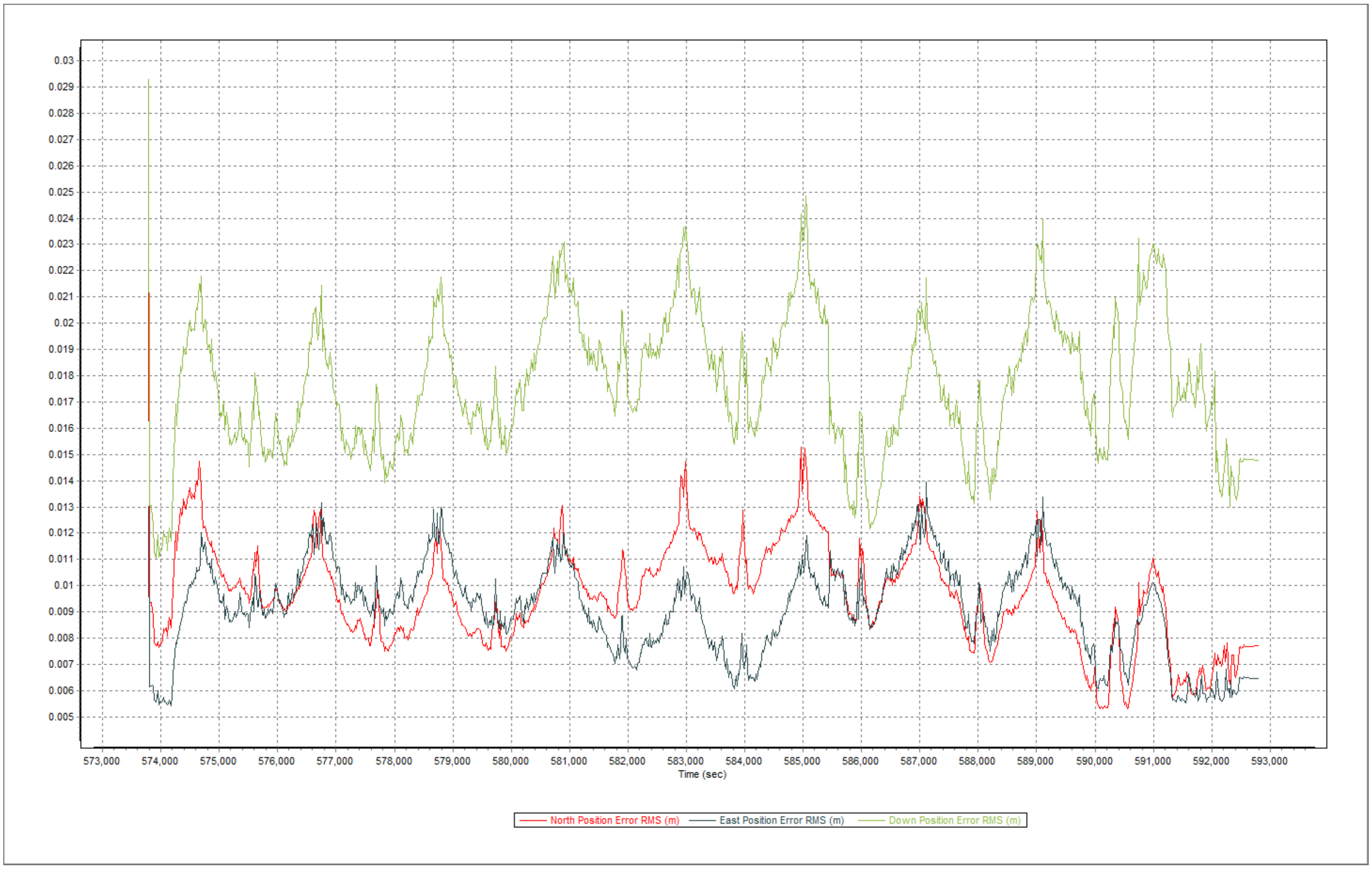
Time (sec)
North (m)
East (m)
Down (m)
DR mode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0.028
0.027
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0.017
0.016
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0.012
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0.008
0.007
0.006
0.005
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574,000
575,000
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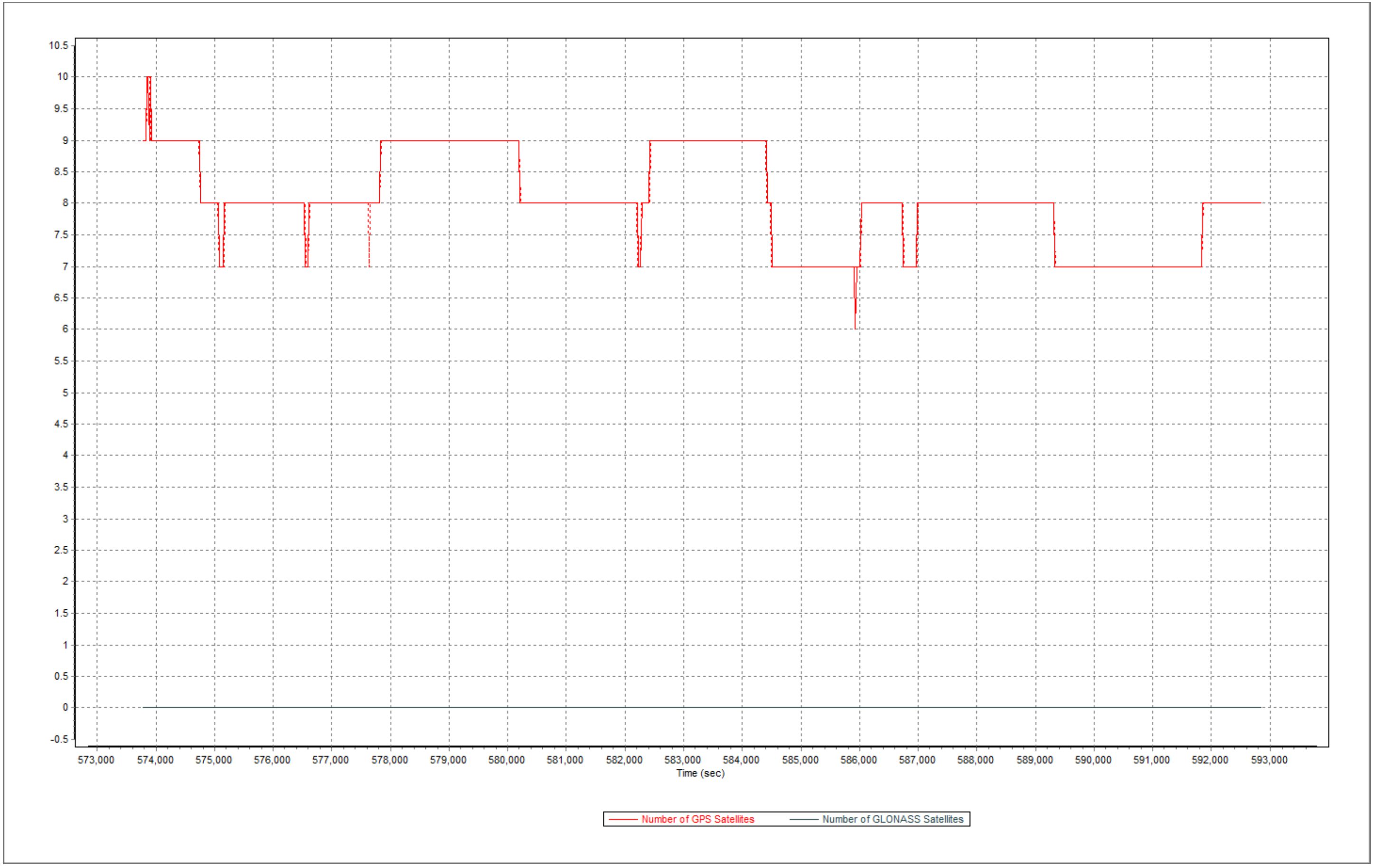
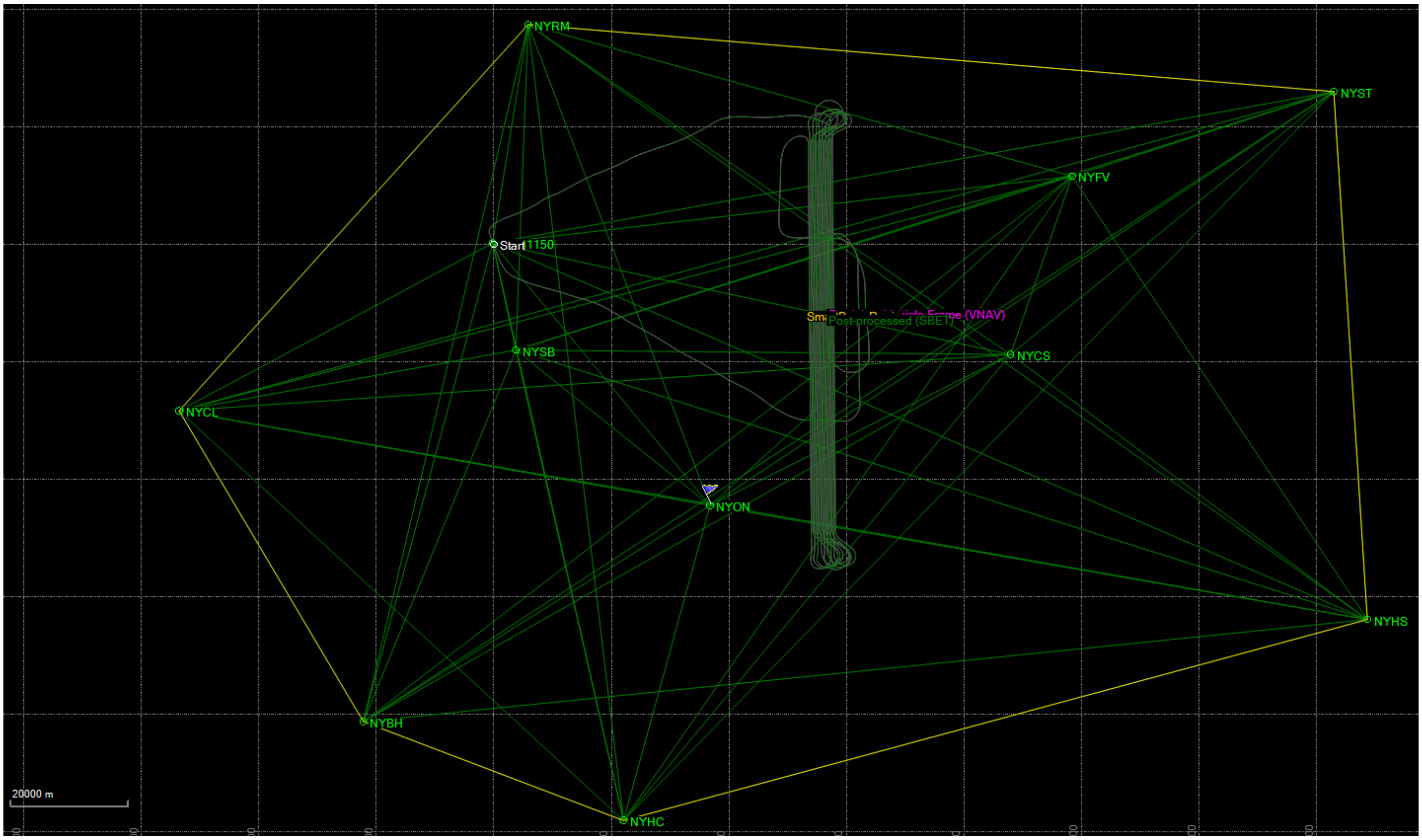
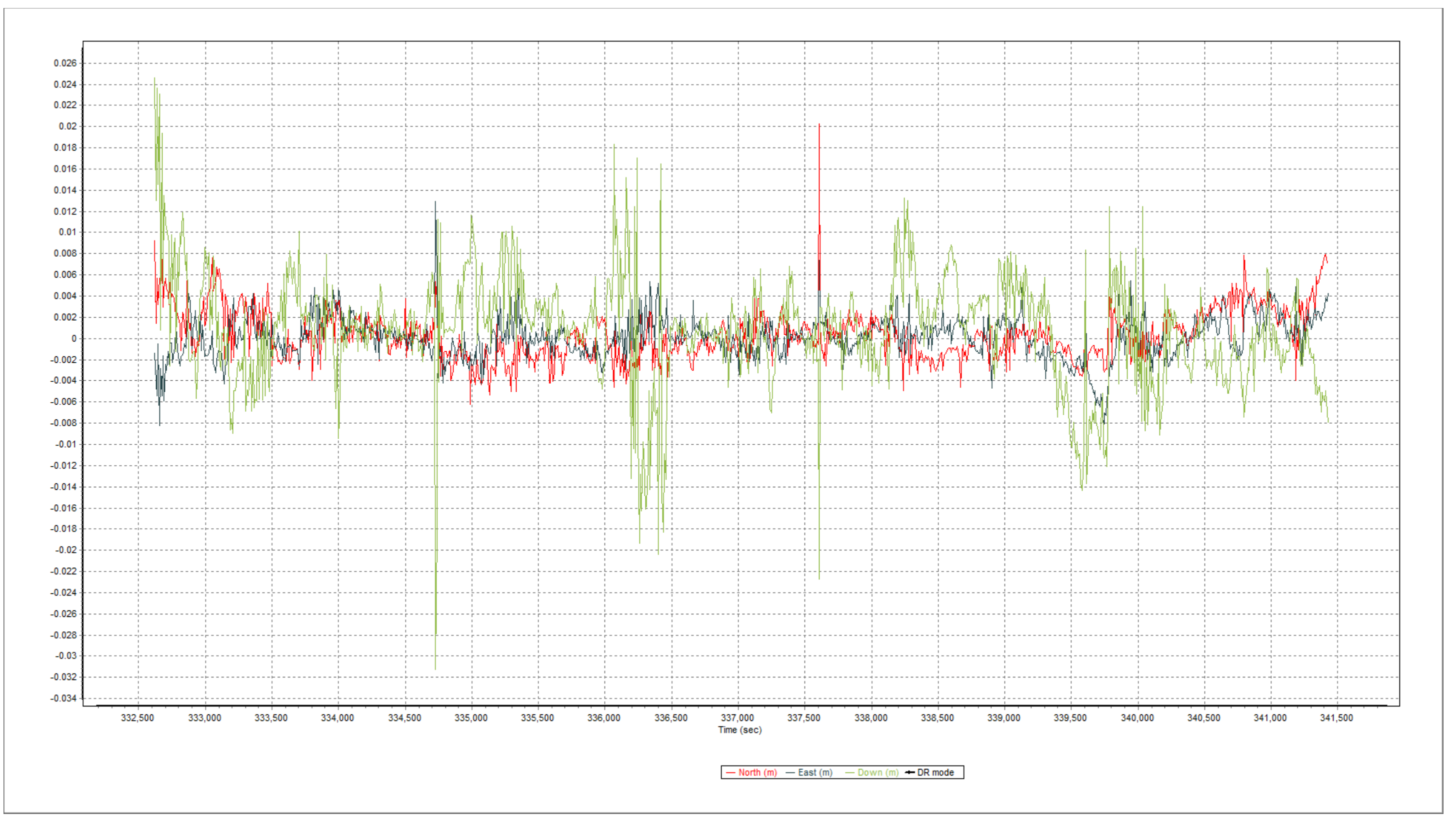
593,000
Time (sec)
North Position Error RMS (m)
East Position Error RMS (m)
Down Position Error RMS (m)


