Northwest Florida Water Management District (NWFWMD)
Calhoun, Holmes, Washington, Jackson, and Liberty Counties (hereafter known as "5-Counties")
LiDAR Mapping Report

Prepared by:

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EXECUTIVE SUMMARY

In the fall of 2007, Merrick & Company (Merrick) was contracted by the Northwest Florida Water Management District via URS Corporation Southern to execute a LiDAR (Light Detection And Ranging) survey for all or portions of the following five (5) counties: Calhoun, Holmes, Washington, Jackson, and Liberty; all located in northern Florida. The purpose of the project is to produce accurate, high-resolution data for planning, analysis, and for use with other data sets. Merrick obtained LiDAR data over approximately 2,102 square miles covering all or portions of 5-Counties in Florida. The LiDAR data has been processed to result in a data set that is suitable for the future generation of 2-foot contours.

CONTRACT INFORMATION

Questions regarding this report should be addressed to:

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Project Completion Report for 5-Counties

The contents of this report summarize the methods used to establish the GPS base station network, perform the LIDAR data collection and post-processing as well as the results of these methods for the 5-Counties in northern Florida.

LIDAR FLIGHT and SYSTEM REPORT

Project Location

The project location for the Counties in Florida is defined by the shapefiles.
"Jackson_LiDAR"
"Holems_LiDAR"
"Calhoun_LiDAR_rev102407"
"Washington_LiDAR"
"Liberty_Lidar_Apal-Bristol_110707"

Duration/Time Period

The LIDAR aircraft, a Cessna 402C, arrived on site on November 11, 2007 and the LIDAR data collection was accomplished on November 12, 2007 thru January 20, 2008. The Tallahassee Regional Airport (TLH) was used as the airfield of operations.

Flight Diagrams

See Below.

Mission Parameters for the 4 Counties in Florida

LiDAR Sensor	Leica Geosystems ALS50 Phase 1
Nominal Ground Sample Distance	3.99 feet
Average Altitude	5500 Feet MSL
Average Airspeed	~154 Knots
Scan Rate	27 Hertz
Scan FOV (scan angle)	35˚
Pulse Rate	56,500 Hertz

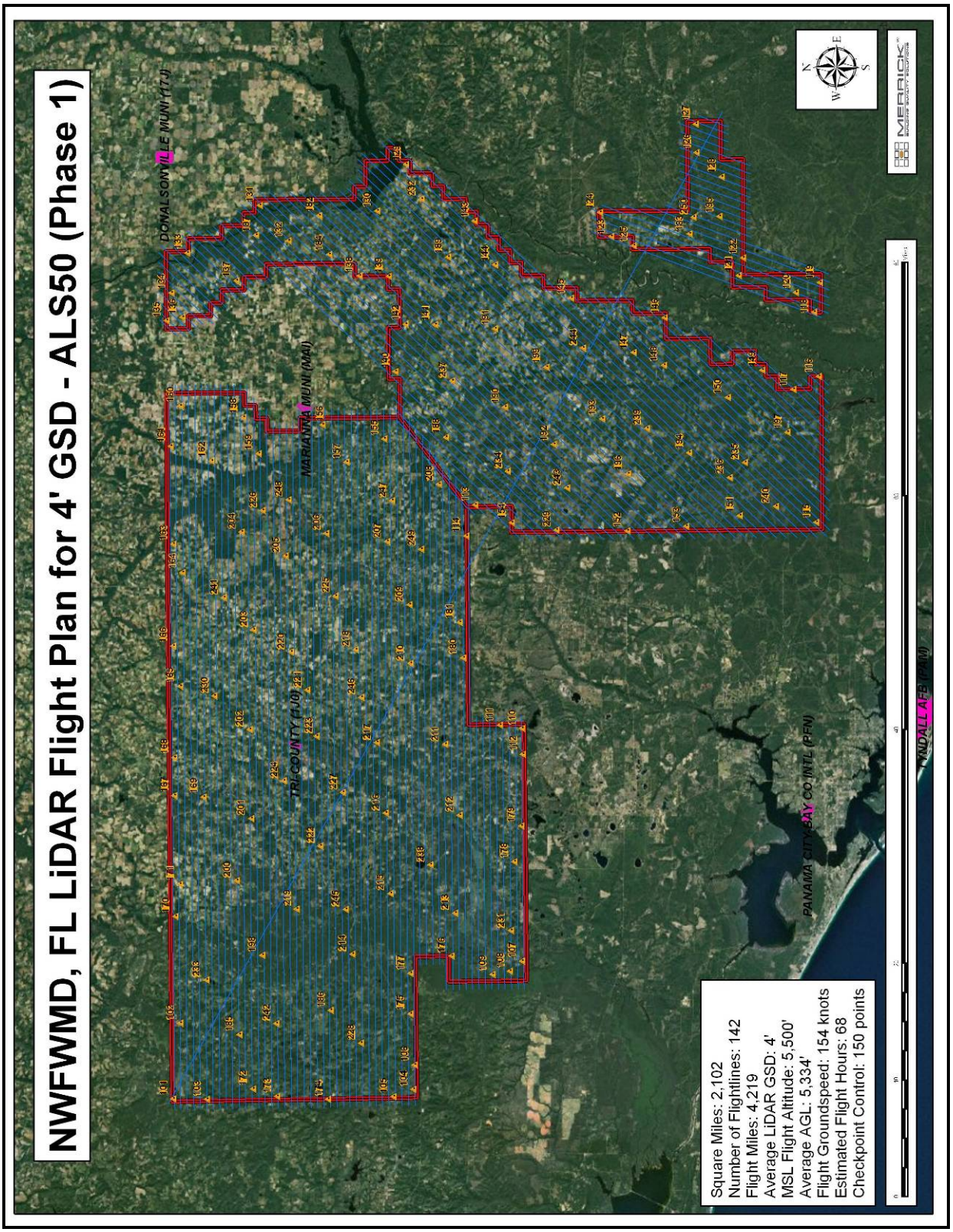
Mission	Date	Start Time GMT	End Time GMT	Length Time
071112A	Nov. 12, 2007	16:48:10	18:17:19	01:29:09
071113A	Nov. 13, 2007	14:02:14	16:44:35	02:42:21
071114A	Nov. 14, 2007	15:01:37	18:13:03	03:11:26
071116A	Nov. 16, 2007	15:03:17	19:46:06	04:42:49
071118A	Nov. 18, 2007	13:59:15	18:35:52	04:36:37
071119A	Nov. 19, 2007	13:55:24	17:32:21	03:36:58
071120A	Nov. 20, 2007	14:15:44	18:02:30	03:46:46
071123A	Nov. 23, 2007	13:54:26	18:23:45	04:29:19
071129A	Nov. 29, 2007	20:39:25	00:14:39	03:35:14
071130A	Nov. 30, 2007	14:43:55	20:32:19	05:48:24
071204A	Dec. 04, 2007	21:57:22	02:50:01	04:52:39
071205A	Dec. 05, 2007	15:28:42	20:40:21	05:11:40
071206A	Dec. 06, 2007	14:57:35	19:58:54	05:01:19
071206B	Dec. 06, 2007	20:32:58	00:10:49	03:37:51
080113A	Dec. 13, 2007	20:43:31	22:44:48	02:01:17
080120A	Dec. 20, 2007	17:08:32	20:20:05	03:11:34

Field Work / Procedures

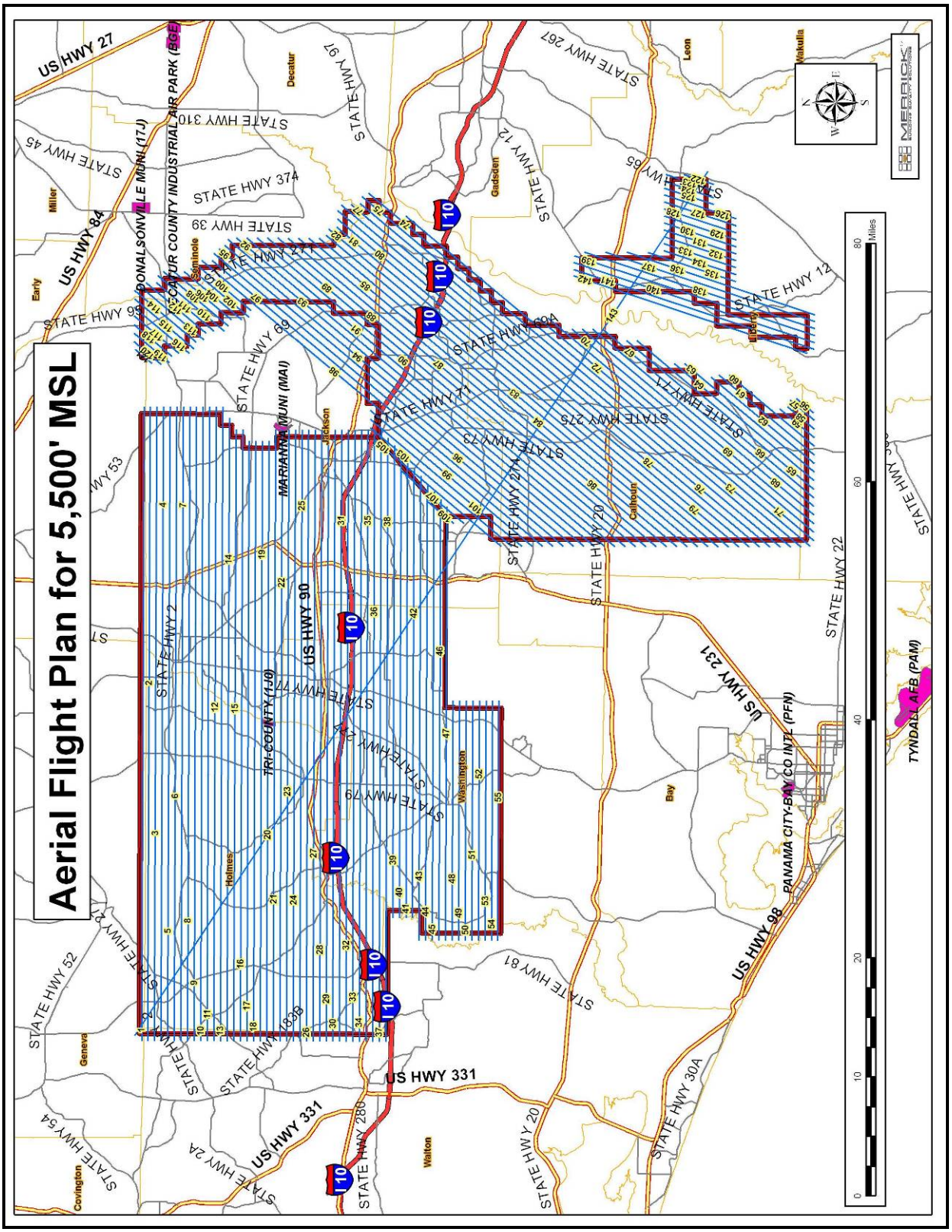
Four Ground Airborne GPS Base Stations, for the LiDAR data collection, were used, the Base station at the airport and base 101, base 102 and base 103, located within the job boundary or under the flight lines for that day.

Pre-flight checks such as cleaning the sensor head glass are performed. A five minute INS initialization is conducted on the ground, with the aircraft engines running, prior to flight, to establish fine-alignment of the INS. GPS ambiguities are resolved by flying within ten kilometers of the base stations. During the data collection, the operator recorded information on log sheets which includes weather conditions, LIDAR operation parameters, and flight line statistics. Data was sent back to the main office and preliminary data processing was performed for quality control of GPS data and to ensure sufficient overlap between flight lines. Any problematic data could then be reflown immediately as required. Final data processing was completed in the Aurora, Colorado office.

Flight Diagram 1 for 5-Counties with Ground Checkpoints

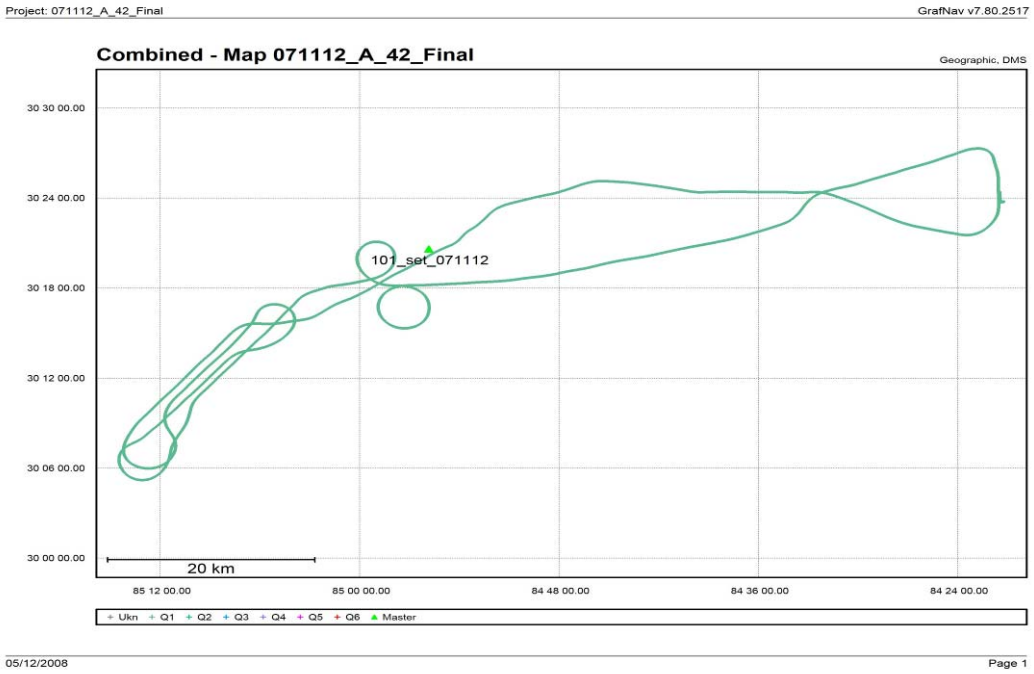


Flight Diagram 2 for 5-Counties

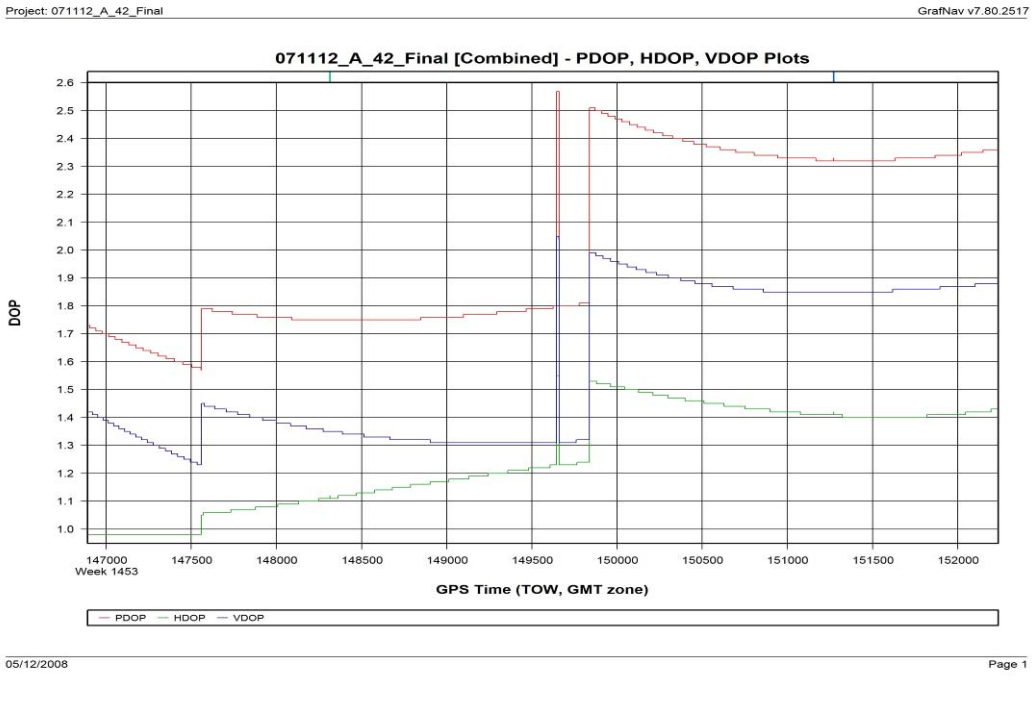


The following graphs show the mission by mission GPS derived flight tracks and PDOP (Positional Dilution Of Precision) Plots.

