The International Laser Ranging Service (ILRS) and Its Impact on GEOSS

http://ilrs.gsfc.nasa.gov/index.html

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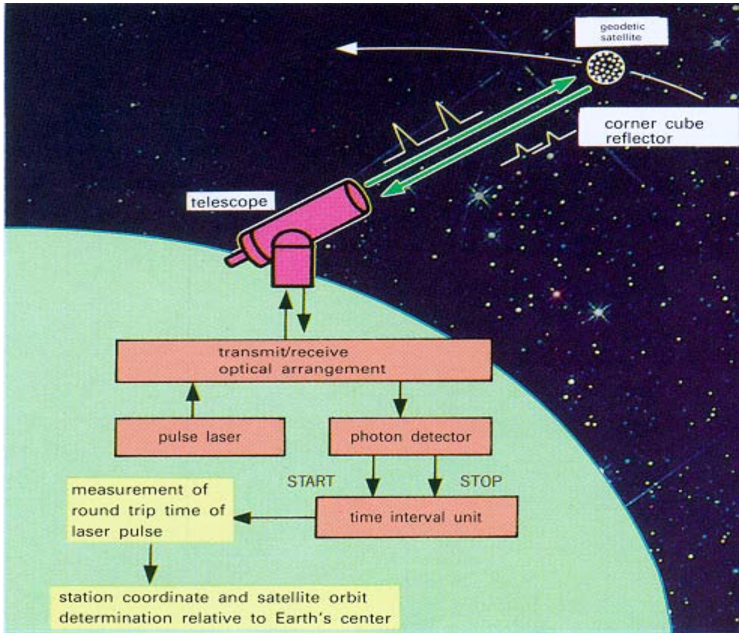
Agenda

- Laser Ranging Technique
- International Laser Ranging Service (ILRS)
- GEOSS and Laser Ranging
- Global Geodetic Observing System (GGOS)

Satellite Laser Ranging Technique

Precise range measurement between an SLR ground station and a retroreflector-equipped satellite using ultrashort laser pulses corrected for refraction, satellite center of mass, and the internal delay of the ranging machine.

- Simple range measurement
- Space segment is passive
- Simple refraction model
- Night / Day Operation
- Near real-time global data availability
- Satellite altitudes from 300 km to synchronous satellites, and the Moon
- Cm satellite Orbit Accuracy
- Able to see small changes by looking at long time series



- Unambiguous centimeter accuracy orbits
- Long-term stable time series

SLR Science and Applications

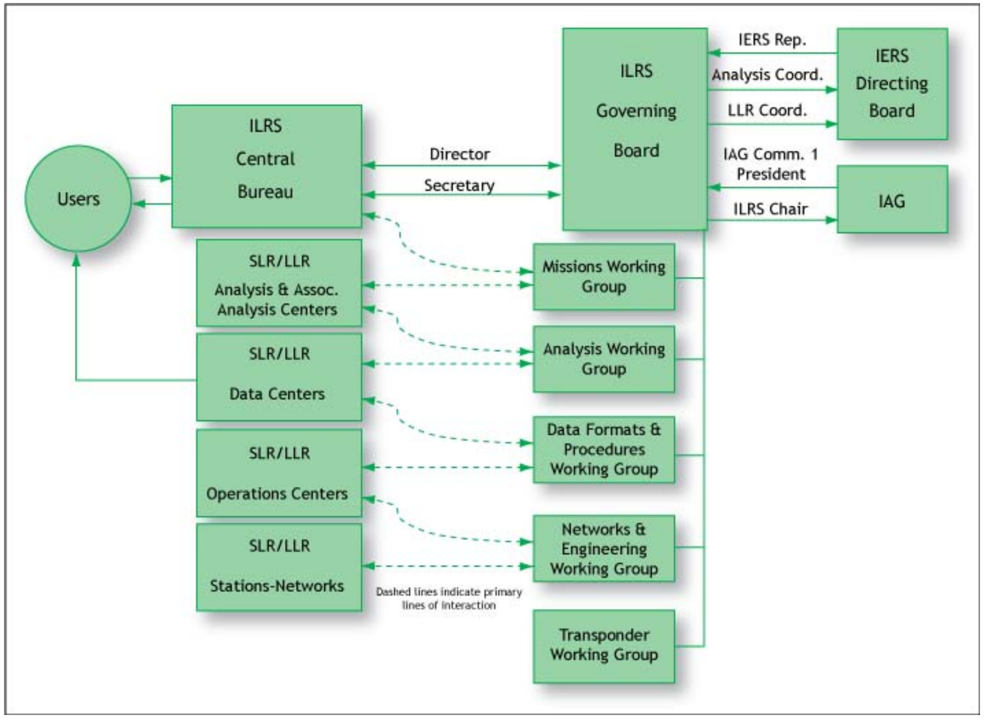
- Measurements
  - Precision Orbit Determination (POD)
  - Time History of Station Positions and Motions
- Products
  - Terrestrial Reference Frame (Center of Mass and Scale)
  - Plate Tectonics and Crustal Deformation
  - Static and Time-varying Gravity Field
  - Earth Orientation and Rotation (Polar Motion, length of day)
  - Orbits and Calibration of Altimetry Missions (Oceans, Ice)
  - Earth Mass Distribution
  - Space Science - Tether Dynamics, etc.
  - Relativity Measurements and Lunar Science
- More than 60 Space Missions Supported since 1970
- Five Missions Rescued in the Last Decade

