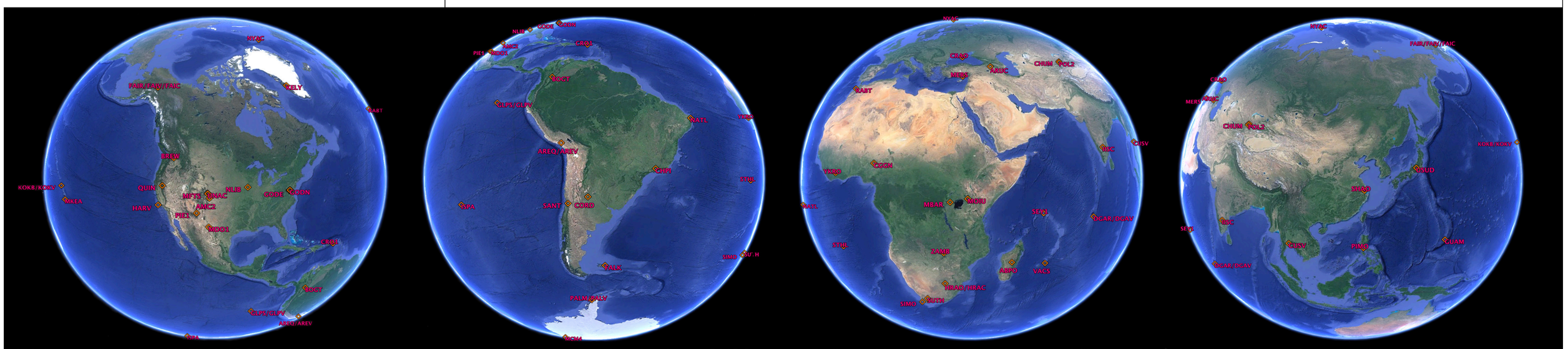
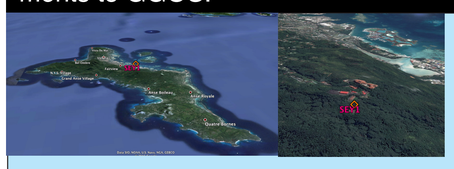
NASA Global GNSS Network (GGN), Status and Plans

Sarah Doelger[1], Dave Stowers[2], F. Blume[1], J. Sklar[1], C. Meertens[1], G. Mattioli[1]
[1]UNAVCO, Boulder, CO 80301 [2]Jet Propulsion Laboratory, Pasadena, CA 91109



JPL in coordination with UNAVCO, and with local site host cooperation, operate and maintain 62 GNSS permanent stations, which include 88 GPS receivers, that comprise the NASA Global GNSS Network (GGN). These sites represent approximately 16% of the ~400 International GNSS Service (IGS) stations, and provide a globally distributed GNSS network supporting NASA operations and its commitments to GGOS.

Daily and hourly 30-second sampled files, and sub-hourly high-rate (1-second) sampled files are publicly available in RINEX format from the Crustal Dynamics Data Information System, NASA's Archive of Space Geodesy data:
http://cddis.gsfc.nasa.gov/Data_and_Derived_Products/GNSS/GNSS_data_holdings.html



Republic of Seychelles: SEY1

Completed 2015

Professional drillers were contracted to drill the borehole for the new SEY2 monument. The hole reaches a depth of 35m. The SEY1 antenna, located on top of the UCSD seismic enclosure is visible to the right

The completed SEY2 monument is composed of 6" diameter steel pipe. It extends to the bottom of the borehole and is secured with a mixture of Portland cement with a sand matrix. The antenna stands approximately 6.5 feet above the ground.

New Antenna Monument

SEY1, on the island of Mahe, is one of several GGN stations co-located with instruments from the International Deployment of Accelerometers (IDA) at the University of San Diego (UCSD). This configuration allows for IDA and NASA to share maintenance and communications operations and costs.