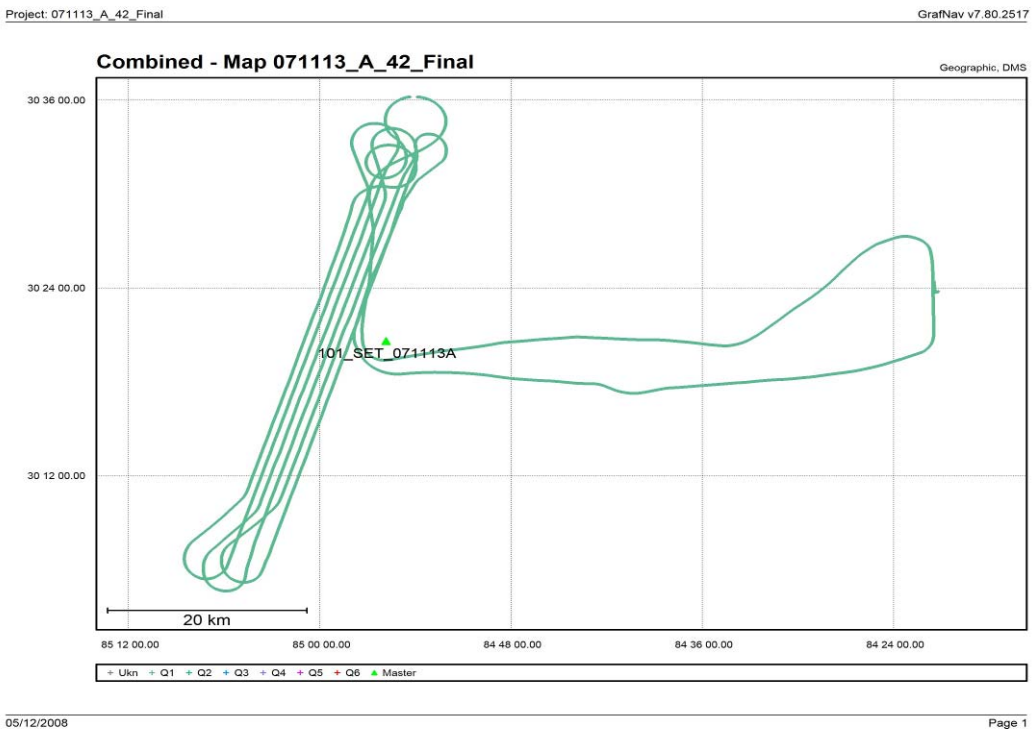
GPS derived flight tracks for mission 071112A



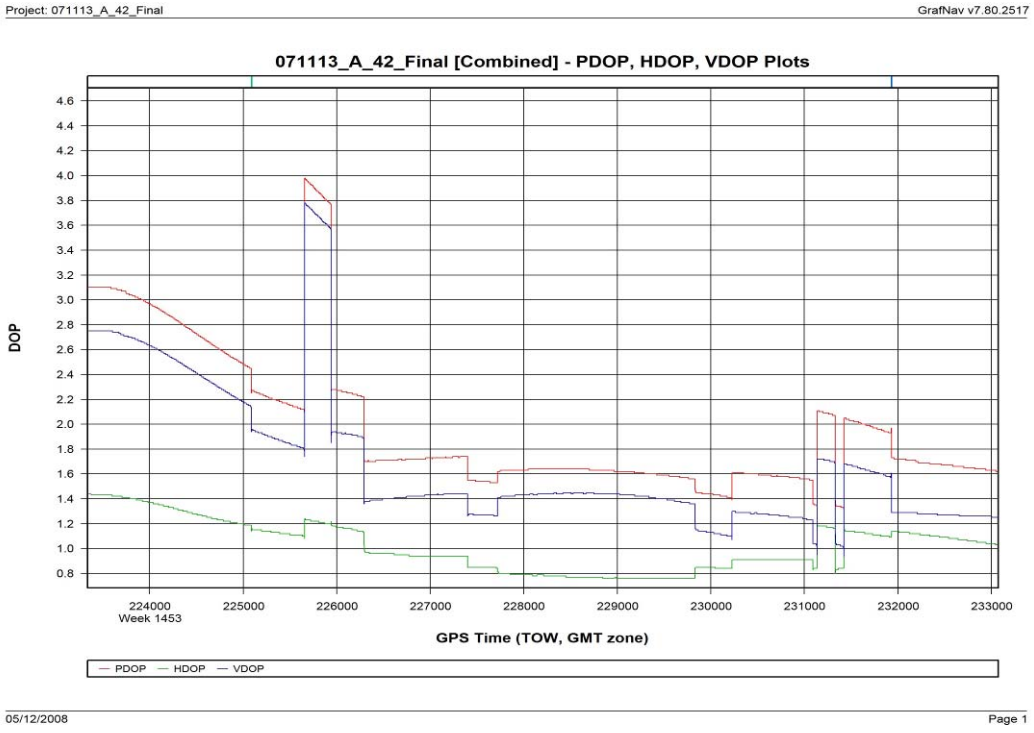
PDOP (Positional Dilution Of Precision) Plot for mission 071112A



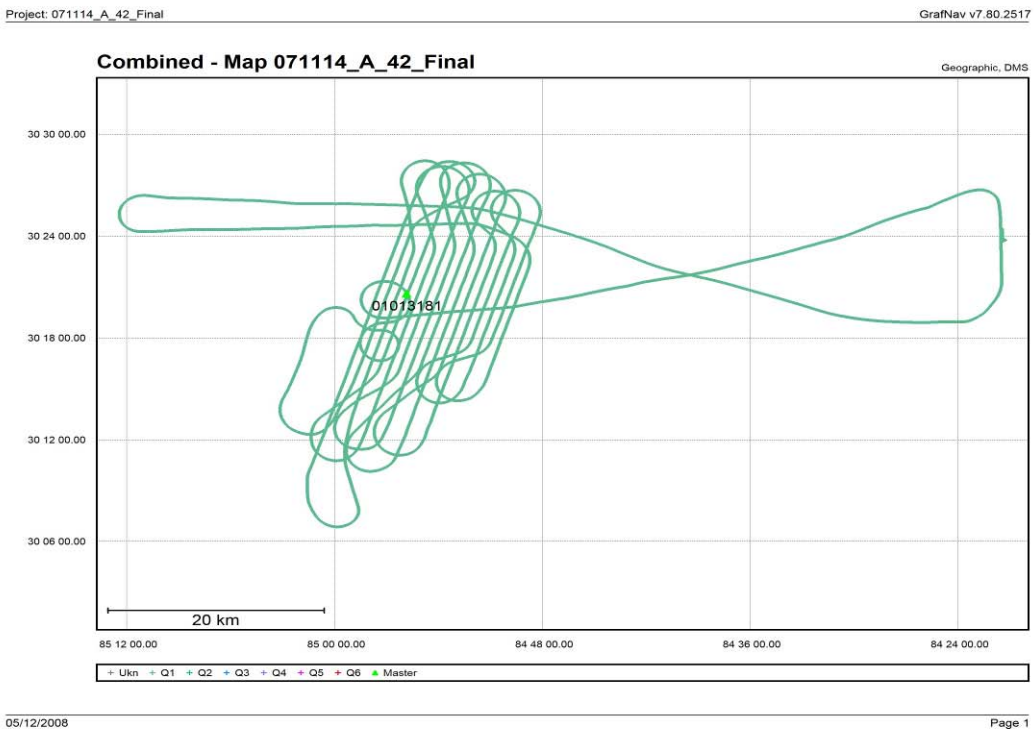
GPS derived flight tracks for mission 071113A



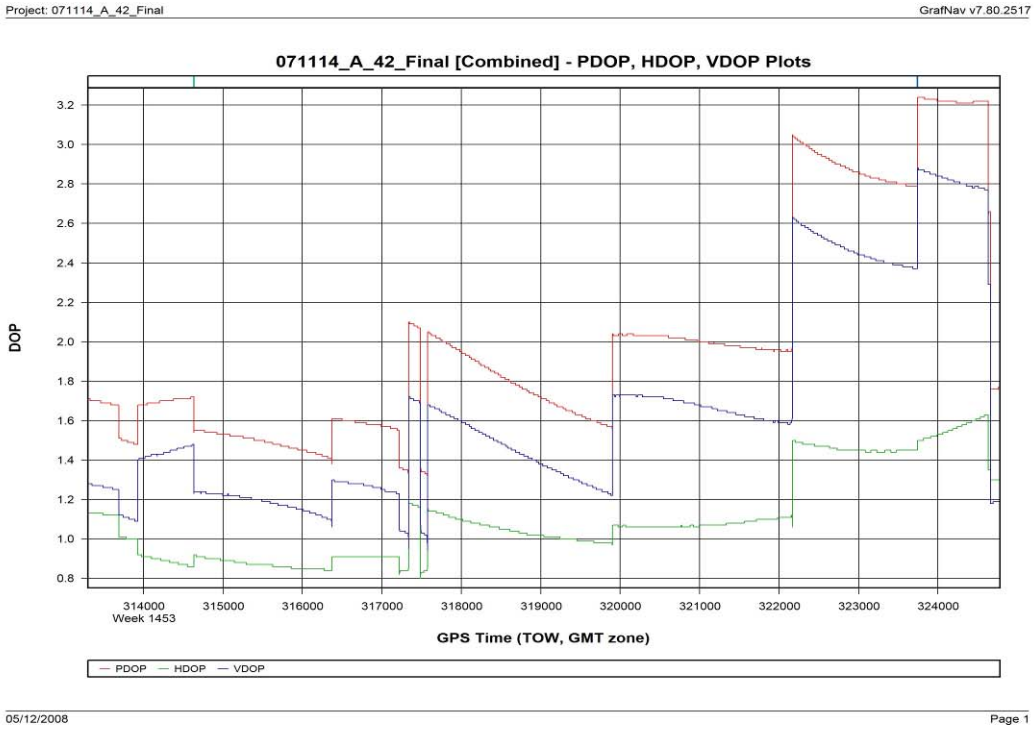
PDOP (Positional Dilution Of Precision) Plot for mission 071113A



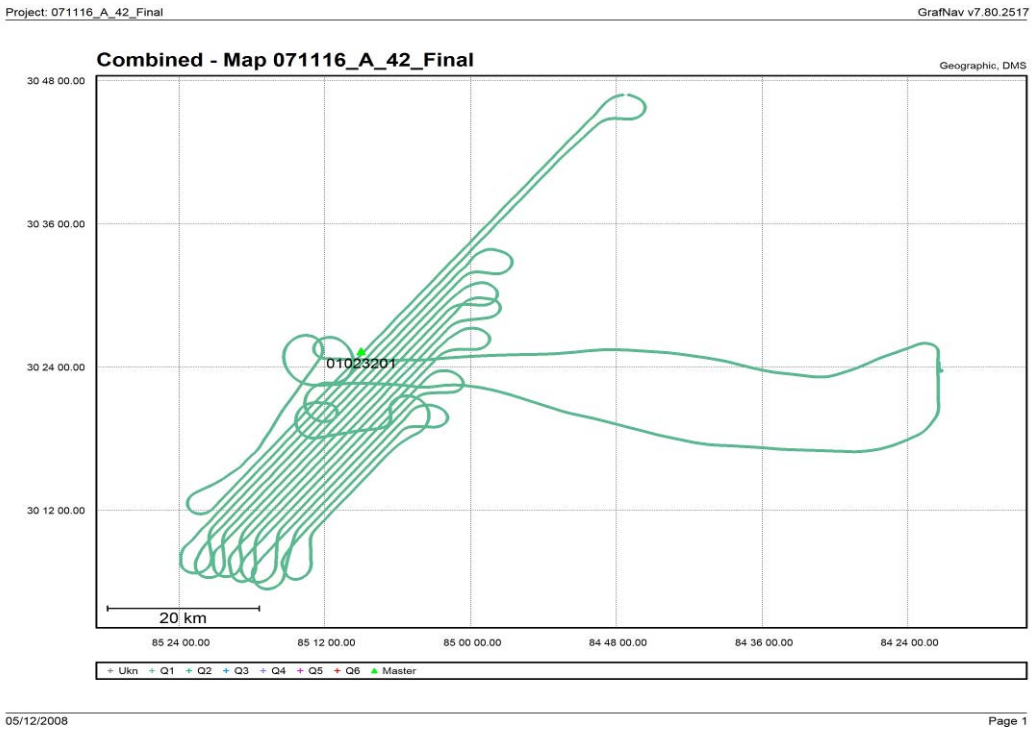
GPS derived flight tracks for mission 071114A



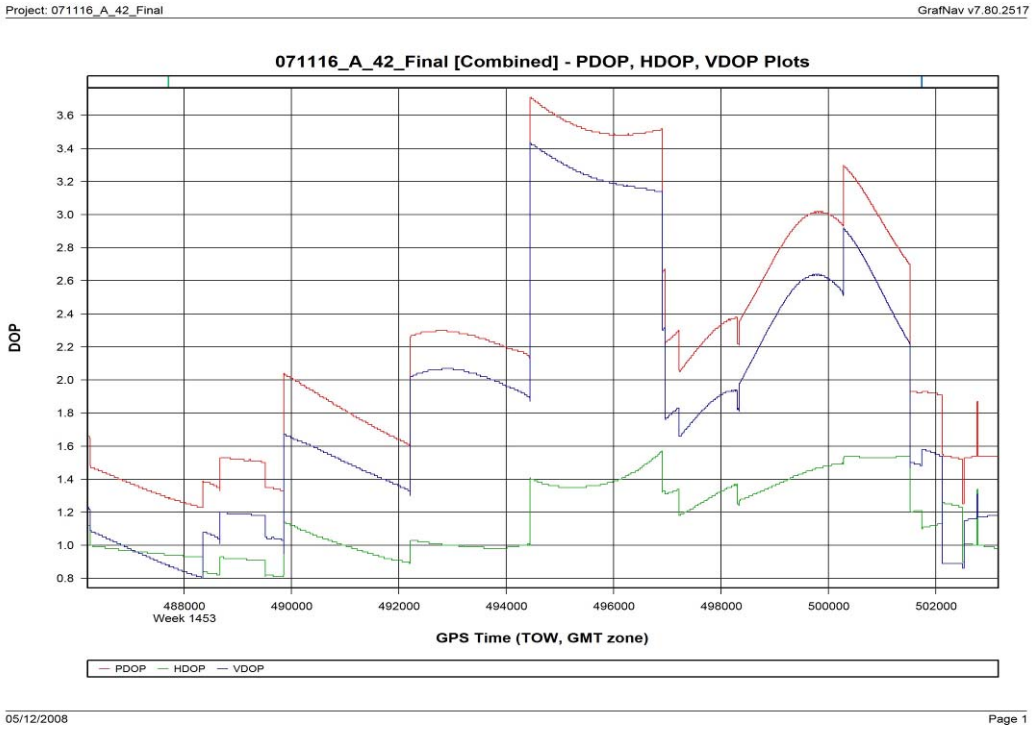
PDOP (Positional Dilution Of Precision) Plot for mission 071114A



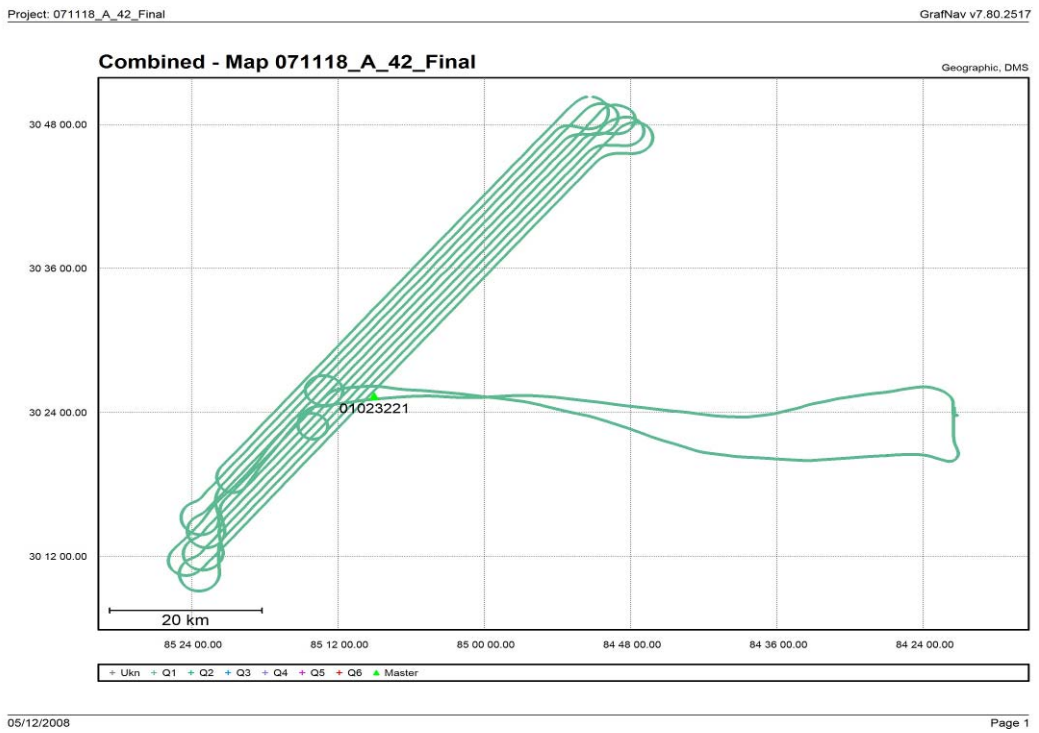
GPS derived flight tracks for mission 071116A



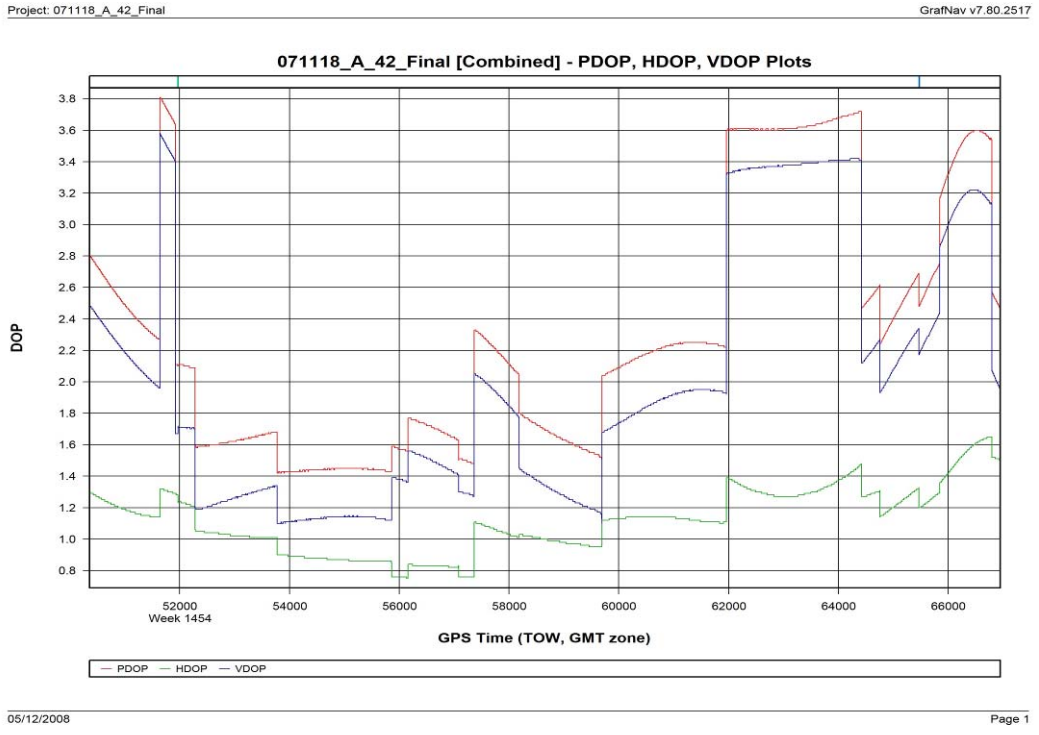
PDOP (Positional Dilution Of Precision) Plot for mission 071116A



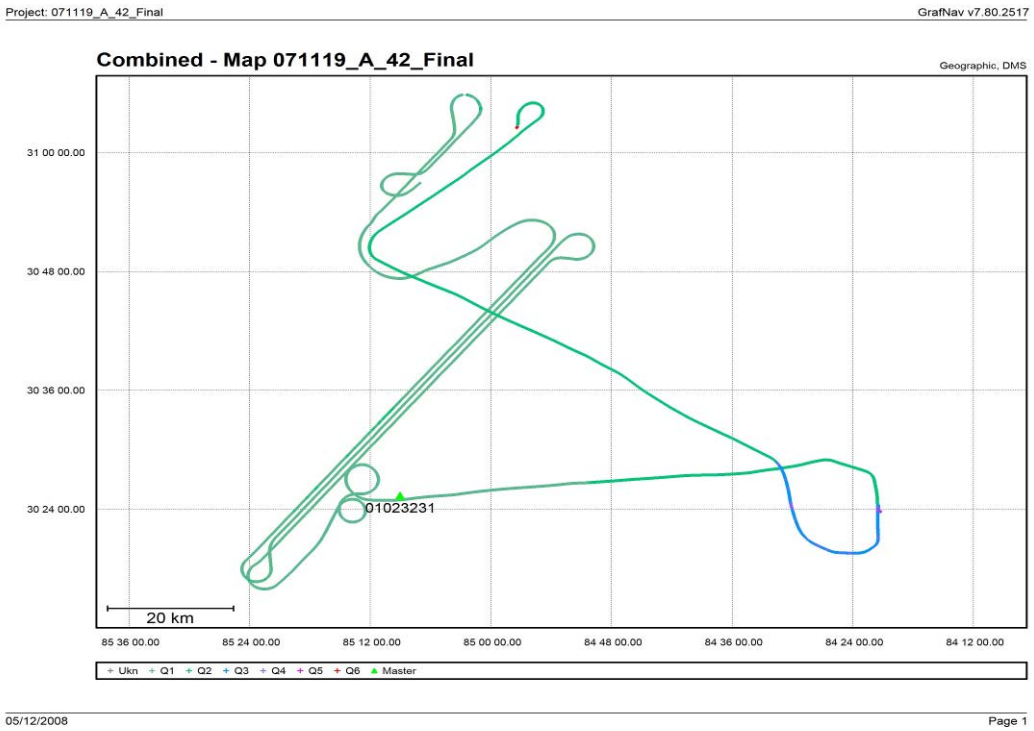
GPS derived flight tracks for mission 071118A



