

Silver Plume, Colorado

Contact Information

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Survey Area

The survey area contained 3 polygons west of Silver Plume, Colorado. As shown in Figure 1, Area 1 is a 0.5 km² box located 8 km northwest, Area 2 is a 2.5 km² box located 12 km southwest, and Area 3 is a 3.5 km² irregular shaped polygon located 5 km southwest. These survey areas were flown and completed on September 29, 2005 (Day 272).

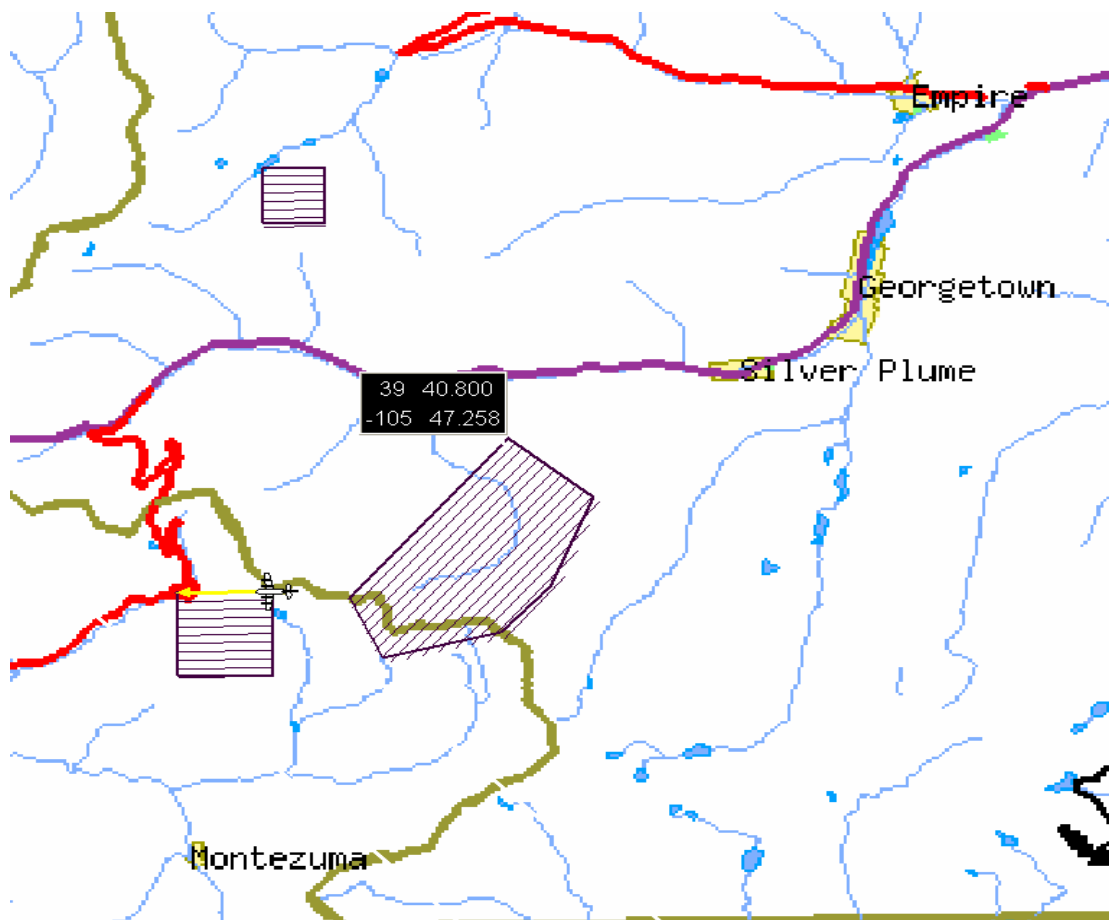


Figure 1. Survey areas located near Silver Plume, Colorado

Survey Parameters

The survey was conducted using an Optech 1233 Airborne Laser Terrain Mapper (<http://www.optech.ca/>) mounted in a twin engine Piper Chieftain (N931SA). Area 1 (lines 1-11) and Area 2 (lines 12-19) was surveyed together in a racetrack pattern heading east-west. Area 3 (lines 20-35) was oriented northeast-southwest and flown after the completion of the other two areas. A total of 35 flight lines were flown, plus two cross lines for field calibration purposes. Laser range was targeted at 600 m above ground level (AGL), but varied between 480-1000 m due to mountainous terrain. The aircraft speed was targeted at 135 knots. Figure 2 shows flight planning parameters for Silver Plume, Colorado.

