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LIDAR PROJECT REPORT

FOR

US GEOLOGICAL SURVEY
NGTOC III
ROLLA, MO

ARKANSAS VALLEY, CO

December 16, 2011

AERO-METRIC PROJECT NO. 1-100805

Airborne GPS Survey Report

For

US GEOLOGICAL SURVEY
NGTOC III

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AERO-METRIC Project No. 1-100805

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USGS – ARKANSAS VALLEY, CO LIDAR TASK ORDER

AERO-METRIC Project No. 1-100805

TITLE **SECTION**

1 INTRODUCTION

This report contains a summary of the LiDAR data acquisition and processing for the **USGS – ARKANSAS VALLEY COLORADO LiDAR TASK ORDER**.

1.1 Contact Info

Questions regarding the technical aspects of this report should be addressed to:

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1.2 Purpose

Aerometric, Inc. acquired highly accurate Light Detection and Ranging (LiDAR) data for the project area which comprised approximately 934 square miles for the United State Geological Survey. Using Towill Inc. Orion M200 LiDAR system, data was collected at a nominal 1500 meters to support the project area's requirements. Additional deliverables were also generated for FEMA in smaller areas contained within the USGS defined area. These included 2 foot contours and DEM bare-surfaces files. The DEM have been included using the same tile layout at delivered to USGS.

1.3 Project Locations

The project area covers the Arkansas River valley from the southern parts of Eagle and Summit counties as it flows south into Saguache County, Colorado. The area was defined and supplied by USGS on July 27, 2010 and as modified on August 5, 2010.

1.4 Time Period

LiDAR data acquisition was completed between September 9th, 2010 and October 28th, 2010. A total of 12 flight missions were required to cover the project area. See Item 3.4 for a sketch of the acquisition missions and Section 7 of the report for each flight log.

1.5 Project Scope

Aerometric, Inc. acquired highly accurate Light Detection and Ranging (LiDAR) data for the project which encompass approximately 934 square miles in Colorado. Using Towill's Orion M200 LiDAR system, data was collected at an altitude of 1500 meters to support the project area's requirements.

As documented in our proposal dated January 15, 2010 we were to achieve a TIN accuracy of 15cm for all areas. The accuracy as tested and published in this report in Section 8 has met the vertical accuracy requirements.

1.6 Conditions Affecting Progress

- None.

2 GEODETIC CONTROL

2.1 Network Scope

Base station information and survey control was collected by the Towill Company.

Aerometric Arkansas Lidar Acquisition
Base Station Summary

GPS Receiver Type: Trimble R7
GPS Antenna Type: Zephyr Geodetic
Antenna Heights: Measured to Bottom of Notch in Meters
[To reduce HI to antenna phase center: $h = (H^2 - 0.16981^2)^{1/2} + 0.00891$]

Date	Julian Day	8257				8284				7248			
		Location	Start	Stop	HI	Location	Start	Stop	HI	Location	Start	Stop	HI
9/9/2010	252	AI5944	9:22	15:08	1.637	AI5957	8:58	14:51	1.729	Not Used			
9/10/2010	253	AI5944	8:31	14:16	1.639	AI5957	9:02	14:59	1.557	AI5932	9:04	13:10	1.549
9/11/2010	254	AI5944	8:26	18:55	1.637	AI5957	8:43	18:50	1.719	AI5932	10:01	15:42	1.603
9/12/2010	255	AI5944	8:28	19:20	1.636	AI5932	10:07	19:43	1.578	AI5958	8:47	18:38	1.486
9/13/2010	256	AI5944	9:26	15:27	1.638	Base1	9:57	15:43	1.518	AI5932	8:58	18:47	1.631
9/14/2010	257	AI5944	8:25	16:07	1.638	Base1	9:17	17:43	1.493	AI5932	8:34	18:23	1.688
9/15/2010	258	AI5944	8:26	16:30	1.638	Base1	9:15	17:17	1.519	AI5932	8:39	16:40	1.543
9/16/2010	259	AI5944			1.638	Base1	8:59	13:25	1.569	AI5932	8:19	14:02	1.605
						AI5957	15:33	19:00	1.579				

Notes:

AI5944	Located at the Buena Vista Airport
AI5957	Located at the Leadville Airport
AI5958	Located at the Leadville Airport (AI5957 was occupied on 9/12/2010)
AI5932	Located at the Salida Airport
Base1	Located at Villa Grove at the south end of the project

3 LiDAR ACQUISITION & PROCEDURES

3.1 Acquisition Time Period

LiDAR data acquisition and Airborne GPS control surveys were completed between September 9th, 2010 and October 28th, 2010. A total of 12 flight missions were required to cover the project areas.

3.2 LiDAR Planning

The LiDAR data for this project was collected with Towill's Orion M200 Airborne LiDAR system. All flight planning and acquisition was completed using Optech's ALTM-Nav, version 2.1.25b (flight planning and LiDAR control software).

The following are the acquisition settings for the project area

- Flying Height (Above Ground): 1500 meters
- Laser Pulse Rate: 70 kHz
- Mirror Scan Frequency: 40 Hz

- Scan Angle (+/-): 18°
- Side Lap: 50 %
- Ground Speed: 160 kts
- Nominal Point Spacing: 1.0 meters

3.3 LiDAR Acquisition

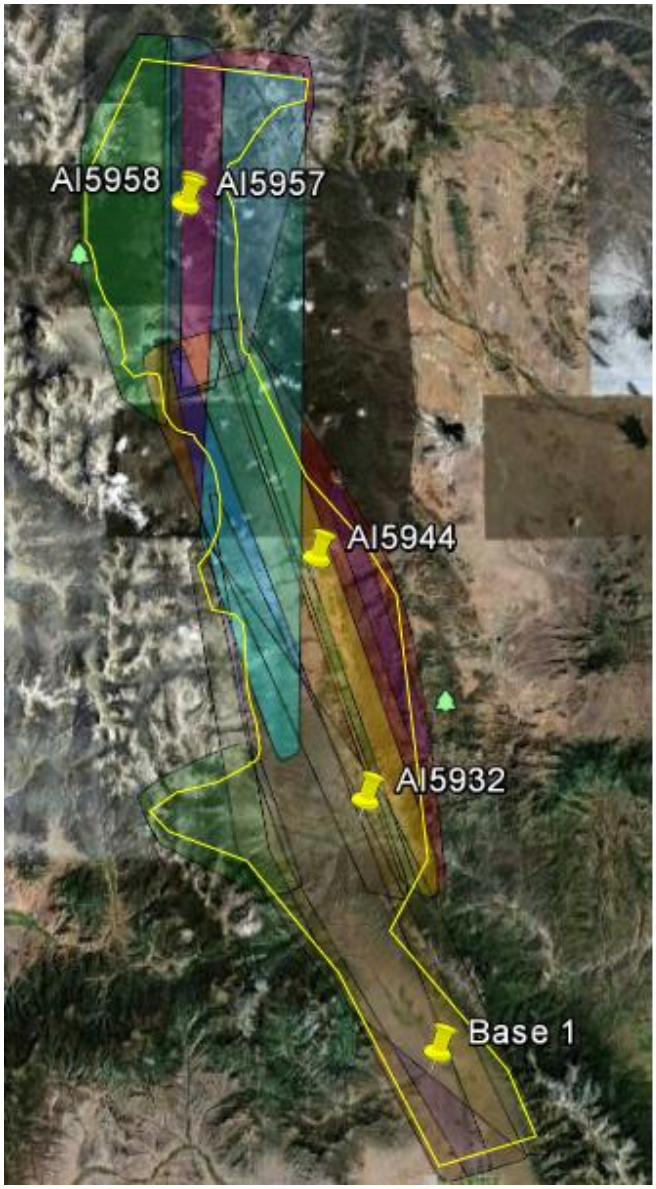
A total of 12 flight missions were required to cover the project area. The missions were flown using the above planned values. See below for a sketch of the acquisition missions and Section 6 of the report for each flight log.

