AIRBORNE LIDAR TASK ORDER REPORT

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AZ AND NM COAL MINES LIDAR

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WOOLPERT
DESIGN | GEOSPATIAL | INFRASTRUCTURE

AIRBORNE LIDAR TASK ORDER REPORT

AZ AND NM COAL MINES LIDAR

WOOLPERT PROJECT #072770

For:

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SECTION 1: OVERVIEW

PROJECT NAME: AZ AND NM COAL MINES LIDAR

WOOLPERT PROJECT #072770

This report contains a comprehensive outline of the airborne LiDAR data acquisition consisting of 191 square miles amongst three different coal mine sites in Arizona and New Mexico for the United States Geological Survey (USGS). The LiDAR was collected and processed to meet a maximum Nominal Pulse Spacing (NPS) of no greater than 1 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 sensor collects up to four returns (echos) per pulse, recording attributes such as time stamp and intensity data, for the first three returns. If a fourth return was captured, the system does not record an associated intensity value. The aerial LiDAR was collected at the following sensor specifications:

Post Spacing (Minimum):	3.28 ft / 1 m
AGL (Above Ground Level) average flying height:	7,800 ft / 2,377m
MSL (Mean Sea Level) average flying height:	Varies by altitude
Average Ground Speed:	150 knots / 173 mph
Field of View (full):	40 degrees
Pulse Rate:	230 kHz
Scan Rate:	35.5 Hz
Side Lap (Minimum):	25%

LiDAR data was processed and projected in UTM, Zone 12N, North American Datum of 1983 (NAD83) in units of meters. The vertical datum used for the task order was referenced to NAVD 1988, meters, GEOID12.

Figure 1.1: Task Order and LiDAR Flight Layout – Black Mesa, AZ

Black Mesa Mine, Arizona

—— Project Boundary (Full Tile Coverage)
—— 1 Meter Lidar Flights (1-25) @ 7,800' AGL

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Issue Date: September 19, 2012
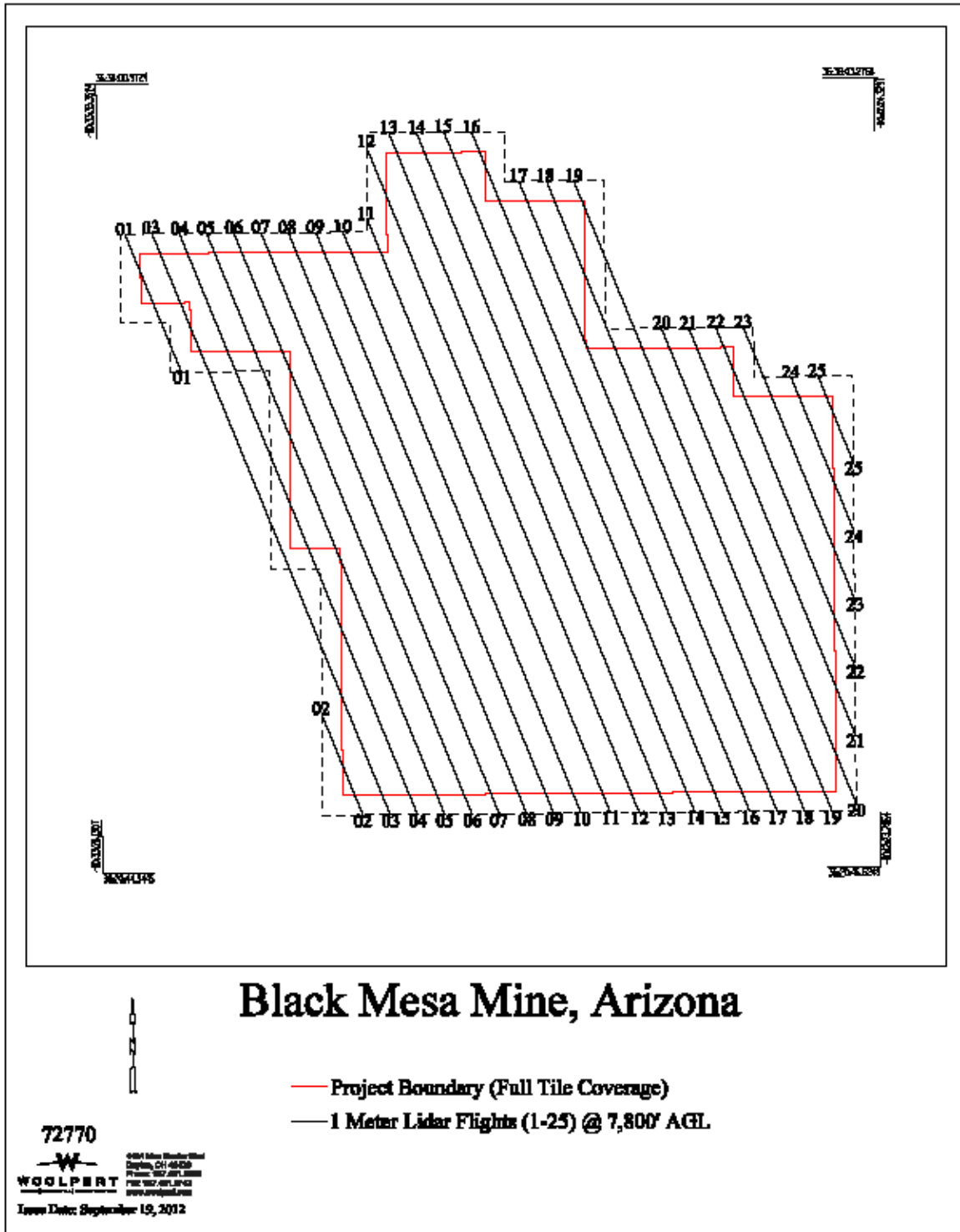
Figure 1.2: Task Order and LiDAR Flight Layout – McKinley, NM

McKin Permit, New Mexico

— Project Boundary (Full Tile Coverage)
— 1 Meter Lidar Flights (1-15) @ 7,800' AGL

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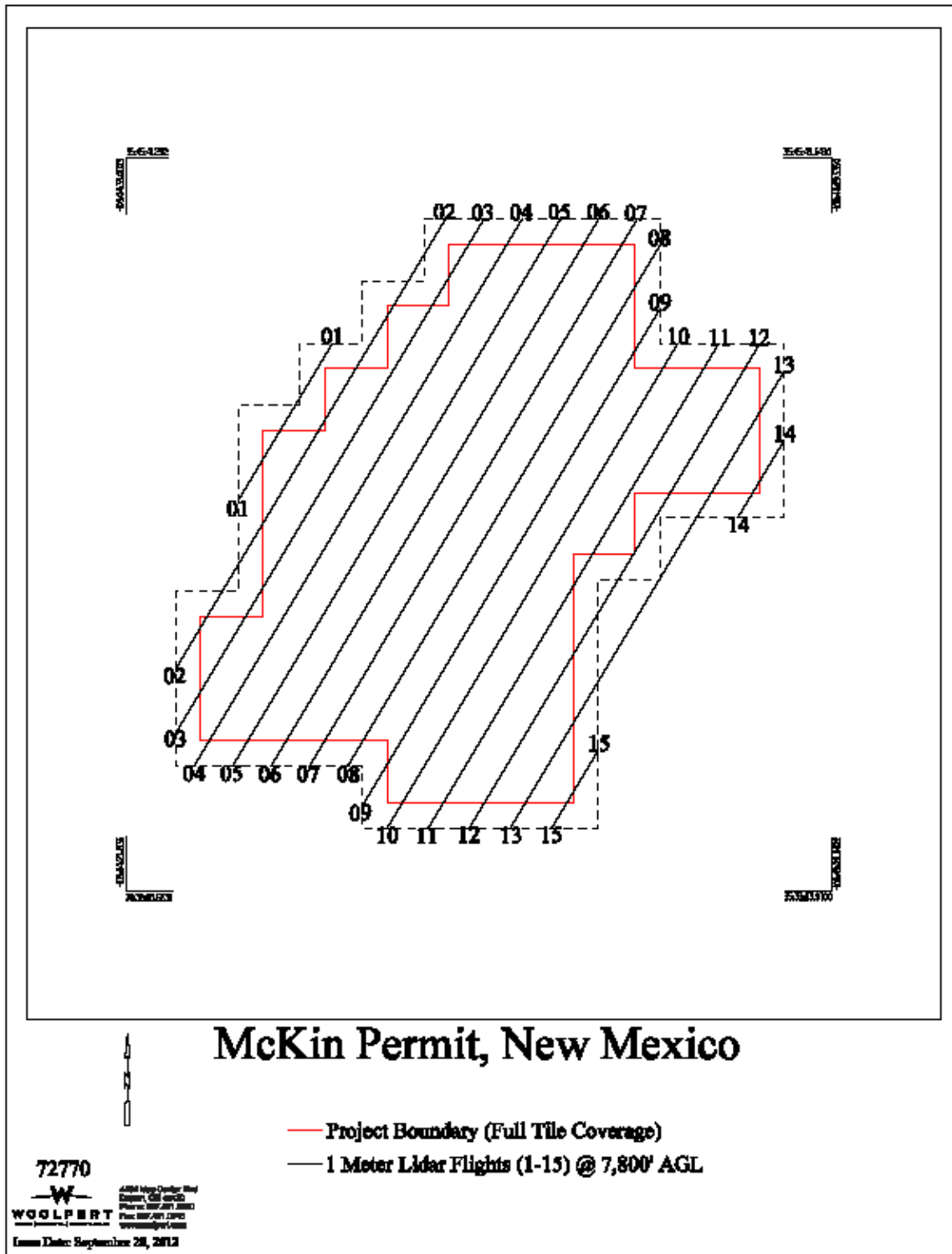
Figure 1.3: Task Order and LiDAR Flight Layout – Navajo-Pinabete, NM

