GROUND CONTROL SURVEY REPORT MENDOCINO (MULE-M4 SLIDE)

GPS SURVEY FOR LIDAR CONTROL

CONTENTS

1. ABSTRACT

This report documents the GPS ground surveys conducted in support of LIDAR data collection for the Modoc Forest area. The surveyed ground control was established on October 20 – 21(Mule-M4 Slide) ,2013. The aerial collection was performed with the Optech ALTM Gemini LiDAR Sensor on October 20th and 21, 2013 . The ground control stations were established utilizing the **Leica RX1205 XC** Survey receiver. There were no problems encountered during this survey. The ground survey was conducted at 14 sites utilizing the CORS stations identified on the ***OPUS*** Data sheets. These surveys established "Ground Truth" data at each site.

A Beechcraft Bonanza A36TC, based out of Chino Airport, CA was utilized on this project for the LiDAR Mission. This aircraft was outfitted with an Optech Gemini ALTM 167kHZ system (s/n 07SEN204).

Mission planning parameters for the LiDAR noted below. These lines would be flown using the following settings:

Altitude:	**800 m**
Overlap:	**60 %**
Speed:	**120 kts**
System PRF:	**70 kHz**
Scan Freq:	**64 Hz**
Scan Half Angle:	**10°**
Cross Track Res.:	**0.491 m**
Down Track Res.:	**0.482 m**

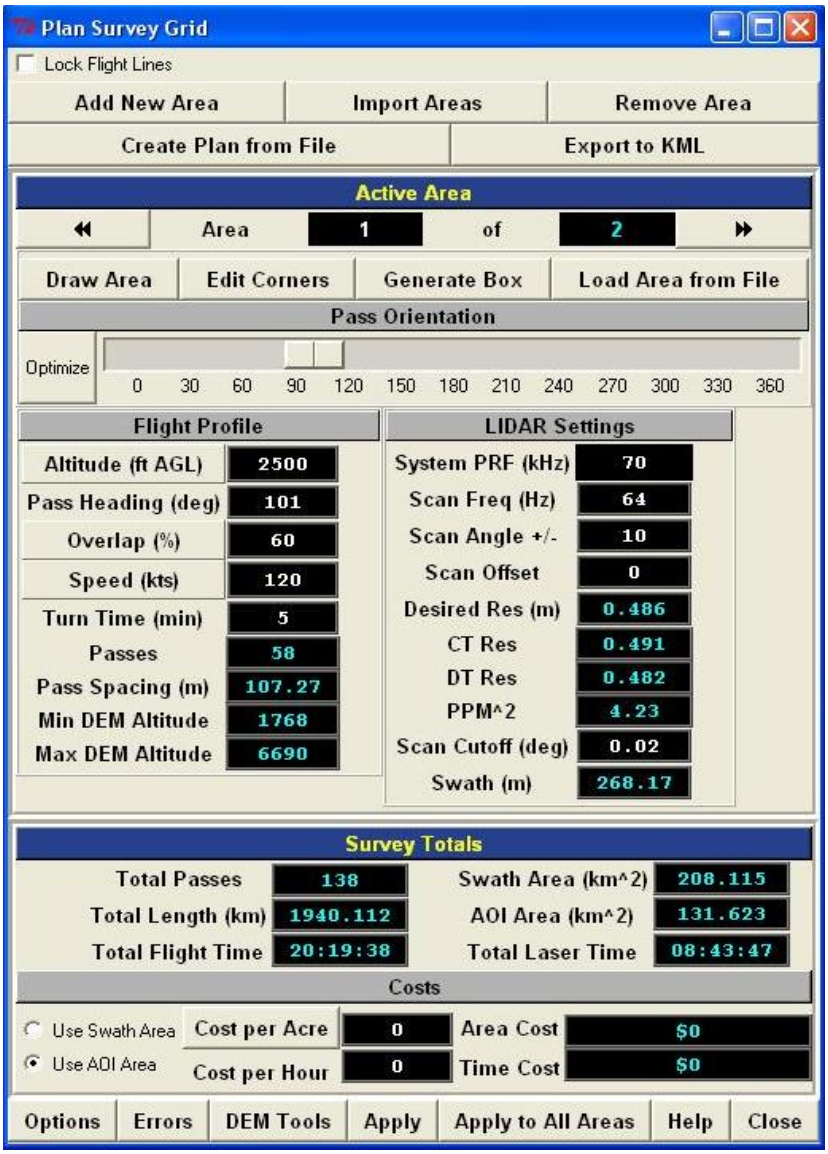
The actual local flight times and duration of flights were controlled by fuel consumption of the aircraft, safety of flight operations in the particular airspace and during times when the GPS constellation was most favorable, producing the highest number of satellites visible in the best geometric configuration relative to the GPS receivers onboard the aircraft as well as at the master stations on the ground. A standard of flying with no less than 6 satellites visible and a PDOP (position dilution of precision) of less than 3.0 was adopted.

Statistical comparisons were made between ground truth points collected in the survey and airborne LIDAR points .

Comparisons were also made between the survey points and the LIDAR derived terrain surface. These comparisons provide an additional verification of the LIDAR data against the survey data.

