



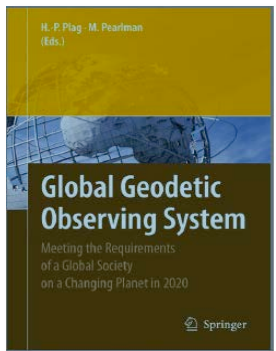
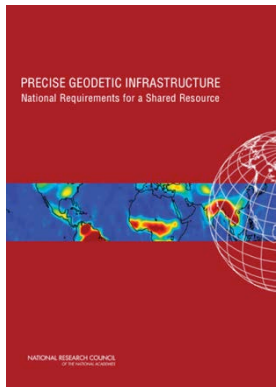
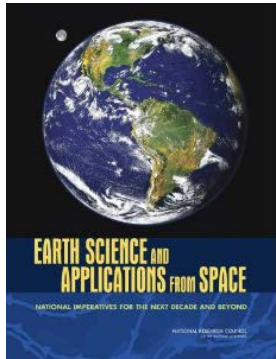
The Space Geodesy Project

Responding to the Recommendations of the
Committee on the National Requirements for
Precision Geodetic Infrastructure

Stephen Merkowitz
NASA Goddard Space Flight Center

Committee on Seismology and Geodynamics
Meeting

November 19, 2012



◆ Science Driver:

- Most stringent requirement on the ITRF comes from sea level studies:
 - “accuracy of 1 mm, and stability at 0.1 mm/year”
 - This is a factor 10-20 beyond current capability.
- About 30 modern integrated stations are required to meet these requirements.

◆ National Research Council Recommendations:

- Upgrade U.S. stations with modern SLR and VLBI,
- Work with international partners to deploy additional stations,
- Establish and maintain a high precision real-time GNSS/GPS national network,
- Make a long-term commitment to maintaining the ITRF,
- Continue to support the activities of the GGOS.

◆ NASA Response

- Contribute to building a new global network of integrated geodetic stations through GGOS and the international services.
- Network should be there for the coming Decadal Survey missions.
- NASA proposes to provide 6-10 of these stations if the next generation technology can be demonstrated to function as required.
- Complete the next generation SLR and VLBI developments.

- ◆ New NASA initiative started at the end of 2011 in response to the Earth Science Decadal and the National Research Council study “Precise Geodetic Infrastructure.” Part of the President’s Climate Initiative.
- ◆ Goddard led in partnership with JPL and participation from the Smithsonian Astrophysical Observatory and the University of Maryland.
- ◆ Goals:
 - Establish and operate a prototype next generation space geodetic station with integrated next generation SLR, VLBI, GNSS, and DORIS systems, along with a system that provides for accurate vector ties between them.
 - Develop a Project Implementation Plan for the construction, deployment and operation of a NASA network of similar next generation stations that will become the core of a larger global network of modern space geodetic stations.

