LiDAR Data Calibration Report

GeoDigital #: 335 _DEW_11 VA MV MD
Data submitted April 30, 2012

Presented to:

Dewberry

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Acquisition QA-QC and Calibration

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EXECUTIVE SUMMARY

This LiDAR project was developed with the goal of providing high accuracy, calibrated multiple return LiDAR for an area of 3,942 square miles (excluding 200* NPS buffer = 150m) representing Dewberry, FEMA III FY12 LiDAR – (TO 1 G12PD00040). Data are collected and delivered in compliance with the "U.S. Geological Survey National Geospatial Program Base LiDAR Specifications, Version 13 – ILMF 2010".

This report concerns the Allegany, Berkley, Frederick (MD), Frederick (VA), Fauquier, Fairfax, Jefferson, Loudoun, Morgan, Washington counties, and the community of Golden Beach. The primary deliverable products are raw calibrated LiDAR point clouds in flight strips, raw laser range data, processed GPS and SBET data.

The elevation data was verified internally prior to delivery to ensure it met fundamental accuracy requirements; vertical accuracy NSSDA RMSEZ = 12.5cm, NSSDA AccuracyZ 95% = 24.5 cm or better; in open, non-vegetated terrain when compared to static GeoDigital GPS checkpoints. Below is the summary for both tests:

- The LiDAR dataset was tested to 0.1207m vertical accuracy at 95% confidence level, based on consolidated $RMSE_z$ (0.0615 x 1.960), when compared to 100 GPS static check points.

Please note that this report focuses solely on the GeoDigital activities pertaining to the LiDAR data calibration component of this project.

All data delivered meets or exceeds GeoDigital deliverable product requirements as set out by GeoDigital Quality Management program.

INTRODUCTION

LiDAR data is remotely sensed high-resolution elevation data. To collect data for this project, GeoDigital used an airborne fixed-wing platform. By positioning laser range finding with the use of 1 second GPS with 200 Hz inertial measurement unit corrections; GeoDigital's LiDAR instruments are able to make highly detailed geospatial elevation products of the ground, man-made structures and vegetation.

The purpose of this LiDAR collection was to produce high accuracy 3D terrain products for flood mapping and other applications.

This report covers the LiDAR calibration and initial processing methods and the development of the deliverable products. A GPS Validation Report has been included as Appendix A.

Please note that this report focuses solely on the GeoDigital activities pertaining to the LiDAR data calibration and initial processing component of this project.

1. LiDAR Data Processing

1.1. Airborne GPS Kinematic

Airborne GPS kinematic data was processed on-site using GrafNav kinematic On-The-Fly (OTF) software. Acquisition flights were performed with a minimum of 6 GPS satellites in view (at least 13° above the horizon) and with a PDOP of better than 4. Distances from base stations to aircraft were kept to a maximum of 40km.

Following GDI review, for all flights, the GPS data can be classified as excellent, with GPS residuals of 5cm average or better but no larger than 10cm being recorded.

1.2. Generation and Calibration of Laser Points (raw data)

The initial step of calibration is to verify availability and status of all needed GPS and Laser data against field notes. Any omissions were rectified at this stage.

Subsequently, the laser points for each mission are output using Optech's Dashmap software, initially using default calibration values from Optech, or with the latest calibrations recorded for the sensor system. The points generated for each mission using the initial calibration are reviewed and verified within Microstation/TerraScan for calibration errors. If a calibration error greater than specification is observed within the mission, the necessary roll, pitch and scanner scale corrections are calculated. The missions determined to require new calibration values are regenerated and validated internally once again to ensure quality.

All missions are validated against the adjoining missions, for relative vertical accuracy, and compared against collected GPS static validation points for absolute vertical accuracy confirmation.