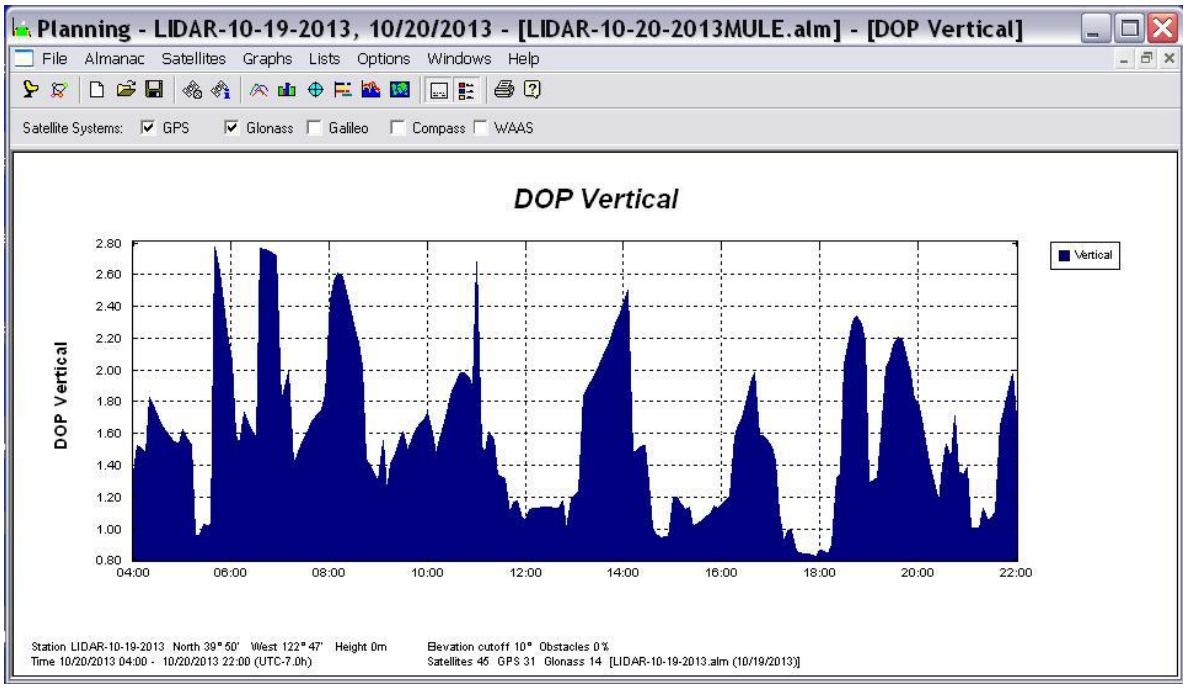
The horizontal and vertical datum used for this project are listed below:

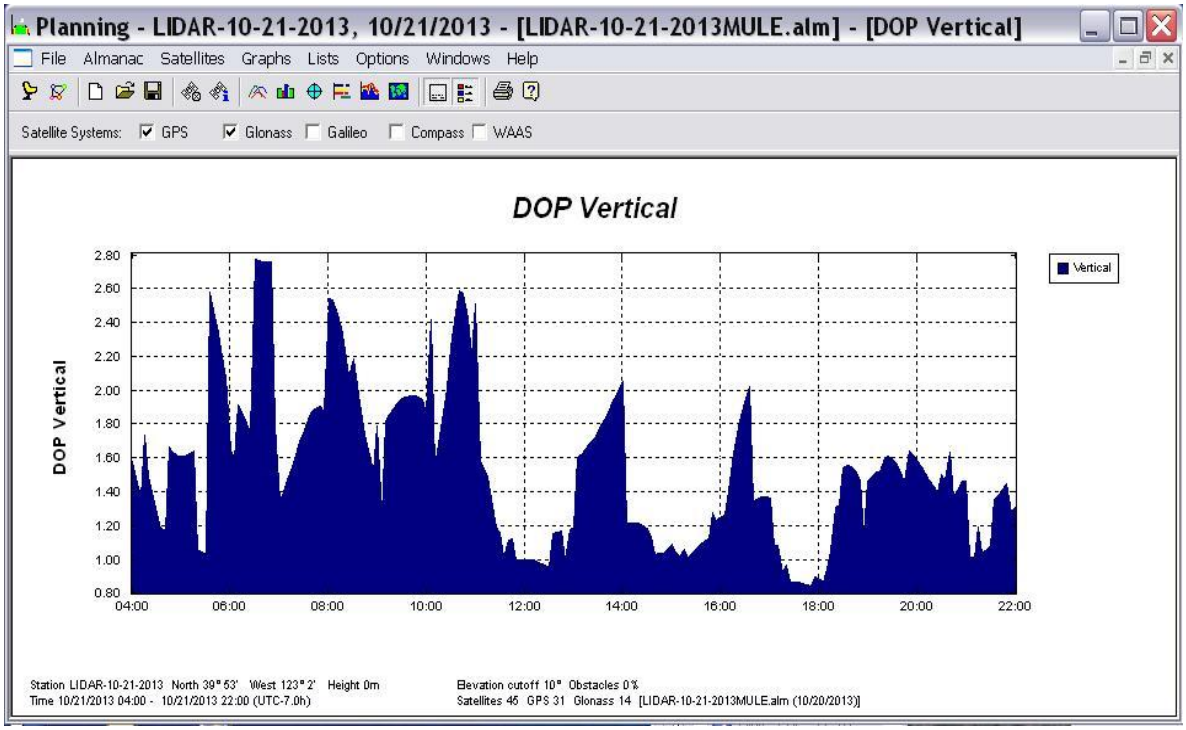
Vertical Datum:	**NAVD88, Geoid12A**
Horizontal Datum:	**NAD83**
Projection:	**UTM Zone 10**
Units:	**METERS**



