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

INTERNATIONAL EARTH ROTATION & REFERENCE SYSTEM SERVICES
PIE TOWN, NM LOCAL SITE SURVEY REPORT

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Dates of Data Collection: May, 2016
Date of Report: June, 2016

Introduction

During May, 2016, the National Geodetic Survey conducted a high precision local site survey at the National Radio Astronomy Observatory's Very Long Baseline Array site in Pie Town, New Mexico. Data collection consisted of leveling using a digital barcode leveling system, traverse procedures using a high precision tacheometer and static Global Positioning System (GPS) observations using survey grade duel frequency instrumentation. The objective of the survey was to establish high precision local ties, referenced to the International Terrestrial Reference Frame (ITRF2008), for the reference points associated with a radio telescope, sometimes used for Very Long Baseline Interferometry (VL BI), a Global Navigation Network System (GNSS) antenna and new and historic ground control marks. This report documents the instrumentation and methodologies used to collect the geo-spatial data set and the data reduction and analysis procedures used to compute the local ties.

Site Description

Site Name: Pietown (New Mexico)
Country Name: UNITED STATES OF AMERICA
Longitude: E 251° 53'
Latitude: N 34° 18'
Tectonic plate: NOAM

SGT Instrument	Name	DOMES#	Description/a.k.a.
GPS	PIE1	40456M001	Instrument Reference Mark
GPS	PIEA		GPS Antenna Reference Point
VLBI	7234	40456S001	Conventional Reference Point

Table 1 – Space Geodetic Technique Instrument (SGT) located at the site.

2. Instrumentation

2.1. Tacheometers

2.1.1. Description

Leica TDM5005
S/N: 441698
<u>Specifications</u>
Angular measurement uncertainty: ± 0.7"
Distance standard deviation of a single measurement: 1 mm + 2 ppm
Distance offset selected for project, +34.4 mm

2.1.2. Calibrations

The tacheometer was originally calibrated by Leica Geosystem AG Heerbrugg, Switzerland.
Inspection date: 08/20/2008
In April, 2016 this instrument's EDMI was evaluated using the NGS Corbin Calibration Baseline and the EDMI was found to be measuring distances within the manufacturer's specifications.

2.1.3. Auxiliary Equipment

Wild NL Collimator, S/N: 279330, Pointing accuracy, 1: 200,000
Hygrometer/Barometer: Omega Nomad, model # OM-CP-PRHTEMP101, S/N P37543
Thermometer: DORIC 450, S/N 00662, with thermistor sensor fabricated by NGS

2.2. GPS Units

2.2.1. Receivers

Trimble NetR5
P/N: 62800-00
S/Ns: 4619K01307, 4624K01648, and 4624K01584 and 462K01631
<u>Specifications for Static GPS Surveying</u>
Horizontal: +/- 5 mm + 0.5 ppm RMS
Vertical: +/- 5 mm + 1 ppm RMS

2.2.2. Antennas

Topcon GPS/GLONASS/Galileo choke ring antenna, model CR-G3
P/N: 1-044301-01
S/Ns 383-1614, -1626 and -1628

2.2.3. Analysis software, mode of operation

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

Leica DNA03 digital level, P/N: 723289
Height measurement accuracy, +/-0.3 mm per km, double-run.

2.3.2. Leveling Staffs

Leica GWCL92 92-cm Invar Bar Code Rod
S/N: 30721
Leica GPCL3 3-m Invar Bar Code Rod
S/N: 30579

2.3.3. Checks carried out before measurements

Prior to observations the instrument's reticle was to checked to ensure it was coincident with the instrument's horizontal line of sight. Instrument collimation test procedures, using the Kukkamaki procedure, were undertaken daily, prior to data collection. Leveling rod bubbles were checked daily, prior to use.

2.4. Tripods

Standard wooden surveying tripods, with collapsible legs, were used to support surveying instrumentation centered over all ground network marks.

2.5. Forced Centering Devices

At each tripod setup, a Leica GDF321 tribrach was plumbed precisely over a survey mark disk using a Wild NL Collimator. The tribrach was "leveled up" using a Leica Geosystems GZR3 carrier with longitudinal bubble. That is, the carrier's standing axis was brought into alignment with the local gravity vector using the tribrach's footscrews.

To facilitate precise measurement of the height of instruments/reflectors above each mark, a tribrach adapter was locked into the tribrach, the top of same serving as a vertical point of reference. Digital leveling equipment was used to transfer a height difference from the survey mark to the vertical point of reference associated with the tribrach adapter. To determine a total height of instruments/reflectors above the mark, an offset constant of 0.1675m was added to the leveled height difference. The constant was previously determined by NGS and represents the distance from the tribrach adapter's vertical point of reference to either the center of the tilt axis of the tacheometer's telescope or the center of a target/reflector.

