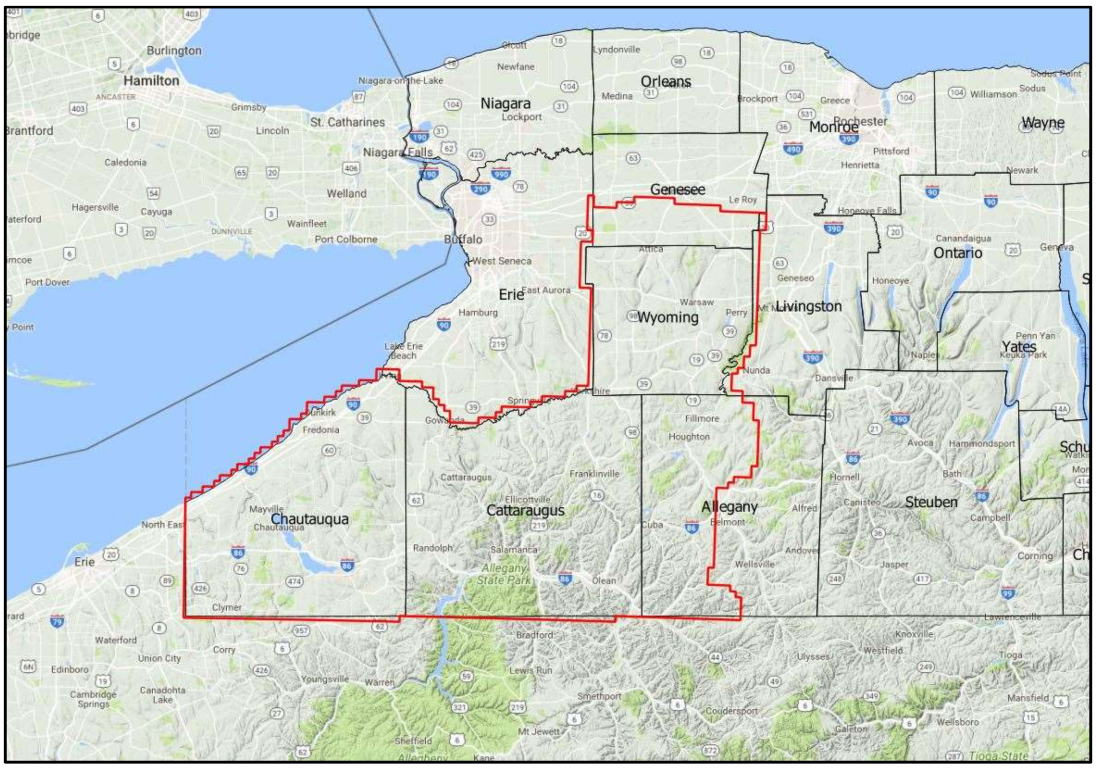
New York State
Airborne LiDAR Acquisition Report

for

New York State Office of Information Technology Services
10B Airline Drive
Albany, New York 12235



Southwest 17-B (Fall)

by

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Axis Project 13367-1710
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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 Chautauqua, Cattaraugus, Allegany, Wyoming and Genesee 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
- 10 Ignored Ground
- 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 Western New York State, south of Buffalo, and covers approximately 3,905.81 square miles. The project area includes the cities of Jamestown and Olean. See Figure 1: "Location of Project Area". The project area measures approximately 90 miles from the eastern boundary to the western boundary and approximately 70 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 stored in a non-proprietary format such as LAS and meets 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 17 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 12B.

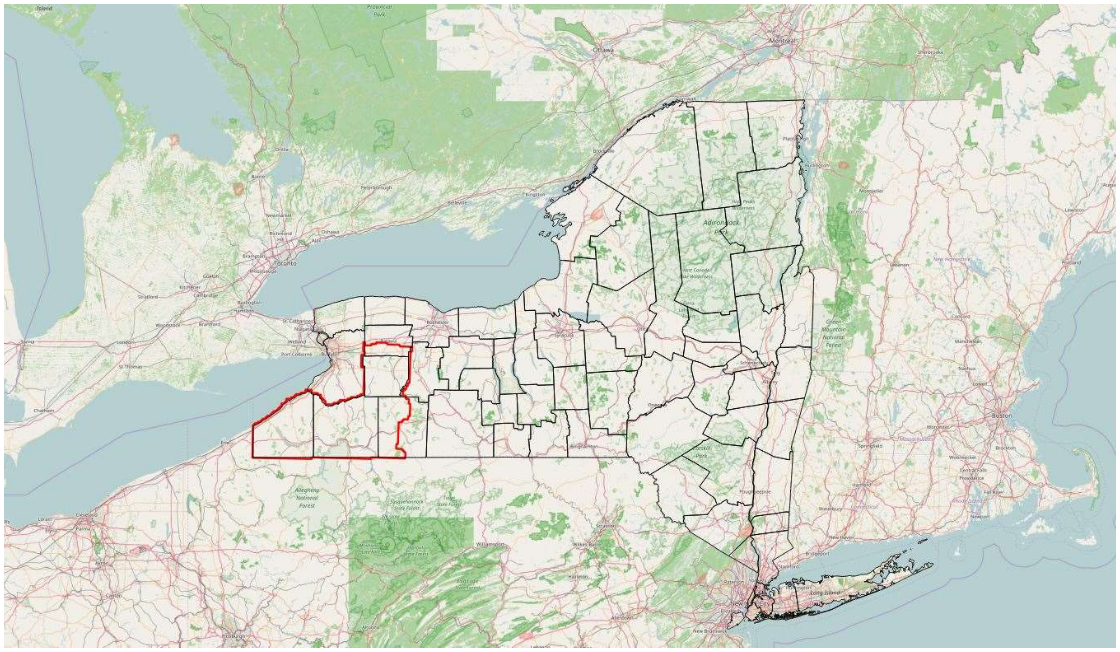


Figure 1: Location of Project Area

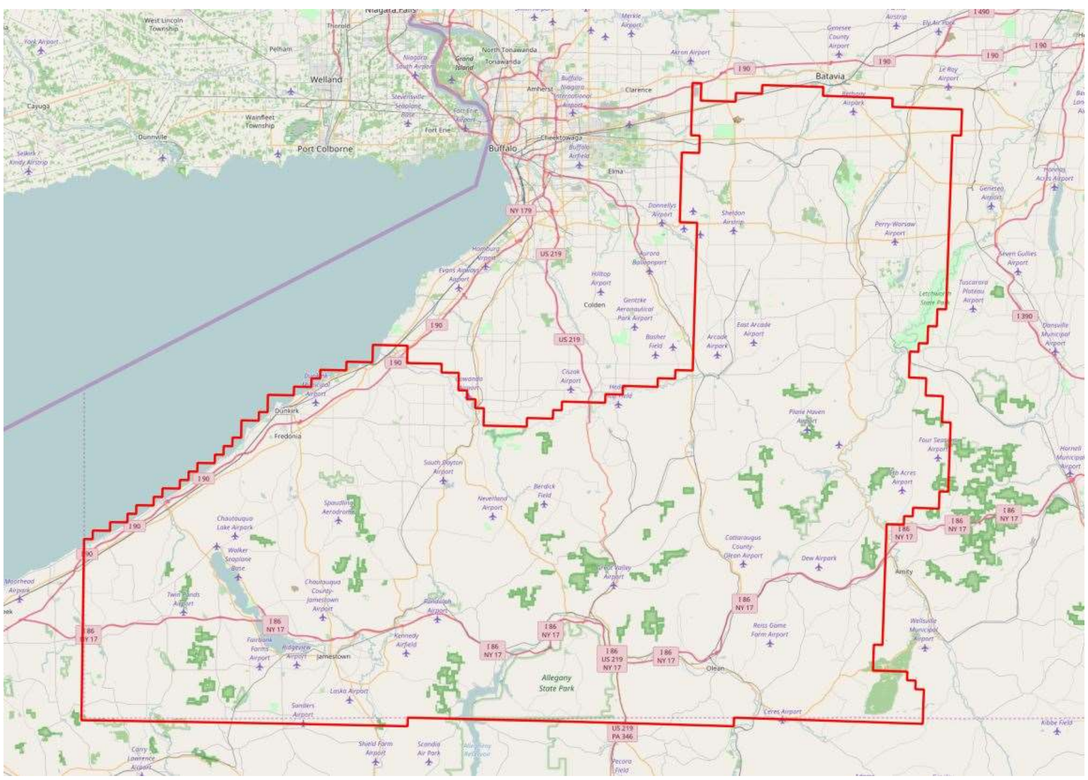


Figure 2: Original Project Area

Due to issues with the LiDAR acquisition, the original project area (as shown above) was divided into two separate projects. The first project, called Southwest 17, is located in the western portion of the original project area and measures approximately 1,722 square miles, or 44% of the original project area. The LiDAR for this area was acquired in the Spring of 2017 by Axis GeoAviation, LLC of Easton, MD and Airborne Imaging of Calgary, Alberta. The processing and classification were completed by Axis GeoSpatial and delivered to the State in November and December of 2017.

See Figure 3 Southwest 17 Project Area; below.

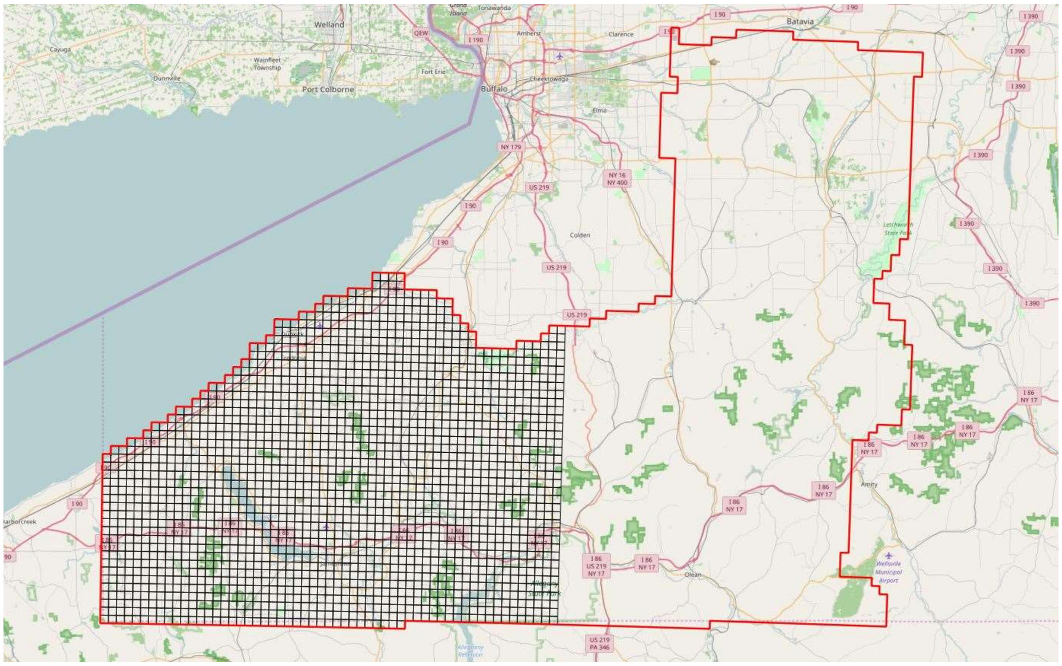


Figure 3: Southwest 17 Project Area

The NY State LiDAR project Southwest 17-B (Fall) consists of the remaining eastern portion of the original project area. The project contains 2,515 delivery tiles each measuring 5,000 m x 5,000 m. The area measures approximately 2,185 square miles or 56% of the original project area. See Figure 4: Southwest 17-B Project Area (below);

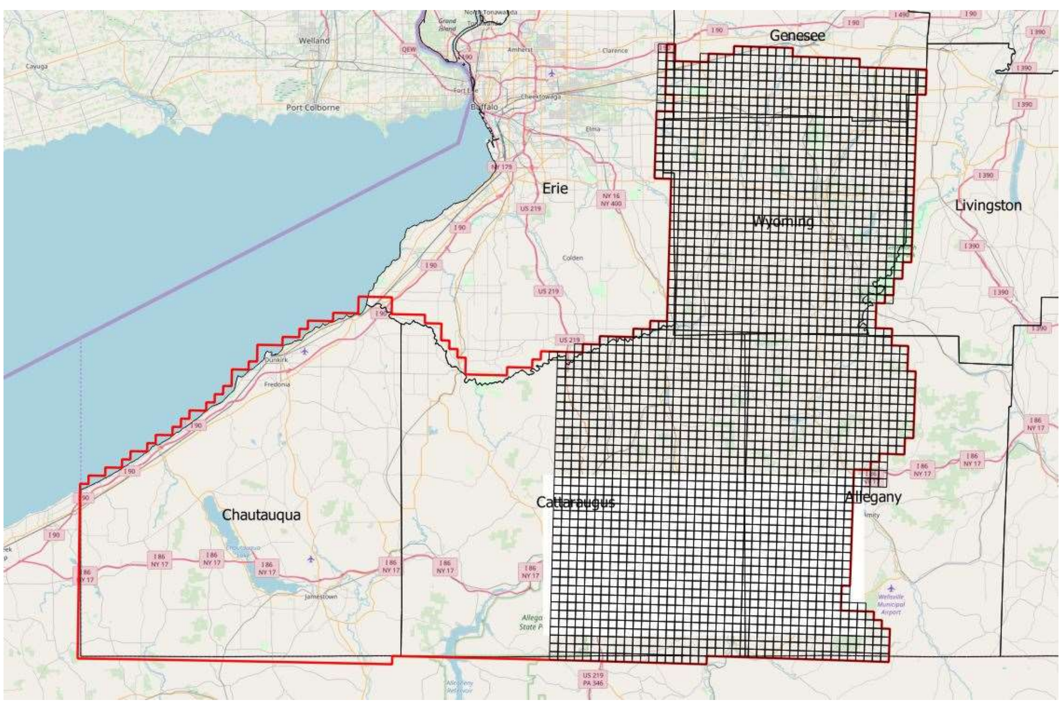


Figure 4: Southwest 17-B Project Area

Section 3: LiDAR Acquisition

3.1 Acquisition

Airborne LiDAR was acquired by Airborne Imaging based in Calgary, Canada with two Riegl LiDAR sensors; a Q1560i and a VQ1560i. The Q1560i sensor was installed in a Piper Aztec twin engine aircraft with the tail number of C-GLZR. The VQ1560i sensor was installed in a Piper PA31 with the tail number of C-GMEC.

Table 2: "Riegl Q1560i Sensor Specifications", and Table 3: "Riegl VQ1560i Sensor Specifications", provide a list of the features and specifications for the LiDAR sensor systems.

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 Q1560i Sensor Specifications

Minimum Range [8)]	100 m
Accuracy [9) 10)]	20 mm
Precision [10) 11)]	20 mm
Laser Pulse Repetition Rate	up to 2 MHz
Effective Measurement Rate	up to 1.33 MHz @ 60° scan angle
Echo Signal Intensity	provided for each echo signal
Laser Wavelength	near infrared
Laser Beam Divergence	≤ 0.18 mrad @ 1/e [12)], ≤ 0.25 mrad @ $1/e^2$ [13)]
Number of Targets per Pulse	with online waveform processing: practically unlimited [14) 15)]
	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 Scan Angle in Non-Nadir Direction	± 8° at the edges
Scan Angle Range	60° total per channel, resulting in an effective FOV of 58°
Total Scan Rate	40 [16)] - 600 lines/sec
Angular Step Width Δϑ	0.006° ≤ Δϑ ≤ 0.180° [17) 18)]
Angle Measurement Resolution	0.001°

Table 3: Riegl VQ1560i Sensor Specifications

3.2 Acquisition Details

Details of the Spring 2017 acquisition are provided in the Southwest 17 acquisition report (NY17_Southwest17_LiDAR_Acquisition_Report_08_22_2018.pdf).

Seventy-one (71) flightlines plus cross ties were planned to complete the LiDAR acquisition for Southwest 17-B. Flightlines were planned in a north-south direction and split in half to prevent IMU "sleep" which tends to occur during long acquisition lines. The split in the lines coincided with northern county boundaries of Cattaraugus and Allegany Counties and with the southern boundary of Wyoming County.

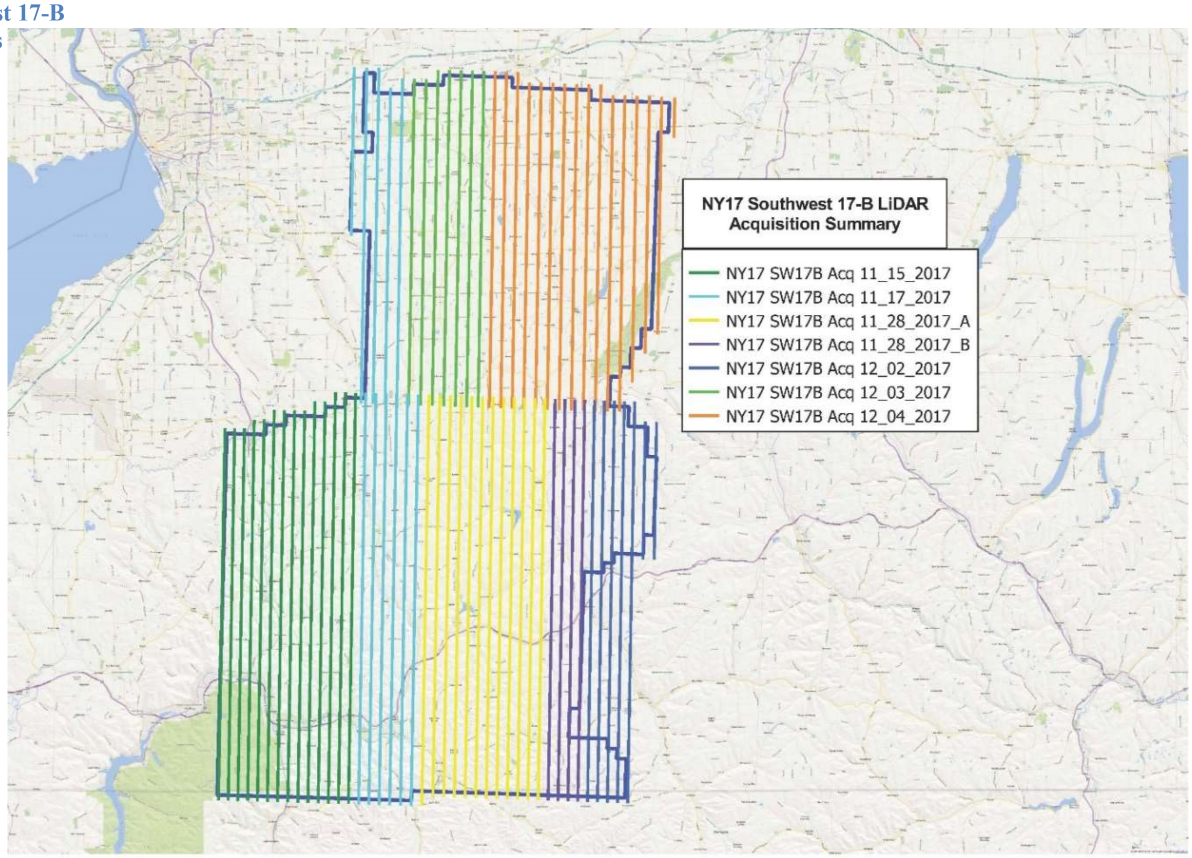
The preferred acquisition plan was to begin acquisition on the west side of the southern tier and continue directly from where the final lines were acquired for Southwest 17. One line of overlap was planned and on Wednesday, November 14, 2017, Airborne Imaging acquired the first 14 lines along the southern tier. Acquisition continued on Friday, November 17 with Airborne Imaging acquiring 6 flightlines along the southern tier and then moving northward to acquire 6 flightlines along the northern tier, starting from the western side. Unfavorable weather conditions prevented acquisition from November 18 through November 27.

