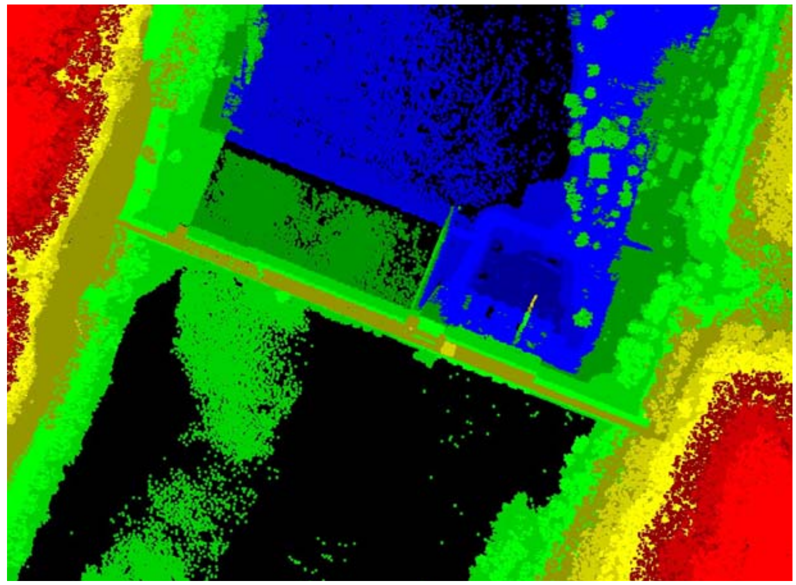
AERIAL LIDAR ACQUISITION REPORT



BLUESTONE LAKE AND DOWNSTREAM DIGITAL ELEVATION MODEL AND ORTHOPHOTOGRAPHY PROJECT

USACE HUNTINGTON DISTRICT

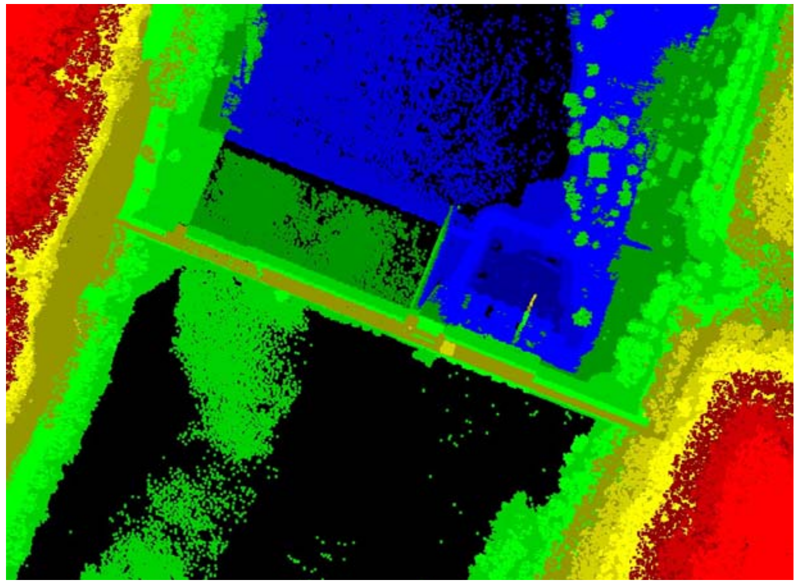
SUBCONTRACT TO 3001 INC. PROJECT 08033.04

WEST VIRGINIA

WOOLPERT PROJECT #69422

May 2009

AERIAL LIDAR ACQUISITION REPORT



BLUESTONE LAKE AND DOWNSTREAM DIGITAL ELEVATION MODEL AND ORTHOPHOTOGRAPHY PROJECT

USACE HUNTINGTON DISTRICT

SUBCONTRACT TO 3001 INC.
PROJECT 08033.04

PREPARED BY:

WOOLPERT
4454 Idea Center Boulevard
Dayton, Ohio 45430-1500

TABLE OF CONTENTS

SECTION 1: OVERVIEW

Project Name: Bluestone Lake and Downstream DEM and Digital Orthophotography Project

Woolpert Project #69422

Woolpert was contracted to perform an aerial acquisition survey of Bluestone Lake and Downstream covering the 1,425 square mile project area, for the purpose of ultimately producing 1"=200' scale orthoimagery with a 1-foot pixel resolution, 1"=400' scale orthoimagery with a 2-foot pixel resolution and a Bare Earth Digital Elevation Model including breaklines. Among other products the data will be used for flood and surface water modeling.

LiDAR data was collected by the Leica ALS50-II 150kHz Multi-Pulse enabled LiDAR system in Leica roll-stabilizing mounts. The ALS type-II 150kHZ LiDAR sensor collects up to four returns per pulse, as well as intensity data. The aerial LiDAR was collected at the following sensor specifications:

Post Spacing (Average):	3.3 ft / 1.0 m
AGL (Above Ground Level) average flying height:	7,500 ft / 2,286 m
MSL (Mean Sea Level) flying height:	varies with terrain
Average Ground Speed:	130 kts / 150 mph
Field of View (full):	35 degrees
Pulse Rate:	104.100 kHz
Scan Rate:	39 Hz
Side Lap (Average):	30%

Flight line acquisition was performed in as few missions as possible, as close together as possible, to ensure consistency across the project area.

The data collected was flown back to the Woolpert Dayton, Ohio office, processed and quality controlled immediately such that re-flights for GNSS and coverage were determined and relayed to the flight crew.

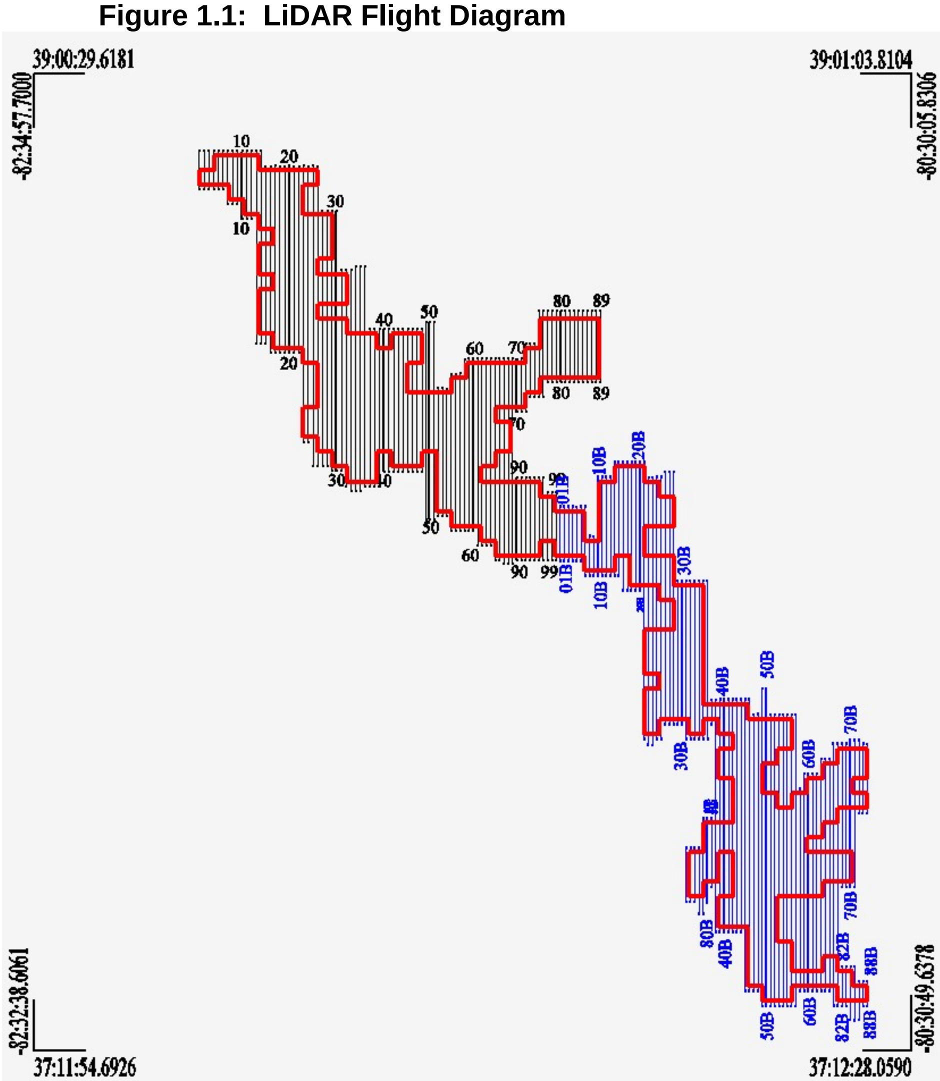
Woolpert’s Aerial Acquisition Team coordinated with the necessary Air Traffic Control and Restricted Airspace personnel prior to flying to ensure access.