Time (sec)
Number of GPS Satellites
Number of GLONASS Satellites


PDOP
Time (sec)
Forward
Reverse

20160106-2


NYRM
NYST
NYFV
Start
1150
Post-processed (SBET)
NYSB
NYCS
NYCL
NYON
NYHS
NYBH
NYHC
20000 m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0.024
0.022
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
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-0.004
-0.006
-0.008
-0.01
-0.012
-0.014
-0.016
-0.018
-0.02
-0.022
-0.024
-0.026
-0.028
-0.03
-0.032
-0.034
332,500
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336,000
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337,000
337,500
338,000
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339,000
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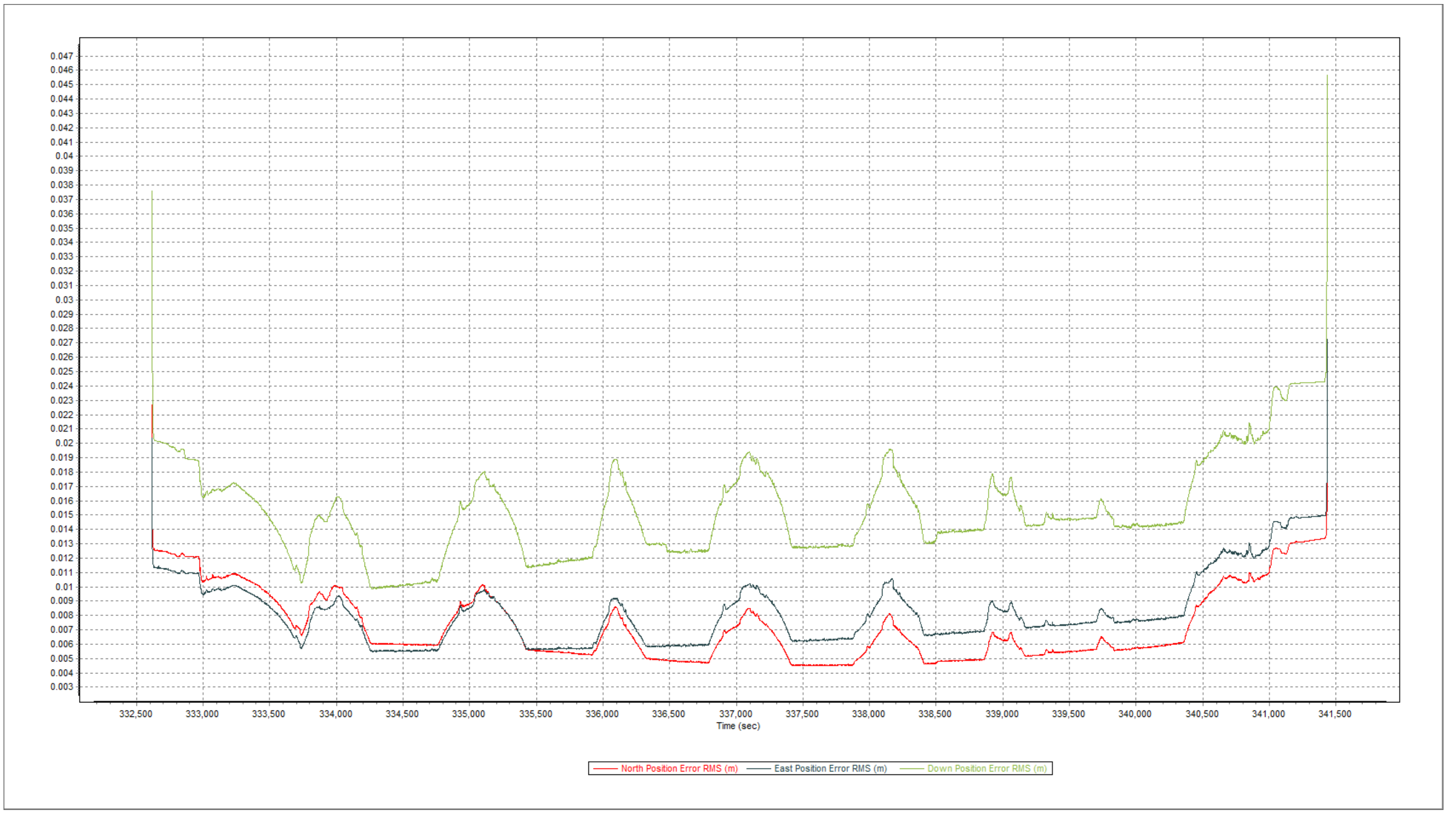
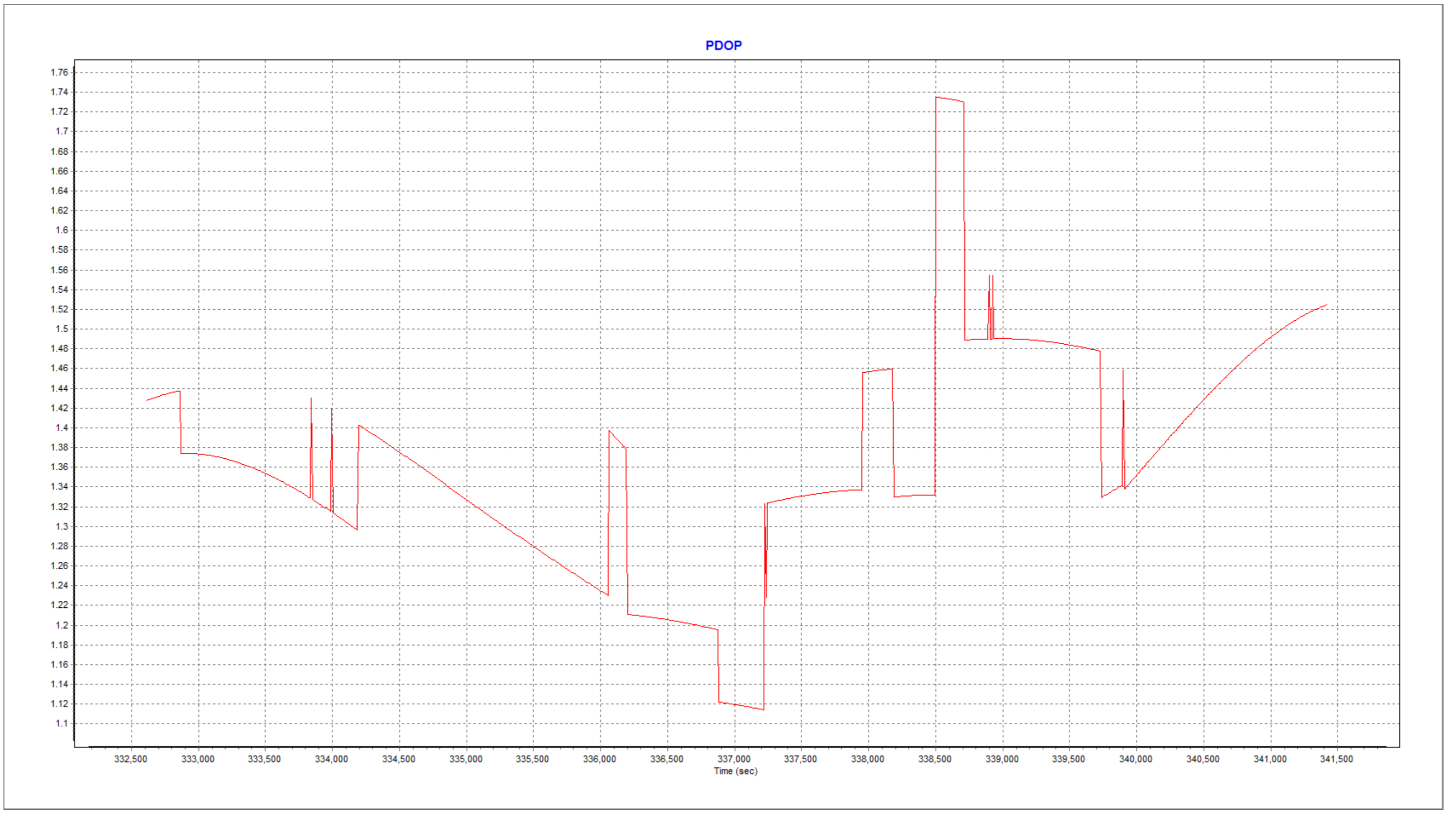
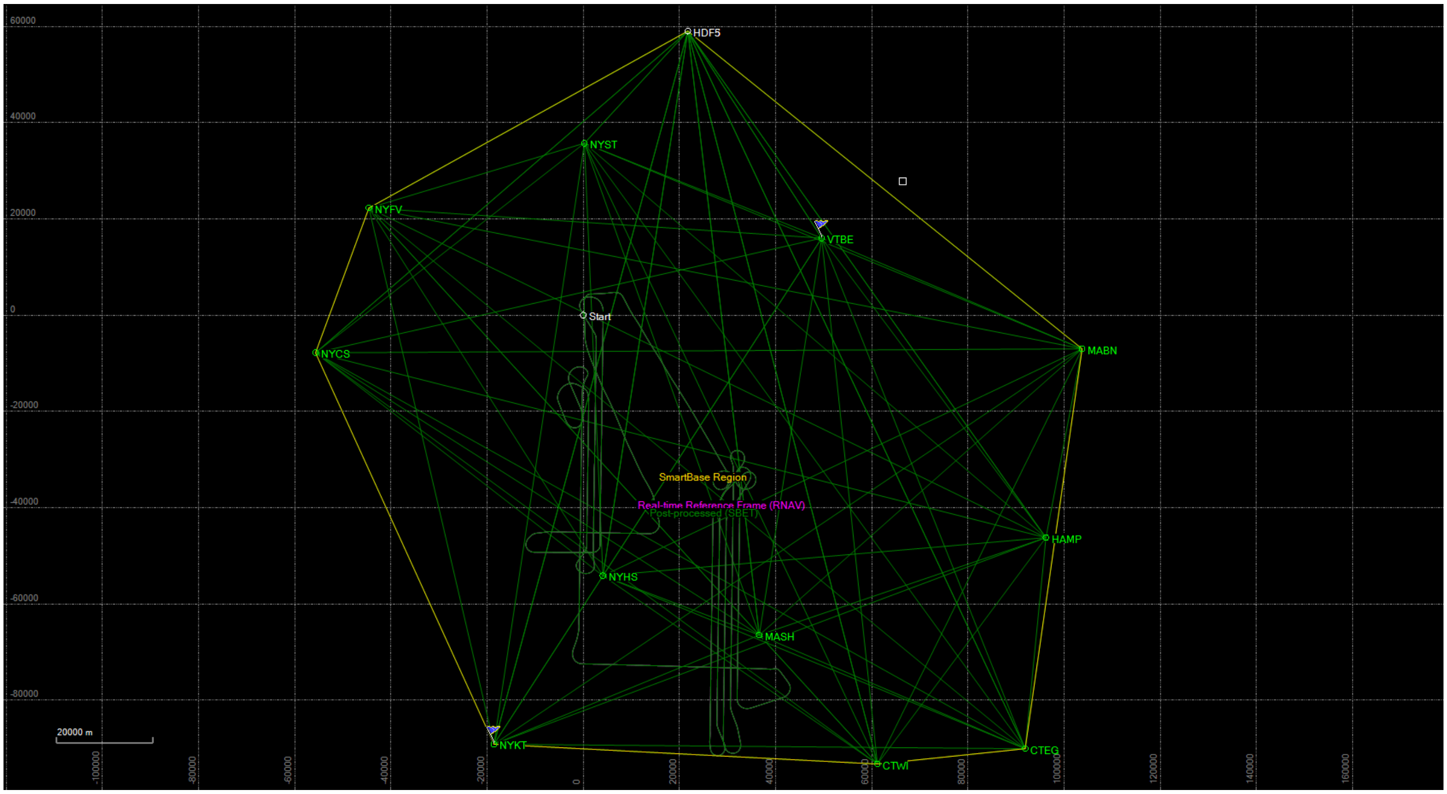
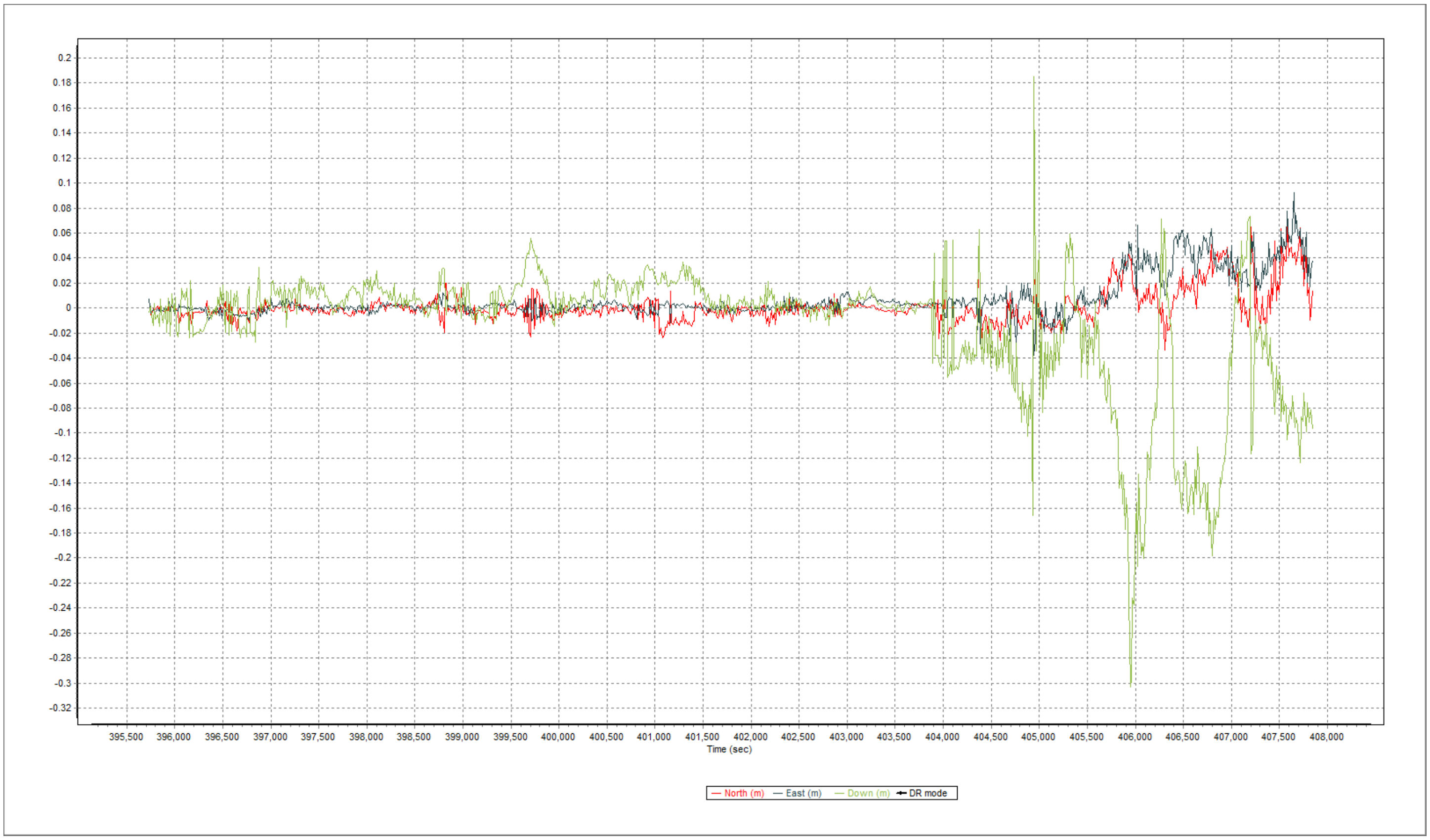
340,000
340,500
341,000
341,500
Time (sec)
North (m)
East (m)
Down (m)
DR mode