2.6. Targets, Reflectors

Leica GDH1P retro-reflectors, model #555631
<u>Specifications</u>
Centering of Optics: $\leq \pm$ 0.03mm
Distance Offset: -34.4 mm

Leica GRT144, Carrier with Stub
Centering Accuracy: ± 1.0 mm

All tacheometer observations were made to Leica GPH1P precision reflectors serving as both target and reflector. The manufacturer-provided offset value of -34.4 mm for the GPH1P was validated prior to the survey. Reflectors were affixed to tribrachs using GRT144 carriers.

To minimize potential loss of precision in distance measurement, care was taken to precisely point all reflectors back to the tacheometer. To that end, reflectors used for SGT 7234 CRP measurements were affixed to radio-controlled, pan-tilt units and remotely controlled by the observer to point reflectors back to the tacheometer after each motion of the radio telescope.

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 angles and distance measurements. Height differences between the marks were determined by precise leveling techniques. Ground network marks are used to tie Space Geodetic Technique (SGT) instruments to the network, and indirectly, to each other. One non-monumented, or temporary mark, (TP01) was used this survey to facilitate horizontal angle measurements to PIE1 IRM and PIETOWN CORS ARP.

3.1.1. Listing

Current Survey	DOMES	IERS 4-char code	Current Survey id	Previous Survey Point Name	NGS PID
Ground Network Marks					
PIE TOWN VLBA RM 1	n/a	n/a	PTR1	PIE TOWN VLBA RM 1	ER0692
PIE TOWN VLBA RM 2	n/a	n/a	PTR2	PIE TOWN VLBA RM 2	ER0693
PIE TOWN VLBA RM 3	n/a	n/a	PTR3	PIE TOWN VLBA RM 3	ER0694
PIE TOWN VLBA RM 4	n/a	n/a	PTR4	-new this survey--	n/a
PIE TOWN VLBA RM 5	n/a	n/a	PTR5	-new this survey-	n/a
SGT Instrument Reference Mark					
PIE1 IRM	40456M001	PIE1	PIE1	-new this survey-	n/a
SGT Conventional Reference Points					
PIETOWN CORS ARP	n/a	n/a	PIEA	-new this survey-	AF9512
SGT 7234 CRP	40456S001	7234	7234	PIE TOWN VLBA ANT 7234	ER0695

Table 2 – Listing of Ground Network Marks, SGT Instrument Reference Marks and SGT Conventional Reference Points.

Ground Network Marks

PIE TOWN VLBA RM 1(PTR1): The mark is a dimple, set in the top center of a rounded stainless steel rod inside a grease filled PVC sleeve. The setting depth of the rod and sleeve are unknown. The mark is set in the center of a PVC pipe with an aluminum logo cover. The aluminum logo cover is stamped PIE TOWN N.M. VLBA RM 1 8 90 7234.

Figure 1 – PIE TOWN VLBA RM 1

PIE TOWN VLBA RM 2(PTR2): The mark is a dimple, cast in the top center of a NASA-SFC brass disk, set flush in the top of a concrete post type monument and inside a PVC pipe with aluminum logo cover. The setting depth of the concrete post is unknown. The brass disk is stamped PIE TOWN NM VLBA RM 2. The aluminum logo cover is stamped PIE TOWN NM. VLBA RM2 7234 AUG 1990.

Figure 2 – PIE TOWN VLBA RM 2

PIE TOWN VLBA RM 3(PTR3): The mark is a dimple, cast in the top center of a NASA-SFC brass disk, set flush in the top of a concrete post type monument and inside a PVC pipe with aluminum logo cover. The setting depth of the concrete post is unknown. The brass disk is stamped PIE TOWN N.M. VLBA RM 3. The aluminum logo cover is stamped PIE TOWN N. M. VLBA RM 3 AUG 1990 7234.

Figure 3 – PIE TOWN VLBA RM 3

PIE TOWN VLBA RM 4(PTR4): The mark is a dimple, cast in the top center of a NGS brass geodetic control disk, set flush in the top of a concrete post type monument set to a depth of 1.2 m. The disk is stamped PIE TOWN VLBA RM 4 2016.

Figure 4 – PIE TOWN VLBA RM 4

PIE TOWN VLBA RM 5(PTR5): The mark is a dimple, cast in the top center of a NGS brass geodetic control disk, set flush in the top of a concrete post type monument set to a depth of 1.2 m. The disk is stamped PIE TOWN VLBA RM 5 2016.

Figure 5 – PIE TOWN VLBA RM 5

Instrument Reference Marks

PIE 1: The Instrument Reference Mark (IRM) is a dimple cast into the top center of a stainless steel plate set in the top center of a concrete pier set to a depth of 3.0 m. The plate is inscribed VLBA SITE GPS STATION MARK JPL 4009-S 1992.

