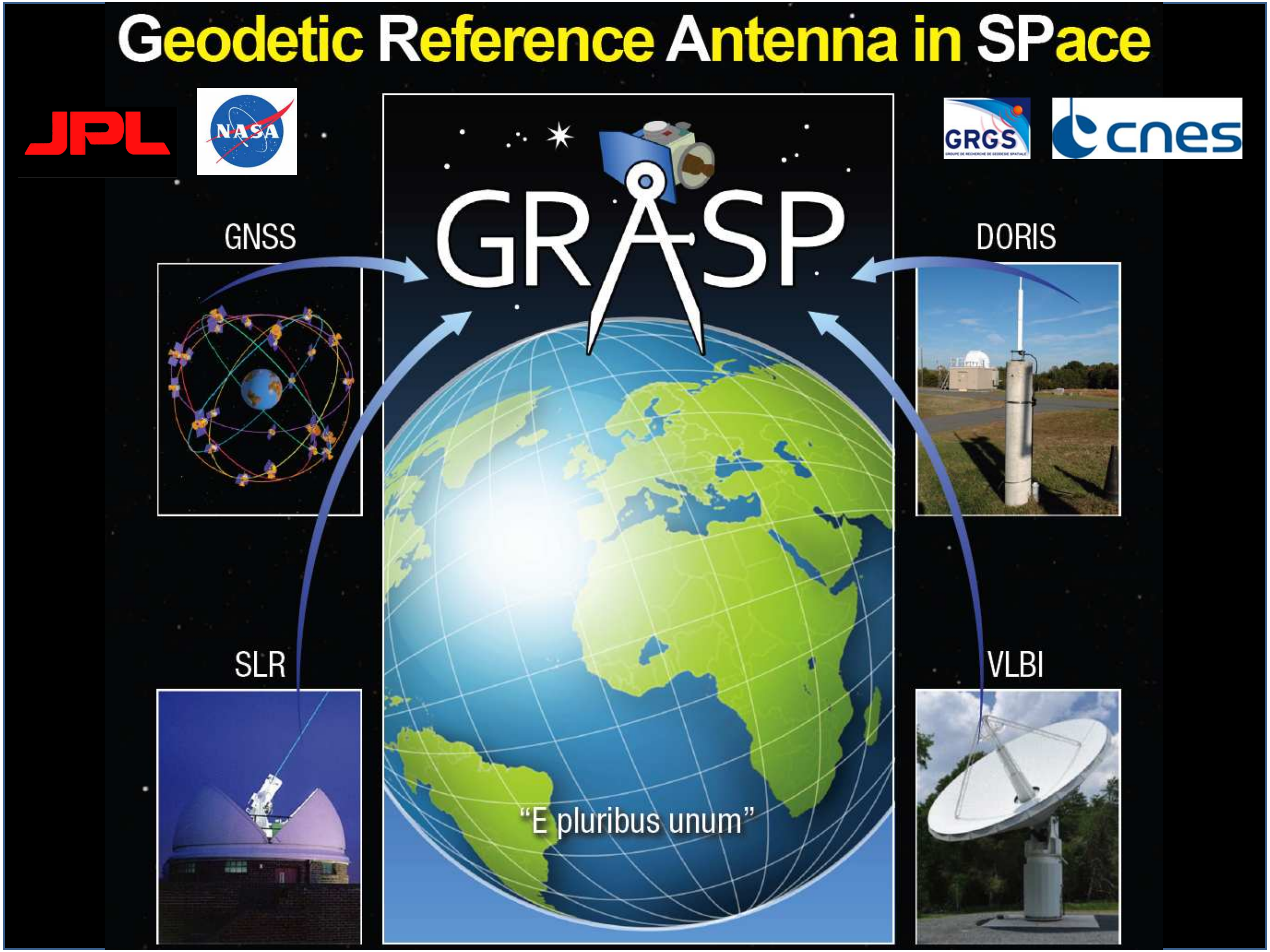

Geodetic Reference Antenna in SPace
JPL
NASA
GRGS
cnes
GRASP
GNSS
DORIS
SLR
VLBI
"E pluribus unum"

