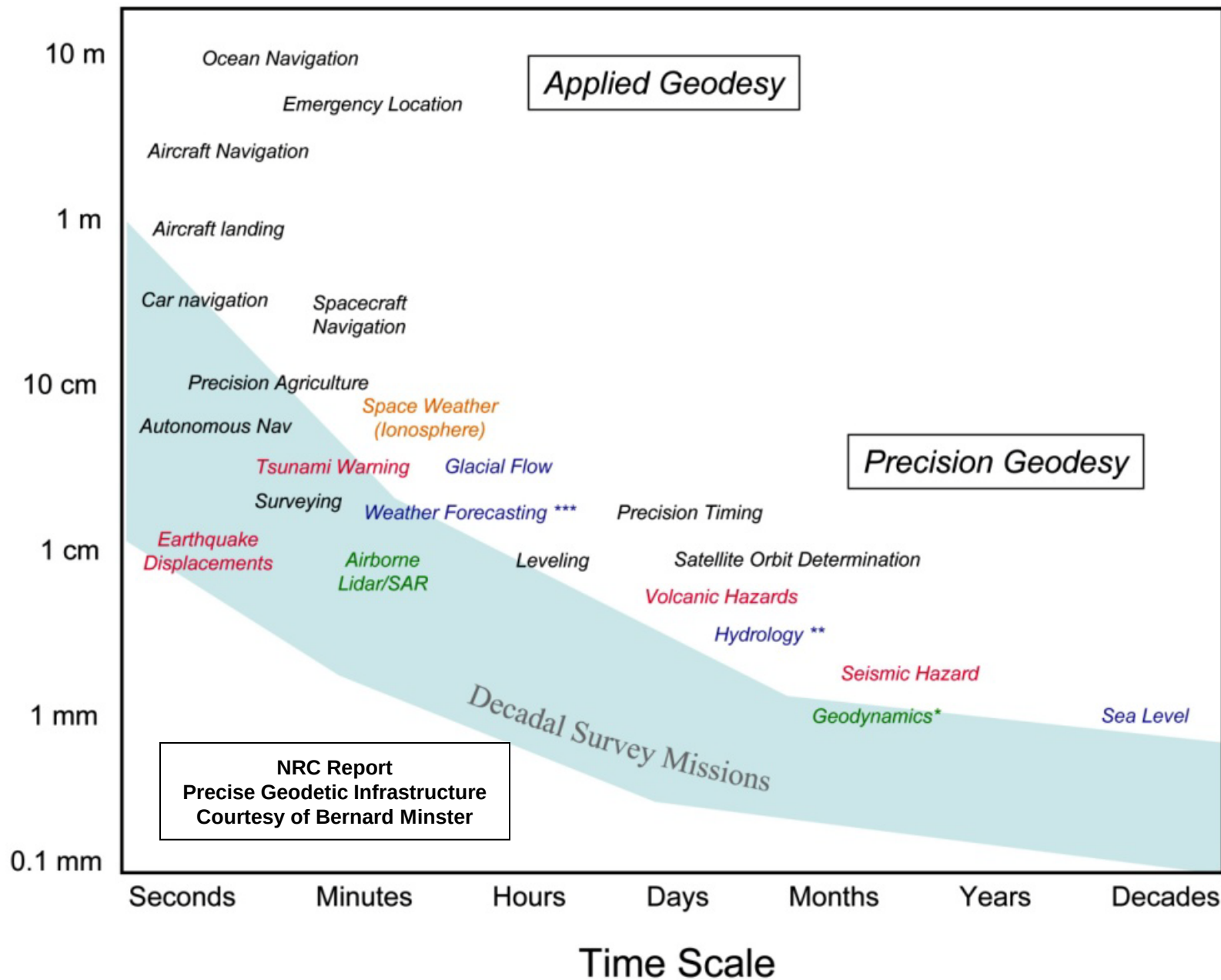


Co-location on Ground and in Space; GGOS Core Site

Michael Pearlman/CfA
Harald Schuh/TUW
Erricos Pavlis/UMBC

Unified Analysis Workshop
Zurich, Switzerland
September 16 – 17, 2011

Positioning Precision



Time Scale

Courtesy of Bernard Minster

<http://dels.nas.edu/Report/Precise-Geodetic-Infrastructure-National-Requirements/12954>

Space Geodesy Networks to Improve the ITRF| EGU 2011, Vienna | April 7, 2011



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 stations to distribute the reference frame globally to the users