Figure 6 – PIE1 IRM mark

3.1.2. Map of Network

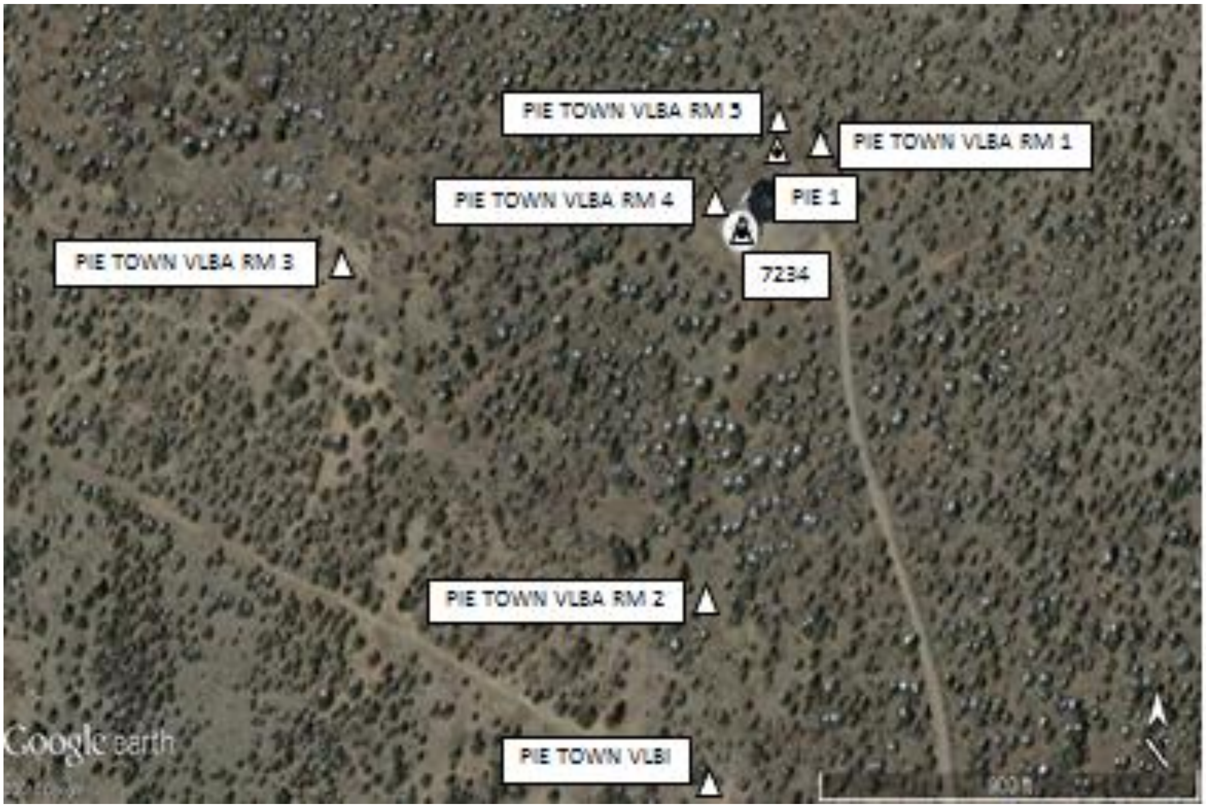

Figure 7 – Pietown ITRF site ground control network map.

3.2. Representation of Technique Reference Points

The conventional reference point (CRP), a.k.a. invariant reference point, is a theoretical point. For the Pie Town VLBA instrument, the CRP can be defined as the intersection of the azimuth axis with the common perpendicular of the azimuth and elevation axis (Johnston et al, 2004).

3.2.1. VLBI

SGT 7234 - The National Radio Astronomy Observatory operates the Very Long Baseline Array (VLBA). SGT 7234 is one of 10 instruments comprising the VLBA. This instrument is used for a variety of astronomic science including periodic VLBI measurements. SGT 7234 is a 25-m AZEL type antenna. This instrument does not have an associated IRM.

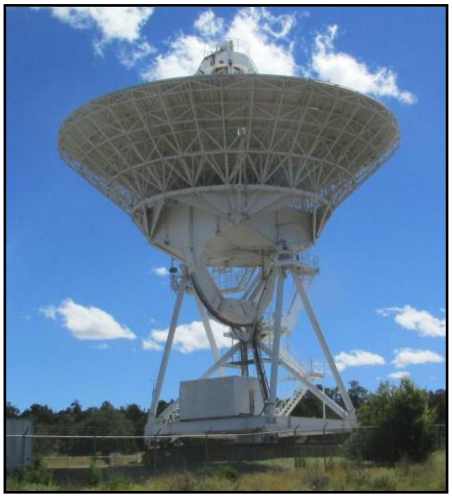

Figure 7 – SGT 7234 25-m radio telescope

Coordinates for the CRP associated with SGT 7234 were determined indirectly this survey by means of a circle fitting routine, using horizontal/vertical angle and distance measurements to targets affixed to the antenna during different rotational sequences.

3.2.2 GPS

PIE1 - The National Aeronautical & Space Administration's Jet Propulsion Laboratory operates GPS 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 model ASH701945E_M NONE (S/N CR520022114). The Antenna Reference Point (ARP) is reported by the IGS to be centered horizontally over the IRM, with a vertical offset of 0.061 m.

