lisa pathfinder

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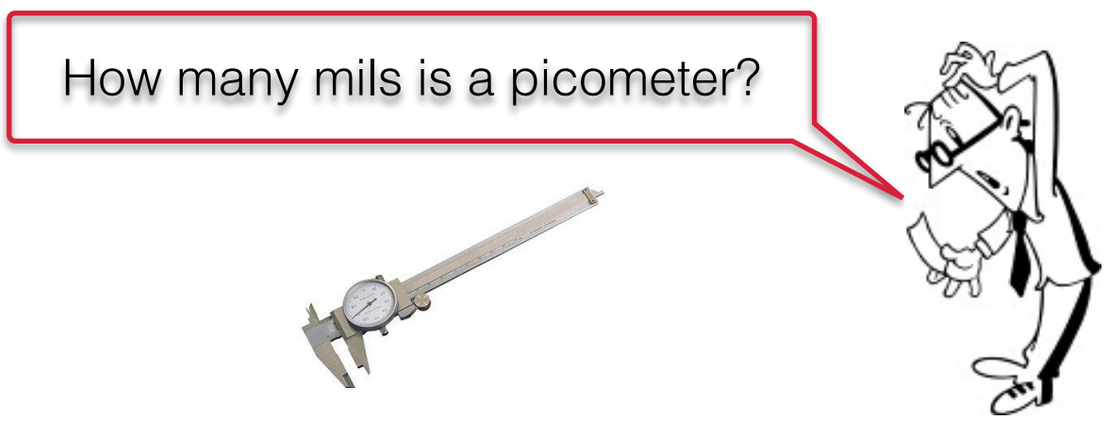
On behalf of the LPF Team
NASA Advisory Council
Astrophysics Subcommittee Meeting
Washington, DC
March 16th, 2016

Why LISA Pathfinder?

$10^{-12} = 0.000000000001$

Picophobia (paɪkoʊ-fōbēə) 1. (*noun*) Extreme or irrational fear of large negative exponents, especially when related to engineering requirements.

(*origins: Spanish, Greek)*



Picophobia for LISA

lisa pathfinder

- Acceleration noise: ~3×10^{-15} m/s^2/Hz$^{1/2}$ @ 1mHz
- Distance measurement: ~7×10^{-12} m/Hz$^{1/2}$ @ 1mHz
- received light power: ~10^{-10} W
- temperature stability: ~10^{-6} K/Hz$^{1/2}$ @ 1mHz
- pointing requirement: ~8×10^{-9} rad/Hz$^{1/2}$ @ 1mHz

Solution: Fly a Tech Demo

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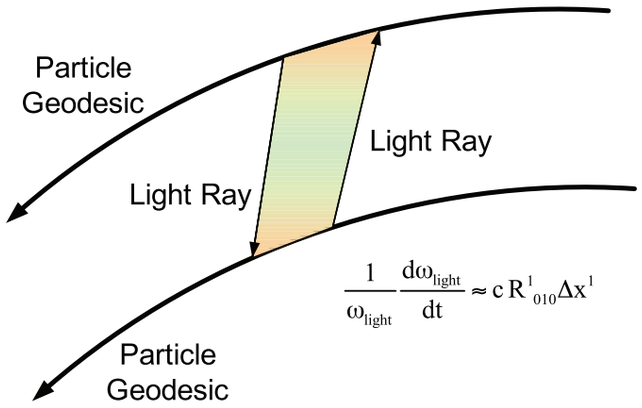
Textbook GW detector



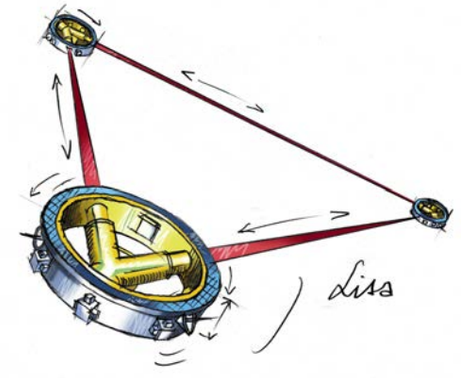
Measure curvature by timing photon travel between freely-falling objects

freely-falling objects → drag-free test masses

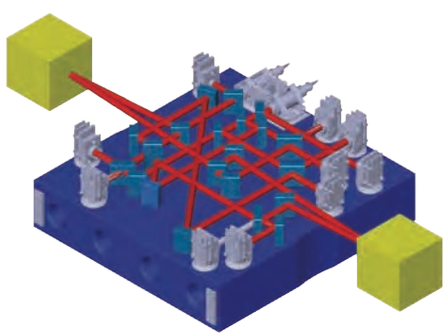
photon timing → heterodyne interferometry

