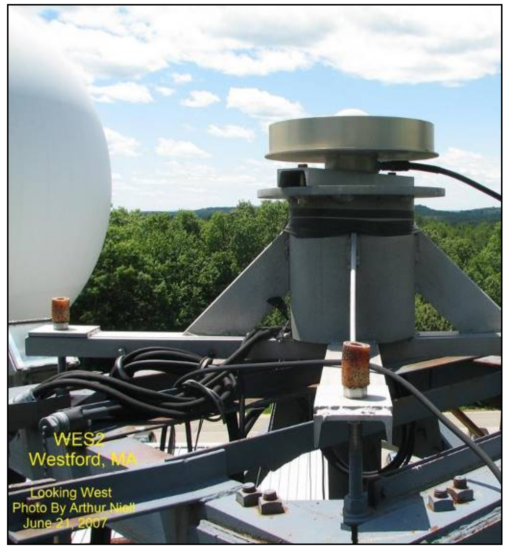
UNITED STATES DEPARTMENT OF COMMERCE
NATIONAL OCEANIC & ATMOSPHERIC ADMINISTRATION
NATIONAL OCEAN SERVICE
NATIONAL GEODETIC SURVEY

FOUNDATION CORS PROGRAM
LOCAL SITE SURVEY REPORT
WESTFORD, MASSACHUSETTS, USA



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Date of Survey: May 2019
Date of Report: October 2019

Introduction

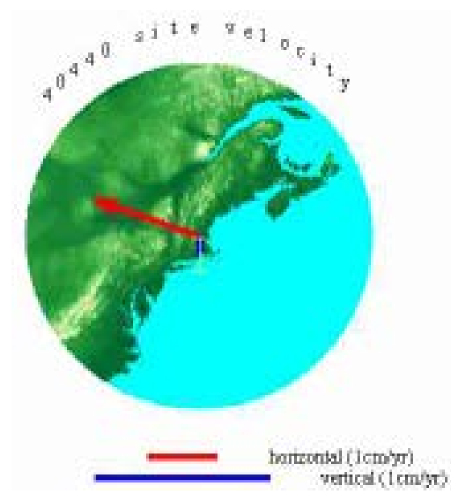
In May 2019, the National Geodetic Survey (NGS) conducted a local tie survey at the Massachusetts Institute of Technology (MIT) Haystack Observatory, located in Westford, Massachusetts, USA. Within the observatory, the Westford Radio Telescope site is an International Earth Rotation and Reference Systems Service (IERS) site, designated Westford. The site features co-located space geodetic technique (SGT) instruments that contribute to realizations of the International Terrestrial Reference Frame (ITRF).

Space geodetic techniques at the site include Very Long Baseline Interferometry (VLBI) and Global Navigation Satellite Systems (GNSS). GNSS station WES2 is an International GNSS Service (IGS) tracking network station and NGS Continuously Operating Reference Stations (CORS). It has been identified by NGS as a Foundation CORS.

The primary objective of the survey was to establish high-precision local tie vectors between the space geodetic technique instruments and their associated reference marks. Data collection consisted of terrestrial observations with an absolute laser tracker system and survey-grade GNSS instrumentation. The local relationships were aligned to the current International Terrestrial Reference Frame at the epoch date of the survey, ITRF2014 (2019/05/17). This report documents the instrumentation, observations, analysis, and results of the survey.

1 Site description

IERS site name: Westford
IERS site number: 40440
Country name: United States of America
Surveying institution: National Geodetic Survey
Dates of survey: May 14 – 21, 2019
Longitude: W 71° 29’
Latitude: N 42° 37’
Tectonic plate: North American



SGT Technique	Name	DOMES#	ITRF Description
GNSS	7209	40440S003	Westford / 18m VLBI reference point
GNSS	WES2	40440S020	Rogue SNR-8000/DM T/BPA 08-FEB-93

Table 1: ITFR site information for space geodetic technique instruments

2 Instrumentation

2.1 Tacheometers, EDMI, theodolites

2.1.1 Description

Leica AT402, S/N 392045 (absolute laser tracker system)
Specifications:
Angular measurement uncertainty of instrument: +/- 0.5”
Combined uncertainty of distance measurement throughout instrument range: +/- 0.014 mm

2.1.2 Calibrations

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

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%

2.1.4 Analysis software

Terrestrial observations and analysis were conducted with commercially available software Spatial Analyzer (version 2017.08.11_29326) from New River Kinematics. Least squares adjustments were conducted with commercially available software Star*Net (version 9,1,4,7868) from MicroSurvey. Coordinate transformations and SINEX generation were conducted with AXIS software from Geoscience Australia.

