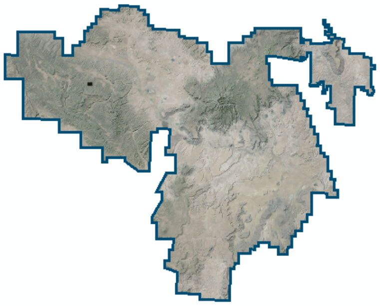
Lidar Mapping Report

Acquisition, Processing, and Delivery of Airborne Lidar Elevation Data for NM Rio San Jose FEMA R6 Lidar_2016_D17



USGS CONTRACT: G16PC00029

CONTRACTOR: Merrick-Surdex JV

TASK ORDER NUMBER: G17PD00012

TASK NAME: NM _ Rio San Jose FEMA R6 Lidar_2016_D17

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TOTAL AWARD: $874,929.00 (Fixed Price)

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Submitted to:

USGS
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Submitted by:

MERRICK SURDEX
JOINT VENTURE

Contractor Job Number: J65219387

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Project Summary

Merrick-Surdex Joint Venture, LLP (“Merrick-Surdex JV”) was awarded the NM_Rio San Jose FEMA R6 Lidar_2016_D17 (Task Order G17PD00012) project by the United State Geological Survey (USGS) to provide a high-resolution data set of lidar for four (4) contiguous Areas of Interest (AOIs) totaling 3,978 square miles located west of Albuquerque, New Mexico. The four AOIs include the partial counties of McKinley, Cibola, Catron, Socorro, Valencia, Bernalillo and Sandoval. This project will support the FEMA Risk MAP program.

Unless otherwise stated, the lidar mapping requirements and deliverables will meet the Quality Level Two (QL2) standards as outlined in the USGS-NGP Lidar Base Specifications, Techniques and Methods 11–B4, Version 1.2, November 2014 (TM11-B4) (http://pubs.usgs.gov/tm/11b4/pdf/tm11-B4.pdf). QL2 lidar specifications suggest a point density of greater than or equal to two points per square meter (≥2ppsm), or less than or equal to seven-tenths of a meter (≤0.71m) Aggregate Nominal Pulse Density (ANPD).

The vertical accuracy requirements of the lidar data meets or exceeds the following:

Vertical accuracy (absolute for the Non-Vegetated Vertical Accuracy [NVA])

- ≤10cm RMSEz
- ≤19.6cm at the 95% confidence level (AccuracyZ)
- Vegetated Vertical Accuracy (VVA) ≤29.4cm at the 95% percentile

Relative accuracy

- ≤6cm Smooth surface repeatability
- ≤8cm RMSDz
- ±16cm maximum difference

Project Spatial Reference

- Projection – Universal Transverse Mercator (UTM), Zones 13N
- Horizontal Datum - North American Datum of 1983 (NAD 83), National Adjustment of 2011 (NA2011)
- Vertical Datum – North American Vertical Datum of 1988 (NAVD 88); GEOID 12B
- Units – Meters
- EPSG Codes - UTM Zone 13 = EPSG 6342

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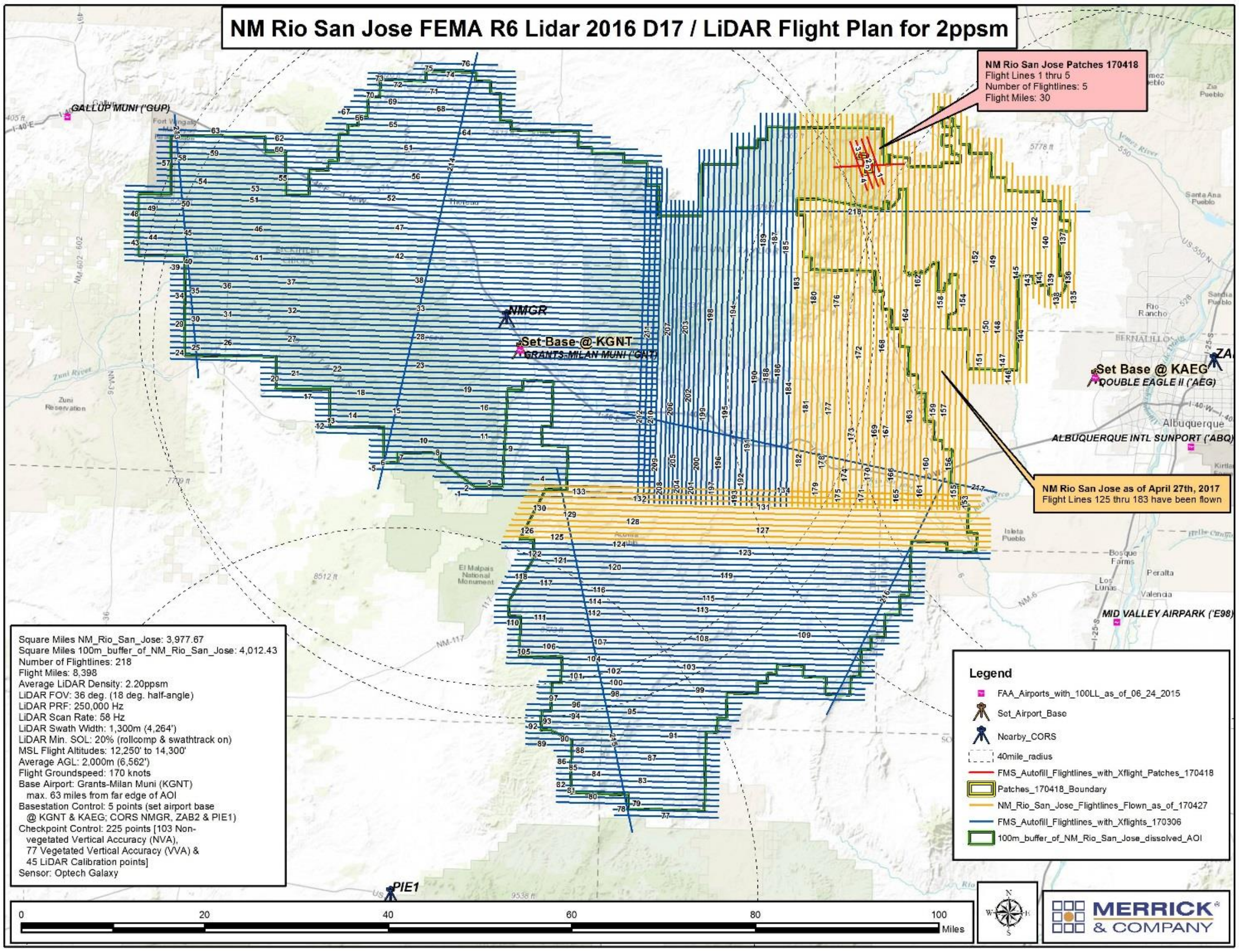
The contents of this report summarize the methods used to calibrate and classify the lidar data as well as the results of these methods for project the NM_Rio San Jose FEMA R6 Lidar_2016_D17 (NM Rio San Jose).

Lidar Flight Information

The acquisition area for the NM Rio San Jose project is defined by the dissolved extent of the client-provided Esri shapefiles. The Merrick-Surdex JV acquired the QL2 lidar point cloud using a utilizing Optech Galaxy lidar sensors. The Galaxy is a high performance 550 kHz lidar sensor capable of collecting large areas efficiently.

Merrick-Surdex JV planned an acquisition area of approximately 4,012.43 square miles to include a one hundred-meter (100m) buffer per TM11-B4. See below illustration of the proposed lidar flight plan.

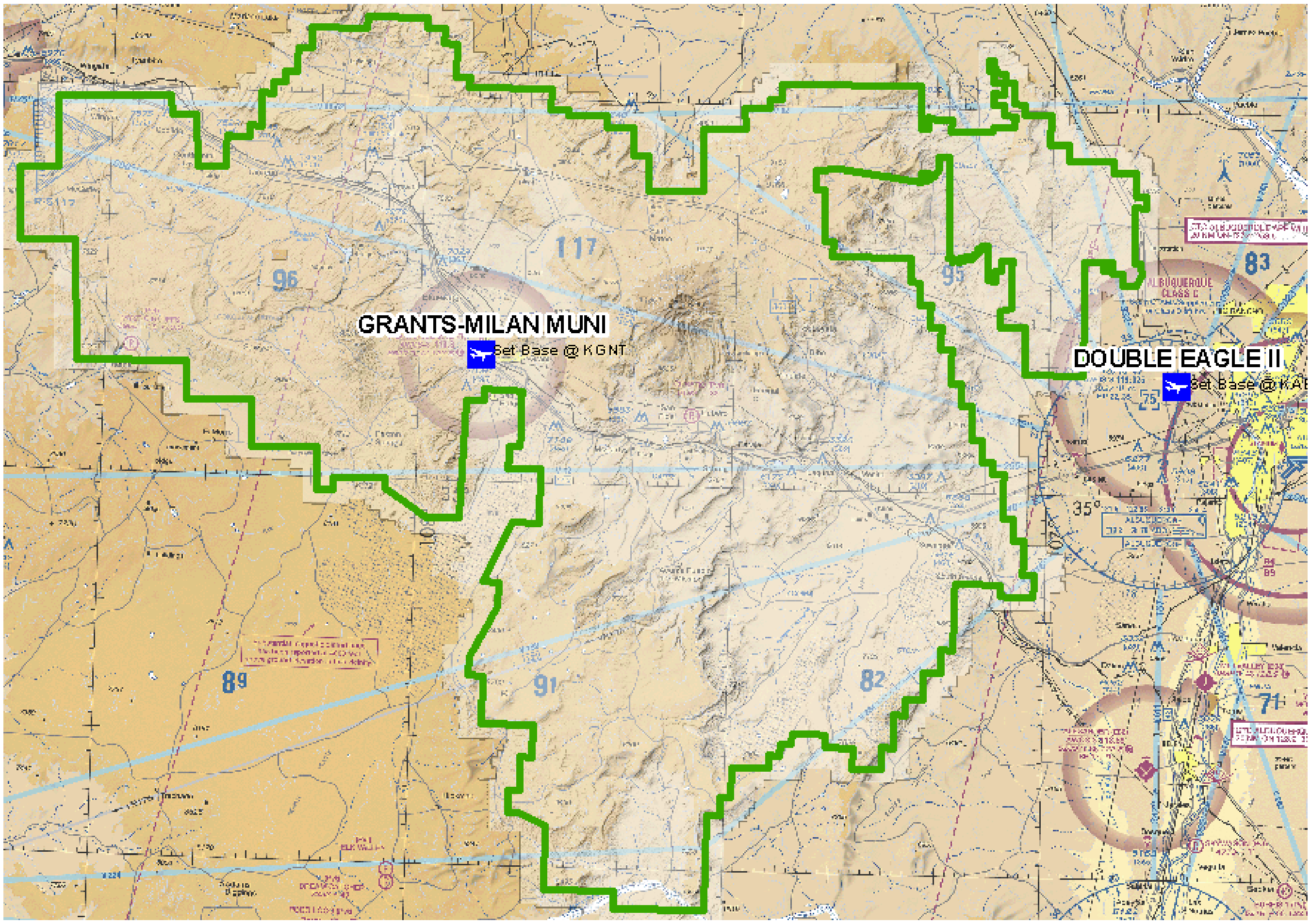


Square Miles NM_Rio_San_Jose: 3,977.67
Square Miles 100m_buffer_of_NM_Rio_San_Jose: 4,012.43
Number of Flightlines: 218
Flight Miles: 8,398
Average LiDAR Density: 2.20ppsm
LiDAR FOV: 36 deg. (18 deg. half-angle)
LiDAR PRF: 250,000 Hz
LiDAR Scan Rate: 58 Hz
LiDAR Swath Width: 1,300m (4,264')
LiDAR Min. SOL: 20% (rollcomp & swathtrack on)
MSL Flight Altitudes: 12,250' to 14,300'
Average AGL: 2,000m (6,562')
Flight Groundspeed: 170 knots
Base Airport: Grants-Milan Muni (KGNT)
max. 63 miles from far edge of AOI
Basestation Control: 5 points (set airport base @ KGNT & KAEG; CORS NMGR, ZAB2 & PIE1)
Checkpoint Control: 225 points [103 Non-vegetated Vertical Accuracy (NVA), 77 Vegetated Vertical Accuracy (VVA) & 45 LiDAR Calibration points]
Sensor: Optech Galaxy

Airports of Operation

Multiple airports were used for the collection of this project. See below for a list of the airports used as well as an image of the project area with all the regional airports displayed.

- Double Eagle II Airport (KAEG) - Albuquerque, New Mexico
- Grants-Milan Municipal Airport (KGNT) - Grants, New Mexico



Aerial Mission(s) Duration / Time

The project was collected with two lidar fixed wing aircraft using two different Optech Galaxy lidar sensors. Lidar data collection for the project was accomplished between December 15, 2016 and June 11, 2017. Each mission represents a lift of the aircraft and system from the ground, collects data, and lands again. Multiple lifts within a day are represented by Mission A, B, C, D. The table below relates each mission to the date collected, the sensor and serial number used, and the start/end times of global navigation satellite system (GNSS) records taken. The time is shown in Global Positioning System (GPS) seconds of the week.

Mission(s)	Date	Sensor S/N	Start Time GPS sec.	End Time GPS sec.
161215A	December 15, 2016	5060380	402371	416808
161218A	December 18, 2016	5060380	58297	75900
170321A	March 21, 2017	5060386	239120	251136
170322A	March 22, 2017	5060386	310876	326782
170322B	March 22, 2017	5060386	330882	347502
170517A	May 17, 2017	5060386	308889	327463
170517B	May 17, 2017	5060386	331578	349436
170517C	May 17, 2017	5060386	352412	360963
170520A	May 20, 2017	5060386	565923	583984
170520B	May 20, 2017	5060386	589752	604587
170520C	May 20, 2017	5060386	2626	12210
170521A	May 21, 2017	5060386	50777	67846
170522A	May 22, 2017	5060386	134928	149725
170523A	May 23, 2017	5060386	220718	235678
170523B	May 23, 2017	5060386	254401	263792
170524A	May 24, 2017	5060386	307662.1	324442
170525A	May 25, 2017	5060386	393369	410491
170526A	May 26, 2017	5060386	480327	497052
170527A	May 27, 2017	5060386	567266	584584
170528A	May 28, 2017	5060386	48273	66280
170528B	May 28, 2017	5060386	73634	81431
170529A	May 29, 2017	5060386	136602	141060
170611A	June 11, 2017	5060386	92646	97654

GNNS / IMU Data

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. Near the end of the mission, GPS ambiguities were again resolved by flying within ten kilometers of the base stations to aid in post-processing. Data is sent back to the main office for preliminary processing to check overall quality of GPS / INS data and to ensure sufficient overlap between flight lines. Any problematic data may be re-flown immediately as required.