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

1.3. Vertical Bias Resolution

In the case of this project, some LiDAR data compared to the GPS static points displayed a vertical bias. Hence the following corrections were applied:

Mission	Total Vertical Adjustment (m)	Mission	Total Vertical Adjustment (m)
o112029a	0.30	o112092a	0.15
o112029b	0.25	o112093a	0.00
o112030a	0.30	o112093b	0.15
o112031a	0.30	o112093c	0.00
o112031b	0.25	o112094a	0.00
o112034a	0.23	o112094b	0.10
o112034b	0.30	o112094c	0.05
o112045a	0.22	o112094d	0.00
o112046a	0.22	o112095a	0.15
o112046b	0.22	o112095b	0.25
o112048a	0.22	o112096a	0.15
o112048b	0.25	o112096b	0.10
o112049a	0.23	o112096c	0.14
o112050a	0.25	o112097a	0.10
o112050b	0.20	o112097b	0.15
o112051a	0.20	o112098a	0.12
o112051b	0.20	o112100a	0.15
o112053a	0.20	o112101a	0.10
o112057a	0.20	o112103a	0.10
o112057b	0.20	o112103b	0.10
o112066a	0.20	o112104a	0.10
o112066b	0.20	o112104b	0.10
o112070a	0.16	o112104c	0.15
o112070b	0.16	o112105a	0.10
o112071a	0.20	o211094a	-0.15
o112071b	0.20	o211095a	0.00
o112072a	0.20	o211096a	0.10
o112072b	0.30	o211096b	0.15
o112073a	0.25	o211097a	-0.03
o112073b	0.20	o211097b	-0.10
o112074a	0.30		
o112082a	0.25		
o112083a	0.25		
o112083b	0.32		
o112086a	0.20		
o112090a	0.15		

1.1. Deliverable Product Generation

The raw, unclassified LiDAR data were delivered in LAS format 1.2, using adjusted GPS time. Data was delivered as raw strips, with any files bigger than 2 GB split in two smaller pieces. The header is populated with the projection information and the withheld angles (+/- 2 Deg.) are flagged using the Withheld bit placeholder. The points at the start and end of flight lines that overlap adjoining counties were also flagged using the Withheld bit placeholder.

All products were delivered in UTM zone 17 or 18 north with the unit being meters, NAD83 (NSRS07), NAVD88 (Geoid09). The LAS data that covers the Allegany, Berkely, Frederick(VA), Jefferson, Morgan counties has been forced to UTM 17. The LAS data the covers Fairfax, Fauquier, Frederick(MD), Loudoun, Washington, counties has been forced to UTM 18.

2. Quality Control for Data Processing and LiDAR Calibration

Quality assurance and quality control procedures for the raw LiDAR data are performed in an iterative fashion through the entire data processing cycle.

The following sections provide a step-by-step explanation of the process used by GeoDigital to review the data prior to delivery:

2.1. Calibration Setup and Data Inventory

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

2.2. Boresight and Relative accuracy

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

All missions are checked for relative accuracy and internal quality. To do so, three regularly spaced QC blocks are placed at the outer extents and

middle of each mission. The blocks are placed over feature rich areas to best test the calibration solution. The size of the QC blocks are created to load no more than 15 million points each. Within the QC blocks all points from all flight lines are loaded and meticulously inspected to ensure the flight lines meet the required specification. Vertical differences between ground surfaces of each line are displayed using a color-by-distance algorithm. Color scale is adjusted so that errors greater than the specifications are flagged. Cross sections are visually inspected across each block to validate point-to-point, flight line-to–flight line and mission-to-mission agreement. For this project the criteria for acceptance were as follows:

- Relative accuracy <= 10cm $RMSE_z$ within individual flight line swaths and
- $RMSE_z$ <=10 cm within swath overlap (between adjacent flight lines)

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

2.3. Absolute Accuracy

A preliminary $RMSE_z$ check is performed at this stage of the project life cycle by comparing the raw LiDAR dataset against static GPS data and $RMSE_z$ project specifications. The LiDAR data is examined in open, flat areas. LiDAR ground points, generated by an automatic classification routine, are used to verify each flight line.

Results:

Prior to delivery, the elevation data was verified internally to ensure it met fundamental accuracy requirements of 24.5cm vertical accuracy at the 95% confidence level (2 sigma = RMSE * 1.96) when compared to GeoDigital static GPS checkpoints.

- The LiDAR dataset was tested to 0.1207m vertical accuracy at 95% confidence level based on consolidated $RMSE_z$ (0.0615 x 1.960) when compared to 100 GPS static check points.