Navajo / Pinabete Mines, New Mexico
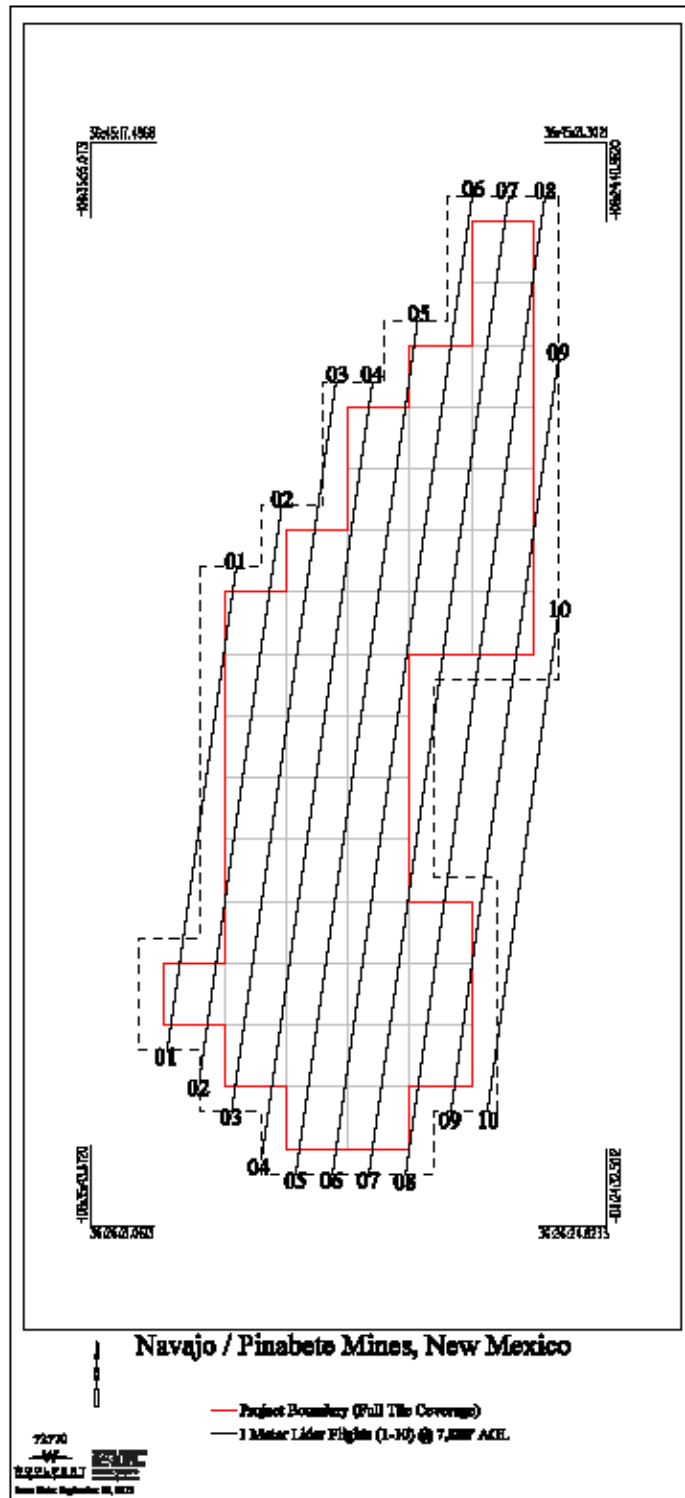
SECTION 2: ACQUISITION

The LiDAR data was acquired with a Leica ALS70 Multiple Pulses in Air (MPiA) LiDAR sensor system, on board a Cessna 404. This LiDAR system, developed by Leica Geosystems of Heerbrugg, Switzerland, includes the simultaneous first, intermediate and last pulse data capture module, the extended altitude range module, and the target signal intensity capture module. The system software is operated on an OC50 Operation Controller aboard the aircraft.

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

Table 2.1: ALS70 LiDAR System Specifications	
Specification	
Operating Altitude	200 – 3,500 meters
Scan Angle	0 to 75° (variable)
Swath Width	0 to 1.5 X altitude (variable)
Scan Frequency	0 – 200 Hz (variable based on scan angle)
Maximum Pulse Rate	500 kHz (Effective)
Range Resolution	Better than 1 cm
Elevation Accuracy	7 - 16 cm single shot (one standard deviation)
Horizontal Accuracy	5 - 38 cm (one standard deviation)
Number of Returns per Pulse	7 (infinite)
Number of Intensities	3 (first, second, third)
Intensity Digitization	8 bit intensity + 8 bit AGC (Automatic Gain Control) level
MPiA (Multiple Pulses in Air)	8 bits @ 1nsec interval @ 50kHz
Laser Beam Divergence	0.22 mrad @ $1/e^2$ (~0.15 mrad @ 1/e)
Laser Classification	Class IV laser product (FDA CFR 21)
Eye Safe Range	400m single shot depending on laser repetition rate
Roll Stabilization	Automatic adaptive, range = 75 degrees minus current FOV
Power Requirements	28 VDC @ 25A
Operating Temperature	0-40°C
Humidity	0-95% non-condensing
Supported GNSS Receivers	Ashtech Z12, Trimble 7400, Novatel Millenium

Prior to mobilizing to the task order site, Woolpert 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 at the Kayenta Airport (0V7) for the airborne GPS support on day 301. Coordinates 36° 42' 38.89"(N), 110° 14' 23.46"(W), Ellipsoid Height 1715.520 meters.

Woolpert survey crews were onsite, operating a Global Navigation Satellite System (GNSS) Base Station at the Window Rock Airport (KRQE) for the airborne GPS support on day 300. Coordinates 35° 39' 33.44" (N), 109° 03' 34.11" (W), Ellipsoid Height 2034.207 meters.

Woolpert survey crews were onsite, operating a Global Navigation Satellite System (GNSS) Base Station at the Four Corners International Airport (KFMN) for the airborne GPS support on day 300. Coordinates 36° 44' 24.12" (N), 108° 13' 10.27" (W), Ellipsoid Height 1655.687 meters.

The LiDAR data was collected in (3) missions.

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

Table 2.2: Airborne LiDAR Acquisition Flight Summary			
Airborne LiDAR Acquisition Flight Summary			
Date of Mission/Sensor	Lines Flown	Mission Time (UTC) Wheels Up/ Wheels Down	Mission Time (Local = EST) Wheels Up/ Wheels Down
Oct 27, 2012 – S/N 7108	Black Mesa, AZ 1-25	18:19 – 21:24	12:19 PM – 03:43 PM
Oct 26, 2012 – S/N 7108	Navajo-Pinabete, NM 1-10	21:41 – 23:21	03:41 PM – 05:21 PM
Oct 26, 2012 – S/N 7108	McKinley, NM 1-15	18:21 – 20:17	12:21 PM – 02:17 PM

SECTION 3: LIDAR DATA PROCESSING

APPLICATIONS AND WORK FLOW OVERVIEW

1. Resolved kinematic corrections for three subsystems: inertial measurement unit (IMU), sensor orientation information and airborne GPS data. Developed a blending post-processed aircraft position with attitude data using Kalman filtering technology or the smoothed best estimate trajectory (SBET).
   Software: POSPac Software v. 5.3, IPAS Pro v.1.35.

2. Calculated laser point position by associating the SBET position to each laser point return time, scan angle, intensity, etc. Created raw laser point cloud data for the entire survey in .LAS format. Automated line-to-line calibrations were then performed for system attitude parameters (pitch, roll, heading), mirror flex (scale) and GPS/IMU drift.
   Software: ALS Post Processing Software v.2.70, Proprietary Software, TerraMatch v. 12.01.

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.12.005.

4. The .LAS files were evaluated through a series of manual QA/QC steps to eliminate remaining artifacts and small undulations from the ground class.
   Software: TerraScan v.12.005.

5. All water bodies greater than two acres and all rivers with a nominal 30.5 meters (100 foot) width or larger were hydrologically flattened using proprietary methods.
   Software: ESRI 10.0, Microstation v8, TerraScan v.12.005, LP360, Woolpert Proprietary Tools.

6. Two (2) foot contours were generated from the LAS1.2 data. These contours were automatically generated and did not undergo a cartographic QAQC process.
   Software: ESRI 10.0, Microstation v8, TerraScan v.12.005

GLOBAL NAVIGATION SATELLITE SYSTEM (GNSS)-INERTIAL MEASUREMENT UNIT (IMU) TRAJECTORY PROCESSING

EQUIPMENT

Flight navigation during the LiDAR data acquisition mission is performed using IGI CCNS (Computer Controlled Navigation System). The pilots are 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 Woolpert survey 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 survey crews were onsite, operating a Global Navigation Satellite System (GNSS) Base Stations for airborne GPS support at Kayenta Airport (0V7) for the Black Mesa site, Window Rock Airport for the McKin site and Four Corners Regional Airport for the Navajo site. The GNSS base stations operated during the LiDAR acquisition missions is listed below:

Table 3.1: GNSS Base Stations			
Station	Latitude	Longitude	Ellipsoid Height (L1 Phase Center)
Name	(DMS)	(DMS)	(Meters)
OV7 (Black Mesa, AZ)	N 36° 42' 38.89"	W 110° 14' 23.46"	1715.520
KRQE (McKinley, NM)	N 35° 39' 33.44"	W 109° 03' 34.11"	2034.207
KFMN (Navajo-Pinabete, NM)	N 36° 44' 24.12"	W 108° 13' 10.27"	1655.687

DATA PROCESSING

All airborne GNSS and IMU data was post-processed and quality controlled using Applanix 5.3 MMS software. GNSS data was processed at a 1 and 2 Hz data capture rate and the IMU data was processed at 200 Hz.