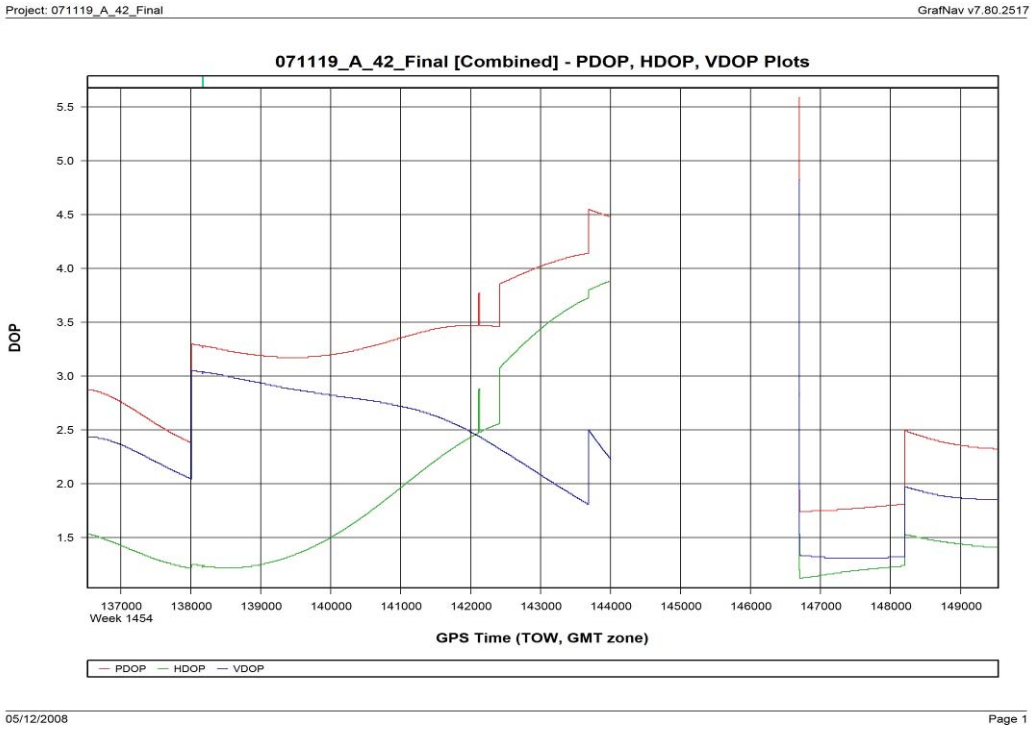
PDOP (Positional Dilution Of Precision) Plot for mission 071118A



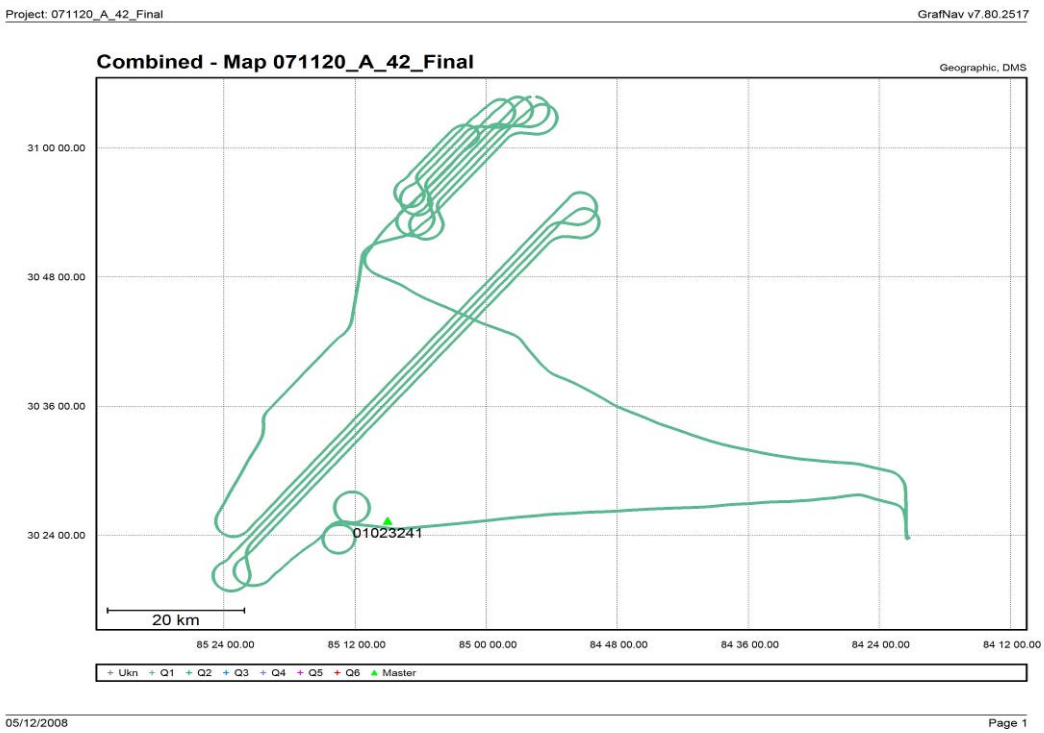
GPS derived flight tracks for mission 071119A



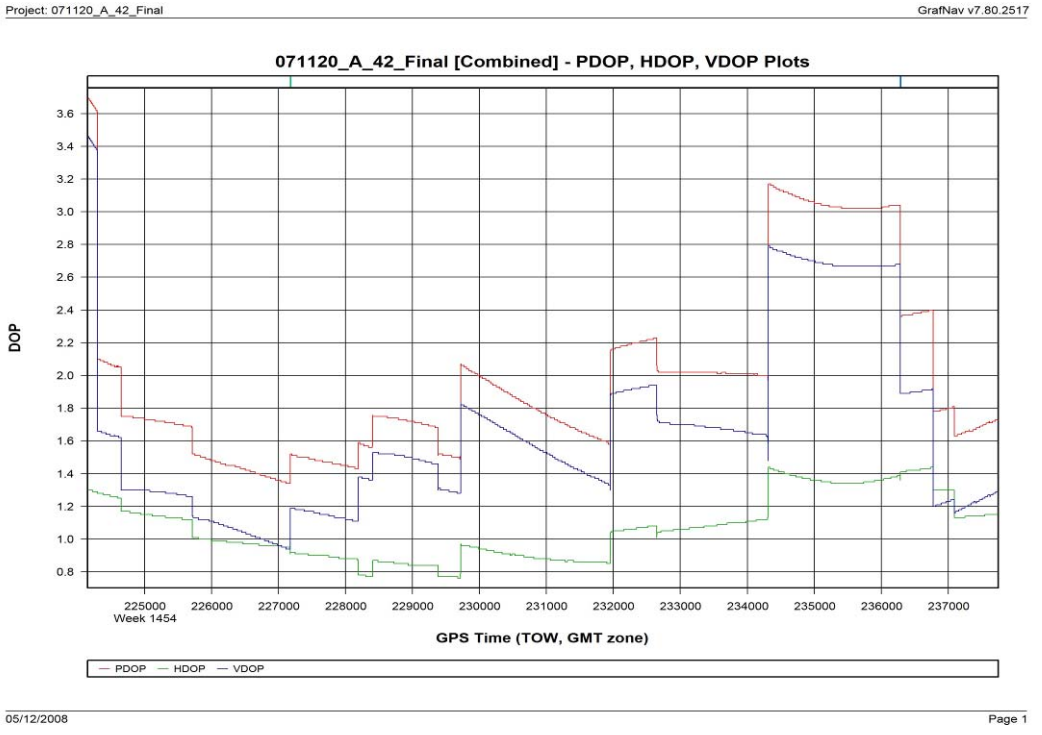
PDOP (Positional Dilution Of Precision) Plot for mission 071119A



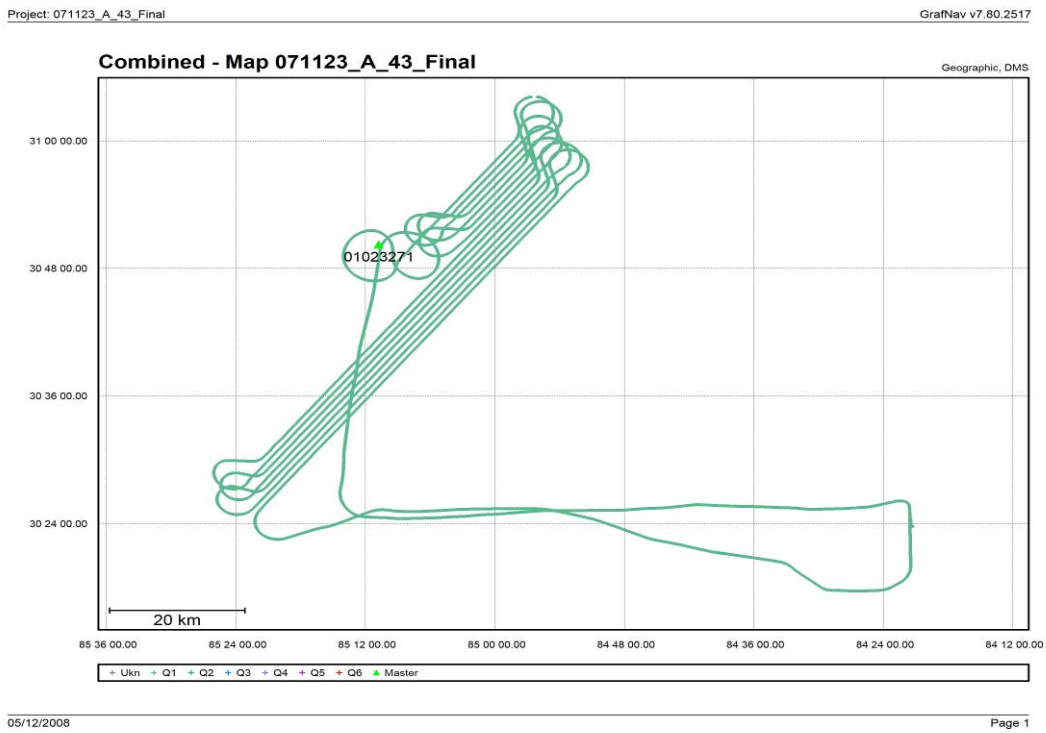
GPS derived flight tracks for mission 071120A



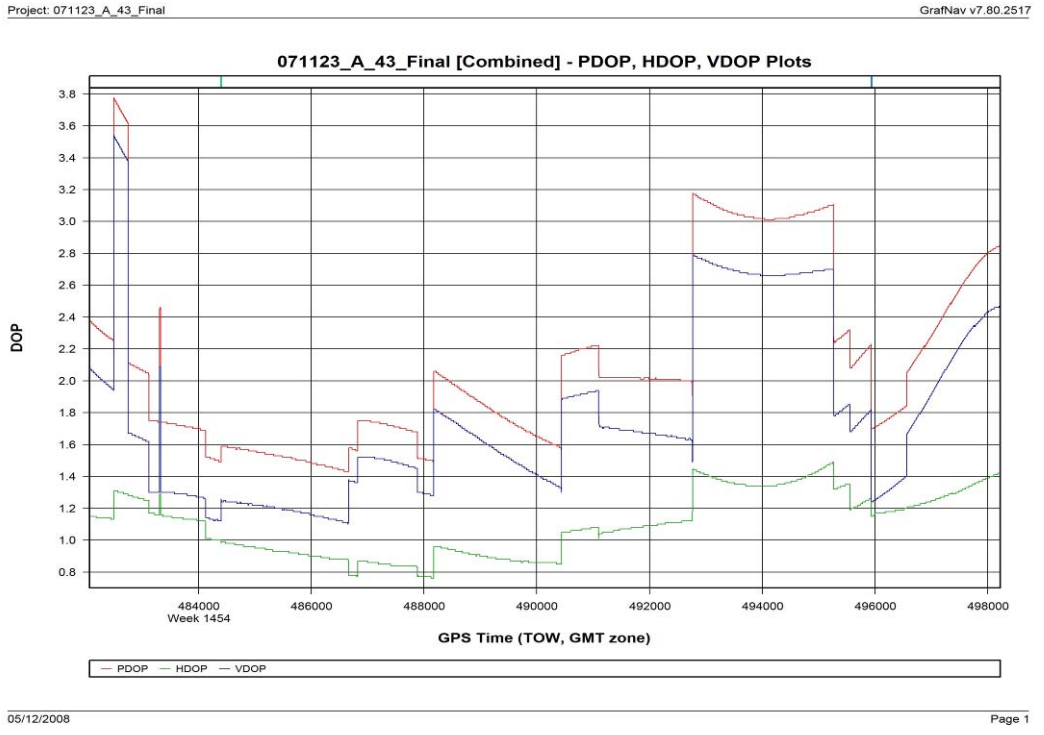
PDOP (Positional Dilution Of Precision) Plot for mission 071120A



GPS derived flight tracks for mission 071123A



PDOP (Positional Dilution Of Precision) Plot for mission 071123A



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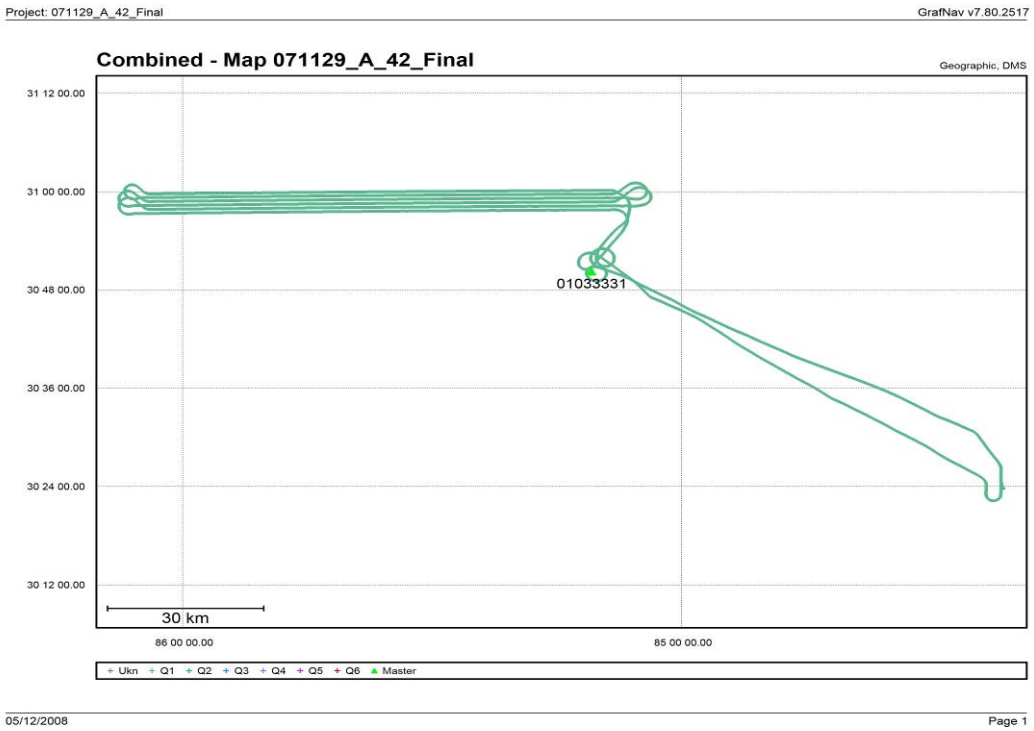
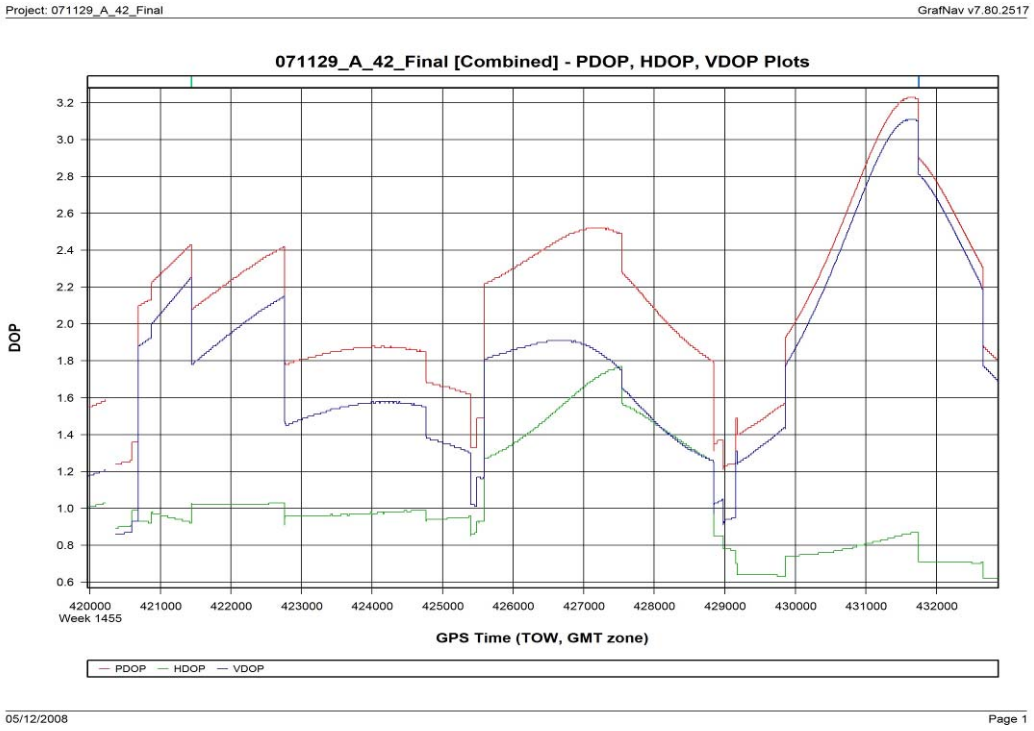
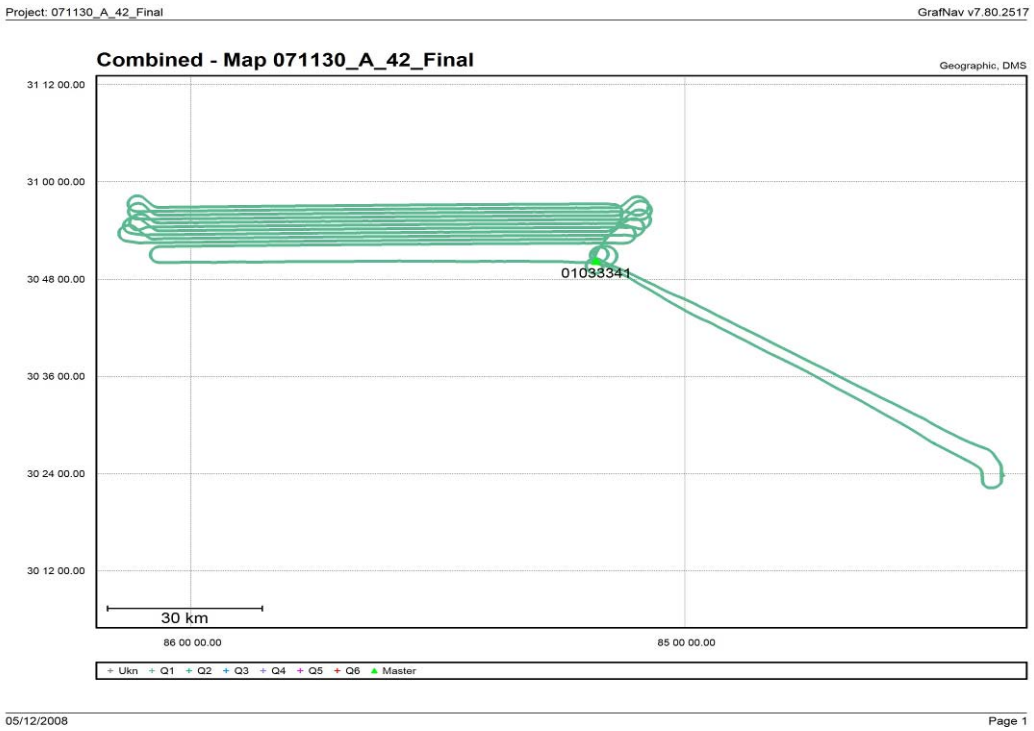


