



 $USGS\,$ FY15 ARS-USDA AZ Walnut Gulch QL1 Lidar

USGS/NGTOC Denver, CO

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Section 1: Overview

Project Name: FY15 ARS-USDA AZ Walnut Gulch QL1 Lidar Woolpert Project: #75861

This report contains a comprehensive outline of the ARS-USDA AZ Walnut Gulch QL1 Lidar task order. This task is issued under USGS Task Order Number: G15PD00889. This task order requires lidar data to be acquired over Walnut Gulch AZ. The total area of the Walnut Gulch Lidar AOI is approximately 60 square miles situated 60 Miles Southeast of Tucson, AZ. The lidar was collected and processed to meet a maximum Nominal Post Spacing (NPS) of 0.35 meter. The NPS assessment is made against single swath, first return data located within the geometrically usable center portion (typically ~90%) of each swath.

The data was collected using a Leica ALS70 500 kHz Multiple Pulses in Air (MPiA) lidar sensor. The ALS70 sensor collects up to four returns per pulse, as well as intensity data, for the first three returns. If a fourth return was captured, the system does not record an associated intensity value. The aerial lidar was collected at the following sensor specifications:

Table 1.1: Acquisition Specs				
Post Spacing	0.8 ft / 0.35m			
AGL (Above Ground Level) average flying height	2,950 ft / 899 m			
Average Ground Speed:	115 knots / 132 mph			
Field of View (full)	32 degrees			
Pulse Rate	198.5 kHz			
Scan Rate	50 Hz			
Side Lap	25%			

The lidar data was processed and projected in UTM, WGS84, Zone 12 in units of meters. The vertical datum used for the task order was referenced EGM 2008, in units of meters.



Figure 1.1: Lidar Task Order AOI

Section 2: Acquisition

The existing lidar data was acquired with a Leica ALS70 500 kHz Multiple Pulses in Air (MPiA) Lidar Sensor System, on board Precision Aerial Reconnaissance (PAR) Cessna aircraft. The ALS70 lidar system, developed by Leica Geosystems of Heerbrugg, Switzerland, includes the simultaneous first, intermediate and last pulse data capture module, the extended altitude range module, and the target signal intensity capture module. The system software is operated on an OC50 Operation Controller aboard the aircraft.

The ALS70 500 kHz Multiple Pulses in Air (MPiA) Lidar System has the following specifications:

Table 2.1: ALS Lidar Syste	em Specifications
Operating Altitude	200 – 3,500 meters
Scan Angle	0 to 75° (variable)
Swath Width	0 to 1.5 X altitude (variable)
Scan Frequency	0 – 200 Hz (variable based on scan angle)
Maximum Pulse Rate	500 kHz (Effective)
Range Resolution	Better than 1 cm
Elevation Accuracy	7 - 16 cm single shot (one standard deviation)
Horizontal Accuracy	5 – 38 cm (one standard deviation)
Number of Returns per Pulse	7 (infinite)
Number of Intensities	3 (first, second, third)
Intensity Digitization	8 bit intensity + 8 bit AGC (Automatic Gain Control)
	level
MPiA (Multiple Pulses in Air)	level 8 bits @ 1nsec interval @ 50kHz
MPiA (Multiple Pulses in Air)	level 8 bits @ 1nsec interval @ 50kHz 0.22 mrad @ 1/e ² (~0.15 mrad @ 1/e)
MPiA (Multiple Pulses in Air) Laser Beam Divergence Laser Classification	level 8 bits @ 1nsec interval @ 50kHz 0.22 mrad @ 1/e ² (~0.15 mrad @ 1/e) Class IV laser product (FDA CFR 21)
MPiA (Multiple Pulses in Air) Laser Beam Divergence Laser Classification Eye Safe Range	level 8 bits @ 1nsec interval @ 50kHz 0.22 mrad @ 1/e ² (~0.15 mrad @ 1/e) Class IV laser product (FDA CFR 21) 400m single shot depending on laser repetition rate
MPiA (Multiple Pulses in Air) Laser Beam Divergence Laser Classification Eye Safe Range Roll Stabilization	level 8 bits @ 1nsec interval @ 50kHz 0.22 mrad @ 1/e ² (~0.15 mrad @ 1/e) Class IV laser product (FDA CFR 21) 400m single shot depending on laser repetition rate Automatic adaptive, range = 75 degrees minus current FOV
MPiA (Multiple Pulses in Air) Laser Beam Divergence Laser Classification Eye Safe Range Roll Stabilization Power Requirements	level 8 bits @ 1nsec interval @ 50kHz 0.22 mrad @ 1/e ² (~0.15 mrad @ 1/e) Class IV laser product (FDA CFR 21) 400m single shot depending on laser repetition rate Automatic adaptive, range = 75 degrees minus current FOV 28 VDC @ 25A
MPiA (Multiple Pulses in Air) Laser Beam Divergence Laser Classification Eye Safe Range Roll Stabilization Power Requirements Operating Temperature	level 8 bits @ 1nsec interval @ 50kHz 0.22 mrad @ 1/e ² (~0.15 mrad @ 1/e) Class IV laser product (FDA CFR 21) 400m single shot depending on laser repetition rate Automatic adaptive, range = 75 degrees minus current FOV 28 VDC @ 25A 0-40°C
MPiA (Multiple Pulses in Air) Laser Beam Divergence Laser Classification Eye Safe Range Roll Stabilization Power Requirements Operating Temperature Humidity	level 8 bits @ 1nsec interval @ 50kHz 0.22 mrad @ 1/e ² (~0.15 mrad @ 1/e) Class IV laser product (FDA CFR 21) 400m single shot depending on laser repetition rate Automatic adaptive, range = 75 degrees minus current FOV 28 VDC @ 25A 0-40°C 0-95% non-condensing

