

# SPACE GEODESY

# NASA's Space Geodesy Project

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NASA's Space Geodesy Network and Plans for the Future

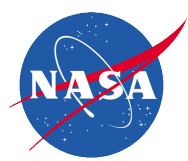
SGP

November 20, 2013

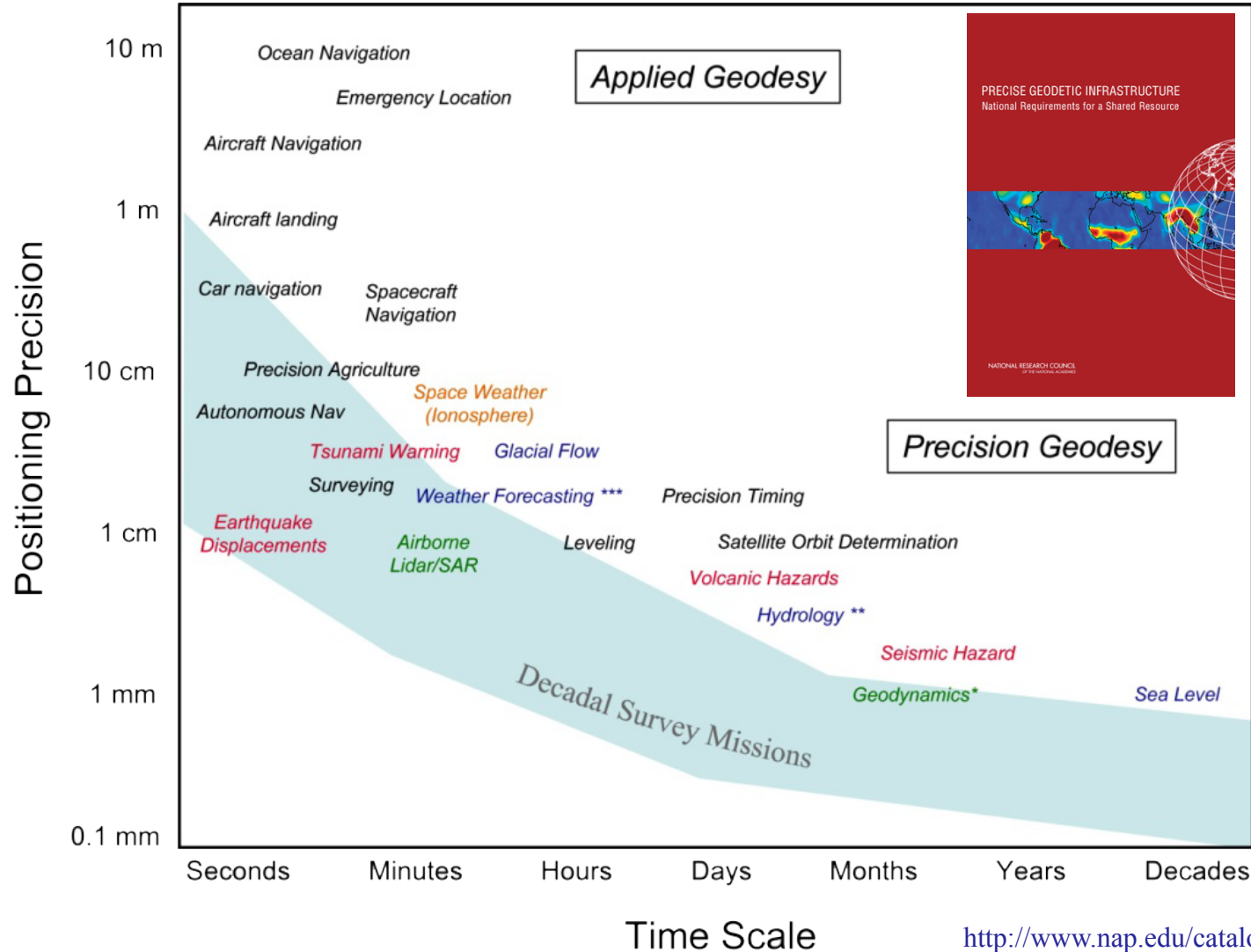
Nigerian Delegation Visit to GSFC

PROJECT





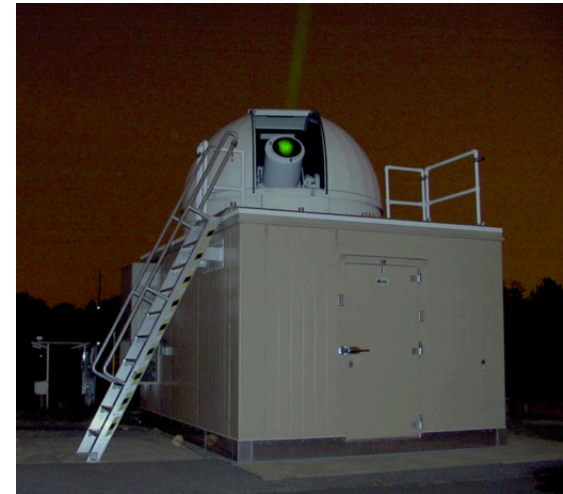
# Space Geodesy Provides Positioning, Navigation, and Timing Reference Frames and Earth System Observations



<http://www.nap.edu/catalog/12954.html>



Very Long Baseline Interferometry (VLBI)



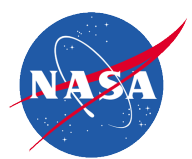
Satellite Laser Ranging (SLR)



Global Navigation Satellite System (GNSS)



Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS)



# Satellite Laser Ranging (SLR)



- ◆ Currently 23 operational stations worldwide acquiring data daily.
- ◆ GSFC operates five SLR stations:
  - GGAO, Greenbelt, Maryland,
  - McDonald Observatory, Fort Davis, Texas (Univ. of Texas at Austin),
  - Monument Peak, Mount Laguna, California,
  - Haleakala, Maui, Hawaii (Univ. of Hawaii, Institute for Astronomy),
  - Arequipa, Peru (Universidad Nacional de San Agustín (UNSA)).
- ◆ GSFC supports three partner stations:
  - Tahiti, French Polynesia (CNES, Univ. of French Polynesia),
  - Hartebeesthoek, South Africa (NRF, Hartebeesthoek Radio Observatory),
  - Yarragadee, Australia (Geoscience Australia).
- ◆ GSFC provides the Central Bureau of the International Laser Ranging Service (ILRS) that coordinates the worldwide SLR network, observing, data processing and analysis.
- ◆ GSFC maintains the archival and distribution of the worldwide SLR data using the Crustal Dynamics Data Information System (CDDIS).