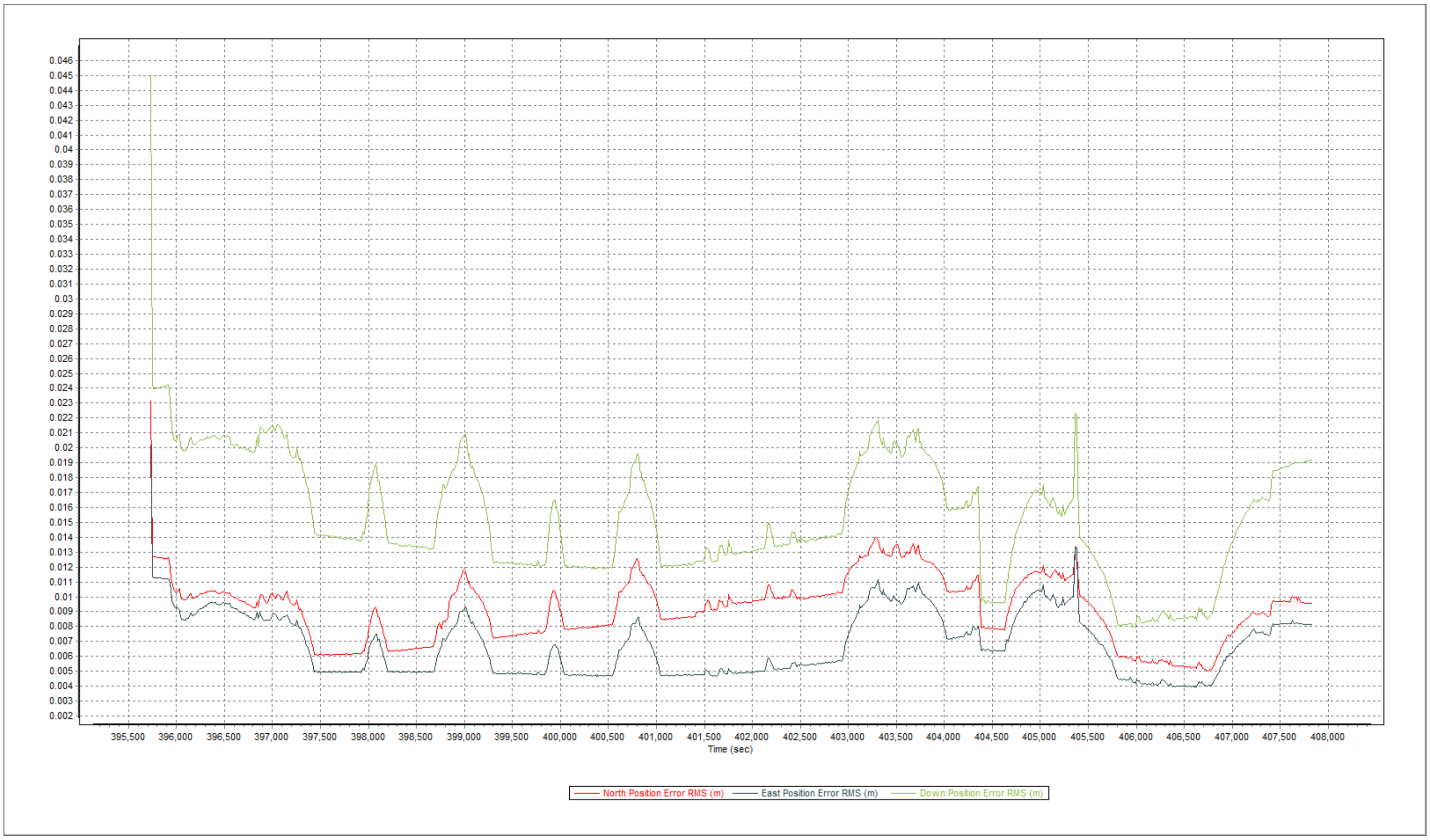

North Position Error RMS (m)
East Position Error RMS (m)
Down Position Error RMS (m)
Time (sec)

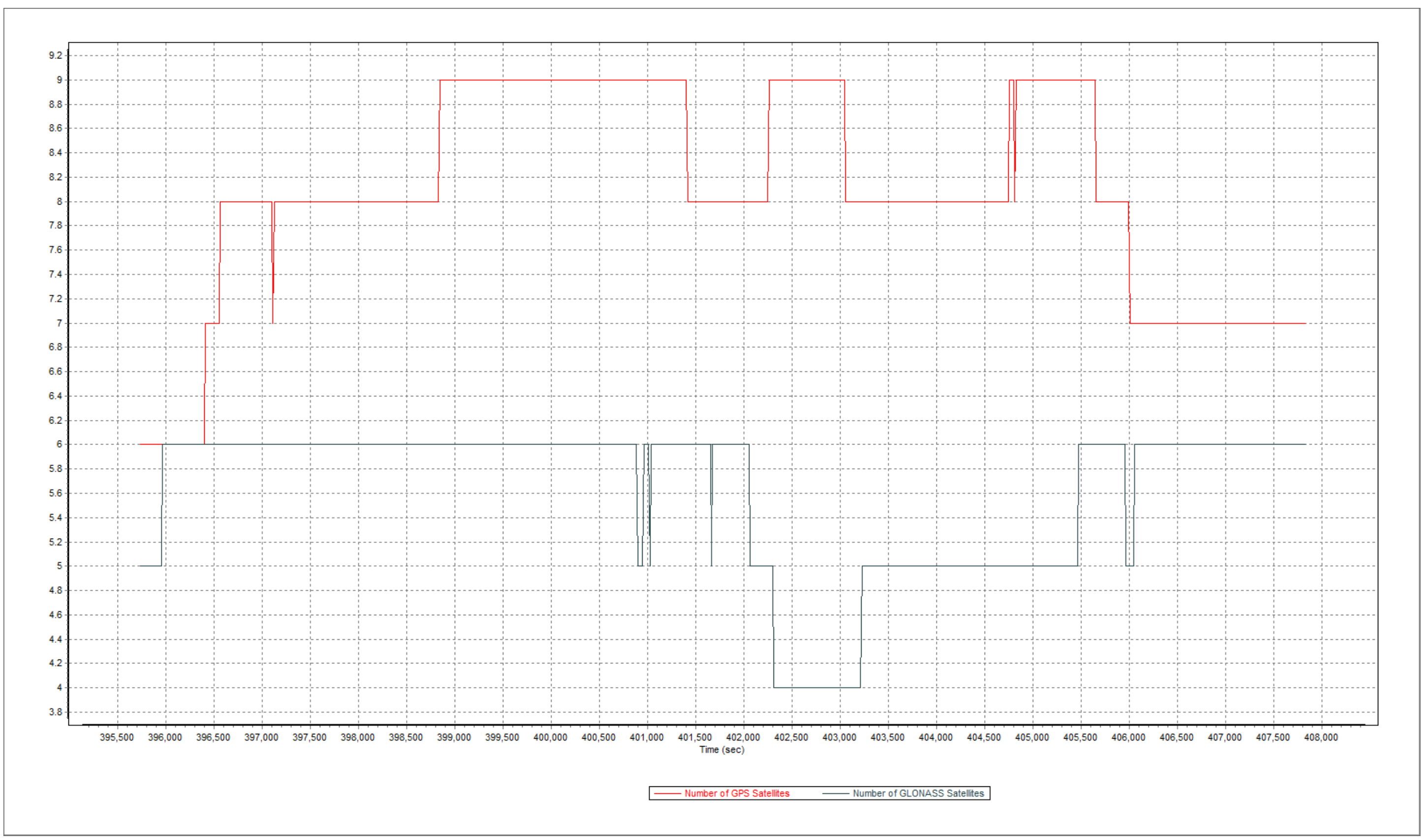

PDOP
Time (sec)

