AERIAL LIDAR ACQUISITION REPORT

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WOOLPERT



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

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PREPARED BY:

WOOLPERT 4454 Idea Center Boulevard Dayton, Ohio 45430-1500

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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 104.100 kHz Pulse Rate: Scan Rate: 39 Hz 30% Side Lap (Average):

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.

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								







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.

Station	Latitude	Longitude	Ellipsoid Height (L1 Phase center)
Name	(DMS)	(DMS)	(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

Table 2.1: GNSS Base Stations:

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.

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73b	033836	s		1.3	10	12	7			OK	
72b	034747	n		2.1	10	12	7	us		ОК	
71b	035639	s		2.3	9	12	7			ОК	
705	040927	n		2.4	8	12	7			ОК	
69b	042109	s		2.4	8	12	7			Pdop was above 3.5/ lp	as was 2.4
68b	043423	n		2.3	9	12	7			ОК	
675	044531	s		2.1	9	12	7			OK	
885	050331	n		1.5	10	12	7			9000 MSL	
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17B		152129	N		2	8	12	7		2	OK		
16B		153711	S		2	8	12	7		2	OK		
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7B		181522	N		1.6	9	12	7		2	OK		
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5B		184137	N		1.6	11	12	7		2	ОК		
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023658	N	-	1.8	11	12	7				
024552	S	-	1.5	11	12	7				
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Op	erator:				Aircraf	<u>t</u> : Пи	7079F	н	obbs Sta	rt	Local Sta	rt Time (Wheels Up)	Zulu Start Time
KB	OHN				M N404		475RC		2626.1			6:21	5:21
									hobbs en	d	Local Ead	Time (Wheels Down)	Zulu End Time
GE	BHART				SH77								
	<u>əseny</u> e	12.		0	□ SH4	6 🗹	SH77		2621.4			8:38	4:36
¥i.	d Direct	inn/Spe	Tiribility	Claud coili	•• (ft):	Claud Ca	eer X:	Departi	ng Airpo	rt	101 2011-2011-20		Arriving Airport
Ter	280/	7	10 Date	ULE.	٩R	Visd/Has	a/Clas	Analania	6PS B		CRW	9	CRW
		20	Paint:			41 Fire	5.44.44						
_	18.0		-2.0 °C	23.3	56								
Ba	se Stat	ion #1:	Operator	krohn		CRV				Using o	r Relying on	CORS	
Ba	se Stat	ion #2	Operator							VES	NO NO		
							7	aser Sp	ecificati	ons "			
	Scan A	ngle	ScanFre	- Pul	se	Mode	Atta	tuatar	Air S	ipaad	AGL:	7500	
			- 4·			2+2	0.0		t	30	MSL:	varies	
	35			10410	0.000	4+3	0.3		Larer	auer X	Max Hange: Avg. Flev	varies	
			39			Single 0.7			10	0%			
2				5		🗹 Multi	34		10	0%			
	Flt Line	Miss	sion ID#	Heading	HDOP	YDOP	S¥s	Course	Fine	AGC		Line Notes	
	<u>JEST</u>	0904	09-231054	w		1.4	9	12	7	N/A	· · · · · · · · · · · · · · · · · · ·	OK	
		▲ Times	entered are	Zulu / GMT	•	Verif	y S-Turn:	s Before I	lission	V Yes	No No		
0.0	89		034814	N		2.4	8	12	7			ОК	
0.0	68		041032	s		2.3	8	12	7			ОК	
							9	2	2	s - s	-		
				· · · · · · · · · · · · · · · · · · ·			9	2		3			
				3			9	2		3	-		
							S) ;	2		S			
							s	2		s			
0	~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~						s	-		· · · · · ·			
0.3							s	-		3	-		
s. 3							s)	2	2	s			
	2		1				s);				-		
	~					<u> </u>	s)			3	-		
						<u> </u>							
							s						
				2			5						
							9						
							sj		2				
			1	2			sj	2	· · · · ·	· · · · · ·	1		
							S	2	· · · · ·	ss	-		
	2		-	2			S			s			-
	2					<u> </u>	59		2	5			
										2	lor 🗌 No		
5.,	plomont	al Hates	e.										
844	4CP REF	LEW LIN	C.										