VLBI



NGSLR



GNSS

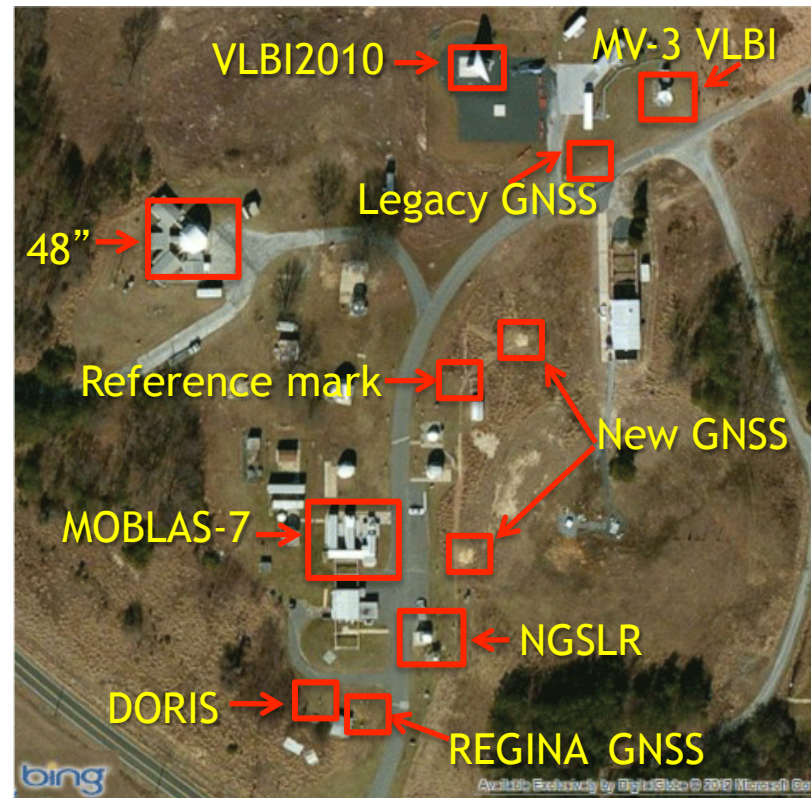
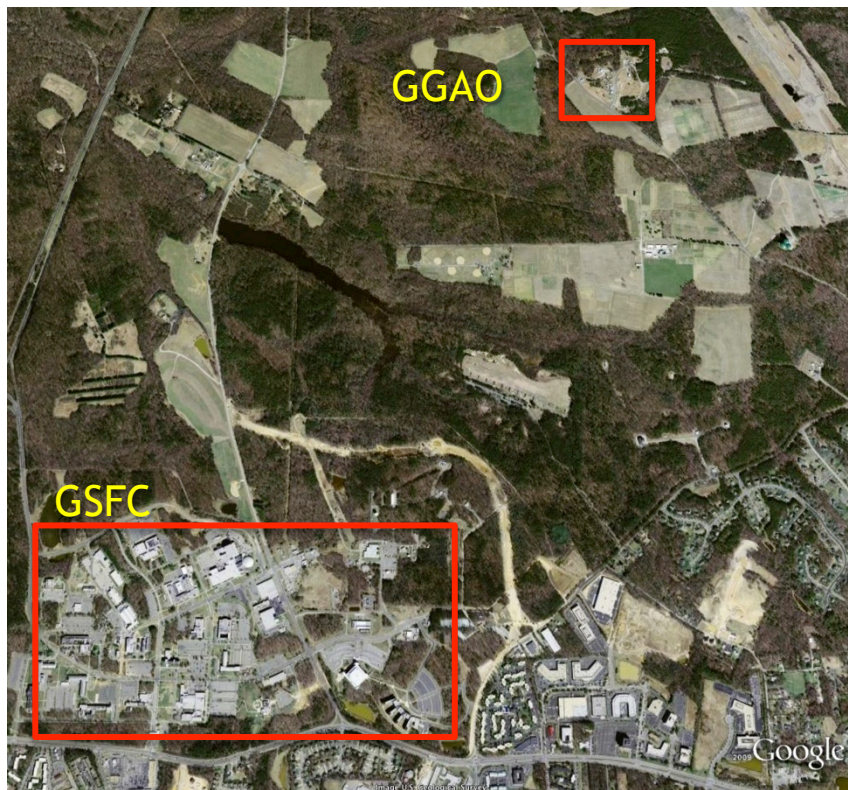


Vector Tie



Prototype Geodetic Station at GGAO

- ◆ Goddard Geophysical and Astronomical Observatory (GGAO) is located 5 km from Goddard Space Flight Center in the middle of the Beltsville Agricultural Research Center. GGAO is one of the few sites in the world to have all four geodetic techniques co-located at a single location.



NGSLR is a high repetition rate single photon detection laser ranging system capable of tracking cube corner reflector (CCR) equipped satellites in Earth orbit. The concept of NGSLR was developed by J. Degnan (GSFC, retired) in the 1990s. Technical development continues at Goddard. The system has demonstrated tracking of Earth orbit satellites with altitudes from 300 km to 20000 km.



- ◆ Successfully tracked most of ILRS satellites.
- ◆ LEO, LAGEOS 1 & 2, and GNSS have all been successfully tracked in both daylight and night.
- ◆ Completed intercomparison testing with MOBLAS-7.
- ◆ Installed new optical bench to support use of 2.5 mJ, 2 kHz Photonics Industries laser.

- ◆ 1 to 2 arcsec pointing/tracking accuracy,
- ◆ Track CCR equipped satellites to 20,000 km altitude, 24/7 operation,
- ◆ Reduced chemical & electrical hazards,
- ◆ Semi automated tracking features,
- ◆ Small, compact, low maintenance, increased reliability,
- ◆ Lower operating/replication costs.

VLBI2010 is an enabling technology upgrade to the existing global geodetic VLBI network. It was developed by Working Group 3 of the International VLBI Service for Geodesy and Astrometry (IVS). Technical development continues at Goddard and MIT Haystack Observatory.



