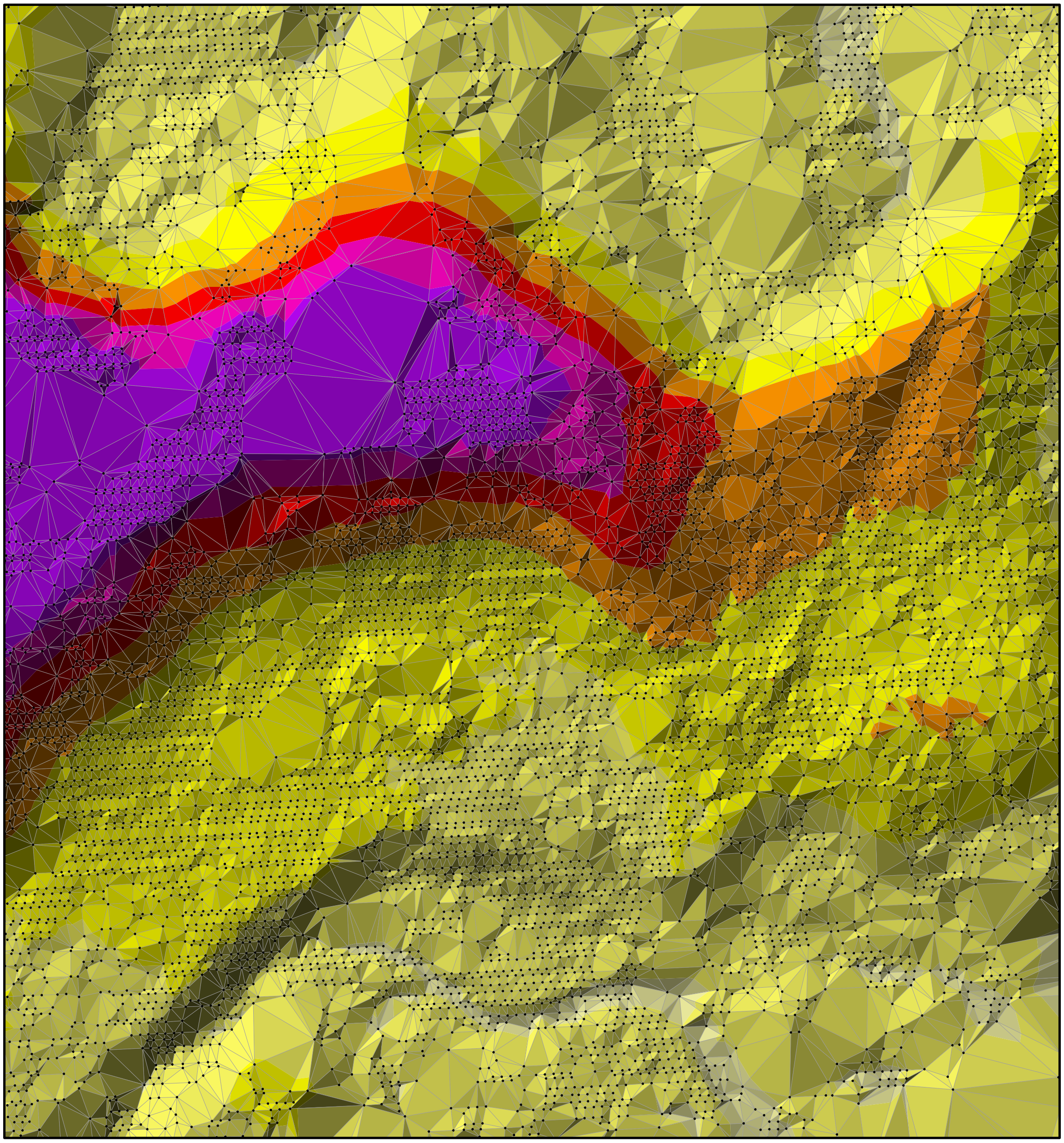
Quality Assurance Report

ENPLAN LIDAR SURVEY CAMPAIGN



January 2006

SANBORN

EXECUTIVE SUMMARY

In the summer of 2004, Sanborn was contracted by ENPLAN to execute a LIDAR (Light Detection and Ranging) survey campaign covering portions of Shasta, Tehama, and Siskiyou counties in California. LIDAR data in the form of three-dimensional positions of a dense set of masspoints was collected for the areas given by the project specifications. The masspoint data was used in the development of digital elevation models (DEMs) delivered for first return, last return, and bare earth datasets.

The LIDAR operation was designed to provide a ground surface dataset with a vertical accuracy of 0.15m (0.5') at 1 sigma. This accuracy specification is equal to that of Sanborn's ALTM (Airborne Laser Terrain Mapping) LIDAR system manufactured by Optech and used for this project. In practice, our refined operational procedures and rigorous post-processing yield accuracies that typically exceed this specification.

The system was calibrated by conducting flight passes over a known ground surface before and after each LIDAR mission. During final data processing, the calibration parameters were inserted into post-processing software. Validation testing of the data showed that accuracy goals were exceeded with an average RMS error of 0.070m (0.23') over 28 test runs. These results were commensurate with Enplan's specified accuracy objective for the campaign.

A control network of five airborne GPS (Global Positioning System) base stations was used in this project. The network design was in accordance with the quality assurance specifications set by Sanborn's licensed surveyors, California included, as well as recommendations by Optech. Four base stations were set on National Geodetic Survey (NGS) markers located at or near the airports. Station 701 was set on the NGS monument at the East North-East side of the Benton Airport. Station 702 was set on the NGS monument at Redding Municipal Airport. Point 801 and 803 were set up on the NGS monuments at the Mott and Bidwell Airports respectively. Point 802 was also set up on an NGS monument in the project area. The above stations were tied to three additional CORS stations to create a GPS network at the common datum. The network observations and adjustments were completed on the GRS80 ellipsoid.

The acquired LIDAR data was initially processed to obtain first and last return point data. Return Intensity values were also provided within the first return point data. The last return data was then further filtered to yield a LIDAR surface representing bare earth. All three datasets were subsequently delivered to Enplan.

The contents of this report summarize the methods used to establish the base station network, perform the LIDAR data collection and post-processing, as well as the results of these methods.

Sanborn's Project Team responsible for production consisted of:

Karen Adkins - Project Manager
Keith Kirkby - LiDAR Manager/Geodetic Engineer
David Sutherland – Geodetic Engineering Technician
Doug Novy – Programmer Analyst/LiDAR Processing and QC

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1. INTRODUCTION

This report contains the technical description of the ENPLAN LIDAR campaign, including system calibration techniques, the establishment of base stations by a differential GPS network survey, collection and post-processing of the LIDAR data, and QA/QC results.

1.1 Duration and Time Period

The LIDAR aircraft arrived on site July 23, 2004 and the LIDAR data collection was accomplished between this date and July 28, 2004. The Benton, Redding, Mott, and Bidwell airports were used as the airfields of operation.

1.2 Contact

Questions regarding the technical aspects of this report should be addressed to:

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1.3 Purpose of the LIDAR Acquisition

This LIDAR operation was designed to provide first return, last return, and bare earth datasets for the area of coverage specified by ENPLAN .