2.2 GNSS units

2.2.1 Receivers

Trimble NetR5, P/N: 62800-00, S/Ns: 4624K01615, 4624K01647, 4624K01583, 4624K01590
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 Model 2, P/N 41249-00, S/Ns: 12545667, 12481390, 60165452, 60125131

2.2.3 Analysis software

Data processing and analysis were conducted with NGS’s Online Positioning User Service (OPUS) and Beta OPUS Projects. Beta OPUS Projects uses NGS’s Program for Adjustment of GPS Ephemerides (PAGES) software as an underlying multi-baseline processing engine. Star*Net and AXIS were also used in the analysis of GNSS data.

2.3 Leveling

No leveling instrumentation was used in this survey.

2.3.1 Leveling instruments

Not applicable.

2.3.2 Leveling rods

Not applicable.

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 or tripods were used with target reflectors and GNSS antennas.

Surveying tripod for instrumentation

Fixed-height range poles for reflectors and GNSS antennas

2.5 Forced-centering devices

Target reflectors and GNSS antennas were centered over marks using fixed-height range poles, a Kern trivet, and adapters with known offsets.

Forced-centering device to occupy a mark

Kern trivet with forced-centering pin

2.6 Targets, reflectors

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

Terrestrial observations were made to Leica 1.5-inch Break Resistant Reflectors, serving as both target and reflector. The reflectors occupied the marks using the forced-centering devices and adapters above.

2.7 Additional instrumentation

No additional instrumentation was used in this survey.

3 Measurement setup

3.1 Ground network

The site has several existing ground marks which were recovered, including one mark indoors, within the radome structure that houses the VLBI telescope 7209. To facilitate the survey, three new marks were set and several non-monumented temporary points were established. The VLBI telescope had no associated ground mark.

3.1.1 Listing

Current Survey	DOMES	IERS 4-char code	Previous Survey Point Name	NGS PID
Space geodetic technique stations				
7209	40440S003	7209	--	--
WES2	40440S020	WES2	--	AF9520
Ground network marks				
BOSTON AB	--	--	--	DE5268
NGS A	--	--	--	--
NGS B	--	--	--	--
NGS C	--	--	--	--
WESTFORD	--	--	--	MY2198
WESTFORD RM1	--	--	--	MY2196
WESTFORD RM 2			--	MY2197

Table 2: Listing of SGT stations and ground network marks

<u>Ground network mark descriptions</u>

WESTFORD is a National Geodetic Survey horizontal control disk, stamped WESTFORD 1977, cemented in a drill hole in a large concrete slab flush with the ground surface. The datum point is a divot in the center of the disk.

WESTFORD RM1 is a National Geodetic Survey reference mark disk, stamped WESTFORD NO 1 1977, cemented in a drill hole in a 2 foot square concrete slab that projects 4 inches above the ground surface. The datum point is a cross in the center of the disk.

WESTFORD RM2 is a National Geodetic Survey reference mark disk, stamped WESTFORD NO 2 1977, cemented in a drill hole in a 2 by 2 foot concrete pier that projects 3.3 feet above the ground surface. The datum point is a cross in the center of the disk.

BOSTON AB is a plug about 1.5 inch in diameter, stamped US AGS 1990, cemented into a drill hole in the floor of the radio telescope enclosure. It was previously used for gravity observations and does not have a published position in the NGS Integrated Database.

NGS A is a plug about 1.5 inch in diameter cemented in a drill hole in the concrete floor of the airlock adjacent to the VLBI radome enclosure. No stamping.


NGS B is a plug about 1.5 inch in diameter cemented in a drill hole in a concrete slab North of the VLBI radome enclosure and adjacent to the facility parking lot. No stamping.

NGS C is a plug about 1.5 inch in diameter cemented in a drill hole on top of a boulder (7.5 ft x 7.2 ft x 2 ft) behind the facility building. No stamping.


3.1.2 Map of network

Surveyed stations at Haystack Observatory

3.2 Representation of technique reference points

3.2.1 VLBI

7209 is a radio telescope with an 18-meter dish antenna, operated by MIT Haystack Observatory. The instrument is enclosed within an inflatable radome and is represented by a theoretical point in space: the invariant point (IVP) about which the azimuth and elevation axes rotate. The invariant point is also known as the conventional reference point or technique reference point.


VLBI radio telescope 7209, mounted on a pedestal structure within a radome

3.2.2 SLR

This space geodetic technique was not represented at the site at the time of survey.