Data is compiled to meet 1m horizontal accuracy at the 95% confidence level (2 sigma = RMSE * 1.96)

A detailed comparison of LiDAR points to the static survey points is provided in Appendix A - GPS Validation.

3. Conclusion

Overall, as displayed in Appendix A, the LiDAR data products collected for Dewberry meet or exceed the requirements set out in the Statement of Work for this project. The quality control requirements of GeoDigital's Quality Management Program were adhered to throughout the acquisition stage of this project.

Appendix A GPS Validation

Static GPS Validation – Control Reports Generated in TerraScan

Static GPS Validation – Overall Summary Statistics

Static GT JD 012 UTM 18

Number	Easting	Northing	Known Z	Laser Z	Dz
1	262197.960	4267956.211	89.112	88.980	-0.132
2	267278.304	4270791.758	95.974	95.920	-0.054
3	257839.218	4270707.691	99.037	99.220	+0.183
4	271239.539	4267370.558	111.808	111.790	-0.018
5	264225.930	4277278.431	85.857	85.890	+0.033
6	261781.683	4279624.156	107.309	107.290	-0.019
7	270694.439	4275262.606	77.040	77.050	+0.010

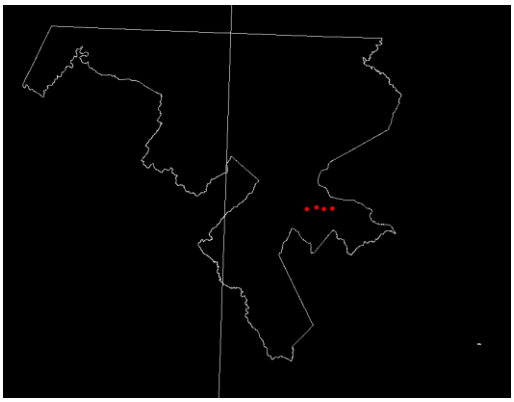
Average dz +0.000
Minimum dz -0.132
Maximum dz +0.183
Average magnitude 0.064
Root mean square 0.089
Std deviation 0.096

Static GT JD 012

Static GT JD 014 UTM 18

Number	Easting	Northing	Known Z	Laser Z	Dz
1	276788.382	4322561.559	89.084	89.000	-0.084
2	281158.118	4323167.745	138.388	138.380	-0.008
3	288036.855	4322760.849	75.747	75.740	-0.007
4	284424.183	4322473.010	89.615	89.540	-0.075

Average dz -0.044
Minimum dz -0.084
Maximum dz -0.007
Average magnitude 0.044
Root mean square 0.057
Std deviation 0.042



Static GT JD 014

Static GT JD 015_A UTM 18

Number	Easting	Northing	Known Z	Laser Z	Dz
1	273834.040	4326433.499	122.284	122.220	-0.064
2	285326.835	4328219.395	101.061	101.080	+0.019
3	278512.777	4333448.349	108.165	outside	*
4	281675.259	4330897.712	97.726	97.680	-0.046
5	278702.827	4328891.559	114.206	114.290	+0.084

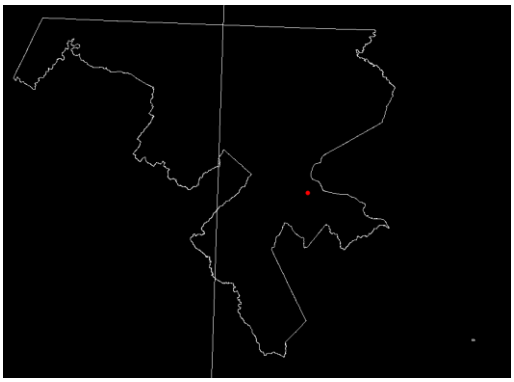
Average dz -0.002
Minimum dz -0.064
Maximum dz +0.084
Average magnitude 0.053
Root mean square 0.058
Std deviation 0.067

Static GT JD

Static GT JD 015 B UTM 18

Number	Easting	Northing	Known Z	Laser Z	Dz
1	280349.032	4326900.183	88.854	88.770	-0.084