Airborne GPS and IMU trajectories for the LiDAR sensor where also acquired during the time of flight.

Each mission was typically four to five hours long. Before take-off, the LiDAR system and the Airborne GPS and IMU system were initiated for a period of five minutes and then again after landing for another five minutes. The missions acquired data according to the planned flight lines and included a minimum of one (usually two) cross flights. The cross flights were flown perpendicular to the planned flight lines and their data used in the in-situ calibration of the sensor.

3.4 LiDAR Trajectory Processing

The airborne positioning was based on the following control stations: AI5944, AI5957, AI5958, AI5932, and Base1.



Arkansas Valley Mission Coverage

4 QC SURVEYS

The check point survey was performed between September 9th and October 28th, 2010 using Rapid Static GPS techniques. A total of 40 check points were surveyed across the project areas. These points were collected in open terrain to assess Fundamental Vertical Accuracy.

The control stations mentioned above to support the Airborne GPS acquisition were also used to complete the QC surveys.

See Section 5 of the control report for a complete listing.

5 FINAL LiDAR PROCESSING

5.1 ABGPS and IMU Processing

Airborne GPS

Applanix - POSGPS
Utilizing carrier phase ambiguity resolution on the fly (i.e., without initialization). The solution to sub-decimeter kinematic positioning without the operational constraint of static initialization as used in semi-kinematic or stop-and-go positioning was utilized for the airborne GPS post-processing.

The processing technique used by Applanix, Inc. for achieving the desired accuracy is Kinematic Ambiguity Resolution (KAR). KAR searches for ambiguities and uses a special method to evaluate the relative quality of each intersection (RMS). The quality indicator is used to evaluate the accuracy of the solution for each processing computation. In addition to the quality indicator, the software will compute separation plots between any two solutions, which will ultimately determine the acceptance of the airborne GPS post processing.

Inertial Data

The post-processing of inertial and aiding sensor data (i.e. airborne GPS post processed data) is to compute an optimally blended navigation solution. The Kalman filter-based aided inertial navigation algorithm generates an accurate (in the sense of least-square error) navigation solution that will retain the best characteristics of the processed input data. An example of inertial/GPS sensor blending is the following: inertial data is smooth in the short term. However, a free-inertial navigation solution has errors that grow without bound with time. A GPS navigation solution exhibits short-term noise but has errors that are bounded. This optimally blended navigation solution will retain the best features of both, i.e. the blended navigation solution has errors that are smooth and bounded.
The resultant processing generates the following data:

- Position: Latitude, Longitude, Altitude
- Velocity: North, East, and Down components
- 3-axis attitude: roll, pitch, true heading
- Acceleration: x, y, z components
- Angular rates: x, y, z components

The Applanix software, version 4.4, was used to determine both the ABGPS trajectory and the blending of inertial data.

The airborne GPS and blending of inertial and GPS post-processing were completed in multiple steps.

1. The collected data was transferred from the field data collectors to the main computer. Data was saved under the project number and separated between LiDAR mission dates. Inside each mission date, a sub-directory was created with the aircraft's tail number and an A or B suffix was attached for the time of when the data was collected. Inside the tail number sub-directory, five sub-directories were also created EO, GPS, IMU, PROC, and RAW.

2. The aircraft raw data (IMU and GPS data combined) was run through a data extractor program. This separated the IMU and GPS data. In addition to the extracting of data, it provided the analyst the first statistics on the overall flight. The program was POSPac (POS post-processing PACkage).

3. Executing POSGPS program to derive accurate GPS positions for all flights:
   Applanix POSGPS
   The software utilized for the data collected was PosGPS, a kinematic on-the-fly (OTF) processing software package. Post processing of the data is computed from each base station (Note: only base stations within the flying area were used) in both a forward and backward direction. This provides the analyst the ability to Quality Check (QC) the post processing, since different ambiguities are determined from different base stations and also with the same data from different directions.

   The trajectory separation program is designed to display the time of week that the airborne or roving antenna traveled, and compute the differences found between processing runs. Processed data can be compared between a forward/reverse solution from one base station, a reverse solution from one base station and a forward solution from the second base station, etc. For the Applanix POSGPS processing, this is considered the final QC check for the given mission. If wrong ambiguities were found with one or both runs, the analyst would see disagreements from the trajectory plot, and re-processing would continue until an agreement was determined.

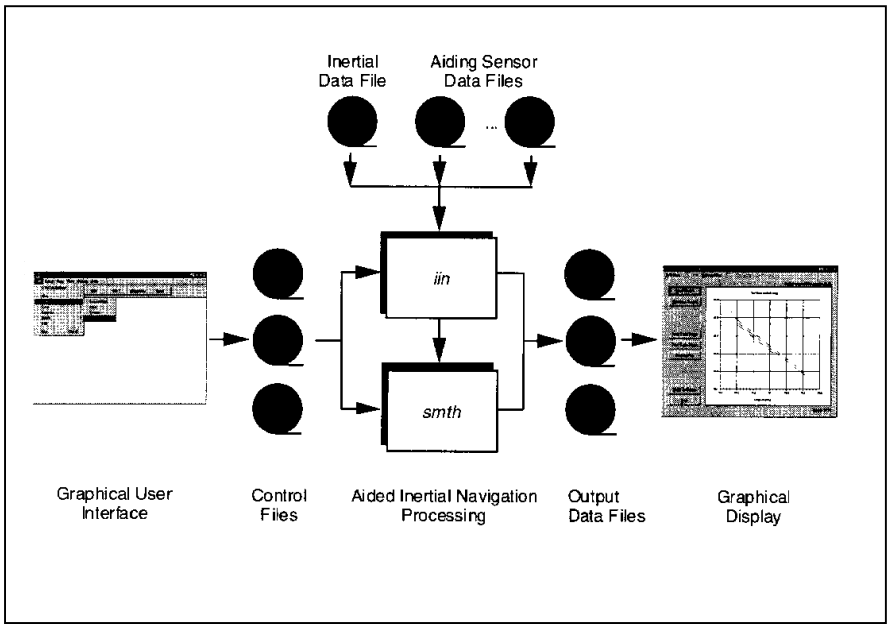
   Once the analyst accepts a forward and reverse processing solution, the trajectory plot is analyzed and the combined solution is stored in a file format acceptable for the IMU post processor.

   Please see Section 7 of the control report for the final accepted trajectory plots.

4. When the processed trajectory (either through POSGPS) data was accepted after quality control analysis, the combined solution is stored in a file format acceptable for the IMU post processor (i.e. POSProc).

