UNITED STATES DEPARTMENT OF COMMERCE
NATIONAL OCEANIC & ATMOSPHERIC ADMINISTRATION
NATIONAL OCEAN SERVICE
NATIONAL GEODETIC SURVEY

FOUNDATION CORS PROGRAM
LOCAL SITE SURVEY REPORT
MONUMENT PEAK, CALIFORNIA

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Introduction

In May 2018, the National Geodetic Survey (NGS) conducted a site survey at NASA's Monument Peak site, located near Mount Laguna, California. The site is an International Terrestrial Reference Frame (ITRF) space geodetic technique co-location site. The onsite GNSS station MONP has been identified as a NGS Foundation CORS. Data collection consisted of terrestrial observations made with an absolute laser tracker and Global Positioning System (GPS) observations with survey-grade instrumentation. The primary objective of the survey was to establish high-precision local ties between a Satellite Laser Ranging system, an International GNSS Service tracking station, and their associated reference marks. The local relationships were aligned to the ITRF2014 reference frame at the epoch date of the survey. This report documents the instrumentation and methodologies used to collect the geospatial data set, data reduction, and analysis procedures used to compute the ties.

1. Site Description

Site Name: Monument Peak
Country Name: UNITED STATES OF AMERICA
Longitude: W 116° 25'
Latitude: N 32° 53'
Tectonic plate: PCFC (Pacific)

SGT Instrument	Name	DOMES#	Description/a.k.a.
SLR	7110	40497M001	ORT station 7110-1981
	7220	40497M002	ARIES ORION STA 7220-1981
VLBI	7274	40497M003	NCMN 1983 mobile VLBI
GPS	MONP	40497M004	PGGA MARK
DORIS		40497M005	Domed brass screw on the DORIS concrete pillar
SLR	MONL	40497S006	LASER MOBLAS-4 / IAR

Table 1 – ITFR site information for Space Geodetic Technique Instruments (SGT) located at the site.

2. Instrumentation

2.1. Tacheometers

2.1.1. Description

Leica AT402 (Absolute Laser Tracking system)
S/N: 392045
Specifications:
Angular measurement uncertainty of instrument: +/- 0.5"

Combined uncertainty of distance measurement throughout instrument range: +/- 0.014 mm

Leica TDM5005 (total station)
S/N: 441698
Specifications:
Angular measurement uncertainty: +/- 0.7”
Distance standard deviation of a single measurement: 1 mm + 2 ppm

2.1.2. Calibrations

Leica AT402, S/N 392045: certified by Leica Geosystem AG Heerbrugg, Switzerland on 08/28/2013.

Leica TDM5005, S/N 441698: originally calibrated by Leica Geosystem AG Heerbrugg, Switzerland (inspection date 8/20/2008). In April, 2016 this instrument’s EDMI was evaluated using the NGS Corbin Calibration Baseline and found to be measuring distances within the manufacturer’s specifications.

2.1.3. Auxiliary Equipment

Leica ATC meteo-station, S/N D214.00.000.002
Accuracy:
Air temperature: +/- 0.30 C
Pressure: +/- 1 hPa
Relative Humidity: +/- 5%

2.2. GPS Units

2.2.1. Receivers

Trimble NetR5, P/N: 62800-00, S/Ns: 4619K01584, 4624K01647, and 4624K01615
Specifications for Static GPS Surveying:
Horizontal: +/- 5 mm + 0.5 ppm RMS
Vertical: +/- 5 mm + 1 ppm RMS

2.2.2. Antennas

Trimble GPS ground plane antenna, Zephyr Geodetic, P/N 41249-00, S/Ns: 60154430, 12481390, 12337624.

2.2.3. Analysis Software

Post-processing and adjustment were undertaken using NGS’s Online Positioning User Service (OPUS) Projects, an interactive web page. OPUS Projects uses as an underlying multi-baseline processor, NGS’s Program for Adjustment of GPS Ephemerides (PAGES) software.

2.3. Leveling

2.3.1. Leveling Instruments

No leveling instruments used during the execution of this survey.

2.3.2. Leveling Staffs

No leveling equipment used during the execution of this survey.

2.3.3. Checks carried out before measurements

Not applicable

2.4. Tripods

Wooden surveying tripods, with collapsible legs, were used to support surveying instrumentation. Fixed-height range poles with attached tripod support legs were used with target reflectors and GPS antennas. See Figure 1.

2.5. Forced Centering Devices

Multiple forced centering devices were used to center the instrumentation over the site's marks. At stations CAL_PIER_C, NCMN_7274, and TP1, a "multipurpose tripod adapter" (MTA) was used to mount reflectors and GPS antennas simultaneously. See Figure 1 and Figure 2.

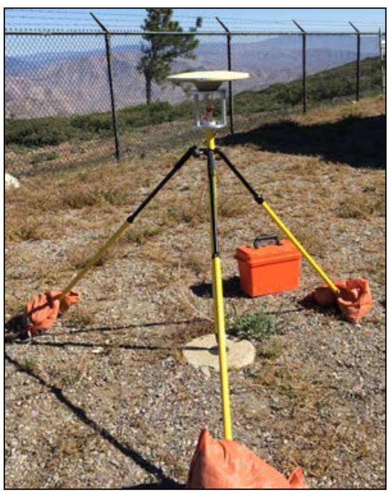

Figure 1 – Fixed height range pole with multipurpose tripod adapter (MTA).

