WV Southwest R3 Lidar Acquisition and Calibration Report

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SUBMITTED BY:

Axis Geospatial LLC.
28640 Marys Court STE 200
Easton, MD 21601
410.822.1441

SUBMITTED TO:
Dewberry
8401 Arlington Blvd,
Fairfax, VA 22031
703.849.0208

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Overview

Dewberry elected to subcontract the lidar acquisition and calibration activities to Axis Geospatial LLC Axis Geospatial LLC. was responsible for providing lidar acquisition, calibration and delivery of lidar data files to Dewberry.

Dewberry received calibrated swath data from Axis Geospatial llc on May 23, 2019.

PROJECT AREA

The project area addressed by this report falls primarily within the State of West Virginia and covers portions of the counties of Wayne, Lincoln, Mingo, Logan, Wyoming, and McDowell. The total size of the project is approximately 1,513 square miles.

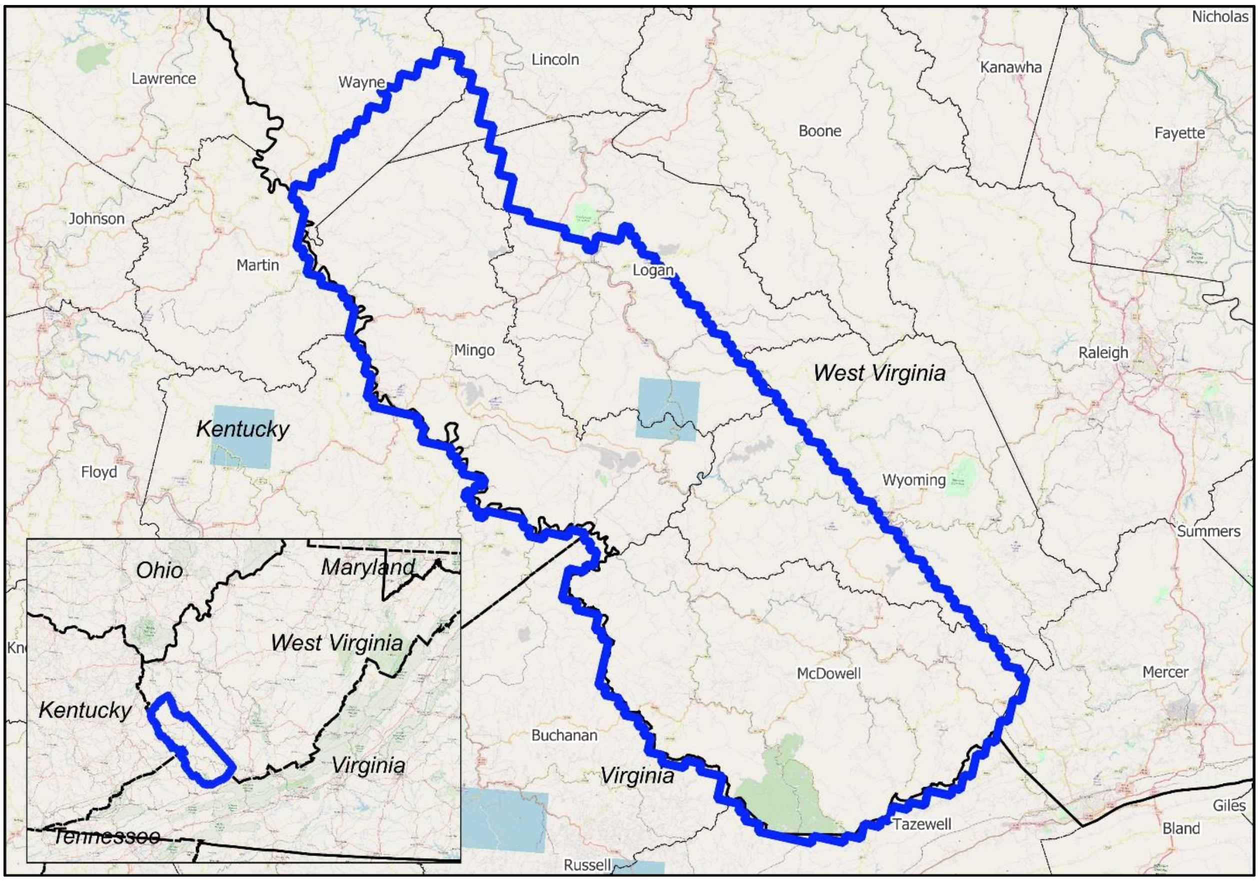

Figure 1 – Area of Interest

ACQUISITION DATES

The lidar survey was conducted between March 11, 2019 and April 11, 2019.