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

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

The lidar data was collected in three (3) separate missions, flown as close together as the weather permitted, to ensure consistent ground conditions across the project area.

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



Figure 2.1: FY15 ARS-USDA AZ Walnut Gulch QL1 Lidar

Table 2.2: Airborne Lidar Acquisition Flight Summary						
Date of Mission	Lines Flown	Mission Time (UTC) Wheels Up/ Wheels Down	Mission Time (Local = EDT) Wheels Up/ Wheels Down			
September 16, 2015_A	1-30, 67	15:13 - 18:57	08:13 AM – 11:57 AM			
September 16, 2015_B	31-67	19:43 - 00:26	12:43 PM - 05:26 PM			
September 18, 2015	1-2, 15-16, 63-64	14:25 - 15:34	07:25 AM – 08:34 AM			

Section 3: Lidar Data Processing

Applications and Work Flow Overview

- Resolved kinematic corrections for three subsystems: inertial measurement unit (IMU), sensor orientation information and 1. airborne GPS data. Developed a blending post-processed aircraft position with attitude data using Kalman filtering technology or the smoothed best estimate trajectory (SBET). Software: POSPac Software v. 5.3, IPAS Pro v.1.35.
- 2. Calculated laser point position by associating the SBET position to each laser point return time, scan angle, intensity, etc. Created raw laser point cloud data for the entire survey in LAS format. Automated line-to-line calibrations were then performed for system attitude parameters (pitch, roll, heading), mirror flex (scale) and GPS/IMU drift. Software: Leica Cloud Pro v 1.2.1, Proprietary Software, TerraMatch v. 15.015.
- 3. Imported processed LAS point cloud data into the task order tiles. Resulting data were classified as ground and non-ground points with additional filters created to meet the task order classification specifications. Statistical absolute accuracy was assessed via direct comparisons of ground classified points to ground RTK survey data. Based on the statistical analysis, the lidar data was then adjusted to reduce the vertical bias when compared to the survey ground control. Software: TerraScan v.15.026.
- The LAS files were evaluated through a series of manual QA/QC steps to eliminate remaining artifacts from the ground 4. class.

Software: TerraScan v.15.026.

Global Navigation Satellite System (GNSS) - Inertial Measurement Unit (IMU) Trajectory Processing

Equipment

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

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

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

A base-station unit was mobilized for each acquisition mission and was operated by a member of the acquisition team. Ground planes were used on the base-station antennas. Data was collected at 1 or 2 Hz.

The GNSS base station operated during the Lidar acquisition missions is listed below:

Table 3.1: GNSS Base Station					
Station	Latitude	Longitude	Ellipsoid Height (L1 Phase center)		
(Name)	(DMS)	(DMS)	(Meters)		
TombstoneBase	31° 40' 04.19862"	-110° 01' 43.92418"	1417.825		

Data Processing

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

Trajectory Quality

The GNSS Trajectory, along with high quality IMU data are key factors in determining the overall positional accuracy of the final sensor data. Within the trajectory processing, there are many factors that affect the overall quality, but the most indicative are the Combined Separation, the Estimated Positional Accuracy, and the Positional Dilution of Precision (PDOP).

Figure 3.1: Trajectory, Day25915_PAR_A

Combined Separation

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

Woolpert's goal is to maintain a Combined Separation Difference of less than ten (10) centimeters. In most cases we results below this threshold are achieved.



Figure 3.2: Combined Separation, Day25915_PAR_A

Estimated Positional Accuracy

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

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



Figure 3.3: Estimated Positional Accuracy, Day25915_PAR_A

PDOP

The PDOP measures the precision of the GPS solution in regards to the geometry of the satellites acquired and used for the solution.

Woolpert's goal is to maintain an average PDOP value below 3.0. Brief periods of PDOP over 3.0 are acceptable due to the calibration and control process if other metrics are within specification.



