LISA

Laser Interferometer Space Antenna

Paris – Feb 3, 2011

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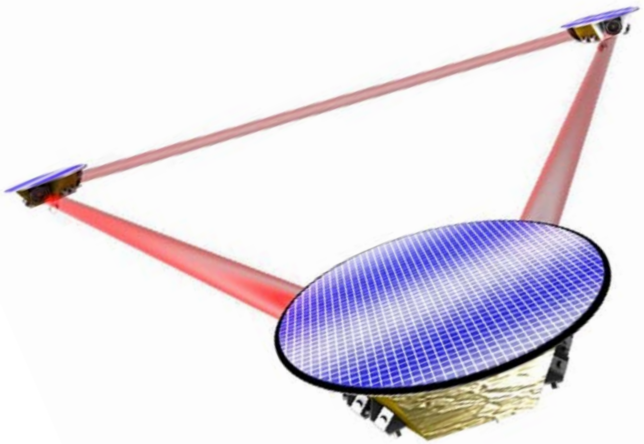
LISA Project Manager

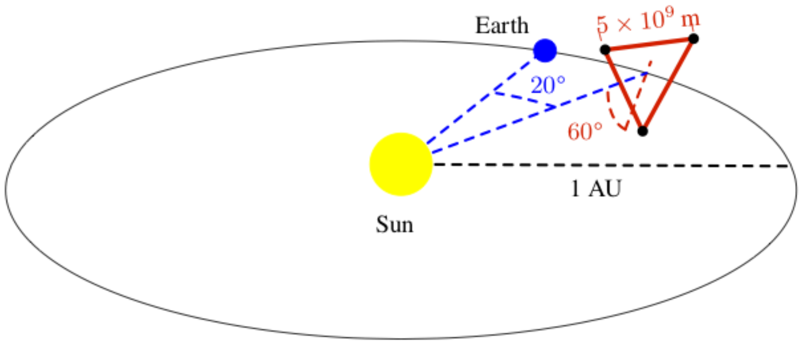
The LISA Mission

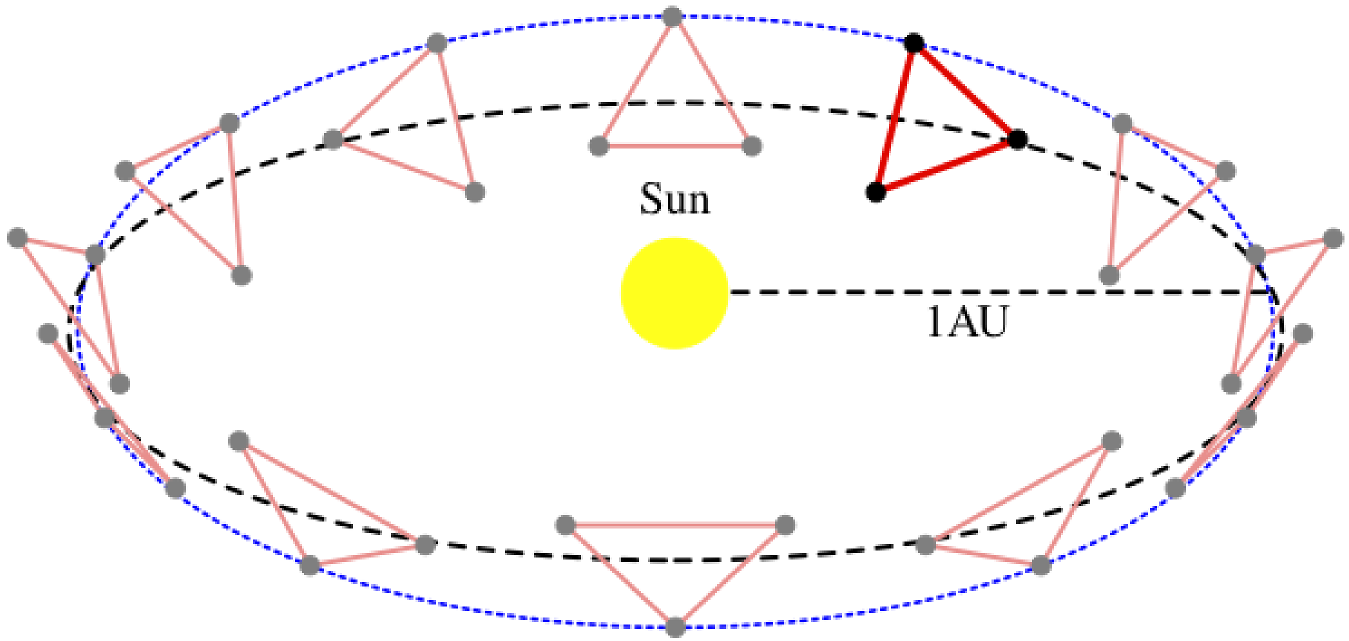
- *Three satellites in heliocentric orbits separated by 5 million km*
- *Laser interferometry to monitor the distance changes between pairs of free-falling test masses*
- *The spacecraft protects its two test masses from all external disturbances*
- *Joint ESA/NASA mission*
  - *Cooperation started in 2000*
- *Ongoing ESA technology validation mission (LISA Pathfinder)*
  - *Implementation started in 2004*
  - *Goal: validate the LISA hardware that cannot be tested on the ground*



The LISA Orbits

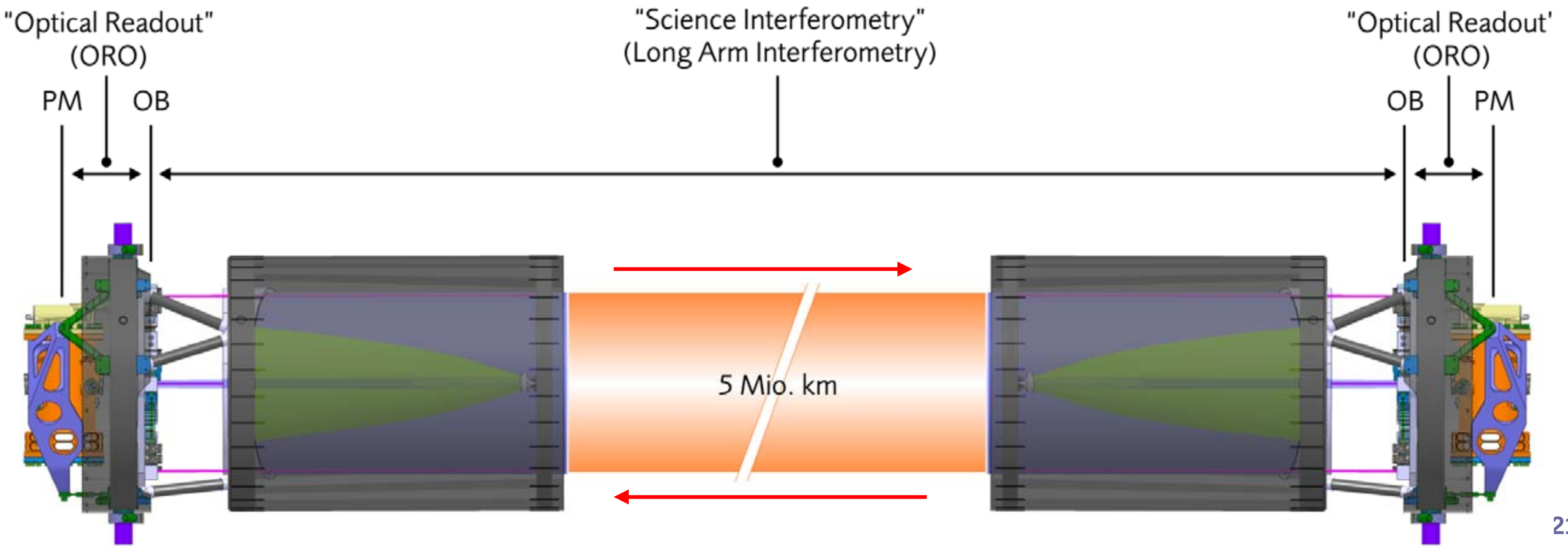
- *Orbits allow for mission duration >5 years without orbit control manoeuvres*
- *Extremely quite environment, required to achieve perfect free-fall*
- *Maintain fix orientation towards the sun*
- *Constellation revolution around the sun provides directional sensitivity*