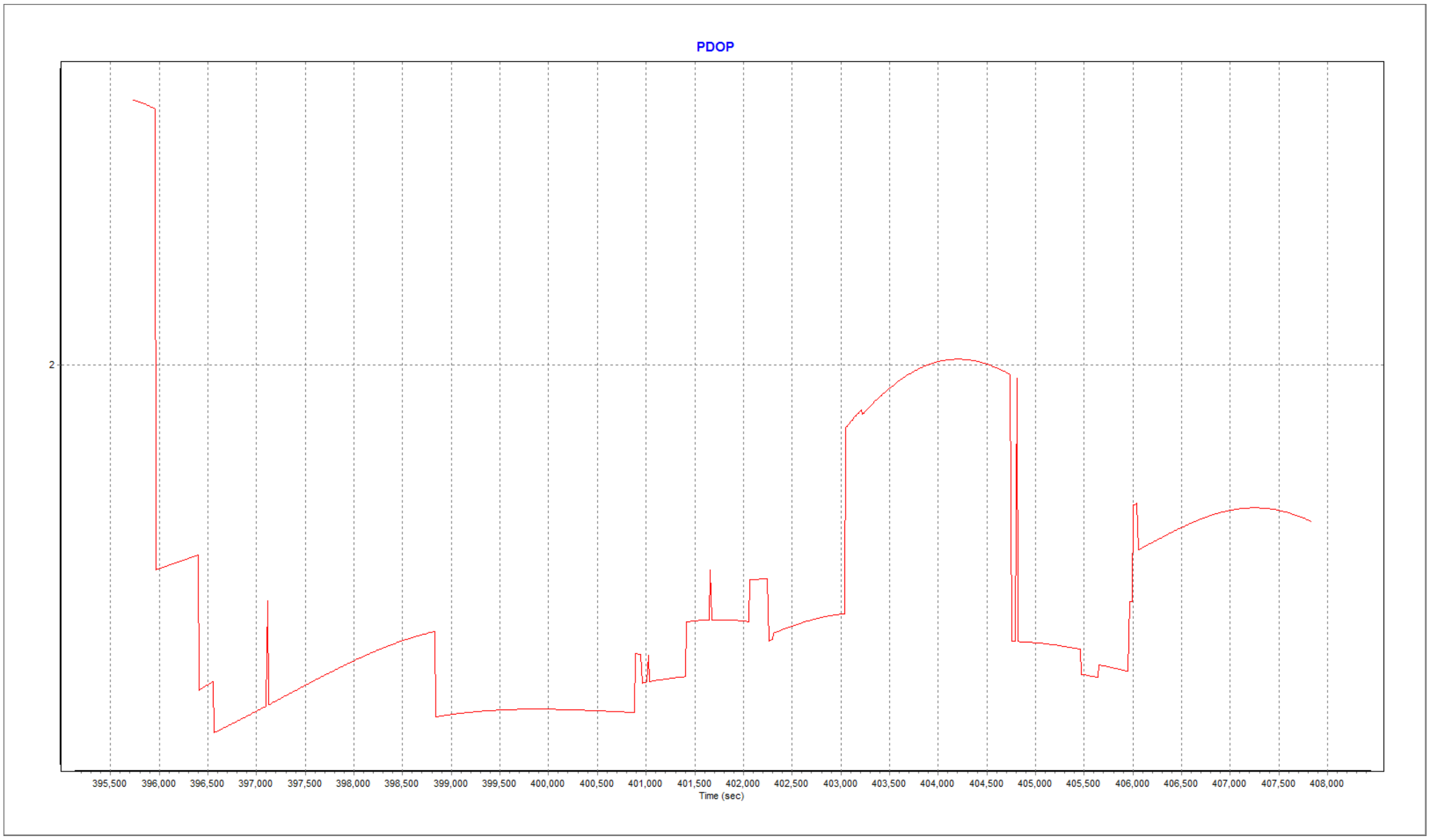
20160107-1


HDF5
NYST
NYFV
VTBE
Start
NYCS
MABN
SmartBase Region
Real-time Reference Frame (RNAV)
Post-processed (SBET)
HAMP
NYHS
MASH
NYKT
CTWI
CTEG
20000 m


Time (sec)
North (m)
East (m)
Down (m)
DR mode


Time (sec)
North Position Error RMS (m)
East Position Error RMS (m)
Down Position Error RMS (m)


Time (sec)
Number of GPS Satellites
Number of GLONASS Satellites


PDOP
2
395,500
396,000
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397,000