Average dz -0.084
Minimum dz -0.084
Maximum dz -0.084
Average magnitude 0.084
Root mean square 0.084
Std deviation 0.000

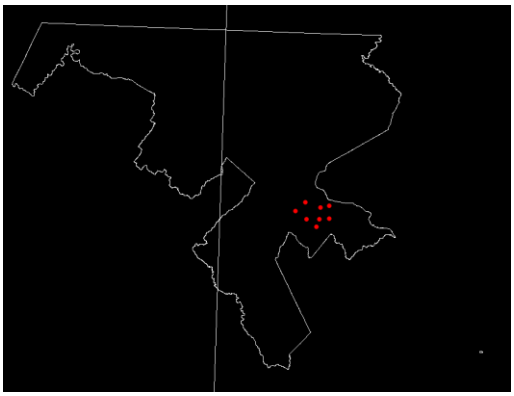


Static GT JD 015B

Static GT JD 016 UTM 18

Number	Easting	Northing	Known Z	Laser Z	Dz
1	281351.679	4324514.821	123.316	outside	*
2	277759.217	4319520.568	113.673	113.700	+0.027
3	283262.292	4319481.402	89.291	89.280	-0.011
4	287659.818	4319716.438	73.572	73.610	+0.038
5	282216.363	4316236.715	86.689	86.650	-0.039
6	283855.753	4324578.759	82.404	82.400	-0.004
7	287661.688	4325183.109	68.758	68.690	-0.068
8	277278.531	4326738.422	109.190	109.140	-0.050
9	273089.720	4322929.146	84.938	85.090	+0.152

Average dz	+0.006
Minimum dz	-0.068
Maximum dz	+0.152
Average magnitude	0.049
Root mean square	0.065
Std deviation	0.069

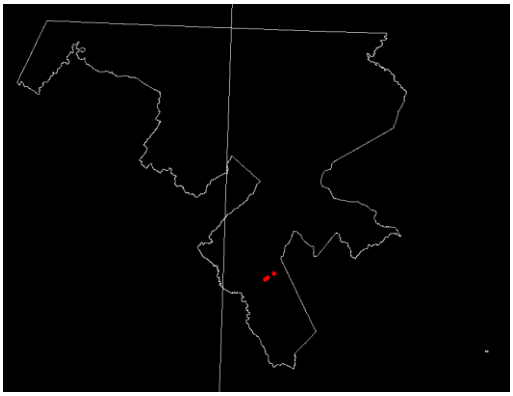


Static GT JD 016

Static GT JD 018 UTM 18

Number	Easting	Northing	Known Z	Laser Z	Dz
1	257678.042	4293007.501	152.731	152.750	+0.019
2	258489.553	4293754.940	170.087	170.090	+0.003
3	261426.469	4295373.510	183.131	183.100	-0.031

Average dz -0.003
Minimum dz -0.031
Maximum dz +0.019
Average magnitude 0.018
Root mean square 0.021
Std deviation 0.026



Static GT JD 018

Static GT JD023a UTM 17

Number	Easting	Northing	Known Z	Laser Z	Dz
1	682414.857	4397227.707	448.117	448.090	-0.027
2	682432.202	4397239.186	450.113	450.030	-0.083
3	681050.786	4392660.493	601.731	601.690	-0.041
4	681042.377	4392672.500	602.189	602.150	-0.039
5	677251.999	4393155.601	660.617	660.590	-0.027
6	677253.052	4393143.772	660.393	660.300	-0.093
7	679783.459	4386862.353	710.709	710.650	-0.059
8	679795.046	4386855.646	710.903	710.840	-0.063
9	686980.470	4385260.822	205.686	205.630	-0.056
10	686969.799	4385244.157	206.132	206.060	-0.072
11	686646.284	4389888.263	287.423	outside	*
12	686640.289	4389903.500	286.059	outside	*

