Space Geodesy Core Sites and Role of GNSS

(Progress on the Global Space Geodesy Network)

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IAG 20th Anniversary Workshop
Pasadena CA
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Global Geodetic Observing System (GGOS)

- Established by the IAG to integrate the three fundamental areas of geodesy (Earth’s shape, gravity field, and rotation), to monitor geodetic parameters and their temporal variations in a global reference frame with a target relative accuracy of 10E-9 or better (See GGOS 2020)

- Provide products & services with the geodetic accuracy necessary to address important geophysical questions and societal needs, and to provide the robustness and continuity of service which will be required of this system in order to meet future needs and make intelligent decisions

- Constituted mainly from the Services (ILRS, IVS, IGS, IDS, IERS, IGFS, etc.)

- Main focus at the moment is the International Terrestrial Reference Frame, but we expect other data products to emerge
Practical applications of Space Geodesy
US National Research Council Study

- **Geodesy** is the science of the Earth’s shape, gravity and rotation, including their evolution in time.
- **Techniques** used to observe the geodetic properties of the Earth provide the basis for the International Terrestrial Reference Frame (ITRF).
- The ITRF is the foundation for virtually all airborne, space-based, and ground-based Earth observations, and is fundamentally important for interplanetary spacecraft tracking and navigation.

The ITRF performance requirement for sea level measurement is 1 mm reference frame accuracy and 0.1 mm/year stability (NRC 2010).

Most stringent requirement on ITRF performance is sea level

Provided through the courtesy of Prof. Bernard Minster

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GGOS Reference Frame Requirement

- Basis upon which we measure change over space, time, and evolving technology
- Most stringent requirement from sea level rise:
  - “accuracy of 1 mm, and stability at 0.1 mm/yr”
  - This is a factor 10-20 beyond current capability
- Accessibility: 24 hours/day; worldwide
  Users anywhere on the Earth can position their measurements in the reference frame
- Space Segment:
  - LAGEOS, LARES, GNSS, DORIS, Quasars to define the reference frame
- Ground Segment (Core Sites):
  - Global distributed network of “modern technology”, co-located SLR, VLBI, GNSS, DORIS stations locally tied together with accurate site ties
  - Dense network of GNSS ground stations to distribute the reference frame globally to the users
Simulation Studies to Scope the Network
(impact on the Reference Frame)
(Erricos Pavlis)

Simulation studies show:

• ~32 globally distributed, well positioned, new technology, co-location sites will be required to define and maintain the reference frame;

• ~16 of these co-location stations must track GNSS satellites with SLR to calibrate the GNSS orbits which are used to distribute the reference frame.

• Major Challenge
  • Will require time, significant resources, and strong international participation
Activity underway on VGOS

based on available information
August 2013
ILRS: Observation Network

- Large geographic gap in the network
- Anachronistic mix of new and legacy technologies
- Non-uniform procedures
Two Recent Initiatives

• Expansion of the Russian Network to Support:
  – GLONASS accuracy and time transfer
  – GGOS

• NASA Space Geodesy Project to support the NASA role in International Space Geodesy and GGOS
Deployment of Russian SLR Network outside Russia

Seeking installation of 6 SLR stations in the following possible places:
Brasilia (Brazil), San Juan (Argentina), Haretbeesthoek (South Africa), Haifa (Israel), Hangzhou (China), Timor (Indonesia), Tahiti (French Polynesia), Maui (USA), Greenbelt (USA), Havana (Cuba)

- 6 new SLR stations being built
- Discussions underway with possible site owners
Proposal for placement of GLONASS receivers at ILRS stations and GLONASS SLR at IVS and IDS stations

Features:
1. Priority placement of GLONASS receivers – collocation nodes of ILRS, VLBI, DORIS

Cooperation proposals

Placement of 40-50 GNSSMS and 6 SLR in ILRS, IVS and IDS networks

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NASA’s Space Geodesy Project

- 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.
- Implementation (with USNO) of new VGOS station in Hawaii underway.
- Completing Western CONUS site selection and preparing for implementation of new core site.
- Upgrade underway to the NASA GNSS network to support new constellations (Galileo, GLONASS, Beidou) in addition to GPS.
- Ongoing discussions and planning with our international partners for the deployment of the new NASA network.

