Outer Solar System (OSS)
A Planetary and Fundamental Physics Mission to Neptune, Triton and KBO

B. Christophe on behalf of OSS Team

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retour sur innovation

OSS, new proposal for Cosmic Vision M3

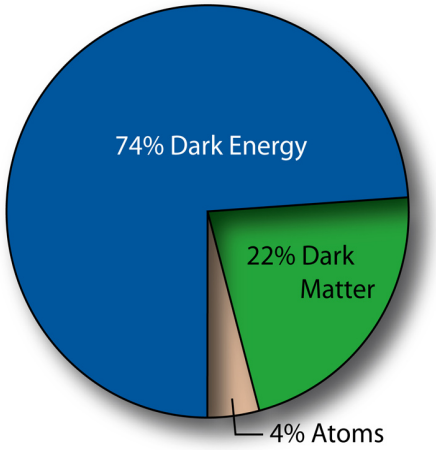
- In agreement with Fundamental Physics Roadmap Advisory Team of ESA (January 2010)
  - « Precise orbit determination of interplanetary spacecraft is an excellent tool to test general relativity and alternate theories of gravity […] This is of particular interest for missions that cover large parts of the Solar system (e.g. missions to outer planets and Kuiper belt) in the light of scale dependent gravity. »
  - « A more modest M-class mission, although less sensitive and less complete, would be of strong interest for the study of large scale gravity, in particular when combined with planetary objectives, like for example the exploration of Neptune and its moon Triton and Kuiper belt objects. However such a mission might be difficult for ESA alone because of the lack of RTG power supplies in Europe […] »

Fundamental physics scientific objectives

Objectives	Deep space gravity
Target precision	$\Delta a < 10$ pm/s^2

Unification models predict deviations from General Relativity

"Dark matter" and "dark energy" are seen as gravitational anomalies; as long as they are not also observed through independent means, they may as well be interpreted as modifications of gravity laws at large scales

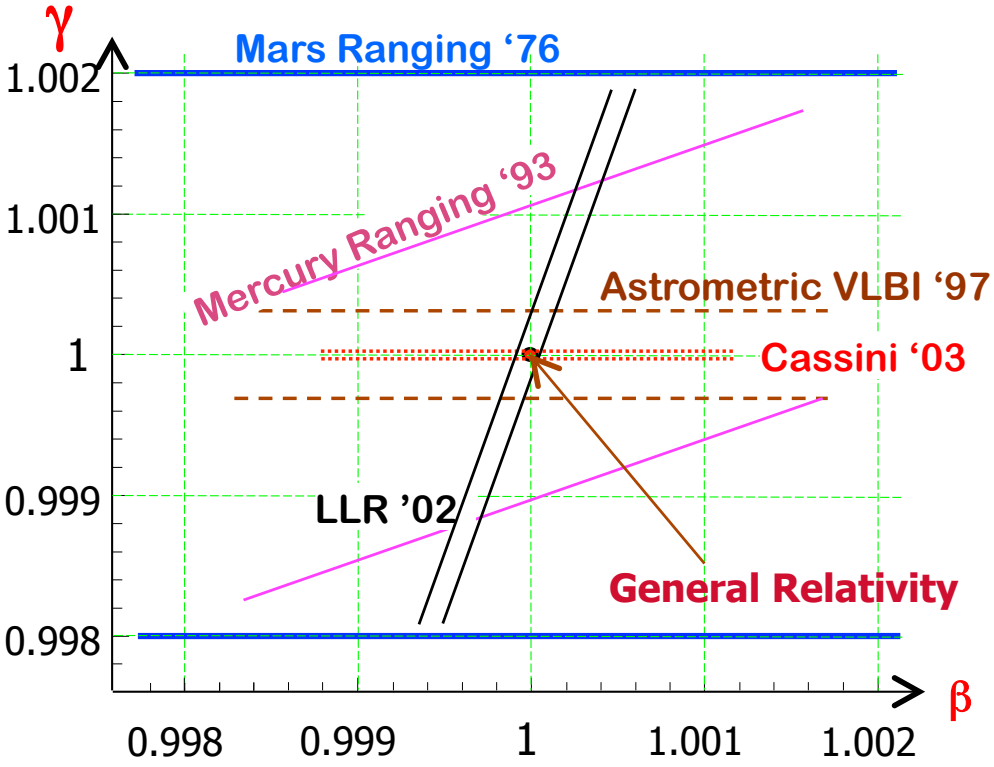


A new photo from NASA of the Bullet Cluster showing what is believed to be dark matter (represented in blue).
Source: NASA / CXC / CIA / STSci / Magellan / Univ. of Ariz. / ESO

