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Project location: Northwest of the Golden Gate Bridge, San Francisco, California

1. Survey area

The project area consisted of two polygons totally approximately 27 square Km located 10 kilometers northwest of the north end of the Golden Gate Bridge. The project area was flown on Thursday, December 7, 2006. It required one flight lasting approximately 3 hours and required 0.75 hours of laser-on time.

Figure 1 (next page) is an image showing the shape and location of the project areas along with the locations of two GPS reference stations used to support the survey.

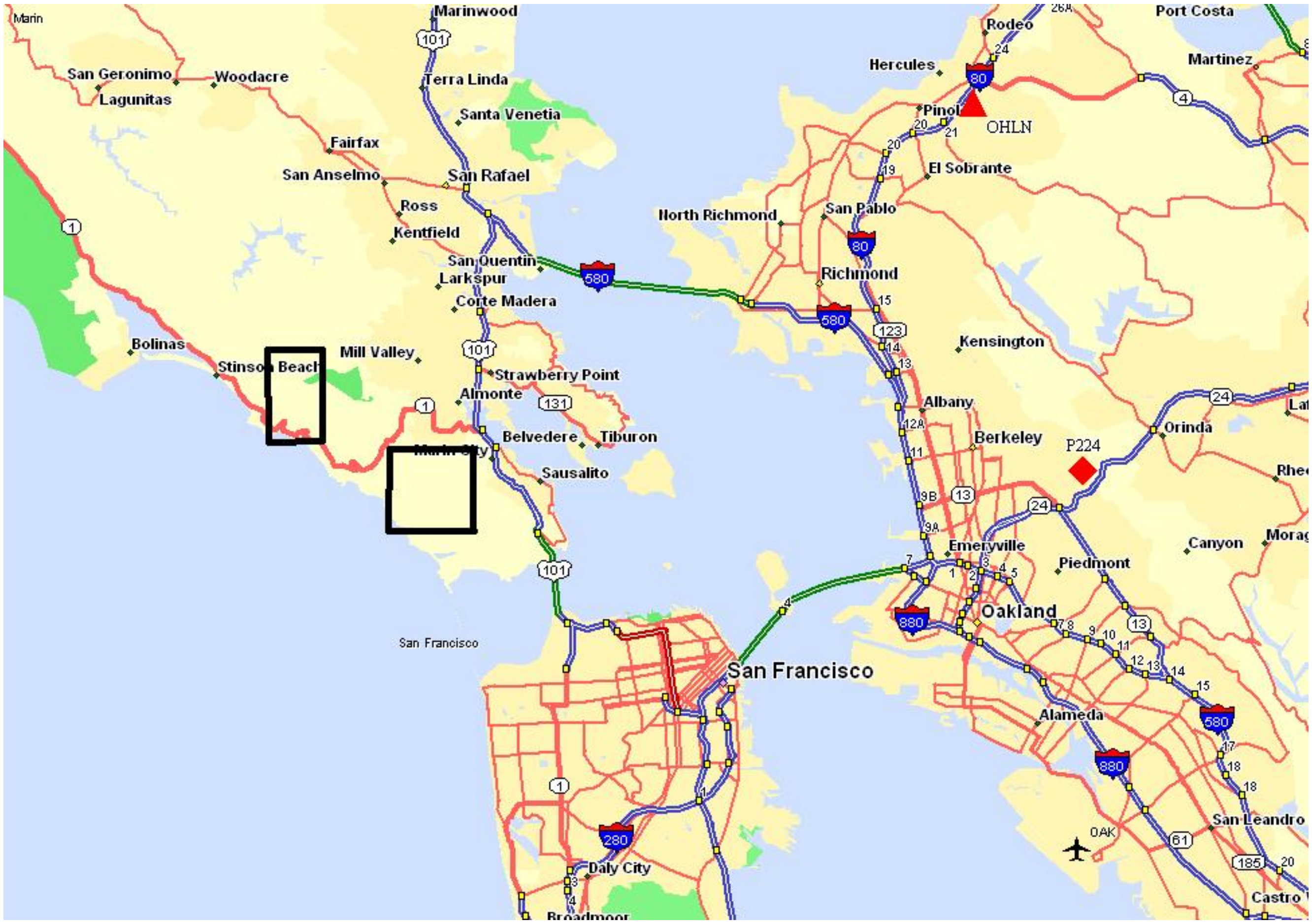

Figure 1 - Project location map: the project polygons are shown in black; northernmost red triangle is the location of OHLONE PARK (OHLN) Continuously Operating Reference Station (CORS) and the southernmost red triangle is the location of SIBLEYVOLCCN2005 (P224), another CORS.

2. Survey Parameters

These project areas were flown using 29 flight lines oriented north-south and 1 additional cross line for field calibration purposes. The flying height was targeted at 600 meters Above Ground Level (AGL) but varied during the survey from 600 to 1100 meters due to the mountainous terrain. Flying speed was targeted at 60 meters/second (117 knots). The Pulse Rate Frequency of the Optech 2033 ALTM (see http://www.optech.ca/ for more information) used in the survey was 33 KHz. The scan angle was set at +/- 20 degrees, with 0.5 degrees cutoff during processing. The scanning frequency (mirror oscillation rate) was 28 Hz. Point spacing per swath was nominally 1.1 meters along-track at nadir, 2.2 meters along-track at the scan edge and 0.73 meters cross-track. Flight line spacing was set at 215 meters which yielded swath overlap of 100%, (50% sidelap). These survey parameters resulted in approximately 2.5 shots per square meter, before filtering.

3. GPS Reference Stations

Two GPS reference station locations were available for post-processing the trajectory of the aircraft. Both of these (OHLN and P224) are Continuously Operating Reference Stations (CORS) managed by Berkeley Seismo and UNAVCO. Both CORS receivers were bumped up to log at 1 second. Final coordinates for these stations are included as Appendix A.

4. Navigation Processing

Airplane trajectories for this survey were processed using KARS software (Kinematic and Rapid Static) written by Dr. Gerry Mader of the NGS Research Laboratory. KARS processing requires dual-frequency carrier phase observations and, in contrast to most commercially-used GPS kinematic processing software, yields a fixed integer (double difference) solution for all 1-second epochs.

For quality assurance purposes the project trajectory was processed separately using two of the reference stations and then coordinate differences between the separate solutions were plotted. Figure 2 (below) is a plot of the component differences in Easting, Northing, and Height of the trajectories as processed from the CORS P224 and the CORS OHLN.