Atelier GRASP

23 octobre 2014 – Salle de l'Espace – CNES/Paris

10h00 - introduction au projet de mission GRASP (R. Biancale)
10h15 - contexte programmatique CNES (P. Ultré-Guérard)
10h30 - proposition d'instrumentation nationale:

- DORIS (Albert Auriol)
- MicroSTAR (Bernard Foulon)
- T2L2 (Pierre Exertier)

11h30 - applications géodésie (coordinateur : Z Altamimi)

- L'ITRF et les sites colocalisés (Zuheir Altamimi)
- GRASP et VLBI, apports mutuels (Géraldine Bourda)

12h15 - analyse orbitale : recherche de configurations optimales (Arnaud Pollet)
12h30 - *pause*
14h00 - applications métrologie temps-fréquence (coordinateur : P. Wolf)

- Applications Temps/Fréquence (Peter Wolf)

14h30 - applications physique fondamentale (coordinateur : G. Métris)

- Physique fondamentale par comparaison d'horloges (Peter Wolf)
- Physique fondamentale par l'orbitographie (Gilles Métris)

15h00 - applications environnement spatial (coordinateur : F. Deleflie)

- Mesure du bilan radiatif : historique des orbites et missions (Michel Capderou)
- L'expérience Biramis (Anne-Marie Mainguy)
- Intérêts éventuels de GRASP pour la thermosphère (Sean Bruinsma)

15h30 - synthèse et discussion
16h30 – *fin*

Context

2011 NASA's Earth Venture-mission call of opportunity
GRASP-2011 not selected but well graded (2nd place after CYGNSS)

Spring 2014 CNES prospective colloquium
F-GRASP mission proposal selected in Solid Earth theme

Fall 2014 GRASP proposed in CNES' phase 0
F-GRASP mission proposal passed the "atouts-attraits" procedure

2015 NASA's Earth Venture-mission call of opportunity (class B mission)
GRASP-2011 concept will be re-proposed with some modifications

Mission in JPL-CNES partnership (3 yrs nominal + extension)
Other partnerships still sought (ISRO?)

Anticipated schedule

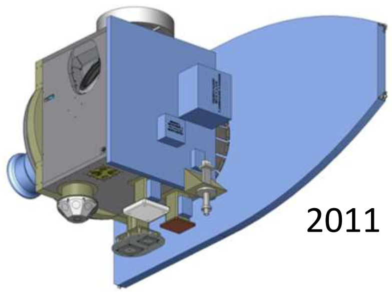
November 2014 :	call announcement
May 2015 :	instrumentation proposal draft
September 2015 :	mission proposal submitted
December 2015 :	selection (?)

Proposal

JPL

- Platform (Flexbus/Airbus Defence & Space, GRAIL/Lookheed Martin…)
- Launcher (2019)
- Operation responsability
- GNSS receiver (TriG)
- VLBI tone transmitter
- Laser reflectometer
- Star sensors

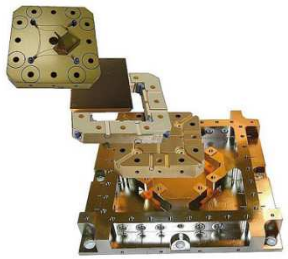
Ball Aerospace & Technologies Corp.
Agility to innovate,
Strength to deliver



2011

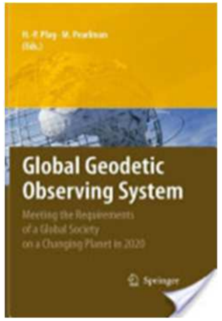
CNES

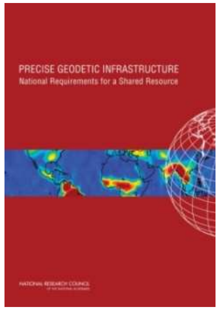
- JPL request:
  - DORIS DGXX-S receiver
- GRGS proposal for additional equipment:
  - 3D MicroSTAR accelerometer
  - T2L2
- Implementation (?)



Need for pre-launch calibration of all on-board systems

Scientific objectives





Primary objective

Unifying the terrestrial reference frame (TRF)
as defined by GGOS for the 2020 horizon:
TRF global accuracy of 1 mm and 0.1 mm/y stability.