1.4 Project Location

The project location is defined by a full tile layout of the coverage area which included portions of Shasta, Tehama, and Siskiyou counties.

1.5 Project Scope

The ENPLAN campaign was designed to collect LIDAR derived masspoints at an approximate ground spacing of 1.5 meters or less within the project area. The data was processed to facilitate the generation of an appropriate DEM for topographic mapping and other geospatial representations.

1.6 Datum Issues

Five existing NGS monuments were set to be used as Airborne GPS base stations for this project. In order to obtain accurate horizontal and vertical coordinates for these stations and adjust them to a common datum, a ground control network was surveyed using GPS and tied to 3 CORS stations. A fully constrained adjustment was run on the network defining the horizontal and vertical datums through the published coordinates and heights of NGS monuments.

1.6.1 Horizontal Datum

The horizontal datum associated with the LIDAR data is NAD83 (1992), as realized by the physical control monuments used to constrain the survey control network.

1.6.2 Vertical Datum

The vertical datum associated with the LIDAR data is NAVD88, as realized by the physical benchmarks used to constrain the survey control network.

2. LIDAR CALIBRATION

2.1 Introduction

LIDAR calibrations are performed to determine and therefore eliminate systematic biases that occur within the hardware of the ALTM system. Once the biases are determined they can be modeled out. The systematic biases that are corrected for include scale, roll, and pitch.

The following procedures are intended to eliminate potential mistakes in the field and office work, and are designed to detect inconsistencies. The emphasis is not only on the quality control (QC) aspects, but also on the documentation, i.e., on the quality assurance (QA).

2.2 Standard Calibration Procedures

Sanborn performs two types of calibrations on its LIDAR system. The first is a building calibration. New calibration parameters are computed and compared with previous calibration runs. If there is any change, the new values are updated internally or during the LIDAR post-processing. These values are applied to all data collected with this particular plane/ALTM system configuration.

Second, once final processing calibration parameters are established from the building data, a precisely-surveyed surface is observed with the LIDAR system to check for stability in the system. This is done several times during each mission. An average of the systematic biases is applied on a per mission basis.

2.2.1 Building Calibration

The rooftop of a large, flat, rectangular building was surveyed on the ground using conventional survey methods, and used as the LIDAR calibration target. Several specified passes were flown over the building with the ATLM system set in both scan and profile (fixed scan angle) modes.

Figure 1 shows a typical pass over the center of a building. The purpose of this pass is to identify a systematic bias in the scale of the system.

Figure 2 shows a pass along a distinct edge of a building to verify the roll compensation performed by the INS.

Additionally, a pass is made in profile mode across the middle of the building to compensate for any bias in pitch.

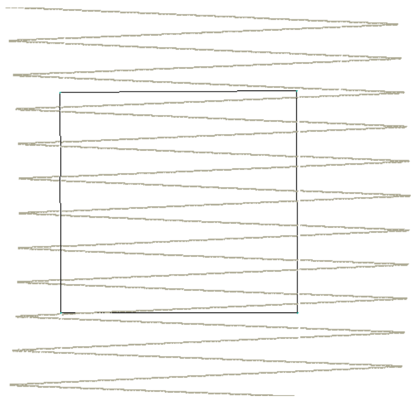

Figure 1. Calibration Pass 1

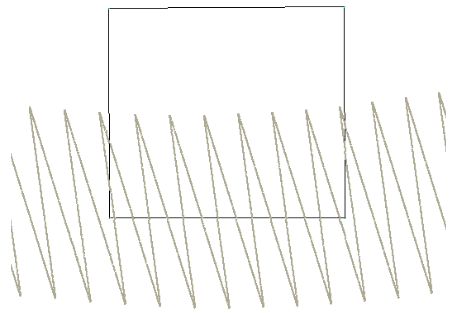

Figure 2. Calibration Pass 2

2.2.2 Runway Calibration and System Performance Validation

For the purpose of the ENPLAN lidar campaign, active asphalt runways were precisely-surveyed at Benton, Redding, Mott, and Bidwell airports using kinematic GPS survey techniques (accuracy: ±3cm at 1σ, along each coordinate axis) to establish an accurate digital terrain model of the runway surface. The LIDAR system was then flown at right angles over the runway several times and residuals were generated from the processed data. Figure 3 shows a typical pass over the runway surface.

Approximately 25,000 LIDAR points are observed with each pass. These points are "draped" over the runway surface TIN (Triangular Irregular Network) to compute vertical residuals for every data point. The residuals are then analyzed with respect to the location *along* the runway to identify the level of noise and system biases.

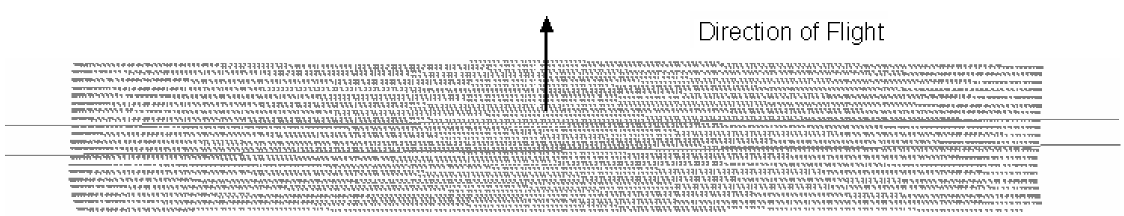

Figure 3. Runway Calibration

The runway over-flights are intended to be a quality check on the calibration and to identify any system irregularities and the overall noise. IMU misalignments and internal system calibration parameters are verified by comparing the collected LIDAR points with the runway surface.

Figure 4 shows the typical results of a runway over-flight analysis. The X-axis represents the position *along* the runway. The overall statistics from this analysis provides evidence of the overall random noise in the data (typically, 7cm standard deviation – an unbiased estimator, and 8cm RMS which includes any biases) and indicate that the system is performing within specifications. As described in later sections of this report, this analysis will identify any peculiarities within the data along with mirror-angle scale errors (identified as a “smile” or “frown” in the data band) or roll biases.

