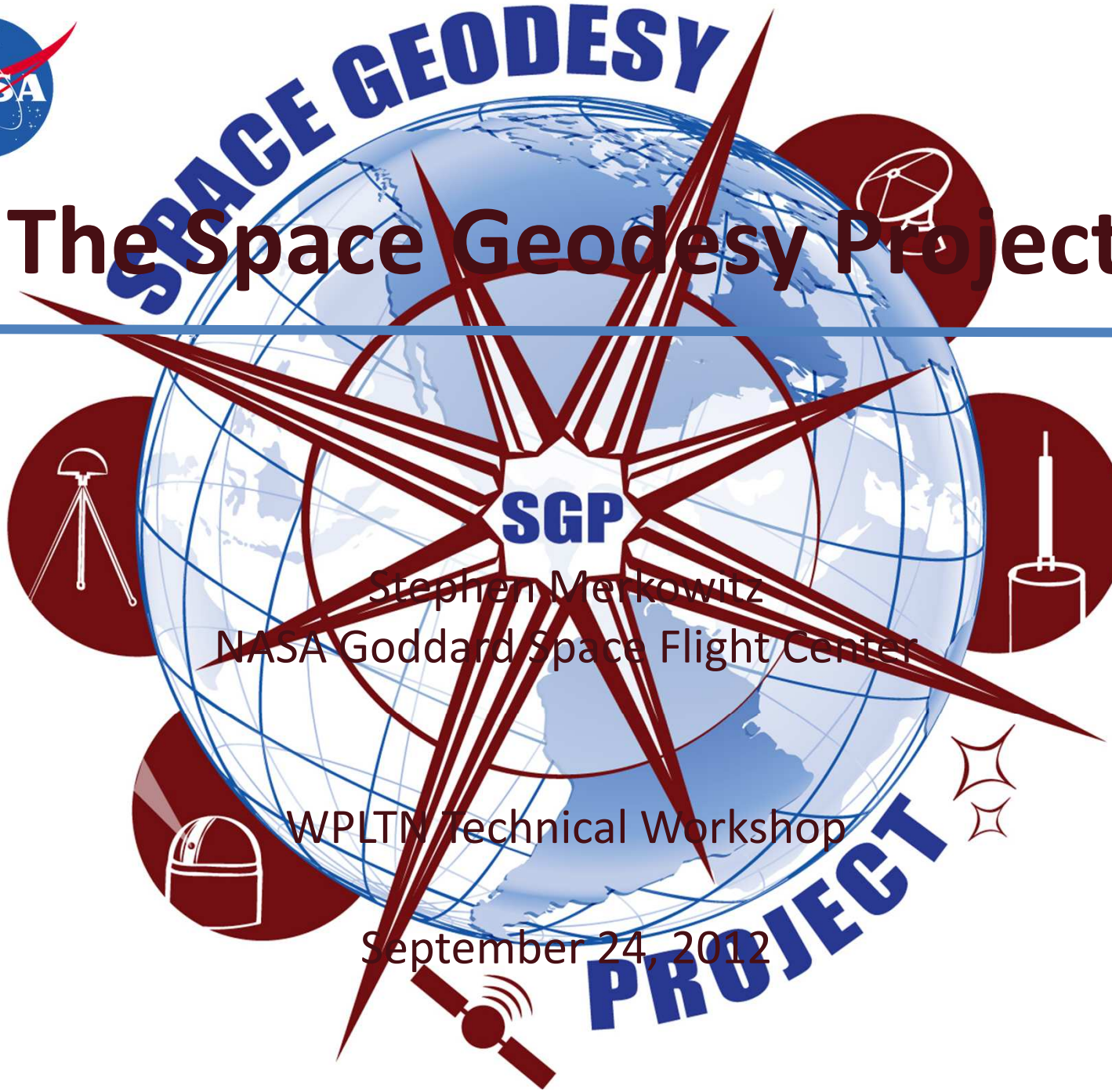
# The Space Geodesy Project

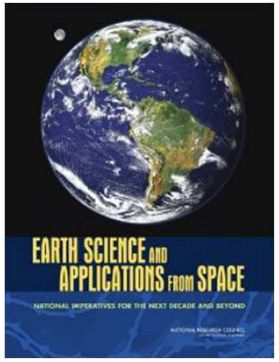


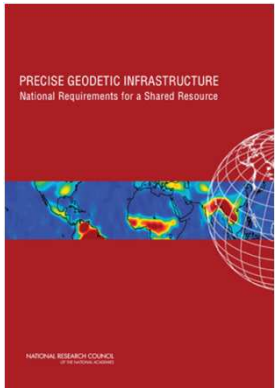

Stephen Merkowitz
NASA Goddard Space Flight Center

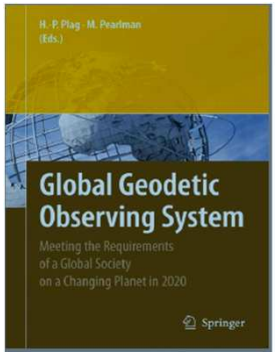
WPLTN Technical Workshop

September 24, 2012

# 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.

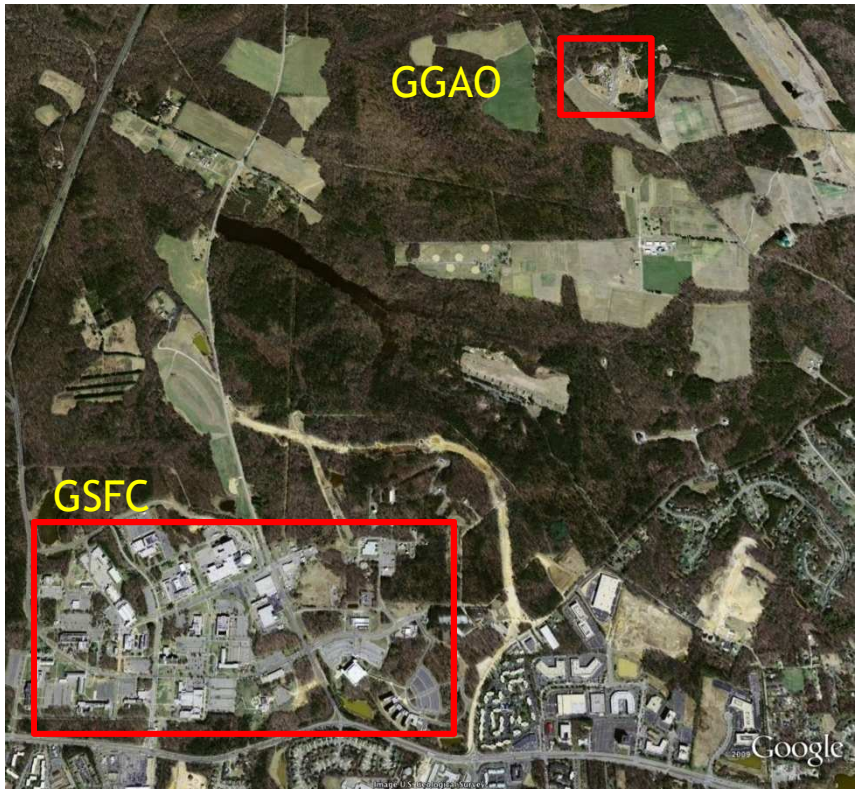
# The Space Geodesy Project

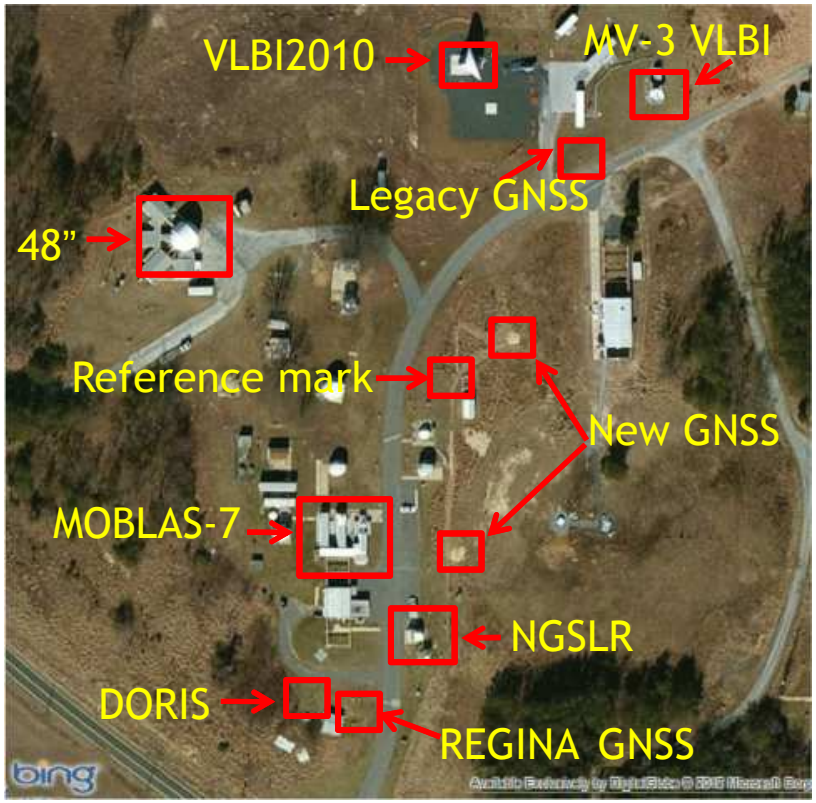
- New NASA initiative started at the end of 2011 in response to the Earth Science Decadal and the National Research Council study "Precise Geodetic Infrastructure." Part of the President's Climate Initiative.
