

LISA free-fall performance:
new results from LISA Pathfinder

Peter Wass on behalf of the LISA Pathfinder Collaboration

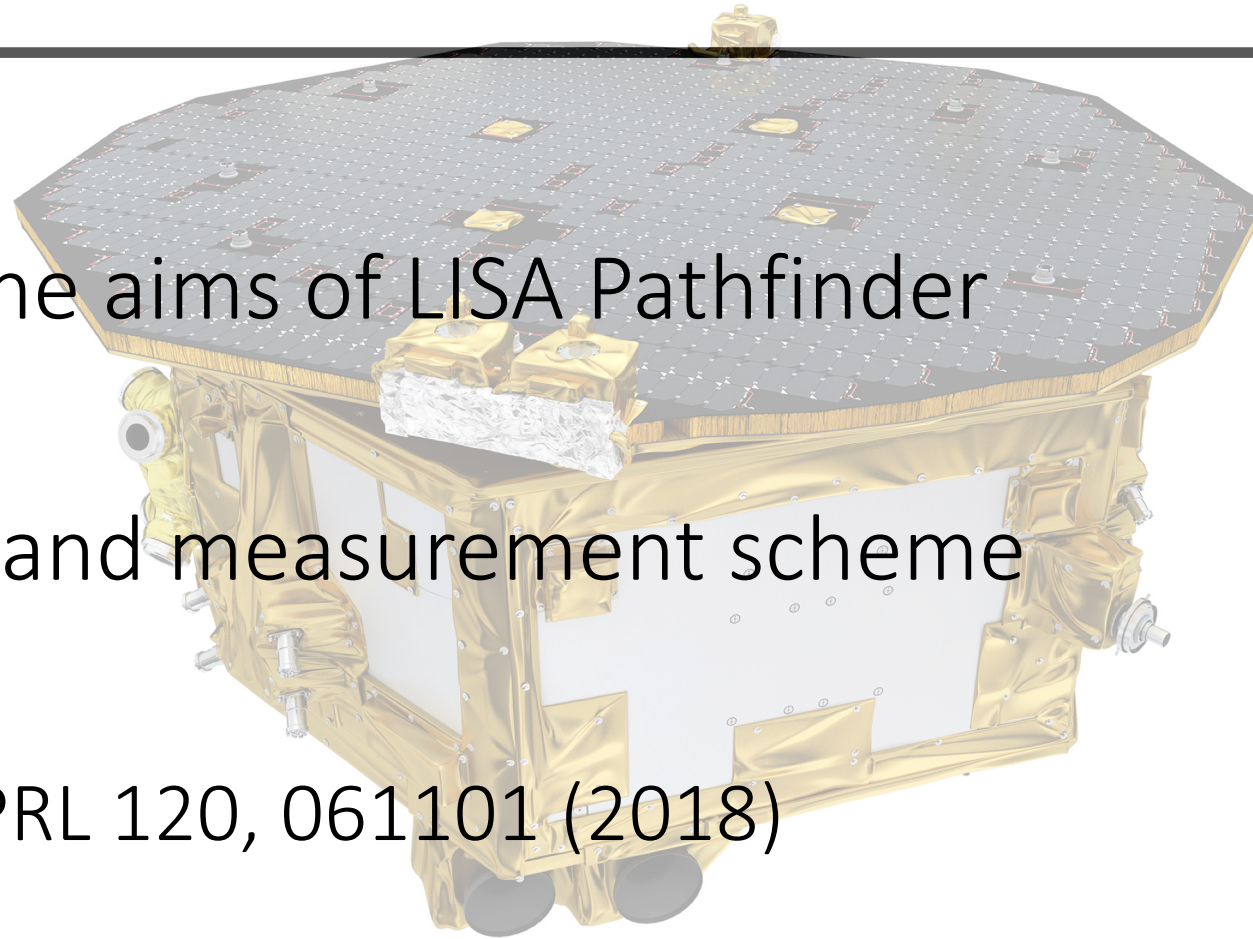
Summary



LISA and the aims of LISA Pathfinder

Hardware and measurement scheme

Results – PRL 120, 061101 (2018)