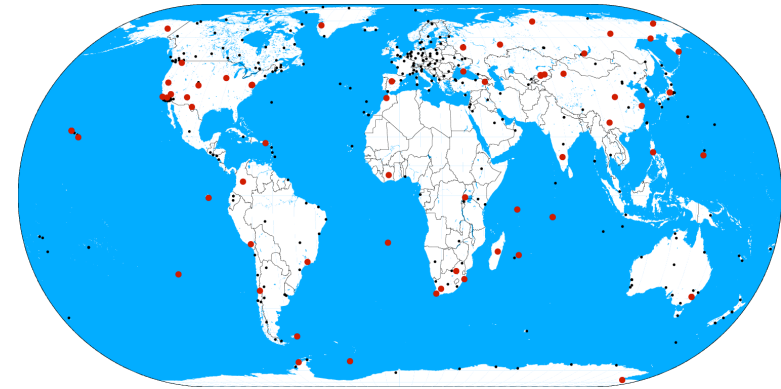
# Very Long Baseline Interferometry (VLBI)



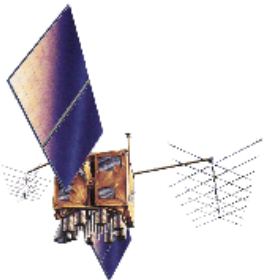
- ◆ 40 stations worldwide acquiring data, some daily.
- ◆ GSFC operates 3 VLBI stations:
  - GGAO, Greenbelt, Maryland,
  - Westford, Massachusetts (MIT, Haystack Observatory),
  - Kokee Park, Hawaii.
- ◆ GSFC provides support for 3 partner stations:
  - Svalbard, Norway (Norwegian Mapping Authority),
  - Fortaleza, Brazil (Mackenzie University),
  - Hobart, Australia (University of Tasmania).
- ◆ GSFC provides oversight and training to VLBI partners.
- ◆ GSFC provides the Coordinating Center and an Analysis Center of the International VLBI Service for Geodesy and Astrometry (IVS) that schedule all international geodetic VLBI networks and observing, oversee data correlation and distribution to the global archive, and perform VLBI data processing and analysis.
- ◆ GSFC maintains the archival and distribution of the worldwide VLBI geodetic data using the Crustal Dynamics Data Information System (CDDIS).



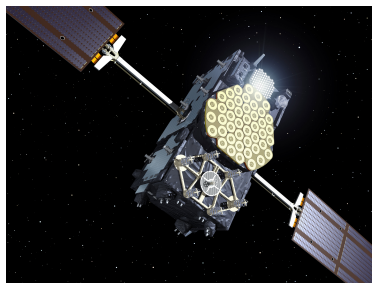
- ◆ 440 GNSS tracking stations within the International GNSS Service (IGS) network.
  - 68 NASA Stations
- ◆ JPL hosts the IGS Central Bureau that is responsible for the executive management of the IGS.