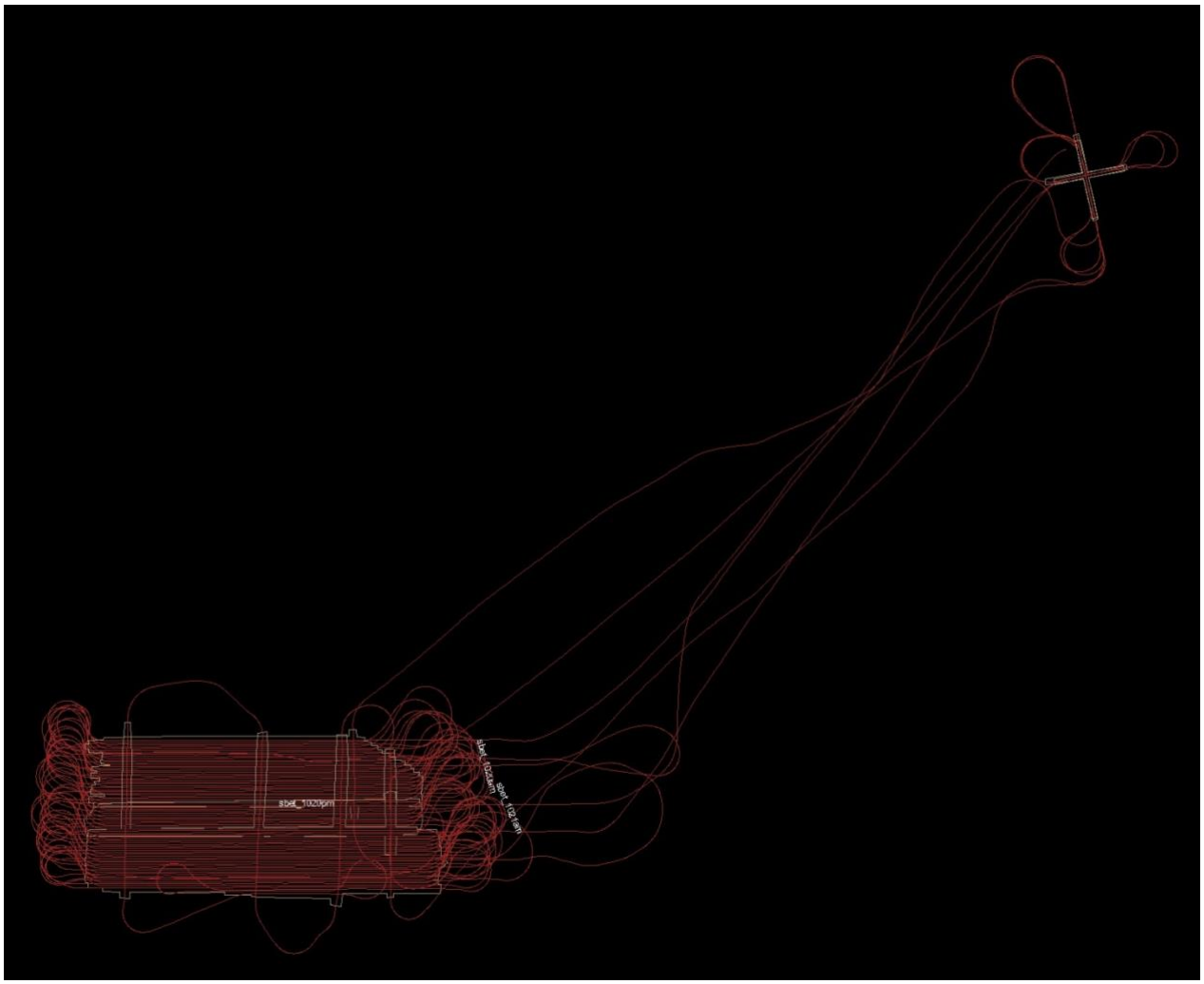
LiDAR MISSION PARAMETERS

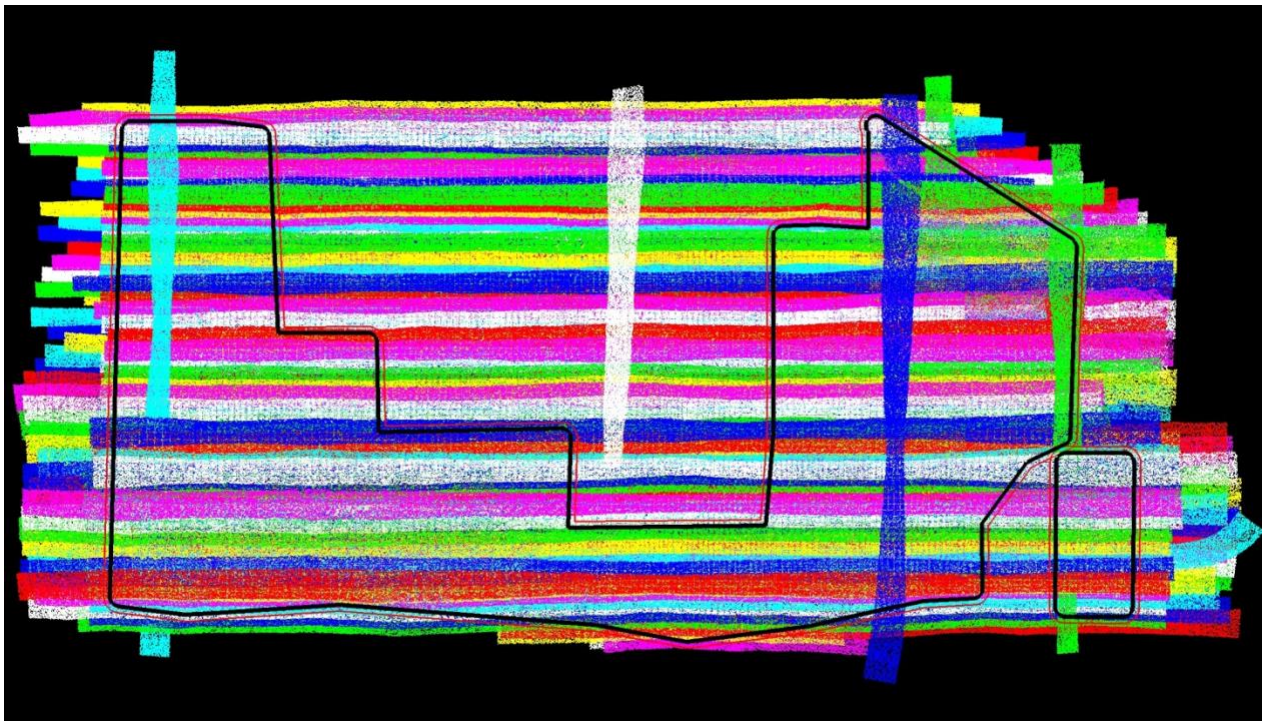
DMI always checked PDOP before commencing flight (weather permitting) – *next page* shows data collection and dates with PDOP report October 20-21, 2013.


