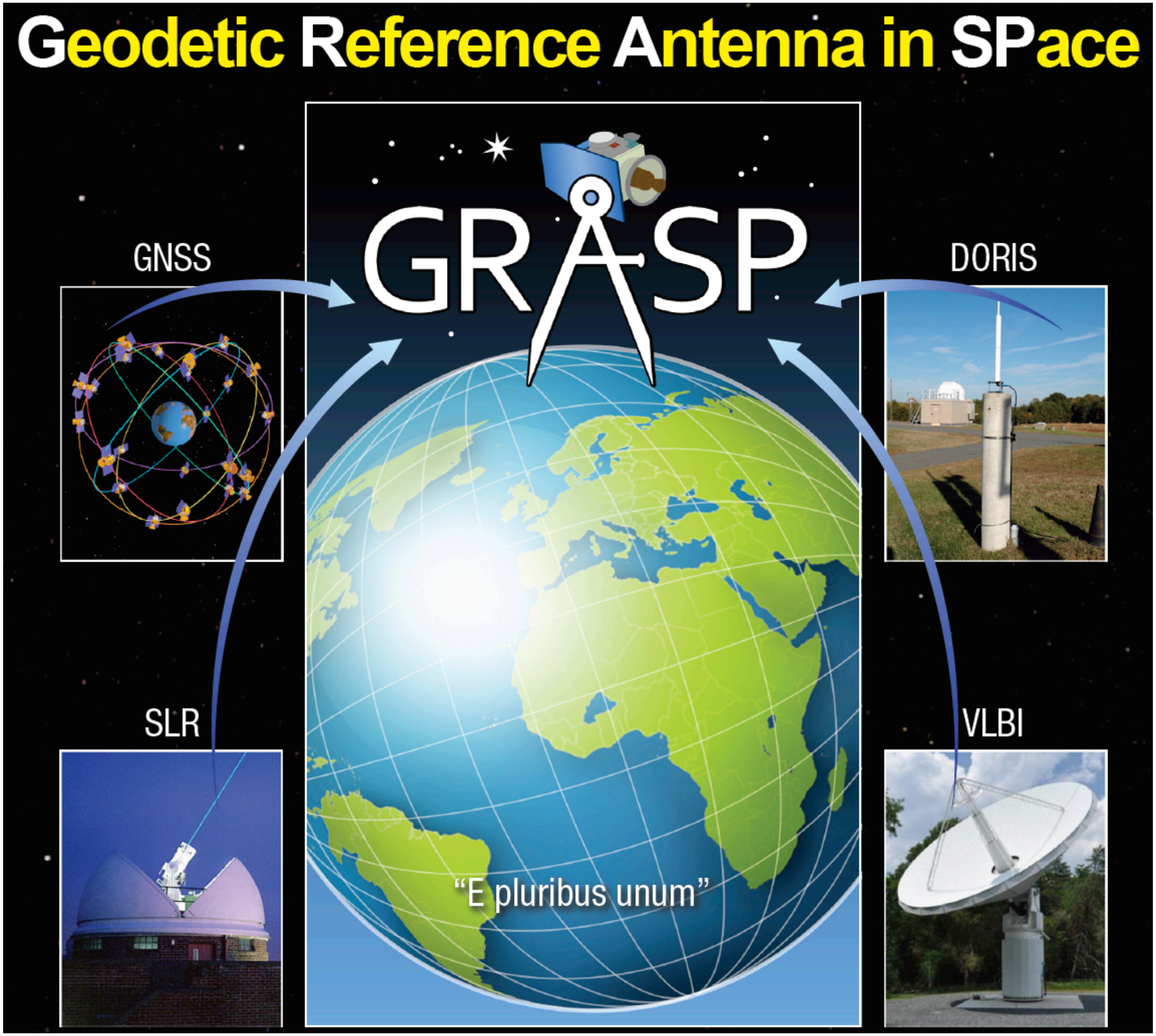
Geodetic Reference Antenna in SPace
GRASP
GNSS
DORIS
SLR
VLBI
"E pluribus unum"