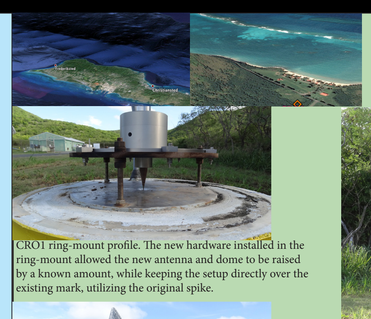
The SEY1 antenna is installed on an adapter attached to an IDA seismic wellhead which raised the antenna above the top of the seismic enclosure. In late 2014, IDA announced plans to replace the enclosure and remove the antenna adapter. In early 2015, UNAVCO contracted a local company to drill a new well on the same property at a distance of 25 feet from the original antenna. A UNAVCO engineer was on-site to oversee the installation.

The new monument (SEY2) , constructed of a six inch diameter pipe, reaches a depth of 105 feet (at bedrock) and is grouted in place with portland cement. An antenna adapter is attached ot the top of the pipe, to which a modern choke ring antenna and radome are mounted. A new multi-GNSS receiver is attached ot the SEY2 antenna and is located a short distance from the monument, in the same enclosure as the SEY1 receiver.

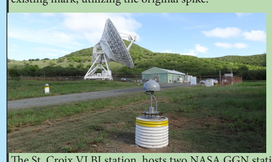
Plans are in place for IDA to visit the site and remove the SEY1 antenna in early 2016. Enough concurrent data has been collected between SEY1 and SEY2 such that when SEY1 is removed, SEY2 will become the new official IGS station.

The new SEY2 monument is located 25 feet from the original SEY1 antenna. The SEY1 monument will be demolished when UCSD visits the station to conduct maintenance on their borehole seismometers in early 2016.

Photos shows original SEY1 antenna with guy wires that supported a nearby cellular communications tower. The tower was no longer in use and was demolished after the SEY2 monument was built. Awkward seismic well-head access (difficult to reoccupy location precisely, and IDA coordination required) were a compelling case for a new monument.



CRO1 ring-mount profile. The new hardware installed in the ring-mount allowed the new antenna and dome to be raised by a known amount, while keeping the setup directly over the existing mark, utilizing the original spike.



The St. Croix VLBI station hosts two NASA GGN stations, CRO1 (background) and CRO2 (background). CRO2 was in stalled in 2013 and now provides a processing reference for the new configuration at CRO1.

St. Croix: CRO1

Completed 2015

Antenna Monument Upgrade

UNAVCO and JPL have collaborated to design antenna mounting hardware that adapts to existing legacy ring-mounts in the GGN (Flinn-type monuments). The hardware introduces a precisely known vertical displacement while minimizing north and east displacements. This allows for the installation of new calibrated antennas and radomes that support the tracking of multi-GNSS satellites and additional signal types.

In September of 2015, this new hardware was installed at CRO1, as well as a modern SCIGN radome and chokering antenna. The monument previously had a legacy JPLA-style radome that was badly weathered and was beginning to deteriorate. The new hardware raised the new antenna by 60cm and introduced near zero horizontal offset.

Station NLIB in North Liberty, Iowa was the first to receive a similar upgrade in 2011, and MDO1 near Fort Davis, Texas was upgraded in January 2015. Several other GGN stations are configured with legacy ring-mounts; however there are no plans to complete additional upgrades in 2016.

New upgraded monument at CRO1 with adapted ring-mount. A stainless steel plate and pipe were added to the existing ring hardware. This allowed for a SCIGN antenna mount to be installed with a new chokering antenna and calibrated SCIS radome.

Completed 2015

Easter Island, Chile: ISPA

Communications Upgrade

At particularly remote sites, the GGN utilizes independent satellite communication links to provide connectivity to the stations. One such station is ISPA, located on the Isla de Pascua on Easter Island. We had previously shared the link with UCSD, however the bandwidth was no longer sufficient to allow for reliable/continuous multi-GNSS data transmission.

UNAVCO personnel traveled to the station in late 2014 to re-configure the communications equipment. Separate links were created for NASA and UCSD while still utilizing the same satellite dish and associated hardware.