- Goddard led in partnership with JPL and participation from the Smithsonian Astrophysical Observatory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

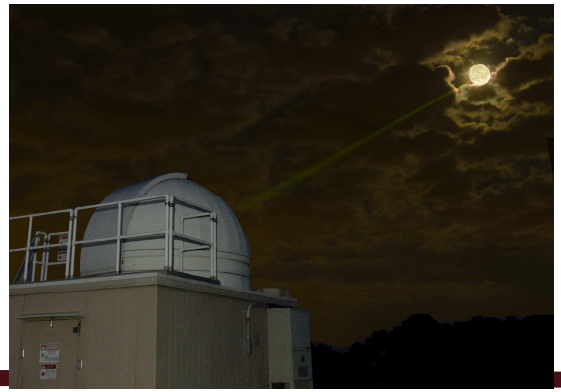
- Goddard Geophysical and Astronomical Observatory (GGAO) is located 5 km from Goddard Space Flight Center in the middle of the Beltsville Agricultural Research Center. GGAO is one of the few sites in the world to have all four geodetic techniques co-located at a single location.



# SLR at GGAO

- GGAO is home to NASA's SLR activities since its original development there in the early 1960's.
- Two SLR systems at GGAO, MOBLAS-7 and NGSLR, support the laser ranging activities of the ILRS.
- "NGSLR (NASA's Next Generation SLR) performs one way (uplink only) ranging to the Lunar Reconnaissance Orbiter (LRO), providing 10 cm accurate ranges used in the determination of onboard clock drift and aging, and eventually for use in more precise orbit determination
- The 1.2 meter telescope is used for research and development, along with periodic on-orbit calibrations of the Lunar Orbiter Laser Altimeter (LOLA) onboard LRO; three successful on-orbit calibrations have been performed so far.



# Next Generation Satellite Laser Ranging System (NGSLR)

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.