multiple arms → noise rejection, improved signal

LISA-like mission



Technology Demonstrator



Single LISA arm reduced to fit on one spacecraft

GW signal vanishes

Instrument Noise remains

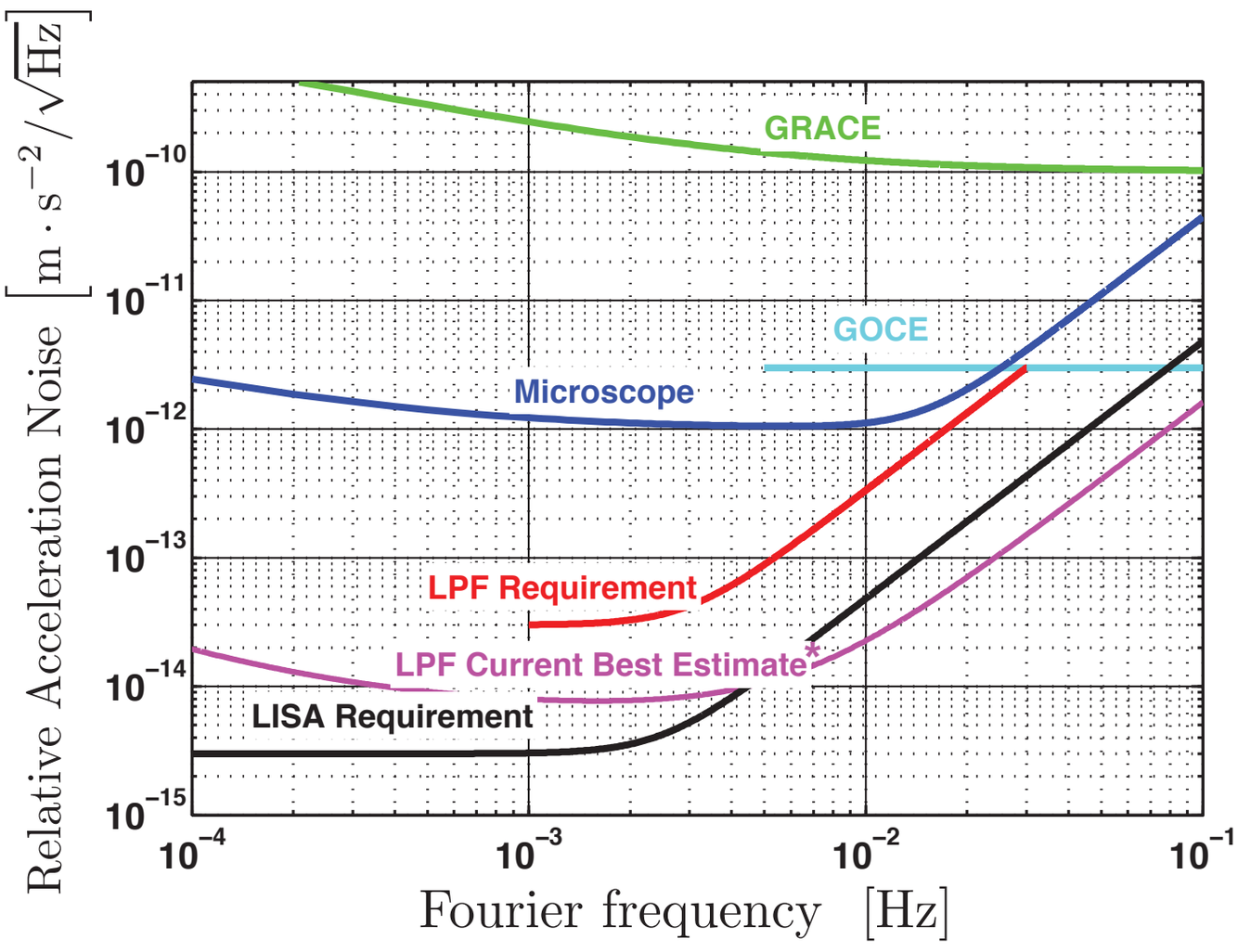
LPF Goals

relative acceleration noise

$$S_a^{1/2}(f) \leq 3 \times 10^{-14} \sqrt{1 + (\frac{f}{3\,\mathrm{mHz}})^4}\ \frac{\mathrm{m}}{\mathrm{s}^2\sqrt{\mathrm{Hz}}}$$

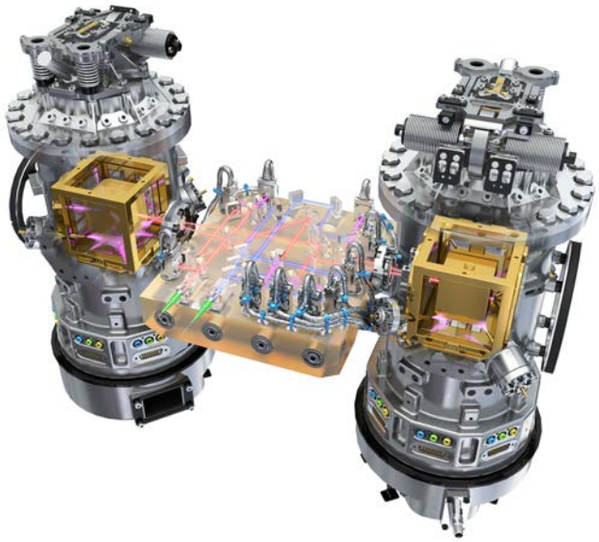
relative displacement measurement noise

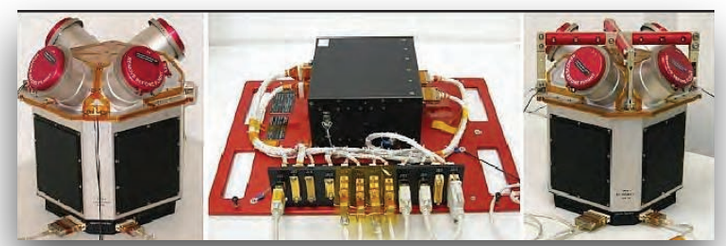
$$S_x^{1/2}(f) \leq 9.1 \times 10^{-12} \sqrt{1 + (\frac{3\,\mathrm{mHz}}{f})^4}\ \frac{\mathrm{m}}{\sqrt{\mathrm{Hz}}}$$