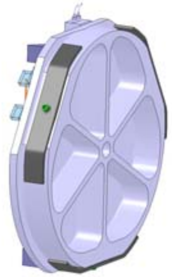
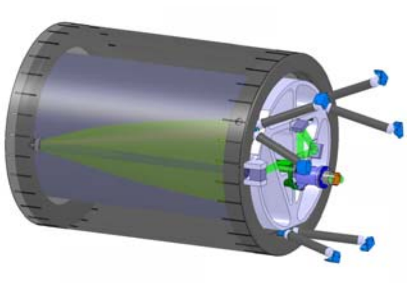
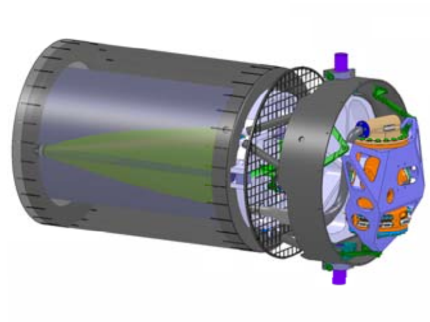
The measurement principle

- **How to achieve strain sensitivity of $h \sim \delta L/L \sim 10^{-21}$**
  - Measuring changes in the difference between the 5 x 10^9 m armlengths with 10^{-12} m precision
  - Measurement feasible thanks to orbits stability within the measurement bandwidth
  - Laser-based version of spacecraft ranging
- **Measurement split into:**
  - long-arm interferometer, between fiducial points on two opposite optical benches
  - local interferometer, test-mass displacement wrt fiducial point
- **Local interferometer will be flight validated by LISA Pathfinder**

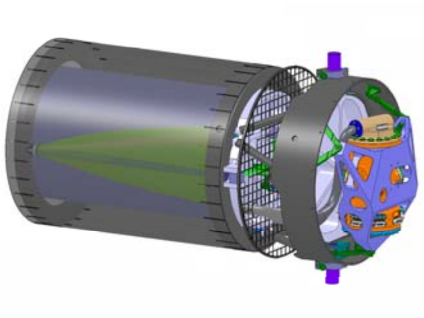
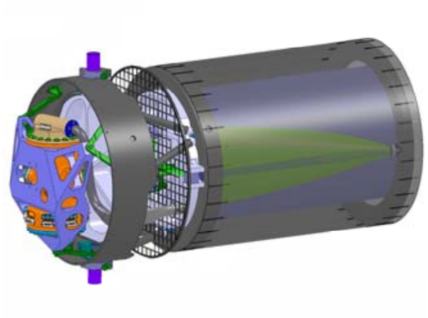
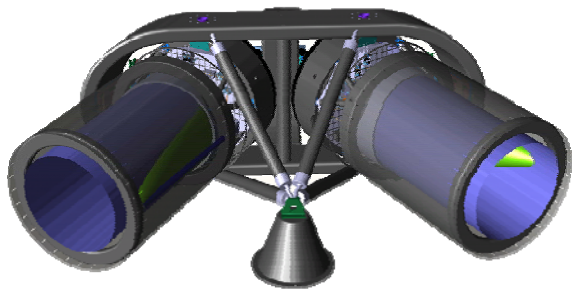


LISA Payload

GRS + *Optical Bench* + *Telescope* = *Optical Assembly*

 +  +  = 

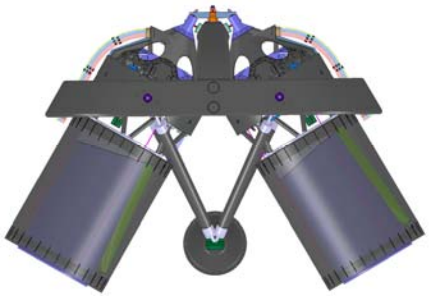
2 x Optical Assemblies = *MOSA*

 +  = 

MOSA + electronics (Phasemeter + Laser + FEE etc.) = *Payload*

Sciencecraft & Composite

Payload + *Spacecraft bus* = *Sciencecraft*



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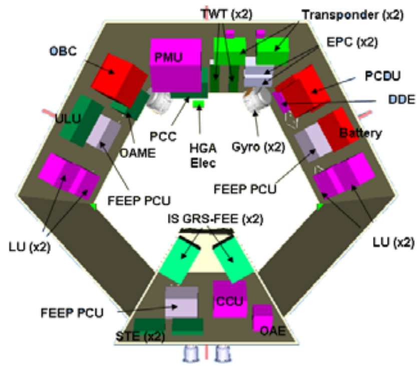

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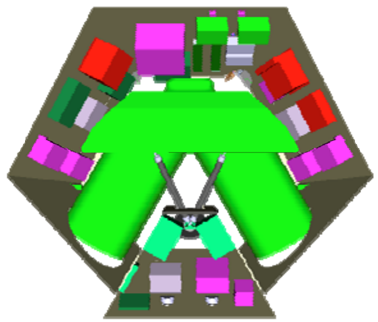
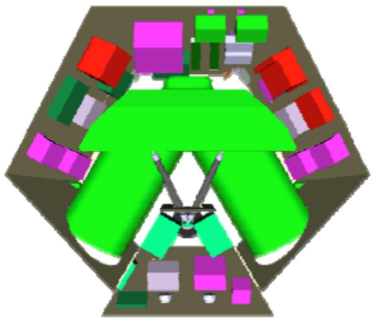


Sciencecraft + *Propulsion Module* = *Composite*



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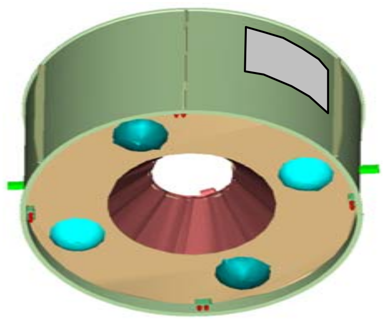

