The Geodetic Reference Antenna in Space (GRASP): A Mission to Enhance the Terrestrial Reference Frame

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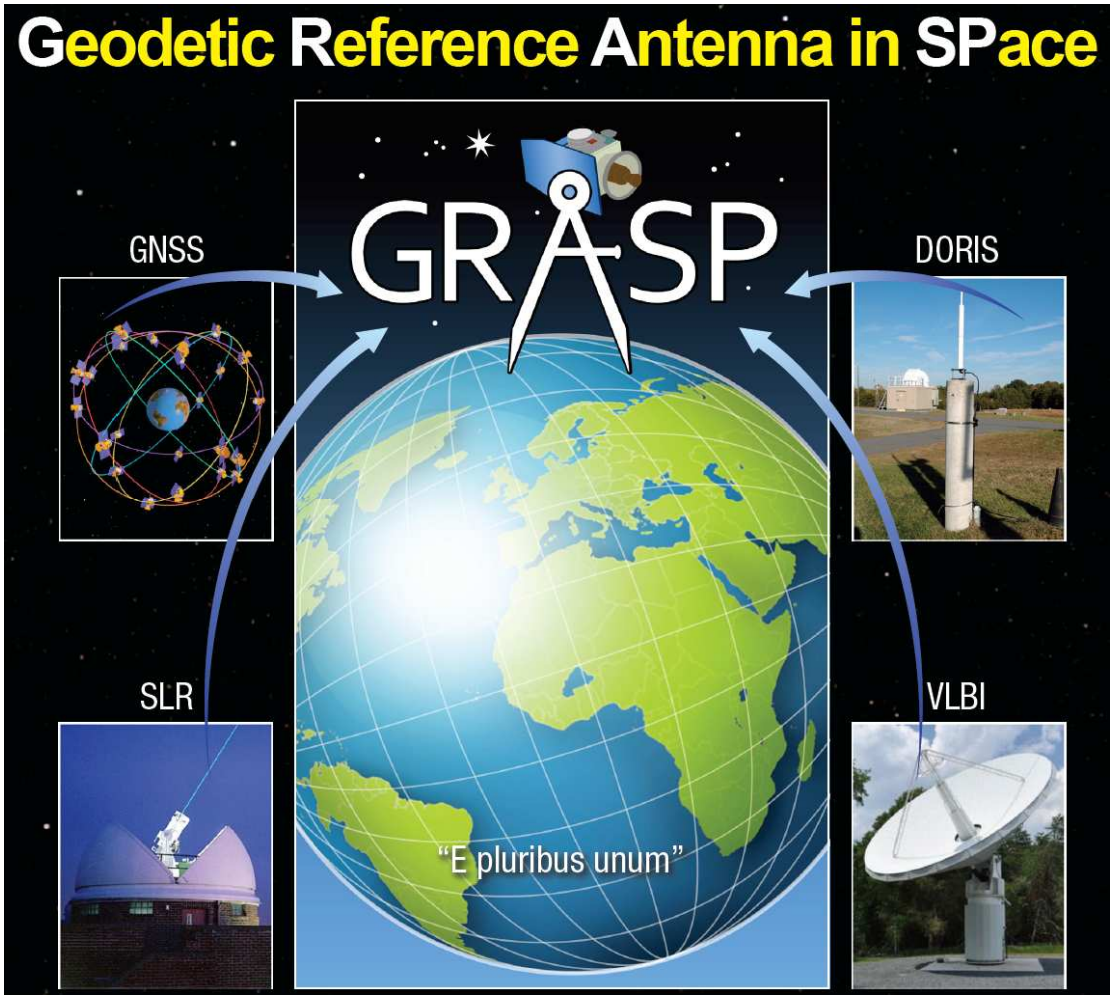
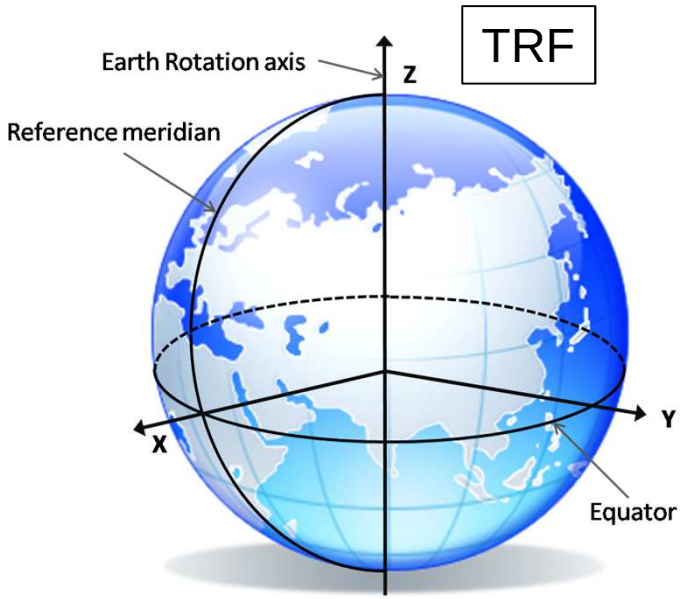
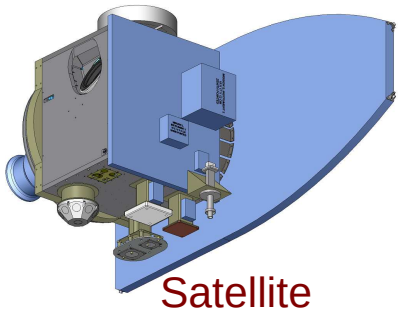