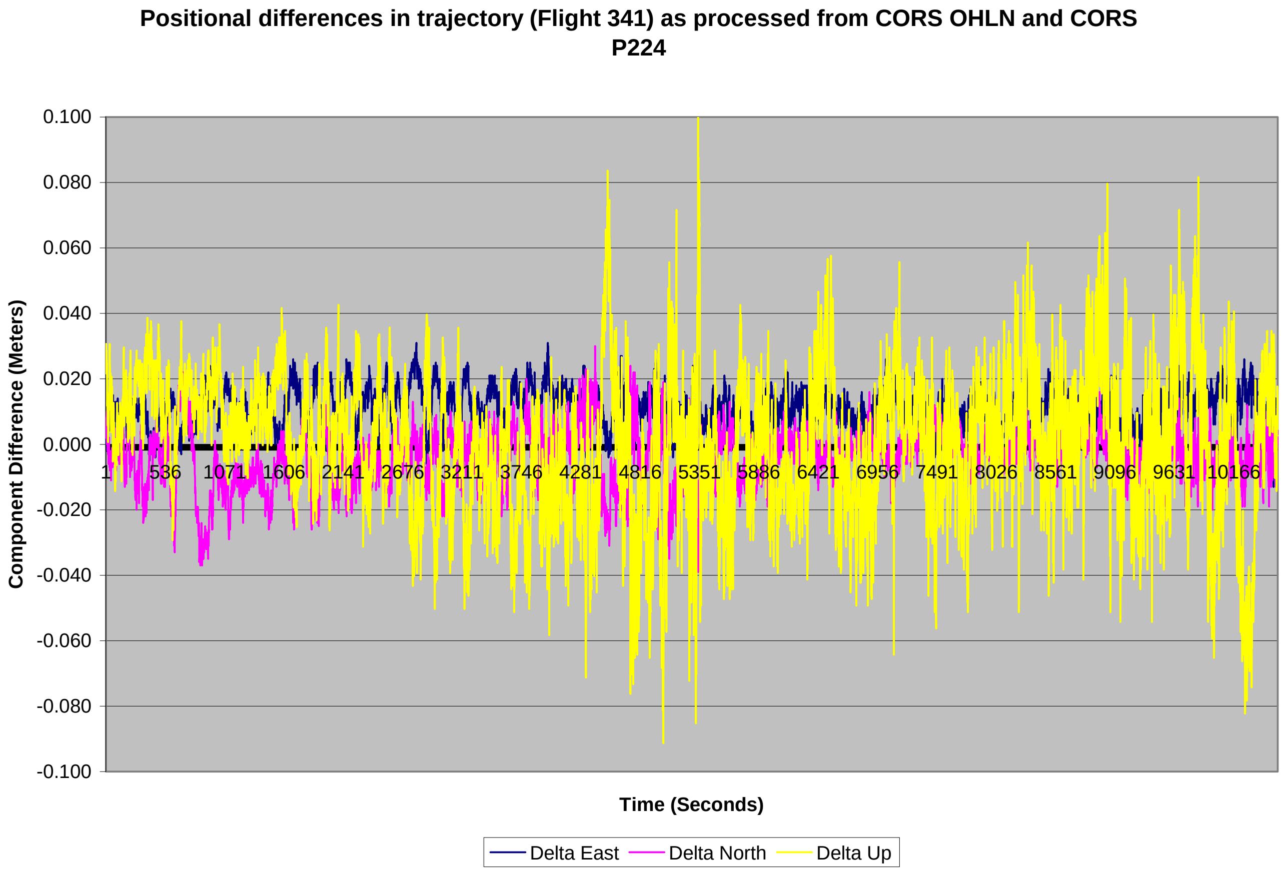

Figure 2 – Positional differences in trajectory positions of the survey flight; these reference stations are 16 Km apart and the distance from reference to airplane ranged out to 35 Km from both P224 and OHLN.

The standard deviation of the trajectory differences is less than 0.008 meters for the horizontal components and less than 0.022 meters for the vertical component.

5. Laser Point Processing

After GPS processing was completed for the flight, the final GPS trajectory and the raw IMU (Inertial Measurement Unit) data collected during the flight were input into APPLANIX software POSPROC. This software employs a Kalman Filter algorithm to combine the 1-Hz final differential GPS solution with the raw 50-Hz IMU orientation measurement data and their respective error models. The final result is a smoothed and blended solution of both aircraft position and orientation at 50 Hz, in SBET format (Smoothed Best Estimated Trajectory). The SBET, laser range, and mirror-angle measurement data were combined using Optech's REALM processing suite to generate point clouds in selected calibration areas, usually locations where cross-lines were flown or ground truth was collected.

System calibration was then performed as a 2-step process: step one (relative calibration) is to adjust the bore sight values of heading, roll, pitch, and scanner mirror scale such that systematic positional errors are minimized; and step two is an absolute calibration such that the laser DEM will match the height values of ground truth collected by vehicle-mounted GPS.

Step 1: Relative calibration was performed in TerraMatch software please see (**http://terrasolid.fi/ENG/Products.htm**) for detailed information.

A general description of the relative calibration procedure follows.

