LiDAR Data Calibration Report

GeoDigital #: 239 DEB11-1
FEMA Virginia LiDAR (T/O G11PD00089) – Counties North
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Presented to:

Dewberry

Submitted by:

Client Program Management Group
Ottawa, Canada

EXECUTIVE SUMMARY

This LiDAR project was to provide high accuracy, calibrated multiple return LiDAR for 1585 square miles (excluding 200* NPS buffer = 150m) representing Dewberry, FEMA Virginia LiDAR acquisition Task Order #6 – (G11PD00089). 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 Prince William, Stafford, King George, Richmond, and Westmoreland counties, the primary deliverable product is raw calibrated LiDAR.

The elevation data was verified internally prior to delivery to ensure it met fundamental accuracy requirements (vertical accuracy NSSDA RMSEZ = 9.25cm (NSSDA AccuracyZ 95% = 18 cm) or better; in open, non-vegetated terrain) when compared to kinematic and static Terrapoint GPS checkpoints. Below is the summary for both tests:

- The LiDAR dataset was tested to 0.083m vertical accuracy at 95% confidence level based on consolidated $RMSE_z$ (0.042m x 1.960) when compared to 9928 GPS kinematic check points.
- The LiDAR dataset was tested to 0.101m vertical accuracy at 95% confidence level based on consolidated $RMSE_z$ (0.051 x 1.960) when compared to 37 GPS static check points.

Please note that this report focuses solely on the GeoDigital activities pertaining to the LiDAR data processing 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 collected by an airborne collection 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 data was to produce high accuracy 3D terrain geospatial products for flood mapping and other applications.

This report covers the LiDAR processing methods and deliverable products. A GPS Validation Report has been included as an appendix.

Please note that this report focuses solely on the GeoDigital activities pertaining to the LiDAR data 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. Flights were flown with a minimum of 6 satellites in view (13° above the horizon) and with a PDOP of better than 4. Distances from base station to aircraft were kept to a maximum of 40km.

For all flights, the GPS data can be classified as excellent, with GPS residuals of 3cm 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 and compile any data if not complete.

Subsequently the mission points are output using Optech's Dashmap, initially with default values from Optech or the last mission calibrated for system. The initial point generation for each mission calibration is verified within Microstation/Terrascan for calibration errors. If a calibration error greater than specification is observed within the mission, the roll pitch and scanner scale corrections that need to be applied are calculated. The missions with the new calibration values are regenerated and validated internally once again to ensure quality.

All missions are validated against the adjoining missions for relative vertical biases and collected GPS kinematic validation points for absolute vertical accuracy purposes.

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

1.3. Vertical Bias Resolution

When the LiDAR data was compared to the GPS kinematic and static points, a bias was detected. Hence the following corrections were applied:

Mission	Total Vertical Adjustment (m)
o111093a	0.22
o111094a	0.10
o111096a	0.20
o111101a	0.22
o111104a	0.26
o111104b	0.10
o111105a	0.20
o111114a	0.20
o111114b	0.20
o111114c	0.20
o111119a	0.20
o111119b	0.22
o111125a	0.12
o211096a	0.22
o211096b	0.21
o211097a	0.27
o211097b	0.32
o211101a	0.32
o211104a	0.24
o211104b	0.25
o211108a	0.22
o211108b	0.20
o211109a	0.20
o211111a	0.20
o211119a	0.26
o211119b	0.30
o211120a	0.28
o211121a	0.24
o211122a	0.32
o211122b	0.24
o211123a	0.22
o211125a	0.22
o211125b	0.18
o211127b	0.07
o511120a	0.39
o511121a	0.32
o511121b	0.33
o511127a	0.50
o511130a	0.25
o511130b	0.15

1.4. Deliverable Product Generation

The raw, unclassified LiDAR data were delivered in LAS format 1.2 adjusted GPS time, both as raw strips, with files bigger than 2 GB split in 2 both. Header is populated with the projection information and the withheld angles (+/-2deg system o1, +/-3deg system o2 o5) are flagged using the Withheld bit. In some isolated areas polygons were used to extend the withheld bit classification in areas of bad data due to extreme wind.

All products were delivered in UTM 18 north meters, NAD83(NSRS 07), NAVD88(Geoid09).

2. Quality Control for Data Processing 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 list provides a step-by-step explanation of the process used by Terrapoint to review the data prior to customer delivery.

2.1. Calibration Setup and Data Inventory

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.

2.2. Boresight and Relative accuracy

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

Relative accuracy and internal quality are checked using at least 3 regularly spaced QC blocks in which points from all lines are loaded and inspected. Vertical differences between ground surfaces of each line are displayed. Color scale is adjusted so that errors greater than the specifications are flagged. Cross sections are visually inspected across each block to validate point to point, flightline to flightline and mission to mission agreement. For this project the specifications used are as follow:
Relative accuracy <= 7cm RMSEZ within individual swaths and <=10 cm RMSEZ or within swath overlap (between adjacent swaths) .

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

2.3. Absolute accuracy

A preliminary $RMSE_z$ error check is performed at this stage of the project life cycle in the raw LiDAR dataset against GPS static and kinematic data and compared to $RMSE_z$ project specifications. The LiDAR data is examined in open, flat areas away from breaks. Lidar ground points for each flightline generated by an automatic classification routine are used.

Results:
Prior to delivery the elevation data was verified internally to ensure it met fundamental accuracy requirements of 18.5cm vertical accuracy at the 95% confidence level (2 sigma = RMSE * 1.96) in when compared to Terrapoint kinematic and static GPS checkpoints.