The airborne GPS data was post-processed using Applanix POSPac Mobile Mapping Suite version 8.x. 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 quality 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. Usually as the number of satellites increase the PDOP decreases. Other quality control checks used for the GPS include analyzing the combined separation of the forward and reverse GPS processing from one base station and the results of the combined separation when processed from two different base stations. An analysis of the number of satellites, present during the flight and data collection times, is also performed.

The GPS trajectory was combined with the raw IMU data and post-processed using POSPac Mobile Mapping Suite version 8.x. The Smoothed Best Estimated Trajectory (SBET) and refined attitude data are then utilized in the LMS 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 Optech lidar Mapping Suite (LMS) processor software for each pulse which ensures the greatest chance of ground returns in a heavily forested area.

GPS Controls

Ground GNSS Base Stations were set up to control the lidar airborne flight lines. In addition, CORS (Continually Operating Reference Stations) are at times used to further enhance the airborne solution. The ground GNSS Base Stations coordinates were obtained from NGS (National Geodetic Survey) Online Positioning User Service (OPUS) solutions. CORS coordinates were obtained from NGS datasheets. See the following table and map for ground GNSS Base Station information and locations:

Point ID	Latitude (NAD83 – 2011)	Longitude (NAD83 – 2011)	Ellipsoid Height (m)
BaseKAEG	N35°09'35.13405"	W106°47'11.83031"	1743.909
BaseKAEG	N35°09'35.13405"	W106°47'11.83031"	1743.909
P107 (CORS)	N35°07'55.83261"	W107°52'48.02919"	1992.591
P107 (CORS)	N35°07'55.83261"	W107°52'48.02919"	1992.591
P107 (CORS)	N35°07'55.83261"	W107°52'48.02919"	1992.591
P107 (CORS)	N35°07'55.83261"	W107°52'48.02919"	1992.591
ZAB1(CORS)	N35°10'24.85464"	W106°34'02.41357"	1620.623
P107 (CORS)	N35°07'55.83261"	W107°52'48.02919"	1992.591
P107 (CORS)	N35°07'55.83261"	W107°52'48.02919"	1992.591
ZAB1(CORS)	N35°10'24.85464"	W106°34'02.41357"	1620.623
NMGR(CORS)	N35°12'59.64999"	W107°55'48.36832"	2021.631
ZAB1(CORS)	N35°10'24.85464"	W106°34'02.41357"	1620.623
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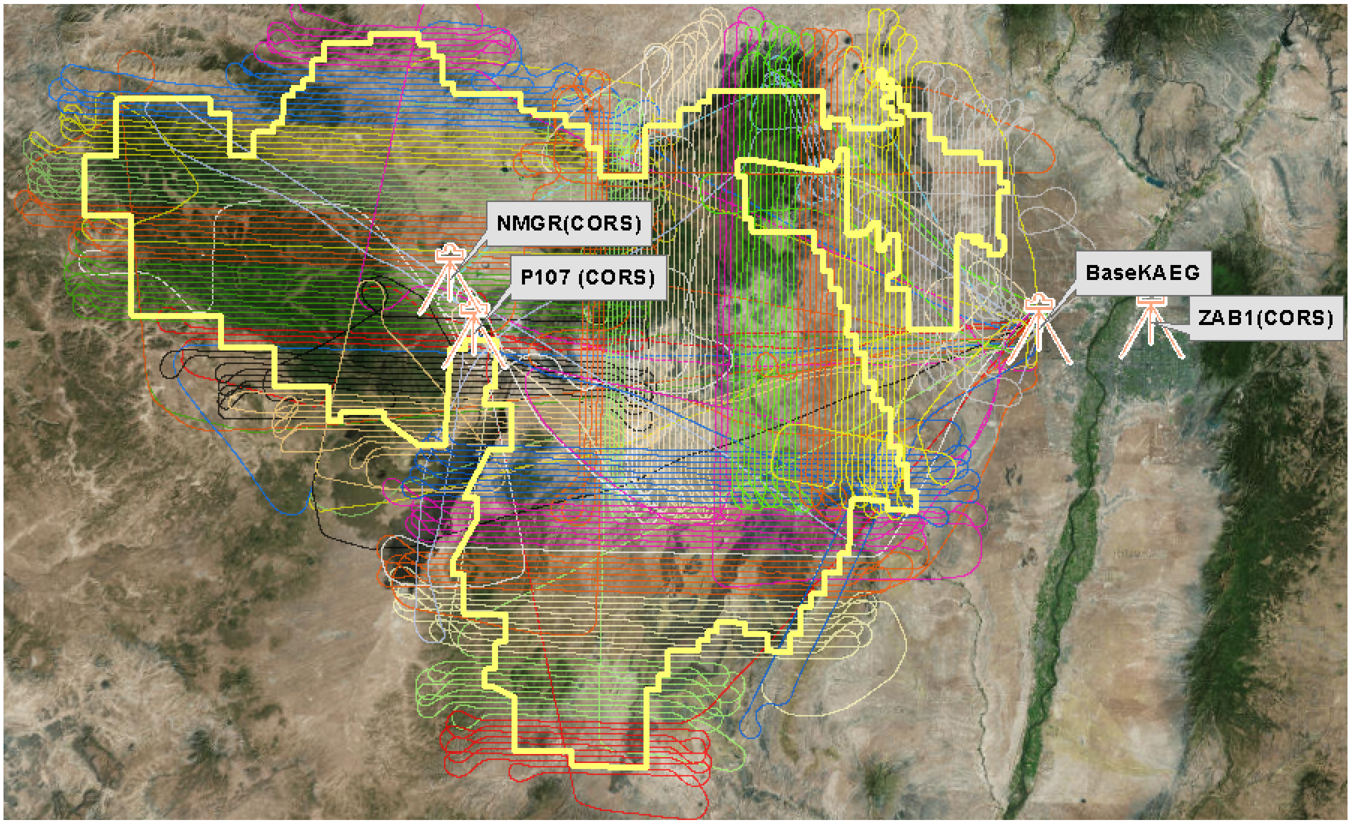
GNSS Base Station Map – missions color coded



Lidar Calibration – see appendix 1 for a more detailed workflow description

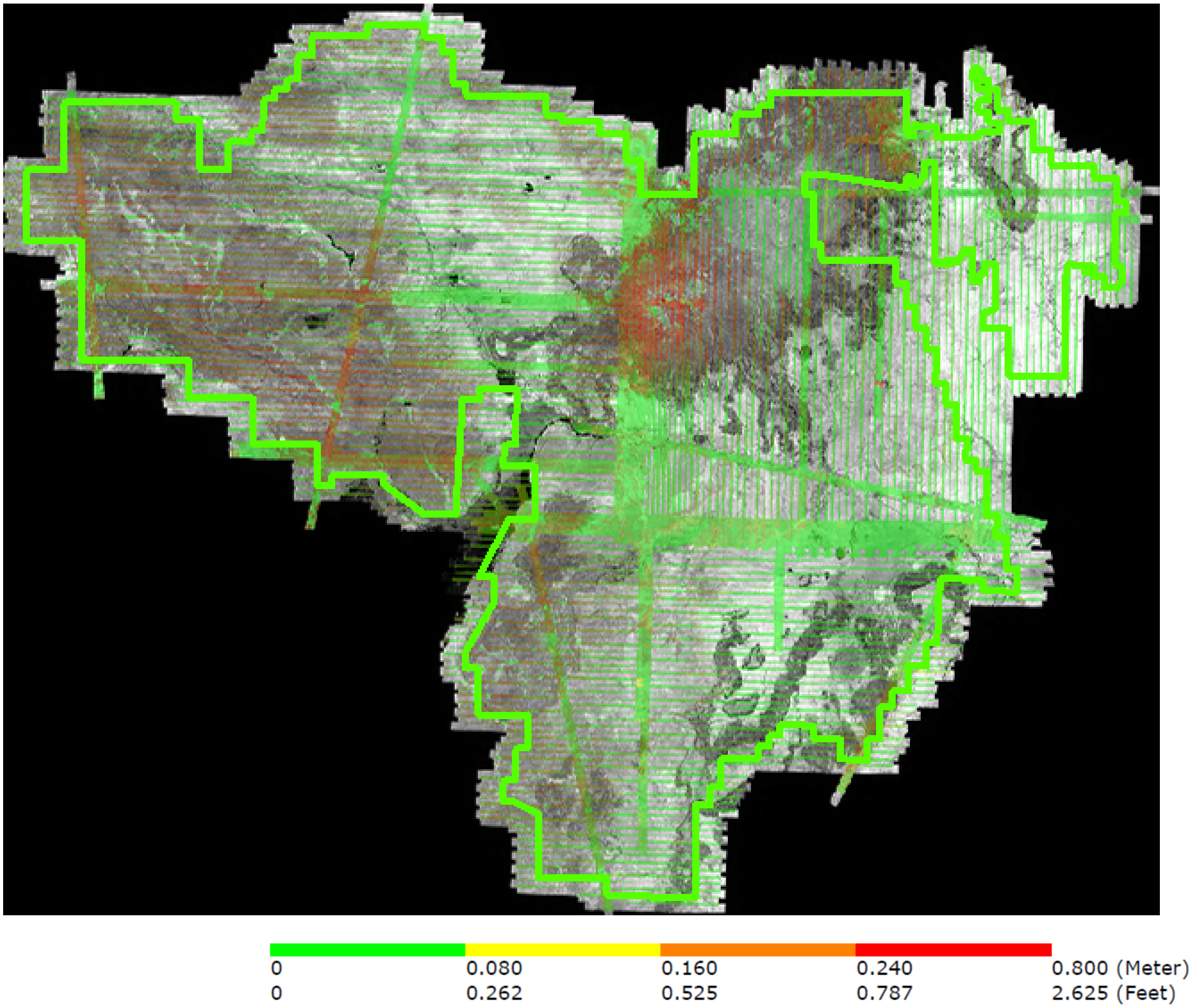
Merrick-Surdex JV takes great care to ensure all lidar acquisition missions are carried out in a manner conducive to post-processing an accurate data set. This begins in the flight-planning stage with attention to GPS baseline distances and GPS satellite constellation geometry and outages. Proper AGPS surveying techniques are always followed including pre- and post-mission static initializations. In-air IMU alignments (figure-eights) are performed both before and after on-site collection to ensure proper calibration of the IMU accelerometers and gyros.

A minimum of one cross-flight is planned throughout the project area across all flightlines and over roadways where possible. The cross-flight provides a common control surface used to remove any vertical discrepancies in the lidar data between flightlines. The cross-flight is critical to ensure flightline ties across the project area. The areas of overlap between flightlines are used to boresight (calibrate) the lidar point cloud to achieve proper flightline to flightline alignment in all three axes. This includes adjustment of both IMU and scanner-related variables such as roll, pitch, heading, timing interval (range), and torsion. Each lidar mission flown is accompanied by a hands-on boresight in the office.

After boresighting is complete a detailed statistical report is generated to check relative and absolute accuracies before filtering of lidar begins.

Relative Accuracy – flight line to flight line

This graphic shows the vertical separation of flight lines by thematically coloring the separation magnitude on a color ramp based on absolute distance. This color thematic rendering is modulated by intensity to show land cover features.



Unfiltered lidar Control Point Report

The following tables illustrate the results of the lidar data compared to the lidar control points post-calibration. The listing is sorted by the Z Error column showing, in ascending order, the vertical difference between the lidar points and the 46 surveyed ground points used for lidar calibration.

Project Data Unit: Meter
Vertical Accuracy Class tested: 10.0-cm
Elevation Calculation Method: Interpolated from TIN
LiDAR Classifications Included: 0-255

Check Points in Report: 46
Check Points with LiDAR Coverage: 46
Check Points (NVA): 46
Check Points (VVA): 0
Average Vertical Error Reported: 0.000 Meter
Maximum (highest) Vertical Error Reported: 0.094 Meter
Median Vertical Error Reported: 0.004 Meter
Minimum (lowest) Vertical Error Reported: -0.122 Meter
Standard deviation of Vertical Error: 0.049 Meter
Skewness of Vertical Error: -0.362
Kurtosis of Vertical Error: 0.189
Non-vegetated Vertical Accuracy (NVA) RMSE(z): 4.797cm PASS
Non-vegetated Vertical Accuracy (NVA) at the 95% Confidence Level +/-: 9.403cm PASS
FGDC/NSSDA Vertical Accuracy at the 95% Confidence Level +/-: 9.403cm
Non-vegetated Vertical Accuracy (NVA) RMSE(z) (DEM): 8.990cm PASS
Non-vegetated Vertical Accuracy (NVA) at the 95% Confidence Level +/- (DEM): 17.621cm PASS

This data set was tested to meet ASPRS Positional Accuracy Standard for Digital Geospatial Data (2014) for a 10.0-cm RMSEz Vertical Accuracy Class. Actual NVA accuracy was found to be RMSEz = 4.797cm, equating to +/- 9.403cm at the 95% confidence level.

Check Point Id	Check Point X	Check Point Y	Coverage	Check Point Z	Z from lidar	Z Error
4001	226695.857	3908985.653	Yes	2029.231	2029.254	0.023
4002	273283.913	3844443.49	Yes	1821.074	1821.102	0.028
4003	207128.209	3921724.726	Yes	2173.721	2173.693	-0.028
4004	178323.611	3930499.004	Yes	2136.643	2136.71	0.067
4005	256223.342	3840589.855	Yes	2248.559	2248.589	0.03
4006	295650.538	3852826.336	Yes	1875.648	1875.698	0.05
4007	202412.674	3898306.679	Yes	2449.935	2449.905	-0.03
4008	242523.893	3830541.428	Yes	2368.146	2368.12	-0.026
4008_2	242049.11	3830518.416	Yes	2377.757	2377.77	0.013
4009	242062.341	3907488.129	Yes	2024.791	2024.805	0.014
4010	246137.552	3859877.569	Yes	2401.178	2401.215	0.037
4011	319746.927	3895017.182	Yes	1679.186	1679.219	0.033
4012	287842.808	3877201.086	Yes	1735.048	1735.087	0.039
4013	216946.162	3878684.005	Yes	2388.475	2388.453	-0.022
4014	276568.254	3887223.851	Yes	1914.463	1914.387	-0.076
4015	257509.909	3822356.152	Yes	2002.639	2002.525	-0.114
4016	238235.704	3890889.946	Yes	1970.653	1970.62	-0.033
4017	308276.497	3916134.654	Yes	1822.449	1822.441	-0.008
4018	308679.908	3873927.209	Yes	1708.152	1708.246	0.094
4019	294476.576	3888994.215	Yes	1792.665	1792.699	0.034
4020	259570.456	3916551.821	Yes	2209.221	2209.21	-0.011
4021	181833.213	3902452.579	Yes	2198.373	2198.333	-0.04
4022	241934.349	3922780.681	Yes	2124.908	2124.883	-0.025
4023	261974.782	3881441.125	Yes	1872.027	1872.069	0.042
4024	215190.66	3927115.903	Yes	2196.595	2196.552	-0.043