Woolpert Flight Crews were onsite, running GNSS base stations at Charleston (KCRW) and Beckley (KBKW), West Virginia Airports.

Table 1.1: Aerial Digital Imagery Flight Summary

Aerial Digital Imagery Flight Summary			
Date of Flying	Lines Flown	Time On/Off Line (UTC)	Time On/Off Line (Local = EDT)
April 04, 2009 – Sensor 77	66B-74B, 82B-88B	03:30 - 05:53	11:30PM - 01:53AM
April 05A, 2009 – Sensor 77	28B-37B, 54B-65B	14:30 - 20:10	10:30AM - 04:10PM
April 05B, 2009 – Sensor 77	01B-20B	23:30 - 02:30	07:30PM - 10:30PM
April 09, 2009 – Sensor 77	68A-97A	23:34 - 04:20	07:34PM - 12:20AM
April 09A, 2009 – Sensor 46	98A-99A, Reflights 88A,89A,97A	14:24 - 15:10	10:24AM - 11:10PM
April 09B, 2009 – Sensor 46	01A-26A	22:39 - 03:22	06:39PM - 11:22PM
April 12A, 2009 – Sensor 46	44B-53B, Mountain Patches	03:01 - 07:00	11:01PM - 03:00AM
April 12B, 2009 – Sensor 46	Reflights 23B, 40B-43B	14:07 - 15:00	10:07AM - 11:00AM
April 12C, 2009 – Sensor 46	21B-27B, 38B, 39B, 63A-69A, 75B-81B	16:37 - 21:40	12:37PM - 05:40PM
April 13, 2009 – Sensor 46	35A-62A	00:49 - 06:11	08:49PM - 02:11AM
April 17, 2009 – Sensor 77	26A-34A	01:04 - 03:35	09:49PM – 11:35PM
April 23, 2009 – Sensor 77	Mountain Patches	14:56 - 16:50	10:56AM – 12:50PM

Figure 1.1: LiDAR Flight Diagram



SECTION 2: GNSS-IMU TRAJECTORY INFORMATION

Equipment

Woolpert owns all the equipment used for the ground control and ABGNSS missions with the exception of CORS stations.

Flight navigation is performed using IGI CCNS (Computer Controlled Navigation System). The pilots are thoroughly trained and 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 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 GNSS receivers collecting at 2 Hz.

All Woolpert aerial sensors are equipped with Litton LN200 series IMU’s operating at 200 Hz.

A base-station unit was mobilized for each acquisition mission, and was operated by a member of the Woolpert survey and/or flight 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 flight crews were onsite, running GNSS base stations at Charleston (KCRW) and Beckley (KBKW), West Virginia Airports.

GNSS Base Stations operated during the acquisition missions, are listed below.

Table 2.1: GNSS Base Stations:

Station Name	Latitude (DMS)	Longitude (DMS)	Ellipsoid Height (L1 Phase center) (Meters)
CRW (NGS PID HX3043)	N 38° 21' 52.73204"	W 81° 35' 19.11736"	266.468
BKW (NGS PID GX1100)	N 37° 46' 58.63605"	W 81° 07' 07.60826"	732.139

Data Processing

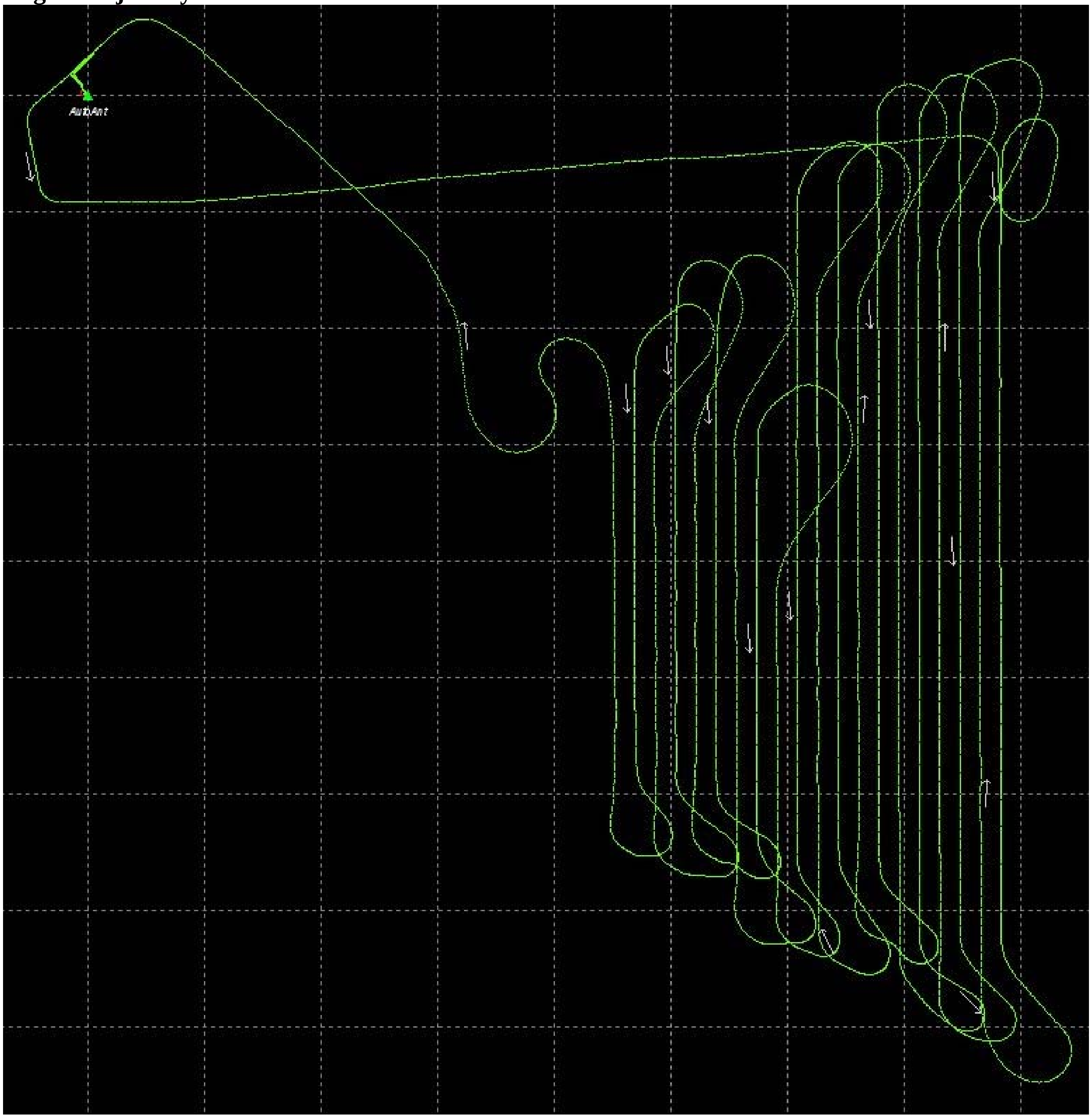
All airborne GNSS and IMU data was post-processed and quality controlled using Grafnav Waypoint software and either Applanix POSPac or Leica IPAS software. GNSS data was processed at a 1 or 2 Hz data capture rate and IMU data was processed at 200 Hz.

