Using LISA Pathfinder as gravity gradiometer

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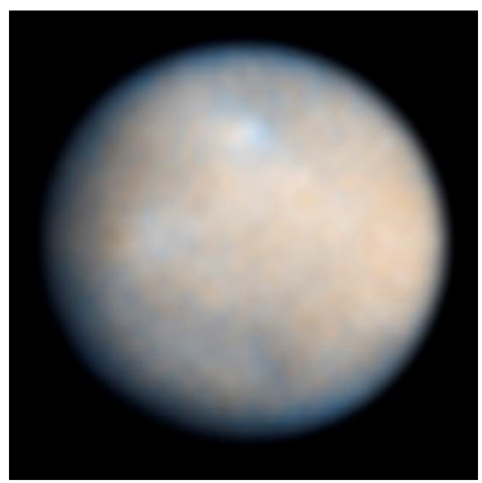
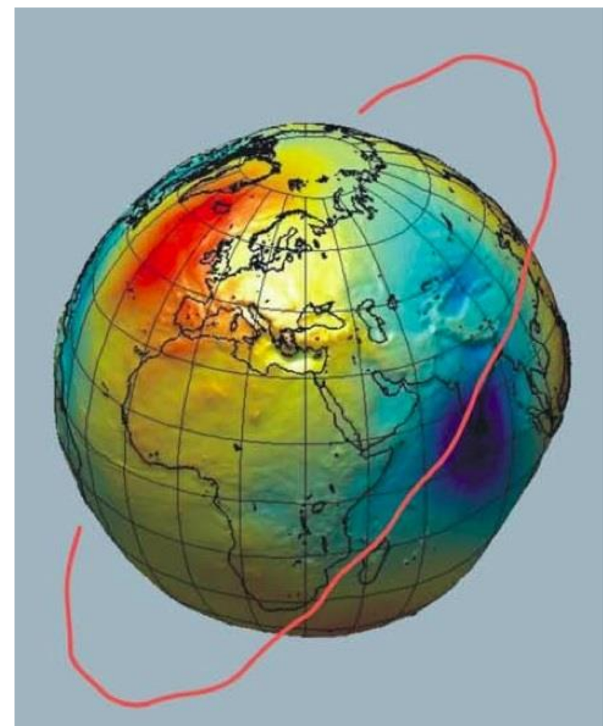
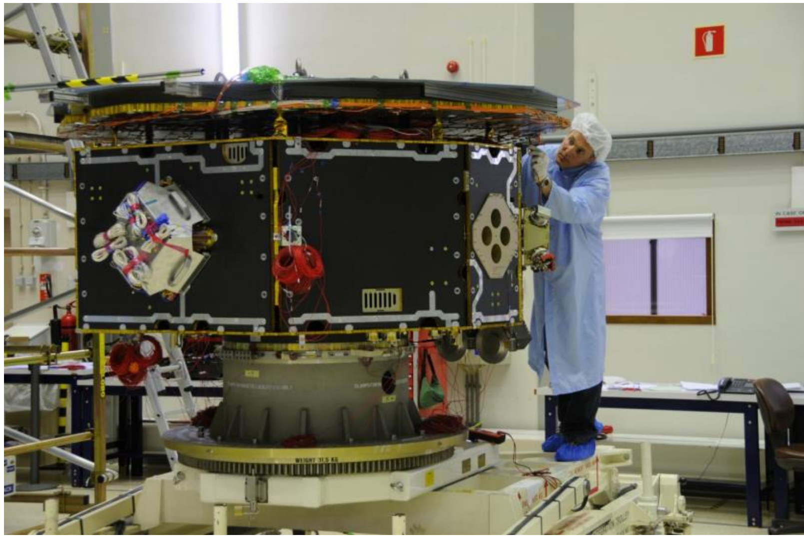
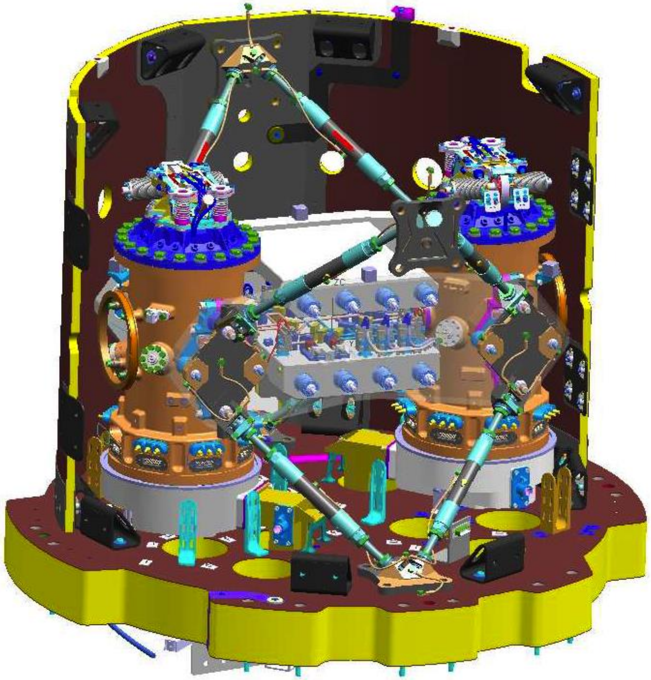