3.2.3 GNSS

WES2 is an IGS tracking station operated by the National Geodetic Survey. It has been identified by NGS as a Foundation CORS. The station is represented by the bottom center of a 5/8-11 threaded rod on an antenna mount atop a steel tower. This point is considered the Geometric Reference Point and, with an antenna in place, is coincident with the Antenna Reference Point (ARP). During the survey, the Geometric Reference Point was occupied with a target reflector while the antenna was removed for replacement.



WES2 atop steel tower

3.2.4 DORIS

This space geodetic technique was not represented at the site at the time of survey.

4 Observations

4.1 Terrestrial survey

The terrestrial survey was completed using an absolute laser tracker system. The instrument measured horizontal angles, vertical angles, and distances to retro-reflector targets which were used to position the marks and techniques. GNSS observations were also collected to support the terrestrial survey.

As part of the observation routine, all angle and distance measurements to ground marks were observed a minimum of three times. Double centering of the instrument was incorporated, measuring in both instrument faces. Meteorological data was observed and atmospheric corrections were applied to all measurements at the time of data collection.

Spatial Analyzer software was used for recording observations and to perform field-level data quality checks for all laser tracker measurements. Star*Net software was used to combine and adjust all observations. A complete list of adjusted observations is available in Star*Net ***.LST*** output file.

The VLBI radio telescope is situated inside an inflatable radome and is not intervisible with any outdoor network stations. The telescope is mounted atop a pedestal structure, with the invariant point (the point about which the azimuth and elevation axes rotate) over 19 meters higher than floor level. Access to the telescope is through an airlock room.

To determine the local tie vector from the GNSS station to the VLBI technique, the survey network had to be extended into the facility building and through the airlock into the radome enclosure. Traversing through the airlock required observing to targets both indoors and outdoors in a sequence so that the interior air pressure of the radome was not disturbed. Mark NGS A was set within the airlock to provide additional stability to the survey network as it was extended through the narrow corridor of the airlock.

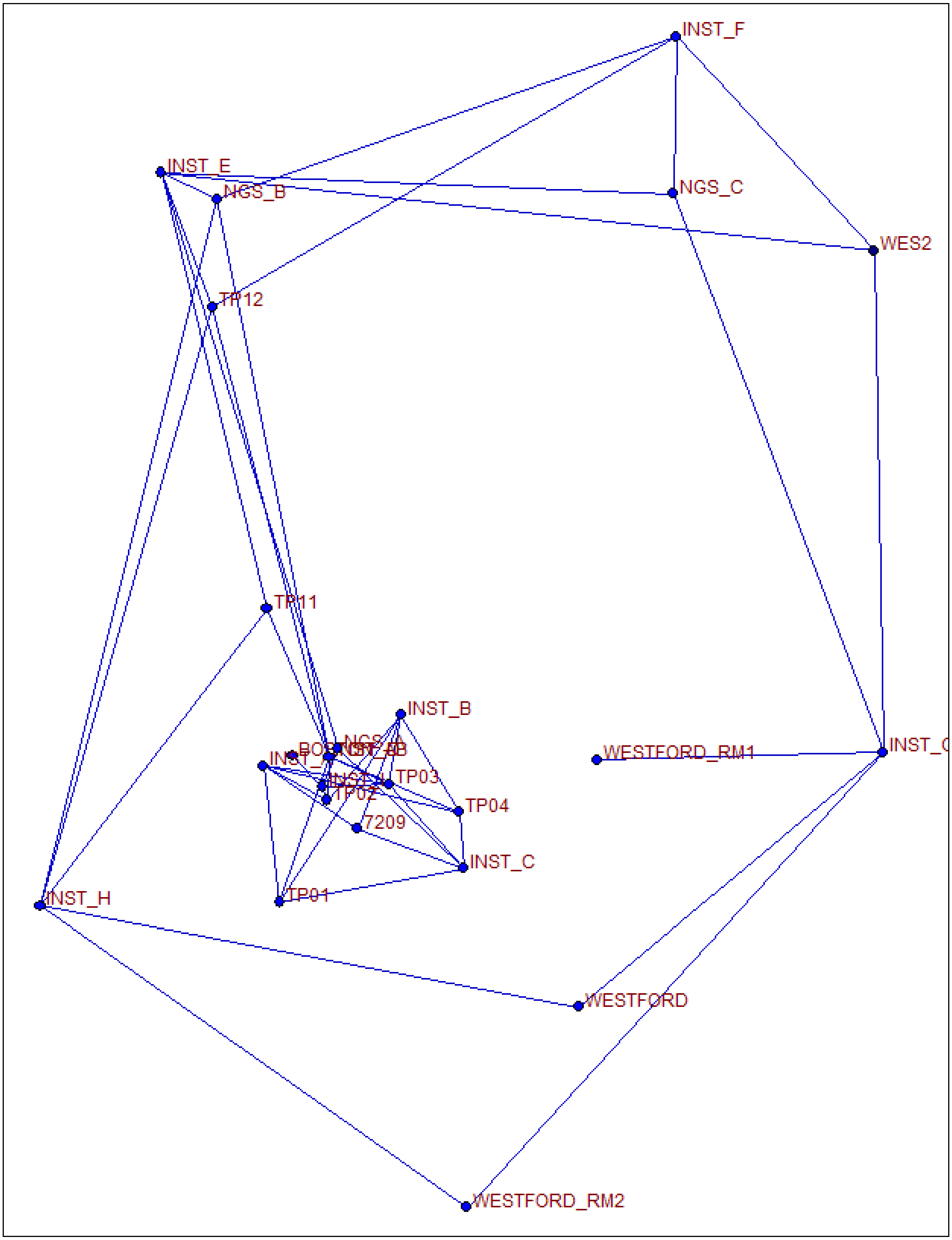
Within the radome enclosure, several temporary points were established by affixing multipurpose tripod adapters (MTAs) or short range poles to the structure as securely as possible. This allowed temporary control to be extended as near as possible to the radio telescope's invariant point.