Figure 3.4: PDOP, Day25915_PAR_A

Lidar Data Processing

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

- Processed individual flight lines to derive a raw "Point Cloud" LAS file. Matched overlapping flight lines, generated statistics for evaluation comparisons, and made the necessary adjustments to remove any residual systematic error.
- Calibrated LAS files were imported into the task order tiles and initially filtered to create a ground and non-ground class. Then additional classes were filtered as necessary to meet client specified classes.
- Once all project data was imported and classified, survey ground control data was imported and calculated for an accuracy assessment. As a QC measure, Woolpert has developed a routine to generate accuracy statistical reports by comparisons against the TIN and the DEM using surveyed ground control of higher accuracy. The lidar is adjusted accordingly to meet or exceed the vertical accuracy requirements.
- The lidar tiles were reviewed using a series of proprietary QA/QC procedures to ensure it fulfills the task order requirements. A portion of this requires a manual step to ensure anomalies have been removed from the ground class.
- The lidar LAS files are classified into the Default (Class 1), Ground (Class 2), Low Noise(Class 7), Bridge Decks (Class 17), and High Noise (Class 18) classifications.
- FGDC Compliant metadata was developed for the task order in .xml format for the final data products.
- The horizontal datum used for the task order was referenced to UTM12N, WGS84. The vertical datum used for the task order was referenced to EGM 2008, meters. Coordinate positions were specified in units of meters.
- Relative accuracy also known as "between swath" accuracy was tested through a series of well distributed flight line overlap locations. The relative accuracy for the Portsmouth DOE Lidar tested at 0.040 meters RMSDz.

Section 4: ACCURACY ASSESSMENT

Accuracy Assessment

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

Table 4.1: Overall Vertical Accuracy Statistics,				
Average error	0.024	Meter		
Minimum error	-0.074	Meter		
Maximum error	+0.105	Meter		
Average magnitude	0.046	Meter		
Root mean square	0.053	Meter		
Standard deviation	0.048	Meter		

Table 4.2: Raw Swath Quality Check Point Analysis NVA					
Point ID	Easting (UTM Meter)	Northing (UTM Meter)	TIN Elevation (Meter)	Dz (Meter)	
2001	577135.542	3509910.189	1180.93	-0.035	
2002	580195.478	3510784.987	1230.11	0.081	
2003	582506.358	3512553.344	1273.55	0.071	
2004	585530.421	3512880.091	1307.23	0.105	
2005	586759.241	3511584.357	1328.66	0.048	
2006	584933.939	3510907.588	1313.75	0.032	
2007	585527.754	3507110.881	1377.3	0.058	
2008	588840.03	3508862.143	1392.93	0.061	
2009	591097.203	3506681.606	1432.69	-0.036	
2010	591854.165	3503955.193	1450.17	-0.061	
2011	595036.832	3504720.016	1444.64	-0.074	
2012	595176.191	3509236.424	1419.13	0.017	
2013	597907.656	3509489.035	1439.93	0.046	
2014	591349.763	3510364.949	1384.33	0.038	
2015	593008.831	3512584.269	1414.59	0.057	
2016	594923.759	3513883.36	1444.06	0.024	
2017	596471.492	3511920.937	1473.69	0.015	
2018	600795.52	3512553.005	1551.55	0.011	
2019	602637.011	3512973.166	1596.66	-0.004	
2020	603921.559	3515010.82	1618.63	0.007	
2021	589044.055	3513330.87	1355.18	0.07	
2022	593220.268	3508131.308	1415.87	-0.04	
2023	582353.737	3510059.467	1285.08	0.072	

2024	599456.015	3510645.262	1486.33	-0.025
2025	587691.543	3505743.605	1496.19	0.069

VERTICAL ACCURACY CONCLUSIONS

Raw LAS Swath Non-Vegetated Vertical Accuracy (NVA) Tested 0.103 meters at a 95 percent confidence level, derived according to NSSDA, in open terrain using (RMSEz) x 1.96000 as defined by the National Standards for Spatial Data Accuracy (NSSDA); assessed and reported using National Digital Elevation Program (NDEP)/ASPRS Guidelines and tested against the TIN using all points.

LAS Swath Non-Vegetated Vertical Accuracy (NVA) Tested 0.088 meters at a 95 percent confidence level, derived according to NSSDA, in open terrain using (RMSEz) x 1.96000 as defined by the National Standards for Spatial Data Accuracy (NSSDA); assessed and reported using National Digital Elevation Program (NDEP)/ASPRS Guidelines and tested against the TIN using ground points.