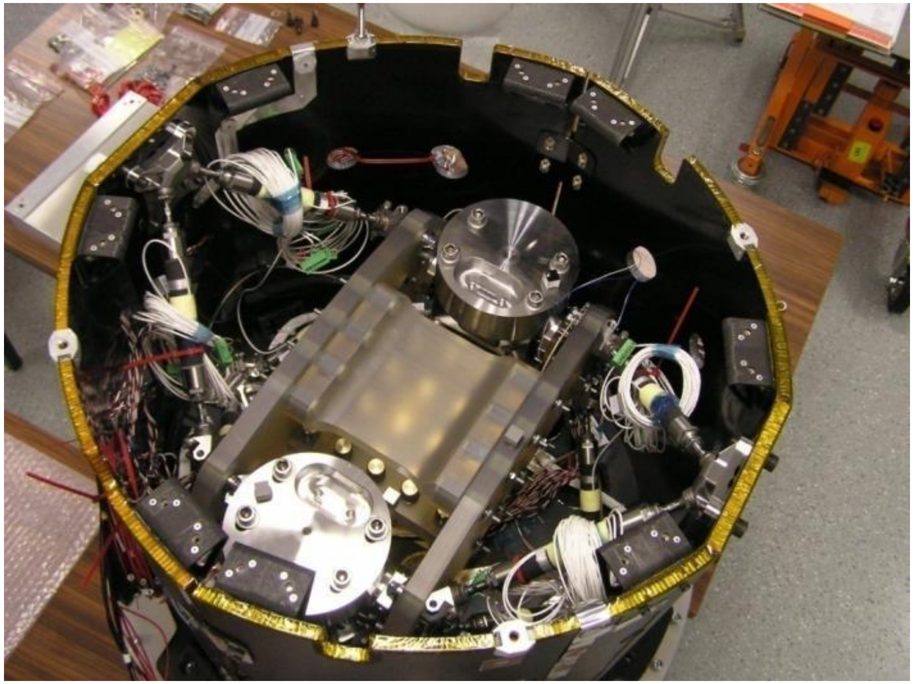


LISA Pathfinder

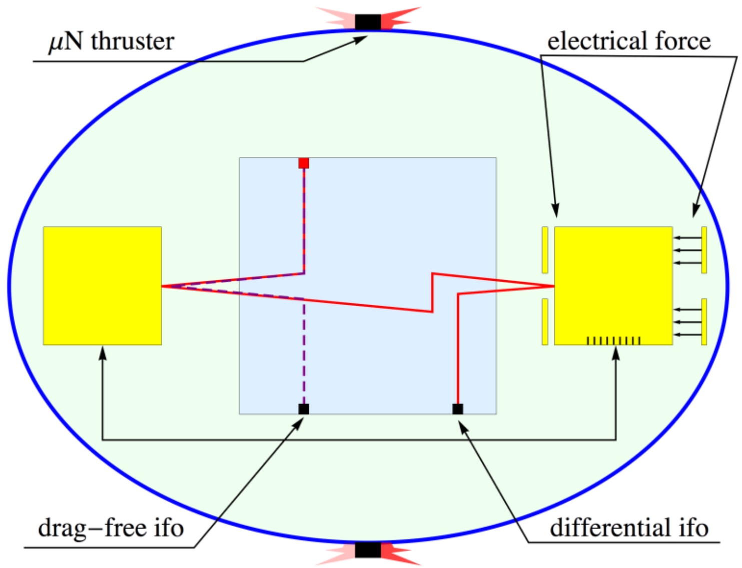
- Technology demonstrator for gravitational wave missions LISA/eLISA/NGO (ESA L3 theme)
- Launch 2015 with VEGA from Kourou

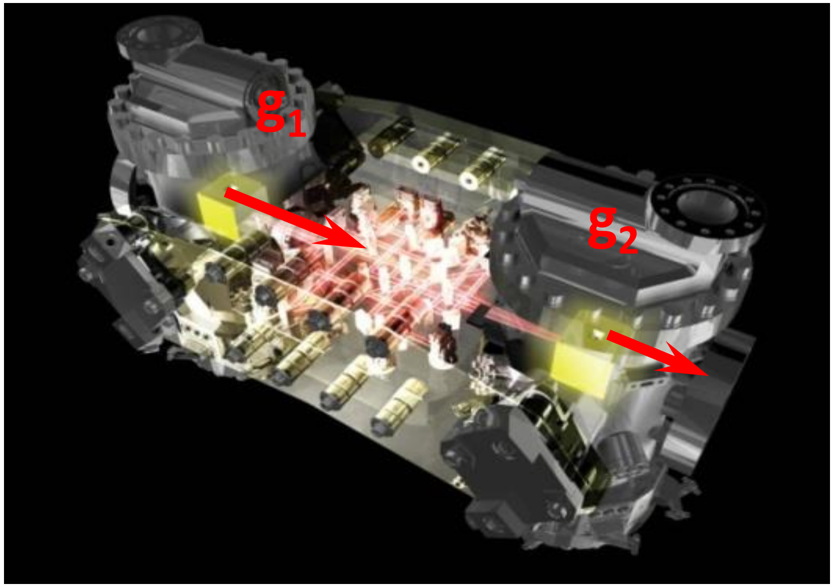






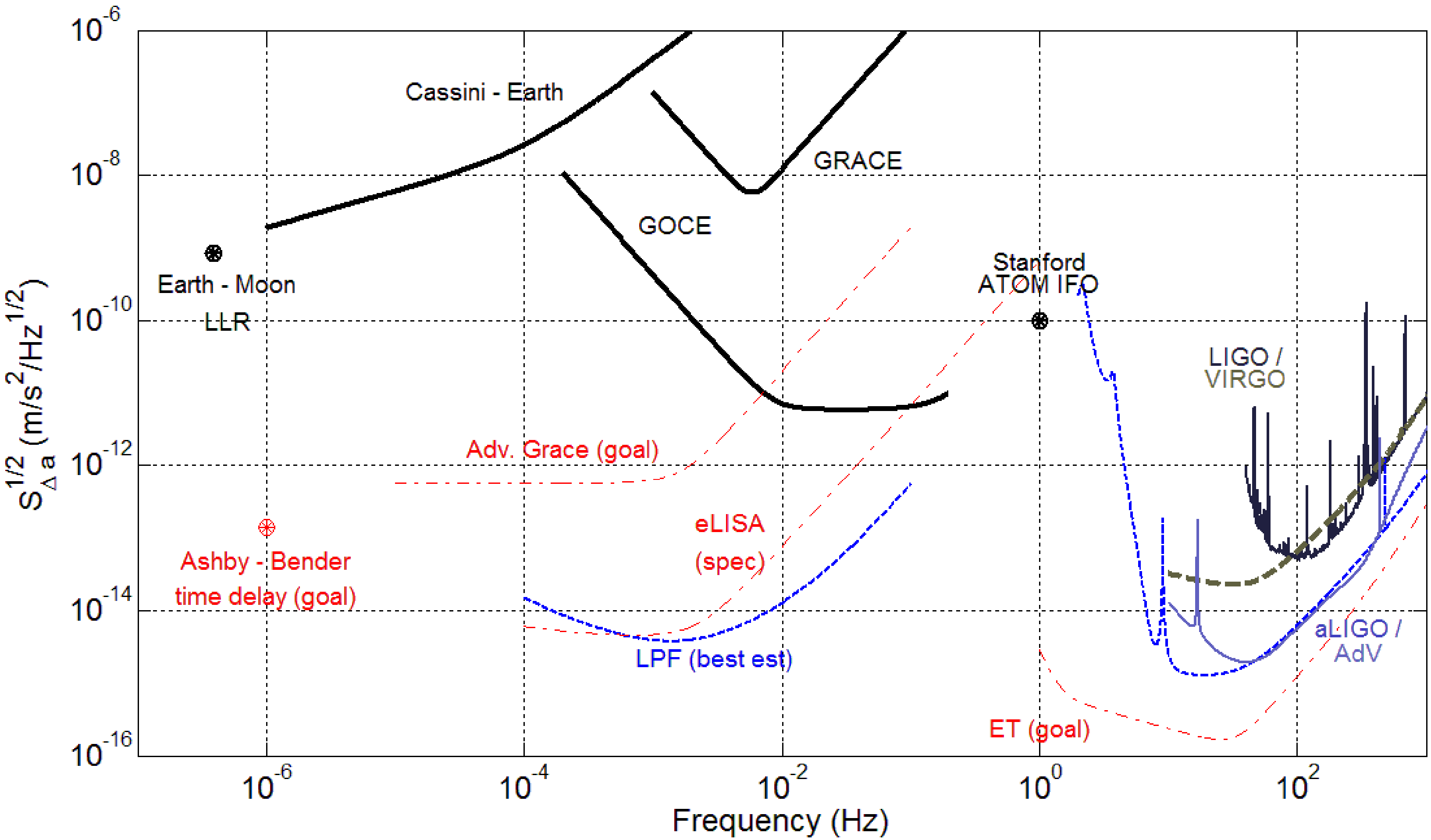
LISA Pathfinder: Einstein's Geodesic Explorer (2015)