Laser tracker setup and mark NGS A, inside the airlock to extend the survey network into the VLBI telescope's radome structure

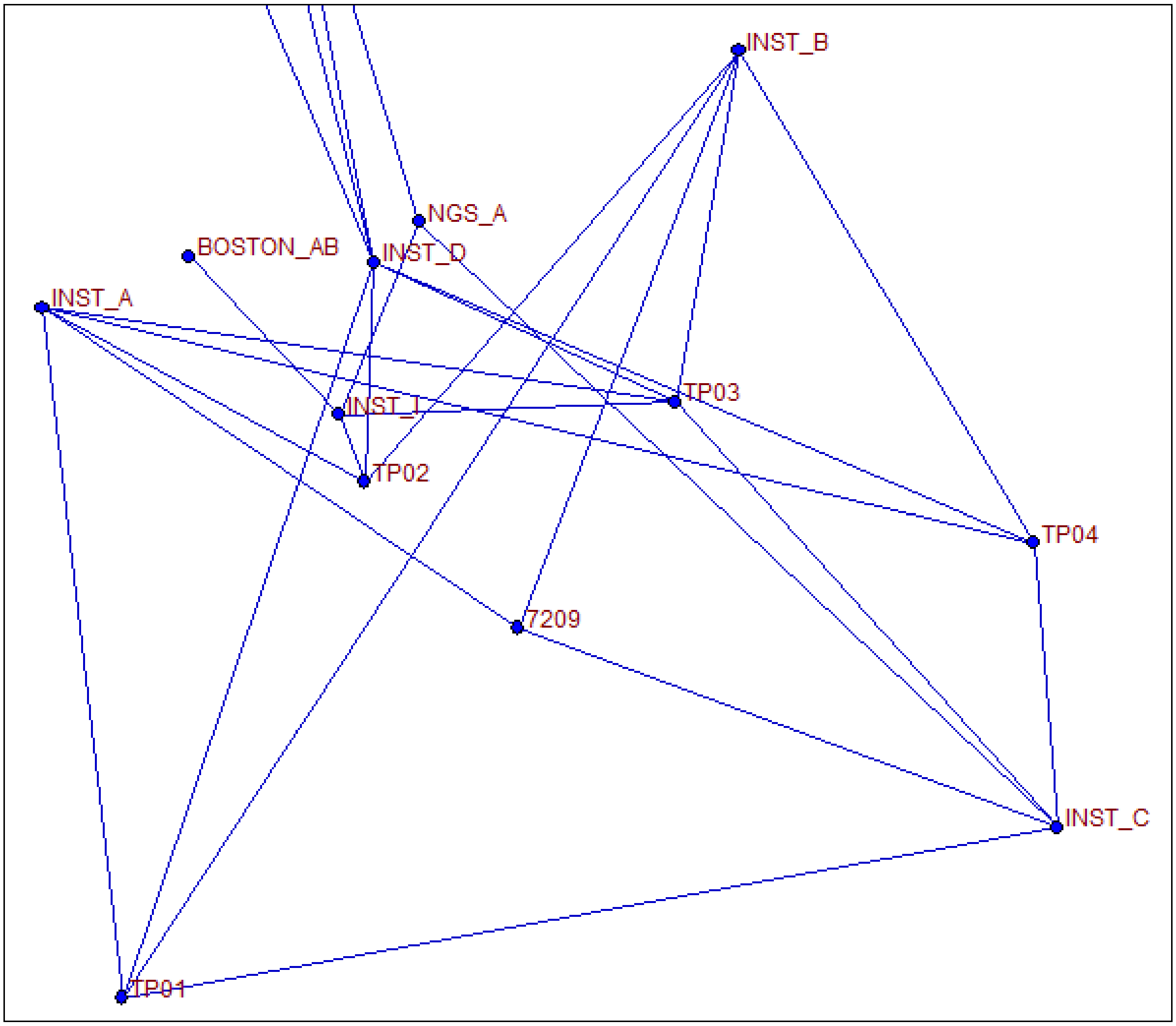
Laser tracker (bottom left), observing from the VLBI airlock to temporary points TP03 (bottom center) and TP04 (right)

