Space Geodesy Networks to Improve the ITRF

Michael Pearlman
Harvard-Smithsonian Center for Astrophysics
Cambridge MA USA
mpearlman@cfa.harvard.edu

Erricos Pavlis
University of Maryland
Baltimore MD USA

Chopo Ma
NASA GSFC
Greenbelt MD USA

Zuheir Altamimi
Institut Geographique National
Champs-sur-Marne, France

Carey Noll
NASA GSFC
Greenbelt MD USA

David Stowers
Jet Propulsion Laboratory
Pasadena CA USA

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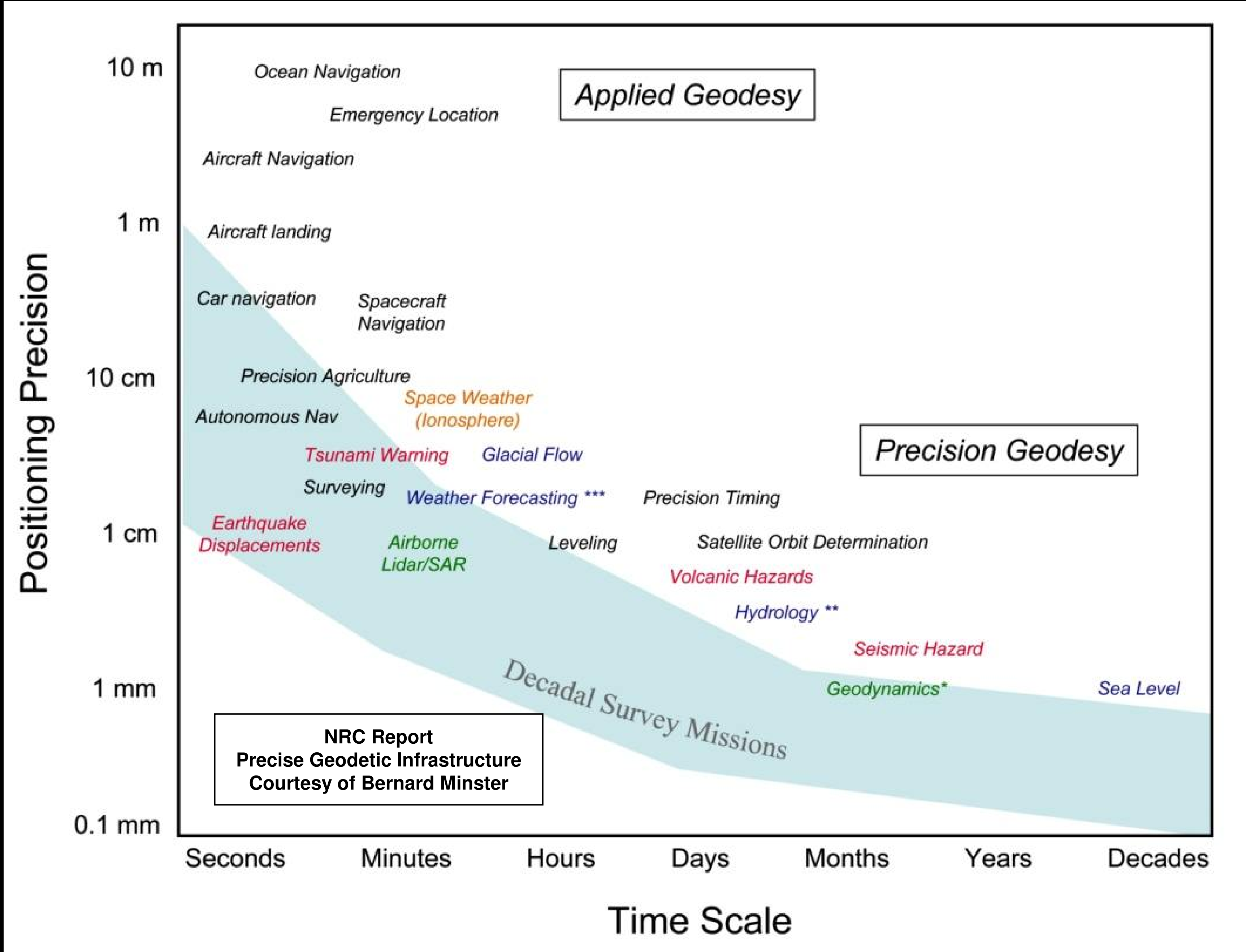
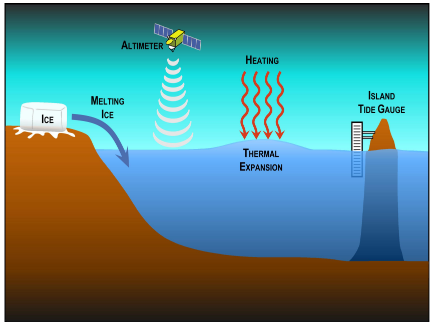


