AIRBORNE LIDAR PROJECT REPORT

SAIC LIDAR

SCIENCE APPLICATIONS INTERNATIONAL CORPORATION (SAIC)

CONTRACT NUMBER: PO10020755_R14

Woolpert Project Number: 66566

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WOOLPERT
DESIGN | GEOSPATIAL | INFRASTRUCTURE

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SECTION 1: OVERVIEW

TASK ORDER NAME: SAIC LIDAR

WOOLPERT PROJECT #66566

This report contains a comprehensive outline of the airborne LiDAR data acquisition for Indianapolis, IN for Science Applications International Corporation (SAIC). The project area was approximately 1397 square kilometers. The LiDAR was collected and processed to meet the Nominal Post Spacing (NPS) requirement of 1.0 meters. The NPS assessment is made against single swath, first return data located within the geometrically usable center portion (typically ~90%) of each swath.

The data was collected using a Leica ALS60 150 kHz Multiple Pulses in Air (MPiA) LiDAR sensor installed in a Leica gyro-stabilized PAV30 mount. The ALS60 150 kHz sensor collects up to four returns per pulse, as well as intensity data, for the first three returns. If a fourth return was captured, the system does not record an associated intensity value. The aerial LiDAR was collected at the following sensor specifications:

Post Spacing (Minimum):	3.2 ft / 1.0 m
AGL (Above Ground Level) average flying height:	6500 ft / 1981 m
MSL (Mean Sea Level) average flying height:	7125 ft / 2088 m
Average Ground Speed:	130 knots / 150 mph
Field of View (full):	40 degrees
Pulse Rate:	115.6 kHz
Scan Rate:	41.8 Hz
Side Lap (Minimum):	29.5%

LiDAR data was produced in Universal Transverse Mercator (UTM) Zone 16N, North American Datum of 1983 (NAD83) for insert site here Coordinate positions were specified in units of meters. The vertical datum used for the project was referenced to NAVD 1988, meters, Geoid09.

SECTION 2: ACQUISITION

The LiDAR data was acquired with a Leica ALS60 150 kHz Multiple Pulses in Air (MPiA) LiDAR sensor system, on board a Cessna 404. The ALS60 LiDAR system, developed by Leica Geosystems of Heerbrugg, Switzerland, includes the simultaneous first, intermediate and last pulse data capture module, the extended altitude range module, and the target signal intensity capture module. The system software is operated on an OC50 Operation Controller aboard the aircraft.

The ALS 60 150 kHz Multiple Pulses in Air (MPiA) LiDAR System has the following specifications:

Table 2.1 ALS60 LiDAR System Specifications

Specification	
Operating Altitude	200 - 6,000 meters
Scan Angle	0 to 75° (variable)
Swath Width	0 to 1.5 X altitude (variable)
Scan Frequency	0 – 90 Hz (variable based on scan angle)
Maximum Pulse Rate	150 kHz
Range Resolution	Better than 1 cm
Elevation Accuracy	8 – 24 cm single shot (one standard deviation)
Horizontal Accuracy	7 – 64 cm (one standard deviation)
Number of Returns per Pulse	4 (first, second, third, last)
Number of Intensities	3 (first, second, third)
Intensity Digitization	8 bit intensity + 8 bit AGC (Automatic Gain Control) level
MPiA (Multiple Pulses in Air)	8 bits @ 1nsec interval @ 50kHz
Laser Beam Divergence	0.22 mrad @ $1/e^2$ (~0.15 mrad @ 1/e)
Laser Classification	Class IV laser product (FDA CFR 21)
Eye Safe Range	400m single shot depending on laser repetition rate
Roll Stabilization	Automatic adaptive, range = 75 degrees minus current FOV
Power Requirements	28 VDC @ 25A
Operating Temperature	0-40°C
Humidity	0-95% non-condensing
Supported GNSS Receivers	Ashtech Z12, Trimble 7400, Novatel Millenium

Prior to mobilizing to the project site, Woolpert flight crews coordinated with the necessary Air Traffic Control personnel to ensure airspace access.