The GGN currently utilizes a 64Kbps allocation of bandwidth at ISPA. The throughput is minimally sufficient for daily downloading of multi-GNSS data from two separate receivers located at the site.

View from the GNSS antenna at station ISPA. The satellite dish pictured is shared between NASA and UCSD which use the same infrastructure but maintain separate communications links. The building in the background is operated by the Comprehensive Nuclear Test Ban Treaty Organization (CTBTO), and is where the ISPA GNSS receivers are housed, along with UCSD's equipment.

This satellite dish, looking West. The ISPA GNSS antenna is visible in the bottom right corner and is mounted on a short drilled braced monument (SDBM) that was constructed by UNAVCO engineers in 2004.

Image source: http://www.easterislandstatues.info/easter-island-heads/

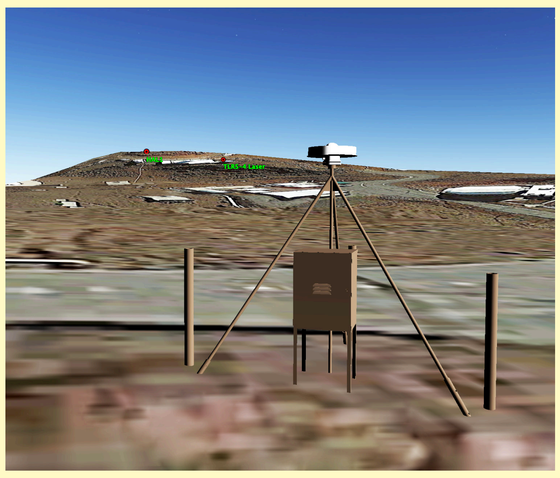
SGP: Current Status and Plans for 2016

The NASA Space Geodesy Project (SGP) encompasses the development, operation, and maintenance of a Global Network of Space Geodetic technique instruments. This network helps maintain a stable terrestrial reference system and contributes data and analysis to help fully realize the measurement potential of the coming generation of earth observing spacecraft. This network is comprised of sites around the globe that utilize the four major space geodetic observing components: Very Long Baseline Interferometry (VLBI), Satellite Laser Ranging (SLR), Global Navigations Satellite System (GNSS), and the Doppler Orbitography and Radio-positioning by Integrated Satellite (DORIS) system.

UNAVCO's role in support of SGP is the permitting, installation, and operation of GNSS infrastructure at selected core sites in the SGP network.

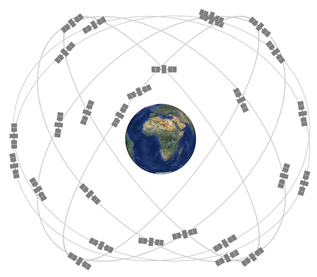
In early 2015, UNAVCO began the first round of SGP GNSS installations at the Kokee Park Geophysical Observatory (KPGO), on the Hawaiian island of Kauai and the Haleakala Observatory on Maui. Both locations will be combined into a single SGP core site containing all foru previously mentioned geodetic techniques. The VLBI antenna is being completed at KPGO with an updated DORIS site nearby. The SLR will be located at Haleakala. Multiple GNSS monuments installed at each site will be used to calibrate the instruments, measure site stability, and provide baselines to tie the two sites together.

A total of five GNSS stations are currently operating at the two observatories.



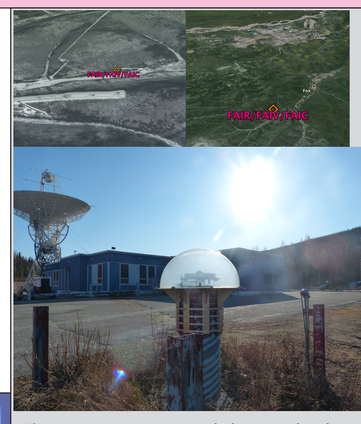
Plans are also underway to install another Short Drilled Braced Monument (SDBM) at Haleakala in early 2016 (see rendered site model above).