"To achieve the GGOS program goals and support future high-precision geodetic science, the ITRF needs to be robust and stable over many decades. Future scientific objectives drive a target accuracy of 0.1 millimeters per year in the realization of the origin of the ITRF relative to the center of mass of the Earth system and 0.02 parts per billion per year (0.1 millimeters per year) in scale stability." (NRC, 2010)

Geodetic goals

TRF, determination of inter-system biases…

Geophysical applications

Sea level rise, tectonics, earthquakes, current ice melting, mass balance of the Earth-Ocean-Atmosphere system…

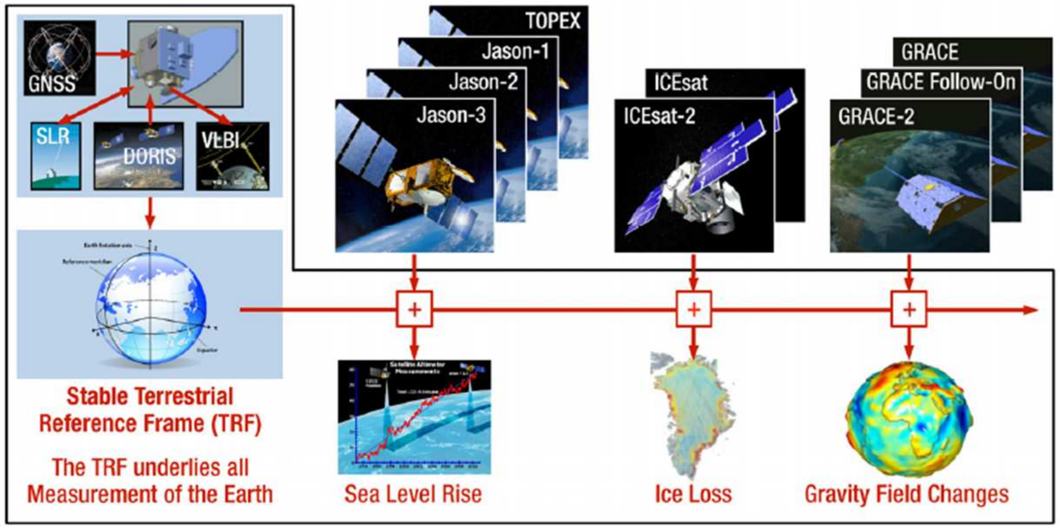
Secondary science

Time transfer and synchronization, fundamental physics, high thermosphere, Earth radiation budget…

Mission goals / JPL

GRASP Remains Dedicated to Providing Stable Reference Frame for Climate Change Measurements

- 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
- 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
- Reinterpret ICESat and GRACE data records to determine ice mass loss relative to the GRASP-based TRF – how is ice mass loss accelerating

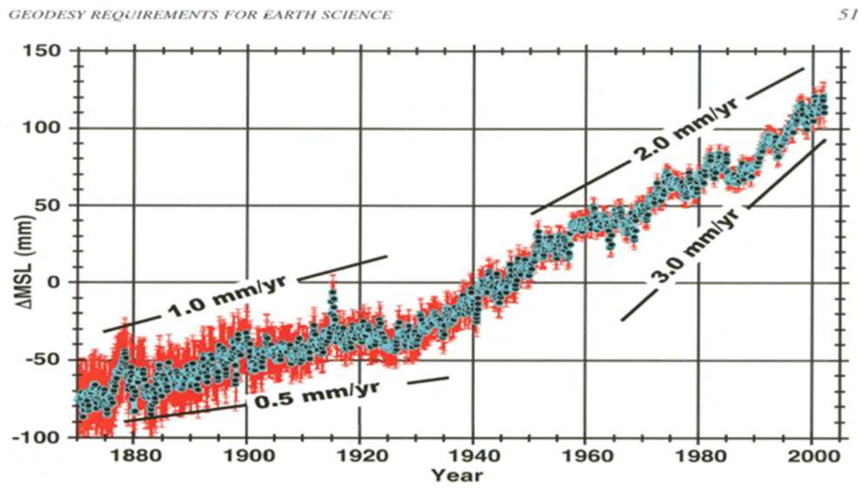


Courtesy Y. Bar-Sever

Impact on sea level

Impact of TRF Error on Global Mean Sea Level (GMSL)