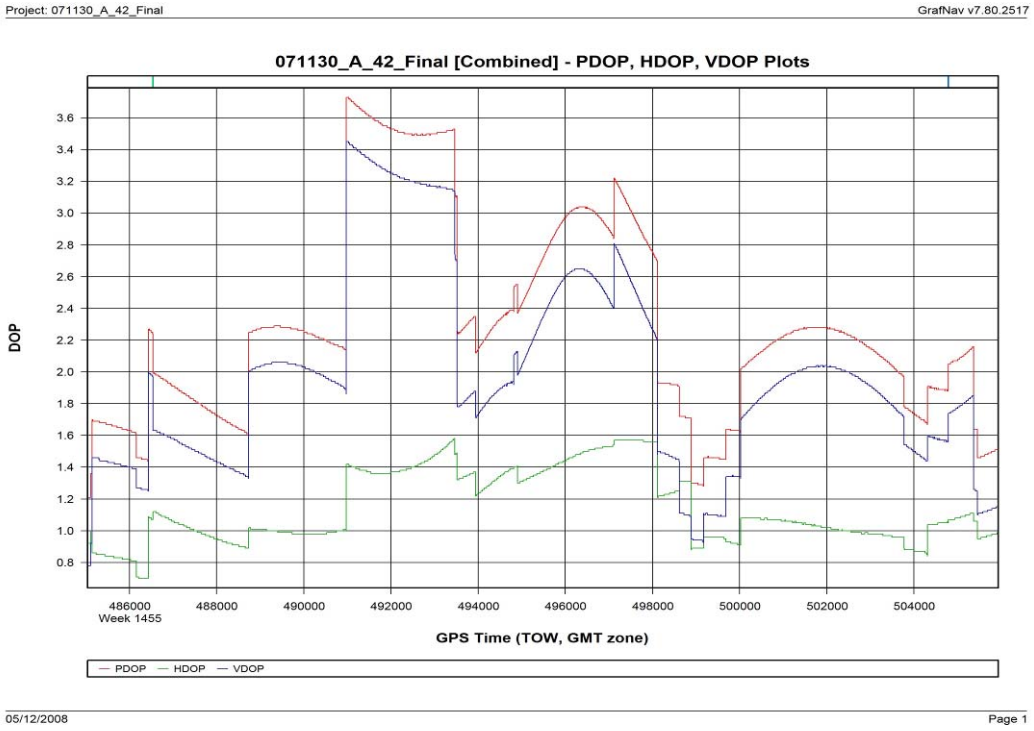
PDOP (Positional Dilution Of Precision) Plot for mission 071129A



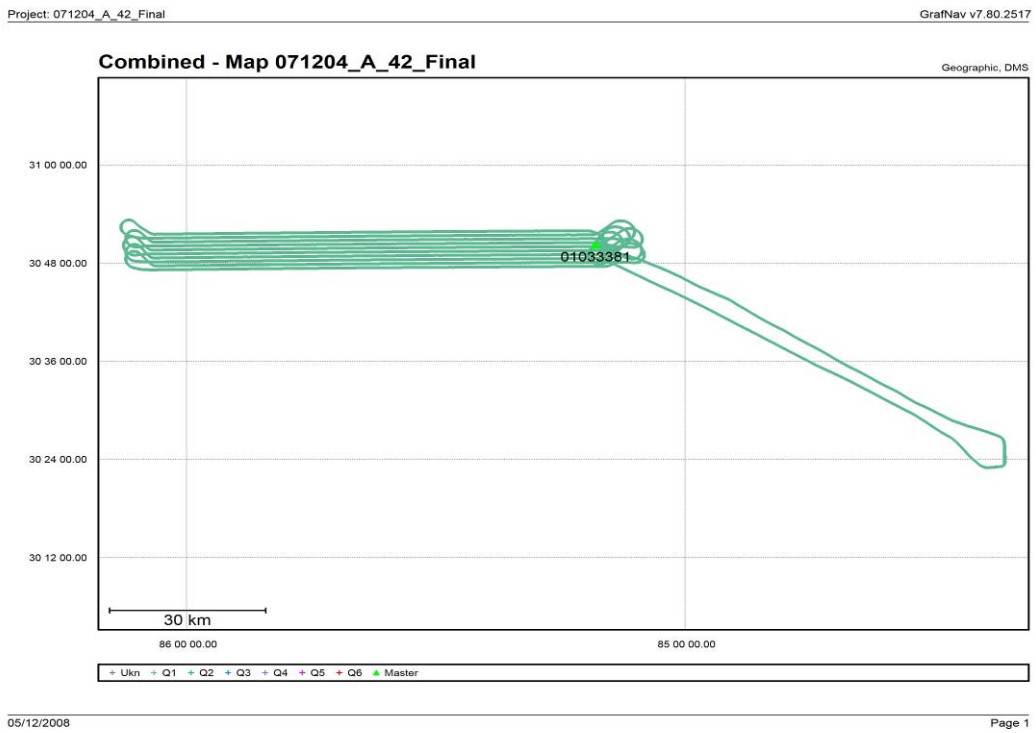
GPS derived flight tracks for mission 071130A



PDOP (Positional Dilution Of Precision) Plot for mission 071130A



GPS derived flight tracks for mission 071204A



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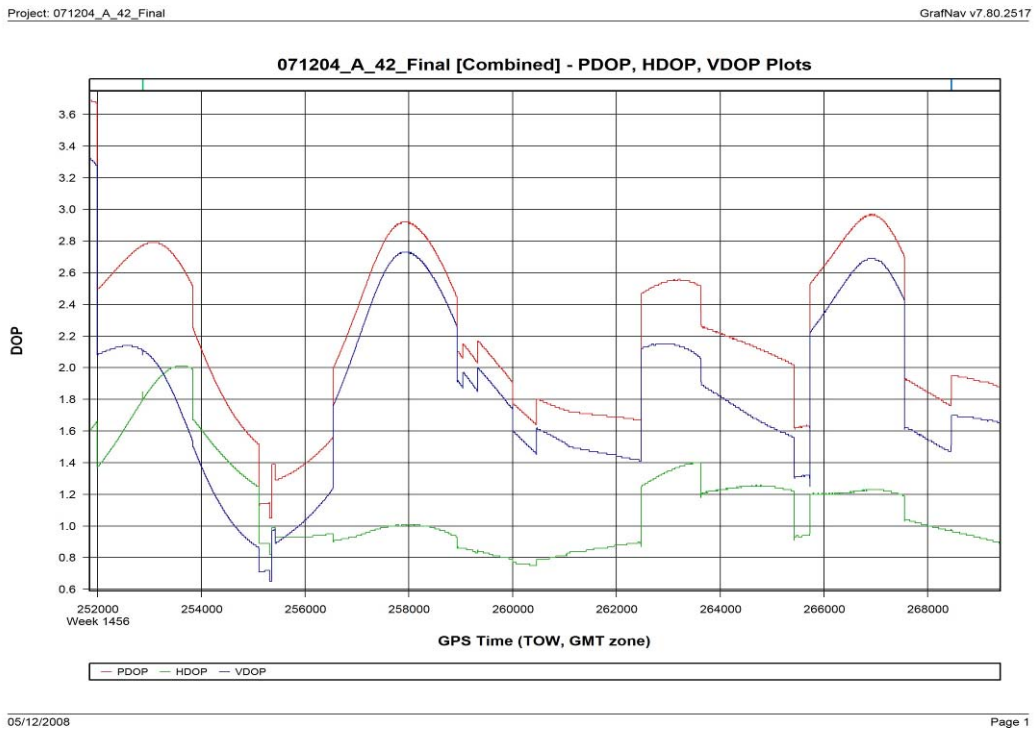
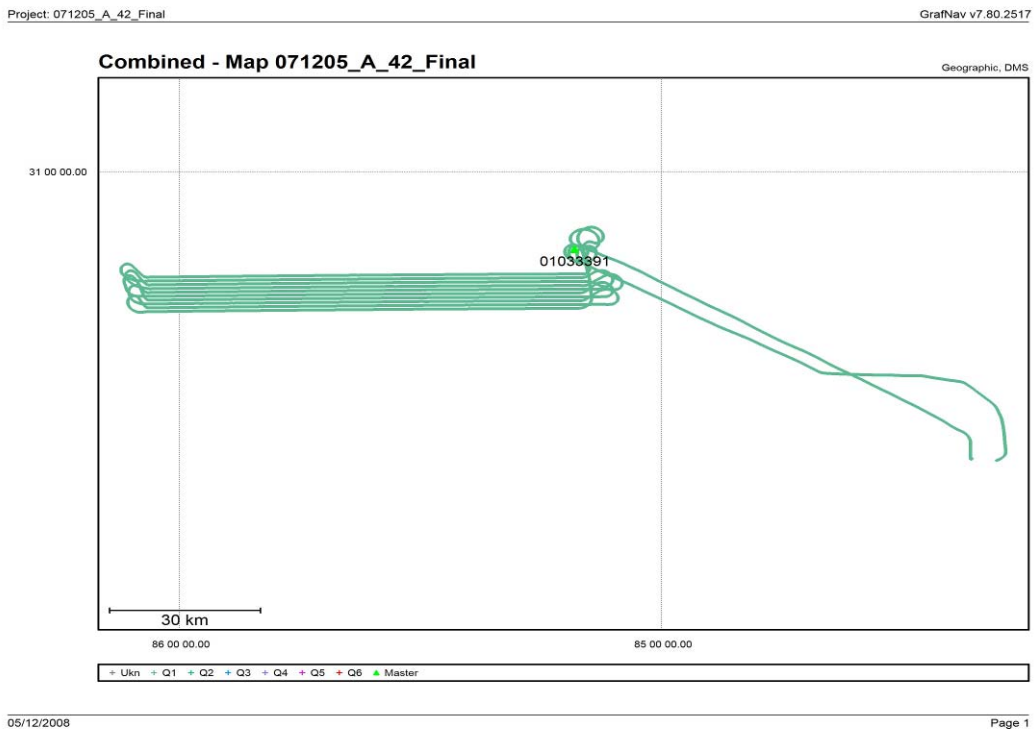


GPS derived flight tracks for mission 071205A



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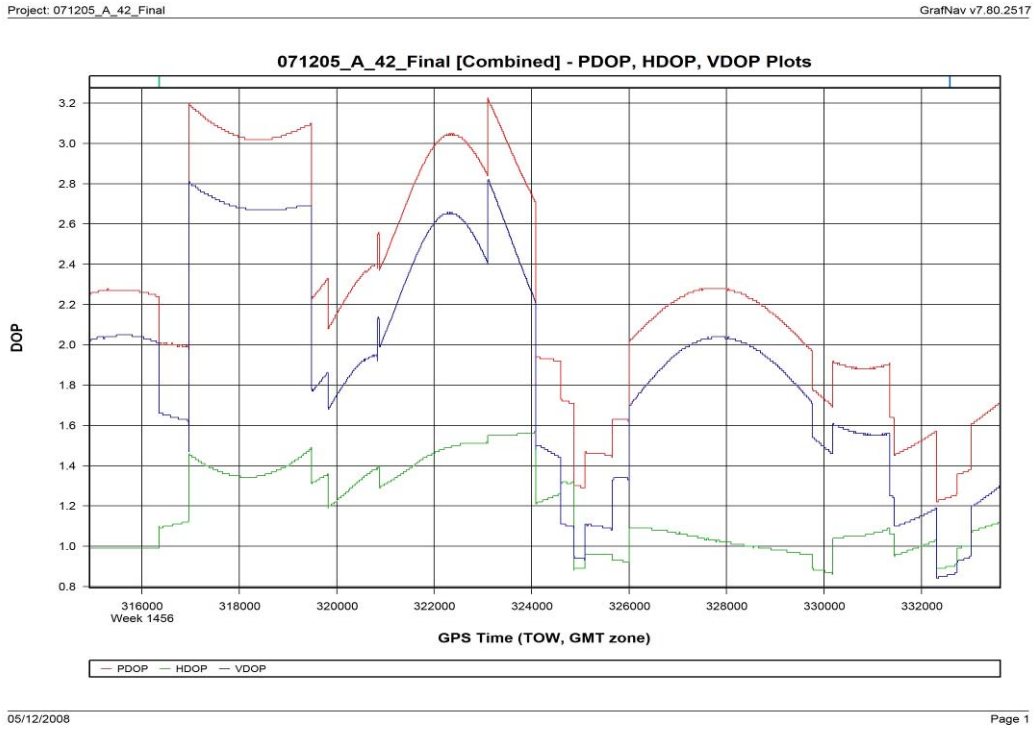
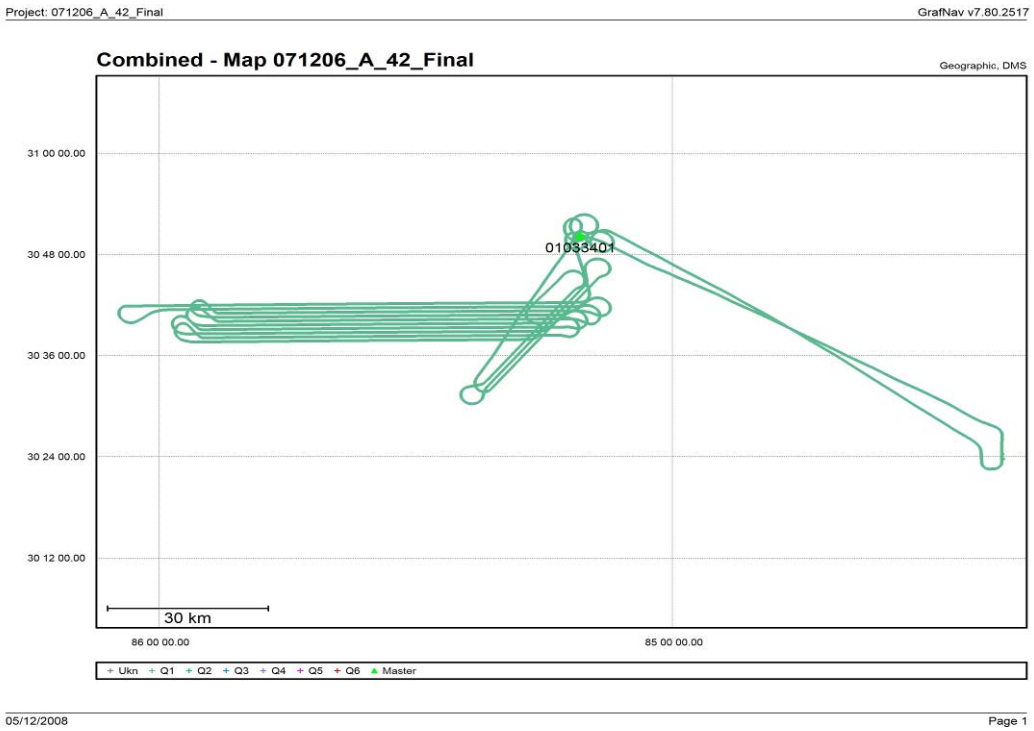
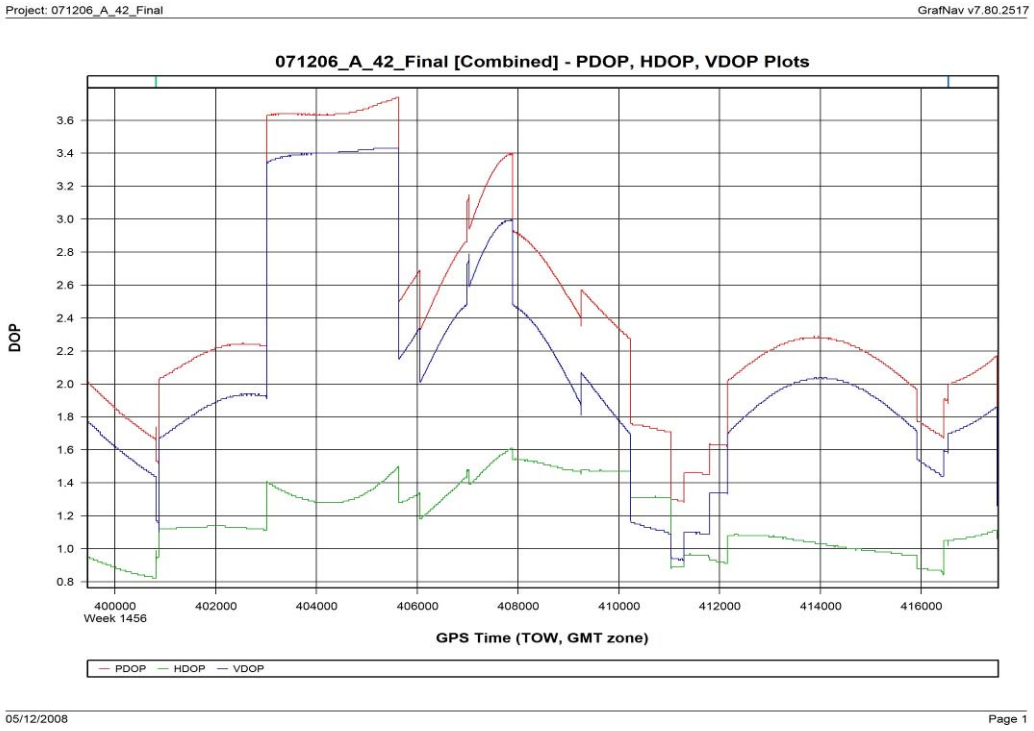


