Mountain Navigation, Inc.

SURVEYORS OF LAND - HYDROGRAPHICS - UAS MAPPING - OFFROAD RACING

STATE OF UTAH - SANPETE VALLEY MAPPING PROJECT
CONTROL SURVEY REPORT OCTOBER 2018

10/25/2018

Control Survey Report

EXECUTIVE SUMMARY

Under contract with the State of Utah, Aerial Surveys International (ASI) performed an aerial Lidar acquisition campaign in portions of the Sanpete Valley in central Utah. As a member of ASI's Team, Mountain Navigations Inc. was responsible for establishing Lidar quality control check points and completing all of the computations required to support the airborne operations.

As part of the survey campaign, existing NGS Survey Control point's were recovered and verified and occupied as ground control base stations during Lidar flight data acquisition.

The survey was performed using a 3 dimensional geodetic network to include local TURN (The Utah Reference Network) NGS (National Geodetic Survey) CORS (Continuously operating Reference Stations) active control stations. The selected horizontal and vertical datum's upon which the Lidar data is processed are NAD83 (2011): epoch of 2010.0 and the North American Vertical Datum of 1988 (NAVD88) as realized by the published coordinates and ellipsoid heights of the TURN stations and the CORS and the absolute application of the geoid model, GEOID 12B. The Primary network satisfies the U.S. Federal Geodetic Control Subcommittee (FGCS) standards for Order B Geodetic GPS Surveys (8mm+1PPM).

In addition, a total of (10) ten Lidar control points and (52) fifty two check points were established and surveyed to demonstrate the absolute accuracy of the Lidar data throughout the original contracted survey area.
The check points consisted of a combination of bare earth and vegetated earth observations to satisfy the vertical accuracy assessment guidelines set forth in the "Positional Accuracy Standards for Digital Geospatial Data" by the ASPRS.

In summary, all of the projects geodetic surveying and mapping support goals were achieved. This report provides detailed documentation of all aspects of the work.

Mountain Navigation Inc.
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October, 2018

State of Utah - Sanpete Valley Mapping Project Control Survey Report October 2018

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1. Introduction

This document provides a comprehensive overview of the campaign to support the acquisition of high density Lidar data along the Sanpete Valley in Central Utah. The report describes the field survey procedures used to survey the Lidar Check points used in the QA/QC of the data. The survey made use of the existing TURN (The Utah Reference Network) and NGS CORS (Continuously Operating Reference Stations) control stations.

The check point survey occurred between September 17th and September 20th 2018, inclusive and October 28th and October 29th. During these periods, 62 points were observed across the project area.

1.1 Points of Contact

Please direct any questions regarding the contents of this document to:

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2. Primary Control Survey and Datums

2.1 Introduction

A primary geodetic network consisting of local TURN (The Utah Reference Network- www.turngps.utah.gov), *NGS-CORS (Continuously Operating Reference Stations – www.ngs.noaa.gov/CORS/), NGS Control Monuments and strategically placed base station points to support the survey campaign was established along the extent of the project mapping area (see Figure 1). The Networks consist of 5 TURN stations, 4 NGS CORS Stations. The NGS control points occupied are identified by their NGS Point Identification (PID).*

Independent TURN and CORS observation data were downloaded in the days prior to the field survey to verify operability, data availability and relative baseline observations between active control stations. The remaining baselines were observed using the data from the base station occupations during acquisition on check point observations on the respective days of field observation.

2.2 Project Survey Datums

The horizontal datum for this project is NAD83 (2011), epoch 2010.0. The datum is realized by the published coordinates of TURN and CORS active reference station websites respectively.

The Vertical datum for this project is NAVD88. The datum is realized by the published ellipsoid heights of TURN and CORS and the absolute application of GEOID12B, these values were obtained via the TURN and CORS websites.

2.3 Field Equipment and Procedures

All GNSS/GPS observations were accomplished using the Trimble Navigation, Model R8 GNSS receivers. Relative position Static Surveying techniques were used for all baseline observations. Instrument heights were measured using both (US-FT) US Survey Feet and (M) Meters before and after the observation session. The values were then reduced and checked in the field prior to departure from the current survey location. In addition ground images were obtained to verify the surface features and vegetation type for Lidar data processing.

In general check point data sites were logged for a minimum of 30 minutes and for as much a 90 minutes depending on the average baseline distance to the TURN and CORS control stations.