Terrestrial Reference Frame (TRF) and GRASP



- TRF is fundamental to all areas of geophysics
- TRF are currently determined by 4 space-ground geodetic techniques:
  - GPS/GNSS
  - DORIS
  - SLR
  - VLBI
- However, geophysics is now limited by accuracy of TRF and how well different geodetic techniques can be tied together:
  - Antenna phase center errors
  - Ground site ties between co-located techniques
- **Need to improve TRF accuracy and technique ties to answer key geophysics science questions**
- **Best way to do this is to use a space-based geodetic 'super-site' GRASP** that co-locates GNSS, DORIS, SLR, and VLBI sensors on a stable well-modeled platform above the atmosphere



Satellite Collocation

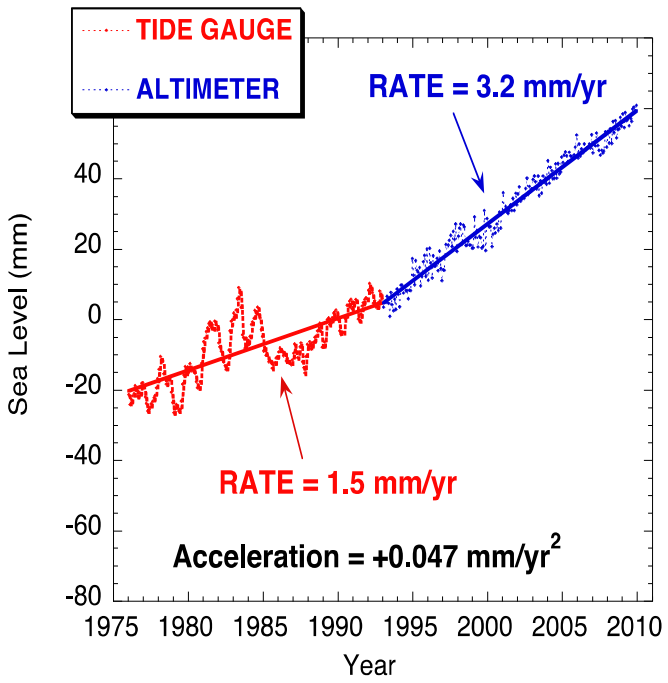
Terrestrial Collocation