GRASP Update

Proposal submitted to NASA on Sep 29

Award is expected April 2012

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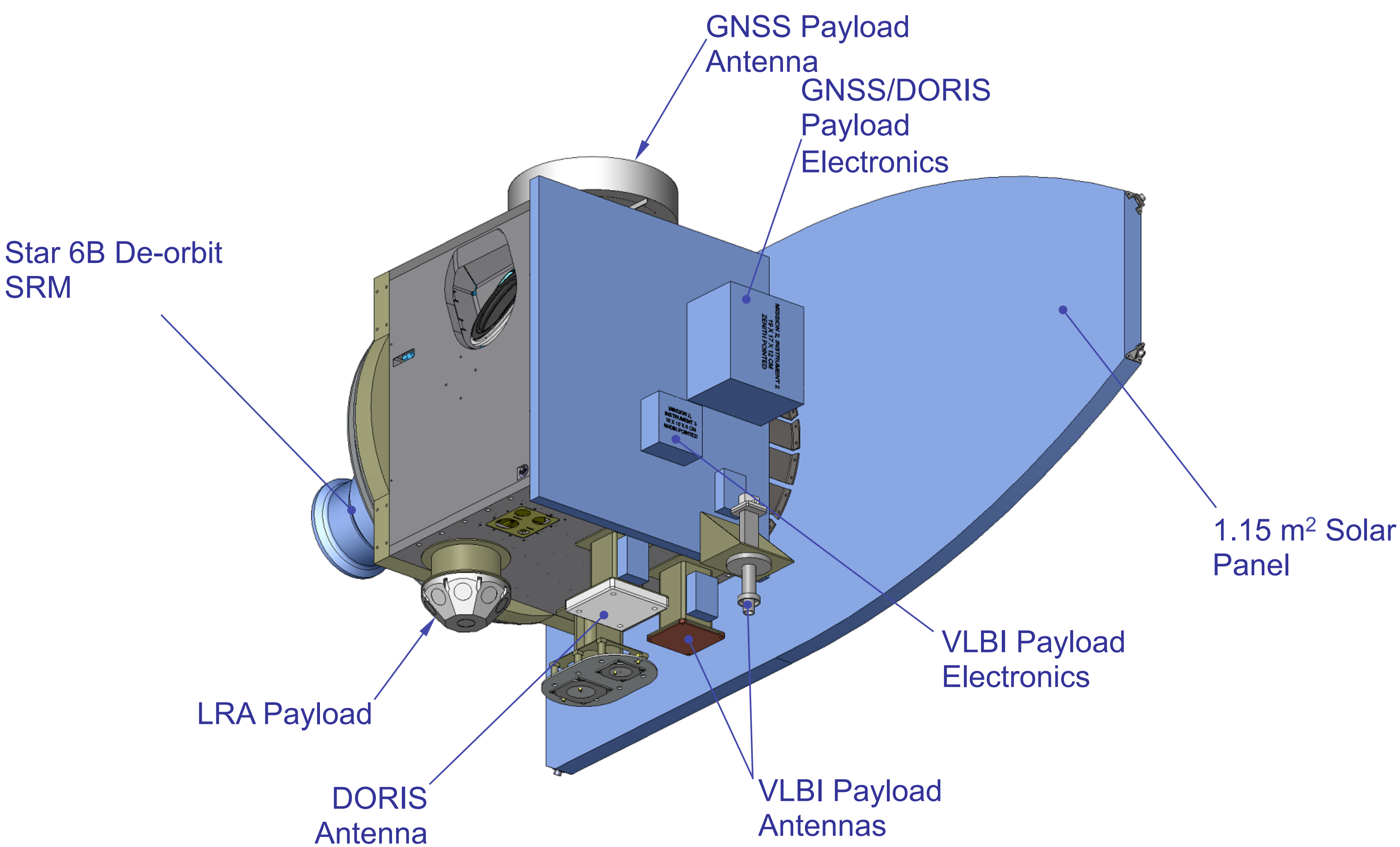
Launch: February 2016; Mission duration: 3 years

Acknowledging the GRASP proposal team at JPL: Zach Bailey, Shailen Desai, Marie Deutsch, Beth Fabinsky, Garth Franklin, Nate Harvey, Mike Heflin, Bill Klipstein, Da Kuang, Chris Landry, Fengchuan Liu, Wenwen Lu, Don Royer, Frank Webb, Frank Wu, Peter Xaypraseuth, Larry Young