On Tuesday, November 28, Airborne Imaging acquired a total of 16 flightlines during two sorties. 12 flightlines were acquired along the southern tier during the first sortie and 4 more flightlines were acquired during the second sortie. Airborne Imaging acquired 7 flightlines on Saturday, December 2. This completed the acquisition of the southern tier of the project. Acquisition continued on Sunday, December 3 with 7 more lines being acquired along the northern tier. Finally, on Monday, December 3, Airborne Imaging completed acquisition by acquiring the final 16 flightlines along the northern tier. Flightline 49 was acquired twice. During the initial mission on Nov 17, only one channel was operating. On Dec 3, Line 49 was reacquired with dual channels operating. Axis included both data sets. As a result, seventy-two (72) lines were acquired.

3.3 LiDAR Flightline Orientation

Figure 5: "Southwest 17-B Actual Flight Lines Acquired (Fall Acquisition)", illustrates the location and number of flightlines that were acquired during the Fall of 2017.

Figure 5: Southwest 17-B Actual Flight Lines Acquired (Fall Acquisition)



3.4 Acquisition Flight Summary

Seven LiDAR acquisition missions were flown between November 15, 2017 and December 4, 2017. Flights were planned at various flying heights above 7,500 ft. AMSL.

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.
Table 4: "Acquisition Dates and Parameters", provides a summary of the acquisition missions.

Date of Mission(s)	Mission Number	Number of Lifts	# of Lines Acquired	Sensor	Mission Time (LTC)	Aircraft Tail Number
November 15, 2017	AI-1	1	14	Q1560i	15:25 – 19:11	C-GLZR
November 17, 2017	AI-2	1	12	Q1560i	20:09 – 23:46	C-GLZR
November 28, 2017	AI-3 AI-4	2	16	VQ1560i	14:46 – 19:11 21:46 - 00:25	C-GMEC
December 2, 2017	AI-5	1	7	VQ1560i	15:29 – 17:45	C-GMEC
December 3, 2017	AI-6	1	7	VQ1560i	15:00 – 17:16	C-GMEC
December 4, 2017	AI-7	1	16	VQ1560i	17:07 – 21:16	C-GMEC

Table 4: Acquisition Dates and Parameters

The System Parameters for LiDAR Acquisition are provided in Section 3.7 in Tables 5 & 6: "System Parameters for LiDAR Acquisition" on Page 10 of this report.

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 paramount 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

The project area is notorious for having cold and unfavorable weather, especially in the autumn and winter months. Fortunately, the weather was mild and very little snow interfered with acquisition. Clouds and rain were the factors that prevented acquisition. When snow did fall, it melted quickly.
The initial data reviews did not show any significant issues in the quality and coverage of the acquired data. However,

subsequent reviews identified two areas of concern.

On the final day of acquisition in one of the last flightlines acquired, a hole in the data was identified and the data reviewed in this area. It was determined that the sensor experienced an MTA (multiple time around capability) issue. Because the issue was located near the eastern edge of the project, data from a previous project, Allegany-Steuben, was reviewed for coverage. Upon further investigation, it was determined that the hole was sufficiently covered by the Allegany Steuben data. This resolution was provided to the State for review and approval. During this period, Axis discovered another area that contained an excessive amount of noise. Again, the data in this area was reviewed and found to have been affected by an MTA issue. The area with the high amount of noise was in the same flightlines as the hole identified earlier. The area where the LiDAR will be reacquired is shown in Figure 6: Area of Re-Acquisition.

After consulting with Airborne Imaging, Axis determined that the best solution was to reacquire the data over these two areas. The area with no data and the high noise area will be required, as soon as weather and ground conditions permit.

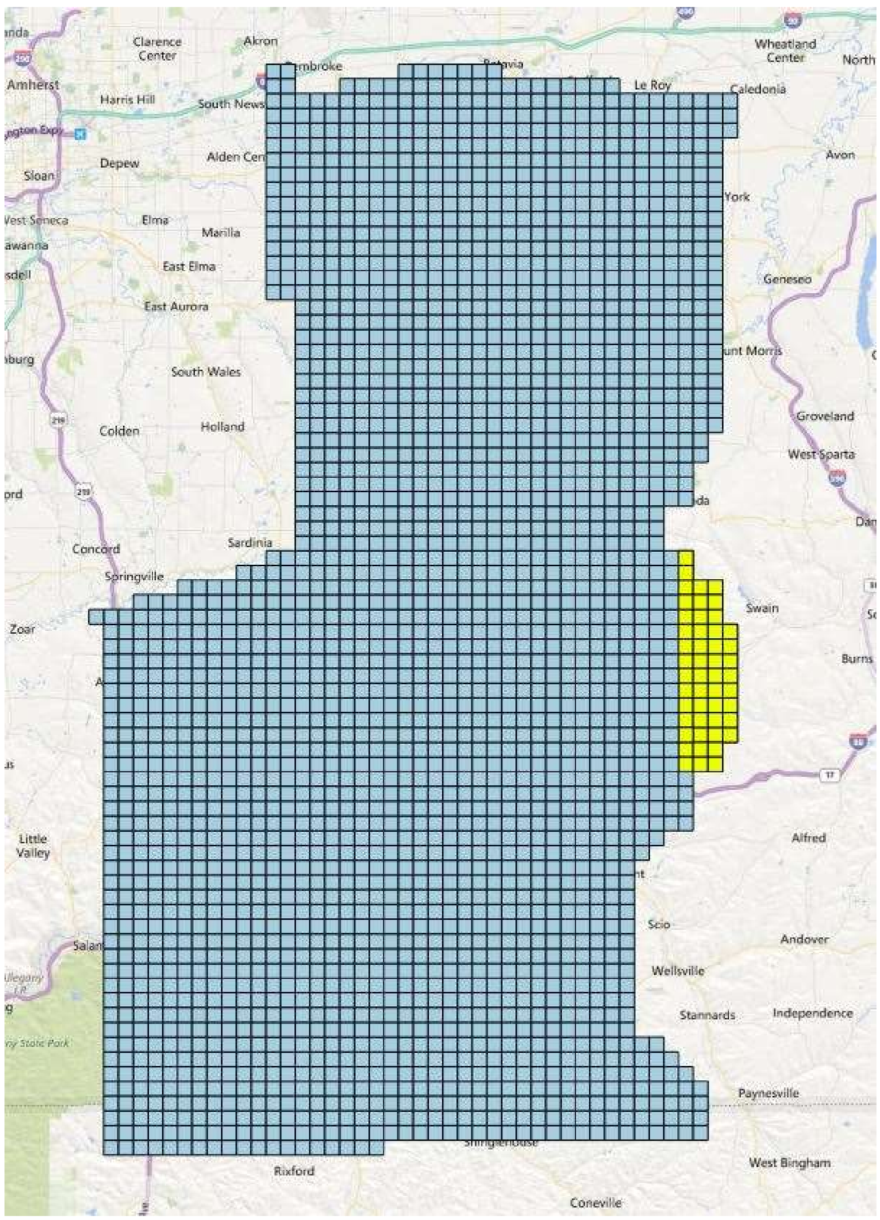


Figure 6: Area of Re-Acquisition

3.7 LiDAR System Acquisition Parameters

LiDAR acquisition was planned to meet the following specifications in Table 5: "System Parameters for LiDAR Acquisition Q1560i". Table 6: "System Parameters for LiDAR Acquisition VQ1560i" provides the acquisition parameters for the VQ1560i sensor.

Item	Parameter
System	Riegl Q1560i
Nominal Pulse Spacing (m)	0.76
Nominal Pulse Density (pls/m²)	2.87
Nominal Flight Height (MSL meters)	2469
Nominal Flight Speed (kts)	135-150
Pass Heading (degree)	180,360
Sensor Scan Angle (degree)	58.52
Scan Rate	162 lps
Pulse Rate of Scanner (kHz)	766 kHz
Line Spacing (m)	.83
Pulse Duration of Scanner (ns)	5
Pulse Width of Scanner (m)	0.60
Central Wavelength of Sensor Laser	1064nm
Sensor Operated with Multiple Pulses	Yes
Beam Divergence (mrad)	0.25
Nominal Swath Width (m)	2561
Nominal Swath Overlap (%)	20%
Scan Pattern	Parallel scan lines per channel, crossed scan lines between channels

Table 5: System Parameters for LiDAR Acquisition Q1560i

Item	Parameter
System	Riegl VQ1560i
Nominal Pulse Spacing (m)	0.63
Nominal Pulse Density (pls/m²)	2.52
Nominal Flight Height (MSL meters)	2300
Nominal Flight Speed (kts)	140
Pass Heading (degree)	180,360
Sensor Scan Angle (degree)	58.52
Scan Rate	156 lps

Pulse Rate of Scanner (kHz)	700 kHz
Line Spacing (m)	.89
Pulse Duration of Scanner (ns)	3
Pulse Width of Scanner (m)	0.60
Central Wavelength of Sensor Laser	1064nm
Sensor Operated with Multiple Pulses	Yes
Beam Divergence (mrad)	0.25
Nominal Swath Width (m)	2577
Nominal Swath Overlap (%)	20%
Scan Pattern	Parallel scan lines per channel, crossed scan lines between channels

Table 6: System Parameters for LiDAR Acquisition VQ1560i

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 7; "GPS Reference Station Coordinates" and Figure 7; "GPS Reference Stations" below contain 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)
NYBT	42°59'17.96241" N	078°07'20.40109" W	262.067 m
NYDV	42°32'56.12556" N	077°41'52.62049" W	187.388 m
NYFD	42°25'41.81700 "N	079°20'22.74609" W	211.313 m
NYFS	42°12'16.82473" N	078°08'37.96443" W	441.350 m
NYHB	42°43'02.69515" N	078°50'47.29975" W	211.326 m
NYPF	43°05'35.51718" N	077°31'31.13761" W	112.319 m
NYLP	43°09'54.88682" N	078°45'13.38358" W	165.129 m
NYSM	42°11'31.41330" N	078°44'50.49096" W	409.409 m
PAJP	40°56'44.68533" N	078°57'03.39516" W	379.265 m
PAPC	41°45'51.89816" N	078°01'24.35457" W	484.597 m
PACS	41°14'21.82931" N	079°25'45.31937" W	413.288 m
UPTC	41°37'43.73270" N	079°39'50.64793" W	341.980 m

Table 7: GPS Reference Station Coordinates

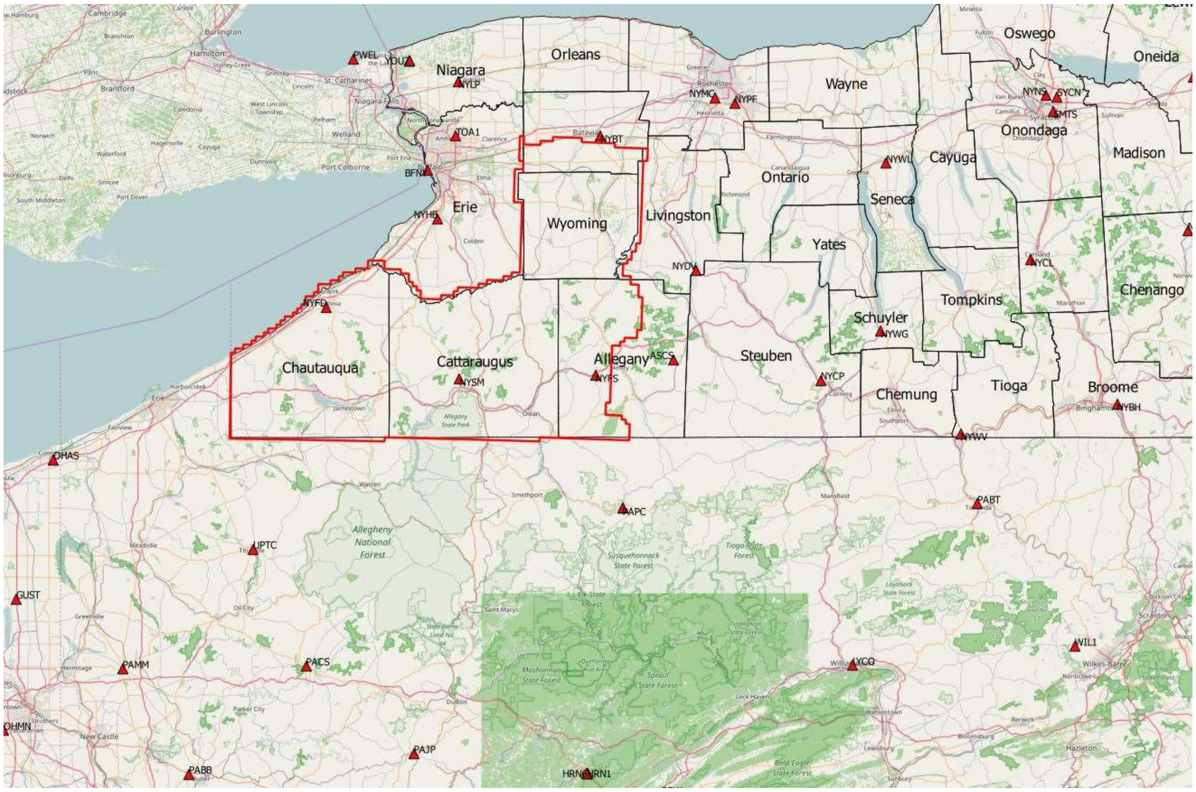


Figure 7: GPS Reference Stations

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.8.1 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 the laser is 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.

Airborne Imaging utilized the latest in Airborne-GPS (AGPS) and Inertial Measurement Unit (IMU) systems to determine the precise three-dimensional trajectory of their 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.

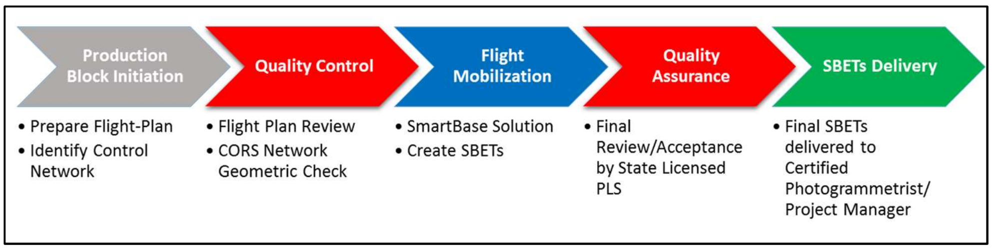
AGPS/IMU Processing

Airborne Imaging used Applanix POS Pac MMS v.8.1 to process Airborne GNSS/IMU datasets and compute Smoothed Best Estimated Trajectory (SBET) files for our LiDAR 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

November 15, 2017

Julian Day 319 | Flight A

LIDAR Flight Log

AIRBORNE IMAGING

Date Nov. 15 2017	Aircraft C-GLZR	System Riegl Q1560i	Additional Notes
Project 3135_Warsaw	Pilot MHB	Unit 2220756	Wind:
Location St. Catherines CYSN	Operator MW	IMU Applanix AV510	Temp:
Mission Objective		GPS Rx	Pressure:
		Scanner 1 Drive	Clouds:
		Scanner 2 Drive	Visibility:

Aircraft Block Time		
Engine On	Ramp Out	Takeoff 14:41
Engine Off	Ramp In	Landing 19:30
Total hrs	Total hrs	Total 4.8 hrs

Mission Plan			
AGL Height	2300 m	Laser Pulse Rate	800 Hz
Target Speed	160 kts	Scan Rate	178 ~~167~~ Hz
Laser Current	100 %	FOV	60 Deg's

Static Alignment	GPS Time Start	GPS Time End
Pre Mission		
Post Mission		

Flight Line	LiDAR File Name	Flight Direction	Flight Altitude	GPS Time Start	GPS Time End	Line Aborted Time	Line Aborted nmi to End	Comments Time Stamp: 171115
01		S		1525	15:38			
02		N		1540	1552			
03		S		1554	1608			
04		N		1610	1622			
05		S		1625	1639			
06		N		1641	1653			
07		S		1656	1711			
08		N		1713	1725			
09		S		1727	1743			
10		N		1745	17:57			
11		S		1800	1816			
12		N		1818	1830			
13		S		1832	1848			
14		N		1850	1901			
X-Tie		W		1905	1911			

Pg of

Julian Day 321	Flight A

LIDAR Flight Log

AIRBORNE IMAGING

Date Nov. 17 2017	Aircraft C-GLZR	System	Q1560	Additional Notes	
Project 3135_Warsaw	Pilot MH	Unit	2220756	Wind:	
Location CY00 Oshawa	Operator MW	IMU	Applanix AV510	Temp:	
Mission Objective		GPS Rx		Pressure:	
		Scanner 1 Drive	B0/B1	Clouds:	
		Scanner 2 Drive	B2	Visibility:	

Aircraft Block Time		
Engine On	Ramp Out	Takeoff 19:40
Engine Off	Ramp In	Landing 00:12
Total 6.0 hrs	Total hrs	Total 4.5 hrs

Mission Plan			
AGL Height	2300 m	Laser Pulse Rate	800 Hz
Target Speed	160 kts	Scan Rate	178 Hz
Laser Current	100 %	FOV	60 Deg's

Static Alignment	GPS Time Start	GPS Time End
Pre Mission		
Post Mission		

Flight Line	LiDAR File Name	Flight Direction	Flight Altitude	GPS Time Start	GPS Time End	Line Aborted Time	Line Aborted nmi to End	Comments Time Stamp:
44		S		2009	2014			North Block
15		S		2019	2033			South Block
16		N		2038	2052			
17		S		2058	2111			
18		N		2115	2130			
45		N		2140	2150			North Block
46		S		2155	2206			
47		N		2211	2212			Abort - pilot error
19		S		2216	2230			South Block
20		N		2233	2247			
47		N		2252	2303			North Block
48		S		2306	2316			
X-Tie		W		2320	2324			South Block
49		N		2328	2339			North Block
X-Tie		W		2342	2346			North Block.