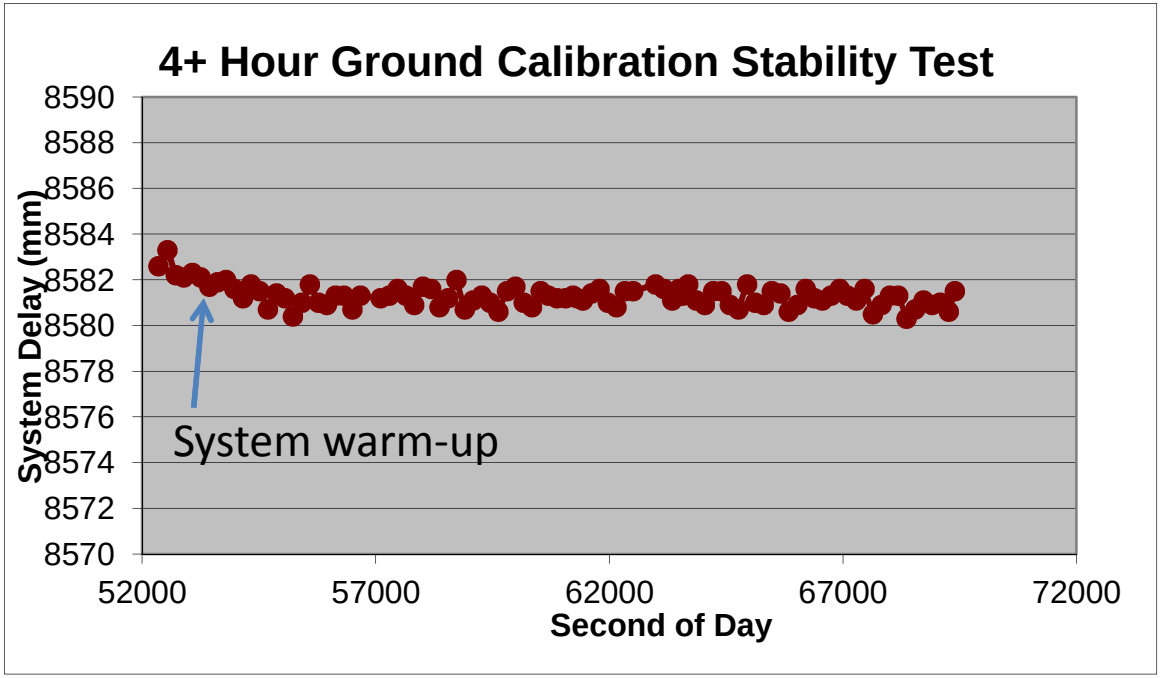
# Final NGSLR configuration taking shape

- Now installed at NGSLR:
  - + optical bench with new layout
  - + high energy, short pulsewidth laser
  - + high QE Hamamatsu detector