DATUM REFERENCE

Data produced for the project were delivered in the following reference system.

Horizontal Datum: The horizontal datum for the project is North American Datum of 1983 (NAD 83 20111)
Vertical Datum: The Vertical datum for the project is North American Vertical Datum of 1988 (NAVD88)
Coordinate System: Albers Equal Area
Units: Horizontal units are in meters, Vertical units are in meters.
Geoid Model: Geoid12B (Geoid12B was used to convert ellipsoid heights to orthometric heights).

Lidar Acquisition Details

Axis Geospatial, LLC Planned a total of 74 parallel aligned flight lines plus calibration cross strips to cover the area of interest. In order to reduce any margin for error in the flight plan, Axis Geospatial llc. followed USGS specifications for flight planning and, at a minimum, includes the following criteria:

- A digital flight line layout using TrackAir flight design software for direct integration into the aircraft flight navigation system.
- Planned flight lines; flight line numbers; and coverage area.
- Lidar coverage extended by a predetermined margin beyond all project borders to ensure necessary over-edge coverage appropriate for specific task order deliverables.
- Local restrictions related to air space and any controlled areas have been investigated so that required permissions can be obtained in a timely manner with respect to schedule. Additionally, Axis Geospatial llc. will file our flight plans as required by local Air Traffic Control (ATC) prior to each mission.

Axis Geospatial llc. monitored weather and atmospheric conditions and conducted lidar missions only when no conditions exist below the sensor that will affect the collection of data. These conditions include leaf-off for hardwoods, no snow, rain, fog, smoke, mist and low clouds. Lidar systems are active sensors, not requiring light, thus missions may be conducted during night hours when weather restrictions do not prevent collection. Axis Geospatial llc. accesses reliable weather sites and indicators (webcams) to establish the highest probability for successful collection in order to position our sensor to maximize successful data acquisition.

Within 72-hours prior to the planned day(s) of acquisition, Axis Geospatial llc. closely monitored the weather, checking all sources for forecasts at least twice daily. As soon as weather conditions were conducive to acquisition, our aircraft mobilized to the project site to begin data collection. Once on site, the acquisition team took responsibility for weather analysis.

Axis Geospatial llc. lidar sensors are calibrated at a designated site located at Easton Airport in Easton Maryland and are periodically checked and adjusted to minimize corrections at project sites.

LIDAR SYSTEM PARAMETERS

Axis Geospatial llc. operated a Cessna 206 single engine aircraft tail number N223TC with a VQ-1560i LiDAR system throughout the collection of the project. Table 1 illustrates Axis Geospatial llc. system parameters for lidar acquisition on this project.

Item	Parameter
System	VQ-1560i
Maximum Number of Returns per Pulse	N/A
Nominal Pulse Spacing (single swath), (m)	.695
Nominal Pulse Density (single swath) (ppsm), (m)	*3.33*
Aggregate NPS (m) (if ANPS was designed to be met through single coverage, ANPS and NPS will be equal)	.695
Aggregate NPD (m) (if ANPD was designed to be met through single coverage, ANPD and NPD will be equal)	3.33
Altitude (AGL meters)	2042
Approx. Flight Speed (knots)	170
Total Sensor Scan Angle (degree)	58.52
Scan Frequency (hz)	2 x 500
Scanner Pulse Rate (kHz)	12 x 108
Pulse Duration of the Scanner (nanoseconds)	3 ns
Pulse Width of the Scanner (m)	
Central Wavelength of the Sensor Laser (nanometers)	1064 nm
Did the Sensor Operate with Multiple Pulses in The Air? (yes/no)	Yes
Beam Divergence (milliradians)	≤ 0.25 mrad
Nominal Swath Width on the Ground (m)	2215
Swath Overlap (%)	20
Computed Down Track spacing (m) per beam	.695
Computed Cross Track Spacing (m) per beam	.695
GNSS positional error (radial, in cm) *	0.05
IMU error (in decimal degrees) *	0.005
Maximum Baseline Length (mi)	47
Line Spacing (m)	1316

* can be derived from published manufacturer specifications for both the GNSS receiver and the IMU