Temporary points TP01 and TP02 within the radome, visible from within the airlock

VLBI 7209 radio telescope



Network stations at Haystack Observatory



Network stations near VLBI telescope 7209

Vertical offsets of terrestrial survey stations (units in meters)

STATION	OFFSET 1	OFFSET 2	PRISM	TOTAL OFFSET
7209	Circle fit 0.0000			0.0000
BOSTON AB	Rod D 1.0426		Brunson Nest with Prism 0.0526	1.0952
NGS A	Rod A 1.0426		Brunson Nest with Prism 0.0526	1.0952
NGS B	2-m Tripod D 2.0005	MTA B, Bottom Plate	Leica Nest with Prism 0.0550	2.0555
NGS C	Rod C 1.0425	MTA C, Bottom Plate	Leica Nest with Prism 0.0550	1.0975
WES2 [1]	None 0.0000		Brunson Nest with Prism 0.0526	0.0526
WES2 [2]	Black Rod 0.1996		Brunson Nest with Prism 0.0526	0.2522
WESTFORD	Rod E 1.0424		Brunson Nest with Prism 0.0526	1.0950
WESTFORD RM1	Rod B 1.0422		Brunson Nest with Prism 0.0526	1.0948
WESTFORD RM2	Trivet Rod 0.0936	MTA A, Bottom Plate 0.0098	Leica Nest with Prism 0.0526	0.1560