Figure 8 – IGS network station PIE1

Without removal of the antenna, the IRM is not accessible for direct occupation of survey Instrumentation. Coordinates for the IRM associated with PIE1 were determined this survey by intersection method from ground network marks PIE TOWN VLBA RM 1, PIE TOWN VLBA RM 4 and a temporary mark (TP01). A site log for PIE1 is available at the IGS web page: https://igscb.jpl.nasa.gov/igscb/station/log/pie1_20160211.log

4. Observations

4.1. Conventional Survey

The conventional survey consisted of measuring horizontal/vertical angles and distances using a high precision tacheometer, employing traverse procedures between and/or to all features of interest. All angular and distance measurements were observed a minimum of four repetitions and incorporated double centering of the tacheometer, otherwise known as measuring in both phase I and phase II. For distance measurements, meteorological data were input into the tacheometer and refractive index corrections were applied internally at time of field measurement. Data collection software GeoObs v1.04.02 was used for recording field measurements and field level data quality checks. A complete list of unadjusted and adjusted tacheometer field observations consisting of directions, zenith distances, slope distances and instrument/target heights are available in Star*Net output file Pietown.lst.

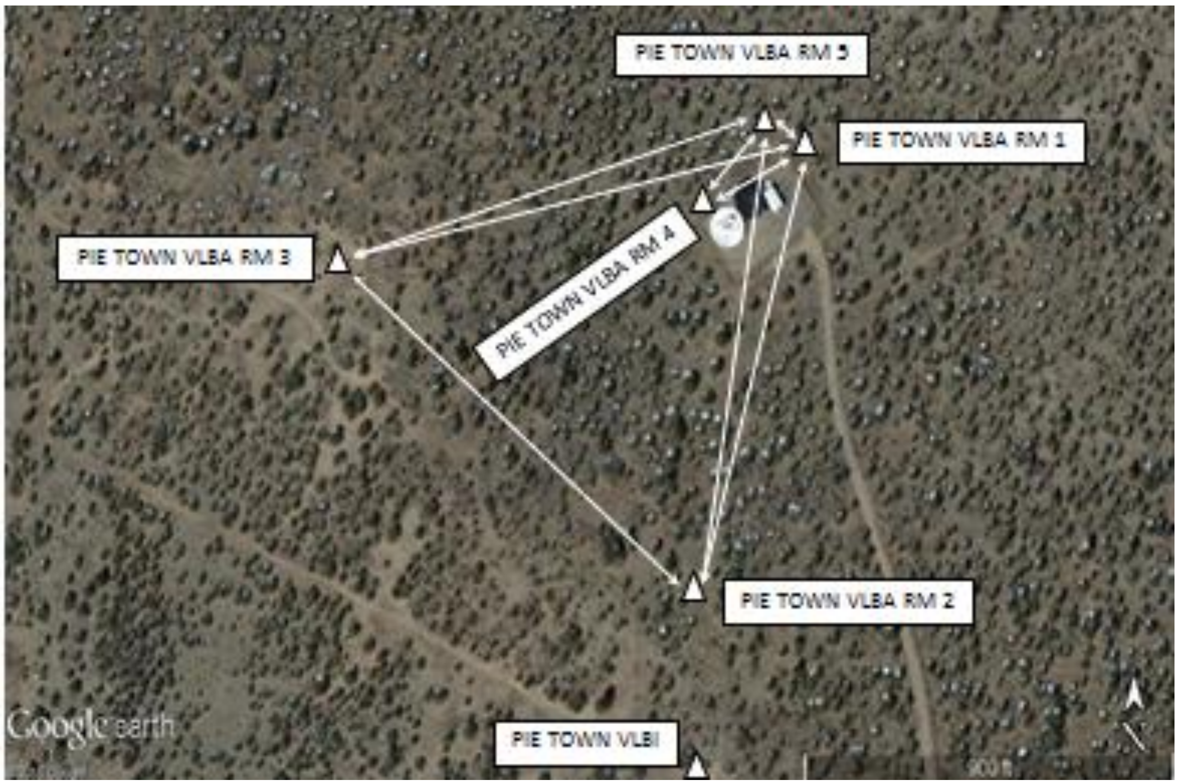

Figure 9 – Horizontal control map

4.2. Leveling

Leveling data was collected for the purpose of determining high precision height difference information referenced to the geoid. Leveling between all ground control network mark, PIE1 IRM and PIETOWN CORS ARP were performed to Federal Geodetic Control Sub-committee (FGCS) First Order, Class 1 standards.