Additionally, UNAVCO plans to complete GNSS installations at the McDonald Observatory near Fort Davis, Texas, another core SGP site. Phase one (early 2016) is the construction of an SDBM offset from a virtual line between the SLR and planned VLBI locations. Phase two will install Deep Drilled Braced monuments closer to the SLR and VLBI locations. Phase two will likely begin early 2017.



Planned 2016

Fairbanks, Alaska: FAIR



The current monument at FAIR. Multiple receivers share the signal from the antenna and are housed in the building in the background. The large radio antenna is a VLBI instrument that the GPS station previously helped calibrate. The VLBI antenna is no longer in use.

New Site Deployment

Many of the stations in the GGN provide data that are critical for helping to realize the International Terrestrial Reference Frame. As part of its support to the GGN, UNAVCO maintains and upgrades these sites with GNSS-capable infrastructure on an ongoing basis, at the direction of JPL. Station FAIR, at the Gilmore Cree Observatory in Fairbanks Alaska, is one such critical "reference frame" station.

The existing monument at the site can not support the installation of an adapter (e.g., CRO1, NLIB), for a modern calibrated radome/antenna pair. UNAVCO plans to install a second monument in the immediate vicinity of FAIR to allow the long-running original monument to remain functioning and undisturbed. The new structure will support a multi-GNSS-capable choke ring antenna and calibrated radome.

UNAVCO plans to break ground for new construction during the summer of 2016. The monument will be an independent deep-drilled well (likely extending to a depth of 100 feet), similar to that installed at GGN-SEY1.

Harvest Oil Platform is located about 10 miles off the coast from Vandenberg Air Force Base near Santa Maria, California. This image shows the location of the GPS antenna, equipment hut, and VSAT communications dish.

Harvest Oil Platform, CA: HARV

New Antenna Monument

In addition to oil drilling, the Harvest Platform is also an important resource for the study of sea level from space. Tide gauges attached to the platform continuously measure and record variations in sea level relative to the platform. Data from two NASA GNSS receivers on the platform are used to calculate the absolute height of the platform relative to the Earth's center. Combining the tide gauge and GPS results gives the local sea-surface height relative the the Earth's center. This is the same quantity measured by altimeter mission satellites that regularly pass directly over the platform. By interpreting these readings (Satellite vs platform based), the errors in the respective measurement systems are exposed. Errors in the platform measurements are minimized by using redundant systems and by careful monitoring and routine maintenance of the Harvest instruments.

The Harvest monument (HARV) was constructred in 1992 and has sustained significant corrosion and degradation since its inception due to the harsh maritime environment. The monument is also a legacy design, using an outdated mounting system that does not easily allow for antenna changes. Additionally, the structure has an old, non-standard acrylic radome that has no calibration available.

In January of 2015, UNAVCO personnel traveled to the Harvest Oil Platform to install a new, temporary monument (HARX), near the original HARV monument. The new system wil be used to provide a tie for HARV, which will be reconstructed in 2016 and have a calibrated antenna/radome pair installed.

The original GPS antenna monument, installed in 1992. The monument is suffering from severe corrosion and has a legacy radome that is uncalibrated. The monument will be rebuilt in 2016 once enough concurrent data has been collected from nearby station HARX.

Antenna monument HARX was installed in early 2015 and willl provide a tie for HARV when the antenna monument is rebuilt there.

HARX is located on the opposite side of the heliocopter platform, at a distance of approximately 100 feet from HARV.

Hardware Upgrades: Data Computers

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UNAVCO is currently in the process of replacing older computers in the GGN with three varieties of fanless mini-machines running the CentOS operating system. The Aleutia T2-R (1), the Tangent MilSpec (2), and the Acrosser AES-HM76Z (3). These example systems offer the benefit of ruggedized enclosures, low power consumption, 60GB+ of solid-state hard disk, and can operate with a wide temperature range as well as having multiple ethernet, serial, and USB ports. They provide the flexibility and durability required to operate reliably in the hightly varied environmental conditions that exist from station to station around the globe.

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