NASA's Space Geodesy Project

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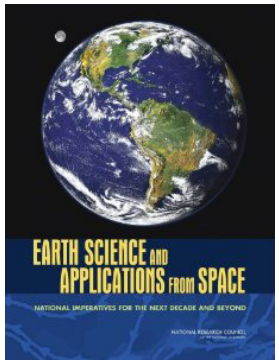
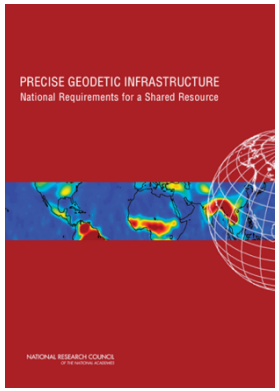
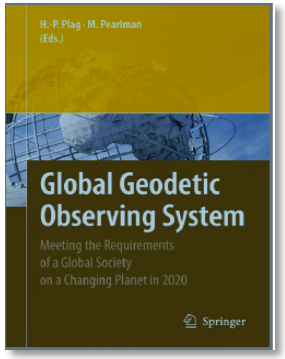
Supporting Future Requirements







- **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.

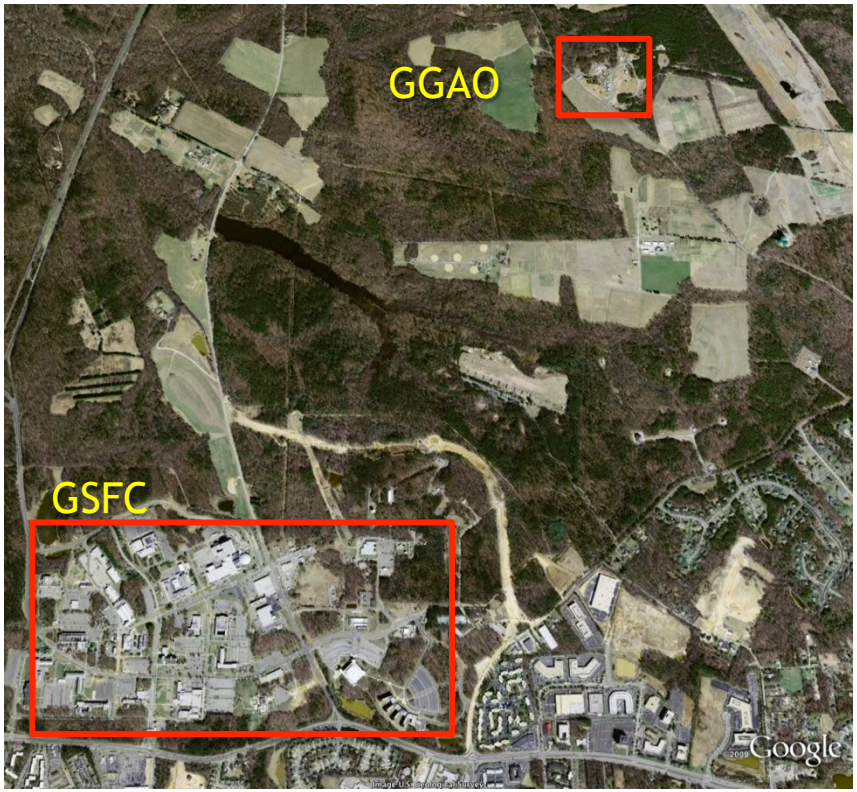
The Space Geodesy Project

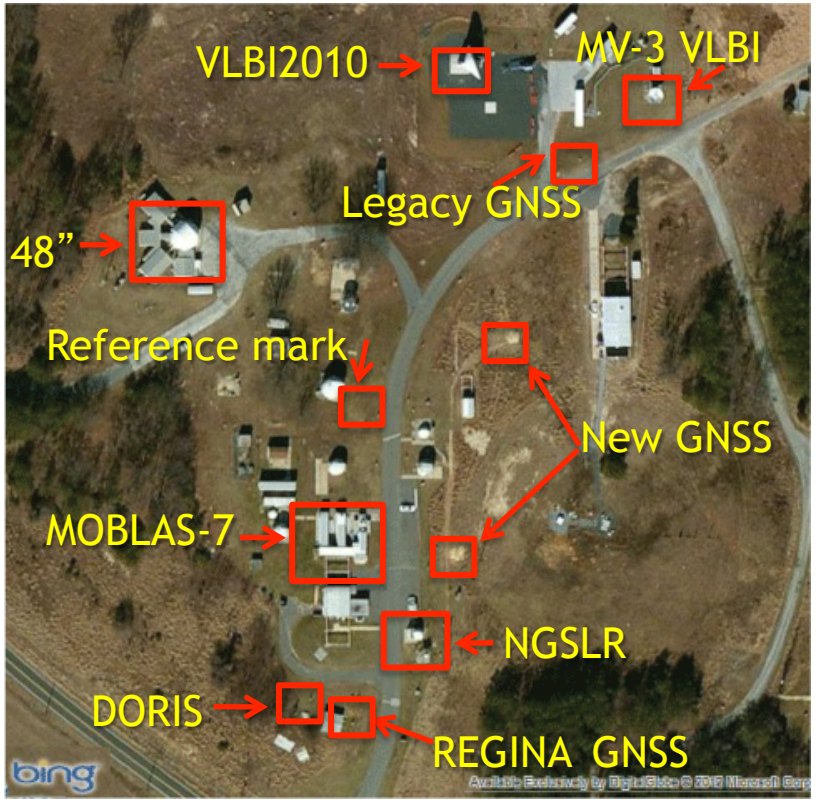
- New NASA initiative started at the end of 2011 in response to the Earth Science Decadal and the National Research Council study "Precise Geodetic Infrastructure." Part of the President's Climate Initiative.
- Goddard led in partnership with JPL and participation from the Smithsonian Astrophysical Observatory 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.