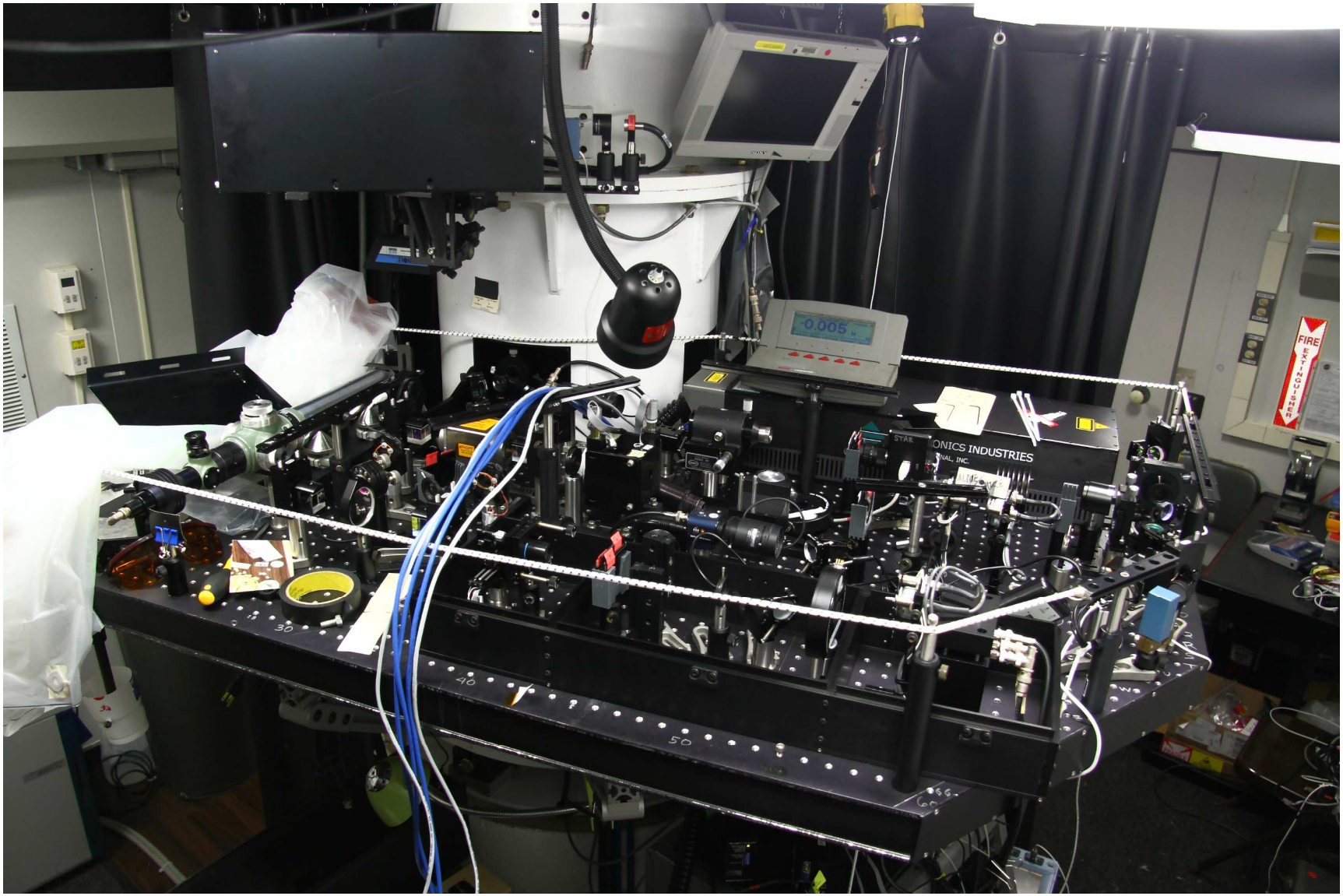

- System alignment completed, star calibrations successfully performed.

- Preliminary ground calibrations look good. Test shown here has RMS < 0.3 mm over 4+ hours period (after system warm-up).

- New IO chassis installed and being tested.



# New Optical Bench Installed at NGSLR



# New IO Chassis Installed at NGSLR


New power distribution chassis

New IO chassis

Event Timer

Range Gate Generator

# VLBI at GGAO

- MV-3 system was originally a mobile VLBI station supporting the Crustal Dynamics Project that began in 1980
- Mobile system made measurements in western U.S., Alaska, and Europe.
- Since 1993, MV-3 has been a fixed site at GGAO and part of the global network supporting the IVS.
- MV-3 now serving as a testbed facility for NASA VLBI R&D, including VLBI2010 development.
- New 12 meter antenna serves as fully configured VLBI2010 prototype system.


# 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.

Achievements & Status:

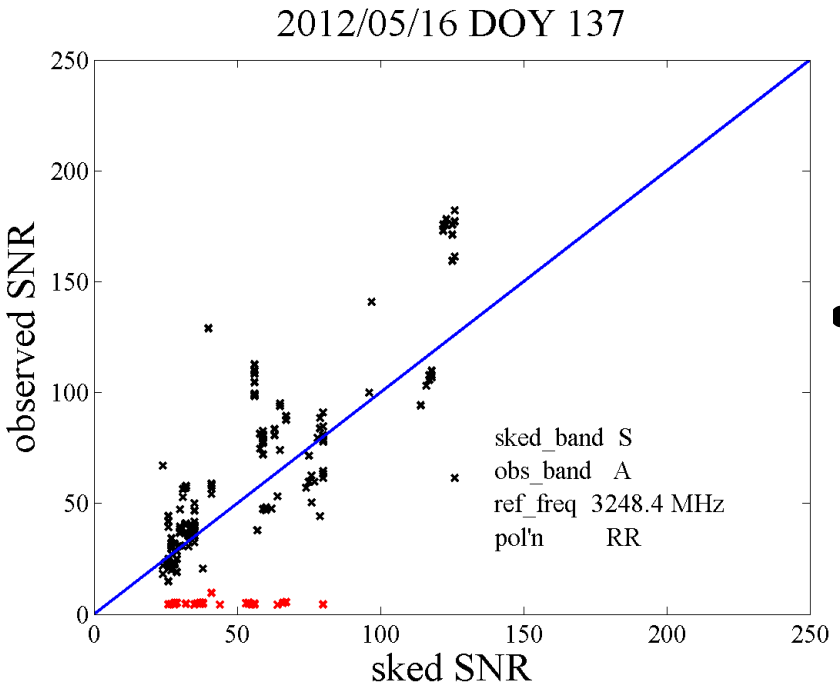
- Demonstrated 60% aperture efficiency.
- Demonstrated 5 deg/sec azimuth slew rate.
- Demonstrated broadband data collection at a rate of 8 Gbps and a 4 ps group delay uncertainty for the GGAO-Haystack baseline.
- On-track to completing system by April 2013.