Three "double run" level loops were completed, with the first loop beginning at PIE TOWN VLBA RM 1 then to PIE TOWN VLBA RM 5 then to PIE TOWN VLBA RM 4, closing back to PIE TOWN VLBA RM 1. A second loop was run from PIE TOWN VLBA RM 5 then to PIE1 IRM, then to PIETOWN CORS ARP, closing back to PIE TOWN VLBA RM 5. A Third loop was run from PIE TOWN VLBA RM 4 then to PIE TOWN VLBA RM 3 then to PIE TOWN VLBA RM 2, closing back to PIE TOWN VLBA RM 1. Two double run spurs were run. The first spur was run off of the third loop to PIE TOWN VLBI from PIE TOWN VLBA RM 2. The second loop was run off of the first loop from PIE TOWN VLBA RM 5 to TP01.

The measured height differences between marks were incorporated into a classical 3-dimensional adjustment of the terrestrial data. A complete listing of unadjusted leveling observations is available in Leica output file Pietown.abs.

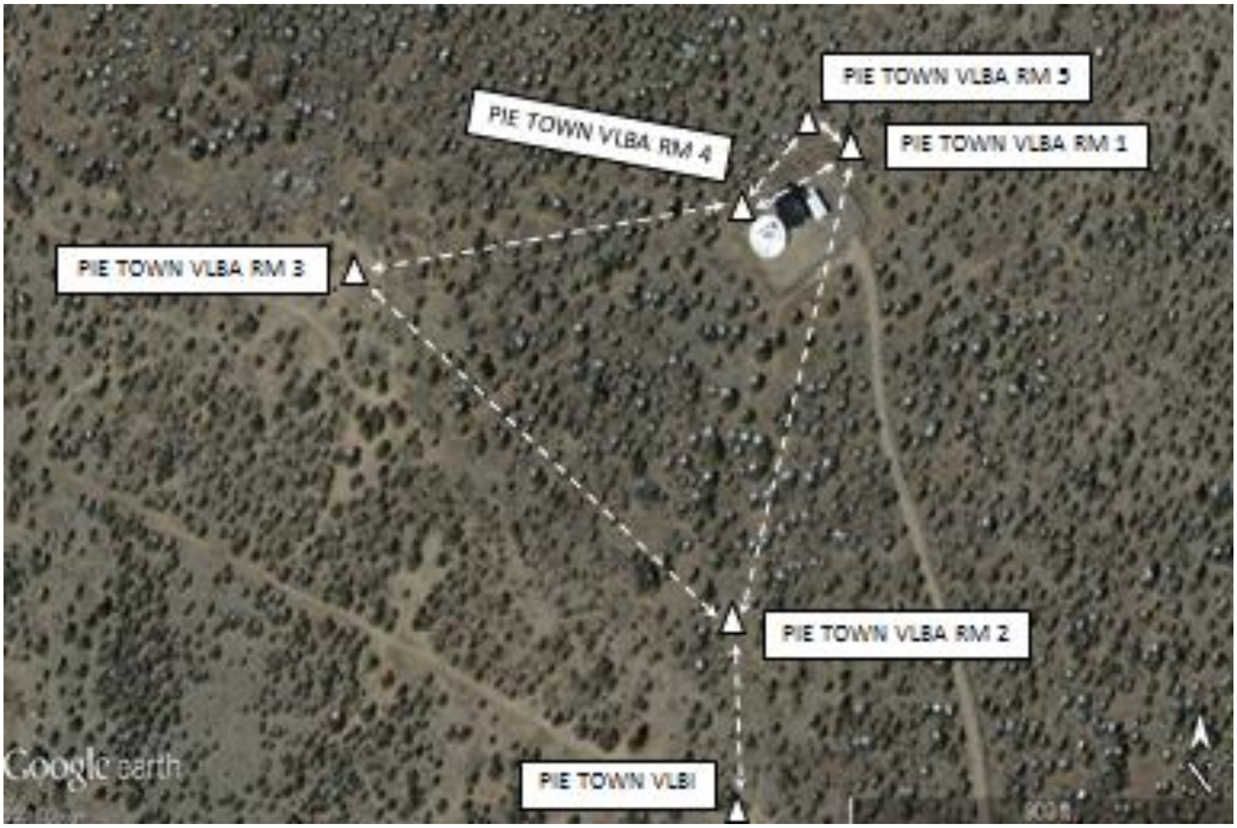

Figure 10 – Vertical control map

4.3. GPS

GPS data was collected for the purpose of determining high-precision, 3-dimensional IGS08(epoch date of survey 2016/05/18, aka eds) coordinates for ground network marks marks (PIE TOWN VLBA RM 1, PIE TOWN VLBA RM 2, PIE TOWN VLBA RM 3 and PIE TOWN VLBA RM 5). GPS data collection consisted of simultaneous and long-session observations conducted over multiple days. GPS derived coordinates for the four marks was used to align or transform the local terrestrial network to ITRF2008(eds).

4.4. General Comments

As noted earlier, determining the local coordinates of the SGT 7234 CRP was achieved using an indirect approach. The "circle fit" theory is straight-forward. 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 seen 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. Tacheometer measurements project coordinates from the local ground network to a target 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 primary axis that is orthogonal to the secondary axis is the CRP associated with the SGT.