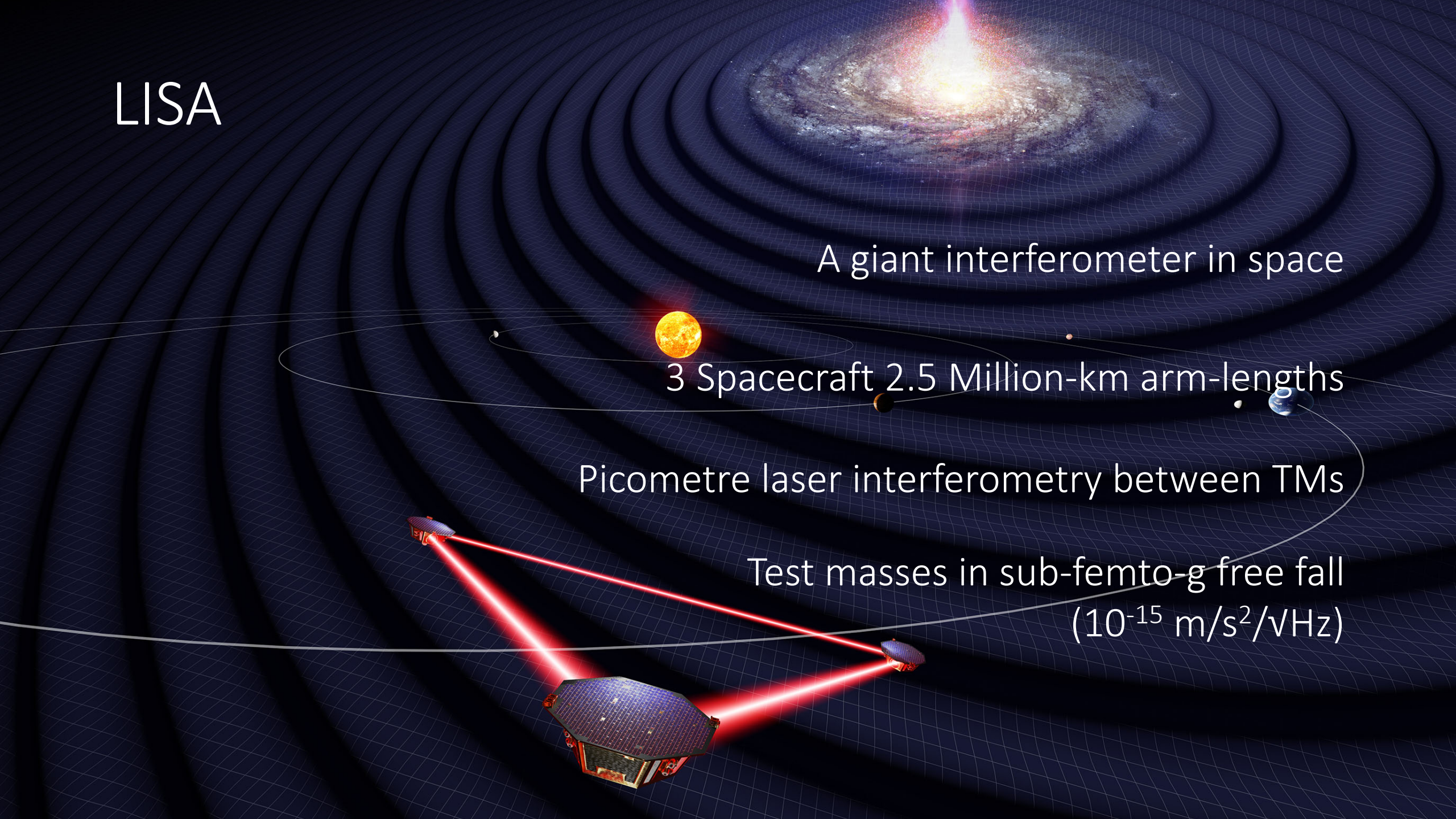
LISA

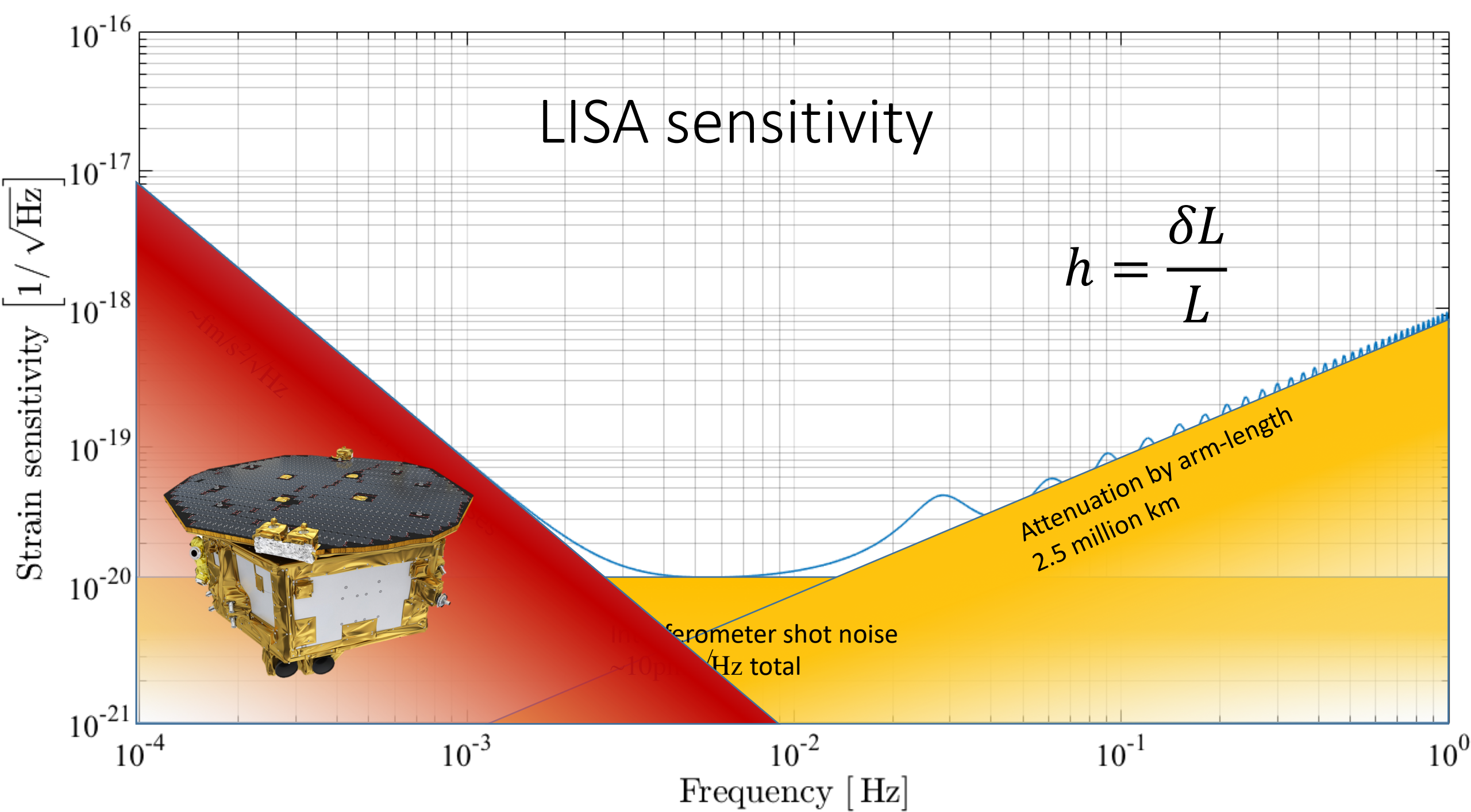
A giant interferometer in space

3 Spacecraft 2.5 Million-km arm-lengths

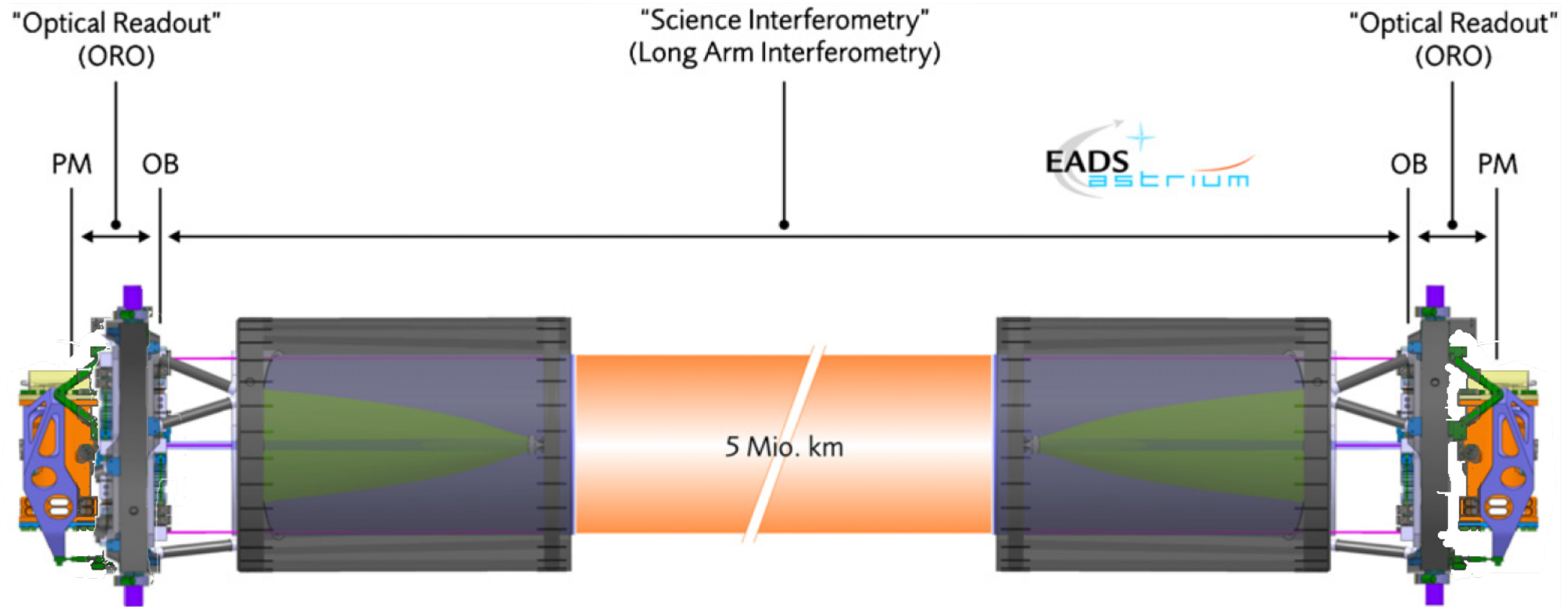
Picometre laser interferometry between TMs

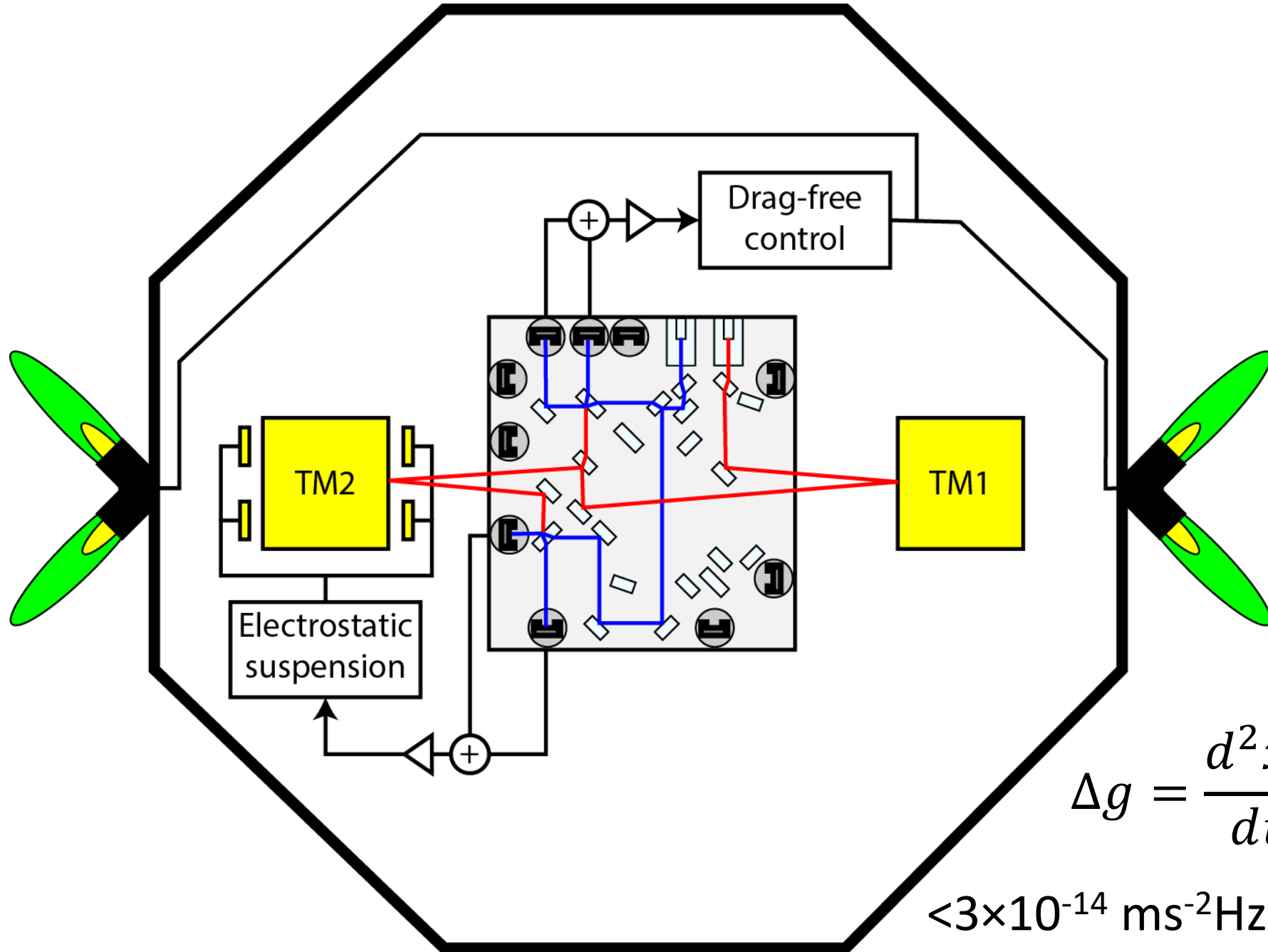
Test masses in sub-femto-g free fall
(10^{-15} m/s²/√Hz)