Figure 2 – MTA with attached optical reflector and GPS antenna.

A Kern trivet was plumbed over the DORIS mark and SLR mark using a forced centering pin and reflector nest with known vertical offsets. See Figure 3.

Figure 3 – Kern trivet on DORIS mark.

Stations CAL PIER A and CAL PIER C are forced-centering devices permanently mounted in concrete piers. They are designed to accept an adapter with protruding 5/8-11 threaded rod, referred to as the NASA Calibration Pier Adapter. See Figure 4. For regular SLR operations, a reflector is mounted on the adapter. See Figure 5 and Figure 6

Figure 4

Figure 5

Figure 6

For this survey, NGS instrumentation was mounted on the adapter. See Figure 7 and Figure 8.

For all ground control marks, the vertical reference point is the bottom of the mark's datum point. These included cast dimples, cast cross marks, and punch marks.

Figure 7

Figure 8

2.6. Targets, Reflectors

Leica Break Resistant 1.5-inch reflector, part # 576-244
Centering of Optics: < ± 0.01mm
Leica Reflector Holder 1.5-inch, part # 577-104
25mm vertical offset
Brunson Reflector Holder, 1.5THT-.625-11
Leica Tripod Adapter, part # 575-837

All terrestrial observations were made to Leica 1.5-inch Break Resistant Reflectors, serving as both target and reflector. The reflectors were affixed to the mark forced-centering devices using the adapters listed above.

2.7. Vertical Offsets

Terrestrial Observation Stations (units given in meters)

STATION	STAGE 1	STAGE 2	PRISM	TOTAL OFFSET
7110	Trivet Rod	Brunson Nest Recession (negative)	Brunson Nest with Prism	
OFFSET	0.0936	-0.0015	0.05258	0.1447
7220	Range Pole 2		Brunson Nest with Prism	
OFFSET	1.04224		0.05258	1.0948
CAL PIER A	NASA Cal Pier Adapter		Brunson Nest with Prism	
OFFSET	0.0130		0.05258	0.0656
CAL PIER C	NASA Cal Pier Adapter	MTA D - Bottom Plate	Leica Nest with Prism	
OFFSET	0.0130	0.00982	0.0550	0.0778

MOOB MARK	Trivet Rod	Brunson Nest Recession (negative)	Brunson Nest with Prism	
OFFSET	0.0936	-0.0015	0.05258	0.1447
MONP	IGS eccentricity to ARP		Leica Nest with Prism (negative)	
OFFSET	0.1176		-0.0550	0.0626
LOOKOUT	Range Pole 4		Brunson Nest with Prism	
OFFSET	1.04261		0.05258	1.0952
7274	Range Pole 1	MTA B - Bottom Plate	Leica Nest with Prism	
OFFSET	1.04260	0.00978	0.0550	1.1074
7274 RM1	Range Pole 3		Brunson Nest with Prism	
OFFSET	1.04248		0.05258	1.0951

Table 2

GPS Observation Stations (units given in meters)

STATION	**STAGE 1**	**STAGE 2**	**PRISM**	**TOTAL OFFSET**
CAL PIER C	NASA Cal Pier Adapter	MTA D - Overall Height		
OFFSET	0.0130	0.15071		0.1637
7274	Range Pole 1	MTA B - Overall Height		
OFFSET	1.04260	0.15070		1.1933
TP01		MTA C - Top Plate	Brunson Nest with Prism	
OFFSET		0.00973	0.05258	0.0623

Table 3

3. Measurement Setup

3.1. Ground Network

Ground network marks are monumented for future reference. The terrestrial survey ties them together in a local coordinate system using high-precision horizontal/zenith angles and distance measurements. Non-monumented temporary mark TP01 was positioned near the center of the project site and was used to facilitate alignment of the absolute tracker measurements.

According to the SLR site log and NASA contractor Troy Carpenter, a site survey was conducted in 1999. The NGS survey team was unable to obtain a copy of the report to determine previous station names or tie values.

3.1.1. Listing

Current Survey	DOMES	IERS 4-char code	Previous Survey Point Name	NGS PID
IERS Site Marker				
7110	40497M001	7110	unknown	n/a
SGT Geometric Reference Points				
MONP	40497M004	MONP	MONUMENT PEAK CORS POINT	AF9705
MONL GRP	40497S006	n/a	unknown	n/a
SGT Auxiliary Mark				
MOOB MARK	40497M005	n/a	unknown	n/a
Ground Network Marks				
7220	40497M002	n/a	ARIES ORION	DC2123
CAL PIER A	n/a	n/a	unknown	n/a
CAL PIER C	n/a	n/a	unknown	n/a
LOOKOUT	n/a	n/a	unknown	n/a
7274	40497M003	7274	MONUMENT PEAK NCMN 7274	DC1438
7274 RM1	n/a	n/a	unknown	n/a

Table 4 – Listing of Ground Network Marks, SGT Instrument Reference Marks, and SGT Conventional Reference Points.

<u>Ground Network Mark Descriptions</u>

7110. A NASA survey disk set in a concrete post surrounded by a concrete pad beneath the trailer housing of the mobile SLR telescope. Stamped ORT STATION 7110 1981. The datum point is the bottom of a punch mark near the center of the disk. This survey has designated this mark as the IERS Site Marker (SM) from which all local tie vectors are referenced.

MONP. MONUMENT PEAK CORS POINT. NGS PID AF9705. An IGS tracking station on a deep-drilled braced monument.