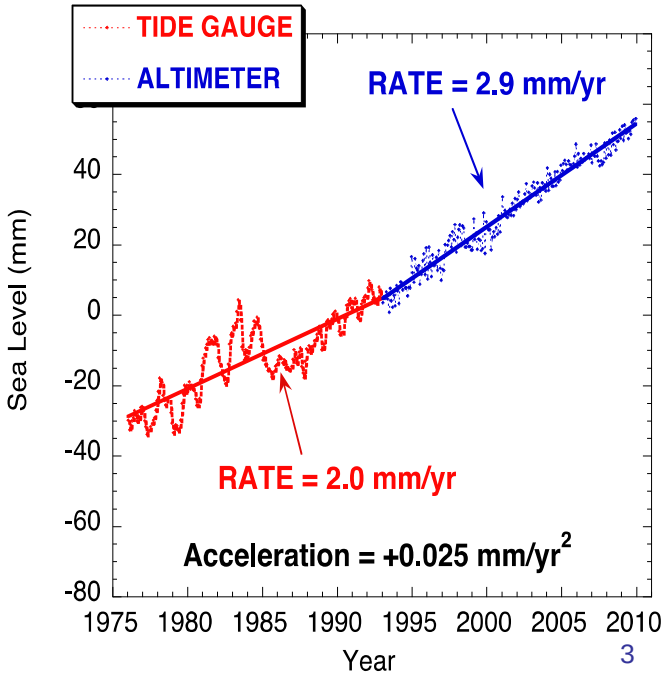
Key Science Goals

- **Meet GGOS goals** for the TRF: ~1 mm accuracy, 0.1 mm/yr stability
- Enable the accurate dissemination of the TRF with GNSS and DORIS to any location on Earth and low Earth orbit
- Calibrate the transmit antennas of all GNSS satellites relative to a single, well-characterizes reference antenna in space
- Measure the long-wavelength variability in the Earth gravity field that are either not observed (degree 1) or poorly observed (J_2) by GRACE
- Reinterpret satellite altimetry and tide gauge records to determine global mean sea level rise relative to the GRASP-based TRF – how is sea level accelerating

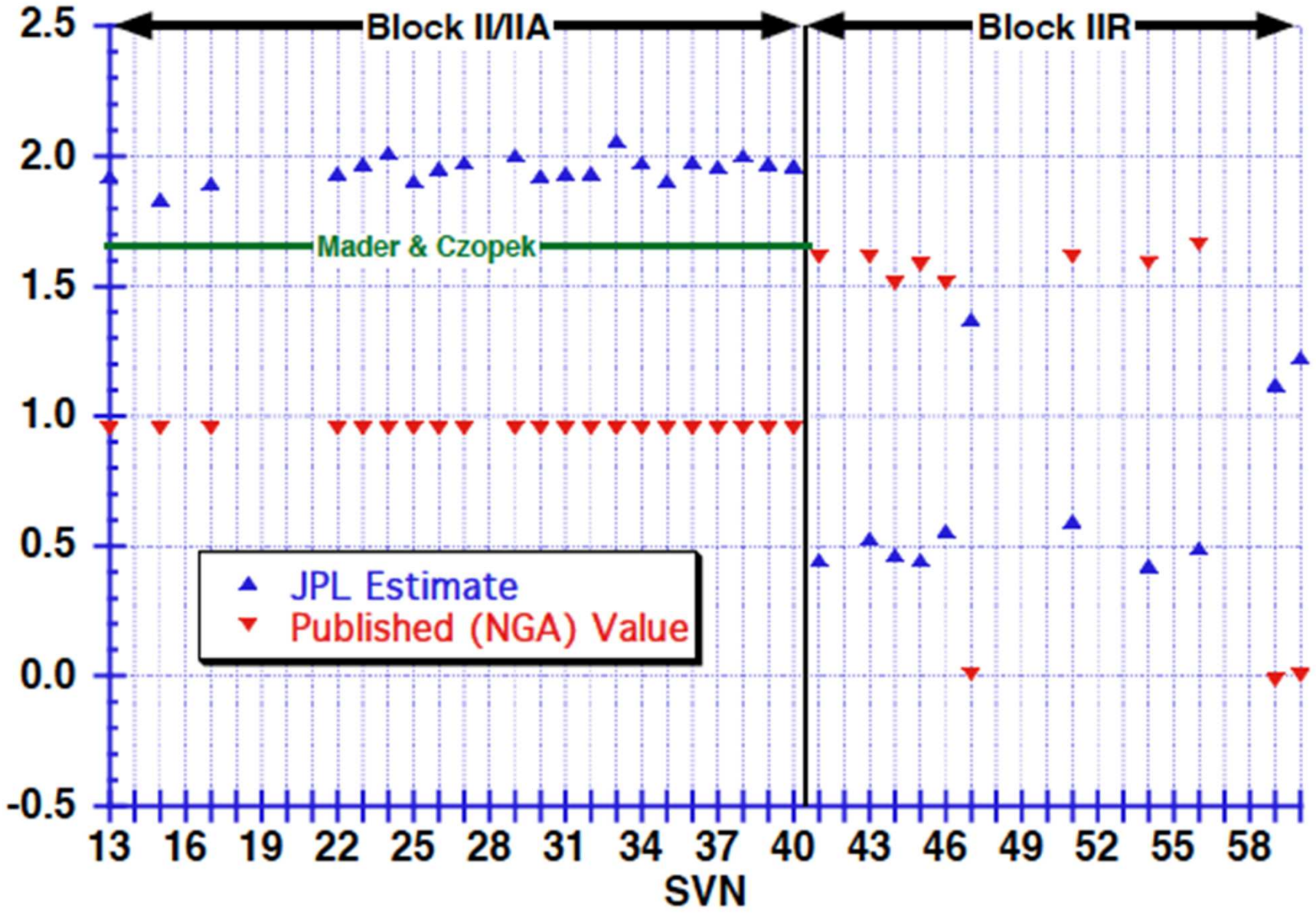
TRF errors readily manifest as spurious sea level rise accelerations