Courtesy of Bernard Minster

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

The Geodetic Reference Frame
(International Terrestrial Reference Frame)

<u>Requirement</u> (Source GGOS 2020):



<1 mm reference frame accuracy

< 0.1 mm/yr stability

Measurement of sea level is the primary driver

Other applications close behind

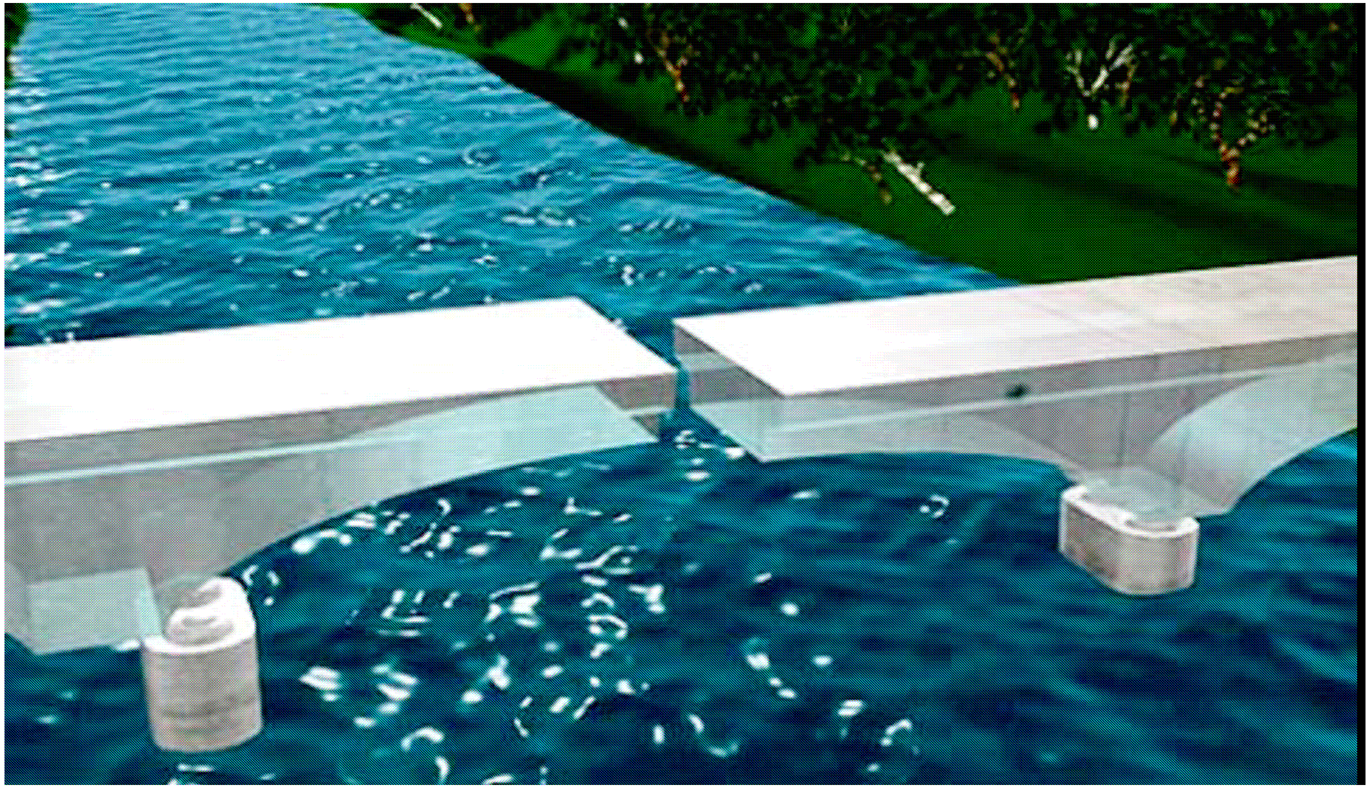
Improvement over current ITRF performance by a factor of 10-20.