		IJD	AB LOG			Date:	-	Julia	Date:	Mission	Name:		
	COLUMN T	811	CICT .		DD	4-Sep-03	YY	3	99	Blueston	e Lake		
Op	erator:				Aircraf	L: 🗹 N	7079F	1	lobbs St	art	Local Start Time (Wheels Up)	Zulu S	Start
Kro	hn				D N404		475RC					14:33	
Pil	ot:				10000000			- 93 	893.5 Hobbs Er	d	9:37 Local End Time (Wheels	Zala Fa	d Tine
Get	hart				Sensor			15			Dows)		
Pa	ssenge	[5:			SH4	6 🗆	SH77		0054			15:22	
Via	4 Directi		Tiribility	Claud ceilin	•• (ft):	Claud Ca	er X:	Depart	ing Airpe	ort	11:22	Arriviac	
	calm		10	cir		few cl-	ouds				CRW	CB	w.
Tee		-	Deu	Pressure:		Wis-4/Hes		Applan	ix GPS Be	qan Luqqii	4 at: 13:26:10		
	7.0°C		Paint: 2010	29.5	33	47 Fira	2						
_			2.0 0		С.	_			_				
Ba	se Stat	ion #	Operator	: Krohn						Using o	r Relying on CORS		
Ba	se Stat	ion #:	Operator	5					14	VES	NO NO		
			a sossaa e			/	aser S	pecific	ations	•			
S	can An	gle 26	Scan	Pul	se 0. 104 1	Mode	Attan	tuatar	Air S	AGL: 7500-10250			
1.5	(FOT):	30	cų (Hz):	пасески	.j: 104.1	2+2	0.0		1:	30	MSL: varies		
			39			🗹 4+3	0.3			66	Maz Range:		_
						🗆 Single 🔲 0.7			Larer	ansı X	Avg. Elev.: varies		
						Multi			100%		Adl. AGC:		-
	-It Line	Mis	sion ID#	Heading	нор	VDOP	S¥s	Cours	Fine	AGC	Line Notes		
2.2	TEOT			The dating				e					
2 8	TEST	0904	+23 132610 is entered ar	a Zulu / GM1		Veri	fu S.Tur	ns Befor	e Mission		OK		
			s entered an			4000	ig of run		-				
2.5	99		142431	N	1.184	1.933	8	6					
2.5	98		143232	5	1.145	1.817	8	6				2	
2.5	97		144058	N	1.183	1.99	7	6			CLUS WP8 WP	5	
2 8	89		145123	N	1.19	1.997	(6	-		CLD WP 9		
2.5	88		150041	S	1.079	1.481	8	6	(CLU CUVER WP1	11	
2.5					35	S	38						
2.5					30	S	3						
2.5					S		3		12				
2.5					9	82 8	3 3						
2.5	· · · · · ·				30	82	3 3						
2.5					5	82	3						
2.5					9	SJ	3 3		12				
2.5					sj	83	s8						
2.5	s				30	80	3						
2 3				-	5	S	3						
20				-	<u></u>		33		12				
2.5				-	9		38						
2.3					S	S	3		8				-
72 - 5					55	S	3						
2.5				-	S	S	3						
2.5					55	89	3						
2. 3					5	S) - 2	33		12		2		
2.5				-	S	s	3 3	-					
2.5					5	s	3						
2.3					55	s	s						
2.3						87	3						
2.5					s	s)							
					2	13			22				
						Ve	erify S-Tu	urns Afte	r Mission	۷ 🗹	or 🗌 No		
Sup	plomont	el Hata	Encoder re-	ading is out o	of spec by will sustem	more than	25 degre	ees, pos	'av headin	g is not wi	thin the user specified bound, laser	not recei	iving
			start puise,		a, system		or orouds						

