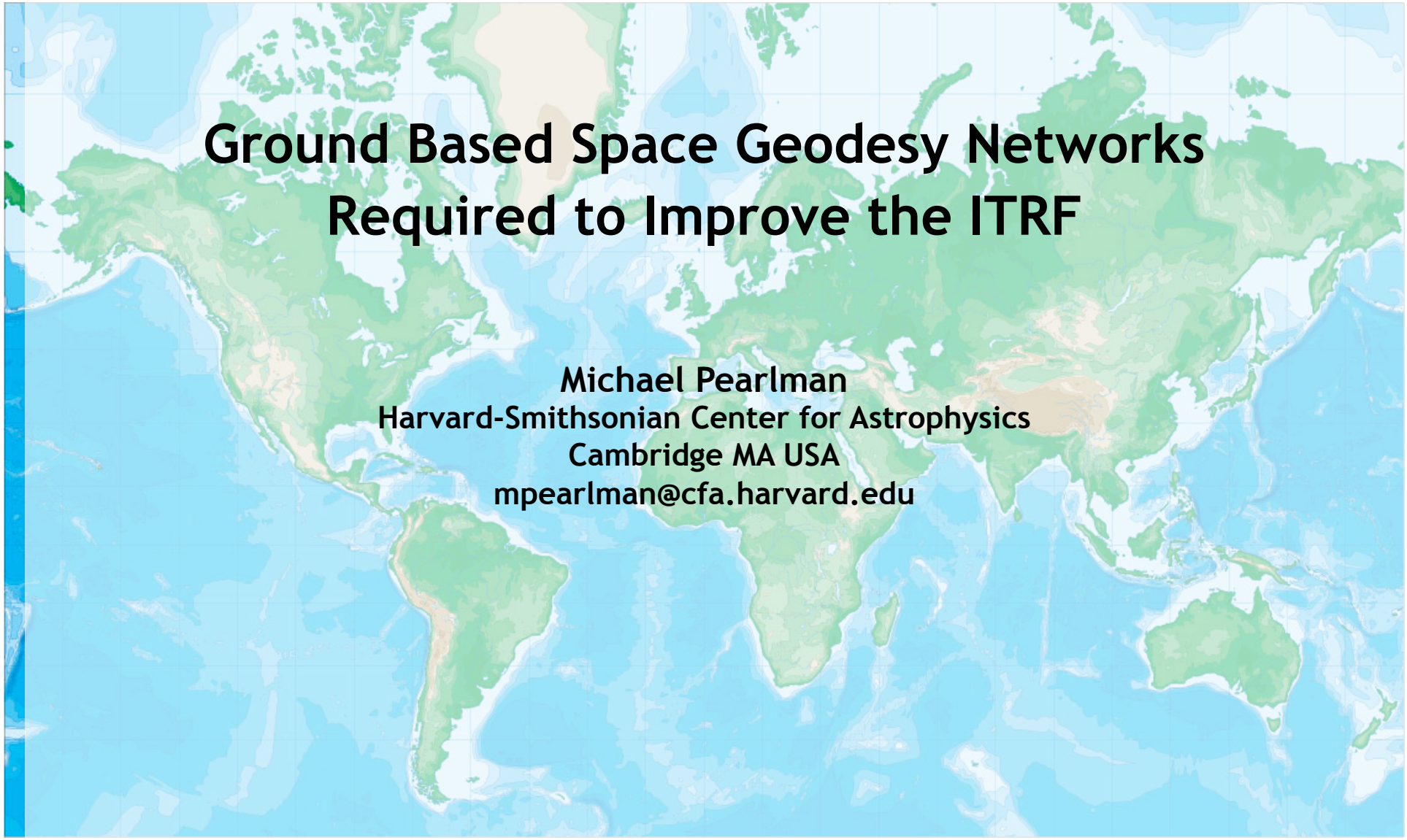

Ground Based Space Geodesy Networks Required to Improve the ITRF

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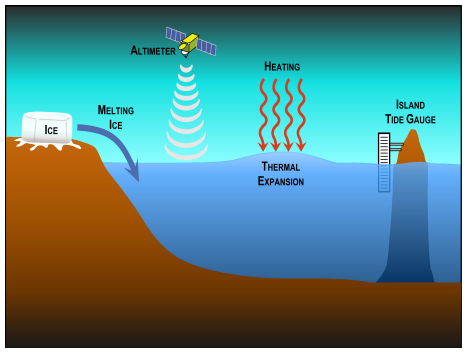
NASA/Goddard Space Flight Center
April 5, 2012