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Julian Day 332	Flight A

LIDAR Flight Log

AIRBORNE IMAGING
A Clean Harbors Company

Date 2017 NOV 28	Aircraft PA-31 C-GMEC
Project 3135 Warsaw	Pilot S. Bouzid
Location CYKF → CYSN	Operator T. Trithardt
Mission Objective	

System	Riegl VQ1560i
Unit	S2222593
IMU	Applanix IMU57
GPS Rx	Trimble
Scanner 1 Drive	Ø
Scanner 2 Drive	1

Additional Notes

- Temp 4°C
- Humidity 80%
- Altimeter 1016
- Terrain Height 320m

Aircraft Block Time		
Engine On 1402	Ramp Out	Takeoff 1426
Engine Off	Ramp In	Landing 2015
Total hrs	Total hrs	Total 5.8 hrs

Mission Plan					
AGL Height	2300	m	Pulse Rate	700	KHz
Target Speed	140	kts	Scan Rate	156	Hz
Laser Current	100	%	FOV	58	Deg's

Static Alignment	GPS Time Start	GPS Time End
Pre Mission	1412	1417
Post Mission	2016	2021

Flight Line	LiDAR File Name	Flight Direction	GPS Time Start	GPS Time End	Line Aborted Time	Line Aborted nmi to End	Mission ID	Comments
KAR CATH	–	G	1446	1451			–	INITIALIZATION
TEST STRIP	–	G	1446	1448			171128_144650	
KAR NYFS	–	G	1515	1520			–	
21	931733201	012	1530	1545			153052	
22	02	192	1550	1604			155003	
23	03	012	1608	1622			160832	
24	04	192	1627	1641			162744	
25	05	012	1645	1700			164543	
26	06	192	1704	1719			170438	
27	07	012	1723	1737			172312	
28	08	192	1742	1756			174204	
29	09	012	1801	1856			180100	
30	10	192	1819	1834			181943	
31	11	012	1838	1852			183841	
32	12	192	1857	1911			185722	

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November 28, 2017; Lift 1 Page 2

Julian Day 332	Flight A

LIDAR Flight Log

AIRBORNE IMAGING
A Clean Harbors Company

Date 2017 Nov 28	Aircraft PA-31 C-GMEC
Project 3135 Warsaw	Pilot S. Bouzid
Location CYSN St Catharines ON	Operator T. Trithardt
Mission Objective	

System	Riegl VQ1560i
Unit	S2222593
IMU	Applanix IMU57
GPS Rx	Trimble
Scanner 1 Drive	Ø
Scanner 2 Drive	1

Additional Notes
Temp
Humidity
Altimeter
Terrain Height

Aircraft Block Time		
Engine On 1402	Ramp Out	Takeoff 1426
Engine Off 2023	Ramp In	Landing 2015
Total 6.4 hrs	Total hrs	Total 5.8 hrs

Mission Plan					
AGL Height	2300	m	Pulse Rate	700	KHz
Target Speed	140	kts	Scan Rate	156	Hz
Laser Current	100	%	FOV	58	Deg's

Static Alignment	GPS Time Start	GPS Time End
Pre Mission	1412	1417
Post Mission	2016	2021

Flight Line	LiDAR File Name	Flight Direction	GPS Time Start	GPS Time End	Line Aborted Time	Line Aborted nmi to End	Mission ID	Comments
XTIE (999)	9317332 13	281	1920	1931			171128_192025	EAST 25NMi COMPLETE
KAR NYFS	—	G	1937	1942			—	

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November 28, 2017; Lift 2 Page 1

Julian Day 332	Flight B

LIDAR Flight Log

AIRBORNE IMAGING
A Clean Harbors Company

Date 2017 NOV 28	Aircraft PA-31 C-GMEC
Project 3135 Warsaw	Pilot S. BOUZID.
Location CYSN St Catharines ON	Operator T. Trithardt
Mission Objective CYSN → CYKF	

System	Riegl VQ1560i
Unit	S2222593
IMU	Applanix IMU57
GPS Rx	Trimble
Scanner 1 Drive	Ø
Scanner 2 Drive	1

Additional Notes	
Temp	18°C
Humidity	30%
Altimeter	1014 hpa
Terrain Height	100 m

Aircraft Block Time		
Engine On 2122	Ramp Out	Takeoff 2137
Engine Off 0058	Ramp In	Landing 0052
Total 3.6 hrs	Total hrs	Total 3.3 hrs

Mission Plan					
AGL Height	2300	m	Pulse Rate	700	KHz
Target Speed	140	kts	Scan Rate	156	Hz
Laser Current	100	%	FOV	58	Deg's

Static Alignment	GPS Time Start	GPS Time End
Pre Mission	2127	2132
Post Mission		

Flight Line	LiDAR File Name	Flight Direction	GPS Time Start	GPS Time End	Line Aborted Time	Line Aborted nmi to End	Mission ID	Comments
TEST STRIP	—	G	2146	2147			171128_214610	
KAR NYFS	—	G	2208	2213			—	
33	9317332 14	012	2223	2237			222330	
34	15	192	2242	2256			224224	
35	16	012	2300	2315			230054	
36	17	192	2319	2334			231954	
XTIE	18	281	2337	2341			233755	
KAR NYFS	—	G	2344	2349			—	
KAR CATH	—	G	0020	0025			—	
								IN AIR SHUTDOWN

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December 02, 2017

Julian Day 336	Flight A

LIDAR Flight Log

AIRBORNE IMAGING
A Clean Harbors Company

Date 2017 DEC 02	Aircraft PA-31 C-GMEC
Project 3135 Warsaw	Pilot S. BOUZID.
Location CYSN St Catharines ON	Operator T. Trithardt
Mission Objective	

System	Riegl VQ1560i
Unit	S2222593
IMU	Applanix IMU57
GPS Rx	Trimble
Scanner 1 Drive	Ø
Scanner 2 Drive	1

Additional Notes

- Temp 2°C
- Humidity 93%
- Altimeter 1023 hpa
- Terrain Height 100m

Aircraft Block Time		
Engine On 1439	Ramp Out	Takeoff 1501
Engine Off 1826	Ramp In	Landing 1816
Total 3.8 hrs	Total hrs	Total 3.3 hrs

Mission Plan					
AGL Height	2300	m	Pulse Rate	700	KHz
Target Speed	140	kts	Scan Rate	156	Hz
Laser Current	100	%	FOV	58	Deg's

Static Alignment	GPS Time Start	GPS Time End
Pre Mission	1445	1450
Post Mission	1818	1823

53100 → 66180

Flight Line	LiDAR File Name	Flight Direction	GPS Time Start	GPS Time End	Line Aborted Time	Line Aborted nmi to End	Mission ID	Comments
TEST STRIP	—	G	1529	1534			171202_152952	
KAR NYFS	—	G	1530	1531			—	
37	931733601	012	1542	1556			154206	
38	02	192	1600	1614			160005	
39	03	012	1618	1632			161828	
40	04	192	1636	1650			163653	
41	05	012	1655	1709			165516	
42	06	192	1713	1718			171314	
43	07	012	1722	1727			172235	'NOISE'
XTIE	08	282	1730	1735			173047	"
KAR NYFS	—	G	1740	1745			—	WX UNSUITABLE OVER
								NORTH BLOCK

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December 03, 2017

Julian Day 337	Flight A

LIDAR Flight Log

AIRBORNE IMAGING
A Clean Harbors Company

Date 2017 DEC 03	Aircraft PA-31 C-GMEC
Project 3135 Warsaw	Pilot S. Bouzid
Location CYSN St. Catherines	Operator T. Trithardt
Mission Objective	

System	Riegl VQ1560i
Unit	S2222593
IMU	Applanix IMU57
GPS Rx	Trimble
Scanner 1 Drive	Ø
Scanner 2 Drive	1

Additional Notes
Temp 4°C
Humidity 90%
Altimeter 1021 hpa VIS 5 NMi HAZE
Terrain Height 100m

Aircraft Block Time		
Engine On 1426	Ramp Out	Takeoff 1442
Engine Off 1742	Ramp In	Landing 1735
Total 3.3 hrs	Total hrs	Total 2.9 hrs

Mission Plan			
AGL Height	2300 m	Pulse Rate	700 KHz
Target Speed	140 kts	Scan Rate	156 Hz
Laser Current	100 %	FOV	58 Deg's

Static Alignment	GPS Time Start	GPS Time End
Pre Mission	1433	1438
Post Mission	1736	1741

570780 → 582060

Flight Line	LiDAR File Name	Flight Direction	GPS Time Start	GPS Time End	Line Aborted Time	Line Aborted nmi to End	Mission ID	Comments
TEST STRIP	—	G	1500	1504			171203_150033	4 NMi IN HAZE
KAR NYBT	—	G	1502	1507			—	
49	931733701	192	1514	1525			151414	
50	02	012	1528	1540			152846	
51	03	192	1543	1554			154324	
52	04	012	1558	1609			155808	
53	05	192	1612	1624			161252	
54	06	012	1627	1639			162746	
55	07	192	1642	1654			164243	LOW CLOUDS FORMING
X TIE	08	102	1702	1706			170251	1500' AGL MISSION
KAR NYBT	—	G	1711	1716			—	ABORT.

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Julian Day 338	Flight A

LIDAR Flight Log

AIRBORNE IMAGING
A Clean Harbors Company

Date 2017 DEC 04	Aircraft PA-31 C-GMEC
Project 3135 Warsaw	Pilot S. Bouzid
Location CYSN St. Catherines	Operator T. Trithardt
Mission Objective	

System	Riegl VQ1560i
Unit	S2222593
IMU	Applanix IMU57
GPS Rx	Trimble
Scanner 1 Drive	Ø
Scanner 2 Drive	1

Additional Notes
Temp 8°C
Humidity 70%.
Altimeter 1024 hpa
Terrain Height 100m

Aircraft Block Time		
Engine On 1630	Ramp Out	Takeoff 1647
Engine Off 2148	Ramp In	Landing 2138
Total 5.3 hrs	Total hrs	Total 4.9 hrs

Mission Plan					
AGL Height	2300 m		Pulse Rate	700 KHz	
Target Speed	140 kts		Scan Rate	156 Hz	
Laser Current	100 %		FOV	58 Deg's	

Static Alignment	GPS Time Start	GPS Time End
Pre Mission	1634	1639
Post Mission	2141	2146

146040 → 164760

Flight Line	LiDAR File Name	Flight Direction	GPS Time Start	GPS Time End	Line Aborted Time	Line Aborted nmi to End	Mission ID	Comments
TEST STRIP	—	G	1707	1709			171204_170705	
KAR NYBT	—	G	1708	1713			—	
56	931733801	192	1717	1729			171723	6NMi HAZE SOUTH END
57	02	012	1731	1743			173151	
58	03	192	1746	1758			174650	
59	04	012	1801	1812			180142	
60	05	192	1816	1827			181628	
61	06	012	1831	1841			183105	
62	07	192	1845	1857			184552	
63	08	012	1900	1910			190003	
64	09	192	1914	1926			191457	
65	10	012	1929	1940			192942	
66	11	192	1944	1955			194454	
67	12	012	1958	2009			195858	
68	13	192	2013	2023			201322	

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December 04, 2017; Lift 1 Page 2

Julian Day 338	Flight A

LIDAR Flight Log

AIRBORNE IMAGING
A Clean Harbors Company

Date 2017 DEC 04	Aircraft PA-31 C-GMEC
Project 3135 Warsaw	Pilot S. Bouzid
Location CYSN St. Catherines	Operator T. Trithardt
Mission Objective	

System	Riegl VQ1560i
Unit	S2222593
IMU	Applanix IMU57
GPS Rx	Trimble
Scanner 1 Drive	Ø
Scanner 2 Drive	1

Additional Notes
Temp
Humidity
Altimeter
Terrain Height

Aircraft Block Time		
Engine On 1630	Ramp Out	Takeoff 1647
Engine Off 2148	Ramp In	Landing 2138
Total 5.3 hrs	Total hrs	Total 4.9 hrs

Mission Plan					
AGL Height	2300	m	Pulse Rate	700	KHz
Target Speed	140	kts	Scan Rate	156	Hz
Laser Current	100	%	FOV	58	Deg's

Static Alignment	GPS Time Start	GPS Time End
Pre Mission	1634	1639
Post Mission	2141	2146

Flight Line	LiDAR File Name	Flight Direction	GPS Time Start	GPS Time End	Line Aborted Time	Line Aborted nmi to End	Mission ID	Comments
69	931733814	012	2026	2035			171204_202655	
70	15	192	2039	2047			203928	
71	16	012	2055	2056			205511	
XTIE	17	282	2100	2108			210035	MOISTURE WEST HALF
KAR NYBT	–	G	2111	2116			–	
		PROJECT COMPLETE						

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NY17 Southwest 17B LiDAR Acquisition Report 2017

Prepared by Axis Geospatial — **Status as of: 12/5/2017**

Project Acquisition Status

NY17 Southwest 17B LiDAR Acquistion 71 of 71 flight lines acquired	**100%** Complete	Notes: On Monday, Nov. 13, the State and Axis agreed that sufficient leaf drop had occurred to allow for acquisition

Ground Condition Report (based on NOAA Snow Cover Observations, NY Discussions, DOT web cameras, flight and survey crews)

A review of various weathercams shows the ground to be snow free;

Current Acquisition Outlook/Weather Status Report

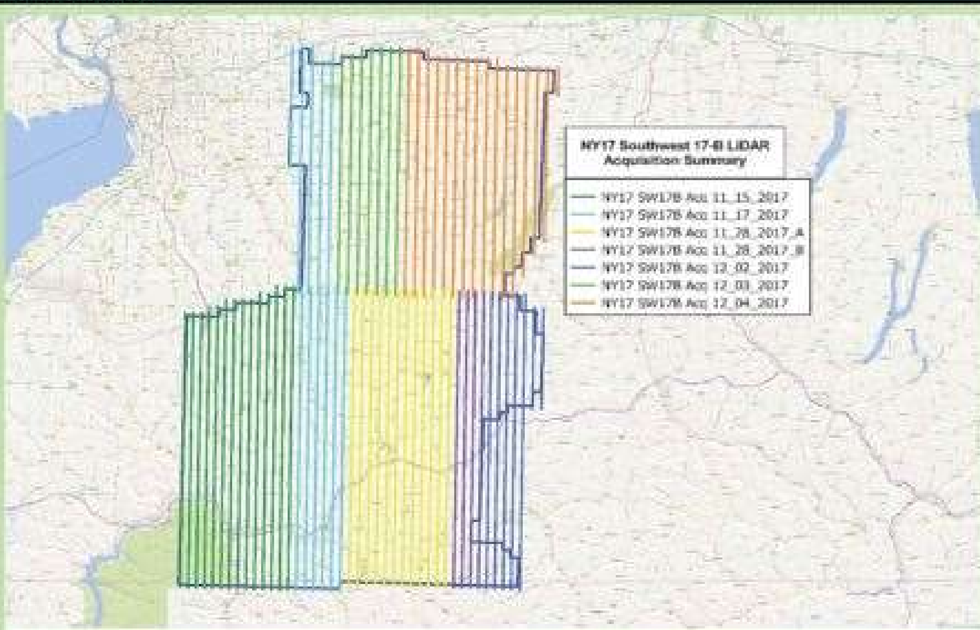
Jamestown, NY

Jamestown, NY 5 Day Weather

8:33 am EST Print

DAY	DESCRIPTION	HIGH / LOW	PRECIP	WIND	HUMIDITY
TODAY DEC 4	Mostly Cloudy	51/41	0%	SSE 14 mph	65%
TUE DEC 5	Rain	48/26	90%	SSW 17 mph	85%
WED DEC 6	Partly Cloudy	33/24	20%	WSW 18 mph	45%
THU DEC 7	Snow Showers	29/20	60%	WSW 13 mph	69%
FRI DEC 8	Mostly Cloudy	32/19	10%	SW 12 mph	52%

Current Project Status Graphic



NYS17B LiDAR Daily Acquisition Report					
Week Day	**Date**	**Total Number of Planes**	**Total Number of Lifts**	**Number of Lines**	**Comments**
Tuesday	11/14/2017	1	0	0	Weather conditions unfavorable; AI (C-GIQC) on stand-by.
Wednesday	11/15/2017	1	1	14	Lines 1-14 Acquired (GREEN Lines above)
Thursday	11/16/2017	1	0	0	Weather conditions unfavorable; AI on stand-by.
Friday	11/17/2017	1	1	12	Lines 15-20 & 44-49 Acquired (LIGHT BLUE Lines above)
Saturday	11/18/2017	1	0	0	Weather conditions unfavorable; Low Clouds
Sunday	11/19/2017	1	0	0	Weather conditions unfavorable; Low Clouds
Monday	11/20/2017	1	0	0	Weather and Ground conditions are unfavorable
Tuesday	11/21/2017	1	0	0	Weather and Ground conditions are unfavorable
Wednesday	11/22/2017	1	0	0	Weather and Ground conditions are unfavorable
Thursday	11/23/2017	1	0	0	Weather and Ground conditions are unfavorable
Friday	11/24/2017	1	0	0	Weather and Ground conditions are unfavorable
Saturday	11/25/2017	1	0	0	Weather conditions are unfavorable; Ground conditions improving
Sunday	11/26/2017	1	0	0	Weather conditions are unfavorable; Ground conditions acceptable
Monday	11/27/2017	1	0	0	Low clouds; Ground conditions acceptable
Tuesday	11/28/2017	1	2	16	Lines 21-32 Acquired (YELLOW lines above); Lines 33-36 Acquired (PURPLE Lines above)
Wednesday	11/29/2017	1	1	0	Crew launched but clouds and turbulance prevented acquisition;
Thursday	11/30/2017	1	0	0	Weather conditions are unfavorable; Ground conditions acceptable
Friday	12/1/2017	1	0	0	Weather conditions are unfavorable; Ground conditions acceptable
Saturday	12/2/2017	1	1	7	Lines 37-43 Acquired (DARK BLUE Lines above) Southern Tier completed
Sunday	12/3/2017	1	1	7	Lnes 49-55 Acquired (LIGHT GREEN lines above)
Monday	12/4/2017	1	1	16	Lines 56-71 Acquired (ORANGE lines above)
					Acquistion Completed