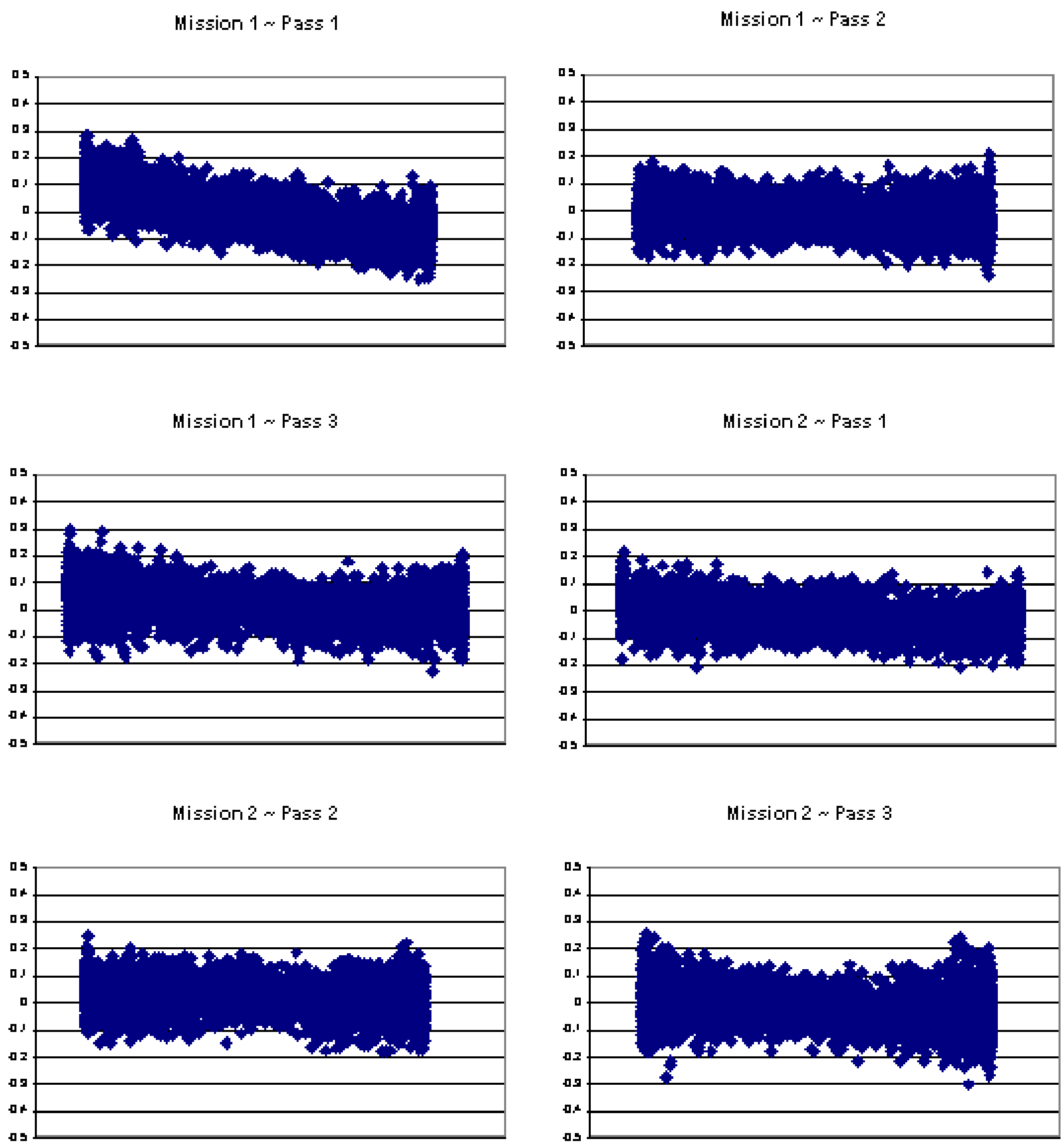

Figure 4. Runway Calibration Results

3. Geodetic Base Network

3.1 Network Scope

Five existing NGS monuments were used as Airborne GPS base stations. The points were choosen within project boundaries, where a GPS receiver can be set up and left to log data for the duration of the LIDAR flight mission. Three additional CORS stations were involved in network adjustment.

During the LIDAR campaign, the Sanborn field crew conducted a GPS field survey to establish a survey network (Figure 5) containing the GPS base stations used to support the campaign. Point number 701 is an existing NGS monument located at Benton Airport. Point number 702 is an existing NGS monument located at Redding Airport. Also, point numbers 801 and 803 are the existing monuments located at Mott and Bidwell airports respectively. Point 802 is also a NGS monument in the project area that was used as an airborne GPS base station. See Table 2 for station names, orders and constraints.

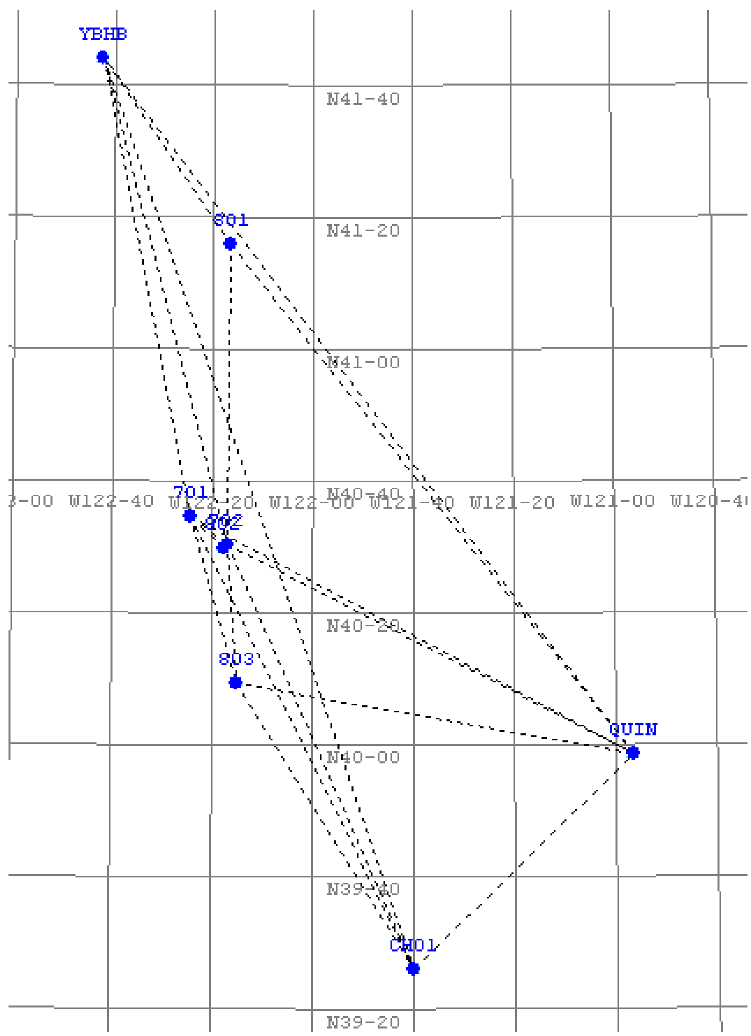

Figure 5. Survey Network Diagram

3.2 Data Processing and Network Adjustment

All static baseline vectors were processed using Trimble Navigation's GPSurvey™ (Ver. 2.35a) software. Fixed bias solutions were obtained for all baselines. The broadcast ephemeris was used, since the accuracy and extent of the network does not warrant the use of the precise ephemeris.

The loop misclosures are summarized in Table 1 below.

The misclosures in each component (X, Y and Z) are given in millimeters and parts per million (ppm) in an ECEF Cartesian coordinate system. The spatial misclosure in ppm is also provided. All loops comprise of quasi-independent baselines from at least two different sessions. Every station in the network appears at least once in a loop. All loops, in fact, satisfy GPS guidelines for first order work, namely:

- in any component (X, Y, Z), the maximum misclosure does not exceed 250 mm ,
- in any component (X, Y, Z), the maximum misclosure in terms of the loop length does not exceed 12.5 ppm,
- in any component (X, Y, Z), the average misclosure in terms of the loop length does not exceed 8 ppm.