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398,000
398,500
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400,000
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401,000
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402,000
402,500
403,000
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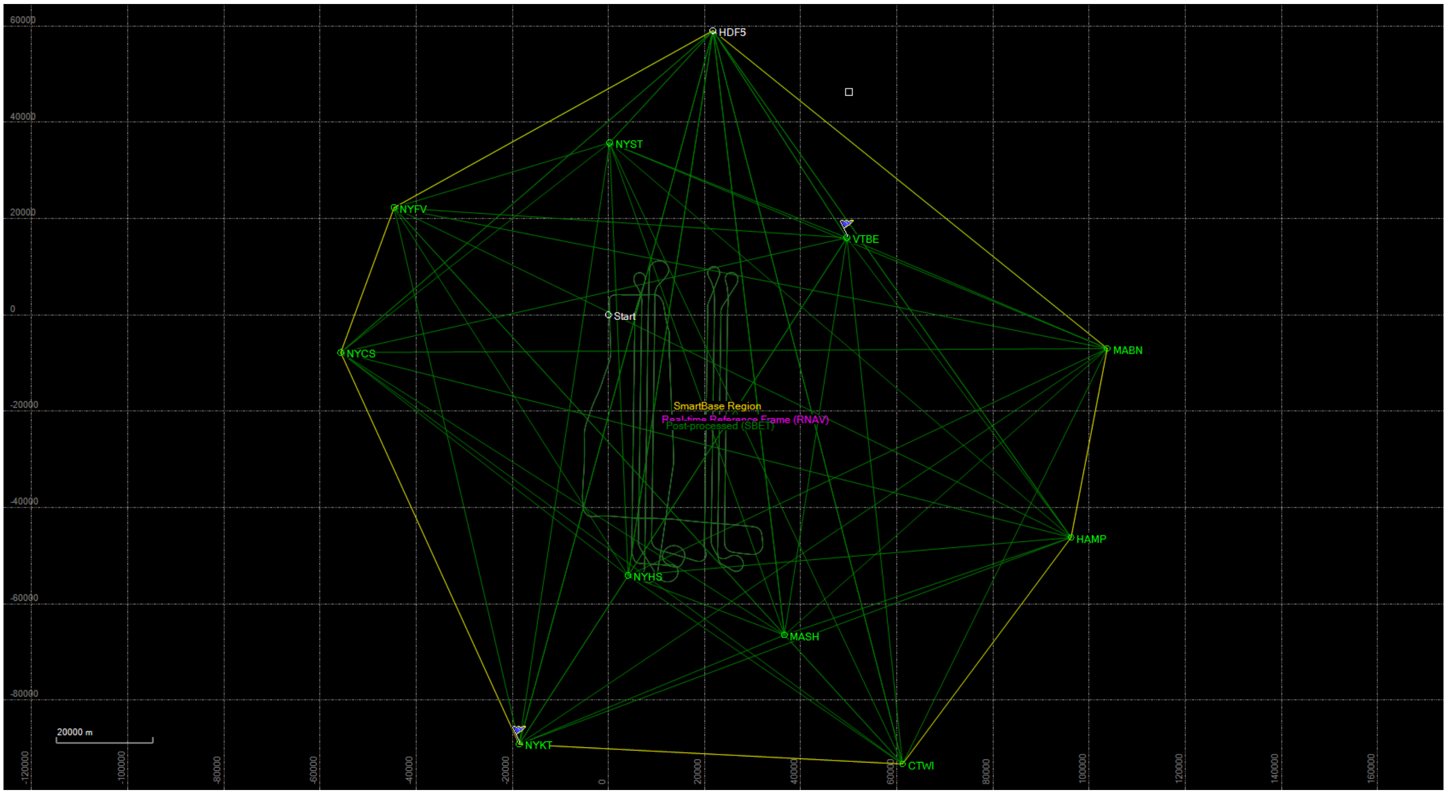
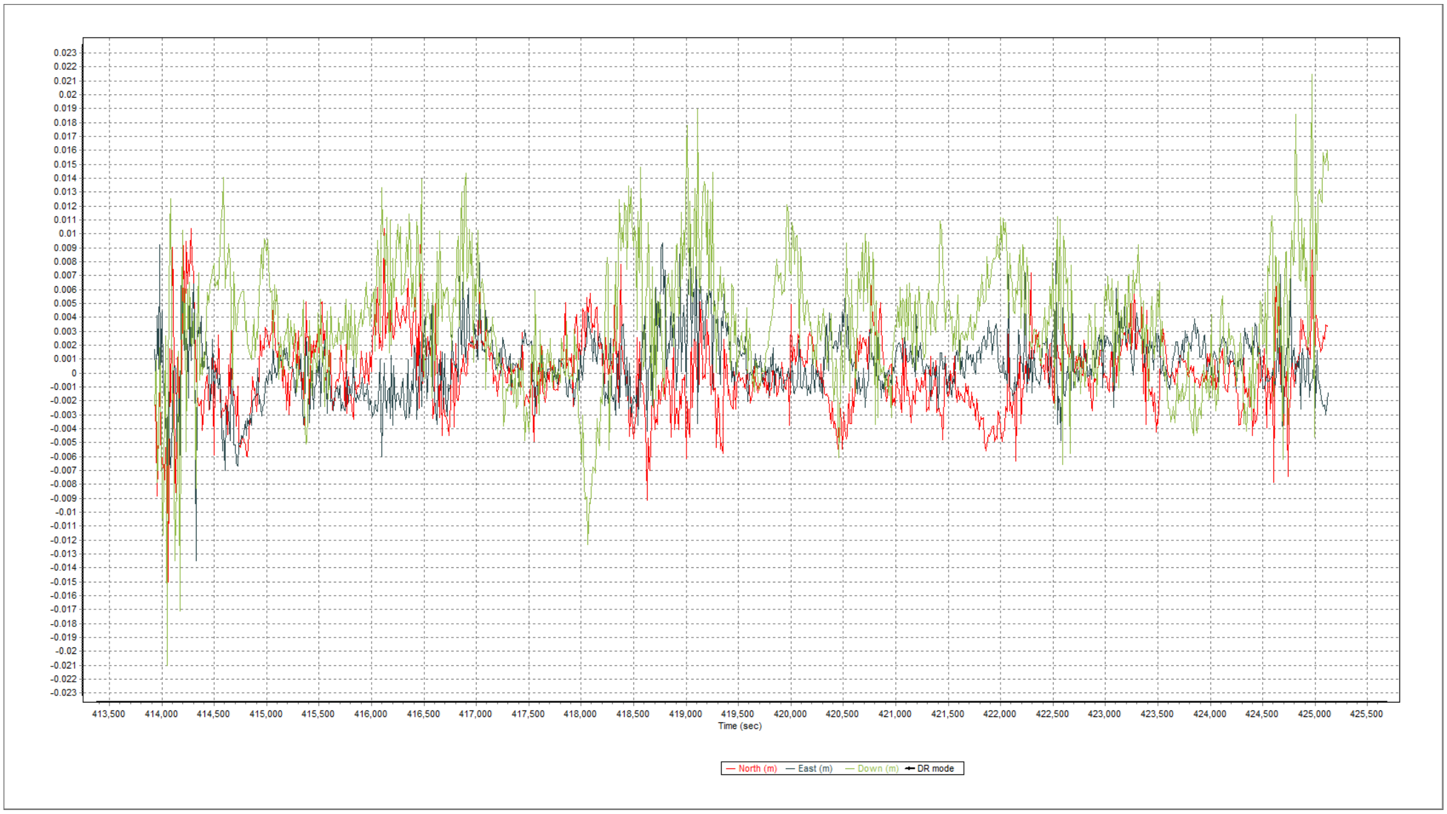
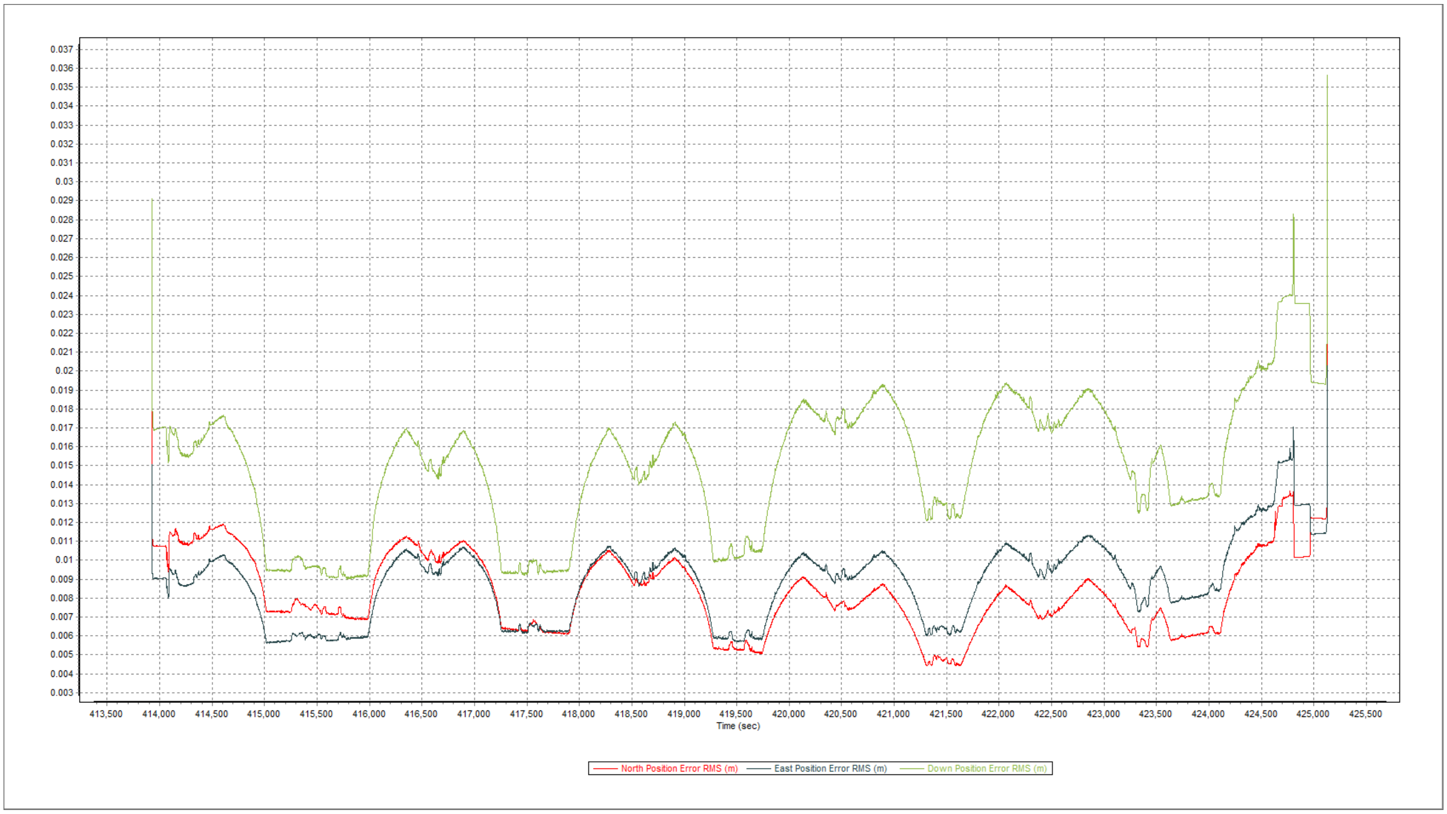
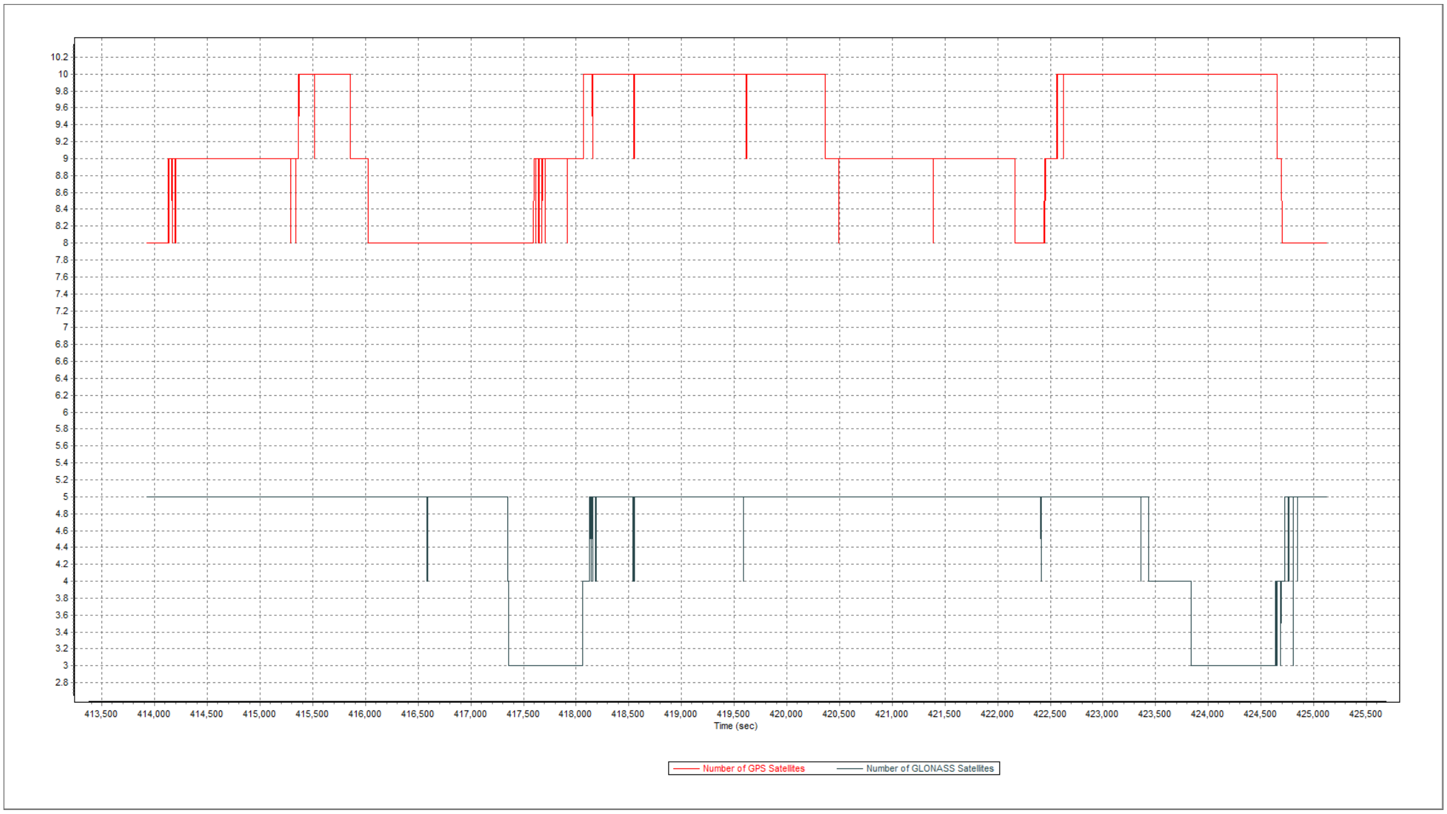
405,500
406,000
406,500
407,000
407,500
408,000
Time (sec)