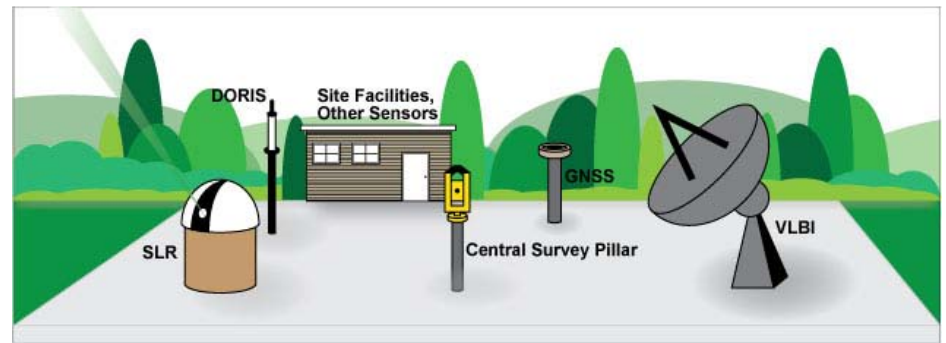
Users anywhere on the Earth can position their measurements in the reference frame

This work is being done by the GGOS Bureau for Networks and Communication with the assistance of the the GGOS InterAgency Committte (GIAC)

What is a Core Site?

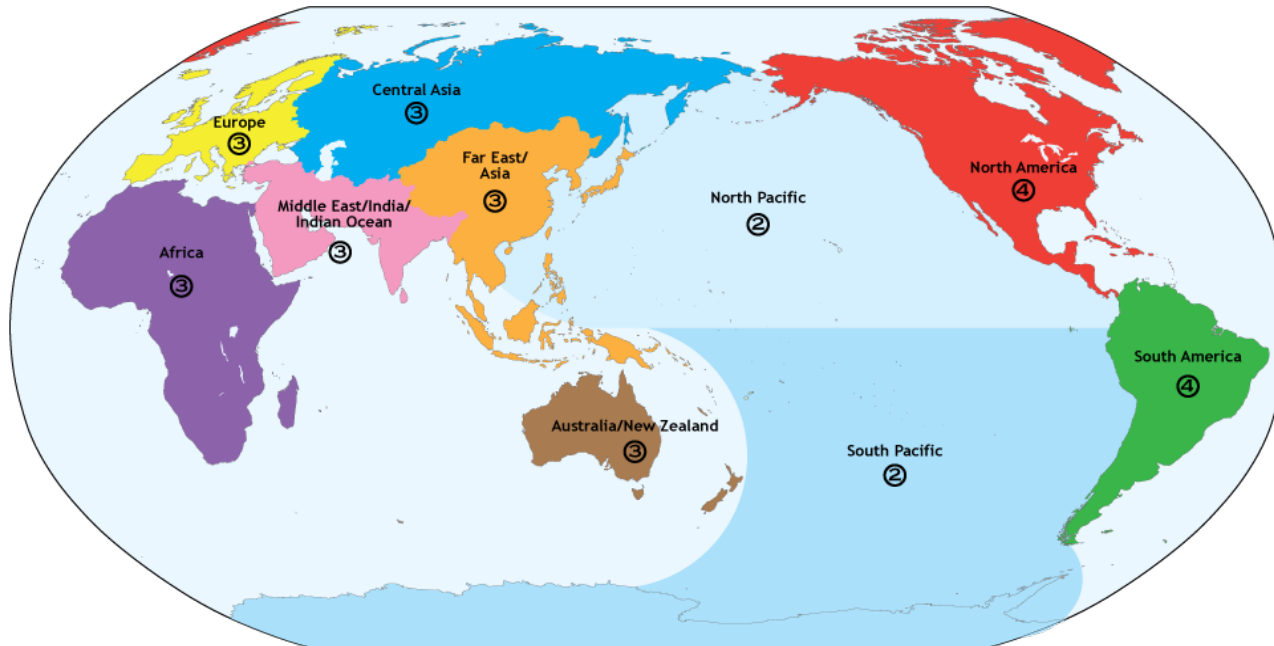
(Terrestrial Reference Frame)

- 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



Simulation Studies to Scope the Network of Core Sites (Fundamental Stations)

(Erricos Pavlis)