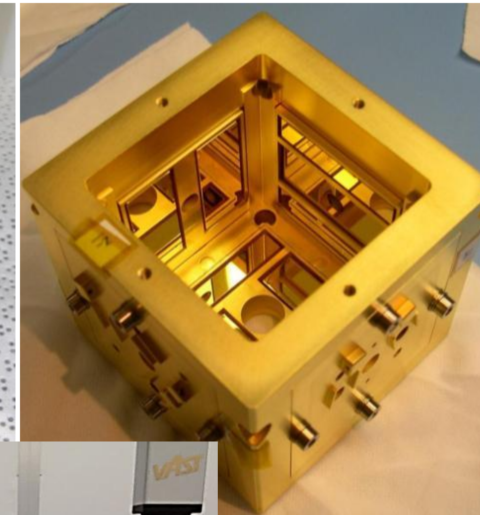
- Compress single eLISA arm to 40 cm inside 1 spacecraft
- Drag-free following TM1, low-frequency suspension of TM2
- Measure differential TM acceleration
- Laser interferometric sensing (10 pm/√Hz) along sensitive axis
- Modest capacitive sensing (3 nm/√Hz) in other axes
- **One-axis gravity gradiometer with 10 fm s^{-2}/√Hz resolution at 1 mHz**

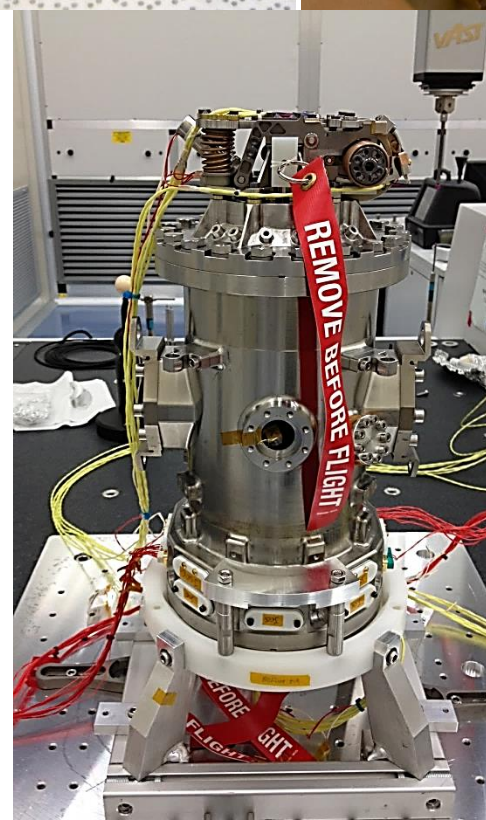
LPF /eLISA GRS in experimental gravitation

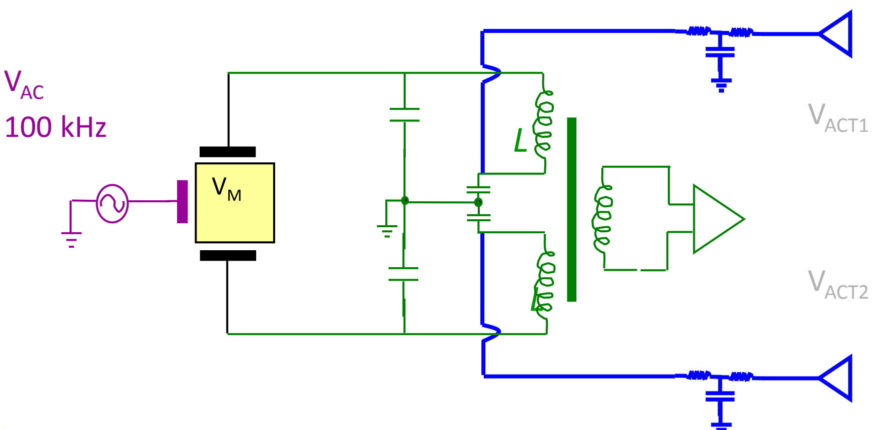


GRS innovations for sub-femto-g/Hz$^{1/2}$ free-fall:

- Heavy Au/Pt test mass
- Large (3-4 mm) gaps
- No discharge wire and contact free injection
- Charge control with UV light
- Audio carrier frequency for «DC» actuation forces