Trajectory Quality

Example graphs from: **Day095B, N404CP & ALS LiDAR S/N77:**

The GNSS Trajectory, along with high quality IMU data, is a key factor in determining the overall positional accuracy of the final sensor data.

Flight Trajectory:

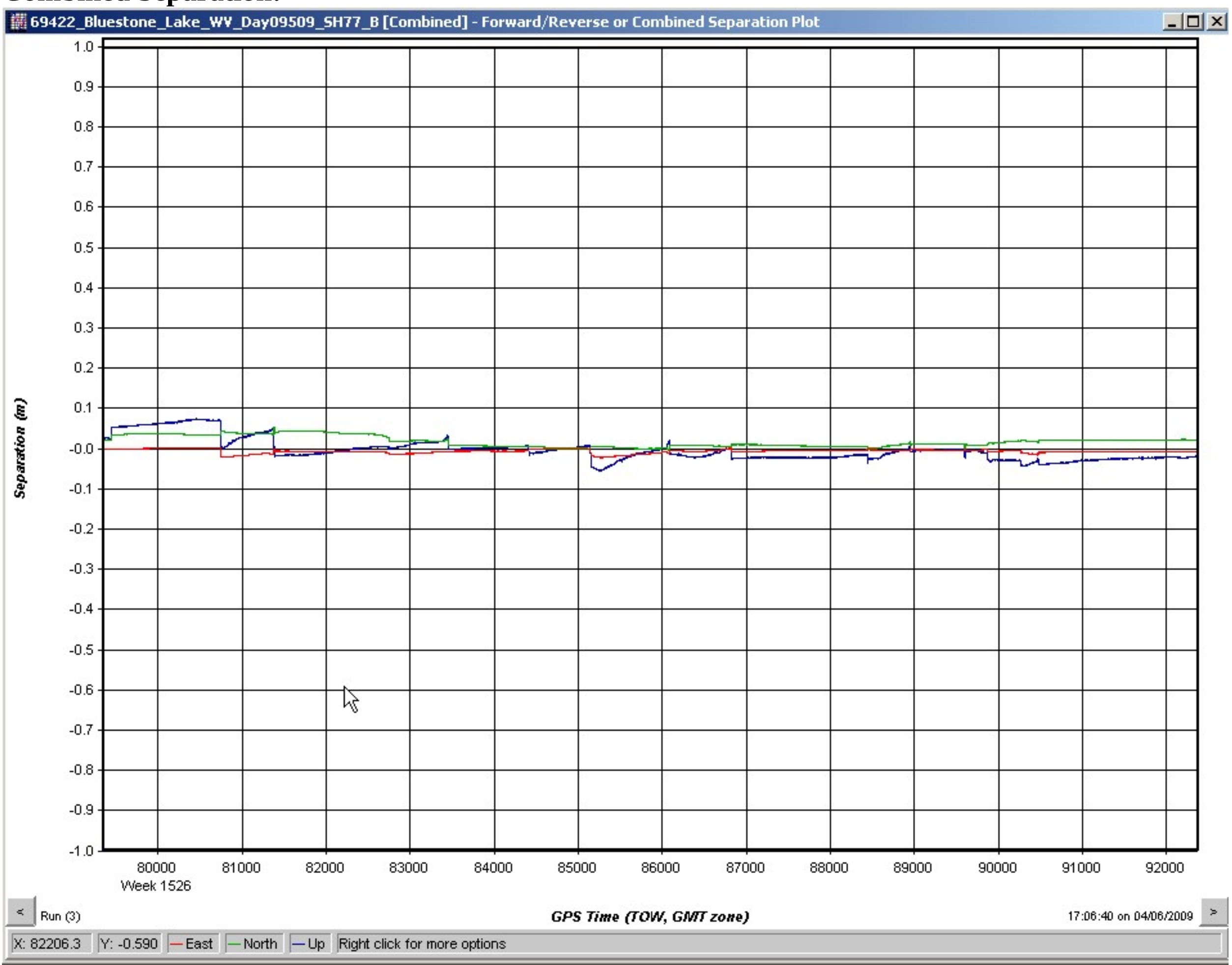


Within the trajectory processing, there are many factors that affect the overall quality, but the most indicative are the Combined Separation, the Estimated Positional Accuracy, and the PDOP.

The Combined Separation is a measure of the difference between the forward run & the backward run solution of the trajectory. The Kalman filter is run in both directions to remove directional specific anomolies. The closer these two solutions match (in general) the better is the overall reliability of the solution.

Woolpert's goal is to maintain a Combined Separation Difference of < 10cm, often achieving results well below this cap.

Combined Separation:



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

Woolpert's goal is to maintain an Estimated Positional Accuracy of < 10 cm, often achieving results well below this cap.

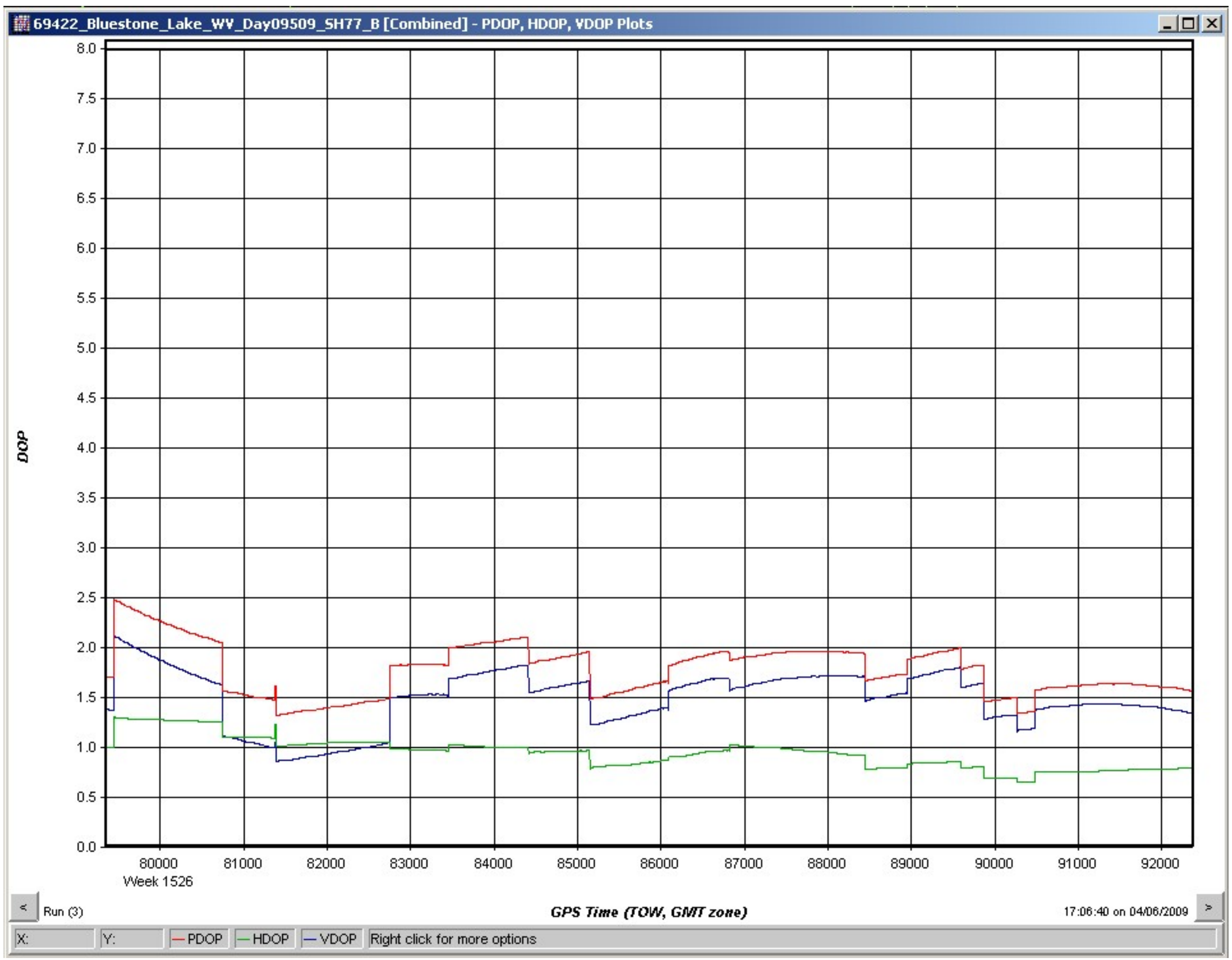
Estimated Positional Accuracy:

PDOP, the Positional Dilution of Precision, is a factor that describes the effects of satellite geometry on the accuracy of the airborne GNSS solution. The geometric distribution of the satellites is measured relative to the locations of the receivers on the ground and in the aircraft. PDOP can be computed in advance, based on the approximate receiver locations and the predicted location of the satellite, which is called the satellite ephemeris.