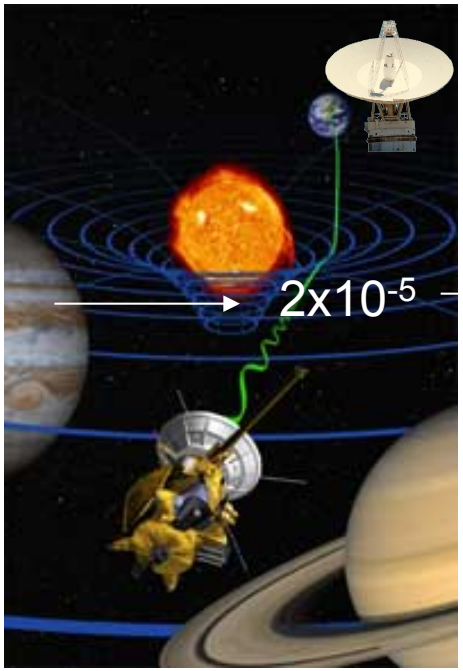
Importance of testing General Relativity at all possible scales beyond existing tests in the Solar System

Fundamental physics scientific objectives

Objectives	Deep space gravity	PPN parameter γ
Target precision	$\Delta a < 10$ pm/s^2	$\Delta\gamma < 10^{-7}$

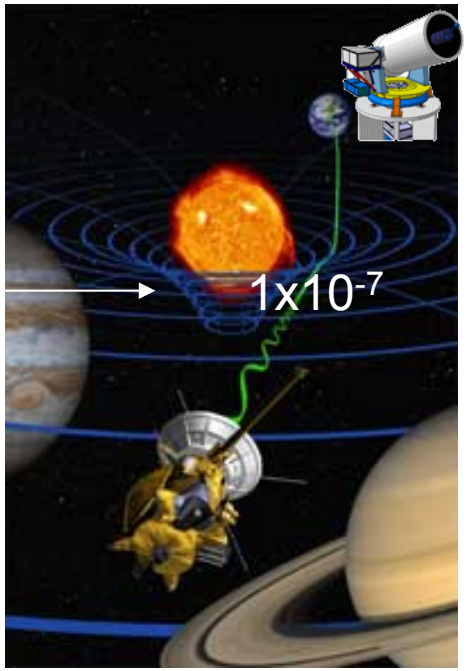


Cassini 2003



with Radio-Science

OSS 2022



with Laser-Science

Courtesy: S. Turyshev

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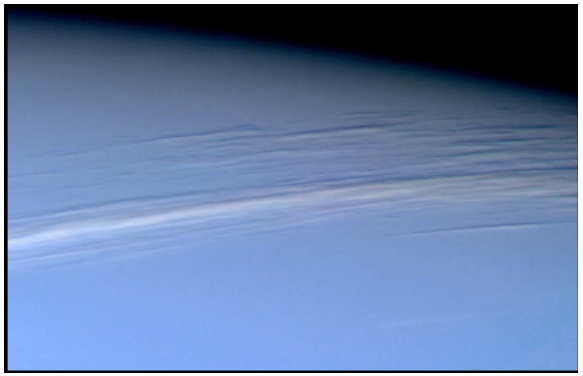
Planetary Objectives: Neptune, Triton & KBO