Table 1: Axis Geospatial llc. Lidar System Parameters

ACQUISITION STATUS REPORT AND FLIGHTLINES

Upon notification to proceed, the flight crew loaded the flight plans and validated the flight parameters. The Acquisition Manager contacted air traffic control and coordinated flight pattern requirements. Lidar acquisition began immediately upon notification that control base stations were in place. During flight operations, the flight crew monitored weather and atmospheric conditions. Lidar missions were flown only when no condition existed below the sensor that would affect the collection of data. The pilot constantly monitored the aircraft course, position, pitch, roll, and yaw of the aircraft. The sensor operator monitored the sensor, the status of PDOPs, and performed the first Q/C review during acquisition. The flight crew constantly reviewed weather and cloud locations. Any flight lines impacted by unfavorable conditions were marked as invalid and re-flown immediately or at an optimal time.

Figure 2 shows the combined trajectory of the flightlines.

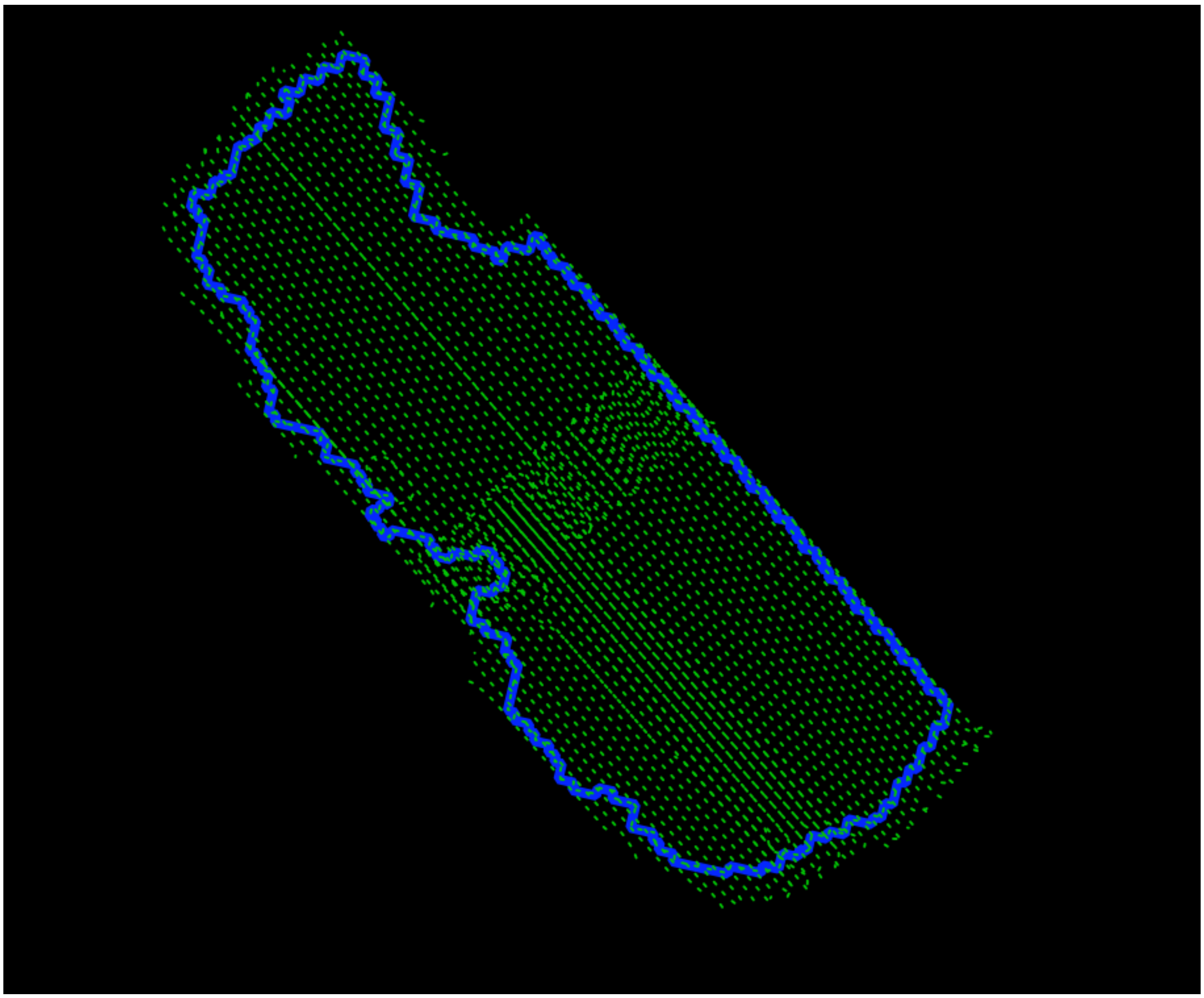

Figure 2: Trajectories as flown by Axis Geospatial

ACQUISITION BASESTATION REPORT

Axis Geospatial, LLC utilized CORS and West Virginia DOT Real Time Network base stations during the acquisition of the West Virginia SW R3. POSPAC MMS was used to import the base station coordinates and elevations to create a "virtual" base station. For each mission one base station was held fixed as the control station while the other surrounding stations were allowed to be adjusted. These base sessions were then incorporated during the post-processing of aircraft position. The coordinates of the control base stations for each mission are provided in the table below.

MISSION	STATION	LATITUDE	LONGITUDE	HEIGHT
20190311A	WVSW	N37°48'19.89683"	W82°05'44.39197"	465.791
20190311B	WVSW	N37°48'19.89683"	W82°05'44.39197"	465.791
20190312A	WVSW	N37°48'19.89683"	W82°05'44.39197"	465.791
20190312B	WVSW	N37°48'19.89683"	W82°05'44.39197"	465.791
20190313	WVSW	N37°48'19.89683"	W82°05'44.39197"	465.791
20190324A	VARL	N37°05'30.51181"	W81°47'00.69400"	594.786
20190324B	WVSA	N37°38'26.93023"	W81°27'19.46164"	588.259
20190326	WVSA	N37°38'26.93023"	W81°27'19.46164"	588.259
20190327	WVSA	N37°38'26.93023"	W81°27'19.46164"	588.259
20190411	WVSA	N37°38'26.93023"	W81°27'19.46164"	588.259

Table 2 – Base stations used as control for each mission

AIRBORNE GPS KINEMATIC

Airborne GPS data was processed using the PosPac MMS software suite. 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 40 km.

For all flights, the GPS data can be classified as excellent, with GPS residuals of 2 cm average or better but no larger than 4.5 cm being recorded.

GPS processing reports for each mission are included in Appendix A.

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 usingRiEGL's RiProcess software, initially with default values from RiEGL or the last mission calibrated for the 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.

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.