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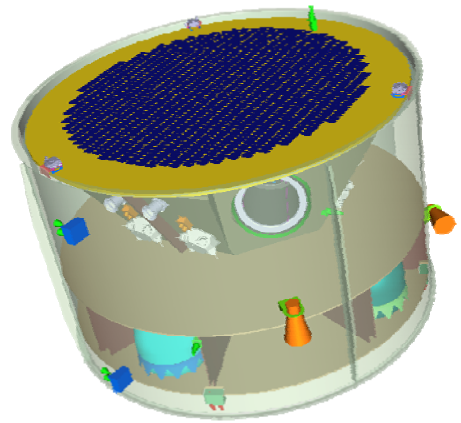
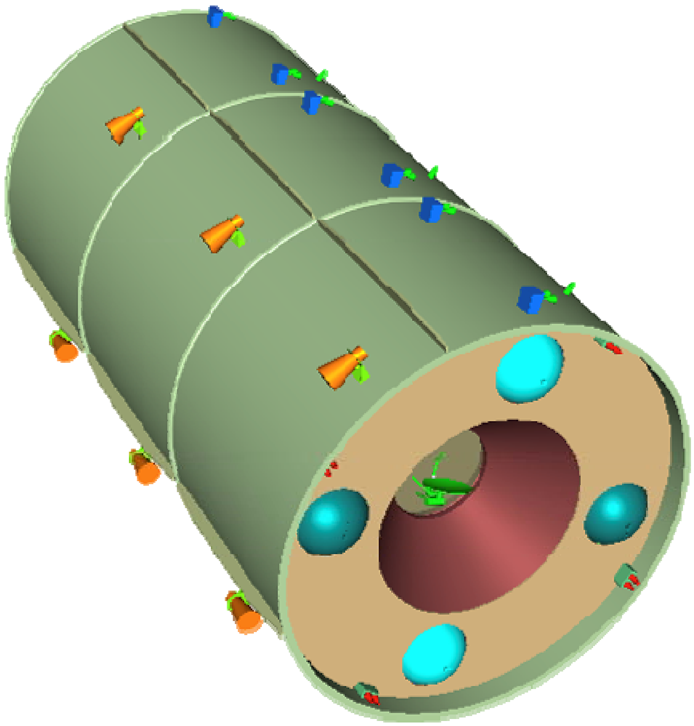


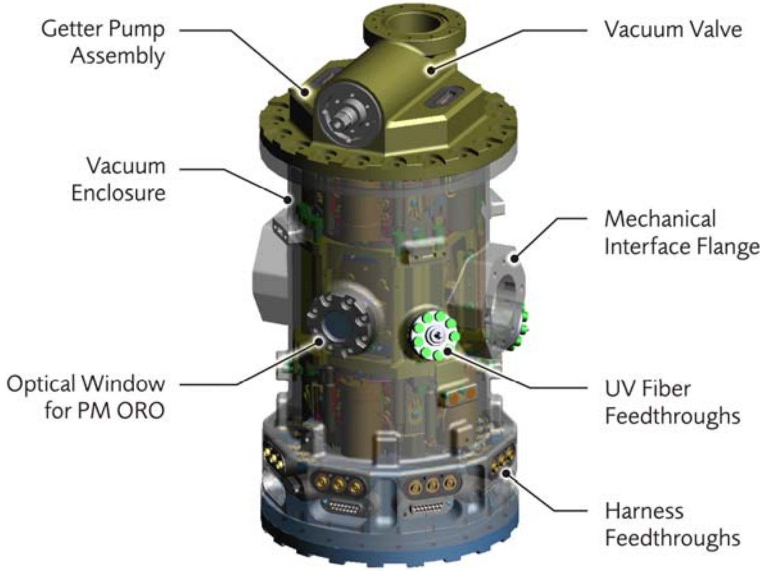
Stack



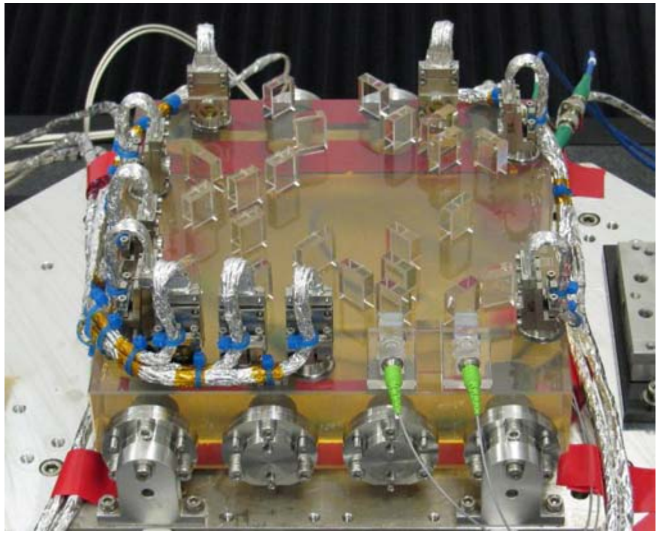
Stack = 3 x Composite modules

The LISA Payload

- *LISA payload consists of two main parts*
  - *Interferometry Measurement System*
  - *Disturbance Reduction System*



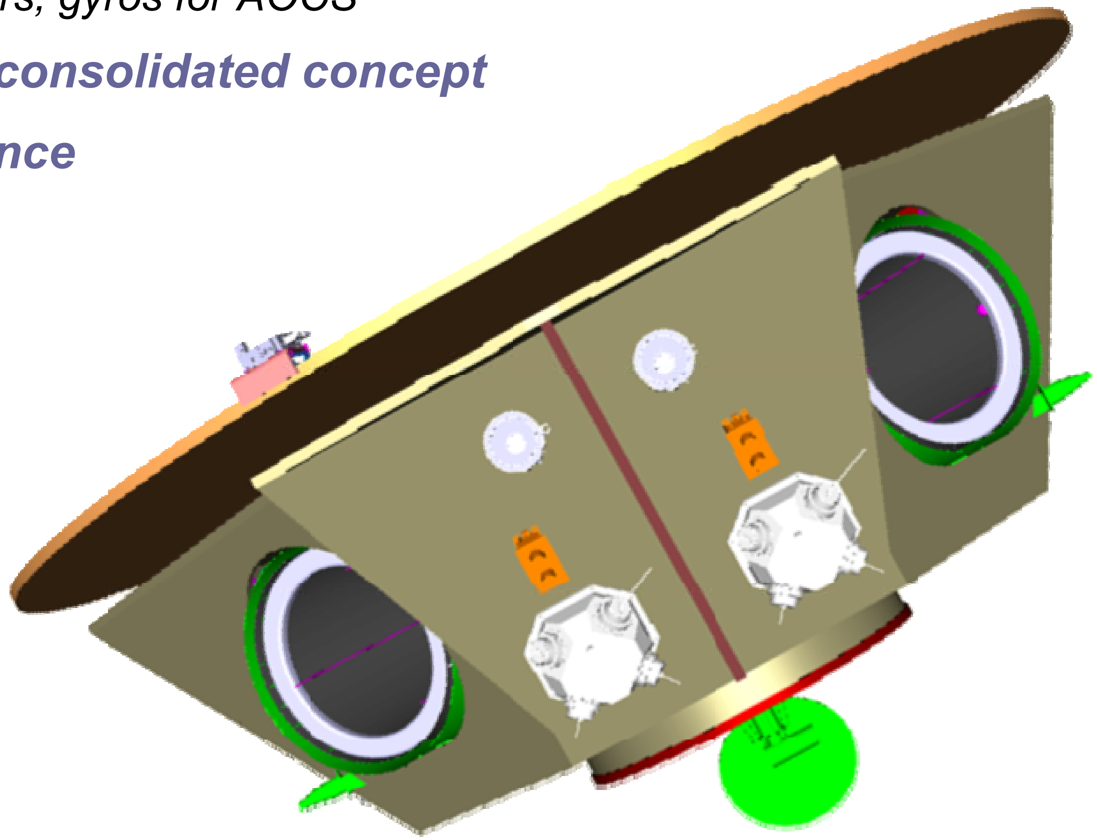
- *Interferometric Measurement System includes:*
  - *40 cm off-axis telescope*
  - *Optical bench*
  - *Laser system (2 W at λ=1064nm)*
  - *Phasemeter*