Table 1. Survey Loop Closure Summary

Loop	dX (cm)	dY (cm)	dZ (cm)	Dist. (m)	ppm
701-YBHB-801-802-701	1.5	3.4	1.1	292097	0.40
803-701-802-801-702-803	2.4	4.9	6.6	270121	0.32
803-702-801-QUIN-803	4.6	4.8	0.6	419156	0.16
CHO1-803-QUIN-CHO1	0.9	0.2	0.1	294206	0.03

A 3-dimensional network adjustment was carried out using GeoLab™ (version 3.61) 3-D adjustment software. The network is displayed in Figure 5.

Initially, a minimally constrained adjustment was performed to examine the internal accuracy of the network. The geodetic latitude, longitude, and elevation of one existing control point were held fixed. The adjustment comprises 8 stations and 33 baseline vector components (11 baselines). *A priori* weights for the observations were based on the (scaled) variance-covariance sub-matrices from the GPSurvey™ solutions.

The relative confidence regions and the associated relative horizontal and vertical precisions were computed for all pairs of points that were directly connected by vectors. All station pairings with the exception of one (801 to 702) meet the horizontal positioning standard for *first order* surveys, i.e., the relative horizontal precision between each pair of points does not exceed 10 mm + 10 ppm of their horizontal separation, at the 95 percent level of confidence. The network is therefore classified as *first order* in terms of its *internal* accuracy.

To complete a fully constrained adjustment, the network was horizontally constrained to control points 701, 702, QUIN, YBHB and CHO1 and vertically constrained by orthometric elevation to 901 and 801. See Table 2 for associated orders and assigned standard deviations.

TABLE 2. NETWORK ADJUSTMENT CONSTRAINTS
(standard deviations in meters)

Horizontal

Code	NGS Station Name	Order	ϕ	λ
701	REDDING	1	0.01	0.01
702	REDDING CBL O C	2	0.04	0.04
QUIN	QUINCY CORS L1	A(SPECIAL)	0.04	0.04
YBHB	YREKA CORS L1	A(SPECIAL)	0.04	0.04
CHO1	CHOCO 1 L1	A(SPECIAL)	0.04	0.04

Vertical

Code	NGS Station Name	Order	Ht
801	MOTT AIRPORT	1 – II	0.01
802	P 742	1 – II	0.05
803	T 742	1 – II	0.05
701	FAA GAF B	1 – II	0.05

A full listing of the constrained adjustment is contained in Appendix A. The residuals and the standardized residuals are also listed in Apendix A. One of the 33 vector components were flagged for possible rejection under the τMAX - test at the 0.05 level of significance. None of the horizontal or vertical constraints were flagged. The slight change in the a posteriori variance factor (σ_o^2= 1.0434) from the minimally constrained adjustment indicates that the network is not being unduly distorted by the imposition of the constraints. The absolute and relative confidence regions were not scaled by the a posteriori variance factor. The relative horizontal confidence ellipses appear in last sections of Appendix A. Examination of the relative precision reveals that the network has maintained its high internal accuracy.

4. LIDAR DATA CAPTURE

4.1 Field Work and Procedures

Data capture began July 23 and was completed July 28, 2004. A minimum of two GPS base stations were set up and operated continuously during capture. One receiver was usually set up at the airport of operation while the second GPS receiver was placed at a survey control point in the area of capture.

Pre-flight checks such as cleaning the sensor head glass were performed. A four minute INS initilization is conducted on the ground, with the engines running, prior to flight, to establish fine-alignment of the INS. GPS ambiguities are resolved by flying within ten kilometers of the base stations.

The flight missions were typically four or five hours in duration including runway calibration flights flown at the beginning and the end of each mission. During the data collection, the operator recorded information on logsheets which includes weather conditions, LIDAR operation parameters, and flight line statistics. Near the end of the mission GPS abiguities are again resolved by flying within ten kilometers of the base stations to aid in post-processing.

Table 3 shows the planned LIDAR acquisition parameters with a flying height of 1,200 meters above gound level (agl) on a mission to mission basis.

Table 3. LIDAR Acquisition Parameters

Average Altitude	1,200 Meters Above Ground Level
Airspeed	~ 140 Knots
Scan Frequency	33 Hertz
Scan Width Half Angle	20 Degrees
Pulse Rate	50000 Hertz

Preliminary data processing was performed in the field immediately following the missions for quality control of GPS data and to ensure sufficient overlap between flight lines. Any problematic data could then be reflown immediately as required. Final data processing was completed in the Colorado Springs office.

4.2 Final LIDAR Processing

Final post-processing of LIDAR data involves several steps. The airborne GPS data was post-processed using Waypoint's GravNAV™ software (version 7.50). A fixed-bias carrier phase solution was computed in both the forward and reverse chronological directions. Whenever practical, LIDAR acquisition was limited to periods when the PDOP was less than 4.0.

The GPS trajectory was combined with the raw IMU data and post-processed using Applanix POSPROC Kalman Filtering software. This generally results in a two-fold improvement in the attitude accuracies over the real-time INS data. The best estimated trajectory (BET) and refined attitude data were then re-introduced into the Optech REALM software to compute the laser point-positions. The trajectory was combined with the attitude data and laser range measurements to produce the 3-dimensional coordinates of the mass points.

First and last return values were produced within REALM software. The first return information provides a useful depiction of the "canopy" within the project area. The last return was further processed to obtain ground-filtered data with a corresponding regular grid DEM.

Laser point filtering was accomplished using TerraScan LIDAR processing and modeling software. The bare earth surface generated by TerraScan was used to produce regular grid DEMs.

4.3 Problems and Delays

No major problems or challenges occurred for the duration of the project.

4.4 Daily Runway Performance and Data Validation Tests

Performance flights over the runway test field were performed before and after each mission. Table 4 shows the standard deviation and RMS values of the residuals between the test flights and the known surface of the test ranges for each pass. The maximum RMS value is 0.104 meters and the maximum standard deviation is 0.059 meters. The average RMS among all test flights is 0.070 meters. Figure 4, above, provides a graphical representation of the runway results.

Rigorous quality assurance procedures were followed to ensure that the appropriate data accuracy was achieved.