Active Area			
◀	Area	1	of 3 ▶
Draw Area	Edit Corners	Generate Box	Load from File
Pass Orientation			
Optimize	<div><div></div></div> <div>0 30 60 90 120 150 180 210 240 270 300 330 360</div>		
Flight Profile		LIDAR Settings	
Altitude (m AGL)	600	System PRF (kHz)	33.33
Pass Heading (deg)	269	Scan Freq (Hz)	28
Overlap (m)	218.38	Scan Angle +/-	20
Speed (m/s)	70	Desired Res (m)	0.992
Turn Time (min)	7	Cross Track Res	0.734
Passes	11	Down Track Res	1.25
Pass Spacing (m)	218.38	Swath (m)	436.76
Survey Totals			
Total Passes	35	Swath Area (km ²)	25.788
Total Length (km)	118.083	AOI Area (km ²)	22.686
Total Flight Time	04:15:52	Total Laser Time	00:28:07

Figure 2. Flight planning parameters for Silver Plume, Colorado.

GPS Reference Stations

Two GPS reference station locations were established and used during the survey. Both stations were newly set marks at the La Quinta Inn & Suites in Louisville, Colorado. These marks were observed on September 27, 2005 (Day 270) for 5 hours and again on September 29 (Day 272 the day of the survey) for 12 hours. All GPS observations were logged at a 1-second rate and were submitted to the NGS online processor OPUS with solution files attached as Appendix A. Final coordinates for the reference stations were based on these OPUS solutions (<http://www.ngs.noaa.gov/OPUS/>). For more information on the CORS network, refer to <http://www.ngs.noaa.gov/CORS/>. Ground equipment at these stations included ASHTECH Z-Extreme receivers with choke ring antennas (Part #700936.D) mounted on a 1.5 m fixed-height tripod.

Navigation Processing

Airplane trajectories were processed using KARS (Kinematic and Rapid Static) software written by Dr. Gerry Mader of the NGS Research Laboratory. The KARS differential GPS solution is dual-frequency, phase-differenced, and fixed integer. Two separate airplane trajectories were processed in KARS software using our two reference stations and then coordinate differences between the separate solutions were plotted (Figure 3).