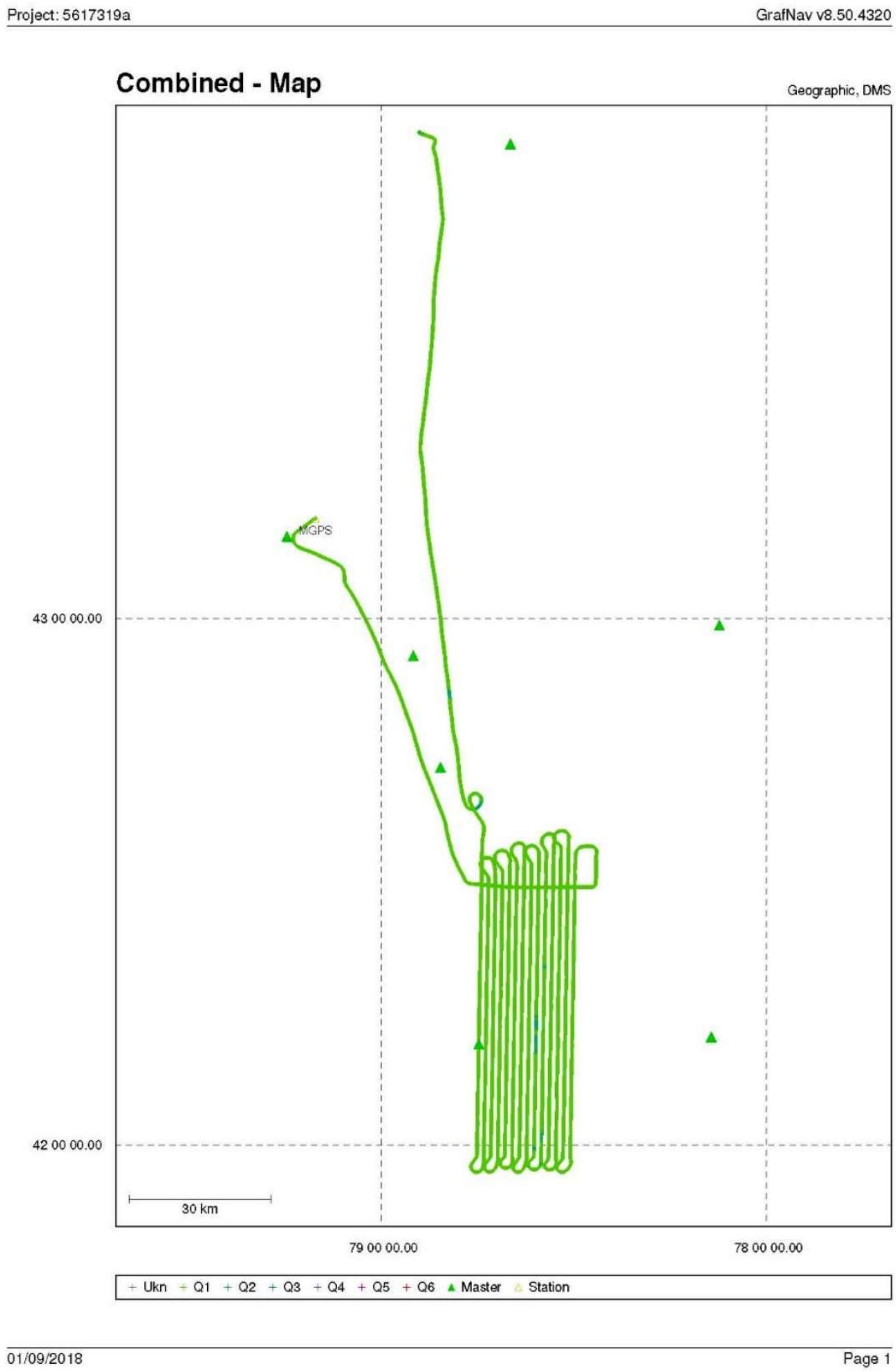
Section 5: GPS Processing Plots

POSPac MMS Version 8.1

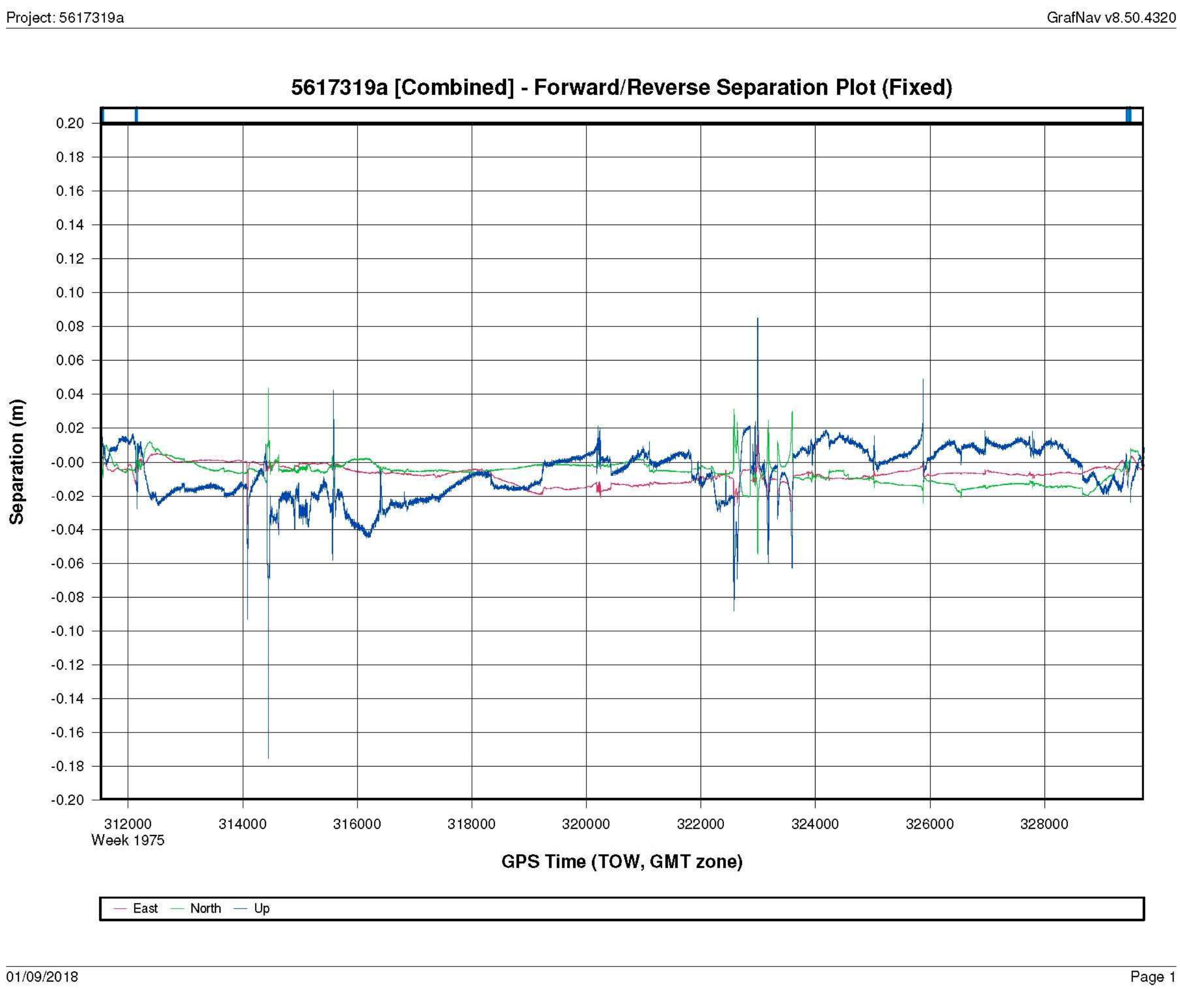
Plots by lift of the Coverage Map, Estimated Position Accuracy, Number of Satellites, Combined Separation, and PDOP.

November 15, 2017

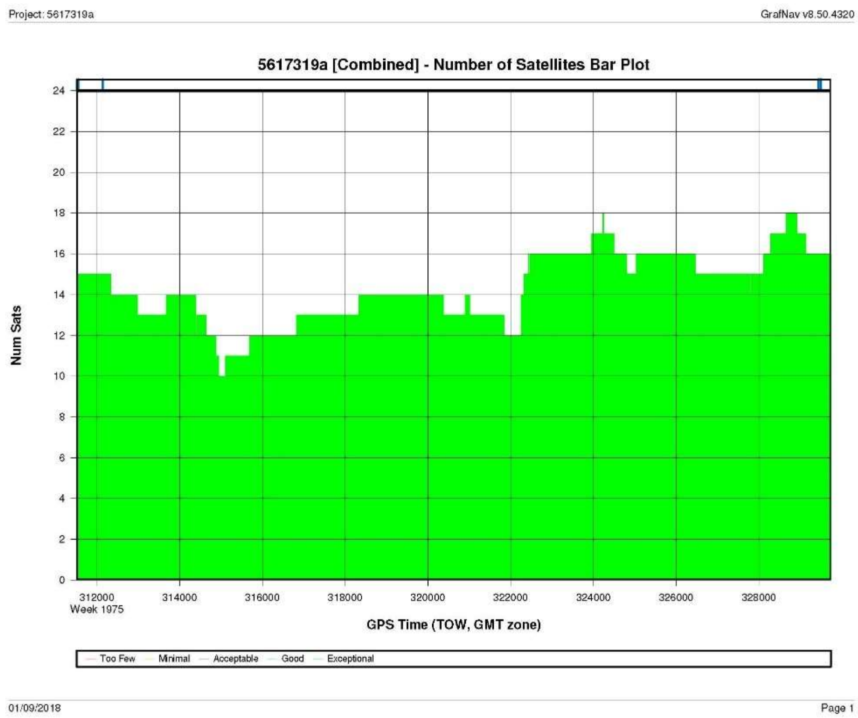
Coverage Map: The Coverage Map plot shows the Aircraft GPS-IMU Trajectory in reference to localized GPS Reference Stations.



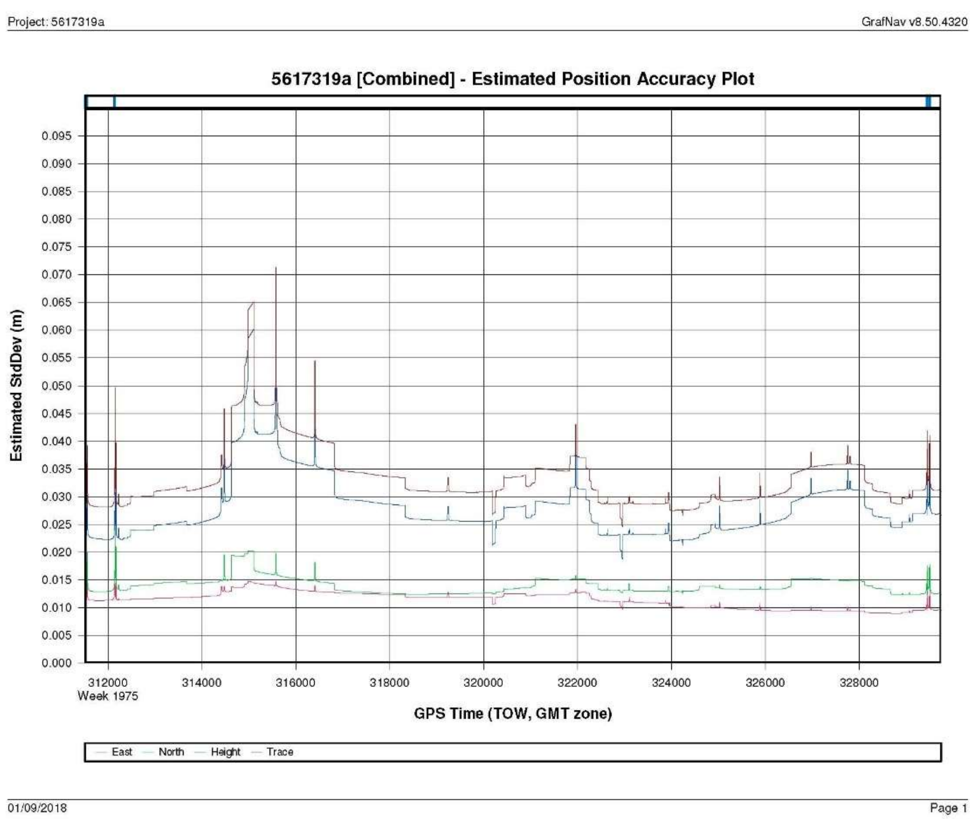
Combined Separation: Plots the north, east, and height position difference between any two solutions loaded into the project. This is most often the forward and reverse processing results, unless other solutions have been loaded from the Combine Solutions dialog. Plotting the difference between forward 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.



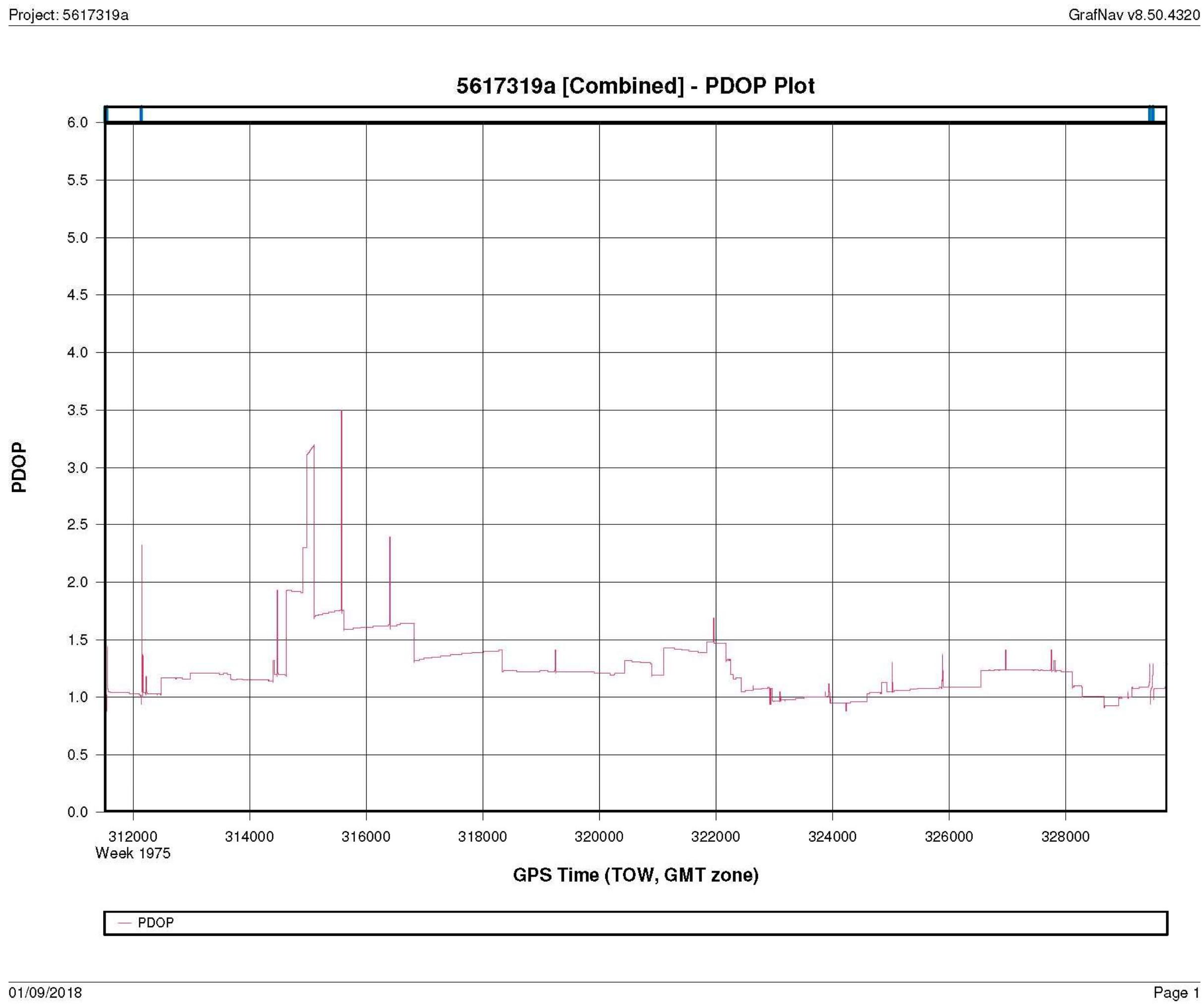
Number of Satellites: Plots the number of satellites used in the solution as a function of time. The number of GPS satellites, GLONASS satellites and the total number of satellites are distinguished with separate lines.



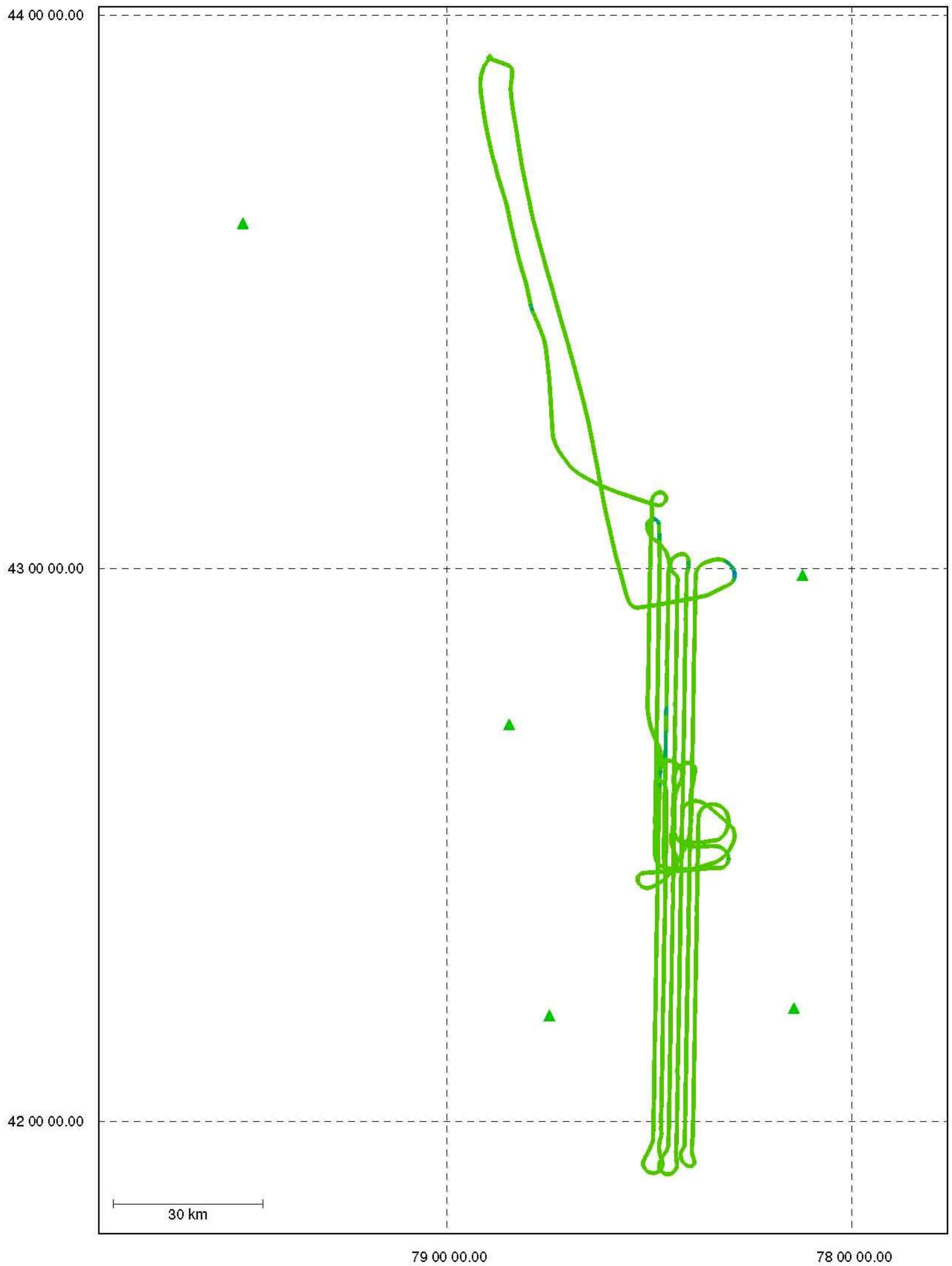
Estimated Position Accuracy: The Estimated Position Accuracy plot shows the standard deviations of the east, north, and up directions versus time for the solution.



PDOP: PDOP is a unit less 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.



Project: 5617321a GrafNav v8.50.4320



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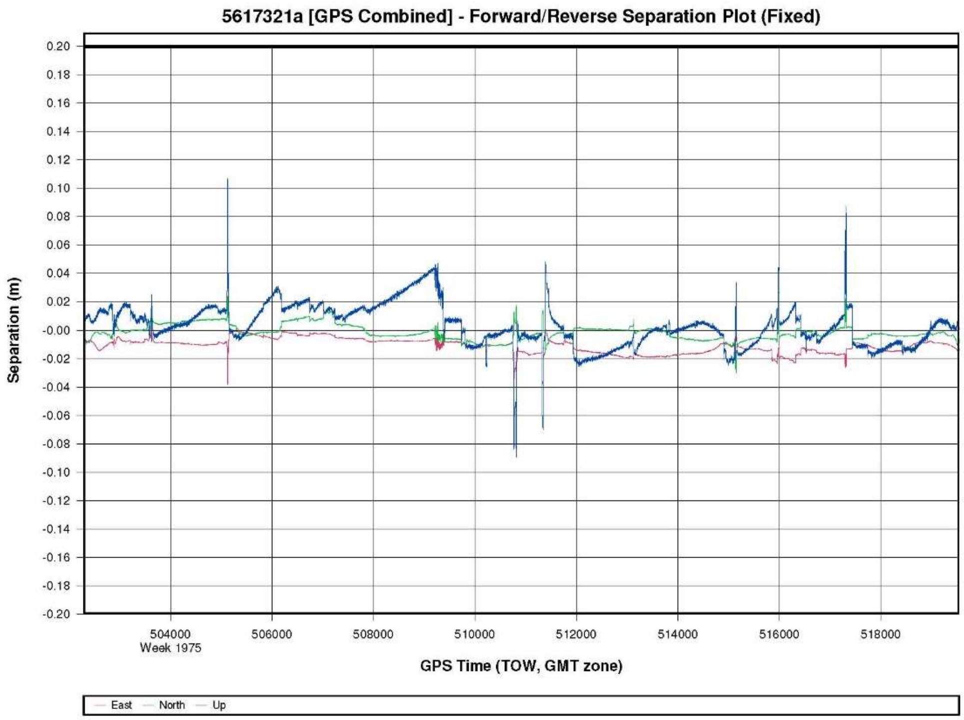
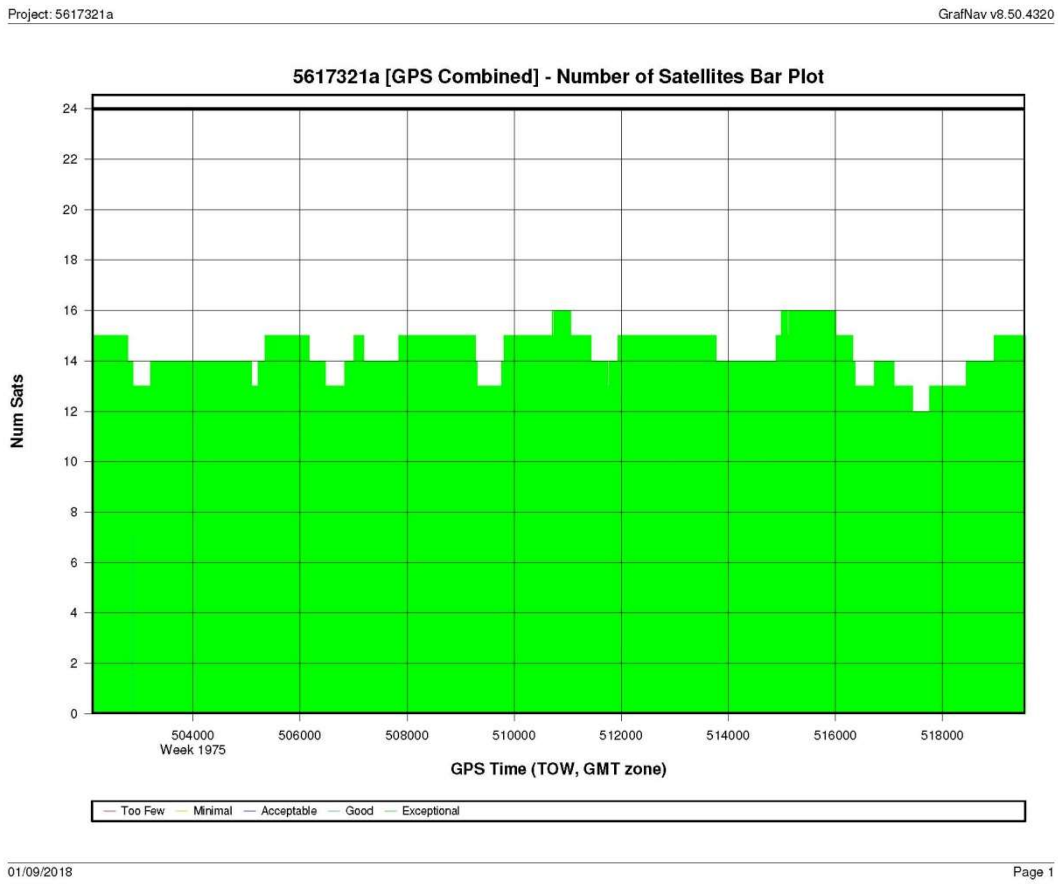
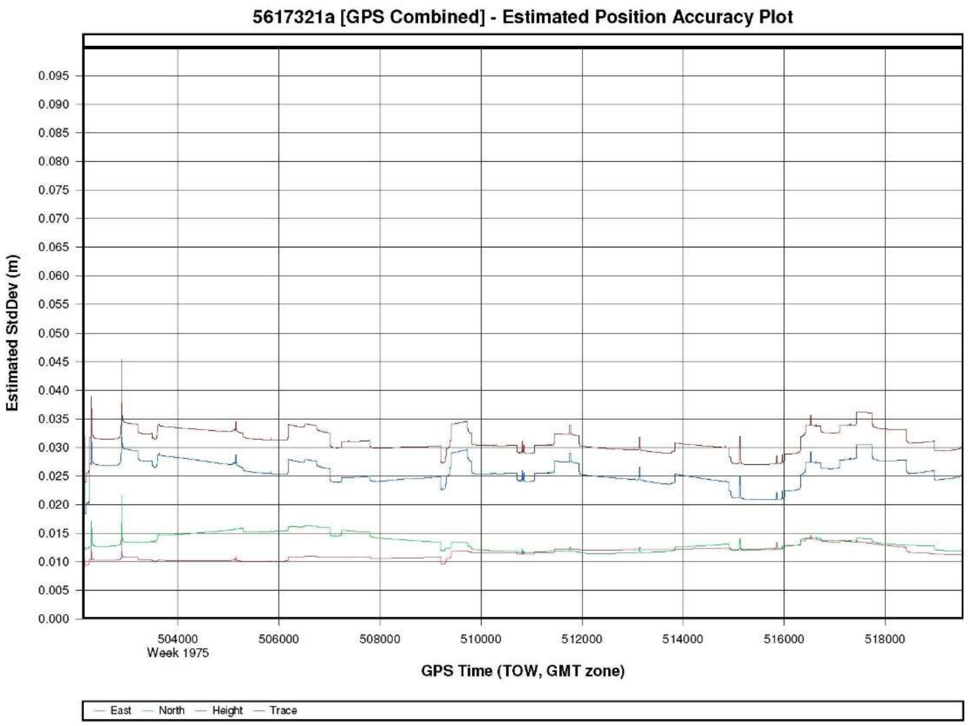
Project: 5617321a GrafNav v8.50.4320