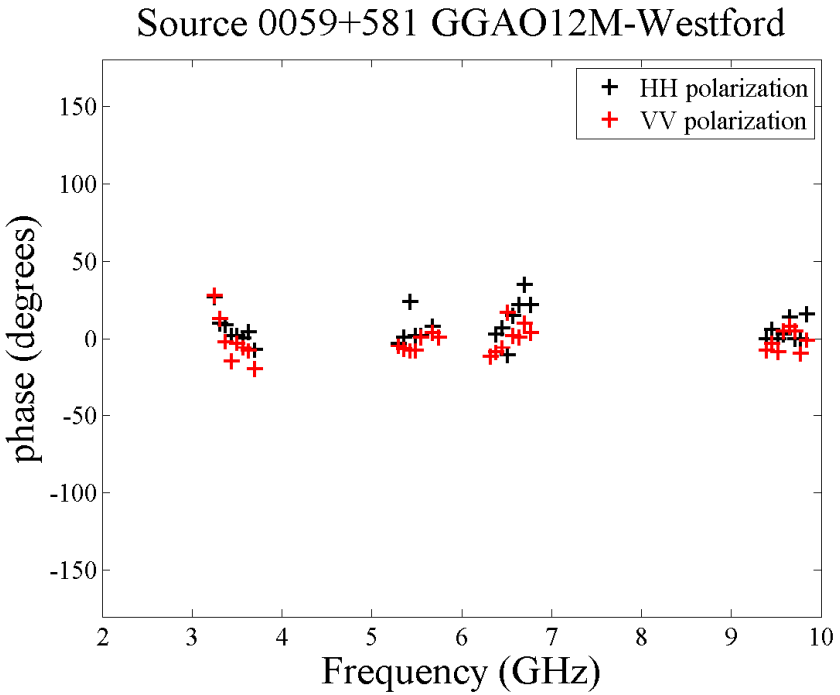
System Features:

- 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.

# May 16th Geodetic Session with Broadband VLBI

- Consistency of delay results across 4 widely spread frequencies. Using NuSolve scatter reduced to 11 psec. Legacy best cases were 25 psec. →