The Geodetic Reference Frame

(International Terrestrial Reference Frame)

Basis for measuring change over space, time and evolving technology



Requirement (Source GGOS 2020):

<1 mm reference frame accuracy

< 0.1 mm/yr stability

–Measurement of sea level is the primary driver

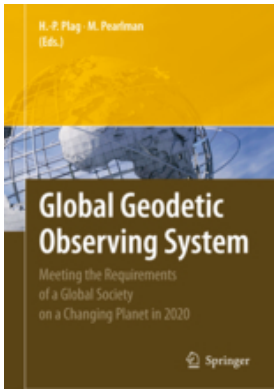
–Improvement over current ITRF performance by a factor of 10-20.

Means of providing the reference frame:

- **Global Network of co-located VLBI/SLR/GNSS/DORIS CORE SITES define the reference frame**
- **Dense network of GNSS ground stations distributes the reference frame globally to the users**

Users anywhere on the Earth can position their measurements in the reference frame

Global Geodetic Observing System (GGOS)



Official Component (Observing System) of the International Association of Geodesy (IAG) with the objective of:

Ensuring the availability of geodetic science, infrastructure, and products to support global change research in Earth sciences to:

- *extend our knowledge and understanding of system processes;*
- *monitor ongoing changes;*
- *increase our capability to predict the future behaviour; and*
- *improve the accessibility of geodetic observations and products for a wide range of users;*
- ***Improve and maintain the International Terrestrial Reference Frame (ITRF)***

Role

- **Facilitate networking** among the IAG Services and Commissions and other stakeholders in the Earth science and Earth Observation communities,
- **Provide scientific advice and coordination** that will enable the IAG Services to develop products with higher accuracy and consistency meeting the requirements of global change research.

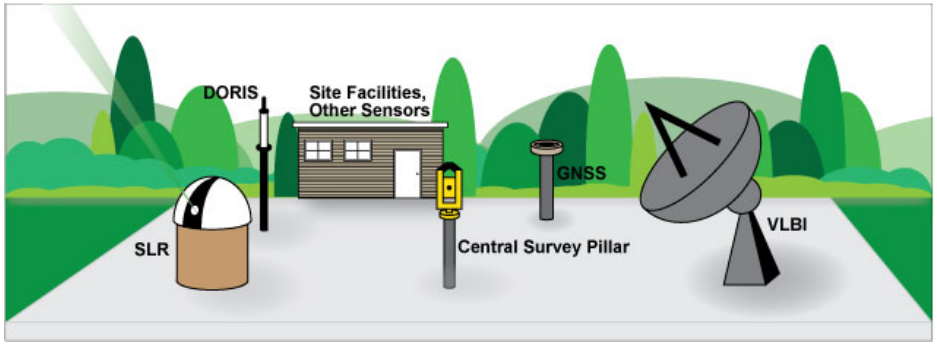
GGOS Bureau for Networks and Communications

- Provide oversight, coordination, and guidance for the development, implementation and operation of the Network of Core (co-location) Sites.
- Develop a strategy to design, integrate and maintain the geodetic core network of co-located instruments and supporting infrastructure in a sustainable way to satisfy the long term (10 - 20 years) requirements identified by the GGOS Science Council.