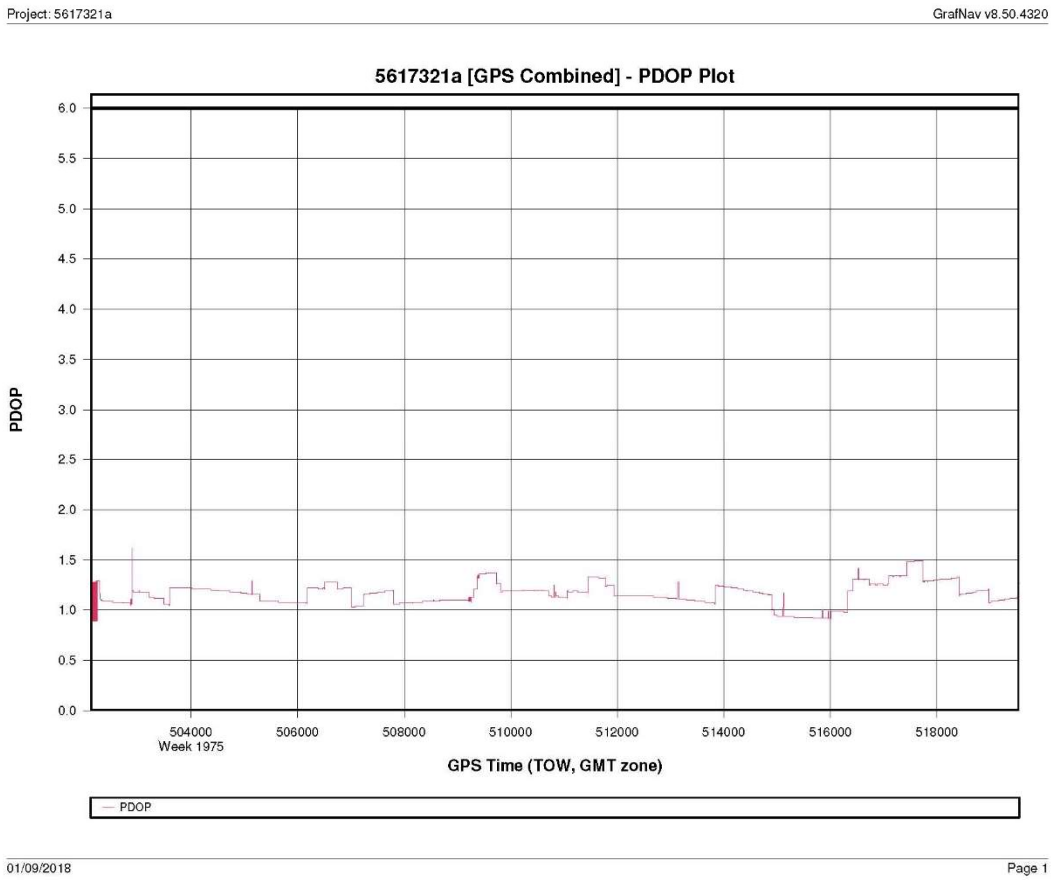
01/09/2018 Page 1


Project: 5617321a
GrafNav v8.50.4320
5617321a [GPS Combined] - Number of Satellites Bar Plot
Num Sats
0
2
4
6
8
10
12
14
16
18
20
22
24
504000
Week 1975
506000
508000
510000
512000
514000
516000
518000
GPS Time (TOW, GMT zone)
Too Few
Minimal
Acceptable
Good
Exceptional
01/09/2018
Page 1

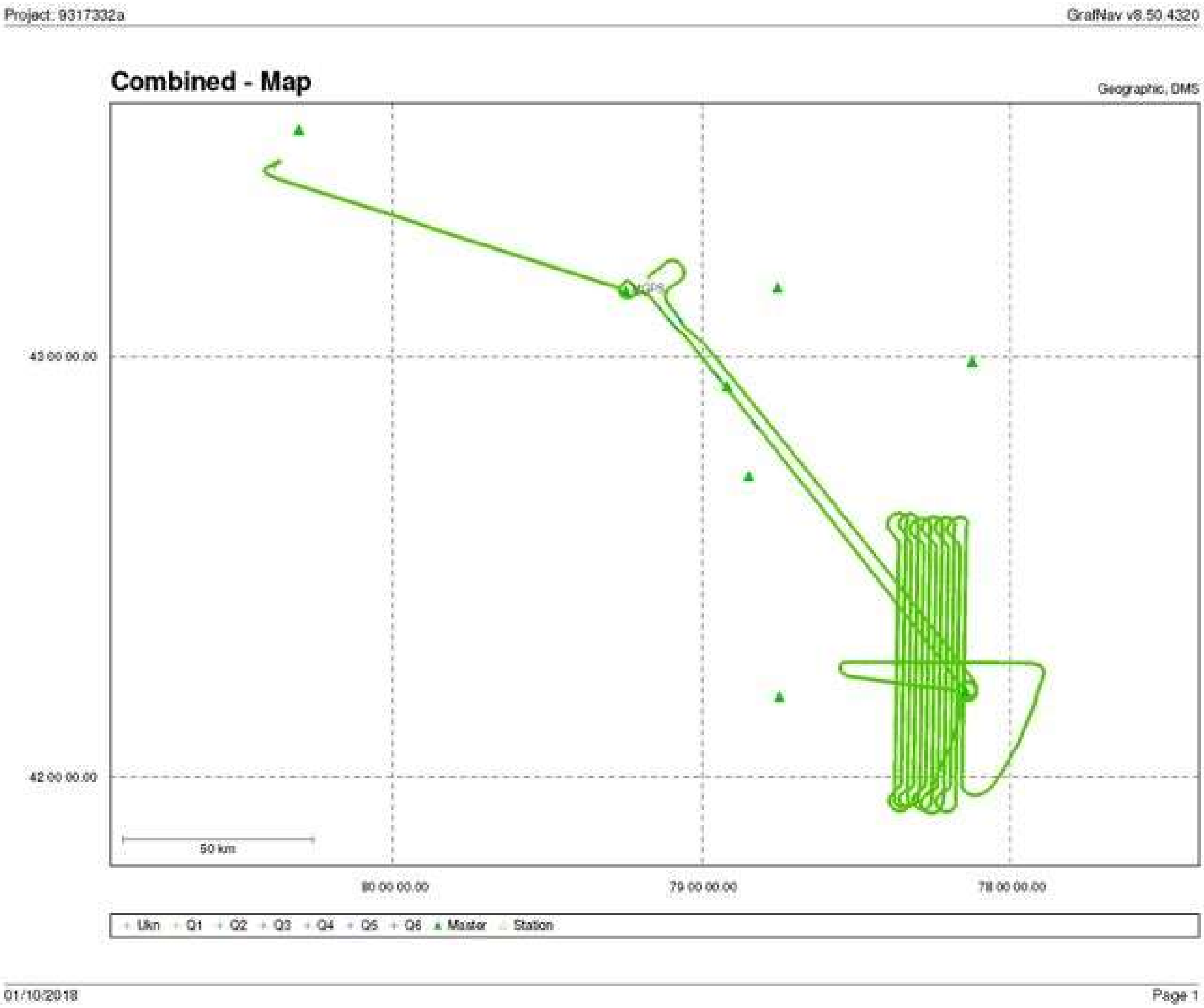
Project: 5617321a GrafNav v8.50.4320

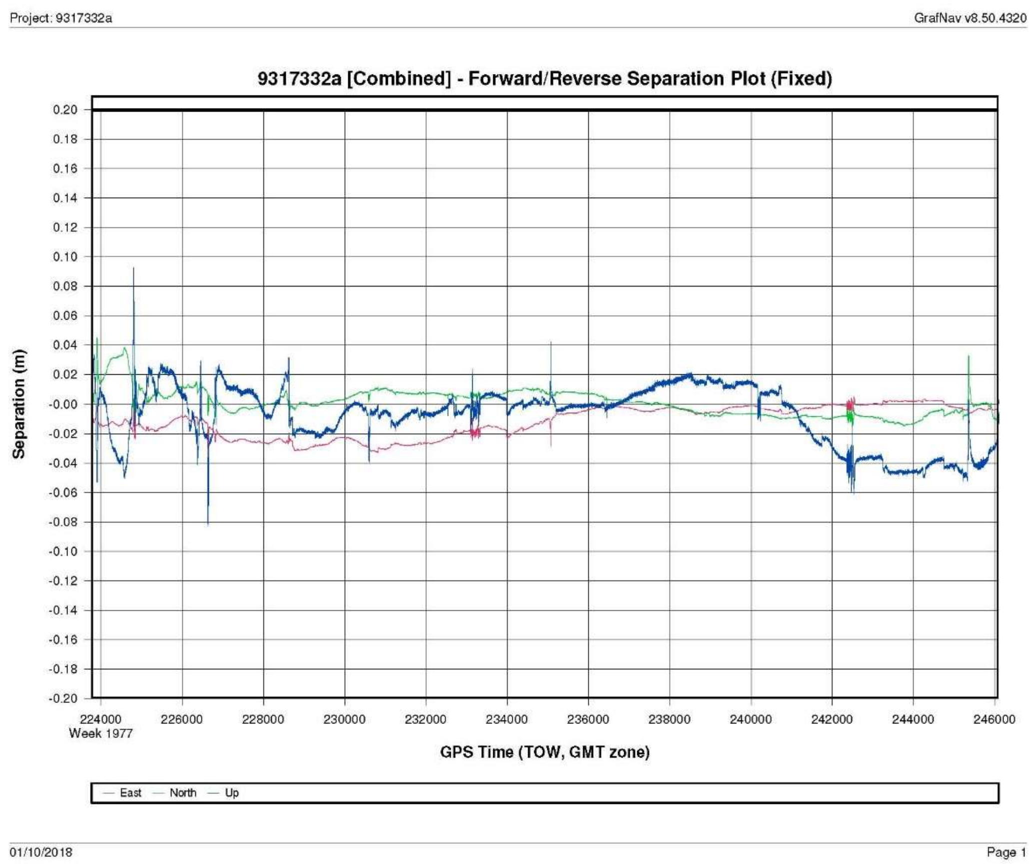


01/09/2018 Page 1

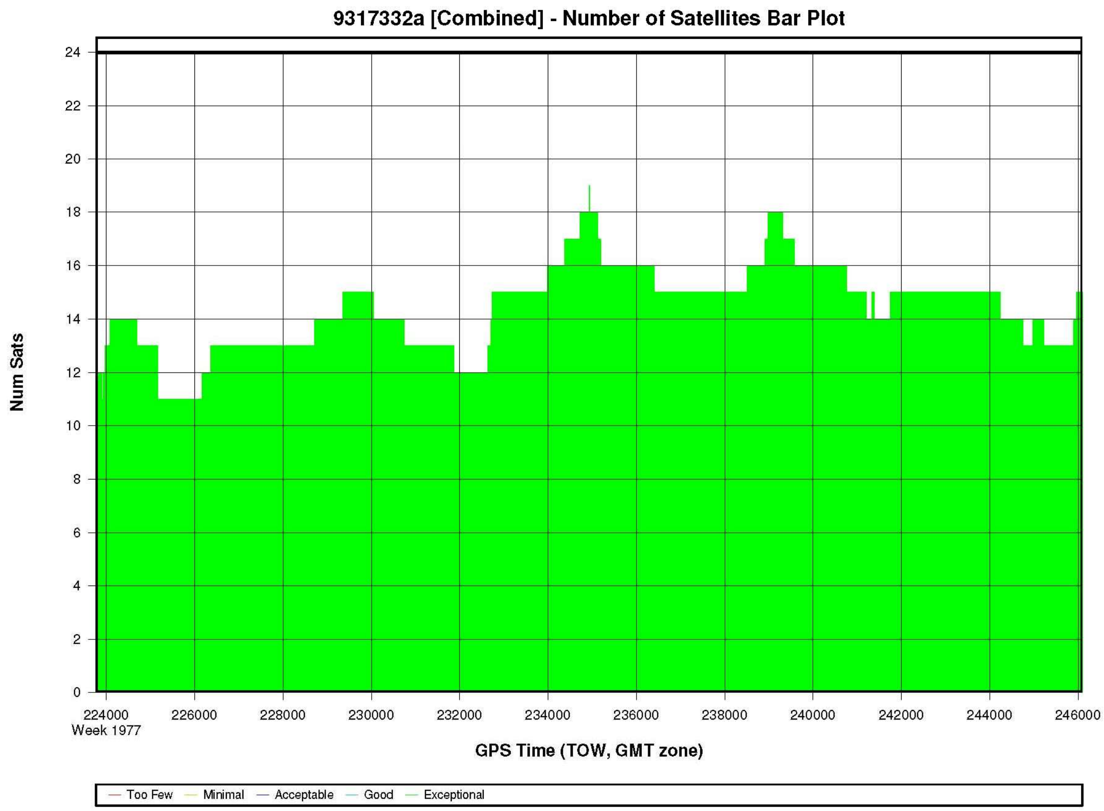


November 28, 2018; Lift 1


Project: 9317332a
GrafNav v8.50.4320
Combined - Map
Geographic, DMS
43 00 00.00
42 00 00.00
50 km
80 00 00.00
79 00 00.00
78 00 00.00
Ukn Q1 Q2 Q3 Q4 Q5 Q6 Master Station
01/10/2018
Page 1


Project: 9317332a
GrafNav v8.50.4320
9317332a [Combined] - Forward/Reverse Separation Plot (Fixed)
Separation (m)
GPS Time (TOW, GMT zone)
Week 1977
East
North
Up
01/10/2018
Page 1