*Pre-flight estimate based on component testing and modeling

Key Components



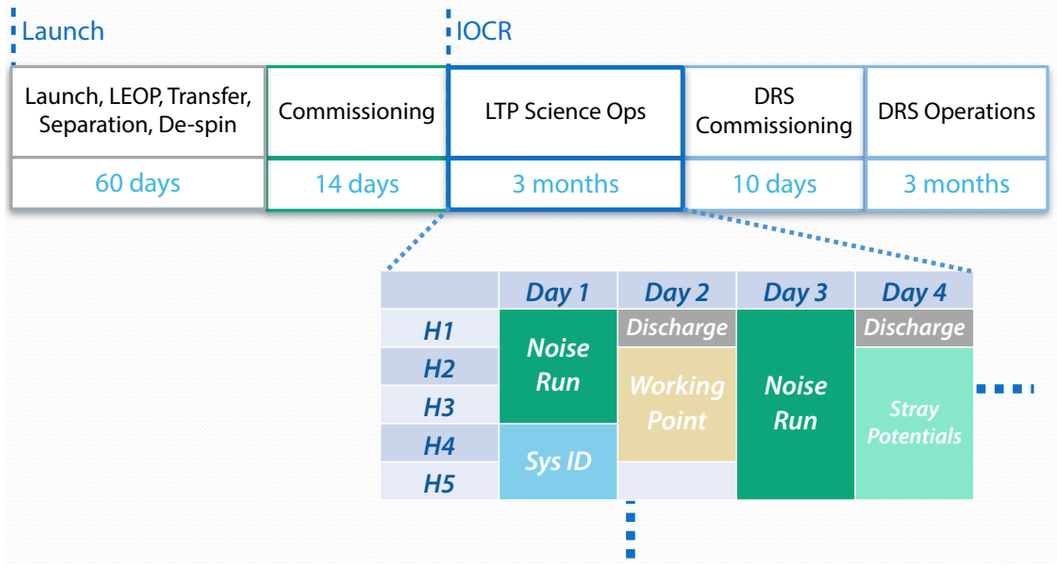


- Spacecraft (ESA)
  - Micronewton thrusters (cold gas)
  - Drag-free control laws
  - Emphasis on mechanical, thermal, & gravitational stability
- LISA Technology Package (ESA & European Consortium)
  - Two gravitational reference sensors
  - Optical Metrology System
  - Thermal/Magnetic Diagnostic System
- ST7-DRS (NASA/JPL)
  - Micronewton thrusters (colloidal)
  - Drag-free control laws (use LTP sensors/actuators)

Operations

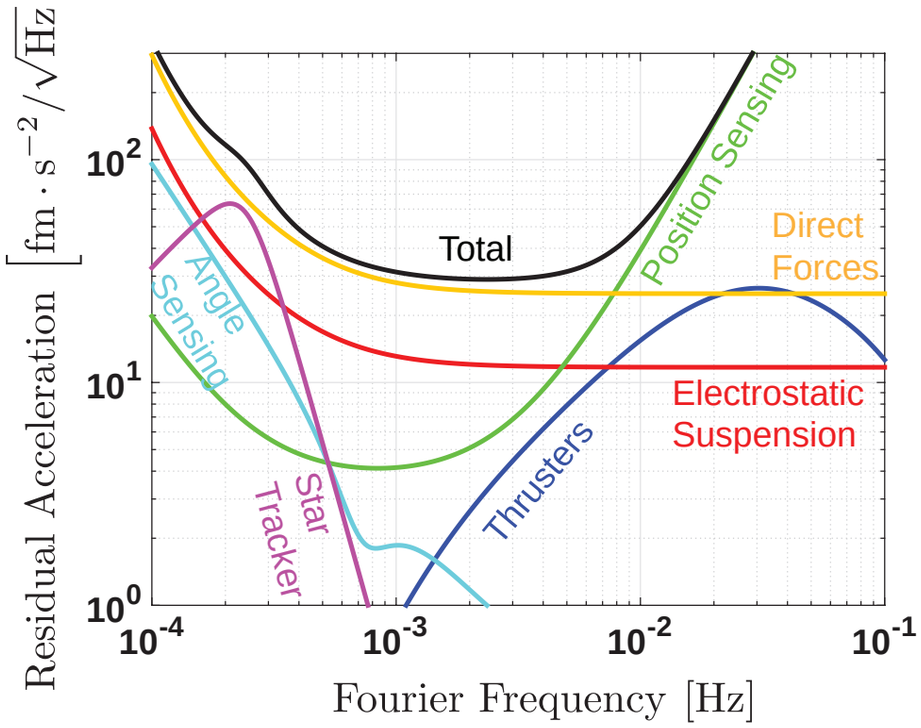
- Industrial Commissioning, LTP Operations, ST7 Operations, Extended Mission?

- Goal: physics-based model for the residual acceleration noise



- Operations are a series of experiments to measure various couplings/noise contributions/etc.

- Data analysis must be rapid & accurate to optimize planning for the remaining mission timeline



Schedule of Events (nominal)

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Dec 7-11: Apogee-raising burns

Dec 12: Trajectory trim

Dec 17-20: Cold Gas Thruster Commissioning

Jan. 2-10: CMNT Commissioning

Jan. 11: LTP Commissioning Begins

Jan 22: Propulsion module separation

Feb 3: Test Mass De-cage (launch lock)

Feb 15/16: Test Mass release (electrostatic control)