Accepted as a Sub-Task under the Group on Earth Observations (GEO)

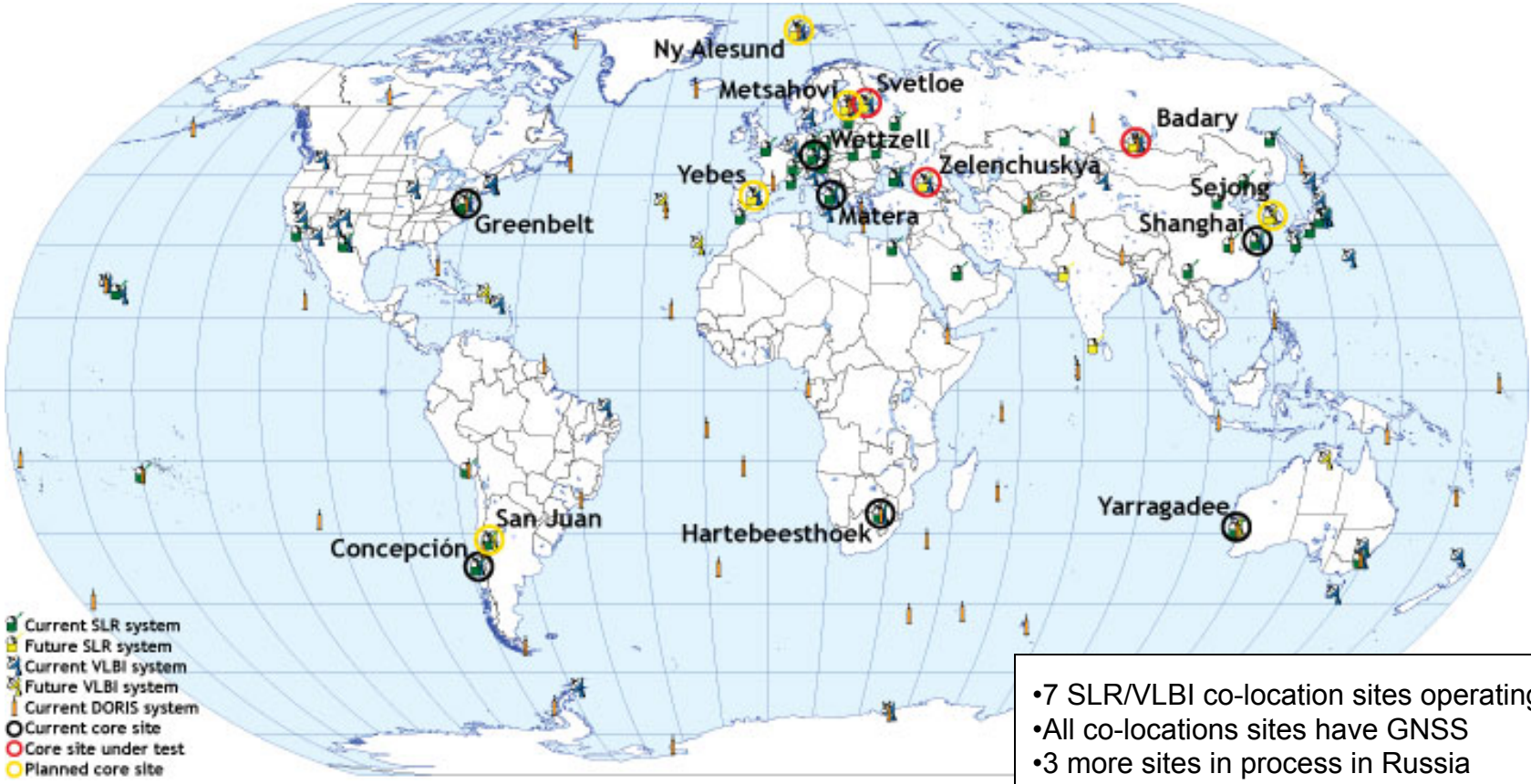
What is a Core Site?
(Terrestrial Reference Frame)