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

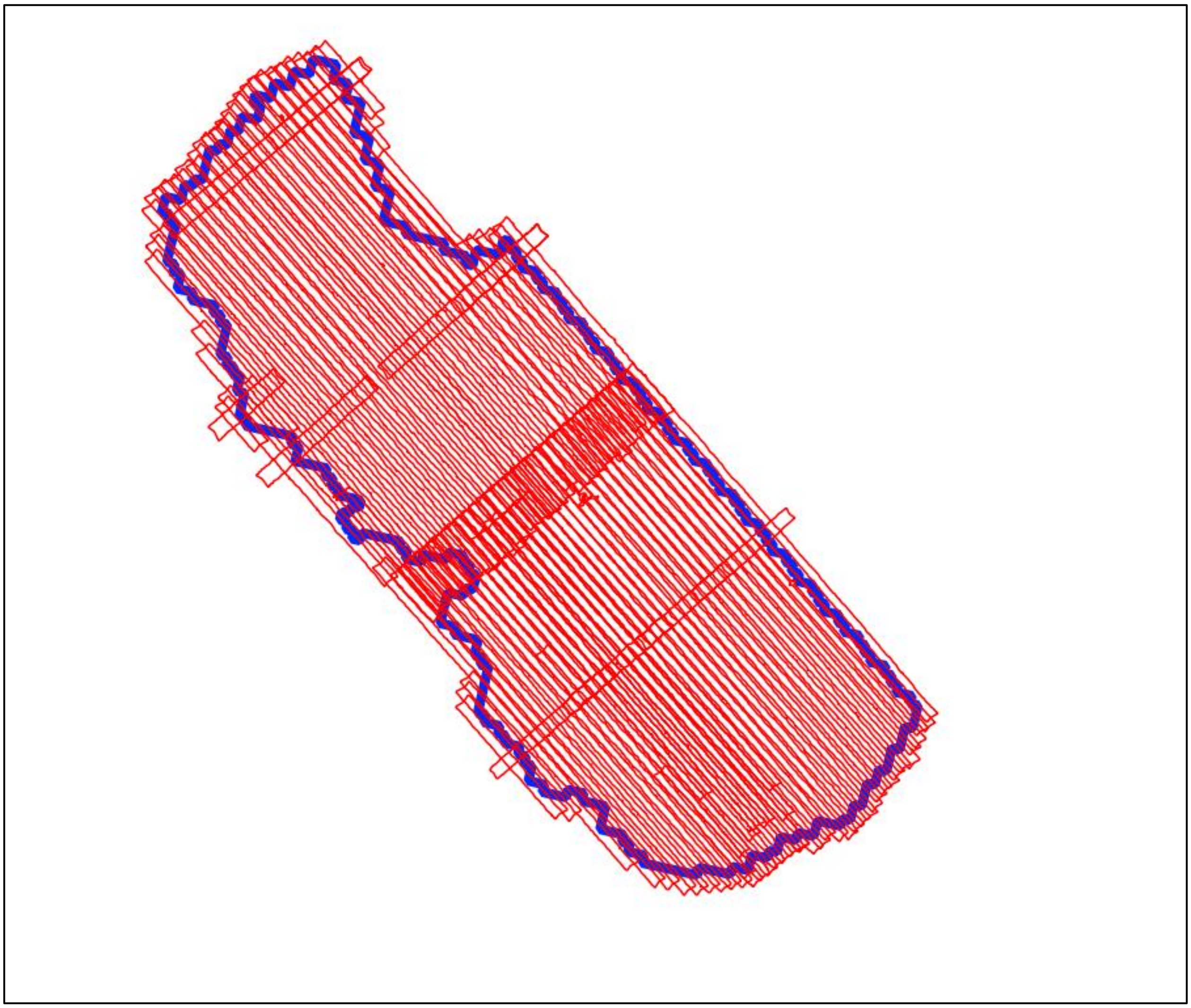

Figure 3 – Lidar swath output showing complete coverage.

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, flight line to flight line and mission to mission agreement.

For this project the specifications used are as follow:

Relative accuracy <= 6 cm maximum differences within individual swaths and <=8 cm RMSDz between adjacent and overlapping swaths.