International Laser Ranging Service

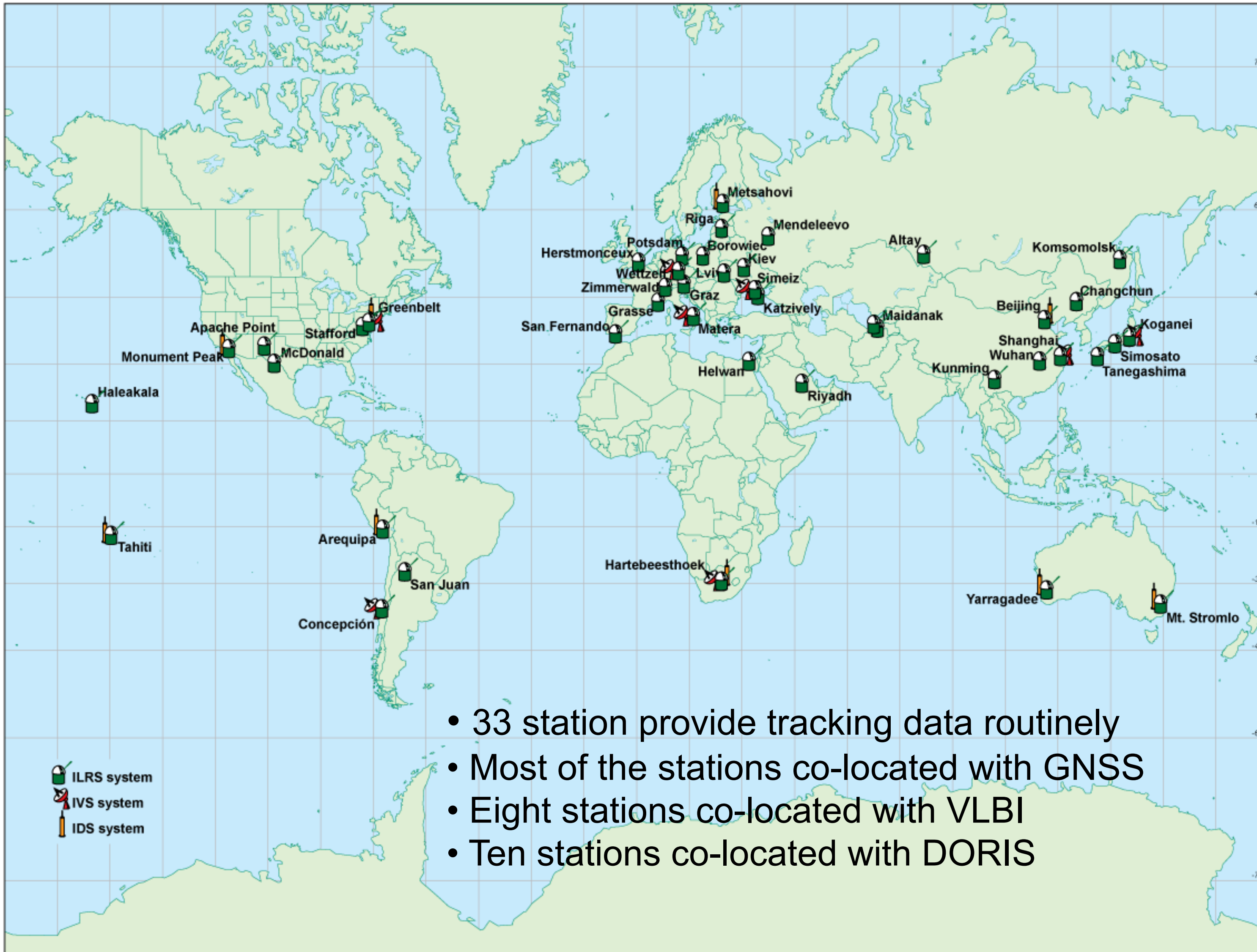
Established in 1998 as a service under the
International Association of Geodesy (IAG)

The ILRS:

- Collects, merges, analyzes, archives and distributes satellite and lunar laser ranging data to satisfy user needs
- Encourages the application of new technologies to enhance the quality, quantity, and cost effectiveness of its data products
- Produces standard products for the scientific and applications communities
- Includes 75 agencies in 26 countries