- A ground site with co-located SLR, VLBI, GNSS and DORIS (where available) so that their measurements can be related to sub-mm accuracy
- Why do we need multiple techniques?
  - Measurement requirements are very stringent
  - Each technique makes its measurements in a different way and therefore each measures something a little different:
    - Terrestrial (satellite) verses celestial (quasar) reference
    - Range verses range difference measurements
    - Broadcast up verses broadcast down
    - Radio verses optical
    - Active verses passive
    - Geographic coverage
  - Each technique has different strengths and weaknesses
  - The combination allows us to take advantage of the strengths and mitigate the weaknesses



SLR+VLBI Networks

(with SLR/VLBI Co-locations noted)



- 7 SLR/VLBI co-location sites operating
- All co-locations sites have GNSS
- 3 more sites in process in Russia
- Several more sites in planning

Example Core Site

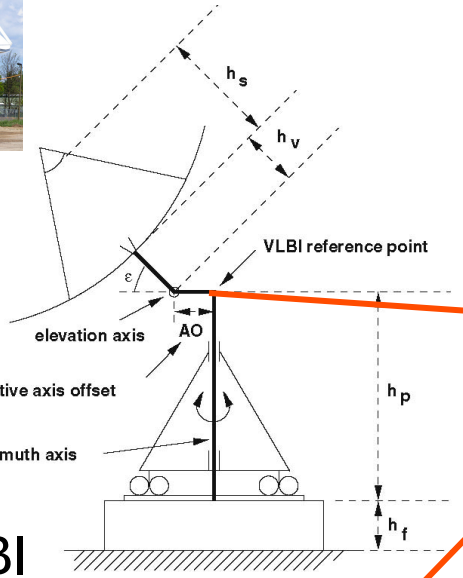
NASA Goddard Space Flight Center, Greenbelt MD, USA

- Goddard Geophysical and Astronomical Observatory (GGAO) has four techniques on site
  - Legacy SLR, VLBI, GPS, DORIS
  - NGSLR semi - “operational”
  - VLBI2010 systems in testing
- GGAO will be the location for the prototype next generation multi-technique station

Concepcion, Chile

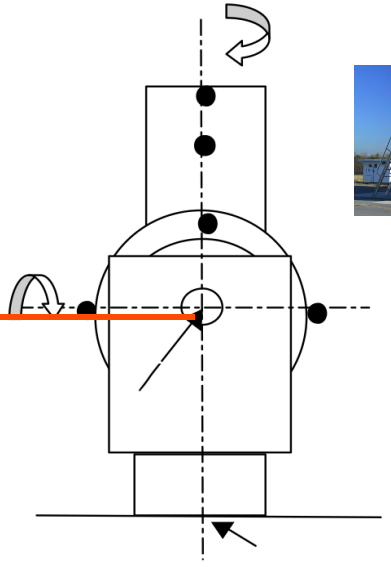
Core Site Ground Co-location

and the essential role of the intersystem vector

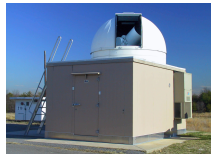


VLBI

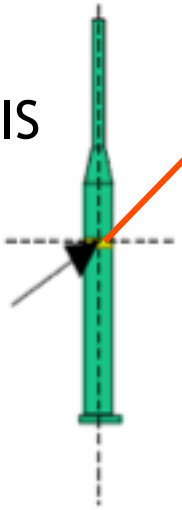
Co-Location System



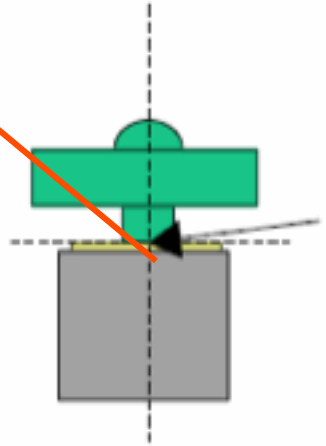
SLR



DORIS



- GNSS and DORIS reference points
  - Extrapolate to measurement phase center
- VLBI and SLR reference points
  - Extrapolate to measurement phase center
  - RP through indirect approach
  - Targets mounted on system structure
  - Rotational sequence about axes of space geodetic instrument
  - Model to determine axes location