Low PDOP numbers are preferable; the higher the PDOP number, the weaker the geometric quality of solution between the satellite, aircraft and reference receivers.

Woolpert's goal is to maintain a final PDOP of < 3.0 during acquisition missions. Satellite geometry and the resultant PDOP levels are dynamic, changing with the position of the aircraft. Occasionally, one satellite in the network will drop below the horizon, breaking its connection to the receiver, and the PDOP level will spike above 3.0 momentarily. Small deviations of this type are accounted for during post-processing of the data through the use of Kalman filtering. If PDOP in the aircraft rises above 3.0 for a significant time period, the survey is usually stopped until the geometry improves or flight is marked for a re-flight if post processing signifies a significant loss of accuracy due to the PDOP.

PDOP:



SECTION 3: FLIGHT LOG(S)

This section contains the Flight Log(s) covering the project. Flight Logs list mission specific details such as crew members, airports, weather conditions, real time DOP values and document any issues encountered during the mission. Flight Logs are filled out by the sensor operator during the acquisition flight.

Page 1 of

LIDAR LOG SHEET	Date: 4/4/2009	Julian Date: 94	Mission Name: wv coe		
Operator: SHULER	Aircraft: ☐ N7079F ☑ N404CP ☐ N475RC	Hobbs Start 2597.3	Local Start Time (Wheels Up) 9:58PM		Zulu Start Time 1:58
Pilot: ALBERS					
Passengers: 0	SH77 ☐ SH46 ☑ SH77	Hobbs End 2600.9	Local End Time (Wheels Down) 1:30AM		Zulu End Time 5:30

Wind Direction/Spe	Visibility	Cloud ceiling (ft):	Cloud Cover %:	Departing Airport	Arriving Airport
CALM	10	CLEAR		CRW	CRW
Temp: 13.0 °C	Dew Point: -2.0 °C	Pressure: 29.96	Wind/Haze/Clou d/ Fire?	Applanix GPS Began Logging at: 9:43PM	

Base Station #1:	Operator: MONUMENT AT BE	BKW	Using or Relying on CORS
Base Station #2	Operator:		☐ YES ☐ NO

"Laser Specifications"

Scan Angle	ScanFreq.	Pulse	Mode	Attenuator	Air Speed		
35	39	104100.000	☐ 2+2 ☑ 4+3 ☐ Single ☑ Multi	☐ 0.0 ☐ 0.3 ☐ 0.7	130	AGL:	7500
						MSL:	varies
					Laser Power %	Max Range:	
					100%	Avg. Elev.:	varies

Flt Line	Mission ID#	Heading	HDOP	VDOP	SVs	Course	Fine	AGC	Line Notes
TEST	090324			1.8	10	12	7	----------	OK
▲Times entered are Zulu / GMT▼				Verify S-Turns Before Mission				☑ Yes ☐ No	
74b	032940	n	"	1.4	11	12	7	"	8750 MSL
73b	033836	s	"	1.3	10	12	7	"	OK
72b	034747	n	"	2.1	10	12	7	"`	OK
71b	035639	s	"	2.3	9	12	7	"	OK
70b	040927	n	"	2.4	8	12	7	"	OK
69b	042109	s	"	2.4	8	12	7	"	Pdop was above 3.5/ lpas was 2.4
68b	043423	n	"	2.3	9	12	7	"	OK
67b	044531	s	"	2.1	9	12	7	"	OK
88b	050331	n	"	1.5	10	12	7	"	9000 MSL
87b	050921	s	"	1.5	10	12	7	"	OK
86b	051510	n	"	1.4	11	12	7	"	OK
85b	052127	s	"	1.4	11	12	7	"	OK
84b	052932	n	"	1.4	11	12	7	"	OK
83b	053603	s	"	1.6	11	12	7	"	OK
82b	054306	n	"	1.6	11	12	7	"	OK
66b	055319	n	"	1.5	10	12	7	":	8750 MSL

Verify S-Turns After Mission ☑ Yes ☐ No

Supplemental Notes

N404CP REFLEW LIN N7079F REFLEW LINE 14

LIDAR LOG SHEET

Date: 9/4/2009	Julian Date: 95 A	Mission Name: wv coe	
Operator: KROHN GEBHART	Aircraft: ☐ N7079F ☑ N404CP ☐ N475RC	Hobbs Start: 893.5	Local Start Time (Wheels Up): 9:37
Passengers: 0	SH77: ☐ SH46 ☑ SH77	hobbs end: 895.1	Local End Time (Wheels Down): 11:22

Zulu Start Time	Zulu End Time
13:37	15:22

Wind Direction/Spd	Visibility	Cloud ceiling (ft):	Cloud Cover %:	Departing Airport	Arriving Airport
CALM	10	CLEAR		CRW	CRW

Temp:	Dew Point:	Pressure:	Wind/Haze/Clou d/ Fire?	Applanix GPS Began Logging at:
7.0 ° C	-2.0 ° C	29.93		23:02:00

Base Station #1:	Operator: krohn	CRW	Using or Relying on CORS
Base Station #2:	Operator:		☐ YES ☑ NO

"Laser Specifications "

Scan Angle	ScanFreq.	Pulse	Mode	Attenuator	Air Speed		
35	39	104100.000	☐ 2+2 ☐ 4+3 ☐ Single ☑ Multi	☐ 0.0 ☐ 0.3 ☐ 0.7	130	AGL:	7500
					Laser Power %: 100%	MSL:	varies
						Max Range:	5351-8031
						Avg. Elev.:	varies

Flt Line	Mission ID#	Heading	HDOP	VDOP	SVs	Coarse	Fine	AGC	Line Notes
TEST	090405-132050	w		1.8	9	12	7	-----------	OK
▲ Times entered are Zulu / GMT ▼			Verify S-Turns Before Mission					☑ Yes ☐ No	
99		N	1.184	1.933	8	6	7	"	OK
98		S	1.145	1.817	8	6	7	"	OK
97		N	1.183	1.99	7	6	7	"`	OK
89		N	1.19	1.997	7	6	7	"	OK
88		S	1.079	1.481	8	6	7		OK

Verify S-Turns After Mission ☑ Yes ☐ No

Supplemental Notes:

N404CP REFLEW LIN N7079F REFLEW LINE 14

Page 1 of

LIDAR LOG SHEET	Date: 5/4/2009	Julian Date: 95B	Mission Name: wv coe		
Operator: SHULER / ALBERS	Aircraft: ☐ N7079F ☑ N404CP ☐ N475RC	Hobbs Start 2608	Local Start Time (Wheels Up) 6:16pm	Zulu Start Time 23:16	
Passengers: 0	SH77 ☐ SH46 ☑ SH77	Hobbs End 2611.3	Local End Time (Wheels Down) 9:33	Zulu End Time 2:33	