Squeezing the LISA arm





$$\Delta g = \frac{d^2 x_{12}}{dt^2} - \frac{F_{x2}}{m}$$

$< 3 \times 10^{-14} \text{ ms}^{-2} \text{ Hz}^{-1/2}$ at 1mHz

Achieving femto-g accelerations

Vacuum control

1.96kg, 46mm TMs,
2.8-4mm gaps

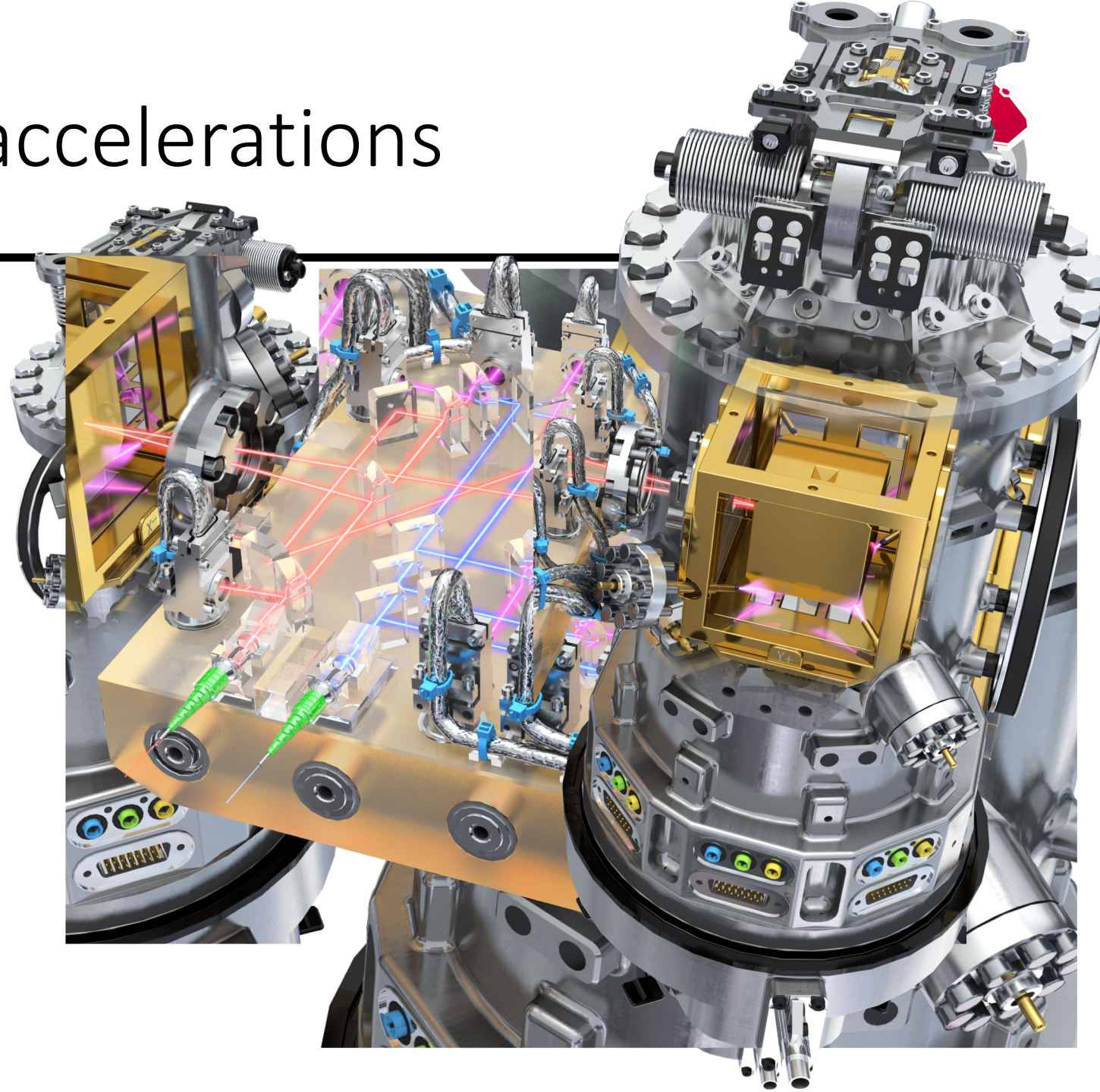
Launch lock and release

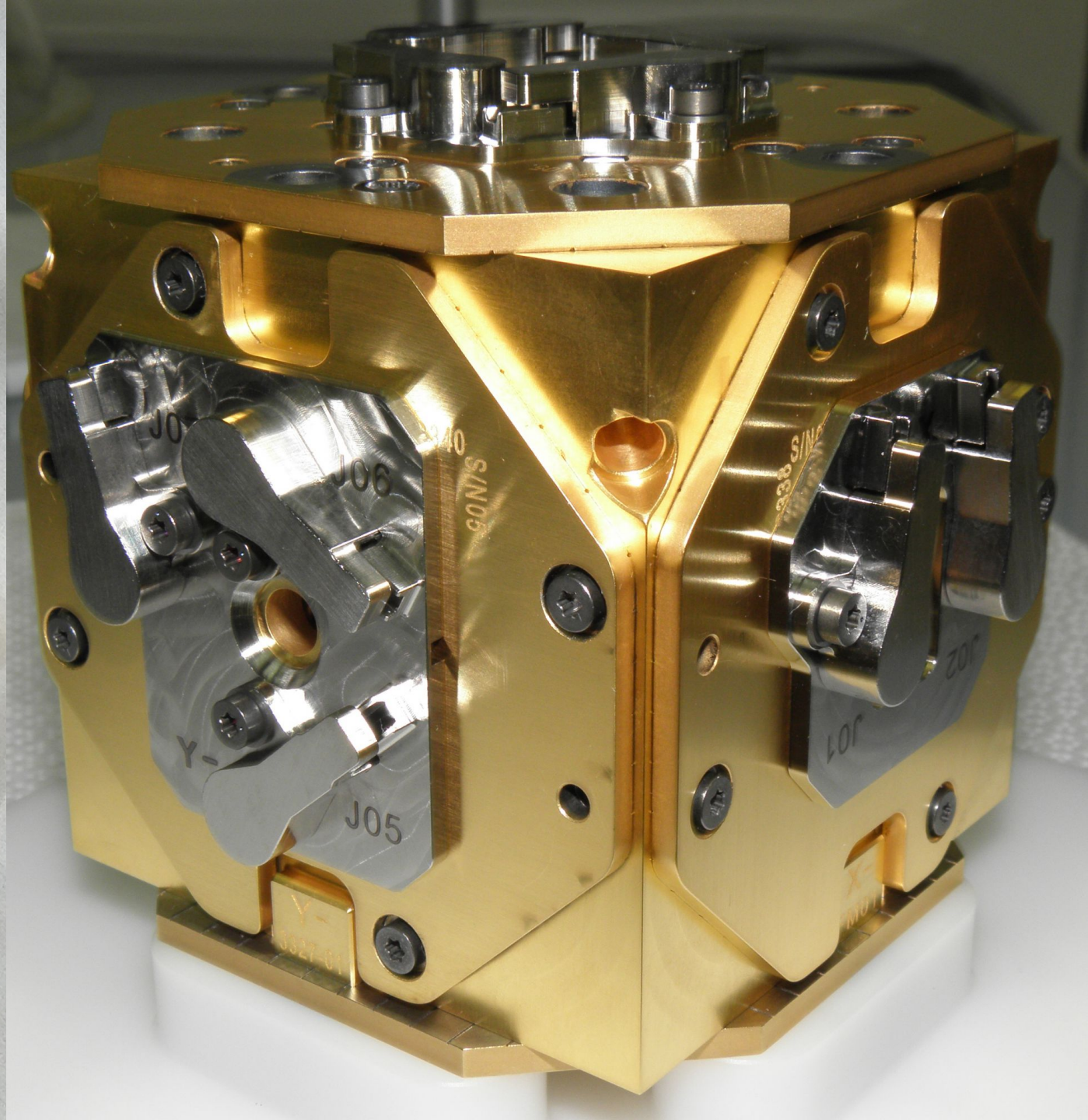
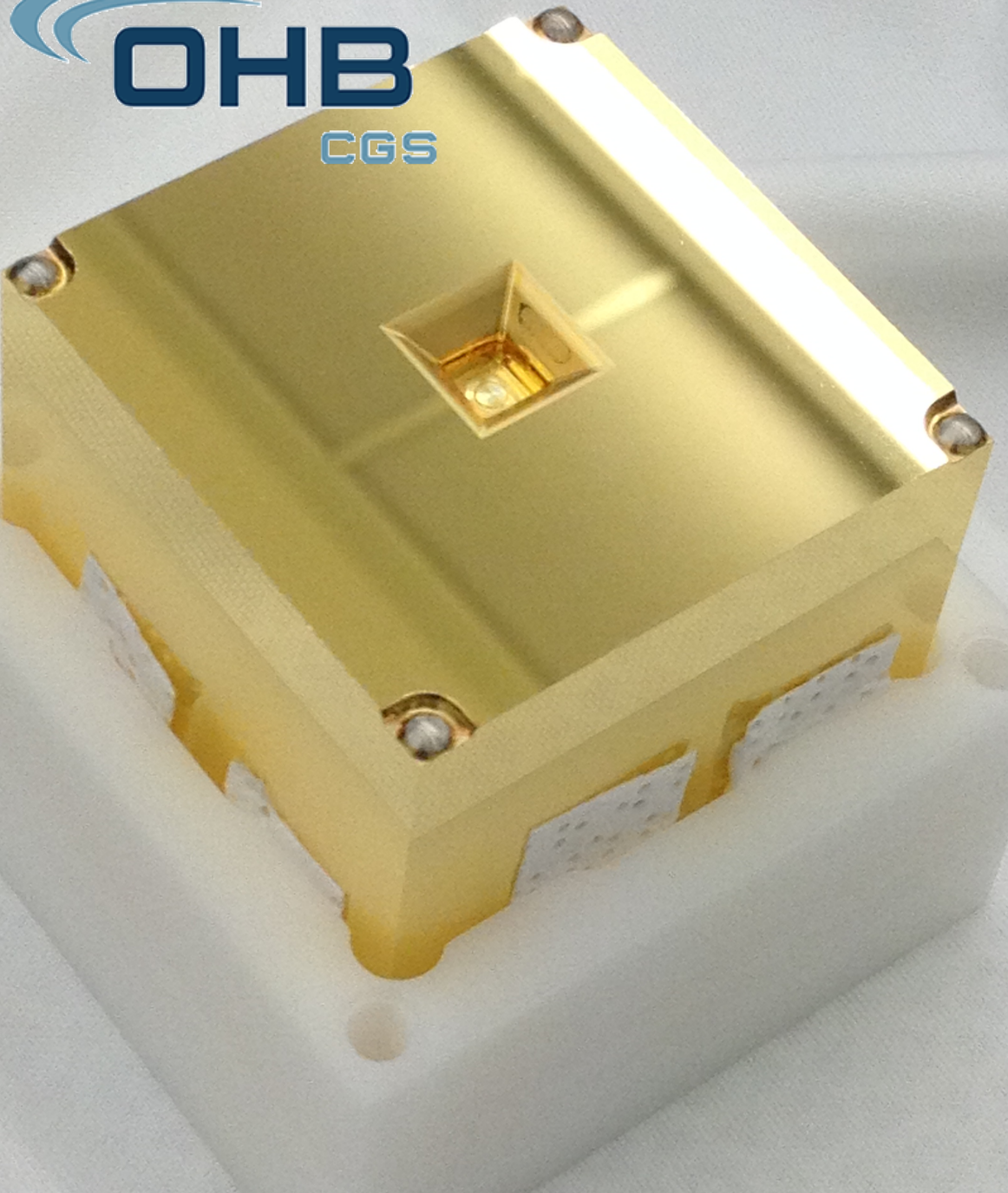
Charge control