Last flyby of Neptune and Triton in 1989 by Voyager 2

Copyright, JPL/NASA

The ring system has changed since Voyager 2
The arcs evolved within 8 years

Neptune's wind possess the largest range in velocity in Solar System



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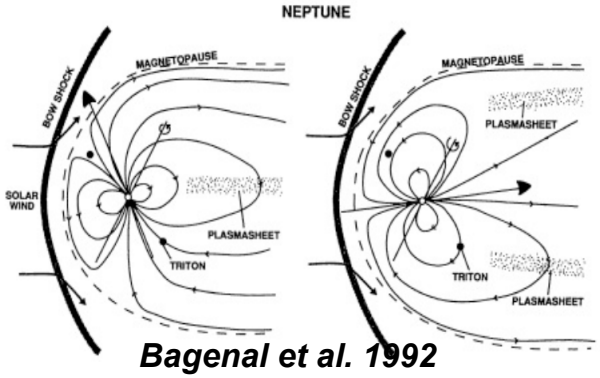
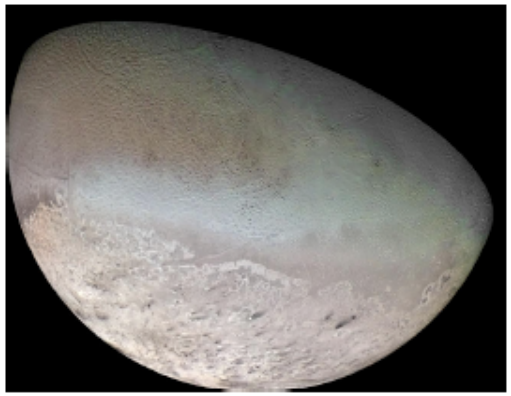
Neptune's magnetosphere is complex, with change over one Neptunian day at Voyager 2 epoch



Bagenal et al. 1992



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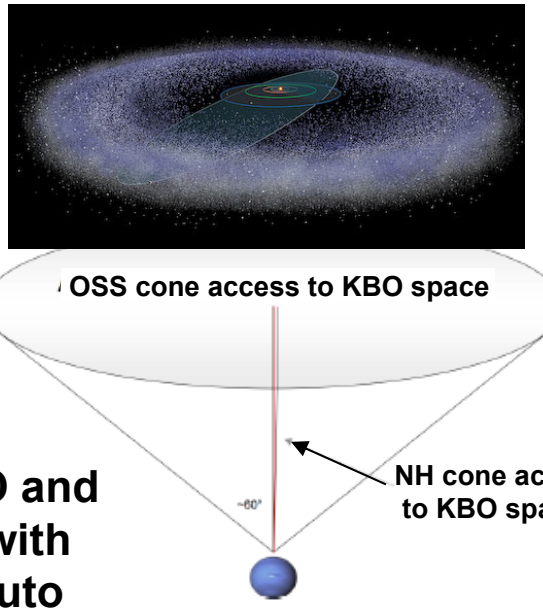
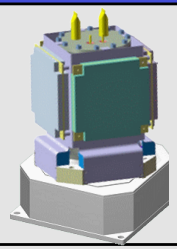
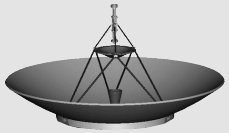
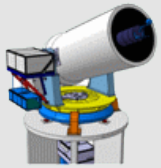
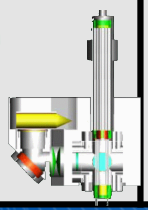
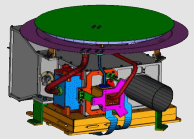
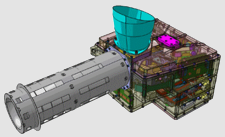
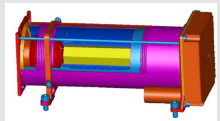
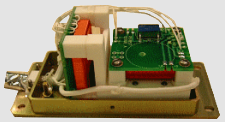
Triton has a young surface with very few impact craters
Triton could be a KBO