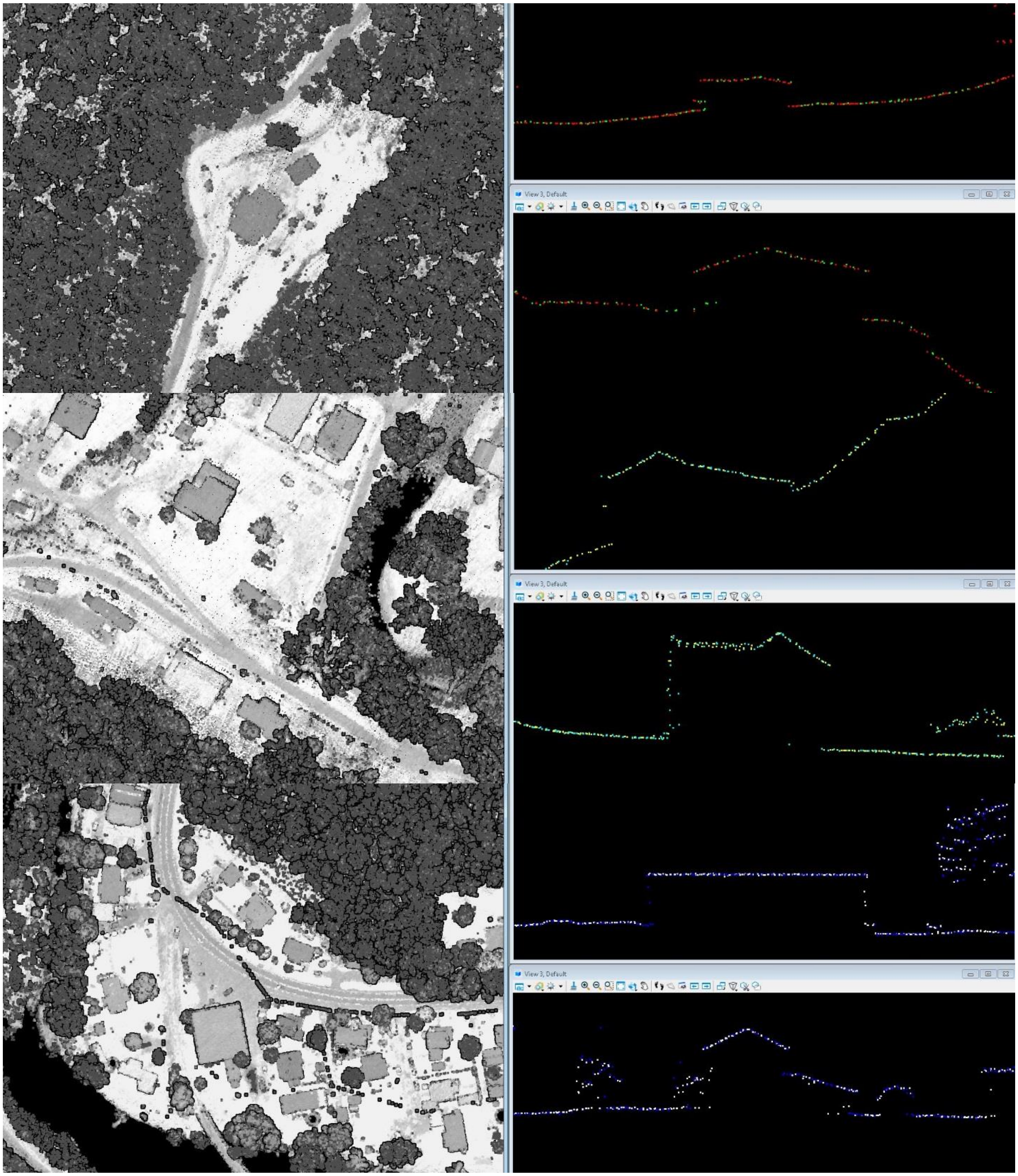

Figure 4 – Profile views showing correct roll and pitch adjustments.