Feb 29: LTP Commissioning Ends

Mar. 7th: In-Orbit Commissioning Review Passed

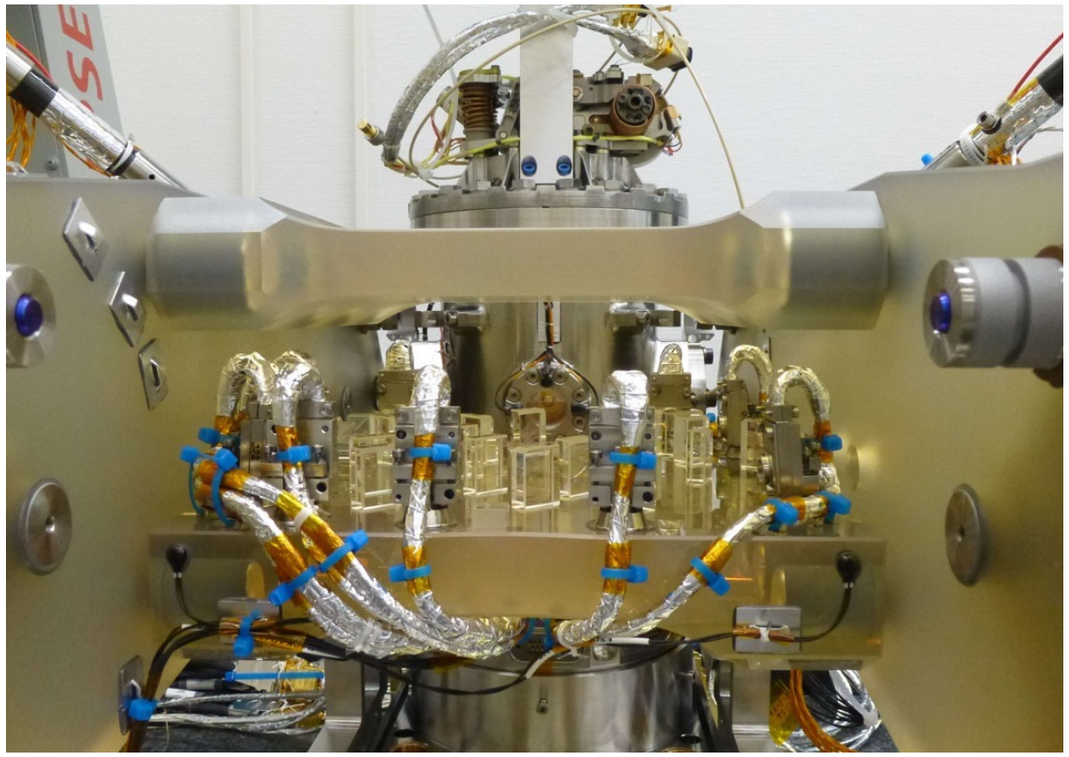
Mar-June: LTP Operations

Late June: DRS Commissioning

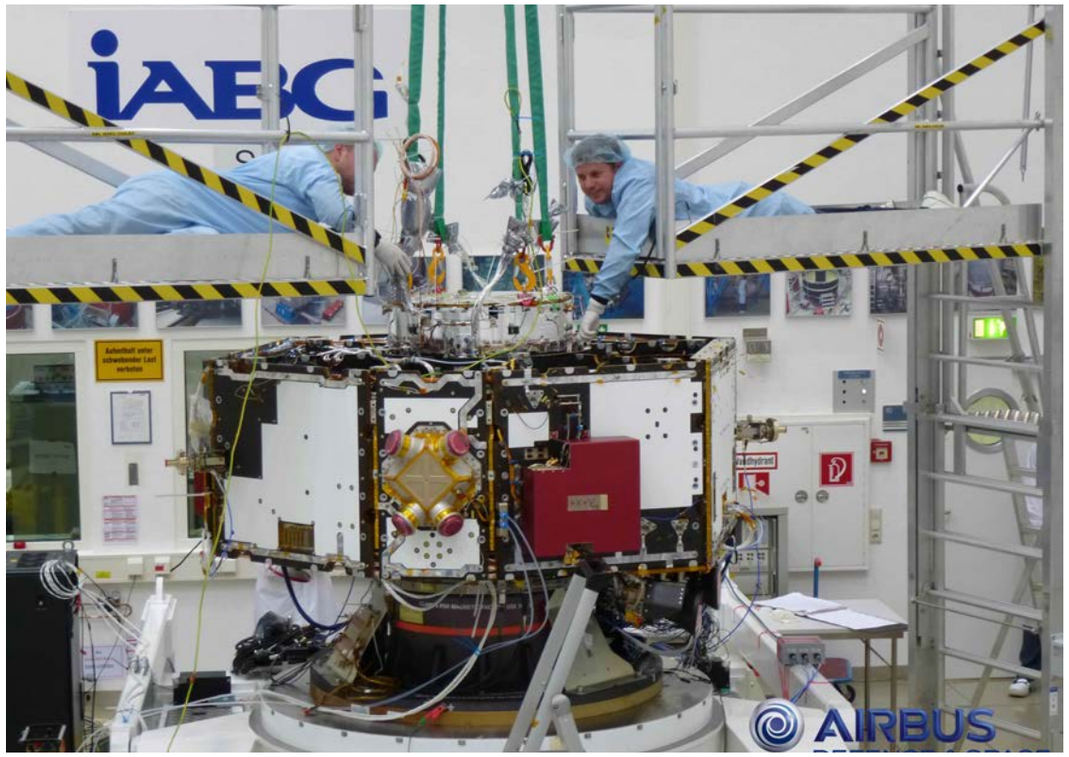
June-Sept: DRS Operations

Extended Mission / Joint Operations ?

I&T and Launch Campaign Highlights




APCO
TECHNOLOGIES


IABG
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TECHNOLOGIES


ASTRIUM


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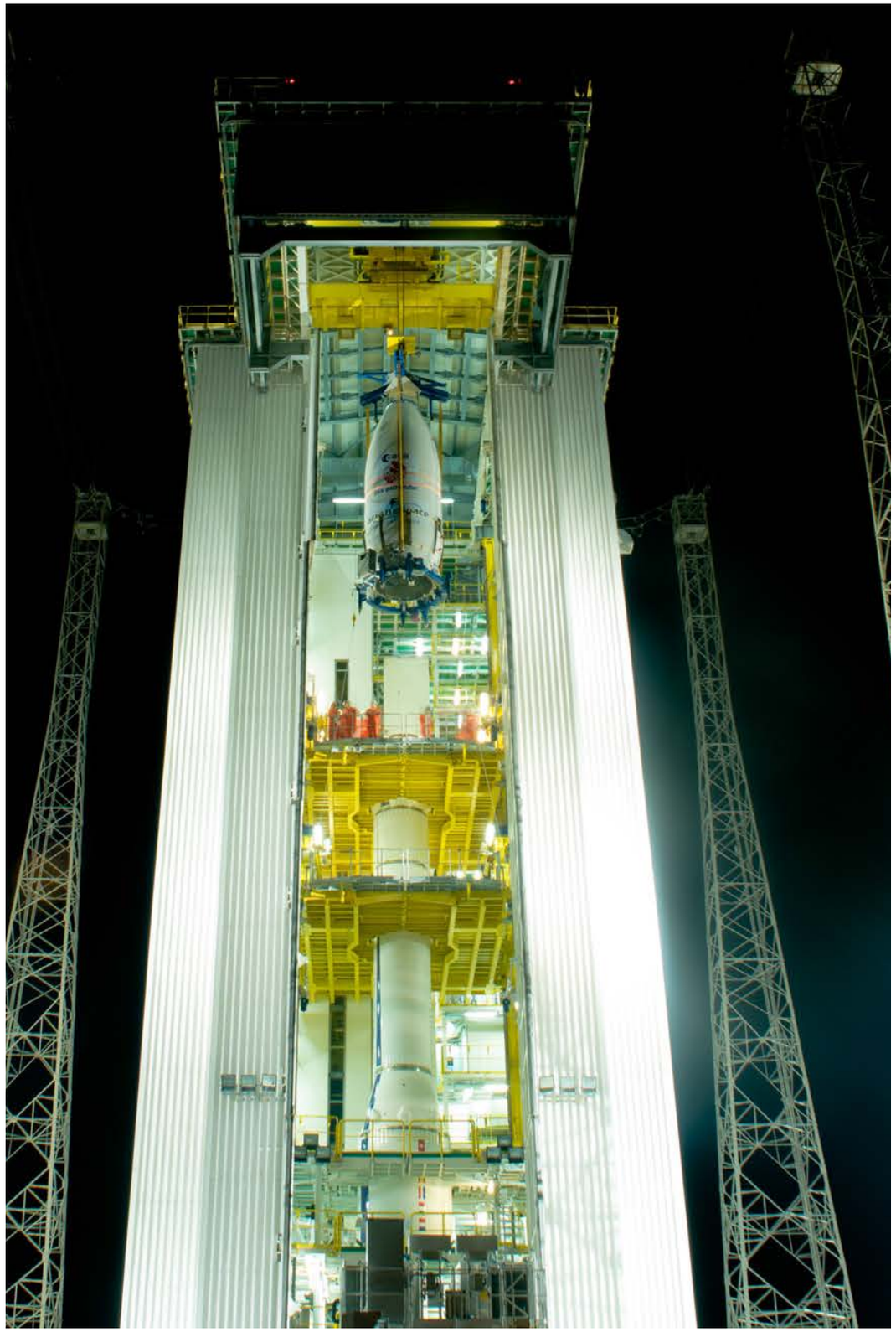