TRAJECTORY QUALITY

The GNSS Trajectory, along with high quality IMU data are key factors in determining the overall positional accuracy of the final sensor data. See **Figure 3.1** for the flight trajectory.

Flight Trajectory

Figure 3.1: Representative Graph from Day0301 - Black Mesa, AZ
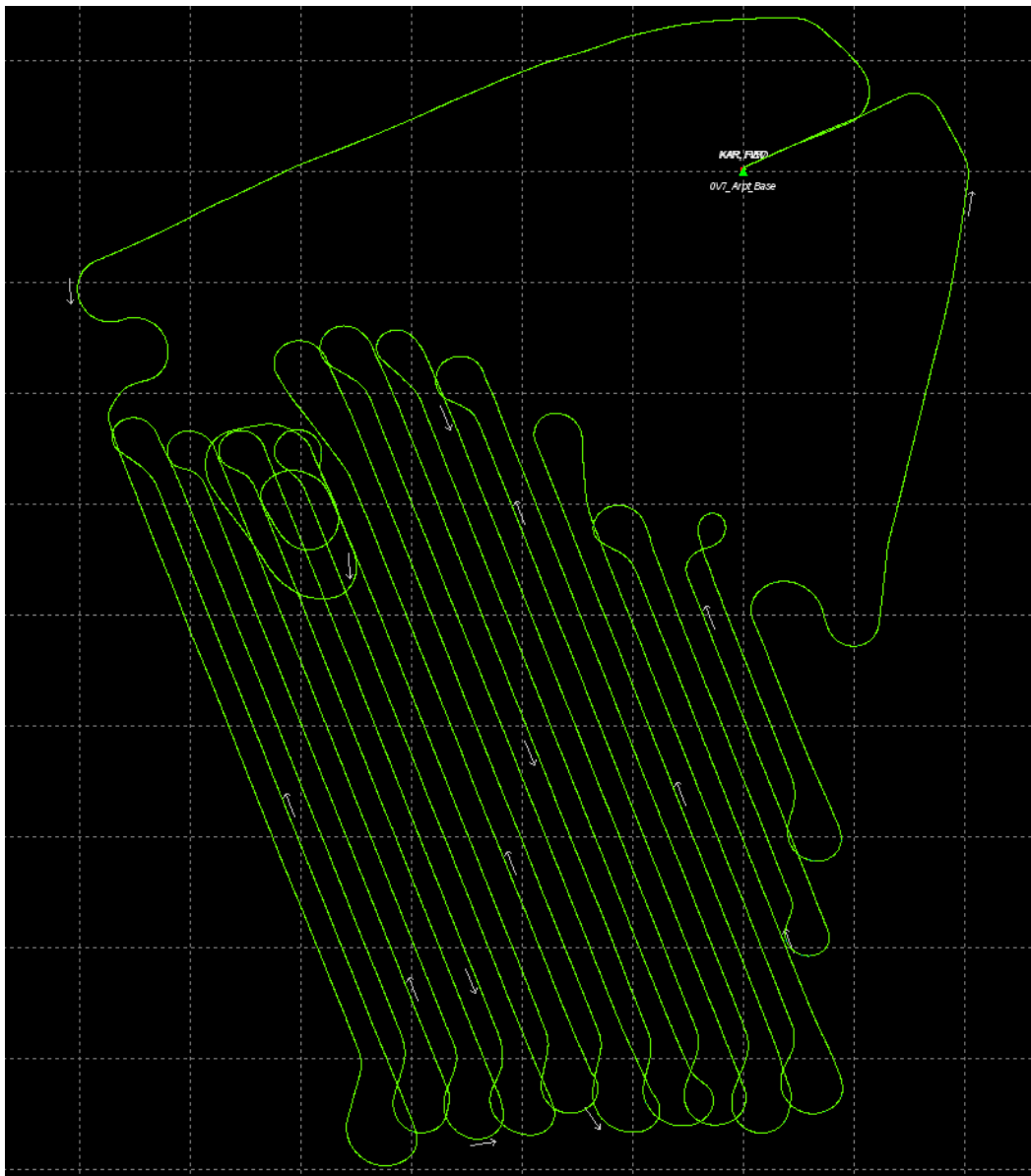
Within the trajectory processing, there are many factors that affect the overall quality, but the most indicative are the Combined Separation, the Estimated Positional Accuracy, and the Positional Dilution of Precision (PDOP).

Combined Separation

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

Woolpert's goal is to maintain a Combined Separation Difference of less than ten (10) centimeters. In most cases we achieve results below this threshold. See **Figure 3.2** for the combined separation graph.

Figure 3.2: Representative Graph from Day0301 of Combined Separation - Black Mesa, AZ
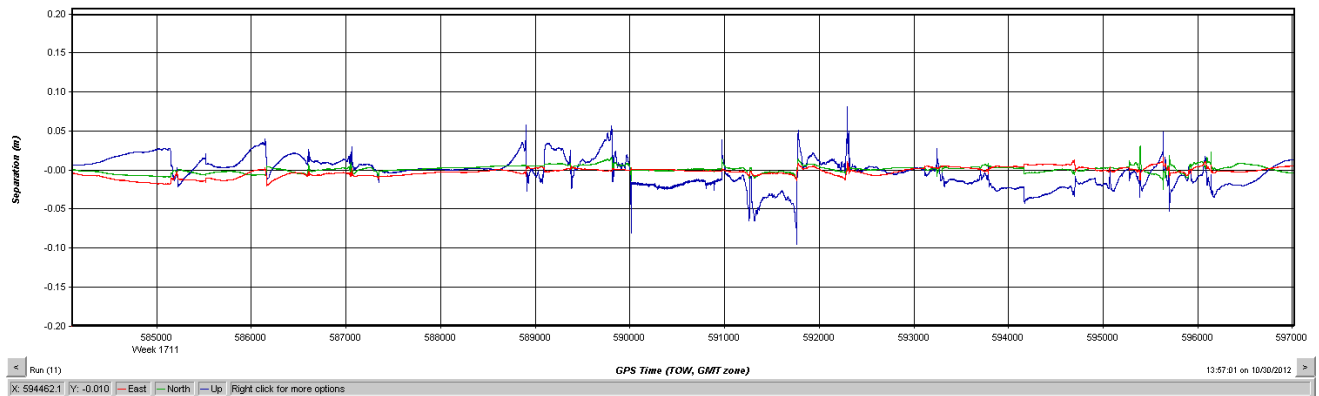
Estimated Positional Accuracy

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

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

Figure 3.3: Representative Graph from Day0301 of Positional Accuracy - Black Mesa, AZ
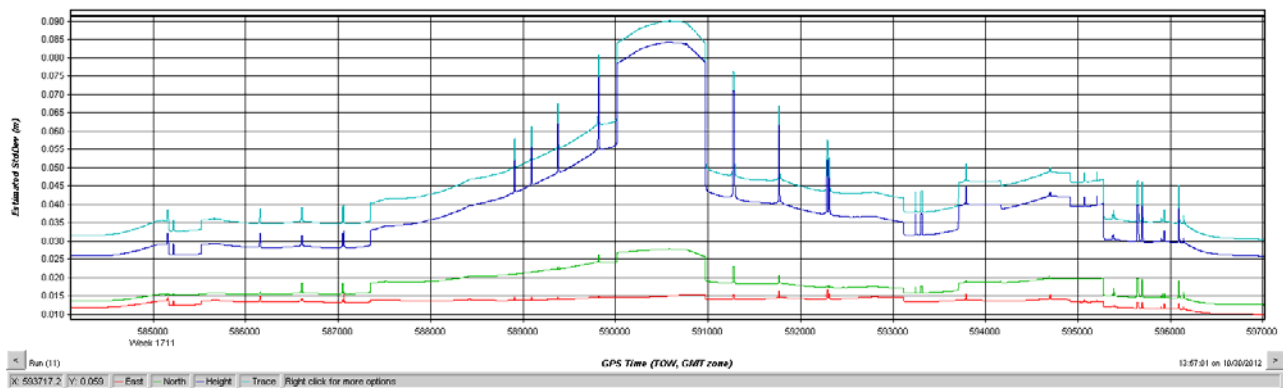
PDOP

Position Dilution of precision (DOP) is a measure of the quality of the GPS data being received from the satellites. Woolpert's goal is to maintain an average PDOP of 3 or less.