NVA/VVA ASSESMENT

Table 4.3: Non-Vegetated Vertical Accuracy Quality Check Point Analysis NVA					
Point ID	Easting	Northing	DEM Elevation	Dz	
Point ID	(UTM Meter)	(UTM Meter)	(Meter)	(Meter)	
2001	577135.542	3509910.189	1180.93	0.035	
2002	580195.478	3510784.987	1230.03	-0.001	
2003	582506.358	3512553.344	1273.53	-0.051	
2004	585530.421	3512880.091	1307.13	-0.005	
2005	586759.241	3511584.357	1328.65	-0.038	
2006	584933.939	3510907.588	1313.71	0.008	
2007	585527.754	3507110.881	1377.26	-0.018	
2008	588840.03	3508862.143	1392.93	-0.061	
2009	591097.203	3506681.606	1432.65	0.076	
2010	591854.165	3503955.193	1450.14	0.091	
2011	595036.832	3504720.016	1444.62	0.094	
2012	595176.191	3509236.424	1419.1	0.013	
2013	597907.656	3509489.035	1439.92	-0.036	
2014	591349.763	3510364.949	1384.27	0.022	
2015	593008.831	3512584.269	1414.57	-0.037	
2016	594923.759	3513883.36	1444.05	-0.014	
2017	596471.492	3511920.937	1473.62	0.055	
2018	600795.52	3512553.005	1551.58	-0.041	
2019	602637.011	3512973.166	1596.66	0.004	
2020	603921.559	3515010.82	1618.65	-0.027	
2021	589044.055	3513330.87	1355.13	-0.02	
2022	593220.268	3508131.308	1415.89	0.02	
2023	582353.737	3510059.467	1285.02	-0.012	
2024	599456.015	3510645.262	1486.29	0.065	
2025	587691.543	3505743.605	1496.17	-0.049	

VERTICAL ACCURACY CONCLUSIONS

Bare-Earth DEM Non-Vegetated Vertical Accuracy (NVA) Tested 0.086 meters at a 95 percent confidence level, derived according to NSSDA, in open terrain using (RMSEz) x 1.96000 as defined by the National Standards for Spatial Data Accuracy (NSSDA); assessed and reported using National Digital Elevation Program (NDEP)/ASPRS Guidelines and tested against the DEM.

Table 4.4: Vegetated Vertical Accuracy Quality Check Point Analysis VVA				
Point ID	Easting	Northing	DEM Elevation	Dz
Politit	(UTM Meter)	(UTM Meter)	(Meter)	(Meter)
3001	603788.634	3514947.548	1608.6	-0.248
3002	576998.991	3509847.723	1177.83	-0.057
3003	595066.014	3504752.957	1443.4	0.017
3004	596774.59	3511934.126	1471.51	-0.018
3005	589149.955	3509018.327	1380.44	-0.093
3006	582466.319	3512567.186	1273.8	-0.07
3007	585378.488	3507305.38	1368.42	-0.006
3008	589060.323	3513307.316	1354.67	-0.105

VERTICAL ACCURACY CONCLUSIONS

Vegetated Vertical Accuracy (VVA) Tested 0.197 meters at the 95th percentile reported using National Digital Elevation Program (NDEP)/ASPRS Guidelines and tested against the DEM. VVA Errors larger than 95th percentile include: Point 3001, Easting 603788.634, Northing 3514947.548, Z-Error 0.248 meters

Relative Accuracy

Relative accuracy also known as "between swath" accuracy was tested through a series of well distributed flight line overlap locations. The relative accuracy for the Portsmouth DOE Lidar tested at 0.040 meters RMSDz.



Figure 4.1: FY15 ARS-USDA AZ Walnut Gulch QL1 Lidar

Approved by:	Name	Signature	Date
Associate Member, Lidar Specialist Certified Photogrammetrist #1381	Qian Xiao	Q:	February 2016

Section 5: Flight Logs

Flight logs for the project are shown on the following pages:

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Х		Pressure	101388 Pa	101321 Pa																																						
V W	cal Conditions		296.15°k 29.94 inHg	300.15°k 29.92 inHg	tion Information	Ant Hat Ant Tune		2.05m Trimble R10		nditions/Comments	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	DO NOT USE			
D	Meteorologi	Temp	23.0°C	27.0°C	GPS Base Sta	RNX File	CHI I VAINI			3																																
F		Elevation	4,743	2950AGL		File Name		19822590.T02				- 20																						2-2	8							
S			Airport	@ Altitude	(c) Altitude			Base 1 Rase 2	Base 3	Operator	Parker	Parker	Parker	Parker	Parker	Parker	Parker	Parker	Parker	Parker	Parker	Parker	Parker	Parker	Parker	Parker	Parker	Parker	Parker	Parker	Parker	Parker	Parker	Parker	Parker	Parker	Parker	Parker	Parker			
ж		AGC	Auto							pDOP																																
o	nformation	19822590.T02			formation		15:13:21		18:57:40	Void "Y"			2				0										10 10		8				.0	8	<i>2</i>			0		50 50	() ()	
a	GPS I	Base 1	Base 2	Base3	Aero 1 IMU Ir		Start Time		Stop Time	Nautical Miles Flown																																
0																																										
Z				Z	077.1-					Speed	-												-																			-
M			Lever Arm	Z /	NZZ.1- NLZ.N					Altitude ellipsoid (ft) Speed	4318	4242	4272	4259	4245	4216	41/3	4222	4160	4232	3917	4249	4091	4193	4219	4049	4186	4039	4242	3871	4321	4009	4236	3904	4137	3911	4098	3881	3999			
L M N	10	R	Lever Arm							Altitude Altitude Speed ellipsoid (m) ellipsoid (tt)	1316 4318	1293 4242	1302 4272	1298 4259	1294 4245	1285 4216	12/2 41/3	128/ 4222	12/4 4160	1290 4232	1194 3917	1295 4249	1247 4091	12/0 4133	1286 4219	1234 4049	1276 4186	1231 4039	1293 4242	1180 3871	1317 4321	1222 4009	1291 4236	1190 3904	1261 4137	1192 3911	1249 4098	1183 3881	1219 3999			
K L M	Daily Log	nul rog	Lever Arm	Z Å X	01271- 012.0 011.0- (m) \$49					Muti Pulse Attitude Attitude Speed (Y,M) ellipsoid (m) ellipsoid (tt)	N 1316 4318	N 1293 4242	N 1302 4272	N 1298 4259	N 1294 4245	N 1285 4216	N 12/2 41/3	N 128/ 4222	N 12/4 4160 N 1279 4196	N 1290 4232	N 1194 3917	N 1295 4249	N 1247 4091	N 12/8 4193 N 1221 4006	N 1286 4219	N 1234 4049	N 1276 4186	N 1231 4039	N 1293 4242	N 1180 3871	N 1317 4321	N 1222 4009	N 1291 4236	N 1190 3904	N 1261 4137	N 1192 3911	N 1249 4098	N 1183 3881	N 1219 3999			
J K L M	I IDAR Daily Log		Lever Arm	X Y Z	0721- 0.210 0.210 - 0.200			E NAME		tz Roll Comp Muti Pulse Altitude Altitude Speed	YES N 1316 4318	YES N 1293 4242	YES N 1302 4272	YES N 1298 4259	YES N 1294 4245	YES N 1285 4216	YES N 12/2 41/3	YES N 128/ 4222	VES N 12/4 4180 VES N 1770 4196	YES N 1290 4232	YES N 1194 3917	YES N 1295 4249	YES N 1247 4091	YES N 12/16 4133 YES N 1221 4006	YES N 1286 4219	YES N 1234 4049	YES N 1276 4186	YES N 1231 4039	YES N 1293 4242	YES N 1180 3871	YES N 1317 4321	YES N 1222 4009	YES N 1291 4236	YES N 1190 3904	YES N 1261 4137	YES N 1192 3911	YES N 1249 4098	YES N 1183 3881	YES N 1219 3999			
I J K L M N	I IDAR Daily Log	LIDAN DUIL TOU	TBA Lever Arm	scription X y Z	thut Gulch GPS (m) -0.110 0.270 -1.220	lion	ma A7	AVIGATION FILE NAME	150916_150932	Pulse Rate Hz Roll Comp Muti Pulse (Y,N) ellipsoid (m) ellipsoid (ft)	198500 YES N 1316 4318	198500 YES N 1293 4242	198500 YES N 1302 4272	198500 YES N 1298 4259	198500 YES N 1294 4245	198500 YES N 1285 4216	19850U YES N 12/2 41/3	198500 YES N 128/ 4222	1362UU TES N 12/4 410U 1985AD VES N 12/4 410C	198500 YES N 1290 4232	198500 YES N 1194 3917	198500 YES N 1295 4249	198500 YES N 1247 4091	1362UU TES N 12/16 4133 198500 YES N 1221 4006	198500 YES N 1286 4219	198500 YES N 1234 4049	198500 YES N 1276 4186	198500 YES N 1231 4039	198500 YES N 1293 4242	198500 YES N 1180 3871	198500 YES N 1317 4321	198500 YES N 1222 4009	198500 YES N 1291 4236	198500 YES N 1190 3904	198500 YES N 1261 4137	198500 YES N 1192 3911	198500 YES N 1249 4098	198500 YES N 1183 3881	197600 YES N 1219 3999			