Left: ITRF2005
(based on Church and White, 2011)
Right: ITRF2000
(simulated into the Church and White records)

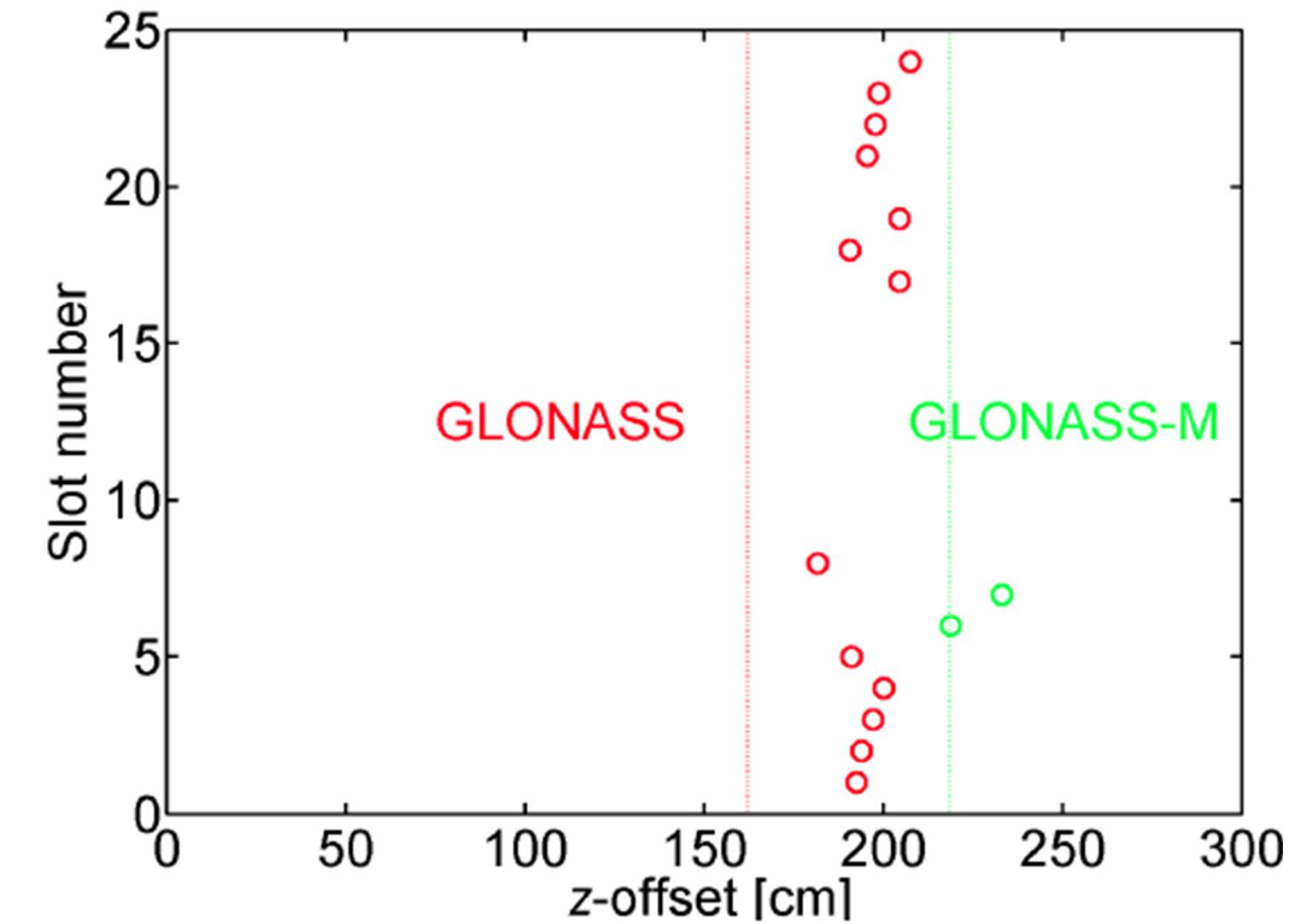




Published GPS Antenna Offsets Proven Incorrect