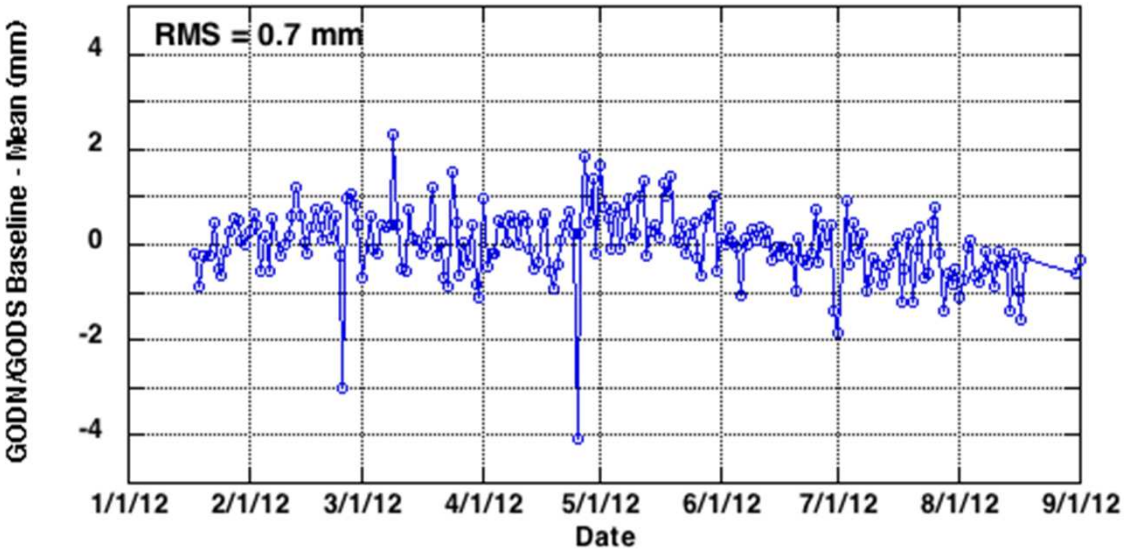


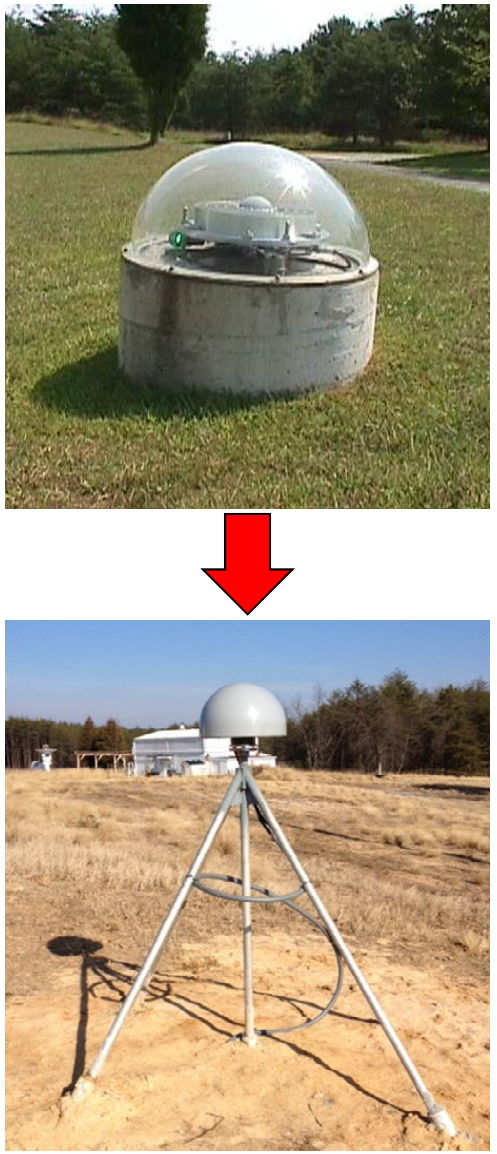




- ←Predicted versus observed signal to noise ratio – and RFI mask limitations

# Modern GNSS Receiver

- Upgrade competed:
  - Multi-constellation (GPS, GLONASS, Galileo) antenna receiver pairs installed and collecting data.
  - Data publicly available from CDDIS.
  - Existing GPS site to remain operational.