Table 4. Runway Validation Results (meters)

Mission	Pass	Standard Deviation	RMS
204a	1	0.057	0.060
204a	2	0.053	0.054
205a	1	0.046	0.104
205a	2	0.046	0.083
205a	3	0.056	0.103
205a	4	0.050	0.095
205b	1	0.059	0.097
205b	2	0.058	0.101
205b	3	0.055	0.096
205b	4	0.051	0.094
207a	1	0.049	0.071
207a	2	0.049	0.065
207a	3	0.048	0.049
207b	1	0.046	0.049
207b	2	0.044	0.051
207b	3	0.051	0.052
207b	4	0.048	0.063
208a	1	0.043	0.074
208a	2	0.052	0.067
208a	3	0.042	0.075
208a	4	0.043	0.065
208b	1	0.043	0.054
208b	2	0.046	0.056
208b	3	0.046	0.054
208b	4	0.048	0.055
209a	1	0.050	0.074
209a	2	0.047	0.047
209a	3	0.045	0.061

APPENDIX A

FULLY CONSTRAINED LEAST SQUARES ADJUSTMENT

Redding, CA - Full. Constrained NAD83(1992)			
GeoLab V3.65	WGS 84	UNITS: m,DMS	Page 0001

14:11:18, Tue Oct 05, 2004

Input file: J:\Redding\GeoLab\Redding_C.iob
Output file: J:\Redding\GeoLab\Redding_C.lst
Options file: C:\glab32v3\default.cfg

Geoid File: C:\GEOID\G2003U05PC.gsp

PARAMETERS		OBSERVATIONS	
Description	Number	Description	Number
No. of Stations	8	Directions	0
Coord Parameters	24	Distances	0
Free Latitudes	8	Azimuths	0
Free Longitudes	8	Vertical Angles	0
Free Heights	8	Zenithal Angles	0
Fixed Coordinates	0	Angles	0
Astro. Latitudes	0	Heights	4
Astro. Longitudes	0	Height Differences	0
Geoid Records	0	Auxiliary Params.	0
All Aux. Pars.	0	2-D Coords.	10
Direction Pars.	0	2-D Coord. Diffs.	0
Scale Parameters	0	3-D Coords.	0
Constant Pars.	0	3-D Coord. Diffs.	33
Rotation Pars.	0		
Translation Pars.	0		
	--------		--------
Total Parameters	24	Total Observations	47
Degrees of Freedom = 23			

SUMMARY OF SELECTED OPTIONS

OPTION	SELECTION
Computation Mode	Adjustment
Maximum Iterations	5
Convergence Criterion	0.00100
Angular Misclosure Limit Factor	0.00
Linear Misclosure Limit Factor	0.00
Residual Rejection Criterion	Tau Max
Confidence Region Types	1D 2D 3D Station Relative
Relative Confidence Regions	Connected Only
Variance Factor (VF) Known	Yes
Scale Covariance Matrix With VF	No
Scale Residual Variances With VF	No
Force Convergence in Max Iters	No
Distances Contribute To Heights	No
Compute Full Inverse	Yes
Optimize Band Width	Yes
Generate Initial Coordinates	Yes
Re-Transform Obs After 1st Pass	Yes
Geoid Interpolation Method	Bi-Quadratic

```
================================================================================
                   Redding, CA - Min. Constrained NAD83(1992)
GeoLab V3.65                 WGS 84            UNITS: m,DMS             Page 0002
================================================================================
Input Station Data:
FFF STATION      ELIP-LATITUDE     ELIP-LONGITUDE    ELIP-HEIGHT
                 ASTRO-LATITUDE    ASTRO-LONGITUDE   ORTHO-HEIGHT
                 N/S DEFLECTION    N/S DEFLECTION    GEOID-HEIGHT
                 NORTHING          EASTING           PROJECTION
--- ------------ ----------------- ----------------- ------------
000 701          N 40 34  36.02678 W122 24  17.24782      193.465
                 N 40 34  36.02678 W122 24  17.24782      218.280
                 -  0  0      8.37    0  0      0.93      -27.407
                       4491935.810        550377.025 UTM 10
000 702          N 40 30  16.00784 W122 17   9.30696      121.290
                 N 40 30  16.00784 W122 17   9.30696      121.290
                 -  0  0      6.35 -  0  0      3.56      -27.643
                       4483993.195        560503.124 UTM 10
000 801          N 41 15  59.67819 W122 16  28.62730      968.457
                 N 41 15  59.67819 W122 16  28.62730      993.183
                 -  0  0      7.34    0  0      2.21      -23.760
                       4568604.041        560759.437 UTM 10
000 802          N 40 29  54.42885 W122 17  41.61083      124.269
                 N 40 29  54.42885 W122 17  41.61083      149.340
                 -  0  0      6.68 -  0  0      3.54      -27.678
                       4483321.720        559748.141 UTM 10
000 803          N 40  9  20.03529 W122 15   3.49135       78.715
                 N 40  9  20.03529 W122 15   3.49135      104.700
                 -  0  0      2.11 -  0  0      8.70      -28.509
                       4445292.587        563791.973 UTM 10
000 CHO1         N 39 25  57.46627 W121 39  53.86634       17.750
                 N 39 25  57.46627 W121 39  53.86634       17.750
                 -  0  0      7.06 -  0  0      2.75      -28.187
                       4365638.061        614897.943 UTM 10
000 QUIN         N 39 58  28.37874 W120 56  39.88710     1108.005
                 N 39 58  28.37874 W120 56  39.88710     1108.005
                 -  0  0      1.08 -  0  0      5.05      -23.838
                       4426955.919        675536.059 UTM 10
000 YBHB         N 41 43  53.97171 W122 42  38.64701     1068.057
                 N 41 43  53.97171 W122 42  38.64701     1068.057
                    0  0      1.21 -  0  0      0.10      -23.635
                       4620023.731        524056.612 UTM 10


================================================================================
                   Redding, CA - Min. Constrained NAD83(1992)
GeoLab V3.65                 WGS 84            UNITS: m,DMS             Page 0003
================================================================================
Misclosures (pass 1):
NOTE: Observation values shown are reduced to mark-to-mark.
TYPE AT           FROM         TO                 OBSERVATION STD.DEV.     MISC
---- ------------ ------------ ------------ ----------------- -------- --------
ELAT 701                                    N 40 34  36.02678    0.010    0.000
ELON 701                                    W122 24  17.24782    0.010    0.000
ELAT 702                                    N 40 30  15.95324    0.040    1.682
ELON 702                                    W122 17   9.22334    0.040   -1.971
```

```
ELAT QUIN                                  N 39 58  28.37579    0.040    0.090
ELON QUIN                                  W120 56  39.88402    0.040   -0.075
ELAT YBHB                                  N 41 43  53.94101    0.040    0.952
ELON YBHB                                  W122 42  38.59169    0.040   -1.275
ELAT CHO1                                  N 39 25  57.48084    0.040   -0.461
ELON CHO1                                  W121 39  53.80602    0.040   -1.439
OHGT 801                                             993.183    0.001   -0.967
OHGT 802                                             149.340    0.050    2.607
OHGT 803                                             104.700    0.050    2.524
OHGT 701                                             218.280    0.050    2.592
GROUP: 00000041.SSF,obs#:    1 day 210  OPT                  210    22
DXCT             701          802                   4873.299    0.013   -0.230
DYCT             701          802                  -9707.191    0.017    0.024
DZCT             701          802                  -6646.297    0.011   -0.120
GROUP: 00000021.SSF,obs#:    2 day 211  OPT                  211     1
DXCT             701          803                  -5108.779    0.012   -0.230
DYCT             701          803                 -32504.620    0.016    0.024
DZCT             701          803                 -35702.799    0.016   -0.120
GROUP: 00000025.SSF,obs#:    3 day 210  OPT                  210    20
DXCT             702          802                   -874.353    0.002   -0.811
DYCT             702          802                     43.440    0.002   -4.460
DZCT             702          802                   -505.392    0.002    1.188
GROUP: 00000228.SSF,obs#:    4 day 206  OPT                  206
DXCT             702          803                 -10856.437    0.015   -0.806
DYCT             702          803                 -22754.004    0.023   -4.445
DZCT             702          803                 -29561.913    0.020    1.207
GROUP: 00000236.SSF,obs#:    5 day 210  OPT                  210     1
DXCT             801          702                 -30051.654    0.009    0.018
DYCT             801          702                 -45791.381    0.011    1.488
DZCT             801          702                 -64546.605    0.011    0.754
GROUP: 00000220.SSF,obs#:    6 day 204  OPT                  204     1
DXCT             801          QUIN                 46847.647    0.022   -0.219
DYCT             801          QUIN               -138643.169    0.028   -2.323
DZCT             801          QUIN               -108829.215    0.028    1.507
GROUP: 00000224.SSF,obs#:    7 day 204  OPT                  204     1
DXCT             801          YBHB                -12369.108    0.015   -1.005
DYCT             801          YBHB                 48375.355    0.021   -1.058
DZCT             801          YBHB                 38756.693    0.022    2.182
GROUP: 00000256.SSF,obs#:    8 day 207  OPT                  207     2
DXCT             803          QUIN                 87755.692    0.012    0.615
DYCT             803          QUIN                -70097.834    0.015    0.684
DZCT             803          QUIN                -14720.691    0.014   -0.459
GROUP: 00000232.SSF,obs#:    9 day 207  OPT                  207     2
DXCT             CHO1         803                 -15416.799    0.016    0.306
DYCT             CHO1         803                  70114.805    0.019   -1.782
DZCT             CHO1         803                  61711.457    0.018    1.533
GROUP: 00000244.SSF,obs#:   10 day 208  OPT                  208
DXCT             CHO1         QUIN                 72338.884    0.011    0.929
DYCT             CHO1         QUIN                    16.973    0.015   -1.100
DZCT             CHO1         QUIN                 46990.767    0.015    1.073
GROUP: 00000240.SSF,obs#:   11 day 210  OPT                  210    22
DXCT             YBHB         701                 -23430.165    0.020    0.408
DYCT             YBHB         701                 -84416.104    0.028   -1.939
DZCT             YBHB         701                 -97162.365    0.027   -0.148


================================================================================
                  Redding, CA - Min. Constrained NAD83(1992)
GeoLab V3.65                 WGS 84             UNITS: m,DMS           Page 0004
================================================================================
Adjusted NEO Coordinates:
                                NORTHING         EASTING   O-HEIGHT
 CODE FFF STATION               STD DEV          STD DEV    STD DEV MAPPROJ
```