Flyby of a KBO and comparison with Triton and Pluto

OSS, Instrument suite

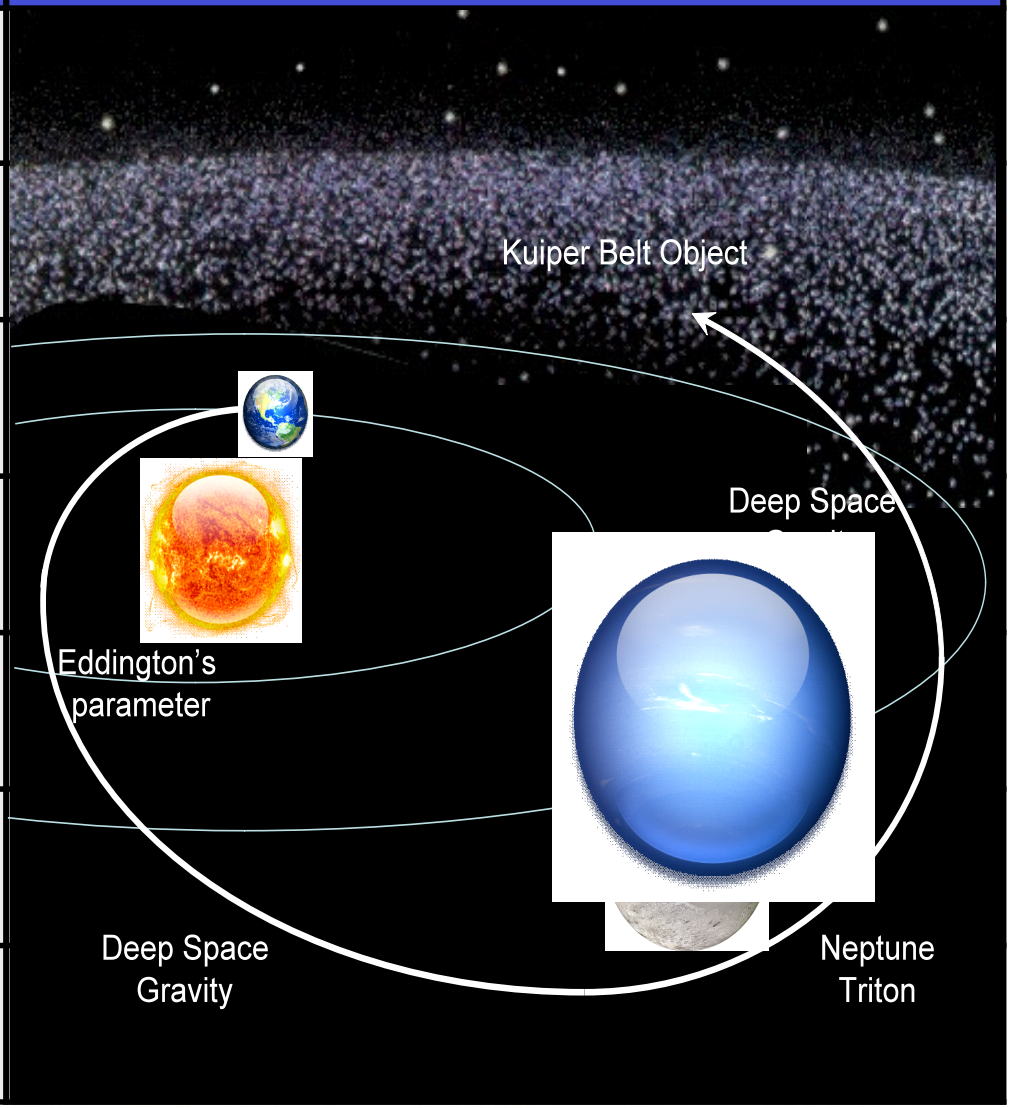
Instruments for Fundamental Physics	Mass Consumption
ACC DC Accelerometer 	3.5 kg 3.0 W
RSI Radio-Science 	3.0 kg 40.0 W
USO Ultra-Stable Oscillator	1.5 kg 5.5 W
LSI-1 Two-ways Laser Science 	25.0 kg 80.0 W
LSI-2 One-way Laser Science  +Clock Atomic Clock 	12.0 kg 12.0 W + 4.0 kg 15.0 W

Instruments for Planetary objectives	Mass Consumption
NIRS Near IR Spectrometer 	10.1 kg 7.5 W
UVS UV Spectrometer 	4.4 kg 4.4 W
NAC Narrow Angle Camera 	9.8 kg 14.0 W
TMI Thermal Map Imager 	3.4 kg 13.0 W
RPW Radio & Plasma Wave 	9.1 kg 5.9 W
MAG Magnetometer 	3.3 kg 3.0 W

OSS, Measurement Scenario

Objectives	Instrument
Deep space gravity	ACC, RSI
PPN parameter γ	LSI, ACC, RSI
Neptune Ring	NAC, NIRS, WAC
Neptune Interior & Atmosphere	RSI, ACC, TMI, UVS, NAC , WAC
Neptune Magnetic field	MAG, RPW, UVS, NIRS, ENA, PMS
Triton	RSI, ACC, MAG, NAC, NIRS, UVS, TMI, PMS
Kuiper Belt Object	RSI, ACC, MAG, NAC, NIRS, UVS, TMI, PMS

