GNSS Session A:
Synergy of SLR and GNSS Data Products

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Purpose of the Position Paper

- The purpose of this position paper is to pose questions to be discussed and answered on the basis of a set of key-presentations and through open discussions with the audience

Invited Stakeholders of GNSS

- Reports from the GNSS missions or on behalf of them:
  - GPS (Dr. Tom Johnson, NGA)
  - GLONASS (Dr. R. Fatkulin, ISS-Reshetnev Co.)
  - Galileo (Dr. Francisco Gonzalez, ESOC)
  - Beidou (Dr. Xiaoya Wang, SHAO)
  - QZSS (Dr. Yoshimi Ohshima, NEC for Japan's Gov.)

Key Questions to Answer

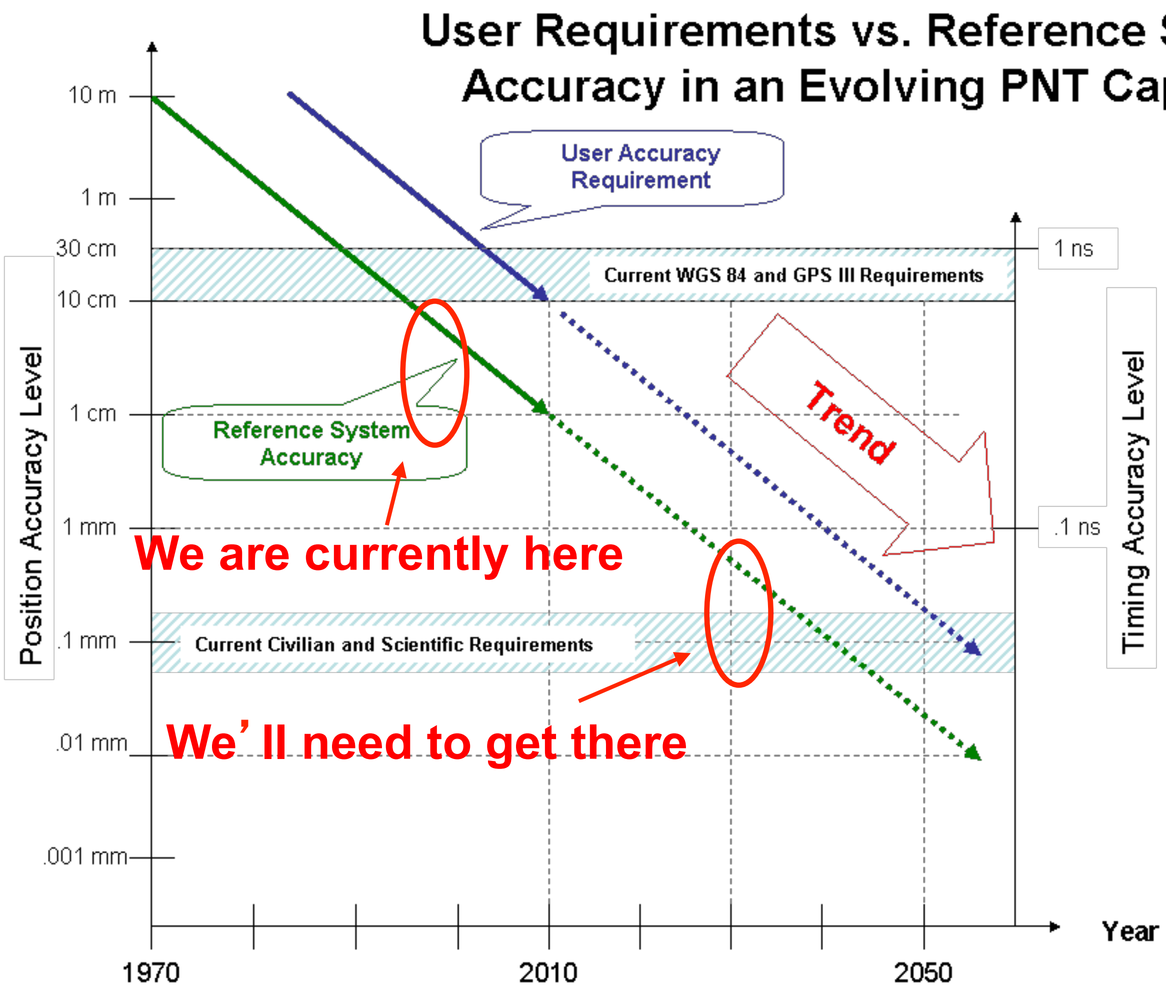
- Who is analyzing the GNSS SLR data?
- What products are being derived and by who?
- Is the ILRS satisfying their present user requirements:
  - Data Volume?
  - Data Accuracy?
  - Data Coverage (spatial and temporal)?
  - What are the shortfalls?
- What is the projection for future requirements?
  - Timeframe?
- What do we learn from SLR-GNSS co-location in space?
- Is SLR having an impact on:
  - GNSS products and if yes, how?
  - Geodetic products in general or facilitate new such products?