Next Generation Satellite Laser Ranging System (NGSLR) Prototype

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 system has demonstrated tracking of Earth orbit satellites with altitudes from 300 km to 20000 km.

- Successfully tracked most of the ILRS satellites.
- LEO, LAGEOS 1 & 2, and GNSS have all been successfully tracked in both daylight and night.
- Completed intercomparison testing with MOBLAS-7.
- Completed installation of new high-power optical bench.

- 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.

NGSLR Prototype System Configuration

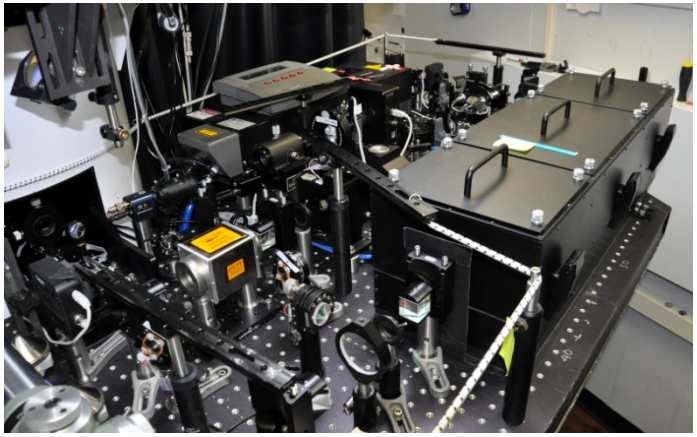
Hamamatsu High QE MCP PMT:

Photonics Industries Short Pulse, Hi Energy, Hi Rep Rate Laser:

NGSLR's new Automation Software controls operations and ties the subsystems together

IO chassis (provides interface between SW & LHRS system):

Automated optical bench with motor controlled optics:



VLBI 2010 Prototype

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.

- 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 May 2013 with final acceptance in July.

- 12-m, 5 deg/s, 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.

VLBI2010 Geodetic Sessions Timeline

- Geodetic sessions (end-to-end VLBI2010 observations with more than one antenna) are performed periodically with ever increasing realism.

January 2012:

1st broadband Baseline ,

Single source, contiguous frequency selection,

5 minute integration time

April 2012:

1st 8 MHz legacy – 32 MHz Broadband data collection

Correlation lessons learned

May 2012:

6 hour broadband baseline

1st automated capture of multiple sources,

30 second integration time,

mask avoidance lessons learned

October 2012:

2 x 6 hr broadband sessions multiple sources, checking

mask avoidance lessons applied

January 2013:

8 MHz legacy –32 MHz Broadband 24 hour data collection

Correlation lessons applied to 9 stations

1st use of S-Band in broadband front end

Realism

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.