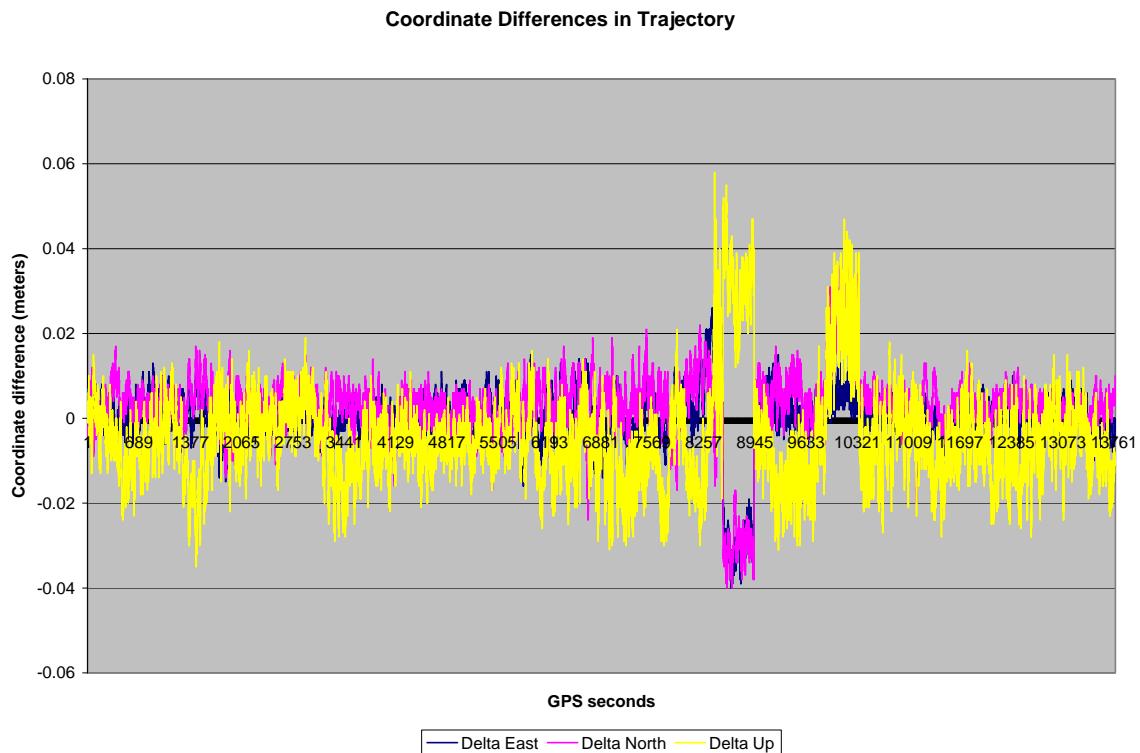


Figure 3. Positional differences in trajectory processed from Day 272.

Laser Point Processing

All coordinates were processed with respect to NAD83 and referenced to the national CORS network. The plane projection used for all output is UTM Zone 13, with ellipsoid heights, and units in meters.

The most complete output format is nine-column ASCII (space delimited), one file per flight strip. The nine columns are as follows:

1. GPS time (seconds of week)
2. Easting last stop
3. Northing last stop
4. Height last stop
5. Intensity last stop
6. Easting first stop
7. Northing first stop
8. Height first stop
9. Intensity first stop

Note that in these 9-column files no geoid model has been applied - height values are ellipsoid.

During processing, a scan cutoff angle of 0.5 degrees was used to eliminate points at the edge of the scan lines. This was done to improve the overall DEM accuracy (points farthest from the scan nadir are the most affected by small errors in pitch, roll and scanner mirror angle measurements). Points with very low intensity values were also filtered out (intensity values less than 7), because these points also tend to be the least accurate. This is due to the fact that very weak return pulses yield the noisiest range measurements. These points represent a very small percentage of the total number of points, usually in the neighborhood of a few hundredths of one percent.

All calibration files as well as all raw observation files (both GPS and ALTM) necessary to reprocess this project in its entirety are archived by UC Berkeley.

Ground Truth and Calibration

In order to provide on-site calibration and ground truth, a section of highway in Louisville was surveyed using vehicle-mounted GPS, and then surveyed with the ALTM. Comparisons were made between the heights of the vehicle-collected GPS and the processed points collected by the airborne laser scanner. This allowed for a check on the calibration of the airborne scanner as well as a measure of the accuracy of the scanner heights. Figure 4 shows a plot of the vehicle-mounted GPS ground truth points overlaid

onto a shaded relief image of the ALTM DEM of the calibration site. Coordinates are UTM Zone 13 (Meters).



Figure 4. Location of Calibration Site.

The standard deviation of the differences between the ALTM nearest neighbor shot and the ground truth points was about 8 cm. After analysis, a height shift of -0.20 meters was applied to the ALTM points. A relative calibration was also performed using TerraMatch software by TerraSolid. Results are shown in Table 1 – values in meters.

TerraScan Calibration			Site 1	Site 2	Site 3	Site 4	FINAL
Starting	average	dz:	0.28	0.60	0.08	0.69	0.411
Final	average	dz:	0.08	0.27	0.05	0.36	0.189
Standard	error		0.034	0.121	0.024	0.158	0.084
Points			944557	2588892	2321434	1838151	7693034
Roll	shift		0.0705	-0.0554	-0.012	-0.0567	-0.049
Pitch	shift		0.0238	0.0193	0.0009	0.0292	0.018
Mirror Scale			0.0068	-0.0067	-0.0011	-0.006	0.00514

Table 1 – TerraScan calibration results.