GNSS Today

- Today we have available a multitude of GNSS constellations:
  - that are operational (GPS, *GLONASS*),
  - or nearly so (*Galileo, Beidou, QZSS*),
  - while there are yet more in the process of development (IRNSS)
- GNSS has evolved as the prime system for a number of geodetic applications, some of which are:
  - precise positioning,
  - monitoring of deformation fields,
  - Earth rotation monitoring,
  - Precise Orbit Determination (POD) of LEO missions,
  - dissemination of the ITRF,
  - etc.

ITRF (the first three items above)

The Geodetic Requirements

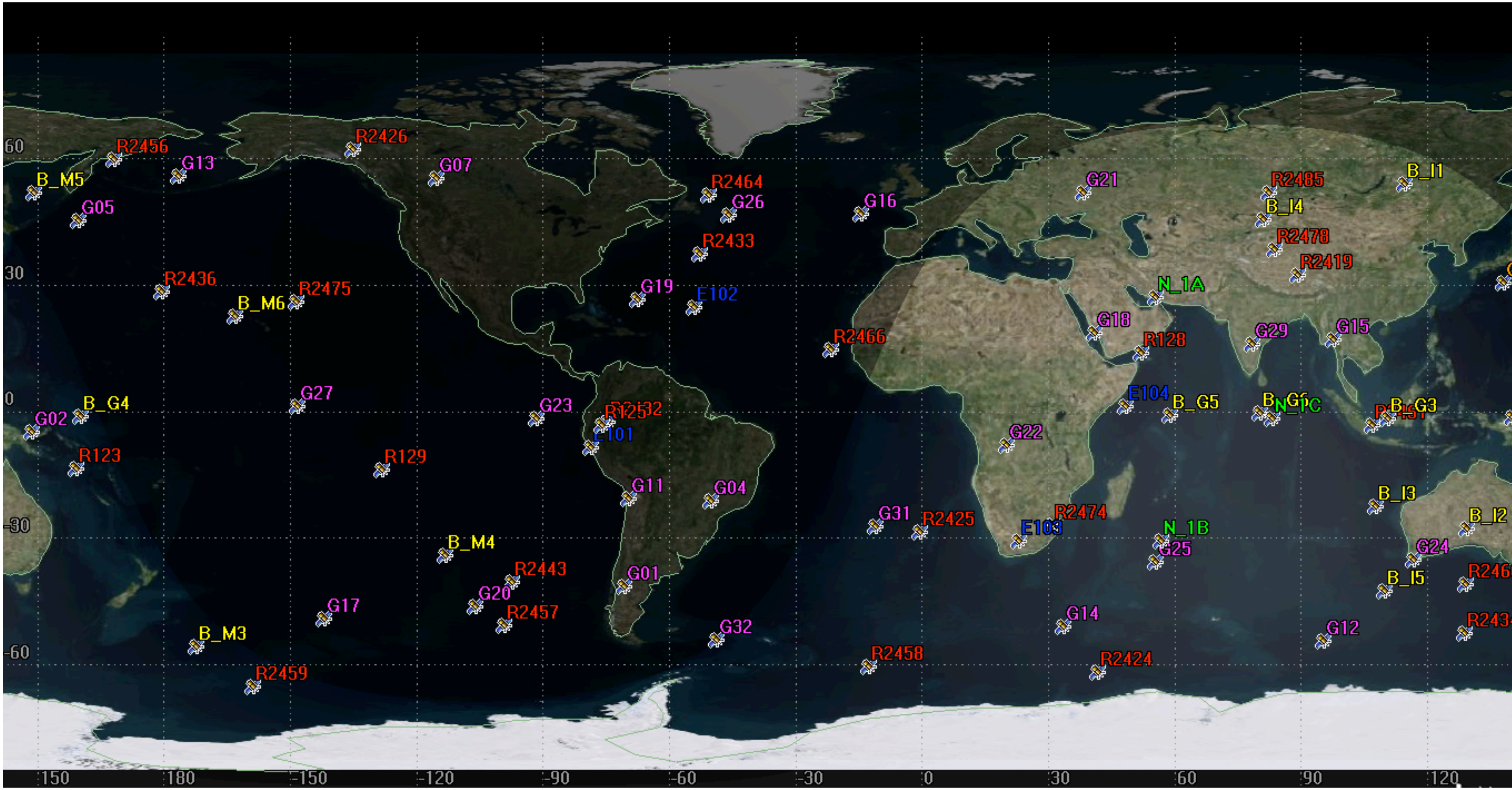


<1 mm reference frame accuracy

< 0.1 mm/yr stability

Improvement over current ITRF performance is factor of 10-20

GNSS in Near Future



Summary of Direct Benefits to GNSS

- SLR, an independent technique, insensitive to the ionosphere and with very small dependence on atmospheric water vapor (refraction delay), will aid their calibration and validation of GNSS orbits

- SLR observations will aid in modeling the onboard clocks, a key part of GNSS techniques

- SLR measurements are independent of the GNSS station positions and onboard clocks, thus the effect of any mis-modeling of the GNSS clocks can be separated from orbit errors, leading to improved understanding of clock behavior in space

Other Areas of Benefit

- Other areas that will benefit directly are:
  - the tracking support in the initial phases of deployment of new constellations,
  - Constellations with tracking network in its infancy (Beidou),
  - the improvement and validation of spacecraft dynamics (albedo),
  - the alignment of the GNSS intrinsic reference frames to ITRF,
  - To enable the interoperability of GNSS systems through a common, independent measurement technique

Additional, Indirect Benefits

- Improved positioning and navigation of instrumented platforms, on the ground, seaborne, airborne, or on spacecraft
- Precise Point Positioning (PPP) for users who do not demand the highest accuracy and rely on precise orbits available through IGS or other individual institutions and agencies
- GNSS tracking for POD will produce a more accurate orbit and higher consistency with the ITRF, leading to better geolocated products and most likely a quicker turn-around of products, sometimes a critical factor

Earth Observing Mission Support

- Oceanographic missions like OST/Jason-2 and in the near future Jason-3 for example will be able to release sea surface height maps in near real-time, with much higher accuracy than it is possible today, leading to various oceanographic applications not possible at present

- Geopotential mapping missions products will benefit from the higher quality of the GNSS orbits to the extent that they can make better use of that tracking data for the resolution of the very low-degree harmonics that are now typically substituted from SLR-based solutions