Figure 3.4: Representative Graph from Day0301 of PDOP - Black Mesa, AZ
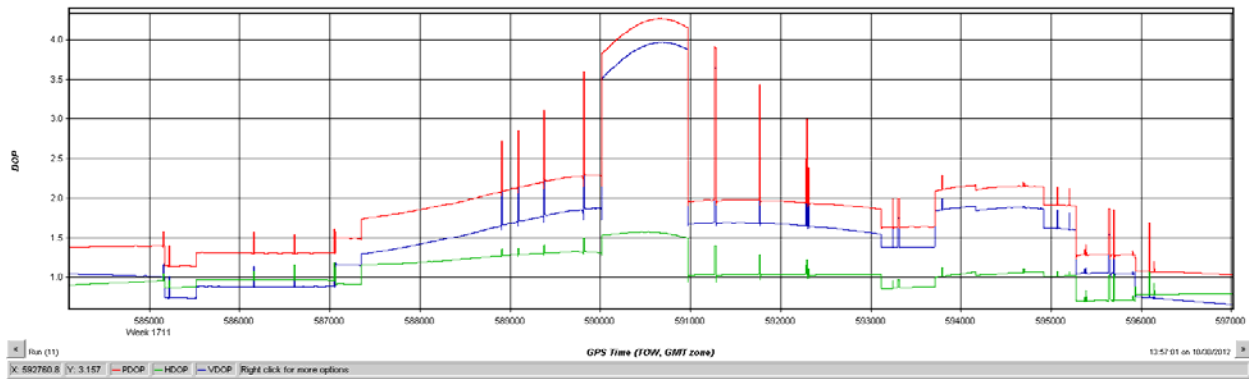
LIDAR DATA PROCESSING

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 of the task order data was imported and classified, cross flights and survey ground control data was imported and calculated for an accuracy assessment. As a QA/QC measure, Woolpert has developed a routine to generate accuracy statistical reports by comparison among LiDAR points, ground control, and TINs. The LiDAR is adjusted accordingly to reduce any vertical bias 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 bare earth DEM surface was hydrologically flattened for water body features that were greater than 2 acres and rivers and streams of 100 feet and greater nominal width.

- The LiDAR LAS files for this task order have been classified into the Default (Class 1), Ground (Class 2), Noise (Class 7), Model Keypoints (Class 8), Water (Class 9), Ignored Ground (Class 10), Overlap Default (Class 17), and Overlap Ground (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 UTM, 12N, North American Datum of 1983. Coordinate positions were specified in units of meters for the AZ/NM mines. The vertical datum used for the task order was referenced to NAVD 1988, meters, GEOID 12a.

SECTION 4: HYDROLOGIC FLATTENING AND FINAL QUALITY CONTROL

HYDROLOGIC FLATTENING OF LIDAR DEM DATA

This task required the compilation of breaklines defining water bodies and rivers. The breaklines were used to perform the hydrologic flattening of water bodies, and gradient hydrologic flattening of double line streams and rivers. Lakes, reservoirs and ponds, at a minimum size of 2-acres or greater, were compiled as closed polygons. The closed water bodies were collected at a constant elevation. Rivers and streams, at a nominal minimum width of 30.5 meters (100 feet), were compiled in the direction of flow with both sides of the stream maintaining an equal gradient elevation.

LIDAR DATA REVIEW AND PROCESSING

Woolpert utilized the following steps to hydrologically flatten the water bodies and for gradient hydrologic flattening of the double line streams within the existing LiDAR data.

1. Woolpert used the newly acquired LiDAR data to manually draw the hydrologic features in a 2D environment using the LiDAR intensity and bare earth surface. Open Source imagery was used as reference when necessary.

2. Woolpert utilizes an integrated software approach to combine the LiDAR data and 2D breaklines. This process "drapes" the 2D breaklines onto the 3D LiDAR surface model to assign an elevation. A monotonic process is performed to ensure the streams are consistently flowing in a gradient manner. A secondary step within the program verifies an equally matching elevation of both stream edges. The breaklines that characterize the closed water bodies are draped onto the 3D LiDAR surface and assigned a constant elevation at or just below ground elevation.

3. The lakes, reservoirs and ponds, at a minimum size of 2-acres or greater, were compiled as closed polygons. **Figure 4.1** illustrates a good example of 2-acre lakes and 30.5 meters (100 feet) nominal streams identified and defined with hydrologic breaklines. The breaklines defining rivers and streams, at a nominal minimum width of 30.5 meters (100 feet), were draped with both sides of the stream maintaining an equal gradient elevation.

Figure 4.1
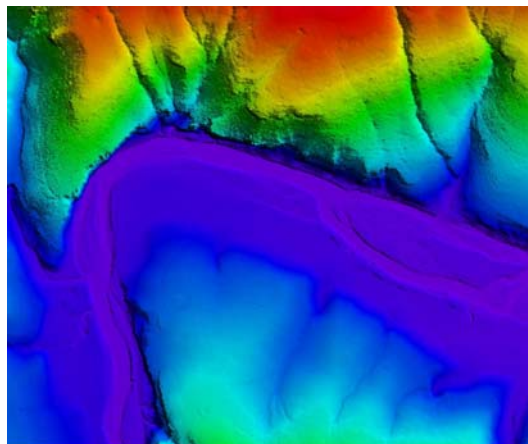
4. All ground points were reclassified from inside the hydrologic feature polygons to water, class nine (9).

5. All ground points were reclassified from within a 1.5 meter (5 foot) buffer along the hydrologic feature breaklines to buffered ground, class ten (10).

6. The LiDAR ground points and hydrologic feature breaklines were used to generate a new digital elevation model (DEM).

Figure 4.2	Figure 4.3

Figure 4.2 reflects a DEM generated from original LiDAR bare earth point data prior to the hydrologic flattening process. Note the "tinning" across the lake surface.

Figure 4.3 reflects a DEM generated from LiDAR with breaklines compiled to define the hydrologic features. This figure illustrates the results of adding the breaklines to hydrologically flatten the DEM data. Note the smooth appearance of the lake surface in the DEM.

Terrascan was used to add the hydrologic breakline vertices and export the lattice models. The hydrologically flattened DEM data was provided to USGS in ERDAS .IMG format at a 1-meter cell size. The hydrologic breaklines compiled as part of the flattening process were provided to the USGS as an ESRI shapefile. The breaklines defining the water bodies greater than 2-acres were provided as a PolygonZ file. The breaklines compiled for the gradient flattening of all rivers and streams at a nominal minimum width of 30.5 meters (100 feet) were provided as a PolylineZ file.

DATA QA/QC

Initial QA/QC for this task order was performed in Global Mapper v11, by reviewing the grids and hydrologic breakline features.

Edits and corrections were addressed individually by tile. If a water body breakline needed to be adjusted to improve the flattening of the ERDAS .IMG file, the area was cross referenced by tile number, corrected accordingly, a new ERDAS .IMG was regenerated and then reviewed in Global Mapper.

SECTION 5: FINAL ACCURACY ASSESSMENT

FINAL VERTICAL ACCURACY ASSESSMENT

BLACK MESA, AZ

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

Table 5.1: Overall Vertical Accuracy Statistics, Black Mesa, AZ Mine		
Average error	-0.041	meters
Minimum error	-0.100	meters
Maximum error	+0.020	meters
Average magnitude	0.053	meters
Root mean square	0.061	meters
Standard deviation	0.048	meters

Table 5.2: Swath LiDAR QA/QC Analysis, UTM12N, NAD83, Black Mesa, AZ Mine				
Point ID	Easting (UTM meters)	Northing (UTM meters)	Elevation (meters)	Dz (meters)
3001	549460.750	4046951.880	2135.910	-0.100
3003	548674.040	4046422.400	2182.950	-0.020
3007	548057.810	4044580.850	2211.710	-0.080
3014	545599.620	4044832.350	2229.770	-0.060
3022	555136.350	4028027.320	1978.430	0.020
3023	561469.130	4028712.790	2143.760	0.020
3025	562042.000	4029877.440	2150.810	-0.070

Vertical Accuracy Conclusions

LAS data covering the Black Mesa, AZ 1m NPS Lidar Task Order was compared to survey control points to determine the FVA of the LAS Swath and of the Bare-Earth DEM. LAS Swath Fundamental Vertical Accuracy (FVA) Tested 0.119m (11.9cm) fundamental vertical accuracy at a 95 percent confidence level, derived according to NSSDA, in open terrain using 0.061m (6.1cm) (RMSE(z) x 1.96000 tested against the TIN. Bare-Earth DEM Fundamental Vertical Accuracy (FVA) Tested 0.123m (12.3cm) fundamental vertical accuracy at a 95 percent confidence level, derived according to NSSDA, in open terrain using 0.063m (6.3cm) (RMSE(z) x 1.96000 tested against the DEM.

SUPPLEMENTAL VERTICAL ACCURACY ASSESSMENT (SVA)

Table 5.3: Bare Earth Open Terrain QA/QC Analysis, UTM12N, NAD83, Black Mesa, AZ Mine				
Point ID	Easting (UTM meters)	Northing (UTM meters)	Elevation (meters)	Absolute Dz (meters)
3001	549460.75	4046952	2135.91	0.05
3003	548674.04	4046422	2182.95	0.03
3007	548057.81	4044581	2211.71	0.1
3014	545599.62	4044832	2229.77	0.06
3022	555136.35	4028027	1978.43	0
3023	561469.13	4028713	2143.76	0.05
3025	562042	4029877	2150.81	0.09

Bare Earth/Open Terrain Land Cover Classification Supplemental Vertical Accuracy (SVA) Tested 0.097 meters supplemental vertical accuracy at the 95th percentile in Bare Earth/Open Terrain. Tested against the DEM. Errors larger than 95th percentile include:

- Point 3007, Easting 548057.81, Northing 4044580.85, Z-Error 0.1

Table 5.4: Brush Lands and Trees QA/QC Analysis, UTM12N, NAD83, Black Mesa, AZ Mine				
Point ID	Easting (UTM meters)	Northing (UTM meters)	Elevation (meters)	Absolute Dz (meters)
3006	547894.420	4045736.320	2214.52	0.03
3010	550846.330	4041816.370	2013.51	0.12
3011	553159.980	4038066.030	2016.88	0
3012	553253.050	4035642.690	1993.89	0.07
3016	553369.660	4030763.240	1946.90	0.10
3028	568545.370	4032890.670	2119.75	0.11
3029	566855.750	4031788.380	2096.43	0.030
2000	541948.680	4044955.800	2009.55	0.04
2001	543507.720	4045794.020	2023.17	0.01
2015	552331.830	4028947.000	1934.36	0.15