Table 3

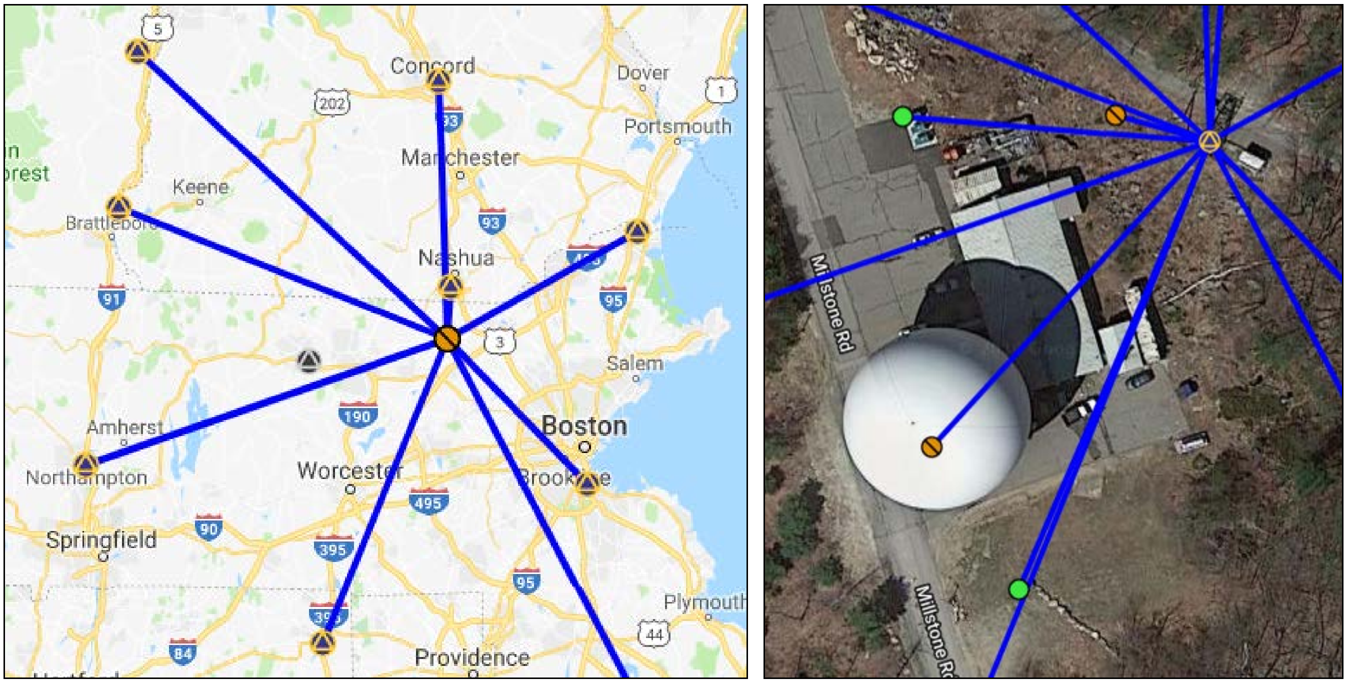
4.2 Leveling

No leveling was conducted for this survey.

4.3 GNSS

GNSS data was collected to generate 3-dimensional ITRF2014 vectors between stations at the epoch date of survey. Over multiple days, simultaneous long-session (20+ hour) observations were taken at several stations. Station TP01 was located inside the VLBI radome. Publicly available observation data was also obtained for CORS in the region.

GNSS observations were processed with a minimally constrained, "hub" design emanating from IGS tracking station WES2. Using the baseline processing engine within NGS's Beta OPUS Projects software, ITRF2014 vectors to the network stations and CORS were generated via ITRF2014 satellite orbits. The resulting GPS vectors were used in a combined network adjustment to align the terrestrial survey to ITRF2014.



GNSS network diagrams

Vertical offsets of GNSS survey stations (units in meters)

STATION	OFFSET 1	OFFSET 2	TOTAL OFFSET
NGS B	2-m Tripod D 2.0005	MTA B, Overall 0.1507	2.1512
NGS C	Rod C 1.0425	MTA C, Overall 0.1507	1.1932
TP01	Brunson Nest with Prism 0.0526	MTA D, Top Plate 0.0098	0.0624
WES2	Reported accent. 0.0000		0.0000
WESTFORD RM2	Trivet Rod 0.0936	MTA A, Overall 0.1507	0.2443

Table 4

4.4 General comments

Resection method for terrestrial observations

In the terrestrial survey, the resection principle was employed to measure between network stations indirectly with the laser tracker. The ground marks were occupied with the reflector targets mounted on range poles. The instrument did not occupy the marks directly but was instead setup at arbitrary points between the stations. At each instrument occupation, a series of measurements were taken to the surrounding visible stations. 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. While the vectors between stations were not observed directly, the measurements were precise enough to determine relative positions with at the sub-millimeter level.

Establishing points via circle-fitting

Coordinates of the VLBI instrument 7209 were determined using an indirect approach. The "circle-fit" theory is briefly described. A point, as it revolves about an axis, scribes an arc. The arc defines a 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 a local coordinate system.

Laser 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 is 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 technique's invariant point (IVP).

Precise observations involving a single target/reflector secured to the VLBI telescope, measurements from three instrument occupations, and numerous measurements per axis serve to ensure a millimeter level of positional precision is achieved. The VLBI IVP was determined in this manner.

5 Data analysis and results

5.1 Terrestrial survey

5.1.1 Analysis software

After data collection, Spatial Analyzer software was used to generate points and lines via circle-fitting, as described above. This allowed for analysis of the VLBI technique's azimuth axis, elevation axis, and axial offset.

Terrestrial observations of the ground network and SGTs were brought from Spatial Analyzer to Star*Net software to be combined with the GNSS observations for rigorous least squares adjustment. The combined geodetic adjustment produced coordinates and variance-covariance information for all surveyed features. Adjustment parameters and results are available in Star*Net ***.LST*** output file.

5.1.2 Topocentric coordinates and covariance

The terrestrial survey was aligned to ITRF2014 (epoch date of survey) using the GNSS observations in a combined geodetic adjustment. AXIS software was used to compile topocentric coordinate estimates with station WES2 as the local origin. Station WES2 is the site marker. Complete covariance information for all network stations is available in AXIS ***.AXS*** output file.