Achievements & Status:

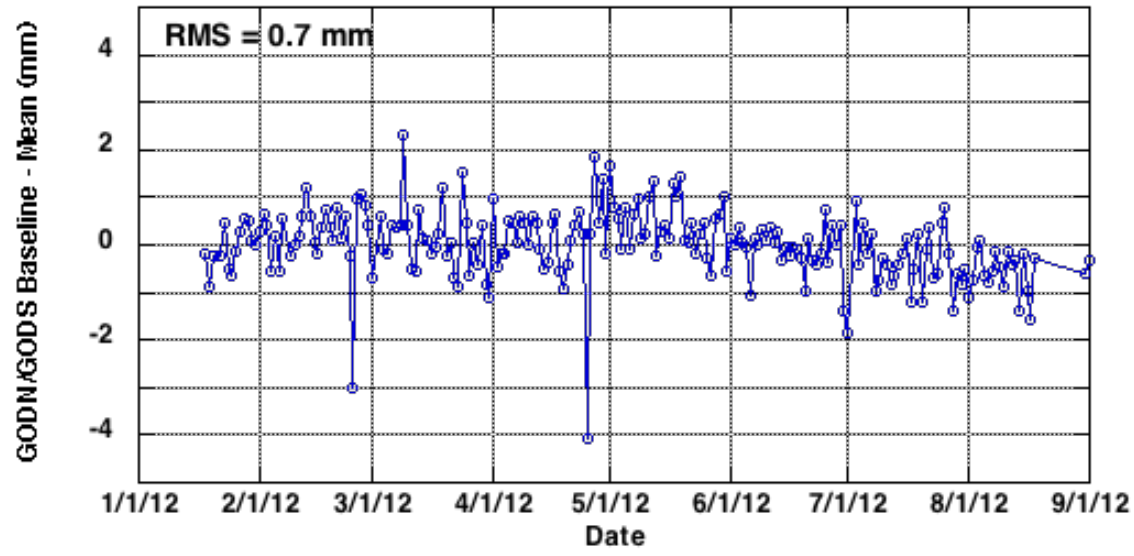
- Demonstrated 60% aperture efficiency.
- Demonstrated 5 deg/sec azimuth slew rate.
- Demonstrated broadband data collection at a rate of 8 Gbps and a 4 ps group delay uncertainty for the GGAO-Haystack baseline.
- On-track to completing system by April 2013.

System Features:

- 12-m / 5 deg per sec / 8 Gbps enables improved troposphere sampling with acceptable SNR for observation by worldwide VLBI network.
- Standardization and commercial-off-the-shelf availability of many key components will lead to lower operation and replication costs.
- Selectable RF band placement will better tolerate radio frequency interference and allow compatibility with legacy S/X systems.
- Improvement in group delay will enable ~1mm position determination when the VLBI2010 technology is incorporated in the expanded global network.

Modern GNSS Stations

- ◆ Upgrade completed:
 - Multi-constellation (GPS, GLONASS, Galileo) stations installed and collecting data.
 - Data publicly available from CDDIS.
 - Existing GPS site to remain operational.





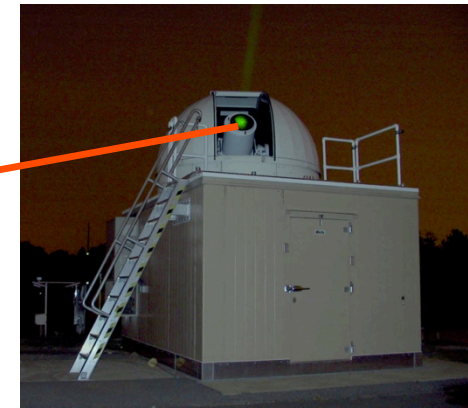
- ◆ GGAO DORIS beacon part of a global network of ~57 stations
- ◆ DORIS located at GGAO since June 2000
- ◆ Beacons emit at 2 Ghz and 400 Mhz; the observable is dual-frequency 1-way Doppler
- ◆ DORIS receivers are located on altimeter (TOPEX/Poseidon, Jason, ENVISAT) and remote sensing (SPOT) satellites; future satellites include: Cryosat-2, Jason-3, SWOT & SENTINEL-3