_		LIDAR LOG	1	1	Date:		Julian	Date:	Missio	n Name:				
		SHFFT	5	8	9/4/2009			9	wy coe					
Opera	tor:			Aircraf		17079F	(H	obbs Sta	art	Local Sta	rt Time (Wheels Up)	Zulu Start Time		
SHULE	R			- N404		475RC		2626.1		ſ	6:25	22:55		
							, I	hobbs en	d	Local End	Time (Wheels Down)	Zulu End Time		
RADEF Passe	naer	·S-		SH77	_									
			0) 🗹 SH4	6 []	SHIT	con 15	2621.4			12:16	4:16		
Wind Di	recti	n/Spa Tiribility	Claud caili	ing (ft):	Claud Ca	ver X:	Departi	ng Airpo	rt			Arriving Airport		
Temp:	200/1	Deu	Pressure:	00	Wind/Ha:	ce/Clau	Applanis	GPS Bre	an Luggin	CRW		CRW		
1	80.0	Paist:	29	86	4/ Fir.	•?	6:16pm							
<u></u>	0.0 0	-2.0 C	20.											
Base	Stati	on #1: Operator	: krohn		CRV				Using o	r Relying on	CORS			
Base	Stati	on #2 Operator	:		20				L YES	M NO				
Sca	n An	ale ScanFre	Pul	SP	Mode	/ Atta	aser Sp	ecificati	ons	4.01	7500			
		q.			□ 2+2	0.0				MSL:	varies			
					4+3 0.3			1:	30	Max Bange	5351-8031			
	35	0.000	10410	0.000	□ Sinale		Larer Pauer 2			Avg. Elev.:	varies			
		39			Multi			10	0%					
Fit	l ine	Mission ID#	Heading HDOP YDOP SYs Course Fine AGC Line N						Line Notes					
72	57	090409-221652	meaning								0K			
	4	Times entered are	Zulu / GMT	Ŧ	Verif	y S-Turn:	s Before M	Aission	Ver Yer		ÖK			
5 10	13	223918	N	1.091	1.927	7	6	7			ОК			
s 20 1	12	225331	S	1,077	1.917	7	6	7			OK			
1. 20	11	230102	N	1.009	1.679	8	6	7	c - 9	ОК				
<u>, a</u> 1	10	230813	S	1.125	1.961	7	6	7	<u> </u>					
2.23	9	231507	N	1.01	1.984	8	6	7	<u> </u>					
	8	232157	S	1.035	1.583	8	6	7	<u> </u>					
	7	232815	N	1.076	1.711	8	6	7	<u> </u>		OK			
	5	233503	N	1.112	1.042	8	8	7						
	4	234633	s	1,179	1.991	8	6	7			OK			
	3	235200	N	1.227	2.153	7	6	7			OK			
. 10	2	235751	S	1.212	2.18	7	6	7			ОК			
5 22	1	000311	N	1.192	2.166	7	6	7			OK			
	14	001000	S	0.978	1.64	8	6	7	c		ОК			
1	15	002340	N	1.006	1.75	8	6	7	c 2		ОК			
	16	003738	S	0.768	1.199	10	6	7	<u> </u>		OK			
	17	005125	N	0.769	1.327	10	6	7	()		OK OK			
	19	010409	N	0.772	1.335	4	8	7						
	20	013223	S	0.878	1.326	11	6	7						
	21	014611	N	0.876	1.363	11	6	7			ОК			
2	22	015948	s	0.922	1.324	10	66	7			ОК			
2	23	021748	N	0.917	1.224	10	6	7	<u> </u>		ОК			
2	24 023613 S				2.657	8	6	7	<u> </u>		ОК			
2	25 025537 N				3.25	8	6	7	c		ОК			
2	26 031536 S				2.9	9	6	7	e		ОК			
3 2/2					51	6 6		8 8	<u> </u>					
2 1/2					3	<u>)</u>		8 8		 07 1 No				
Supple	nente	il Mater												
H404CF	REF	LEW LIN												