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 ---- --- ------------ ---------------- ---------------- ---------- -------
 NEO  000 701                4491935.815       550377.023    218.333 UTM 10  m
0
                                   0.009            0.009      0.016
 NEO  000 702                4483991.543       560505.041    150.367 UTM 10  m
0
                                   0.012            0.010      0.012
 NEO  000 801                4568603.757       560760.554    993.183 UTM 10  m
0
                                   0.012            0.011      0.001
 NEO  000 802                4483321.880       559748.347    149.412 UTM 10  m
0
                                   0.012            0.010      0.012
 NEO  000 803                4445292.715       563792.186    104.680 UTM 10  m
0
                                   0.012            0.010      0.018
 NEO  000 CHO1               4365638.501       614899.371     45.408 UTM 10  m
0
                                   0.013            0.012      0.025
 NEO  000 QUIN               4426955.812       675536.145   1130.283 UTM 10  m
0
                                   0.013            0.012      0.021
 NEO  000 YBHB               4620022.762       524058.005   1090.119 UTM 10  m
0
                                   0.013            0.012      0.025


================================================================================
                   Redding, CA - Min. Constrained NAD83(1992)
GeoLab V3.65                 WGS 84              UNITS: m,DMS          Page 0005
================================================================================
Adjusted PLH Coordinates:
                                        LATITUDE         LONGITUDE  ELIP-HEIGHT
 CODE FFF STATION                        STD DEV           STD DEV      STD DEV
 ---- --- ------------ ----------------- ----------------- ------------
 PLH  000 701          N 40 34  36.02691 W122 24  17.24788      190.926 m       0
                                   0.009             0.009        0.016
 PLH  000 702          N 40 30  15.95376 W122 17   9.22607      122.724 m       0
                                   0.012             0.010        0.012
 PLH  000 801          N 41 15  59.66868 W122 16  28.57939      969.423 m       0
                                   0.012             0.011        0.001
 PLH  000 802          N 40 29  54.43400 W122 17  41.60200      121.734 m       0
                                   0.012             0.010        0.012
 PLH  000 803          N 40  9  20.03938 W122 15   3.48232       76.171 m       0
                                   0.012             0.010        0.018
 PLH  000 CHO1         N 39 25  57.47985 W121 39  53.80633       17.220 m       0
                                   0.013             0.012        0.025
 PLH  000 QUIN         N 39 58  28.37520 W120 56  39.88359     1106.445 m       0
                                   0.013             0.012        0.021
 PLH  000 YBHB         N 41 43  53.94017 W122 42  38.58686     1066.485 m       0
                                   0.013             0.012        0.025


================================================================================
                   Redding, CA - Min. Constrained NAD83(1992)
GeoLab V3.65                 WGS 84              UNITS: m,DMS          Page 0006
================================================================================
Geoid Values:
 CODE     STATION         N/S DEFLECTION    E/W DEFLECTION   UNDULATION
 ----     ------------ ----------------- ----------------- ------------
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```
 GEOI     701           -  0  0      8.37    0  0      0.93       -27.407 m
 GEOI     702           -  0  0      6.35 -  0  0      3.56       -27.643 m
 GEOI     801           -  0  0      7.34    0  0      2.21       -23.760 m
 GEOI     802           -  0  0      6.68 -  0  0      3.54       -27.678 m
 GEOI     803           -  0  0      2.11 -  0  0      8.70       -28.509 m
 GEOI     CHO1          -  0  0      7.06 -  0  0      2.75       -28.187 m
 GEOI     QUIN          -  0  0      1.08 -  0  0      5.05       -23.838 m
 GEOI     YBHB             0  0      1.21 -  0  0      0.10       -23.635 m