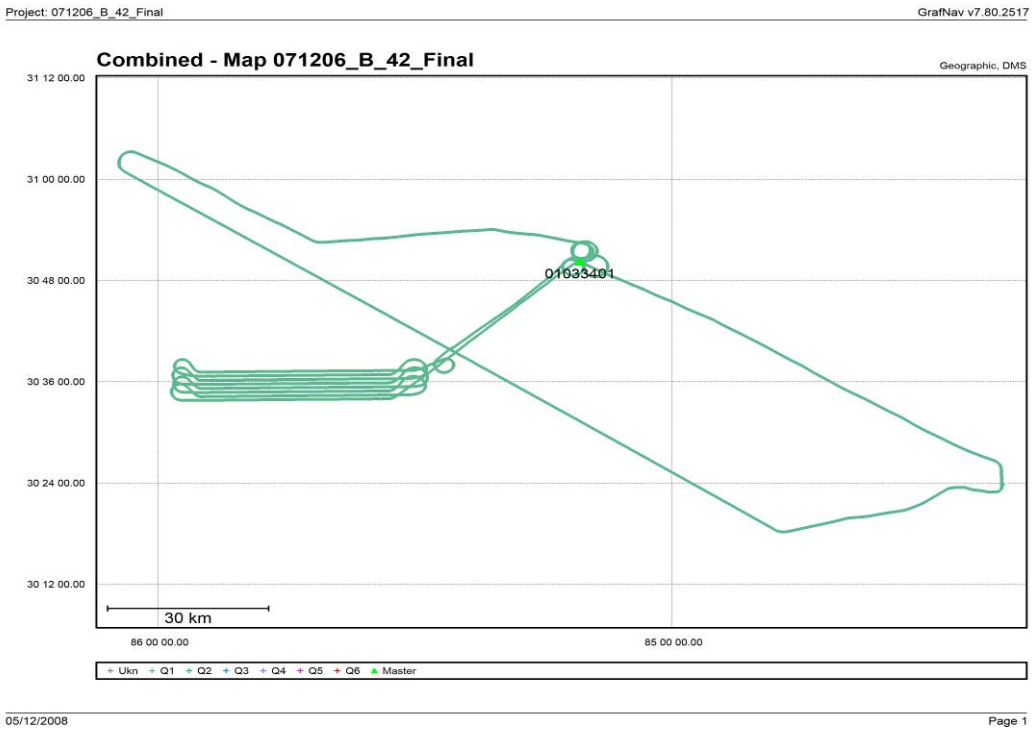
GPS derived flight tracks for mission 071206A



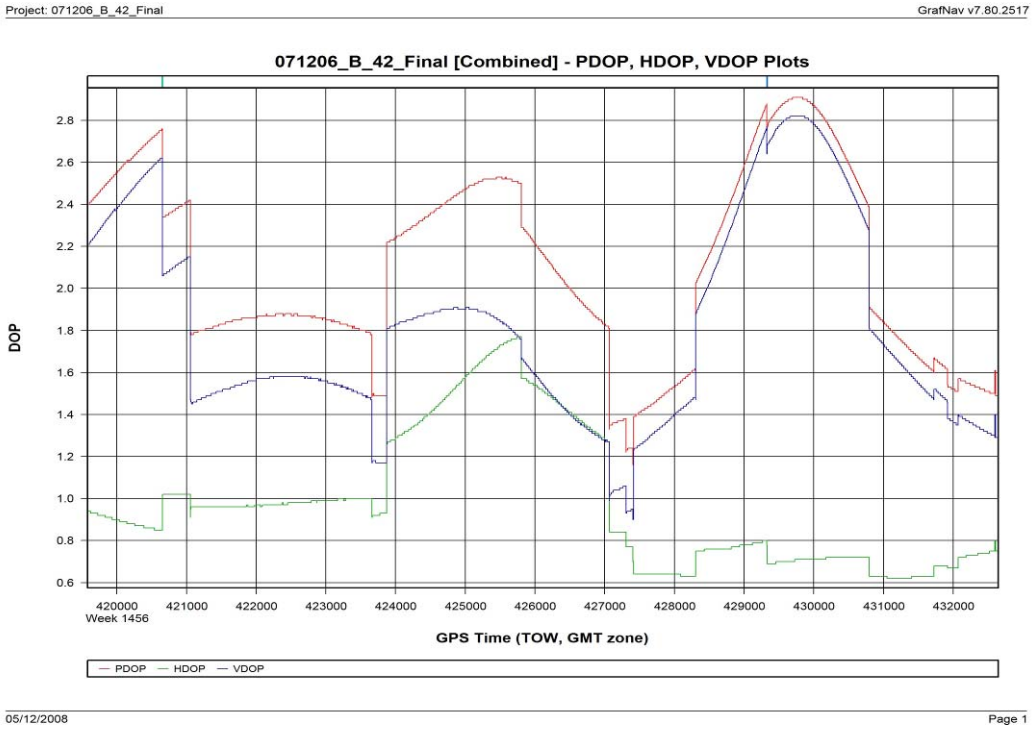
PDOP (Positional Dilution Of Precision) Plot for mission 071206A



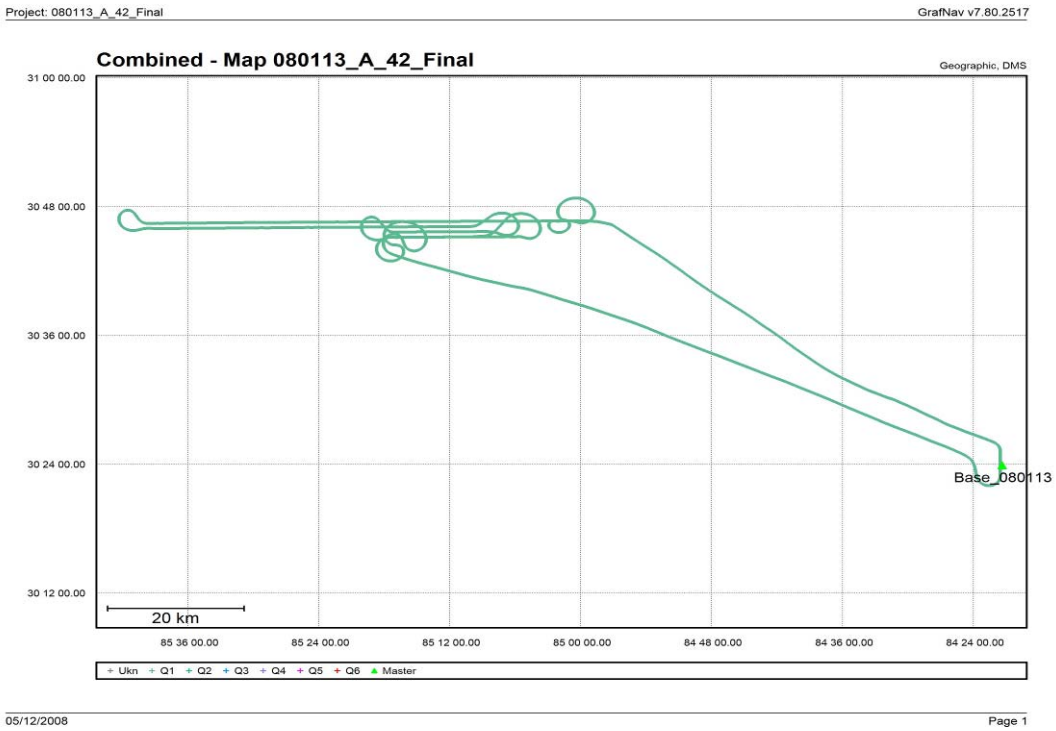
GPS derived flight tracks for mission 071206B



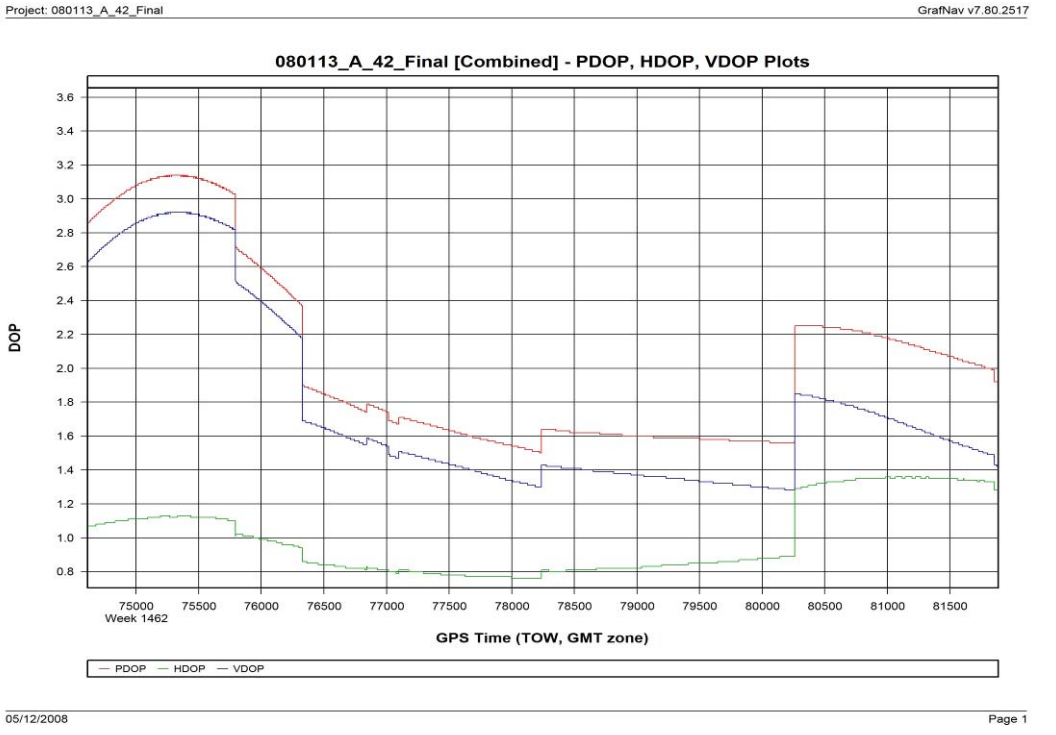
PDOP (Positional Dilution Of Precision) Plot for mission 071206B



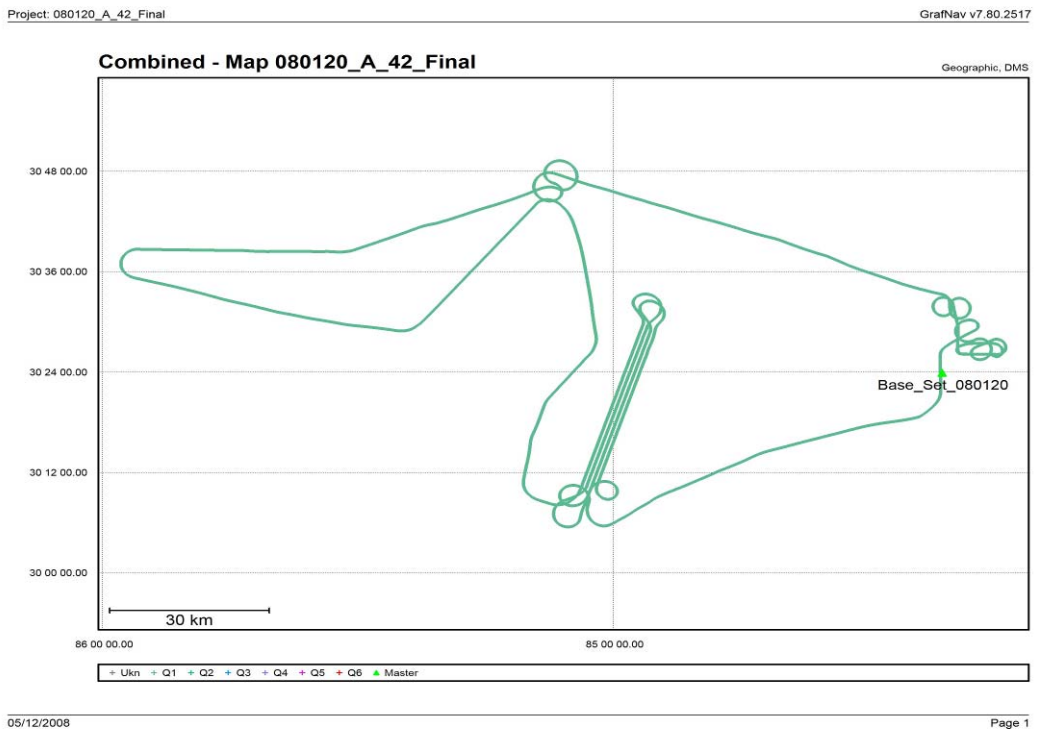
GPS derived flight tracks for mission 080113A



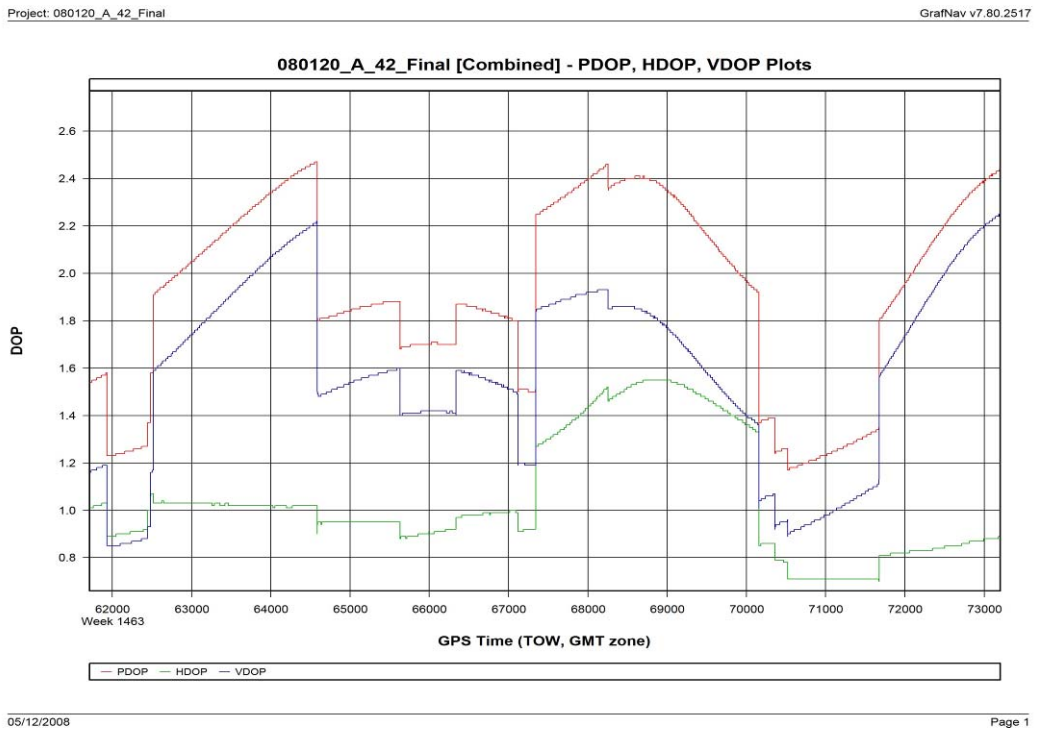
PDOP (Positional Dilution Of Precision) Plot for mission 080113A



GPS derived flight tracks for mission 080120A



PDOP (Positional Dilution Of Precision) Plot for mission 080120A



LIDAR Data Processing

The airborne GPS data was post-processed using Waypoint's GravNAV software version 4.2. A fixed-bias carrier phase solution was computed in both the forward and reverse chronological directions. Whenever practical, LIDAR acquisition was limited to periods when the PDOP (Positional Dilution Of Precision) was less than 4.0. PDOP indicates satellite geometry relating to position. Generally PDOP's of 4.0 or less result in a good solution, however PDOP's between 4.0 and 5.0 can still yield good results most of the time. PDOP's over 6.0 are of questionable results and PDOP's of over 7.0 usually result in a poor solution. HDOP stands for Horizontal Dilution Of Precision and VDOP stands for Vertical Dilution Of Precision. Other quality control checks used for the GPS include analyzing the combined separation of the forward and reverse GPS processing from one base station. Also analysis of the number of satellites present during the flight and the number of satellites present during data collection times.

The GPS trajectory was combined with the raw IMU data and post-processed using POSPac version 4.2. The smoothed best estimated trajectory (SBET) and refined attitude data are then utilized in the ALS Post Processor to compute the laser point-positions – the trajectory is combined with the attitude data and laser range measurements to produce the 3-dimensional coordinates of the mass points. Up to four return values are produced within the ALS Post Processor software for each pulse which ensures the greatest chance of ground returns in a heavily forested area.

Laser point classification was completed using Merrick Advanced Remote Sensing (MARS) LIDAR processing and modeling software. Several algorithms are used when comparing points to determine the best automatic ground solution. Each filter is built based on the projects terrain and land cover to provide a surface that is 95% free of anomalies and artifacts. After the auto filter has been completed the data is then reviewed by an operator utilizing MARS to remove any other anomalies or artifacts not resolved by the automated filter process. During these final steps the operator also verifies that the data set is consistent and complete with no data voids.

GROUND CONTROL REPORT / CHECK POINT SURVEY RESULTS

GPS Controls

Four ground airborne GPS Base Stations, for the LiDAR collection, were used for this project, one GPS receiver located at the airport and three secondary airborne GPS receiver placed within the job boundary or under the Flight lines for that day. The main airborne GPS base station was located at the Tallahassee Regional Airport (TLH). The secondary airborne GPS base stations were tied directly to the main airborne GPS base station by post processing using Trimble Geomatics Office Software version 1.63 and checked with OPUS (Online Positioning User Service) solutions from NGS (National Geodetic Survey).

See the spreadsheet below for Airborne GPS Base Station information.