Published GLONASS Antenna Offsets Proven Incorrect



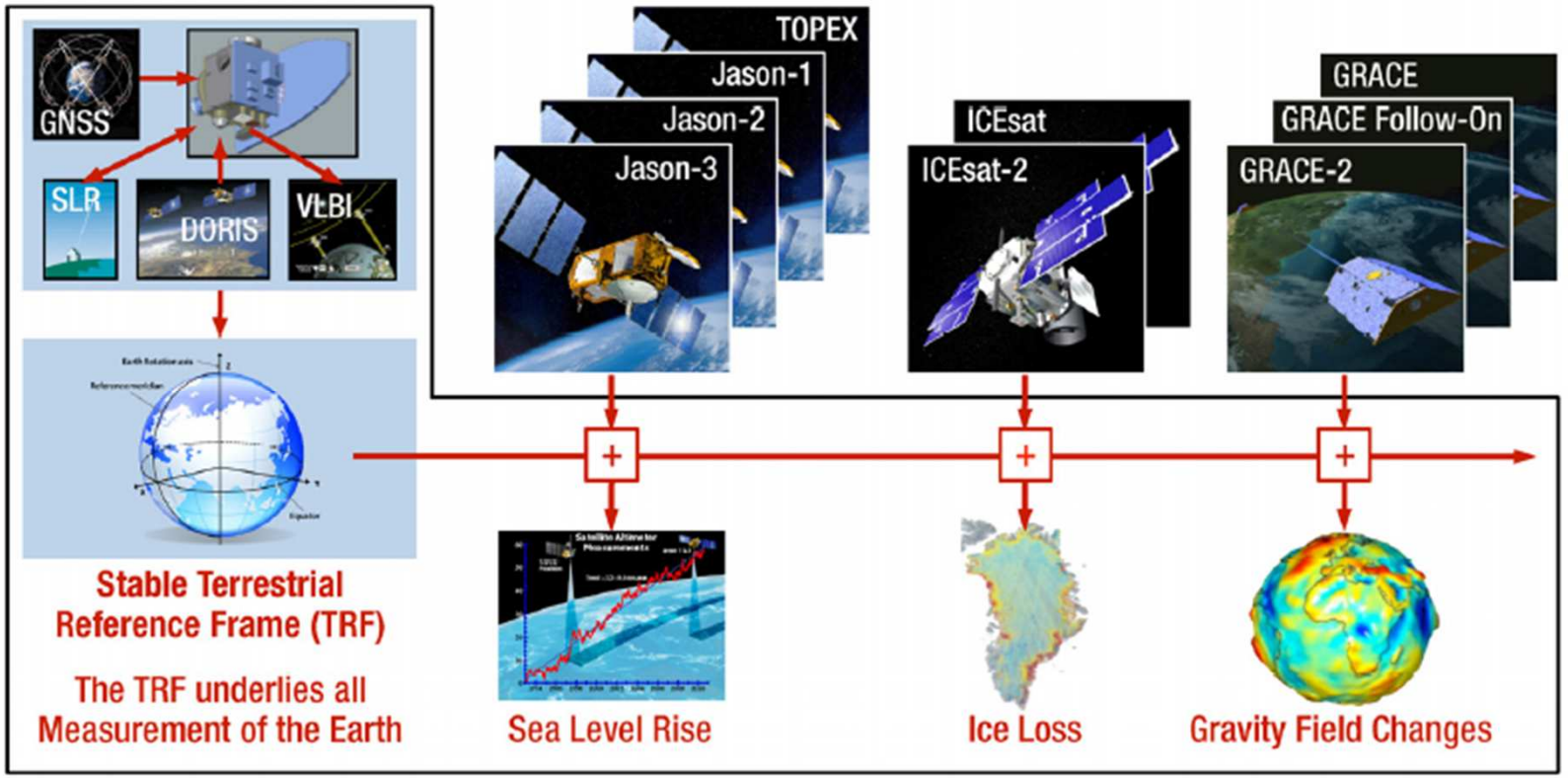
From Schmid et al., 2006

The Most Complete Geodesy Mission

Collocate all the geodetic technique