Measurement Scenario



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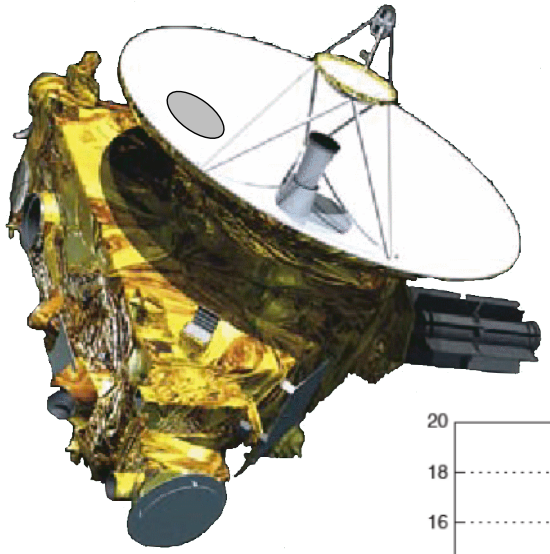
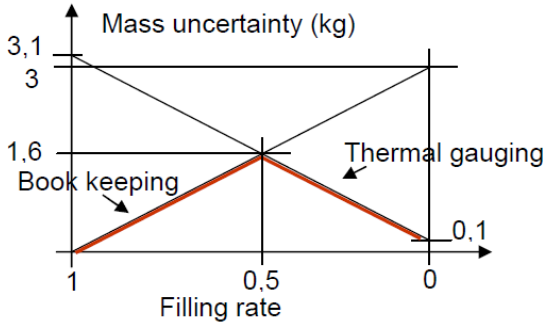
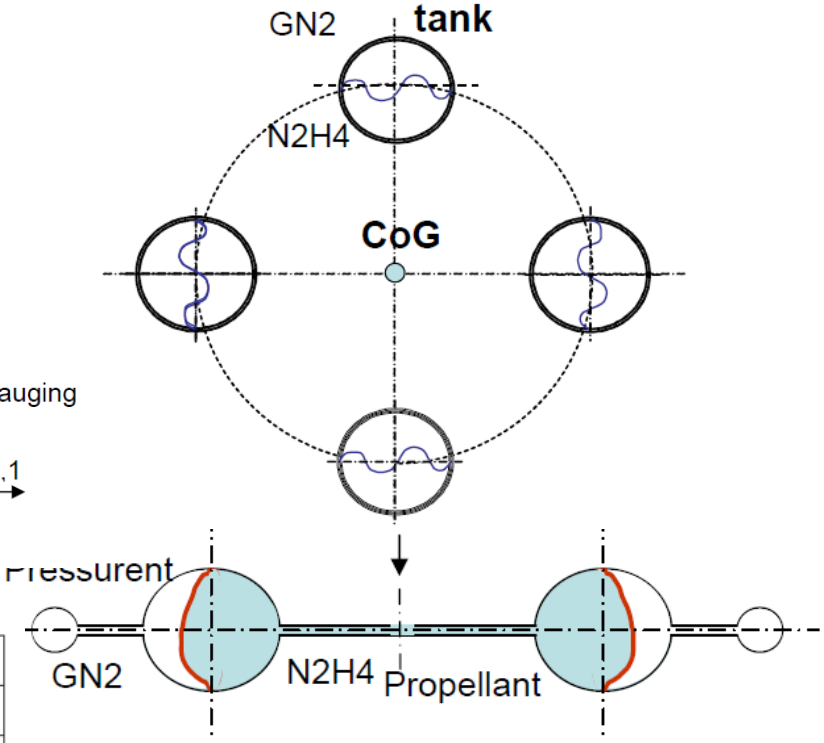
OSS, Spacecraft Design