7220. A metal plate in a square concrete post. Stamped ARIES ORION STA 7220. The datum point is the bottom of the punch mark near the center of the plate.

7274. MONUMENT PEAK NCMN 7274. An NGS horizontal control mark disk set in a round concrete post. Stamped MONUMENT PEAK NCMN 1983. The datum point is the bottom of a cast dimple near the center of the disk.

MOOB MARK. A domed brass screw near the center of the DORIS concrete pillar. No stamping. The datum point is the bottom of a punch mark in the top center of the screw. The DORIS antenna has been decommission and removed.

LOOKOUT. A NASA BFEC survey disk set in the west side of a round concrete pad used for helicopter landings. Stamped LOOKOUT 1988. The datum point is the bottom of cast dimple near the center of the disk.

CAL PIER A. A forced-centering device permanently mounted in the top of a concrete pier. The datum point is a geometric reference point (an intangible point) coincident with the top center of the device. No stamping. A NASA Calibration Pier Adapter is used to occupy the point. See Figure 4 and Figure 5.

CAL PIER C. A forced-centering device permanently mounted in the top of a concrete pier. The datum point is a geometric reference point (an intangible point) coincident with the top center of the device. No stamping. A NASA Calibration Pier Adapter is used to occupy the point. See Figure 4 and Figure 5.

7274 RM1. An NGS reference mark disk set in a round concrete post. Stamped MONUMENT PEAK NCMN NO. 1 1983. The datum point is the bottom of the center of a cast cross near the center of the disk.