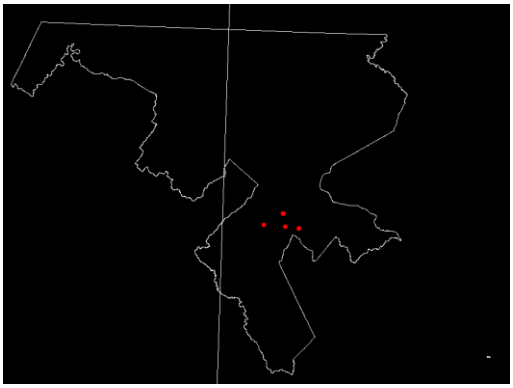
Average dz -0.056
Minimum dz -0.093
Maximum dz -0.027
Average magnitude 0.056
Root mean square 0.060
Std deviation 0.023

Static GT JD 023

Static GT JD 023B UTM 18

Number	Easting	Northing	Known Z	Laser Z	Dz
1	266046.151	4322861.909	135.310	135.230	-0.080
2	272827.807	4316632.274	109.097	109.040	-0.057
3	257732.829	4318283.483	142.164	142.100	-0.064
4	266027.317	4322868.447	135.717	135.630	-0.087
5	272820.969	4316642.207	109.258	109.240	-0.018
6	266898.021	4317427.988	141.993	141.920	-0.073

Average dz -0.063
Minimum dz -0.087
Maximum dz -0.018
Average magnitude 0.063
Root mean square 0.067
Std deviation 0.025



Static GT JD 023B

Static GT JD 036 UTM 17

Number	Easting	Northing	Known Z	Laser Z	Dz
1	751729.166	4365269.491	238.869	outside	*
2	753779.397	4367216.647	201.721	201.810	+0.089
3	753781.750	4367167.658	201.643	201.660	+0.017
4	756067.939	4366308.386	189.397	189.440	+0.043
5	756059.178	4366291.195	189.412	189.430	+0.018
6	757098.526	4363438.461	169.780	169.810	+0.030
7	757111.477	4363438.238	169.570	169.650	+0.080
8	755272.226	4361162.843	172.133	removed	*
9	755279.033	4361179.487	172.146	removed	*
10	754801.274	4359854.167	168.715	168.800	+0.085
11	754783.821	4359865.688	169.038	169.120	+0.082
12	751592.130	4361773.363	204.565	204.610	+0.045
13	751603.169	4361758.169	204.412	204.480	+0.068
14	748944.702	4363952.709	328.066	328.110	+0.044
15	748944.231	4363974.293	329.142	329.180	+0.038
16	745527.384	4365879.035	163.330	163.380	+0.050
17	745523.620	4365896.789	162.572	162.540	-0.032
18	746468.689	4368816.695	150.533	150.570	+0.037
19	746478.119	4368828.008	150.481	150.610	+0.129
20	748732.183	4366792.593	253.743	253.790	+0.047
21	748727.700	4366774.619	254.911	254.980	+0.069

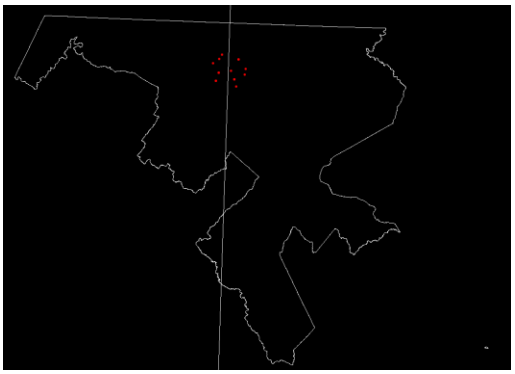
Average dz +0.052
Minimum dz -0.032
Maximum dz +0.129
Average magnitude 0.056
Root mean square 0.062
Std deviation 0.035