Planning - LIDAR-10-19-2013, 10/20/2013 - [LIDAR-10-20-2013MULE.alm] - [DOP Vertical]
File Almanac Satellites Graphs Lists Options Windows Help
Satellite Systems: GPS Glonass Galileo Compass WAAS
DOP Vertical
DOP Vertical
Vertical
2.80
2.60
2.40
2.20
2.00
1.80
1.60
1.40
1.20
1.00
0.80
04:00
06:00
08:00
10:00
12:00
14:00
16:00
18:00
20:00
22:00
Station LIDAR-10-19-2013 North 39° 50' West 122° 47' Height 0m
Time 10/20/2013 04:00 - 10/20/2013 22:00 (UTC-7.0h)
Elevation cutoff 10° Obstacles 0%
Satellites 46 GPS 31 Glonass 14 [LIDAR-10-19-2013.alm (10/19/2013)]


Planning - LIDAR-10-21-2013, 10/21/2013 - [LIDAR-10-21-2013MULE.alm] - [DOP Vertical]
File Almanac Satellites Graphs Lists Options Windows Help
Satellite Systems: GPS Glonass Galileo Compass WAAS
DOP Vertical
DOP Vertical
Vertical
2.80
2.60
2.40
2.20
2.00
1.80
1.60
1.40
1.20
1.00
0.80
04:00
06:00
08:00
10:00
12:00
14:00
16:00
18:00
20:00
22:00
Station LIDAR-10-21-2013 North 39° 53' West 123° 2' Height 0m
Time 10/21/2013 04:00 - 10/21/2013 22:00 (UTC-7.0h)
Elevation cutoff 10° Obstacles 0%
Satellites 46 GPS 31 Glonass 14 [LIDAR-10-21-2013MULE.alm (10/20/2013)]

SBET IMAGES and FLIGHT LINES





OPUS: Online Positioning User Service – Solution Report
@ ½ Second

Ground Receiver UNIT 1 AM - 10/20/2013

START: 2013/10/20 14:05:00
STOP: 2013/10/20 19:47:00

ANT NAME: LEIAX1202 NONE # FIXED AMB: 46 / 48 : 96%

ARP HEIGHT: 1.5798 OVERALL RMS: 0.0009(m)

REF FRAME: NAD_83(2011)(EPOCH:2010.0000)			IGS08 (EPOCH:2013.8019)	
X:	-2648912.512(m)	0.006(m)	-2648913.383(m)	0.006(m)
Y:	-4129271.833(m)	0.010(m)	-4129270.551(m)	0.010(m)
Z:	4063754.415(m)	0.016(m)	4063754.402(m)	0.016(m)
LAT:	39 49 32.18016	0.004(m)	39 49 32.19248	0.004(m)
E LON:	237 19 11.92538	0.002(m)	237 19 11.86545	0.002(m)
W LON:	122 40 48.07462	0.002(m)	122 40 48.13455	0.002(m)
EL HGT:	969.757(m)	0.020(m)	969.281(m)	0.020(m)
ORTHO HGT:	998.031(m)	0.040(m)	[NAVD88 (Computed using GEOID12A)]	

UTM COORDINATES STATE PLANE COORDINATES

	UTM (Zone 10)	SPC (0401 CA 1)
Northing (Y) [meters]	4408450.409	554888.609
Easting (X) [meters]	527382.717	1941780.714
Convergence [degrees]	0.20493295	-0.44465488
Point Scale	0.99960923	1.00004847
Combined Factor	0.99945718	0.99989635

US NATIONAL GRID DESIGNATOR: 10SEK2738208450(NAD 83)

BASE STATIONS USED

PID	DESIGNATION	LATITUDE	LONGITUDE	DISTANCE(m)
DN9089	P334 SHEETIRON_CN2007 CORS ARP	N392936.918	W1224409.083	37194.4
DN5651	P339 VALENTINE_CN2007 CORS ARP	N400202.785	W1224005.643	23176.0
DN7390	P335 BLACKBUTTECN2008 CORS ARP	N394334.270	W1225225.038	19968.5

NEAREST NGS PUBLISHED CONTROL POINT

KT0718	3168.7	USGS	N394936.	W1224034.	354.5

Ground Receiver UNIT 2 AM - 10/20/2013

START: 2013/10/20 23:11:00
STOP: 2013/10/20 02:12:00

ANT NAME: LEIAX1202 NONE # FIXED AMB: 33 / 37 : 89%

ARP HEIGHT: 1.6778 OVERALL RMS: 0.011(m)

REF FRAME:	NAD_83(2011)(EPOCH:2010.0000)		IGS08 (EPOCH:2013.8019)	
X:	-2648958.942(m)	0.007(m)	-2648959.813(m)	0.007(m)
Y:	-4129346.945(m)	0.004(m)	-4129345.663(m)	0.004(m)
Z:	4063659.521(m)	0.005(m)	4063659.508(m)	0.005(m)
LAT:	39 49 27.98443	0.005(m)	39 49 27.99674	0.005(m)
E LON:	237 19 11.98745	0.004(m)	237 19 11.92753	0.004(m)
W LON:	122 40 48.01255	0.004(m)	122 40 48.07247	0.004(m)
EL HGT:	976.791(m)	0.007(m)	976.315(m)	0.007(m)
ORTHO HGT:	1005.062(m)	0.025(m)	[NAVD88 (Computed using GEOID12A)]	

	UTM COORDINATES	STATE PLANE COORDINATES
	UTM (Zone 10)	SPC (0401 CA 1)
Northing (Y) [meters]	4408321.060	554759.190
Easting (X) [meters]	527384.655	1941781.186
Convergence [degrees]	0.20493900	-0.44464361
Point Scale	0.99960923	1.00004883
Combined Factor	0.99945607	0.99989561

US NATIONAL GRID DESIGNATOR: 10SEK2738408321(NAD 83)

BASE STATIONS USED

PID	DESIGNATION	LATITUDE	LONGITUDE	DISTANCE(m)
DN5651	P339 VALENTINE_CN2007 CORS ARP	N400202.785	W1224005.643	23305.3
DN7390	P335 BLACKBUTTECN2008 CORS ARP	N394334.270	W1225225.038	19898.1
DN9089	P334 SHEETIRON_CN2007 CORS ARP	N392936.918	W1224409.083	37066.1