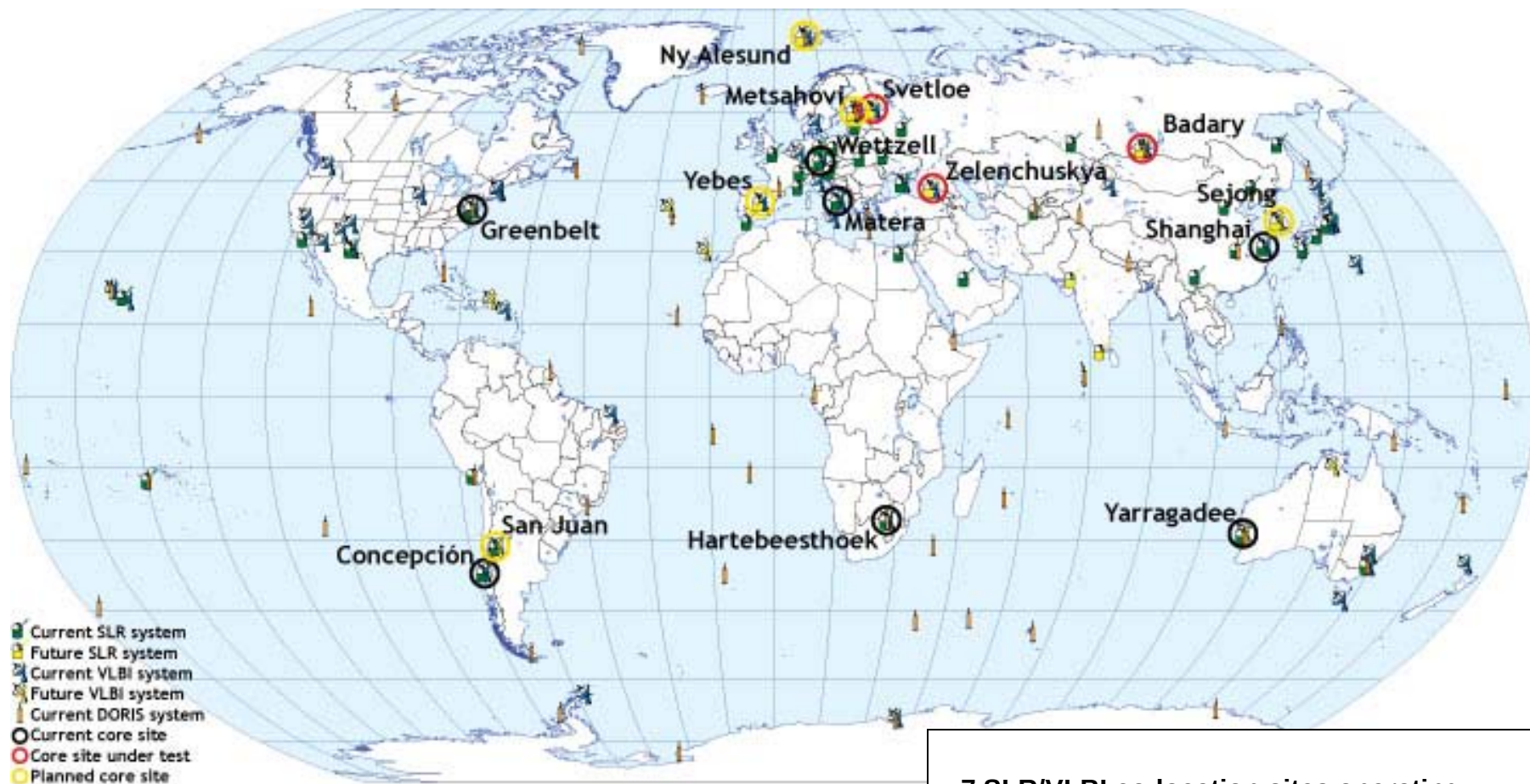


30 Core Sites required to satisfy reference frame requirements

- Globally well distributed;
- Proper conditions;
- Modern technology;
- Operate routinely;
- Day/Night SLR tracking on GNSS complexes to calibrate the GNSS orbits;

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
- 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



New Co-located Sites in Russia



Badary



Zelenchukskaya



Techniques are all Making Progress

- **Satellite Laser Ranging**
 - Many systems working in the 0.1 - 2 KHz regime;
 - Single photon detection;
 - Increased data yield and daylight ranging on the GNSS satellites;
 - Several new systems in Russia;
 - Progress on the GPS-3 arrays;
- **VLBI**
 - Prototype VLBI 2010 in testing at GSFC and Wettzell;
 - New Systems Systems
 - Tasmania, Katherine, Yarragadee Stations;
 - Wettzell twin telescopes;
- **GNSS**
 - Multiple constellations
 - Additional frequencies
 - New ground stations
- **DORIS**
 - Nearly complete network already
 - Additional satellites
 - New beacons