- *Disturbance Reduction System includes:*
  - *Gravitational Reference Sensor (GRS) with free-falling test masses*
  - *Drag-Free and Attitude Control Software (DFACS)*
  - *Micropropulsion system*

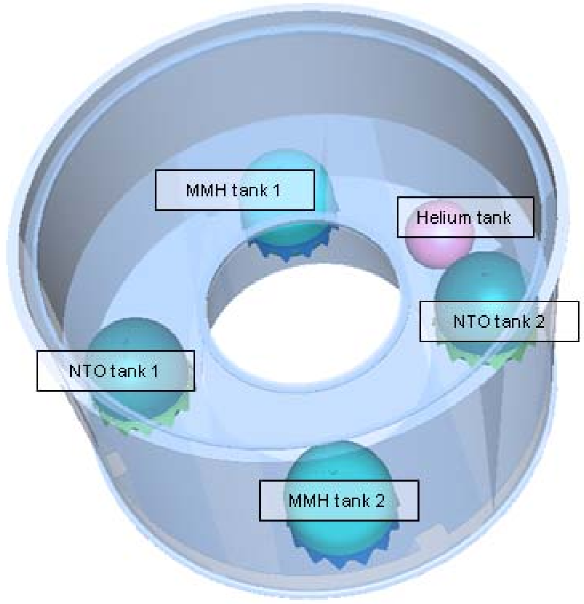
LISA Spacecraft bus

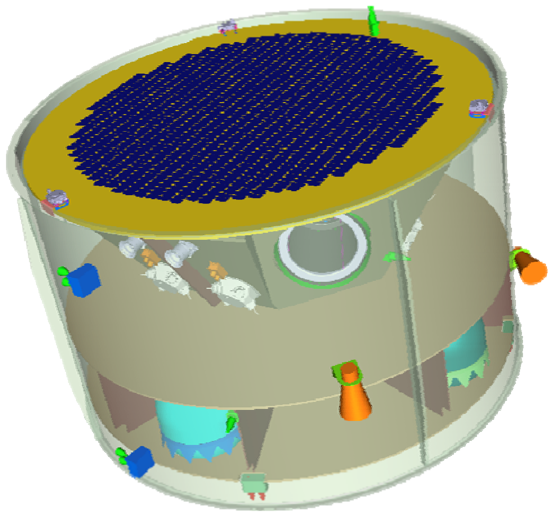
- *Standard architecture*
  - *5.4 m^2 solar array, ~1 kW, 28V regulated bus*
  - *X-band communication, 1 High-gain, 3 low-gain antennae*
  - *2 processing units, 3 MIL1553B buses, 12.2 Gbit memory*
  - *Star tracker, sun sensors, gyros for AOCS*
- *Very well studied and consolidated concept*
- *Builds on LPF experience*
  - *Gravitational balance*
  - *Magnetic cleanliness*