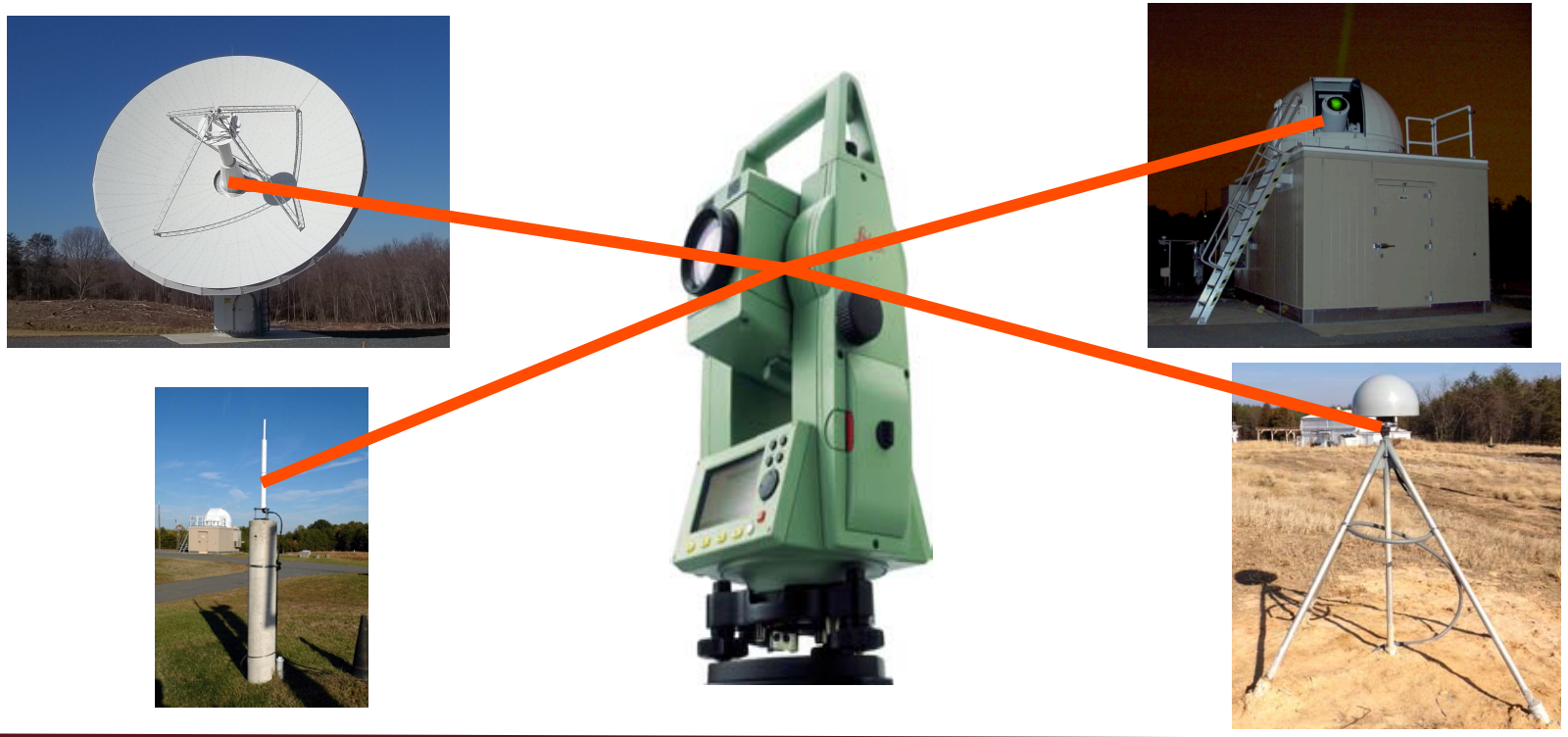
DORIS at GGAO

DORIS Global Network

- 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 satellites (TOPEX/ Poseidon, Jason1-2, ENVISAT, Cryosat-2) and remote sensing satellites (SPOT-2, SPOT-3, SPOT-4, SPOT-5); future satellites include: SARAL/Altika, Jason-3, SENTINEL-3, Jason-CS & SWOT.

Monitoring of Tie Vectors

- Accurate estimation of tie vectors between instrument reference points is an essential aspect of an integrated space geodesy site.
- Local ties provide connections between terrestrial reference frames derived from different Space Geodesy techniques.
- Leica TS 30 robotic total station is basis of system being developed at GGAO to monitor the relative local stability of the instrument conventional reference points.
- Developing error budgets for each technique to estimate the connection between the conventional reference point and the electronic reference point.



Preparation for New Core Geodetic Sites

- GGOS 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
  - McDonald Observatory, Fort Davis, Texas
  - Westford, Massachusetts
  - Gilmore Creek, Alaska
- Investigating alternative west coast sites.
- Site evaluations underway for remaining US partner sites.


Global Geodetic Observing System (GGOS)

Site Requirements for GGOS Core Sites

August 1, 2011

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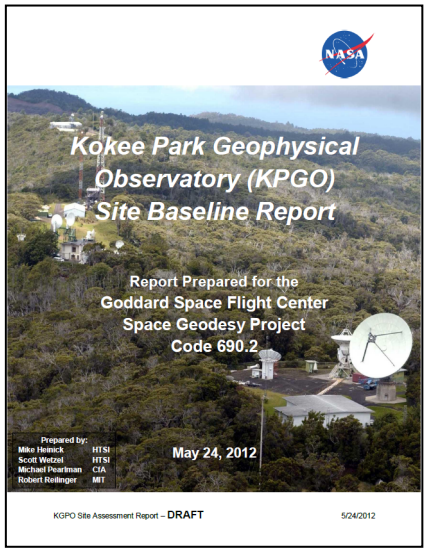

Project Status Summary

- 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 existing US locations. More underway.
- An implementation plan is being developed to upgrade the NASA network and establish new sites with our international partners.