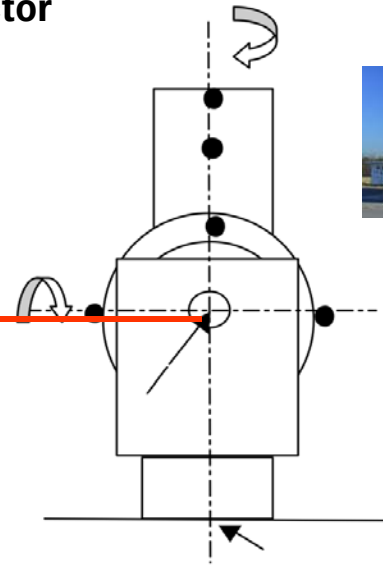
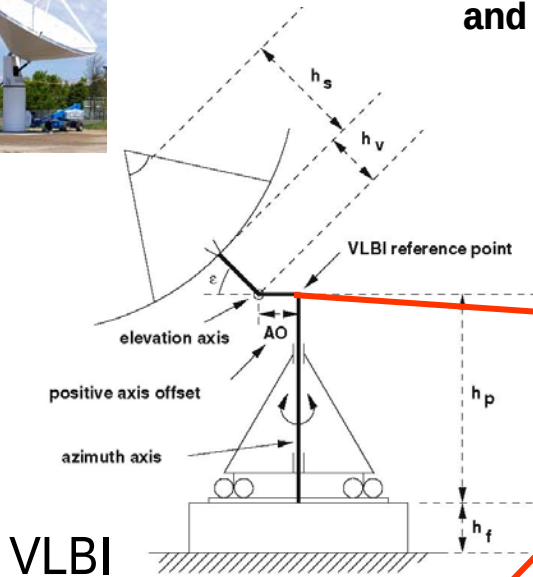
SLR+VLBI Networks (with SLR/VLBI Co-locations noted)



Current Situation:

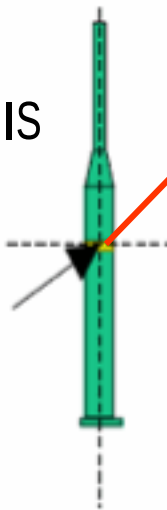
- Too few co-location sites;
- Inadequate geographic coverage;
- Not all sites are well positioned geographically;
- Some sites have poor local conditions;
- Some sites are inadequately funded;
- Mix of new and legacy technologies and procedures

and the essential role of the intersystem vector



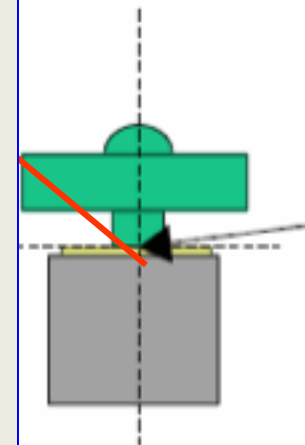
SLR

DORIS



PROBLEM

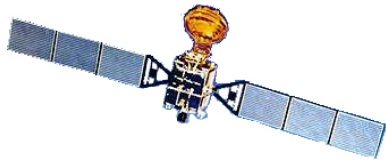
- **Reference Points are either not accessible or not well defined;**
- **Complex procedures and modeling required to estimate the reference points;**
- **Ground survey infrequently performed;**
- **Limited accuracy**



GPS



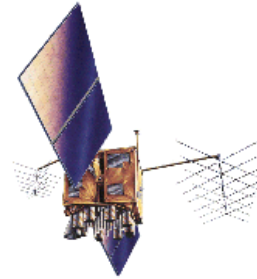
Co-location in Space (Complimentary to Ground Survey)