3.1.2. Map of Network

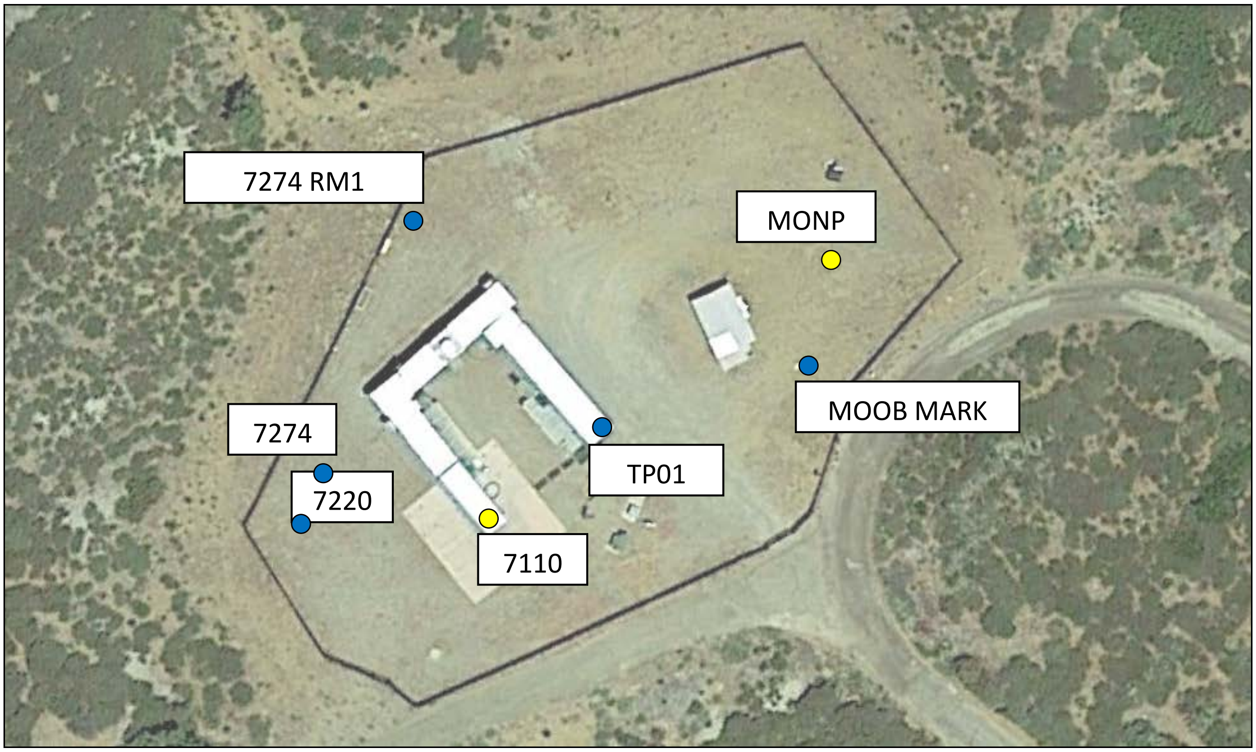

Figure 9

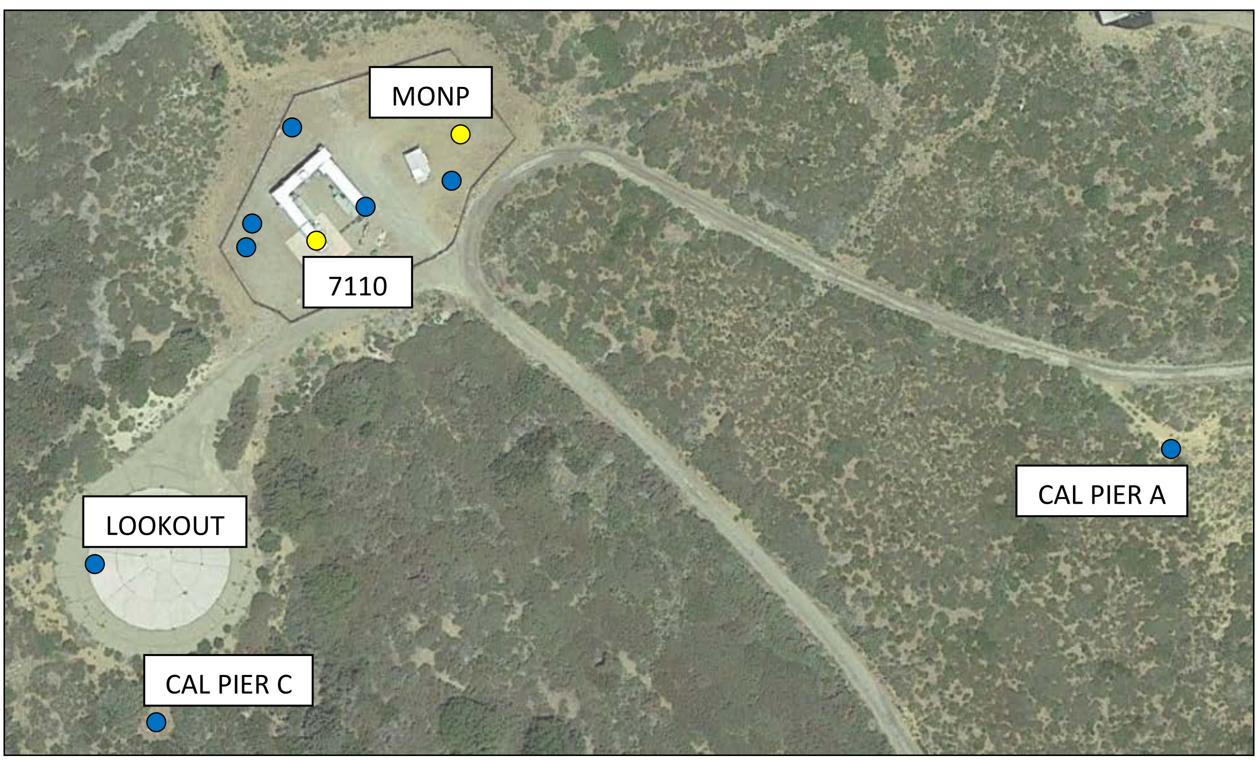

Figure 10

3.2. Representation of Technique Reference Points

The geometric reference point (GRP), a.k.a. conventional reference point, invariant point, or system reference point, is an intangible point. For the Monument Peak SLR instrument, the GRP is a point at the theoretical intersection of the telescope's azimuth and elevation axes.

3.2.1. SLR

MONL. LASER MOBLAS-4 / IAR – NASA operates the SLR telescope. Ground mark 7110 is the SLR's instrument reference mark. Coordinates for the instrument's geometric reference point (GRP) were determined indirectly during this survey by means of a circle-fitting routine. Horizontal/vertical angle and distance measurements were observed to a target affixed to the telescope during different rotational sequences.

Figure 11 – SLR instrument MONL

3.2.2. GNSS

MONP. Scripps Orbit and Permanent Array Center operates this GNSS tracking station. The station is included in the International GNSS Service (IGS) tracking network. The antenna type at time of this survey was an Ashtech choke ring antenna (part number 701945-01, IGS antenna code ASH701945B_M). The IGS site log states antenna serial number CR519991751, but the antenna label was too faded to confirm. IGS reports eccentricities from the geometric reference point (GRP, an inaccessible point) to the ARP of 0.1176 m Up, 0.0 m North, and 0.0 m East. Coordinates for the GRP were determined this survey by a circle fitting routine. The site log is available at the IGS site: http://www.igs.org/igsnetwork/network_by_site.php?site=monp

Figure 12 – IGS network station MONP

4. Observations

4.1. Conventional Survey

The conventional survey was completed using a high-precision Absolute Laser Tracker system and a total station tacheometer. These instruments measured horizontal angles, vertical angles, and distances to retro-reflector targets which were used to position features of interest.

The resection principle was employed to measure between network stations indirectly. The reference marks were occupied with the reflector targets mounted on range poles or trivets. A temporary point was also established by affixing a short range pole with a reflector target to a stable surfaces near the center of the project. Except for station CAL PIER A, the instruments did not occupy the reference marks directly but were instead setup on arbitrary points between the stations. At each instrument occupation, a series of measurements were taken to the visible features of interest. By observing common features from different instrument occupations, the relative positions of both the instrument and targets were established.

The resection procedure was chosen to take advantage of the laser tracker's high-precision capabilities and mitigate setup errors. By setting up at arbitrary points rather than occupying the marks, horizontal and vertical centering errors were statistically insignificant. Likewise, the reference marks were occupied with range poles and targets, then left undisturbed for the duration of the survey. While the vectors between stations were not observed directly, the measurements were precise enough to determine relative positions with sub-millimeter accuracies. See Figure 13 for a diagram of the included network stations.