The GRASP Spacecraft



YEB, Sep 2011

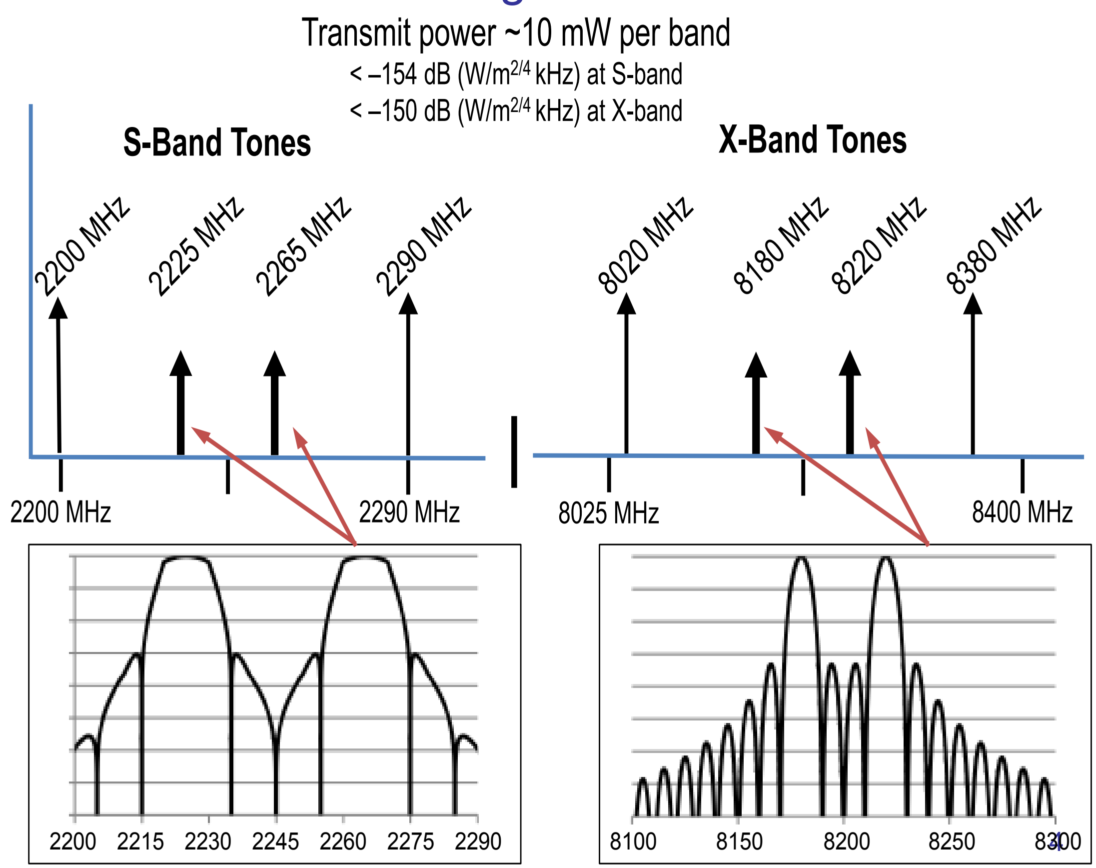
Novel Instruments on GRASP

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

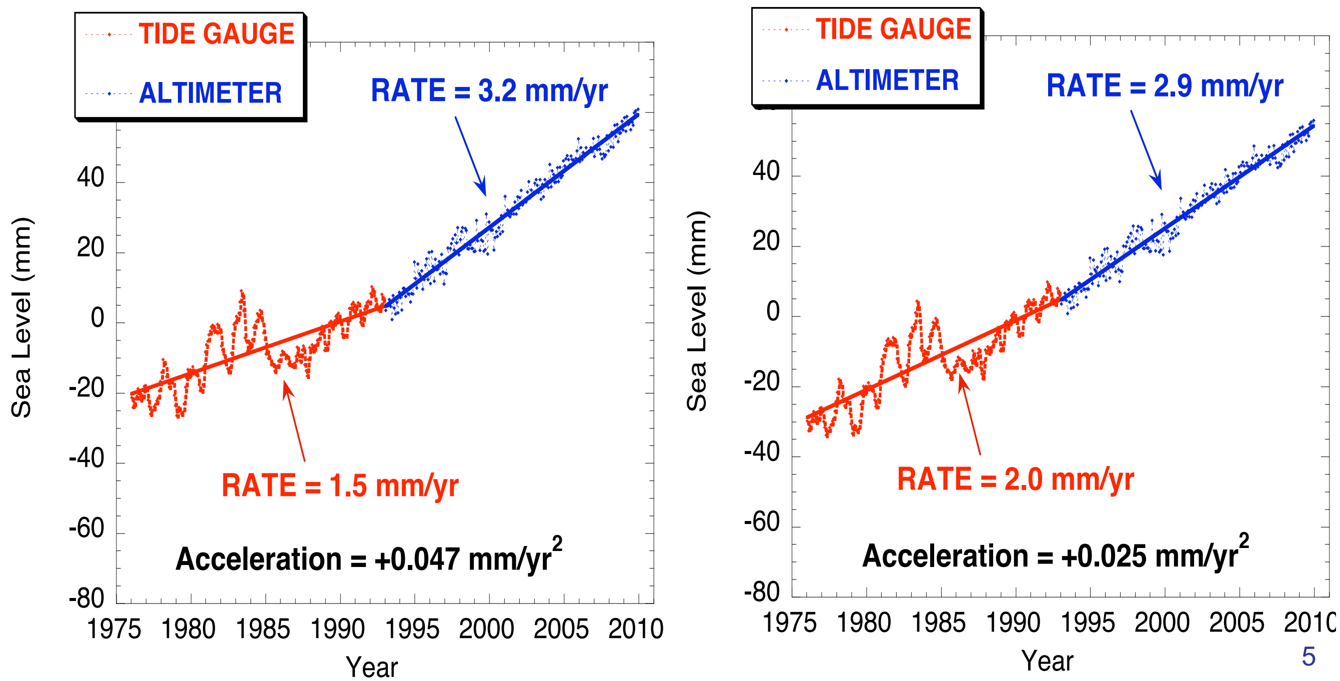


Key Science Goals

- **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
- 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 satellite ICESat and GRACE data records to determine ice mass loss 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)



GRASP Simulations: TRF Errors

Simulate GPS (50 sites) and SLR (24) tracking sites to GPS and GRASP; add key error sources, one at a time