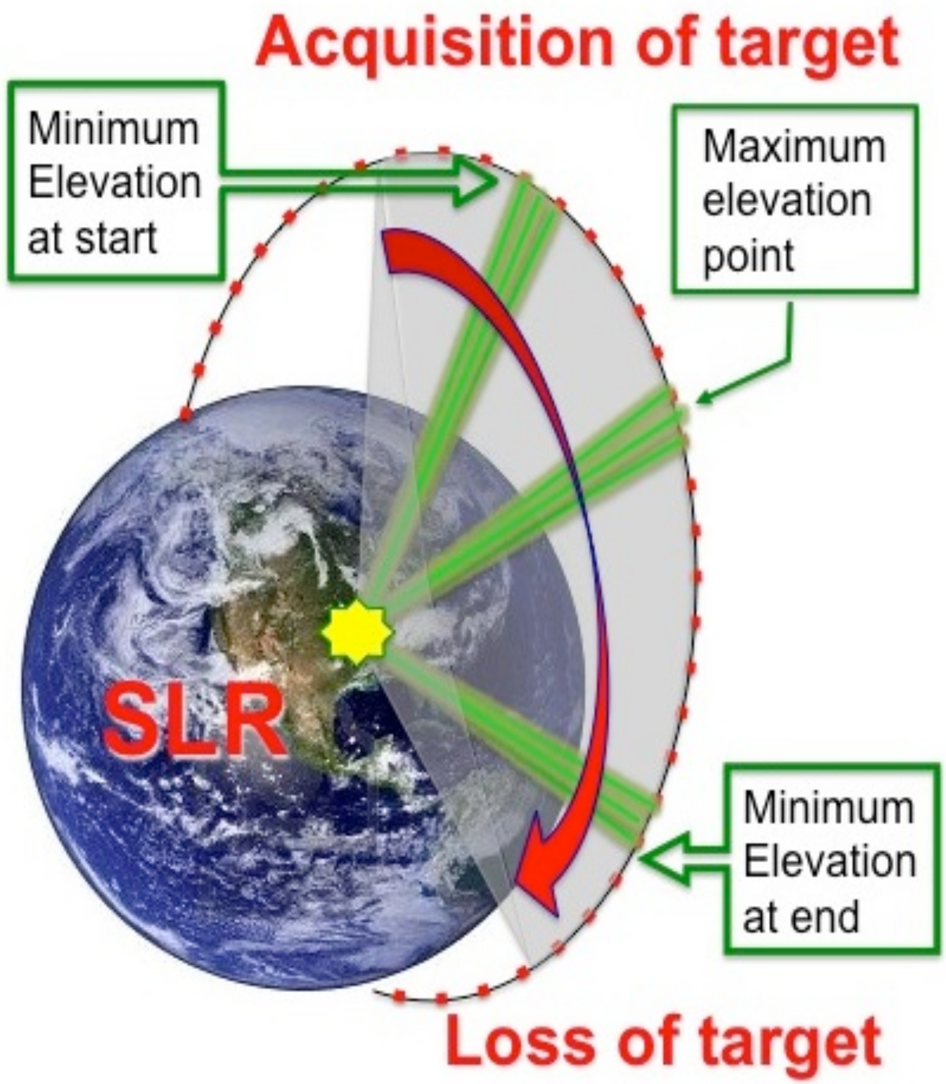
Key Factors for Success

- A requirement for meaningful results from laser ranging to GNSS satellites is the very precise knowledge of the location of the effective reflecting plane of the corner-cube retro-reflector (CCR) array with respect to the center of gravity (CoG) of the spacecraft
- The scale of the ITRF is directly related to this "CoG offset" correction that must be applied to the ranges
- Taking into account the size of the GNSS orbits, we estimate that their CoG offset must be known with an accuracy significantly less than 1 cm

Key Factors for Success (cont.)

- High accuracy GNSS orbits and clocks will require the detailed description of the spacecraft geometry and its attitude routine
- Geometry will be crucial in defining an accurate model of non-conservative forces acting on the spacecraft
- Spacecraft attitude and dynamics are also important, so any future use of the GNSS s/c will require a full knowledge of the attitude routine and description of any maneuvers or at least notification of attitude changes
- It is highly likely that these parameters will vary from spacecraft to spacecraft as well as from block to block. This variability underscores the need to track all satellites over time and to develop spacecraft specific models

ILRS Tracking Scenario for GNSS



Summary

- GNSS orbits improved with SLR tracking will result in higher accuracy applications of GNSS (e.g. positioning/ ITRF, navigation, time-transfer, POD, etc.)
- For such tracking to be effective, we require that GNSS s/c parameters such as the CoG, size, shape, surface properties, attitude routine, maneuvers, and above all, the LRA offset from the s/c CoG (over time!) be known
- In all cases we require that the GNSS onboard LRAs follow at least the minimum requirements set by ILRS, to avoid excessive data loss and poor tracking geometry, plus undue waste of network resources