GPS



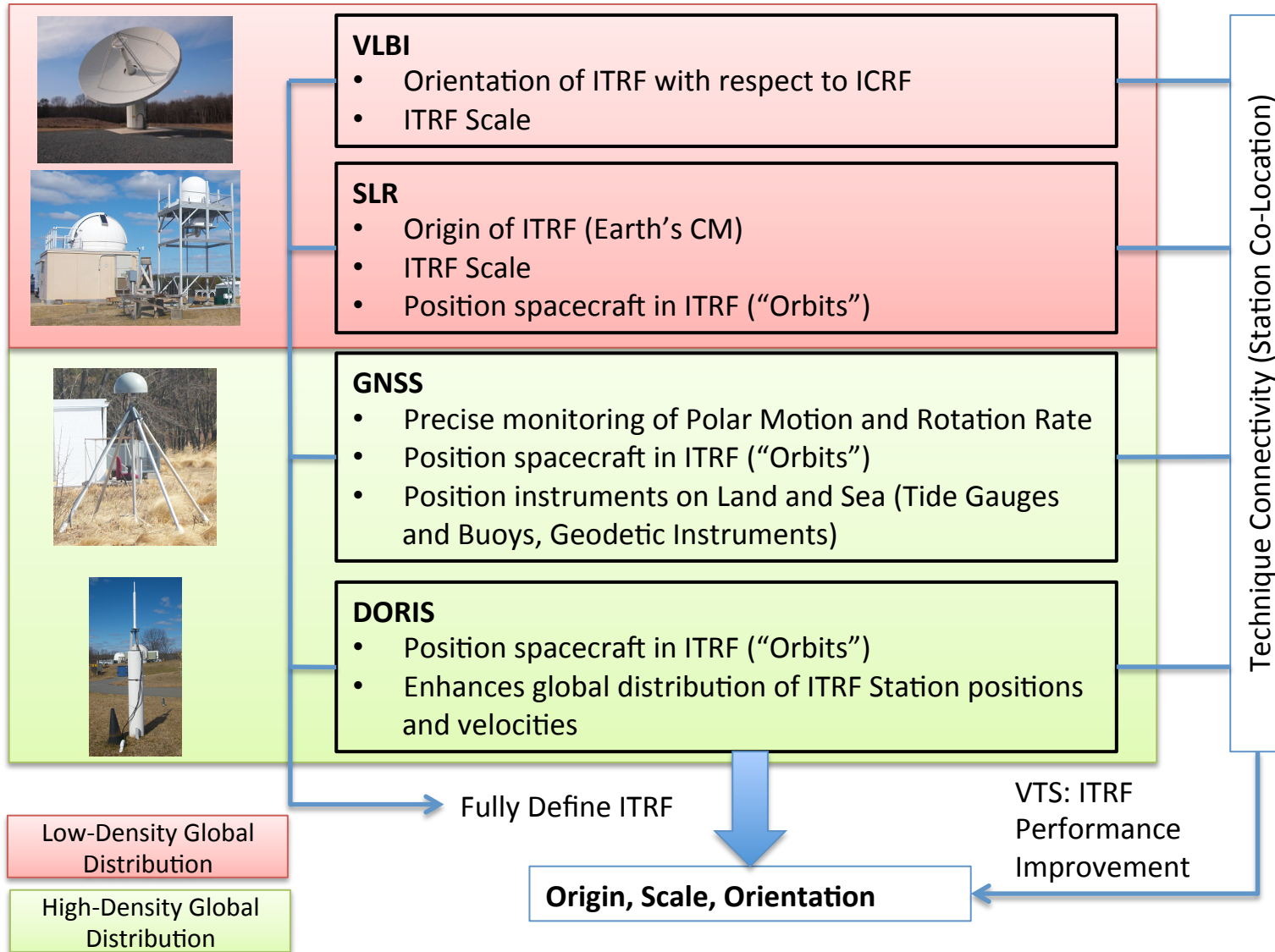
Galileo

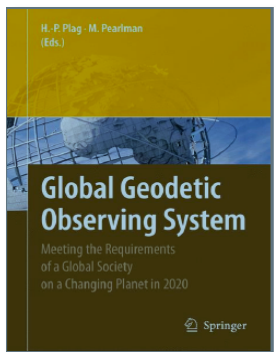
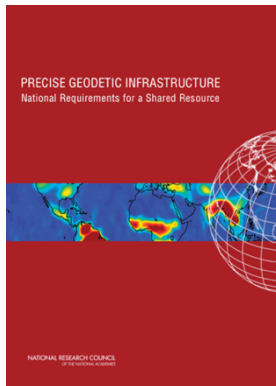
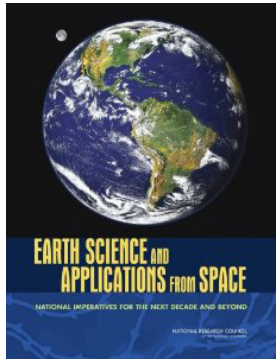


GLONASS



# The Geodetic Measurement System





## ◆ 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.
- ◆ 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.
  - Plan and implement 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



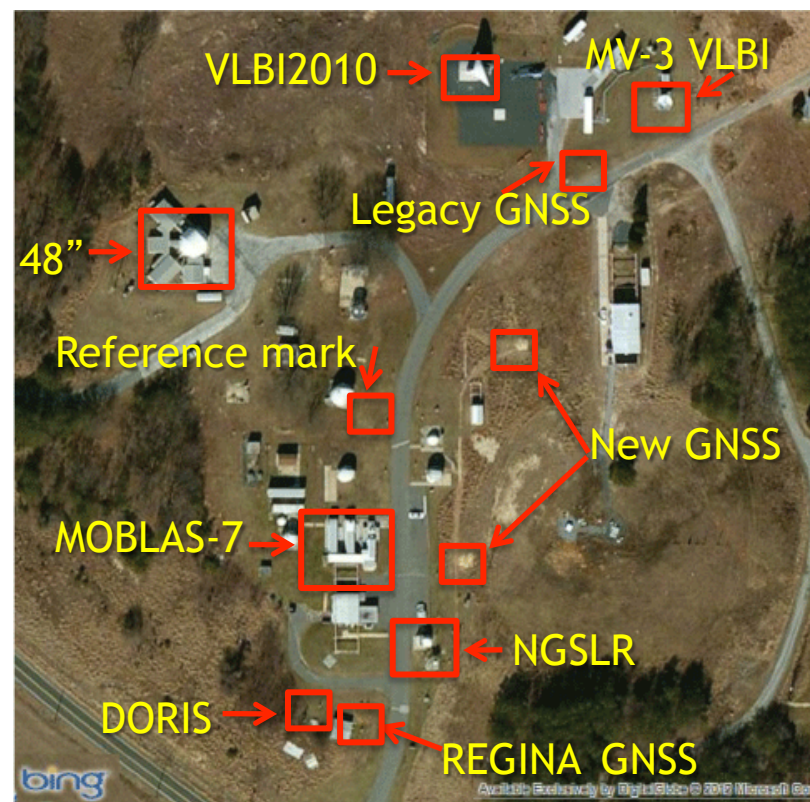
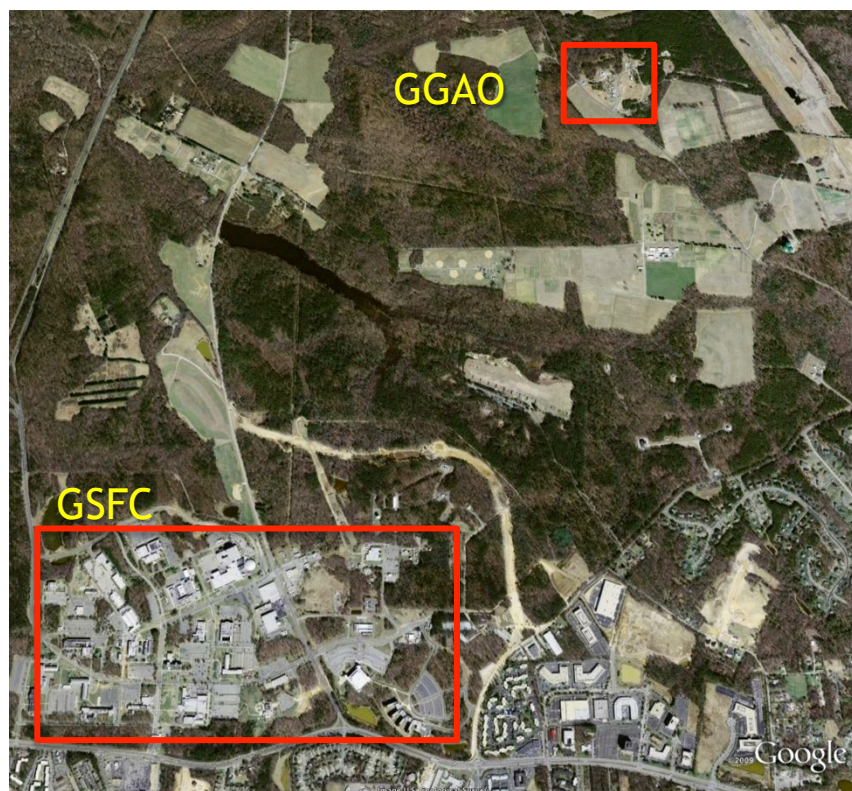
GNSS