Surveyed topocentric coordinates, ITRF2014 (epoch 2019/05/17)						
STATION	***E(m)***	***N(m)***	***U(m)***	***SE(m)***	***SN(m)***	***SU(m)***
Space geodetic technique stations						
WES2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
7209	-38.4199	-43.0071	1.7373	0.0003	0.0003	0.0002
Ground network marks						
BOSTON AB	-43.2509	-37.5426	-17.6138	0.0003	0.0003	0.0002
NGS A	-39.8818	-37.0367	-17.5285	0.0003	0.0003	0.0002
NGS B	-48.8471	3.8507	-17.4231	0.0001	0.0003	0.0002
NGS C	-14.8978	4.2319	-13.9043	0.0001	0.0001	0.0002
WESTFORD	-21.9731	-56.2154	-18.0477	0.0004	0.0002	0.0002
WESTFORD RM1	-20.5743	-37.8594	-17.4901	0.0003	0.0002	0.0002
WESTFORD RM2	-30.2969	-71.1338	-17.6409	0.0005	0.0002	0.0003

Table 5

5.1.3 Correlation matrix

Complete correlation matrix information for all network stations can be found in AXIS ***.AXS*** output file.

5.1.4 Reference temperature of radio telescope

The International VLBI Service reports a reference temperature for VLBI SGT 7209 of 8.9 degrees Celsius and a reference pressure of 1001.3 hPa. At the time of writing, file ***antenna-info.txt*** is available online. https://ivscc.gsfc.nasa.gov/program/control_files.html

During survey observations of the radio telescope, the mean temperature was 14.0 degrees Celsius and the mean pressure was 1001.8 hPa. No corrections were applied for thermal expansion of the radio telescope.

5.2 GNSS

5.2.1 Analysis software

NGS's Beta OPUS Projects software was used to process and analyze ITRF2014 vectors between stations at the epoch date of survey. As noted, Star*Net software was used to combine the terrestrial and GNSS observations in a rigorous least squares adjustment. The combined geodetic adjustment produced coordinates and variance-covariance information. Adjustment parameters and results are available in Star*Net ***.LST*** output file.

5.2.2 Results

AXIS was used to compile geocentric coordinate estimates from the combined geodetic adjustment. Using the GNSS observations, the survey was aligned to the reference frame ITRF2014 (epoch data of survey). Complete covariance information for all network station is available in AXIS ***.AXS*** output file.

Surveyed geocentric coordinates, ITRF2014 (epoch 2019/05/17)						
STATION	***X(m)***	***Y(m)***	***Z(m)***	***SX(m)***	***SY(m)***	***SZ(m)***
Space geodetic technique stations						
WES2	1492233.0247	-4458089.5076	4296046.0971	0.0000	0.0000	0.0000
7209	1492206.2399	-4458130.5271	4296015.6227	0.0003	0.0002	0.0003
Ground network marks						
BOSTON AB	1492195.9640	-4458115.0474	4296006.5426	0.0003	0.0002	0.0003
NGS A	1492199.0701	-4458113.7127	4296006.9727	0.0003	0.0002	0.0002
NGS B	1492181.8061	-4458090.3809	4296037.1347	0.0001	0.0003	0.0003
NGS C	1492214.7398	-4458081.8158	4296039.7976	0.0001	0.0002	0.0002
WESTFORD	1492220.0530	-4458119.9793	4295992.5068	0.0004	0.0002	0.0002
WESTFORD RM1	1492217.5649	-4458108.1392	4296006.3932	0.0003	0.0002	0.0002
WESTFORD RM2	1492215.4607	-4458132.4834	4295981.8032	0.0005	0.0002	0.0002

Table 6: Coordinate estimates for network stations

The local tie vector emanating from the site marker, station WES2, is provided below for the ITRF space geodetic techniques using the coordinates determined this survey.

Surveyed topocentric ties				
STATION	***EAST (m)***	***NORTH (m)***	***UP (m)***	***DIST (m)***
WES2	0.0000	0.0000	0.0000	0.0000
7209	-38.4199	-43.0071	1.7373	57.6950
Surveyed geocentric ties				
STATION	***X (m)***	***Y (m)***	***Z (m)***	***DIST (m)***
WES2	0.0000	0.0000	0.0000	0.0000
7209	-26.7848	-41.0195	-30.4744	57.6950

Table 7: Local tie vector emanating from WES2

5.3 Additional parameters

VLBI radio telescope axis offset

The survey observations were used with Spatial Analyzer software to determine the offset between the azimuth and elevation axes. VLBI 7209 offset: 0.3185 m +/- 0.0002 m

The International VLBI Service reports the telescope's axis offset as 0.3182 meters, estimated in 2014 per the ***antenna-info.txt*** file. At the time of writing, the file is available online.
https://ivscc.gsfc.nasa.gov/program/control_files.html

5.4 Transformations

ITRF2014 GNSS vectors were generated to 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 software was used to generate a SINEX file with full variance-covariance matrix information. All stations with DOMES numbers are included in the ***.SNX*** SINEX file ***NGSWEST1905GA.SNX***.