As part of the observation routine, all angle and distance measurements to ground marks and temporary points were observed a minimum of three times. Double centering of the instrument was incorporated, measuring in both phase I and phase II. Meteorological data was observed and atmospheric corrections were applied to all measurements at the time of data collection.
Data collection software Spatial Analyzer was used for recording observations and to perform field-level data quality checks for all laser tracker measurements. Data collection software GeoObs was used for recording observations and to perform field-level data quality checks for all total station measurements. To combine and adjust all observations, software program Star*Net was used. A complete list of unadjusted and adjusted observations is available consisting of horizontal direction, zenith angles, slope distances, and target heights. See Star*Net output file MonumentPeak.lst.

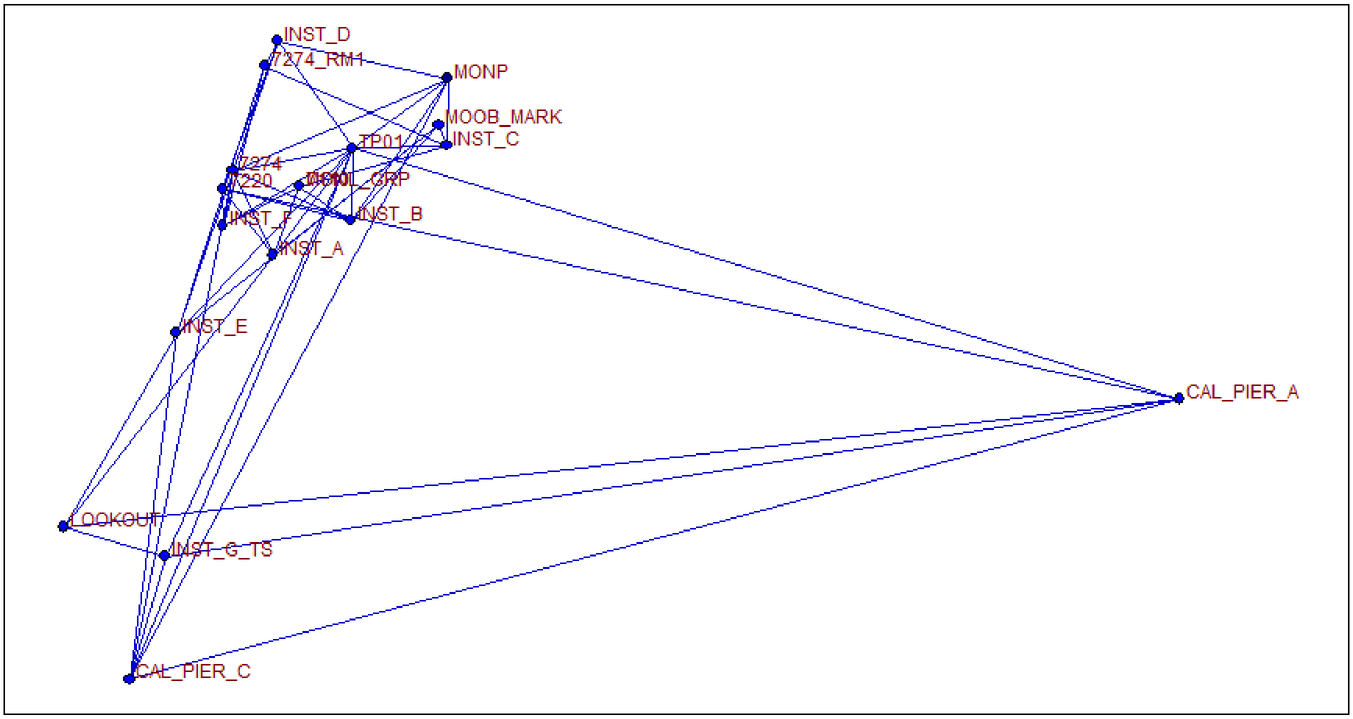

Figure 13 – Terrestrial network diagram

4.2. Leveling

No leveling was required to complete this survey.

4.3. GPS

GPS data was collected to generate 3-dimensional IGS2014 vectors between stations at the epoch date of survey (2018/05/17). At the project site, simultaneous long-session observations over multiple days were taken at CAL PIER C, 7274, and TP01. Publicly available GPS data was also obtained for Continuously Operating Reference Stations (CORS), including MONP and others in the region.

The GPS observations were processed with a minimally-constrained, "hub" design emanating from station MONP. Using the baseline processing engine within NGS's OPUS Projects software, IGS2014 vectors to the network stations and CORS were generated via IGS2014 satellite orbits. For the purpose of this survey, IGS2014 is aligned to ITRF2014 and the two are interchangeable.

The resulting GPS vectors were used in a combined network adjustment to align the terrestrial survey to ITRF2014.