esa
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service & solutions

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Current Status

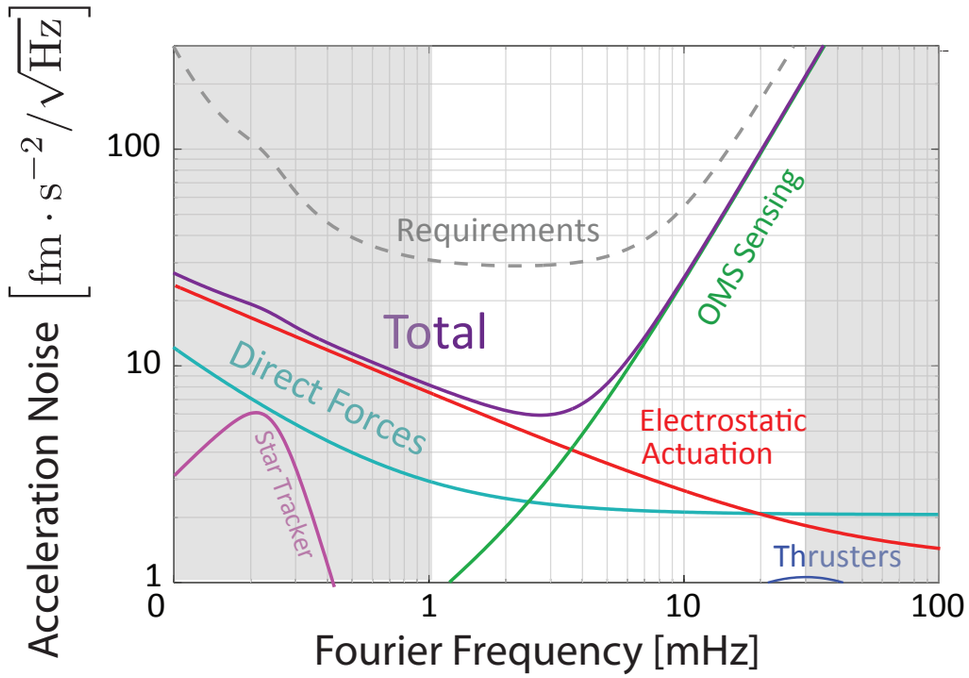
- LTP Science Operations Week 3
- Philosophy
  - take it slow
  - understand system
  - gradually introduce more aggressive experiments
- Hope to release intermediate results at some point during LTP operations
- Keep up-to-date

http://www.cosmos.esa.int/web/lisa-pathfinder

http://lisapathfinder.org/

@ESA_LPF, #LISAPathfinder

LTP Science Team Members working at ESOC in Darmstadt, Germany



Pre-flight noise breakdown estimate for LTP

Backup

History of LPF

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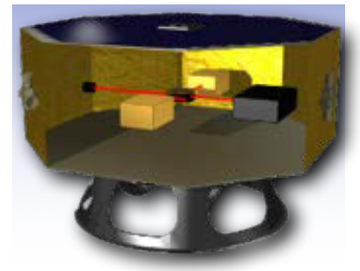
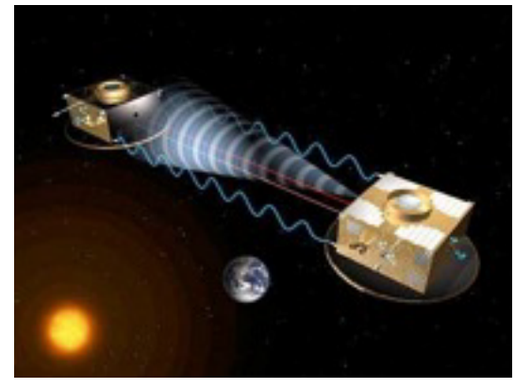
- 1998: **ELITE** (**E**uropean **LI**sa **TE**chnology) proposed
  - Homodyne interferometer
  - Launch date 2002