In practice, a complex system of precise observations involving three targets 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. SGT 7234 CRP was determined in this manner.

5. Terrestrial Survey

5.1. Analysis software

Commercially available, least squares adjustment software Star*Net (version 8,1,2,990) 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, intermediate target points affixed to the VLBA antenna. The adjustment produced geodetic coordinates and variance-covariance information for all features surveyed. The adjustment included height differences between ground network marks determined by leveling and included PIE1 IRM and PIETOWN CORS ARP. Terrestrial adjustment parameters and results can be found in Star*Net output file Pietown.lst. Terrestrial adjustment variance-covariance estimates can be found in the Star*Net output file Pietown.dmp.

AXIS 1.07 software, developed by Geoscience Australia (GA), was used to perform 3-dimensional arc fitting to compute a number of axes in space, which were in turn used to estimate the CRP associated with the SGT 73234. A Star*Net output file (Pietown.dmp) containing coordinate and variance-covariance estimates for intermediate targets affixed to the SLR was converted to VCV format file (Pietown.vcv) using NGS software HALF2VCV and used as initial input. Circle fitting constraints can be found in AXIS input file setup.axs. Circle fitting parameters and results can be found in section 3.0 "Least Squares Estimation" of AXIS output file output.axs.

5.1.2. Topocentric Coordinates and Covariance

Topocentric coordinates and covariance information, from the classical adjustment of the terrestrial data, for ground network marks, VLBA targets 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 the ground network marks, the CRP associated with SGT 7234 can be found in section 6. "SINEX GENERATION" in AXIS output file output.axs.

5.2. GPS Observations

NGS's Online Positioning User's Service (OPUS) Projects was used to post-process and analyze GPS data and to compute least-squares, 3-dimensional estimates of mark positions. Resulting adjusted positions can be found in (OPUS) Projects output file "network-final.snx".

5.3. Additional Parameters

5.3.1. VLBA antenna Axis Offset Computation

AXIS software was used to compute the offset distance between the elevation and azimuthal axis. The offset value was computed to be 2.1380 ± 0.3 mm. The International VLBI Service reports the axial offset to be 2.1377 +- 0.0089 m. Offset computation results can be found in section 3.7 "IVP/TOUCH/INTERSECT PARAMETER VALUES AND THEIR PRECISION" of the AXIS output file output.axs.

5.3.2. GPS Antenna Reference Point Offset from Instrument Mark Computation

NGS Program INVERS3d was used to compute offset values from PIE1 IRM to PIETOWN CORS ARP. Final coordinates for these marks, provided in Table 5, was used as input. Offset values were computed to be delta north 0.0001 m, delta east 0.0000 m and delta up 0.0609 m. The International GNSS Service reports offset values to be delta north 0.000 m, delta east 0.000 m and delta up 0.061 m.

5.4. Transformation

Local tie vectors from the terrestrial survey were accurately aligned, or transformed, from a geodetic frame to ITRF2008(eds) using AXIS software. For the alignment, AXIS requires coordinates in the desired reference frame and epoch date, at a minimum of four co-observed sites (PIE TOWN VLBA RM 1, PIE TOWN VLBA RM 2, PIE TOWN VLBA RM 3 and PIE TOWN VLBA RM 5). The spatial integrity of the terrestrial survey is maintained throughout the transformation process. Transformation parameters and results can be found in section 5. "FRAME ALIGNMENT" in the AXIS output file output.axs.

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 GSA 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 ***NGSPIE1605GA.snx*** is found in Attachment A.

5.6. Discussion of Results

Least-Squares Estimates of Terrestrial Observations

A classical 3-dimensional adjustment of terrestrial observation was conducted using Star*Net. The adjustment produced geodetic coordinates, in a geodetic reference frame, for all stations included in the survey and the targets intended for use in determination of SGT 7234 CRP. A statistical summary from the adjustment is included in Table 3.

Adjustment Statistical Summary

Iterations	2
Number of Stations	74
Number of Observations	1295
Number of Unknowns	357
Number of Redundant Obs	938

Observation	Count	Sum Squares of StdRes	Error Factor
Coordinates	3	0.000	0.000
Directions	512	78.772	0.461
Distances	486	10.395	0.172
Az/Bearings	1	0.000	0.000
Zeniths	271	129.044	0.811
Level Data	22	1.245	0.279
Total	1295	219.456	0.484

Table 3 – Terrestrial survey classical 3-dimensional adjustment statistical summary

For additional details concerning the classical adjustment of the terrestrial survey, see Star*Net output Pietown.lst.

AXIS was used to produce coordinates and variance-covariance estimates for the CRP associated with SGT 7234. A VCV file, containing coordinates and associated variance-covariance estimates for main scheme network marks and targets affixed to the VLBA antenna, was used as input. The VCV file (Pietown.vcv) was created from Star*Net output file Pietown.dmp using NGS program HALF2VCV. AXIS performed 3-dimensional arc fitting to compute multiple axes in space, which were in turn used to estimate the CRP associated with SGT 7234. Table 4 contains statistics from the least squares solution. For additional details, see AXIS output file, output.axs, Section 3.2 "SOLUTION STATISTICS".