The roll, pitch, and scanner mirror scale calibration values from 4 sites within the project showed good agreement; the shifts were then applied to the parameter files in the laser-processing software.

Filtering and DEM Production

Digital elevation models (DEMs) were produced at 1.0 meter spacing for all areas from last stop elevations using Surfer 8 (Golden Software). Vegetation removal (filtering) was completed using TerraScan, an MDL application of Microstation. Areas with heavy

vegetation were marked with a fence and filtered within that boundary. Areas of no vegetation were not filtered to preserve and maximize all ground points.

The resulted Surfer grid tile set was exported to ESRI ArcInfo floating point binary format and using an in-house C++ application the overlap was trimmed from each tile. The trimmed tiles were exported to ESRI ArcInfo GRID format and merged into a seamless raster dataset for each of the 3 areas. Shaded relief maps and contour maps (from the filtered DEMs) were generated based on the seamless ArcInfo grids.

APPENDIX A.

GPS Reference Station Coordinates from OPUS

NGS OPUS SOLUTION REPORT
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USER: michael@ufl.edu
RINEX FILE: lq_s270s.05o

DATE: October 06, 2005
TIME: 14:21:07 UTC

SOFTWARE: page5 0411.19 master4.pl
EPHEMERIS: igr13422.eph [rapid]
NAV FILE: brdc2700.05n
ANT NAME: ASH700936D_M
ARP HEIGHT: 1.500

START: 2005/09/27 18:30:00
STOP: 2005/09/27 23:31:00
OBS USED: 10855 / 10932 : 99%
FIXED AMB: 41 / 43 : 95%
OVERALL RMS: 0.016(m)

REF FRAME: NAD_83(CORS96)(EPOCH:2002.0000) ITRF00 (EPOCH:2005.7394)

X:	-1280707.477(m)	0.015(m)	-1280708.169(m)	0.015(m)
Y:	-4726483.070(m)	0.016(m)	-4726481.760(m)	0.016(m)
Z:	4075524.323(m)	0.010(m)	4075524.255(m)	0.010(m)
LAT:	39 57 31.05860	0.014(m)	39 57 31.07946	0.014(m)
E LON:	254 50 20.21655	0.010(m)	254 50 20.17398	0.010(m)
W LON:	105 9 39.78345	0.010(m)	105 9 39.82602	0.010(m)
EL HGT:	1648.703(m)	0.017(m)	1647.829(m)	0.017(m)
ORTHO HGT:	1665.165(m)	0.030(m)	[Geoid03 NAVD88]	

	UTM COORDINATES	STATE PLANE COORDINATES
	UTM (Zone 13)	SPC (0501 CO N)
Northing (Y) [meters]	4423177.696	374282.191
Easting (X) [meters]	486244.442	943362.510
Convergence [degrees]	-0.10343261	0.21900632
Point Scale	0.99960233	0.99996977
Combined Factor	0.99934385	0.99971120

US NATIONAL GRID DESIGNATOR: 13SDE8624423178(NAD 83)

BASE STATIONS USED

PID	DESIGNATION	LATITUDE	LONGITUDE	DISTANCE(m)
AI2151	DSRC BOULDER CORS ARP	N395929.129	W1051539.675	9286.4
AF9516	TMGO TABLE MOUNTAIN CORS ARP	N400751.345	W1051357.717	20090.2
DG7429	P041 MARSHALL FIELD CORS ARP	N395658.150	W1051139.316	3015.3

NEAREST NGS PUBLISHED CONTROL POINT

KK1553	T 413	N395726.	W1050951.	308.5
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This position and the above vector components were computed without any knowledge by the National Geodetic Survey regarding the equipment or field operating procedures used.