		LIN	AR LOS	3		Date:		Julia	Date:	Missio	n Name:		
		0111		0		12/4/2009	~~	10	2 A	Blueston	ne Lake 69422		
O	erator:	981			Aircraf	t: Du	11		lobbs St	art	Local Start Time (Wheels Up)	Zulu	Start
Kre	ohn						10191	°			22:45	2.45	0.00000000
Pi	lot:						475RC		906.6		10000-0	2:90	
P.	abort				Concer	-	5	1	Hobbs E	hd	Local End Time (Wheels	Zulu En	d Time
Pa	ssenae	[5:			Selisor		CU77		09:08				
1	<i>.</i> 77	19			E SH4	6 []	SHIT				3:18	7:18	
¥i.	d Directi	as/Sp	Tiribility	Claud coilin	•• (ft):	Claud Ca	ver X:	Depart	ing Airpo	ort		Arriving	,
	330/7		10	cir						a20154 - 101	BKW	ВК	<u>v</u>
Ter			Deu Paist:	Pressure:		diad/Has	cafClau }	Applani	iz GPS Be	qan Luqqi	ng at: 02:35:30		
	6.0°C		-2.0 ° C	30.1	14								
				Provinsi Courton Ac									
Ba	se Stat	ion #	Operator	: Schneider		raleigh				Using o	r Relying on CORS	-	<u>.</u>
Ba	se Stat	ion #:	Operator	5	13					U YES	NO NO	8	8
1							Laser S	pecific	ations	•	-		
1	Scan An	gle 25	Scan	Pul	se 3. 104 1	Mode	Attes	tuator	Air S	ipaad	AGL: 7500-10250	2	
	(FUT):	30	cu (Hz):	пасески	j: 104.1	□ 2+2	0.0		t.	30	MSL: varies		
			39			🗹 4+3	0.3				Max Range: 5351-8031		
						Single	0.7		100%		Avg. Elev.: varies		
						Multi		2	100%		Aul. Aur.:		
								Cours					
	FIt Line	Mis	sion IU#	Heading	HDOP	ADOb	S¥s	e	Fine	AGC	Line Notes		
	<u>_TEST</u>	0904	12-023504								ok		
		Time	s entered ar	e Zulu / GMT	•	Ver	ify S-Turi	ns Befor	e Mission	1 🗹 Yor	□ N₀		
	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		
1	49B		"051156	s	0.958		9	6	7				
1	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		a a	6	7		2		
		-			0.020		Ť		100		2 2		
			-				-		i i		8		
			-	1	1		-		i î		8		
						<u> </u>					1		
							-				50 20		
							-	1	-				
				-			-		-		8		
							-	- 1			8		
							-						
							-				400 20		
				-			-				8		
				-			-				8		
F			(lane back	line EOD (Vi to pitel:	erity S-Tu	urns Afte	r Mission	121 V	or 📙 No		
5.	plomont	el fiet:	i naps proke	mie oob ron	ceu nose i	to pitch up							

Page 1 of _____

						Page	1	of		ĺ.			
		LID	AB LOG	3		Date:	a	Julia	Date:	Mission	Name:		
w	TRIPLICO	8H1	EET		DD	121412005	YY	10)2 B	Blueston	e Lake 69422		
Ope	erator:				Aircraf	t: 🗆 н	7079F	N	lobbs Sta	art	Local Start Time (Wheels Up)	Zele	Start
Krol	hn ot:				□ N404		475RC		000.0		9:55	13:55	
ЕЩ	01.							-	Hobbs E	d	Local End Time (Wheels	Zulu En	d Time
Pro	bert scenge				Sensor				09-02		Dows)		
L d:	ssenge	2.			SH4	. 🗆	SH77		03:00		11:30	15:30	
Win-	d Directi		Tiribility	Claud coilin	• • (f+):	Claud Ca	eer Z:	Depart	ting Airpo	ort		Arriving	9
	030/7	8 - 18	10	cir	8	M:- 110					BKW	ВК	W
			Paint:	Prassura:		47 Fire	2	Applan	IX GP 5 84	446 L 8440	13:44		
	3.0°C		7.0°C	30.2	28								
Bas	se Stat	ion #	Operator	Krohn						Usina o	r Beluina on COBS		
Bat	se Stat	ion #	Operator							VES	NO NO		
Da.	SE JIAL		operator				acer 6	necilio	ations .			-	
S	can An	gle	Scan	Pul	se	Mode	Attan	pecase tuatur	Air S		AGL: 7500-10250		
	(FO¥):	35	Frequen	Rate(kHz): 104.1	2+2	0.0			20	MSL: varies		
			39			₽ 4+3	0.3		'		Max Range: 5351-8031		
						Single	0.7		Larer P	anet X	Avg. Elev.: varies		
						🗹 Multi			100%		Adl. Adl:		
	Flt Line	Mis	sion ID#	Heading	HDOP	YDOP	SVs	Cours	Fine	AGC	Line Notes		
	TEST	0904	412-134703					• •			ok		
	▲ Times entered are Zulu / GM				Ŧ	Veri	ify S-Turi	ns Befor	e Mission	Ver Yer	□ 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				
				36									
								×					
				2 C					s	6 6			
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						-							
		6				-		×		8			
				1	-			-	s	-			
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		с. Г				-		1	<u> </u>				
		8			-	-		<u> </u>					
				-		-		-					
		1						<u> </u>					
		1											
		į –											
						1							
								24					
			10 10 100			Ve	erify S-Tu	irns Afte	r Mission	🗹 Y	or 🗌 No		
Sup	plomont	al Hatı	land at CR	w to set up F	7 for arriv	ing ADS ci	rew						