Woolpert survey crews were onsite, operating a Global Navigation Satellite System (GNSS) Base Station for the airborne GPS support.

The LiDAR data was collected in three missions, as the weather permitted, to ensure consistent ground conditions across the project area.

An initial quality control process was performed immediately on the LiDAR data to review the data coverage, airborne GPS data, and trajectory solution. Any gaps found in the LiDAR data were relayed to the flight crew, and the area was re-flown.

Table 2.2 Airborne LiDAR Acquisition Flight Summary

Date of Mission	Lines Flown	Mission Time (UTC) Wheels Up/ Wheels Down	Mission Time (Local = EDT) Wheels Up/ Wheels Down
August 22, 2011	1-3	13:30-16:30	9:30AM-12:30PM
August 23, 2011	4-39, 2-3(reflights)	10:31-19:17	6:31AM-3:17PM
August 25, 2011	2,3,7,8,15,39 (reflights), 40	13:11-15:07	9:11AM-11:07AM

SECTION 3: LIDAR DATA PROCESSING

APPLICATIONS AND WORK FLOW OVERVIEW

1. Resolved kinematic corrections for three subsystems: inertial measurement unit (IMU), sensor orientation information and airborne GPS data. Developed a blending post-processed aircraft position with attitude data using Kalman filtering technology or the smoothed best estimate trajectory (SBET).
   Software: POSPac Software v. 5.3, IPAS Pro v.1.3.
2. Calculated laser point position by associating the SBET position to each laser point return time, scan angle, intensity, etc. Created raw laser point cloud data for the entire survey in .LAS format. Automated line-to-line calibrations were then performed for system attitude parameters (pitch, roll, heading), mirror flex (scale) and GPS/IMU drift.
   Software: ALS Post Processing Software v.2.70, Proprietary Software, TerraMatch v. 10.04.
3. Imported processed .LAS point cloud data into project tiles. Resulting data were classified as ground and non-ground points with additional filters created to meet the project classification specifications. Statistical absolute accuracy was assessed via direct comparisons of ground classified points to ground RTK survey data. Based on the statistical analysis, the LiDAR data was then adjusted in relation to the survey ground control.
   Software: TerraScan v.10.018.
4. The .LAS files were evaluated through a series of QA/QC steps to eliminate remaining artifacts and small undulations from the ground class.
   Software: TerraScan v.10.018.

GLOBAL NAVIGATION SATELLITE SYSTEM (GNSS)-INERTIAL MEASUREMENT UNIT (IMU) TRAJECTORY PROCESSING

EQUIPMENT

Flight navigation during the LiDAR data acquisition mission is performed using IGI CCNS (Computer Controlled Navigation System). The pilots are highly skilled at maintaining their planned trajectory, while holding the aircraft steady and level. If atmospheric conditions are such that the trajectory, ground speed, roll, pitch and/or heading cannot be properly maintained, the mission is aborted until suitable conditions occur.

The aircraft are all configured with a NovAtel Millennium 12-channel, L1/L2 dual frequency Global Navigation Satellite System (GNSS) receivers collecting at 2 Hz.

All Woolpert aerial sensors are equipped with a Litton LN200 series Inertial Measurement Unit (IMU) operating at 200 Hz.

A base-station unit was mobilized for each acquisition mission, and was operated by a member of the Woolpert survey crew. Each base-station setup consisted of one Trimble 4000 – 5000 series dual frequency receiver, one Trimble Compact L1/L2 dual frequency antenna, one 2-meter fixed-height tripod, and essential battery power and cabling. Ground planes were used on the base-station antennas. Data was collected at 1 or 2 Hz.