5. Execute POSProc.
   POSProc comprises a set of individual processing interface tools that execute and provide the following functions:

   The diagram below shows the organization of these tools, and is a function of



   the

   POSProc processing components.

   - Integrated Inertial Navigation (*iin*) Module.
     The name *iin* is a contraction of Integrated Inertial Navigation. *iin* reads inertial data and aiding data from data files specified in a processing environment file and computes the aided inertial navigation solution. The inertial data comes from a strapdown IMU. *iin* outputs the navigation data between start and end times at a data rate as specified in the environment file. *iin* also outputs Kalman filter data for analysis of estimation error statistics and smoother data that the smoothing program *smth* uses to improve the navigation solution accuracy.
     iin implements a full strapdown inertial navigator that solves Newton's equation of motion on the earth using inertial data from a strapdown IMU. The inertial navigator implements coning and sculling compensation to handle potential problems caused by vibration of the IMU.

- Smoother Module (*smth*).
  smth is a companion processing module to *iin*. *smth* is comprised of two individual functions that run in sequence. *smth* first runs the *smoother function* and then runs the *navigation correction function*.

  The *smth* smoother function performs backwards-in-time processing of the forwards-in-time blended navigation solution and Kalman filter data generated by *iin* to compute smoothed error estimates. *smth* implements a modified Bryson-Frazier smoothing algorithm specifically designed for use with the *iin* Kalman filter. The resulting smoothed strapdown navigator error estimates at a given time point are the optimal estimates based on all input data before and after the given time point. In this sense, *smth* makes use of all available information in the input data. *smth* writes the smoothed error estimates and their RMS estimation errors to output data files.

  The *smth* navigation correction function implements a feedforward error correction mechanism similar to that in the *iin* strapdown navigation solution using the smoothed strapdown navigation errors. s*mth* reads in the smoothed error estimates and with these, corrects the strapdown navigation data. The resulting navigation solution is called a Best Estimate of Trajectory (BET), and is the best obtainable estimate of vehicle trajectory with the available inertial and aiding sensor data.

The above mentioned modules provide the analyst the following statistics to ensure that the most optimal solution was achieved: a log of the *iin* processing, the Kalman filter Measurement Residuals, Smoothed RMS Estimation Errors, and Smoothed Sensor Errors and RMS.

5.2 LiDAR "Point Cloud" Processing

The ABGPS/IMU post processed data along with the LiDAR raw measurements were processed using Optech Incorporated's ASDA software. This software was used to match the raw LiDAR measurements with the computed ABGPS/IMU positions and attitudes of the LiDAR sensor. The result was a "point cloud" of LiDAR measured points referenced to the ground control system.

5.3 LiDAR CALIBRATION

Introduction

The purpose of the LiDAR system calibration is to refine the system parameters in order for the post-processing software to produce a "point cloud" that best fits the actual ground.

The following report outlines the calibration techniques employed for this project.

Calibration Procedures

Towill routinely performs two types of calibrations on its Orion M200 LiDAR system. The first calibration, system calibration, is performed whenever the LiDAR system is installed in the aircraft. This calibration is performed to define the system parameters affected by the physical misalignment of the system versus aircraft. The second calibration, in-situ calibration, is performed for each mission using that missions data. This calibration is performed to refine the system parameters that are affected by the on site conditions as needed.

System Calibration and Correction Software

Optech has developed a proprietary calibration software in December of 2009 that performs system calibration. The results from this new software achieved excellent results and an accuracy that meets the project requirements.

This new calibration tool incorporates Optech's proprietary optical sensor models to compute laser point positions and provide laser point calibration improvements on a per flightline basis for the entire project area. It furthermore calculates planar surfaces at different angles from each flight line and then uses a robust least squares solution to compute the orientation parameters at the optical level instead of the traditional methods relating to the ground points. Determining and correcting at the optical level is critical when correcting the data especially when working in terrain and aggressive design parameters as found in this project. Each flight line was computed individually and output in LAS 1.2 format.

In-situ Calibration

The in-situ calibration is performed as needed using the mission's data. This calibration is performed to refine the system parameters that are affected by the on site conditions.

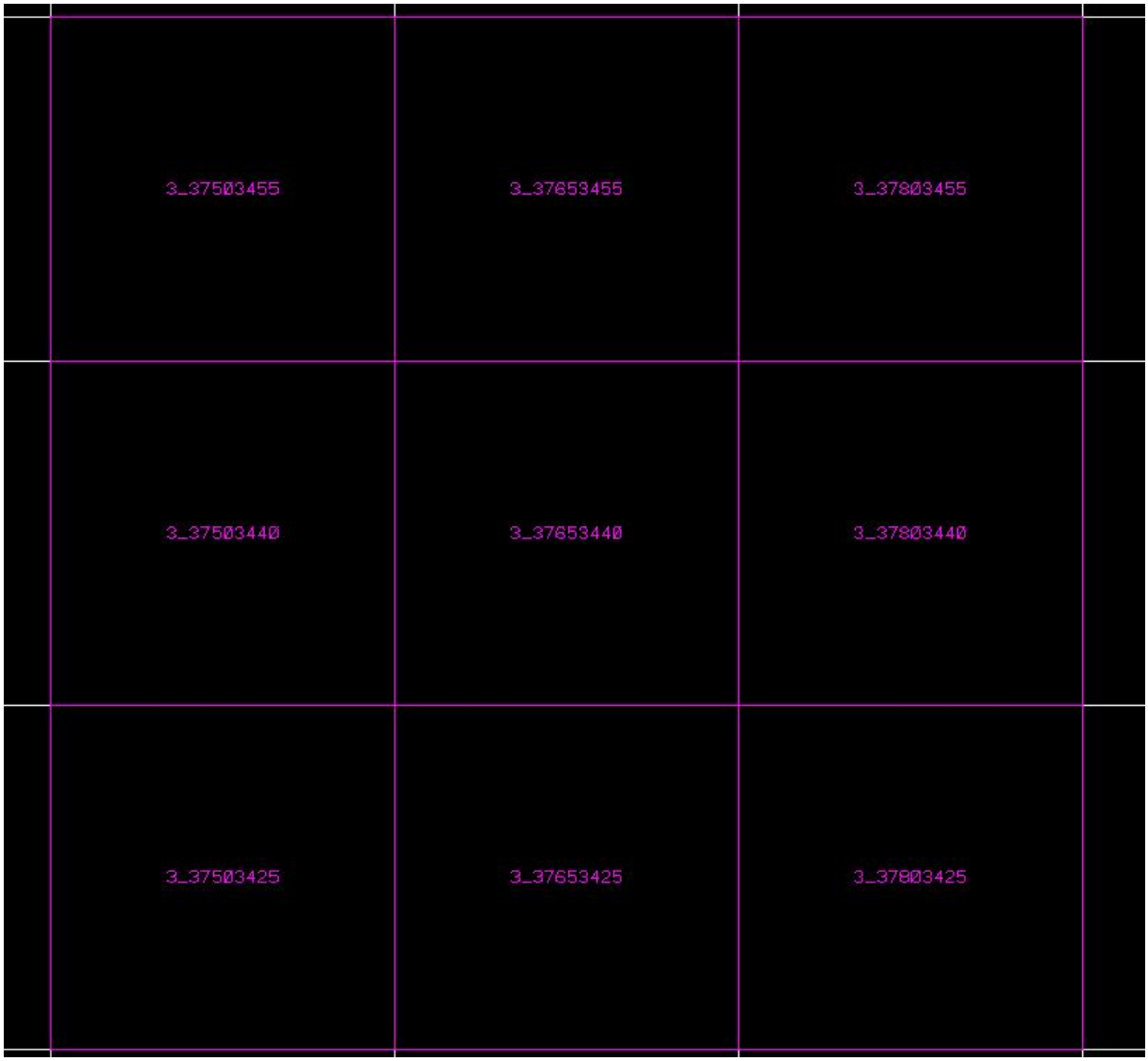
For each mission, LiDAR data for at least one cross flight is acquired over the mission's acquisition site. The processed data of the cross flight is compared to the perpendicular flight lines using either the Optech proprietary software or TerraSolid's TerraMatch software to determine if any systematic errors are present. In this calibration, the data of individual flight lines are compared against each other and their systematic errors are corrected in the final processed data.