1. Cross-lines are flown for every flight with a heading perpendicular to the project flight line heading.
2. Small polygons containing these cross lines along with project flight lines are processed using approximate calibration values for heading, roll, pitch, and scanner mirror scale. Each line is processed separately.
3. Continuing to process each line separately, all lines are filtered (if necessary) to remove vegetation; then individual flight line surfaces are created.
4. Using TerraMatch, an iterative algorithm is applied to compute the best-fit between the individual flight line surfaces: simultaneously solving for the optimal bore sight values of heading, roll, pitch, and scanner mirror scale.
5. These updated bore sight values are then entered into REALM; new output is produced and checked for all flights.
6. Complete and final output is run using the optimized calibration values for each flight.

The above procedure was run on two areas of the project; calibration values were computed and used to generate final output.

Step 2: Absolute calibration is usually done by comparing the height of the nearest neighbor laser point to the height of a set of check points that are collected by vehicle-mounted GPS. No check points were collected for this project; a typical bias of 0.10 meters was removed from generated output. This bias was noted in the previous project flown (through December 2, 2006) and is typical for many projects processed with KARS trajectories.

All coordinates were processed with respect to NAD83 Reference Frame (CORS96) (EPOCH: 2002.0000). The projection is UTM Zone 10, with units in meters. Heights are referenced to the GRS80 ellipsoid; they have been converted to NAVD88 elevations using the NOAA GEOID03 geoid model.

The most complete output format is a 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 the UTM zone code (10) is appended to the Easting coordinate in this five-column format.

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 5), 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.

APPENDIX A.

