AIRBORNE LIDAR PROJECT REPORT

SAIC LIDAR
SCIENCE APPLICATIONS INTERNATIONAL CORPORATION (SAIC)
CONTRACT NUMBER: PO10020755_R33

Woolpert Project Number: 66566
May 2013

WOOLPERT
DESIGN | GEOSPATIAL | INFRASTRUCTURE

AIRBORNE LIDAR PROJECT REPORT

SAIC LIDAR

CONTRACT: #66566

For:

Science Applications International Corporation
(SAIC)
14668 Lee Road
Chantilly, VA 20151
Tel 703.676.9315

By:

Woolpert
4454 Idea Center Boulevard
Dayton, OH 45430-1500
Tel 937.461.5660

Summary of Contents

List of Figures

List of Tables

SECTION 1: OVERVIEW

TASK ORDER NAME: SAIC LIDAR

WOOLPERT PROJECT #66566

This report contains a comprehensive outline of the airborne LiDAR data acquisition for Milwaukee, WI for Science Applications International Corporation (SAIC). The project area was approximately 1286 square kilometers. The LiDAR was 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 ALS70 500 kHz Multiple Pulses in Air (MPiA) LiDAR sensor. This 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:	7800 ft / 2377 m
MSL (Mean Sea Level) average flying height:	8377 ft / 2553 m
Average Ground Speed:	150 knots / 173 mph
Field of View (full):	40 degrees
Pulse Rate:	230 kHz
Scan Rate:	35.5 Hz
Side Lap (Minimum):	25.2%

LiDAR data was produced in Universal Transverse Mercator (UTM) Zone 16N, North American Datum of 1983 (NAD83). Coordinate positions were specified in units of meters. The vertical datum used for the project was referenced to NAVD 1988, meters, Geoid12A.

SECTION 2: ACQUISITION

The LiDAR data was acquired with a Leica ALS70 500 kHz Multiple Pulses in Air (MPiA) LiDAR sensor system, on board a Cessna 404. The ALS70 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 ALS70 500 kHz Multiple Pulses in Air (MPiA) LiDAR System has the following specifications:

Table 2.1 ALS70 LiDAR System Specifications

Specification	
Operating Altitude	200 – 3,500 meters
Scan Angle	0 to 75° (variable)
Swath Width	0 to 1.5 X altitude (variable)
Scan Frequency	0 – 200 Hz (variable based on scan angle)
Maximum Pulse Rate	500 kHz (Effective)
Range Resolution	Better than 1 cm
Elevation Accuracy	7 - 16 cm single shot (one standard deviation)
Horizontal Accuracy	5 – 38 cm (one standard deviation)
Number of Returns per Pulse	7 (infinite)
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 crews were onsite, running a GPS base station at Waukesha County Airport (KUES) for the airborne GPS support.

The LiDAR data was collected in two 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

Airborne LiDAR Acquisition Flight Summary			
Date of Mission	Lines Flown	Mission Time (UTC) Wheels Up/ Wheels Down	Mission Time (Local = CDT) Wheels Up/ Wheels Down
October 29, 2012	1-7	18:08-19:31	1:08PM-2:31PM
November 13, 2012	8-31	17:15-22:32	11:15AM-4:32PM

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, POSGNSS Software v. 5.20, IPAS Pro v.1.35.

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.2.74, Proprietary Software, TerraMatch v. 12.01.

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.12.005.

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.12.005.

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.

Woolpert survey crews were onsite, operating a Global Navigation Satellite System (GNSS) Base Station for the ground control and at Waukesha County Airport (KUES) for the airborne GPS support. The base station used during the LiDAR acquisition mission is listed on the next page:

Table 3.1: GNSS Base Stations

Station	Latitude	Longitude	Ellipsoid Height (L1 Phase Center)
Name	(DMS)	(DMS)	(Meters)
KUES Airport Base	N 39° 40’ 22.90265”	W 75° 36’ 02.65049”	-10.972