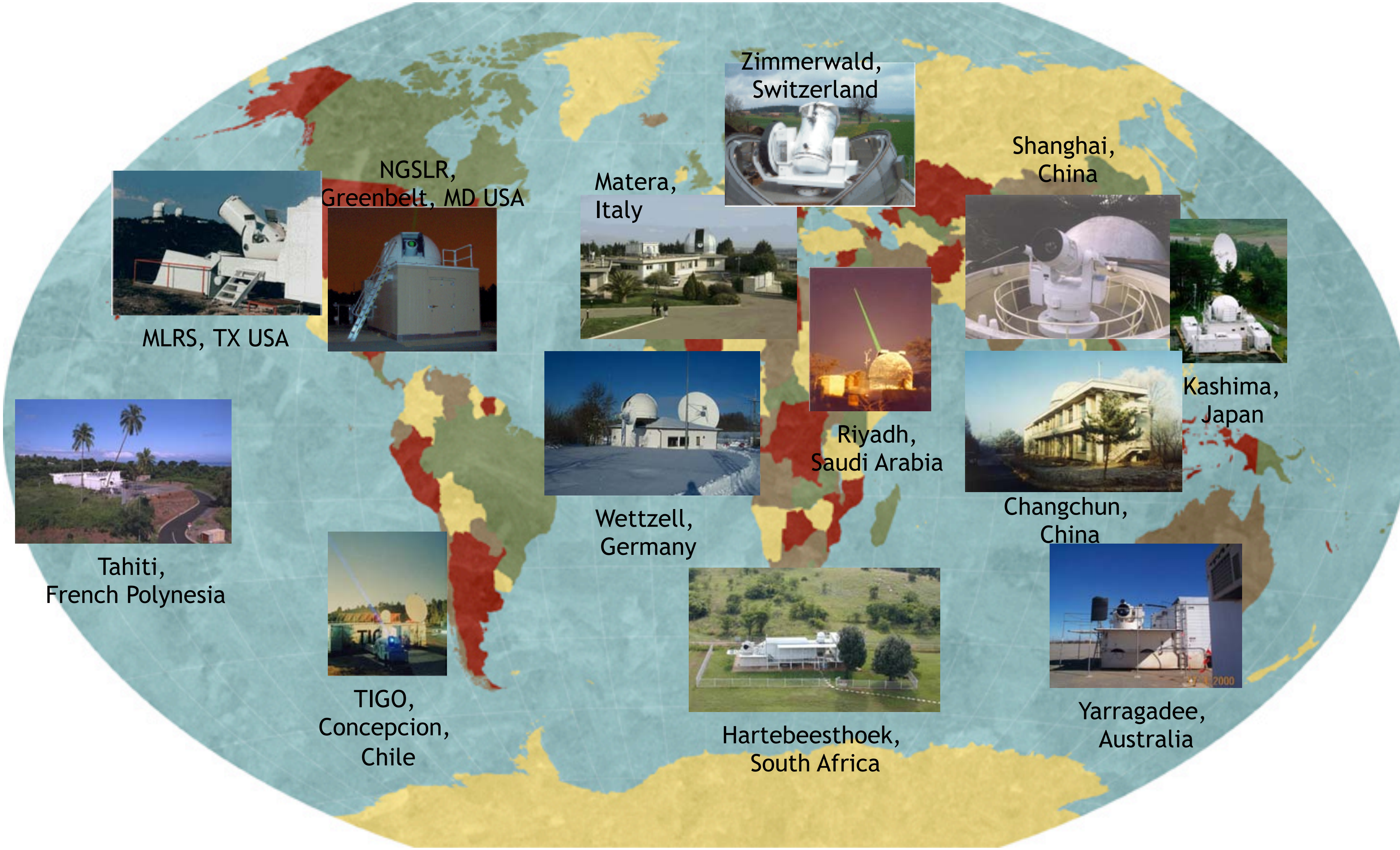


ILRS Network



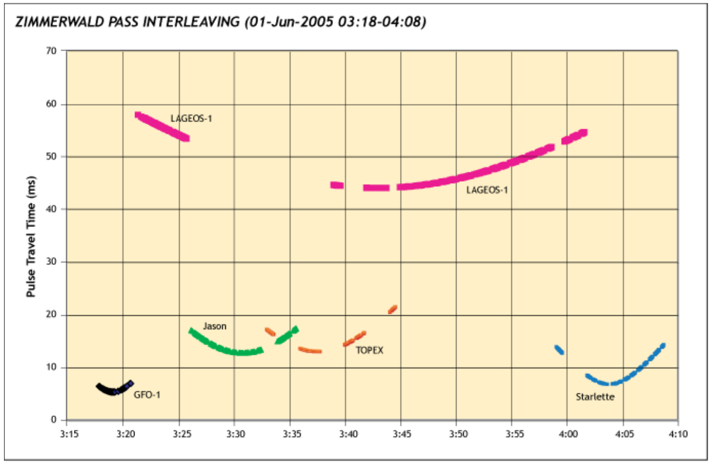
- 33 station provide tracking data routinely
- Most of the stations co-located with GNSS
- Eight stations co-located with VLBI
- Ten stations co-located with DORIS

Selected SLR Stations Around the World

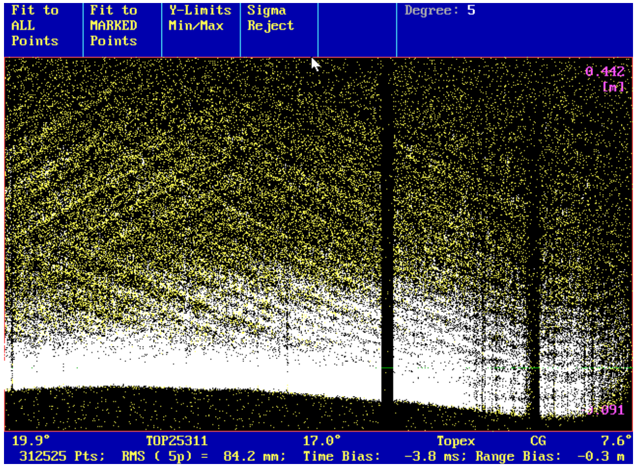


SLR Developments

- 2 kHz operation to increase data yield and improve pass-interleaving
- Eye-safe operations and auto tracking
- Automation (unattended operation)
- Event timers with near-ps resolution
- Web-based restricted tracking to protect optically vulnerable satellites (ICESat, ALOS, etc.)
- Two wavelength experiments to test refraction models
- Experiments continue to demonstrate optical transponders for interplanetary ranging
  – LRO-LR one-way ranging to the Lunar Orbiter presently underway