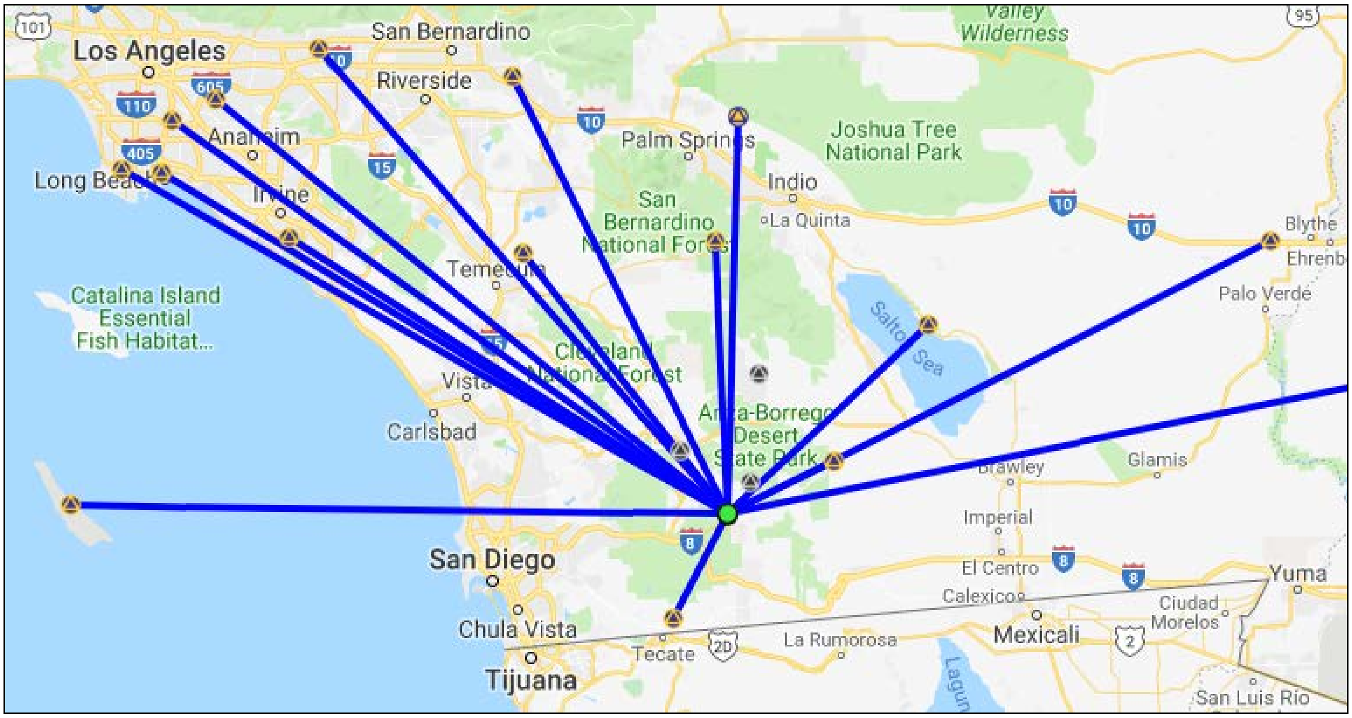

Figure 14 – GPS network diagram

4.4. General Comments

As noted earlier, determining the local coordinates of the SLR geometric reference point (GRP) was achieved using an indirect approach. The "circle fit" theory is described herein. A point, as it revolves about an axis, scribes a perfect arc. The arc defines a perfect circle and a plane simultaneously. The axis can then be defined as it passes through the center of the circle, orthogonal to the plane. By assigning coordinates to the points observed along an arc rotated about an axis, one can assign parameters to the axis relative to an established local coordinate system.

Tracker measurements project coordinates from the local ground network to a target/reflector attached to a geodetic technique instrument as it moves about the instrument's axis, thereby providing the necessary information to locate a single axis. The same procedure must be done for the opposing axis of the instrument in the same local reference frame. The point along the azimuth axis that is orthogonal to the elevation axis is the GRP associated with the SGT.

In practice, precise observations involving a single target/reflector secured to the telescope, measurements from at least two ground network marks, and numerous measurements per axis serve to ensure a millimeter level of positional precision is achieved. The SLR GRP was determined in this manner.

Local coordinates for the IGS station's GRP were determined using a circle fitting routine. 3-dimensional measurements were taken to a target/reflector at multiple points along the circumference of a base plate, directly attached at the bottom of the antenna mount. The center of the bottom of the antenna mount is the antenna reference point (ARP). See Figure 14.

A sufficient number of points were measured to scribe a circle in space. Coordinates corresponding to the center of the scribed circle were computed to represent the GRP. Corrections were applied to account for reflector and holder offset constants and the reported vertical offset from the GRP to the ARP. Measurements were taken from four independent locations for redundancy.

Figure 14 – Taking measurements to MONP's antenna.

5. Terrestrial Survey

5.1. Analysis software

Commercially available software Spatial Analyzer (version 2017.08.11_29326) was used to collect all field measurements with the absolute laser tracking system. The software was also used to conduct circle fitting computations for MONP and the MONL GRP.

Commercially available, least squares adjustment software Star*Net (version 9,0,3,6298) was used to perform a classical 3-dimensional adjustment of the terrestrial data. Measurements included in the adjustment consisted of terrestrial observations of all ground network marks and intermediate target points affixed to the SLR telescope. The adjustment produced coordinates and variance-covariance information for all features surveyed. Terrestrial adjustment parameters and results can be found in Star*Net output file MonumentPeak.lst. Terrestrial adjustment variance-covariance estimates can be found in the Star*Net output file MonumentPeak.dmp.

5.1.2. Topocentric Coordinates and Covariance

Topocentric coordinates and covariance information, from the classical adjustment of the terrestrial data for all network stations can be found in section 2.1 "SOLUTION PARAMETER SUMMARY" and section 2.2 SOLUTION VARIANCE COVARIANCE MATRIX REDUCTION" in AXIS output file output.axs.

5.1.3. Correlation Matrix

Reduced correlation matrix information for network stations can be found in section 5, "SINEX GENERATION" in AXIS output file output.axs.