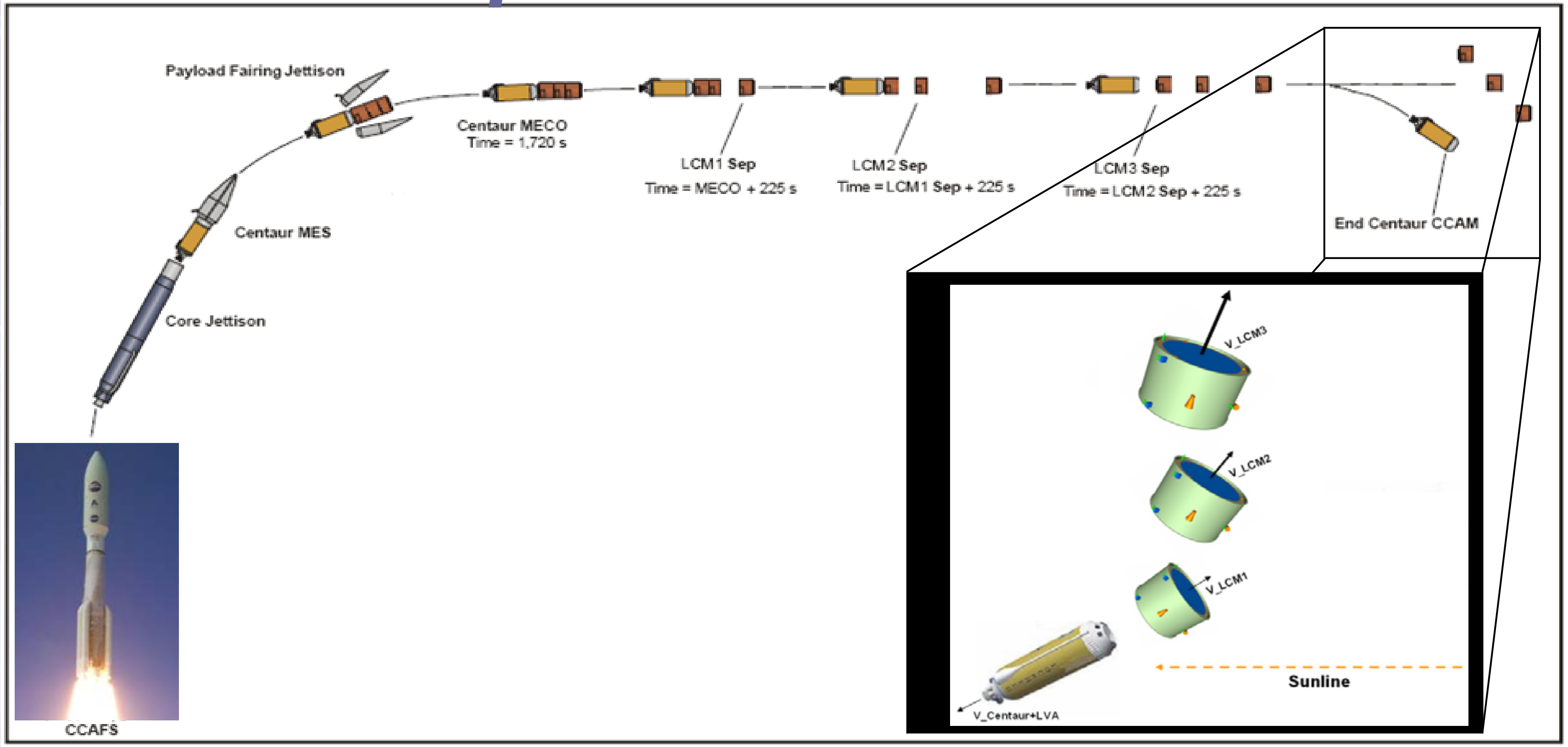
Propulsion Module

- **Bi-propellant system providing up to 1130 m/s of ΔV**
- **Carries launch loads of stack configuration**
- **Provides propulsion to the composite during cruise phase**
- **Jettisoned prior to scientific operations**
- **5 tanks**
  - 4 propellant
  - 1 pressurant
- **8 thrusters**
  - 4 x 22N Orbit Control
  - 4 x 5N Reaction Control





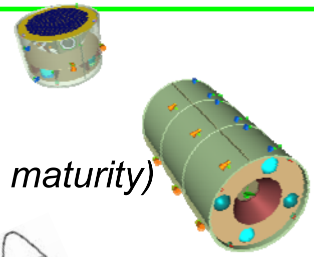
Launch sequence



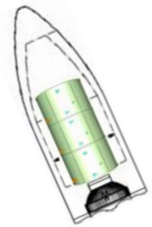
- *Atlas V 541 places the stack in escape orbit*
- *The 3 Composites separate and proceed for 14 months to their final orbital position*

LISA System Budgets

- **Composite Spacecraft dry mass = 1368kg**
- **Stack wet mass incl. launch adapter = 6155kg**
  - *Includes units contingency (3% to 20% depending on maturity)*
  - *20% system margin*



- **Stack fits on Atlas V 541**
  - *Launch capability 6200kg*
  - *Atlas V 551 (6500kg) is the next available launcher*



MASS

POWER

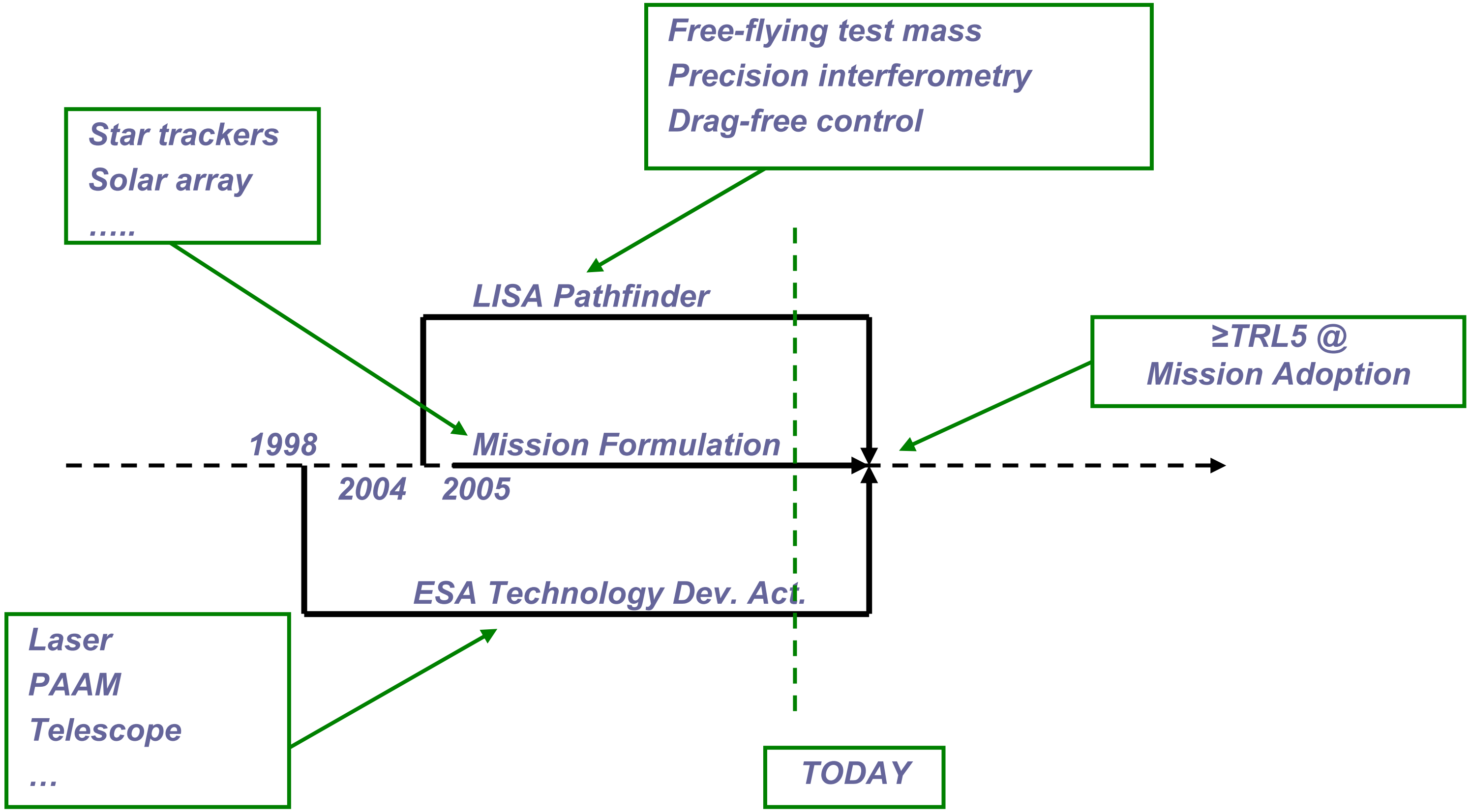
- **Highest Power requirement = 1006W**
  - *Includes losses, life degradations and 25% system margin*
- **Compatible with Solar Array size**
  - *Still has growth margin*

- **Communication Budget**
  - *Allows full data downlink in X-band within the visibility windows*
  - *Contains the required 3dB margin*

DATA

LISA Technology

- *LISA technologies fall in three main categories:*
  - *Off the shelf components*
  - *Technologies validated on LISA Pathfinder (those that cannot be tested on the ground)*
  - *Technologies developed through CTP/TRP activities*



LISA Pathfinder (LPF)