DATA PROCESSING

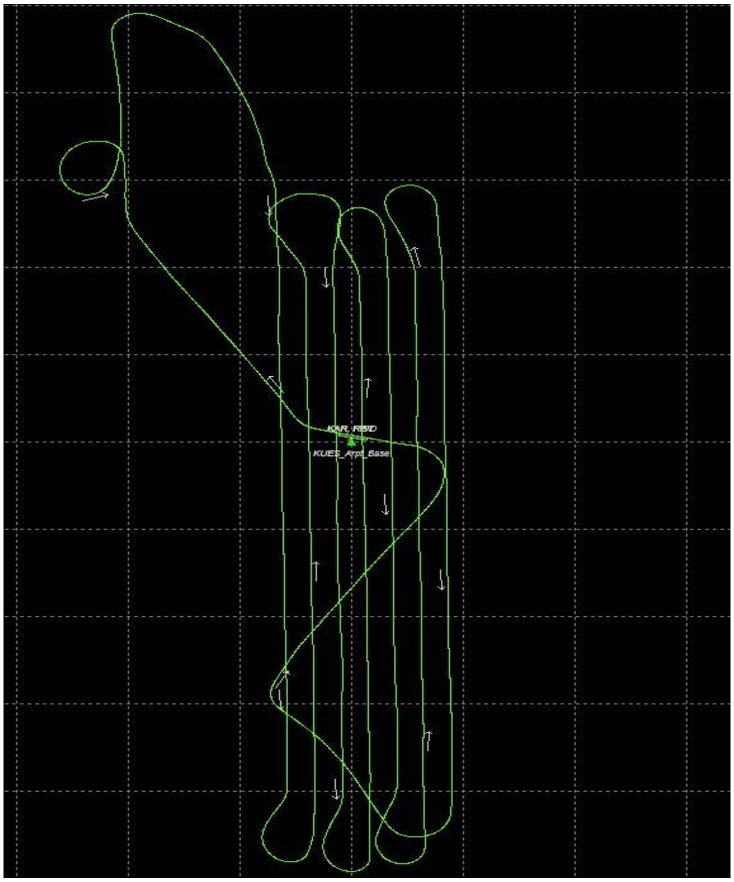
All airborne GNSS and IMU data was post-processed and quality controlled using Applanix MMS software. GNSS data was processed at a 1 and 2 Hz data capture rate and the IMU data was processed at 200 Hz.

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 Day30312: N475RC and ALS LiDAR S/N7177



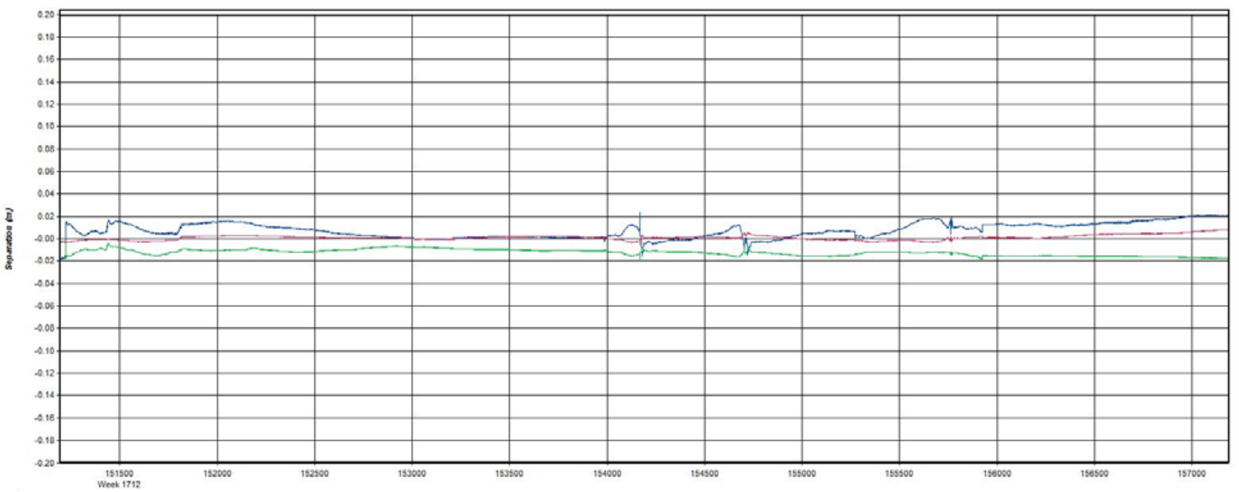
Within the trajectory processing, there are many factors that affect the overall quality, but the most indicative are the Combined Separation, the Estimated Positional Accuracy, and the Positional Dilution of Precision (PDOP).

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 Day30312 of Combined Separation

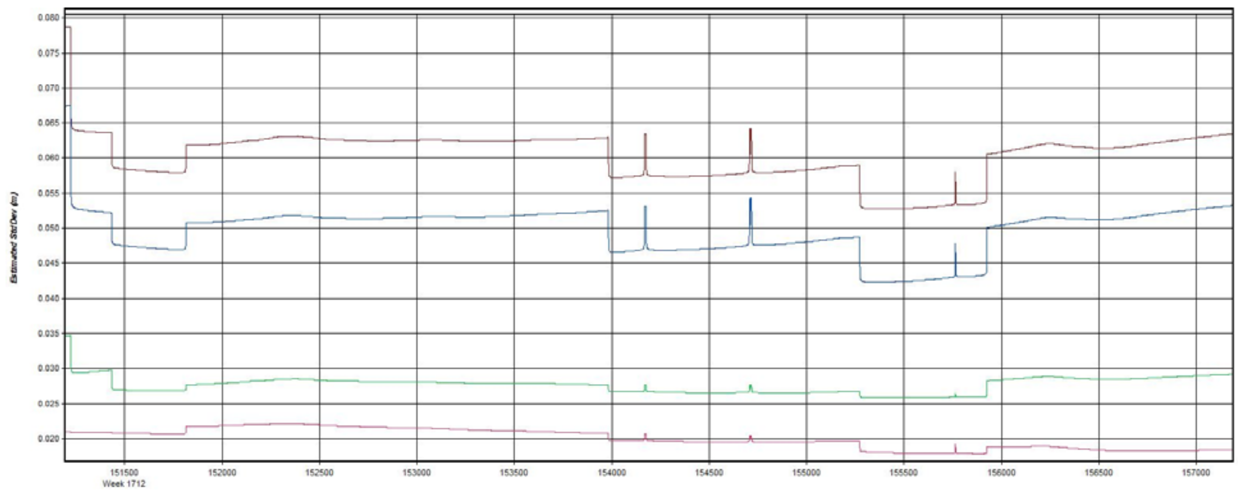


Estimated Positional Accuracy

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.