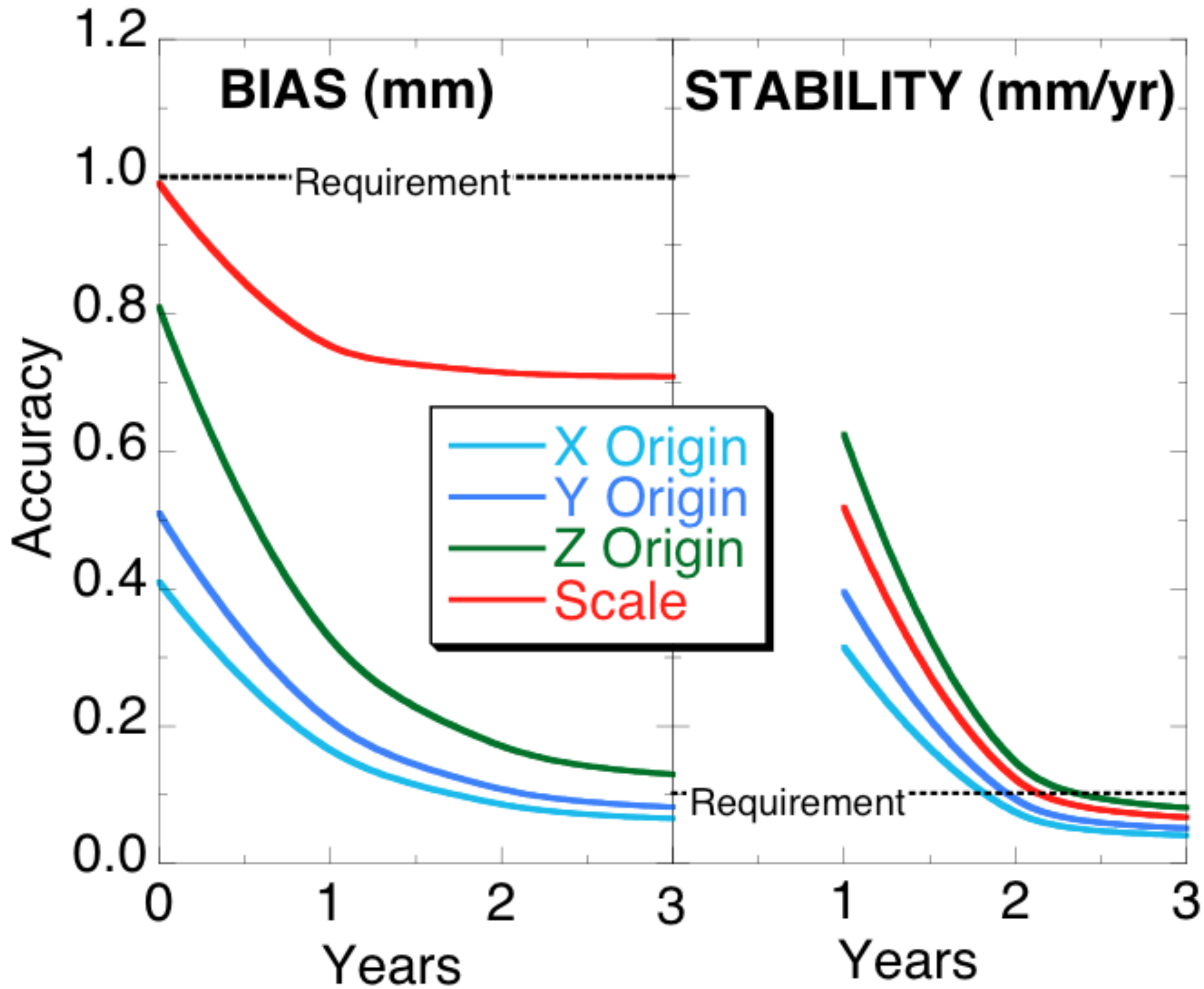
Perform *Fiducial-free, reduced-dynamics* network solution, estimating GPS and GRASP states, plus all site position,

Compute the Helmert transformation between the estimated network and the ‘true’ network, and extract the X,Y,Z geocenter shift, and scale.

Error Source	X (mm)	Y (mm)	Z (mm)	Scale (mm)
Measurement Noise	-0.32	-0.48	-0.20	-0.40
Troposphere	0.01	-0.06	0.10	-0.26
GPS Solar Pressure	-0.10	0.00	-0.58	0.02
Gravity	0.13	-0.03	0.42	0.18
Tides	0.09	0.15	-0.01	-0.04
Drag	0.17	-0.10	0.02	-0.05
GRASP Solar Pressure	0.01	0.04	0.15	0.08
Earth albedo	0.01	0.00	-0.28	0.05
Dynamic CM-APV Calib	0.00	0.00	0.00	0.30
RSS (Dynamic)	**0.41**	**0.51**	**0.81**	**0.67**
Static CM-APV Calib	0.00	0.00	0.00	0.70
RSS (Dyn + Static)	**0.41**	**0.51**	**0.81**	**0.99**

GRASP Simulations: TRF Errors (cont)