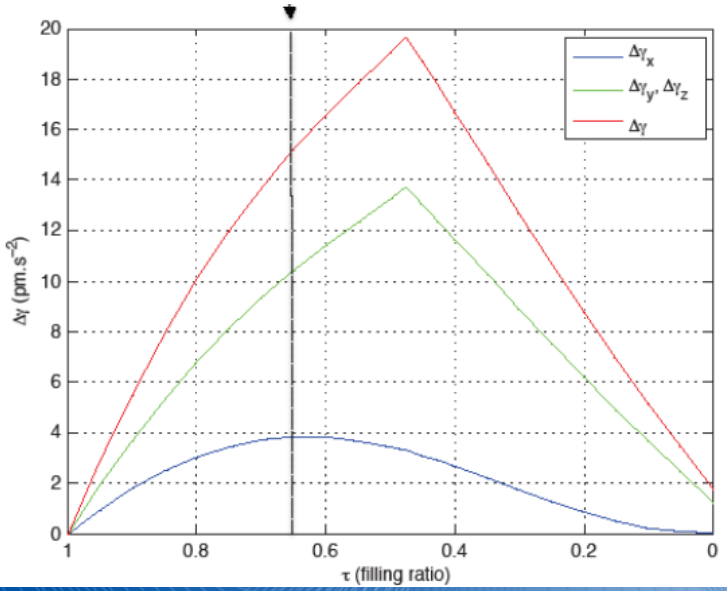
Based on New Horizons,
- **with HGA, 2,3 m diameter**
- **2 MMRTG (125 W – 110 W)**
- **or 2 ASRG (146 W – 125 W)**





Management of Propellant Self-Gravity





Self-gravity uncertainty of propellant during mission

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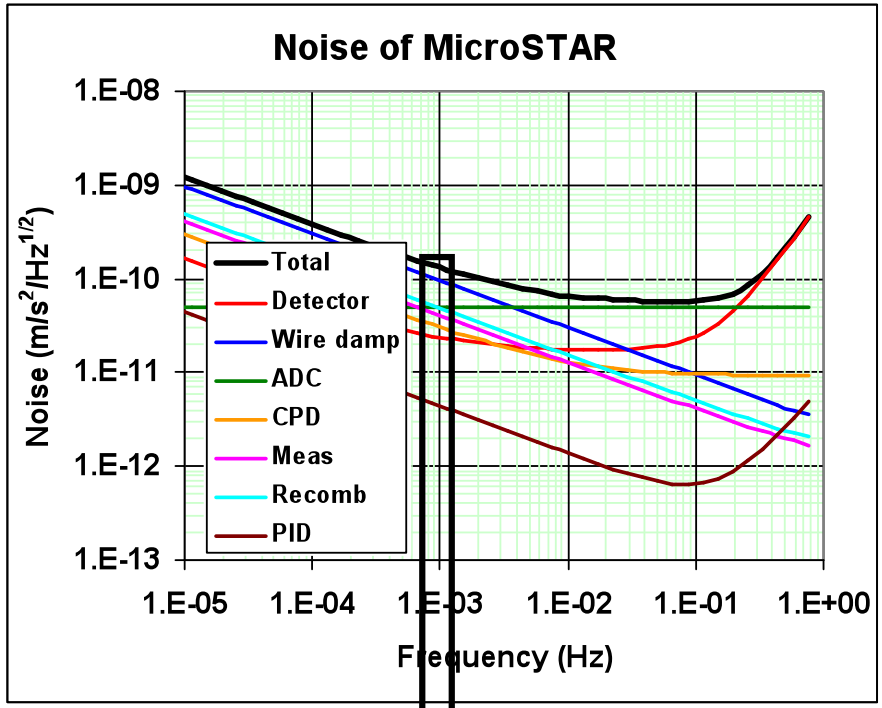
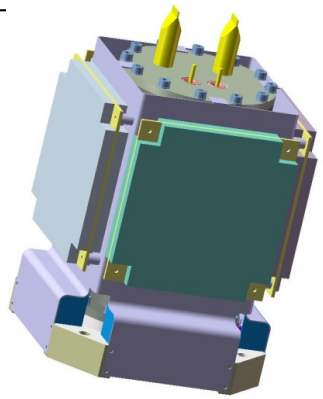
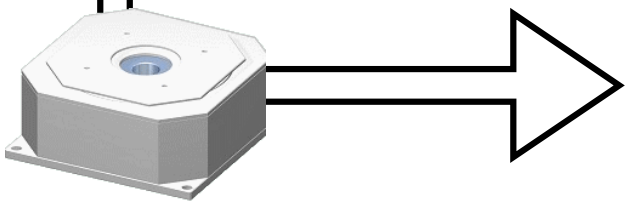
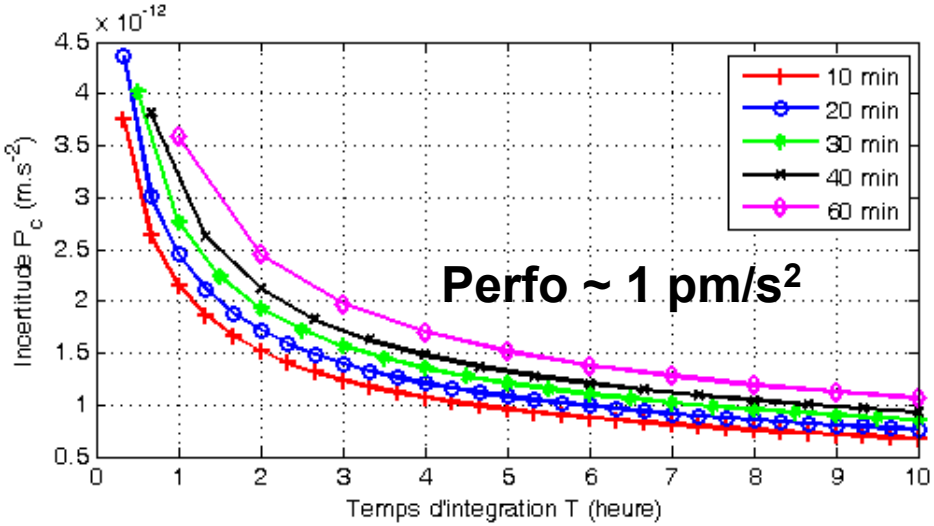
DC Accelerometer