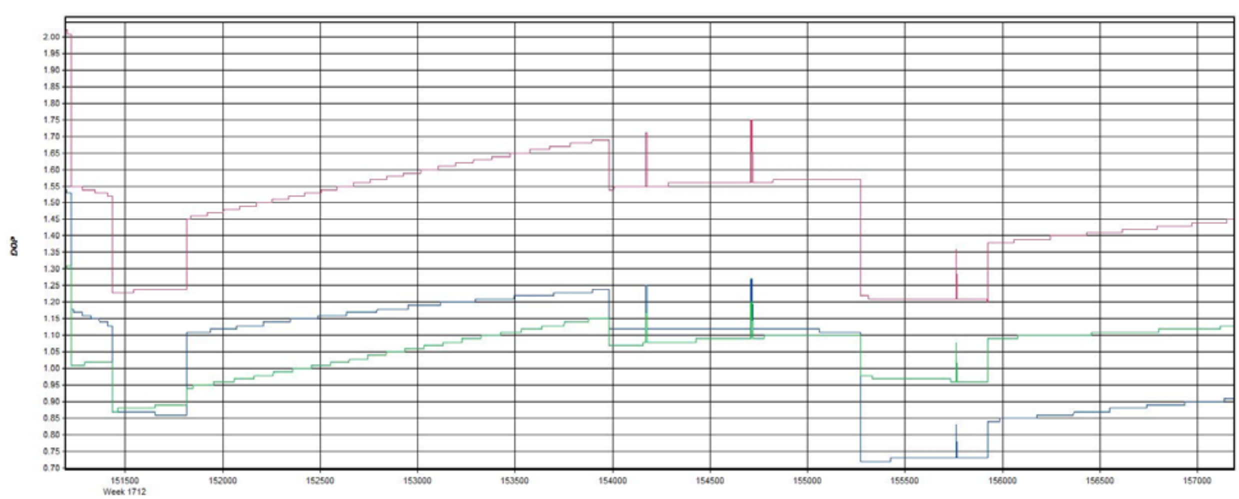
Figure 3.3: Representative Graph from Day30312 of Positional Accuracy



Positional Dilution of Precision (PDOP)

The PDOP measures the precision of the GPS solution in regards to the geometry of the satellites acquired and used for the solution. Woolpert's goal is to maintain an average PDOP value below 3.0. Brief periods of PDOP over 3.0 are acceptable due to the calibration and control process if other metrics are within specification. See **Figure 3.4** for the PDOP Graph.

Figure 3.4 Representative Graph from Day30312 of PDOP



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	-0.001	meters
Minimum error	-0.04	meters
Maximum error	0.05	meters
Average magnitude	0.029	meters
Root mean square	0.033	meters
Standard deviation	0.034	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)
6001	429305.13	4747937.82	216.3	216.29	-0.01
6002	417184.6	4748240.59	234.52	234.51	-0.01
6003	406396.66	4749234.65	240.86	240.87	0.01
6004	396463.81	4748577.68	259.84	259.88	0.04
6005	419823.76	4758061.8	238.06	238.11	0.05
6006	408910.13	4757414.31	268.43	268.47	0.04
6007	399245.84	4759298.78	248.68	248.69	0.01
6008	425934.81	4764125.25	179.52	179.48	-0.04
6009	414739.03	4765571.95	232.51	232.47	-0.04
6011	396602.84	4773546.4	281.35	281.39	0.04
6012	405221.94	4773518.3	253.11	253.1	-0.01
6013	416098.25	4775017.23	226.47	226.43	-0.04
6014	426927.44	4773094.2	197.12	197.17	0.05
6015	428114.9	4780014.59	207.25	207.21	-0.04
6016	417453.63	4781802.45	223.38	223.35	-0.03
6017	407533.85	4781285.55	267.83	267.8	-0.03
6018	405111.06	4789300.63	280.7	280.73	0.03
6019	413541.35	4787735.28	271.22	271.22	0
6020	424663.75	4788281.93	206.93	206.9	-0.03

VERTICAL ACCURACY CONCLUSIONS

- **Data Accuracy** tested 0.033 meters RMSE.

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

Approved By:			
Title	Name	Signature	Date
Associate Member LiDAR Specialist Certified Photogrammetrist #1281	Qian Xiao		May 6, 2013

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 v1.2 classified point cloud and bare earth point files in tile format.
- The project data was delivered on a USB Drive.

WOOLPERT

DESIGN | GEOSPATIAL | INFRASTRUCTURE