<pm Interferometry

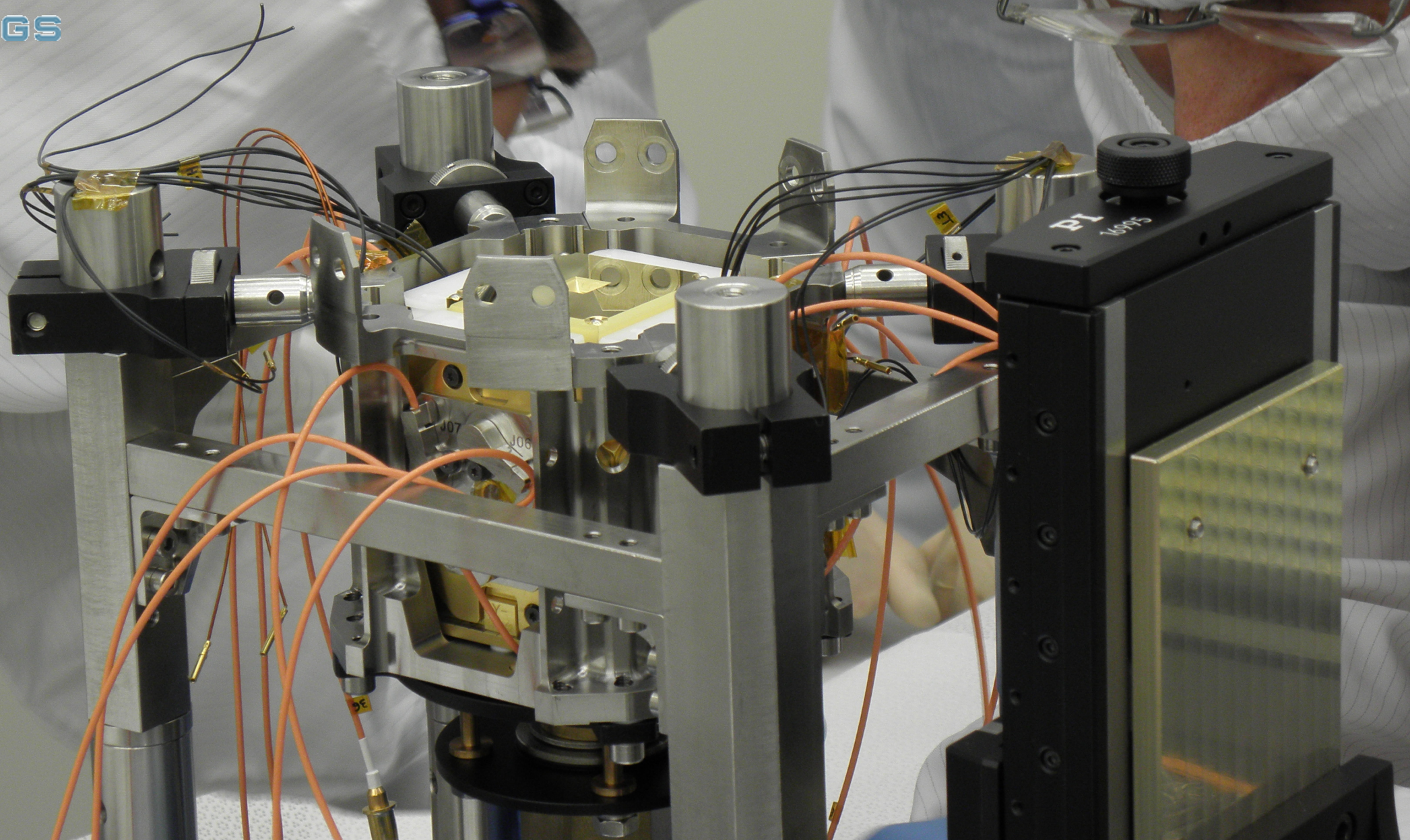
Mass control

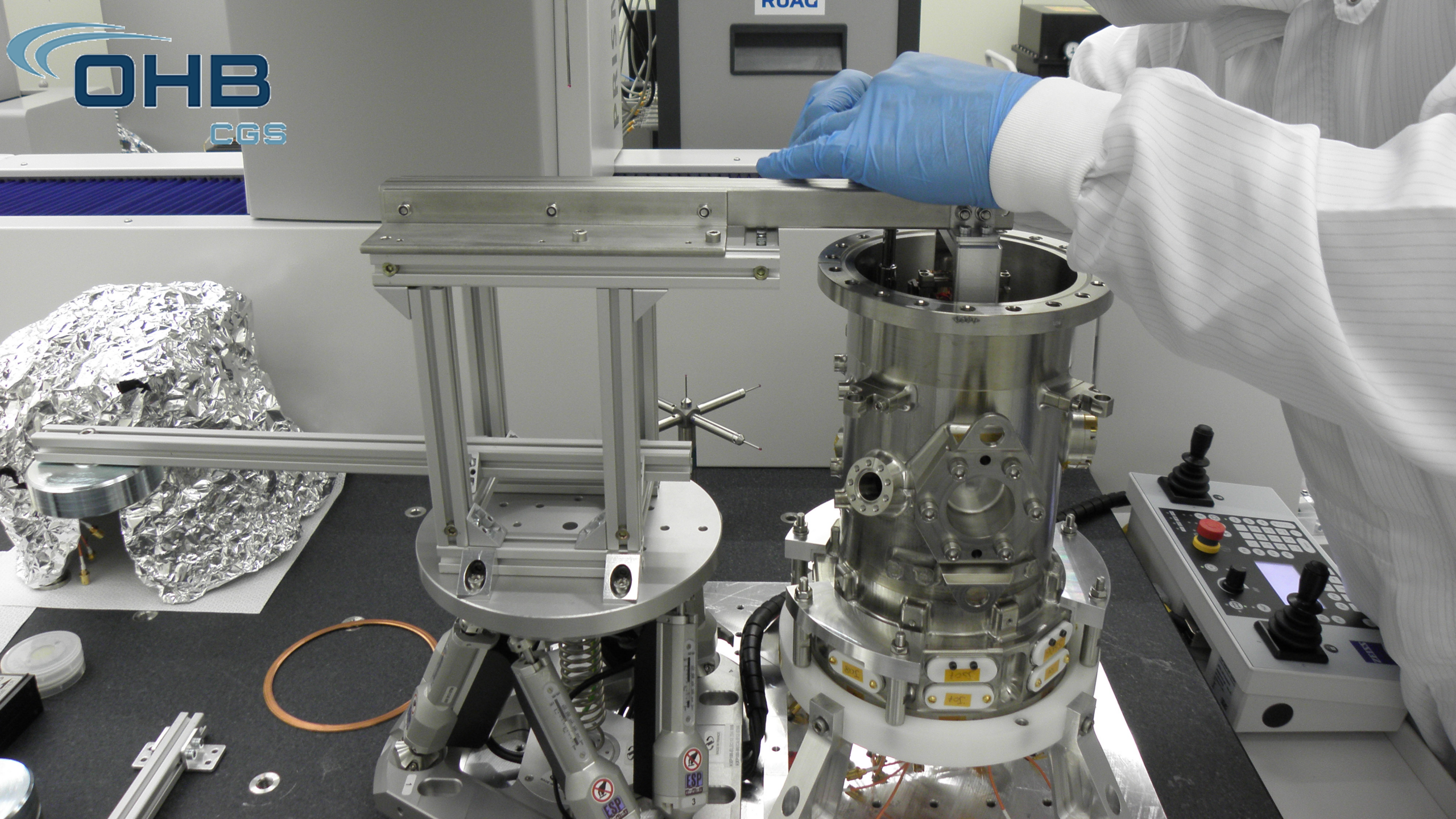
Magnetic control

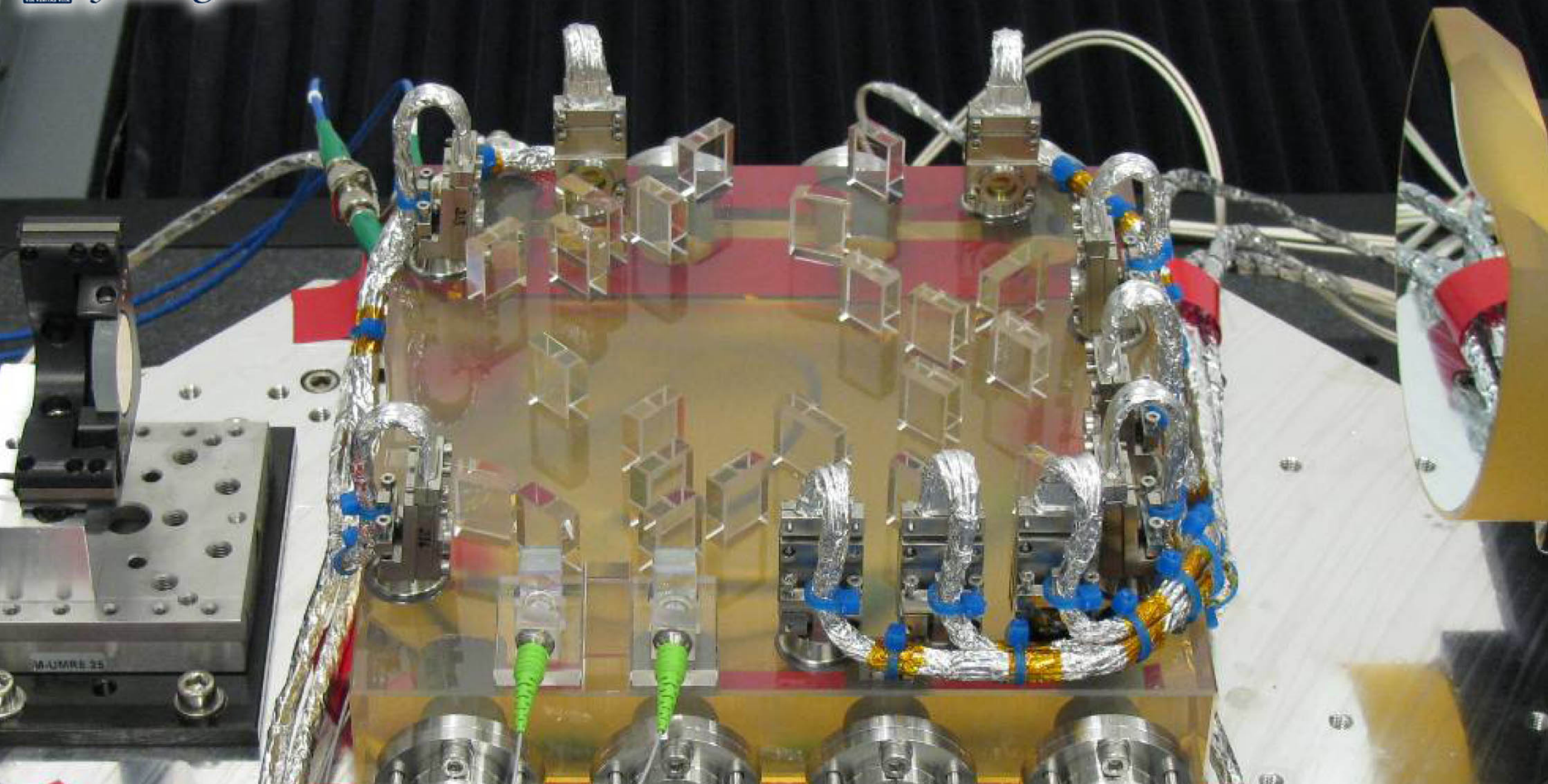


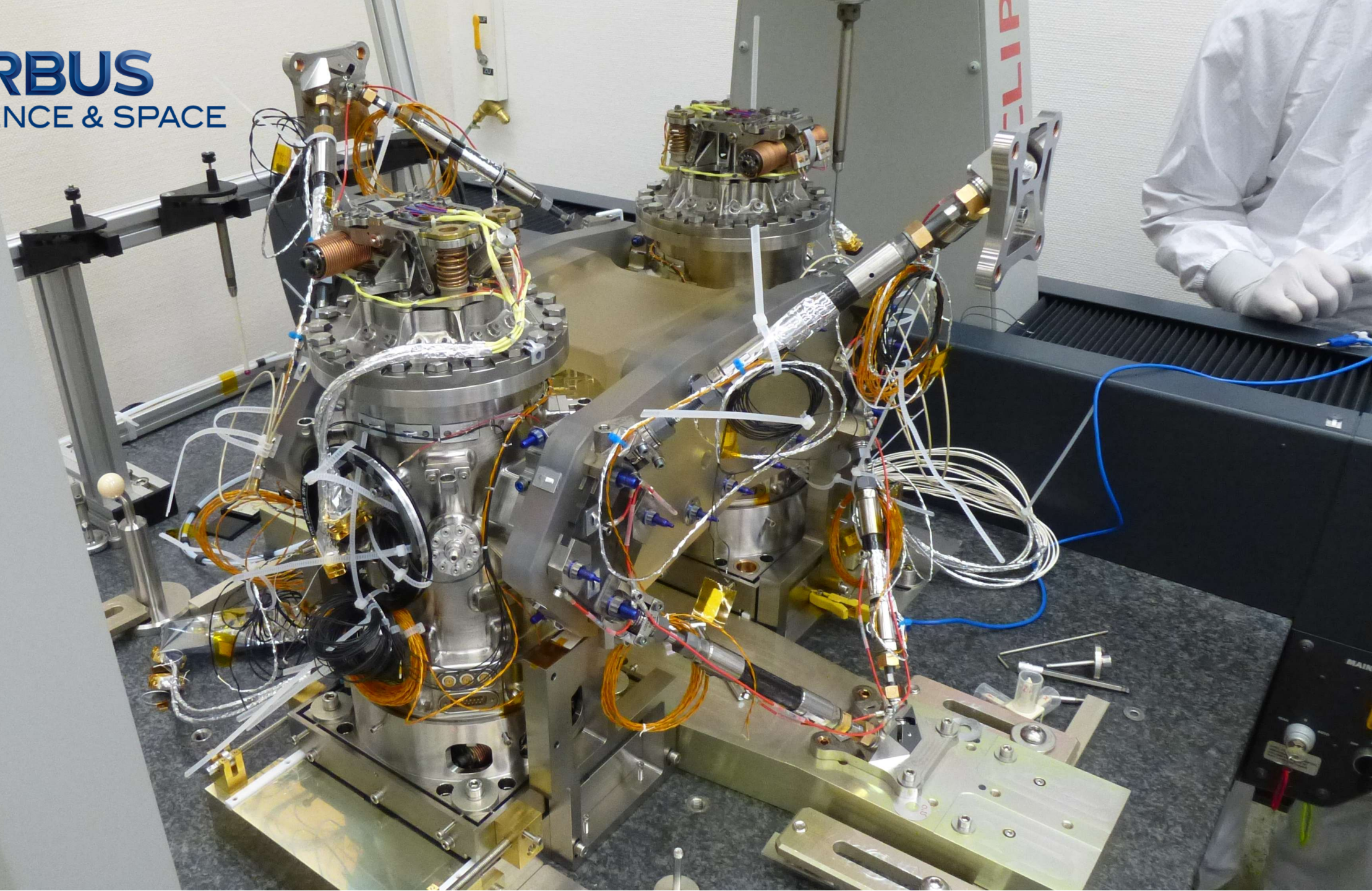






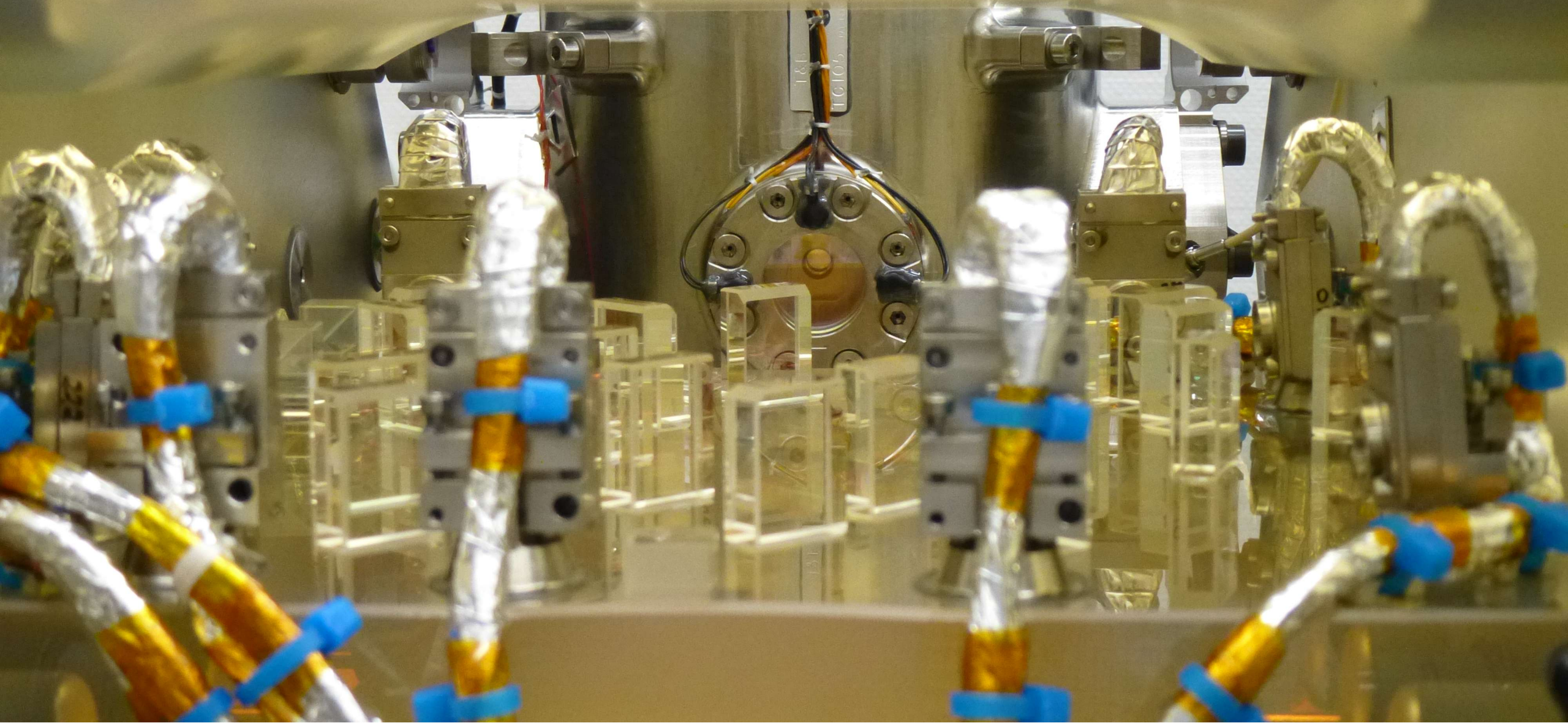


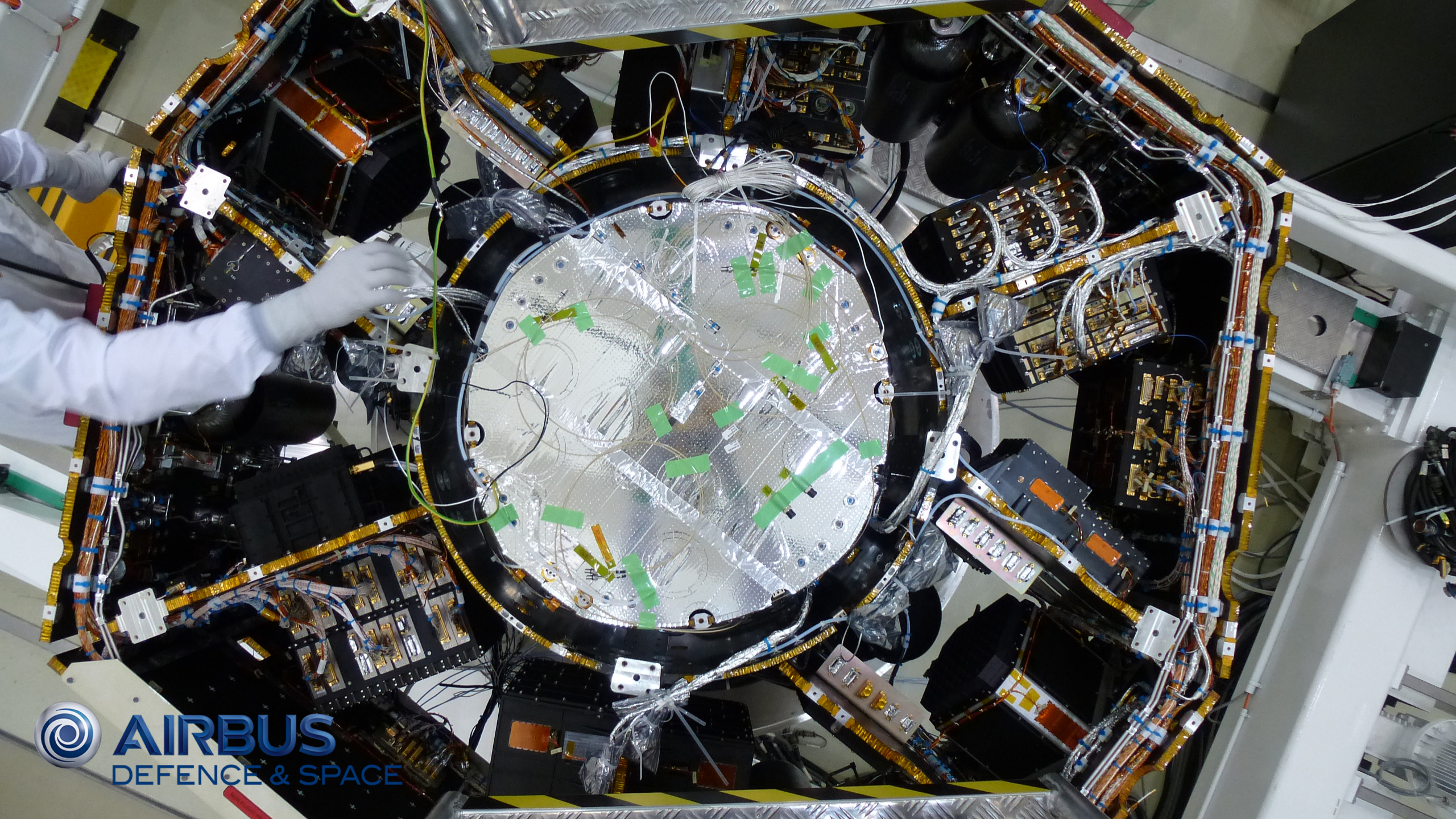






AIRBUS
DEFENCE & SPACE





lisa pathfinder



AIRBUS
DEFENCE & SPACE

WEIGHT EMPTY 1700kg
MAXIMUM GROSS WEIGHT 3700 kg SWL 20700kg
DIMENSIONS: L x W x H = 6467 x 2854 x 3053
ITEM 531 00201
HANDLE WITH CARE

DO NOT DROP