Table 5.4: Brush Lands and Trees QA/QC Analysis, UTM12N, NAD83, Black Mesa, AZ Mine				
Point ID	Easting (UTM meters)	Northing (UTM meters)	Elevation (meters)	Absolute Dz (meters)
2020	569500.720	4032354.480	2145.34	0.02

Brush Lands and Trees Land Cover Classification Supplemental Vertical Accuracy (SVA) Tested 0.135 meters supplemental vertical accuracy at the 95th percentile in Brush Lands and Trees. Tested against the DEM. Brush Lands and Trees Errors larger than 95th percentile include:

- Point 2015, Easting 552331.83, Northing 4032354.48, Z-Error 0.15

Table 5.5: Forest Canopy QA/QC Analysis, UTM12N, NAD83, Black Mesa, AZ Mine				
Point ID	Easting (UTM meters)	Northing (UTM meters)	Elevation (meters)	Absolute Dz (meters)
3000	550282.61	4047106	2087.39	0.07
3009	549201.28	4042692	2071.62	0.01
3002	549480.88	4046945	2136.59	0.06
3019	556270.18	4030421	2009.86	0.06
3004	548708.37	4046421	2181.73	0.02
3005	547875	4045764	2216.14	0.01
3021	555114.84	4028036	1979.96	0.09
3024	561449.68	4028710	2143.21	0.01
3027	569573.71	4032715	2156.87	0.01
2002	544610.52	4046260	2041	0.08
2004	544638.63	4044489	2158.67	0.07
2005	546998.86	4045290	2233.36	0.04
2013	550873.99	4047277	2054.26	0.1
2017	562054.86	4029896	2150.87	0

Forested and Fully Grown Land Cover Classification Supplemental Vertical Accuracy (SVA) Tested 0.093 meters supplemental vertical accuracy at the 95th percentile in Forested and Fully Grown. Tested against the DEM. Forested and Fully Grown Errors larger than 95th percentile include:

- Point 2013, Easting 550873.99, Northing 4047277.43, Z-Error 0.1

Point ID	Easting (UTM meters)	Northing (UTM meters)	Elevation (meters)	Absolute Dz (meters)
2006	548234.47	4043472	2149.83	0.08
2009	550904.44	4047232	2051	0.01
2010	552973.19	4039040	1981.71	0.07
2011	548085.76	4044561	2211.23	0.05
2012	553263.56	4035627	1994.46	0.06
2014	544965.75	4046568	2027.87	0.08
2019	552962.09	4029860	1936.72	0.03
2021	555525.55	4030651	1976.56	0.04
3008	555439.39	4029780	1987.91	0.02
3013	553171.89	4033913	1900.6	0.03
3015	567813.52	4034935	2168.42	0
3017	552856.81	4038137	1997.01	0.1
3018	553363.24	4036575	1989.75	0.04
3020	554357.6	4032004	1949.43	0.01
3026	569092.76	4032829	2142.81	0.04
3032	569506.68	4033082	2135.46	0.06

Table 5.6: Tall Weeds and Crops QA/QC Analysis, UTM12N, NAD83, Black Mesa, AZ Mine

Tall Weeds and Crops Land Cover Classification Supplemental Vertical Accuracy (SVA) Tested 0.085 meters supplemental vertical accuracy at the 95th percentile in Tall Weeds and Crops. Tested against the DEM. Tall Weeds and Crops Errors larger than 95th percentile include:

- Point 3017, Easting 552856.81, Northing 4038137.35, Z-Error 0.1

CONSOLIDATED VERTICAL ACCURACY ASSESMENT (CVA)

Point ID	Easting (UTM meters)	Northing (UTM meters)	Elevation (meters)	Absolute Dz (meters)
Table 5.7: Consolidated Vertical Accuracy Assessment Statistics, UTM12N, NAD83, Black Mesa, AZ Mine				
3001	549460.8	4046952	2135.91	0.05
3003	548674	4046422	2182.95	0.03
3007	548057.8	4044581	2211.71	0.1
3014	545599.6	4044832	2229.77	0.06
3022	555136.4	4028027	1978.43	0
3023	561469.1	4028713	2143.76	0.05
3025	562042	4029877	2150.81	0.09
4002	684185.5	3945177	2147.26	0.06
4004	686708.5	3944492	2080.56	0.01
4009	691633.8	3947320	2084.8	0
4014	686025.5	3938802	2020.15	0.04
4017	684492.4	3954590	2227.07	0.07
4018	685211.2	3955054	2228.45	0
5000	720807	4051411	1662.59	0.02
5003	720412.2	4052175	1635.38	0.05
5005	719319.2	4052720	1607.29	0.01
5009	721442.1	4055065	1616.45	0.03
5010	722341	4055371	1616.73	0.03
5013	723757.2	4057820	1592.47	0.04
5014	725039.9	4057685	1603.69	0.02
5015	725062.8	4058683	1611.05	0.01
5016	722472.6	4038543	1647.18	0.06

Table 5.7: Consolidated Vertical Accuracy Assessment Statistics, UTM12N, NAD83, Black Mesa, AZ Mine				
Point ID	Easting (UTM meters)	Northing (UTM meters)	Elevation (meters)	Absolute Dz (meters)
5017	721288	4042219	1645.3	0.05
5021	724889.4	4046636	1655.23	0.09
5022	726355.7	4048852	1707.12	0.11
3006	547894.4	4045736	2214.52	0.03
3010	550846.3	4041816	2013.51	0.12
3011	553160	4038066	2016.88	0
3012	553253.1	4035643	1993.89	0.07
3016	553369.7	4030763	1946.9	0.1
3028	568545.4	4032891	2119.75	0.11
3029	566855.8	4031788	2096.43	0.03
2000	541948.7	4044956	2009.55	0.04
2001	543507.7	4045794	2023.17	0.01
2015	552331.8	4028947	1934.36	0.15
2020	569500.7	4032354	2145.34	0.02
4005	688450.3	3944859	2044.42	0.16
4010	691370.1	3945536	2041.25	0.14
4021	679595.9	3945821	2087.48	0.03
4022	680551.1	3945713	2100.72	0.21
4024	682199	3945631	2152.26	0.18
4028	681032.5	3949146	2117.7	0.04
4029	682654.8	3951715	2146.53	0.06
2039	681539.9	3952363	2142.93	0.04
2042	692021	3945616	2061.29	0.06
2044	688552.1	3939436	1999.35	0.09

Point ID	Easting (UTM meters)	Northing (UTM meters)	Elevation (meters)	Absolute Dz (meters)
5001	720757.7	4051903	1650.4	0.09
5023	725027.5	4051200	1708.13	0.25
5019	723488.2	4042362	1634.45	0.14
5025	726758.7	4049646	1721.36	0.05
5011	723026.7	4056264	1604.47	0.04
5031	727374	4067784	1651.66	0.07
2026	728730.3	4062440	1656.99	0.11
2027	726153.8	4063174	1635.29	0.13
3000	550282.6	4047106	2087.39	0.07
3009	549201.3	4042692	2071.62	0.01
3002	549480.9	4046945	2136.59	0.06
3019	556270.2	4030421	2009.86	0.06
3004	548708.4	4046421	2181.73	0.02
3005	547875	4045764	2216.14	0.01
3021	555114.8	4028036	1979.96	0.09
3024	561449.7	4028710	2143.21	0.01
3027	569573.7	4032715	2156.87	0.01
2002	544610.5	4046260	2041	0.08
2004	544638.6	4044489	2158.67	0.07
2005	546998.9	4045290	2233.36	0.04
2013	550874	4047277	2054.26	0.1
2017	562054.9	4029896	2150.87	0
4007	690320.4	3945246	2057.72	0.06
4008	691445.4	3946679	2077.28	0.02

Table 5.7: Consolidated Vertical Accuracy Assessment Statistics, UTM12N, NAD83, Black Mesa, AZ Mine

Table 5.7: Consolidated Vertical Accuracy Assessment Statistics, UTM12N, NAD83, Black Mesa, AZ Mine				
Point ID	Easting (UTM meters)	Northing (UTM meters)	Elevation (meters)	Absolute Dz (meters)
4013	684300.6	3939424	2047.32	0.01
4015	683437.5	3953571	2190.37	0.03
4016	684502.8	3954586	2228.96	0.06
4003	685405	3944197	2109.44	0.04
4023	681615.2	3945606	2130.75	0.07
4031	681953.9	3951929	2147.02	0.08
2043	688499.6	3941208	2016.46	0.03
2034	688499.6	3941208	2016.46	0.03
5028	727610.6	4064443	1625.09	0.09
5032	727110.2	4065489	1625.22	0.15
2006	548234.5	4043472	2149.83	0.08
2009	550904.4	4047232	2051	0.01
2010	552973.2	4039040	1981.71	0.07
2011	548085.8	4044561	2211.23	0.05
2012	553263.6	4035627	1994.46	0.06
2014	544965.8	4046568	2027.87	0.08
2019	552962.1	4029860	1936.72	0.03
2021	555525.6	4030651	1976.56	0.04
3008	555439.4	4029780	1987.91	0.02
3013	553171.9	4033913	1900.6	0.03
3015	567813.5	4034935	2168.42	0
3017	552856.8	4038137	1997.01	0.1
3018	553363.2	4036575	1989.75	0.04
3020	554357.6	4032004	1949.43	0.01