Vector Tie



- ◆ 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.

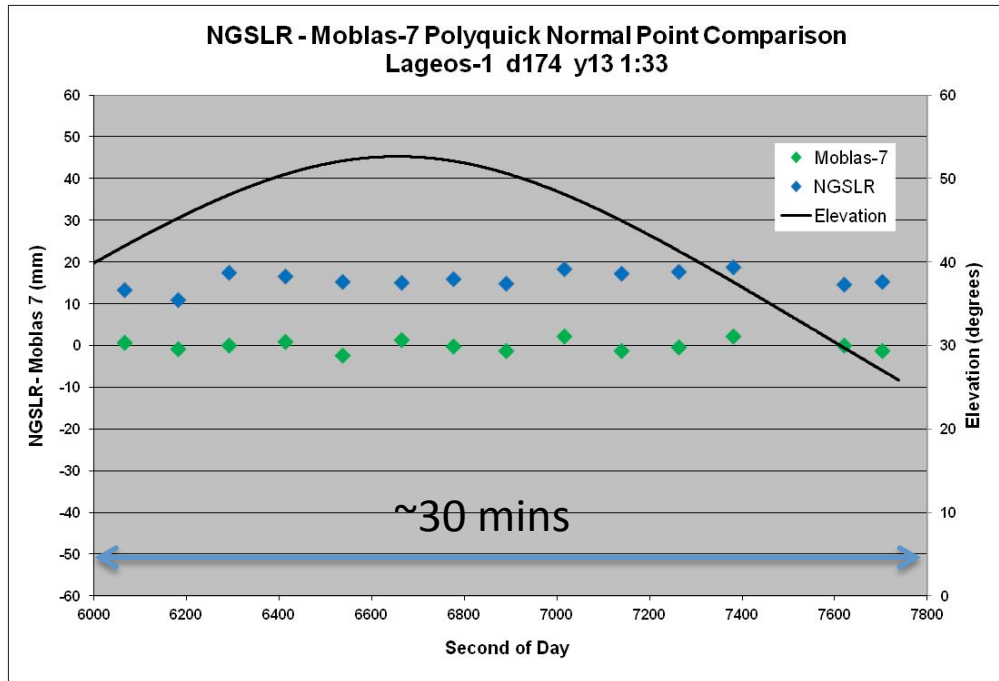


## System Requirements

- ◆ 24 hour tracking of LEO, LAGEOS, & GNSS satellites
- ◆ One millimeter normal point precision on LAGEOS
- ◆ Ground cal stability at the 1mm level over hour
- ◆ Successful collocation with MOBILAS-7
- ◆ Semi-autonomous operations
- ◆ Automated aircraft avoidance laser safety system



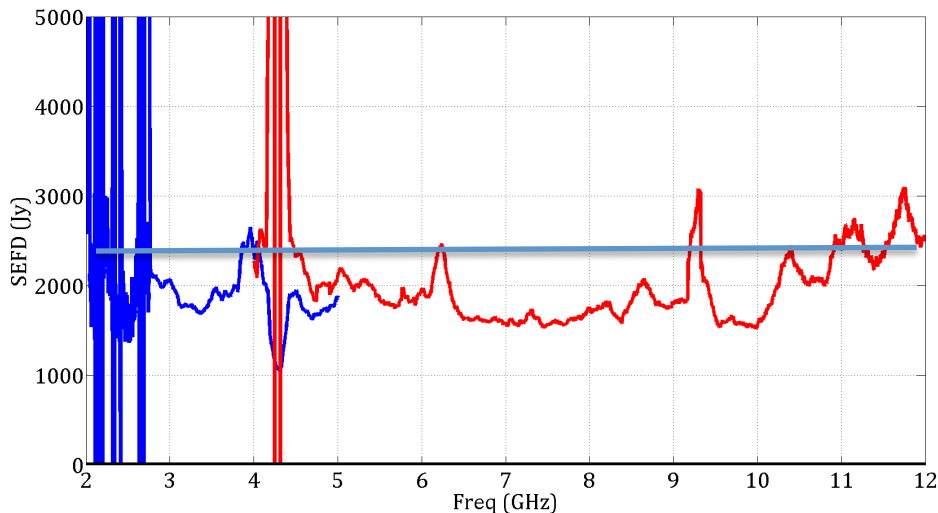
NGSLR - Moblas-7 Polyquick Normal Point Comparison  
Lageos-1 d174 y13 1:33



NGSLR and MOBILAS-7 simultaneously tracking Lageos-1 at the mm level and demonstrating the differences between single and multi photon systems!