<u>Means of providing the reference</u> :

- **Global Network of co-located VLBI/SLR/GNSS/DORIS FUNDAMENTAL STATIONS 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

When National Reference Frames are not integrated!

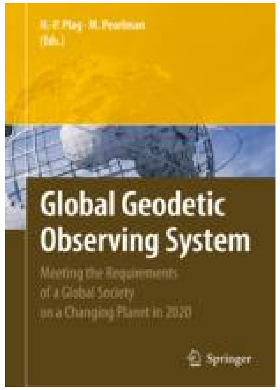


Design error at bridge construction in Laufenburg (2003): During the construction of the bridge across the Rhine river in Laufenburg, a control showed that a height difference of 54 centimeters exists between the bridge built from the Swiss side and the roadway of the German side. Reason of the error is the fact that the horizons of the German and Swiss side are based on different reference frames. Germany refers to the sea level of the North Sea, Switzerland to the Mediterranean.

Courtesy of Hermann Drewes/DGFI

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.

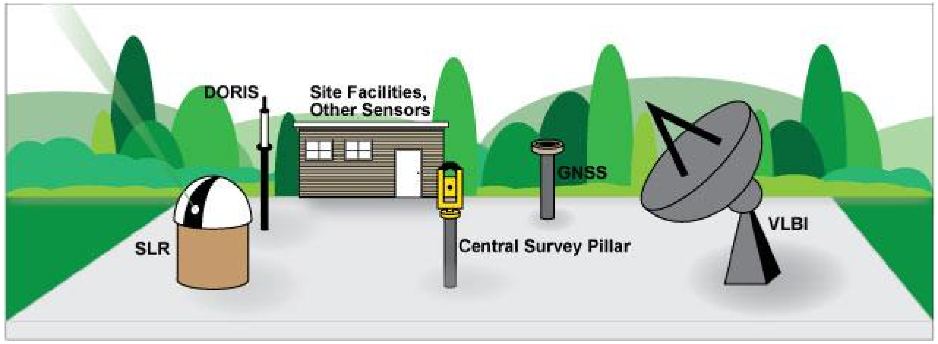
GGOS Bureau for Networks and Communications

- 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 fundamental geodetic 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.

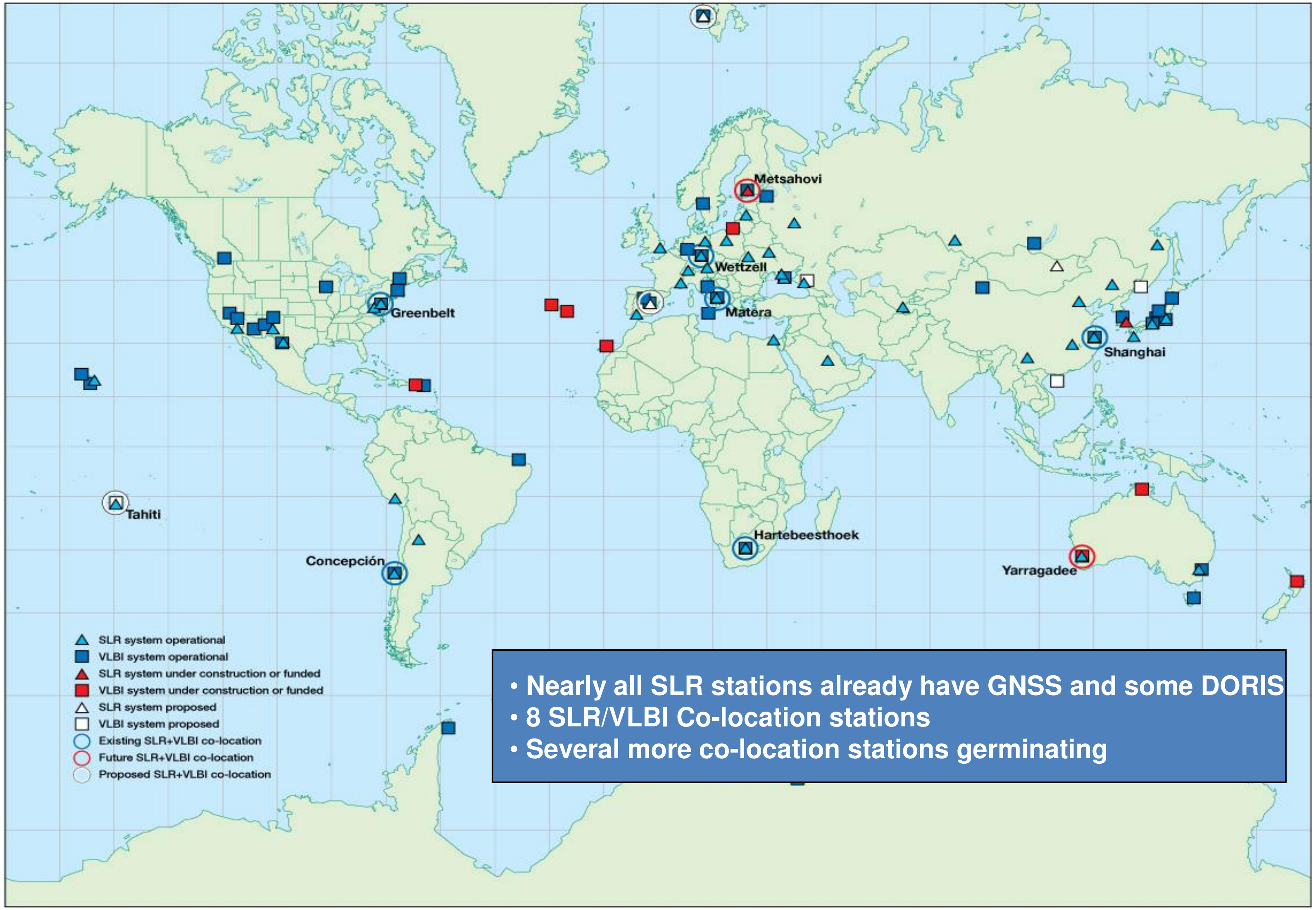
Accepted as a Sub-Task under the Group on Earth Observations (GEO)