on a supremely calibrated satellite

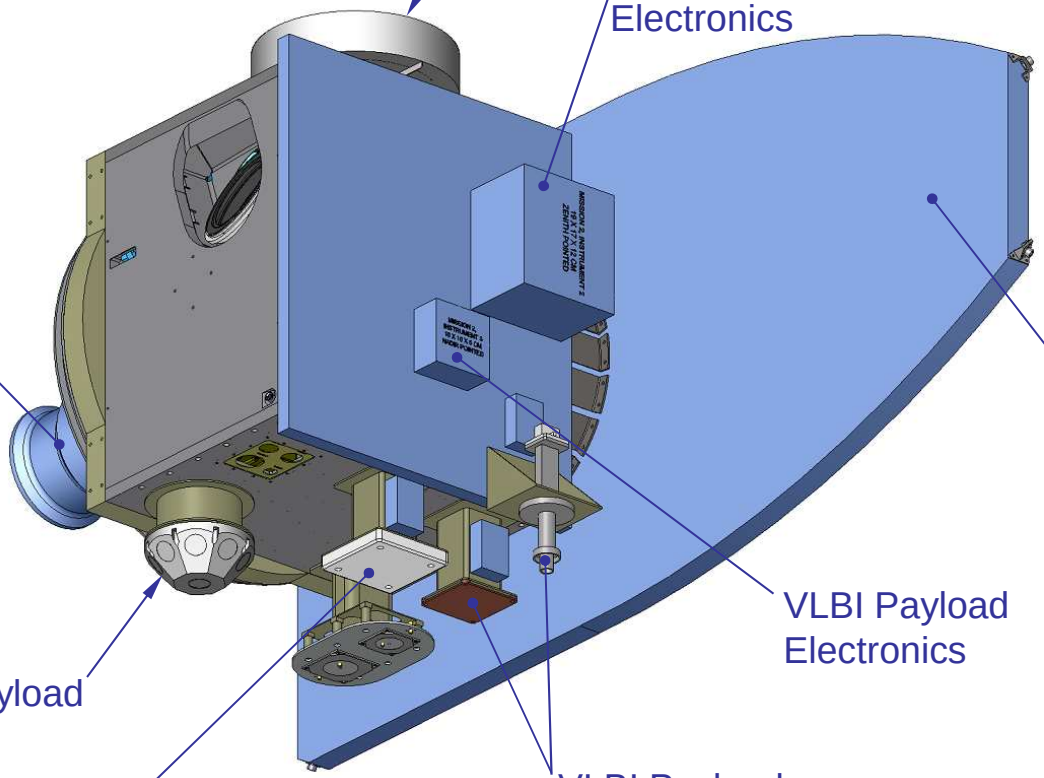
- Use as reference for all GNSS antennas (space and ground)
- Determine ground collocation at arbitrary baselines