OPEN ONLY IN THE PRESENCE OF
OF A REPRESENTATIVE OF QUALITY CONTROL
AND IN ACCORDANCE WITH OPERATING INSTRUCTIONS
DO NOT OPEN IN ANY CONDITIONS WHICH MAY CAUSE
CONDENSATION TO OCCUR ON THE PACKAGED EQUIPMENT



CoG Loaded with LPF
CoG Unloaded

COVER ONLY
LIFT HERE

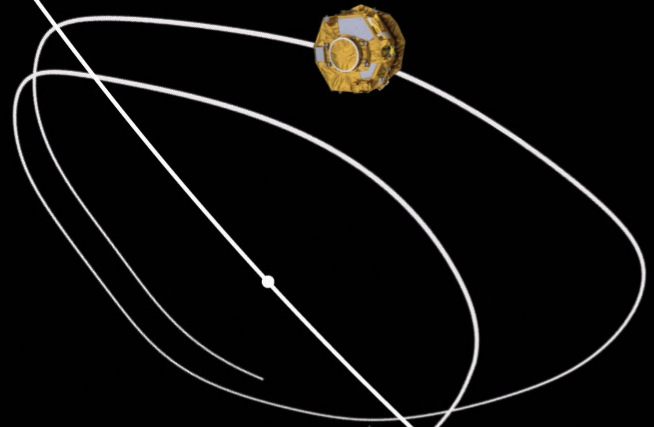
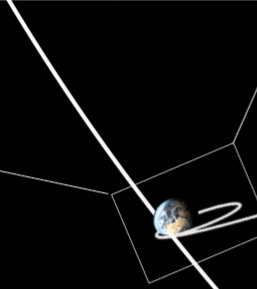
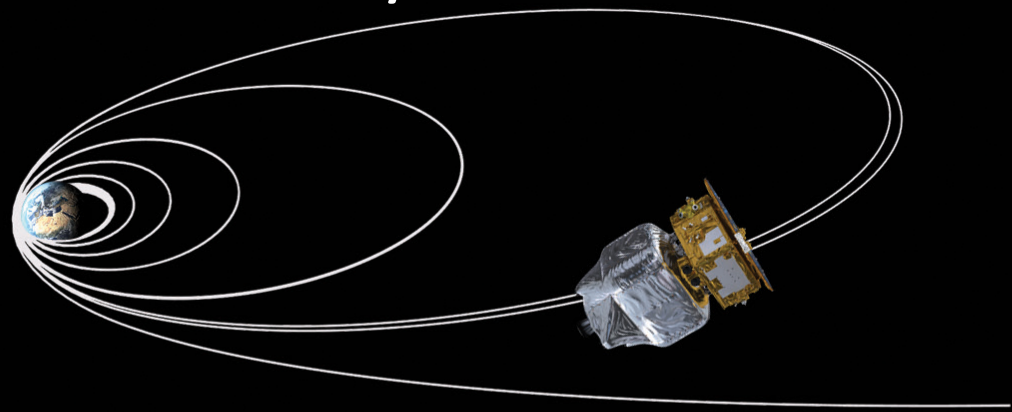
PORTE
301 B

LIFT HERE

FRONT



Journey to L1



Mission timeline



Science mission 1 Mar 2016 – 30 June 2017

Share of nominal mission timeline :