4025	260854.37	3905430.422	Yes	2885.302	2885.222	-0.08
4026	273143.201	3915185.396	Yes	2583.763	2583.641	-0.122
4027	213442.29	3896386.157	Yes	2585.202	2585.189	-0.013
4028	274512.216	3855471.509	Yes	1775.913	1775.984	0.071
4029	243086.967	3848853.838	Yes	2443.325	2443.25	-0.075
4030	312342.34	3860368.341	Yes	1609.658	1609.74	0.082
4031	315200.731	3906065.553	Yes	1739.084	1739.077	-0.007
4032	258571.708	3857069.462	Yes	2207.843	2207.851	0.008
4033	174390.547	3918760.641	Yes	2419.893	2419.879	-0.014
4034	293061.719	3898717.547	Yes	1904.861	1904.853	-0.008
4035	251336.796	3900615.488	Yes	2191.112	2191.121	0.009
4036	194827.938	3891360.343	Yes	2201.948	2201.913	-0.035
4037	284015.346	3868660.277	Yes	1784.758	1784.789	0.031
4038	286436.277	3839339.718	Yes	1991.139	1991.142	0.003
4039	231725.862	3872206.447	Yes	2110.93	2110.948	0.018
4040	270596.559	3872127.241	Yes	1856.697	1856.686	-0.011
4041	329596.637	3917340.216	Yes	1912.455	1912.459	0.004
4042	216490.105	3938072.668	Yes	2215.871	2215.964	0.093
4043	187163.716	3914116.454	Yes	2411.932	2411.895	-0.037
4044	243923.944	3881284.676	Yes	1985.1	1985.13	0.03
4045	282983.358	3931673.904	Yes	2446.118	2446.145	0.027

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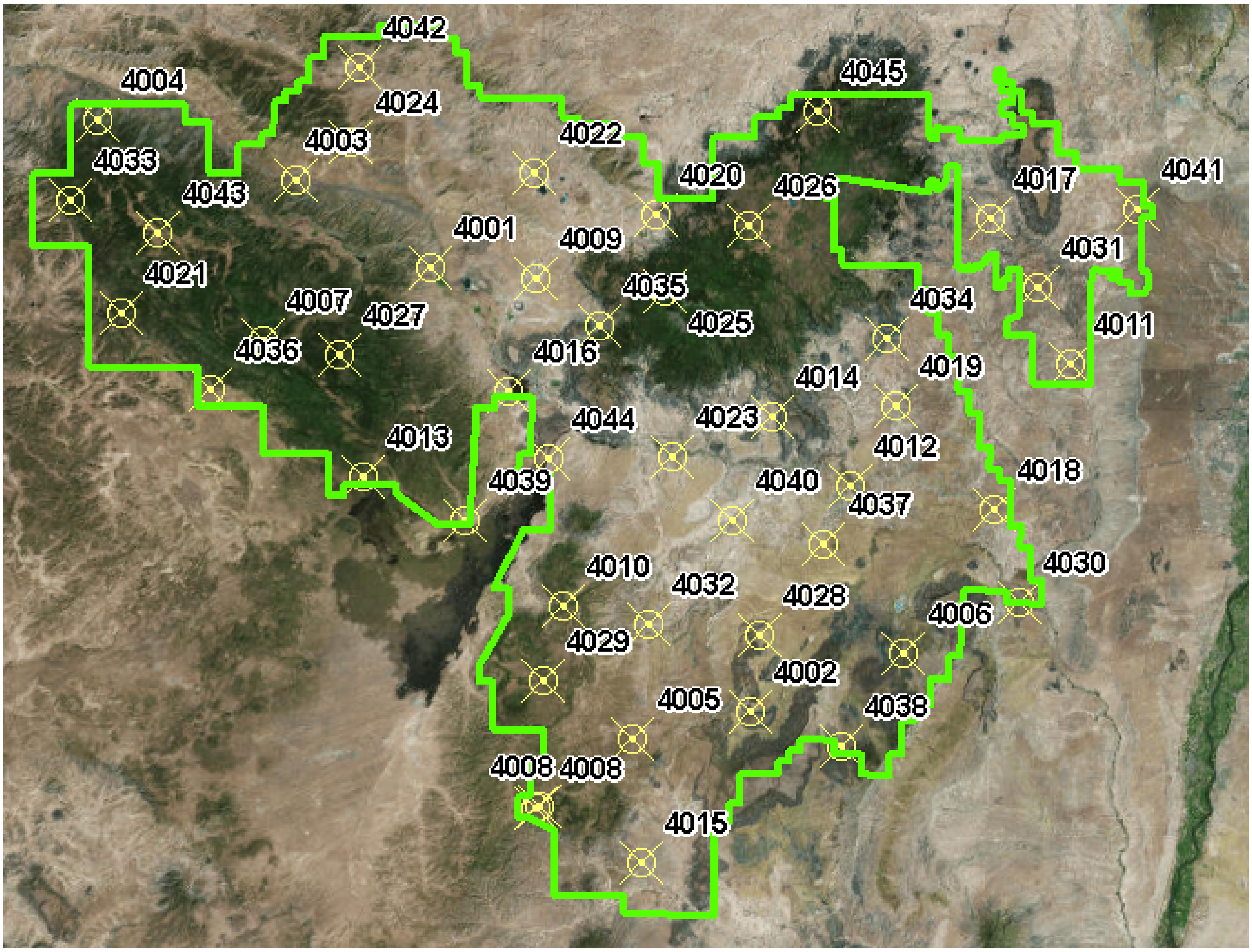
Lidar Control Point Layout



Lidar Filtering and Classification

The lidar filtering process encompasses a series of automated and manual steps to classify the boresighted point cloud data set. Each project represents unique characteristics in terms of cultural features (urbanized vs. rural areas), terrain type and vegetation coverage. These characteristics are thoroughly evaluated at the onset of the project to ensure that the appropriate automated filters are applied and that subsequent manual filtering yields correctly classified data. Data is most often classified by ground and "unclassified", but specific project applications can include a wide variety of classifications including but not limited to buildings, vegetation, power lines, etc. MARS® software is used for the auto-filtering, manual filtering and QC of the classified data.

Merrick-Surdex JV used the American Society for Photogrammetry and Remote Sensing's (ASPRS) LAS Specification Version 1.4 – Point Data Record Format 6, 7, 8, 9, or 10.R13, 15 July 2013 for this project and classified the lidar point cloud in accordance with the following classification classes and bitflags. Classes highlighted in GREEN represent project specific requirements.

- Class 1 = Unclassified
- Class 2 = Bare-earth Ground
- Class 3 = Low Vegetation

- Class 4 = Medium Vegetation
- Class 5 = High Vegetation
- Class 6 = Buildings
- Class 7 = Low point (noise)
- Class 8 = Model Key Points
- Class 9 = Water
- Class 10 = Ignored ground (near a breakline)
- Class 17 = Bridge decks
- Class 18 = High noise
- Bitflags
  - Overlap: Any part of a swath that also is covered by any part of any other swath.
  - Withhled: Within the LAS file specification, a single bit flag indicating that the associated lidar point is geometrically anomalous or unreliable and should be ignored for all normal processes.

Merrick-Surdex JV has developed several customized automated filters that are applied to the lidar data set based on project specifications, terrain, and vegetation characteristics. A filtering macro, which may contain one or more filtering algorithms, is executed to derive LAS files separated into the different classification groups as defined in the ASPRS classification table. The macros are tested in several portions of the project area to verify the appropriateness of the filters. Often, there is a combination of several filter macros that optimize the filtering based on the unique characteristics of the project. Automatic filtering generally yields a ground surface that is 85-90% valid, so additional editing (hand-filtering) is required to produce a more robust ground surface.

Lidar data is next taken into a graphic environment using MARS® to manually re-classify (or hand-filter) "noise" and other features that may remain in the ground classification after auto filter. A cross-section of the post auto-filtered surface is viewed to assist in the reclassification of non-ground data artifacts. The following is an example of re-classification of the non-ground points (elevated features) that need to be excluded from the true ground surface. Certain features such as berms, hilltops, cliffs and other features may have been aggressively auto-filtered and points will need to be re-classified into the ground classification. Data in the profile view displays non-ground (Unclassified, class 1) in grey and ground in brown/tan (Class 2). In figure 1, a small building was not auto-filtered and needs to be manually re-classified. Note that figure 2 has the building points reclassified to unclassified from the true ground surface.

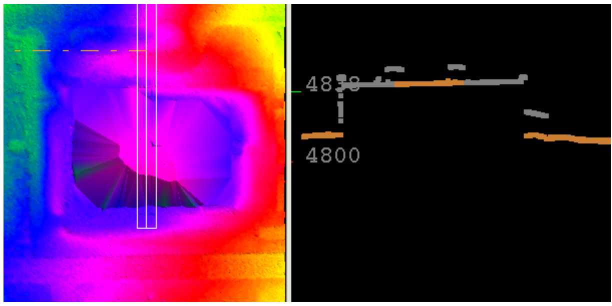


Figure 1

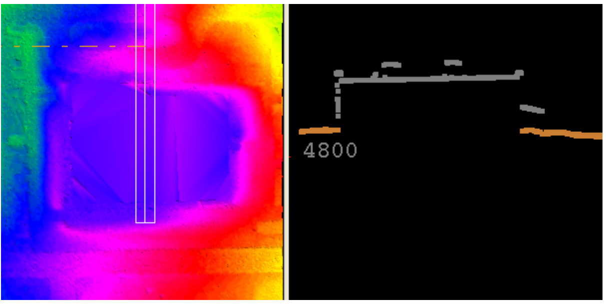


Figure 2

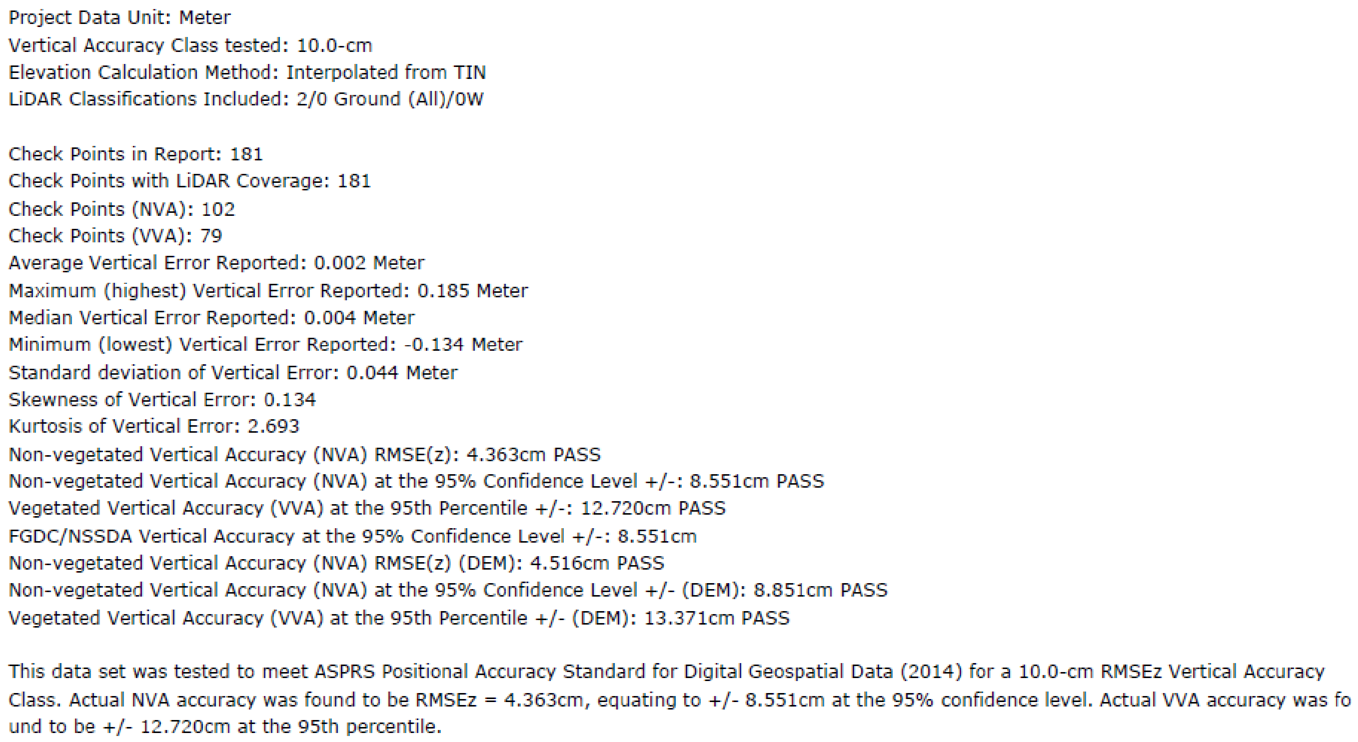
A combination of automated and semi-automated routines to classify buildings and vegetation. We expect that the classified buildings will meet a filtering criterion in the range of 90-95%.

At this point, individual lidar points from the original point cloud have now been parsed into separate classifications.

After the hand-filtering has been completed and quality checked, a Check Point Report is generated to validate that the accuracy of the ground surface is within the defined accuracy specifications. Each surveyed ground check point is compared to the lidar surface by interpolating an elevation from a Triangulated Irregular Network (TIN) of the surface. The MARS® derived report provides an in-depth statistical report, including an RMSE of the vertical errors; a primary component in most accuracy standards and a statistically valid assessment of the overall accuracy of the ground surface.

The below lidar check point report provides statistics for 101 NVA and 79 VVA ground survey points used to validate the final filtered lidar surface. Two NVA points were not included in the final vertical accuracy assessment due to access issues in the area resulting in the points being outside the Defined Project Area (DPA) boundary. Point numbers 2004 and 2063. An Esri shapefile was included showing these points (pts_NVA_NotUsed_OutsideDPA_2total.shp) and displayed in the below graphic.

Filtered lidar Check Point Report



Project Data Unit: Meter
Vertical Accuracy Class tested: 10.0-cm
Elevation Calculation Method: Interpolated from TIN
LiDAR Classifications Included: 2/0 Ground (All)/0W

Check Points in Report: 181
Check Points with LiDAR Coverage: 181
Check Points (NVA): 102
Check Points (VVA): 79
Average Vertical Error Reported: 0.002 Meter
Maximum (highest) Vertical Error Reported: 0.185 Meter
Median Vertical Error Reported: 0.004 Meter
Minimum (lowest) Vertical Error Reported: -0.134 Meter
Standard deviation of Vertical Error: 0.044 Meter
Skewness of Vertical Error: 0.134
Kurtosis of Vertical Error: 2.693
Non-vegetated Vertical Accuracy (NVA) RMSE(z): 4.363cm PASS
Non-vegetated Vertical Accuracy (NVA) at the 95% Confidence Level +/-: 8.551cm PASS
Vegetated Vertical Accuracy (VVA) at the 95th Percentile +/-: 12.720cm PASS
FGDC/NSSDA Vertical Accuracy at the 95% Confidence Level +/-: 8.551cm
Non-vegetated Vertical Accuracy (NVA) RMSE(z) (DEM): 4.516cm PASS
Non-vegetated Vertical Accuracy (NVA) at the 95% Confidence Level +/- (DEM): 8.851cm PASS
Vegetated Vertical Accuracy (VVA) at the 95th Percentile +/- (DEM): 13.371cm PASS

This data set was tested to meet ASPRS Positional Accuracy Standard for Digital Geospatial Data (2014) for a 10.0-cm RMSEz Vertical Accuracy Class. Actual NVA accuracy was found to be RMSEz = 4.363cm, equating to +/- 8.551cm at the 95% confidence level. Actual VVA accuracy was found to be +/- 12.720cm at the 95th percentile.