H I J K L W N	I IDAP Daily I on	בובעוז במוול בטק	TBA Lever Arm	Project Description x y z	Woolpert Walnut Gulch Gulch C.110 U.210 220	Location	Tombetona A7	SENSOR NAVIGATION FILE NAME	20150916_150932	Scan Rate Pulse Rate Hz Roll Comp Mutif Pulse Attitude Attitude Speed	50.0 196500 YES N 1316 4318	50.0 198500 YES N 1293 4242	50.0 198500 YES N 1302 4272	50.0 198500 YES N 1298 4259	50.0 198500 YES N 1294 4245	50.0 198500 YES N 1285 4216	50.0 198500 YES N 12/2 41/3	50.0 198500 YES N 128/ 4222	50.0 196500 YES N 12/4 4180 4166	50.0 198500 YES N 1290 4232	50.0 198500 YES N 1194 3917	50.0 198500 YES N 1295 4249	50.0 198500 YES N 1247 4091	50 0 198500 YES N 12/0 4193	50.0 198500 YES N 1286 4219	50.0 198500 YES N 1234 4049	50.0 198500 YES N 1276 4186	50.0 198500 YES N 1231 4039	50.0 198500 YES N 1293 4242	50.0 198500 YES N 1180 3871	50.0 198500 YES N 1317 4321	50.0 198500 YES N 1222 4009	50.0 198500 YES N 1291 4236	50.0 196500 YES N 1190 3904	50.0 198500 YES N 1261 4137	50.0 198500 YES N 1192 3911	50.0 198500 YES N 1249 4098	50.0 198500 YES N 1183 3881	50.0 197600 YES N 1219 3999			
G H L M N	I IDAR Daily Lon		Project # TBA Lever Arm	Project Description x y Z	Woolpert Wahut Gulch Gerch Gerch -1.220 July 1.220	Location	Temberona A7	Alterati SENSOR NAVIGATION FILE NAME	N799AC 20150916_150932	FOV Scan Rate Pulse Rate Hz Roll Comp Muti Pulse Altitude Altitude Speed (M) ellipsoid (M) ellipsoid (M)	30.5 50.0 198500 YES N 1316 4318	30.6 50.0 198500 YES N 1293 4242	30.5 50.0 196500 YES N 1302 4272	30.5 50.0 198500 YES N 1298 4259	30.5 50.0 198500 YES N 1294 4245	30.6 50.0 198500 YES N 1285 4216	30.5 50.0 196500 YES N 12/2 41/3	30.5 50.0 198500 YES N 1287 4222	30.5 50.0 1905000 TES N 12/4 4180 30.5 50.0 1905000 YES N 12/4 4160	30.6 50.0 198500 YES N 1290 4232	30.6 50.0 198500 YES N 1194 3917	30.6 50.0 198500 YES N 1295 4249	30.6 50.0 199500 YES N 1247 4091	30.6 50.0 199500 TES N 12/6 4193	30.5 50.0 198500 YES N 1286 4219	30.5 50.0 198500 YES N 1234 4049	30.6 50.0 198500 YES N 1276 4186	30.5 50.0 196500 YES N 1231 4039	30.6 50.0 198500 YES N 1293 4242	30.6 50.0 198500 YES N 1180 3871	30.5 50.0 198500 YES N 1317 4321	30.6 50.0 196500 YES N 1222 4009	30.6 50.0 198500 YES N 1291 4236	30.6 50.0 198500 YES N 1190 3804	30.5 50.0 198500 YES N 1261 4137	30.6 50.0 198500 YES N 1192 3911	30.6 50.0 198500 YES N 1249 4098	30.6 50.0 196500 YES N 1183 3881	30.6 50.0 197600 YES N 1219 3999			
F G H	I IDAP Daily I on	Field Crew	Project # TBA Lever Arm	Project Description X Y Z	KLU S Woolpert Wahnt Guich -0.710 -0.210 -1.220 DRIVE 012 DRIVE 012	Location	Tombetona A7	MISSION 1 Alterraft SENSOR MAVIGATION FILE NAME	ALS70 N799AC 20150916_150932	Total Time FOV Scan Rate Pulse Rate Hz Roll Comp Multi Pulse Attitude Attitude Speed	0:00:40 30.5 50.0 198500 YES N 1316 4318	0:00:41 30.6 50.0 198500 YES N 1293 4242	0:00:46 30.5 50.0 198500 YES N 1302 4272	0.00:46 30.5 50.0 198500 YES N 1298 4259	0.00:58 30.5 50.0 198500 YES N 1294 4245	0.01:04 30.6 50.0 198500 YES N 1285 4216	UUTUU 30.5 50.0 T96500 YES N 12/2 41/3	0.01:03 30.5 50.0 198500 YES N 128/ 4222	U.U.U.9 3U.5 5U.0 1365U0 YES N 12/4 4180 1496	0.01.21 30.6 50.0 198500 YES N 1290 4232	0:01:31 30.6 50.0 198500 YES N 1194 3917	0.01:37 30.6 50.0 198500 YES N 1295 4249	001:37 30.6 50.0 198500 YES N 1247 4091	U.U.1.44 3U.0 3U.0 1365UU TES N 12/0 4133	0.02.06 30.5 50.0 198500 YES N 1286 4219	0.02.01 30.5 50.0 198500 YES N 1234 4049	0.02:12 30.6 50.0 198500 YES N 1276 4186	0.02:07 30.5 50.0 198500 YES N 1231 4039	0.02:12 30.6 50.0 198500 YES N 1293 4242	0.02:12 30.6 50.0 198500 YES N 1180 3871	0.02:47 30.5 50.0 198500 YES N 1317 4321	0.02:58 30.6 50.0 198500 YES N 1222 4009	0.03:04 30.6 50.0 198500 YES N 1291 4236	0.13:14 30.6 50.0 138500 YES N 1199 3904	0:03:10 30.5 50.0 198500 YES N 1261 4137	0.02:58 30.6 50.0 198500 YES N 1192 3911	0.03:04 30.6 50.0 198500 YES N 1249 4098	0:02:46 30.6 50.0 196500 YES N 1183 3881	0.25:18 30.6 50.0 197600 YES N 1219 3999			