Project: 9317332a GrafNav v8.50.4320



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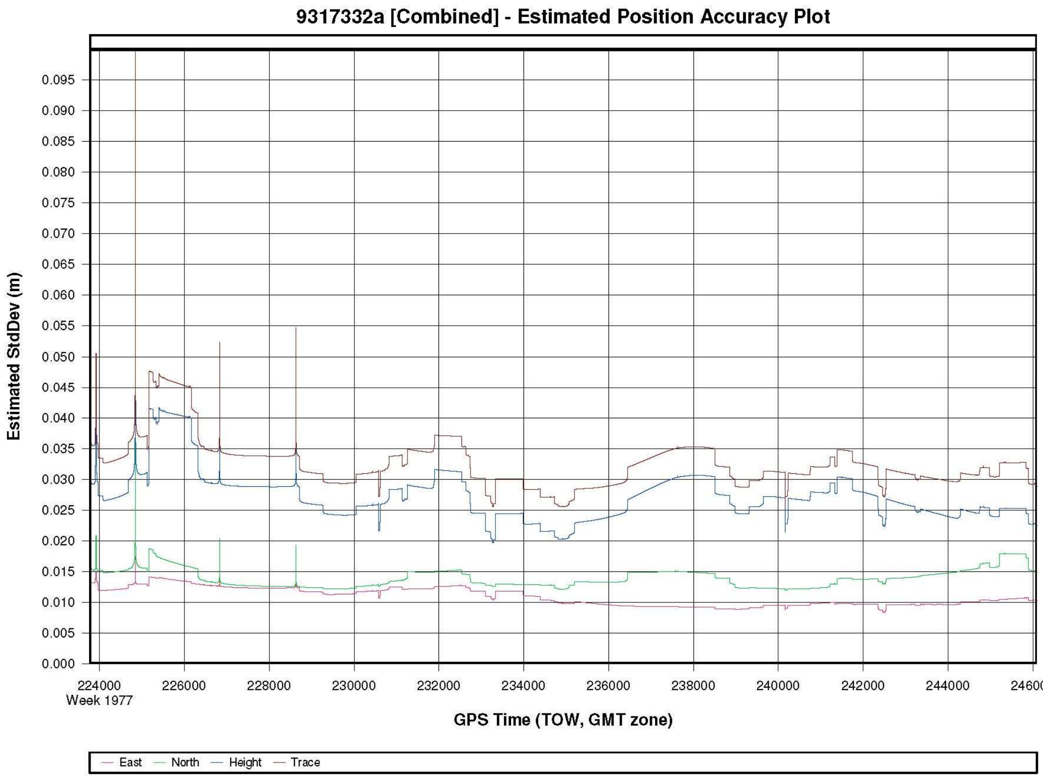
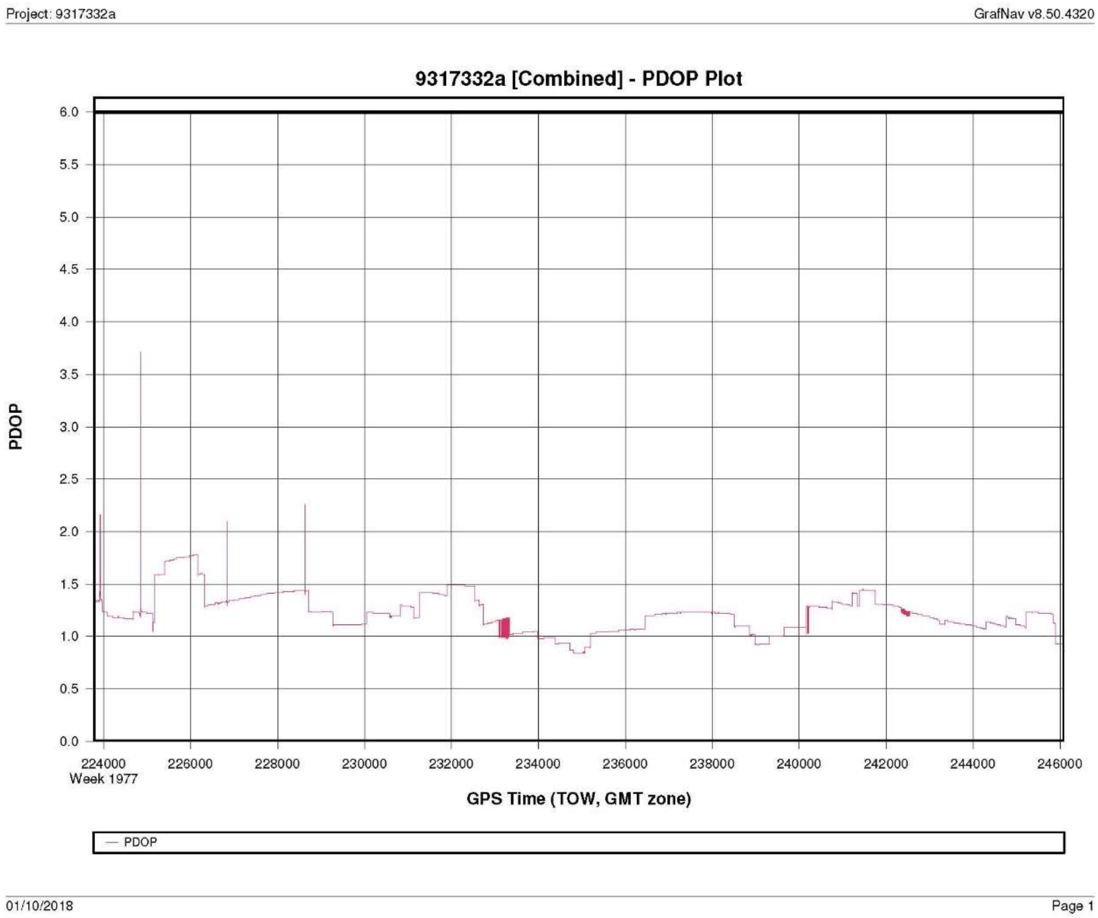
Project: 9317332a GrafNav v8.50.4320

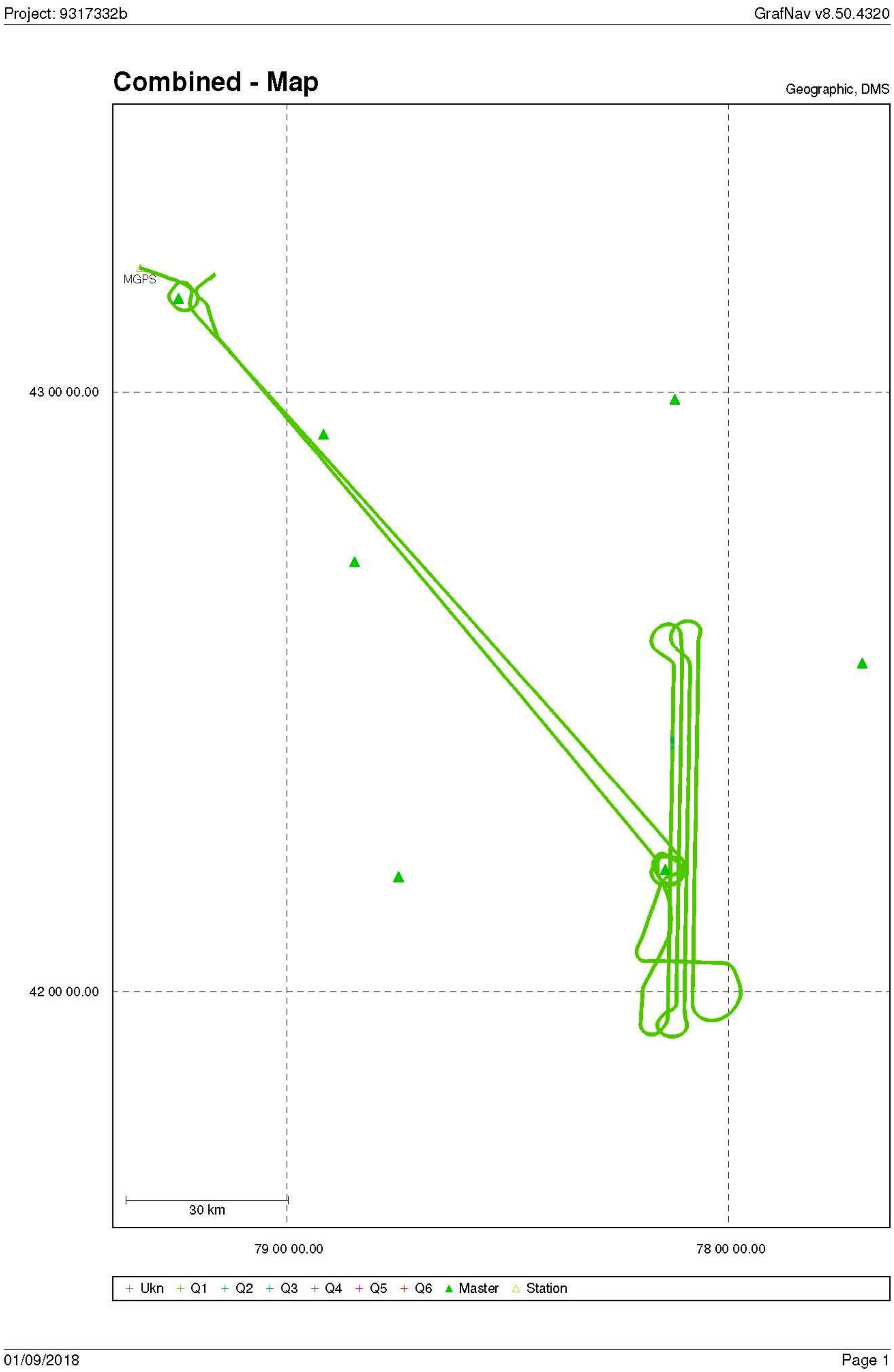


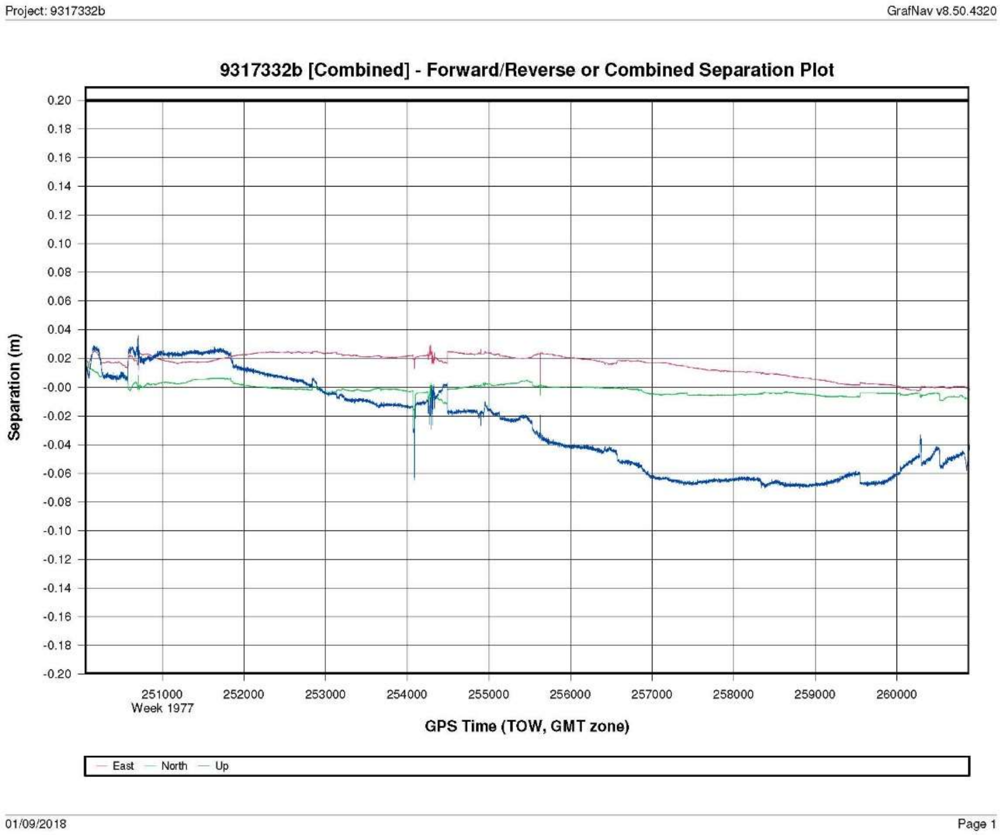
01/10/2018 Page 1

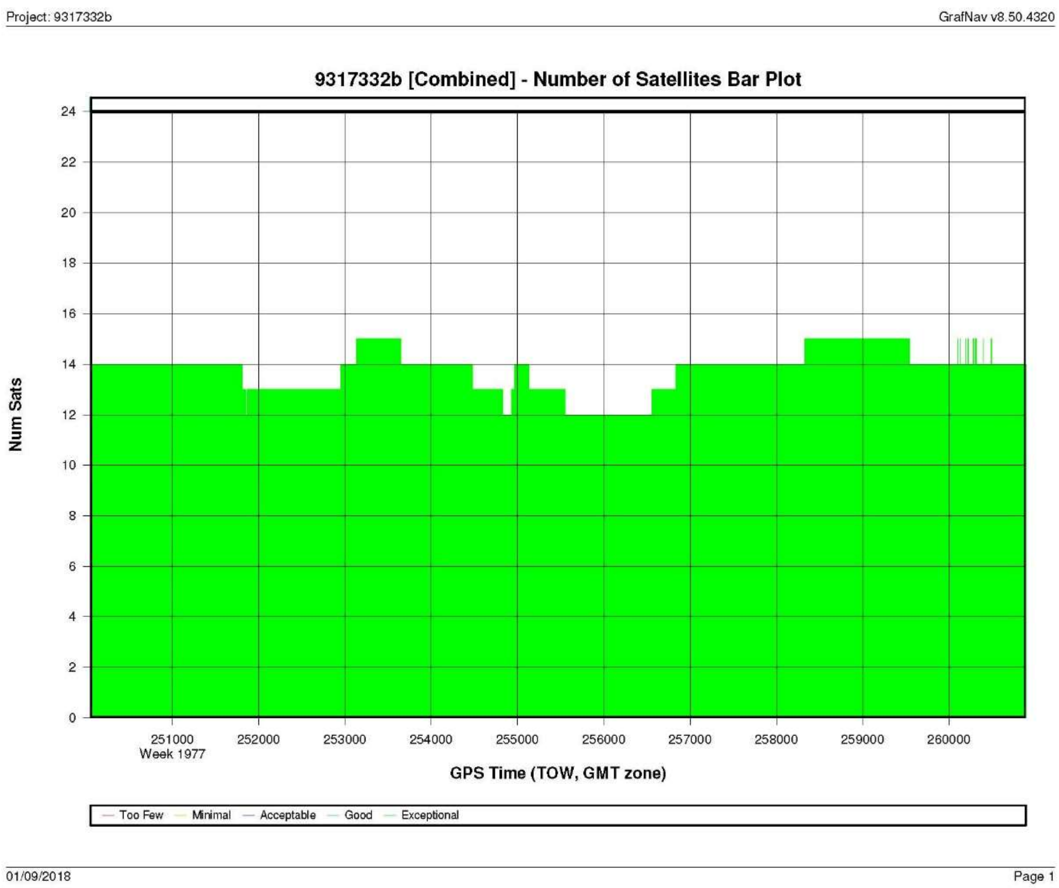


Project: 9317332a
GrafNav v8.50.4320
9317332a [Combined] - PDOP Plot
PDOP
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
224000
Week 1977
226000
228000
230000
232000
234000
236000
238000
240000
242000
244000
246000
GPS Time (TOW, GMT zone)
PDOP
01/10/2018
Page 1

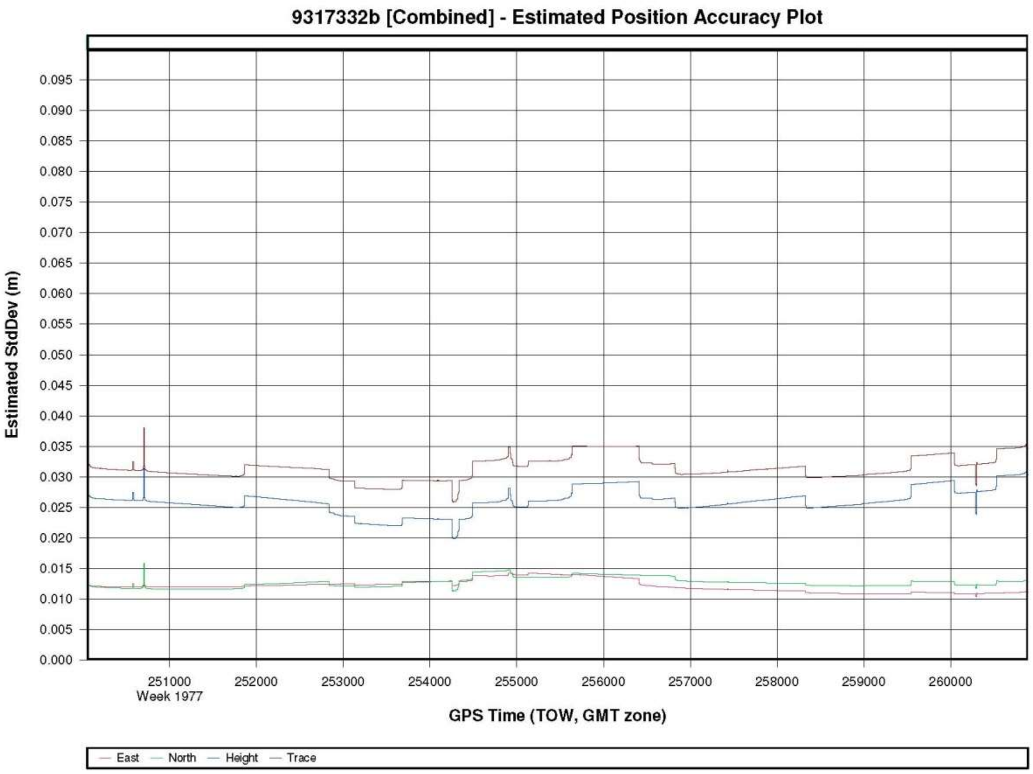
November 28, 2018; Lift 2




Project: 9317332b
GrafNav v8.50.4320
9317332b [Combined] - Forward/Reverse or Combined Separation Plot
Separation (m)
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
-0.00
-0.02
-0.04
-0.06
-0.08
-0.10
-0.12
-0.14
-0.16
-0.18
-0.20
251000
Week 1977
252000
253000
254000
255000
256000
257000
258000
259000
260000
GPS Time (TOW, GMT zone)
East
North
Up
01/09/2018
Page 1


Project: 9317332b
GrafNav v8.50.4320
9317332b [Combined] - Number of Satellites Bar Plot
Num Sats
0
2
4
6
8
10
12
14
16
18
20
22
24
251000
Week 1977
252000
253000
254000
255000
256000
257000
258000
259000
260000
GPS Time (TOW, GMT zone)
Too Few
Minimal
Acceptable
Good
Exceptional
01/09/2018
Page 1

Project: 9317332b GrafNav v8.50.4320



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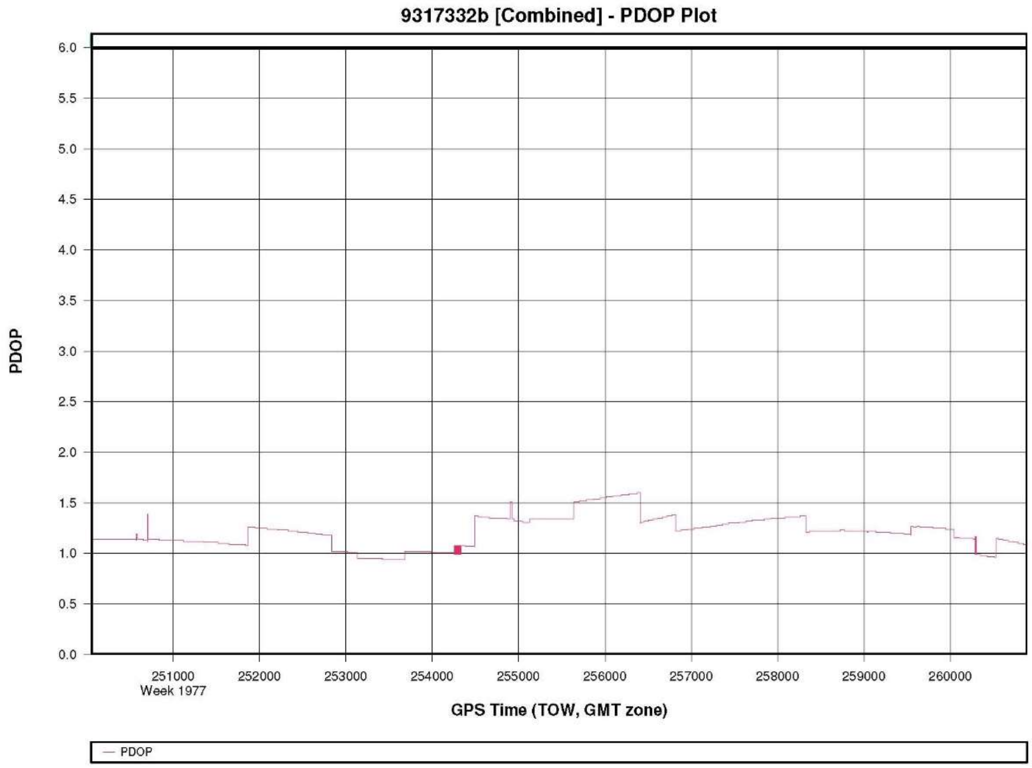
Project: 9317332b GrafNav v8.50.4320