Check Point Id	Check Point X	Check Point Y	Coverage	Check Point Z	Z from Lidar	Z Error	NVA or VVA
2065	273455.922	3914765.565	Yes	2602.317	2602.183	-0.134	NVA
2017	289417.753	3934120.322	Yes	2460.252	2460.136	-0.116	NVA
2067	271303.747	3895908.05	Yes	2213.058	2212.96	-0.098	NVA
2088	276272.042	3895486.397	Yes	2330.511	2330.433	-0.078	NVA
2086	263587.808	3907308.259	Yes	2722.605	2722.537	-0.068	NVA
2021	174920.481	3918902.029	Yes	2515.035	2514.976	-0.059	NVA
2011	192650.767	3908264.436	Yes	2493.108	2493.05	-0.058	NVA
2096	278925.676	3925581.865	Yes	2521.223	2521.166	-0.057	NVA
2044	224382.361	3891863.033	Yes	2351.417	2351.365	-0.052	NVA

2008	246753.396	3888101.953	Yes	1939.44	1939.389	-0.051	NVA
2030	196222.002	3891419.378	Yes	2213.354	2213.306	-0.048	NVA
2025	250997.784	3907714.867	Yes	2450.512	2450.465	-0.047	NVA
2075	202705.453	3898200.575	Yes	2448.189	2448.143	-0.046	NVA
2041	257676.819	3892296.416	Yes	2044.035	2043.989	-0.046	NVA
2085	277188.148	3881278.942	Yes	1807.679	1807.638	-0.041	NVA
2018	213930.2	3933408.467	Yes	2264.138	2264.102	-0.036	NVA
2058	292603.299	3932990.763	Yes	2416.674	2416.639	-0.035	NVA
2026	267734.309	3832776.565	Yes	2213.884	2213.852	-0.032	NVA
2024	281450.555	3929864.333	Yes	2484.547	2484.515	-0.032	NVA
2080	295329.71	3902908.054	Yes	1998.66	1998.628	-0.032	NVA
2033	242395.488	3932121.712	Yes	2263.496	2263.465	-0.031	NVA
2049	194336.008	3927968.816	Yes	2177.556	2177.526	-0.03	NVA
2046	220351.762	3918635.273	Yes	2099.248	2099.22	-0.028	NVA
2081	251721.992	3915064.269	Yes	2114.509	2114.482	-0.027	NVA
2005	183197.344	3916278.243	Yes	2418.645	2418.621	-0.024	NVA
2013	230399.166	3919521.421	Yes	2173.255	2173.232	-0.023	NVA
2090	269259.495	3917517.537	Yes	2510.469	2510.447	-0.022	NVA
2048	286381.941	3879669.788	Yes	1731.46	1731.441	-0.019	NVA
2047	253994.911	3848109.065	Yes	2306.305	2306.287	-0.018	NVA
2038	260433.869	3816309.153	Yes	1959.941	1959.926	-0.015	NVA
2072	185710.365	3898333.476	Yes	2123.19	2123.176	-0.014	NVA
2016	241107.012	3913445.393	Yes	2122.899	2122.887	-0.012	NVA
2103	206878.713	3930358.351	Yes	2531.685	2531.673	-0.012	NVA
2102	303709.914	3920965.619	Yes	1834.723	1834.712	-0.011	NVA
2014	206558.029	3895900.648	Yes	2441.097	2441.086	-0.011	NVA
2040	314456.261	3907952.623	Yes	1749.668	1749.657	-0.011	NVA
2006	265321.487	3849067.1	Yes	2193.586	2193.576	-0.01	NVA
2056	259829.228	3863861.222	Yes	1954.022	1954.012	-0.01	NVA
2019	301766.529	3882657.174	Yes	1965.287	1965.278	-0.009	NVA
2031	178111.575	3929402.621	Yes	2204.706	2204.699	-0.007	NVA
2055	309491.479	3936609.814	Yes	1820.037	1820.031	-0.006	NVA
2093	326954.917	3922386.499	Yes	1842.176	1842.17	-0.006	NVA
2062	212924.091	3911258.108	Yes	2282.9	2282.894	-0.006	NVA
2060	219149.111	3883448.902	Yes	2379.17	2379.165	-0.005	NVA
2022	295661.339	3857586.401	Yes	1779.116	1779.112	-0.004	NVA
2037	216615.208	3930065.465	Yes	2247.764	2247.762	-0.002	NVA
2066	225759.182	3935599.235	Yes	2177.969	2177.968	-0.001	NVA
2087	315667.458	3918328.627	Yes	2074.909	2074.909	0	NVA
2059	251009.918	3869198.369	Yes	2049.068	2049.069	0.001	NVA
2010	273952.892	3888736.838	Yes	1933.701	1933.703	0.002	NVA
2034	260066.676	3823192.982	Yes	2055.302	2055.306	0.004	NVA
2007	290750.937	3886112.551	Yes	1804.748	1804.752	0.004	NVA
2101	266398.341	3853701.569	Yes	2180.469	2180.473	0.004	NVA

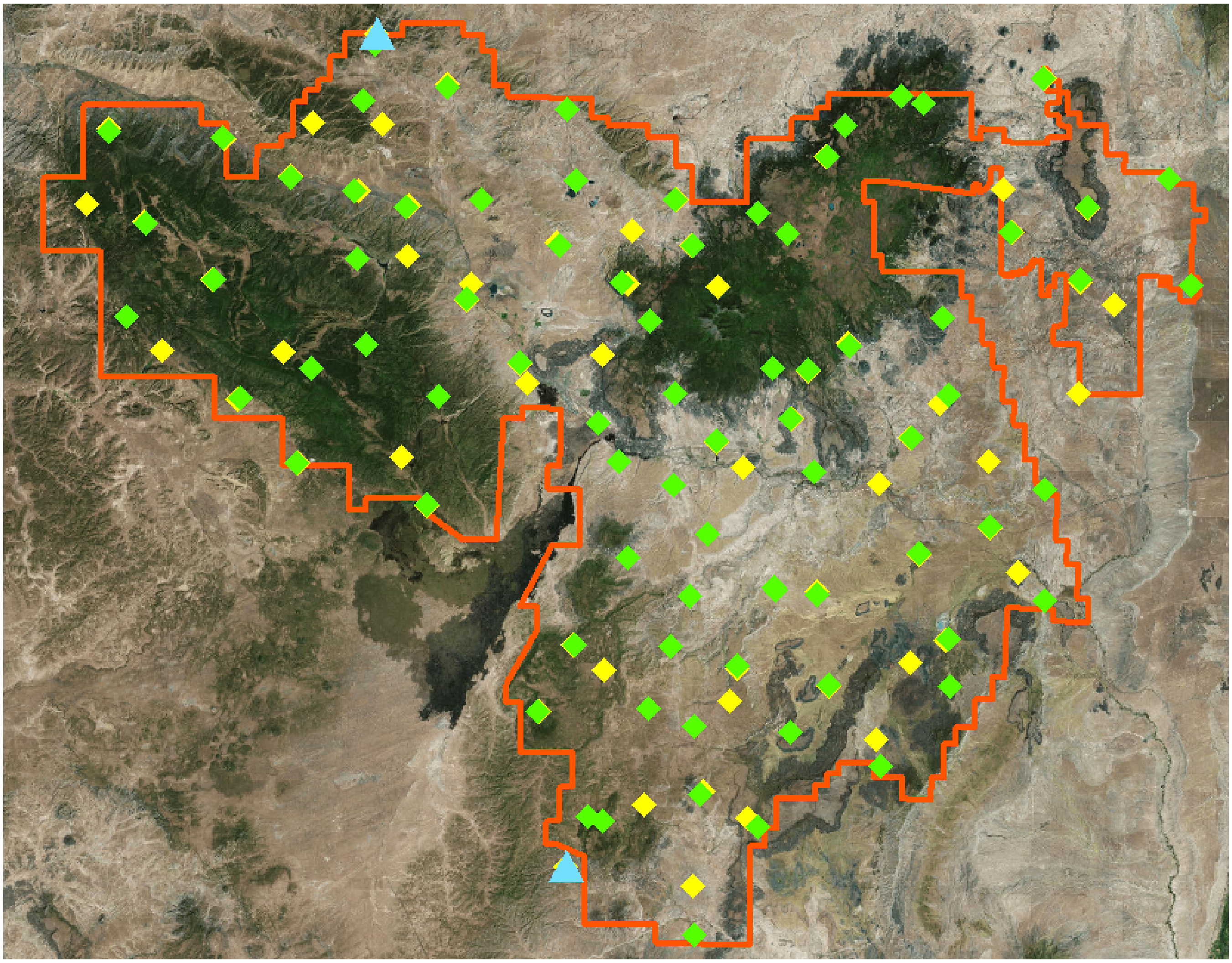
2039	235930.304	3896343.573	Yes	1987.4	1987.405	0.005	NVA
2043	222750.689	3876596.439	Yes	2282.685	2282.69	0.005	NVA
2045	213205.377	3920666.357	Yes	2139.629	2139.636	0.007	NVA
2079	254208.679	3902474.605	Yes	2279.712	2279.72	0.008	NVA
2009	204714.134	3882458.549	Yes	2251.936	2251.944	0.008	NVA
2094	247613.803	3853557.056	Yes	2403.697	2403.707	0.01	NVA
2029	260022.101	3913052.143	Yes	2239.564	2239.574	0.01	NVA
2091	220043.409	3911650.171	Yes	2223.791	2223.803	0.012	NVA
2057	273874.981	3844655.912	Yes	1820.22	1820.235	0.015	NVA
2076	267167.108	3881803.483	Yes	1832.784	1832.8	0.016	NVA
2074	305906.654	3867198.932	Yes	1659.494	1659.511	0.017	NVA
2042	257038.087	3856786.194	Yes	2178.363	2178.38	0.017	NVA
2071	277665.424	3864409.029	Yes	1780.484	1780.501	0.017	NVA
2097	271848.756	3864731.004	Yes	1833.392	1833.413	0.021	NVA
2073	314399.99	3892257.371	Yes	1758.272	1758.293	0.021	NVA
2001	294840.82	3890772.662	Yes	1807.543	1807.564	0.021	NVA
2002	257351.506	3879450.929	Yes	1914.467	1914.488	0.021	NVA
2003	253222.307	3834483.097	Yes	2208.747	2208.768	0.021	NVA
2070	180553.467	3903012.78	Yes	2168.976	2169	0.024	NVA
2032	286532.171	3839927.711	Yes	1985.523	1985.548	0.025	NVA
2052	260336.972	3845654.716	Yes	2235.773	2235.799	0.026	NVA
2020	229008.657	3907550.654	Yes	2022.243	2022.269	0.026	NVA
2064	243404.146	3857054.732	Yes	2406.275	2406.303	0.028	NVA
2054	262282.837	3872485.049	Yes	2021.433	2021.463	0.03	NVA
2053	245323.645	3833000.765	Yes	2322.73	2322.76	0.03	NVA
2051	319324.134	3904697.949	Yes	1677.971	1678.007	0.036	NVA
2092	228338.543	3905352.313	Yes	2022.963	2022.999	0.036	NVA
2083	330177.232	3907385.359	Yes	1877.069	1877.106	0.037	NVA
2012	282045.535	3899286.467	Yes	1979.468	1979.506	0.038	NVA
2068	249692.732	3882754.869	Yes	1947.022	1947.06	0.038	NVA
2035	243820.233	3922240.655	Yes	2124.052	2124.091	0.039	NVA
2095	301818.023	3873439.824	Yes	1699.467	1699.507	0.04	NVA
2082	257786.872	3919467.75	Yes	2272.171	2272.212	0.041	NVA
2036	203749.419	3922703.685	Yes	2190.65	2190.691	0.041	NVA
2028	238481.808	3847636.132	Yes	2482.108	2482.151	0.043	NVA
2078	304904.531	3914832.828	Yes	1853.241	1853.285	0.044	NVA
2015	247551.75	3897582.236	Yes	2091.238	2091.285	0.047	NVA
2077	309509.608	3878773.81	Yes	1701.242	1701.289	0.047	NVA
2084	214274.354	3899196.803	Yes	2470.72	2470.77	0.05	NVA
2050	291963.805	3869742.073	Yes	1700.972	1701.028	0.056	NVA
2061	290573.056	3854452.88	Yes	1855.944	1856.002	0.058	NVA
2027	296189.817	3851176.461	Yes	1898.972	1899.032	0.06	NVA
2023	261531.973	3836409.149	Yes	2135.261	2135.322	0.061	NVA
2099	236840.141	3893808.716	Yes	1990.158	1990.222	0.064	NVA