2.4 Primary Survey Network and Adjustment

Observed relative GNSS baselines were processed using Trimble Business Center geodetic software. All processed observations consist of Quasi-independent baselines (i.e. in accordance with the "n-1 baselines rule" (where n = the number of receivers in a given static GNSS observation session). The International GPS Service for Geodynamics (IGS) rapid precise orbits (igr) were used in the processing of the baseline vectors. The "igr" orbits are published with a latency of 30 hours. These orbit calculations are globally accurate to within >5cm and are utilized in the processing of baselines over 10,000 meters.

One primary survey network was designed to provide a basis for the Lidar project control and establishing additional quality control points throughout the project area. A minimally constrained

adjustment was performed to verify the internal integrity of the network and establish *a priori* weights factor for the GNSS observations and determine the internal integrity of the control stations.

The GNSS baselines vector components were adjusted using Trimble Business Center Geodetic processing software (version 3.61) in the resulting adjustments, the estimated variances for all networks passed the X/2-test indicating appropriate *a priori* estimates for the accuracy of the GNSS baseline vectors. None of the respective vector component residual or associated standardized residuals were flagged for possible rejection under the *t-max* test at 95% level of confidence. The relative horizontal accuracy of the network can be assessed by reviewing the relative 95% confidences regional ellipses of the adjustment. All station parings meet the Federal Geodetic Control Subcommittee (FGCS) relative positioning standard of Order B surveys (8mm+1ppm).

In a second, fully constrained adjustment of the network the published coordinates of the TURN and CORS were held and weighted constraints along with the publishes ellipsoidal heights (see table 3). The estimated variance factor of (1.960) indicates that the network is not being unduly distorted by the imposition of the constraints and is maintaining its internal integrity. The adjustment yields coordinates on the NAD83 (2011), epoch 2010.0 and orthometeric elevations relative to NAVD88/GEIOD12B geoidal model (see Table 1 and appendix I for the adjusted coordinate and elevation values).

The final adjustment was run to incorporate the control and check point observations. The adjusted coordinate values from the fully constrained adjustment were held as fixed constraints to derive the final coordinate and elevation values of the check points. Appendix I tabulates the final adjusted coordinate and elevation values of all surveyed points.

Primary Survey Control Network

Source:
UTMN-NGS CORS
PUC2- NGS CORS
P105- NGS CORS
P009- NGS CORS
SPIC- TURN CORS
P108-TURN CORS
P109-TURN CORS
P110-TURN CORS
P112-TURN CORS