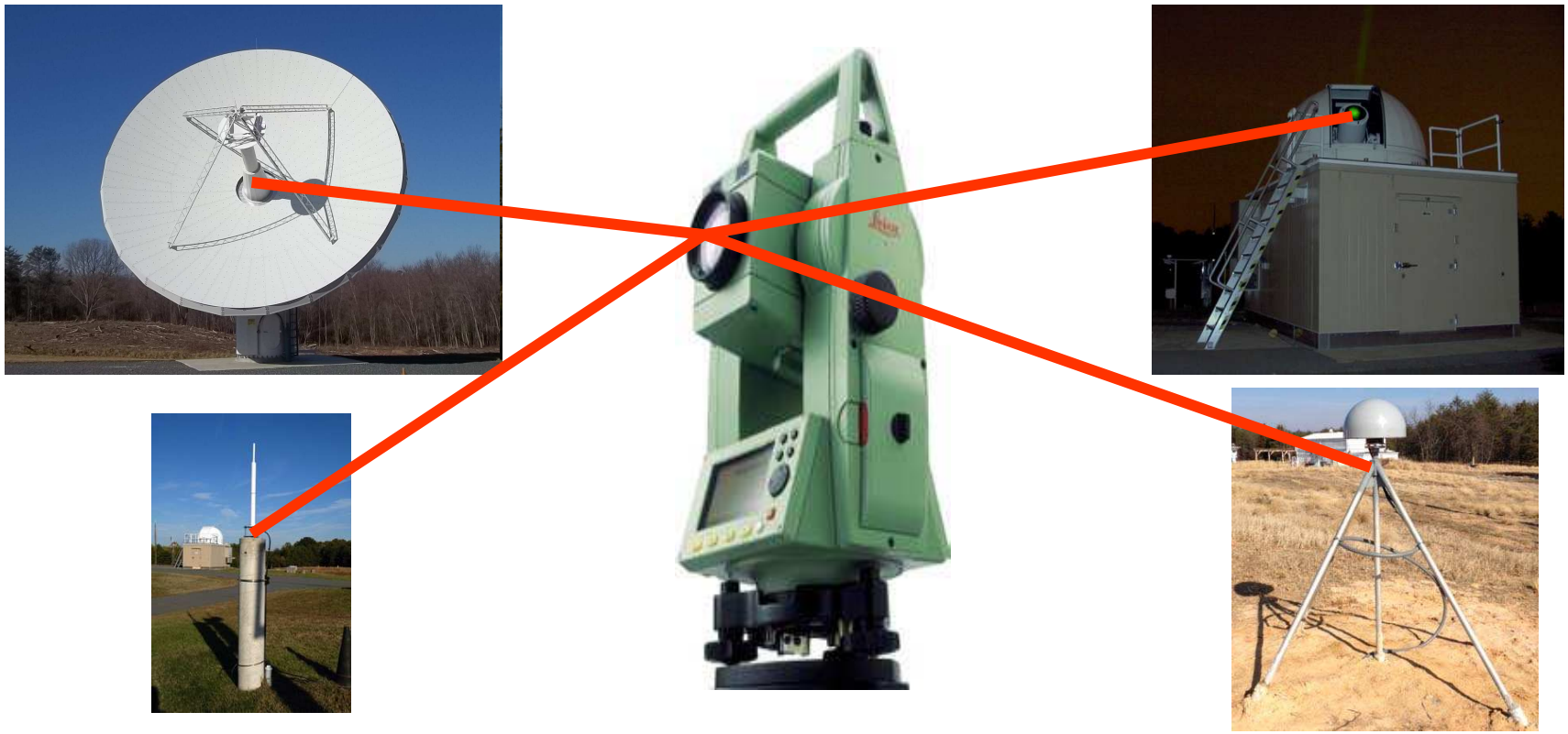
# DORIS at GGAO

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 (TOPEX/Poseidon, Jason, ENVISAT) and remote sensing (SPOT) satellites; future satellites include: Cryosat-2, Jason-3, SWOT & SENTINEL-3

# Co-location Vector Monitoring

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



# Site Assessments

- First update to the Site Requirements released:
  - 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.


Global Geodetic Observing System (GGOS)

Site Requirements
for
GGOS Core Sites

August 1, 2011

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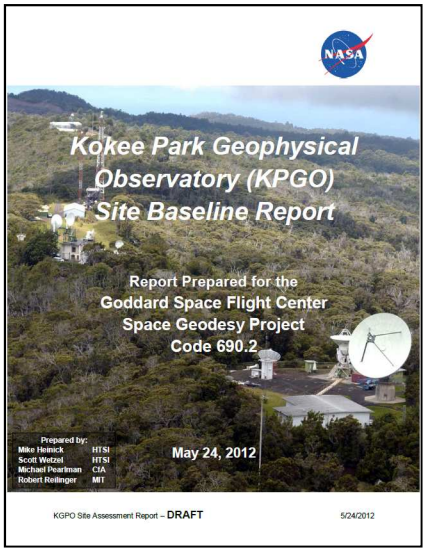

# Project Status Summary

- Prototype station 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).
- NGSLR met a major milestone by completing the development and installation of a new high-power optical bench.
- Prototype VLBI2010 antenna performed first end-to-end geodetic session on May 16, 2012.
- New GNSS receivers continue to operate well for >6 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.