NEAREST NGS PUBLISHED CONTROL POINT

KT0717	H 601	N394928.	W1224032.	380.3

Ground Receiver UNIT 1 PM - 10/20/2013

START: 2013/10/20 23:31:00
STOP: 2013/10/21 02:29:00

ANT NAME: LEIAX1202 NONE # FIXED AMB: 31 /31 : 100%

ARP HEIGHT: 1.6748 OVERALL RMS: 0.008(m)

REF FRAME:	NAD_83(2011)(EPOCH:2010.0000)		IGS08 (EPOCH:2013.8029)	
X:	-2648912.510(m)	0.007(m)	-2648913.381(m)	0.007(m)
Y:	-4129271.823(m)	0.005(m)	-4129270.541(m)	0.005(m)
Z:	4063754.400(m)	0.005(m)	4063754.387(m)	0.005(m)
LAT:	39 49 32.17999	0.006(m)	39 49 32.19230	0.006(m)
E LON:	237 19 11.92522	0.007(m)	237 19 11.86530	0.007(m)
W LON:	122 40 48.07478	0.007(m)	122 40 48.13470	0.007(m)
EL HGT:	969.740(m)	0.003(m)	969.264(m)	0.003(m)
ORTHO HGT:	998.014(m)	0.023(m)	[NAVD88 (Computed using GEOID12A)]	

	UTM COORDINATES	STATE PLANE COORDINATES
	UTM (Zone 10)	SPC (0401 CA 1)
Northing (Y) [meters]	4408450.403	554888.603
Easting (X) [meters]	527382.713	1941780.710
Convergence [degrees]	0.20493292	-0.44465491
Point Scale	0.99960923	1.00004847
Combined Factor	0.99945718	0.99989635

US NATIONAL GRID DESIGNATOR: 10SEK2738208450(NAD 83)

BASE STATIONS USED

PID	DESIGNATION		LATITUDE	LONGITUDE	DISTANCE(m)
DN5651	P339 VALENTINE_CN2007	CORS ARP	N400202.785	W1224005.643	23176.1
DN7390	P335 BLACKBUTTECN2008	CORS ARP	N394334.270	W1225225.038	19968.5
DK6402	P336 HUBBARDRDGCN2007	CORS ARP	N393141.074	W1222549.687	39375.4

NEAREST NGS PUBLISHED CONTROL POINT

KT0718	3168.7	USGS	N394936.	W1224034.	354.5

Ground Receiver UNIT 2 PM - 10/20/2013

START: 2013/10/20 23:36:00
STOP: 2013/10/21 02:26:00

ANT NAME: LEIAX1202 NONE # FIXED AMB: 36/ 36 : 100%
ARP HEIGHT: 1.6098 OVERALL RMS: 0.010(m)

REF FRAME: NAD_83(2011)(EPOCH:2010.0000) IGS08 (EPOCH:2013.8029)

X:	-2648958.948(m)	0.006(m)	-2648959.819(m)	0.006(m)
Y:	-4129346.948(m)	0.007(m)	-4129345.666(m)	0.007(m)
Z:	4063659.516(m)	0.004(m)	4063659.503(m)	0.004(m)
LAT:	39 49 27.98418	0.008(m)	39 49 27.99650	0.008(m)
E LON:	237 19 11.98731	0.004(m)	237 19 11.92738	0.004(m)
W LON:	122 40 48.01269	0.004(m)	122 40 48.07262	0.004(m)
EL HGT:	976.792(m)	0.005(m)	976.316(m)	0.005(m)
ORTHO HGT:	1005.063(m)	0.024(m)	[NAVD88 (Computed using GEOID12A)]	

UTM COORDINATES STATE PLANE COORDINATES

	UTM (Zone 10)	SPC (0401 CA 1)
Northing (Y) [meters]	4408321.053	554759.182
Easting (X) [meters]	527384.652	1941781.182
Convergence [degrees]	0.20493897	-0.44464363
Point Scale	0.99960923	1.00004883
Combined Factor	0.99945607	0.99989561

US NATIONAL GRID DESIGNATOR: 10SEK2738408321(NAD 83)

BASE STATIONS USED

PID	DESIGNATION	LATITUDE	LONGITUDE	DISTANCE(m)
DN9089	P334 SHEETIRON_CN2007 CORS ARP	N392936.918	W1224409.083	37066.1
DN7390	P335 BLACKBUTTECN2008 CORS ARP	N394334.270	W1225225.038	19898.1
DN5651	P339 VALENTINE_CN2007 CORS ARP	N400202.785	W1224005.643	23305.3

NEAREST NGS PUBLISHED CONTROL POINT

KT0717	H 601	N394928.	W1224032.	380.3

Ground Receiver UNIT 1 - 10/21/2013

START: 2013/10/21 13:25:00
STOP: 2013/10/21 19:38:00

ANT NAME: LEIAX1202 NONE # FIXED AMB: 52 /52 : 100%

ARP HEIGHT: 1.5838 OVERALL RMS: 0.010(m)

REF FRAME:	NAD_83(2011)(EPOCH:2010.0000)		IGS08 (EPOCH:2013.8046)	
X:	-2648912.511(m)	0.001(m)	-2648913.382(m)	0.001(m)
Y:	-4129271.832(m)	0.004(m)	-4129270.550(m)	0.004(m)
Z:	4063754.414(m)	0.012(m)	4063754.401(m)	0.012(m)
LAT:	39 49 32.18017	0.007(m)	39 49 32.19248	0.007(m)
E LON:	237 19 11.92539	0.003(m)	237 19 11.86547	0.003(m)
W LON:	122 40 48.07461	0.003(m)	122 40 48.13453	0.003(m)
EL HGT:	969.755(m)	0.009(m)	969.279(m)	0.009(m)
ORTHO HGT:	998.029(m)	0.027(m)	[NAVD88 (Computed using GEOID12A)]	