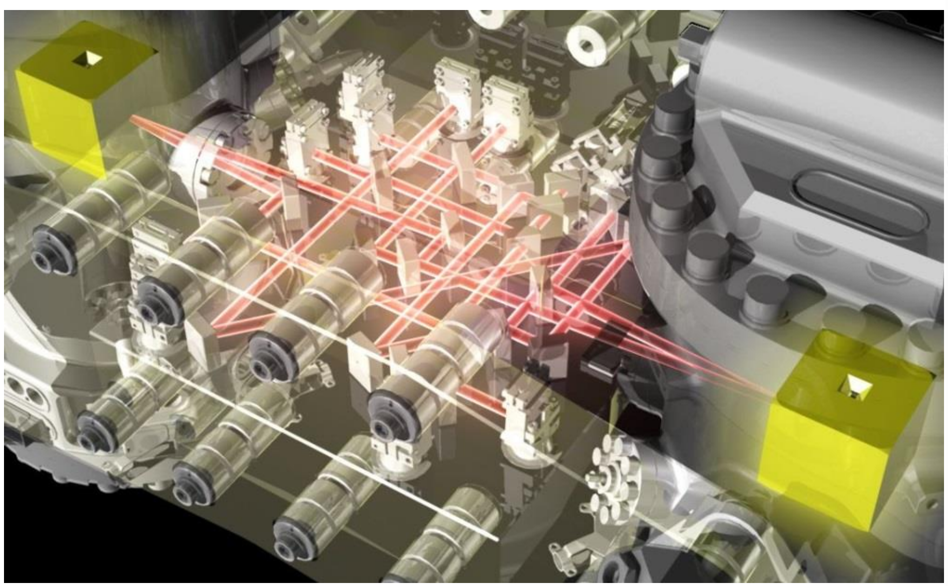


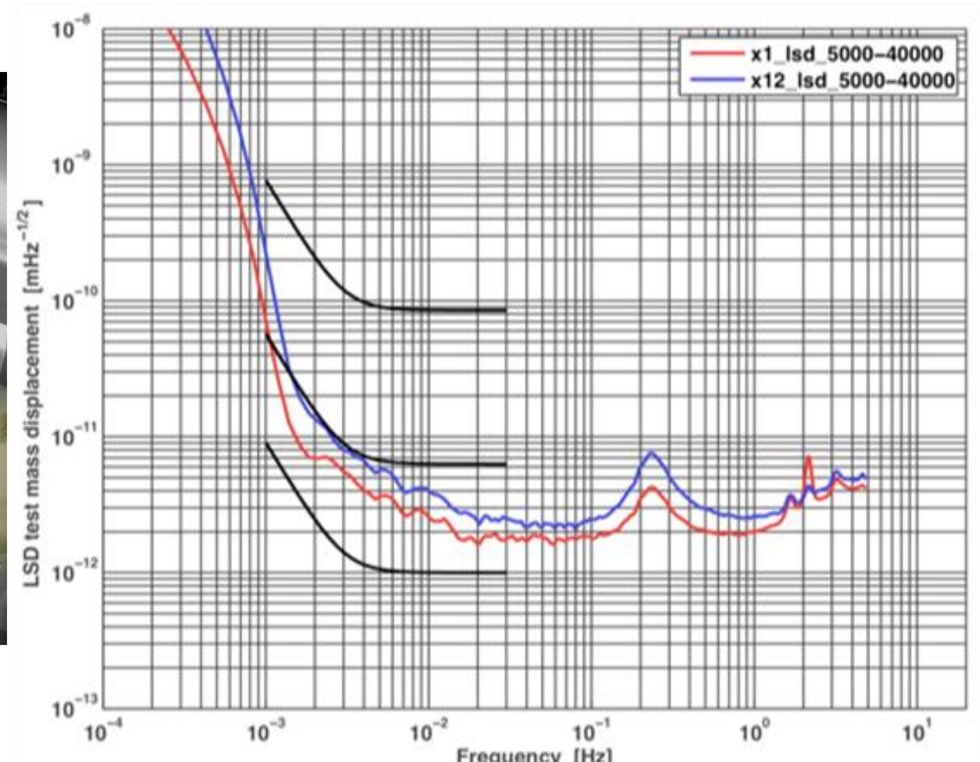




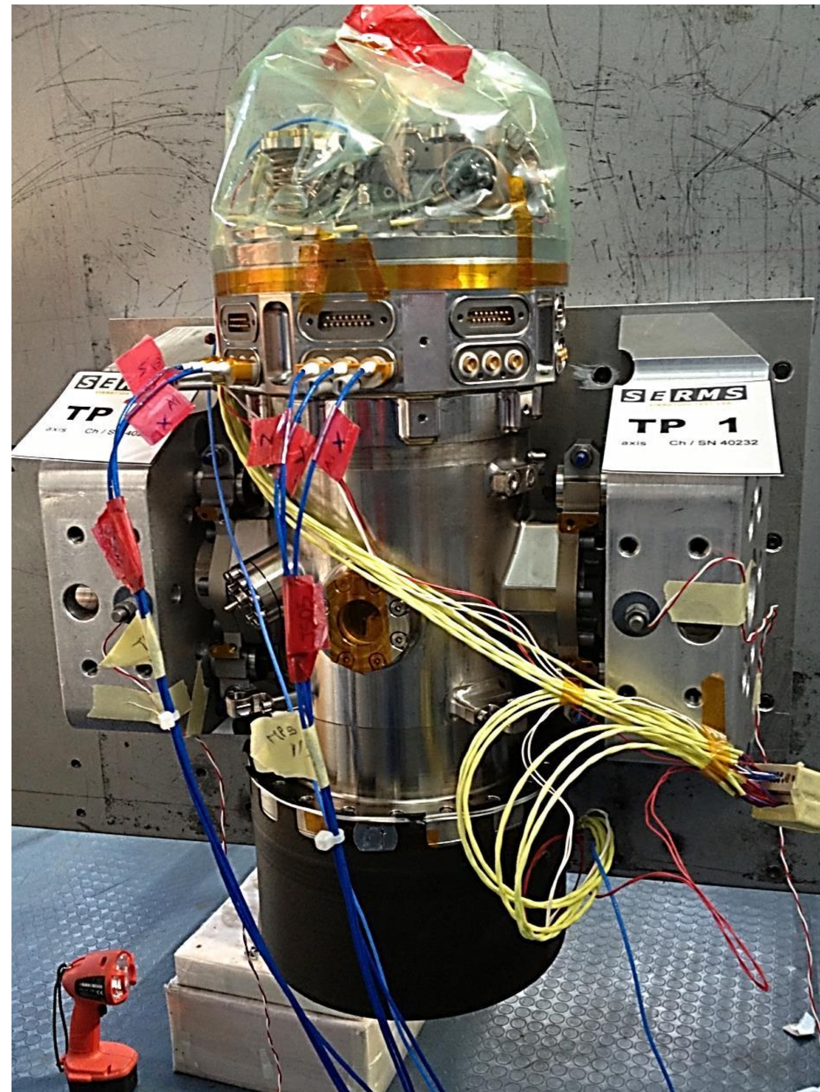
Laser interferometry

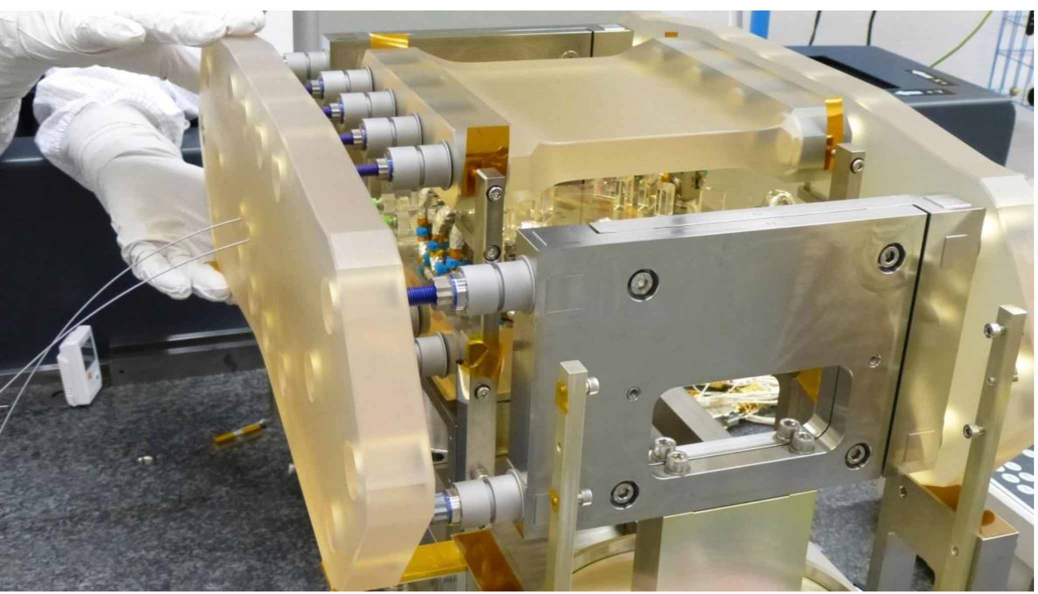
- Heterodyne interferometer using a single laser, kHz heterodyne frequencies, and digital phasemeter
- Measures TM relative motion to pm/√Hz
- Measures TM angles to nrad/√Hz
- Frequency range mHz to Hz