20160107-2


HDF5
NYST
NYFV
VTBE
Start
NYCS
MABN
SmartBase Region
Real-time Reference Frame (RNAV)
Post-processed (SBET)
HAMP
NYHS
MASH
NYKT
CTWI
20000 m


Time (sec)
North (m)
East (m)
Down (m)
DR mode


Time (sec)
North Position Error RMS (m)
East Position Error RMS (m)
Down Position Error RMS (m)


Time (sec)
Number of GPS Satellites
Number of GLONASS Satellites


PDOP
2
413,500
414,000
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415,000
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416,000
416,500
417,000
417,500
418,000
418,500
419,000
419,500
420,000
420,500
421,000
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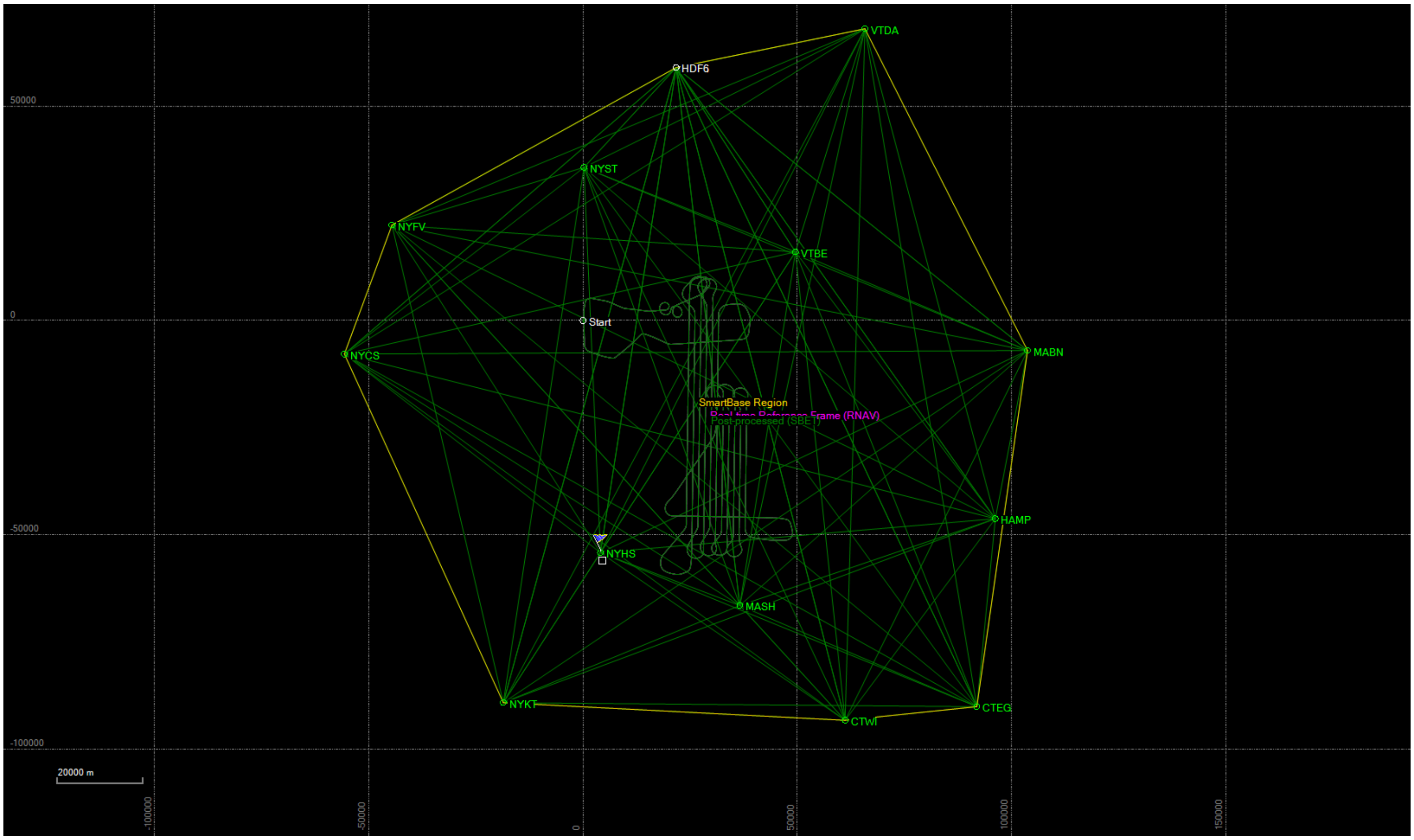
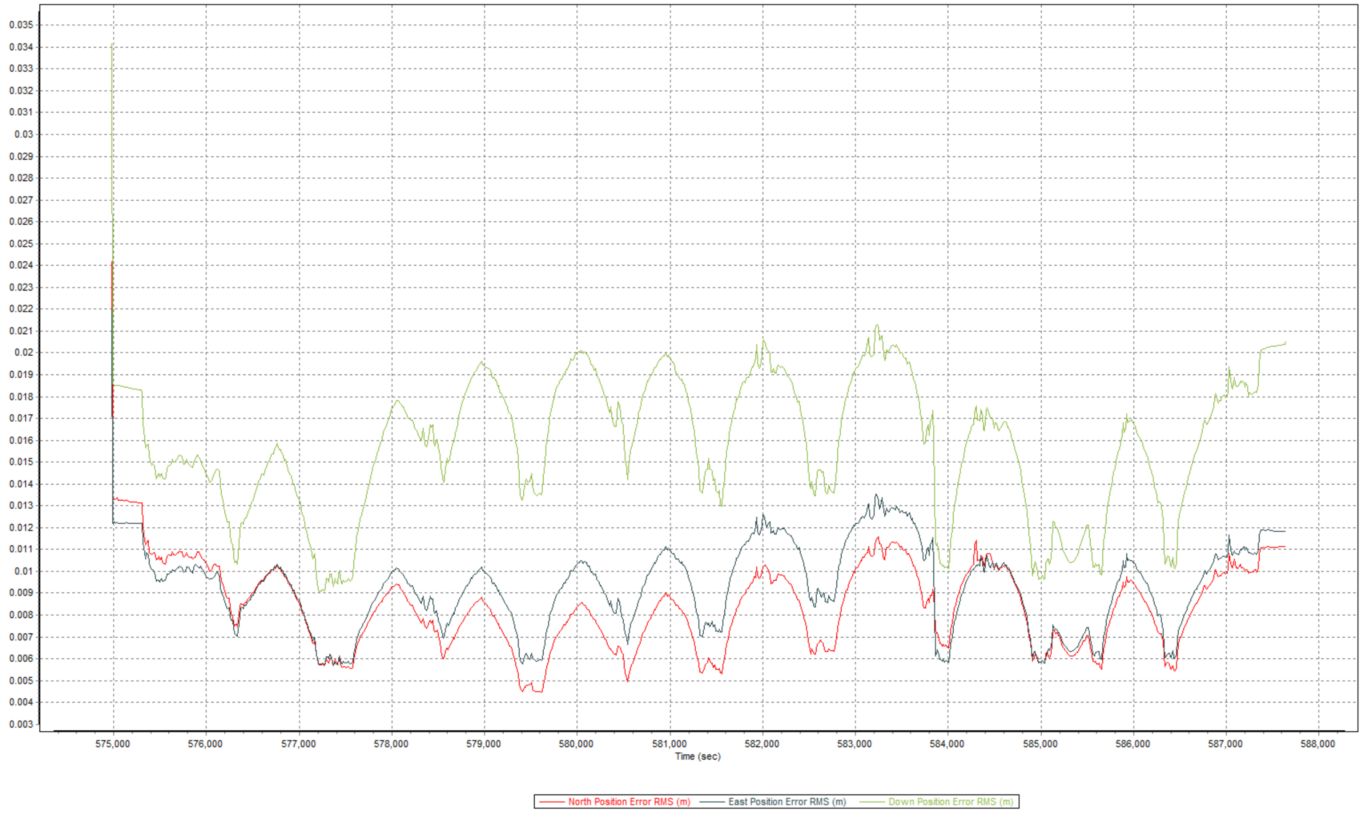
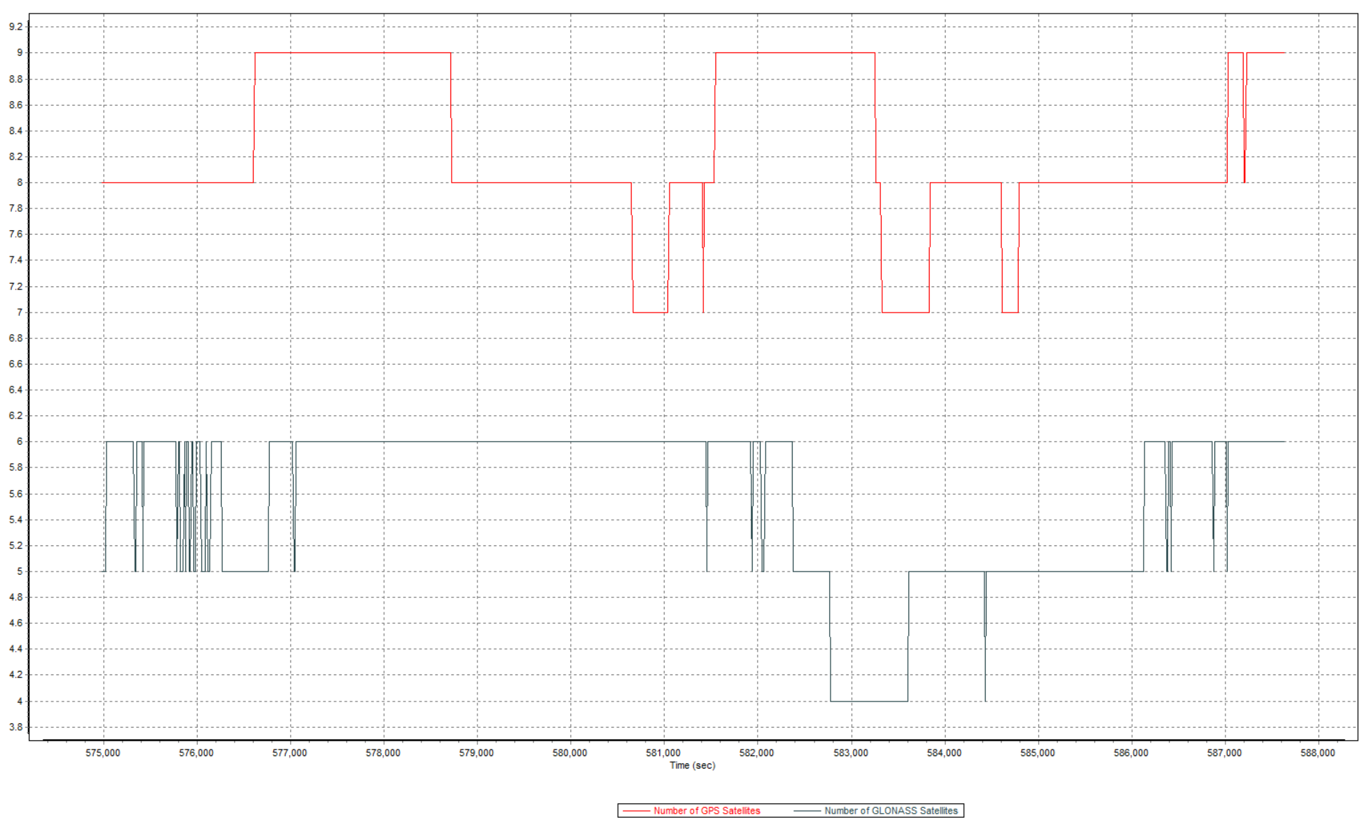
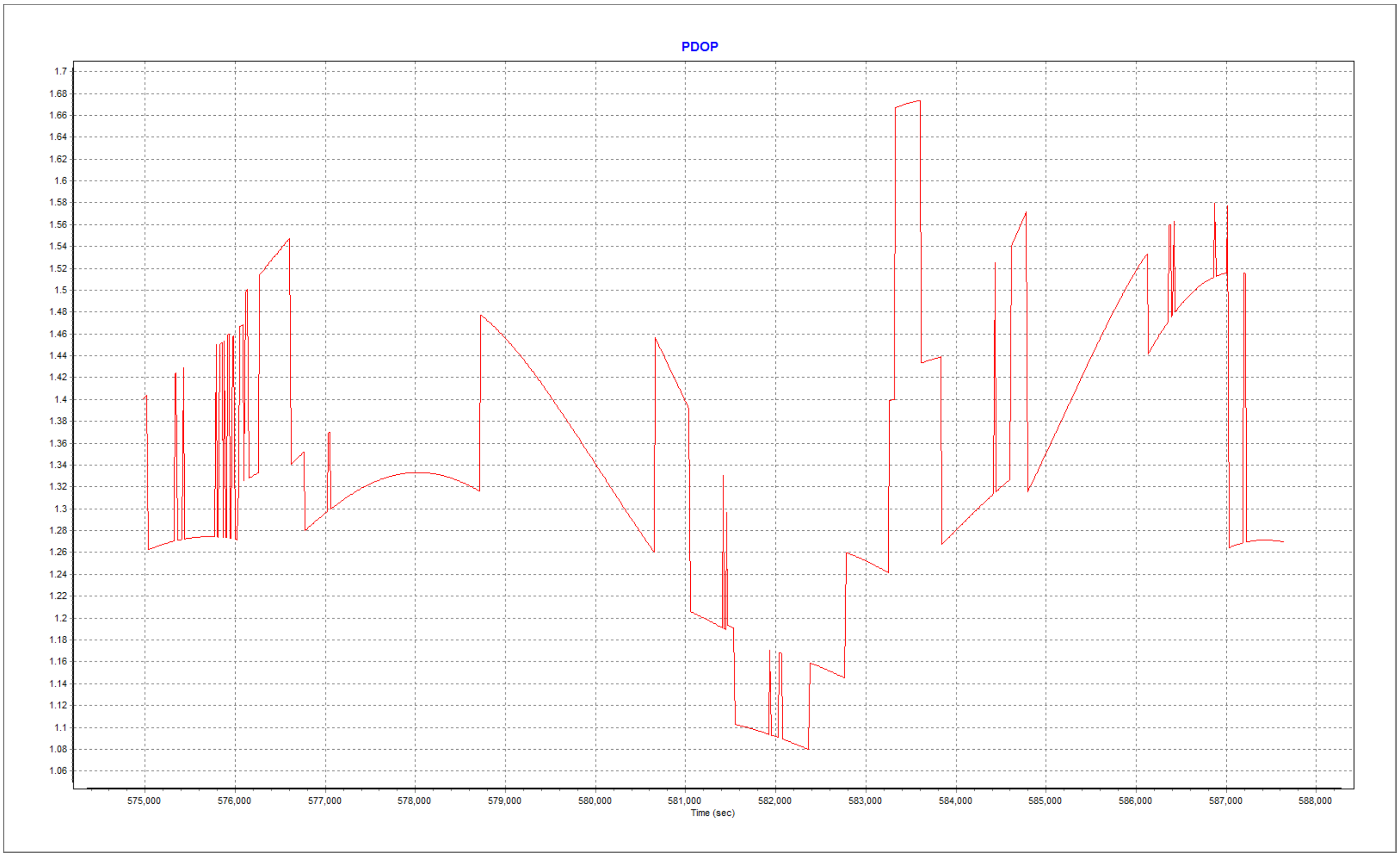
422,500
423,000
423,500
424,000
424,500
425,000
425,500
Time (sec)

20160305-1


VTDA
HDF6
NYST
NYFV
VTBE
Start
NYCS
MABN
SmartBase Region
HAMP
NYHS
MASH
NYKT
CTWI
CTEG
50000
0
-50000
-100000
20000 m


Time (sec)
North Position Error RMS (m)
East Position Error RMS (m)
Down Position Error RMS (m)