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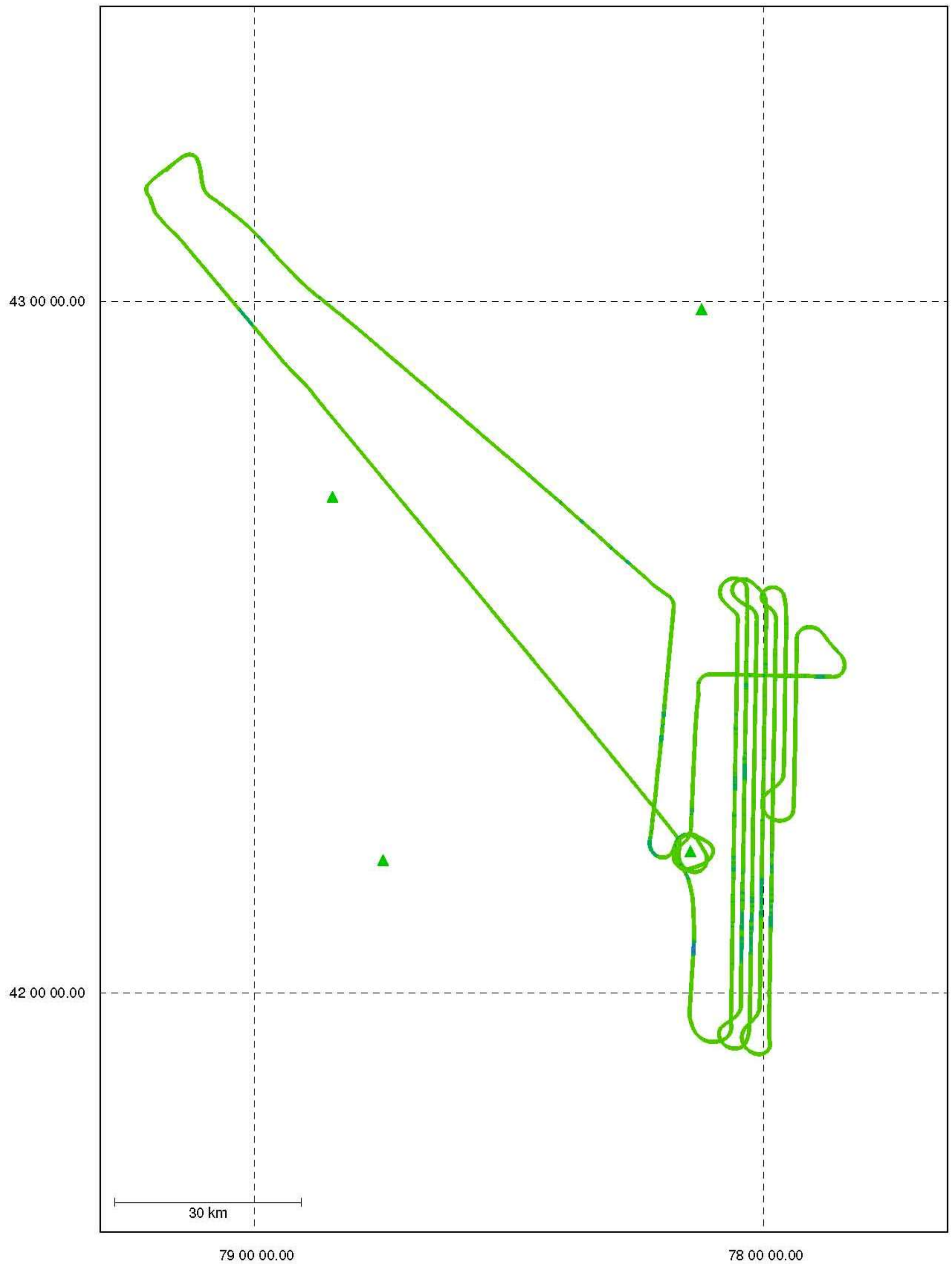
December 2, 2018

Project: 9317336a GrafNav v8.50.4320



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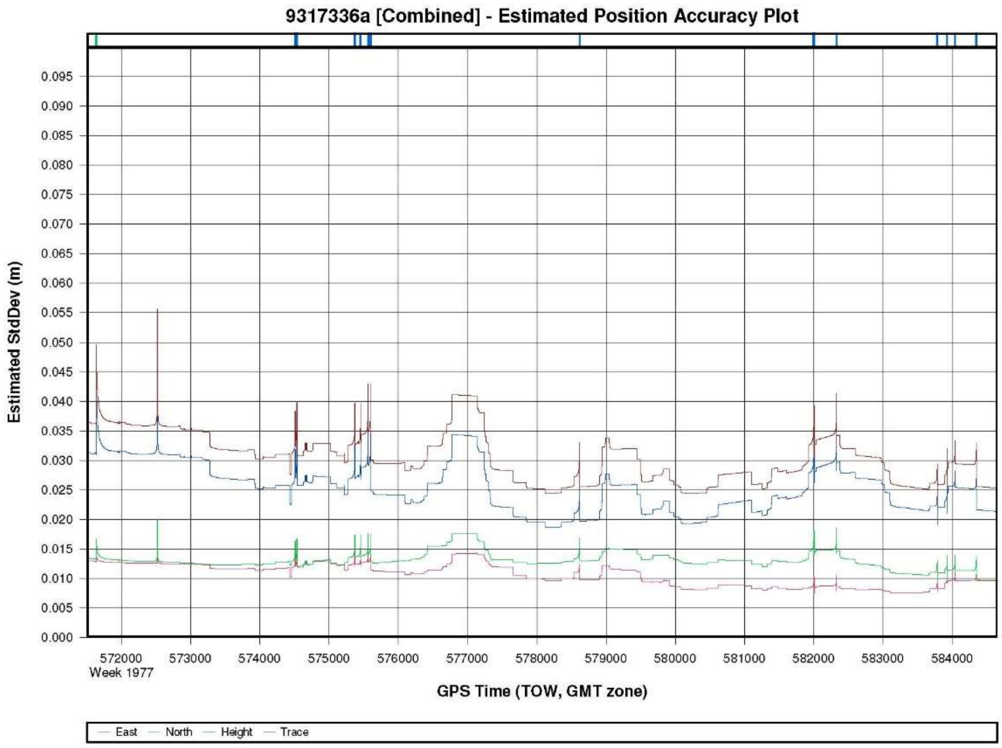
Project: 9317336a GrafNav v8.50.4320



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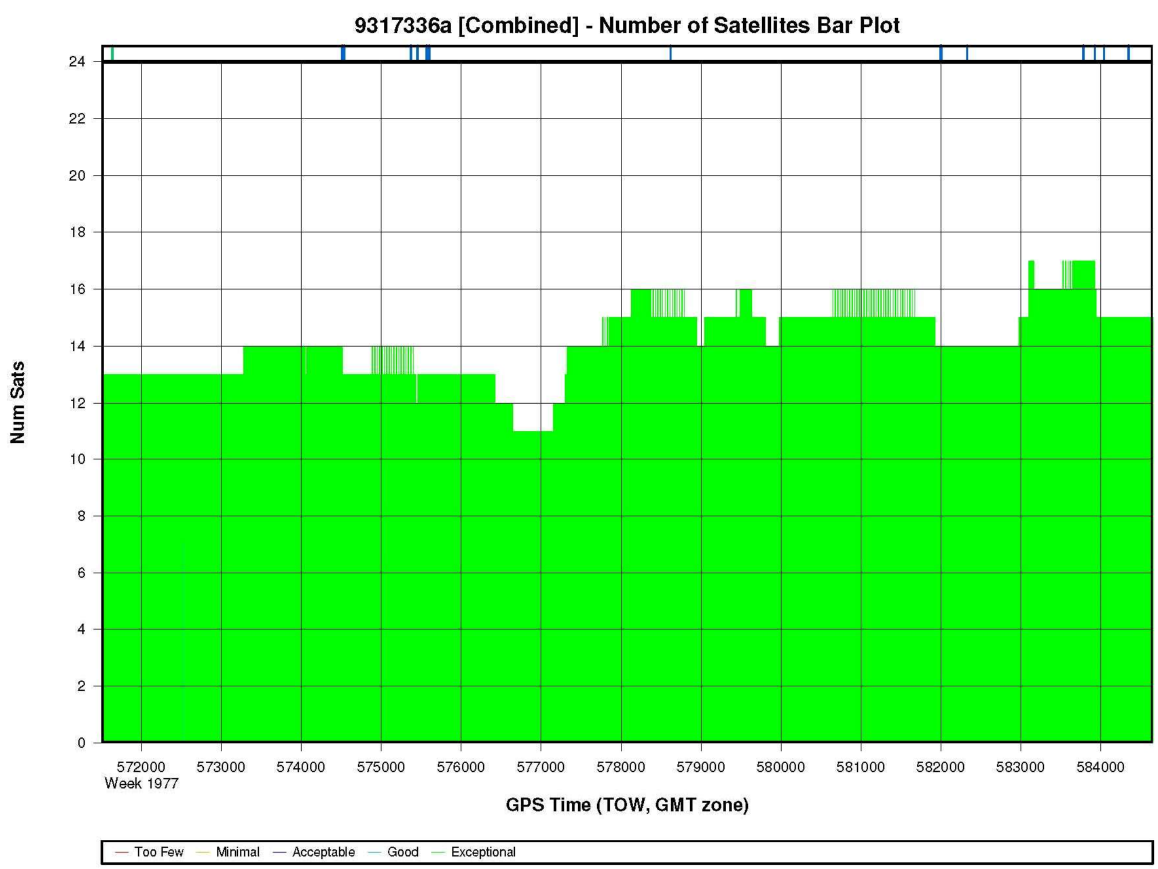
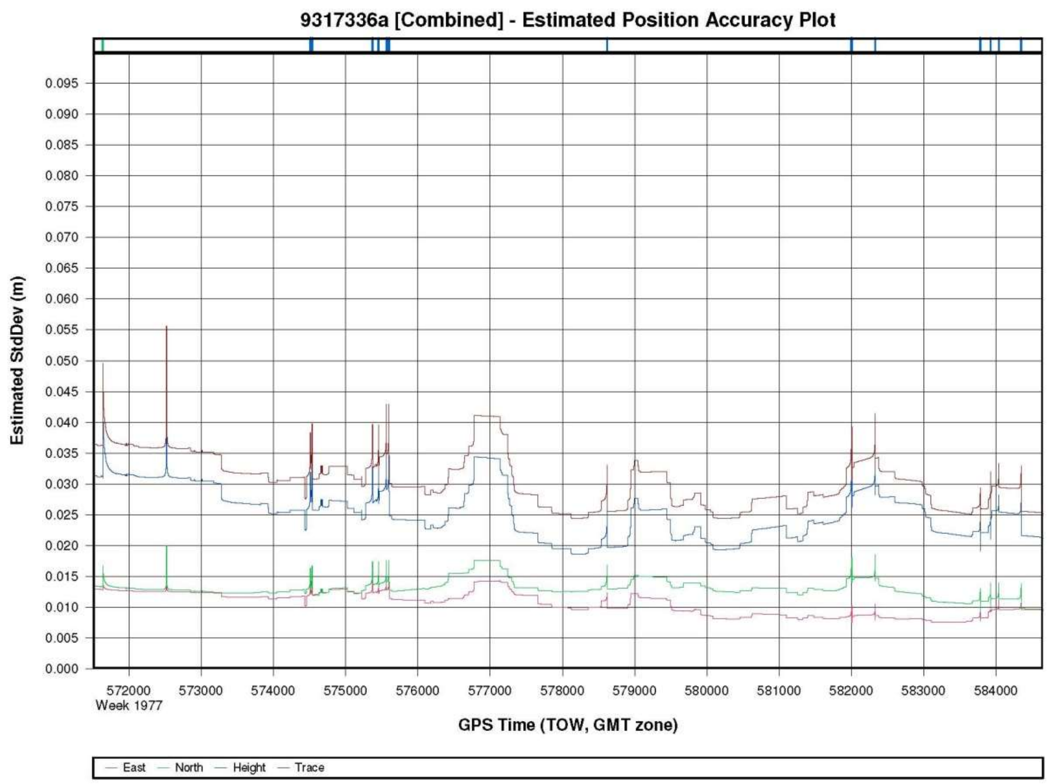


Project: 9317336a GrafNav v8.50.4320



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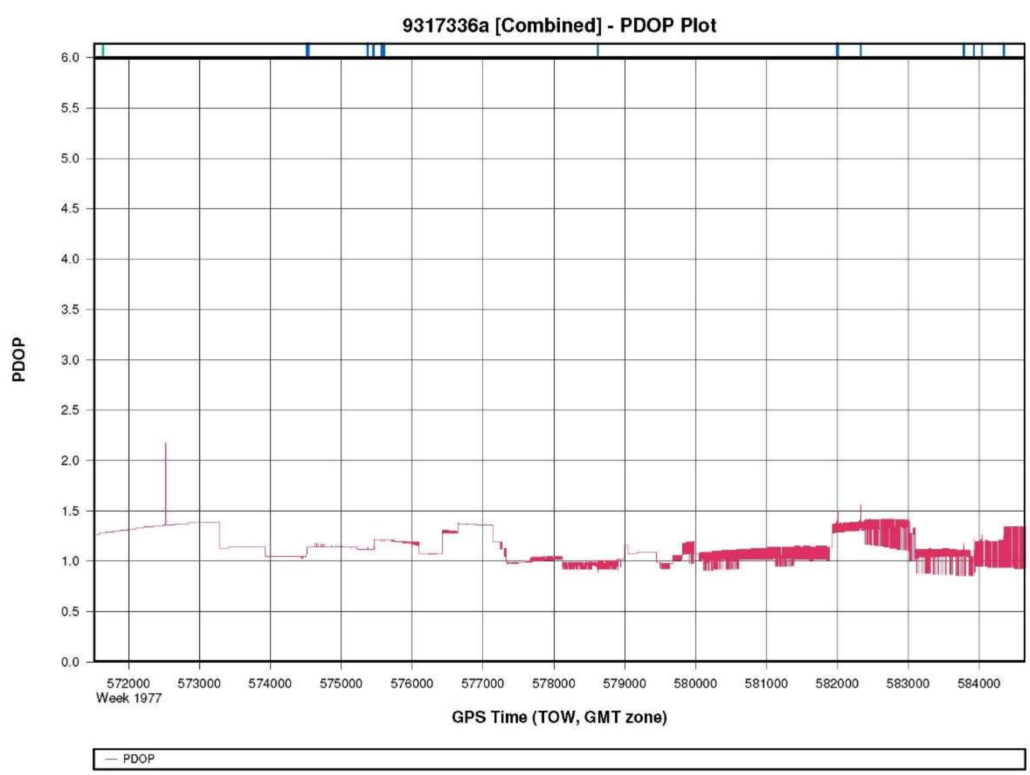

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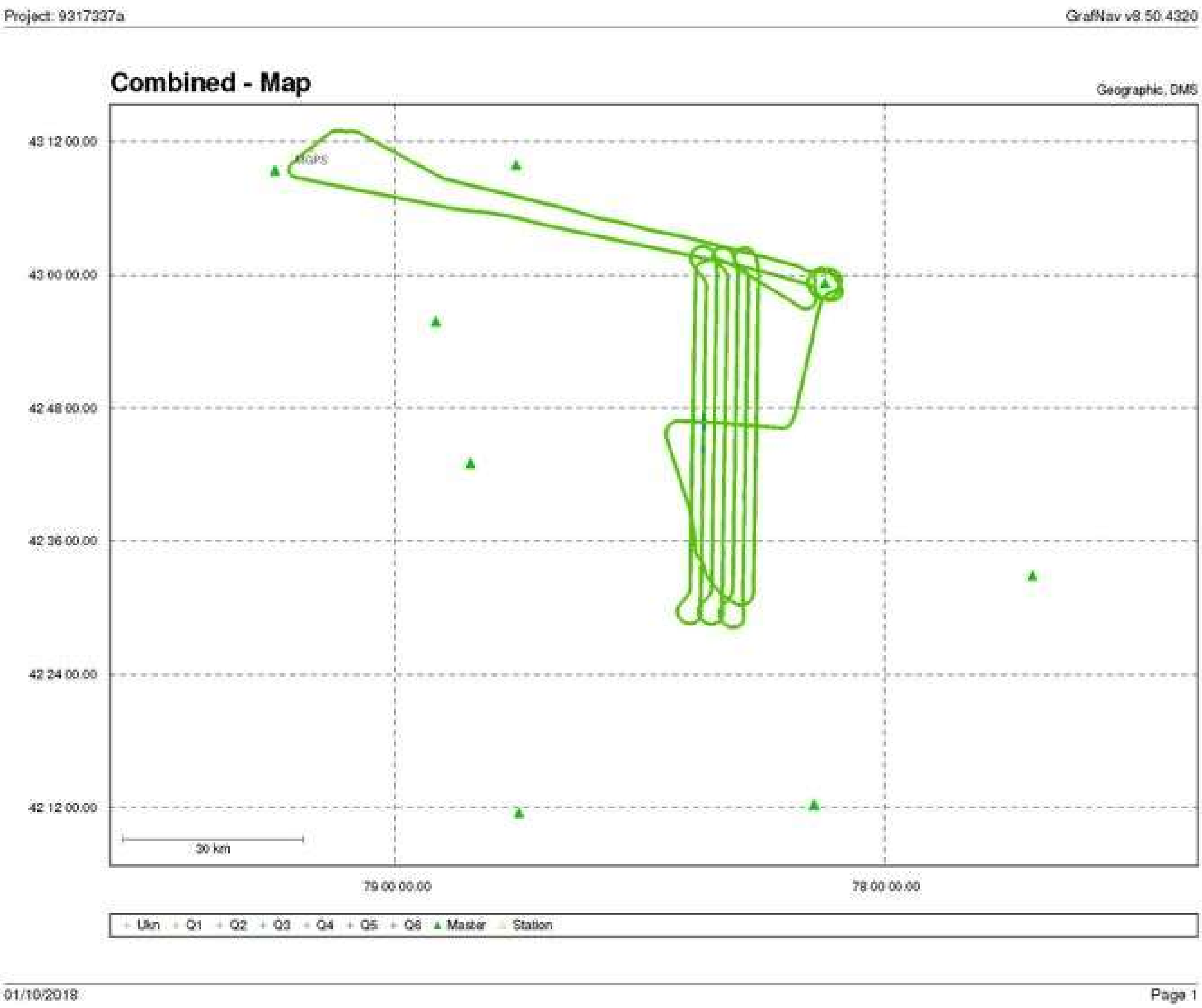
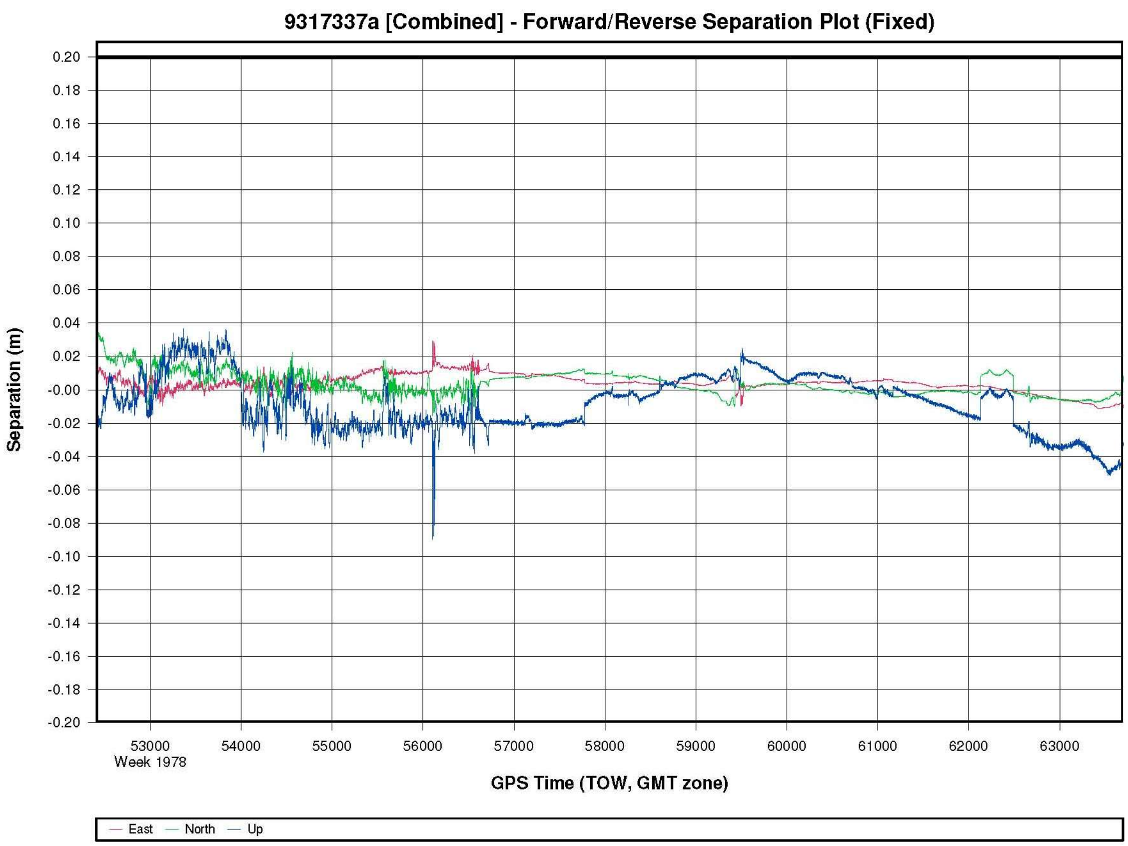