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P.0. Box 72	357					Locati								A Subscreen		2000	File Name	RNX File	Ant Hgt A	unt Type		
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1	ght Date (UTC)	Pilot	Operator	Sensor	Aircraft	SENSOR MAY	IGATION FIL	E NAME		Ī			i i	0.000	1	Base 2						a
	3/16/2015	Farrar	Parker	ALS70	N799AC	201	0916_194021						Stop II	• U2020		Base 3				-		_
Reflight Li	e Ei	Start	Stop	Total Time	FOV	Scan Rate	Pelse Rate Hz	Roll Comp	Muti Pulse (Y,N)	Altitude ellipsoid [m]	Altitude ellipsoid [ft]	Speed	Nautical Miles Flown	-Y- bioV	AOOA	Operator		Cor	nditions/Con	iments		
	66 LDR150916 201627	20:16:43	20:19:59	0:03:16	30.6	2010	198500	YES	z	1294	4245					Parker	100		0009			
	65 LDR150916 202741	20:27:58	20:28:50	0:00:52	30.6	50.0	198500	YES	z	1299	4262					Parker			600D			
	64 LDR150916 203204	20:32:21	20:33:07	0:00:46	30.6	200	198500	YES	z	1285	4216					Parker	0.00		6000			
	62 LUH150916 203/10 62 LITE150916 204124	203626	20:38:18	14:00:0	908	200	198500	ά Υ Έ	zz	1210	4232					Parker	1.00		6000			
	61 LDR150916 204550	20:46:07	20:47:10	0:01:03	30.5	200	198500	YES	z	1227	4026					Parker			000			
	60 LDR150916 205027	20:50:44	20:51:47	0:01:03	30.6	50.0	198500	YES	N	1324	4344					Parker			600D		0.5.0	
	59 LDR150916_205542	20:55:59	20:57:08	0:01:09	30.6	50.0	198500	YES	z	1268	4160					Parker			000			
	58 LDR150916 210027	21:00:43	21:01:58	0:01:15	30.5	50.0	198500	YES	z	1301	4268					Parker			000			
	57 LDR150916 210525	21:05:41	21:07:19	0:01:38	30.5	200	198500	YES	z	1235	4052					Parker			6000			
	56 LUHIOUSI6 21103	200000	21:12:46	0.0149	908 908	201	138200	2 y	zz	1283	4242 AD0A					Darker			000		5.5	_
	54 I DRIENGIE 212133	21.0220	10/0/17	0.01555	305	200	198500	3 ŭ	2 2	1300	4265					Parkar			000		1.5	
	53 LDRIE0916 212703	21/2/12	21:23:01	0.02-01	305	200	198500	AES -	2	1010	3970					Parker			anon UUU9			
	52 LDR150916 213248	21:33:05	21:35:00	0.0155	30.5	20.0	198500	S S	2 2	1295	4249					Parker			000			
	51 LDR150916 213836	21:38:52	21:40:53	0:02:01	30.5	20:0	198500	YES	z	1241	4072					Parker			6000			
	50 LDR150916 214411	21:44:27	21:46:28	0:02:01	30.5	50.0	198500	YES	z	1279	4196					Parker			000		0448	
	49 LDR150916 214936	21:49:53	21:51:59	0:02:06	30.5	50.0	198500	YES	z	1219	3999					Parker			000			
	48 LDR150916 215517	21:55:34	21:57:40	0:02:06	30.5	200	198500	YES	z	1332	4370			.215		Parker			6000			
	47 LDR150916 220128	22:01:44	22:04:01	0:02:17	30.5	200	198500	KES	2:	1232	4042					Parker			6000			
	46 LURIDUBIE 220/30	02/022	01:01:22	47:20:0	900 900	20.0	136300		2 2	447	4068 A040					Darker			000			
	44 I FIEIGIGIE 222031	22:30:47	02:02:22	0.02.67	305	200	198500	AES -	2 2	422	4239					Parker			enon			
	43 LDR150916 222650	22:27:06	22:30:15	0.03.09	30.6	200	198500	S SS	2 2	1210	3970					Parker			000			
	42 LDR150916 223304	22:33:20	22:36:36	0:03:16	30.5	50.0	198500	YES	z	1263	4144					Parker			6000		0.5.5	
	41 LDR150916 224015	22:40:31	22:43:58	0.03.27	30.6	50.0	198500	YES	z	1234	4049					Parker			000D			
	40 LDR150916 224700	22:47:16	22:50:37	0:03:21	30.6	50.1	198500	YES	z	1285	4216					Parker			6000		05.00	
	39 LDR150916 225339	22:53:55	22:57:22	0:03:27	30.5	2000	198500	ES I	2:	1242	4075					Parker			6000			
	38 LUHIDUBI6 23004.	90:00:07	23:04:17	12:000	30.5	0.00	100200	210	2 2	000	4314	-		4.		Parker	-0.		000			
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	35 LDP150916 232050	9 23:21:15	23:24:41	0.03.26	30.5	200	198500	KES	22	1253	4111					Parker			000			
	34 LDRI50916 23273	4 23:27:50	23:31:M	0:03:21	30.5	50.0	198500	YES	z	1218	3996					Parker	-		GOOD		0.0.0	
	33 LDP150916 23344	23:34:57	23:38:24	0.03:27	30.6	200	198500	ΥES	2:	1222	4009					Parker			6000			
	24 LUPRIDUAID 234200	23:40:40	20:44:00	0:05:04	908 908	50.0 F0.0	136200		2 2	1050	5307			-		Darkar			000		2.0	
	67 LDP150916 23562:	23.56.39	0:03:04	0.06.25	30.6	200	198500	YES	z	1038	3406					Parker	100		0009			
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			Hobbs Start	2527.6																		
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-20	Average Nautical Line L	niles Per Mission Ho	=	10//IO#	Ave	rage Nautical Line I	Ailes Per Re-	Flight How	r #DIV/0!											-	- 10	-