## System Requirements

- ◆ Fast antenna - More observations for troposphere
- ◆ Smaller antenna - Reduced cost
- ◆ Broadband feed - RFI avoidance, increased sensitivity
- ◆ Multiple bands - Increased sensitivity, data precision
- ◆ Much higher data recording rate - Increased sensitivity
- ◆ Digital signal processing - Stable instrumentation

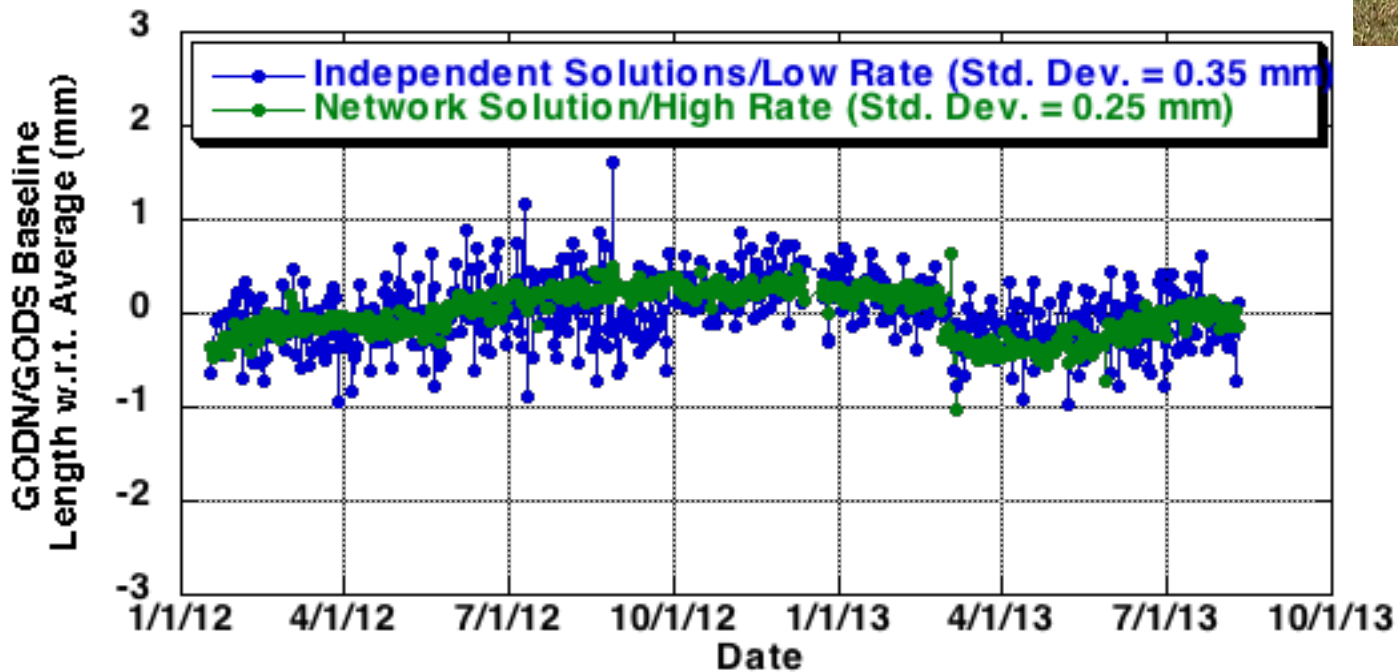


**May 2013**

Completed 1<sup>st</sup> 24-hour  
broadband geodetic  
session performing 1139  
30-second scans.

# Modern GNSS Stations at GGAO

- ◆ Two new GNSS stations installed at GGAO (GODN and GODS):
  - Collecting data since 2012-01-17.
    - Multi-constellation (GPS, GLONASS, Galileo)
- ◆ Standard deviation of GPS-based baseline lengths  $< 0.5$  mm.
  - Independent GPS-based positioning of each station and simultaneous network positioning (both with dual frequency data).
- ◆  $< 1$  mm agreement between baseline length from GPS and independent local tie survey.





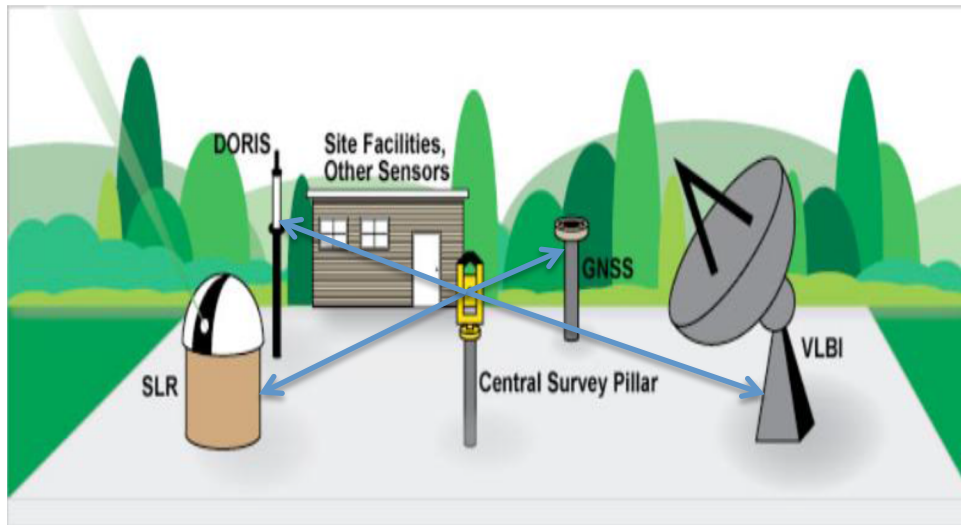
DORIS Global Network



- ◆ 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.

# Vector Tie System at GGAO

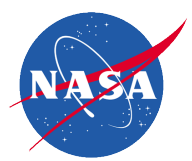
- ◆ The Vector Tie System (VTS) is a combination of a precise local-tie survey and a periodic monitoring system for measuring site stability.
- ◆ Demonstrated sub-mm accuracy at GGAO.
- ◆ Demonstrated semi-autonomous operation of monitoring system:
  - Find and identify target prism; verify prism correction,
  - Process distances measurements to correct for atmospheric correction.