2089	309625.758	3863306.629	Yes	1620.56	1620.629	0.069	NVA
2100	263564.916	3885521.128	Yes	1887.1	1887.172	0.072	NVA
2069	285959.163	3843705.049	Yes	1949.252	1949.328	0.076	NVA
2098	279294.046	3851264.111	Yes	1761.962	1762.147	0.185	NVA
3052	273421.845	3914745.517	Yes	2602.177	2602.099	-0.078	VVA
3024	196572.977	3891662.48	Yes	2220.16	2220.084	-0.076	VVA
3073	278947.047	3925560.432	Yes	2521.608	2521.536	-0.072	VVA
3006	246801.438	3888147.767	Yes	1935.86	1935.793	-0.067	VVA
3054	271289.801	3895856.389	Yes	2213.02	2212.968	-0.052	VVA
3033	257663.532	3892314.025	Yes	2046.006	2045.955	-0.051	VVA
3036	224373.107	3891854.914	Yes	2351.182	2351.136	-0.046	VVA
3015	213930.162	3933391.697	Yes	2264.538	2264.493	-0.045	VVA
3040	194065.81	3928120.388	Yes	2174.971	2174.93	-0.041	VVA
3039	253971.509	3848083.645	Yes	2305.9	2305.864	-0.036	VVA
3061	295314.898	3902911.437	Yes	1998.807	1998.773	-0.034	VVA
3064	214240.284	3899204.25	Yes	2472.14	2472.11	-0.03	VVA
3020	269262.015	3831505.898	Yes	2257.603	2257.58	-0.023	VVA
3019	250088.235	3907910.532	Yes	2458.119	2458.096	-0.023	VVA
3011	230404.258	3919507.341	Yes	2172.548	2172.53	-0.018	VVA
3053	225684.201	3935213.423	Yes	2168.229	2168.223	-0.006	VVA
3074A	271859.827	3864749.293	Yes	1833.956	1833.95	-0.006	VVA
3063	330154.32	3907425.888	Yes	1874.642	1874.64	-0.002	VVA
3004	183363.47	3916258.607	Yes	2413.097	2413.098	0.001	VVA
3045	309418.891	3936551.346	Yes	1819.374	1819.376	0.002	VVA
3001	296067.044	3892094.367	Yes	1876.631	1876.636	0.005	VVA
3077	266341.975	3854030.82	Yes	2164.275	2164.281	0.006	VVA
3060	254202.529	3902432.784	Yes	2278.668	2278.676	0.008	VVA
3009	192814.812	3908242.13	Yes	2496.098	2496.108	0.01	VVA
3067	276309.189	3895525.641	Yes	2329.898	2329.911	0.013	VVA
3047	292525.535	3932907.705	Yes	2416.288	2416.305	0.017	VVA
3049	212939.402	3911243	Yes	2282.664	2282.681	0.017	VVA
3079	259812.95	3863873.277	Yes	1953.978	1953.998	0.02	VVA
3066	315649.012	3918357.318	Yes	2075.92	2075.94	0.02	VVA
3023	260054.456	3913026.349	Yes	2242.781	2242.802	0.021	VVA
3032	314440.358	3908326.71	Yes	1754.401	1754.426	0.025	VVA
3038	219967.366	3918428.595	Yes	2102.35	2102.375	0.025	VVA
3070	228340.063	3905471.792	Yes	2020.824	2020.849	0.025	VVA
3013	241413.455	3913060.046	Yes	2106.489	2106.516	0.027	VVA
3042	260340.93	3845669.71	Yes	2235.993	2236.021	0.028	VVA
3057	314373.906	3892232.117	Yes	1757.525	1757.554	0.029	VVA
3071	326939.586	3922387.294	Yes	1841.873	1841.902	0.029	VVA
3055	180559.487	3903018.386	Yes	2168.688	2168.717	0.029	VVA
3076	263545.129	3885578.481	Yes	1887.971	1888.002	0.031	VVA
3074	271662.657	3865148.596	Yes	1840.293	1840.325	0.032	VVA

3005	290775.917	3886112.34	Yes	1806.051	1806.088	0.037	VVA
3059	304873.653	3914840.207	Yes	1853.695	1853.733	0.038	VVA
3058	309495.436	3878809.349	Yes	1702.046	1702.085	0.039	VVA
3034	257020.998	3856804.117	Yes	2177.498	2177.539	0.041	VVA
3025	178157.13	3928996.272	Yes	2216.904	2216.945	0.041	VVA
3007	204600.982	3882440.982	Yes	2251.947	2251.993	0.046	VVA
3030	260439.438	3816326.323	Yes	1959.315	1959.365	0.05	VVA
3018	281434.85	3929855.241	Yes	2484.802	2484.852	0.05	VVA
3043	245316.732	3832987.852	Yes	2324.373	2324.424	0.051	VVA
3002	257381.314	3879439.687	Yes	1913.809	1913.864	0.055	VVA
3069	269291.881	3917515.673	Yes	2511.252	2511.314	0.062	VVA
3046	273878.196	3844700.726	Yes	1820.2	1820.264	0.064	VVA
3072	301782.135	3873634.6	Yes	1699.135	1699.201	0.066	VVA
3017	261284.487	3836044.402	Yes	2116.213	2116.281	0.068	VVA
3031	235947.05	3896627.517	Yes	1987.711	1987.783	0.072	VVA
3062	257744.23	3919451.251	Yes	2266.501	2266.58	0.079	VVA
3027	242408.963	3932126.79	Yes	2262.998	2263.078	0.08	VVA
3026	286510.566	3839958.035	Yes	1984.493	1984.574	0.081	VVA
3075	279318.078	3851280.755	Yes	1762.322	1762.405	0.083	VVA
3048	250995.189	3869226.93	Yes	2051.297	2051.382	0.085	VVA
3068	309636.244	3863318.28	Yes	1620.094	1620.182	0.088	VVA
3014	289421.093	3934098.987	Yes	2460.134	2460.227	0.093	VVA
3021	296187.96	3851190.671	Yes	1899.149	1899.242	0.093	VVA
3022	238446.892	3847616.745	Yes	2481.401	2481.494	0.093	VVA
3051	243503.313	3857009.769	Yes	2409.88	2409.976	0.096	VVA
3065	277201.027	3881345.908	Yes	1807.765	1807.861	0.096	VVA
3078	249667.749	3882762.73	Yes	1947.122	1947.22	0.098	VVA
3010	282222.472	3898885.431	Yes	1972.94	1973.045	0.105	VVA
3012	206617.961	3895891.495	Yes	2440.688	2440.795	0.107	VVA
3044	262294.934	3872477.534	Yes	2022.152	2022.268	0.116	VVA
3008	273943.201	3888771.798	Yes	1933.828	1933.947	0.119	VVA
3037	212554.768	3920804.653	Yes	2144.033	2144.154	0.121	VVA
3056	277591.422	3863987.474	Yes	1778.064	1778.189	0.125	VVA
3016	296023.634	3857734.195	Yes	1779.452	1779.579	0.127	VVA
3035	222761.112	3876614.891	Yes	2281.568	2281.698	0.13	VVA
3050	215429.509	3941248.577	Yes	2280.363	2280.5	0.137	VVA
3028	243825.217	3922263.103	Yes	2123.488	2123.628	0.14	VVA
3029	203749.063	3922689.411	Yes	2190.244	2190.373	0.129	VVA
3041	291991.363	3869786.007	Yes	1700.89	1701.009	0.119	VVA

Lidar Check Point Layout

- Yellow = NVA
- Green = VVA
- Blue = 2 NVA not used (outside the boundary)



Hydro-flattening Breakline Collection

Hydro- flattening breaklines are captured per the USGS National Geospatial Program Lidar Base Specification Version 1.2. Final hydro-flattened breaklines features are appropriately turned into polygons (flat elevations) and polylines (decreasing by elevation) and are used to reclassify ground points in water to Water (Class 9). The lidar points around the breaklines are reclassified to Ignored Ground (Class 10) based on predetermined buffer.

Linear hydrographic features

To collect hydrographic features, Merrick-Surdex JV uses a methodology that directly interacts with the lidar bare-earth data to collect drainage breaklines. To determine the alignment of a drainageway, the technician first views the area as a TIN of bare-earth points using a color ramp to depict varying elevations. In areas of extremely flat terrain, the technician may need to determine the direction of flow based on measuring lidar bare-earth points at each end of the drain. The operator will then use the color ramped TIN to digitize the drainage in 2D with the elevation being attributed directly from the bare-earth LAS data. MARS® software has the capability of "flipping" views between the elevation TIN, Intensity and imagery, as necessary, to further assist in the determination of the drainage. All drainage breaklines are collected in a downhill direction. For each point collected, the software uses a five-foot (5') search radius to identify the lowest point within that proximity. Within each radius, if a bare-earth point is not found that is lower than the previous point, the elevation for subsequent point remains the same as the previous point. This forces the drain to always flow in a downhill direction. Waterbodies that are embedded along a drainageway are validated to ensure consistency with the downhill direction of flow.

This methodology may differ from those of other vendors in that Merrick-Surdex JV relies on the bare-earth data to attribute breakline elevations. As a result of our methodology, there is no mismatch between lidar bare-earth data and breaklines that might otherwise be collected in stereo 3D as a separate process. This is particularly important in densely vegetated areas where breaklines collected in 3D from imagery will most likely not match (either horizontally or vertically), the more reliable lidar bare-earth data.

Merrick-Surdex JV has the capability of "draping" 2D breaklines to a bare-earth elevation model to attribute the "z" as opposed to the forced downhill attribution methodology described above. However, the problem with this process is the "pooling "effect or depressions along the drainageway caused by a lack of consistent penetration in densely vegetated areas.

Criteria of linear hydrographic breaklines are as follows:

- Linear hydrographic features (e.g., visible streams, rivers, shorelines, canals, etc.) greater than one hundred feet (100') wide will be captured as a double-lined polygon
    - linear hydrographic features must be flat and level bank-to-bank (perpendicular to the apparent flow centerline) with gradient following the immediately surrounding terrain
    - water surface edge must be at or just below the immediately surrounding terrain
    - streams should break at road crossings (e.g., culverts), and streams and rivers should not break at bridges

Waterbodies

Waterbodies are digitized from the color ramped TIN, similar to the process described above. The elevation attribute is determined as the technician collects the hydro feature by using the lowest bare-earth point within the polygon.

Criteria of waterbody breaklines are as follows:

- Waterbodies (e.g., lakes, ponds, reservoirs) greater than two (2) acres in size are surrounded by a water breakline (i.e., closed polygon)
    - waterbodies must be flat and level with a single elevation for every bank vertex
    - water surface edge must be at or just below the immediately surrounding terrain
    - long impoundments, such as reservoirs or inlets, whose water surface elevations drop when moving downstream should be treated as rivers

Color cycles provide a clear indication of where breaklines are to be collected, especially hydrographic breaklines. Figure 3 demonstrates no breaklines, where Figure 4 is breakline enforced displayed using color cycles within the MARS® software environment.

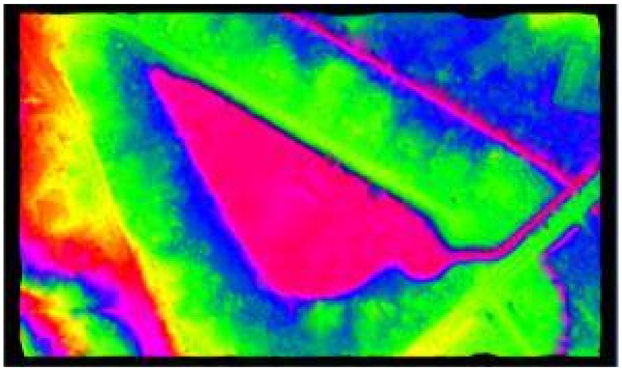


Figure 3

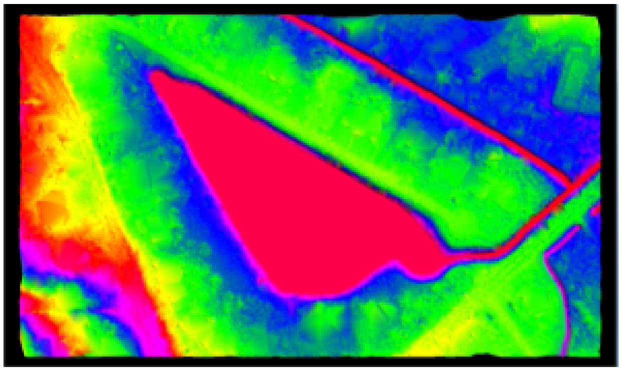


Figure 4

Bare-Earth Surface (DEM)

Merrick-Surdex JV exports the hydro-flattening breakline enforced Class 2 (ground) lidar points to a one-meter (1m) cell size, 32-bit format using MARS®, the DEMs are exported to the project tiling scheme. Projection information is applied that reflects the project requirements.

Intensity Images

Merrick-Surdex JV exports all lidar points to a one-meter (1m) cell size 16-bit client desired format using MARS®, the intensity images are exported to the project tiling scheme and / or project-wide boundary. Projection information is applied that reflects the project requirements.

List of Deliverables

- Raw lidar point cloud
    - Fully compliant ASPRS LAS 1.4, point record format 6, 7, 8, 9 or 10
    - Calibrated
    - By swath
    - Intensity values normalized to 16-bit
    - FGDC-compliant metadata
- Classified lidar point cloud
    - Fully compliant ASPRS LAS 1.4, point record format 6, 7, 8, 9 or 1
    - By tile
    - Intensity values normalized to 16-bit
    - FGDC-compliant metadata
- Bare-earth DEM
    - 1m cell size 32-bit DEM development in ERDAS IMG format
    - Bare-earth (hydro-flattened)
        - Culverts will not be removed from the DEMs

        - Bridges will be removed from the DEMs
    - By tile and by county
    - FGDC-compliant metadata
- Hydro-flattened breaklines
    - Project-wide Esri feature class(es) for insertion into file geodatabase
    - FGDC-compliant metadata
- Intensity Images
    - 1m cell size in GeoTIFF format
    - By tile and by county
    - FGDC-compliant metadata
- Control
    - Survey report
    - Esri shapefile format
    - FGDC-compliant metadata
- FGDC-compliant metadata (project level)
- Detailed lidar Mapping / Project Report

Appendix 1

Following is a more detailed lidar calibration workflow description.

LIDAR CALIBRATION AND BLOCK LAS OUTPUT

Note: All figures represented on the following pages are for general illustration purposes, and are not examples derived from the project.

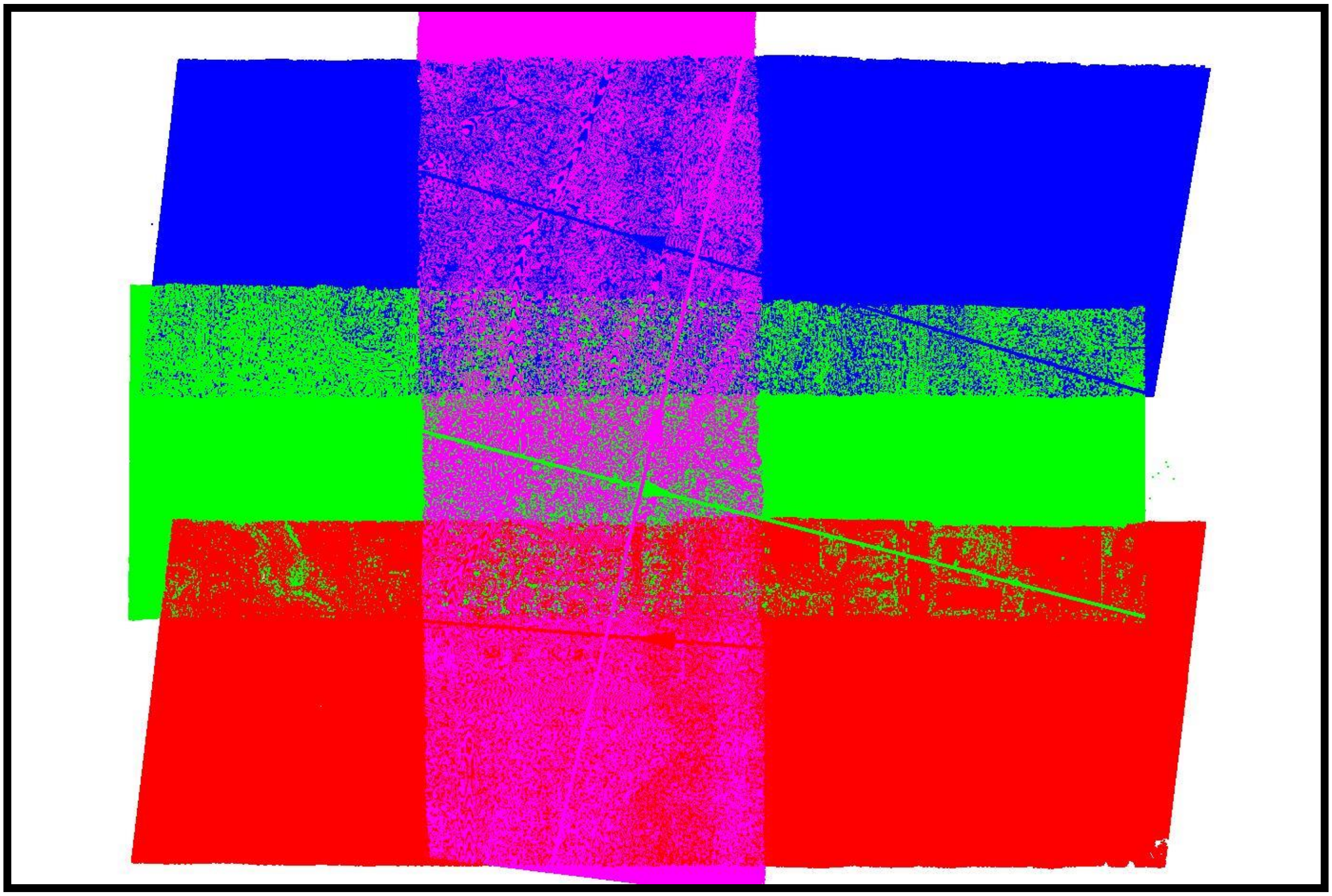
Initial Processing

Lidar data is output as LAS point data using Optech's Lidar Mapping Suite (LMS). LMS matches ground and roof planes plus roof lines to self-calibrate and correct system biases. These biases occur within the hardware of the laser scanning systems, within the Inertial Measurement Unit (IMU) and because of environmental conditions which affect the refraction of light. The systemic biases that are corrected for include scale, roll, pitch, and heading.