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================================================================
    Antenna Reference Point(ARP): SIBLEYVOLCCN2005 CORS ARP            |
|         -------------------------------------------------------     |
|                           PID = DH3879                              |
|                                                                     |
|                                                                     |
| ITRF00 POSITION (EPOCH 1997.0)                                      |
| Computed in June 2005 using 26 days of data.                        |
|     X =  -2688201.056 m     latitude    =  37 51 50.02374 N         |
|     Y =  -4265643.846 m     longitude   = 122 13 08.60261 W         |
|     Z =   3893778.514 m     ellipsoid height =  407.336   m         |
|                                                                     |
| ITRF00 VELOCITY                                                     |
| Predicted with HTDP_2.7 June 2005.                                  |
|     VX =  -0.0241 m/yr      northward =   0.0053 m/yr               |
|     VY =   0.0184 m/yr      eastward  =  -0.0302 m/yr               |
|     VZ =   0.0046 m/yr      upward    =   0.0007 m/yr               |
|                                                                     |
|                                                                     |
| NAD_83 (CORS96) POSITION (EPOCH 2002.0)                             |
| Transformed from ITRF00 (epoch 1997.0) position in June 2005.       |
|     X =  -2688200.518 m     latitude    =  37 51 50.00906 N         |
|     Y =  -4265645.014 m     longitude   = 122 13 08.55850 W         |
|     Z =   3893778.486 m     ellipsoid height =  407.872   m         |
|                                                                     |
| NAD_83 (CORS96) VELOCITY                                            |
| Transformed from ITRF00 velocity in June 2005.                      |
|     VX =  -0.0076 m/yr      northward =   0.0197 m/yr               |
|     VY =   0.0191 m/yr      eastward  =  -0.0166 m/yr               |
|     VZ =   0.0156 m/yr      upward    =   0.0000 m/yr               |
|_____________________________________________________________________|
|                                                                     |
| L1 Phase Center of the current GPS antenna: SIBLEYVOLCCN2005 CORS L1 PC C |
| ------------------------------------------------------------------- |
| The D/M element, chokerings, -radome antenna                        |
| (Antenna Code = TRM29659.00) was installed on 03/03/05.             |
|        The L2 phase center is 0.018 m above the L1 phase center.    |
|                           PID = DH3880                              |
|                                                                     |
|                                                                     |
| ITRF00 POSITION (EPOCH 1997.0)                                      |
| Computed in June 2005 using 26 days of data.                        |
|     X =  -2688201.102 m     latitude    =  37 51 50.02377 N         |
|     Y =  -4265643.919 m     longitude   = 122 13 08.60259 W         |
|     Z =   3893778.582 m     ellipsoid height =  407.446   m         |
|                                                                     |
| The ITRF00 VELOCITY of the L1 PC is the same as that for the ARP.   |
|                                                                     |
|                                                                     |
| NAD_83 (CORS96) POSITION (EPOCH 2002.0)                             |
| Transformed from ITRF00 (epoch 1997.0) position in June 2005.       |
|     X =  -2688200.564 m     latitude    =  37 51 50.00910 N         |
|     Y =  -4265645.087 m     longitude   = 122 13 08.55848 W         |
|     Z =   3893778.555 m     ellipsoid height =  407.982   m         |
|                                                                     |
| The NAD_83 (CORS96) VELOCITY of the L1 PC is the same as that for the ARP. |
|_____________________________________________________________________|