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Given programmatic and technical constraints, the NASA SGP core sites (those either wholly owned or supported by NASA) required to cover gaps in the global site coverage are shown here (labeled “Proposed Core Sites”)

Circles highlight suggested NASA and NASA partnership core sites
Some would be upgrades from legacy technology
Some would be new sites to fill geographic gaps
Sejong Site (South Korea)

- **VLBI, GNSS and Gravimeter**: NGII (National Geographic Information Institute)
  - In testing
- **SLR**: KASI (Korea Astronomy & Space Science Institute)
  - Operational at KASI HQ in Daejeon,
  - To be relocated to Sejong site in late 2014

- 40cm Rx and 10cm Tx telescope
- 2kHz repetition rate
- 2.5mJ/pulse and 50ps pulse width
- Aircraft detection using a radar
- 22m Cassegrain antenna
- Rx frequency: 2, 8, 22 and 43GHz
- Aperture efficiency: ~60%
- GNSS receiver and Gravimeter
Ny Alesund Core Site
(From Ina Elsrud, PM)

- Planned to be a core station including VLBI, SLR, GNSS, DORIS, absolute gravity- and super conducting gravity meter
- Extreme interest because of the very high latitude (~80 Deg)
- Site infrastructure work is now underway
- 2018 - two VGOS telescopes, GNSS, DORIS and gravimeters
- 2020 – SLR
- 2021 – Closeout of the legacy VLBI after 3 year parallel run
Map of Sites in Japan
Response to GGOS CfP

- Legacy Core Site at Koganei
- VGOS planned for Ishioka and Kashima
- Potential Core site at Syowa (Antarctica)
- Many of the stations have gravimeter measurements
- Joined the GGOS Network through the CfP
Planned SLR Installations in India
(Construction underway)

SLR in India

- 1 meter Telescope;
- Photometry, debris tracking, SLR;
- Lasercom (future);

Site #1, Mount Abu,
24° 36' Lat, 72° 42' Long
near Jodhpur, Rajasthan

Site #2, Ponmudi,
8° 45' Lat, 77° 6' Long
near Trivandrum, Kerala

Courtesy of Dr. Tom Varghese, CybiomsCorp
Joint GGOS/ILRS Study Group
LARGE: LAser Ranging to GNSS s/c Experiment
Expanded SLR Tracking of GNSS Satellites

Background:
• Large expansion in GNSS satellites with retroreflectors over the next 8 – 10 years;
• Strong need for SLR coverage for ITRF and calibration/co-location
• GGOS/ILRS Study group has been formed, first meeting held on 4/28;

Objectives of this Study Group (SG) are:
• Define an operational GNSS tracking strategy for the ILRS that addresses all of requirements;
• Tests its realization with a tracking campaign Pilot Project;
• Clarify outstanding ILRS and IGS issues with the GNSS satellites and ground stations.

Action to date:
• Tracking tests underway to evaluate network capability
• Simulations being organized to examine value of different options/tradeoffs
• Memorandum between GGOS and RAS/ROSCOSMOS
  – Increase expand SLR tracking on GNSS and for GGOS objectives
  – Advocate for deployment of new systems
Possible Core Site Layout at McDonald

- Ground survey where sufficient
- GNSS geodetic connection among the other techniques both locally and globally (1-2 GNSS receivers at each instrument)
- SGSLR calibration targets.
Hawaii – KPGO to Haleakala

(Distance Between Sites is Approximately 380 km)
The Geodetic Reference Antenna in Space (GRASP): A Mission to Enhance the Terrestrial Reference Frame

Yoaz Bar-Sever¹, R. Steven Nerem², and the GRASP Team

¹ Jet Propulsion Laboratory
² University of Colorado, Boulder
Responses to the GGOS CfP

19 submissions covering 45 sites plus the DORIS Network
Sample Page from the Site Model
(Network Projection)

<table>
<thead>
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<th>Region/Class</th>
<th>Sites</th>
<th>Current Config.</th>
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Reality

Recognizing that:

• Many sites will not be at ideal locations nor have ideal conditions;
• Some new technology stations are being deployed, but not co-located;
• Core site deployment will occur over many years;
• We will have a mix of new and legacy technologies for many years;

As a result:

• Co-location sites (non-core sites) will continue to play a vital role in our data products;
• Quality of our output will be the product of network Core Sites, Co-location sites, mix of technologies, adherence to proper operational and engineering procedures, and making best use of the data once it leaves the field;

But – many groups are taking the initiative to join, build and upgrade