LEAST SQUARES SOLUTION

LEAST SQUARES SOLUTION

# OF TARGETS	12
# OF IVP ESTIMATES	2
# OF COORDINATE-OBSERVATIONS	213
# OF UNKNOWNS	100
# OF CONDITIONS	132
# OF CONSTRAINTS	28
# OF ADD. CONSTRAINTS	42
# OF CONSTRAINTS TOTAL	70
DEGREES OF FREEDOM	315
ITERATIONS TO COMPLETE	2
MAXIMUM RESIDUAL (METRE)	0.00203
VARIANCE (CONDITIONS)	0.19080
VARIANCE (CONSTRAINTS)	0.00001
VARIANCE (APRIORI)	0.00000
VARIANCE FACTOR	0.19081
SIGMA	0.43681

Table 4 –Statistical summary from least squares adjustment of VLBA targets

Final Coordinate Listing

AXIS was used to compute final coordinate estimates, aligned to reference frame ITRF2014 (eds), for all ground network marks, the IRM and ARP associated with PIE1 and SGT 7234 CRP associated with the current NGS survey. See Table 5 for the compiled coordinate listing. Final coordinates for the CRP associated with SGT 7234 and the IRM for PIE1 are in SINEX format in Attachment A and in AXIS output file ngsPIE11605ga.snx. Final transformed coordinates for the main scheme network marks are provided in section 5.2 "FRAME ALIGNMENT RESULTS" in AXIS output file output.axs

SITE	***X (m)***	***Y (m)***	***Z (m)***	***SX(m)***	***SY(m)***	***SZ(m)***
PTR1	***-1640893.8347***	***-5014787.4355***	***3575446.4981***	***0.0007***	***0.0005***	***0.0006***
PTR2	***-1641023.4647***	***-5014951.7831***	***3575203.0628***	***0.0013***	***0.0009***	***0.0008***
PTR3	***-1641219.2192***	***-5014742.1704***	***3575405.3424***	***0.0007***	***0.0010***	***0.0012***
PTR4	***-1640975.5797***	***-5014787.8891***	***3575413.5526***	***0.0010***	***0.0011***	***0.0012***
PTR5	***-1640915.5377***	***-5014772.5602***	***3575457.6973***	***0.0007***	***0.0006***	***0.0006***
PIE1	***-1640917.0655***	***-5014781.2027***	***3575447.0528***	***0.0010***	***0.0009***	***0.0009***
PIEA	***-1640917.0811***	***-5014781.2505***	***3575447.0872***	***0.0009***	***0.0009***	***0.0009***
7234	***-1640953.9914***	***-5014816.0234***	***3575411.7903***	***0.0009***	***0.0007***	***0.0010***

Table 5 –Listing of final ITRF2008(eds) coordinate estimates for ground network marks, SGT 7234 IRM and PIE1 IRM

Table 6 provides the local tie vectors, determined during this survey, emanating from SGT 7234 CRP to PIE1 IRM. NGS program INVERSE3D was used to compute the tie vector information.

```
                First Station : SGT 7234 CRP - NGS
                           ----------------
X =   -1640953.9914 m  LAT =  34 18  3.65921 North
Y =   -5014816.0234 m  LON = 108  7  9.09205 West
Z =    3575411.7903 m  EHT =      2364.6980  Meters

                Second Station : PIE1 -NGS
                           ----------------
X =   -1640917.0655 m  LAT =  34 18  5.41921 North
Y =   -5014781.2027 m  LON = 108  7  8.14346 West
Z =    3575447.0528 m  EHT =      2347.7449  Meters

Forward azimuth        FAZ =  24  5 53.6626 From North
Back azimuth           BAZ = 204  5 54.1971 From North
Ellipsoidal distance     S =        59.4090 m
Delta height            dh =       -16.9530 m
Mark-to-mark distance    D =        61.8017 m

DX =        36.9259 m   DN =        54.2513 m
DY =        34.8207 m   DE =        24.2657 m
DZ =        35.2625 m   DU =       -16.9533 m
```

Table 6 – Local tie vector emanating from SGT 7234 CRP (meters)

6. Planning Aspects

Contact information

The primary contact for information regarding SGT 7234 is NRAO employee Eric Carlow. Eric's contact information is:'

Eric Carlowe
National Radio Astronomy Observatory (NRAO)
Array Operations Center
P.O. Box O
1003 Lopezville Road
Socorro, NM 87801-0387
Phone: (575) 835-7000, Fax: (575) 835-7027
ecarlowe@nrao.edu

Recommendations:

Plan all measurements to VLBA antenna targets around weekly maintenance days to minimize impact on the NRAO data collection mission. At time of this survey, every Wednesday is a maintenance day. Once each month the VLBA has two consecutive maintenance days during a single week. This would be the optimal week to conduct the local site survey.