What is a Fundamental Station?
(Terrestrial Reference Frame)

- A ground station with four space geodesy techniques co-located so that the measurements among them can be related to sub-mm accuracy
- The four techniques: GNSS, VLBI, SLR, DORIS
- Why do we need four 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



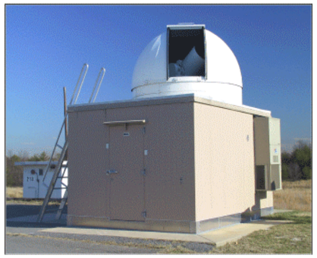
Network of Co-located Stations with VLBI and SLR is Expanding



- Nearly all SLR stations already have GNSS and some DORIS
- 8 SLR/VLBI Co-location stations
- Several more co-location stations germinating

Example Fundamental Station

NASA Goddard Space Flight Center, Greenbelt MD, USA

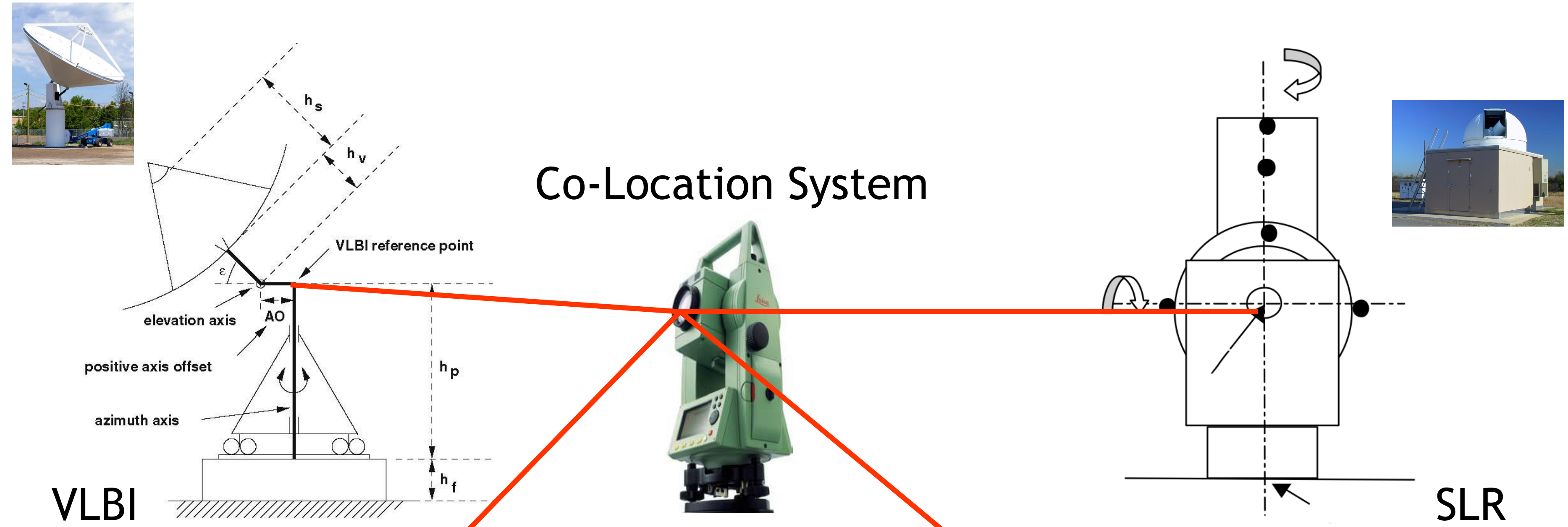


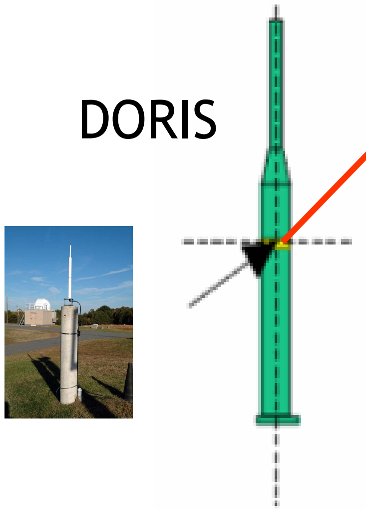
- Goddard Geophysical and Astronomical Observatory (GGAO) has four techniques on site
  - Legacy SLR, VLBI, GPS, DORIS
  - NGSLR semi - “operational”
  - VLBI2010 systems in testing
- GGAO will be the location for the prototype next generation multi-technique station