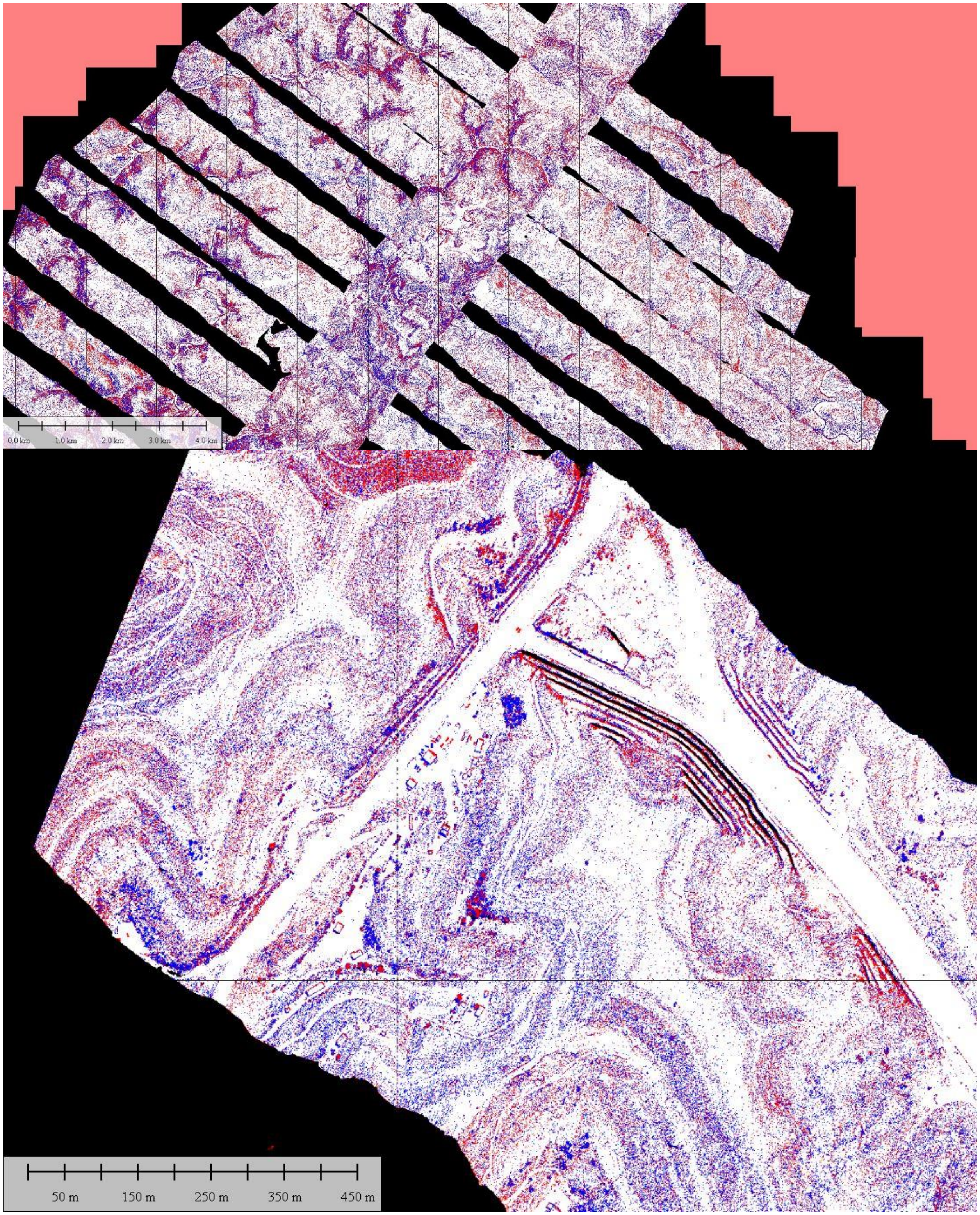

Figure 5 – QC block colored by distance to ensure accuracy at swath edges.

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

Final Calibration Verification

Dewberry conducted the survey for 23 ground control points (GCPs) which were used to test the accuracy of the calibrated swath data. These 23 GCPs were available to use as control in case the swath data exhibited any biases which would need to be adjusted or removed. The coordinates of all GCPs are provided in table 3 and the accuracy results from testing the calibrated swath data against the GCPs is provided in table 4; no further adjustments to the swath data were required based on the accuracy results of the GCPs.

Point ID	NAD83 (2011) Albers Equal Area		NAVD88 (Geoid 12B)		Offset
	Easting X (m)	Northing Y (m)	Z-Survey (m)	Z-LiDAR (m)	Dz (m)
Number	Easting	Northing	Known_Z	Laser_Z	Dz
GCP-101	1180184.502	1732486.958	189.467	189.550	0.083
GCP-103	1195579.559	1753466.609	330.891	330.940	0.049
GCP-107	1216572.633	1735730.116	208.118	208.150	0.032
GCP-102	1190673.037	1741917.924	244.673	244.700	0.027
GCP-201	1282307.696	1694955.574	931.906	931.930	0.024
GCP-110	1229831.209	1727376.695	238.411	238.430	0.019
GCP-116	1230454.694	1695634.078	288.241	288.260	0.019