NGS OPUS SOLUTION REPORT
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USER: michael@ufl.edu
RINEX FILE: lq_n272n.05o

DATE: October 06, 2005
TIME: 14:21:12 UTC

SOFTWARE: page5 0411.19 master3.pl
EPHEMERIS: igr13424.eph [rapid]
NAV FILE: brdc2720.05n
ANT NAME: ASH700936D_M
ARP HEIGHT: 1.500

START: 2005/09/29 13:49:00
STOP: 2005/09/30 01:51:00
OBS USED: 22200 / 25273 : 88%
FIXED AMB: 105 / 106 : 99%
OVERALL RMS: 0.009(m)

REF FRAME: NAD_83(CORS96)(EPOCH:2002.0000)

ITRF00 (EPOCH:2005.7448)

X:	-1280708.233(m)	0.014(m)	-1280708.925(m)	0.014(m)
Y:	-4726479.431(m)	0.030(m)	-4726478.121(m)	0.030(m)
Z:	4075528.332(m)	0.016(m)	4075528.264(m)	0.016(m)
LAT:	39 57 31.22721	0.010(m)	39 57 31.24807	0.010(m)
E LON:	254 50 20.14572	0.010(m)	254 50 20.10316	0.010(m)
W LON:	105 9 39.85428	0.010(m)	105 9 39.89684	0.010(m)
EL HGT:	1648.737(m)	0.032(m)	1647.863(m)	0.032(m)
ORTHO HGT:	1665.199(m)	0.041(m)	[Geoid03 NAVD88]	

	UTM COORDINATES	STATE PLANE COORDINATES
	UTM (Zone 13)	SPC (0501 CO N)
Northing (Y) [meters]	4423182.897	374287.385
Easting (X) [meters]	486242.771	943360.809
Convergence [degrees]	-0.10344535	0.21899360
Point Scale	0.99960233	0.99996977
Combined Factor	0.99934385	0.99971119

US NATIONAL GRID DESIGNATOR: 13SDE8624323183(NAD 83)

BASE STATIONS USED				
PID	DESIGNATION	LATITUDE	LONGITUDE	DISTANCE(m)
AI2151	DSRC BOULDER CORS ARP	N395929.129	W1051539.675	9282.8
AF9516	TMGO TABLE MOUNTAIN CORS ARP	N400751.345	W1051357.717	20084.7
DG7429	P041 MARSHALL FIELD CORS ARP	N395658.150	W1051139.316	3015.4

NEAREST NGS PUBLISHED CONTROL POINT				
KK1553	T 413	N395726.	W1050951.	309.7

This position and the above vector components were computed without any knowledge by the National Geodetic Survey regarding the equipment or field operating procedures used.

NGS OPUS SOLUTION REPORT

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USER: michael@ufl.edu
RINEX FILE: lq_n270s.05o

DATE: October 06, 2005
TIME: 14:18:39 UTC

SOFTWARE: page5 0411.19 master11.pl
EPHEMERIS: igr13422.eph [rapid]
NAV FILE: brdc2700.05n
ANT NAME: ASH700936D_M
ARP HEIGHT: 1.500

START: 2005/09/27 18:20:00
STOP: 2005/09/27 23:34:00
OBS USED: 11326 / 11415 : 99%
FIXED AMB: 43 / 45 : 96%
OVERALL RMS: 0.016(m)

REF FRAME: NAD_83(CORS96)(EPOCH:2002.0000)

ITRF00 (EPOCH:2005.7394)

X:	-1280708.235(m)	0.015(m)	-1280708.927(m)	0.015(m)
Y:	-4726479.422(m)	0.012(m)	-4726478.112(m)	0.012(m)
Z:	4075528.329(m)	0.009(m)	4075528.261(m)	0.009(m)

LAT:	39 57 31.22730	0.015(m)	39 57 31.24817	0.015(m)
E LON:	254 50 20.14554	0.011(m)	254 50 20.10298	0.011(m)
W LON:	105 9 39.85446	0.011(m)	105 9 39.89702	0.011(m)
EL HGT:	1648.729(m)	0.012(m)	1647.855(m)	0.012(m)
ORTHO HGT:	1665.191(m)	0.028(m)	[Geoid03 NAVD88]	