In addition to the self-calibration mode LMS runs a "production" mode which applies the self-calibration parameters and then analyzes each individual flight line and applies small adjustments to each line to tie overlapping lidar points even more tightly together.

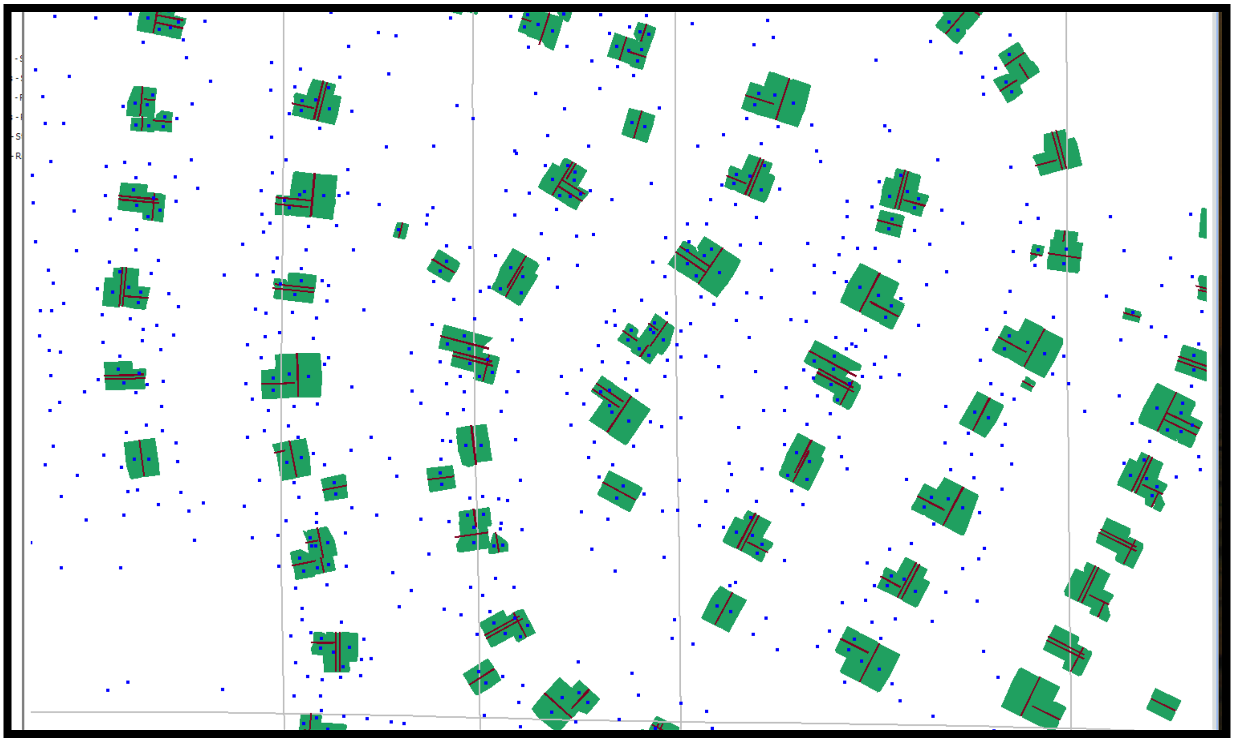
Boresight Self-Calibration Processing Procedures

An LMS boresight calibration is performed on an as-needed basis to correct scale, roll, pitch and heading biases. A minimum of three overlapping flights are flown in opposing directions with one cross flight.



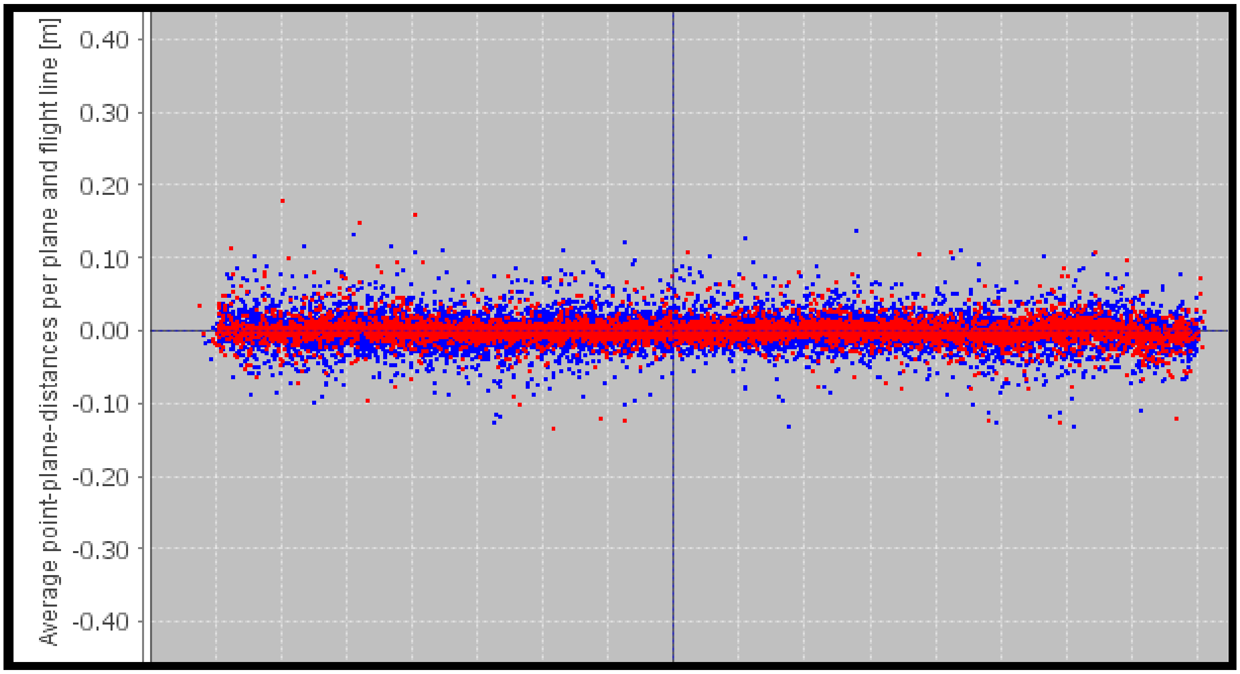
The Boresighting module frees scan angle scale, scan angle lag, XYZ boresight corrections and elevation position corrections while locking scan angle offset and XY position corrections.

The picked calibration site will have a good distribution of buildings for the self-calibration software to match ground planes, roof planes and roof lines.

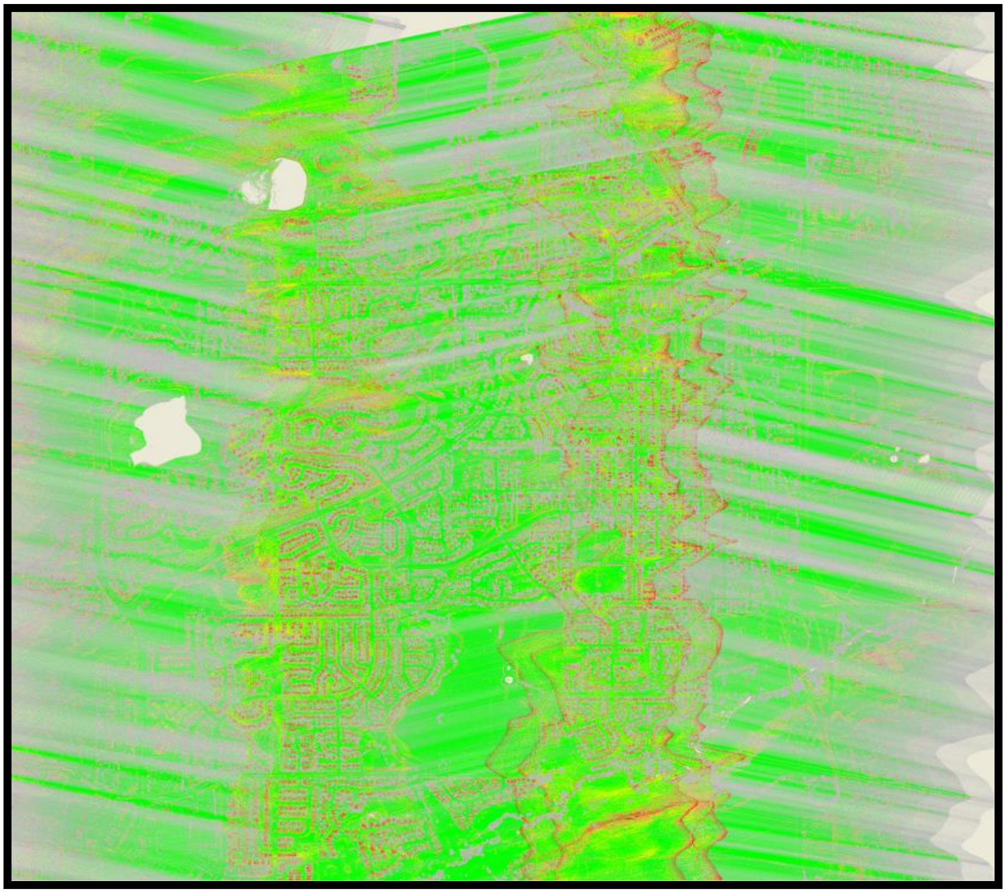


At the conclusion of the self-calibration run the data is quality checked with LMS plots

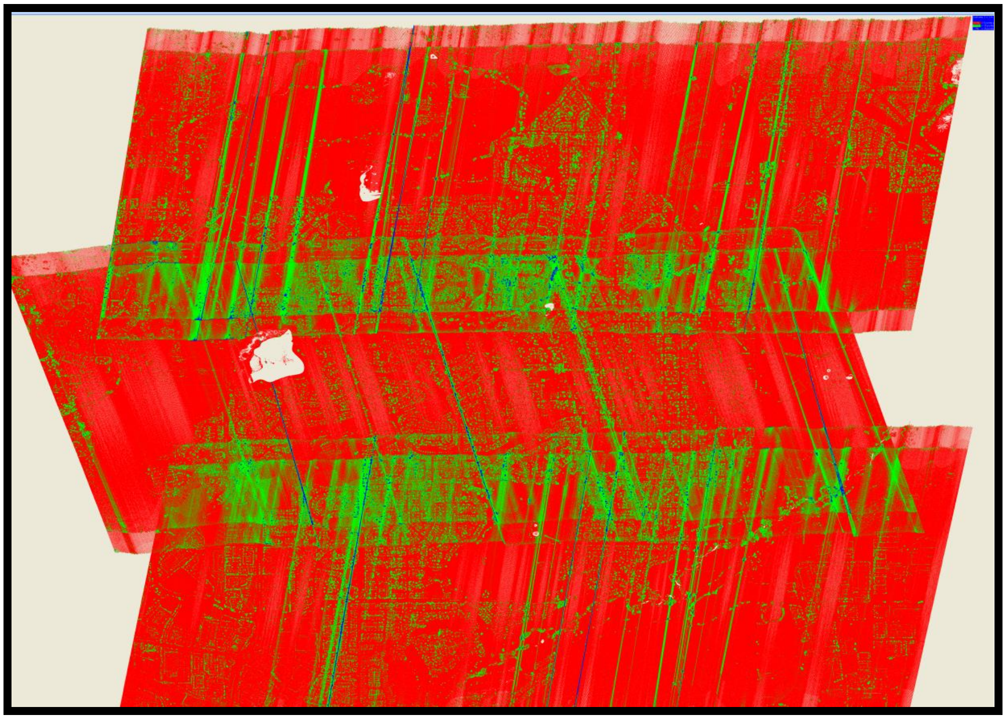
Plot of plane vertical distances from datum plane.