Record from Spaceborne Altimetry



Altimeter Global Mean Sea Level Measurement Error Budget	
Glacial isostatic adjustment (affects volume of ocean basins)	0.1 mm/y
Altimeter drift error (predominantly radiometer drift)	0.4 mm/y
Altimeter bias errors (the ability to link overlapping missions)	0.4 mm/y
Reference frame origin error (affects the satellite orbits)	0.2 mm/y
Systematic vertical motion error (affects the altimeter calibration)	0.4 mm/y
Total error (root-sum-squared)	**0.6 mm/y**

RSS = 0.45 mm/yr

Impact of TRF on GMSL Record from Tide Gauges: competing approaches for TRF realization yield estimates for sea-level rise ranging from 1.2 to 1.6 mm/yr.

Desired accuracy for measuring global mean sea level (GMSL) rise is 0.1 mm/yr.

Courtesy Y. Bar-Sever

Specification validation

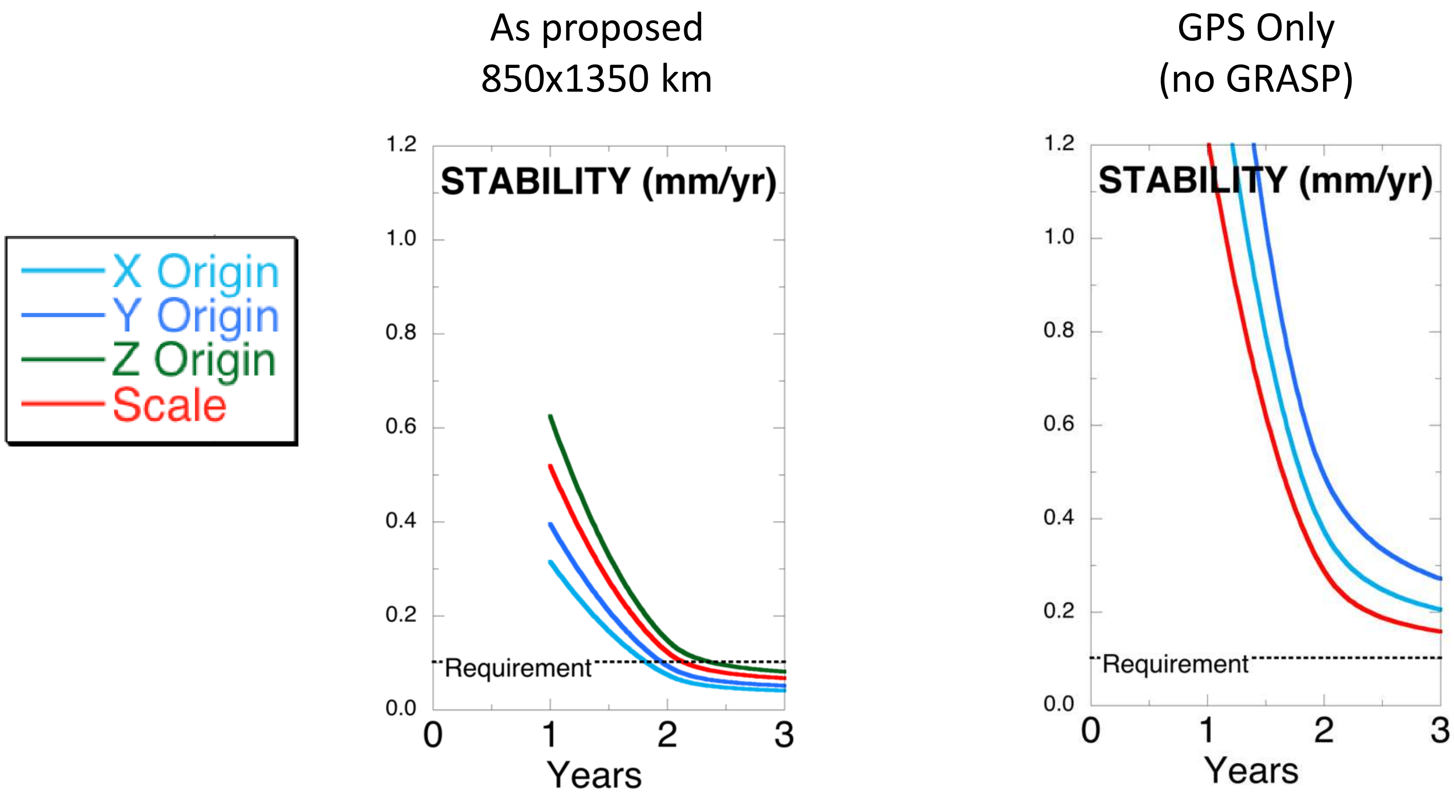
Mission analysis / GRGS
Simulations based on analytical approaches and stochastic optimization to provide a set of possible orbital configurations which fulfill different requirements such as visibility constraints.