GRASP enhances science from past and future Earth science missions; ~30 year impact from a 3 year mission



The GRASP Spacecraft

Orbit: 850x1350 Sun-synch
Collocate sensors and CM to 1 mm
1 mm orbit determination
3 years lifetime



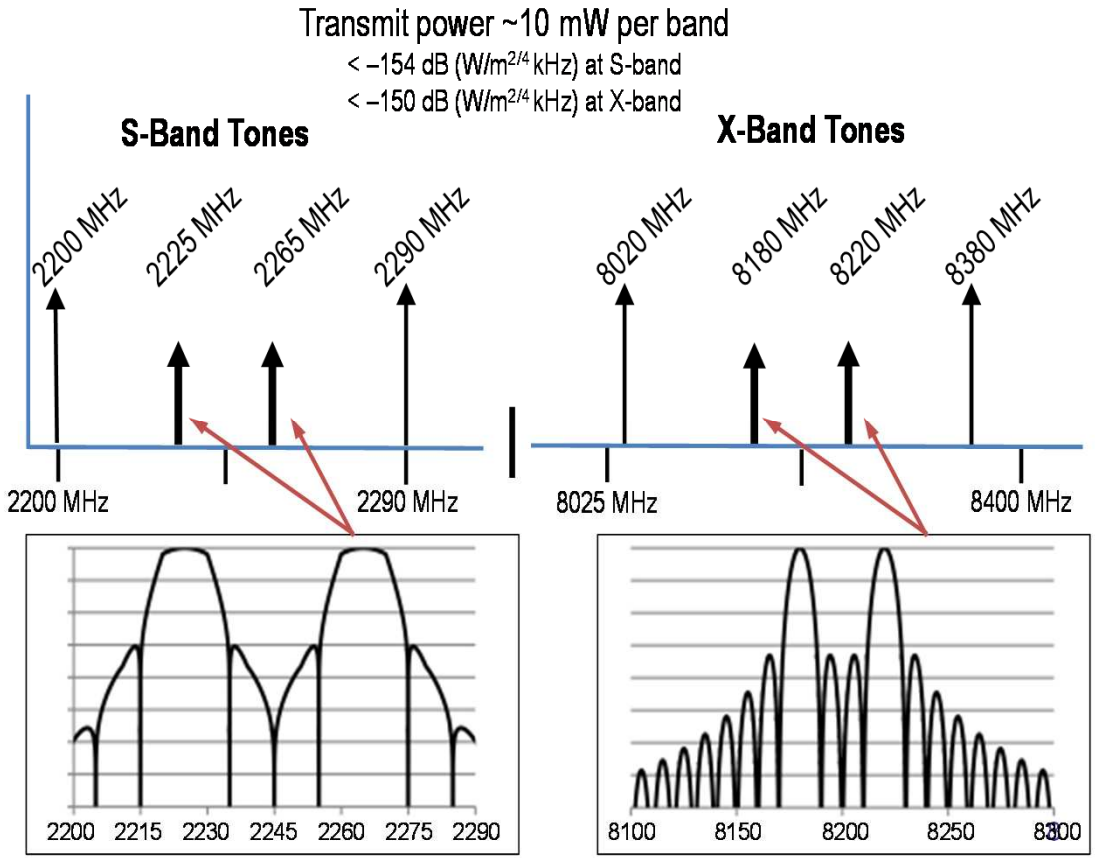
Novel Instruments on GRASP

DORIS: New receiver capability incorporated into the JPL's *TriG* GNSS receiver (next generation BlackJack, with GPS, GLONASS, and Galileo all-in-view capability)

- DORIS *phase* measurements from up to 7 beacons
- Common time tags with GNSS measurements
- CNES already provided ICD; may ultimately contribute the standard DORIS receiver

VLBI Tone Transmitter (VTT): A new instrument with heritage in several GRAIL sub-systems

- Signal is compliant with NTIA regulations while compatible with both present-day VLBI and VLBI2010
- High precision ionospheric-free observables (1-σ, 1-sec)
  - 0.2 mm pseudorange (1 sec)
  - 0.01 mm phase (1 sec)
- JPL will write ground software to extract Level-1 (phase and pseudorange) observables from the broadband VLBI data; publish in RINEX-like format