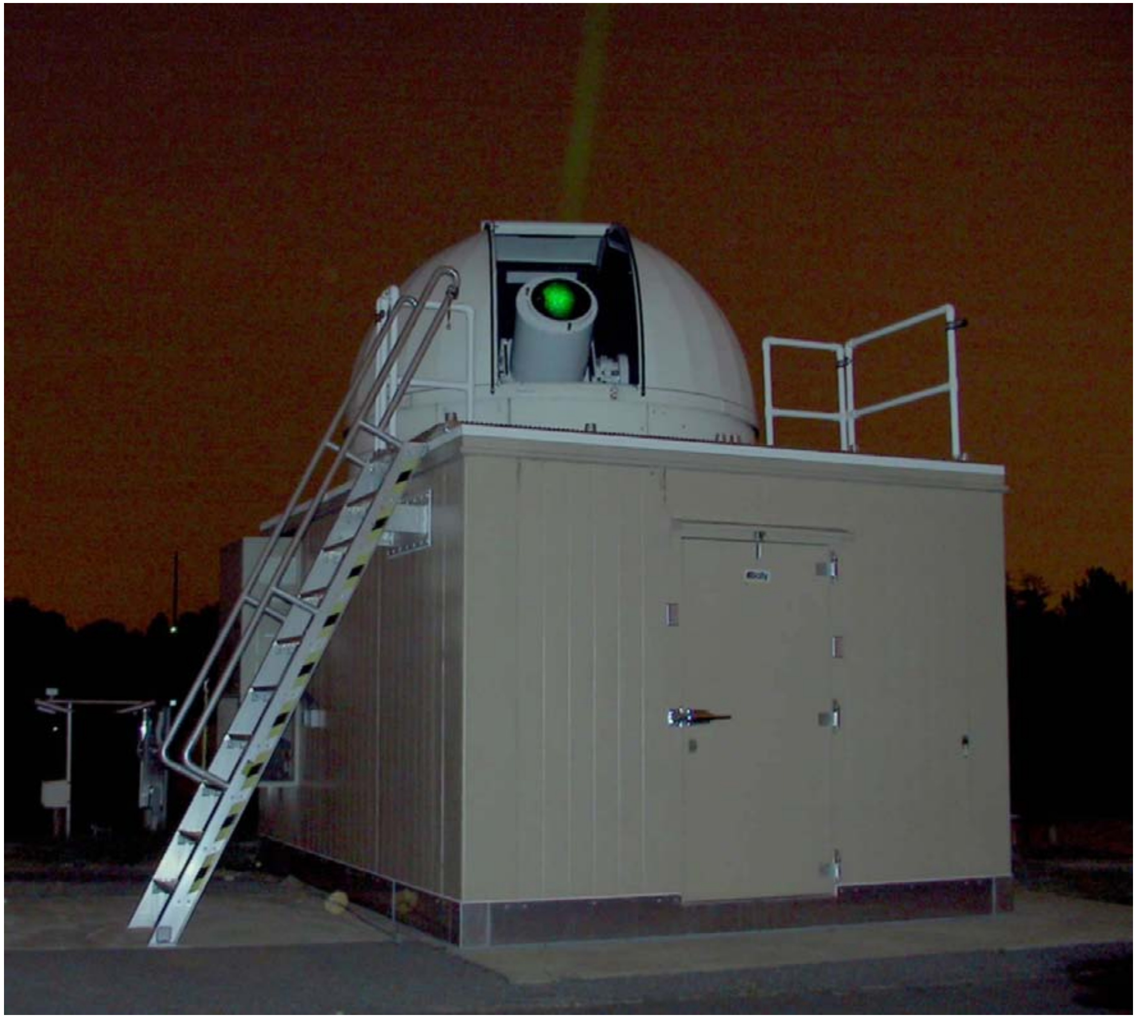
Pass Interleaving at Zimmerwald Station



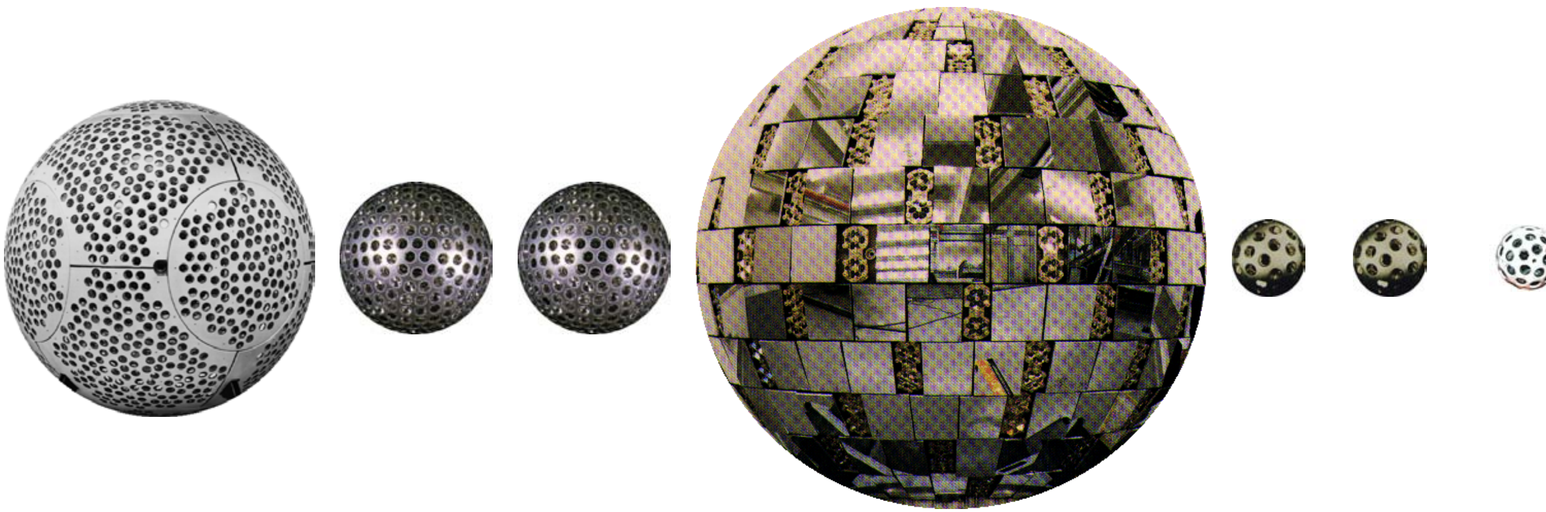
2-KHz returns from Graz Station

NASA New Generation SLR System (NGSLR)

NASA Goddard Space Flight Center

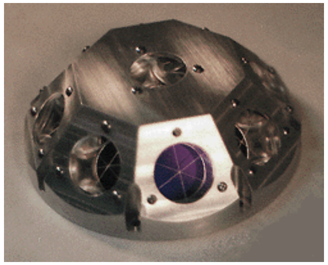


SLR Geodetic Satellite Constellation

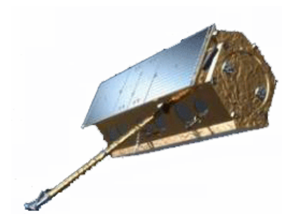
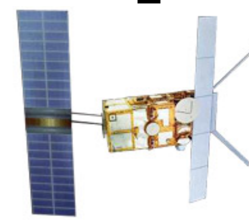


	Etalon-I & -II	LAGEOS-1	LAGEOS-2	Ajisai	Starlette	Stella	GFZ-1
Inclination	64.8°	109.8°	52.6°	50°	50°	98.6°	51.6°
Perigee ht. (km)	19,120	5,860	5,620	1,490	810	800	396
Diameter (cm)	129.4	60	60	215	24	24	20
Mass (kg)	1415	407	405.4	685	47.3	47.3	20.6