Performance / GRGS
Simulations based on numerical processing in realistic orbit computation environment to provide precisely the required level of quality for the calibration of the GRASP instruments, the needed orbit accuracy… to reach the mission goals. Actual multi-technique missions such as Jason-2 and GRACE satellites can also be used as prototypes to get a preliminary assessment of the GRASP requirements.

Network improvement
“The committee recommends that the United States should work with its international partners to increase the number of multi-geodetic technique sites (particularly co-locating VLBI and SLR), with a goal of reaching a global geodetic network of at least 24 fundamental stations.” (NRC, 2010)
“The first objective of the cooperation is to update the Implementing Agencies’ existing space geodesy networks. As a first step, CNES will upgrade the Tahiti Geodesy Observatory.” (NASA-CNES Implementing Arrangement, 2013)

JPL simulations

Extensive simulations supported the proposed mission goals with 850x1350 km orbit



Additional simulations after the submission of the 2011 proposal should explore different orbital configurations

The addition of an accelerometer may open up new orbit trades → ~2000 km altitude

JPL simulations

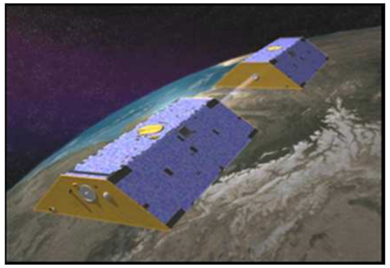
Extrapolating GRASP performance from present-day missions

Inter-technique biases and drifts are obstacles to achieving the required TRF stability

GRASP will offer a common target for all techniques with which to explore the nature of technique-specific systematic errors

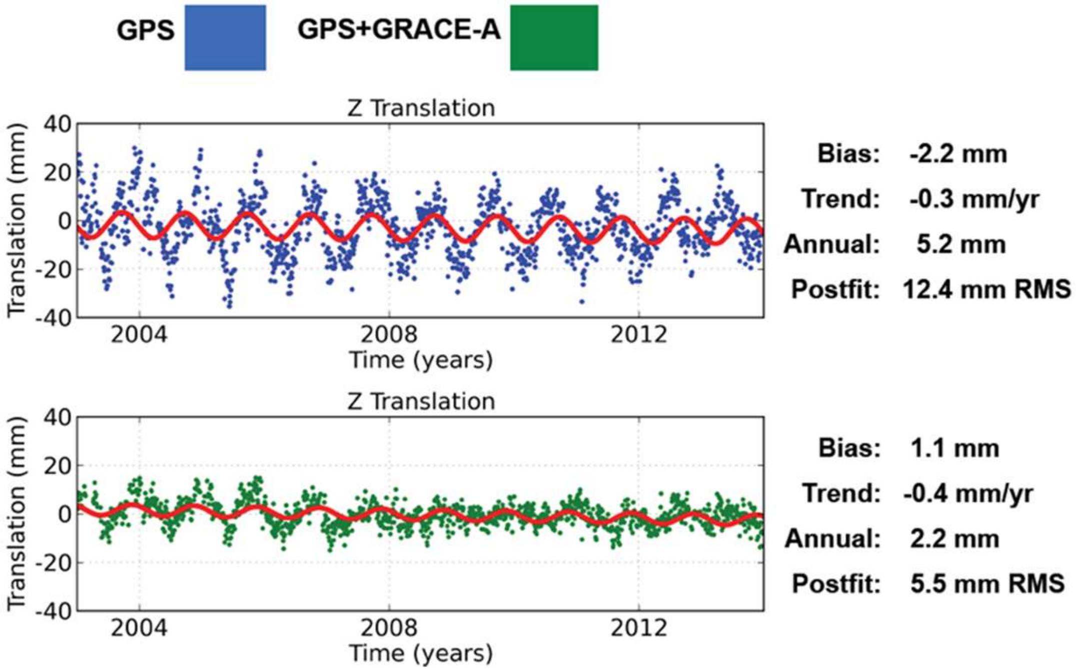
Using GRACE-A as a GRASP proxy (only SLR and GPS data available) shows promise