Concepcion, Chile

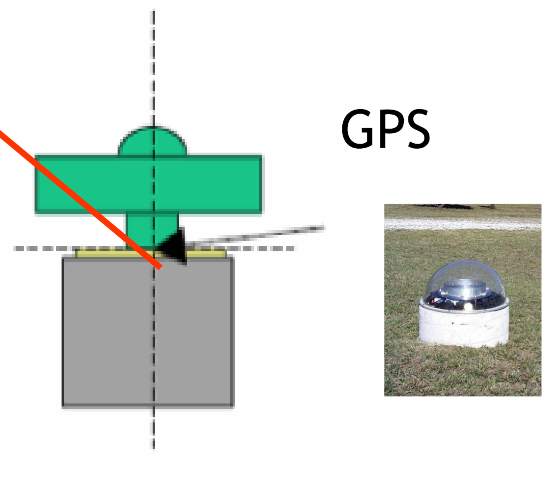
Fundamental Station Ground Co-location

and the essential role of the intersystem vector





- 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



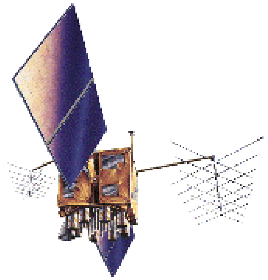
Co-location in Space

Compass

GNSS/SLR

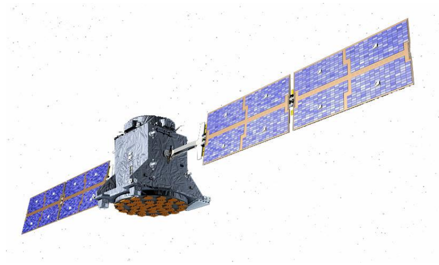
GLONASS

GNSS/SLR



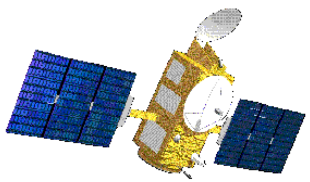
GPS

GNSS/SLR



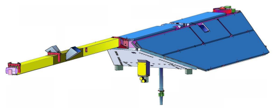
GIOVE/Galileo

GNSS/SLR



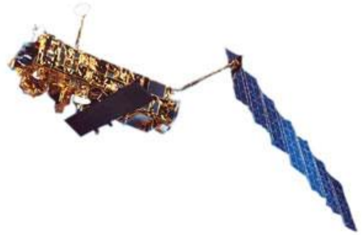
Jason

DORIS/GNSS/SLR



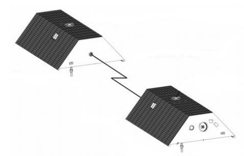
CHAMP

GNSS/SLR



Envisat

DORIS/SLR

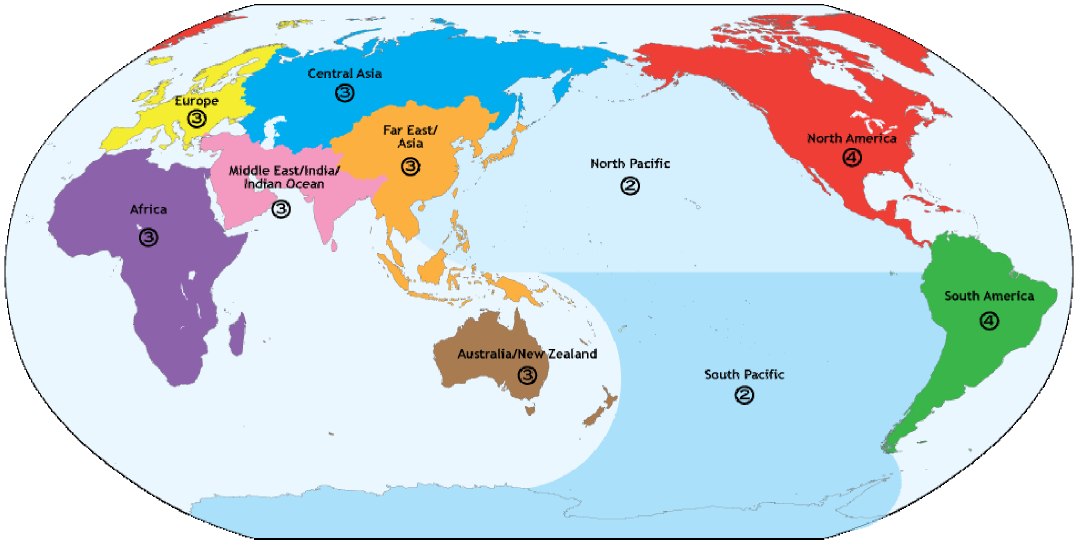


GRACE

GNSS/SLR

Simulation Studies to Scope the Network

(Erricos Pavlis)



- ~30 globally distributed, well positioned, co-location (fundamental) stations with proper conditions;
- 16 of these co-location stations must track GNSS satellites with SLR to calibrate the GNSS orbits;

Technique Activities Making Progess

- Satellite Laser Ranging
  - Several systems working at higher repetition rate and new technology
  - Increased data yield and daylight ranging on the GNSS satellites