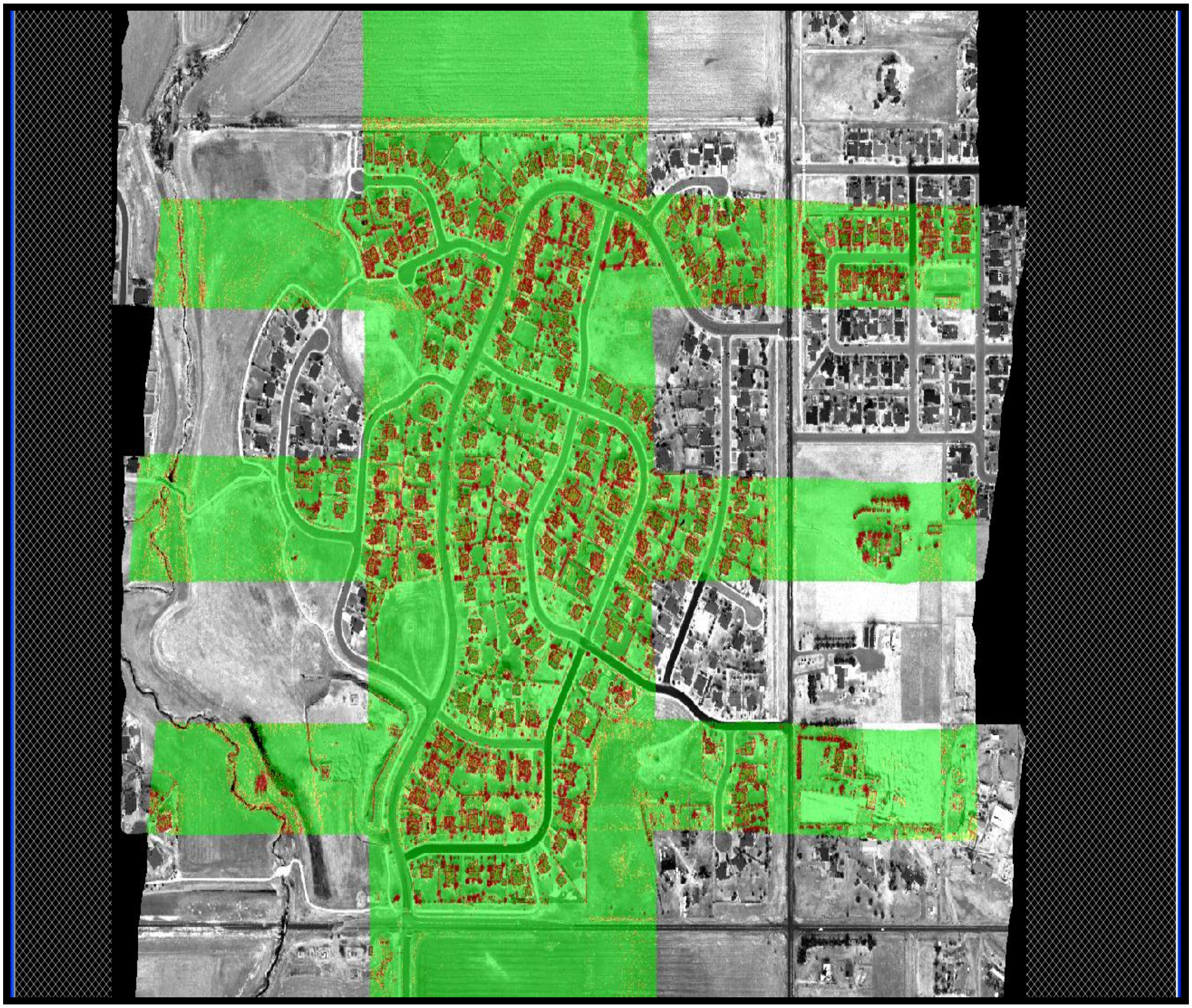
Plot of height differenced between flight lines. (Green=less than 5cm).



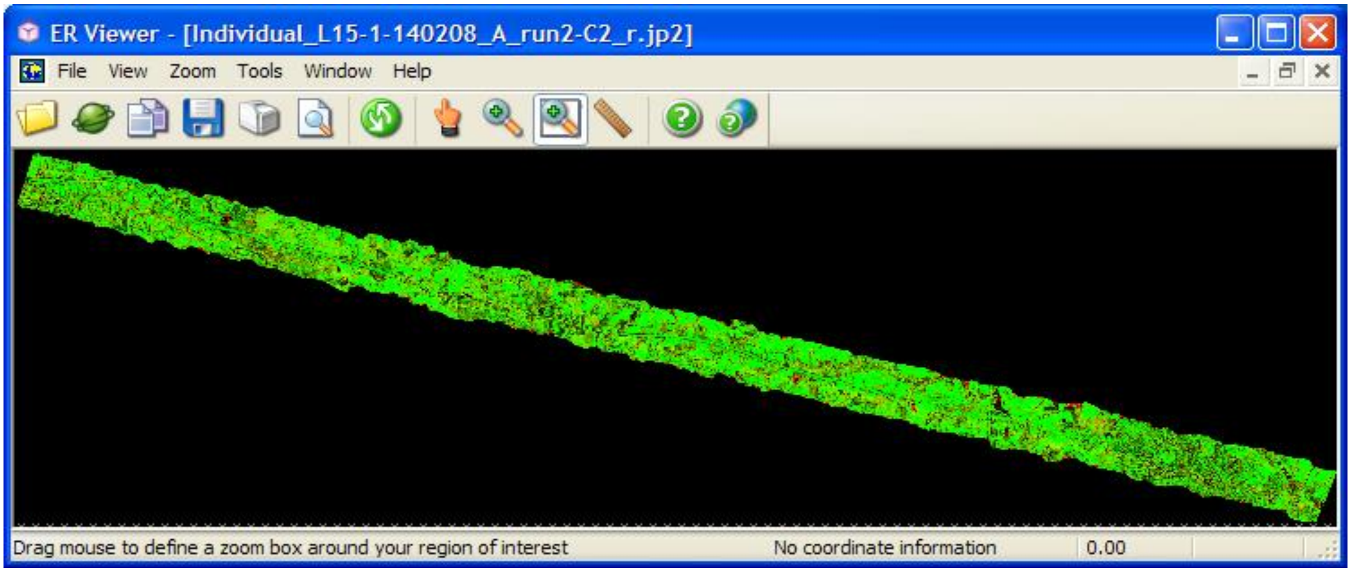
Plot of point densities. (Red=5-9 points per cell, green 10+ points per cell).



A Flight Line Separation Raster image is generated in Merrick Advanced Remote Sensing Software (MARS®), in this example ground returns from multiple flight lines that are fitting within 3 centimeters are colored green.



MARS® tests for internal relative vertical accuracy using inbound and outbound scan values. Again, Green is showing inbound and outbound scan data fitting to 3 centimeters.

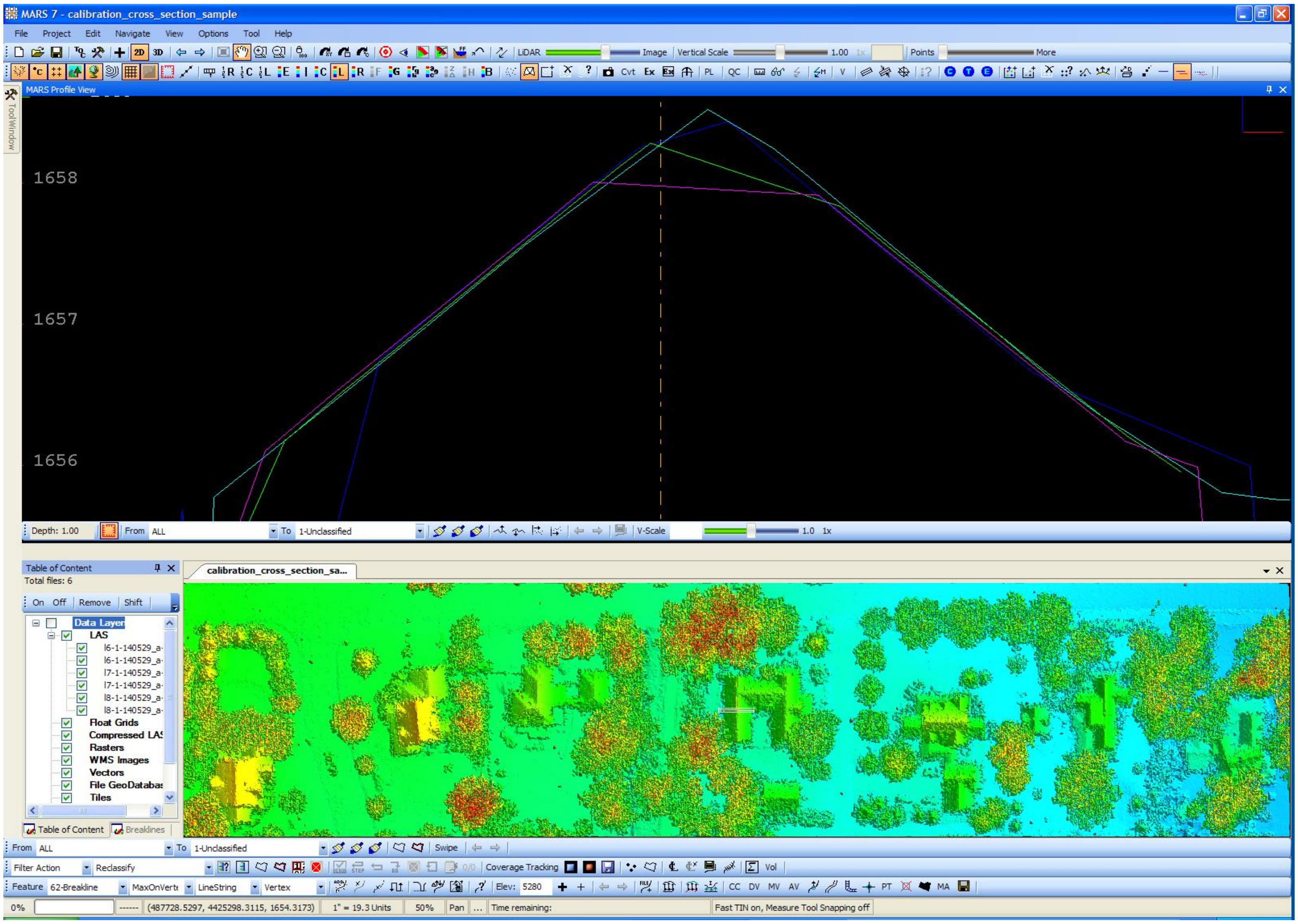

ER Viewer - [Individual_L15-1-140208_A_run2-C2_r.jp2]

Drag mouse to define a zoom box around your region of interest

No coordinate information

0.00

Building cross sections are checked for good alignment. Pitch and heading are checked on roof planes parallel to the flight direction.


MARS 7 - calibration_cross_section_sample

Depth: 1.00 From ALL To 1-Unclassified

Total files: 6

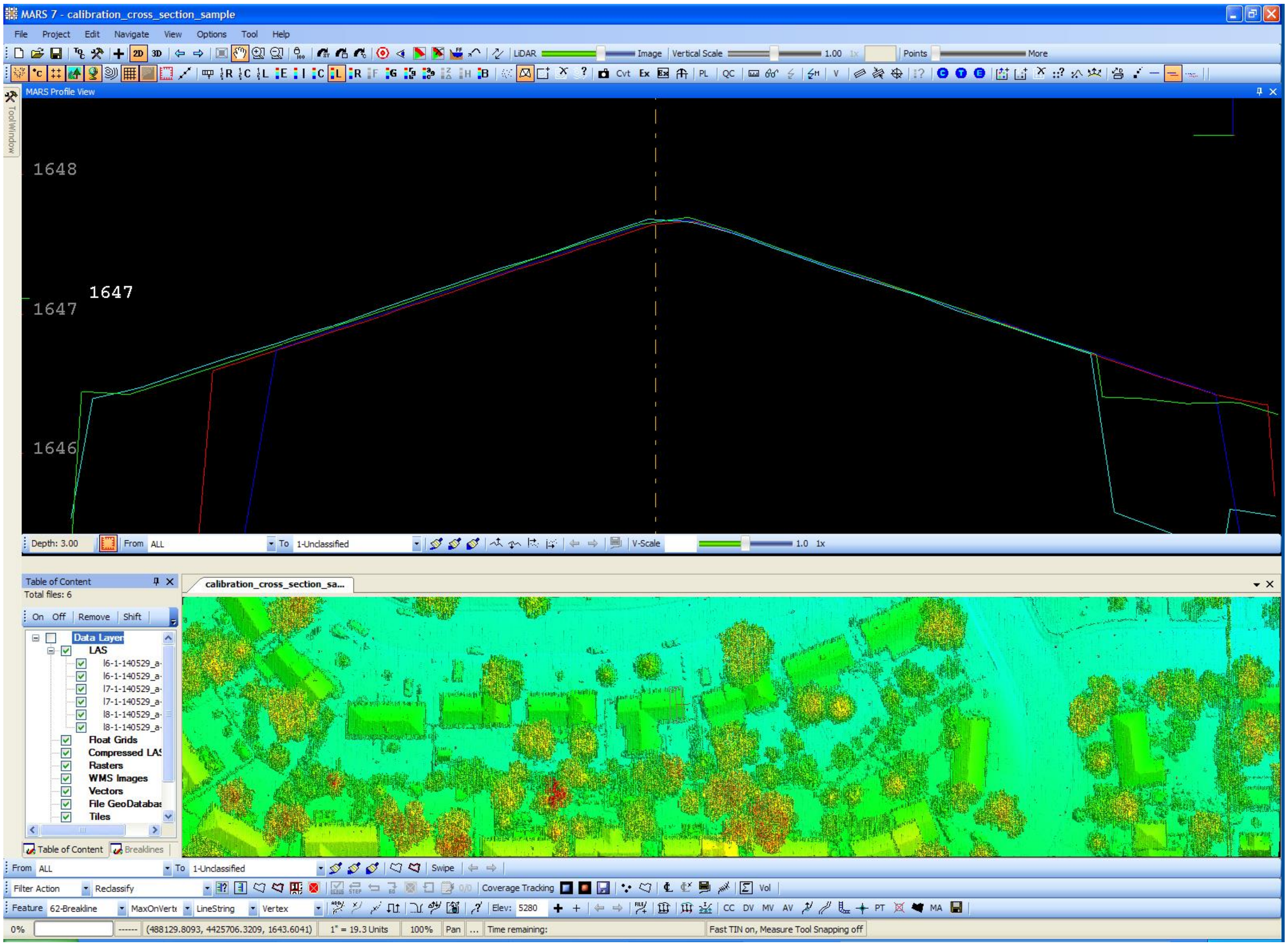
From ALL To 1-Unclassified

Filter Action Reclassify

Feature 62-Breakline MaxOnVerte LineString Vertex Elev: 5280

0% (487728.5297, 4425298.3115, 1654.3173) 1" = 19.3 Units 50% Pan Time remaining: Fast TIN on, Measure Tool Snapping off

Roll and scale are checked on roof planes perpendicular to the flight direction.