- Reduces some TRF biases relative to SLR
- Also shows limitations of GRACE and need for full GRASP capabilities: few SLR measurements, relatively poorly-understood dynamics, no DORIS, VLBI,…
- Note that GPS alone is already competitive with other techniques



GPS Only

GPS + GRACE-A



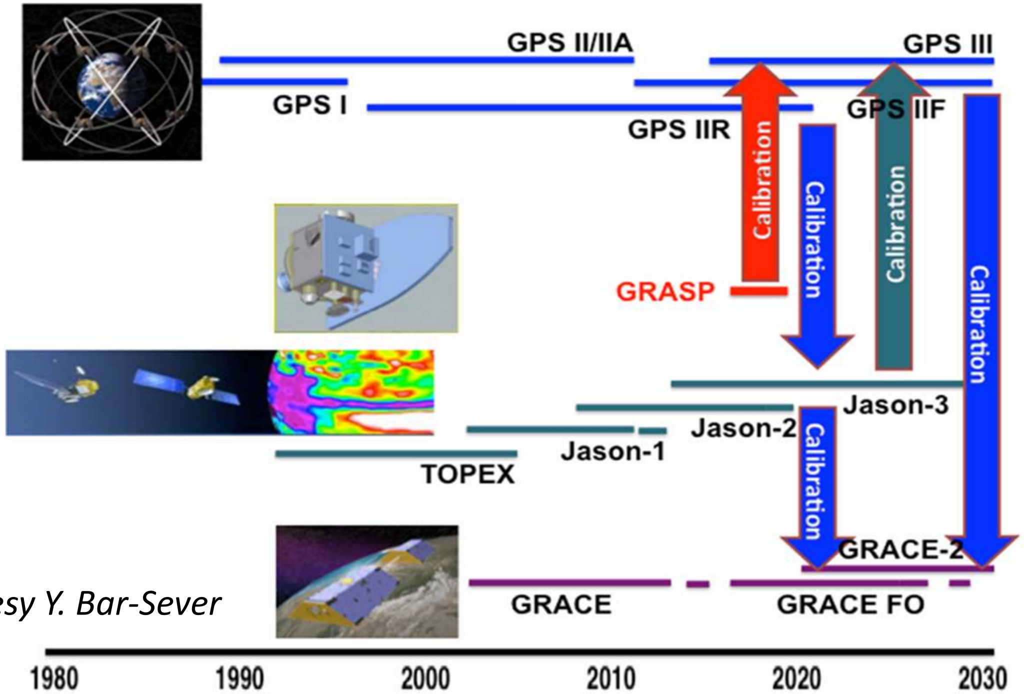
Courtesy Y. Bar-Sever

Summary

GRASP is the most complete geodesy-focused mission ever: all the techniques participate, all geodetic disciplines benefits

GRASP is a flying geodetic super-site, offering a straightforward path to meeting the demanding TRF stability and accuracy requirements of the geodetic community

GRASP's benefits extend well beyond the mission lifetime, into the past and into the future, through a cascade of secondary GNSS antenna calibrations



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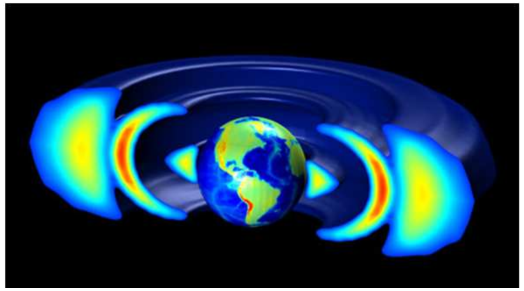

Instrument capability to be checked in phase 0 study

TRL > 5 necessary