Point ID	Easting (UTM meters)	Northing (UTM meters)	Elevation (meters)	Absolute Dz (meters)
3026	569092.8	4032829	2142.81	0.04
3032	569506.7	4033082	2135.46	0.06
4000	684091.3	3945271	2147.07	0.03
4011	688498.8	3943818	2042.51	0.04
4012	688499.3	3941839	2012.46	0
4006	689384.6	3945061	2044.95	0.07
4019	679021.3	3946122	2081.42	0.02
4025	681094.5	3950573	2116.95	0.01
4027	678952.3	3947776	2083.21	0.02
4032	681737.9	3951136	2128.58	0.03
2037	678378.8	3946594	2076.83	0.03
2040	683881.1	3952720	2162.89	0
2047	683289.5	3945554	2115.86	0.01
4001	684177.3	3945179	2146.94	0.01
5002	720403.7	4052187	1635.52	0.03
5004	719709.1	4052215	1624.55	0.08
5006	719755.1	4053218	1606.73	0.09
5007	720144.8	4053670	1615.79	0.02
5008	720775.9	4054380	1622.54	0.09
5012	723342.2	4057013	1615.15	0.03
5018	721228.2	4043015	1645.36	0.03
5020	724528.8	4043859	1619.58	0.03
5024	728314.1	4053237	1701.34	0.02
2024	728735.5	4066757	1633.21	0.06

Table 5.7: Consolidated Vertical Accuracy Assessment Statistics, UTM12N, NAD83, Black Mesa, AZ Mine

Table 5.7: Consolidated Vertical Accuracy Assessment Statistics, UTM12N, NAD83, Black Mesa, AZ Mine				
Point ID	Easting (UTM meters)	Northing (UTM meters)	Elevation (meters)	Absolute Dz (meters)
2029	724313.9	4057523	1606.3	0.04
2031	718934.9	4052282	1607.59	0.02
2033	728231.1	4049913	1721.68	0.08
2034	723419.7	4039725	1650.55	0.06

Consolidated Vertical Accuracy (CVA) Tested 0.115 meters consolidated vertical accuracy at the 95th percentile level, derived according to ASPRS Guidelines for Vertical Accuracy Reporting for LiDAR Data. This data set was tested against the DEM using independent check points. Based on the 95th percentile error in all land cover categories combined. Combined Land Cover Errors larger than 95% include:

- Point 3010, Easting 550846.33, Northing 4041816.37, Z-Error 0.12
- Point 2015, Easting 552331.83, Northing 4028947, Z-Error 0.15

MCKINLEY, NM

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

Table 5.8: Overall Vertical Accuracy Statistics, McKinley, NM Mine		
Average error	-0.022	meters
Minimum error	-0.060	meters
Maximum error	+0.030	meters
Average magnitude	0.032	meters
Root mean square	0.037	meters
Standard deviation	0.033	meters

Table 5.9: Swath LiDAR AQ/QC Analysis, UTM12N, NAD83, McKinley, NM Mine				
Point ID	Easting (UTM meters)	Northing (UTM meters)	Elevation (meters)	Dz (meters)
4002	684185.470	3945176.930	2147.220	-0.040
4004	686708.500	3944492.410	2080.560	-0.020
4009	691633.760	3947319.590	2084.800	0.030
4014	686025.510	3938802.190	2020.150	-0.040
4017	684492.380	3954590.190	2227.070	-0.060
4018	685211.170	3955053.530	2228.450	0.000

Vertical Accuracy Conclusions

LAS data covering the McKinley Permit 1m NPS Lidar Task Order was compared to survey control points to determine the FVA of the LAS Swath and of the Bare-Earth DEM. LAS Swath Fundamental Vertical Accuracy (FVA) Tested 0.072m (7.2cm) fundamental vertical accuracy at a 95 percent confidence level, derived according to NSSDA, in open terrain using 0.037m (3.7cm) (RMSE(z) x 1.96000 tested against the TIN. Bare-Earth DEM Fundamental Vertical Accuracy (FVA) Tested 0.08m (8.0cm) fundamental vertical accuracy at a 95 percent confidence level, derived according to NSSDA, in open terrain using 0.041m (4.1cm) (RMSE(z) x 1.96000 tested against the DEM.

SUPPLEMENTAL VERTICAL ACCURACY ASSESSMENT (SVA)

Table 5.10: Bare Earth Open Terrain QA/QC Analysis, UTM12N, NAD83, McKinley, NM Mine				
Point ID	Easting (UTM meters)	Northing (UTM meters)	Elevation (meters)	Absolute Dz (meters)
4002	684185.47	3945177	2147.26	0.06
4004	686708.5	3944492	2080.56	0.01
4009	691633.76	3947320	2084.8	0
4014	686025.51	3938802	2020.15	0.04
4017	684492.38	3954590	2227.07	0.07
4018	685211.17	3955054	2228.45	0

Bare Earth/Open Terrain Land Cover Classification Supplemental Vertical Accuracy (SVA) Tested 0.067 meters supplemental vertical accuracy at the 95th percentile in Bare Earth/Open Terrain. Tested against the DEM. Errors larger than 95th percentile include:

- Point 4017, Easting 684492.38, Northing 3954590.19, Z-Error 0.07

Table 5.11: Brush Lands and Trees QA/QC Analysis, UTM12N, NAD83, McKinley, NM Mine				
Point ID	Easting (UTM meters)	Northing (UTM meters)	Elevation (meters)	Absolute Dz (meters)
4005	688450.3	3944859	2044.42	0.16
4010	691370.07	3945536	2041.25	0.14
4021	679595.86	3945821	2087.48	0.03
4022	680551.09	3945713	2100.72	0.21
4024	682198.96	3945631	2152.26	0.18
4028	681032.52	3949146	2117.7	0.04
4029	682654.75	3951715	2146.53	0.06
2039	681539.87	3952363	2142.93	0.04
2042	692021.01	3945616	2061.29	0.06
2044	688552.13	3939436	1999.35	0.09

Brush Lands and Trees Land Cover Classification Supplemental Vertical Accuracy (SVA) Tested 0.196 meters supplemental vertical accuracy at the 95th percentile in Brush Lands and Trees. Tested against the DEM. Brush Lands and Trees Errors larger than 95th percentile include:

- Point 4022, Easting 680551.09, Northing 3945713.26, Z-Error 0.21

Table 5.12: Forest Canopy QA/QC Analysis, UTM12N, NAD83, McKinley, NM Mine				
Point ID	Easting (UTM meters)	Northing (UTM meters)	Elevation (meters)	Absolute Dz (meters)
4007	690320.37	3945246	2057.72	0.06
4008	691445.42	3946679	2077.28	0.02
4013	684300.62	3939424	2047.32	0.01
4015	683437.51	3953571	2190.37	0.03
4016	684502.75	3954586	2228.96	0.06
4003	685404.96	3944197	2109.44	0.04
4023	681615.16	3945606	2130.75	0.07
4031	681953.87	3951929	2147.02	0.08
2043	688499.59	3941208	2016.46	0.03
2034	688499.59	3941208	2016.46	0.03

Forested and Fully Grown Land Cover Classification Supplemental Vertical Accuracy (SVA) Tested 0.075 meters supplemental vertical accuracy at the 95th percentile in Forested and Fully Grown. Tested against the DEM. Forested and Fully Grown Errors larger than 95th percentile include:

- Point 4031, Easting 681953.87, Northing 3951929.09, Z-Error 0.08

Table 5.13: Tall Weeds and Crops QA/QC Analysis, UTM12N, NAD83, McKinley, NM Mine				
Point ID	Easting (UTM meters)	Northing (UTM meters)	Elevation (meters)	Absolute Dz (meters)
4000	684091.29	3945271	2147.07	0.03
4011	688498.76	3943818	2042.51	0.04
4012	688499.33	3941839	2012.46	0
4006	689384.61	3945061	2044.95	0.07
4019	679021.33	3946122	2081.42	0.02
4025	681094.53	3950573	2116.95	0.01
4027	678952.25	3947776	2083.21	0.02
4032	681737.91	3951136	2128.58	0.03
2037	678378.82	3946594	2076.83	0.03
2040	683881.09	3952720	2162.89	0
2047	683289.52	3945554	2115.86	0.01

Tall Weeds and Crops Land Cover Classification Supplemental Vertical Accuracy (SVA) Tested 0.053 meters supplemental vertical accuracy at the 95th percentile in Tall Weeds and Crops. Tested against the DEM. Tall Weeds and Crops Errors larger than 95th percentile include:

- Point 4006, Easting 689384.61, Northing 3945061.33, Z-Error 0.07

CONSOLIDATED VERTICAL ACCURACY ASSESMENT (CVA)

Table 5.14: Consolidated Vertical Accuracy Assessment Statistics, McKinley, NM Mine				
Point ID	Easting (UTM meters)	Northing (UTM meters)	Elevation (meters)	Absolute Dz (meters)
4002	684185.47	3945177	2147.26	0.06
4004	686708.5	3944492	2080.56	0.01
4009	691633.76	3947320	2084.8	0

Table 5.14: Consolidated Vertical Accuracy Assessment Statistics, McKinley, NM Mine				
Point ID	Easting (UTM meters)	Northing (UTM meters)	Elevation (meters)	Absolute Dz (meters)
4014	686025.51	3938802	2020.15	0.04
4017	684492.38	3954590	2227.07	0.07
4018	685211.17	3955054	2228.45	0
4005	688450.3	3944859	2044.42	0.16
4010	691370.07	3945536	2041.25	0.14
4021	679595.86	3945821	2087.48	0.03
4022	680551.09	3945713	2100.72	0.21
4024	682198.96	3945631	2152.26	0.18
4028	681032.52	3949146	2117.7	0.04
4029	682654.75	3951715	2146.53	0.06
2039	681539.87	3952363	2142.93	0.04
2042	692021.01	3945616	2061.29	0.06
2044	688552.13	3939436	1999.35	0.09
4007	690320.37	3945246	2057.72	0.06
4008	691445.42	3946679	2077.28	0.02
4013	684300.62	3939424	2047.32	0.01
4015	683437.51	3953571	2190.37	0.03
4016	684502.75	3954586	2228.96	0.06
4003	685404.96	3944197	2109.44	0.04
4023	681615.16	3945606	2130.75	0.07
4031	681953.87	3951929	2147.02	0.08
2043	688499.59	3941208	2016.46	0.03
2034	688499.59	3941208	2016.46	0.03
4000	684091.29	3945271	2147.07	0.03