Project: NWFWMD_FL_GPS_Bases
Job#: 02015713
Date: Nov. 2007

Coordinate System: UTM ZONE 16 NORTH
Zone: 16 NORTH
Project Datum: NAD 1983(1999)
Vertical Datum: NAVD88 (GEOID2003 will be used to convert ellipsoid heights to orthometric**)**
Units: Meters (and US survey feet Vertical)

PT#	GEODETIC NAD83(1999)		ELLIPSOID	DESCRIPTION
NAME	LATITUDE	LONGITUDE	HEIGHT	
	NORTH	WEST	GEOID2003	
	DEG MIN SEC	DEG MIN SEC	METERS	
BASE	30°23'53.92484"N	84°21'20.63747" W	-12.421	Base at Airport
101	30°20'35.79700"N	84°55'50.17131" W	4.572	60d
102	30°25'20.58471"N	85°09'01.47821" W	1.706	60d
103	30°50'14.66733"N	85°10'47.28517" W	6.292	60d
104	30°50'51.14006"N	85°36'05.56938" W	-2.469	1JO A (Control Check)
200	30°47'40.12134"N	85°40'53.68201" W	16.522	Bonifay Az Mk (Control Check)
201	30°49'39.61594"N	85°11'10.78091" W	3.105	Mariport (Control Check)
202	30°27'28.56112"N	85°11'25.28937" W	7.147	Cal19H (Control Check)
203	30°44'52.27220"N	85°15'37.30782" W	18.637	I1078_A26 (Control Check)

PT#	UTM ZONE 16		NAVD88	DESCRIPTION
NAME	NORTHING	EASTING	ELEVATION	
	Y	X	Z	
	METERS	METERS	METERS	
BASE	3365890.700	754053.169	15.276	Base at Airport
101	3358639.449	698919.369	32.559	60d
102	3367042.730	677643.475	29.864	60d
103	3413000.512	674075.316	34.452	60d
104	3413542.499	633723.068	25.335	1JO A (Control Check)
200	3407568.392	626138.989	44.287	Bonifay Az Mk (Control Check)
201	3411911.081	673468.559	31.265	Mariport (Control Check)
202	3370921.004	673743.013	35.336	Cal19H (Control Check)

203	3402951.034	666523.942	46.781	I1078_A26 (Control Check)

Ground Control Parameters

Horizontal Datum: The horizontal datum for the project is the Universal Transverse Mercator (UTM), Zone 16 North, North American Datum of 1983, adjustment 1999 (NAD 83/99).

Coordinate System: The project coordinate system is Universal Transverse Mercator (UTM), Zone 16 North

Vertical Datum: The Vertical datum for the project is North American Vertical Datum of 1988 (NAVD88)

Geiod Model: Geoid03 (Geoid 03 will be used to convert ellipsoid heights to orthometric heights).

Units: Horizontal units are in Meters, Vertical units are in US Survey Feet.

Ground Survey Control Report

The following listing shows the newly established GPS ground control, collected for LiDAR check points. The new ground control points (check points) were established and surveyed by Allen Nobles & Associates, Inc. Surveyors

Project: NWFWMD_FL
Job#: 02015713
Date: May 2008

Coordinate System: UTM ZONE 16 NORTH
Zone: 16 NORTH
Project Datum: NAD 1983(1999)
Vertical Datum: NAVD88 (GEOID2003 will be used to convert ellipsoid heights to orthometric)
Units: Meters (and US survey feet Vertical)

PT#	UTM ZONE 16		NAVD88	NAVD88
NAME	NORTHING	EASTING	ELEVATION	ELEVATION
	Y	X	Z	Z
	METERS	METERS	METERS	US Feet
47-01-A07G	3356543.101	680054.598	26.615	87.32
47-02-C10G	3362047.100	671449.233	29.854	97.95
47-99-C48V	3380858.712	673791.594	29.825	97.85
AB2566	3348237.576	645194.256	14.674	48.14
AJ7400	3369374.303	605575.723	9.865	32.37
ANA GDALE	3414932.938	584518.669	90.248	296.09
ANAL394	3430291.049	652001.173	46.346	152.05
BE0040	3407422.888	626389.154	46.546	152.71
BE2610	3400746.993	670836.849	36.144	118.58
BE2747	3389825.068	711221.848	46.900	153.87
BE2847	3388646.647	679190.910	66.883	219.43
BE2905	3368134.765	657665.321	47.333	155.29
BE3524	3379423.335	662011.563	60.919	199.87

BE3526	3379798.744	652709.457	76.290	250.29
BE3764	3381573.972	641689.976	86.550	283.96
BE3768	3391605.107	614404.295	30.335	99.52
BE3936	3384298.216	689668.487	39.401	129.27
BE3942	3406384.459	641094.044	32.285	105.92
BE3943	3409945.450	602603.428	61.173	200.70
BE3944	3411911.072	673468.571	31.276	102.61
BG1410	3399159.655	583567.640	80.639	264.56
BT0385	3432597.839	702362.319	43.167	141.62
BT1135	3432345.878	673156.329	42.517	139.49
BT2245	3435842.840	608531.447	28.473	93.42
BT2372	3430744.536	628814.862	71.013	232.98
CRESTVIEW	3399348.403	547279.037	61.338	201.24
DF5696	3417914.882	656145.097	48.094	157.79
DF5703	3426407.182	674763.959	45.254	148.47
DF5706	3428453.919	683373.250	39.911	130.94
DF5729	3397629.145	683945.665	37.167	121.94
FB170P24	3351652.875	669283.909	23.011	75.50
FB173P16	3340067.859	678169.488	8.149	26.74
FB173P17	3367737.137	625982.575	29.191	95.77
FB174P16	3335618.459	666451.555	14.733	48.34
FB175P06	3342351.034	718922.512	18.131	59.48
GC054	3368216.269	674054.423	34.322	112.60
GPS202	3426369.555	675521.043	43.028	141.17
GPS203	3427152.812	680013.790	46.485	152.51
GPS204	3431654.277	682002.286	43.822	143.77
GPS207	3416623.330	671647.067	40.121	131.63
GPS208	3416667.656	676936.887	37.881	124.28
GPS209	3418636.941	688551.698	35.783	117.40
GPS210	3420265.237	682150.396	38.294	125.64
GPS211	3415362.958	682323.445	37.785	123.97
GPS212	3408821.008	673442.009	50.864	166.88
GPS213	3399989.483	673731.628	28.837	94.61
GPS214	3402032.137	680724.282	47.641	156.30
GPS215	3401745.576	687990.030	47.014	154.25
GPS217	3408379.153	681408.376	40.735	133.64
GPS218	3410999.185	685736.755	33.396	109.57
GPS219	3412357.600	690030.965	31.394	103.00
REDBAY 1938	3384679.971	597117.961	56.232	184.49
TALH	3365692.063	754047.155	21.972	72.09
WMD101	3429485.506	590852.140	37.910	124.38
WMD102	3428771.585	600664.332	59.282	194.49
WMD103	3425149.614	591803.610	42.464	139.32
WMD104	3396641.341	593255.338	87.158	285.95
WMD105	3399167.494	592070.929	74.614	244.80
WMD106	3396266.118	595507.792	80.886	265.37
WMD107	3381963.907	608486.441	20.701	67.92
WMD108	3383592.878	606852.540	8.183	26.85

WMD109	3386007.566	607401.956	10.420	34.19
WMD110	3382243.808	636148.372	61.986	203.37
WMD111	3385354.467	636457.068	81.589	267.68
WMD112	3382150.076	633115.987	50.322	165.10
WMD113	3388674.380	662402.558	69.598	228.34
WMD114	3389850.707	659172.467	87.337	286.54
WMD115	3342454.506	660729.762	19.176	62.91
WMD116	3341845.685	678902.933	8.673	28.45
WMD117	3345641.592	677073.190	9.595	31.48
WMD118	3343397.852	686022.941	14.091	46.23
WMD119	3342204.324	689857.666	15.245	50.02
WMD120	3345455.071	688643.142	15.077	49.47
WMD121	3353398.931	690528.454	16.986	55.73
WMD122	3352804.649	692650.737	16.257	53.34
WMD123	3370545.186	695045.436	50.653	166.18
WMD124	3372535.334	697700.527	57.917	190.02
WMD125	3367785.498	693827.503	50.372	165.26
WMD126	3359408.882	705061.534	36.143	118.58
WMD127	3359581.950	708463.011	36.167	118.66
WMD128	3355904.609	702230.950	33.934	111.33
WMD129	3398473.721	703009.338	27.622	90.62
WMD130	3403113.686	696802.195	32.027	105.08
WMD131	3419226.821	697656.471	38.172	125.24
WMD132	3415214.848	693540.144	27.103	88.92
WMD133	3429085.670	691860.879	32.129	105.41
WMD134	3431001.570	687202.271	40.509	132.90
WMD135	3431656.660	683794.591	41.630	136.58
WMD136	3429537.666	684186.364	39.257	128.80
WMD137	3421787.215	688506.833	32.591	106.93
WMD138	3404848.635	689561.342	36.328	119.19
WMD139	3401422.395	689578.331	37.337	122.50
WMD140	3400295.332	678292.362	41.702	136.82
WMD141	3394888.380	683962.539	39.483	129.54
WMD142	3398928.125	683947.103	40.537	133.00
WMD143	3389739.433	696384.109	30.003	98.43
WMD144	3386810.199	691175.045	40.447	132.70
WMD145	3376495.136	687418.284	26.271	86.19
WMD146	3363426.698	685322.162	19.669	64.53
WMD147	3367631.087	681084.219	30.696	100.71
WMD148	3363436.244	679644.787	29.627	97.20
WMD149	3350658.963	679016.399	12.118	39.76
WMD150	3354622.279	675949.124	25.987	85.26
WMD151	3352727.076	661876.150	24.247	79.55
WMD152	3368126.338	659945.378	47.204	154.87
WMD153	3360074.019	660525.612	32.152	105.49
WMD154	3384026.534	660609.030	76.259	250.19
WMD155	3401680.610	670274.782	37.051	121.56
WMD156	3410193.878	671927.203	35.382	116.08

WMD157	3406896.750	667443.980	55.322	181.50
WMD158	3421074.400	672226.435	43.588	143.00
WMD159	3418949.502	668248.729	29.045	95.29
WMD160	3429719.376	673752.899	45.623	149.68
WMD161	3430965.699	669005.287	38.300	125.66
WMD162	3425320.892	667302.294	37.282	122.32
WMD163	3430324.584	657265.834	45.114	148.01
WMD164	3429135.158	654031.608	44.766	146.87
WMD165	3429262.361	640516.364	49.389	162.04
WMD166	3430319.964	645246.499	51.294	168.29
WMD167	3429883.154	627630.904	51.190	167.95
WMD168	3429851.500	632083.501	68.244	223.90
WMD169	3426429.458	629251.529	58.878	193.17
WMD170	3429142.215	613284.031	30.204	99.09
WMD171	3429018.589	617078.992	65.747	215.70
WMD172	3418764.048	592958.451	87.780	287.99
WMD173	3415463.492	592148.800	86.707	284.47
WMD174	3408418.151	591814.239	72.286	237.16
WMD175	3397573.448	602112.408	17.802	58.41
WMD176	3391079.863	608876.080	18.860	61.88
WMD177	3397232.111	606860.947	15.171	49.77
WMD178	3383357.395	620301.261	58.984	193.52
WMD179	3382259.435	624554.049	49.236	161.54
WMD180	3390565.124	644406.515	32.791	107.58
WMD181	3391034.301	648614.799	77.319	253.67
WMD182	3411565.640	696297.870	31.351	102.86
WMD183	3360005.487	695240.012	37.088	121.68
WMD184	3409635.809	692008.726	26.968	88.48
WMD185	3420688.871	599397.622	38.288	125.62
WMD186	3408350.763	602307.496	29.758	97.63
WMD187	3420612.041	693690.372	35.501	116.47
WMD188	3393216.021	670608.084	30.014	98.47
WMD189	3393275.498	691989.300	56.344	184.86
WMD190	3385147.946	674317.940	28.555	93.68
WMD191	3386679.036	683603.697	55.223	181.18
WMD192	3378401.654	669973.555	35.554	116.65
WMD193	3371814.773	673144.740	38.480	126.25
WMD194	3359601.030	669488.449	28.928	94.91
WMD195	3356153.863	697518.596	33.048	108.42
WMD196	3368162.443	666646.315	52.920	173.62
WMD197	3346364.927	671971.537	21.333	69.99
WMD198	3417641.940	608829.530	22.813	74.85
WMD199	3379556.269	679171.570	53.142	174.35
WMD200	3421189.234	617632.159	43.541	142.85
WMD201	3419356.022	625000.732	29.607	97.14
WMD202	3419642.034	635535.514	40.360	132.41
WMD203	3419297.186	647347.870	55.409	181.79
WMD204	3421074.656	658935.105	39.967	131.13

WMD205	3415013.838	656469.739	36.683	120.35
WMD206	3409473.353	658951.551	44.621	146.39
WMD207	3401103.882	658139.884	43.670	143.27
WMD208	3394789.387	665270.623	30.190	99.05
WMD209	3397793.363	650602.669	41.978	137.72
WMD210	3397502.863	643646.839	50.394	165.33
WMD211	3392821.831	634105.742	29.975	98.34
WMD212	3390755.898	625763.094	17.246	56.58
WMD214	3405238.532	609105.276	21.938	71.97
WMD215	3400111.608	616335.421	37.232	122.15
WMD216	3400860.631	625843.298	29.015	95.19
WMD217	3402193.423	634209.972	23.362	76.65
WMD218	3405224.732	645201.414	44.454	145.85
WMD219	3413227.118	614213.449	22.168	72.73
WMD220	3414105.789	644765.975	38.509	126.34
WMD221	3412487.583	640297.410	27.962	91.74
WMD222	3409810.264	621879.236	37.511	123.07
WMD223	3410475.186	634863.603	22.786	74.76
WMD224	3414907.680	629517.625	51.310	168.34
WMD225	3408092.145	651543.389	41.699	136.81
WMD226	3418289.868	661197.719	33.876	111.14
WMD228	3404038.231	598029.303	63.921	209.71
WMD229	3377876.989	659596.464	61.321	201.18
WMD230	3424525.279	639362.669	38.229	125.42
WMD231	3383531.514	612093.740	10.060	33.01
WMD232	3397025.906	698794.992	30.753	100.90
WMD233	3425272.807	605802.161	55.798	183.06
WMD234	3384688.471	666715.018	43.282	142.00
WMD235	3352163.998	668246.262	24.800	81.36
WMD236	3354201.623	666394.728	23.219	76.18
WMD237	3392452.910	677302.415	29.375	96.37
WMD238	3394649.773	619778.499	33.037	108.39
WMD239	3365634.996	672105.920	36.451	119.59
WMD240	3347799.158	663072.162	23.472	77.01
WMD241	3423458.986	651119.754	47.978	157.41
WMD242	3416275.626	600586.989	36.492	119.72
WMD243	3376520.447	664835.532	59.964	196.73
WMD244	3374538.419	681490.754	35.703	117.14
WMD245	3406253.546	614372.958	20.002	65.62
WMD246	3404372.467	639403.098	38.632	126.75
WMD247	3400477.386	662973.756	34.608	113.54
WMD248	3414702.989	662876.162	26.887	88.21
WMD249	3396395.825	657271.425	30.000	98.42
WMD250	3359602.193	697405.168	33.492	109.88
WMD401	3431569.103	675300.250	46.316	151.96
WMD406	3419816.558	674758.032	41.160	135.04
WMD416	3407297.892	690386.701	28.067	92.08

LiDAR Control Report (LiDAR Accuracy / Validation Results)

The following listing shows the results of the LiDAR data compared to the GPS ground survey control data. The listing is sorted by the **Z Error** column showing, in ascending order, the vertical difference between the LiDAR points and the surveyed ground control points.

Post-Filter Control Report for NWFWMD

Project File : MARSProject NWFWMD
Date : April 30, 2008
Vertical Accuracy Objective
Requirement Type : Accuracy(z)
Accuracy(z) Objective : 1.20
Confidence Level : 95%
Control Points in Report : 204
Elevation Calculation Method : Interpolated from TIN
Control Points with LiDAR Coverage : 176
Control Points with Required Accuracy (+/- 1.20) : 174
Percent of Control Points with Required Accuracy (+/- 1.20) : 98.86
Average Control Error Reported : -0.05
Maximum (highest) Control Error Reported : 1.32
Median Control Error Reported : -0.11
Minimum (lowest) Control Error Reported : -1.25
Standard deviation (sigma) of Z for sample : 0.49
RMSE of Z for sample (RMSE(z)) : 0.49 : PASS
FGDC/NSSDA Vertical Accuracy (Accuracy(z)) : 0.95 : PASS
NSSDA Achievable Contour Interval : 2.0
ASPRS Class 1 Achievable Contour Interval : 2.0
NMAS Achievable Contour Interval : 2.0

Control Point Id	Control Pt. X(East) Meters	Control Pt. Y(North) Meters	Coverage	Control Pt. Z(Elev) USFeet	from LiDAR Z(Elev) USFeet	**Z Error** **USFeet**	Min Z USFeet	Median Z USFeet	Max Z USFeet
WMD113	662402.56	3388674.38	Yes	228.35	227.10	-1.25	227.07	227.10	227.20
WMD193	673144.74	3371814.77	Yes	126.25	125.10	-1.15	125.07	125.12	125.14
WMD221	640297.41	3412487.58	Yes	91.73	90.59	-1.14	90.58	90.61	90.65
WMD130	696802.19	3403113.69	Yes	105.09	104.08	-1.01	104.02	104.21	104.51
WMD170	613284.03	3429142.21	Yes	99.08	98.15	-0.93	96.70	98.53	98.56
WMD210	643646.84	3397502.86	Yes	165.32	164.44	-0.88	164.31	164.39	164.46
WMD199	679171.57	3379556.27	Yes	174.34	173.52	-0.82	173.47	173.53	173.58
WMD237	677302.42	3392452.91	Yes	96.39	95.59	-0.80	95.41	95.67	95.77
WMD198	608829.53	3417641.94	Yes	74.84	74.04	-0.80	72.34	74.18	74.30
WMD171	617078.99	3429018.59	Yes	215.71	214.94	-0.77	214.69	214.70	215.38
WMD106	595507.79	3396266.12	Yes	265.39	264.62	-0.77	264.57	264.64	264.67
WMD246	639403.10	3404372.47	Yes	126.74	126.03	-0.71	125.82	125.96	126.05
WMD242	600586.99	3416275.63	Yes	119.72	119.01	-0.71	118.97	118.99	119.05
WMD129	703009.34	3398473.72	Yes	90.62	89.93	-0.69	89.80	89.83	89.96
WMD141	683962.54	3394888.38	Yes	129.53	128.86	-0.67	128.71	128.84	128.94
WMD173	592148.80	3415463.49	Yes	284.48	283.82	-0.66	283.72	284.20	284.27
WMD203	647347.87	3419297.19	Yes	181.79	181.14	-0.65	180.76	180.78	181.19