GCP-104	1200324.241	1736040.299	297.569	297.580	0.011
GCP-111	1231887.749	1717111.732	234.131	234.140	0.009
GCP-202	1259998.078	1712097.899	391.691	391.700	0.009
GCP-115	1258494.380	1693126.360	401.092	401.100	0.008
GCP-117	1241346.066	1683066.225	357.470	357.470	0.000
GCP-119	1261802.806	1699381.815	525.812	525.810	-0.002
GCP-112	1223630.463	1703516.990	259.554	259.550	-0.004
GCP-118	1254397.404	1675529.907	450.196	450.190	-0.006
GCP-108	1203561.630	1714253.322	249.769	249.760	-0.009
GCP-105	1192081.068	1726217.250	197.081	197.070	-0.011
GCP-204	1223269.035	1737510.936	505.766	505.750	-0.016
GCP-113	1237306.300	1708383.490	319.377	319.360	-0.017
GCP-106	1207487.825	1724509.756	487.955	487.930	-0.025
GCP-120	1273577.444	1692227.182	571.460	571.420	-0.040
GCP-109	1218802.499	1718031.354	341.818	341.760	-0.058
GCP-114	1254422.306	1711236.960	369.388	369.320	-0.068

Average dz	0.001
Minimum dz	-0.068
Maximum dz	0.083
Average magnitude	0.024
Root mean square	0.032
Std deviation	0.033

Table 3 – Axis Geospatial residuals of surveyed ground control points (GCPs).

Appendix 1: GPS and IMU Processing Reports for Each Mission

See attachments for indepth POSPac generated IMU and GPS reports for missions 20190311A, 20190311B, 20190312A, 20190312B, 20190313A, 20190324A, 20190324B, 20190326A, 20190327A, and 20190411A.