Noise: 197.13 days

Calibration: 5.68 days

Crosstalk: 6.48 days

Thruster: 3.50 days

Electrostatics: 21.50 days

Laser: 8.35 days

Thermal: 24.79 days

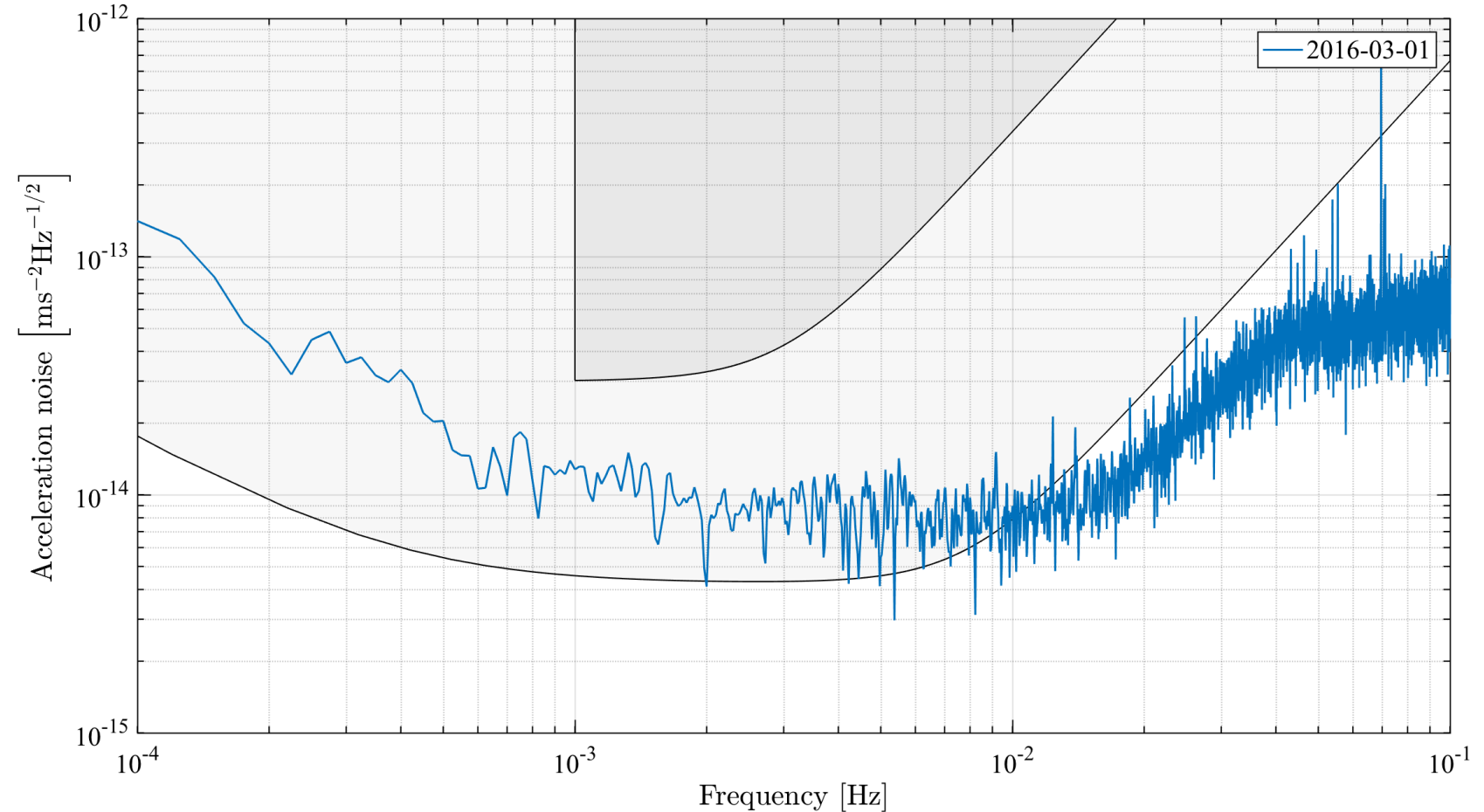
Magnetic: 5.50 days

Out of the box performance



Simplest analysis:

$$\Delta g = \frac{d^2(x_{12})}{dt^2} - \frac{F}{m}$$



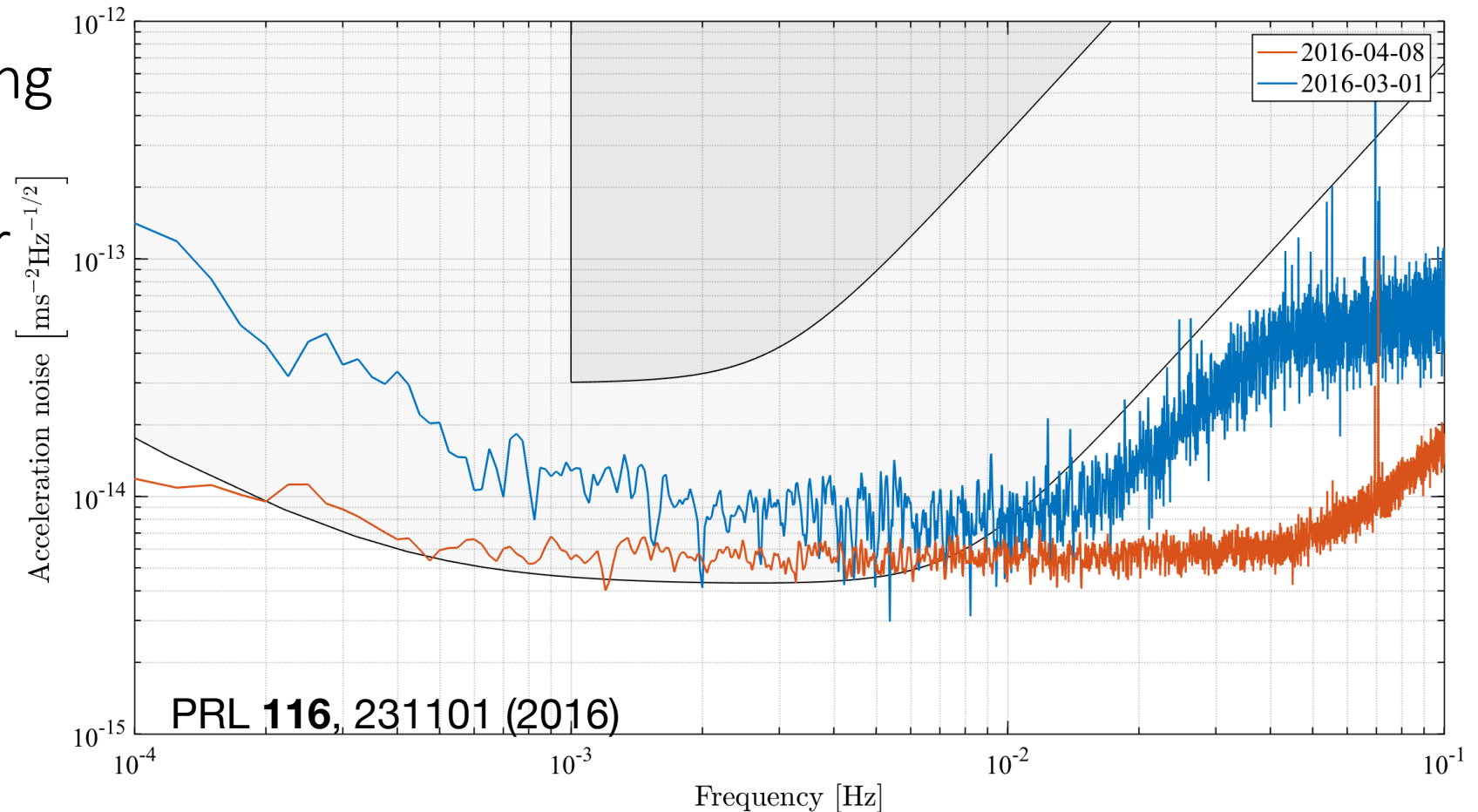
Noise performance



Gravitational balancing
= lower actuation

Cross-talk from other
degrees of freedom
due to test mass
misalignment

Centrifugal
acceleration



Known Noise Sources

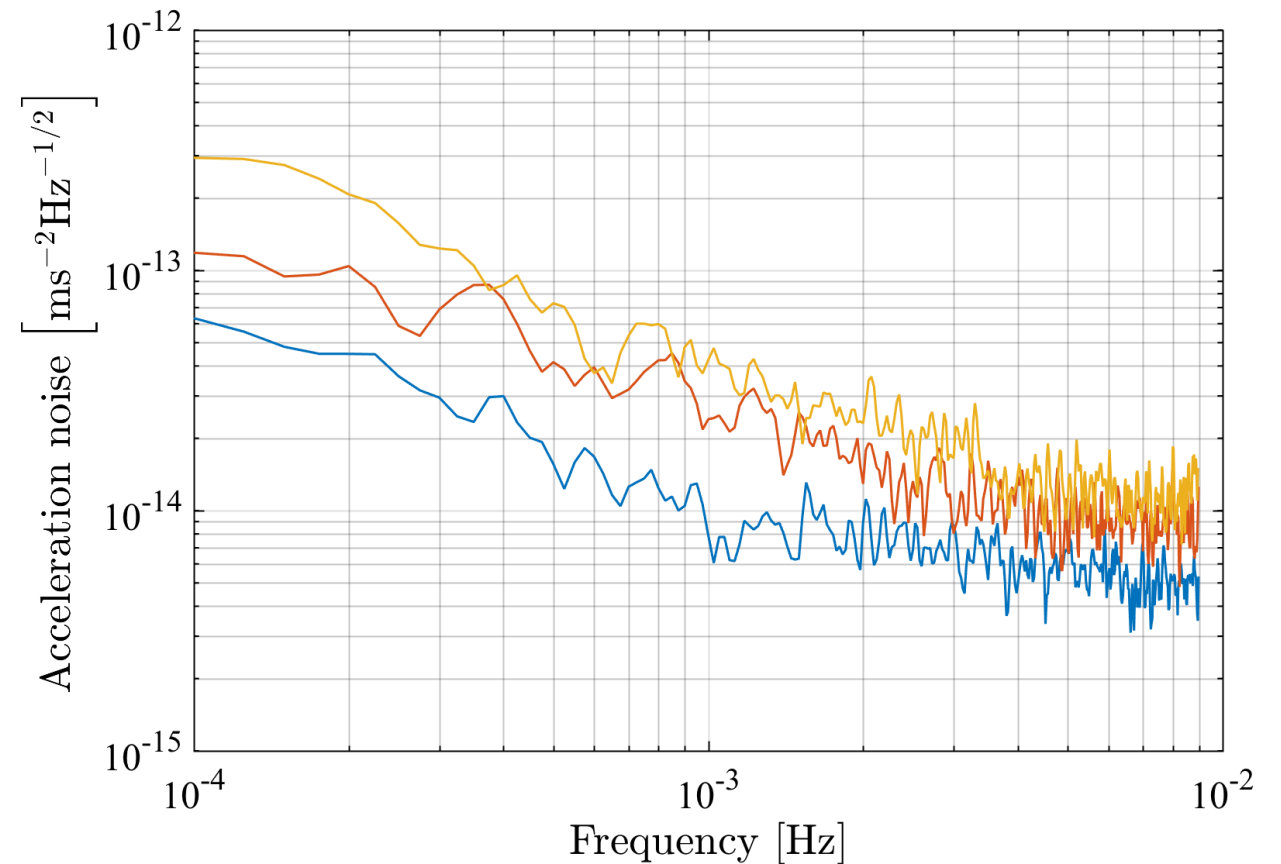


Thermal gradients

Magnetic fields

Electrostatic (TM charge)
PRL **118** 171101 (2018)