================================================================================
                   Redding, CA - Min. Constrained NAD83(1992)
GeoLab V3.65                WGS 84            UNITS: m,DMS            Page 0007
================================================================================
Residuals (critical value = 3.135):
NOTE: Observation values shown are reduced to mark-to-mark.
                                                  OBSERVATION RESIDUAL  STD RES
TYPE AT           FROM         TO                     STD DEV  STD DEV      PPM
---- ------------ ------------ ------------ ----------------- -------- --------
ELAT 701                                    N 40 34  36.02678    0.004    0.004
                                                        0.010    0.000
ELON 701                                    W122 24  17.24782   -0.001   -0.001
                                                        0.010    0.000
ELAT 702                                    N 40 30  15.95324    0.014    0.373
                                                        0.040    0.038
ELON 702                                    W122 17   9.22334   -0.062   -1.599
                                                        0.040    0.039
ELAT QUIN                                   N 39 58  28.37579   -0.002   -0.073
                                                        0.040    0.028
ELON QUIN                                   W120 56  39.88402   -0.020   -0.524
                                                        0.040    0.038
ELAT YBHB                                   N 41 43  53.94101   -0.058   -2.172
                                                        0.040    0.027
ELON YBHB                                   W122 42  38.59169    0.118    3.083
                                                        0.040    0.038
ELAT CHO1                                   N 39 25  57.48084   -0.020   -0.748
                                                        0.040    0.027
ELON CHO1                                   W121 39  53.80602   -0.013   -0.329
                                                        0.040    0.038
OHGT 801                                                993.18300    0.000    0.000
                                                        0.001    0.000        *
OHGT 802                                                149.34000    0.072    1.490
                                                        0.050    0.048
OHGT 803                                                104.70000   -0.020   -0.440
                                                        0.050    0.047
OHGT 701                                                218.28000    0.053    1.110
                                                        0.050    0.047
GROUP: 00000041.SSF,obs#:    1 day 210  OPT                      210    22
DXCT              701          802                   4873.29940   -0.003   -0.277
                                                        0.013    0.011     0.23
DYCT              701          802                  -9707.19070   -0.002   -0.157
                                                        0.017    0.013     0.17
DZCT              701          802                  -6646.29690    0.003    0.518
                                                        0.011    0.007     0.27
GROUP: 00000021.SSF,obs#:    2 day 211  OPT                      211      1
DXCT              701          803                  -5108.77930   -0.002   -0.198
                                                        0.012    0.008     0.03
DYCT              701          803                 -32504.62000   -0.008   -0.788
                                                        0.016    0.010     0.17
DZCT              701          803                 -35702.79930   -0.016   -1.363
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                                                  0.016    0.012     0.33
GROUP: 00000025.SSF,obs#:    3 day 210  OPT                210    20
DXCT            702          802              -874.35290    0.000    1.313
                                                  0.002    0.000     0.33
DYCT            702          802                43.44000    0.000    1.015
                                                  0.002    0.000     0.22
DZCT            702          802              -505.39170    0.000   -1.304
                                                  0.002    0.000     0.39
GROUP: 00000228.SSF,obs#:    4 day 206  OPT                206
DXCT            702          803            -10856.43700    0.007    0.579
                                                  0.015    0.012     0.18
DYCT            702          803            -22754.00390    0.009    0.453
                                                  0.023    0.019     0.23
DZCT            702          803            -29561.91340    0.000   -0.027
                                                  0.020    0.017     0.01
GROUP: 00000236.SSF,obs#:    5 day 210  OPT                210     1
DXCT            801          702            -30051.65410    0.016    3.151
                                                  0.009    0.005     0.19
================================================================================
                 Redding, CA - Min. Constrained NAD83(1992)
GeoLab V3.65              WGS 84            UNITS: m,DMS              Page 0008
================================================================================
Residuals (critical value = 3.135):
NOTE: Observation values shown are reduced to mark-to-mark.
                                                OBSERVATION RESIDUAL  STD RES
TYPE AT             FROM         TO                 STD DEV  STD DEV      PPM
---- ------------ ------------ ------------ ---------------- -------- --------
                                              ^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^
DYCT            801          702            -45791.38090    0.006    1.179
                                                  0.011    0.005     0.07
DZCT            801          702            -64546.60490   -0.001   -0.105
                                                  0.011    0.005     0.01
GROUP: 00000220.SSF,obs#:    6 day 204  OPT                204     1
DXCT            801          QUIN            46847.64680   -0.021   -1.150
                                                  0.022    0.018     0.12
DYCT            801          QUIN          -138643.16920   -0.028   -1.229
                                                  0.028    0.023     0.15
DZCT            801          QUIN          -108829.21530    0.005    0.204
                                                  0.028    0.023     0.03
GROUP: 00000224.SSF,obs#:    7 day 204  OPT                204     1
DXCT            801          YBHB           -12369.10770   -0.003   -0.355
                                                  0.015    0.009     0.05
DYCT            801          YBHB            48375.35450    0.006    0.524
                                                  0.021    0.012     0.10
DZCT            801          YBHB            38756.69280   -0.008   -0.593
                                                  0.022    0.013     0.12
GROUP: 00000256.SSF,obs#:    8 day 207  OPT                207     2
DXCT            803          QUIN            87755.69170    0.002    0.297
                                                  0.012    0.008     0.02
DYCT            803          QUIN           -70097.83420    0.007    0.756
                                                  0.015    0.009     0.06
DZCT            803          QUIN           -14720.69120    0.000   -0.011
                                                  0.014    0.009     0.00
GROUP: 00000232.SSF,obs#:    9 day 207  OPT                207     2
DXCT            CHO1         803            -15416.79860   -0.008   -0.700
                                                  0.016    0.011     0.08
DYCT            CHO1         803             70114.80460   -0.004   -0.295
                                                  0.019    0.013     0.04
DZCT            CHO1         803             61711.45700    0.002    0.120