5.4 LiDAR Processing

The LAS files were then imported, verified, and parsed into manageable, tiled grids using GeoCue version 7.0.34.5. GeoCue allows for ease of data management and process tracking.

The first step after the data has been processed and calibrated is to perform a relative accuracy assessment on the flightline to flightline comparisons and also a data density test prior any further processing.

In addition to the relative accuracy assessment, Aerometric also reviews a few tiles to ensure that the desired density has been met. Aerometric utilizes an in-house proprietary software to complete this task. Initially a grid was placed according to the version 12 specification that is based on the nominal post spacing. The results indicated that the density of the sampled tiles achieved only 93% of the points meeting the specified data density criteria. However, using the latest USGS specification, version 13, which modifies the requirements to allow up to 2 times the nominal post spacing our data tests now easily meets the desired density requirements. Below are the statistics from the results of the inspected tiles as shown in the next image.



Sampled tiles: Arkansas Valley (3_37503425, 3_37503440, 3_37503455, 3_37653425, 3_37653440, 3_37653455, 3_37803425, 3_37803440, and 3_37803455)

Run 1 (Version 12 – 1.0 meter)
Total number of cells: 20,277,009
Total number of cells with one or more points : 18,869,739
Percentage of tiles with 1 point or more: 93%

Run 2 (Version 13 – 2.0 meter)
Total number of cells: 5,076,009
Total number of cells with one or more points: 5,061,393
Percentage of tiles with 1 point or more: 99.7%

Once both the accuracy between swaths and data density is accepted an automated classification algorithm is performed using TerraSolid's TerraScan, version 11.017. This will produce the majority of the bare-earth datasets.

The remainder of the data was classified using manual classification techniques. The majority of the manual edit moved points misclassified as ground (class 2) to unclassified (class 1). Erroneous low points, high points, including clouds are classified to class 7.

5.4 Check Point Validation

The data was then verified using the ground control data collected by Towill. TerraScan then computes the vertical differences between the surveyed elevation and the LiDAR derived elevation for each point.

A report listing the differences and common statistics was created and can be found in Section 8 of this report.

5.5 LiDAR Data Delivery

Raw point cloud data supplied is in the following format:

- LAS, version 1.2
- GPS times adjusted to GPS Absolute
- Full swaths and delivered as 1 file per swath which did not exceed 2gb.

Classified point cloud data is also being supplied using the following criteria.

- LAS, version 1.2
- GPS times adjusted to GPS Absolute
- Classification scheme:
  - Code 1 – Processed, but unclassified
  - Code 2 – Ground
  - Code 7 – Noise
  - Code 9 - Water
  - Code 10 – Ignored Ground (Breakline proximity)

The 1 meter bare-earth DEMs were created in the following manner. First, ArcGrids in ASCII format were created using TerraModeler version 11.005 (TerraSolid Ltd.). The ASCII grids were then imported into ARC and translated to raster format and placed in a geodatabase DEM feature dataset.

The first return 1 meter intensity images were created using GeoCue. These images are in GeoTiff format.

Arkansas Valley Intensity Raster

Collected breaklines are first collected in a Microstation environment using the base specifications. Upon acceptance the breaklines, either polygons or lines, are translated into ARC and imported to the final geodatabase as separate features.

6 CONCLUSION

Because of the rigorous procedures and use of new technology, this project will serve the USGS and all users requiring the provided LiDAR derivative products for the project area of Arkansas Valley in Colorado well into the future. Although this project tested the limits of both the equipment and personnel, the results are extremely accurate and reliable.

TOWILL Surveying, Mapping and GIS Services

LIDAR FLIGHT LOG

Date: 09/09/2010

Mission: 252A

Survey Information		Base Station Data	
Project Name:	Aero-Metric Arkansas River Valley	Station Name:	AI5944
Flight Vendor / Tail No:	Marc – N1009S	Receiver Type & SN:	Trimble R7 - #8257
METs: temp, press, humid)	19 deg. C ; 757 mB	Antenna & Measurement Type:	Zephyr Geodetic – bot. notch
Airport Start/End:	KAEJ – Rwy 15/33	Antenna Height – meters:	1.637 m
Planned Parameters: (scan angle, freq., height)	18 deg; 40 Hz; 1500 meters AGL; 70 kHz	Antenna Height – feet:	5.37 ft Checks?

Line Number	Start Time (UTC)	End Time (UTC)	Average Range	Approximate Heading	Range Strip Number	Comments
	15:51	15:58			1	Laser warmup
C1	15:59	16:00	1600	W	4	Perpendicular Runway Pass
C2	16:03	16:04	1580	E	5	Perpendicular Runway Pass
40	16:06	16:09	1400	S	6	
41	16:12	16:13	1500	N	7	Laser shut-off early
41	16:16	16:19	1500	S	8	Reflight
42	16:22	16:25	1500	N	9	
43	16:28	16:33	1500	S	10	
44	16:35	16:40	1500	N	11	
45	16:46	16:52	1500	S	12	

TOWILL | Surveying, Mapping and GIS Services

LIDAR FLIGHT LOG

Date: 09/09/2010

Mission: 252A

Line Number	Start Time (UTC)	End Time (UTC)	Average Range	Approximate Heading	Range Strip Number	Comments
46	16:55	17:02	1500	N	13	
47	17:05	17:13	1500	S	14	
48	17:16	17:24	1500	N	15	
49	17:27	17:37	1500	S	16	
50	17:39	17:48	1500	N	17	
51	17:53	18:03	1500	S	18	
52	18:07	18:18	1500	N	19	
53	18:22	18:36	1500	S	20	
54	18:40	18:54	1500	N	21	
55	18:57	19:14	1500	S	22	
56	19:17	19:33	1500	N	23	
57	19:37	19:55	1500	S	24	
58	19:59	20:14	1500	N	25	
C3	20:22	20:23	1500	E	26	Perpendicular Runway Pass
C4	20:26	20:27	1450	W	27	Perpendicular Runway Pass

TOWILL Surveying, Mapping and GIS Services

LIDAR FLIGHT LOG

Date: 09/10/2010

Mission: 253A

Survey Information		Base Station Data	
Project Name:	Aero-Metric Arkansas River Valley	Station Name:	AI5944
Flight Vendor / Tail No:	Marc – N1009S	Receiver Type & SN:	Trimble R7 - #8257
METs: temp, press, humid)	15 deg. C ; 749 mB	Antenna & Measurement Type:	Zephyr Geodetic – bot. notch
Airport Start/End:	KAEJ – Rwy 15/33	Antenna Height – meters:	1.639 m
Planned Parameters: (scan angle, freq., height)	18 deg; 40 Hz; 1500 meters AGL; 70 kHz	Antenna Height – feet:	5.38 ft Checks?