- FM built and tested





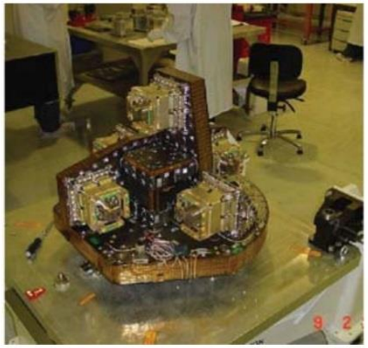
LPF Flight Model Units





Gravity gradiometry

- Pioneered by GOCE (2009-2013), using electrostatic gradiometer by ONERA
- Orders of magnitude improvement possible with LISA Pathfinder Interferometer and GRS hardware (in quiet orbit)



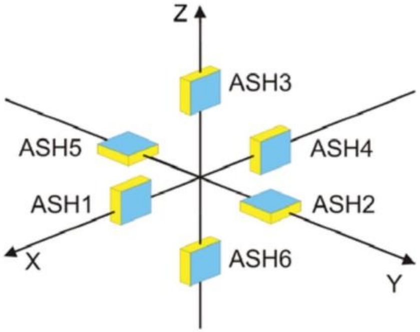
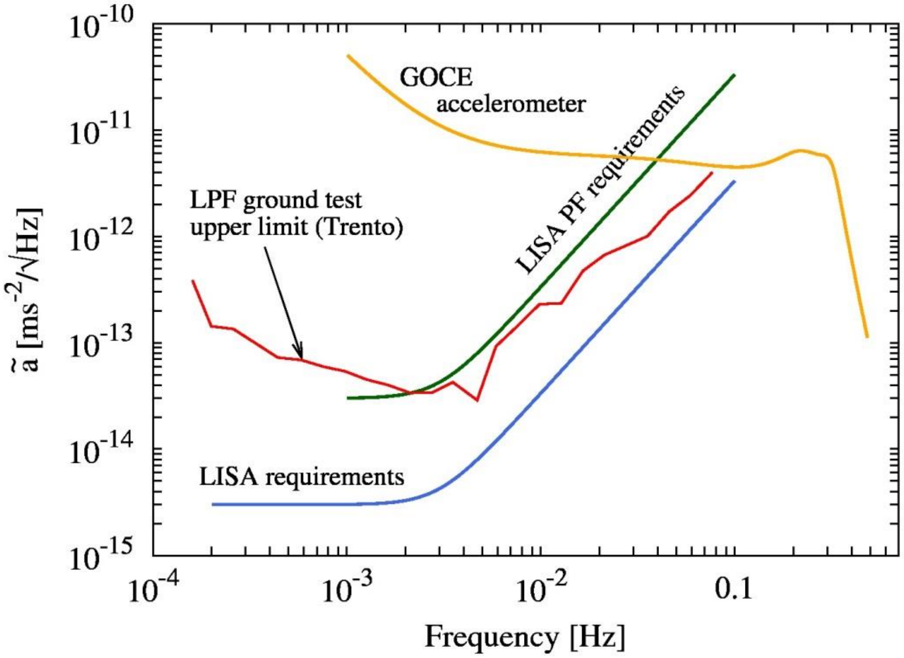