*Local Reference Frame tie to all geodetic Stations*



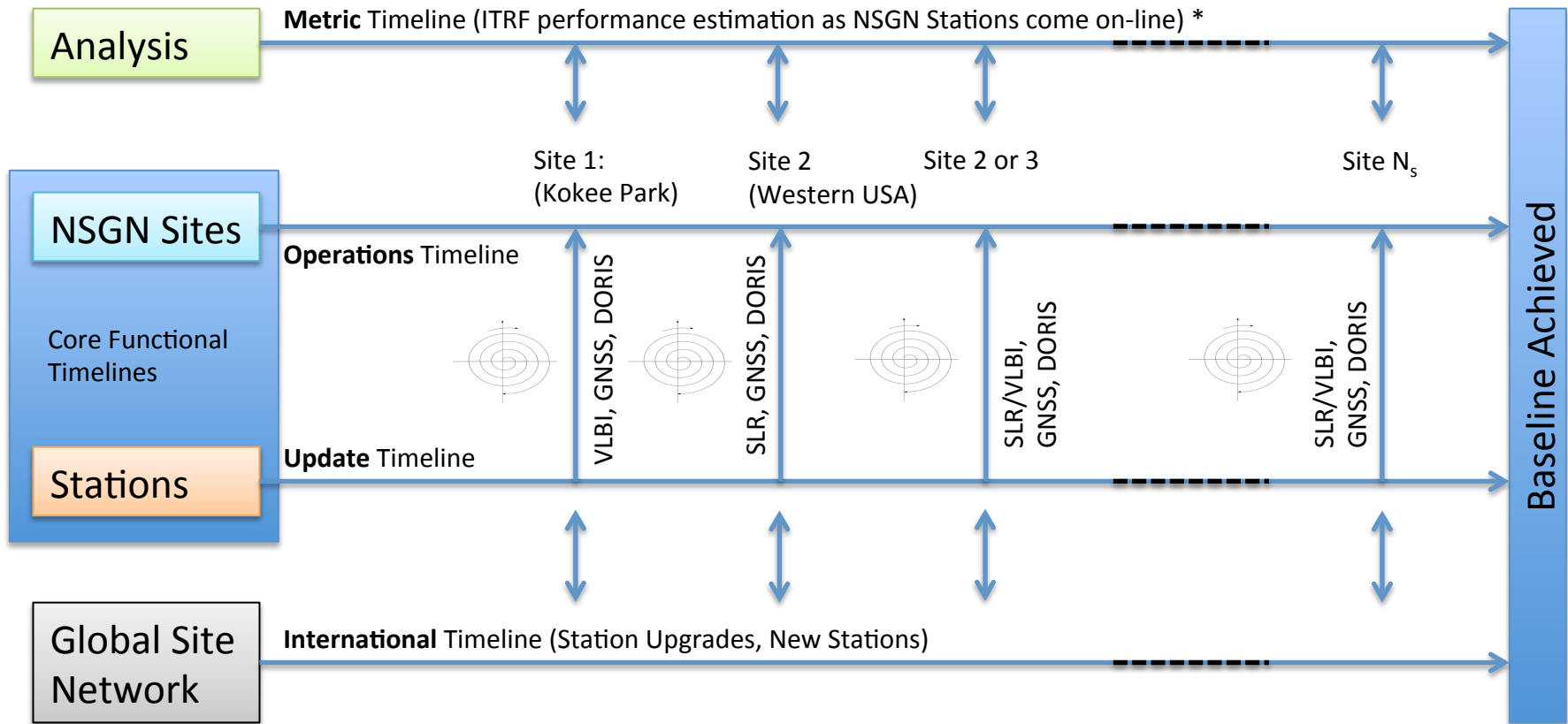
*GGAO Robotic Total (Range) Station*



# NASA Network Deployment Timelines: Meeting the Baseline ITRF Performance



- The NASA Space Geodesy Network (NSGN) is deployed within the context of a global network, and in timelines that reflect different functional aspects.



\* Technique-specific analysis also carried out concurrently to measure individual performance changes.