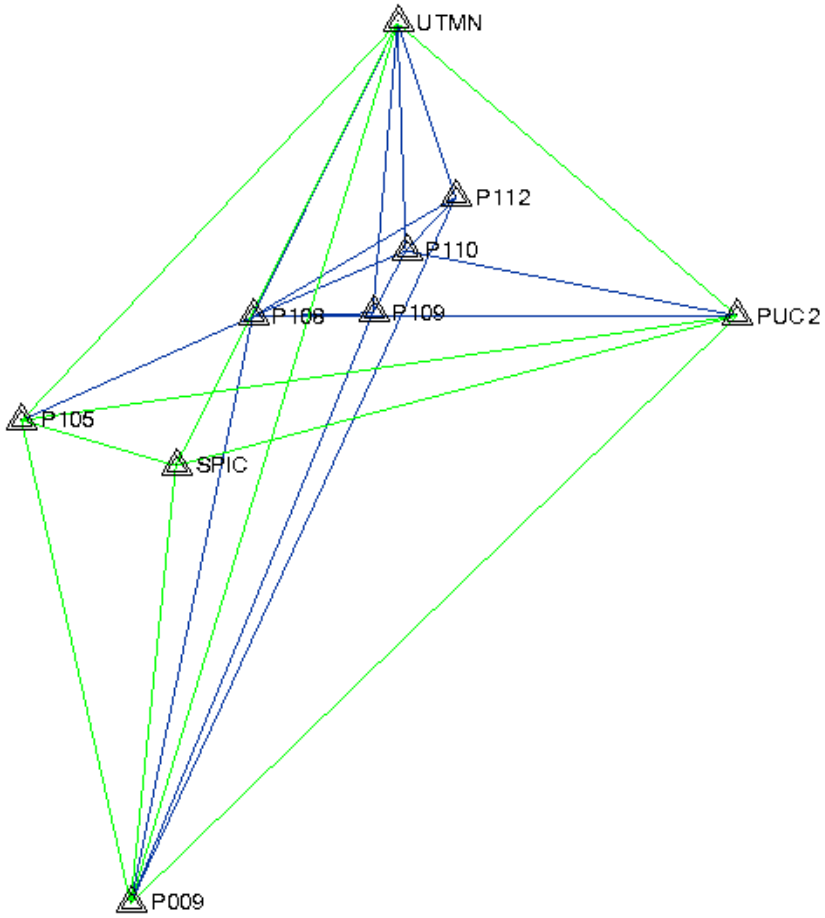

Table 1

Primary Network Adjustment Weighted Constraints
Horizontal Datum: NAD83 (2011)
Epoch 2010.0
Linear units: Meter

Point	Source	Latitude	Longitude	Ellipsoid Height	Adjustment Constraint
UTMN	*NGS*	*N* 40° 08′ 39.69951"	W 111° 35' 44.07502"	1426.992	*L, L, h*
PUC2	*NGS*	*N* 39° 35′38.10058"	W 110° 45' 41.52524"	1714.225	*L, L, h*
P105	*NGS*	*N* 39° 23′15.14007"	W 112° 30' 14.66907"	1432.213	*L, L, h*
P009	*NGS*	*N* 38° 28′47.73269"	W 112° 13' 21.72562"	1762.278	*L, L, h*
SPIC	*TURN*	*N* 39° 18′22.35386"	W 112° 07' 38.86225"	1671.188	*L, L, h*
P108	*TURN*	*N* 39° 35′19.94567"	W 111° 56' 40.33561"	1684.009	*L, L, h*
P109	*TURN*	*N* 39° 35′50.93095"	W 111° 39' 02.95024"	1761.718	*L, L, h*
P110	*TURN*	*N* 39° 42′ 54.80178	W 111° 34' 16.06279"	2266.974	*L, L, h*
P112	*TURN*	*N* 39° 49′00.84356"	W 111° 26' 59.93845"	1931.130	*L, L, h*

3.0 LIDAR CONTROL and CHECK POINTS

3.1 Introduction

In order to control and validate the accuracy of the Lidar data, (62) Lidar control and check points were surveyed in the project area. Of the 62 Lidar points observed on the project, the following breakdowns of point classification were reported.

- (10) Lidar Ground Control Points
- (32) Non-Vegetated Vertical Area (NVA)
- (7) Vegetated Vertical Area Bare Earth (VVA-B)
- (6) Vegetated Vertical Area Forest (VVA-F)
- (7) Vegetated Vertical Area Grass (VVA-G)

3.2 Survey Observations and Data Processing

At each of the Lidar control and check points, a Static GNSS/GPS observation was acquired for a minimum of 30 minutes using a Trimble Navigation R8 GNSS receiver.

The Static measurements were post-processed against the TURN Stations and NGS-CORS stations operating in the in the project area at the time of check point observations. The processing and network adjustment procedures were completed using Trimble Business Center geodetic software.

The final adjusted coordinates of the control and check points were derived via network adjustment of the resulting observed baselines. The published coordinates and ellipsoid heights of the TURN and CORS stations were held fixed for the network adjustment. The latest published Geoid model, Geoid12B was applied to derive the orthometeric elevations.

3.3 Lidar Control and Check Point Results

Ground images of the control and check points were taken at the time of survey and are available for each of the 62 locations.

See appendix I for a listing of the final control values.

Appendix I
Final Coordinates and Elevations

Sanpete Valley, Utah Lidar Campaign
Final Adjusted Coordinates

Horizontal Datum: NAD83(2011): Epoch 2010.0
Vertical Datum: NAVD88
Projection: UTM Zone 12
Unit of Measure: Meter

Point ID	Latitude	Longitude	Ellipsoid Height	Northing	Easting	Elevation
GNSS/GPS Base Stations						
UTMN	N40°08'39.69951"	W111°35'44.07502"	1426.992	4443950.070	449268.841	1444.090
PUC2	N39°35'38.10058"	W110°45'41.52524"	1714.255	4382714.698	520475.394	1731.156
P105	N39°23'15.14007"	W112°30'14.66907"	1432.213	4360862.614	370470.053	1451.391
P009	N39°35'50.93095"	W111°39'02.95024"	1761.718	4259774.098	393351.594	1781.404
P108	N39°35'19.94567"	W111°56'40.33561"	1684.009	4382553.919	418892.408	1702.067
P109	N39°35'50.93095"	W111°39'02.95024"	1761.718	4383285.370	444121.199	1779.146
P110	N39°42'54.80178"	W111°34'16.06279"	2266.974	4396306.407	451046.573	2283.903
P112	N39°49'00.84356"	W111°26'59.93845"	1931.130	4407532.183	461487.128	1947.668
SPIC	N39°18'22.35386"	W112°07'38.86255"	1671.188	4351363.770	402792.052	1689.367