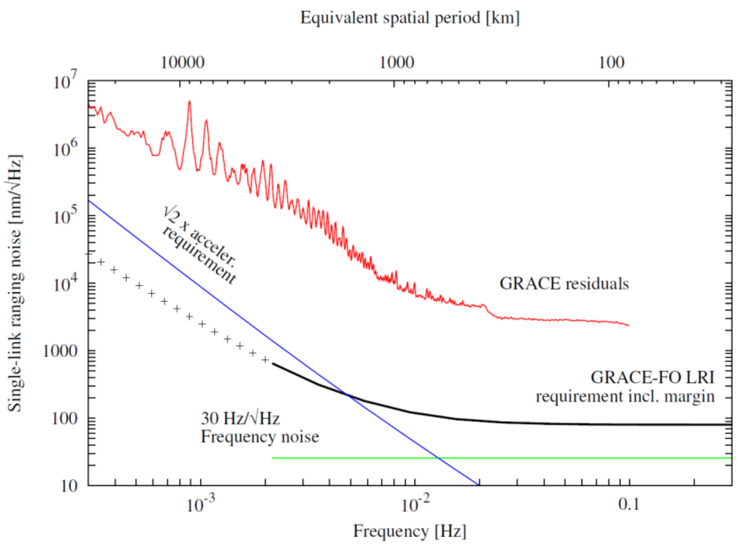
Image credit: ESA

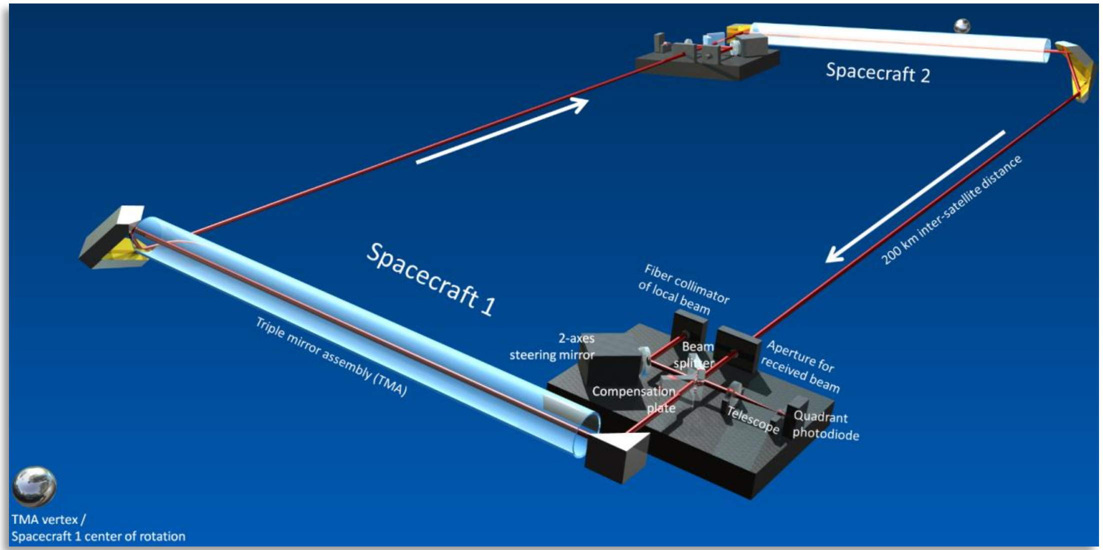


GOCE accelerometer performance using data from:
Stummer, Claudia S.: PhD Thesis, DGK, Reihe C, Heft 695
Torsion pendulum measurement data: courtesy of W.J. Weber, Trento

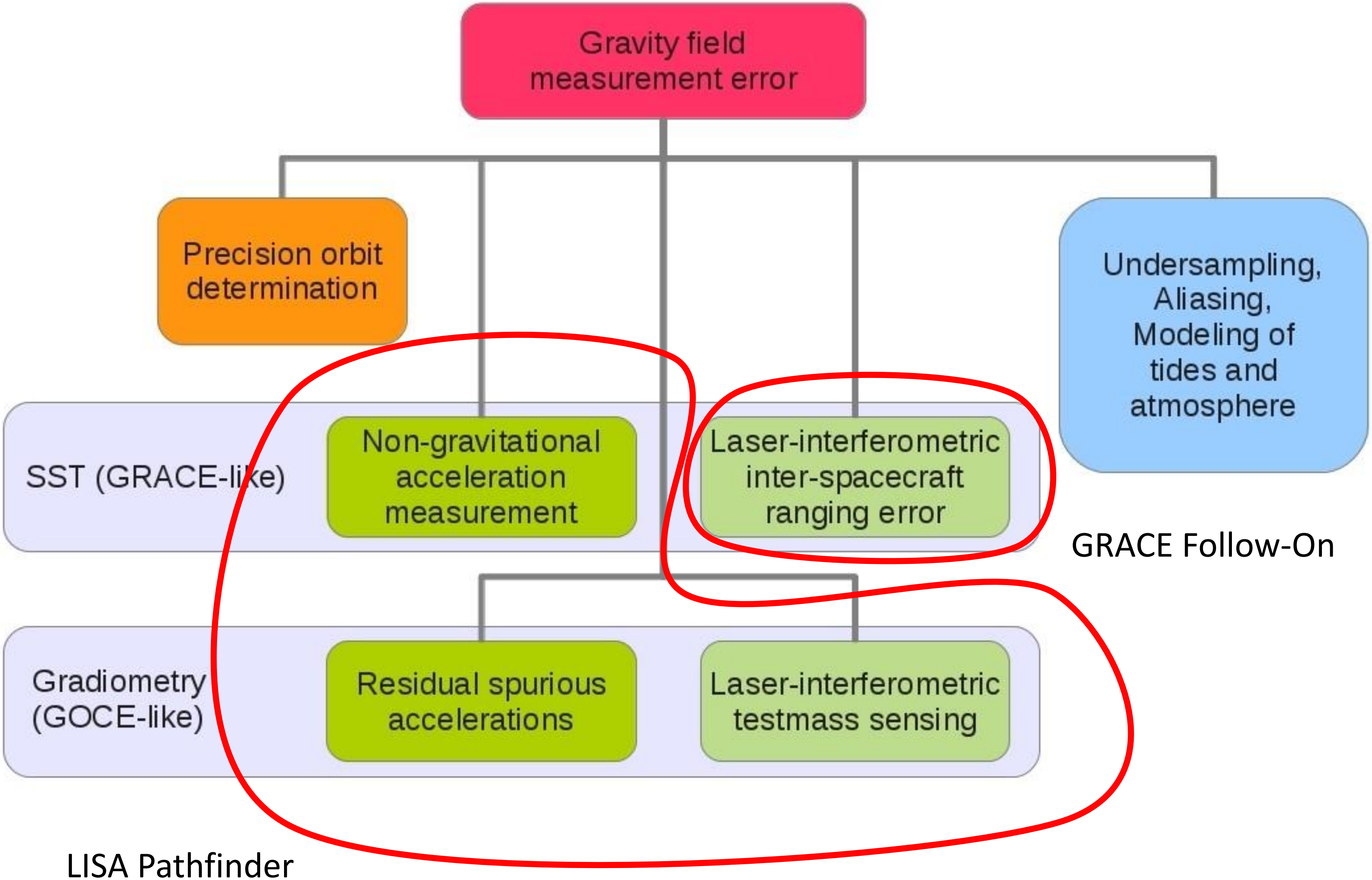
Laser Ranging Interferometer (LRI) on GRACE Follow-On

- US-German collaboration, launch in 2017,
- Interferometry design and breadboarding from AEI Hannover,
- First interspacecraft laser interferometer, designed as experimental demonstrator,
  complimentary to traditional μ-Wave ranging system,
- System PDR successfully passed in Jan. 2014