                                                  0.018    0.013     0.02
GROUP: 00000244.SSF,obs#:   10 day 208  OPT                208
DXCT            CHO1         QUIN            72338.88420    0.003    0.598
                                                  0.011    0.006     0.04
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DYCT                  CHO1          QUIN                  16.97270    0.001    0.092
                                                             0.015    0.008     0.01
DZCT                  CHO1          QUIN               46990.76720    0.000    0.001
                                                             0.015    0.008     0.00
GROUP: 00000240.SSF,obs#:   11 day 210  OPT                         210    22
DXCT                  YBHB          701               -23430.16490   -0.012   -0.793
                                                             0.020    0.015     0.09
DYCT                  YBHB          701               -84416.10430    0.002    0.097
                                                             0.028    0.021     0.02
DZCT                  YBHB          701               -97162.36550   -0.023   -1.188
                                                             0.027    0.020     0.18
```

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================================================================================
                  Redding, CA - Min. Constrained NAD83(1992)
GeoLab V3.65                WGS 84             UNITS: m,DMS            Page 0009
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                                   |:::|:::|
   0.4 -                           |::***::|
                                   |:*:|:*:|
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R                                  |:::|:::|
e                                 *|:::|:::|*
l                                  |:::|:::|
a                                  |:::|:::|
t  0.3 -                         * |:::|:::| *
i                                  |:::|:::|
v                                *  |:::|:::|  *
e                                  |:::|:::|
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F                              *:::|:::|:::|   *
r                              |:::|:::|:::|
e                             *|:::|:::|:::|    *
q  0.2 -                    ---|:::|:::|:::|--- ---
u                          |:*:|:::|:::|:::|:::|:*:|
e                          |:::|:::|:::|:::|:::|:::|
n                          |:::|:::|:::|:::|:::|:::|
c                          |*::|:::|:::|:::|:::|::*|
y                          |:::|:::|:::|:::|:::|:::|
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   0.1 -                  *|:::|:::|:::|:::|:::|:::|*
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                        |:::|:::|:::|:::|:::|:::|            ---
                     *  |:::|:::|:::|:::|:::|:::|  *        |:::|
                    *   |:::|:::|:::|:::|:::|:::|   *       |:::|
                   *    |:::|:::|:::|:::|:::|:::|    *      |:::|
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               ***::|:::|:::|:::|:::|:::|:::|:::|      ***  |:::|
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
   -4      -3      -2      -1       0       1       2       3       4
                       ALL RESIDUALS (47 residuals)
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================================================================================
                  Redding, CA - Min. Constrained NAD83(1992)
GeoLab V3.65                 WGS 84              UNITS: m,DMS          Page 0010
================================================================================
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S T A T I S T I C S   S U M M A R Y

Residual Critical Value Type	Tau Max
Residual Critical Value	3.1350
Number of Flagged Residuals	1
Convergence Criterion	0.0010
Final Iteration Counter Value	2
Confidence Level Used	95.0000
Estimated Variance Factor	1.0434
Number of Degrees of Freedom	23

Chi-Square Test on the Variance Factor:

9.3233e-01 < 1.0000 < 3.0371e+00 ?

THE TEST PASSES

NOTE: All confidence regions were computed using the following factors:

Variance factor used	=	1.0000
1-D expansion factor	=	1.9600
2-D expansion factor	=	2.4477
3-D expansion factor	=	2.7955

Note that, for relative confidence regions, precisions are computed from the ratio of the major semi-axis and the spatial distance between the two stations.

==
Redding, CA - Min. Constrained NAD83(1992)
GeoLab V3.65 WGS 84 UNITS: m,DMS Page 0011
==

2-D and 1-D Station Confidence Regions (95.000 and 95.000 percent):

STATION	MAJOR SEMI-AXIS	AZ	MINOR SEMI-AXIS	VERTICAL
701	0.022	3	0.022	0.031
702	0.029	5	0.023	0.024
801	0.030	3	0.027	0.002
802	0.029	6	0.023	0.024
803	0.029	1	0.024	0.036
CHO1	0.032	4	0.029	0.049
QUIN	0.032	3	0.029	0.042
YBHB	0.031	0	0.029	0.050

==
Redding, CA - Min. Constrained NAD83(1992)
GeoLab V3.65 WGS 84 UNITS: m,DMS Page 0012
==

3D Station Confidence Regions (95.000 percent):

STATION	MAJ-SEMI (AZ,VANG)	MED-SEMI (AZ,VANG)	MIN-SEMI (AZ,VANG)
701	0.044 (180, 88)	0.025 (0, 2)	0.025 (90, 0)
702	0.034 (185, 56)	0.032 (6, 34)	0.027 (275, 1)
801	0.035 (3, 0)	0.031 (93, 0)	0.003 (0, 90)
802	0.035 (185, 60)	0.032 (6, 30)	0.027 (276, 0)
803	0.051 (223, 88)	0.033 (360, 1)	0.028 (90, 1)
CHO1	0.070 (258, 88)	0.037 (3, 1)	0.033 (93, 2)
QUIN	0.060 (255, 88)	0.037 (2, 1)	0.033 (92, 2)
YBHB	0.071 (216, 89)	0.035 (0, 1)	0.033 (90, 1)

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Redding, CA - Min. Constrained NAD83(1992)
GeoLab V3.65 WGS 84 UNITS: m,DMS Page 0013
==

2-D and 1-D Relative Station Confidence Regions (95.000 and 95.000 percent):

FROM	TO	MAJ-SEMI	AZ	MIN-SEMI	VERTICAL	DISTANCE	PPM
701	702	0.022	5	0.010	0.026	12877.150	1.70
701	802	0.022	5	0.009	0.026	12733.885	1.74
701	803	0.022	1	0.012	0.031	48552.461	0.45
701	CHO1	0.027	3	0.021	0.047	141868.05	0.19
701	QUIN	0.027	3	0.021	0.040	141068.44	0.19
701	YBHB	0.025	1	0.020	0.052	130826.53	0.19
702	801	0.017	4	0.016	0.024	84653.501	0.21
702	802	0.005	12	0.003	0.006	1010.842	4.94
702	803	0.014	8	0.010	0.034	38852.453	0.37
702	CHO1	0.023	16	0.020	0.048	130292.90	0.17
702	QUIN	0.022	12	0.020	0.041	128436.39	0.17

702	YBHB	0.023	179	0.020	0.052	140895.76	0.16
801	QUIN	0.025	7	0.023	0.042	182374.43	0.14
801	YBHB	0.018	170	0.015	0.050	63207.998	0.28
803	CHO1	0.019	49	0.018	0.037	94668.196	0.20
803	QUIN	0.019	28	0.018	0.029	113276.06	0.16
CHO1	QUIN	0.018	33	0.017	0.034	86261.505	0.20
CHO1	YBHB	0.029	1	0.027	0.067	270212.06	0.11
QUIN	YBHB	0.028	178	0.026	0.062	245487.60	0.12

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Redding, CA - Min. Constrained NAD83(1992)

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3D Relative Confidence Regions (95.000 percent):

FROM	TO	MAJ-SEMI(AZ,VANG)	MED-SEMI(AZ,VANG) DISTANCE	MIN-SEMI(AZ,VANG) PPM
701	702	0.039 (183,70)	0.022 (6,20) 12877.150	0.011 (275, 1) 3.00
701	802	0.038 (183,68)	0.022 (6,22) 12733.885	0.011 (276, 1) 3.01
701	803	0.045 (191,81)	0.024 (0, 9) 48552.461	0.013 (90, 2) 0.93
701	CHO1	0.067 (212,86)	0.031 (2, 4) 141868.049	0.024 (92, 2) 0.47
701	QUIN	0.058 (201,85)	0.030 (1, 5) 141068.445	0.024 (92, 2) 0.41
701	YBHB	0.074 (190,87)	0.028 (0, 3) 130826.531	0.023 (90, 0) 0.57
702	801	0.034 (203,87)	0.020 (0, 3) 84653.501	0.019 (90, 1) 0.40
702	802	0.008 (0,90)	0.006 (0, 0) 1010.842	0.004 (90, 0) 8.18
702	803	0.048 (188,85)	0.016 (8, 5) 38852.453	0.011 (278, 0) 1.24
702	CHO1	0.069 (217,87)	0.026 (14, 3) 130292.896	0.023 (104, 1) 0.53
702	QUIN	0.059 (204,87)	0.025 (10, 3) 128436.392	0.023 (101, 1) 0.46
702	YBHB	0.074 (199,88)	0.026 (0, 2) 140895.762	0.022 (90, 1) 0.53
801	QUIN	0.060 (226,88)	0.028 (360, 2) 182374.431	0.027 (90, 2) 0.33
801	YBHB	0.071 (234,89)	0.020 (350, 1) 63207.998	0.017 (80, 1) 1.13
803	CHO1	0.053 (246,87)	0.021 (46, 3) 94668.196	0.021 (136, 1) 0.56
803	QUIN	0.042 (227,88)	0.021 (360, 1) 113276.061	0.021 (90, 1) 0.37
CHO1	QUIN	0.048 (270,89)	0.020 (0, 0) 86261.505	0.020 (90, 1) 0.56
CHO1	YBHB	0.095 (227,88)	0.033 (360, 1) 270212.062	0.031 (90, 1) 0.35
QUIN	YBHB	0.088 (220,88)	0.032 (0, 1) 245487.595	0.030 (90, 1) 0.36