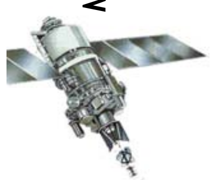
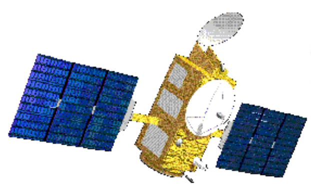
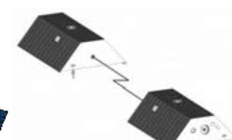
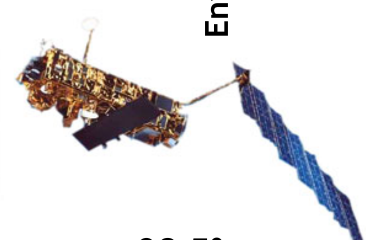
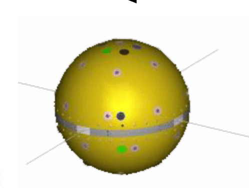
Sample of SLR LEO Satellite Constellation





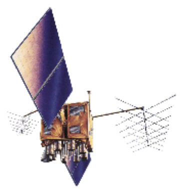
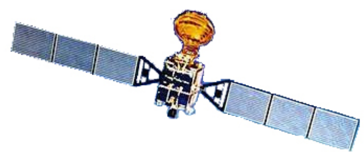
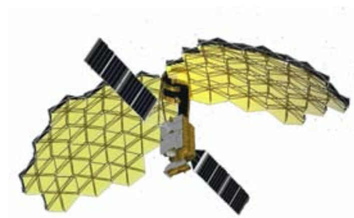




	GFO-1	ERS-1	Terra-SAR-X	ERS-2	CHAMP
Inclination	**108°**	**98.5°**	**97.4°**	**98.5°**	**87.27°**
Perigee ht. (km)	**800**	**780**	**514**	**785**	**474**
Mass (kg)	**300**	**2,400**	**1,230**	**2,516**	**400**

	Meteor-3M	Jason-1	GRACE	Envisat	ANDE-RR
Inclination	**99.64°**	**66°**	**89°**	**98.5°**	**51.6°**
Perigee ht. (km)	**1,012**	**1,336**	**450**	**796**	**250**
Mass (kg)	**2.477**	**500**	**432/sat.**	**8,211**	**50**

SLR HEO Satellite Constellation

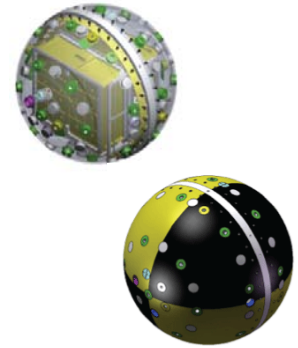
	GLONASS	GPS	COMPASS	GIOVE	ETS-8
					
Inclination	65°	64.8°	55.5°	56°	0°
Perigee ht. (km)	19,140	20,195	21,500	23,920	36,000
Mass (kg)	1,400	930	2,200	600	2,800