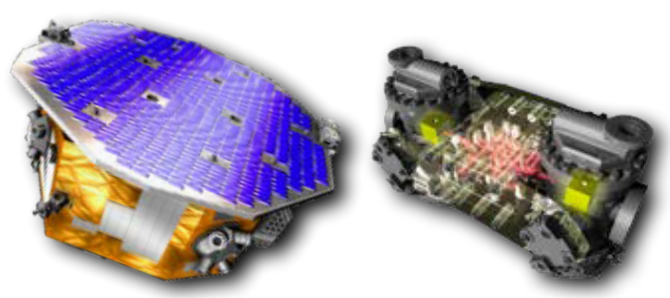


- 2000: ELITE proposed as **SMART-2** (**S**mall **M**issions for **A**dvanced **R**esearch in **T**echnology)
  - Two spacecraft, three payloads
  - LISA Pathfinder (ESA), Darwin Pathfinder (ESA), Disturbance Reduction System (NASA)



- 2001: **SMART-2** Descoped and re-named **LISA Pathfinder**
  - Darwin Pathfinder cancelled
  - single spacecraft, two payloads
  - LISA Technology Package (Europe) and DRS (NASA)

- 2005: DRS Descoped
  - DRS interferometer and inertial sensor removed
  - DRS control laws and thrusters will use LTP sensors



Drag Free Control

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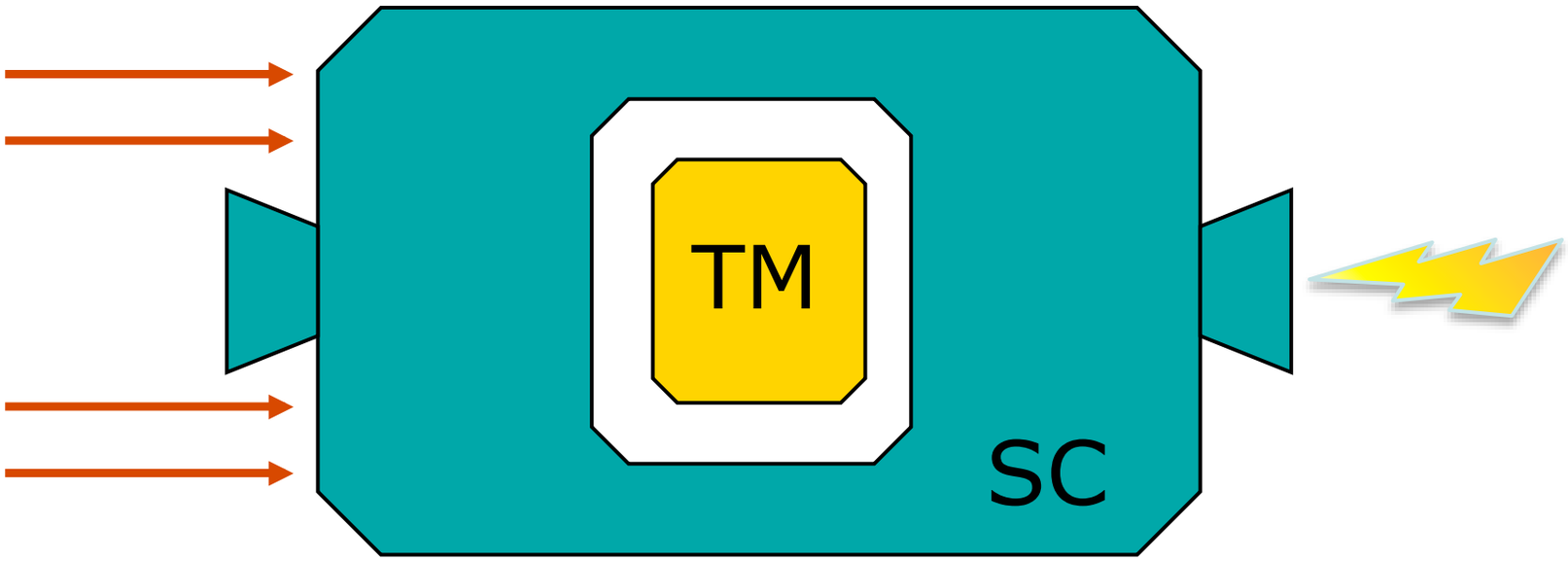

SC fires thrusters, TM remains in free fall

Mission Design

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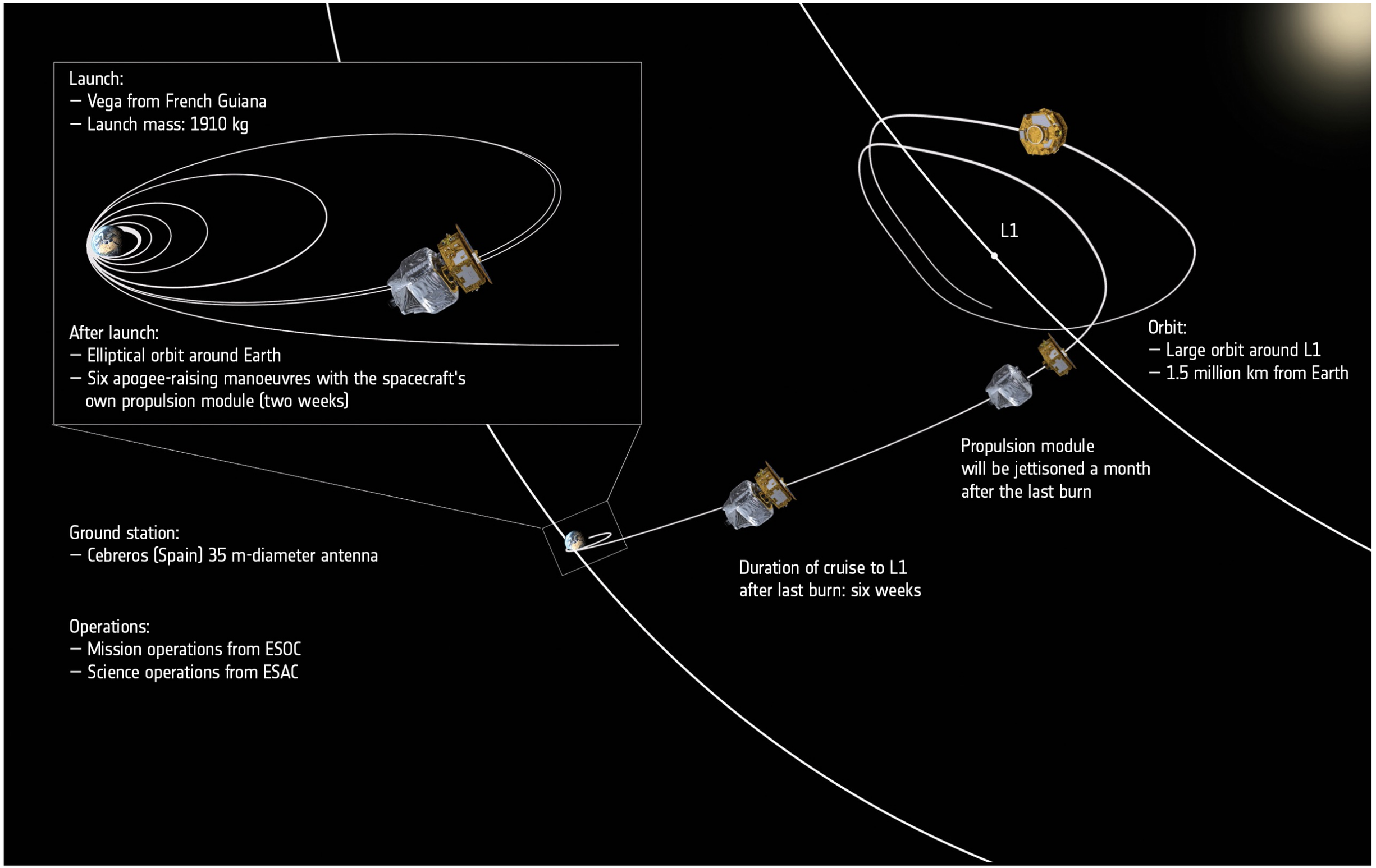