22			_		850	12.03					3
	LIDAB LOG	3		Date:		Julia	n Date:	Missio	n Name:		
WEDDER SHEET DD				12/4/2003		102 C		Bluestone Lake 69422			
Operator: Aircraf			L: 🗆 н	Hobbs St		art	art Local Start Time (Wheels Up) Zulu St		Start		
Krohn			- N404		475RC		1000000		12:22	16:22	
Pilot:							908.2 Hobbs Er	d	Local End Time (Wheels	Zulu En	d Time
Rader Sen			Sensor						Dows)		
Passenge	Passengers:			6 🗌 SH77					5.54	21:54	
Wind Direct	Wind Direction/Sp Tiribility Claud coiling (ft)			Claud Ca	ver Z:	Depart	ting Airp	ort	0.04	Arrivine	9
070/8	10	clr							BKW	CR	W
Temp:	Deu	Pressure:		Wind/Has	e/Clas	Applan	iz GPS Bø	qan Luqqi	ng at: 16:10		
9.0°C	-5.0°C	30.3	34	.	•=						
											-
Base Stat	ion # Operator	: Krohn						Using o	r Relying on CORS	L	
Base Stat	ion #: Operator	:						VES	NO NO		
a		- 			aser S	pecific	ations	-	a		
Scan Ar	igle Scan 35 Frequen	Pul: Bate(kHz	se 1. 104 1	Mode	Attes	teater	Air S	Speed .	AGL: 7500-10250		
[F07].	cy (Hz):	nate[kn/	.j. 104.1	□ 2+2	0.0		1	30	MSL: varies		_
	39			4+3	0.3			P 74	Max Range: 5351-8031		
				🗌 Single	0.7		100%		Avg. Elev.: varies		
				🗹 Multi			1007.				-
The Line	Mission ID#	Heading	UDOD	VDOP	SVe	Cours	Fine	400	Line Notes		
-it Line	MISSIONIDE	Heading	HUUP	TDOF	375	e	r me	AGC	Line Notes		
JEST	090412-161201	. 7.1.1.0147							ok		ŝ.
	 Limes entered ar 	e Zulu 7 GiMi T	•	Ver	ity S-Turi T	ns Befor I	re Mission) 🗹 Yer			ģ
27	"" 163749	S	0.862	1.115	11	6	7	81	Blines		
26	"" 165341	N	1.003	1.608	10	6	7	81	Blines		2
25	···· 171006	S	0.957	1.622	10	6	7	84	B lines SEE NOTES		2
24	"" 172637	N	0.89	1.495	11	6	7	81	Blines		
23	174346	S	0.852	1.478	11	6	7	81	Blines		3
22	""180012	N	0.827	1.349	11	6	7	81	Blines		
21	***181754	S	0.847	1.272	10	6	7	84	Blines	2	
20	""184107	S	0.847	1.606	8	6	7	81	Blines		
36	185545	N	1.305	1.533	8	6	7	31	Blines		
81	""191516	S	1.161	2.706	7	6	7	81	Blines		2
80	""192243	N	1.692	2.253	8	6	7	8	Blines		
79	""193018	S	1.471	2.173	8	6	7	84	Blines		3
78	""193814	N	1.402	2.043	8	6	7	84	Blines		
77	***194454	S	1.315	1.923	8	6	7	81	Blines		3
76	""195059	N	1.267	1.795	8	6	7	8	Blines		2
75	""195653	S	1.216	1.681	8	6	7	8	Blines		2
68	201945	N	1.265	1.971	7	6	7	84	Alines		
68	201945	S			2 - 2 Ca		12		LINE ALREADY FLOWN /	RORTE	0
67	""203625	S	1.083	1.566	8	6	7	84	Alines		2
66	""205024	N	1.023	1.62	8	6	7		Alines		2
65		S	1.083	1.576	8	6	7		A lines		2
64	""211706	N	1.023	1.473	8	6	7	81	Alines		2
63		S	0.976	1.37	8	6	7	84	Alines		2
				S >	2 - 2						
			8	8	2 2	- 33					2
				S >	2 - 2	100					
					arifu C. T.	une Alter	n Miceire				3
S				Vi sition pot :	aithis us	ans Alte	ied bound	. 1921 S	er 📋 Ma		ġ
						opeon		-			