5.2. GPS Observations

NGS's OPUS Projects software was used to process and analyze IGS2014 vectors between stations at the epoch date of survey (2018/05/17). For the purpose of this survey, IGS2014 vectors are interchangeable with ITRF2014 vectors. The resulting vectors can be found in OPUS Projects output file “network-final.gfile.”

5.3. Additional Parameters

5.3.1. SLR Telescope Axis Offset Computation

Spatial Analyzer software was used to compute the offset distance between the SLR telescope’s elevation and azimuthal axes. The axial offset was computed from three independent observations with an average value of 0.0003 m ± 0.0001 m.

5.3.2. SLR Telescope Reference Mark to GRP Offsets

The SLR site log reports eccentricities from the ground reference mark to the instrument geometric reference point of North -0.026 m, East -0.019 m, and Up 3.189 m. This survey determined values of North -0.0242 m, East -0.0148 m, and Up 3.1895 m.

5.4. Transformation

IGS2014 GPS vectors (considered interchangeable with ITRF2014 vectors) were generated to Continuously Operating Reference Stations (CORS) in the surrounding region. The vectors were used in a combined geodetic adjustment to align, or transform, the surveyed local ties to ITRF2014 at the epoch date of survey.

5.5. Description of SINEX generation

AXIS was used to generate a final solution output file in SINEX format with full variance-covariance matrix information. The following SINEX file naming convention, adopted by Geoscience Australia for local survey data, was also used for this survey.

XXXNNNNYYMMFV.SNX

Where:

XXX is a three-character organization designation.
NNNN is a four-character site designation.
YY is the year of the survey.
MM is the month of the survey.
F is the frame code (G for global, L for local).
V is the file version.

Axis generated SINEX file ***NGSMONP1805GA.snx*** is found in the Attachment: SINEX File.

5.6. Discussion of Results

Least-Squares Estimates of Terrestrial Observations

A classical 3-dimensional adjustment of terrestrial observation was conducted using Star*Net. A statistical summary from the adjustment is included in Table 5. For additional details concerning the classical adjustment of the terrestrial survey, see Star*Net output file MonumentPeak.lst.

```
            Adjustment Statistical Summary
            ==============================

           Iterations                =      4

           Number of Stations        =     35

           Number of Observations    =    610
           Number of Unknowns        =    133
           Number of Redundant Obs   =    477

 Observation    Count    Sum Squares         Error
                          of StdRes          Factor
 Coordinates       3         0.000           0.000
  Directions     126        98.071           0.998
   Distances     127        99.384           1.000
     Zenith      113        88.053           0.998
  Elev Diffs       1         0.000           0.000
  GPS Deltas     240       188.179           1.001

       Total     610       473.687           0.997

       The Chi-Square Test at 5.00% Level Passed
            Lower/Upper Bounds (0.937/1.063)
```

Table 5

Coordinate Listing

AXIS was used to compute final coordinate estimates, aligned to reference frame ITRF2014 (epoch 2018/5/17) for all network stations determined in the current NGS survey. See Table 6 for the compiled coordinate listing. Final coordinates for the SLR GRP and the IGS tracking station MONP are in SINEX format in the Attachment and in AXIS output file NGSMONP1805GA.snx.

SITE	***X (m)***	***Y (m)***	***Z (m)***	***SX(m)***	***SY(m)***	***SZ(m)***
7110	-2386278.8889	-4802353.5731	3444881.9005	0.0003	0.0003	0.0003
7220	-2386293.1689	-4802346.6968	3444881.3044	0.0002	0.0003	0.0004
7274	-2386290.2778	-4802345.7720	3444884.4236	0.0002	0.0003	0.0004
MONP	-2386247.5207	-4802359.0313	3444902.4294	0.0000	0.0000	0.0000
CAL PIER A	-2386133.1874	-4802467.8169	3444854.2544	0.0009	0.0011	0.0013
CAL PIER C	-2386335.3785	-4802389.2778	3444797.8333	0.0007	0.0007	0.0005
MONL GRP	-2386280.0998	-4802355.9767	3444883.6123	0.0003	0.0003	0.0003
MONP ARP	-2386247.5647	-4802359.1197	3444902.4933	0.0002	0.0001	0.0002
MOOB MARK	-2386251.3504	-4802362.7628	3444894.4577	0.0002	0.0002	0.0003

Table 6 – ITRF2014 (epoch 2018/05/17) coordinate estimates for Monument Peak network stations.

Table 7 provides the local tie vectors using the final ITRF2014 (epoch 2018/05/17) coordinates determined this survey, emanating from 7110 as previously published at the ITRF website.

Surveyed ties, ITRF2014 (2018/05/17)							
SITE	***X (m)***	***Y (m)***	***Z (m)***	***E (m)***	***N (m)***	***U (m)***	***DISTANCE***
7110	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
7220	-14.2800	6.8763	-0.5961	-15.8481	-0.6072	-0.1587	15.8605
7274	-11.3889	7.8011	2.5231	-13.6706	3.1603	-0.2405	14.0332
MONP	31.3682	-5.4582	20.5289	30.5202	22.1639	3.5318	37.8840

Table 7 – Local tie vectors emanating from 7110.

Additional ties are provided emanating from the SLR instrument's geometric reference point.