GPS207	671647.07	3416623.33	Yes	131.63	130.97	-0.66	130.74	131.07	131.10
WMD222	621879.24	3409810.26	Yes	123.06	122.42	-0.64	122.27	122.35	122.54
WMD189	691989.30	3393275.50	Yes	184.84	184.20	-0.64	184.04	184.11	184.28
WMD166	645246.50	3430319.96	Yes	168.27	167.65	-0.62	167.22	167.67	167.71
WMD124	697700.53	3372535.33	Yes	190.03	189.40	-0.63	189.32	189.48	189.85
WMD235	668246.26	3352164.00	Yes	81.36	80.74	-0.62	80.64	80.74	80.77
WMD152	659945.38	3368126.34	Yes	154.86	154.26	-0.60	154.13	154.26	154.49
WMD104	593255.34	3396641.34	Yes	285.96	285.39	-0.57	285.34	285.37	285.49
GPS212	673442.01	3408821.01	Yes	166.86	166.30	-0.56	165.30	166.37	166.60
WMD188	670608.08	3393216.02	Yes	98.46	97.90	-0.56	97.82	97.88	98.31
WMD139	689578.33	3401422.40	Yes	122.51	121.97	-0.54	121.75	122.05	122.21
WMD225	651543.39	3408092.15	Yes	136.81	136.28	-0.53	136.10	136.12	136.32
WMD167	627630.90	3429883.15	Yes	167.95	167.44	-0.51	167.22	167.32	167.62
GPS214	680724.28	3402032.14	Yes	156.30	155.81	-0.49	155.28	156.59	156.79
WMD200	617632.16	3421189.23	Yes	142.85	142.36	-0.49	141.86	142.20	142.86
WMD156	671927.20	3410193.88	Yes	116.08	115.60	-0.48	115.45	115.72	115.80
WMD197	671971.54	3346364.93	Yes	69.98	69.52	-0.46	69.36	69.45	69.55
WMD112	633115.99	3382150.08	Yes	165.09	164.64	-0.45	164.41	164.54	165.18
WMD245	614372.96	3406253.55	Yes	65.62	65.17	-0.45	64.86	65.18	65.27
WMD226	661197.72	3418289.87	Yes	111.15	110.71	-0.44	110.23	110.76	110.76
WMD110	636148.37	3382243.81	Yes	203.38	202.95	-0.43	202.90	203.06	203.11
GPS209	688551.70	3418636.94	Yes	117.39	116.96	-0.43	116.57	117.32	117.45
WMD174	591814.24	3408418.15	Yes	237.17	236.76	-0.41	236.41	236.56	236.94
WMD118	686022.94	3343397.85	Yes	46.23	45.82	-0.41	45.69	45.70	45.94
DF5696	656145.10	3417914.88	Yes	157.78	157.38	-0.40	151.75	158.50	158.51
WMD214	609105.28	3405238.53	Yes	71.98	71.59	-0.39	71.56	71.62	71.63
WMD233	605802.16	3425272.81	Yes	183.07	182.69	-0.38	182.59	182.61	182.96
WMD126	705061.53	3359408.88	Yes	118.57	118.19	-0.38	118.05	118.31	118.35
WMD134	687202.27	3431001.57	Yes	132.91	132.53	-0.38	132.12	132.22	132.91
WMD146	685322.16	3363426.70	Yes	64.53	64.17	-0.36	64.04	64.11	64.24
WMD109	607401.96	3386007.57	Yes	34.19	33.83	-0.36	33.62	33.76	33.99
WMD142	683947.10	3398928.13	Yes	133.00	132.66	-0.34	132.48	132.64	132.78
WMD184	692008.73	3409635.81	Yes	88.48	88.14	-0.34	88.09	88.12	88.25
WMD180	644406.52	3390565.12	Yes	107.58	107.26	-0.32	107.17	107.26	107.43
WMD216	625843.30	3400860.63	Yes	95.21	94.90	-0.31	94.87	94.88	95.01
GPS213	673731.63	3399989.48	Yes	94.62	94.32	-0.30	94.06	94.31	94.44
WMD236	666394.73	3354201.62	Yes	76.18	75.88	-0.30	75.74	75.93	76.05
WMD172	592958.45	3418764.05	Yes	287.99	287.70	-0.29	287.68	287.70	287.74
WMD148	679644.79	3363436.24	Yes	97.21	96.93	-0.28	96.85	96.92	96.98
WMD185	599397.62	3420688.87	Yes	125.62	125.34	-0.28	125.07	125.25	125.47
WMD102	600664.33	3428771.59	Yes	194.49	194.21	-0.28	194.04	194.11	194.30
WMD111	636457.07	3385354.47	Yes	267.68	267.42	-0.26	267.31	267.44	267.52
WMD105	592070.93	3399167.49	Yes	244.78	244.53	-0.25	244.50	244.50	244.56
WMD215	616335.42	3400111.61	Yes	122.15	121.90	-0.25	121.80	121.85	122.05
BE2847	679190.91	3388646.65	Yes	219.42	219.18	-0.24	219.09	219.19	219.22
WMD231	612093.74	3383531.51	Yes	33.01	32.76	-0.25	32.73	32.74	32.85
WMD121	690528.45	3353398.93	Yes	55.74	55.52	-0.22	55.28	55.72	55.94
WMD125	693827.50	3367785.50	Yes	165.26	165.04	-0.22	164.88	165.00	165.11

WMD250	697405.17	3359602.19	Yes	109.88	109.67	-0.21	109.58	109.65	109.74
WMD244	681490.75	3374538.42	Yes	117.13	116.93	-0.20	116.85	116.87	116.95
WMD162	667302.29	3425320.89	Yes	122.31	122.11	-0.20	121.97	122.15	122.55
WMD232	698794.99	3397025.91	Yes	100.89	100.70	-0.19	100.65	100.74	100.77
WMD149	679016.40	3350658.96	Yes	39.76	39.58	-0.18	39.40	39.60	39.83
WMD115	660729.76	3342454.51	Yes	62.93	62.75	-0.18	62.60	62.70	62.86
WMD207	658139.88	3401103.88	Yes	143.27	143.10	-0.17	143.06	143.09	143.35
WMD127	708463.01	3359581.95	Yes	118.67	118.50	-0.17	118.43	118.47	118.51
WMD107	608486.44	3381963.91	Yes	67.91	67.76	-0.15	67.18	67.66	68.09
BE3768	614404.30	3391605.11	Yes	99.54	99.39	-0.15	99.20	99.35	99.48
WMD169	629251.53	3426429.46	Yes	193.18	193.03	-0.15	193.00	193.03	193.07
WMD133	691860.88	3429085.67	Yes	105.41	105.27	-0.14	105.22	105.30	105.56
WMD159	668248.73	3418949.50	Yes	95.31	95.17	-0.14	94.88	95.41	95.41
BT2372	628814.86	3430744.54	Yes	232.97	232.84	-0.13	232.43	233.24	233.71
WMD175	602112.41	3397573.45	Yes	58.40	58.27	-0.13	58.08	58.29	58.33
WMD187	693690.37	3420612.04	Yes	116.47	116.34	-0.13	116.14	116.27	116.54
GPS202	675521.04	3426369.56	Yes	141.17	141.06	-0.11	140.67	141.03	141.12
BE0040	626389.15	3407422.89	Yes	152.72	152.60	-0.12	152.50	152.71	152.83
4799C48V	673791.59	3380858.71	Yes	97.83	97.72	-0.11	97.70	97.70	98.42
WMD247	662973.76	3400477.39	Yes	113.55	113.44	-0.11	113.20	113.34	113.59
WMD131	697656.47	3419226.82	Yes	125.23	125.12	-0.11	124.97	125.23	125.36
WMD120	688643.14	3345455.07	Yes	49.47	49.36	-0.11	49.28	49.60	49.62
WMD248	662876.16	3414702.99	Yes	88.22	88.11	-0.11	88.05	88.08	88.18
WMD238	619778.50	3394649.77	Yes	108.40	108.29	-0.11	108.22	108.39	108.53
WMD119	689857.67	3342204.32	Yes	50.00	49.90	-0.10	49.28	49.84	50.12
WMD181	648614.80	3391034.30	Yes	253.67	253.58	-0.09	253.35	253.66	253.79
WMD208	665270.62	3394789.39	Yes	99.05	98.96	-0.09	98.88	99.00	99.29
WMD123	695045.44	3370545.19	Yes	166.17	166.09	-0.08	165.91	166.12	166.15
WMD182	696297.87	3411565.64	Yes	102.85	102.77	-0.08	102.39	102.49	102.85
WMD192	669973.56	3378401.65	Yes	116.63	116.56	-0.07	116.47	116.54	116.90
WMD165	640516.36	3429262.36	Yes	162.04	161.97	-0.07	161.89	161.92	162.06
WMD243	664835.53	3376520.45	Yes	196.72	196.66	-0.06	196.55	196.62	196.72
WMD137	688506.83	3421787.21	Yes	106.92	106.87	-0.05	106.40	107.09	107.12
WMD178	620301.26	3383357.40	Yes	193.50	193.50	0.00	193.24	193.48	193.63
WMD239	672105.92	3365635.00	Yes	119.59	119.59	0.00	119.54	119.59	119.67
WMD143	696384.11	3389739.43	Yes	98.42	98.43	0.01	98.26	98.59	98.82
WMD218	645201.41	3405224.73	Yes	145.83	145.84	0.01	145.71	145.83	145.91
WMD196	666646.31	3368162.44	Yes	173.62	173.63	0.01	173.62	173.65	173.69
WMD191	683603.70	3386679.04	Yes	181.17	181.18	0.01	181.07	181.16	181.33
WMD190	674317.94	3385147.95	Yes	93.70	93.71	0.01	93.66	93.70	93.80
WMD212	625763.09	3390755.90	Yes	56.59	56.61	0.02	56.54	56.67	56.82
BE3944	673468.57	3411911.07	Yes	102.62	102.65	0.03	102.55	102.65	102.87
GPS215	687990.03	3401745.58	Yes	154.23	154.27	0.04	154.10	154.25	154.38
WMD157	667443.98	3406896.75	Yes	181.50	181.54	0.04	181.33	181.39	181.83
WMD147	681084.22	3367631.09	Yes	100.72	100.77	0.05	100.59	100.79	100.85
WMD117	677073.19	3345641.59	Yes	31.50	31.56	0.06	31.46	31.53	31.63
WMD217	634209.97	3402193.42	Yes	76.64	76.71	0.07	76.66	76.82	76.91
WMD155	670274.78	3401680.61	Yes	121.55	121.63	0.08	121.51	121.66	121.75

WMD145	687418.28	3376495.14	Yes	86.19	86.26	0.07	86.25	86.25	86.28
WMD220	644765.97	3414105.79	Yes	126.34	126.43	0.09	126.13	126.47	126.53
WMD241	651119.75	3423458.99	Yes	157.41	157.50	0.09	157.05	157.41	157.58
WMD160	673752.90	3429719.38	Yes	149.67	149.77	0.10	149.75	149.91	150.05
WMD163	657265.83	3430324.58	Yes	148.00	148.11	0.11	148.07	148.11	148.26
WMD153	660525.61	3360074.02	Yes	105.48	105.62	0.14	105.61	105.61	105.91
WMD183	695240.01	3360005.49	Yes	121.69	121.83	0.14	121.64	121.69	122.14
WMD177	606860.95	3397232.11	Yes	49.77	49.92	0.15	49.90	50.28	50.30
WMD224	629517.63	3414907.68	Yes	168.34	168.49	0.15	168.47	168.49	168.70
WMD128	702230.95	3355904.61	Yes	111.32	111.47	0.15	111.38	111.48	111.55
WMD204	658935.10	3421074.66	Yes	131.13	131.30	0.17	131.09	131.26	131.39
WMD176	608876.08	3391079.86	Yes	61.88	62.04	0.16	62.03	62.29	62.35
WMD401	675300.25	3431569.10	Yes	151.97	152.17	0.20	152.13	152.44	152.61
ANAL394	652001.17	3430291.05	Yes	152.07	152.28	0.21	152.20	152.24	152.39
DF5703	674763.96	3426407.18	Yes	148.46	148.67	0.21	148.53	148.60	149.21
WMD138	689561.34	3404848.63	Yes	119.19	119.43	0.24	118.97	119.05	119.56
WMD116	678902.93	3341845.69	Yes	28.44	28.68	0.24	28.54	28.69	28.76
WMD161	669005.29	3430965.70	Yes	125.66	125.92	0.26	125.60	125.77	126.00
WMD234	666715.02	3384688.47	Yes	141.99	142.27	0.28	142.06	142.52	142.65
WMD229	659596.46	3377876.99	Yes	201.18	201.47	0.29	201.21	201.28	201.54
DF5729	683945.67	3397629.15	Yes	121.95	122.24	0.29	122.14	122.49	122.51
WMD211	634105.74	3392821.83	Yes	98.36	98.66	0.30	98.25	98.57	98.79
BE2610	670836.85	3400746.99	Yes	118.57	118.87	0.30	118.53	118.79	118.95
WMD154	660609.03	3384026.53	Yes	250.20	250.51	0.31	250.40	250.53	250.54
BE3943	602603.43	3409945.45	Yes	200.69	201.00	0.31	200.73	200.77	201.08
WMD103	591803.61	3425149.61	Yes	139.30	139.62	0.32	139.58	139.63	139.74
WMD114	659172.47	3389850.71	Yes	286.55	286.87	0.32	286.81	286.83	287.05
WMD201	625000.73	3419356.02	Yes	97.15	97.49	0.34	97.36	97.38	97.57
WMD168	632083.50	3429851.50	Yes	223.88	224.25	0.37	224.24	224.24	224.26
WMD150	675949.12	3354622.28	Yes	85.27	85.64	0.37	85.60	85.66	85.73
WMD132	693540.14	3415214.85	Yes	88.91	89.29	0.38	89.11	89.24	89.37
WMD144	691175.05	3386810.20	Yes	132.71	133.10	0.39	132.74	133.13	133.18
FB170P24	669283.91	3351652.88	Yes	75.49	75.88	0.39	75.79	75.95	76.08
WMD223	634863.60	3410475.19	Yes	74.77	75.17	0.40	74.99	75.22	75.24
WMD205	656469.74	3415013.84	Yes	120.34	120.74	0.40	120.71	120.80	120.83
WMD209	650602.67	3397793.36	Yes	137.73	138.15	0.42	138.08	138.12	138.22
WMD164	654031.61	3429135.16	Yes	146.88	147.32	0.44	147.26	147.30	147.41
WMD206	658951.55	3409473.35	Yes	146.39	146.83	0.44	146.60	146.69	147.14
BE3936	689668.49	3384298.22	Yes	129.26	129.70	0.44	129.53	129.60	129.87
WMD151	661876.15	3352727.08	Yes	79.56	80.02	0.46	79.78	79.84	80.08
WMD202	635535.51	3419642.03	Yes	132.41	132.88	0.47	132.80	132.88	132.99
WMD179	624554.05	3382259.44	Yes	161.55	162.02	0.47	161.99	162.02	162.12
DF5706	683373.25	3428453.92	Yes	130.94	131.46	0.52	131.36	131.66	131.79
WMD195	697518.60	3356153.86	Yes	108.43	108.96	0.53	108.89	108.92	109.15
WMD219	614213.45	3413227.12	Yes	72.74	73.32	0.58	73.26	73.38	73.46
WMD240	663072.16	3347799.16	Yes	77.00	77.59	0.59	77.53	77.53	77.66
WMD186	602307.50	3408350.76	Yes	97.64	98.23	0.59	98.20	98.37	98.39
WMD108	606852.54	3383592.88	Yes	26.84	27.51	0.67	27.43	27.52	27.59

WMD140	678292.36	3400295.33	Yes	136.81	137.49	0.68	137.20	137.53	137.53
WMD249	657271.43	3396395.83	Yes	98.42	99.16	0.74	99.11	99.12	99.27
WMD228	598029.30	3404038.23	Yes	209.71	210.47	0.76	210.42	210.56	210.81
WMD136	684186.36	3429537.67	Yes	128.81	129.58	0.77	129.43	129.56	129.63
WMD122	692650.74	3352804.65	Yes	53.35	54.13	0.78	54.06	54.15	54.25
WMD230	639362.67	3424525.28	Yes	125.43	126.23	0.80	125.89	126.40	126.48
WMD194	669488.45	3359601.03	Yes	94.91	95.72	0.81	95.54	95.70	95.86
BE3942	641094.04	3406384.46	Yes	105.91	106.75	0.84	106.45	106.66	106.89
WMD158	672226.44	3421074.40	Yes	143.01	143.96	0.95	143.92	143.93	144.08
4701A07G	680054.60	3356543.10	Yes	87.30	88.27	0.97	88.16	88.32	88.48
BE3524	662011.56	3379423.34	Yes	199.87	200.90	1.03	200.88	200.95	201.02
WMD135	683794.59	3431656.66	Yes	136.58	137.63	1.05	137.57	137.66	137.79
WMD416	690386.70	3407297.89	Yes	92.09	93.22	1.13	93.14	93.21	93.67
4702C10G	671449.23	3362047.10	Yes	97.93	99.11	1.18	98.58	98.83	99.50
GC054	674054.42	3368216.27	Yes	112.60	113.91	1.32	113.50	113.74	114.00

LIDAR CALIBRATION

Introduction

A LIDAR calibration or 'boresight' is performed on every mission to determine and eliminate systemic biases that occur within the hardware of the Leica ALS50 laser scanning system, the inertial measurement unit (IMU), and because of environmental conditions which affect the refraction of light. The systemic biases that are corrected for include roll, pitch, and heading.

Calibration Procedures

In order to correct the error in the data, misalignments of features in the overlap areas of the LiDAR flightlines must be detected and measured. At some point within the mission, a specific flight pattern must be flown which shows all the misalignments that can be present. Typically, Merrick flies a pattern of at least three opposing direction and overlapping lines, three of which provide all the information required to calibrate the system.

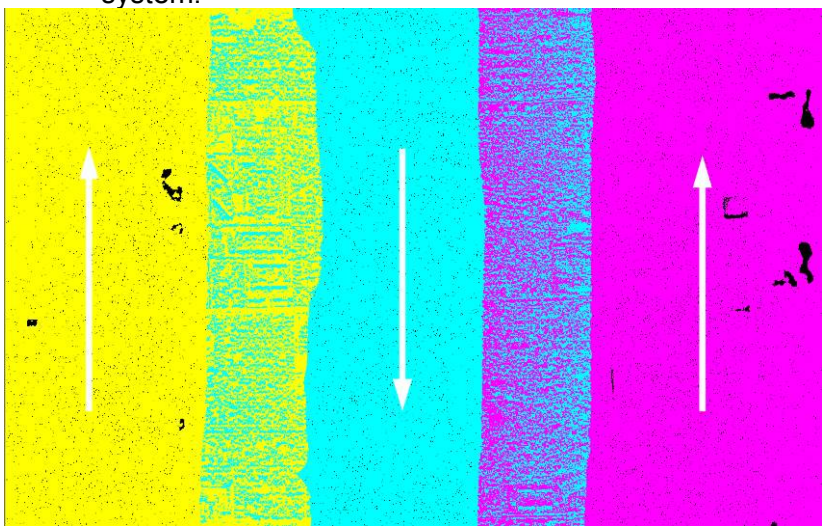


Figure 1: Flight pattern required for calibration

Correcting for Pitch and Heading Biases

There are many settings in the ALS40/50 post processor that can be used to manipulate the data; six are used for boresighting. They are roll, pitch, heading, torsion, range and atmospheric correction. The order in which each is evaluated is not very important and may be left to the discretion of the operator. For this discussion, pitch and heading will be evaluated first. It is important to remember that combinations of error can be very confusing, and this is especially true with pitch and heading. They affect the data in similar ways, so error attributed to pitch may be better blamed on heading and vice versa. To see a pitch/heading error, one must use the profile tool to cut along the flight path at a pitched roof or any elevation feature that is perpendicular to the flight path. View the data by elevation to locate these scenarios.