Woolpert survey crews were onsite, operating a Global Navigation Satellite System (GNSS) Base Station at the INMT CORS station for the airborne GPS support. The GNSS base station operated during the LiDAR acquisition missions is listed below:

Table 3.1 GNSS Base Station

Station	Latitude	Longitude	Ellipsoid Height (L1 Phase Center)
Name	(DMS)	(DMS)	(Meters)
INMT CORS Station	N 39°46'16.15785"	W 86° 02' 34.88872"	232.539

DATA PROCESSING

All airborne GNSS and IMU data was post-processed and quality controlled using Applanix MMS software. GNSS data was processed at a 1 and 2 Hz data capture rate and the IMU data was processed at 200 Hz.

TRAJECTORY QUALITY

The GNSS Trajectory, along with high quality IMU data are key factors in determining the overall positional accuracy of the final sensor data. See **Figure 3.1** for the flight trajectory.

FLIGHT TRAJECTORY

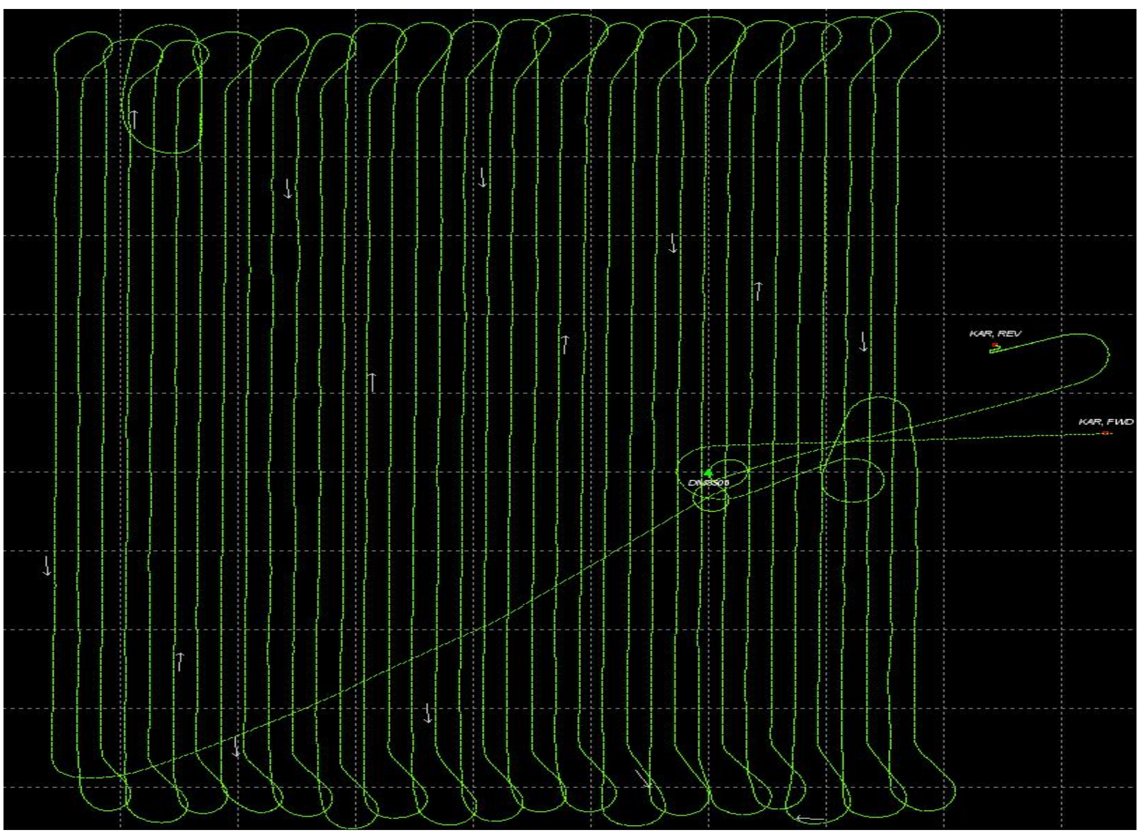

Figure 3.1: Representative Graph from Day23511: N7079F and ALS LiDAR S/N6157

Within the trajectory processing, there are many factors that affect the overall quality, but the most indicative are the Combined Separation, the Estimated Positional Accuracy, and the Positional Dilution of Precision (PDOP).