DORIS Global Network

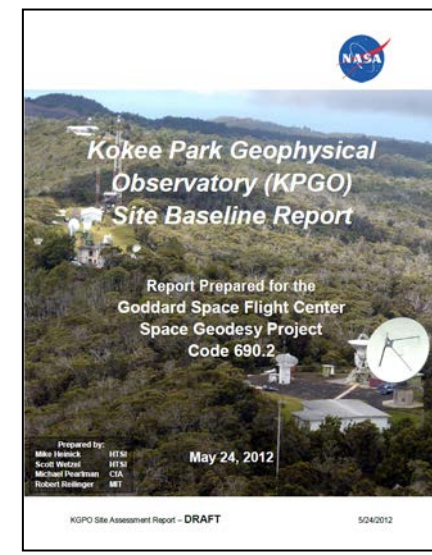
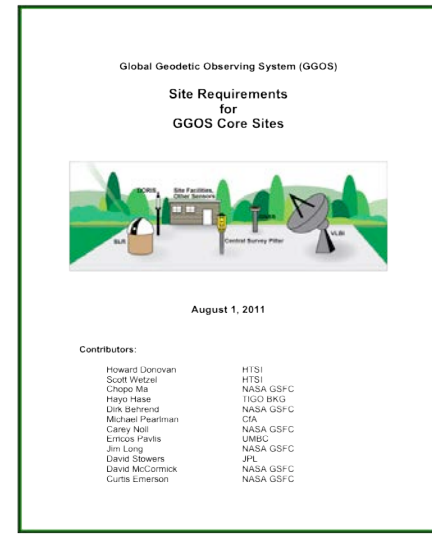


Co-location Vector Monitoring

- ◆ Accurate measurement of inter-station vectors is an essential aspect of an integrated space geodesy site.
- ◆ Measurements provide closure between terrestrial reference frames derived from different space geodesy techniques.
- ◆ Tests of technologies and currently available systems underway at GGAO.



- ◆ Released Site Requirements Document:
 - http://cddis.gsfc.nasa.gov/docs/GGOS_SiteReqDoc.pdf
- ◆ Site evaluations completed for:
 - Kokee Park Geophysical Observatory (Kauai), Hawaii
 - Haleakala (Maui), Hawaii
 - GGAO, Greenbelt Maryland
 - Monument Peak, California
- ◆ Site evaluations underway for remaining US and US partner sites.
- ◆ Holding bilateral discussions with potential international partners on establishing new geodetic sites.





Project Status Summary



- ◆ Prototype core site is currently on-schedule for completing co-location demonstration by August 2013.
- ◆ NGSLR successfully tracked 20 of the 33 current ILRS satellites, including daylight ranging to GNSS (GLONASS-109 & 115).
- ◆ Prototype VLBI2010 antenna successfully performed several end-to-end geodetic sessions.
- ◆ New GNSS stations continue to operate well for >9 months.
- ◆ Completed site assessments for 4 US locations. More underway.
- ◆ An implementation plan is being developed to upgrade the NASA network and establish new sites with our international partners.



Education and Public Outreach



- ◆ “the committee found that one of the ‘weakest links’ in the implementation of a precision geodetic infrastructure was a lack of a trained workforce to develop and maintain the infrastructure in the coming decades.” - *Committee on the National Requirements for Precision Geodetic Infrastructure*
- ◆ The SGP EPO program is focused on:
 - Training undergraduate and graduate level engineers and scientists.
 - Generating public excitement and awareness of space geodesy and its applications.

Training the next generation



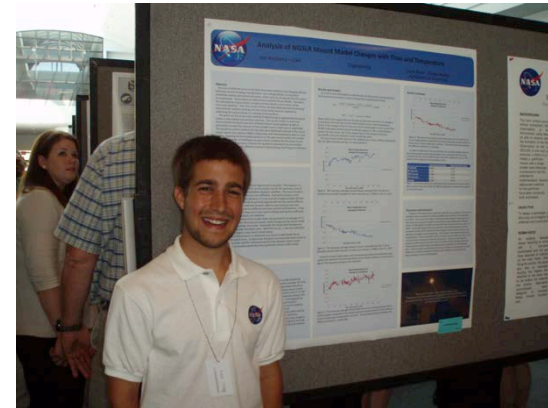
Six interns worked with the SGP team on tasks ranging from the NGSRLR telescope mount, to VLBI radio interference, to analysis of geodetic data.



SGP hosted a summer intern tour of the Goddard prototype station on July 3 for all Goddard summer interns.



The interns also performed surveying tasks at the prototype station.



The summer interns presented their work at the Intern Poster Session on July 25, 2012.



Public Outreach



- ◆ New Space Geodesy Website:
 - <http://space-geodesy.nasa.gov>
- ◆ Timely features (such as the leap second on June 30) on NASA Portal
- ◆ Entries in the NASA Visualization Explorer App
- ◆ Staff Profile Videos
- ◆ Animated Videos