LIDAB LOG SHEET				БО	Date: 13/04/09 / MM /	YY	Jelia 1	Date: 03	Missio Bluestor	n Name: ne Lake 69422			
Operator: Schneider						Hobbs Start		art	Local Start Time (Wheels Up) Zulu Start				
									20:34	0:34			
Pilot	-				1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 -	91 - 2 7 8583	90,89393 1		913.8 Hobbs F	ed.	Local Fed Time (Wheels	Zala Fa	d Time
Rader S Passengers:			Sensor				NODD'S L		Dows)	2414 1.4			
			🗹 SH4	SH46 SH77						6:40			
Mind Discoving Sc. Viribility Claud callin			•• (ft):	Cined Ca	ver X:	Depart	919.9 ing Airp	ort	2:40	Arriving	a		
	030/6		10	cir		1000000000000					BKW	CB	, w
Tomp:	3	1	Deu	Pressure:		Wis.d/Ha:	ze/Clau	Applani	x GPS B.	qan Luqqi	nq at: 00:20:20		l.
	9.0°C		-10.0 °C	30.1	18	47 Fir.	•!						
Base	Stat	ion #	Operator	: Schneider		вку				Using a	or Relying on CORS		
Base	Stat	ion #	Operator	: Schneider		CRV				U YES	S M NO		
		-	_				Laser S	pecific	ations				
Sea	an An MVI-	gle 35	Scan Frequen	Pul: BatefkHz	se 1- 104 1	Mode	Attes	tuator	Air S	Speed	AGL: 7500-10250		
	01).		cy (Hz):	indice (with	.j. 101.1	2+2	0.0		1	30	MSL: varies		
			39			4+3	0.3			P 7	Max Range: 5351-8031		
						Single	0.7		100*/	r auer z	Avg. Elev.: varies		
						🗹 Multi			100%		out. out.		
FIL	t Line	Mis	sion ID#	Heading	HDOP	VDOP	S¥s	Cours	Fine	AGC	Line Notes		
7	TEST	0904	413-002151								ok		
		Time	s entered ar	e Zulu / GM1	Ŧ	Ver	ify S-Tur	ns Befor	e Missior	1 🗹 Yer	N₀		
	62		004859	N	0.772	1	10	6	7		1		
	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 VP	T 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				1
	45		042140	s	0.892		10	6	7				1
	44		043248	N	0.939		9	6	7				
	43		044338	S	0.934		9	6	7				
	42		045447	N	0.937		9	6	7				1
	41		050555	S	0.961		9	6	7				1
	40		051803	N	0.942		9	6	7				î
	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	Ň	1.117		7	6	7				1
	35		062019	S	0.967		7	6	7				
						۷	erify S-T	urns Afte	r Mission		Yos 🗌 No		
Suppl		al Hata	ALINES				100						