Table 5.14: Consolidated Vertical Accuracy Assessment Statistics, McKinley, NM Mine				
Point ID	Easting (UTM meters)	Northing (UTM meters)	Elevation (meters)	Absolute Dz (meters)
4011	688498.76	3943818	2042.51	0.04
4012	688499.33	3941839	2012.46	0
4006	689384.61	3945061	2044.95	0.07
4019	679021.33	3946122	2081.42	0.02
4025	681094.53	3950573	2116.95	0.01
4027	678952.25	3947776	2083.21	0.02
4032	681737.91	3951136	2128.58	0.03
2037	678378.82	3946594	2076.83	0.03
2040	683881.09	3952720	2162.89	0
2047	683289.52	3945554	2115.86	0.01
4001	684177.28	3945179	2146.94	0.01
4002	684185.47	3945177	2147.26	0.06
4004	686708.5	3944492	2080.56	0.01
4009	691633.76	3947320	2084.8	0
4014	686025.51	3938802	2020.15	0.04
4017	684492.38	3954590	2227.07	0.07
4018	685211.17	3955054	2228.45	0
4005	688450.3	3944859	2044.42	0.16
4010	691370.07	3945536	2041.25	0.14
4021	679595.86	3945821	2087.48	0.03
4022	680551.09	3945713	2100.72	0.21
4024	682198.96	3945631	2152.26	0.18
4028	681032.52	3949146	2117.7	0.04
4029	682654.75	3951715	2146.53	0.06

Table 5.14: Consolidated Vertical Accuracy Assessment Statistics, McKinley, NM Mine				
Point ID	Easting (UTM meters)	Northing (UTM meters)	Elevation (meters)	Absolute Dz (meters)
2039	681539.87	3952363	2142.93	0.04
2042	692021.01	3945616	2061.29	0.06
2044	688552.13	3939436	1999.35	0.09
4007	690320.37	3945246	2057.72	0.06
4008	691445.42	3946679	2077.28	0.02
4013	684300.62	3939424	2047.32	0.01
4015	683437.51	3953571	2190.37	0.03
4016	684502.75	3954586	2228.96	0.06
4003	685404.96	3944197	2109.44	0.04
4023	681615.16	3945606	2130.75	0.07
4031	681953.87	3951929	2147.02	0.08
2043	688499.59	3941208	2016.46	0.03
2034	688499.59	3941208	2016.46	0.03
4000	684091.29	3945271	2147.07	0.03
4011	688498.76	3943818	2042.51	0.04
4012	688499.33	3941839	2012.46	0
4006	689384.61	3945061	2044.95	0.07
4019	679021.33	3946122	2081.42	0.02
4025	681094.53	3950573	2116.95	0.01
4027	678952.25	3947776	2083.21	0.02
4032	681737.91	3951136	2128.58	0.03
2037	678378.82	3946594	2076.83	0.03
2040	683881.09	3952720	2162.89	0
2047	683289.52	3945554	2115.86	0.01

Table 5.14: Consolidated Vertical Accuracy Assessment Statistics, McKinley, NM Mine				
Point ID	Easting (UTM meters)	Northing (UTM meters)	Elevation (meters)	Absolute Dz (meters)
4001	684177.28	3945179	2146.94	0.01
4002	684185.47	3945177	2147.26	0.06
4004	686708.5	3944492	2080.56	0.01
4009	691633.76	3947320	2084.8	0
4014	686025.51	3938802	2020.15	0.04

Consolidated Vertical Accuracy (CVA) Tested 0.181 meters consolidated vertical accuracy at the 95th percentile level, derived according to ASPRS Guidelines for Vertical Accuracy Reporting for LiDAR Data. This data set was tested against the DEM using independent check points. Based on the 95th percentile error in all land cover categories combined. Combined Land Cover Errors larger than 95% include:

- Point 4024, Easting 682198.96, Northing 3945630.71, Z-Error 0.18
- Point 4022, Easting 680551.09, Northing 3945713.26, Z-Error 0.21

NAVAJO-PINABETE, NM

Table 5.15: Overall Vertical Accuracy Statistics, Navajo-Pinabete, NM		
Average error	-0.011	meters
Minimum error	-0.100	meters
Maximum error	+0.080	meters
Average magnitude	0.051	meters
Root mean square	0.057	meters
Standard deviation	0.059	meters

Table 5.16: Swath LiDAR AQ/QC Analysis, UTM12N, NAD83, Navajo-Pinabete, NM				
Point ID	Easting (UTM meters)	Northing (UTM meters)	Elevation (meters)	Dz (meters)
5000	720806.990	4051410.530	1662.610	0.020
5003	720412.190	4052174.690	1635.430	0.050
5005	719319.190	4052720.120	1607.240	-0.050
5009	721442.050	4055065.300	1616.500	0.050
5010	722340.950	4055370.540	1616.690	-0.040
5013	723757.210	4057820.190	1592.550	0.080
5014	725039.930	4057684.890	1603.710	0.020
5015	725062.780	4058682.670	1611.070	0.020
5016	722472.590	4038542.660	1647.120	-0.060
5017	721287.990	4042218.900	1645.270	-0.030
5021	724889.420	4046636.350	1655.130	-0.100
5022	726355.720	4048852.320	1707.030	-0.090

Vertical Accuracy Conclusions

LAS data covering the Navajo Permit Pinabete Mine Plan 1m NPS Lidar Task Order was compared to survey control points to determine the FVA of the LAS Swath and of the Bare-Earth DEM. LAS Swath Fundamental Vertical Accuracy (FVA) Tested 0.111m (11.1cm) fundamental vertical accuracy at a 95 percent confidence level, derived according to NSSDA, in open terrain using 0.057m (5.7cm) (RMSE(z) x 1.96000 tested against the TIN. Bare-Earth DEM Fundamental Vertical Accuracy (FVA) Tested 0.103m

(10.3cm) fundamental vertical accuracy at a 95 percent confidence level, derived according to NSSDA, in open terrain using 0.053m (5.3cm) (RMSE(z) x 1.96000 tested against the DEM.

SUPPLEMENTAL VERTICAL ACCURACY ASSESSMENT (SVA)

Table 5.17: Bare Earth Open Terrain QA/QC Analysis, UTM12N, NAD83, Navajo-Pinabete, NM Mine				
Point ID	Easting (UTM meters)	Northing (UTM meters)	Elevation (meters)	Absolute Dz (meters)
5000	720806.99	4051411	1662.59	0.02
5003	720412.19	4052175	1635.38	0.05
5005	719319.19	4052720	1607.29	0.01
5009	721442.05	4055065	1616.45	0.03
5010	722340.95	4055371	1616.73	0.03
5013	723757.21	4057820	1592.47	0.04
5014	725039.93	4057685	1603.69	0.02
5015	725062.78	4058683	1611.05	0.01
5016	722472.59	4038543	1647.18	0.06
5017	721287.99	4042219	1645.3	0.05
5021	724889.42	4046636	1655.23	0.09

Bare Earth/Open Terrain Land Cover Classification Supplemental Vertical Accuracy (SVA) Tested 0.099 meters supplemental vertical accuracy at the 95th percentile in Bare Earth/Open Terrain. Tested against the DEM. Errors larger than 95th percentile include:

- Point 5022, Easting 726355.72, Northing 4048852.32, Z-Error 0.11

Table 5.18: Brush Lands and Trees QA/QC Analysis, UTM12N, NAD83, Navajo-Pinabete, NM Mine				
Point ID	Easting (UTM meters)	Northing (UTM meters)	Elevation (meters)	Absolute Dz (meters)
5001	720757.68	4051903	1650.4	0.09
5023	725027.46	4051200	1708.13	0.25

Table 5.18: Brush Lands and Trees QA/QC Analysis, UTM12N, NAD83, Navajo-Pinabete, NM Mine				
Point ID	Easting (UTM meters)	Northing (UTM meters)	Elevation (meters)	Absolute Dz (meters)
5019	723488.24	4042362	1634.45	0.14
5025	726758.71	4049646	1721.36	0.05
5011	723026.7	4056264	1604.47	0.04
5031	727374	4067784	1651.66	0.07
2026	728730.34	4062440	1656.99	0.11
2027	726153.75	4063174	1635.29	0.13

Brush Lands and Trees Land Cover Classification Supplemental Vertical Accuracy (SVA) Tested 0.211 meters supplemental vertical accuracy at the 95th percentile in Brush Lands and Trees. Tested against the DEM. Brush Lands and Trees Errors larger than 95th percentile include:

- Point 5023, Easting 725027.46, Northing 4051200.12, Z-Error 0.25

Table 5.19: Forested Canopy QA/QC Analysis, UTM12N, NAD83, Navajo-Pinabete, NM Mine				
Point ID	Easting (UTM meters)	Northing (UTM meters)	Elevation (meters)	Absolute Dz (meters)
5028	727610.62	4064443	1625.09	0.09
5032	727110.17	4065489	1625.22	0.15