Actuation stability



Low(er) frequency noise



Low-frequency noise runs take a long time

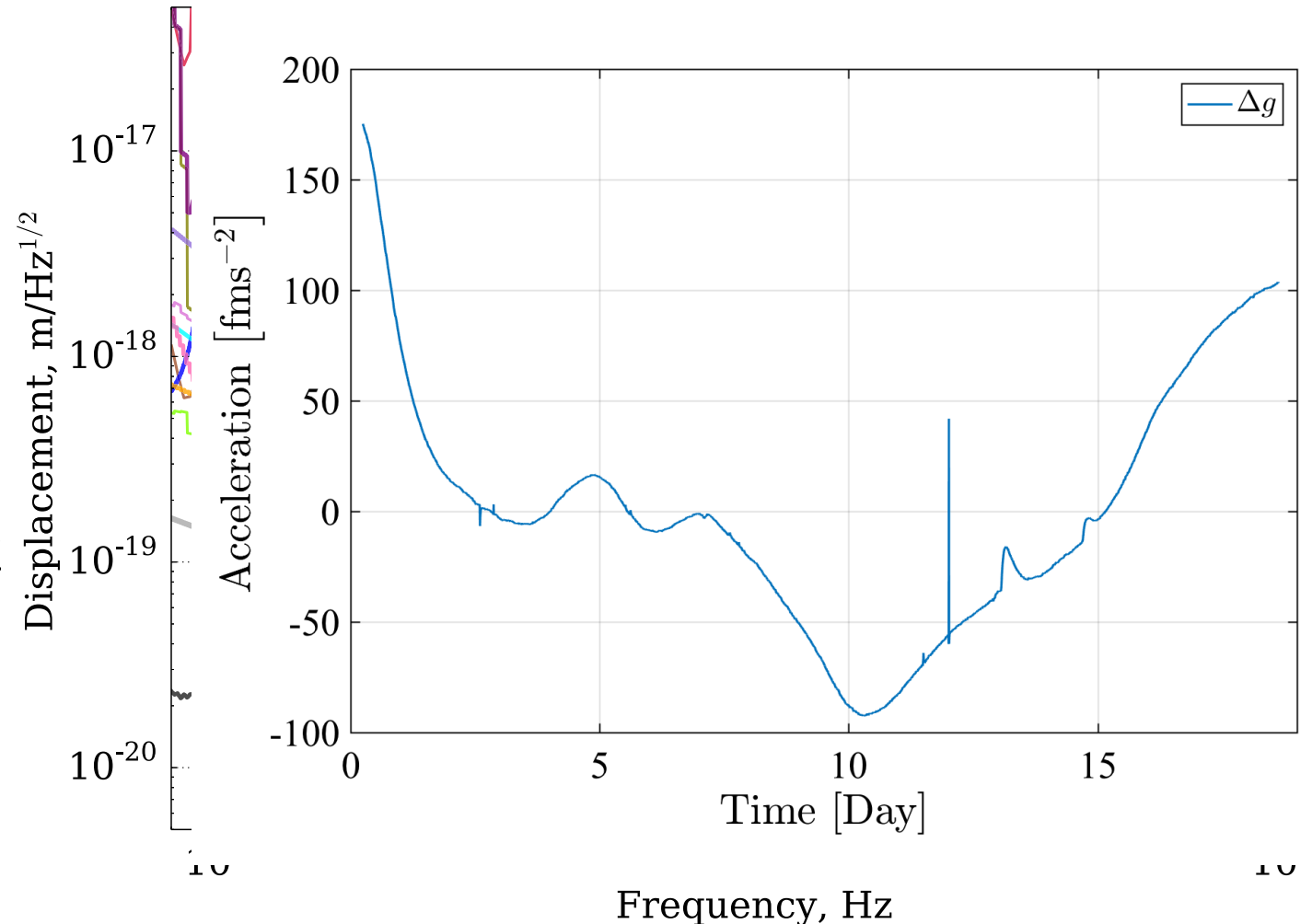
Only ~ 3400 cycles at 0.1mHz since start of mission

Compare with VIRGO/LIGO $\sim 1\text{hr}$ of 1Hz data

LISA band extends to $20\mu\text{Hz}$

Need long runs

Glitches!



Glitches

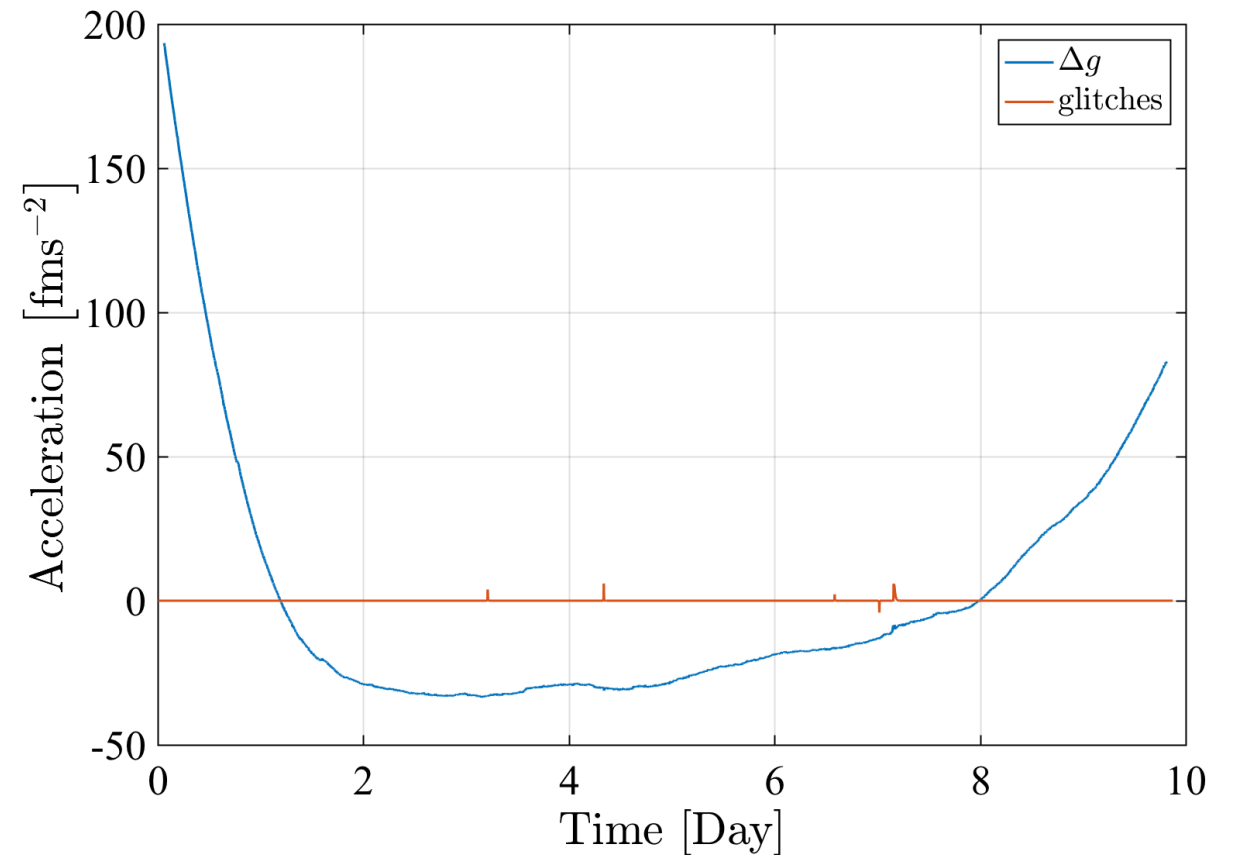


Δg impulses limit noise run length

Origin unknown

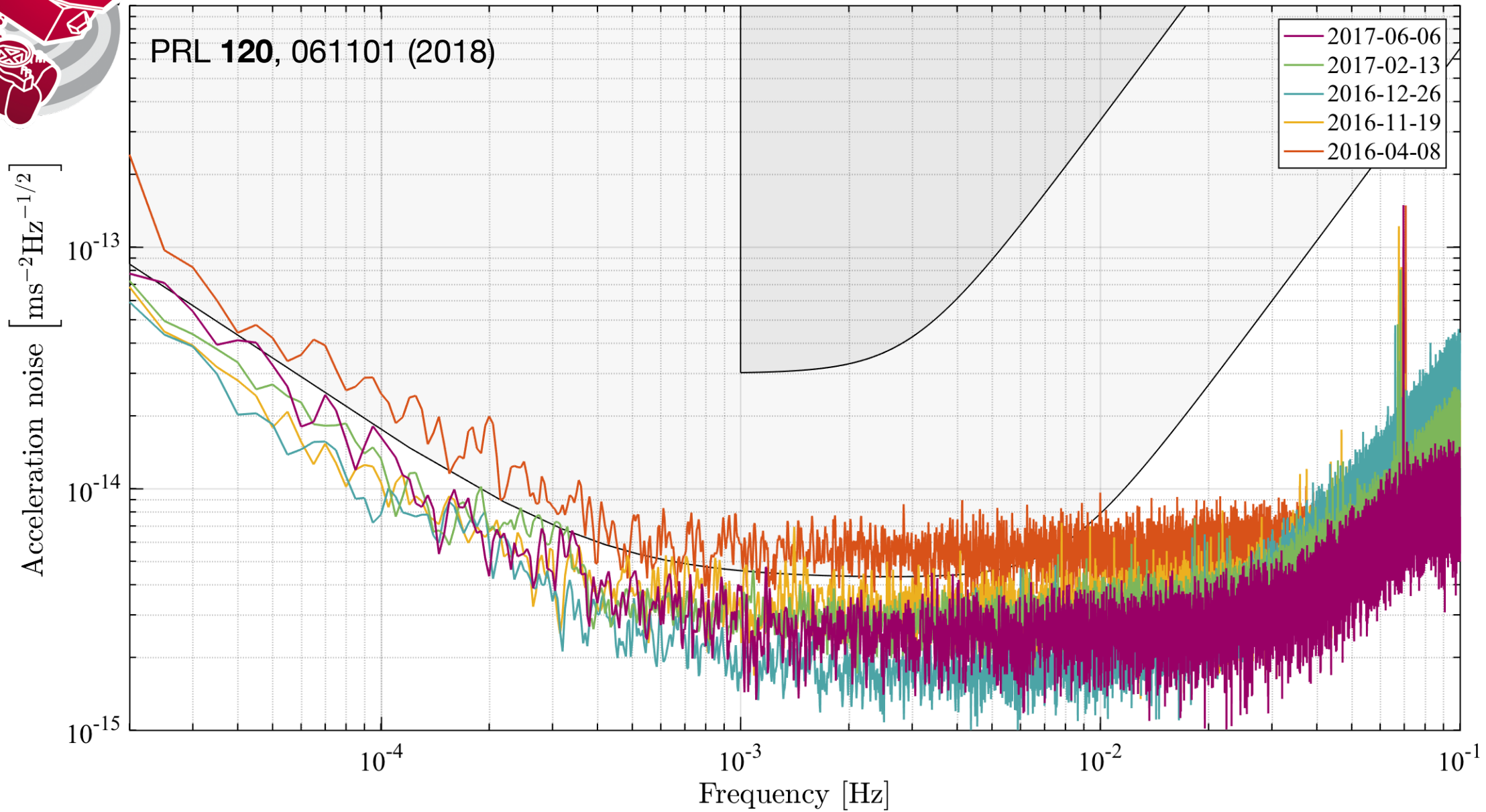
Fit by simple, consistent model

Removed to compare underlying noise





PRL **120**, 061101 (2018)