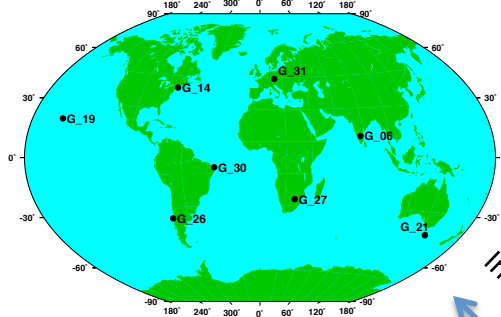




# Site Selections: Ideal versus Reality

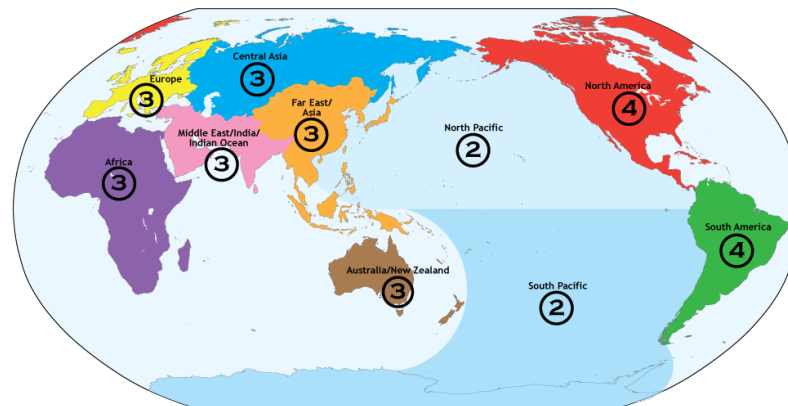


## Current Co-located Sites (VLBI, SLR, GNSS)



Ideal

4 Stations per Site

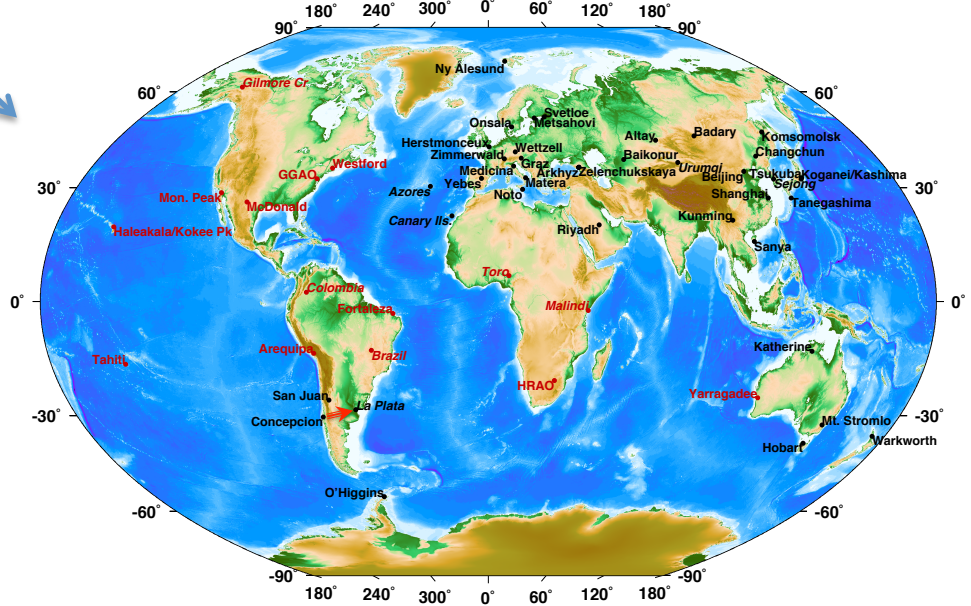


## Conceptual Network Distribution

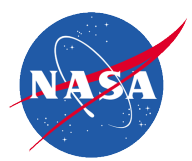
Reality Circle  
Agreements, NASA Contributions,  
International Plans, GGOS Call

- Operational, Technology, Deployment Costs
- Site Assessments
- ITRF Performance Predictions
- Phasing Plan
- Other factors

Iterative Analysis



## Current & Proposed Sites under Discussion



# SGP Site Selection Strategy




- ◆ Conceptual global site distribution based on simulation results for a 32 site network as a starting point by regions;
- ◆ Recognize existing and projected international sites that other groups plan to bring to new technology status;
- ◆ Examine present NASA and NASA partnership sites as potential sites;
- ◆ Seek candidate sites in the under-populated regions with a reasonable chance of success.
- ◆ For each identified site:
  - Examine value added of the geodetic position,
  - Examine Site Conditions (cloud cover, ground stability, etc.),
  - Examine human imposed conditions (RF/optical interference, air traffic, etc.),
  - Examine Political / Programmatic Conditions (agreement situation, land ownership and control, partnership arrangements),
  - Examine site accessibility, logistics, infrastructure, security, power, communications).
- ◆ Qualify the Site (good or bad candidate)

August 8, 2011

**Call for Participation  
The Global Geodetic Core  
Network: Foundation for  
Monitoring the Earth  
System**

*A Project of the Global Geodetic  
Observing System (GGOS) as a  
contribution to the Global Earth  
Observation System of Systems  
(GEOSS)*

Global Geodetic Observing System (GGOS)  
Site Requirements  
for  
GGOS Core Sites