Forested and Fully Grown Land Cover Classification Supplemental Vertical Accuracy (SVA) Tested 0.147 meters supplemental vertical accuracy at the 95th percentile in Forested and Fully Grown. Tested against the DEM. Forested and Fully Grown Errors larger than 95th percentile include:

- Point 5032, Easting 727110.17, Northing 4065489.4, Z-Error 0.15

Table 5.20: Tall Weeds and Crops QA/QC Analysis, UTM12N, NAD83, Navajo-Pinabete, NM Mine				
Point ID	Easting (UTM meters)	Northing (UTM meters)	Elevation (meters)	Absolute Dz (meters)
5002	720403.68	4052187	1635.52	0.03
5004	719709.11	4052215	1624.55	0.08
5006	719755.08	4053218	1606.73	0.09
5007	720144.78	4053670	1615.79	0.02
5008	720775.88	4054380	1622.54	0.09
5012	723342.21	4057013	1615.15	0.03
5018	721228.16	4043015	1645.36	0.03
5020	724528.78	4043859	1619.58	0.03
5024	728314.06	4053237	1701.34	0.02
2024	728735.54	4066757	1633.21	0.06
2029	724313.89	4057523	1606.3	0.04
2031	718934.92	4052282	1607.59	0.02
2033	728231.14	4049913	1721.68	0.08
2034	723419.65	4039725	1650.55	0.06

Tall Weeds and Crops Land Cover Classification Supplemental Vertical Accuracy (SVA) Tested 0.09 meters supplemental vertical accuracy at the 95th percentile in Tall Weeds and Crops. Tested against the DEM. Tall Weeds and Crops Errors larger than 95th percentile include:

- Point 5006, Easting 719755.08, Northing 4053218.28, Z-Error 0.09
- Point 5008, Easting 720775.88, Northing 4054379.53, Z-Error 0.09

CONSOLIDATED VERTICAL ACCURACY ASSESMENT (CVA)

Table 5.21: Consolidated Vertical Accuracy Statistics, UTM12N, NAD83, Navajo-Pinabete, NM Mine				
Point ID	Easting (UTM meters)	Northing (UTM meters)	Elevation (meters)	Absolute Dz (meters)
5000	720806.99	4051411	1662.59	0.02
5003	720412.19	4052175	1635.38	0.05
5005	719319.19	4052720	1607.29	0.01
5009	721442.05	4055065	1616.45	0.03
5010	722340.95	4055371	1616.73	0.03
5013	723757.21	4057820	1592.47	0.04
5014	725039.93	4057685	1603.69	0.02
5015	725062.78	4058683	1611.05	0.01
5016	722472.59	4038543	1647.18	0.06
5017	721287.99	4042219	1645.3	0.05
5021	724889.42	4046636	1655.23	0.09
5022	726355.72	4048852	1707.12	0.11
5001	720757.68	4051903	1650.4	0.09
5023	725027.46	4051200	1708.13	0.25
5019	723488.24	4042362	1634.45	0.14
5025	726758.71	4049646	1721.36	0.05
5011	723026.7	4056264	1604.47	0.04
5031	727374	4067784	1651.66	0.07
2026	728730.34	4062440	1656.99	0.11
2027	726153.75	4063174	1635.29	0.13
5028	727610.62	4064443	1625.09	0.09
5032	727110.17	4065489	1625.22	0.15
5002	720403.68	4052187	1635.52	0.03

Table 5.21: Consolidated Vertical Accuracy Statistics, UTM12N, NAD83, Navajo-Pinabete, NM Mine				
Point ID	Easting (UTM meters)	Northing (UTM meters)	Elevation (meters)	Absolute Dz (meters)
5004	719709.11	4052215	1624.55	0.08
5006	719755.08	4053218	1606.73	0.09
5007	720144.78	4053670	1615.79	0.02
5008	720775.88	4054380	1622.54	0.09
5012	723342.21	4057013	1615.15	0.03
5018	721228.16	4043015	1645.36	0.03
5020	724528.78	4043859	1619.58	0.03
5024	728314.06	4053237	1701.34	0.02
2024	728735.54	4066757	1633.21	0.06
2029	724313.89	4057523	1606.3	0.04
2031	718934.92	4052282	1607.59	0.02
2033	728231.14	4049913	1721.68	0.08
2034	723419.65	4039725	1650.55	0.06

Consolidated Vertical Accuracy (CVA) Tested 0.165 meters consolidated vertical accuracy at the 95th percentile level, derived according to ASPRS Guidelines for Vertical Accuracy Reporting for LiDAR Data. This data set was tested against the DEM using independent check points. Based on the 95th percentile error in all land cover categories combined. Combined Land Cover Errors larger than 95% include:

- Point 5023, Easting 725027.46, Northing 4051200.12, Z-Error 0.25

FINAL SUPPLEMENTAL VERTICAL ACCURACY ASSESMENT (SVA)

LAS data covering the areas interest Black Mesa, AZ, McKinley, NM, and Navajo-Pinabete, NM. 1m NPS Lidar Task Order was compared to survey control points to determine the FVA of the LAS Swath and of the Bare-Earth DEM. In addition, this LAS data was compared to supplemental points from categories: Bare Earth Open Terrain, Tall Weeds/Crops, Brush Lands and Trees, and Forested Fully Grown. LAS Swath Fundamental Vertical Accuracy (FVA) Tested 0.105m (10.5cm) fundamental vertical accuracy at a 95 percent confidence level, derived according to NSSDA, in open terrain using 0.054m (7.0cm) (RMSE(z) x 1.96000 tested against the TIN. Bare-Earth DEM Fundamental Vertical Accuracy (FVA) Tested 0.104m (10.4cm) fundamental vertical accuracy at a 95 percent confidence level, derived according to NSSDA, in open terrain using 0.53m (5.3cm) (RMSE(z) x 1.96000 tested against the DEM.

LAS Swath Fundamental Vertical Accuracy (FVA) Tested 0.105 meters fundamental vertical accuracy at a 95 percent confidence level, derived according to NSSDA, in open terrain using RMSE(z) x 1.96000. This data set was tested against the TIN using independent check points.

Bare-Earth DEM Fundamental Vertical Accuracy (FVA) Tested 0.104 meters fundamental vertical accuracy at a 95 percent confidence level, derived according to NSSDA, in open terrain using RMSE(z) x 1.96000. This data set was tested against the DEM using independent check points.

Bare Earth/Open Terrain Land Cover Classification Supplemental Vertical Accuracy (SVA) Tested 0.107 meters supplemental vertical accuracy at the 95th percentile in Bare Earth/Open Terrain. Tested against the DEM. Errors larger than 95th percentile include:

- Point 5022, Easting 726355.72, Northing 4048852.32, Z-Error 0.11

Brush Lands and Trees Land Cover Classification Supplemental Vertical Accuracy (SVA) Tested 0.23 meters supplemental vertical accuracy at the 95th percentile in Brush Lands and Trees. Tested against the DEM. Brush Lands and Trees Errors larger than 95th percentile include:

- Point 5023, Easting 725027.46, Northing 4051200.12, Z-Error 0.25

Forested and Fully Grown Land Cover Classification Supplemental Vertical Accuracy (SVA) Tested 0.132 meters supplemental vertical accuracy at the 95th percentile in Forested and Fully Grown. Tested against the DEM. Forested and Fully Grown Errors larger than 95th percentile include:

- Point 5032, Easting 727110.17, Northing 4065489.4, Z-Error 0.15

Tall Weeds and Crops Land Cover Classification Supplemental Vertical Accuracy (SVA) Tested 0.09 meters supplemental vertical accuracy at the 95th percentile in Tall Weeds and Crops. Tested against the DEM. Tall Weeds and Crops Errors larger than 95th percentile include:

- Point 5006, Easting 719755.08, Northing 4053218.28, Z-Error 0.09

- Point 5008, Easting 720775.88, Northing 4054379.53, Z-Error 0.09

FINAL CONSOLIDATED VERTICAL ACCURACY ASSESMENT (CVA)

Consolidated Vertical Accuracy (CVA) Tested 0.148 meters consolidated vertical accuracy at the 95th percentile level, derived according to ASPRS Guidelines for Vertical Accuracy Reporting for LiDAR Data. This data set was tested against the DEM using independent check points. Based on the 95th percentile error in all land cover categories combined. Combined Land Cover Errors larger than 95% include:

- Point 2015, Easting 552331.83, Northing 4028947, Z-Error 0.15

- Point 5032, Easting 727110.17, Northing 4065489.4, Z-Error 0.15

- Point 4005, Easting 688450.3, Northing 3944859.36, Z-Error 0.16

- Point 4024, Easting 682198.96, Northing 3945630.71, Z-Error 0.18

- Point 4022, Easting 680551.09, Northing 3945713.26, Z-Error 0.21

- Point 5023, Easting 725027.46, Northing 4051200.12, Z-Error 0.25

Approved By:

Title	Name	Signature	Date
Associate LiDAR Specialist Certified Photogrammetrist #1281	Qian Xiao		January 2013

SECTION 6: FINAL DELIVERABLES

FINAL DELIVERABLES

The final LiDAR deliverables are listed below:

- LAS v1.2 classified point cloud.

- LAS v1.2 raw unclassified point cloud flight line strips no greater than 2GB. Long swaths greater than 2GB will be split into segments.

- Hydrologically flattened Polygon z and Polyline z shapefiles.

- Hydrologically flattened bare earth 1-meter DEM in ERDAS .IMG format.

- 1-meter pixel 8-bit lidar intensity imagery in GeoTIFF format.

- Tile Layout and data extent provided as an ESRI shapefile.

- LiDAR processing report in pdf format.

- Two (2) foot contours provided as a file geodatabase.

- FGDC compliant metadata in XML format