LIDAR LOG SHEFT Operator: Krohn Bilot: Gebhart Passengers: Wind Directions/Sp 030/6 Tiribility 10 Cloud ceilin clr Temp: Deu Print: 18.0°C Prezzure: 30.3 Base Station # Operator: Krohn			Date: 17/04/09 Julian Date: 107 Mission Name: Bluestone Lake 69422 Aircraft: Mobbs Start N7079F Hobbs Start Local Start Time (Local Start Time (2636.7 ModeP N475RC 2636.7 Local End Time Down) Sensor: 2639.8 Local End Time Down) SH46 SH77 2639.8 (ft): Claud Caver Z: Vind/Haze/Clau Departing Airport CRW Wind/Haze/Clau Applaniz GPS Began Lagging at: Vising or Relging on COF Using or Relging on COF						n Name: e Lake 69422 Local Start Time (Wheels Up) 7:44 PM Local End Time (Wheels Down) 10:47 PM CRW CRW et: 00:34:17	Up) Zulu Start PM 0:44 S Zulu End Time 3:47 Arriving CRW		
Base Stat Scan Ar (FO¥):	Base Station & Ope Scan Angle Sc (FO¥): 35 Fre- cy (3		Pul Rate(kHz	Pulse Rate(kHz): 104.1		Claser Specific Mode Attentuator 2+2 0.0 2 4+3 0.3 Single 0.7 Multi 0.7		Air Speed 130 Larer Pauer Z 100%		AGL: 7500-10250 MSL: varies Maz Range: Avg. Elev.: varies Adj. AGL:		
Flt Line	Mis	sion ID#	Heading	HDOP	YDOP	S¥s	Cours e	Fine	AGC	Line Notes		
JEST	0904	417-003417	7.4.101							ok		
	▲ Time	s entered ar	e Zulu / GM1	•	Ver	ity S-Turi	ns Befor	e Mission	Yes Yes	L No		
26		010346	S	-	1.7	11	12	7				
27		01/2410	N 0	-	1.9	10	12	7				
20		020030	N		19	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 VP1	Г 11	
a			· · · ·				<u>, , , , , , , , , , , , , , , , , , , </u>					
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			<u>.</u>	-		1	9 P					
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34			-									
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			· · · · ·	-								
				222 - 224	V.	erify S-Tu	irns Afte	r Mission	🗹 Y	or 🗌 No		
Supplement	al Mat	IPAS recor	d 2.5 TracGl	JI reads 3.9	5 on line 34	starting	wpt 11					

LIDAB LOG			Date: 23/04/09		Julian Date: Mission		Missio	n Name:					
WOODER SHEET			DD	1 MM 1	YY	113 Bluestor		Blueston	ne Lake				
Op	Operator:		Aircraf	Aircraft: INTOTOF		Hobbs Start		art	Local Start Time (Wheels Up)	art Time (Wheels Up) Zulu Start			
Kro	hn ot:				- 🗹 N404CP 🔲 N475RC			2017.0		10.22	14:33		
	<u>.</u>				in the second se				Hobbs E	nd .	Local End Time (Wheels	Zulu En	d Time
Gel	bhart SSenge				Sensor		999996				Dows)		
1-9				SH4	6 12	SH77		2653.4		4:59	19:59		
¥i.	d Directi	inn/Sp	Tiribility	Claud coilin	• (ft):	Claud Ca	eer Z:	Depart	ing Airpe	ort		Arriving	
	350/5		10	cir						175	CRW	CR	w
Tee			Deu Paist:	Pressure:		Wind/Has 4/ Fire	efClas	Applani	ix GPS B.	qan Luqqi	ng at: 14:23		
	10.0 ° C		1.0 ° C	30.1	16								
D.			Onerster	Venha						Using a	- Balaina an COBC		
Ва	se stat		Uperator	Kronn		5			10		I Relying on CURS		8
Ba	se Stat	ion #	Operator										
	ican An	ماه	Scan	Pul	50	 Mode	aser S	pecific	ations		101 7500 40050		
	(FO¥):	35	Frequen	Rate(kHz): 104.1	□ 2+2					AGL: 7500-10250		
			cy (Hz):						1	30	Max Bange		
			33			E 4+3		3	Larer Pauer Z		Avg. Elev.: varies		
						L Single	L 0.7	2	100%		Adj. AGL:		
			a			🗹 Multi							
	Flt Line	Mis	sion ID#	Heading	HDOP	YDOP	S¥s	Cours	Fine	AGC	Line Notes		
	TEST	090	423 14308								ok		
		▲ Time	s entered ar	e Zulu / GMT	TT	Veri	ify S-Tur	ns Befor	e Mission	Yes Yes	□ No		
	29		145637	N		1.9	9	12	7		2-6 WP LOW RETF	NS	
	29		150452	N		1.9	10	12	7		reflt wpt 2-6		
	28		151228	N		1.6	10	12	7		refit wpt 2-6		
	26		152251	N		1.5	10	12	7		refit10-14		
	25		153124	N		1.5	10	12	7		refit 9-14		
	24		153956	N		1.6	10	12	7		reflt 1-13		
	23		155608	N		1.9	10	12	7		refit 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		refit 6-10		
	7		164041	N		1.5	11	12	7		reflt 6-10		
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-						Ve	erify S-To	urns Afte	r Mission	12 V	or 📙 No		
5.	plement	el Mata											

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:

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							

Table 4.	1: ALS50-	II LIDAR	System	Specifications