Wind Direction/Spe	Visibility	Cloud ceiling (ft):	Cloud Cover %:	Departing Airport	Arriving Airport
200/7	10	FEW 8000 SCT 10000		CRW	CRW
Temp: 26.0 ˚C	Dew Point: -3.0 ˚C	Pressure: 29.54	Wind/Haze/Clouds/Fire?	Applanix GPS Began Logging at: 23:02:00	

Base Station #1: Operator: SHULER	CRW	Using or Relying on CORS	
Base Station #2 Operator:		☐ YES ☑ NO	

"Laser Specifications"

Scan Angle	ScanFreq.	Pulse	Mode	Attenuator	Air Speed		
35	39	104100.000	☐ 2+2 ☐ 4+3 ☐ Single ☑ Multi	☐ 0.0 ☐ 0.3 ☐ 0.7	130	AGL:	7500
						MSL:	varies
					Laser Power %	Max Range:	5351-8031
					100%	Avg. Elev.:	varies

Flt Line	Mission ID#	Heading	HDOP	VDOP	SVs	Course	Fine	AGC	Line Notes
TEST	090405-132050	w		1.8	9	12	7	-----------	OK
▲ Times entered are Zulu / GMT ▼				Verify S-Turns Before Mission				☑ Yes ☐ No	
20B	143009	S	"	1.4	9	12	7	"	OK
19B	144659	N	"	1.8	9	12	7	"	OK
18B	150409	S	"	2	9	12	7	"'	OK
17B	152129	N	"	2	8	12	7	"	OK
16B	153711	S	"	2	8	12	7	"	OK
15B	155333	N	"	2.2	9	12	7	"	OK
14B	160598	S	"	1.7	8	12	7	"	OK
13B	162556	N	"	1.5	8	12	7	"	OK
12B	164522	S	"	1.5	8	12	7	"	OK
11B	170521	N	"	1.5	8	12	7	"	OK
10B	172524	S	"	1.7	8	12	7	"	OK
9B	174551	N	"	1.7	8	12	7	"	OK
8B	180839	S	"	1.7	8	12	7	"	OK
7B	181522	N	"	1.6	9	12	7	"	OK
6B	182821	S	"	1.7	11	12	7	"	OK
5B	184137	N	"	1.6	11	12	7	":	OK
4B	185449	S	"	1.4	11	12	7	"	OK
3B	190811	N	"	1.5	10	12	7	"	OK
2B	193325	S	"	1.9	10	12	7	"	OK
1B	194607	N	"	1.9	10	12	7	"	OK

Verify S-Turns After Mission ☑ Yes ☐ No

Supplemental Notes:

N404CP REFLEW LIN N7079F REFLEW LINE 14

Page 1 of

LIDAR LOG SHEET	Date: 9/4/2009	Julian Date: 99A	Mission Name: wv coe		
Operator: KROHN GEBHART	**Aircraft:** ☐ N7079F ☑ N404CP ☐ N475RC	Hobbs Start 2626.1	Local Start Time (Wheels Up) 6:21		Zulu Start Time 29:21:00
Passengers: 0	**SH77** ☐ SH46 ☑ SH77	hobbs end 2621.4	Local End Time (Wheels Down) 8:38		Zulu End Time 4:36

Wind Direction/Spd	Visibility	Cloud ceiling (ft):	Cloud Cover %:	Departing Airport	Arriving Airport
280/7	10	CLEAR		CRW	CRW
Temp: 18.0 ° C	Dew Point: -2.0 ° C	Pressure: 29.86	Wind/Haze/Clou d/ Fire?	Applanix GPS Began Logging at: 5:09:00	

Base Station #1:	Operator: krohn	CRW	Using or Relying on CORS	
Base Station #2	Operator:		☐ YES ☑ NO	

"Laser Specifications "

Scan Angle	ScanFreq.	Pulse	Mode	Attenuator	Air Speed		
35	39	104100.000	☐ 2+2 ☐ 4+3 ☐ Single ☑ Multi	☐ 0.0 ☐ 0.3 ☐ 0.7	130	AGL:	7500
						MSL:	varies
						Max Range:	
					Laser Power % 100%	Avg. Elev.:	varies

Flt Line	Mission ID#	Heading	HDOP	VDOP	SVs	Course	Fine	AGC	Line Notes
TEST	090409-231054	w		1.4	9	12	7	N/A	OK
▲ Times entered are Zulu / GMT ▼				Verify S-Turns Before Mission				☑ Yes ☐ No	
97	233424	N		1.9	9	12	7	"	OK
96	234319	S		2	8	12	7	"	OK
95	235242	N		2	8	12	7	"`	OK
94	000150	S		2.1	9	12	7	"	OK
93	001126	N		1.7	9	12	7	"	OK
92	002041	S		1.5	8	12	7	"	
91	002953	N		1.5	8	12	7	"	
90	003843	S		1.5	8	12	7	"	
69	004819	N		1.7	8	12	7	"	
70	010359	S		1.7	8	12	7	"	
71	011115	N		1.7	8	12	7	"	
72	011957	S		1.6	8	12	7	"	
73	012744	N		1.6	11	12	7	"	
74	013559	S		1.6	11	12	7	"	
75	014327	N		1.4	11	12	7	"	
76	015246	S		1.5	10	12	7	"	
77	020138	N		1.9	10	12	7	"	
78	021049	S		1.9	10	12	7	"	
79	021906	N		1.9	10	12	7	"	
80	022810	S		1.9	11	12	7	"	
81	023658	N		1.8	11	12	7	"	
82	024552	S		1.5	11	12	7	"	
83	025403	N		1.5	11	12	7	"	
84	030254	S		1.4	11	12	7	"	
85	031137	N		1.5	0	12	7	"	
86	032050	S		2	10	12	7	"	
87	032937	N		2.2	10	12	7	"	
88	033906	S		2.3	8	12	7	"	
							89	☑ Yes ☐ No	

Supplemental Notes:

N404CP REFLEW LIN N7079F REFLEW LINE 14

Page 1 of

LIDAR LOG SHEET	**Date:** 9/4/2009	**Julian Date:** 99A	**Mission Name:** wv coe		
Operator: KROHN	**Aircraft:** ☐ N7079F ☑ N404CP ☐ N475RC	**Hobbs Start** 2626.1	**Local Start Time (Wheels Up)** 6:21	**Zulu Start Time** 5:21	
GEBHART	**SH77** ☐ SH46 ☑ SH77	**hobbs end** 2621.4	**Local End Time (Wheels Down)** 8:38	**Zulu End Time** 4:36	
Passengers: 0					

Wind Direction/Spe	**Visibility**	**Cloud ceiling (ft):**	**Cloud Cover %:**	**Departing Airport**	**Arriving Airport**
280/7	10	CLEAR		CRW	CRW
Temp: 18.0 ˚C	**Dew Point:** -2.0 ˚C	**Pressure:** 29.86	**Wind/Haze/Cloud/Fire?**	**Applanix GPS Began Logging at:** 5:09:00	

Base Station #1:	**Operator:** krohn	CRW	**Using or Relying on CORS**
Base Station #2	**Operator:**		☐ YES ☑ NO

"Laser Specifications"

Scan Angle	**ScanFreq.**	**Pulse**	**Mode**	**Attenuator**	**Air Speed**		
35	39	104100.000	☐ 2+2 ☐ 4+3 ☐ Single ☑ Multi	☐ 0.0 ☐ 0.3 ☐ 0.7	130	**AGL:**	**7500**
						MSL:	**varies**
					Laser Power %	**Max Range:**	
					100%	**Avg. Elev.:**	**varies**

Flt Line	Mission ID#	Heading	HDOP	VDOP	SVs	Course	Fine	AGC	Line Notes
TEST	090409-231054	w		1.4	9	12	7	N/A	OK
▲ Times entered are Zulu / GMT ▼				Verify S-Turns Before Mission				☑ Yes ☐ No	
89	034814	N		2.4	8	12	7	"	OK
68	041032	S		2.3	8	12	7	"	OK