	UTM COORDINATES	STATE PLANE COORDINATES
	UTM (Zone 10)	SPC (0401 CA 1)
Northing (Y) [meters]	4408450.409	554888.609
Easting (X) [meters]	527382.717	1941780.714
Convergence [degrees]	0.20493295	-0.44465488
Point Scale	0.99960923	1.00004847
Combined Factor	0.99945718	0.99989635

US NATIONAL GRID DESIGNATOR: 10SEK2738208450(NAD 83)

BASE STATIONS USED

PID	DESIGNATION		LATITUDE	LONGITUDE	DISTANCE(m)
DN9089	P334 SHEETIRON_CN2007	CORS ARP	N392936.918	W1224409.083	37194.4
DN7390	P335 BLACKBUTTECN2008	CORS ARP	N394334.270	W1225225.038	19968.5
DN5651	P339 VALENTINE_CN2007	CORS ARP	N400202.785	W1224005.643	23176.0

NEAREST NGS PUBLISHED CONTROL POINT

KT0718	3168.7 USGS		N394936.	W1224034.	354.5

Ground Receiver UNIT 2 - 10/21/2013

START: 2013/10/21 13:23:00
STOP: 2013/10/21 19:36:00

ANT NAME: LEIAX1202 NONE # FIXED AMB: 36/ 36 : 100%
ARP HEIGHT: 1.6448 OVERALL RMS: 0.011(m)

REF FRAME: NAD_83(2011)(EPOCH:2010.0000) IGS08 (EPOCH:2013.8046)

X:	-2648958.935(m)	0.014(m)	-2648959.806(m)	0.014(m)
Y:	-4129346.928(m)	0.022(m)	-4129345.646(m)	0.022(m)
Z:	4063659.507(m)	0.029(m)	4063659.494(m)	0.029(m)
LAT:	39 49 27.98445	0.009(m)	39 49 27.99677	0.009(m)
E LON:	237 19 11.98732	0.005(m)	237 19 11.92739	0.005(m)
W LON:	122 40 48.01268	0.005(m)	122 40 48.07261	0.005(m)
EL HGT:	976.768(m)	0.038(m)	976.292(m)	0.038(m)
ORTHO HGT:	1005.039(m)	0.069(m)	[NAVD88 (Computed using GEOID12A)]	

	UTM COORDINATES	STATE PLANE COORDINATES
	UTM (Zone 10)	SPC (0401 CA 1)
Northing (Y) [meters]	4408321.061	554759.191
Easting (X) [meters]	527384.652	1941781.182
Convergence [degrees]	0.20493897	-0.44464363
Point Scale	0.99960923	1.00004883
Combined Factor	0.99945608	0.99989561

US NATIONAL GRID DESIGNATOR: 10SEK2738408321(NAD 83)

BASE STATIONS USED

PID	DESIGNATION	LATITUDE	LONGITUDE	DISTANCE(m)
DN7390	P335 BLACKBUTTECN2008 CORS ARP	N394334.270	W1225225.038	19898.1
DN9089	P334 SHEETIRON_CN2007 CORS ARP	N392936.918	W1224409.083	37066.1
DK6402	P336 HUBBARDRDGCN2007 CORS ARP	N393141.074	W1222549.687	39266.3

NEAREST NGS PUBLISHED CONTROL POINT

KT0717	H 601	N394928.	W1224032.	380.3

2. GROUND TRUTH SUMMARY

Surveys were conducted to establish ground truth data at representative sites throughout the project area. These sites were selected on the basis of the optimizing visibility needed for the LIDAR survey over the area.

MULE-M4 SLIDE ANNEX LIDAR 2013 / DIGITAL MAPPING INC./ UTM 10

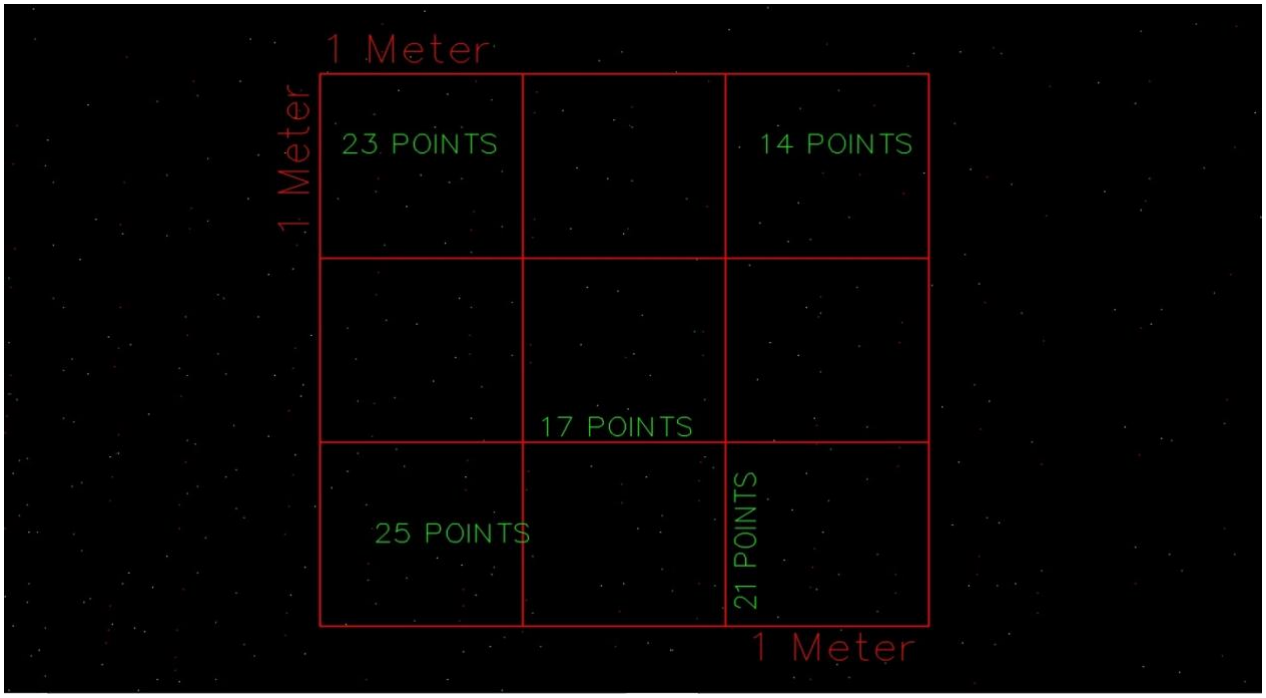
AERIAL POINT#	LATITUDE	LONGITUDE	NORTH (M)	EAST (M)	TARGET ELEV.	DESCRIPTION
ML 1	39°51'52.39662" N	122°52'34.84807" W	4412731.597	510575.836	1117.145	SET 60D SPIKE
ML 2	39°51'06.08175" N	122°50'40.45760" W	4411307.957	513295.987	1227.263	SET 60D SPIKE
ML 3	39°50'38.29596" N	122°49'49.11830" W	4410453.544	514517.550	1623.782	SET 60D SPIKE
ML 4	39°50'01.85598" N	122°50'56.06301" W	4409327.255	512928.512	1563.671	SET 60D SPIKE
ML 5	39°49'05.10915" N	122°52'52.77505" W	4407573.583	510156.774	1149.325	SET 60D SPIKE
ML 6	39°47'51.63238" N	122°50'40.26909" W	4405313.149	513310.885	1262.322	SET 60D SPIKE
ML 7	39°49'45.92262" N	122°47'11.41432" W	4408846.915	518269.229	1471.610	SET 60D SPIKE
ML 8	39°48'28.80415" N	122°46'34.55439" W	4406471.518	519151.333	1553.731	SET 60D SPIKE
ML 9	39°51'10.79933" N	122°44'58.07630" W	4411471.870	521431.337	1437.850	SET 60D SPIKE
ML 10	39°48'56.90312" N	122°44'43.44532" W	4407344.864	521790.744	1416.494	SET 60D SPIKE
ML 13	39°48'18.05798" N	122°42'52.13233" W	4406155.264	524440.996	1531.296	SET 60D SPIKE
ML 14	39°50'05.26048" N	122°44'05.32517" W	4409454.932	522690.793	1472.667	SET 60D SPIKE
ML 15	39°50'08.25466" N	122°42'37.21844" W	4409553.738	524784.625	1374.214	SET 60D SPIKE
ML 16	39°49'14.25322" N	122°41'13.63942" W	4407895.574	526776.962	1061.495	SET 60D SPIKE