Missions for 2009

SOHLA
JAXA/Japan

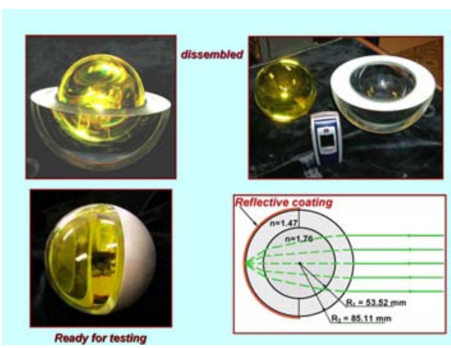
GOCE
ESA

LRO
NASA/USA

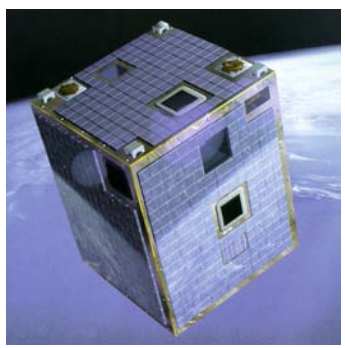


ANDE
NRL/USA

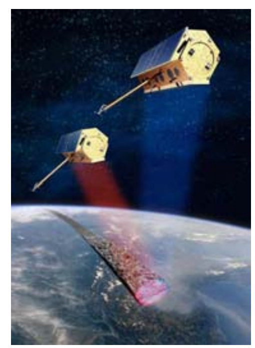
STSAT-2
KASI/Korea



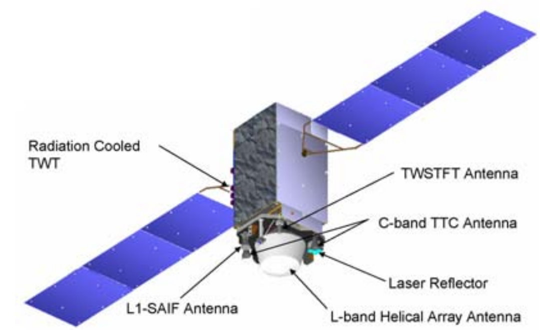
BLITS
IPIE/Russia



PROBA-2
ESA



TanDEM-X
DLR, GFZ/Germany

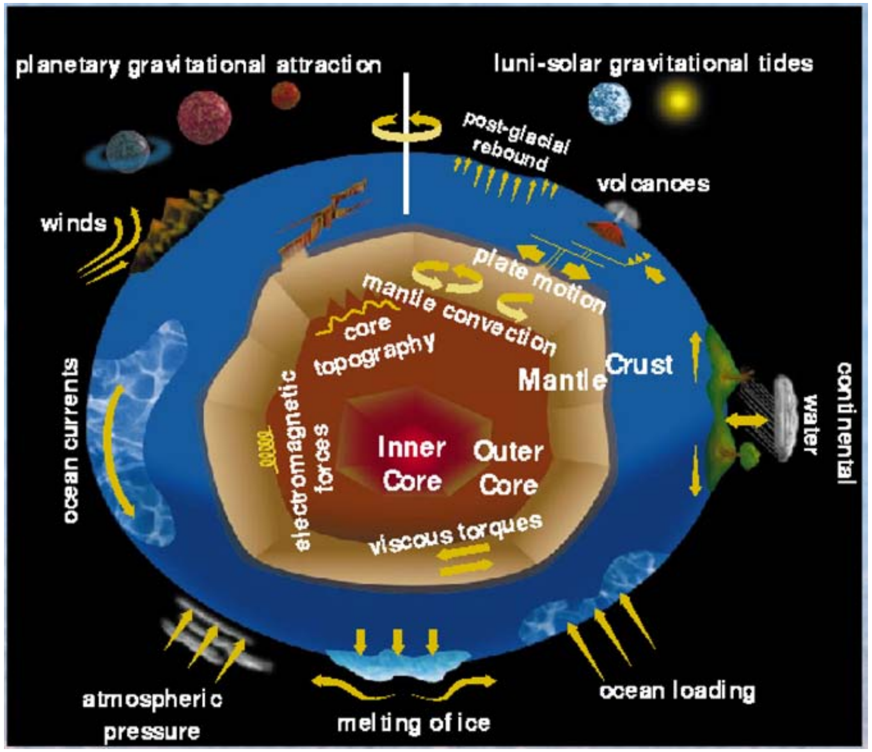


QZS-1
JAXA/Japan

The Earth

Some people think the Earth looks like this:

But really – it looks like this:



Terrestrial Reference Frame (TRF)

- Provides the stable coordinate system that allows us to measure change (link measurements) over space, time and evolving technologies.
- An accurate, stable set of station positions and velocities.
- Foundation for virtually all space-based and ground-based metric observations of the Earth.
- Established and maintained by the global space geodetic networks.
- Network measurements must be precise, continuous, and worldwide.
- Must be robust, reliable, geographically distributed
  - proper density over the continents and oceans
  - interconnected by co-location of different observing techniques
- Most stringent requirement: Measuring sea level rise requires accuracy of 1.0 mm and a stability of 0.1 mm/yr.

Complex of Space Geodesy instruments

for development and maintenance of the reference frame

SLR/LLR

VLBI

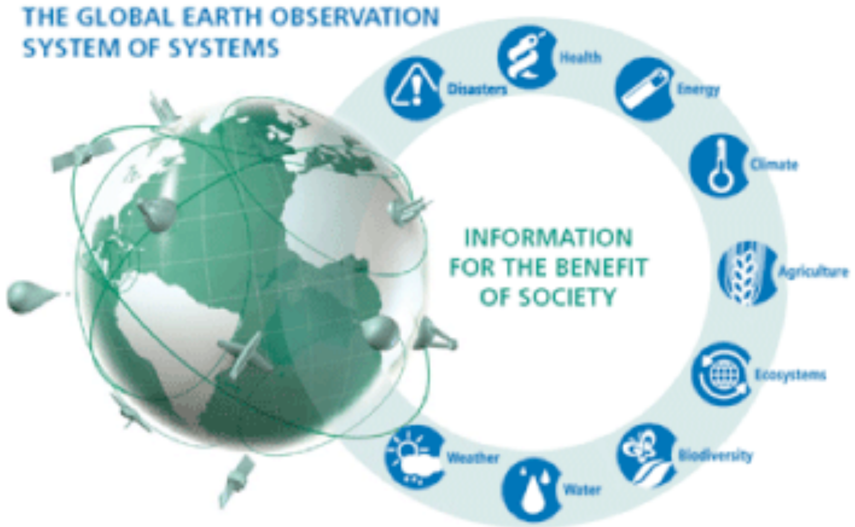
GPS

DORIS

GEO and GEOSS: A Brief Introduction

- 2002: World Summit on Sustainable Development in Johannesburg, South Africa:
  - *Urgent need for coordinated observations of the state of the Earth*
- June 2003: G8 Meeting in Evian:
  - *Re-emphasizes the importance of Earth Observations*
- July 2003: First Earth Observation Summit (EOS-I) in Washington DC with 33 Countries, the EC, and 21 International Organizations:
  - *Establishes the ad hoc Intergovernmental Group on Earth Observations (ad GEO)*
  - *Task of ad hoc GEO: initial 10 year Implementation Plan by February 2005*
- April 2004: EOS-II in Tokyo with 43 Countries, the EC, and 25 International organizations;
  - *Adopts the 'Framework Document' which defines nine societal benefit areas for Earth Observations*
- February 2005: EOS-III in Brussels:
  - *Adopts the 10 Year Implementation Plan for a Global Earth Observation Systems of Systems (GEOSS)*
  - *Establishes the Group on Earth Observation (GEO) with the task of implementing GEOSS.*

Global Earth Observation System of Systems (GEOSS)



- Disasters
- Health
- Energy
- Climate
- Agriculture
- Ecosystems
- Biodiversity
- Water
- Weather

Vision: to realize a future wherein decisions and actions for the benefit of humankind are informed by coordinated, comprehensive, and sustained Earth observations and information

http://www.earthobservations.org/documents/10-Year%20Implementation%20Plan.pdf

Terrestrial Reference Frame Role within GEOSS

- Two of the most demanding requirements for the TRF within GEOSS:
  - monitoring the water cycle at global to regional scales;
  - monitoring and modeling sea surface and ocean mass changes in order to detect global change signals in ocean currents, volume, mass and sea level;
- Quantitatively:
  - TRF should be accurate to 1 mm and stable to a 0.1 mm/yr, and
  - Static geoid should be accurate to 1 mm and stable to a 0.1 mm/yr. (GGOS 2020, WCRP)
- A number of satellite missions are currently observing sea and ice topography with altimetry and mass transport in the water cycle through gravity missions;
- Future altimetry and gravity field missions with improved capability are in the pipeline;
- The current reference frame based on the equivalent of 8 co-located sites is about 1 ½ orders of magnitude less that what we need;
- SLR, VLBI, GNSS and DORIS are all developing the next generation systems;
- Simulations indicate the we will need 25 – 30 co-located stations well distributed around the world to achieve the TRF quality;