Line Number	Start Time (UTC)	End Time (UTC)	Average Range	Approximate Heading	Range Strip Number	Comments
	15:08	15:11			1	Laser warmup
C1	15:15	15:16	1500	E	2	Perpendicular Runway Pass
C2	15:19	15:21	1500	W	3	Perpendicular Runway Pass
54	15:41	15:53	1500	S	6	
55	16:00	16:16	1500	N	7	Laser shut-off early
56	16:21	16:36	1500	S	8	Reflight
57	16:42	16:58	1500	N	9	
58	17:01	17:18	1500	S	10	
59	17:25	17:43	1500	N	11	
60	17:47	18:04	1500	S	12	

TOWILL | Surveying, Mapping and GIS Services

LIDAR FLIGHT LOG

Date: 09/10/2010

Mission: 253A

Line Number	Start Time (UTC)	End Time (UTC)	Average Range	Approximate Heading	Range Strip Number	Comments
61	18:09	18:25	1500	N	13	
62	18:28	18:44	1500	S	14	
C3	18:52	18:54	1500	W	15	Perpendicular Runway Pass
C4	18:56	18:57	1500	E	16	Perpendicular Runway Pass

TOWILL | Surveying, Mapping and GIS Services

LIDAR FLIGHT LOG

Date: 09/11/2010

Mission: 254A

Survey Information		Base Station Data	
Project Name:	Aero-Metric Arkansas River Valley	Station Name:	AI5944
Flight Vendor / Tail No:	Marc – N1009S	Receiver Type & SN:	Trimble R7 - #8257
METs: temp, press, humid)	12 deg. C ; 766 mB	Antenna & Measurement Type:	Zephyr Geodetic – bot. notch
Airport Start/End:	KAEJ – Rwy 15/33	Antenna Height – meters:	1.637 m
Planned Parameters: (scan angle, freq., height)	18 deg; 40 Hz; 1500 meters AGL; 70 kHz	Antenna Height – feet:	5.37 ft Checks?

Line Number	Start Time (UTC)	End Time (UTC)	Average Range	Approximate Heading	Range Strip Number	Comments
	15:01	15:09			1	Laser warmup
C1	15:09	15:10	1550	W	2	Perpendicular Runway Pass
C2	15:13	15:14	1550	E	3	Perpendicular Runway Pass
167	15:22	15:32	1500	N	4	
168	15:35	15:44	1500	S	5	
169	15:47	15:56	1500	N	6	
170	16:00	16:09	1500	S	7	
171	16:13	16:20	1500	N	8	
172	16:24	16:31	1500	S	9	
173	16:38	16:44	1500	N	10	

TOWILL | Surveying, Mapping and GIS Services

LIDAR FLIGHT LOG

Date: 09/11/2010

Mission: 254A

Line Number	Start Time (UTC)	End Time (UTC)	Average Range	Approximate Heading	Range Strip Number	Comments
174	16:48	16:54	1500	S	11	
175	16:58	17:04	1500	N	12	
176	17:07	17:12	1500	S	13	
177	17:15	17:20	1500	N	14	
178	17:23	17:27	1500	S	15	
179	17:31	17:34	1500	N	16	
180	17:38	17:41	1500	S	17	
166	17:46	17:56	1500	N	18	
165	18:00	18:09	1500	S	19	
164	18:12	18:22	1500	N	20	
163	18:25	18:34	1500	S	21	
162	18:38	18:47	1500	N	22	
161	18:51	19:00	1500	S	23	
160	19:05	19:14	1500	N	24	
159	19:17	19:28	1500	S	25	
C3	19:32	19:33	1500	E	26	Perpendicular Runway Pass

TOWILL | Surveying, Mapping and GIS Services

LIDAR FLIGHT LOG

Date: 09/11/2010

Mission: 254A

Line Number	Start Time (UTC)	End Time (UTC)	Average Range	Approximate Heading	Range Strip Number	Comments
C4	19:36	19:37	1500	W	27	Perpendicular Runway Pass

TOWILL | Surveying, Mapping and GIS Services

LIDAR FLIGHT LOG

Date: 09/11/2010

Mission: 254B

Survey Information		Base Station Data	
Project Name:	Aero-Metric Arkansas River Valley	Station Name:	AI5944
Flight Vendor / Tail No:	Marc – N1009S	Receiver Type & SN:	Trimble R7 - #8257
METs: temp, press, humid)	20 deg. C ; 763 mB	Antenna & Measurement Type:	Zephyr Geodetic – bot. notch
Airport Start/End:	KAEJ – Rwy 15/33	Antenna Height – meters:	1.637 m
Planned Parameters: (scan angle, freq., height)	18 deg; 40 Hz; 1500 meters AGL; 70 kHz	Antenna Height – feet:	5.37 ft Checks?

Line Number	Start Time (UTC)	End Time (UTC)	Average Range	Approximate Heading	Range Strip Number	Comments
	21:10	21:13			1	Laser warmup
C1	21:17	21:18	1400	W	2	Perpendicular Runway Pass
C2	21:21	21:22	1520	E	3	Perpendicular Runway Pass
158	21:29	21:38	1500	N	4	
157	21:43	21:52	1500	S	5	
156	21:55	22:04	1500	N	6	
155	22:09	22:18	1500	S	7	
154	22:22	22:31	1500	N	8	
153	22:34	22:41	1500	S	9	North 15 miles of line only
152	22:47	22:56	1500	N	10	

TOWILL | Surveying, Mapping and GIS Services

LIDAR FLIGHT LOG

Date: 09/11/2010

Mission: 254B

Line Number	Start Time (UTC)	End Time (UTC)	Average Range	Approximate Heading	Range Strip Number	Comments
151	22:59	23:08	1500	S	11	
150	23:11	23:20	1500	N	12	
149	23:24	23:34	1500	S	13	
148	23:36	23:45	1500	N	14	
147	23:47	23:56	1500	S	16	
146	00:01	00:10	1500	N	17	Week Roll Over
145	00:13	00:22	1500	S	18	
C3	00:27	00:28	1580	E	20	Perpendicular Runway Pass
C4	00:31	00:32	1550	W	21	Perpendicular Runway Pass
						Perpendicular Runway Pass

TOWILL Surveying, Mapping and GIS Services

LIDAR FLIGHT LOG

Date: 09/12/2010

Mission: 255A

Survey Information		Base Station Data	
Project Name:	Aero-Metric Arkansas River Valley	Station Name:	AI5944
Flight Vendor / Tail No:	Marc – N1009S	Receiver Type & SN:	Trimble R7 - #8257
METs: temp, press, humid)	17 deg. C ; 767 mB	Antenna & Measurement Type:	Zephyr Geodetic – bot. notch
Airport Start/End:	KAEJ – Rwy 15/33	Antenna Height – meters:	1.637 m
Planned Parameters: (scan angle, freq., height)	18 deg; 40 Hz; 1500 meters AGL; 70 kHz	Antenna Height – feet:	5.37 ft Checks?