Electrostatic accelerometer
based on heritage of
CHAMP, GRACE and GOCE missions
(developed by ONERA)







Bias Rejection System
rotating stage with piezo-electric motor
(developed by ZARM)

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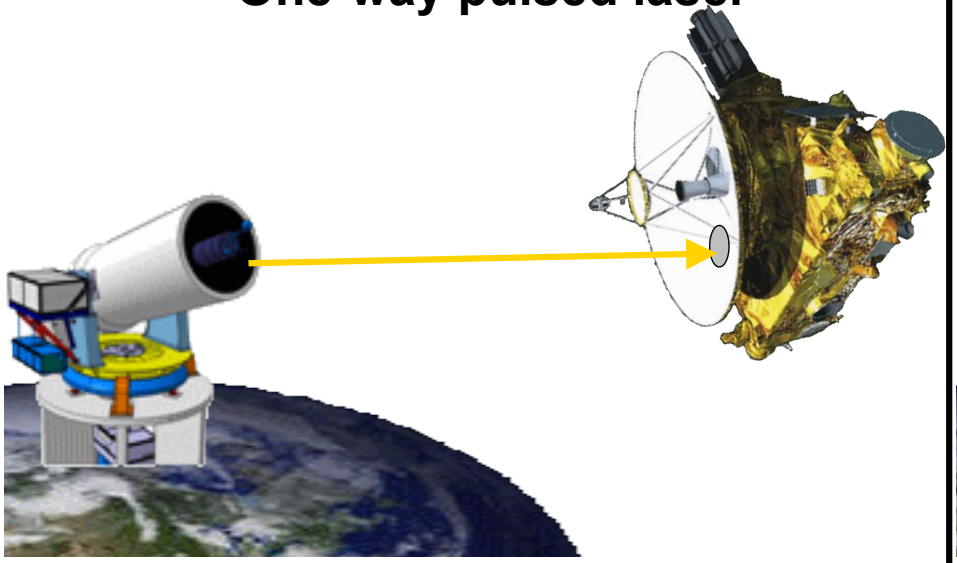
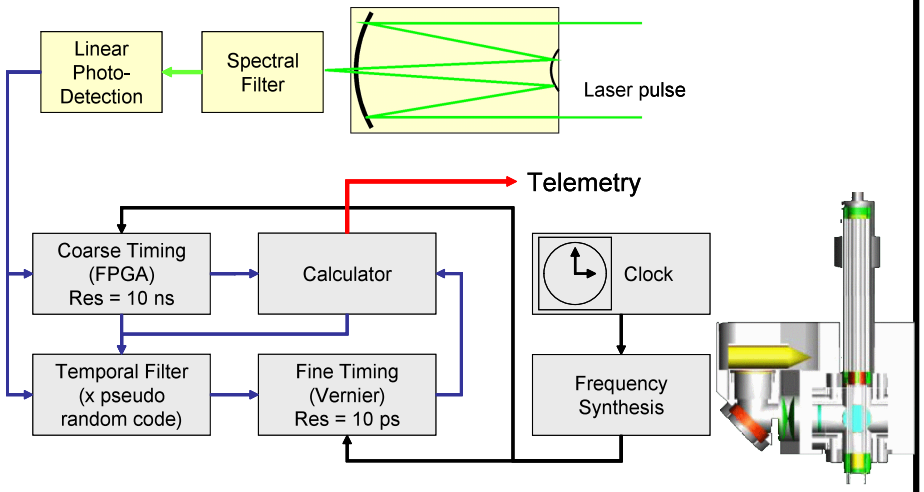
Laser Science: two concepts