Depth: 3.00

From ALL

To 1-Unclassified

Filter Action: Reclassify

Feature: 62-Breakline

MaxOnVerte

LineString

Vertex

Elev: 5280

0%

(488129.8093, 4425706.3209, 1643.6041)

1" = 19.3 Units

100%

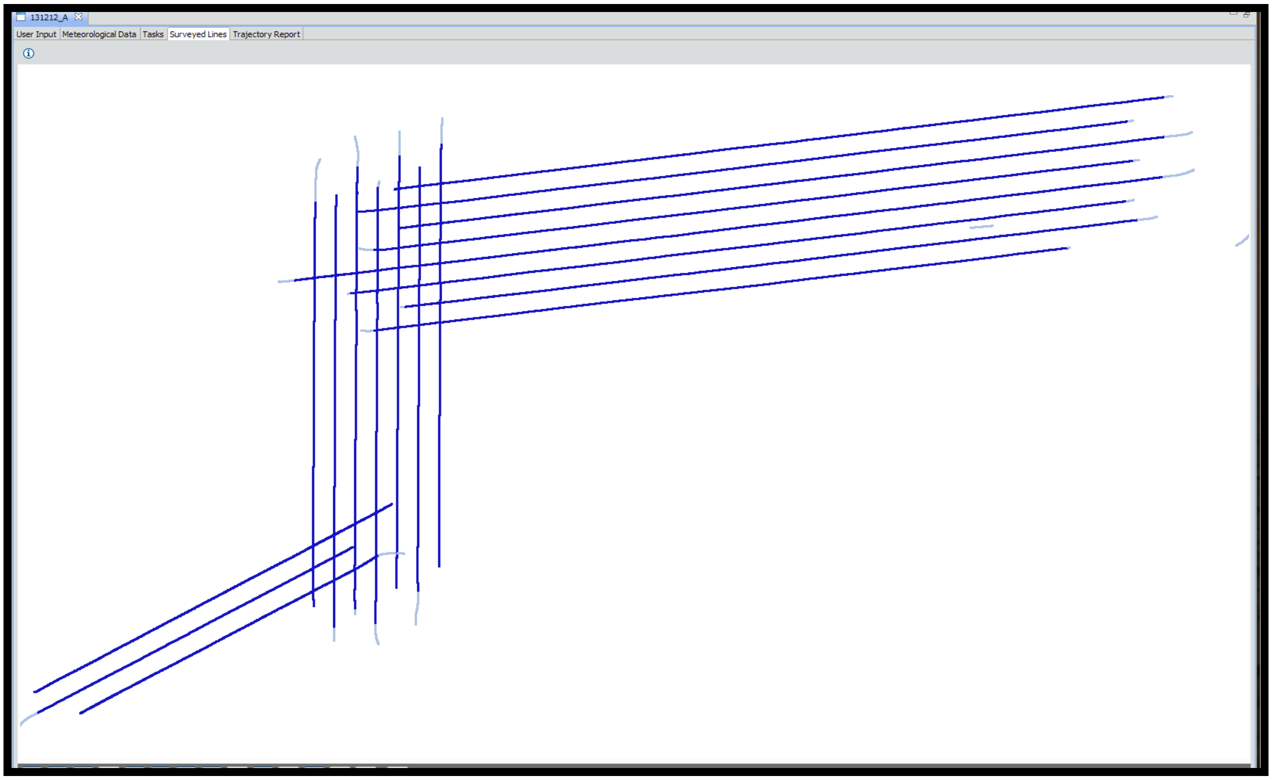
Fast TIN on, Measure Tool Snapping off

The LMS program outputs a "LCP" file with all the correction parameters. The calibration process may be run several times until the boresight adjustments are acceptable. When the boresight solution is acceptable the LCP file adjustments are saved and also applied to subsequent projects. Each new project is again analyzed and when the adjustment biases show too much drift a new boresight calibration is run. The LCP file may hold calibration tolerances for several projects.

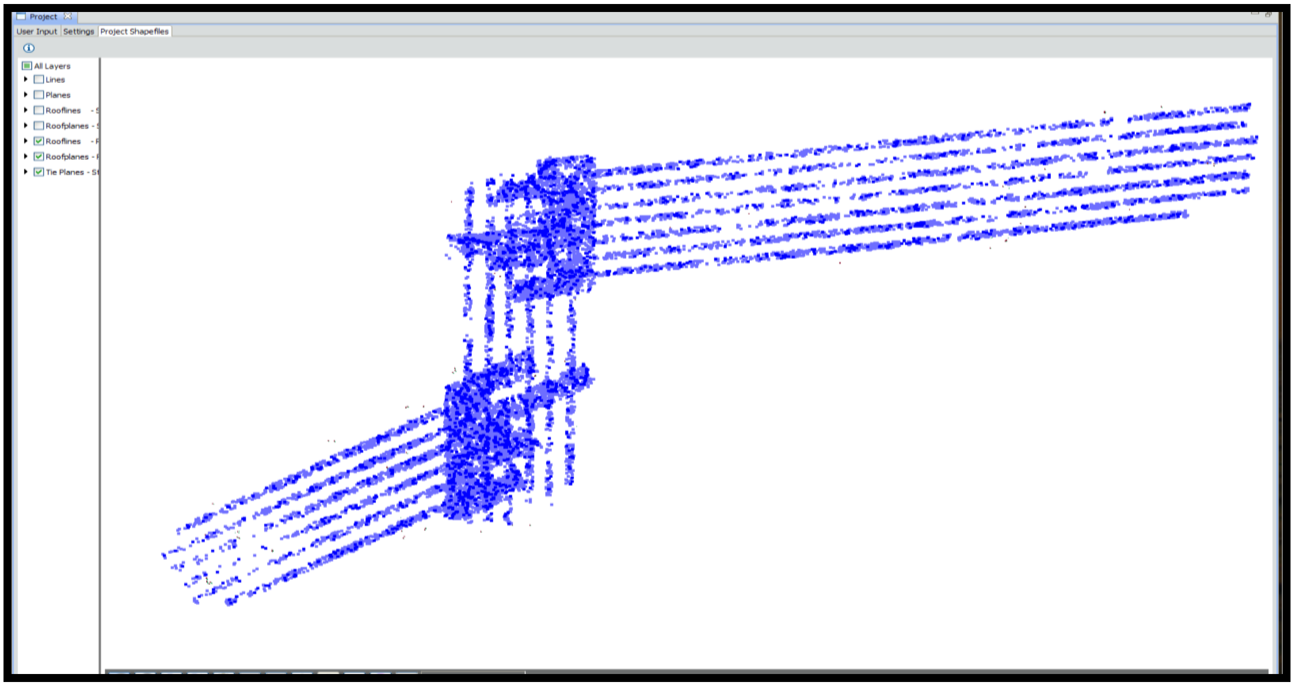
Block LAS Production Processing Procedures

The LMS production mode is run on each flight line to further tie the final lidar LAS flight line files tightly together. Production settings allow scan angle scale, scan angle lag to float and allows elevation to move slightly during flight line to flight line comparison thus further tying flight lines together. A cross flight with locked elevation data is used for controlling flight line elevations.

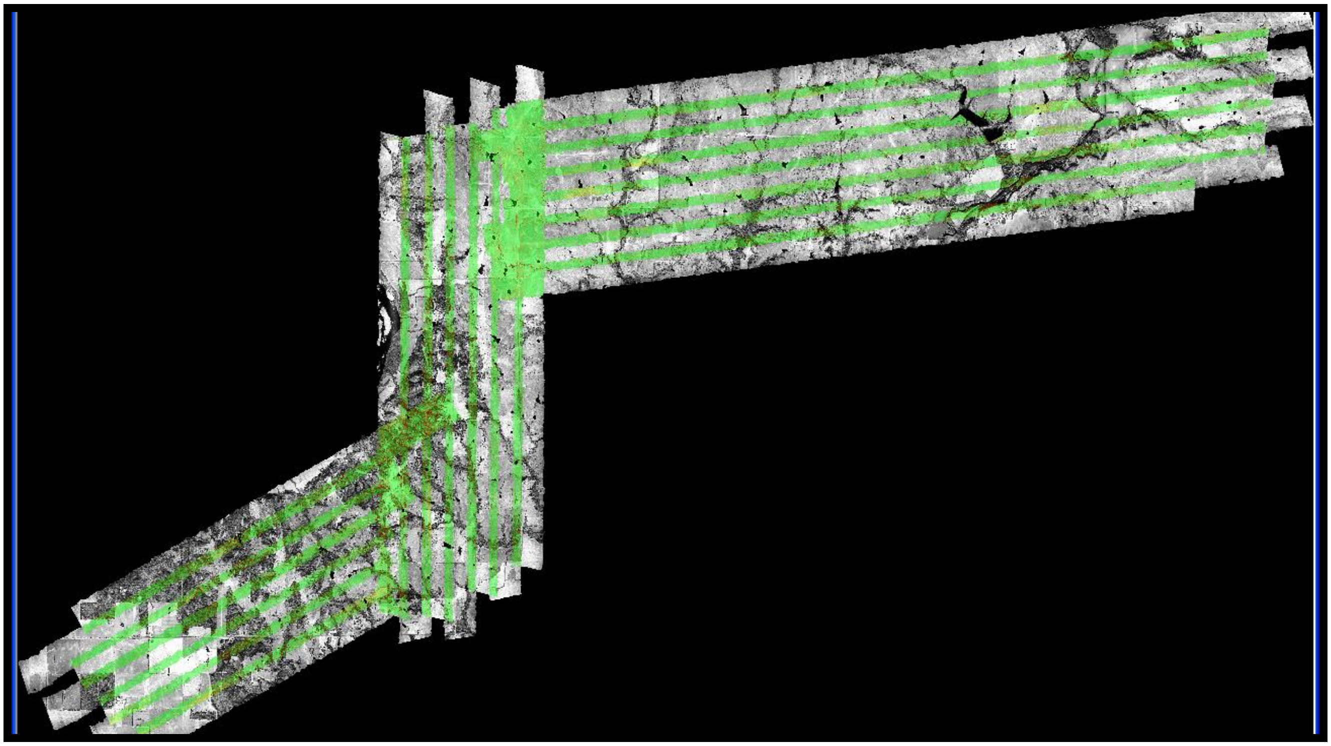
A block of data is selected to process with LMS production settings. Data collected during turns at the ends of flight lines is deselected (light blue lines).



As in self-calibration the LMS production program analyses ground, roof planes and rooflines. One cross flight is locked in elevation and all other lines are adjusted to it. Unlike the calibration site the distribution of roof planes is usually much less dense. Here matched ground tie planes are blue.

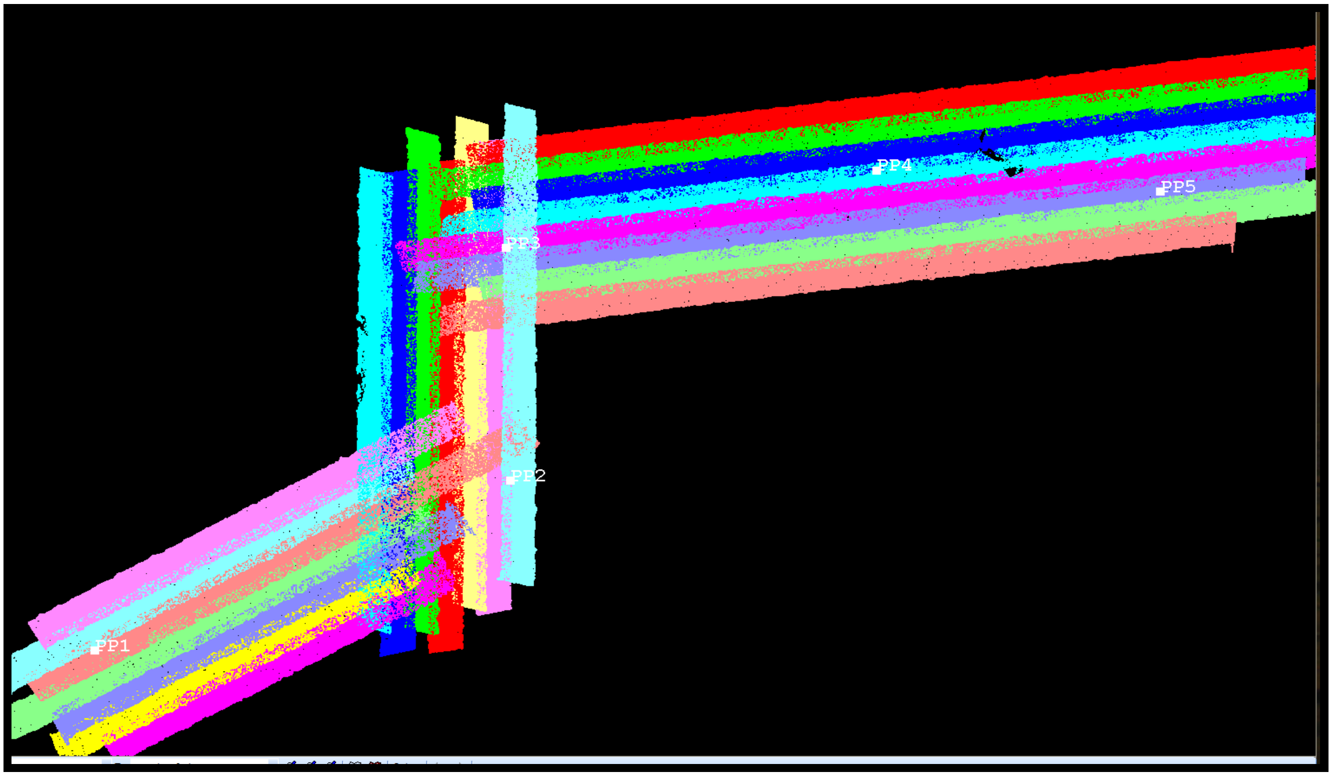


The same quality control outputs used to check self-calibrations are available to analyze the production run. Output plots are again available in LMS and cross sections plus a Flight Line Separation Raster are generated in MARS® to check coverage and quality.



Correcting the Final Elevation

After all the lines are tied together a ground control network is imported into MARS®. The ground control network may be pre-existing or collected by a licensed surveyor.



The next step is to match the ground control elevations to the lidar data set. A control report is run and the data set is shifted slightly to zero out the average elevation error and points checked for quality.

The final step before boresighted, leveled LAS files are ready for filtering is to run the MARS® QC Module on the block data. The Boresighted lidar QC Report outputs individual reports on Point Density, Nominal Pulse Spacing, Data Voids, Spatial Distribution, Scan Angles, Control Report, Flight Line Separation, Flight Line Overlap, Buffered Boundary, LAS Formats, Datums and Coordinates.
These reports are checked with the required specifications in the Project Management Plan.

LIDAR CLASSIFICATION

Auto-Filter (automated)

Merrick-Surdex JV uses customizable software to classify an automated bare-earth (i.e., ground / Class 2) solution from the lidar point cloud. The software uses several different algorithms combined in a macro to determine the classification for each point. Filter parameters are adjusted based on the terrain and land cover for each project to produce the best ground result and to minimize hand-filter. Automated filters typically classify 85- to 90-percent of the ground.

Hand-Filter (manual editing)

The remaining 10- to 15-percent of the points resulting from the automated filtering techniques are possibly misclassified and require final editing. Merrick-Surdex JV has several manual edit tools which allow us to re-classify these features to the appropriate class. All the data within the project extent is viewed by an operator to ensure all artifacts are removed, and that we are meeting project specifications. Bridges are classified to Class 17. Once it is deemed the best ground solution is met, a final auto-filter is run to classify all points to meet the ASPRS LAS 1.4 specification. During this process, all non-ground and non-bridge points are classified to Class 1 (Unclassified), and following this is a height-from-surface auto-filter is run to re-class noise to Classes 7 and 18.

The following table represents the ASPRS LAS 1.4 classifications used:

- Class 0 = Never classified (Noise Withheld Flags set)
- Class 1 = Unclassified (Noise Withheld Flags set)
- Class 2 = Bare-earth Ground (Note: Model keypoints bitflagged)
- Class 2 MKP bit-flag = Model Keypoint bitflag
- Class 7 = Low point (noise)
- Class 9 = Water
- Class 10 = Ignored ground (near a breakline)
- Class 17 = Bridge decks
- Class 18 = High noise