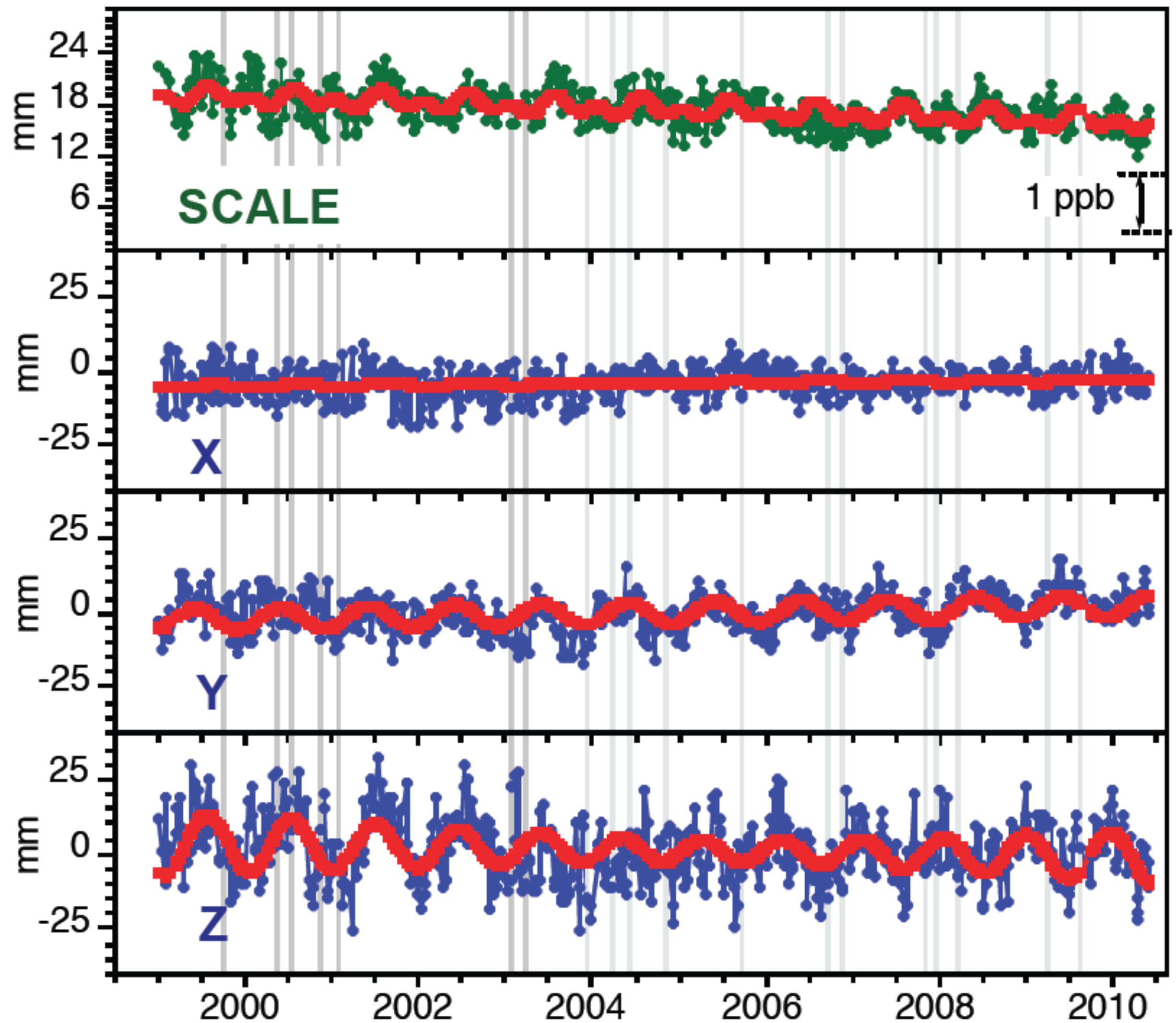
Assume that the dynamic error is mostly random over three years, and perform least squares fit of $f(t) = A + B\,t + C \cos 2\pi\, t + D \sin 2\pi\, t$, where t is in years, to the TRF components



Too Optimistic?

GPS frame (ground data only) already agrees with ITRF08 to within its stated errors

- Fiducial-free network solution



Bias (2005)	+17 mm
Trend	–0.3 mm/yr
Annual	1 mm
Semi Ann	1 mm
RMS Res	2 mm
Bias (2005)	–4 mm
Trend	+0.2 mm/yr
Annual	1 mm
RMS Res.	5 mm
Bias (2005)	+0 mm
Trend	+0.4 mm/yr
Annual	4 mm
RMS Res.	5 mm
Bias (2005)	+1 mm
Trend	–0.4 mm/yr
Draconitic	9 mm
Annual	5 mm
RMS Res.	10 mm

Source: Haines et al., 2010

GRASP Simulations: VLBI PPP

Assume GRASP orbit is truth, and perform precise point positioning of VLBI sites with the VTT phase measurements