COMBINED SEPARATION

The Combined Separation is a measure of the difference between the forward run and the backward run solution of the trajectory. The Kalman filter is processed in both directions to remove the combined directional anomalies. In general, when these two solutions match closely, an optimally accurate reliable solution is achieved.

Woolpert's goal is to maintain a Combined Separation Difference of less than ten (10) centimeters. In most cases we achieve results below this threshold. See **Figure 3.2** for the combined separation graph.

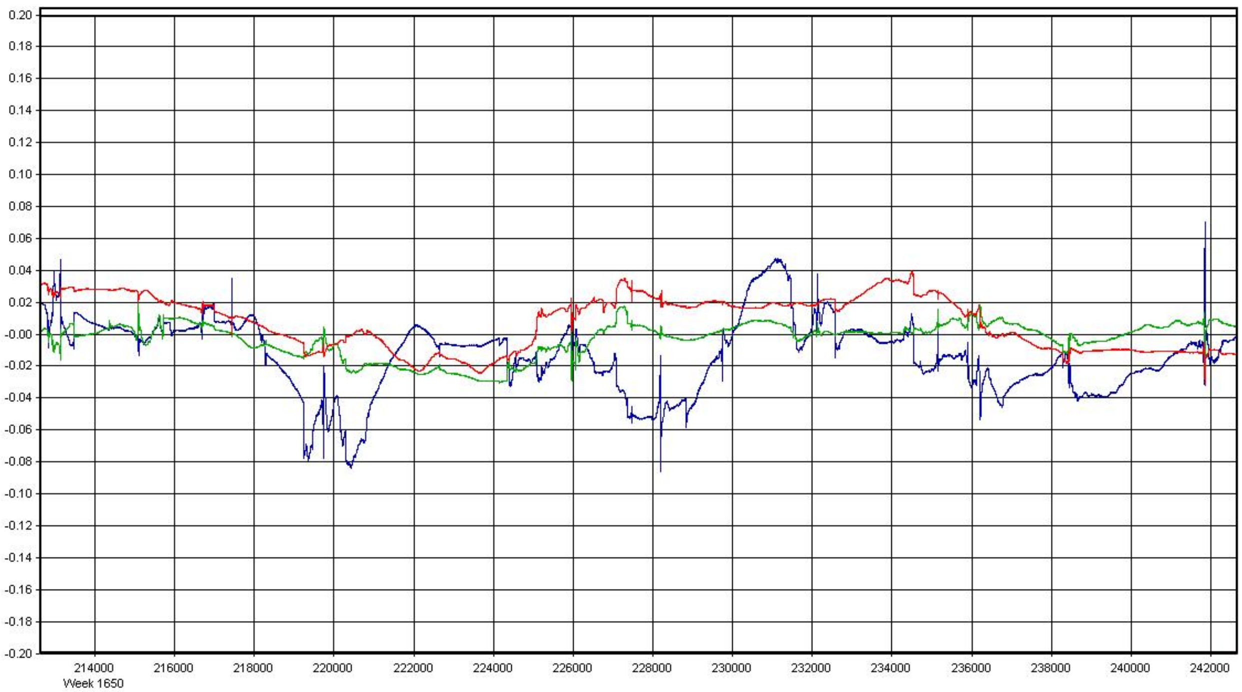

Figure 3.2: Representative Graph from Day23511 of Combined Separation

ESTIMATED POSITIONAL ACCURACY

The Estimated Positional Accuracy plots the standard deviations of the east, north, and vertical directions along a time scale of the trajectory. It illustrates loss of satellite lock issues, as well as issues arising from long baselines, noise, and/or other atmospheric interference.