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     Antenna Reference Point(ARP): OHLONE PARK CORS ARP                    |
|         --------------------------------------------------                |
|                           PID = AM7021                                    |
|                                                                           |
|                                                                           |
| ITRF00 POSITION (EPOCH 1997.0)                                            |
| Computed in Aug. 2006 using 396 days of data.                             |
|     X =  -2686856.197 m     latitude    =  38 00 22.50814 N               |
|     Y =  -4254626.204 m     longitude   = 122 16 22.74923 W               |
|     Z =   3905990.488 m     ellipsoid height =   -0.520   m               |
|                                                                           |
| ITRF00 VELOCITY                                                           |
| Adapted from NGS multiyear 1994-2003 in Aug. 2006.                        |
|     VX =  -0.0203 m/yr      northward =   0.0047 m/yr                     |
|     VY =   0.0190 m/yr      eastward  =  -0.0273 m/yr                     |
|     VZ =   0.0019 m/yr      upward    =  -0.0029 m/yr                     |
|                                                                           |
|                                                                           |
| NAD_83 (CORS96) POSITION (EPOCH 2002.0)                                   |
| Transformed from ITRF00 (epoch 1997.0) position in Aug. 2006.             |
|     X =  -2686855.640 m     latitude    =  38 00 22.49334 N               |
|     Y =  -4254627.368 m     longitude   = 122 16 22.70444 W               |
|     Z =   3905990.445 m     ellipsoid height =   -0.005   m               |
|                                                                           |
| NAD_83 (CORS96) VELOCITY                                                  |
| Transformed from ITRF00 velocity in Aug. 2006.                            |
|     VX =  -0.0037 m/yr      northward =   0.0192 m/yr                     |
|     VY =   0.0197 m/yr      eastward  =  -0.0136 m/yr                     |
|     VZ =   0.0129 m/yr      upward    =  -0.0036 m/yr                     |
|___________________________________________________________________________|
|                                                                           |
| L1 Phase Center of the current GPS antenna: OHLONE PARK CORS L1 PC C      |
| ------------------------------------------------------------------        |
| The D/M element,REV.B,chokering with radome antenna                       |
| (Antenna Code = ASH701945B_M    SCIT) was installed on 04/04/02.          |
|        The L2 phase center is 0.018 m above the L1 phase center.          |
|                           PID = DH5958                                    |
|                                                                           |
|                                                                           |
| ITRF00 POSITION (EPOCH 1997.0)                                            |
| Computed in Aug. 2006 using 396 days of data.                             |
|     X =  -2686856.242 m     latitude    =  38 00 22.50814 N               |
|     Y =  -4254626.276 m     longitude   = 122 16 22.74923 W               |
|     Z =   3905990.555 m     ellipsoid height =   -0.412   m               |
|                                                                           |
| The ITRF00 VELOCITY of the L1 PC is the same as that for the ARP.         |
|                                                                           |
|                                                                           |
| NAD_83 (CORS96) POSITION (EPOCH 2002.0)                                   |
| Transformed from ITRF00 (epoch 1997.0) position in Aug. 2006.             |
|     X =  -2686855.685 m     latitude    =  38 00 22.49334 N               |
|     Y =  -4254627.440 m     longitude   = 122 16 22.70444 W               |
|     Z =   3905990.512 m     ellipsoid height =   0.102   m                |
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