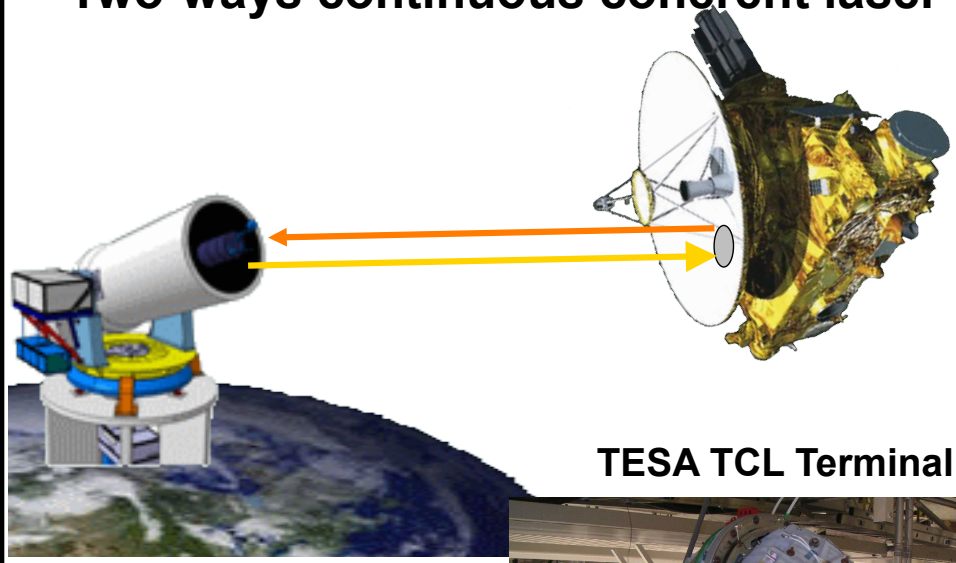
One-way pulsed laser



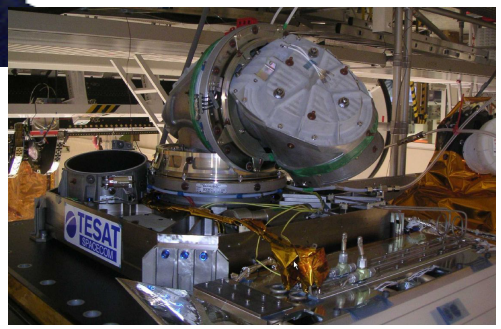


Mercury Ion JPL or Horace Syrte clock

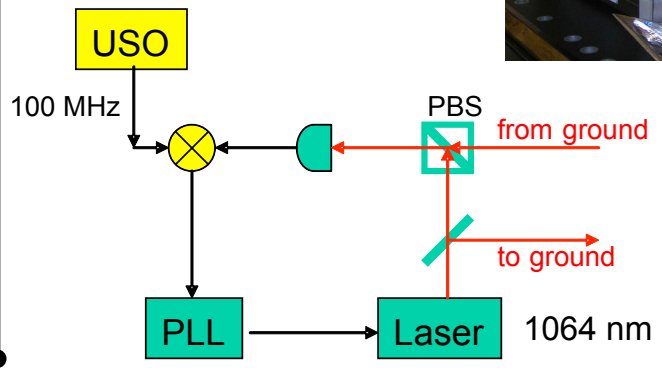
Two-ways continuous coherent laser



TESA TCL Terminal



Adaptative Optics on ground



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Conclusions

- **OSS, Fundamental Physics Mission with planetary objectives on Neptune/Triton/KBO**
  - In-line with ESA Fundamental Physics Roadmap
  - Proposed for next M3 call, in cooperation with US
  - Deep Space Gravity test constrained the S/C design (e.g. propellant for self-gravity)
  - DC Accelerometer accurate at 1 pm/s2
  - Laser-Science : 2 concepts to be analysed during the assessment phase

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