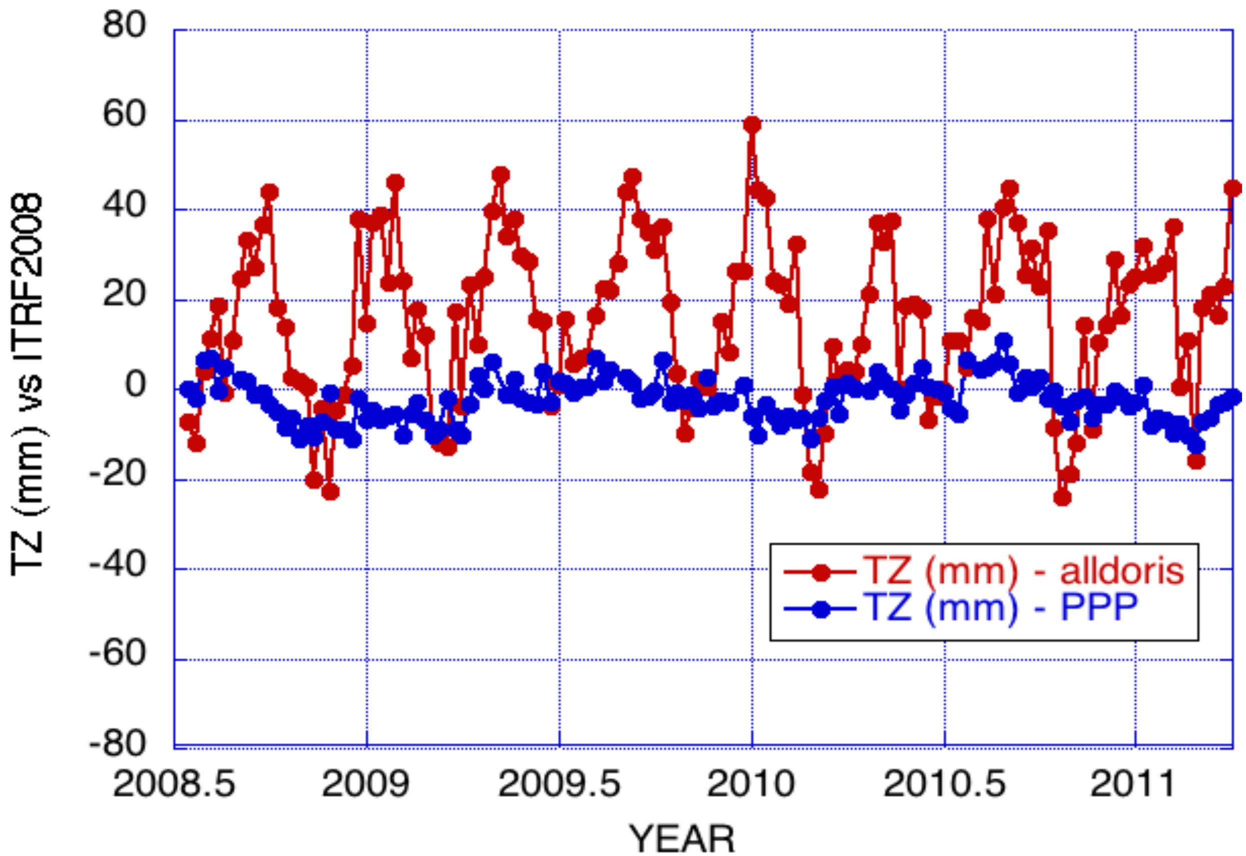
- Iono-free signal combination
- 5 degrees elevation cutoff (~1000 sec pass)
- 3-4 passes per day depending on site
- 10 sec data rate
- 2 mm white noise (much larger than the VTT system noise)
- Troposphere perturbed by VMFGRID-GMF
- GRASP clock is reference to ground maser via GPS

Estimate:
- VLBI site position, unconstrained
- Phase bias, unconstrained
- Zenith troposphere delay as random walk 0.05 mm/sqrt(s) with 5 min updates
- VLBI clock as random walk with 1 mm/sqrt(s) (corresponding to 10^{-13} Allen Deviation at 1000 s) and 10 sec updates

=> 1 cm site position obtained after just 7 days

DORIS Dissemination of the TRF

Using Jason-2 as a proxy for GRASP, perform ppp of DORIS sites using the GPS-determined orbit of Jason-2. Compare to DORIS internal network solution with all DORIS satellites.



Summary

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

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

GRASP is likely to produce a lot more science than we can now envision