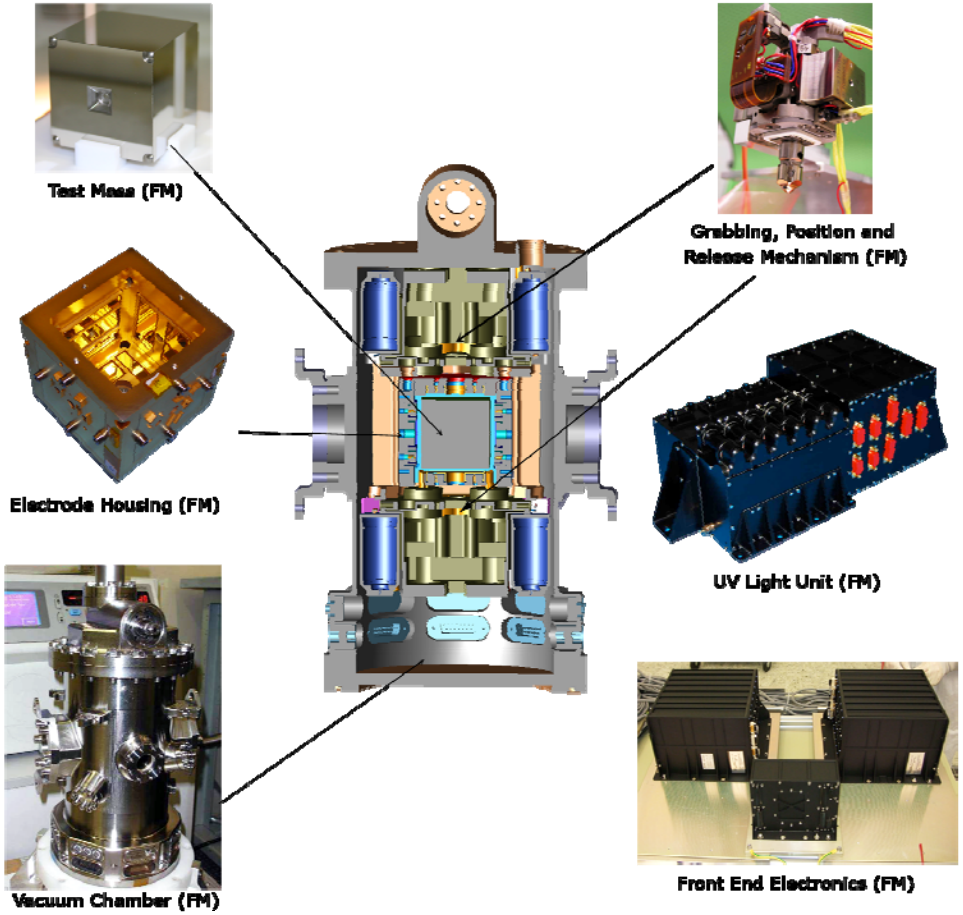
- **LISA Pathfinder is a validation step in the LISA development**
  - LPF hardware designed to be the LISA hardware
  - Flight results will validate error budget for extrapolation to LISA
- **LPF system performance approaching LISA requirements**
- **Nearly all flight hardware available to LPF**
  - Launch lock and micropropulsion to be delivered

LPF launch composite being prepared for thermal balance test campaign at IABG

Gravitational Reference Sensor

- *Gravitational Reference Sensor (GRS):*
  - *Test Mass*
  - *Electrode Housing*
  - *Vacuum Enclosure*
  - *Caging Mechanism*
  - *Charge Management*
  - *Front-End Electronics*

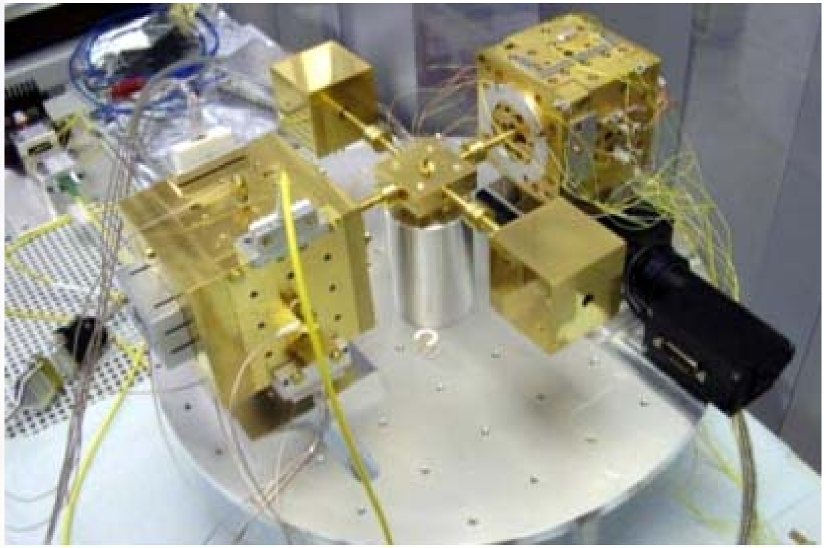
Much of this hardware is ready-for-use in LISA



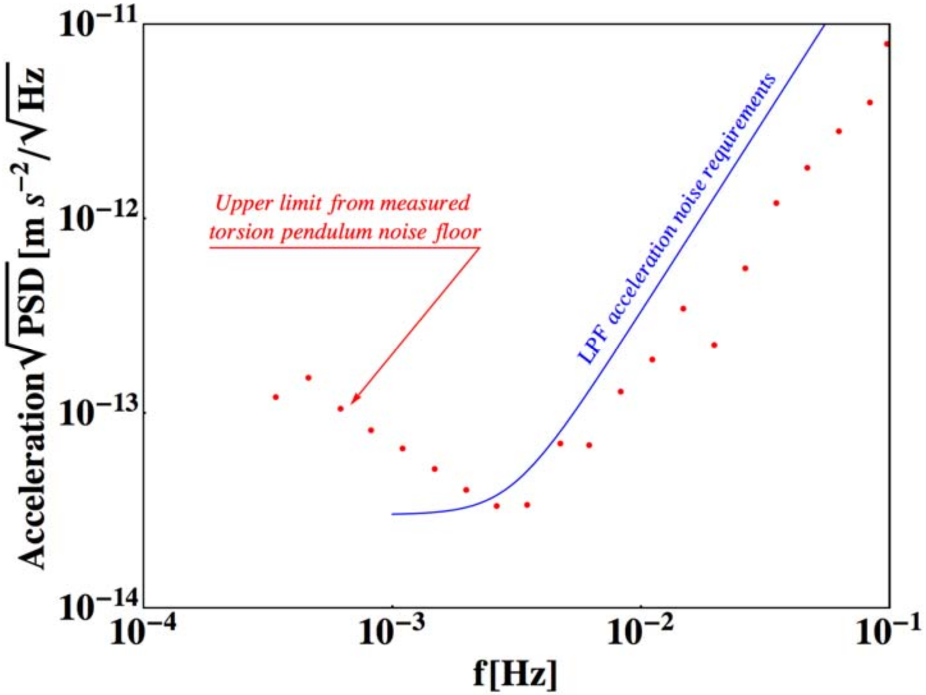
LPF flight hardware

GRS Ground Testing

- ***Performed with torsion pendulum***
- ***Provides verification of surface disturbances***
- ***Results used to validate the LPF payload (LPF Test Package - LTP) noise model***
- ***Noise performance exceed expectations***
  - *Torsion pendulum sensitivity*