Static GT JD 036

Static GT JD 039 UTM 17

Number	Easting	Northing	Known Z	Laser Z	Dz
1	765218.294	4382183.824	139.450	139.470	+0.020
2	765196.841	4382183.716	139.437	139.440	+0.003
3	762017.971	4385924.470	136.614	136.530	-0.084
4	762041.842	4385906.768	137.219	137.190	-0.029
5	754589.528	4387592.002	182.625	182.750	+0.125
6	754574.058	4387596.646	182.372	182.500	+0.128
7	753649.925	4385584.007	152.885	152.870	-0.015
8	753663.696	4385594.338	152.073	152.110	+0.037
9	751109.634	4383513.294	181.046	181.020	-0.026
10	751103.430	4383526.539	180.529	180.540	+0.011
11	753799.241	4379737.551	139.777	139.720	-0.057
12	753826.320	4379728.597	139.788	139.760	-0.028
13	752792.552	4376084.784	143.306	143.330	+0.024
14	752782.878	4376086.224	143.454	143.460	+0.006
15	760625.614	4377347.541	166.861	166.810	-0.051
16	760616.478	4377327.258	167.112	167.080	-0.032
17	761634.529	4374364.236	143.607	143.660	+0.053
18	761654.881	4374335.534	143.292	removed	*
19	764972.536	4379726.955	125.374	125.420	+0.046
20	764971.506	4379714.668	125.315	removed	*
21	759104.623	4380886.545	157.042	removed	*

Average dz +0.007
Minimum dz -0.084
Maximum dz +0.128
Average magnitude 0.043
Root mean square 0.056
Std deviation 0.057



Static GT JD 039

Static GT JD 040 UTM 17

Number	Easting	Northing	Known Z	Laser Z	Dz
1	751729.166	4365269.491	238.869	outside	*
2	748010.633	4344054.506	209.161	209.140	-0.021
3	739568.714	4348453.540	248.625	248.610	-0.015
4	742339.932	4344846.502	265.321	265.350	+0.029
5	752659.211	4340692.013	158.962	159.010	+0.048
6	754066.166	4340490.304	176.658	176.630	-0.028
7	759075.369	4339466.503	196.698	196.610	-0.088
8	737875.611	4337865.014	252.519	252.500	-0.019
9	742667.762	4334724.243	228.100	228.110	+0.010
10	749071.601	4334119.683	198.723	198.680	-0.043
11	755095.016	4337356.689	195.534	195.460	-0.074
12	740685.075	4348213.230	243.073	243.080	+0.007

Average dz -0.018
Minimum dz -0.088
Maximum dz +0.048
Average magnitude 0.035
Root mean square 0.043
Std deviation 0.041

Static GT JD 040

Static GT JD 043 UTM 18

Number	Easting	Northing	Known Z	Laser Z	Dz
1	279093.760	4374676.390	183.800	183.850	+0.050
2	282785.740	4382529.200	284.080	284.080	+0.000
3	272956.550	4384285.840	174.060	174.080	+0.020
4	272994.240	4381218.690	175.990	175.910	-0.080
5	271369.180	4378310.610	171.110	171.230	+0.120
6	272147.460	4373265.150	184.250	184.350	+0.100
7	270513.270	4368190.360	209.050	209.000	-0.050
8	275392.630	4364697.460	158.840	158.830	-0.010
9	288165.620	4367186.480	123.870	123.810	-0.060
10	288970.700	4370137.700	124.030	124.140	+0.110
11	292218.640	4371316.740	98.350	98.410	+0.060

Average dz +0.024
Minimum dz -0.080
Maximum dz +0.120
Average magnitude 0.060
Root mean square 0.071
Std deviation 0.070

Static GT JD 043

Static GT JD 066 UTM 17

Number	Easting	Northing	Known Z	Laser Z	Dz
1	715441.374	4379962.941	202.636	202.780	+0.144
2	713454.985	4381270.486	309.568	309.670	+0.102
3	713354.064	4383127.369	364.779	364.840	+0.061
4	706918.763	4384526.379	301.450	301.470	+0.020
5	705688.014	4386230.384	276.974	277.040	+0.066
6	711907.106	4387746.177	218.655	218.680	+0.025
7	708797.247	4389579.315	209.282	209.340	+0.058
8	702148.015	4391049.601	384.694	384.710	+0.016
9	704092.111	4392689.617	327.822	327.810	-0.012
10	704027.231	4394554.950	342.971	343.010	+0.039

Average dz +0.052
Minimum dz -0.012
Maximum dz +0.144
Average magnitude 0.054
Root mean square 0.067
Std deviation 0.045

Static GT JD 066

Sample Size	100	Points
Average	0.0023	meters
RMSE	0.06159	meters
NSSDA	0.12071	meters