Prospects for LISA



SMBH science reliant on LISA
low-frequency performance

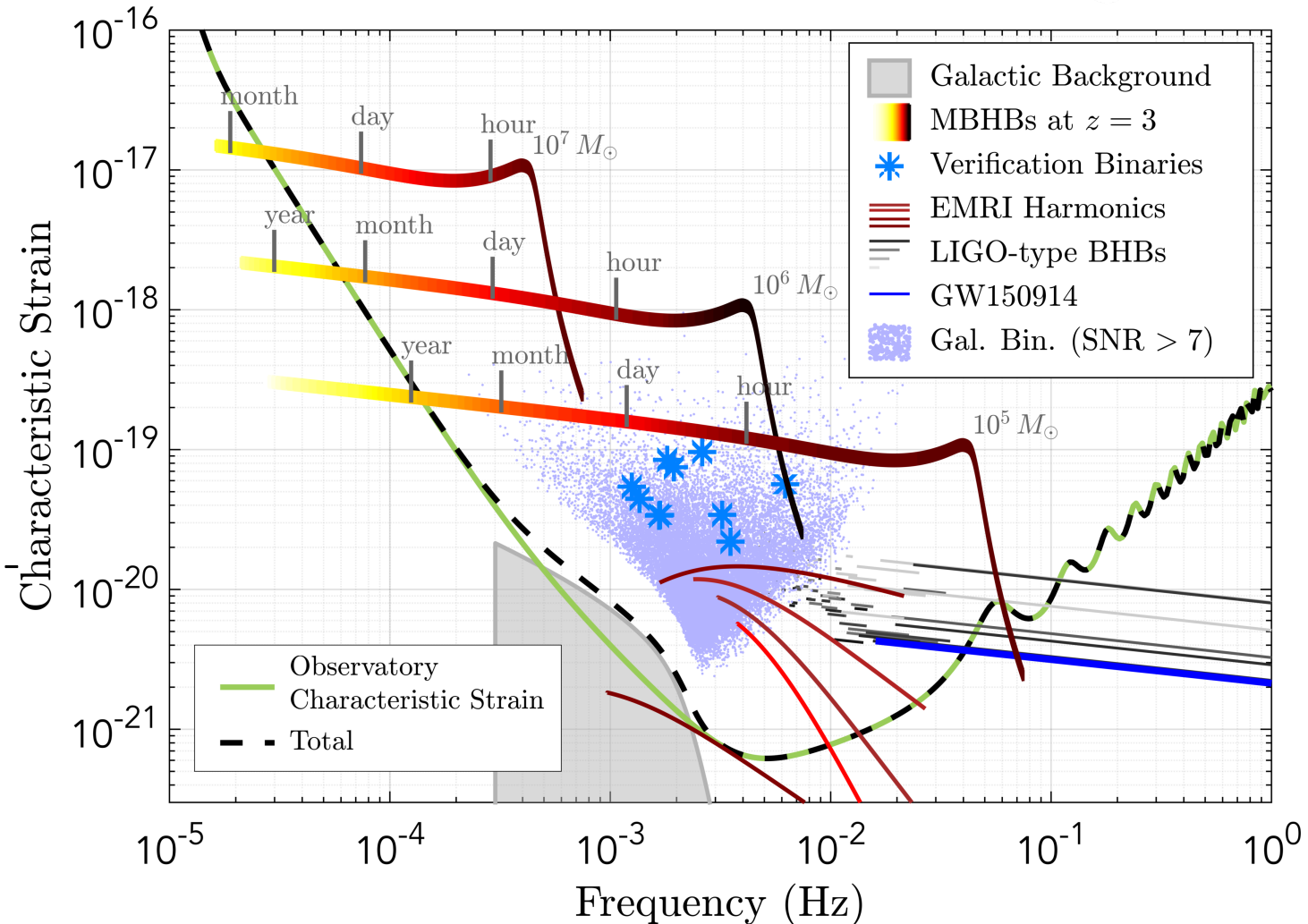
Measured on LISA Pathfinder
and compatible with all
science goals

Challenges remain:

Noise characterization via time-
delay interferometry

Unknown noise

Impact of glitches



Prospects for LISA



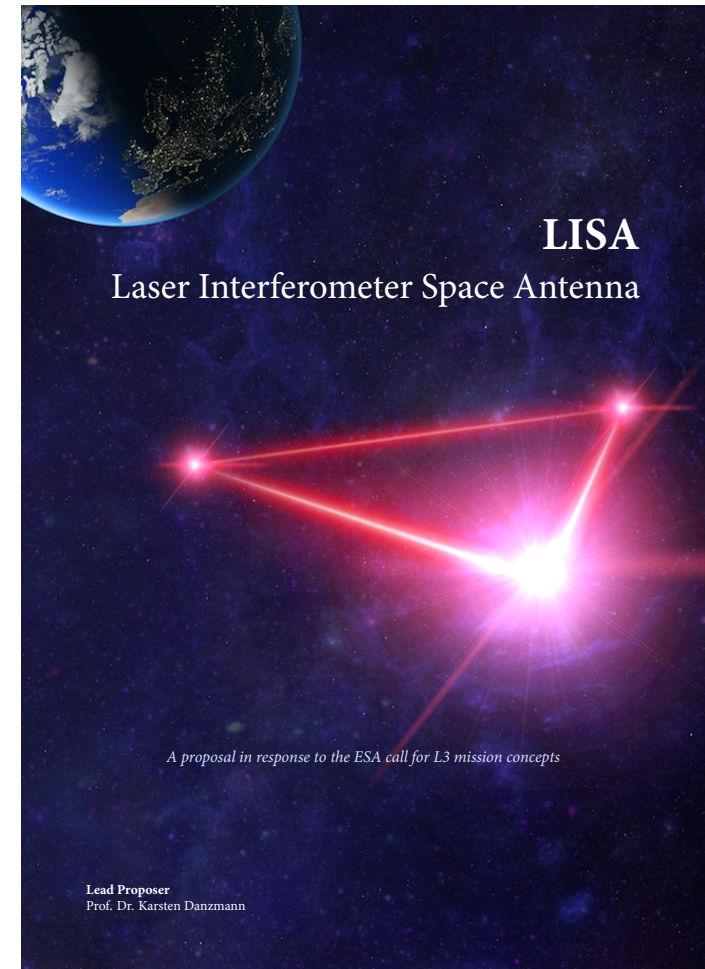
LISA selected as European Space Agency 'L3' mission

arXiv 1702.00786

Major contribution from NASA

Phase-A industrial study (how to build it) started

Launch 2030-2034





United States

NASA-JPL, NASA-GSFC, Busek

LISA Pathfinder Contributions

Norway

Det Norske Veritas

Denmark

Terma

United Kingdom

Airbus Defence & Space, ABSL Power Solutions, SCISYS
University of Birmingham, Mullard Space Science Laboratory,
University of Glasgow, Imperial College London

Belgium

SpaceBel, Thales Alenia Space

France

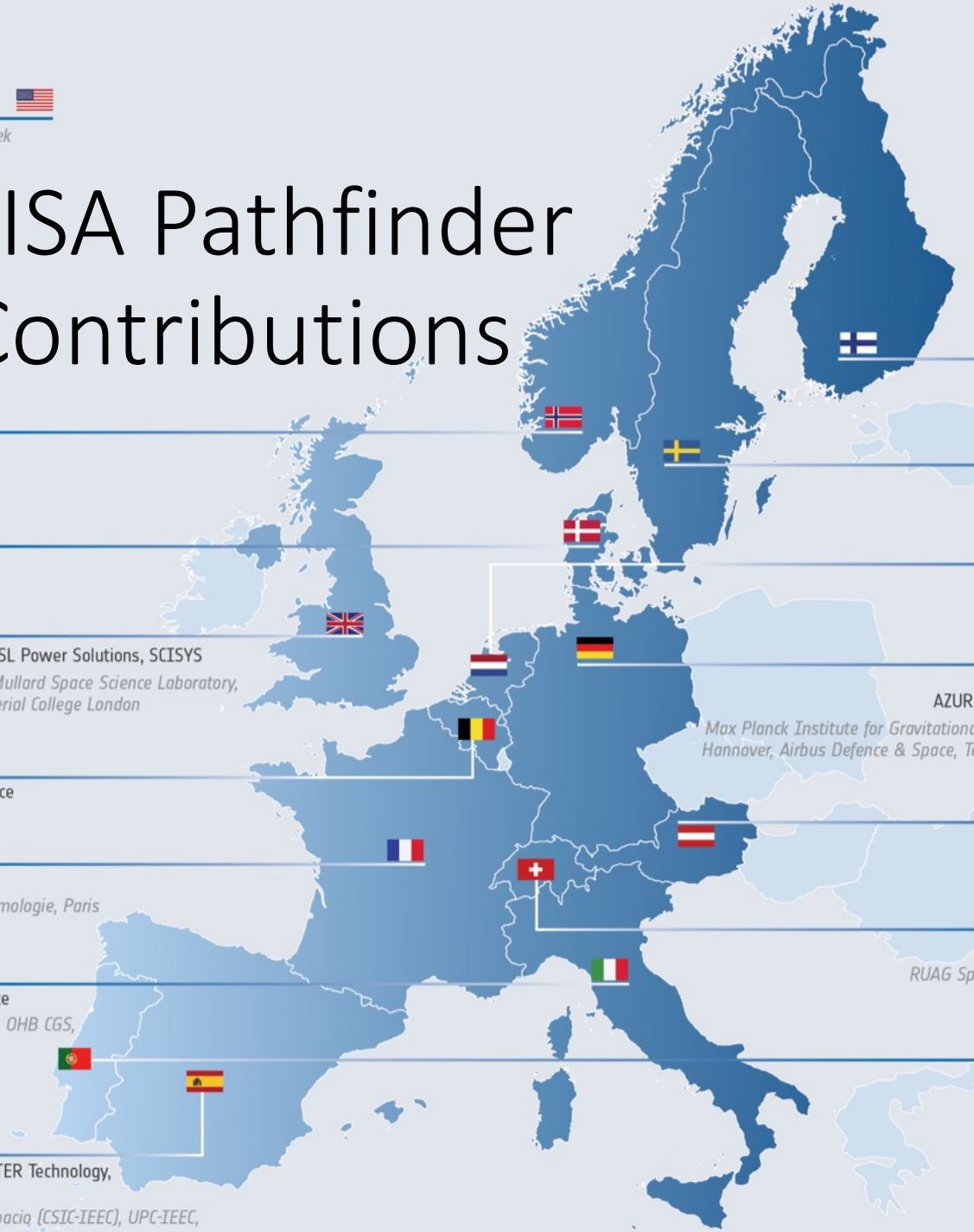
Thales Alenia Space
APC – AstroParticule et Cosmologie, Paris

Italy

Selex ES, Thales Alenia Space
Università di Trento – INFN, OHB CGS,
Thales Alenia Space

Spain

Airbus Defence & Space, ALTER Technology,
RYMSA Espacio
Instituto de Ciencias del Espacio (CSIC-IEEC), UPC-IEEC,
TEAF, NTE-SENER, GMV



Finland

RUAG Space

Sweden

RUAG Space

Netherlands

SSBV
SRON

Germany

Airbus Defence & Space, IABG,
AZUR SPACE Solar Power, ZARM Technik
Max Planck Institute for Gravitational Physics (AEI), Leibniz Universität
Hannover, Airbus Defence & Space, Tesat-Spacecom, OHB System, IABG

Austria

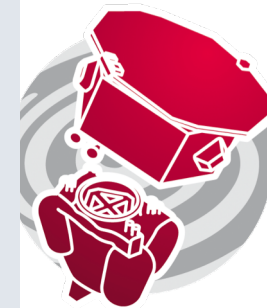
RUAG Space, Siemens
Magna Steyr

Switzerland

RUAG Space
RUAG Space, ETH Zürich, Universität Zürich,
HES-SO Valais

Portugal

Critical Software



UK SPACE AGENCY