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; and***
- ***increase our capability to predict the future behaviour.***

IAG Services: Backbone of GGOS

Geometry

Gravimetry

Ocean

Std

IERS:	**International Earth Rotation and Reference Systems Service**
IGS:	**International GNSS Service**
IVS:	**International VLBI Service**
ILRS:	**International Laser Ranging Service**
IDS:	**International DORIS Service**
IGFS:	**International Gravity Field Service**
BGI:	**Bureau Gravimetrique International**
IGeS:	**International Geoid Service**
ICET:	**International Center for Earth Tides**
ICGEM:	**International Center for Global Earth Models**
PSMSL:	**Permanent Service for Mean Sea Level**
IAS:	**International Altimetry Service (in preparation)**
BIPM:	**Bureau International des Poids et Mesures**
IBS:	**IAG Bibliographic Service**

Role of GGOS

- **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;**
- **Improve the accessibility of geodetic observations and products for a wide range users**
- ***<u>Working with the IAG Services, provide the geodetic infrastructure necessary for monitoring the Earth system and for global change research;</u>***
- ***Global Call for Participation distributed through the Member States for contribution to the ground network: network design, research, development, sites, infrastructure, operations, etc.***

We invite you to visit our website @

http://ilrs.gsfc.nasa.gov/index.html

The Construction of the Reference Frame from the Three Pillars of Geodesy

1. Geometry and deformation of the Earth
2. Orientation and rotation of the Earth and its variation
3. Gravity field of the Earth and its temporal changes

GEOMETRY

GPS, Altimetry,
INSAR
Remote Sensing
Leveling
Sea Level

REFERENCE SYSTEMS

VLBI, SLR, LLR,
GPS, DORIS

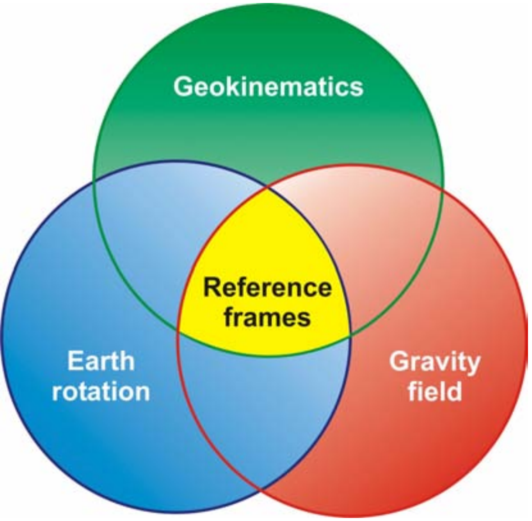
EARTH ROTATION

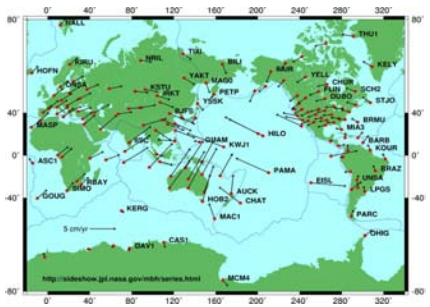
VLBI, SLR, LLR,
GPS, DORIS
Classical: Astronomy
New: Ringlasers, Gyros

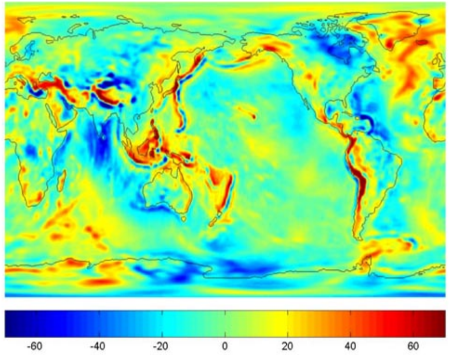
GRAVITY FIELD

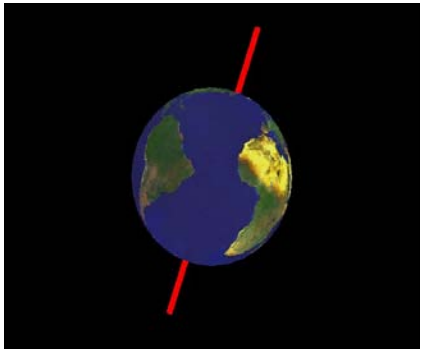
Orbit Analysis
Satellite Gradiometry
Ship-& Airborne Gravimetry
Absolute Gravimetry
Gravity Field Determination

Underlying Concepts and Main Issues









The 'three pillars of geodesy':

- Earth's Shape (Geokinematics)
- Earth's Gravity Field
- Earth Rotation

Output:

- Reference Frame
- Observations of the Shape, Gravitational Field and Rotation of the Earth

Challenges:

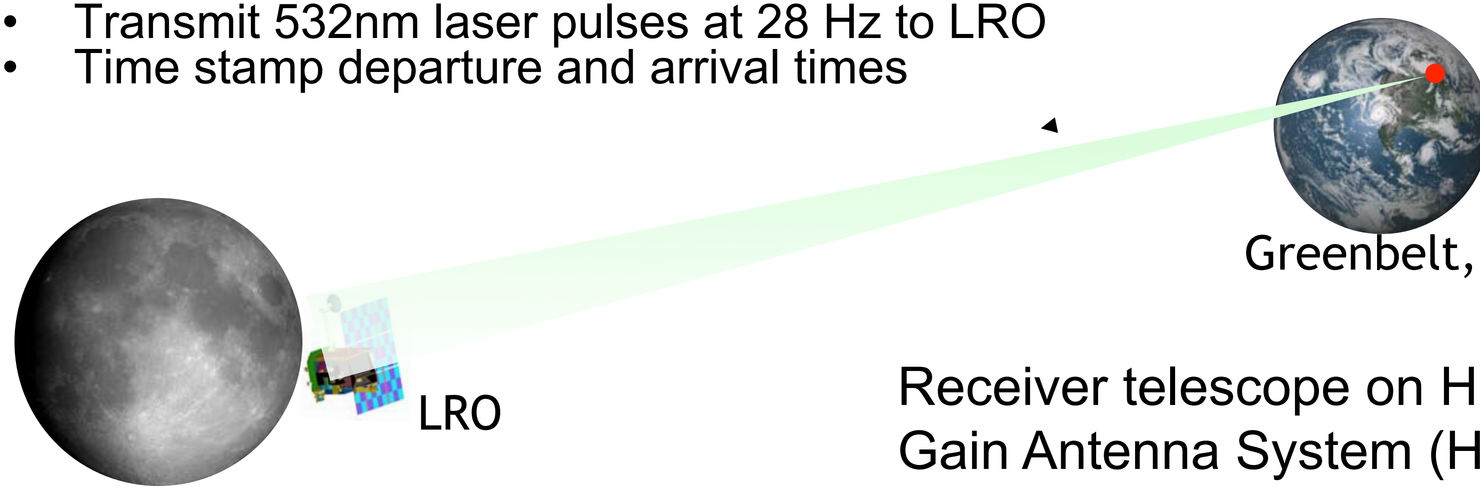
- Consistency of the three pillars
- Global change effects are small
- Reference frame available anywhere, any time