	UTM COORDINATES	STATE PLANE COORDINATES
	UTM (Zone 13)	SPC (0501 CO N)
Northing (Y) [meters]	4423182.900	374287.388
Easting (X) [meters]	486242.767	943360.804
Convergence [degrees]	-0.10344538	0.21899357
Point Scale	0.99960233	0.99996977
Combined Factor	0.99934385	0.99971119

US NATIONAL GRID DESIGNATOR: 13SDE8624323183(NAD 83)

BASE STATIONS USED

PID	DESIGNATION	LATITUDE	LONGITUDE	DISTANCE(m)
AI2151	DSRC BOULDER CORS ARP	N395929.129	W1051539.675	9282.8
AF9516	TMGO TABLE MOUNTAIN CORS ARP	N400751.345	W1051357.717	20084.7
DG7429	P041 MARSHALL FIELD CORS ARP	N395658.150	W1051139.316	3015.4

NEAREST NGS PUBLISHED CONTROL POINT

KK1553	T 413	N395726.	W1050951.	309.7
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This position and the above vector components were computed without any knowledge by the National Geodetic Survey regarding the equipment or field operating procedures used.

NGS OPUS SOLUTION REPORT

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USER: michael@ufl.edu
RINEX FILE: lq_s272n.05o

DATE: October 06, 2005
TIME: 14:28:12 UTC

SOFTWARE: page5 0411.19 master28.pl
EPHEMERIS: igr13424.eph [rapid]
NAV FILE: brdc2720.05n
ANT NAME: ASH700936D_M
ARP HEIGHT: 1.500

START: 2005/09/29 13:56:00
STOP: 2005/09/30 01:50:30
OBS USED: 24744 / 25031 : 99%
FIXED AMB: 86 / 86 : 100%
OVERALL RMS: 0.009(m)

REF FRAME: NAD_83(CORS96)(EPOCH:2002.0000)

ITRF00 (EPOCH:2005.7448)

X:	-1280707.469(m)	0.012(m)	-1280708.161(m)	0.012(m)
Y:	-4726483.072(m)	0.025(m)	-4726481.762(m)	0.025(m)
Z:	4075524.328(m)	0.014(m)	4075524.260(m)	0.014(m)

LAT:	39 57 31.05873	0.008(m)	39 57 31.07959	0.008(m)
E LON:	254 50 20.21689	0.009(m)	254 50 20.17433	0.009(m)
W LON:	105 9 39.78311	0.009(m)	105 9 39.82567	0.009(m)
EL HGT:	1648.706(m)	0.030(m)	1647.832(m)	0.030(m)
ORTHO HGT:	1665.168(m)	0.039(m)	[Geoid03 NAVD88]	

	UTM COORDINATES	STATE PLANE COORDINATES
	UTM (Zone 13)	SPC (0501 CO N)
Northing (Y) [meters]	4423177.700	374282.195
Easting (X) [meters]	486244.450	943362.518
Convergence [degrees]	-0.10343255	0.21900638
Point Scale	0.99960233	0.99996977
Combined Factor	0.99934385	0.99971120

US NATIONAL GRID DESIGNATOR: 13SDE8624423178(NAD 83)

BASE STATIONS USED

PID	DESIGNATION	LATITUDE	LONGITUDE	DISTANCE(m)
AI2151	DSRC BOULDER CORS ARP	N395929.129	W1051539.675	9286.4
AF9516	TMGO TABLE MOUNTAIN CORS ARP	N400751.345	W1051357.717	20090.2
DG7429	P041 MARSHALL FIELD CORS ARP	N395658.150	W1051139.316	3015.3

NEAREST NGS PUBLISHED CONTROL POINT

KK1553	T 413	N395726.	W1050951.	308.5
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This position and the above vector components were computed without any knowledge by the National Geodetic Survey regarding the equipment or field operating p