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2	1				Field Crew					III LUG			Bas	e 1 19822610.7	02 AGI		Eleva	tion Te	emp		Pressure	
3	~					Project #		TBA	Π		Lever	Vm	Bas	e 2	Aut	Airp	ort 4,7	43 23.0'c	296.151	< 29.94 inHg	101388 Pa	
4			LIL				Project Des	cription		*	y	z	Bas	e3		@ All	itude 2950.	4GL 27.0°c	300.151	< 29.92 inHg	101321Pa	
10					RCD B		Voolnert Vale	ut Gulek	8	P.C. (m) Sc	10 0.21	0 -1220	Aer	01		@ All	itude					
9	ž	כרואות אבאואר אברטאוו	NOOMICE		DRIVE 011								_	MU Information		8	1	GPS Base (Station Info	rmation		
7 P.O.	Box 72357				1990		Locatic	E.									File N	lame RNX File	e Ant Hg	t Ant Type		
8 Bossi	er City, LA	72357			MISSION 3		Tombston	e. AZ	_				Start	Fime 14:25:10		Ba	te 1 198226	10.7.02	2.05m	Trimble R10		
5	Flight D	Date (UTC)	Pilot	Operator	Sensor	Aircraft	SENSOR NAV	IGATION FILE	AME		10				r	Bas	e 2					
g	346	18/2015	Farrar	Parker	0/STV	N799AC	20150	1918_142229					Stop	Time 15:34:01	_	Bas	e 3					
Reflig	M Line	ä	Start	Stop	Total Time	FOV	Scan Rate	Pulse Rate Hz	Roll	Muti Altitu ³ ulse ellips (Y,N) (m)	ude Altitu oid ellips) (ft	ide oid Speed	Naut Nije Flo	ical ss Void "Y	004	P Oper	ator	0	Conditions	Comments		
12	18	LDR150918_144300_	14:43:19	14:45:02	0:01:43	30.5	50.0	198500	YES	N	1222 400	6				Pa	ker		8	8		<u> </u>
2	5	LDR150918_144833_	14:48:51	14:50:34	0:01:43	30.5	20.0	198500	YES	N	1294 424	5	10.53		-	Pa	ker		99	8		
14	UL0011	LDR150918_145411_	14:54:30	14:55:04	0:00:34	30.5	20.0	198500	YES	N	1247 405					Pa	ker		09	00		
Sol 1	64 1	LDR150918_150458_	15:05:17	15:06:08	0:00:51	30.6	50.0	198500	YES	Z	1300 426	2				Pa	ker		8	8		
9	8	LDR150918_150947_	15:10:05	15:10:51	0:00:46	30.5	20:0	198500	YES	z	1299 426	2				Pa	ker		8	8		
2	UL002 I	LDR150918_151642_	15:17:01	15:20:05	0:03:04	30.5	20:0	198500	ΥES	N	1344 440	5			_	Ъ	ker		8	8		
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Section 6: Final Deliverables

The final lidar deliverables are listed below.

- LAS v1.4 classified point cloud
- LAS v1.4 raw unclassified point cloud flight line
- Bare Earth Surface Raster DEM
- First Return DSM IMG Format
- 8-bit gray scale intensity Tiff images
- Tile layout USNG and data extent provided as ESRI shapefile
- FGDC compliant metadata per product in XML format
- Lidar processing report in pdf format
- Survey report in .pdf format