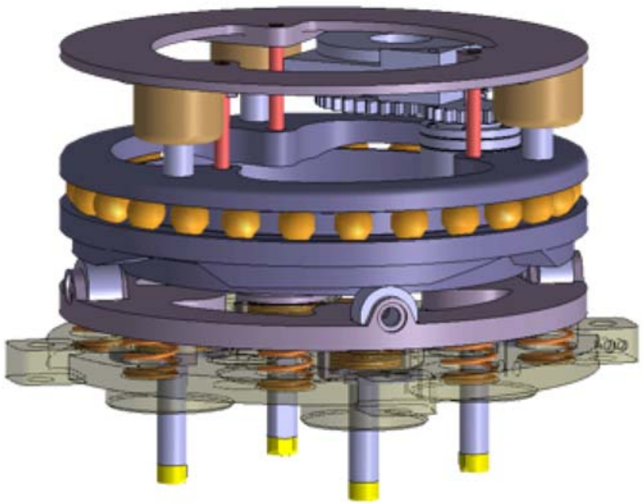


GRS ground test facility

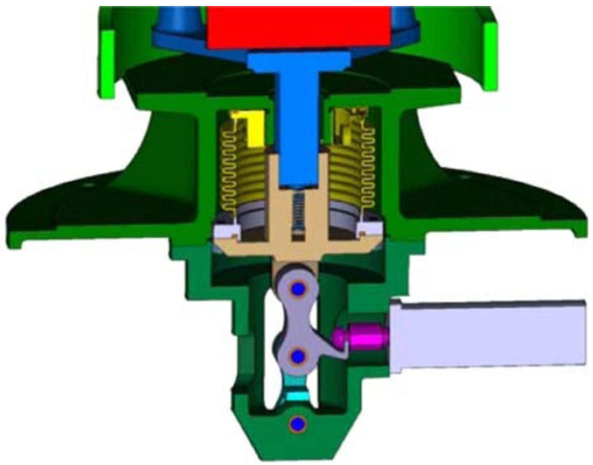


LPF Launch Lock

- *Holds the test-mass in place during launch*
- *Problems in hydraulic parts encountered during FM unit testing*
- *Investigation of the problem led to alternative design options that replace hydraulic system with motor-driven system or with a one-off lock system*
- *Design Review and go-ahead milestone in April 2011*

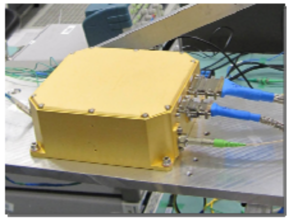


Open issue is manufacturing of a piece of mechanics, not identification of new technology to perform the function

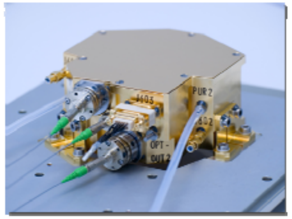


LTP Metrology Interferometer

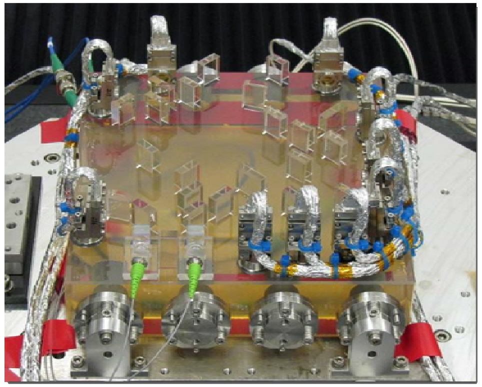
- **Comprises**
  - Reference Laser Unit
    - Can be used as LISA seed laser
  - Laser Modulator
  - Optical Bench
    - Components and construction processes identical on LISA
  - Phasemeter
  - Data Management Unit



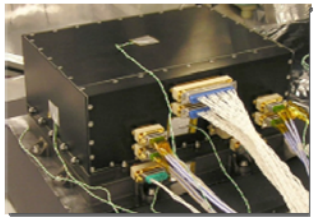
Reference Laser Unit (FM)



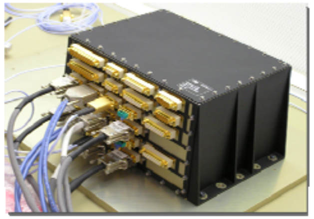
Laser Modulator (FM)



Optical Bench Interferometer (FM)