Time (sec)
Number of GPS Satellites
Number of GLONASS Satellites


PDOP
1.7
1.68
1.66
1.64
1.62
1.6
1.58
1.56
1.54
1.52
1.5
1.48
1.46
1.44
1.42
1.4
1.38
1.36
1.34
1.32
1.3
1.28
1.26
1.24
1.22
1.2
1.18
1.16
1.14
1.12
1.1
1.08
1.06
575,000
576,000
577,000
578,000
579,000
580,000
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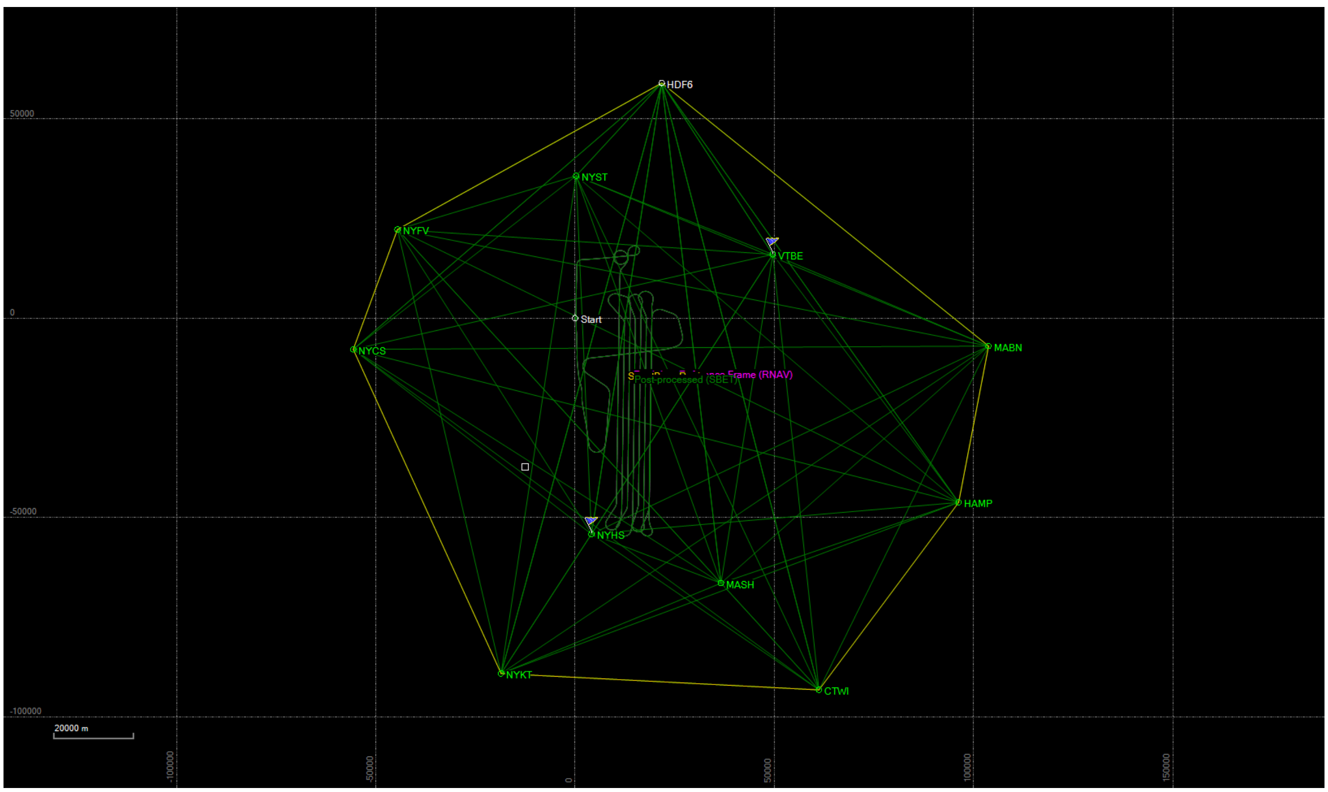
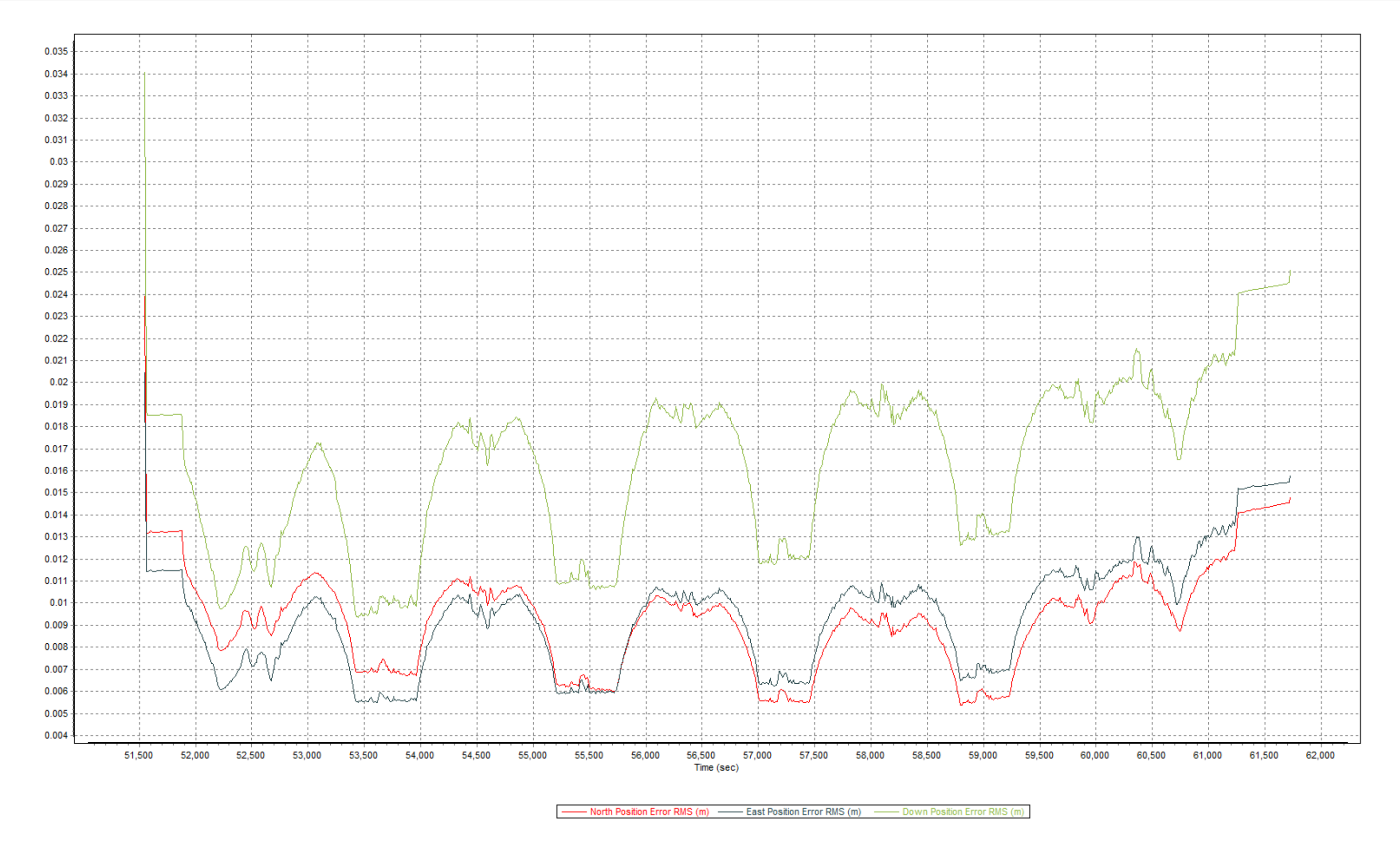
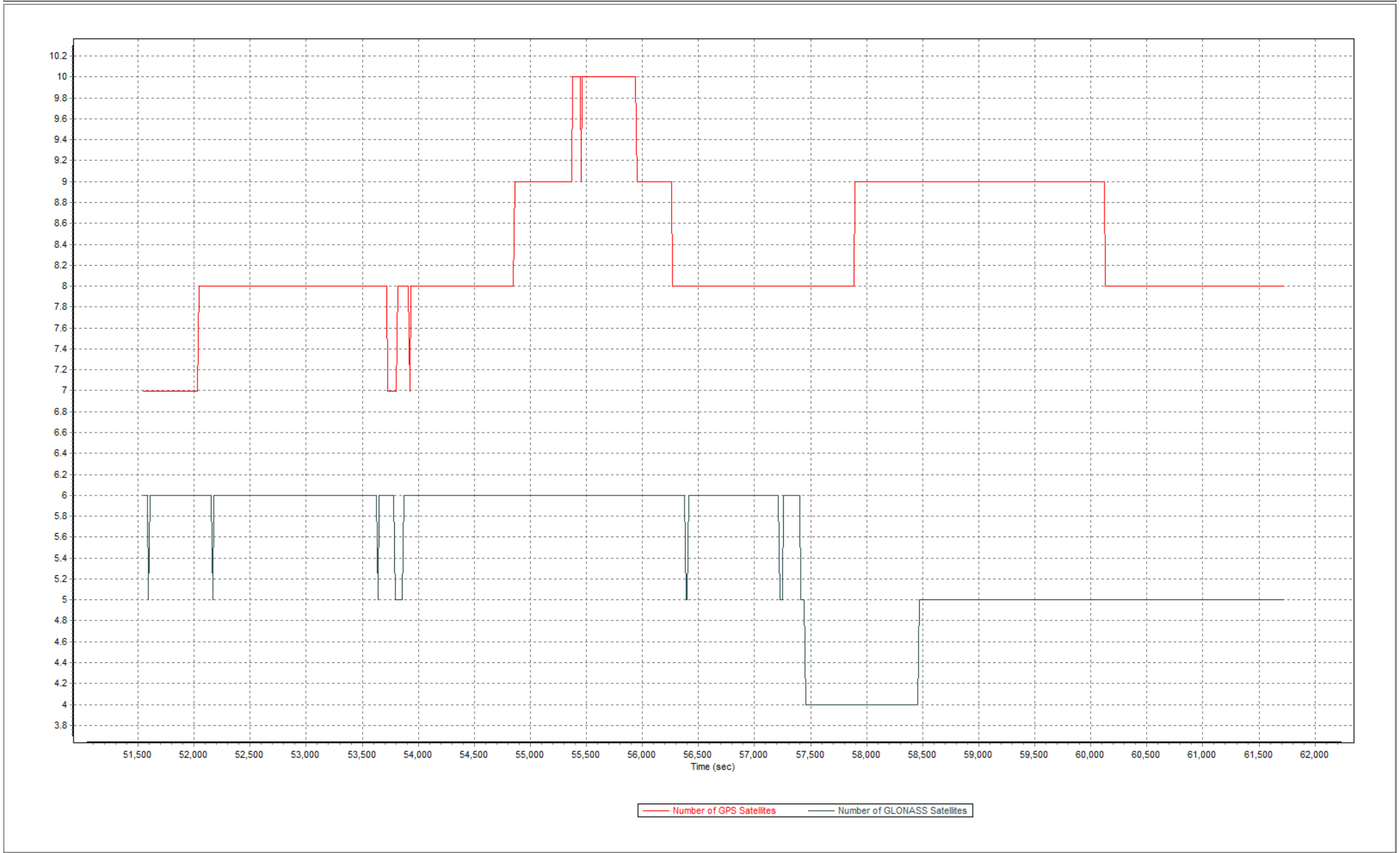
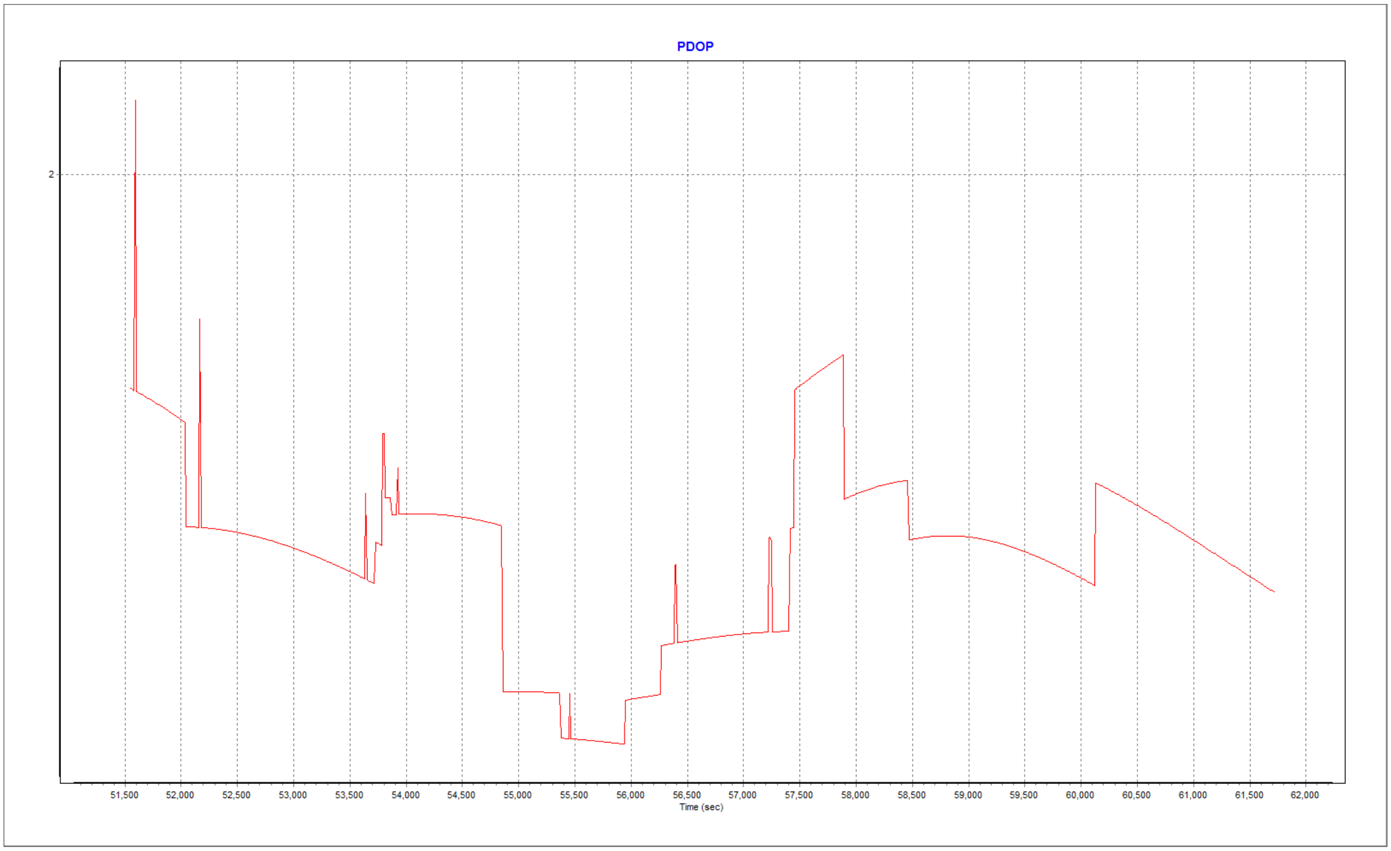
583,000
584,000
585,000
586,000
587,000
588,000
Time (sec)

20160306-1


HDF6
NYST
NYFV
VTBE
Start
NYCS
MABN
HAMP
NYHS
MASH
NYKT
CTWI
50000
0
-50000
-100000
20000 m
-100000
-50000
0
50000
100000
150000


Time (sec)
North Position Error RMS (m)
East Position Error RMS (m)
Down Position Error RMS (m)