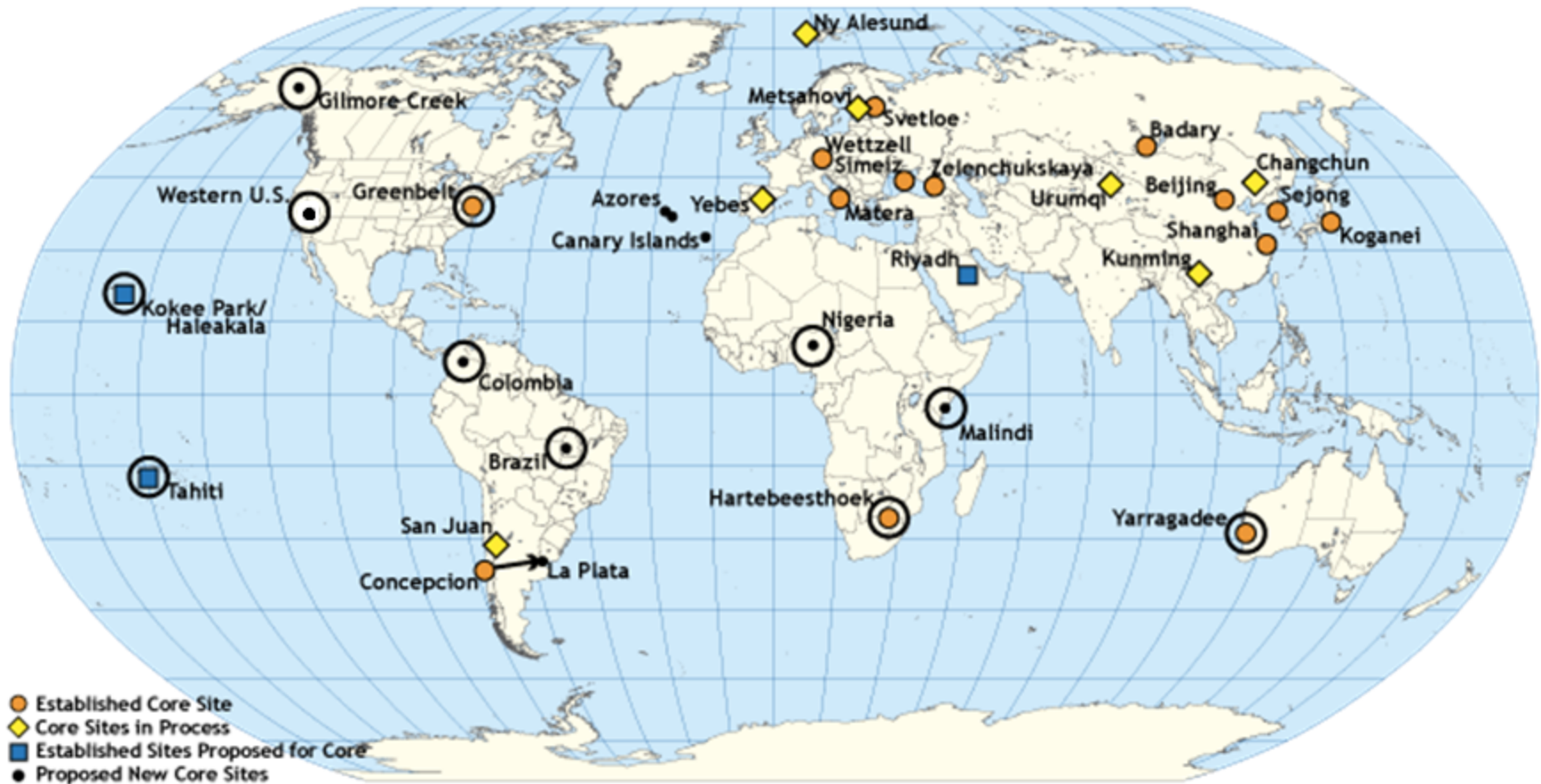
August 1, 2011

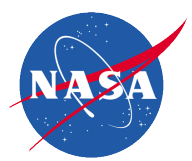
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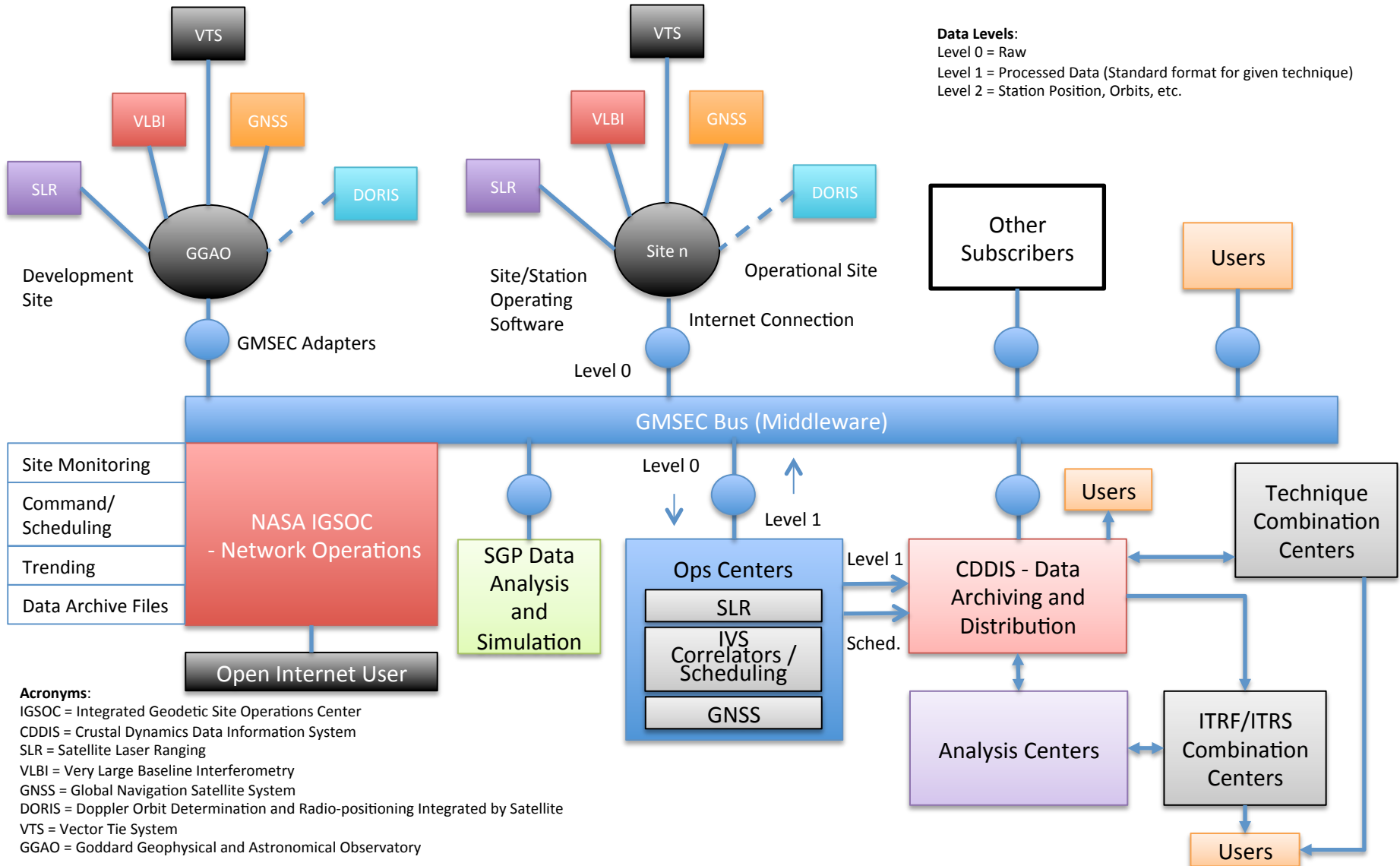
# Current and Candidate Core Sites

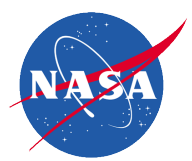




# Connecting the Network:

# Integrated Geodetic Site Operations Center





# Project Status Summary



- ◆ Completed demonstration of prototype next-generation core site:
  - NGSLR demonstrated required performance and is tracking current ILRS satellites including daylight ranging to GNSS.
  - Prototype VLBI2010 system demonstrated required performance and successfully performed several end-to-end geodetic sessions.
  - New GNSS stations continue to operate well for >9 months.
- ◆ Developed architecture for an Integrated Geodetic Site Operations Center with demonstration at GGAO planned for 2014.
- ◆ Preparations underway for site selections and deployment of the new NASA network!!!