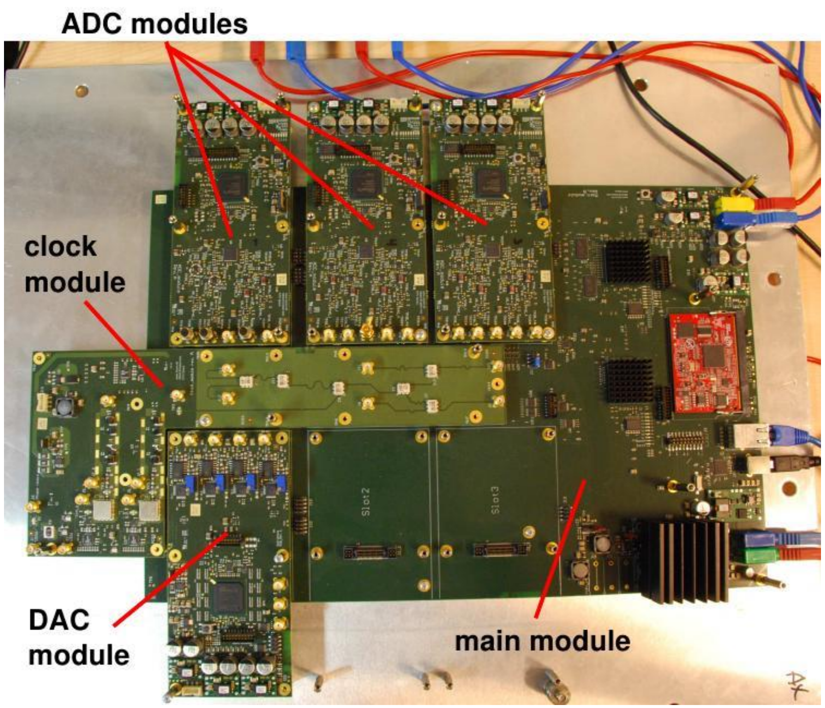


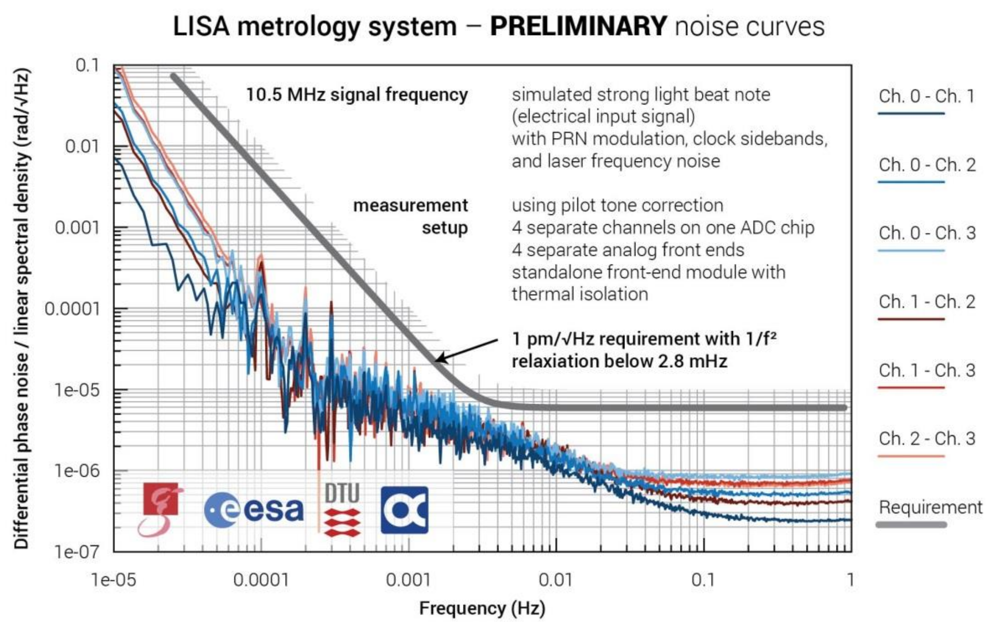
Gravity field results



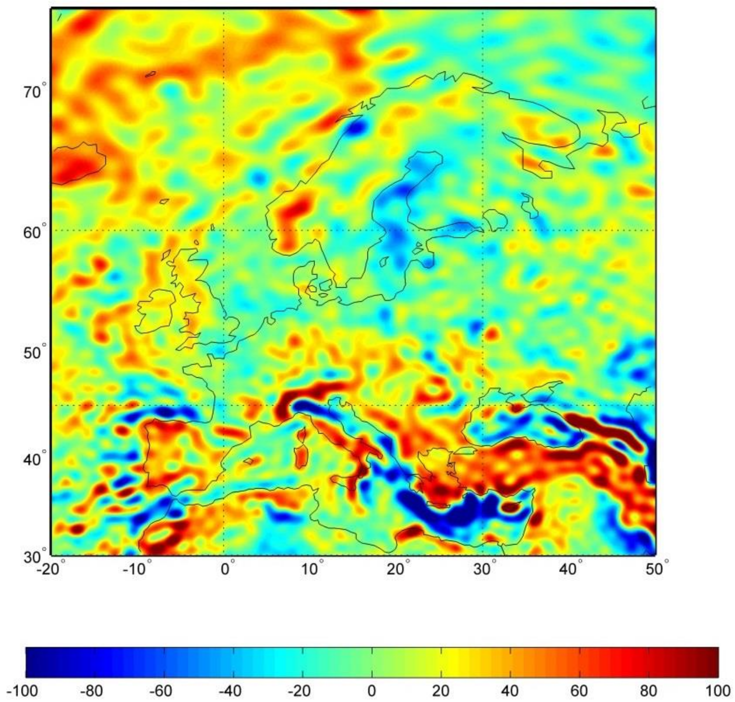
Phase measurement system for intersatellite ranging

- LRI on GRACE Follow-on will use NASA/JPL phasemeter
- ESA development of LISA phasemeter completed (DK-D consortium, AEI technical lead)
- Fulfills all LISA requirements which are harder then LRI (µrad carrier phase=pm, absolute ranging, data transfer)

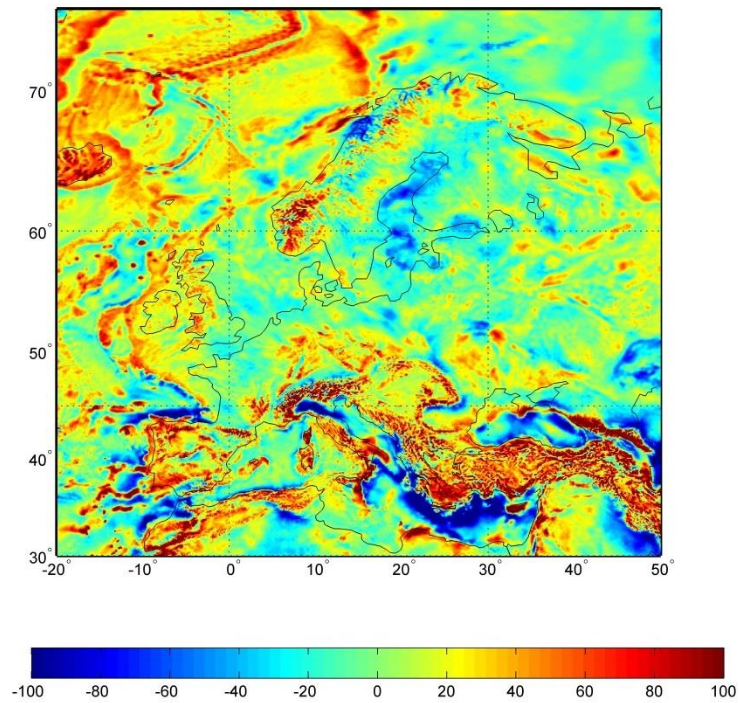




Gravity field solutions



GOCE: global, gravity only



EGM2008: not globally same resolution, combining with local measurements, altimetry, modelling.