Gravitational Reference Sensor

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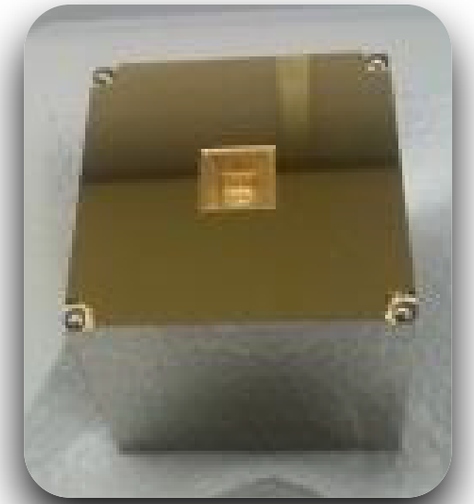
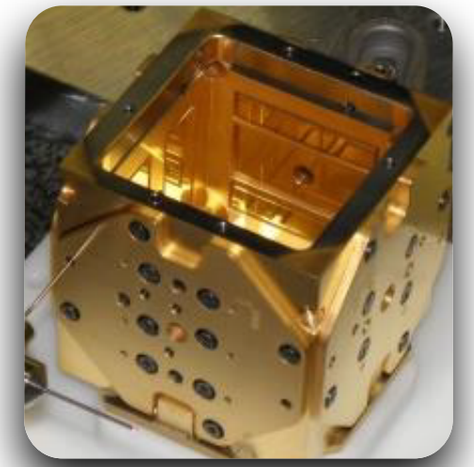
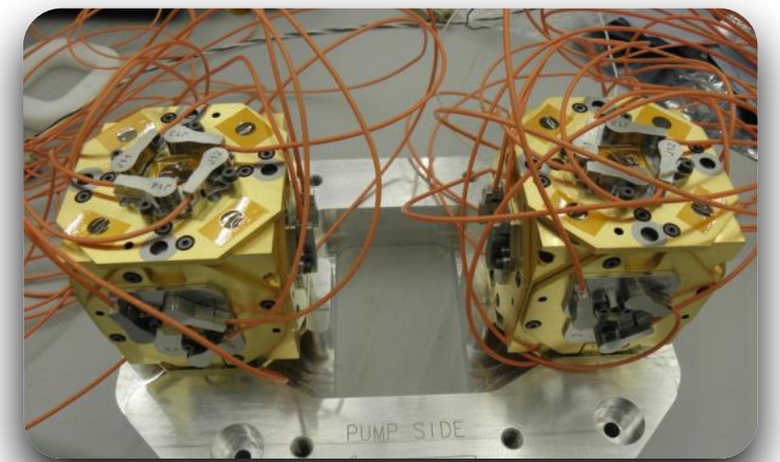
- Test mass: 46mm cube of Au-Pt alloy (2 kg)
- surrounded by electrode housing with 3-4mm gaps
- electrodes used to sense position/ attitude and apply forces/torques
- Non-contact charge control via UV lamps
- Housed in titanium vacuum vessel
- Caged during launch, released to electrostatic suspension on orbit