Solutions:

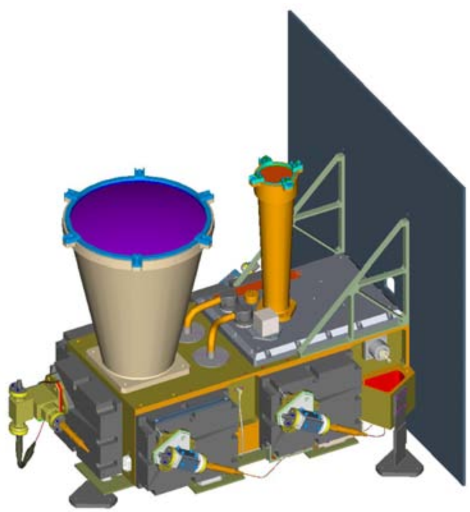
- Integration of Systems, Observations, Analysis, and Models

Lunar Orbiter Laser Ranging

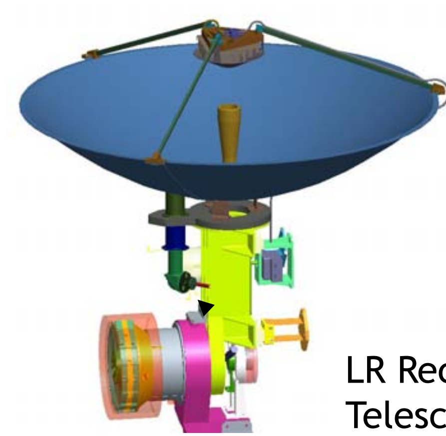
- Transmit 532nm laser pulses at 28 Hz to LRO
- Time stamp departure and arrival times



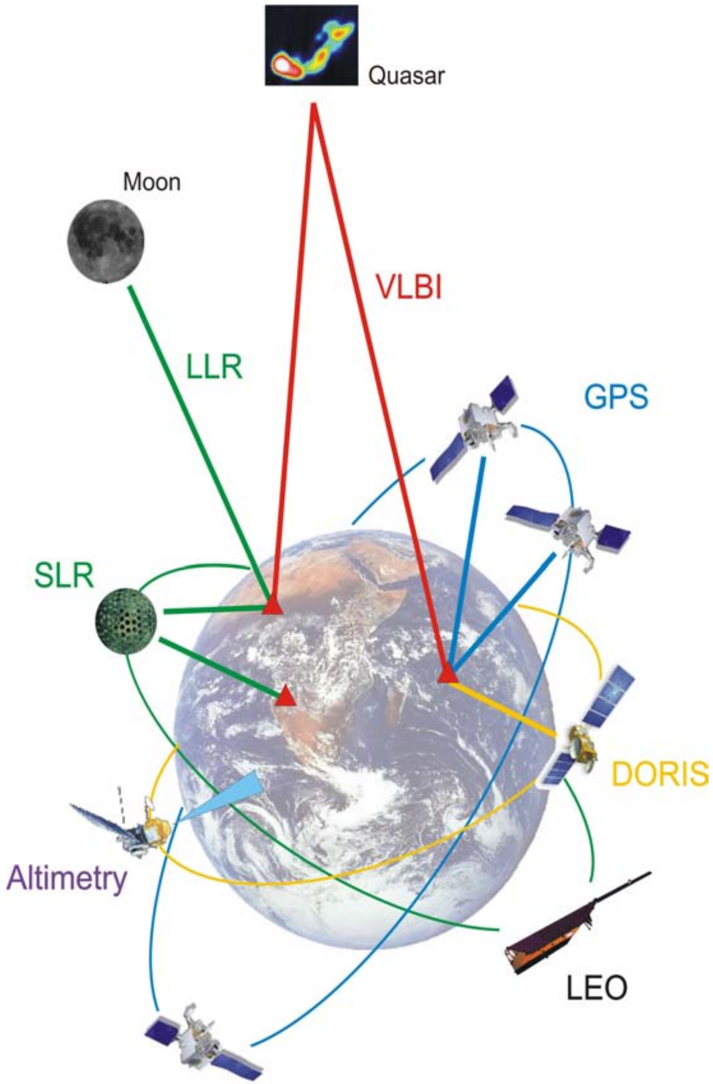
Receiver telescope on High Gain Antenna System (HGAS) routes LR signal to LOLA



LOLA channel 1 detects LR signal



Combination / Integration



- Ensure the **consistency** and can improve the **accuracy** of the resulting geodetic products
- **Complementary use** of the individual techniques to strengthen the solutions
- Benefits from observing instruments **co-located at the same site/satellite**
- Distinguish **genuine geodetic/geo-physical signals** from **technique-specific systematic biases**
- Crucial to **separate different components and processes** in the Earth System (e.g. mass transport)

SLR provides the Center of Mass and with VLBI the scale for the reference frame