Woolpert's goal is to maintain an Estimated Positional Accuracy of less than ten (10) centimeters, often achieving results well below this threshold.

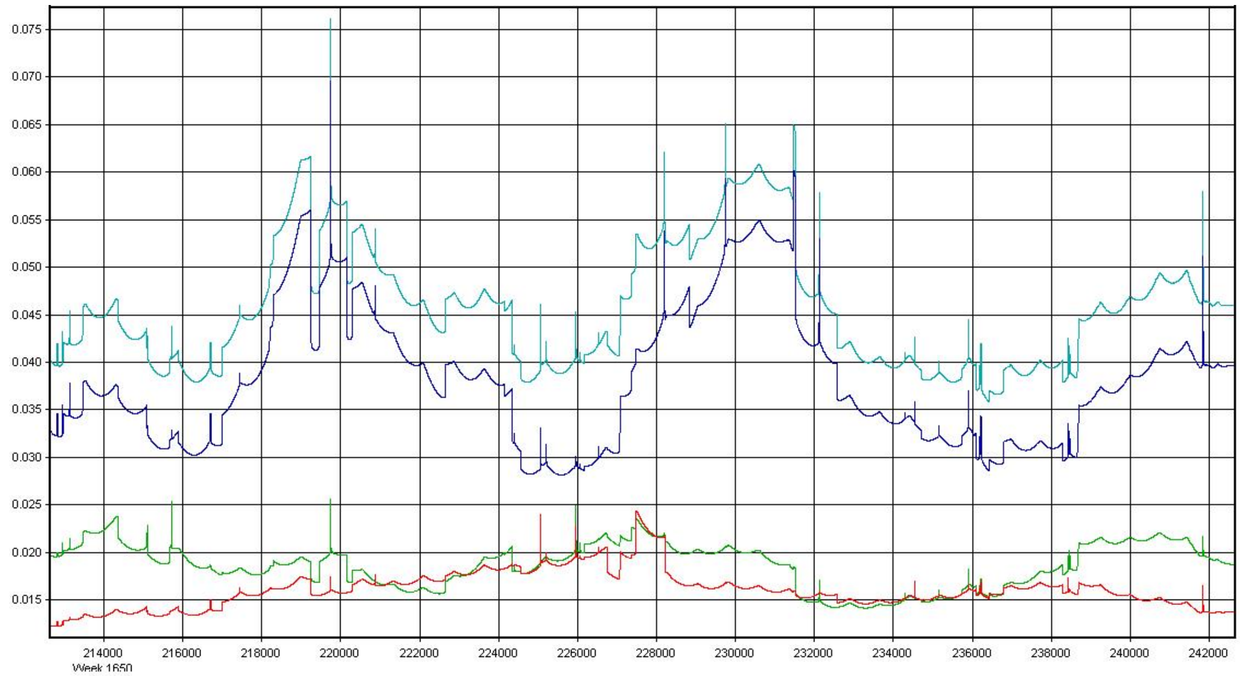

Figure 3.3: Representative Graph from Day23511 of Positional Accuracy

LIDAR DATA PROCESSING

When the sensor calibration, data acquisition, and GPS processing phases were complete, the formal data reduction processes by Woolpert LiDAR specialists included:

- Processed individual flight lines to derive a “Point Cloud”. Matched overlapping flight lines, generated statistics for evaluation comparisons, and made the necessary adjustments to remove any residual systematic error.
- Calibrated LAS files were imported into project tiles and initially filtered to create a ground and non-ground class. Then additional classes are filtered as necessary to meet client specified classes.
- Once all project data was imported and classified, cross flights and survey ground control data was imported and calculated for an accuracy assessment. As a QA/QC measure, Woolpert has developed a routine to generate accuracy statistical reports by comparison among LiDAR points, ground control, and TINs. The LiDAR is adjusted accordingly to meet or exceed the vertical accuracy requirements.
- The LiDAR data in LAS format was reviewed using a series of proprietary QA/QC procedures to ensure it fulfills the project requirements.
- The LiDAR LAS files for this project have been classified into the Default (Class 1), Ground (Class 2), Noise (Class 7), and Vegetation (Class 5) classifications.
- Final deliverable data was derived from the adjusted classified LiDAR data.