Time (sec)
Number of GPS Satellites
Number of GLONASS Satellites


PDOP
2
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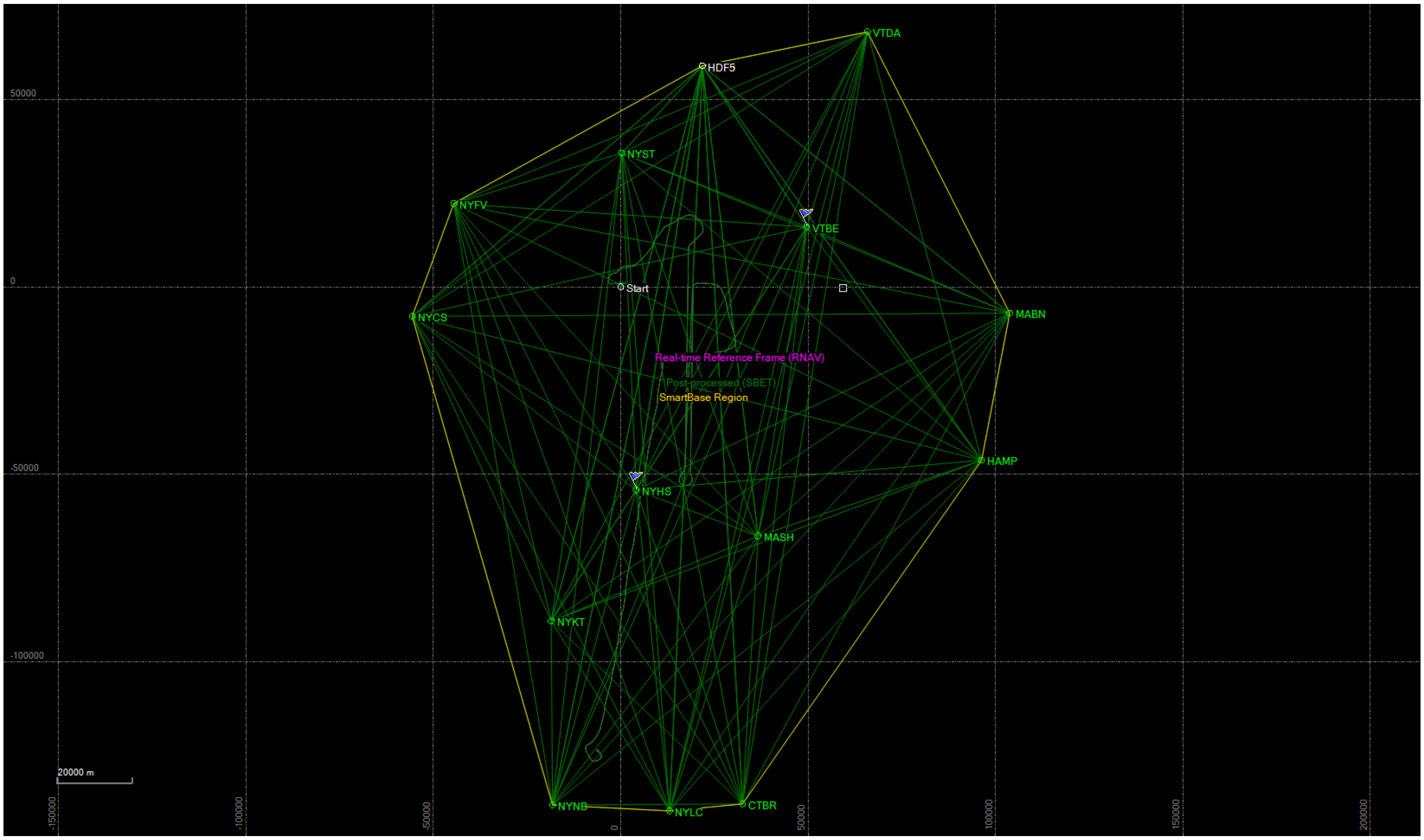
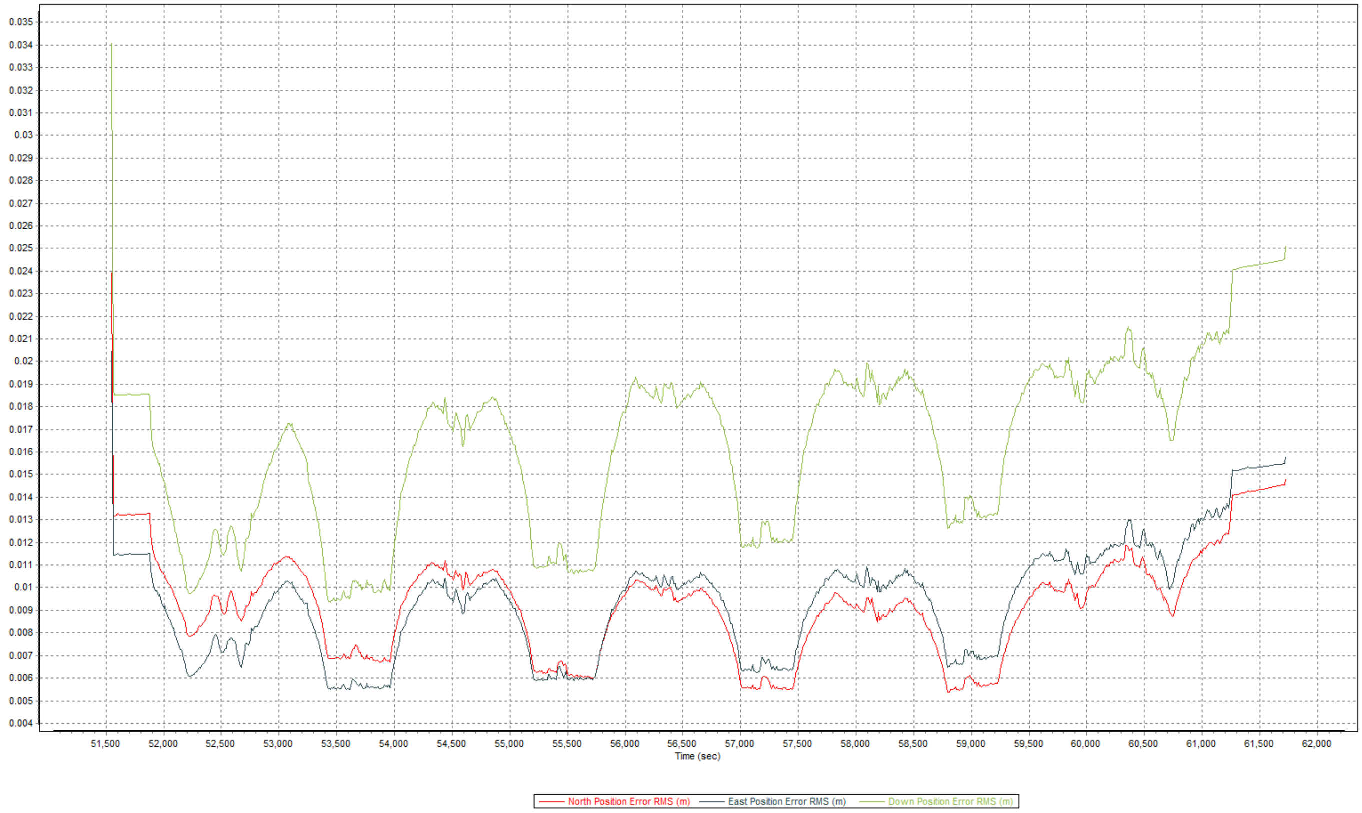
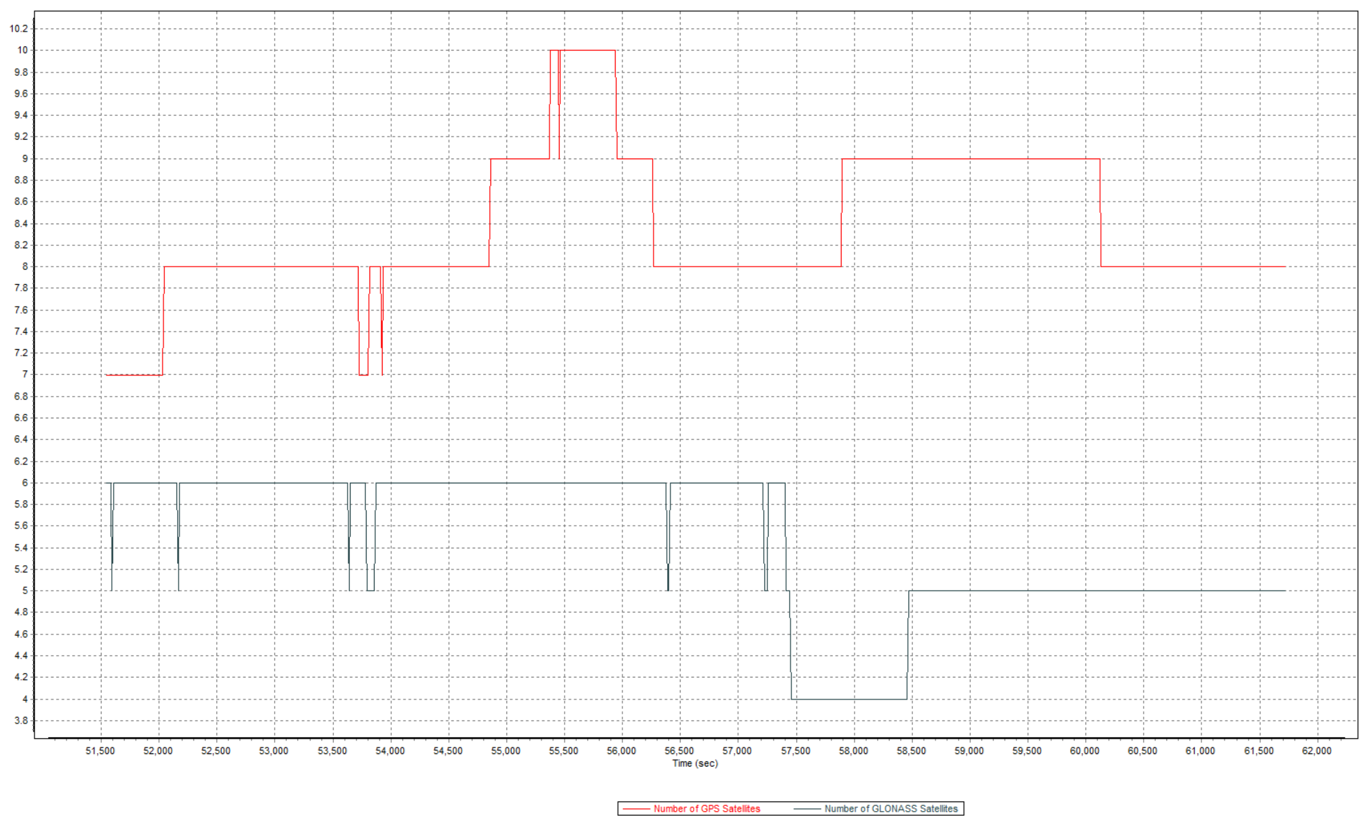
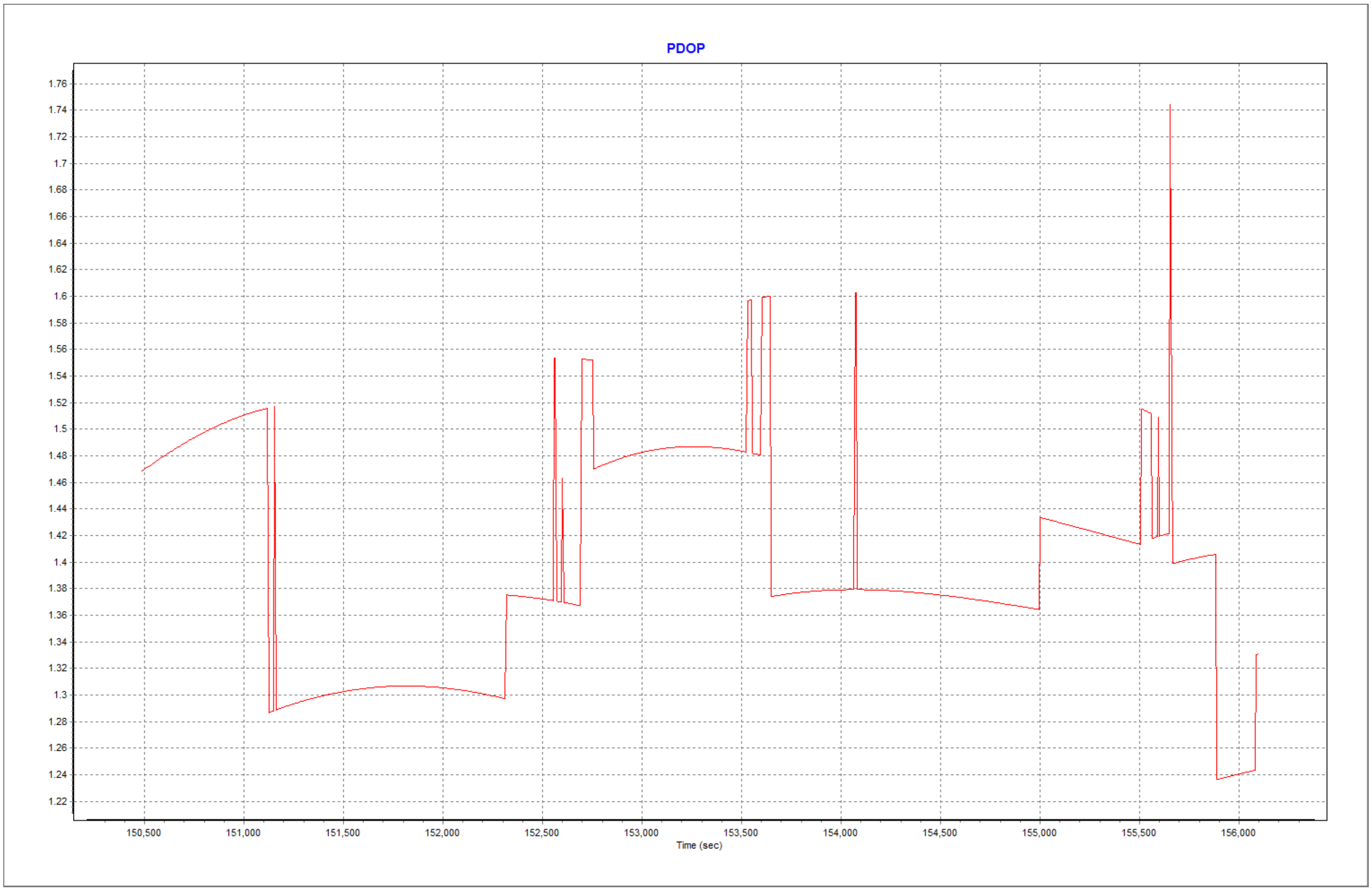
58,000
58,500
59,000
59,500
60,000
60,500
61,000
61,500
62,000
Time (sec)

20160321-1


VTDA
HDF5
NYST
NYFV
VTBE
Start
MABN
NYCS
Real-time Reference Frame (RNAV)
Post-processed (SBET)
SmartBase Region
HAMP
NYHS
MASH
NYKT
NYNB
NYLC
CTBR
20000 m
50000
0
-50000
-100000


Time (sec)
North Position Error RMS (m)
East Position Error RMS (m)
Down Position Error RMS (m)


Time (sec)
Number of GPS Satellites
Number of GLONASS Satellites


PDOP
1.76
1.74
1.72
1.7
1.68
1.66
1.64
1.62
1.6
1.58
1.56
1.54
1.52
1.5
1.48
1.46
1.44
1.42
1.4
1.38
1.36
1.34
1.32
1.3
1.28
1.26
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1.22
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151,000
151,500
152,000
152,500
153,000
153,500
154,000
154,500
155,000
155,500
156,000
Time (sec)