GPS

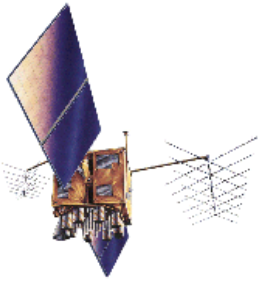
Co-location in Space

Compass

GNSS/SLR

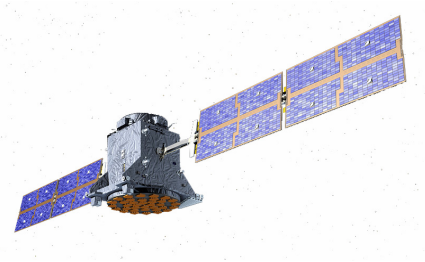
GLONASS

GNSS/SLR



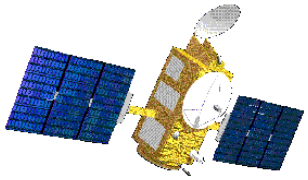
GPS

GNSS/SLR



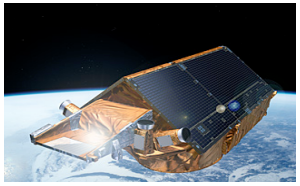
GIOVE/Galileo

GNSS/SLR



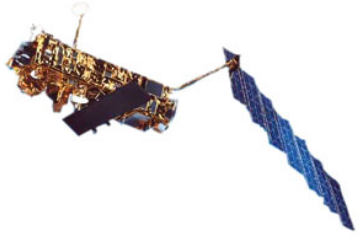
Jason1-3

DORIS/GNSS/SLR



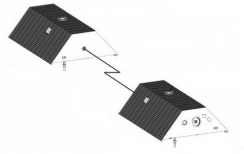
Cryosat-2

DORIS/SLR



Envisat

DORIS/SLR

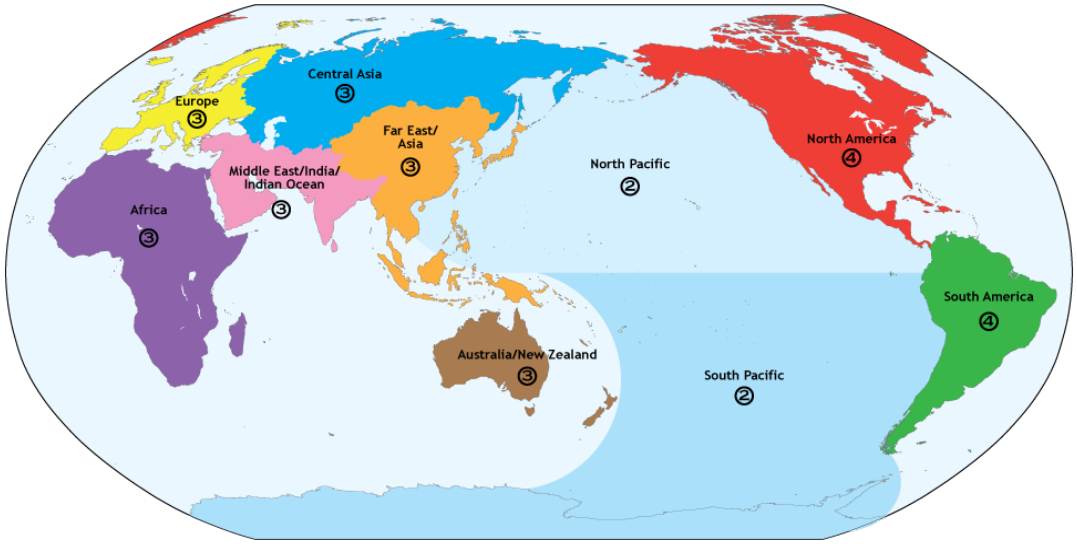


GRACE

GNSS/SLR

Simulation Studies to Scope the Network

(Erricos Pavlis)