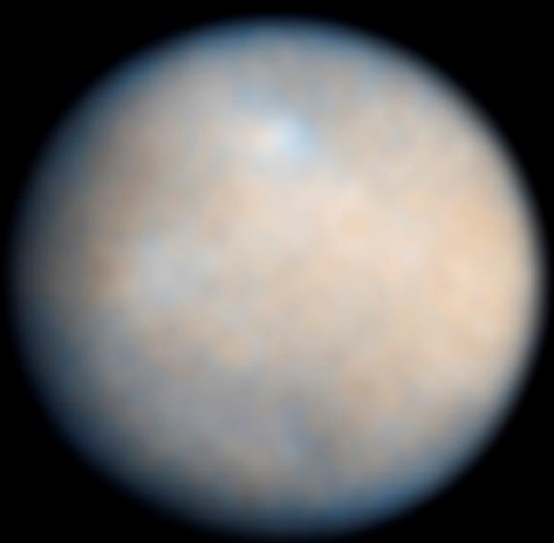
Long-term aim: globally high resolution from gravity alone

Options for 2020

- LISA Pathfinder as gradiometer
- Two smaller drag-free spacecraft with one TM each and intersatellite ranging (GRACE-FO like)

Options for 2020

- Explore gravity of Ceres, an „embryonic planet“ with water



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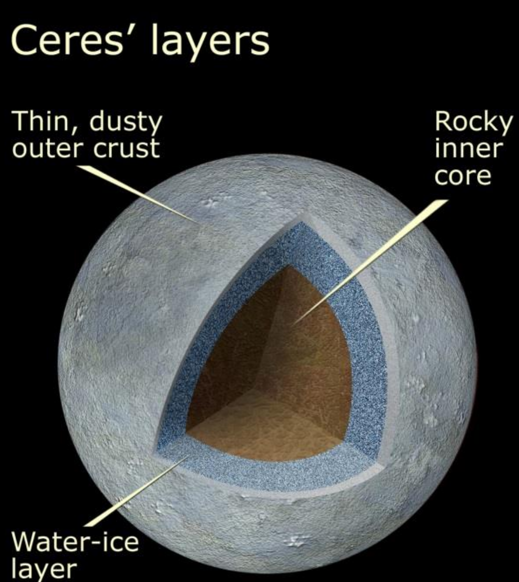


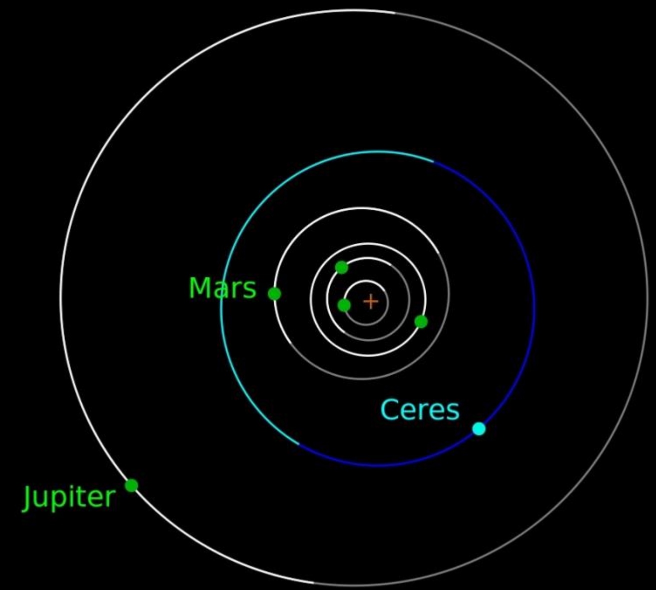


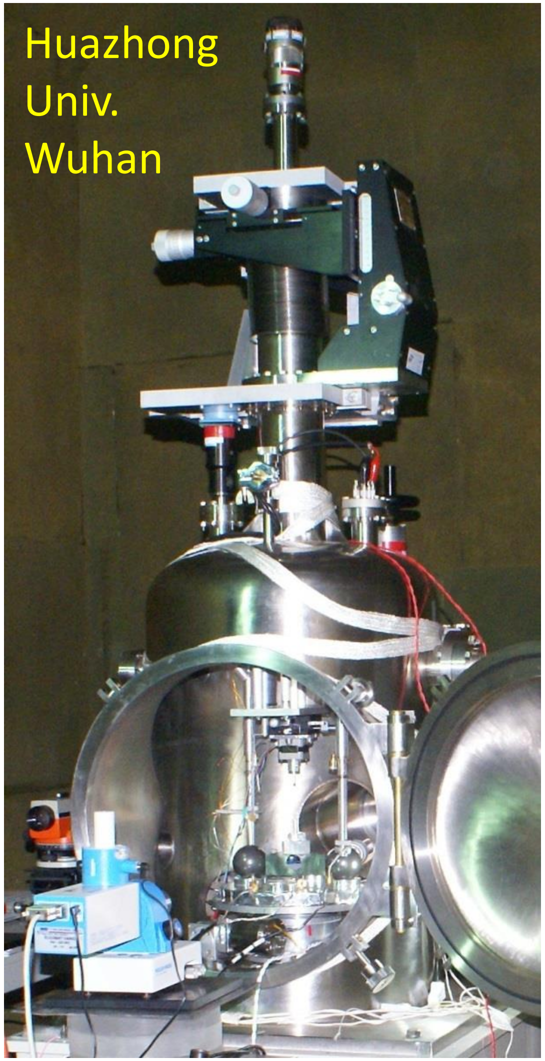
Image credits: NASA

Collaboration

- Accelerometer and test-mass development at Wuhan collaborating with Trento
- Interferometry and phase measurement developments in Beijing (CAS) and Wuhan collaborating with AEI Hannover
- Working together since 2006 in the context of laser interferometry for gravitational physics

Possible split Europe/China

- Possible parts from China:
  - Accelerometer development and ground testing
  - Charge management (UV LEDs)
  - Interferometry and phase measurement components
  - Ion thrusters
  - Spacecraft / propulsion module
  - Operations



Ceres 谷神星

- Most important parameters
  - Radius: 455-487 km
  - Low orbiter velocity: 0.36 km/s
  - Low orbiter period: 2h 12min
  - Proper rotation: 9 h
- DAWN mission (NASA)
  - Launched 2007, Vesta 2011, Ceres 2015
  - 1240 kg wet mass, 450 Mio US$ (2007)
  - 90 mN Xe Ion thrusters
  - 1.3 kW solar panels, no RTG