Compass
GNSS/SLR



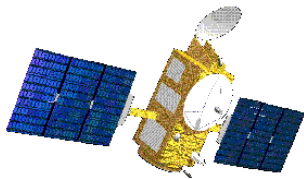
GLONASS
GNSS/SLR



GPS
GNSS/SLR



GIOVE/Galileo
GNSS/SLR



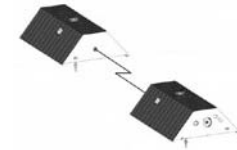
Jason
DORIS/GNSS/SLR



CHAMP
GNSS/SLR



Envisat
DORIS/SLR



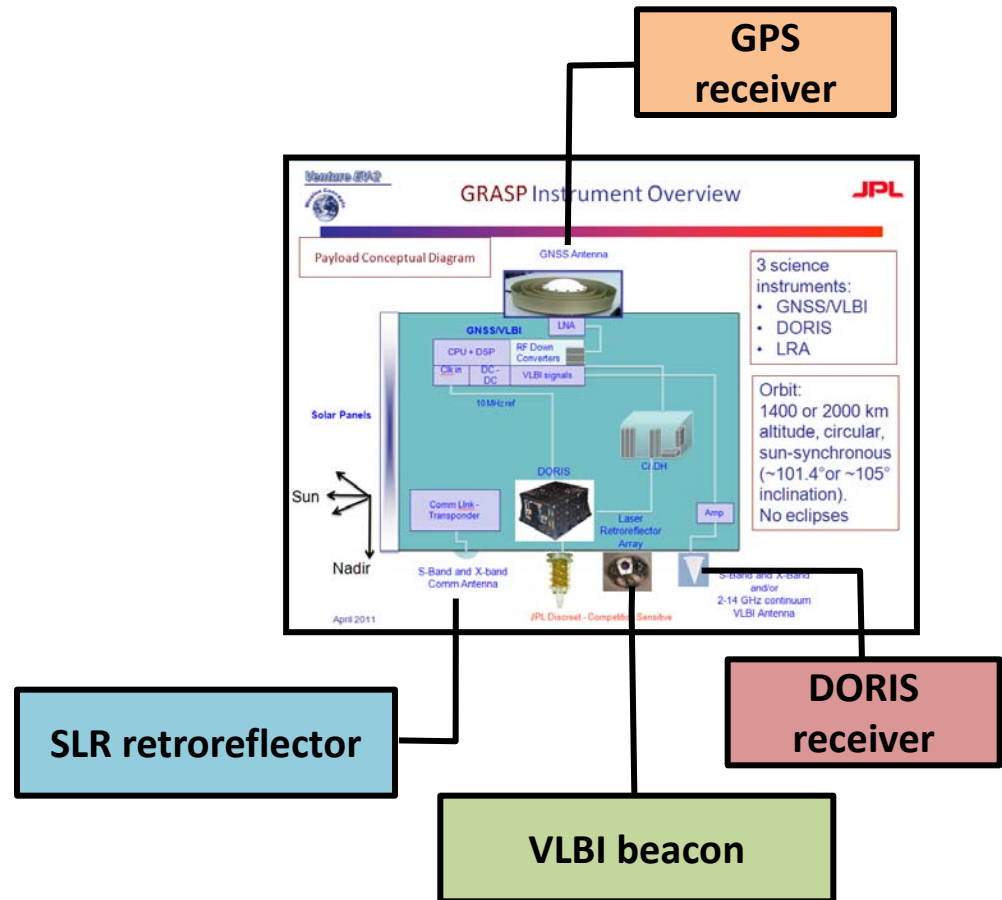
GRACE
GNSS/SLR

PROBLEM: Limited technique combinations and inadequate spacecraft calibrations

GRASP

Geodetic Reference Antenna in Space

- Co-location of geodetic techniques contributing to the TRF.
- Determine TRF with 1 mm accuracy and 0.1 mm/yr stability.
- Orbit:
H = 1400 – 2000 km
polar, sun-synchronous.





GGOS Site Requirements Document

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



- **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 accommodations
 - Electric power
 - Site security and safety
 - Local commitment



**GGOS Call for Participation;
The Global Geodetic Core Network:
Foundation for Monitoring the Earth System
(Issued 15 August 2011; due 15 November 2011)**

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.**
- **The Call is available on the NEWS page at: <http://www.ggos.org/>**



Summary

- Requirements Document
- CfP issued
- Working with the GIAC to make contacts
- Meeting with groups to explore and convince
- GEO sub-task established
- Bureau meets at AGU and EGU; everyone is welcome



Session on Co-location on Ground and in Space

September 16, 2011

Session: 11:00 - 12:15

- **Pearlman M., Schuh, H., Pavlis E.: Position paper / introduction (15')**
- **Bar-Sever Y.: GRASP mission status and insights (10')**
- **Thaller D.: GNSS/SLR combination with co-location on satellites (10')**
- **Springer T.: Multi-technique analysis at ESOC, recent developments (10')**
- **Haas R.: Observation of GLONASS satellites with VLBI (10')**
- **Schuh H., Plank L., Schönberger C., Böhm J.: VLBI for Space Applications (10')**

Session: 13:45 - 14:30

- **Appleby G.: SLR target signature model improvements, SLR and co-locations with gravity measurements (10')**
- **Ma C.: NASA Space Geodesy Program at GGAO (10')**
- **Schreiber U.: The next generation timing system at the Geodetic Observatory Wettzell (goals and prospects) (10')**
- **Nothnagel A.: New options with twin telescopes in VLBI (10')**