The tripod setup at PIETOWN VLBA RM 1 will need to be at least 2.0 m above the mark to ensure line of sight to PIE TOWN VLBA RM 2 is above the chain link fence encircling the VLBA observatory.

Line of sight between PIETOWN VLBA RM 2 and PIETOWN VLBA RM 3 will likely have to be cleared by next survey. Possible obstructions consist of the canopies of several trees on line.

Line of sight between PIETOWN VLBA RM 3 and PIETOWN VLBA RM 5 will likely have to be cleared by next survey. Possible obstructions consist of the canopies of several trees on line.

Watch out for snakes on sunny warm days. There are rattlesnakes in the vicinity of the VLBA observatory.

7. References

7.1. Name of person(s) responsible for observations

Kendall Fancher (Kendall.Fancher@noaa.gov)
Charles Geoghegan (Charles.Geoghegan@noaa.gov)

National Geodetic Survey
15351 Office Drive
Woodford, VA 22580
Phone – (540) 373-1243

7.2. Name of person(s) responsible for analysis

Kendall Fancher (Kendall.Fancher@noaa.gov)
Charles Geoghegan (Charles.Geoghegan@noaa.gov)

National Geodetic Survey
15351 Office Drive
Woodford, VA 22580
Phone – (540) 373-1243

7.3. Location of observation data and results archive

Output files referenced in this report:
http://www.ngs.noaa.gov/corbin/iss/index.shtml

Observation files associated with this survey:
National Geodetic Survey
Instrumentation & Methodologies Branch
15351 Office Drive
Woodford, VA 22580
Phone – (540) 373-1243

Attachment A.

```
%=SNX 1.00 AUS 16:172:57300 AUS 16:139:00000 16:140:00000 C 00006 2 X
+FILE/REFERENCE
 DESCRIPTION         Terrestrial Survey Tie
 OUTPUT              SSC SINEX
 CONTACT             __________________________________________________
 SOFTWARE            axis version 1.07
 HARDWARE            __________________________________________________
 INPUT               Terrestrial Survey Solution
-FILE/REFERENCE
+FILE/COMMENT
* axis software by John Dawson Geoscience Australia
-FILE/COMMENT
+SITE/ID
 PIE1  A 40456M001 C GNSS Instrument Refere -108  7  8.1  34 18  5.4  2347.7
 7234  A 40456S001 C SGT 7234 CRP
          -108  7  9.1  34 18  3.7  2364.7
-SITE/ID
+SITE/DATA
 PIE1  A    1 PIE1  A    1 16:139:00000 16:140:00000 --- 16:139:43200
 7234  A    1 7234  A    1 16:139:00000 16:140:00000 --- 16:139:43200
-SITE/DATA
+SOLUTION/EPOCHS
 PIE1  A    1 C 16:139:00000 16:140:00000 16:139:43200
 7234  A    1 C 16:139:00000 16:140:00000 16:139:43200
-SOLUTION/EPOCHS
+SOLUTION/STATISTICS
 VARIANCE FACTOR                  1.908053253357270e-01
 SQUARE SUM OF RESIDUALS          6.010367748075401e+01
 NUMBER OF OBSERVATIONS                             321
 NUMBER OF UNKNOWNS                                   6
-SOLUTION/STATISTICS
+SOLUTION/ESTIMATE
     1 STAX   PIE1  A    1 16:139:43200 m    2 -1.64091706549504e+06 9.59363e-04
     2 STAY   PIE1  A    1 16:139:43200 m    2 -5.01478120268742e+06 9.03997e-04
     3 STAZ   PIE1  A    1 16:139:43200 m    2  3.57544705283907e+06 9.32030e-04
     4 STAX   7234  A    1 16:139:43200 m    2 -1.64095399142191e+06 9.06023e-04
     5 STAY   7234  A    1 16:139:43200 m    2 -5.01481602343514e+06 7.15315e-04
     6 STAZ   7234  A    1 16:139:43200 m    2  3.57541179031717e+06 9.78733e-04
-SOLUTION/ESTIMATE
+SOLUTION/MATRIX_ESTIMATE U COVA
     1     1  9.20376707650880e-07  2.07620271541434e-08  7.26287814561936e-08
     1     4  2.77989442316806e-07  3.36108831645191e-08  8.19318969226927e-08
     2     2  8.17209744300323e-07  3.03785261102758e-08  3.61015789427474e-08
     2     5  1.96542436495191e-07  2.82669615644369e-08
     3     3  8.68680620905794e-07  6.24586819052541e-08  2.14337557711471e-08
     3     6  2.38545257156616e-07
     4     4  8.20877423198746e-07  1.85909835789488e-08  1.56946216763721e-07
     5     5  5.11676185200101e-07  3.38287198820833e-08
     6     6  9.57918161417759e-07
-SOLUTION/MATRIX_ESTIMATE U COVA
%ENDSNX
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