☑ Yes ☐ No

Supplemental Notes

N404CP REFLEW LIN

Page 1 of

LIDAR LOG SHEET	Date: 4-Sep-09 DD / MM / YY	Julian Date: 99	Mission Name: Bluestone Lake		
Operator: Krohn	Aircraft: ☑ N7079F ☐ N404CP ☐ N475RC	Hobbs Start 893.5	Local Start Time (Wheels Up) 9:37	Zulu Start 14:33	
Pilot: Gebhart	Sensor: ☑ SH46 ☐ SH77	Hobbs End 895.1	Local End Time (Wheels Down) 11:22	Zulu End Time 15:22	
Passengers:					

Wind Direction/Sp	Visibility	Cloud ceiling (ft):	Cloud Cover %:	Departing Airport	Arriving
calm	10	clr	few clouds	CRW	CRW
Temp: 7.0 ° C	Dew Point: 2.0 ° C	Pressure: 29.93	Wind/Haze/Cloud/Fire?	Applanix GPS Began Logging at: 13:26:10	

Base Station #1	Operator: Krohn		Using or Relying on CORS
Base Station #2	Operator:		☐ YES ☑ NO

"Laser Specifications"

Scan Angle (FOV): 35	Scan Frequency (Hz): 39	Pulse Rate(kHz): 104.1	Mode	Attenuator	Air Speed	AGL: 7500-10250
			☐ 2+2	☐ 0.0	130	MSL: varies
			☑ 4+3	☐ 0.3		Max Range:
			☐ Single	☐ 0.7	Laser Power %	Avg. Elev.: varies
			☑ Multi		100%	Adj. AGL:

Flt Line	Mission ID#	Heading	HDOP	VDOP	SVs	Course	Fine	AGC	Line Notes
TEST	090423 132610		-----------	-----------	-----------	----	-----------	-----------	ok
▲ Times entered are Zulu / GMT ▼				Verify S-Turns Before Mission			☑ Yes	☐ No	
99	"" 142431	N	1.184	1.933	8	6	7		
98	"" 143232	S	1.145	1.817	8	6	7		
97	"" 144058	N	1.183	1.99	7	6	7		CLDS WP 8 WP 5
89	"" 145123	N	1.19	1.997	7	6	7		CLD WP 9
88	"" 150041	S	1.079	1.481	8	6	7		CLD COVER WPT 11

Verify S-Turns After Mission ☑ Yes ☐ No

Supplemental Notes: Encoder reading is out of spec by more than 25 degrees, pos/av heading is not within the user specified bound, laser not receiving start pulse, reboot at bkw, systems ok, lots of clouds

Page 1 of

LIDAR LOG SHEET

Date: 9/4/2009	**Julian Date:** 99	**Mission Name:** wv coe	
Operator: SHULER; RADER	**Aircraft:** ☑ N7079F ☐ N404CP ☐ N475RC	**Hobbs Start:** 2626.1	**Local Start Time (Wheels Up):** 6:25
Passengers: 0	**SH77:** ☑ SH46 ☐ SH77	**hobbs end:** 2621.4	**Local End Time (Wheels Down):** 12:16

Zulu Start Time: 22:55	**Zulu End Time:** 4:16

Wind Direction/Speed	Visibility	Cloud ceiling (ft):	Cloud Cover %:	Departing Airport	Arriving Airport
280/7	10	CLEAR		CRW	CRW

Temp:	Dew Point:	Pressure:	Wind/Haze/Clouds/ Fire?	Applanix GPS Began Logging at:
18.0 °C	-2.0 °C	29.86		6:16pm

Base Station #1:	**Operator:** krohn	CRW	**Using or Relying on CORS**
Base Station #2	**Operator:**		☐ YES ☑ NO

Laser Specifications

Scan Angle	ScanFreq.	Pulse	Mode	Attenuator	Air Speed	Laser Power %
35	39	104100.000	☐ 2+2 ☐ 4+3 ☐ Single ☑ Multi	☐ 0.0 ☐ 0.3 ☐ 0.7	130	100%

AGL:	7500
MSL:	varies
Max Range:	5351-8031
Avg. Elev.:	varies

Flt Line	Mission ID#	Heading	HDOP	VDOP	SVs	Course	Fine	AGC	Line Notes
TEST	090409-221652								OK
▲ Times entered are Zulu / GMT ▼			Verify S-Turns Before Mission				☑ Yes ☐ No		
13	223918	N	1.091	1.927	7	6	7	"	OK
12	225331	S	1,077	1.917	7	6	7	"	OK
11	230102	N	1.009	1.679	8	6	7		OK
10	230813	S	1.125	1.961	7	6	7		OK
9	231507	N	1.01	1.984	8	6	7		OK
8	232157	S	1.035	1.583	8	6	7		OK
7	232815	N	1.076	1.711	8	6	7		OK
6	233503	S	1.112	1.842	8	6	7		OK
5	234105	N	1.164	1.937	8	6	7		OK
4	234633	S	1.179	1.991	8	6	7		OK
3	235200	N	1.227	2.153	7	6	7		OK
2	235751	S	1.212	2.18	7	6	7		OK
1	000311	N	1.192	2.166	7	6	7		OK
14	001000	S	0.978	1.64	8	6	7		OK
15	002340	N	1.006	1.75	8	6	7		OK
16	003738	S	0.768	1.199	10	6	7		OK
17	005125	N	0.769	1.327	10	6	7		OK
18	010459	S	0.772	1.396	10	6	7		OK
19	011850	N	0.919	1.767	9	6	7		OK
20	013223	S	0.878	1.326	11	6	7		OK
21	014611	N	0.876	1.363	11	6	7		OK
22	015948	S	0.922	1.324	10	66	7		OK
23	021748	N	0.917	1.224	10	6	7		OK
24	023613	S	1.207	2.657	8	6	7		OK
25	025537	N	1.246	3.25	8	6	7		OK
26	031536	S	1.245	2.9	9	6	7		OK

☑ Yes ☐ No

Supplemental Notes

N404CP REFLEW LIN

LIDAR LOG SHEET

Date: 12/4/2009 DD / MM / YY	**Julian Date:** 102 A	**Mission Name:** Bluestone Lake 69422	
Operator: Krohn	**Aircraft:** ☐ N7079F ☐ N404CP ☐ N475RC	**Hobbs Start** 906.6	**Local Start Time (Wheels Up)** 22:45
Zulu Start 2:45			
Pilot: Probert	**Sensor:** ☑ SH46 ☐ SH77	**Hobbs End** 09:08	**Local End Time (Wheels Down)** 3:18
Zulu End Time 7:18			
Passengers:			

Wind Direction/Sp	Visibility	Cloud ceiling (ft):	Cloud Cover %:	Departing Airport	Arriving
330/7	10	clr		BKW	BKW
Temp: 6.0 ˚C	**Dew Point:** -2.0 ˚C	**Pressure:** 30.14	**Wind/Haze/Cloud/Fire?**	**Applanix GPS Began Logging at:** 02:35:30	

Base Station #	**Operator:** Schneider	**raleigh**	**Using or Relying on CORS**
Base Station #	**Operator:**		☐ YES ☑ NO

Laser Specifications

Scan Angle (FOV): 35	Scan Frequency (Hz): 39	Pulse Rate(kHz): 104.1	Mode	Attenuator	Air Speed	
			☐ 2+2	☐ 0.0	130	**AGL:** 7500-10250
			☑ 4+3	☐ 0.3		**MSL:** varies
			☐ Single	☐ 0.7	**Laser Power %**	**Max Range:** 5351-8031
			☑ Multi		100%	**Avg. Elev.:** varies
						Adj. AGL:

	Flt Line	Mission ID#	Heading	HDOP	VDOP	SVs	Course	Fine	AGC	Line Notes
	TEST	090412-023504		-----------	-----------	-----------	----	-----------	-----------	ok
	▲ Times entered are Zulu / GMT ▼				Verify S-Turns Before Mission			☑ Yes ☐ No		
	53 B	"" 0300124	S	1.257		8	6	7		
	53B	"" 032332	N	1.1		9	6	7		
	54B	"" 032931	S	1.071		9	6	7		
	55B	"" 033743	N	0.902		10	6	7		
	60C	""034559	SW	0.907		10	6	7		
	59C	""035529	NE	0.821		11	6	7		
	52B	""040906	N	0.812		11	6	7		
	51B	""042820	S	0.879		10	6	7		
	50B	""044658	N	0.938		9	6	7		flaps out
	49B	""051156	S	0.958		9	6	7		
	48B	""053317	N	1.032		8	6	7		
	47B	""055217	S	1.129		7	6	7		
	46B	""061226	N	1.117		7	6	7		
	45B	"" 063216	S	0.959		8	6	7		
	44B	"" 065229	N	0.929		9	6	7		

Verify S-Turns After Mission ☑ Yes ☐ No

Supplemental Notes: flaps broke line 50B forced nose to pitch up

Page 1 of

LIDAR LOG SHEET

LIDAR LOG SHEET	Date: 12/4/2009 DD / MM / YY	Julian Date: 102 B	Mission Name: Bluestone Lake 69422	
Operator: Krohn	Aircraft: ☐ N7079F ☐ N404CP ☐ N475RC	Hobbs Start 906.6	Local Start Time (Wheels Up) 9:55	Zulu Start 13:55
Pilot: Probert	Sensor: ☑ SH46 ☐ SH77	Hobbs End 09:08	Local End Time (Wheels Down) 11:30	Zulu End Time 15:30
Passengers:				

Wind Direction/Sp	Visibility	Cloud ceiling (ft):	Cloud Cover %:	Departing Airport	Arriving
030/7	10	clr		BKW	BKW
Temp: 3.0 ˚C	Dew Point: 7.0 ˚C	Pressure: 30.28	Wind/Haze/Cloud/Fire?	Applanix GPS Began Logging at: 13:44	

Base Station #1	Operator: Krohn	Using or Relying on CORS
Base Station #2	Operator:	☐ YES ☑ NO

"Laser Specifications"

Scan Angle (FOV): 35	Scan Frequency (Hz): 39	Pulse Rate(kHz): 104.1	Mode	Attenuator	Air Speed	
			☐ 2+2	☐ 0.0	130	AGL: 7500-10250
			☑ 4+3	☐ 0.3		MSL: varies
			☐ Single	☐ 0.7	Laser Power %	Max Range: 5351-8031
			☑ Multi		100%	Avg. Elev.: varies
						Adj. AGL:

Flt Line	Mission ID#	Heading	HDOP	VDOP	SVs	Course	Fine	AGC	Line Notes
TEST	090412-134703		-----------	-----------	-----------	----	-----------	-----------	ok
▲ Times entered are Zulu / GMT ▼				Verify S-Turns Before Mission				☑ Yes ☐ No	
43 B	"" 140648	S	1.229	2.002	8	6	7		
42B	"" 142146	N	1.126	1.814	8	6	7		
41B	"" 143822	S	1.176	1.997	7	6	7		
40B	"" 145251	N	1.019	1.252	9	6	7		

Verify S-Turns After Mission ☑ Yes ☐ No

Supplemental Notes: land at CRW to set up R7 for arriving ADS crew

Page 1 of

LIDAR LOG SHEET	Date: 12/4/2009 DD / MM / YY	Julian Date: 102 C	Mission Name: Bluestone Lake 69422	
Operator: Krohn	Aircraft: ☐ N7079F ☐ N404CP ☐ N475RC	Hobbs Start 908.2	Local Start Time (Wheels Up) 12:22	Zulu Start 16:22
Pilot: Rader	Sensor: ☑ SH46 ☐ SH77	Hobbs End	Local End Time (Wheels Down) 5:54	Zulu End Time 21:54
Passengers:				

Wind Direction/Sp	Visibility	Cloud ceiling (ft):	Cloud Cover %:	Departing Airport	Arriving	
070/8	10	clr		BKW	CRW	
Temp: 9.0 ˚C	Dew Point: -5.0 ˚C	Pressure: 30.34	Wind/Haze/Cloud Fire?	Applanix GPS Began Logging at: 16:10		

Base Station #	Operator: Krohn		Using or Relying on CORS	
Base Station #	Operator:		☐ YES ☑ NO	

"Laser Specifications "

Scan Angle (FOV): 35	Scan Frequency (Hz): 39	Pulse Rate(kHz): 104.1	Mode	Attenuator	Air Speed	AGL: 7500-10250
			☐ 2+2	☐ 0.0	130	MSL: varies
			☑ 4+3	☐ 0.3		Max Range: 5351-8031
			☐ Single	☐ 0.7	Laser Power %	Avg. Elev.: varies
			☑ Multi		100%	Adj. AGL:

Flt Line	Mission ID#	Heading	HDOP	VDOP	SVs	Course	Fine	AGC	Line Notes
TEST	090412-161201		----------	----------	----------	----	----------	----------	ok
	▲ Times entered are Zulu / GMT ▼			Verify S-Turns Before Mission			☑ Yes ☐ No		
27	"" 163749	S	0.862	1.115	11	6	7		B lines
26	"" 165341	N	1.003	1.608	10	6	7		B lines
25	"" 171006	S	0.957	1.622	10	6	7		B lines SEE NOTES
24	"" 172637	N	0.89	1.495	11	6	7		B lines
23	"" 174346	S	0.852	1.478	11	6	7		B lines
22	""180012	N	0.827	1.349	11	6	7		B lines
21	""181754	S	0.847	1.272	10	6	7		B lines
20	""184107	S	0.847	1.606	8	6	7		B lines
36	"" 185545	N	1.305	1.533	8	6	7		B lines
81	""191516	S	1.161	2.706	7	6	7		B lines
80	""192243	N	1.692	2.253	8	6	7		B lines
79	""193018	S	1.471	2.173	8	6	7		B lines
78	""193814	N	1.402	2.043	8	6	7		B lines
77	""194454	S	1.315	1.923	8	6	7		B lines
76	""195059	N	1.267	1.795	8	6	7		B lines
75	""195653	S	1.216	1.681	8	6	7		B lines
68	""201945	N	1.265	1.971	7	6	7		A lines
68	""201945	S							LINE ALREADY FLOWN ABORTED
67	""203625	S	1.083	1.566	8	6	7		A lines
66	""205024	N	1.023	1.62	8	6	7		A lines
65	""210330	S	1.083	1.576	8	6	7		A lines
64	""211706	N	1.023	1.473	8	6	7		A lines
63	""212944	S	0.976	1.37	8	6	7		A lines

Verify S-Turns After Mission ☑ Yes ☐ No

Supplemental Notes: ERROR MESSAGE: POS/AV position not within user specified bounds

LIDAR LOG SHEET

Date: 13/04/09 DD / MM / YY	**Julian Date:** 103	**Mission Name:** Bluestone Lake 69422	
Operator: Schneider	**Aircraft:** ☑ N7079F ☐ N404CP ☐ N475RC	**Hobbs Start** 913.8	**Local Start Time (Wheels Up)** 20:34
Zulu Start 0:34			
Pilot: Rader	**Sensor:** ☑ SH46 ☐ SH77	**Hobbs End** 919.9	**Local End Time (Wheels Down)** 2:40
Zulu End Time 6:40			
Passengers:			

Wind Direction/Sp	Visibility	Cloud ceiling (ft):	Cloud Cover %:	Departing Airport	Arriving
030/6	10	clr		BKW	CRW

Temp:	Dew Point:	Pressure:	Wind/Haze/Cloud/Fire?	Applanix GPS Began Logging at:
9.0 ° C	-10.0 ° C	30.18		00:20:20

Base Station #	Operator: Schneider	BKW	Using or Relying on CORS
Base Station #	Operator: Schneider	CRW	☐ YES ☑ NO

"Laser Specifications"