Line Number	Start Time (UTC)	End Time (UTC)	Average Range	Approximate Heading	Range Strip Number	Comments
	15:46	15:49			1	Laser warmup
C1	15:52	15:53	1520	W	2	Perpendicular Runway Pass
C2	15:56	15:57	1500	E	3	Perpendicular Runway Pass
153	16:04	16:13	1500	N	4	Reflight of line
144	16:16	16:24	1500	S	5	
143	16:27	16:36	1500	N	6	
142	16:39	16:47	1500	S	9	
141	16:51	16:59	1500	N	10	
140	17:03	17:11	1500	S	11	
139	17:14	17:23	1500	N	12	

TOWILL | Surveying, Mapping and GIS Services

LIDAR FLIGHT LOG

Date: 09/12/2010

Mission: 255A

Line Number	Start Time (UTC)	End Time (UTC)	Average Range	Approximate Heading	Range Strip Number	Comments
138	17:27	17:30	1500	S	12	North section within boundary
137	17:33	17:36	1500	N	13	
136	17:41	17:43	1500	S	14	
135	17:46	17:49	1500	N	16	
134	17:52	17:55	1500	S	17	
133	17:57	18:00	1500	N	18	
132	18:04	18:06	1500	S	19	
131	18:09	18:11	1500	N	20	
130	18:14	18:16	1500	S	21	
129	18:19	18:20	1500	N	22	
128	18:24	18:26	1500	S	23	
127	18:29	18:30	1500	N	24	
126	18:34	18:35	1500	S	25	
125	18:39	18:40	1500	N	27	
124	18:44	18:45	1600	S	28	
123	18:48	18:49	1600	N	29	

TOWILL | Surveying, Mapping and GIS Services

LIDAR FLIGHT LOG

Date: 09/12/2010

Mission: 255A

Line Number	Start Time (UTC)	End Time (UTC)	Average Range	Approximate Heading	Range Strip Number	Comments
122	18:52	18:53	1500	S	31	
121	18:56	18:57	1600	N	32	
X1	19:00	19:05	1500 - 2200	S	33	Cross strip north side of north box – 50kHz
X2	19:13	19:18	800 - 1900	N	34	Cross strip south side of north box
138	19:21	19:23	1500	S	35	South section within boundary
C3	19:29	19:30	1450	E	36	Perpendicular Runway Pass
C4	19:32	19:33	1500	W	37	Perpendicular Runway Pass

TOWILL Surveying, Mapping and GIS Services

LIDAR FLIGHT LOG

Date: 09/12/2010

Mission: 255B

Survey Information		Base Station Data	
Project Name:	Aero-Metric Arkansas River Valley	Station Name:	AI5944
Flight Vendor / Tail No:	Marc – N1009S	Receiver Type & SN:	Trimble R7 - #8257
METs: temp, press, humid)	23 deg. C ; 770 mB	Antenna & Measurement Type:	Zephyr Geodetic – bot. notch
Airport Start/End:	KAEJ – Rwy 15/33	Antenna Height – meters:	1.637 m
Planned Parameters: (scan angle, freq., height)	18 deg; 40 Hz; 1500 meters AGL; 70 kHz	Antenna Height – feet:	5.37 ft Checks?

Line Number	Start Time (UTC)	End Time (UTC)	Average Range	Approximate Heading	Range Strip Number	Comments
	21:24	21:27			1	Laser warmup
C1	21:30	21:31	1500	W	2	Perpendicular Runway Pass
C2	21:34	21:35	1500	E	3	Perpendicular Runway Pass
100	21:43	21:47	1500	S	4	
101	21:50	21:53	1500	N	5	
102	21:56	21:59	1500	S	6	
103	22:02	22:06	1500	N	7	
104	22:09	22:11	1500	S	8	
105	22:14	22:18	1500	N	9	
139	22:20	22:23	1500	S	10	

TOWILL | Surveying, Mapping and GIS Services

LIDAR FLIGHT LOG

Date: 09/12/2010

Mission: 255B

Line Number	Start Time (UTC)	End Time (UTC)	Average Range	Approximate Heading	Range Strip Number	Comments
107	22:26	22:29	1500	N	12	
108	22:32	22:34	1500	S	13	
109	22:37	22:40	1500	N	14	
110	22:43	22:45	1500	S	15	
111	22:49	22:51	1500	N	16	
112	22:54	22:57	1600	S	17	
113	22:59	23:01	1600	N	18	
114	23:05	23:07	1500	S	19	
115	23:09	23:11	1500	N	20	
116	23:14	23:16	1500	S	21	
117	23:19	23:21	1500	N	22	
118	23:24	23:26	1500	S	23	
119	23:28	23:29	1500	N	24	
120	23:32	23:33	1500	S	25	
99	23:38	23:41	1500	N	26	
98	23:44	23:48	1500	S	27	

TOWILL | Surveying, Mapping and GIS Services

LIDAR FLIGHT LOG

Date: 09/12/2010

Mission: 255B

Line Number	Start Time (UTC)	End Time (UTC)	Average Range	Approximate Heading	Range Strip Number	Comments
97	23:52	23:56	1500	N	28	
96	23:59	00:02	1500	S	29	
95	00:05	00:09	1500	N	30	
94	00:12	00:15	1500	S	31	
93	00:18	00:22	1500	N	32	
92	00:25	00:29	1600	S	33	
91	00:32	00:36	1500	N	34	
90	00:39	00:43	1500	S	35	
89	00:46	00:50	1500	N	36	
C3	00:54	00:55	1500	E	37	Perpendicular Runway Pass
C4	00:57	00:58	1500	W	38	Perpendicular Runway Pass

TOWILL | Surveying, Mapping and GIS Services

LIDAR FLIGHT LOG

Date: 09/13/2010

Mission: 256A

Survey Information		Base Station Data	
Project Name:	Aero-Metric Arkansas River Valley	Station Name:	AI5944
Flight Vendor / Tail No:	Marc – N1009S	Receiver Type & SN:	Trimble R7 - #8257
METs: temp, press, humid)	18 deg. C ; 760 mB	Antenna & Measurement Type:	Zephyr Geodetic – bot. notch
Airport Start/End:	KAEJ – Rwy 15/33	Antenna Height – meters:	1.638 m
Planned Parameters: (scan angle, freq., height)	18 deg; 40 Hz; 1500 meters AGL; 70 kHz	Antenna Height – feet:	5.37 ft Checks?