  - Progress on the GPS-3 arrays;
- VLBI
  - Prototype VLBI 2010 at GSFC
    - New 12-m antenna; new front and back ends installed;
    - First fringes last week.
  - Other Systems
    - Tasmania, Katherine, Yarragadee Stations
    - Wettzell twin telescopes are being constructed;
- GNSS
  - Multiple Constellations
  - Additional Frequencies
- DORIS
  - Nearly complete network already
  - Additional satellites
  - New beacons
- Calibration
  - GRASP Concept

GGOS Site Requirements Document

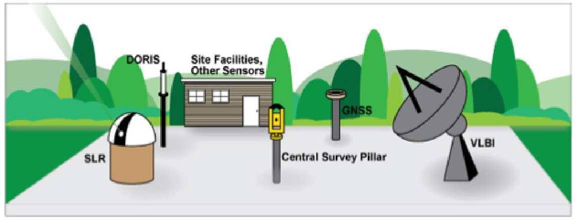
(http://cddis.gsfc.nasa.gov/docs/SiteRecDoc_MarchS3_cen.pdf)

(DRAFT)

DRAFT S1

Global Geodetic Observing System (GGOS)

Site Requirements
for
GGOS Fundamental Stations



April 1, 2011

Contributors:

Howard Donovan	HTSI
Scott Wetzel	HTSI
Chopo Ma	NASA GSFC
Hayo Hase	TIGO BKG
Dirk Behrend	NASA GSFC
Michael Pearlman	CfA
Carey Noll	NASA GSFC
Erricos Pavlis	UMBC
Jim Long	NASA GSFC
David Stowers	JPL
David McCormick	NASA GSFC
Curtis Emerson	NASA GSFC

- 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 fundamental stations;
- 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;