SECTION 4: FINAL ACCURACY ASSESSMENT

FINAL VERTICAL ACCURACY ASSESSMENT

The vertical accuracy statistics were calculated by comparison of the LiDAR bare earth points to the ground surveyed QA/QC points.

Table 4.1: Overall Vertical Accuracy Statistics

Average error	-0.004	meters
Minimum error	-0.122	meters
Maximum error	0.098	meters
Average magnitude	0.057	meters
Root mean square	0.065	meters
Standard deviation	0.066	meters

Table 4.2: QA/QC Analysis UTM 16N, NAD83

Point ID	Easting (UTM meters)	Northing (UTM meters)	Elevation (meters)	Laser Elevation (meters)	Dz (meters)
1	572010.658	4401583.423	214.328	214.38	0.052
2	553859.614	4421917.239	281.803	281.69	-0.113
3	555985.545	4393344.044	233.621	233.57	-0.051
4	557956.413	4420397.379	271.709	271.67	-0.039
5	560044.636	4392223.307	240.368	240.25	-0.118
6	561942.874	4423407.877	274.076	274.02	-0.056
7	564007.687	4395552.269	226.56	226.54	-0.02
8	565960.208	4415010.778	250.964	250.9	-0.064
9	568108.81	4389845.4	205.075	205.03	-0.045
10	574084.036	4423284.979	252.718	252.76	0.042
11	572121.233	4397236.414	219.059	219.13	0.071
12	570022.842	4419717.821	250.426	250.45	0.024
13	576195.122	4390443.123	239.375	239.4	0.025
14	578237.621	4418197.179	225.718	225.74	0.022
15	580245.86	4396499.726	255.666	255.69	0.024
16	582160.285	4423274.859	242.269	242.32	0.051
17	584390.771	4392043.46	254.93	254.99	0.06
18	586181.426	4412137.21	261.387	261.42	0.033
19	588162.074	4401320.935	257.286	257.38	0.094
20	589135.768	4423491.177	246.84	246.87	0.03
21	581282.542	4407107.78	262.671	262.71	0.039
22	575032.591	4413272.175	227.112	227.21	0.098
23	567073.56	4406412.028	226.29	226.2	-0.09
24	559103.032	4398480.811	230.242	230.12	-0.122
25	556954.615	4406658.175	258.102	258.06	-0.042

VERTICAL ACCURACY CONCLUSIONS

- **Data Accuracy** tested 0.065 meters RMSE vertical accuracy at 95% percent confidence level.

Based on the analysis of the LiDAR data, the accuracy of the data meets the task order requirements.

Approved By:			
Title	Name	Signature	Date
LiDAR Specialist Certified Photogrammetrist #1281	Qian Xiao		October 13, 2011

SECTION 5: FINAL DELIVERABLES

FINAL DELIVERABLES

The final deliverables are listed below:

- One set of LiDAR data reflective surface tiles in 1 meter ArcGRID format in 2,000 meter x 2,000 meter overlapping tiles.
- One set of LiDAR data bare earth tiles in 1 meter ArcGRID format in 2,000 meter x 2,000 meter overlapping tiles.
- One set of LiDAR data last return tiles in 1 meter ArcGRID format in 2,000 meter x 2,000 meter overlapping tiles.
- One set of LiDAR data intensity tiles in 1 meter ArcGRID format in 2,000 meter x 2,000 meter overlapping tiles.
- LAS v1.1 classified point cloud and bare earth point files in tile format.
- The project data was delivered on DVDR.