Line Number	Start Time (UTC)	End Time (UTC)	Average Range	Approximate Heading	Range Strip Number	Comments
	15:58	16:03			1	Laser warmup
C1	16:03	16:05	1500	W	2	Perpendicular Runway Pass
C2	16:09	16:10	1500	E	3	Perpendicular Runway Pass
205	16:16	16:19	1500	N	4	
206	16:22	16:25	1500	S	5	
207	16:29	16:35	1500	N	6+7	Laser Eye-Safe Shutdown
208	16:38	16:42	1500	S	8	
209	16:44	16:47	1500	N	9	
210	16:50	16:52	1500	S	10	
211	16:56	16:58	1500	N	11	

TOWILL | Surveying, Mapping and GIS Services

LIDAR FLIGHT LOG

Date: 09/13/2010

Mission: 256A

Line Number	Start Time (UTC)	End Time (UTC)	Average Range	Approximate Heading	Range Strip Number	Comments
212	17:02	17:04	1500	S	12	
63	17:11	17:26	1500	S	13	
64	17:32	17:48	1500	N	14	
65	17:52	18:07	1500	S	15	
66	18:11	18:27	1500	N	16	
67	18:31	18:46	1500	S	17	
68	18:50	19:06	1500	N	18	
69	19:09	19:24	1500	S	19	
70	19:28	19:43	1500	N	20	
71	19:47	20:01	1500	S	21	
72	20:04	20:20	1500	N	22	
C3	20:27	20:28	1500	E	23	Perpendicular Runway Pass
C4	20:31	20:32	1500	W	24	Perpendicular Runway Pass

TOWILL Surveying, Mapping and GIS Services

LIDAR FLIGHT LOG

Date: 09/14/2010

Mission: 257A

Survey Information		Base Station Data	
Project Name:	Aero-Metric Arkansas River Valley	Station Name:	AI5944
Flight Vendor / Tail No:	Marc – N1009S	Receiver Type & SN:	Trimble R7 - #8257
METs: temp, press, humid)	14 deg. C ; 754 mB	Antenna & Measurement Type:	Zephyr Geodetic – bot. notch
Airport Start/End:	KAEJ – Rwy 15/33	Antenna Height – meters:	1.638 m
Planned Parameters: (scan angle, freq., height)	18 deg; 40 Hz; 1500 meters AGL; 70 kHz	Antenna Height – feet:	5.37 ft Checks?

Line Number	Start Time (UTC)	End Time (UTC)	Average Range	Approximate Heading	Range Strip Number	Comments
	15:56	16:00			1	Laser warmup
C1	16:03	16:05	1500	E	2	Perpendicular Runway Pass
C2	16:08	16:09	1500	W	3	Perpendicular Runway Pass
73	16:18	16:33	1500	S	4	
74	16:37	16:53	1500	N	5	
75	16:57	17:12	1500	S	6	
76	17:16	17:21	1500	N	7	
77	17:24	17:28	1500	S	8	
78	17:32	17:36	1500	N	9	
79	17:39	17:43	1500	S	10	

TOWILL | Surveying, Mapping and GIS Services

LIDAR FLIGHT LOG

Date: 09/14/2010

Mission: 257A

Line Number	Start Time (UTC)	End Time (UTC)	Average Range	Approximate Heading	Range Strip Number	Comments
80	17:46	17:50	1500	N	11	
81	17:53	17:58	1500	S	12	
82	18:00	18:04	1500	N	13	
83	18:07	18:11	1500	S	14	
84	18:14	18:18	1500	N	15	
85	18:21	18:25	1500	S	16	
86	18:28	18:32	1500	N	17	
87	18:34	18:38	1500	S	18	
88	18:41	18:45	1500	N	19	
89	18:47	18:50	1500	S	20	
181	18:56	19:03	1500	N	21	
182	19:05	19:12	1500	S	22	
21	19:15	19:24	1500	S	23	
20	19:28	19:37	1500	N	24	
19	19:40	19:49	1500	S	25	
18	19:53	20:03	1500	N	26	

TOWILL | Surveying, Mapping and GIS Services

LIDAR FLIGHT LOG

Date: 09/14/2010

Mission: 257A

Line Number	Start Time (UTC)	End Time (UTC)	Average Range	Approximate Heading	Range Strip Number	Comments
17	20:05	20:14	1500	S	27	
16	20:18	20:27	1500	N	28	
183	20:30	20:37	1200 - 2000	N	29	
184	20:41	20:47	1200 - 2000	S	30	
C3	20:52	20:53	1500	W	31	Perpendicular Runway Pass
C4	20:55	20:56	1500	E	32	Perpendicular Runway Pass

TOWILL | Surveying, Mapping and GIS Services

LIDAR FLIGHT LOG

Date: 09/15/2010

Mission: 258A

Survey Information		Base Station Data	
Project Name:	Aero-Metric Arkansas River Valley	Station Name:	AI5944
Flight Vendor / Tail No:	Marc – N1009S	Receiver Type & SN:	Trimble R7 - #8257
METs: temp, press, humid)	14 deg. C ; 740 mB	Antenna & Measurement Type:	Zephyr Geodetic – bot. notch
Airport Start/End:	KAEJ – Rwy 15/33	Antenna Height – meters:	1.638 m
Planned Parameters: (scan angle, freq., height)	18 deg; 40 Hz; 1500 meters AGL; 70 kHz	Antenna Height – feet:	5.37 ft Checks?

Line Number	Start Time (UTC)	End Time (UTC)	Average Range	Approximate Heading	Range Strip Number	Comments
	15:10	15:14			1	Laser warmup
C1	15:17	15:18	1500	W	2	Perpendicular Runway Pass
C2	15:21	15:22	1500	E	3	Perpendicular Runway Pass
185	15:30	15:37	1500	S	4	
15	15:40	15:49	1500	S	5	
14	15:53	16:03	1500	N	6	
13	16:06	16:15	1500	S	7	
12	16:18	16:29	1500	N	8	
11	16:31	16:40	1500	S	9	
10	16:46	16:54	1500	N	10	

TOWILL | Surveying, Mapping and GIS Services

LIDAR FLIGHT LOG

Date: 09/15/2010

Mission: 258A

Line Number	Start Time (UTC)	End Time (UTC)	Average Range	Approximate Heading	Range Strip Number	Comments
9	16:58	17:08	1500	S	11	
22	17:12	17:22	1500	N	12	
23	17:25	17:34	1500	S	13	
24	17:37	17:47	1500	N	14	
25	17:50	17:59	1500	S	15	
26	18:02	18:12	1500	N	16	
27	18:15	18:24	1500	S	17	
28	18:26	18:36	1500	N	18	
29	18:40	18:48	1500	S	19	
30	18:51	19:02	1500	N	21	
		LASER SYSTEM CRASH! – no cal flights				

TOWILL Surveying, Mapping and GIS Services

LIDAR FLIGHT LOG

Date: 09/16/2010

Mission: 259A

Survey Information		Base Station Data	
Project Name:	Aero-Metric Arkansas River Valley	Station Name:	AI5944
Flight Vendor / Tail No:	Marc – N1009S	Receiver Type & SN:	Trimble R7 - #8257
METs: temp, press, humid)	16 deg. C ; 742 mB	Antenna & Measurement Type:	Zephyr Geodetic – bot. notch
Airport Start/End:	KAEJ – Rwy 15/33	Antenna Height – meters:	1.638 m
Planned Parameters: (scan angle, freq., height)	18 deg; 40 Hz; 1500 meters AGL; 70 kHz	Antenna Height – feet:	5.37 ft Checks?