3. DATA ANALYSIS

Data analysis was accomplished by comparing ground truth checkpoints with LIDAR points from the edited data set. The only exception to this were the ground truth points collected under the tree/forest canopy, where comparisons were made with LIDAR pulses that fell near known positions. This is because fewer LIDAR pulses are able to reach the ground in heavily forested areas, so the point spacing is larger than in cleared areas.

The base stations used to collect survey data were included in the static GPS network, and were selected on the basis of their having an unobstructed view of the sky, as well as being in a location considered favorable for collecting ground truth data. The vertical and horizontal accuracy of each base station was determined by the statistical tests performed in the least squares adjustment process.

Note that the edited LIDAR points are simply a subset of the raw LIDAR points. The points that fell above the ground surface on vegetation canopies, buildings, or other obstructions were removed from the data set. Comparisons were also made between the survey points and the LIDAR derived terrain surface. These comparisons provide an additional verification of the LIDAR data against the survey data.



ONE METER SQUARE > 9 points

LiDAR POINT CHECK

Our ground control check from QA/QC supported in attached documents

4. GROUND TRUTH SURVEY

A. Map of Control Point Locations/ Base Station- Both Days

10/20/2013 AM

10

10/20/2013 PM

10/21/2013 AM

B. Ground Truth Analysis of LIDAR Points

GROUND TRUTH ANALYSIS

Comparison of LIDAR Points to Ground Truth Points

GeoCue software was used to compare known , position established and occupied for twenty-minutes , control points versus identical position of LiDAR XYZ point data. The intensity image produced from the *LIDAR collection, was used to pick areas where ground and truth data collection could be collected. In areas of flat terrain or areas where detail is important it can be used as areas to collect X,Y,Z ground truth data for accessing the accuracy of the LIDAR data. Ground truth data can be collected using conventional survey techniques or DGPS techniques.*

SPATIAL REFERENCE FRAMEWORK

Vertical Datum **NAVD88, Geoid12A**
Horizontal Datum **NAD83**
Projection **UTM Zone 10**
Units **METERS**

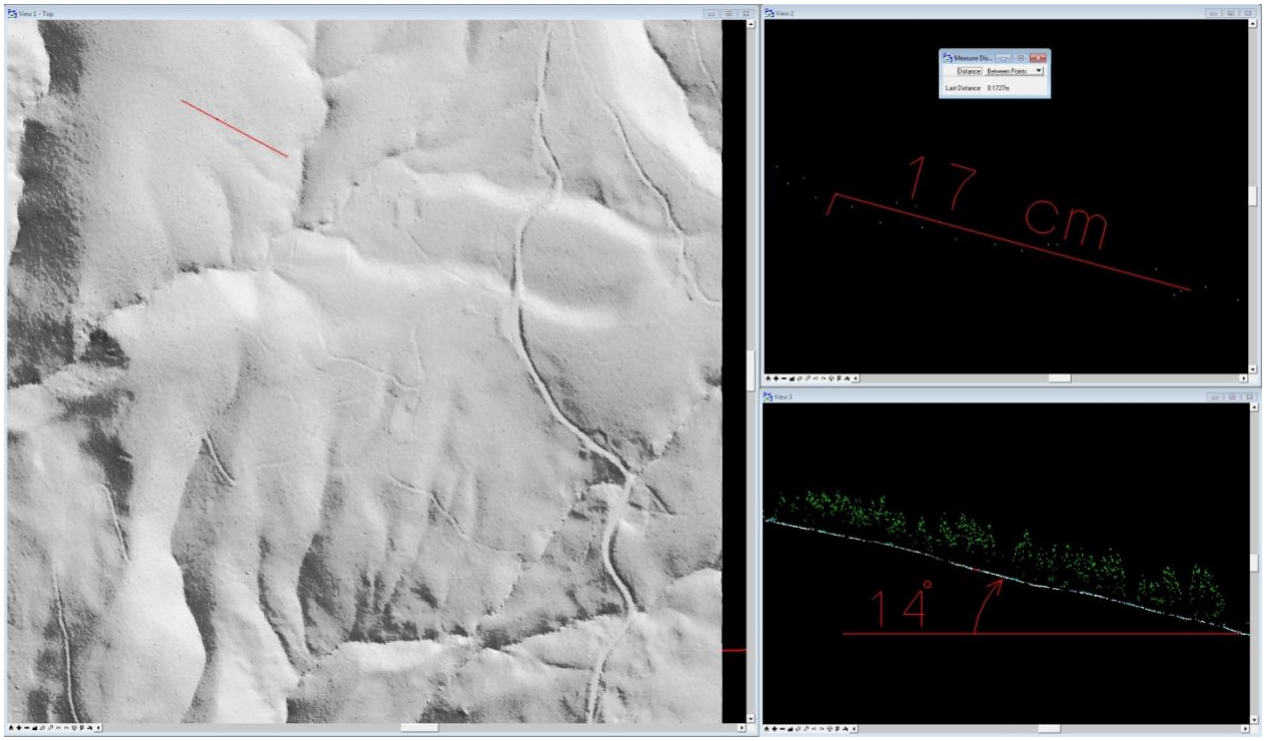
Ground Control Z vs. Aerial Surveyed/ Laser Pointing Z (QA/QC)