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

- The LiDAR dataset was tested to 0.083m vertical accuracy at 95% confidence level based on consolidated $RMSE_z$ (0.042m x 1.960) when compared to 9928 GPS kinematic check points.
- The LiDAR dataset was tested to 0.101m vertical accuracy at 95% confidence level based on consolidated $RMSE_z$ (0.051 x 1.960) when compared to 37 GPS static check points.

A detailed comparison is provided in Appendix A - GPS Validation.

3. Conclusion

Overall the LiDAR data products collected for Dewberry meets or exceed the requirements set out in the Statement of Work for this project. The quality control requirements of Terrapoint's Quality management program were adhered to throughout the acquisition stage of this project to ensure product quality.

Appendix A GPS Validation

Static GPS Validation

UTM18 meters

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Number	Easting	Northing	Known Z	Laser Z	Dz
STA28	281153.761	4281454.317	62.840	62.970	+0.130
STA34	302747.294	4277510.687	37.291	37.410	+0.119
STA21	274022.611	4300463.320	100.567	100.640	+0.073
STA32	288060.128	4279076.220	125.889	125.950	+0.061
STA29	298409.374	4272256.211	31.471	31.520	+0.049
STA27	276499.870	4285584.578	77.353	77.400	+0.047
STA26	275744.462	4290510.703	80.658	80.700	+0.042
10301bac	280616.193	4289436.916	56.136	56.170	+0.034
STA31	296423.408	4284488.195	82.911	82.940	+0.029
STA25	280921.518	4290707.593	64.982	65.000	+0.018
STA22	268959.453	4295987.909	98.624	98.640	+0.016
STA18	274540.913	4304492.196	110.465	110.460	-0.005
sta25b	279932.955	4290774.473	64.106	64.100	-0.006
STA24	286695.339	4293378.928	90.742	90.730	-0.012
STA36	292071.135	4262347.074	27.503	27.490	-0.013
STA16	271425.573	4312613.789	135.944	135.930	-0.014
STA33	296030.314	4269290.764	45.908	45.890	-0.018
STA30	287993.478	4286633.409	65.953	65.930	-0.023
STA17	271509.801	4309131.081	125.395	125.370	-0.025
1110301	280636.550	4289408.308	55.657	55.630	-0.027
STA23	282053.811	4297784.963	76.622	76.590	-0.032
STA35	285768.288	4260593.202	93.992	93.890	-0.102
STA19	272853.977	4316630.607	109.189	outside	*

Average dz +0.016
Minimum dz -0.102
Maximum dz +0.130
Average magnitude 0.041
Root mean square 0.05
Std deviation 0.052

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Number	Easting	Northing	Known Z	Laser Z	Dz
5	273020.600	4254563.088	95.032	95.050	+0.018
2	289511.682	4255572.284	46.458	46.450	-0.008
7	281671.727	4241719.236	70.811	70.800	-0.011
3	286467.169	4246513.729	55.891	55.880	-0.011
11	305330.478	4235645.784	15.190	15.170	-0.020
14	314140.747	4244925.908	45.352	45.330	-0.022
4	280544.681	4248326.305	94.024	94.000	-0.024
15	321062.575	4236820.227	5.402	5.370	-0.032
6	291975.763	4251354.944	22.785	22.750	-0.035
9	297513.268	4241375.041	60.986	60.950	-0.036
8	289579.962	4238735.191	25.728	25.690	-0.038
16	320500.848	4228312.198	54.970	54.930	-0.040
1	297530.186	4241390.878	61.632	61.590	-0.042
12	308579.149	4228006.482	11.941	11.890	-0.051
10	303828.363	4244652.996	11.249	11.180	-0.069
13	311912.506	4234456.598	54.996	54.880	-0.116

Average dz -0.033
Minimum dz -0.116
Maximum dz +0.018
Average magnitude 0.036
Root mean square 0.044
Std deviation 0.030

I:\11103u_Virginia\2_Operations\5_Ground_Truthing\11103U_Static Tappahannock Area.txt

Number	Easting	Northing	Known Z	Laser Z	Dz
2	323820.633	4214124.101	22.928	23.050	+0.122
17	341920.389	4217724.303	44.759	44.830	+0.071
5	324877.872	4209653.159	45.374	45.400	+0.026
9	328940.863	4188603.016	52.334	52.340	+0.006
4	316698.020	4209271.297	55.917	55.920	+0.003
19	348186.345	4206936.622	43.739	43.740	+0.001
13	356727.216	4194588.978	32.020	32.020	+0.000
7	329273.894	4204617.144	41.816	41.810	-0.005
14	361589.103	4210453.321	2.487	2.480	-0.007
6	332891.140	4192229.759	38.719	38.710	-0.009
3	317374.368	4218817.241	9.917	9.900	-0.017
20	345581.047	4202731.926	41.380	41.360	-0.020
21	348204.244	4180297.740	36.351	36.330	-0.021
8	324355.994	4196286.837	45.945	45.920	-0.025
1	332983.127	4192146.999	38.917	38.880	-0.037
16	335391.597	4223828.417	48.767	48.730	-0.037
18	336440.536	4212623.043	45.491	45.450	-0.041
10	339771.732	4191644.872	36.734	36.690	-0.044
11	343397.131	4185560.930	38.799	38.720	-0.079
15	355034.365	4221596.417	3.370	3.260	-0.110
12	360908.784	4189943.320	31.275	31.130	-0.145

Average dz -0.018
Minimum dz -0.145
Maximum dz +0.122
Average magnitude 0.039
Root mean square 0.057
Std deviation 0.056

Kinematic GPS Validation

Sample Size	9928	Points
average	0.000291	metres
RMSE	0.04285	metres
NSSDA	0.083985	metres