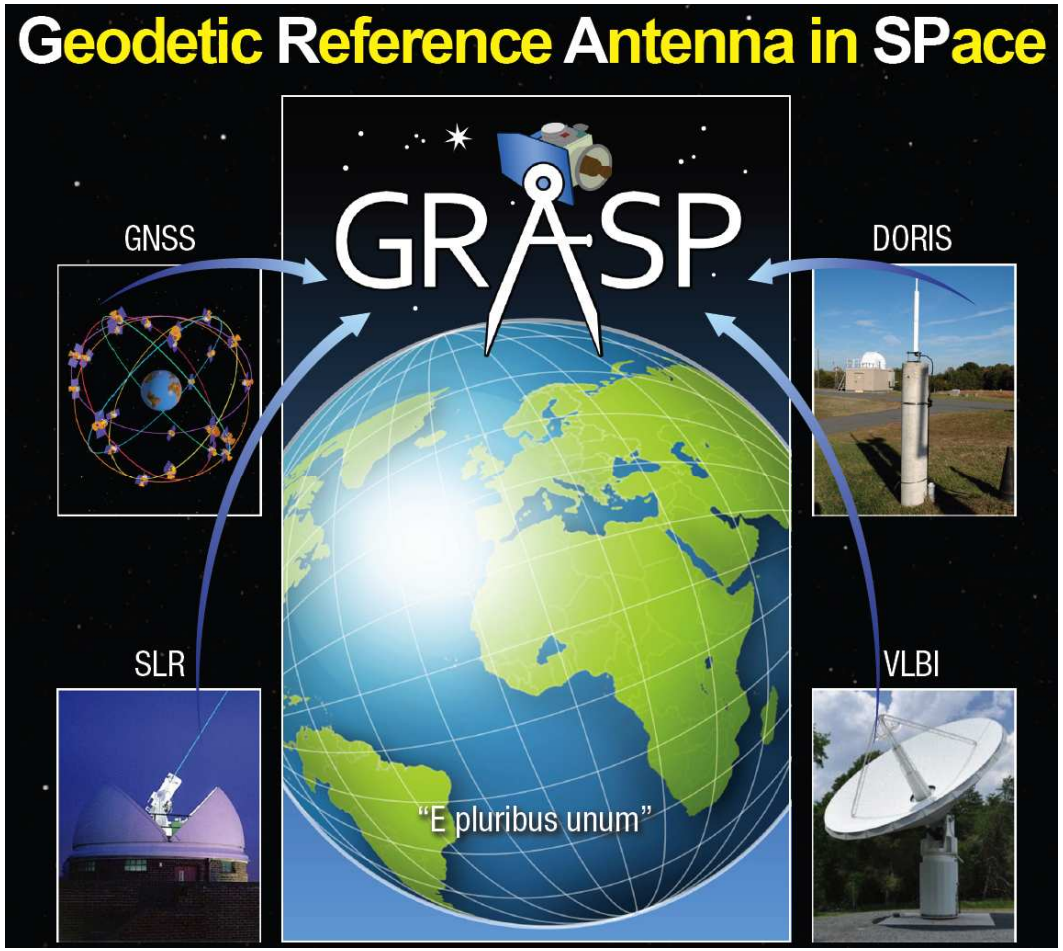


Well Reviewed Mission Concept

With the formal support of the entire international geodetic community, the GRASP mission was proposed to NASA in September 2011 in response to the Venture II mission call.

- Prof. R. Steven Nerem, PI
- Dr. Yoaz Bar-Sever, Project Scientist
- A large international Science Team

GRASP was ranked second out of 19 submitted proposals



Next Step: Looking for Partnerships

- We have a well-reviewed, complete mission concept
- We have a very strong and broad support from the geodetic community
- We have a broad base international scientific and technical leadership
- We aim to unify and calibrate all GNSS to enhance science inter-operability
- We have an open data policy

We are soliciting partnerships with agencies that are able to provide cost sharing or in-kind services, for example:

- Launch services
- Payload components
- Bus
- Ground system

Estimated total mission cost: $150M over 6 years.