MULE-M4 SLIDE ANNEX

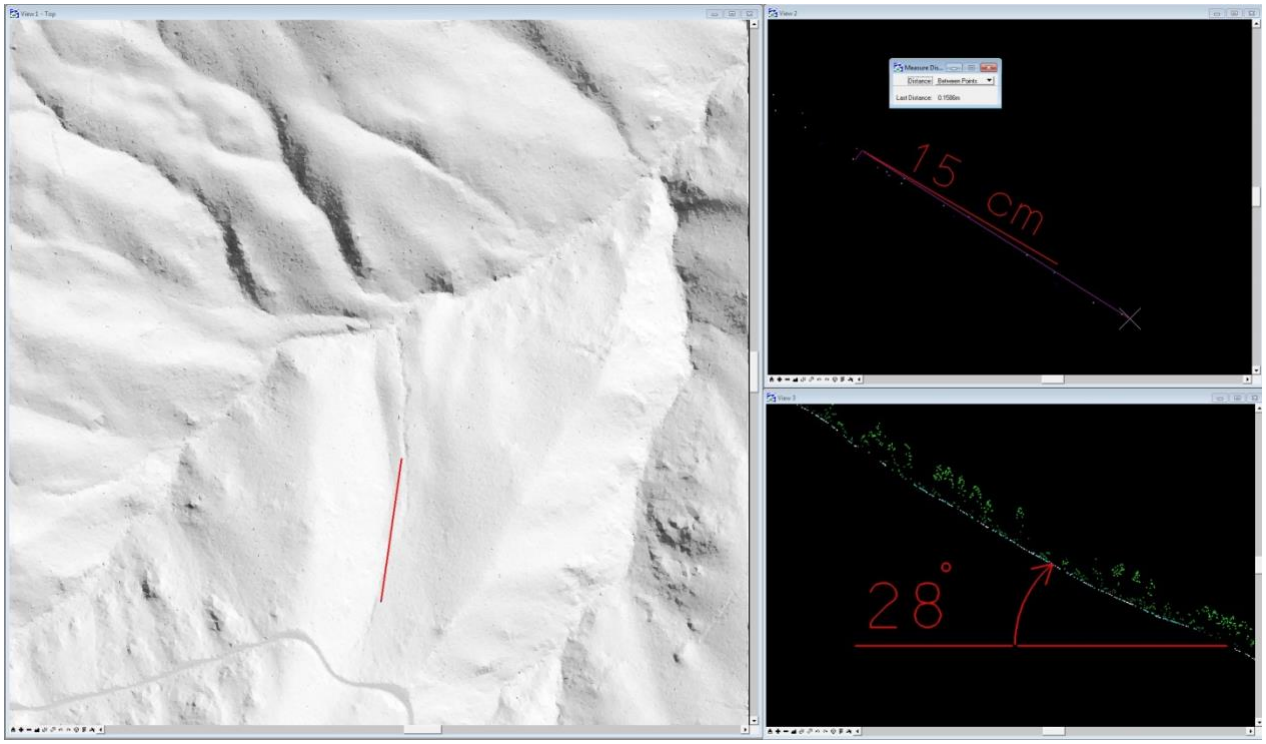
Number	Easting	Northing	Known Z	Laser Z	Dz
ML1	510575.836	4412731.597	1117.145	1117.180	+0.035
ML2	513295.987	4411307.957	1227.263	1227.150	-0.113
ML3	514517.550	4410453.544	1623.782	1623.860	+0.078
ML4	512928.512	4409327.255	1563.671	1563.730	+0.059
ML5	510156.774	4407573.583	1149.325	1149.260	-0.065
ML6	513310.885	4405313.149	1262.322	outside	*
ML7	518269.229	4408846.915	1471.610	outside	*
ML8	519151.333	4406471.518	1553.731	1553.750	+0.019
ML9	521431.337	4411471.870	1437.850	1437.940	+0.090
ML10	521790.744	4407344.864	1416.494	1416.370	-0.124
ML13	524440.996	4406155.264	1531.296	1531.270	-0.026
ML14	522690.793	4409454.932	1472.667	1472.730	+0.063
ML15	524784.625	4409553.738	1374.214	1374.320	+0.106
ML16	526776.962	4407895.574	1061.495	1061.400	-0.095

Average dz	+0.002
Minimum dz	-0.124
Maximum dz	+0.106
Average magnitude	0.073
Root mean square	0.080
Std deviation	0.083

14 DEGREE SLOPE



28 DEGREE SLOPE



40 DEGREE SLOPE