Point ID	Latitude	Longitude	Ellipsoid Height	Northing	Easting	Elevation
Lidar Control and Check Points						
CTL-ALT-1	N 39°46'29.30268"	W 111°29'29.02865"	1803.088	4402878.864	457916.954	1819.837
CTL-ALT-2	N 39°12'25.37859"	W 111°39'54.04686"	1784.263	4339964.144	442583.300	1801.950
CTL-ALT-3-V-ONLY	N 39°20'22.99150"	W 111°40'44.70947"	1643.659	4354696.615	441478.713	1661.404
CTRL-ALT-4-2	N 39°38'12.24467"	W 111°39'00.47151"	1822.825	4387641.496	444211.839	1840.170
CTL-ALT-5	N 39°38'04.15960"	W 111°26'24.10267"	1810.857	4387282.824	462239.729	1827.667
CTL-ALT-6	N 39°21'39.57045"	W 111°34'47.15927"	1678.689	4356997.743	450052.935	1696.105
CTL-ALT-7	N 39°32'03.34517"	W 111°34'51.96970"	1704.628	4376228.199	450061.739	1722.099
CTL-ALT-8	N 39°29'30.11212"	W 111°29'38.42591"	1749.390	4371459.593	457520.594	1766.552
CTL-ALT-9	N 39°33'10.80531"	W 111°27'43.88366"	1770.144	4378248.661	460291.484	1787.162
CRL-ALT-10	N 39°27'57.17531"	W 111°38'48.59181"	1744.967	4368677.723	444358.694	1762.501
NVA-H-1	N 39°48'16.50647"	W 111°29'16.75854"	1802.820	4406182.328	458226.861	1819.536
NVA-H-2	N 39°38'03.50544"	W 111°38'04.87960"	1793.405	4387362.596	445535.051	1810.743
NVA-H-3	N 39°37'36.23470"	W 111°26'20.88120"	1798.343	4386421.557	462312.311	1815.167
NVA-H-4	N 39°32'12.00740"	W 111°26'56.62199"	1803.994	4376430.306	461410.341	1820.945
NVA-H-5-2	N 39°31'14.43450"	W 111°35'22.01194"	1667.128	4374725.024	449334.710	1684.631
NVA-H-7	N 39°16'29.79583"	W 111°38'18.59311"	1678.007	4347482.323	444925.715	1695.626
NVA-H-8	N 39°28'39.78725"	W 111°29'38.80970"	1769.108	4369908.223	457502.919	1786.253
NVA-H-9	N 39°29'03.48938"	W 111°38'20.78687"	1713.265	4370717.327	445037.591	1730.802
NVA-H-10	N 39°32'33.42536"	W 111°39'04.23974"	1751.912	4377196.751	444046.360	1769.401
NVA-H-11	N 39°19'39.39341"	W 111°36'52.08891"	1656.536	4353312.748	447038.076	1674.099
NVA-H-12-2	N 39°42'20.24241"	W 111°28'12.56157"	1942.537	4395190.714	459695.739	1959.264
NVA-H-13	N 39°12'16.95799"	W 111°40'56.94813"	1683.510	4339715.778	441072.762	1701.304
NVA-H-14	N 39°37'11.92228"	W 111°26'19.81603"	1785.410	4385671.910	462334.043	1802.248
NVA-15	N 39°43'50.26645"	W 111°31'07.29469"	1929.286	4397989.035	455550.927	1946.118
NVA-16	N 39°39'22.91995"	W 111°39'07.81830"	1876.373	4389821.621	444052.543	1893.661
NVA-17	N 39°39'31.67923"	W 111°33'17.41392"	1963.335	4390035.530	452404.244	1980.418
NVA-18	N 39°35'10.47440"	W 111°37'37.62309"	1696.011	4382023.677	446147.546	1713.463
NVA-19	N 39°33'48.51010"	W 111°29'32.74404"	1725.524	4379424.825	457699.886	1742.669
NVA-20	N 39°33'59.07329"	W 111°33'50.60824"	1778.591	4379786.606	451548.898	1795.973
NVA-21	N 39°25'09.61699"	W 111°38'34.36730"	1662.372	4363509.799	444661.766	1679.958
NVA-22	N 39°25'56.34727"	W 111°33'42.72234"	1664.670	4364903.837	451644.232	1682.099
NVA-23	N 39°28'35.94239"	W 111°32'38.36299"	1673.562	4369814.401	453212.518	1690.941
NVA-24	N 39°20'25.16810"	W 111°40'42.32714"	1643.882	4354763.286	441536.245	1661.625
NVA-25	N 39°22'38.40138"	W 111°39'07.03351"	1650.628	4358853.758	443847.017	1668.287
NVA-26	N 39°17'05.90651"	W 111°41'17.88974"	1636.617	4348627.005	440638.195	1654.426
NVA-27	N 39°15'18.85972"	W 111°39'35.44104"	1661.796	4345308.775	443068.483	1679.509
NVA-28	N 39°40'28.98671"	W 111°25'28.36091"	1906.652	4391741.295	463589.563	1923.293
NVA-29	N 39°42'40.22850"	W 111°36'15.41893"	2067.050	4395875.748	448201.739	2084.060
NVA-30	N 39°23'31.02566"	W 111°33'22.74526"	1705.544	4360420.935	452094.194	1722.878
NVA-31	N 39°28'45.77398"	W 111°32'31.09549"	1684.021	4370116.444	453387.971	1701.393
NVA-32	N 39°22'37.51916"	W 111°38'58.05028"	1648.348	4358825.013	444061.748	1666.005