Surveyed ties, ITRF2014 (2018/05/17)							
SITE	***X (m)***	***Y (m)***	***Z (m)***	***E (m)***	***N (m)***	***U (m)***	***DISTANCE***
MONL GRP	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
MONP	32.5791	-3.0546	18.8171	30.5350	22.1880	0.3423	37.7467
MONP_ARP	32.5351	-3.1430	18.8810	30.5349	22.1880	0.4599	37.7479
CAL_PIER_A	146.9124	-111.8402	-29.3579	181.3330	-43.5405	13.2638	186.9582
CAL_PIER_C	-55.2787	-33.3011	-85.7790	-34.6854	-101.5819	-0.8856	107.3440

Table 8 – Local tie vectors emanating from SLR MONL Geometric Reference Point.

ITRF2014 (epoch 2018/05/17) computed coordinates were obtained from IERS representative Zuheir Altamimi and are provided in Table 9. A comparison of the surveyed tie vectors against the computed ties is also provided.

Computed coordinates, ITRF2014 (epoch 2018/05/17)						
SITE	***SOL***	***X (m)***		***Y (m)***		***Z (m)***
7110	3	-2386278.8898		-4802353.5873		3444881.9090
7220	--	-2386293.1825		-4802346.6884		3444881.3426
7274	--	-2386290.3531		-4802345.6931		3444884.2704
MONP	8	-2386247.5208		-4802359.0312		3444902.4295
Surveyed ties vs. Computed ties						
SITE	***DX (mm)***	***DY (mm)***	***DZ (mm)***	***DE (mm)***	***DN (mm)***	***DU (mm)***
7110	0.0	0.0	0.0	0.0	0.0	0.0
7220	12.7	-22.6	-29.7	21.5	-32.8	-3.8
7274	74.4	-93.1	161.7	108.0	108.4	130.1
MONP	-0.8	-14.3	8.4	5.7	0.0	15.6

Table 9 – ITRF computed coordinates

For reference, the latest local ties (DX, DY, DZ from geocentric coordinates) published to the ITRF website are provided below. Per the associated site SINEX file, the ties are referenced to ITRF2000 (epoch 1997.00) and are assumed to be generated from the 1999 field survey.

```
Local tie used in the ITRF2000 primary combination

Site           : 40497
Local tie file : 40497.TIE
Release        : 2003  22  5
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40497 MONUMENT PEAK
 40497M001  40497M002     -14.269        6.872        -0.596
 40497M001  40497M003     -11.395        7.802         2.523
 40497M001  40497M004     31.3649       -5.4557      20.5255
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Table 10 – Latest reported ties

As a check on the results of the field survey, AXIS software was used to align the current survey to ITRF2000 (epoch 1997.00). The resulting coordinates and comparisons are shown below.

Surveyed coordinates, ITRF2000 (epoch 1997.00)						
SITE	***X (m)***		***Y (m)***		***Z (m)***	
7110	-2386278.0843		-4802354.2461		3444881.5345	
7220	-2386292.3643		-4802347.3698		3444880.9384	
7274	-2386289.4732		-4802346.4450		3444884.0576	
MONP	-2386246.7161		-4802359.7043		3444902.0634	
Surveyed ties vs. latest reported ties						
SITE	***DX (mm)***	***DY (mm)***	***DZ (mm)***	***DE (mm)***	***DN (mm)***	***DU (mm)***
7110	0.0	0.0	0.0	0.0	0.0	0.0
7220	-11.0	4.3	-0.1	-11.7	-0.6	0.9
7274	6.1	-0.9	0.1	5.8	1.1	-1.5
MONP	3.3	-2.5	3.4	4.1	2.5	2.5

Table 11 – Comparison to previous survey

Analyzing the tie vector between SLR mark 7110 and GNSS station MONP, the survey results agreed with the latest reported tie at the 4 millimeter level in each component.

Comparing against the ITRF2014 computed coordinates, the current survey has a discrepancy of about 16 millimeters in the up component. MONP’s up component is entirely dependent on the vertical offset (eccentricity) reported in the IGS site log, which was not able to be verified in this survey. Given the magnitude of the discrepancy, MONP’s antenna reference point (ARP) is also provided, for further examination of any issue with the vertical offset.

Discrepancies from the computed coordinates were also found in the ground marks 7220 (up to 33 millimeters) and 7274 (up to 130 millimeters). According to correspondence with the IERS, the computed coordinates for these two stations are unreliable at the epoch date of survey.

6. Planning Aspects

Contact information

The primary contact for information regarding the NASA Monument Peak site is Ronald Sebeny. Ronalds's contact information is:

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P.O. Box 130
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Email: RSEBENY@harris.com

Recommendations

The site operators were flexible with access to the telescope and network stations. Calibration Pier A is the primary pier during operations and could not be occupied for long-session (overnight) GPS. The site is accessible during weekdays, but unmanned and locked on weekends. Plan work schedule accordingly. The access road leading to the site locked. Call in advance for access. For this survey, equipment was not shipped directly to the site, but to a UPS Customer Center in San Diego.

7. References

7.1. Name of person(s) responsible for observations

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7.3. Location of observation data and results archive

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Phone: (540) 373-1243

7.4. Works Referenced

International Earth Rotation and Reference System Service. Resolution on the nomenclature of space geodetic reference points and local tie measurements. July 16, 2009.

Jean-Claude Poyard et al.: IGN best practice for surveying instrument reference points at ITRF co-location sites. (IERS Technical Note ; 39) Frankfurt am Main: Verlag des Bundesamts für Kartographie und Geodäsie, 2017. 45 pp., ISBN 978-3-86482-129-5 (print version), in press.

Attachment: SINEX Format