Line Number	Start Time (UTC)	End Time (UTC)	Average Range	Approximate Heading	Range Strip Number	Comments
	15:36	15:40			1	Laser warmup
C1	15:43	15:45	1500	E	2	Perpendicular Runway Pass
C2	15:49	15:49	1500	W	3	Perpendicular Runway Pass
31	15:57	16:06	1500	S	4	
32	16:10	16:19	1500	N	5	
33	16:23	16:31	1500	S	6	
34	16:34	16:44	1500	N	7	
35	16:47	16:49	1500	S	8	
36	16:50	16:52	1500	N	9	
37	16:55	16:56	1500	S	10	

TOWILL | Surveying, Mapping and GIS Services

LIDAR FLIGHT LOG

Date: 09/16/2010

Mission: 259A

Line Number	Start Time (UTC)	End Time (UTC)	Average Range	Approximate Heading	Range Strip Number	Comments
38	16:59	17:00	1500	N	11	
61	17:04	17:07	1500	N	12	
35	17:15	17:19	1500	S	13	
36	17:22	17:26	1500	N	14	
37	17:29	17:32	1500	S	15	
X1	17:34	17:38	1500	W	16	Cross Strip
8	17:42	17:47	1500	N	17	
7	17:50	17:53	1500	S	18	
6	17:57	18:00	1500	N	19	
5	18:05	18:07	1500	S	20	
4	18:10	18:13	1500	N	21	
3	18:15	18:17	1500	S	22	
X2	18:18	18:20	1500	W	23	Cross Strip
202	18:24	18:34	1200-2000	N	24	
201	18:38	18:43	1200-2000	S	25	
200	18:47	18:53	1200-2000	N	26	

TOWILL | Surveying, Mapping and GIS Services

LIDAR FLIGHT LOG

Date: 09/16/2010

Mission: 259A

Line Number	Start Time (UTC)	End Time (UTC)	Average Range	Approximate Heading	Range Strip Number	Comments
199	18:55	19:02	1200-2000	S	27	
198	19:06	19:11	1200-2000	N	28	
197	19:14	19:15	1200-2000	S	29	
196	19:23	19:29	1200-2000	N	30	
195	19:32	19:37	1200-2000	S	31	
C3	19:42	19:43	1500	E	32	Perpendicular Runway Pass
C4	19:44	19:47	1500	W	33	Perpendicular Runway Pass

TOWILL Surveying, Mapping and GIS Services

LIDAR FLIGHT LOG

Date: 09/16/2010

Mission: 259B

Survey Information		Base Station Data	
Project Name:	Aero-Metric Arkansas River Valley	Station Name:	AI5944
Flight Vendor / Tail No:	Marc – N1009S	Receiver Type & SN:	Trimble R7 - #8257
METs: temp, press, humid)	24 deg. C ; 748 mB	Antenna & Measurement Type:	Zephyr Geodetic – bot. notch
Airport Start/End:	KAEJ – Rwy 15/33	Antenna Height – meters:	1.638 m
Planned Parameters: (scan angle, freq., height)	18 deg; 40 Hz; 1500 meters AGL; 70 kHz	Antenna Height – feet:	5.37 ft Checks?

Line Number	Start Time (UTC)	End Time (UTC)	Average Range	Approximate Heading	Range Strip Number	Comments
	22:00	22:01			1	Laser warmup
C1	22:06	22:08	1500	W	2	Perpendicular Runway Pass
C2	22:11	22:12	1500	E	3	Perpendicular Runway Pass
123	22:26	22:26	1500	N	4	
142	22:37	22:38	1500	N	7	
194	22:52	22:58	1200-2000	S	8	
193	23:01	23:07	1200-2000	N	9	
192	23:08	23:15	1200-2000	S	10	
191	23:18	23:25	1200-2000	N	11	
190	23:28	23:35	1200-2000	S	12	

TOWILL | Surveying, Mapping and GIS Services

LIDAR FLIGHT LOG

Date: 09/16/2010

Mission: 259B

Line Number	Start Time (UTC)	End Time (UTC)	Average Range	Approximate Heading	Range Strip Number	Comments
189	23:38	23:44	1200-2000	N	13	
188	23:47	23:53	1200-2000	S	14	
187	23:54	00:03	1200-2000	N	15	
186	00:05	00:12	1500	S	16	
C3	00:19	00:25	1500	E	17	Perpendicular Runway Pass
X1	00:31	00:36	1500	W	18	Cross Strip
C5	00:38	00:39	1500	E	19	Perpendicular Runway Pass

TOWILL Surveying, Mapping and GIS Services

LIDAR FLIGHT LOG

Date: 10/28/2010

Mission: 301A

Survey Information		Base Station Data	
Project Name:	Aero-Metric Arkansas River Valley	Station Name:	AI5944
Flight Vendor / Tail No:	Marc – N1009S	Receiver Type & SN:	Trimble R7 - #8257
METs: temp, press, humid)	2 deg. C ; 796 mB	Antenna & Measurement Type:	Zephyr Geodetic – bot. notch
Airport Start/End:	KAEJ – Rwy 15/33	Antenna Height – meters:	1.612 m
Planned Parameters: (scan angle, freq., height)	18 deg; 40 Hz; 1500 meters AGL; 70 kHz	Antenna Height – feet:	5.29 ft Checks?

Line Number	Start Time (UTC)	End Time (UTC)	Average Range	Approximate Heading	Range Strip Number	Comments
	17:53	17:55			1	Laser warmup
C1	17:58	18:00	1500	W	2	Perpendicular Runway Pass
C2	18:02	18:03	1500	E	3	Perpendicular Runway Pass
45	18:11	18:15	1500	S	4	
47	18:20	18:25	1500	N	5	
48	18:30	18:38	1500	S	6	
47.5	18:42	18:46	1500	N	7	
C3	18:49	18:50	1500	W	8	Perpendicular Runway Pass
C4	18:53	18:54	1500	E	9	Perpendicular Runway Pass

Q:\1100805\Lidar\QAQC\AME_Control_1100805_UTM13m.txt

Number	Easting	Northing	Known Z	Laser Z	Dz
Base1	417220.887	4233611.751	2430.546	2430.570	+0.024
CK02	397476.000	4360755.873	3425.320	3425.320	+0.000
CK03	383851.576	4355863.484	3144.147	3144.100	-0.047
CK04	376120.340	4348598.939	3014.574	3014.490	-0.084
CK07	392625.307	4343259.980	3305.007	3305.050	+0.043
CK08	378585.946	4334660.915	3044.281	3044.190	-0.091
CK12	393995.957	4317466.444	2647.576	2647.470	-0.106
CK14	401681.501	4306796.161	2680.538	2680.520	-0.018
CK16	399763.038	4299083.410	2456.416	2456.370	-0.046
CK18	409126.819	4291005.467	2502.694	2502.600	-0.094
CK19	397916.497	4287258.827	2533.231	2533.210	-0.021
CK22	405996.379	4276807.121	2280.972	2280.970	-0.002
CK23	401131.008	4273606.012	2542.709	2542.630	-0.079
CK24	392935.898	4271621.978	2908.747	2908.730	-0.017
CK25	387587.881	4267816.296	2913.218	2913.210	-0.008
CK29	416552.992	4262308.556	2122.546	2122.510	-0.036
CK30	403397.269	4256136.919	2568.697	2568.630	-0.067
CK32	408012.679	4249031.641	2635.706	2635.650	-0.056
CK36	422106.567	4236341.246	2512.543	2512.380	-0.163
CK38	422838.174	4229820.114	2404.886	2404.780	-0.106

Average dz	-0.049
Minimum dz	-0.163
Maximum dz	+0.043
Average magnitude	0.055
Root mean square	0.069
Std deviation	0.051