Point ID	Latitude	Longitude	Ellipsoid Height	Northing	Easting	Elevation
Lidar Control and Check Points						
VVA-B-1	N 39°42'26.74904"	W 111°28'04.40914"	1932.459	4395390.293	459890.916	1949.177
VVA-B-2	N 39°18'21.58265"	W 111°36'30.09846"	1683.876	4350910.490	447548.438	1701.362
VVA-B-3	N 39°20'28.89105"	W 111°32'52.61282"	1857.690	4354801.768	452780.909	1874.817
VVA-B-4	N 39°47'52.69409"	W 111°27'17.84582"	1914.308	4405433.304	461050.711	1930.888
VVA-B-5	N 39°42'40.16218"	W 111°36'16.13317"	2066.063	4395873.818	448184.719	2083.074
VVA-B-6	N 39°17'06.87078"	W 111°41'18.26875"	1637.960	4348656.800	440629.341	1655.769
VVA-B-7	N 39°23'30.53871"	W 111°33'23.76154"	1705.626	4360406.074	452069.792	1722.962
VVA-F-3	N 39°38'43.90139"	W 111°24'22.37699"	1964.773	4388494.349	465146.856	1981.381
VVA-F-4	N 39°33'20.33279"	W 111°39'33.11758"	1840.045	4378647.860	443367.676	1857.503
VVA-F-1-2	N 39°46'05.93641"	W 111°29'03.88348"	1823.972	4402155.232	458511.233	1840.702
VVA-F-2-2	N 39°41'43.92622"	W 111°38'49.48287"	1955.122	4394165.578	444520.817	1972.268
VVA-F-5-2	N 39°20'29.12853"	W 111°32'54.83588"	1853.016	4354809.412	452727.739	1870.149
VVA-F-6-2	N 39°17'58.24534"	W 111°36'22.95003"	1705.906	4350189.915	447714.817	1723.360
VVA-G-1-2	N 39°32'02.14628"	W 111°38'48.06693"	1721.997	4376229.679	444425.456	1739.500
VVA-G-2-2	N 39°28'37.06919"	W 111°32'34.70852"	1675.689	4369848.611	453300.038	1693.064
VVA-G-3-2	N 39°22'47.25679"	W 111°38'51.80204"	1648.909	4359124.128	444213.393	1666.560
VVA-G-4-2	N 39°12'22.02725"	W 111°40'44.11698"	1683.966	4339869.736	441381.677	1701.741
VVA-G-5-2	N 39°37'23.86546"	W 111°25'45.08664"	1799.911	4386036.104	463163.823	1816.699
VVA-G-6-2	N 39°39'59.35441"	W 111°26'01.64319"	1862.397	4390831.551	462792.255	1879.099
VVA-G-7-2	N 39°19'31.26399"	W 111°36'36.57509"	1664.091	4353059.624	447407.820	1681.626