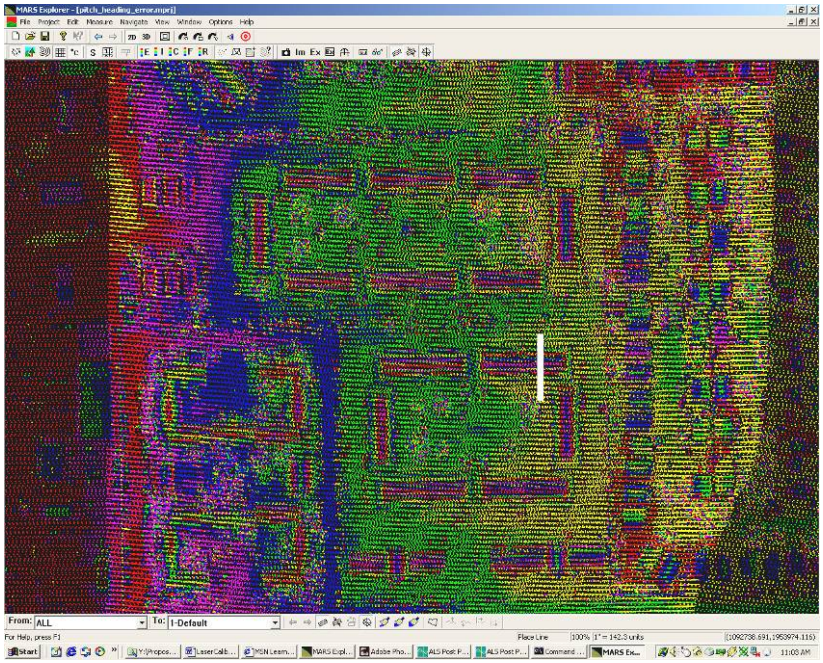


Figure 2: Orthographic view with profile line

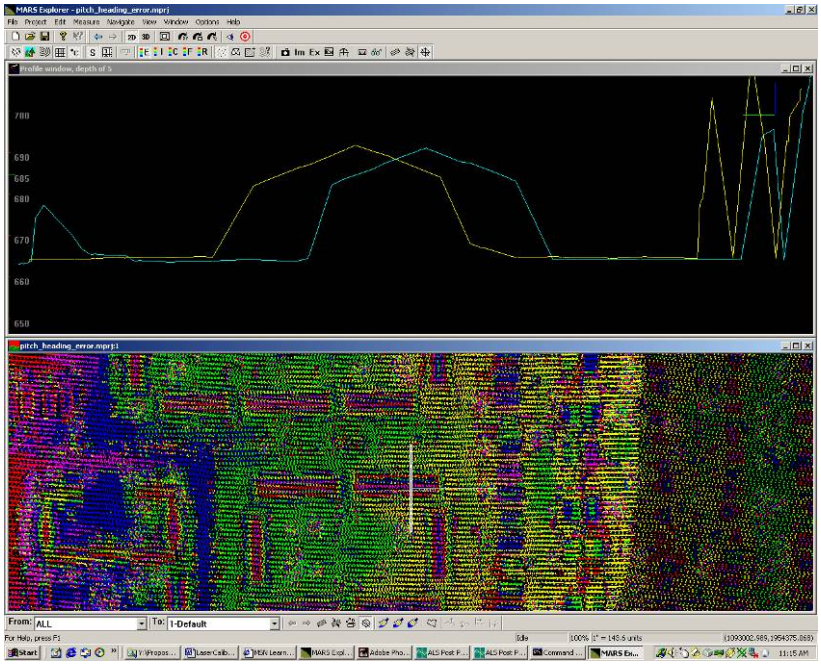


Figure 3: Profile view of misalignment

The profile line in figures 2 and 3 has an additional thin line perpendicular to the cut that shows the direction of the view. In this case, the line is pointing to the right, or east. In the profile window, we are looking through two separate TINs, so there are two lines showing the location of the same building. The yellow line is from the flight line on the left (flown north); the light blue line is from the flight line in the middle (flown south).

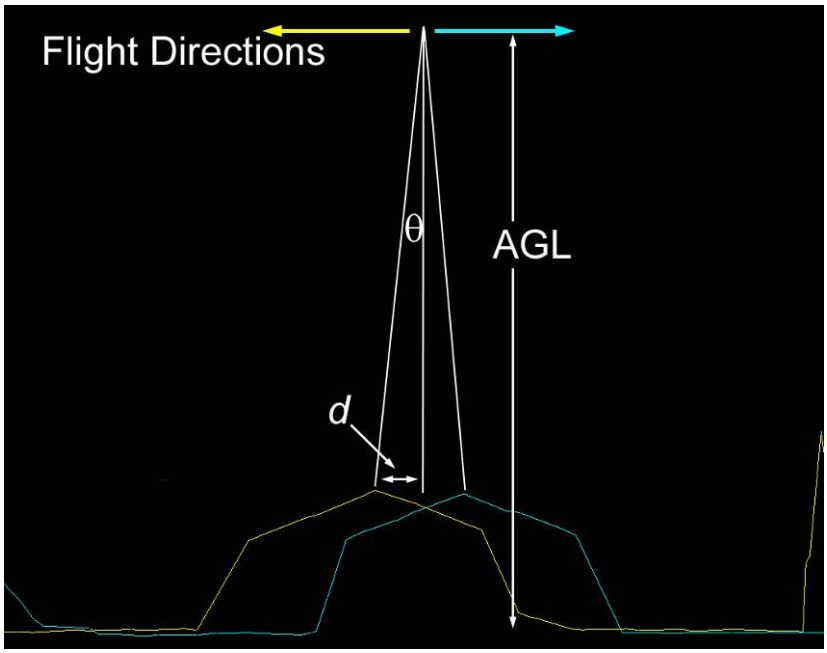


Figure 4: Adjusting pitch

The top arrows represent each respective flight direction. We are looking east, the yellow flight line was flown north, and the blue line is flown south. Adjusting pitch changes the relationship between the pitch from the IMU and the actual pitch of the plane. Increasing pitch sends the nose of the plane up and the data ahead in the flight direction. Lowering pitch does the opposite. In this example, pitch needs to decrease in order to bring these two roof lines together. The angle theta must be expressed in radians. The formula to arrive at this angle is…

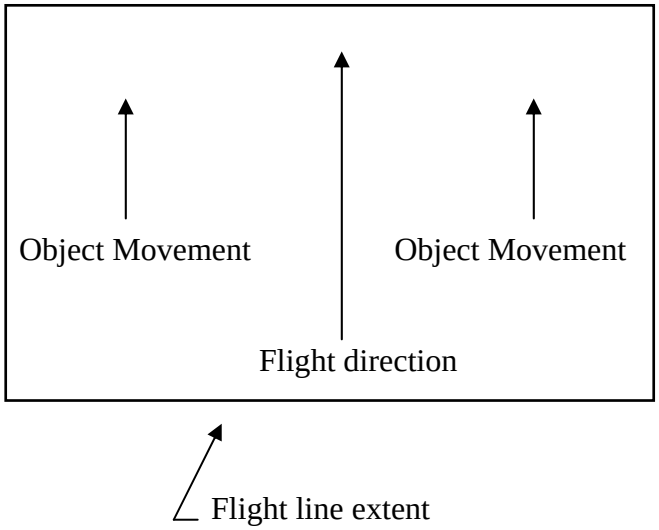
$$\theta = \frac{\arctan\left(\frac{d}{AGL}\right)}{57.2958}$$

where *d* is the distance from nadir (directly under the plane) to the peak of the roof and AGL is the 'above ground level' of the plane. The conversion from degrees to radians is one radian equals 57.2958 degrees. This number is then subtracted from the pitch value that was used to create the data.

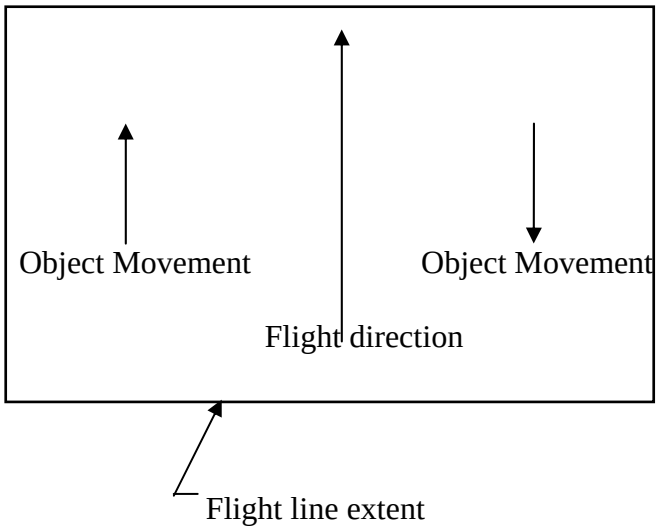
The next issue to resolve, before actually changing the pitch value, is to determine if this shift is at all due to an incorrect heading value, since heading will move data in the direction of flight also. The difference is that heading rotates the data, meaning that when heading is changed, objects on opposite sides of the swath move in opposite directions.

Figures 5 and 6: Pitch and Heading movement

Pitch increases, objects throughout the data move forward.



Heading increases, objects move clockwise.



When heading changes, objects on the sides of the flight line move in opposite directions. If heading is increased, objects in the flight line move in a clockwise direction. If heading is decreased, objects move in a counter-clockwise direction.

To find out if heading is correct, a similar profile line must be made in the overlap area between the middle flight line and the one to the east, or right side. If the distance *d* (see figure 4) is different on the right verses the left, then heading is partially responsible for the error. If the distance *d* is the same on both sides then heading *or* pitch is fully responsible.

Correcting for the Roll Bias

The purpose of a 'truth survey' is to evaluate roll and to ensure that the surface is accurate vertically. This survey is typically done in a localized area and the purpose is to provide a truth reference to every mission and to help in the calibration effort. Since every mission's data must be compared to this survey, it makes sense for this survey to be done at a place where the plane will be for every mission, i.e., the airport. The survey is done along a taxiway or runway, and the calibration flight lines are flown perpendicular to it, which makes it perfect for evaluating roll.

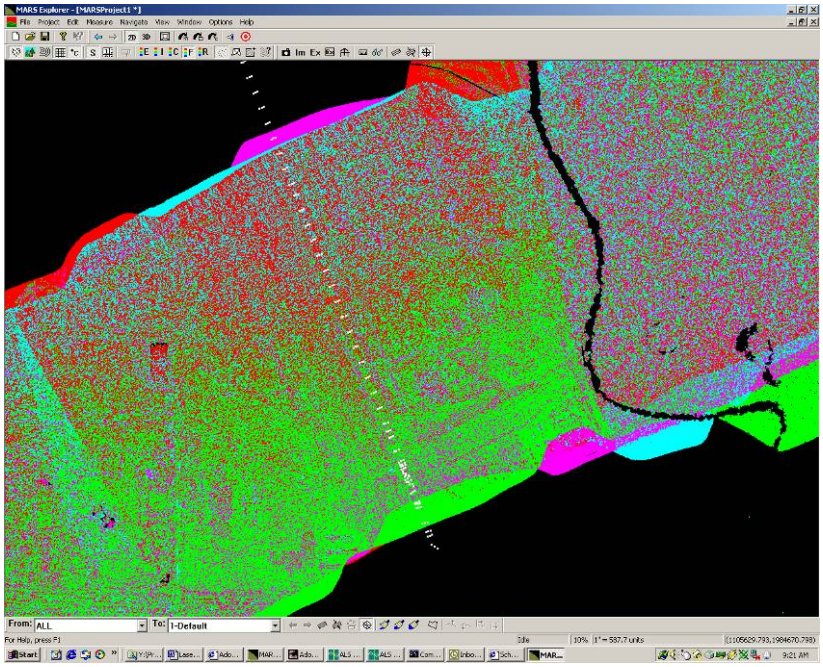


Figure 7: The truth survey

The white dots represent the survey, and four flight lines, two from the beginning of the mission and two from the end, have been flown. Each pair of flight lines was flown in opposite directions, and in this case the red and blue lines were flown east and the green and magenta lines were flown west. The first step is to make a profile line across the survey. It is important to create this cut on one side of the taxiway so as to avoid cutting through and over the crown. Once the profile is created, exaggeration of the elevation by 100 times is necessary to see the pattern. (figure 8)

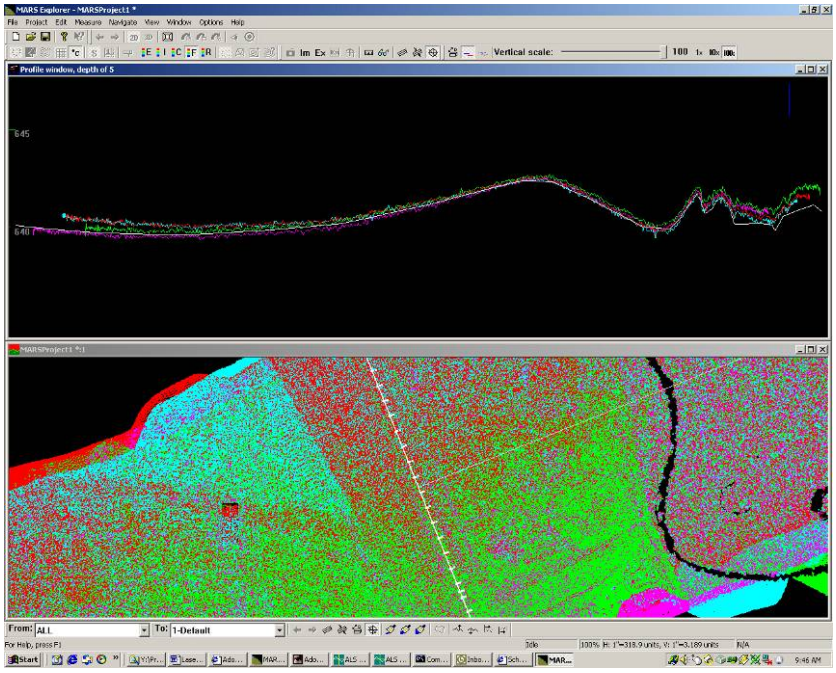


Figure 8: Profile view of calibration flight lines

Even without zooming in, a pattern is already apparent. The two east flown lines, red and blue, are high on the left compared to the west flown lines, and low on the right. Since the profile line was created with the view eastward, it is easiest to think about what the east lines are doing. The east lines are low on the right, which means the relationship between the IMU and the right wing of the plane must be adjusted up. As in heading adjustments, sending the data in a clockwise direction is positive. If the axis of the clock is the tail/nose axis of the plane, then it is obvious this data must go in a counter clock-wise, or negative direction. The method for determining the magnitude of the adjustment is similar to determining the magnitude of the adjustment for the pitch. The only difference is how the triangles are drawn in relationship to the data. (figures 9 and 10)

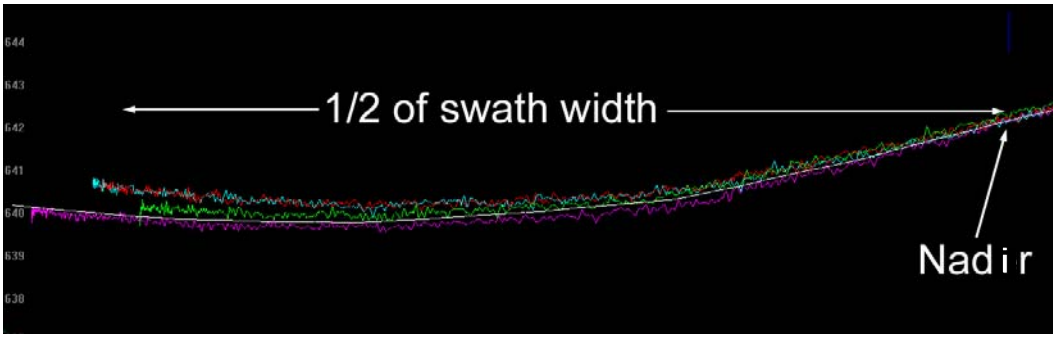


Figure 9: Half of calibration profile

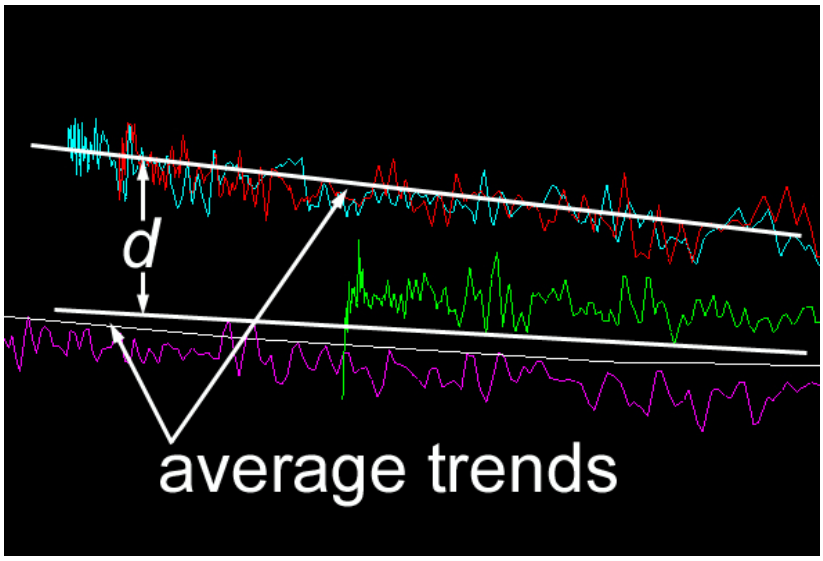


Figure 10: Differences in average roll trends

The important measurements for this formula are the distance from nadir to the edge of the swath, or ½ swath width, and d, the distance from the two average trend lines for each group. Since any adjustments made to roll effect both east and west lines, we are really interested in ½ d; this will give the value that will bring both sets of lines together. The formula is:

$$\theta = \frac{\arctan\left(\frac{d/2}{EdgeToNadir}\right)}{57.2958}$$

Correcting the Final Elevation

The next step is to ensure that all missions have the same vertical offset. Two techniques are used to achieve this. The first is to compare all calibration flight lines and shift the missions appropriately. The second is to fly an extra 'cross flight' which touches all flight lines in the project. Each mission's vertical differences can then be analyzed and corrected. However, the result of this exercise is only proof of a high level of relative accuracy. Since many of the calibration techniques affect elevation, project wide GPS control must be utilized to place the surface in the correct location. This can be achieved by utilizing the elevation offset control in the post processor or by shifting the data appropriately in MARS. The control network may be pre-existing or collected by a licensed surveyor. This is always the last step and is the only way to achieve the high absolute accuracy that is the overall goal.