- First Phase completed
  - ~30 globally distributed, well positioned, co-location Core Sites with proper conditions;
  - 16 of these Core Sites must track GNSS satellites with SLR to calibrate the GNSS orbits;
- Follow-on Phases (Impact on the ITRF)
  - Phased deployment; evolution of the products
  - Impact of errors and outages;
  - Additional space objects
  - Tracking scenarios
  - Impact of GRASP

Techniques are all Making Progress

- Satellite Laser Ranging
  - Several systems working in the Khz regime; increased automation
  - Increased data yield and daylight ranging on the GNSS satellites
  - Steady progress on the new SLR prototype at GSFC;
  - Progress on the GPS-3 arrays;
- VLBI
  - Prototype VLBI 2010 in testing at GSFC
  - New Systems Systems
    - Tasmania, Katherine, Yarragadee Stations
    - Wettzell twin telescopes are being constructed;
- GNSS
  - Multiple constellations
  - Additional frequencies
  - New ground stations
- DORIS
  - Nearly complete network already
  - Additional satellites
  - New beacons
- Calibration
  - GRASP Concept

GGOS Site Requirements Document

(http://cddis.gsfc.nasa.gov/docs/GGOS_SiteReqDoc.pdf)

Global Geodetic Observing System (GGOS)

Site Requirements
for
GGOS Core Sites

August 1, 2011

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- Introduction and Justification
  - What is a Fundamental Station?
  - Why do we need the Reference Frame?
  - Why do we need a global network?
  - What is the current situation?
  - What do we need?
- Site Conditions
  - Global consideration for the location
  - Geology
  - Site area
  - Weather and sky conditions
  - Radio frequency and optical Interference
  - Horizon conditions
  - Air traffic and aircraft Protection
  - Communications
  - Land ownership
  - Local ground geodetic networks
  - Site Accessibility
  - Local infrastructure and accmmodations
  - Electric power
  - Site security and safety
  - Local commitment

NASA Space Geodesy Project

- Provide NASA's contribution to a worldwide network of modern space geodesy Core Sites;
- Phase 1 Proposal developed for a 2–year activity:
  - Complete network simulations to scope the network and examine geographic, operational and technical tradeoffs based on LAGEOS and GNSS tracking with SLR;
  - Complete the prototype SLR (NGSLR) and VLBI (VLBI 2010) instruments;
  - Co-locate these instrument with the newest generation GNSS and DORIS ground stations at GSFC;
  - Implement a modern survey system to measure inter-technique vectors for co-location;
  - Develop generalized station layout considering RFI and operations constraints;
  - Undertake supporting data analysis;
  - Begin site evaluation for network station deployment;
  - Develop a full network implementation plan;
- Follow-on phase for deployment for up to 10 stations;

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

We seek proposals from organizations that would participate in the development, implementation and maintenance of the GGOS Global Geodetic Core Network.

- **To implement and operate core space geodesy stations including:**
  - **existing stations that already have the four techniques implemented and plan for upgrade to the next generation systems;**
  - **existing stations that have one or more techniques operational, are planning for upgrade to the next generation systems and for the implementation of the remaining techniques;**
- **To support the network design and planning activity with analysis, simulations, site research (geology, weather, logistics, personnel, etc). To help design and develop the inter-technique vector systems and operational procedures.**
- **To provide applicable space geodetic instruments for implementation at a GGOS Global Geodetic Core Site in cooperation with a local organization.**
- **To implement and operate core stations offered by others;**
- **Call for Participation has been issued through the Services and the IAG.**

Final Message

- Very long history of cooperation between NASA and CNES, going all the way back the beginning of the Space Geodesy Programs;
- GGOS Network will require many partnerships;
- We need:
  - a well-functioning Core Site in Tahiti
  - High performance system with extended range (GNSS, synchronous, lunar, transponders, etc) at Grasse.
- We need CNES participation in the GGOS Network