uncoated TM



electrode housing



integrated electrode housings

vacuum can

Optical Metrology System

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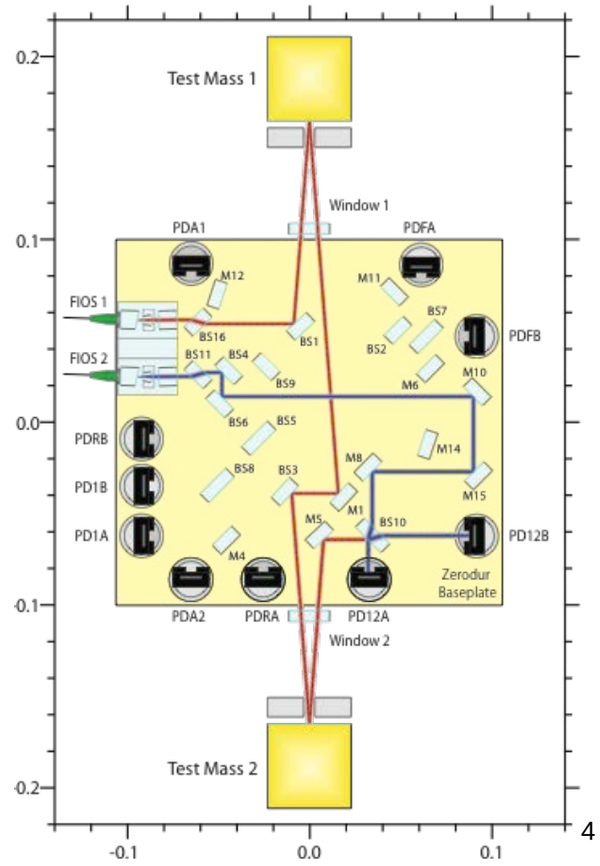
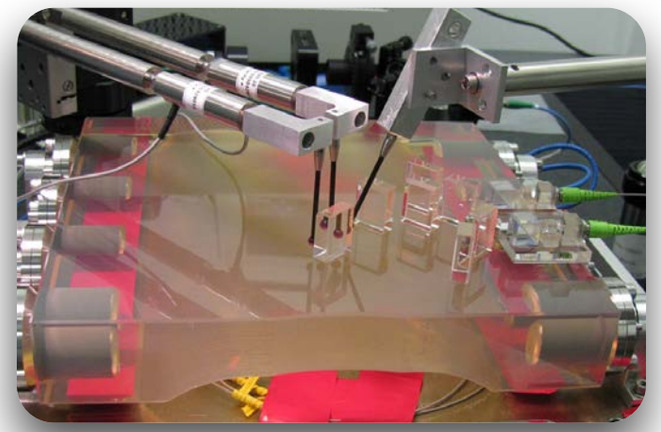
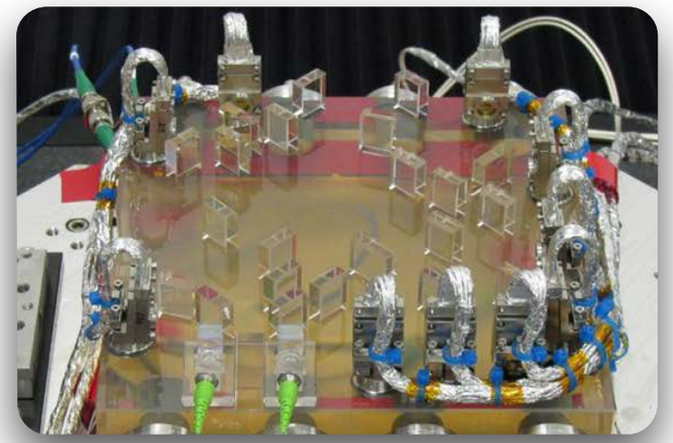
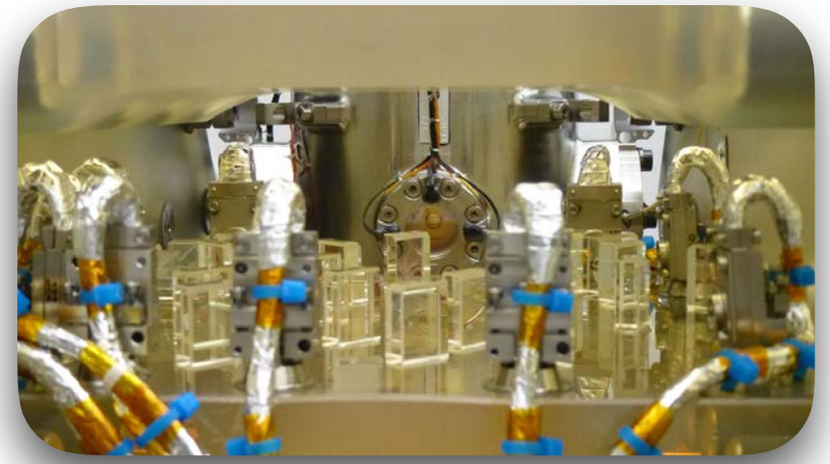
- Four separate Mach-Zehnder interferometers to measure positions and angles
- Hydroxy-catalysis bonding to maintain alignment & provide dimensional stability









Micropropulsion Systems

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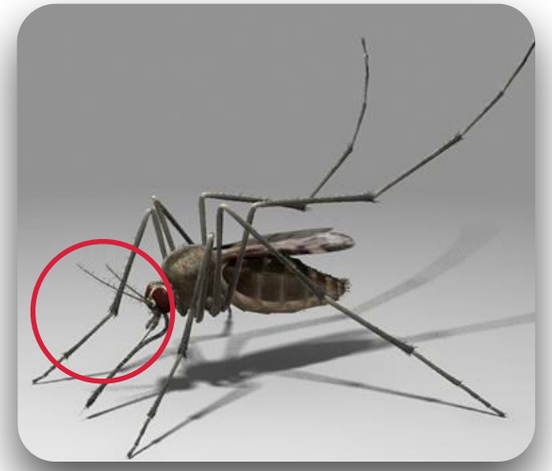
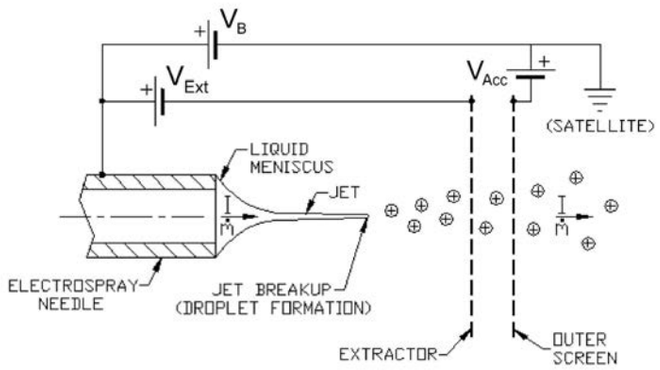
- Maximum thrust ~ 30μN
- Thrust precision ~ 0.1μN





Colloidal MicroNewton Thruster (JPL/BUSEK)

Cold Gas Microthruster (used on GAIA)

Platform for Precision Measurement

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- 2.3 m x 1.0 m
- 422kg
- magnetically clean
- precision gravitational balance
- thermally clean