Scan Angle (FOV): 35	Scan Frequency (Hz): 39	Pulse Rate(kHz): 104.1	Mode	Attenuator	Air Speed	
			☐ 2+2	☐ 0.0	130	AGL: 7500-10250
			☑ 4+3	☐ 0.3		MSL: varies
			☐ Single	☐ 0.7	Laser Power %	Max Range: 5351-8031
			☑ Multi		100%	Avg. Elev.: varies
						Adj. AGL:

Flt Line	Mission ID#	Heading	HDOP	VDOP	SVs	Course	Fine	AGC	Line Notes
TEST	090413-002151		-----------	-----------	-----------	----	-----------	-----------	ok
▲ Times entered are Zulu / GMT ▼				Verify S-Turns Before Mission			☑ Yes ☐ No		
62	"" 004859	N	0.772		10	6	7		
61	"" 010304	S	0.919		9	6	7		
60	"" 011753	N	0.916		10	6	7		
59	"" 013032	S	0.879		11	6	7		
58	"" 014311	N	0.876		11	6	7		
57	""015518	S	0.919		10	6	7		
56	""020704	N	0.918		10	6	7		
55	"" 021944	S	1.228		8	6	7		
54	"" 023152	N	1.217		8	6	7		HIGH PDOP WPT 11
53	"" 024211	S	1.239		8	6	7		
52	""025247	N	1.26		8	6	7		
51	""030613	S	1.249		8	6	7		
50	""032001	N	1.087		9	6	7		
49	""033450	S	1.034		9	6	7		
48	""034820	N	0.825		11	6	7		
47	"" 035940	S	0.819		11	6	7		
46	""041043	N	0.911		10	6	7		
45	""042140	S	0.892		10	6	7		
44	""043248	N	0.939		9	6	7		
43	""044338	S	0.934		9	6	7		
42	""045447	N	0.937		9	6	7		
41	""050555	S	0.961		9	6	7		
40	""051803	N	0.942		9	6	7		
39	""052919	S	1.023		8	6	7		
38	""054040	N	1.152		7	6	7		
37	""055203	S	1.119		7	6	7		
36	"" 060333	N	1.117		7	6	7		
35	"" 062019	S	0.967		7	6	7		
				Verify S-Turns After Mission			☑ Yes ☐ No		

Supplemental Notes: A LINES

Page 1 of

LIDAR LOG SHEET	Date: 17/04/09 DD / MM / YY	Julian Date: 107	Mission Name: Bluestone Lake 69422
Operator: Krohn	Aircraft: ☐ N7079F ☑ N404CP ☐ N475RC	Hobbs Start 2636.7	Local Start Time (Wheels Up) 7:44 PM	Zulu Start 0:44
Pilot: Gebhart	Sensor: ☐ SH46 ☑ SH77	Hobbs End 2639.8	Local End Time (Wheels Down) 10:47 PM	Zulu End Time 3:47
Passengers:				

Wind Direction/Sp	Visibility	Cloud ceiling (ft):	Cloud Cover %:	Departing Airport	Arriving
030/6	10	clr		CRW	CRW
Temp: 18.0 ° C	Dew Point: 2.0 ° C	Pressure: 30.30	Wind/Haze/Cloud Fire?	Applanix GPS Began Logging at: 00:34:17	

Base Station #1	Operator: Krohn		Using or Relying on CORS
Base Station #2	Operator:		☐ YES ☑ NO

"Laser Specifications"

Scan Angle (FOV): 35	Scan Frequency (Hz): 39	Pulse Rate(kHz): 104.1	Mode	Attenuator	Air Speed	
			☐ 2+2 ☑ 4+3 ☐ Single ☑ Multi	☐ 0.0 ☐ 0.3 ☐ 0.7	130	AGL: 7500-10250 MSL: varies Max Range:
					Laser Power % 100%	Avg. Elev.: varies Adj. AGL:

	Flt Line	Mission ID#	Heading	HDOP	VDOP	SVs	Course	Fine	AGC	Line Notes
	TEST	090417-003417		-----------	-----------	-----------	----	-----------	-----------	ok
	▲ Times entered are Zulu / GMT ▼				Verify S-Turns Before Mission ☑ Yes ☐ No					
	26	"" 010346	S		1.7	11	12	7		
	27	"" 012410	N		1.5	10	12	7		
	28	"" 014223	S		1.9	10	12	7		
	29	"" 020030	N		1.9	11	12	7		
	30	"" 021854	S		1.4	11	12	7		
	31	"" 023705	N		1.4	11	12	7		
	32	"" 025251	S		2.1	10	12	7		
	33	"" 030902	N		2.3	8	12	7		
	34	"" 032519	S		2.5	8	12	7		HIGH PDOP WPT 11

Verify S-Turns After Mission ☑ Yes ☐ No

Supplemental Notes: IPAS record 2.5 TracGUI reads 3.5 on line 34 starting wpt 11

LIDAR LOG SHEET	Date: 23/04/09 DD / MM / YY	Julian Date: 113	Mission Name: Bluestone Lake		
Operator: Krohn	Aircraft: ☐ N7079F ☑ N404CP ☐ N475RC	Hobbs Start 2647.9	Local Start Time (Wheels Up) 10:33	Zulu Start 14:33	
Pilot: Gebhart	Sensor: ☐ SH46 ☑ SH77	Hobbs End 2653.4	Local End Time (Wheels Down) 4:59	Zulu End Time 19:59	
Passengers:					

Wind Direction/Sp	Visibility	Cloud ceiling (ft):	Cloud Cover %:	Departing Airport	Arriving
350/5	10	clr		CRW	CRW
Temp: 10.0 ˚C	Dew Point: 1.0 ˚C	Pressure: 30.16	Wind/Haze/Cloud/Fire?	Applanix GPS Began Logging at: 14:23	

Base Station #	Operator: Krohn	Using or Relying on CORS
Base Station #	Operator:	☐ YES ☑ NO

"Laser Specifications "

Scan Angle (FOV): 35	Scan Frequency (Hz): 39	Pulse Rate(kHz): 104.1	Mode	Attenuator	Air Speed	
			☐ 2+2	☐ 0.0	130	AGL: 7500-10250
			☑ 4+3	☐ 0.3		MSL: varies
			☐ Single	☐ 0.7	Laser Power %	Max Range:
			☑ Multi		100%	Avg. Elev.: varies
						Adj. AGL:

Flt Line	Mission ID#	Heading	HDOP	VDOP	SVs	Course	Fine	AGC	Line Notes
TEST	090423 14308		----------	----------	----------	----	----------	----------	ok
▲ Times entered are Zulu / GMT ▼		Verify S-Turns Before Mission ☑ Yes ☐ No							
29	"" 145637	N		1.9	9	12	7		2-6 WP LOW RETRNS
29	"" 150452	N		1.9	10	12	7		reflt wpt 2-6
28	"" 151228	N		1.6	10	12	7		reflt wpt 2-6
26	"" 152251	N		1.5	10	12	7		reflt10-14
25	"" 153124	N		1.5	10	12	7		reflt 9-14
24	"" 153956	N		1.6	10	12	7		reflt 1-13
23	"" 155608	N		1.9	10	12	7		reflt 1-13
22	"" 161006	N		2	10	12	7		reflt 8-13
21	"" 161751	N		1.7	11	12	7		reflt 8-13
20	"" 162633	N		1.8	11	12	7		
8	"" 163314	N		1.8	11	12	7		reflt 6-10
7	"" 164041	N		1.5	11	12	7		reflt 6-10

Verify S-Turns After Mission ☑ Yes ☐ No

Supplemental Notes

SECTION 4: LIDAR SYSTEM SPECIFICATIONS

The LiDAR data was acquired using two ALS50-II 150kHz Multi-Pulse enabled LiDAR systems, both which are on board Cessna 404 Titans. The ALS50-II 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 ALS50-II LiDAR System has the following specifications:

Table 4.1: ALS50-II LiDAR System Specifications

Nominal	
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