The following SINEX file naming convention was used.

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.

5.6 Discussion of results

A geodetic least squares adjustment of the observations was conducted using Star*Net. The statistical summary from the adjustment is included. For additional details concerning the adjustment, see Star*Net ***.LST*** output file.

```
                     Adjustment Statistical Summary
                     ==============================
                    Iterations                =      3
                    Number of Stations        =     33
                    Number of Observations    =    711
                    Number of Unknowns        =    135
                    Number of Redundant Obs   =    576

          Observation   Count   Sum Squares         Error
                                  of StdRes         Factor
          Coordinates       3         0.000          0.000
           Directions     176       140.340          0.992
            Distances     175       136.389          0.981
              Zeniths     174       131.718          0.967
           GPS Deltas     183       148.279          1.000

                Total     711       556.726          0.983

                The Chi-Square Test at 5.00% Level Passed
                     Lower/Upper Bounds (0.942/1.058)
```

Comparison with IERS computed tie

ITRF2014 (epoch date of survey) computed coordinates were obtained from the IERS. A comparison of the surveyed tie vector against the computed tie is provided where available.

IERS geocentric computed coordinates, ITRF2014 (epoch 2019/05/17)				
STATION	***SOL***	***X (m)***	***Y (m)***	***Z (m)***
WES2	-	1492233.0246	-4458089.5075	4296046.0971
7209	-	1492206.2398	-4458130.5392	4296015.6255

Table 8: IERS computed coordinates

Surveyed tie vs. IERS computed tie						
	NGS 2019 geocentric tie discrepancies			NGS 2019 topocentric tie discrepancies		
STATION	***DX(mm)***	***DY(mm)***	***DZ(mm)***	***DE(mm)***	***DN(mm)***	***DU(mm)***
WES2	0.0	0.0	0.0	0.0	0.0	0.0
7209	0.0	12.3	-2.8	3.8	5.8	-10.4

Table 9: Tie discrepancies between surveyed and computed ties (surveyed minus computed)

Comparing against the ITRF2014 computed coordinates, the current survey has a maximum tie discrepancy of -10.4 millimeters in the up component.

5.7 Comparison with previous surveys

A previous survey was carried out at the site by Troy Carpenter and James Richardson of AlliedSignal Technical Services Corporation, with field observations in 1996 and 1999. As a check on the results of the current survey, Star*Net software was used to align the current survey to the previous survey in NAD 83 (1986). Topocentric tie vector comparisons are provided for the common surveyed stations. Complete coordinate information is available in the included data products.

Surveyed ties vs. Previous survey (AlliedSignal Technical Services 1996/1999) Topocentric tie discrepancies			
STATION	***DE (mm)***	***DN (mm)***	***DU (mm)***
WES2	0.0	0.0	0.0
7209	7.3	6.5	-9.6
WESTFORD	-0.6	-5.0	-1.5
WESTFORD RM2	-1.4	1.5	4.0

Table 10: Tie discrepancies between current survey and previous survey (current minus previous)

6 Planning aspects

Physical address of project site:
Westford Radio Telescope
MIT Haystack Observatory
99 Millstone Rd
Westford, MA 01886

On-site contacts:
Mike Poirier
mpoirier@mit.edu

Alex Burns
617-715-4510
aburns6@mit.edu

Recommendations
The VLBI airlock and radome structure are challenging environments for survey observations. There are constrained spaces, limited sight lines, and significant vertical change. Before executing the survey, thorough reconnaissance is needed to sufficiently plan the placement of instrument setups and targets.

Coordinate the survey schedule with the on-site staff in advance to take advantage of non-observing periods. During survey observations, site personnel will drive the radio telescope under survey team direction. Fall protection training and a climbing harness are required to access the radio telescope for mounting survey targets.

7 References

7.1 Name of person(s) responsible for observations

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Steve Breidenbach (Steve.Breidenbach@noaa.gov)

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Woodford, VA 22580
Phone: (540) 373-1243

7.2 Name of person(s) responsible for analysis

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Kevin Jordan (Kevin.Jordan@noaa.gov)

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

7.3 Location of observation data and results archive

National Geodetic Survey
15351 Office Drive
Woodford, VA 22580
Phone: (540) 373-1243
https://www.ngs.noaa.gov/corbin/iss/

7.4 Works referenced

Nothnagel, Axel (2003). Layout of Local Tie Report. Proceedings of the IERS Workshop on site co-location. Matera, Italy, 23–24 October 2003 (IERS Technical Note No. 33).
https://www.iers.org/IERS/EN/Publications/TechnicalNotes/tn33.html

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