Project: 9317337a
GrafNav v8.50.4320
Combined - Map
Geographic, DMS
43 12 00.00
43 00 00.00
42 48 00.00
42 36 00.00
42 24 00.00
42 12 00.00
79 00 00.00
78 00 00.00
30 km
Ukn
Q1
Q2
Q3
Q4
Q5
Q6
Master
Station
01/10/2018
Page 1

Project: 9317337a GrafNav v8.50.4320



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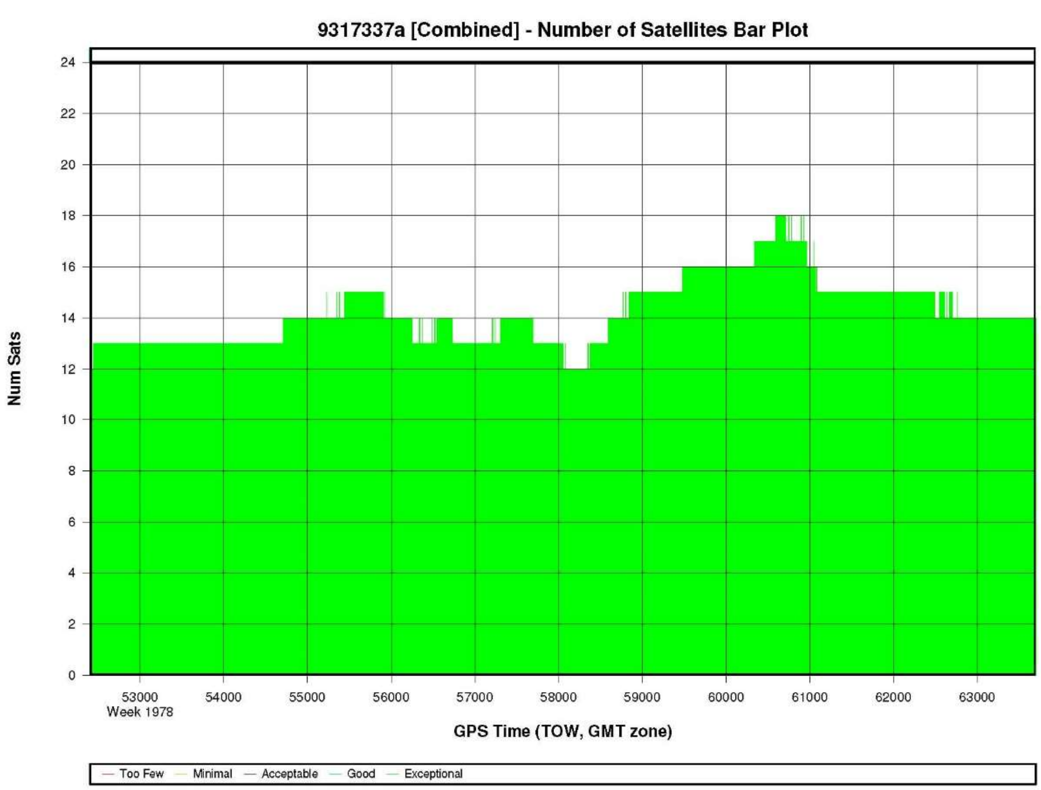
Project: 9317337a GrafNav v8.50.4320



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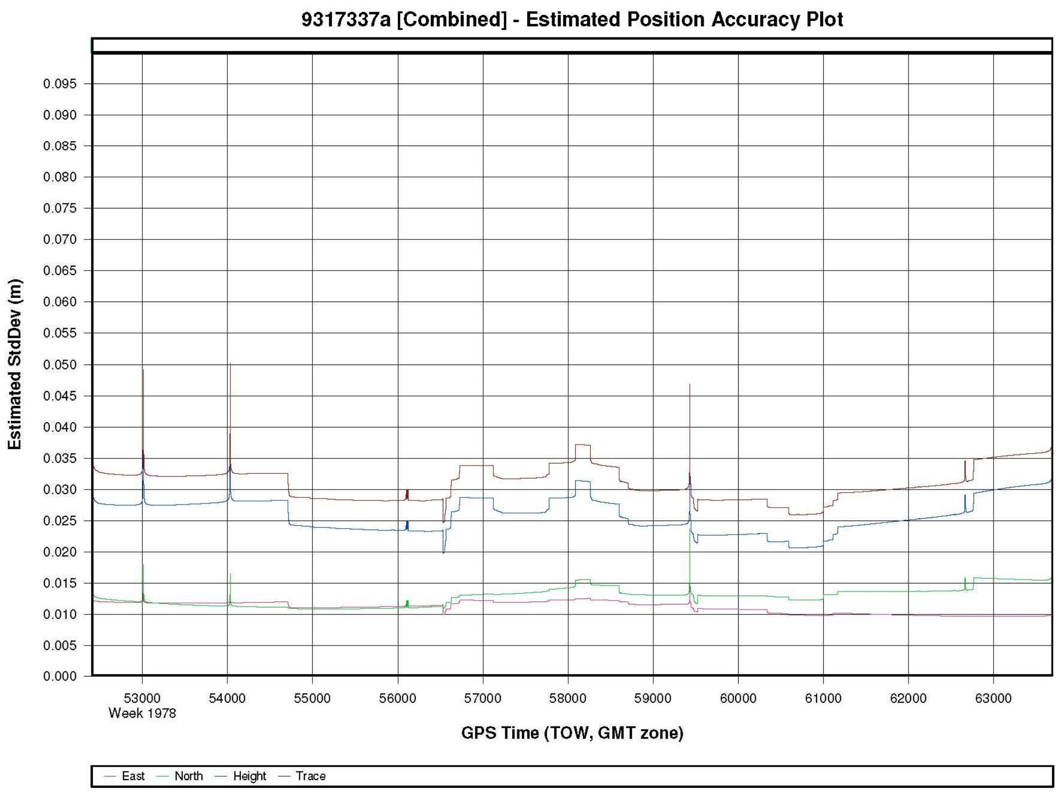
Project: 9317337a GrafNav v8.50.4320



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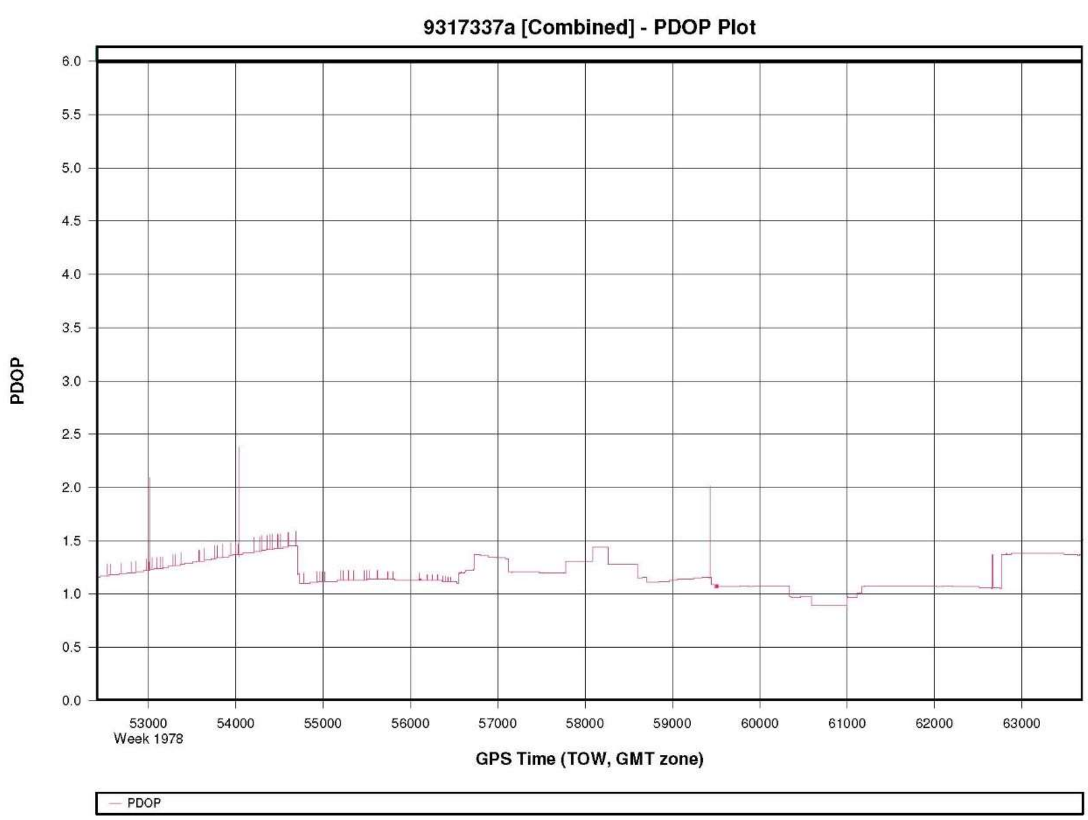
Project: 9317337a GrafNav v8.50.4320



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December 4, 2018

Project: 9317338a GrafNav v8.50.4320

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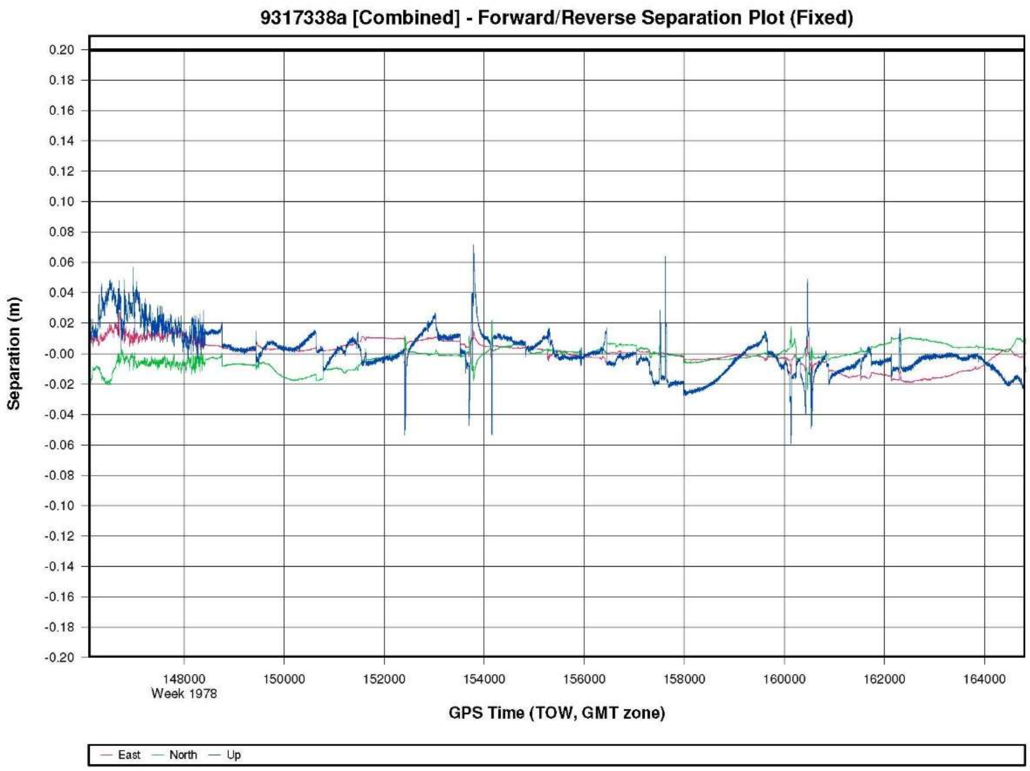
Project: 9317338a GrafNav v8.50.4320



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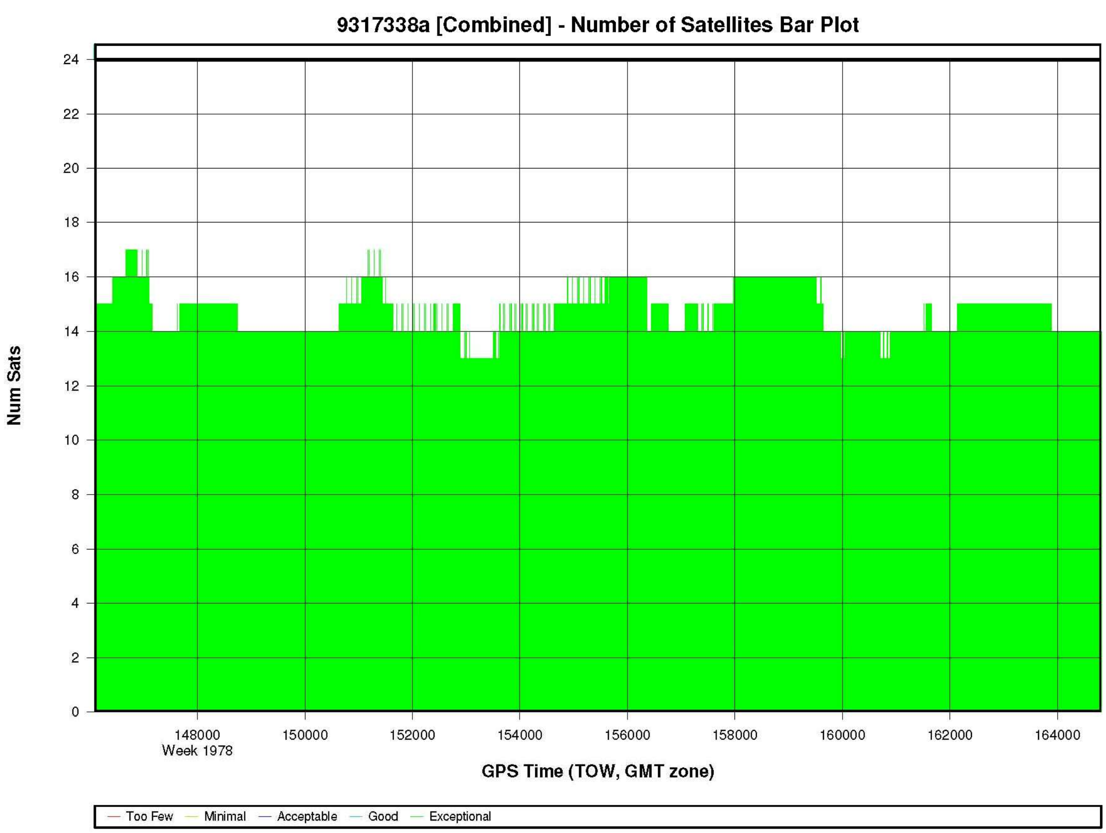
Project: 9317338a GrafNav v8.50.4320



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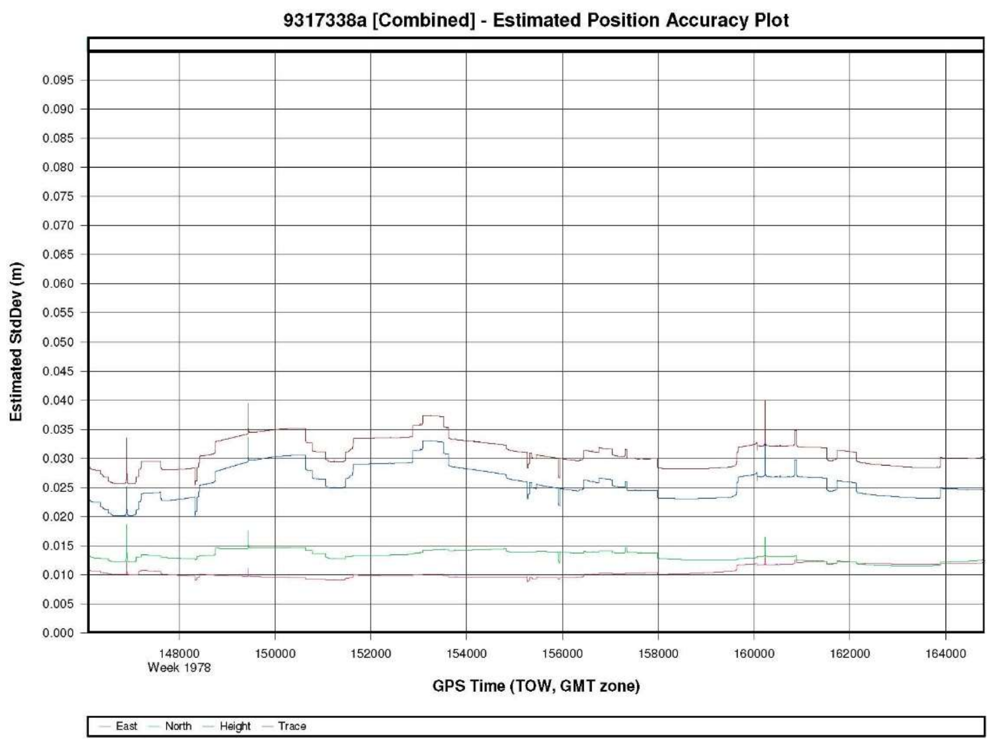
Project: 9317338a GrafNav v8.50.4320



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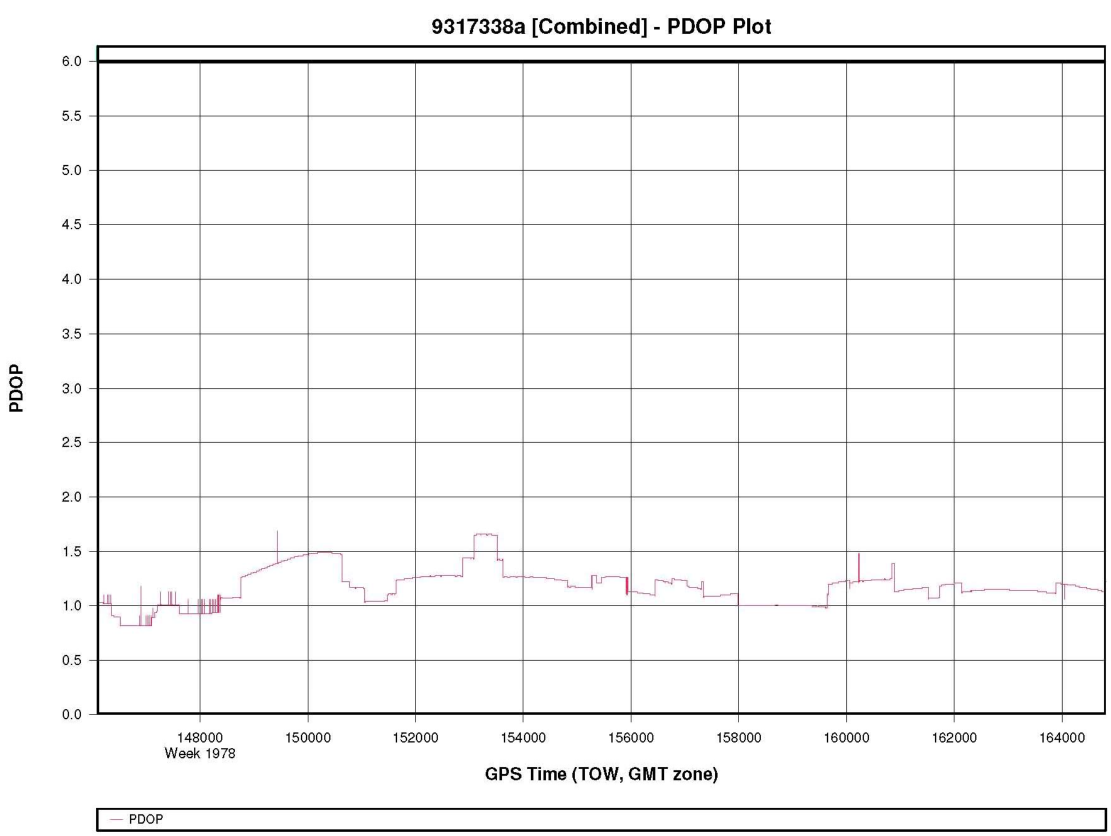
Project: 9317338a GrafNav v8.50.4320



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