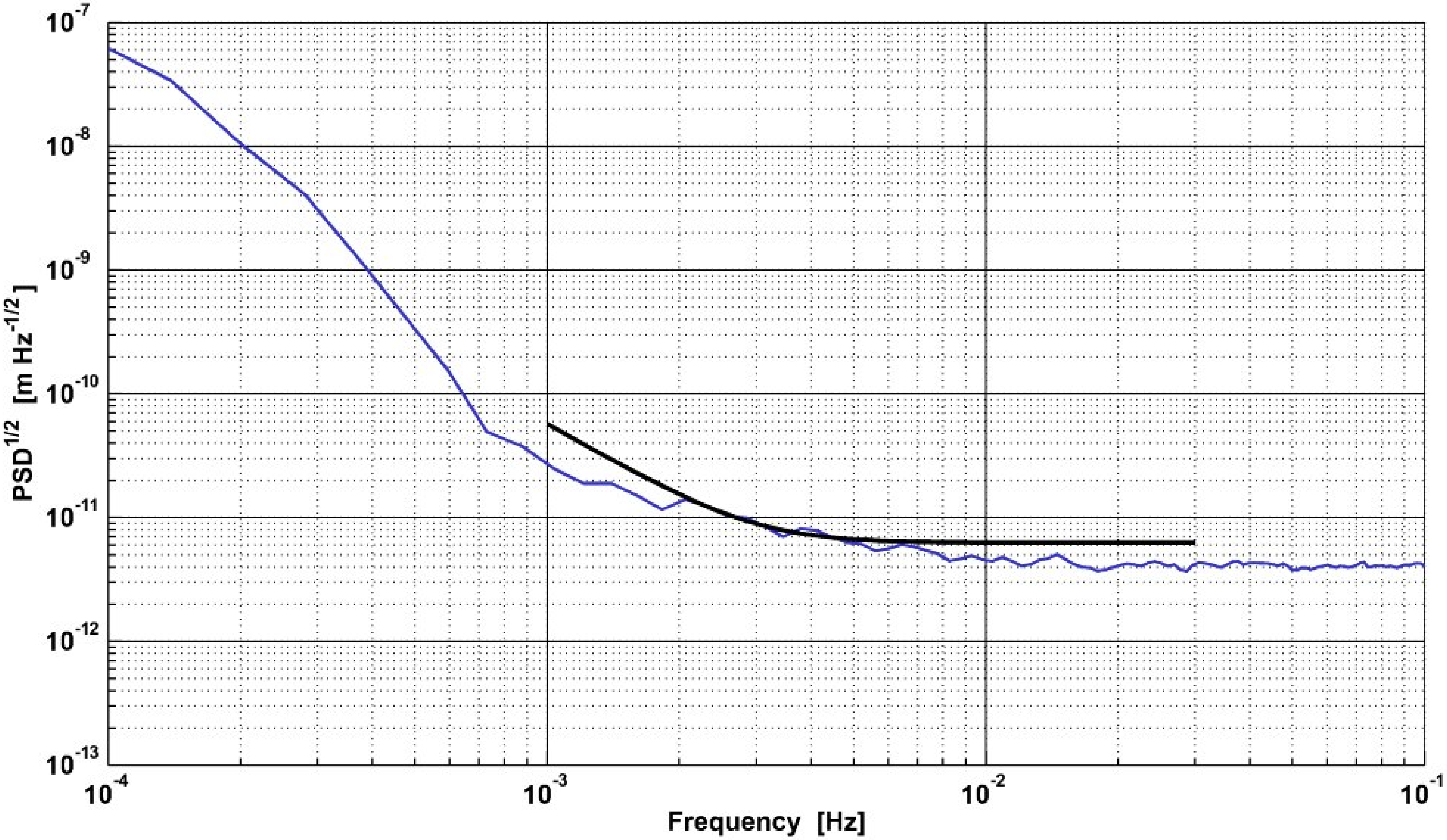


Phasemeter (FM)



Data Management Unit (FM)

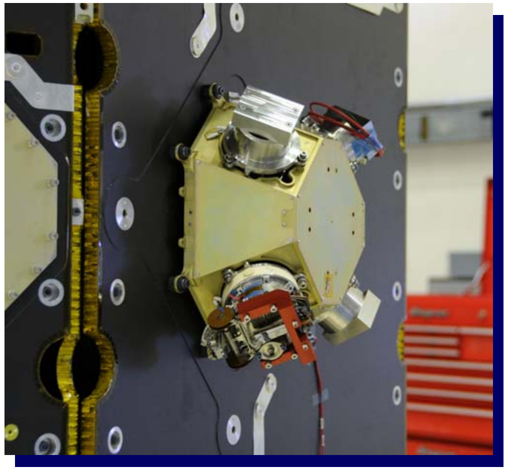
LTP Metrology Interferometer



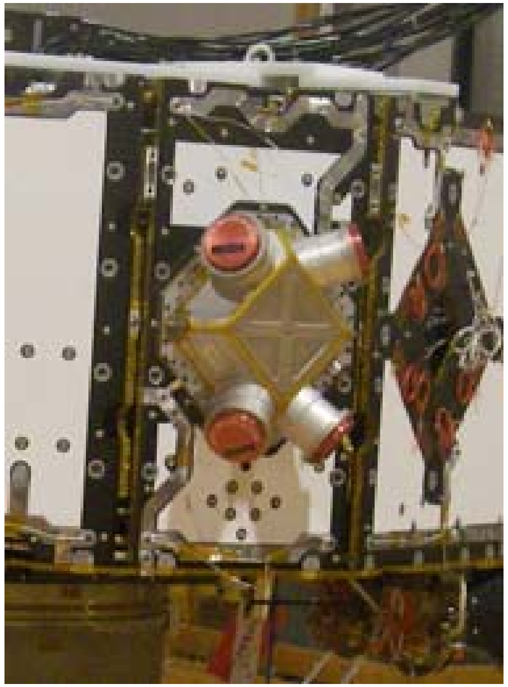
Optical Metrology System flight hardware ground test results

Micropropulsion System

- *Micro-Newton thrust required for drag-free performance*
- *Field Emission Electric Propulsion (FEEP) thrusters developed in Europe for LPF and LISA*
  - *Based on a slit emitter with Caesium propellant*
- *Colloidal micro-Newton thrusters developed by NASA, will fly on LPF*
  - *Flight units have already been integrated onto the S/C*
- *Life test of FEEPs and colloidal thrusters will be done for LISA*



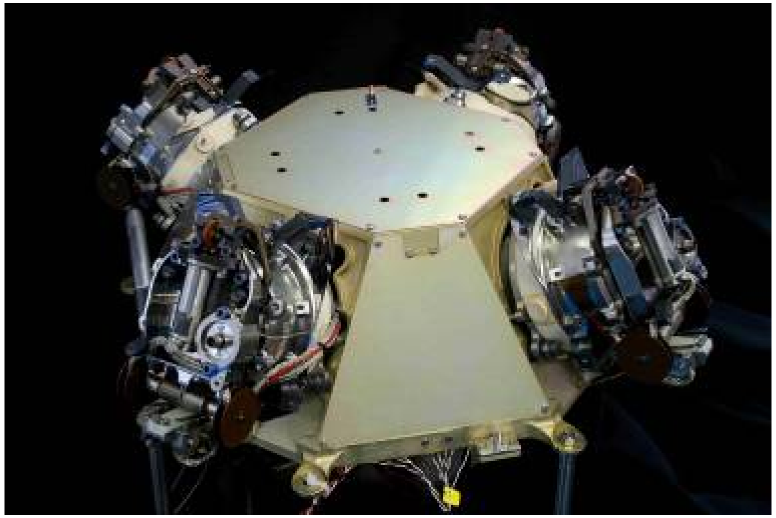
Cs Slit FEEP

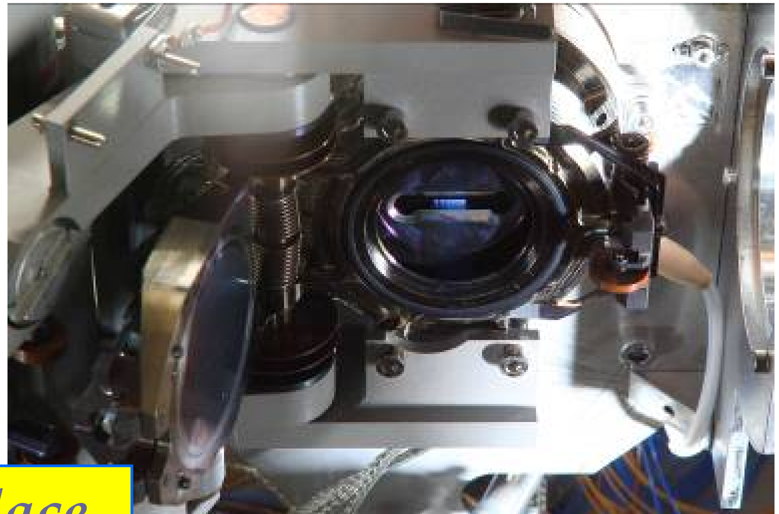


Colloidal Thruster

LPF FEEPs

- *>3200 hours extended firing on flight-representative device*
- *All thrusters functions demonstrated by repeatable tests*
- *Problem encountered during Qualification Confirmation Tests*
- *Test interrupted, investigations started and ongoing*
- *Series of tests defined, planned and partly executed*
- *Backup strategy considered for LPF and LISA for risk mitigation*
- *Status review and decision on way forward in April 2011*

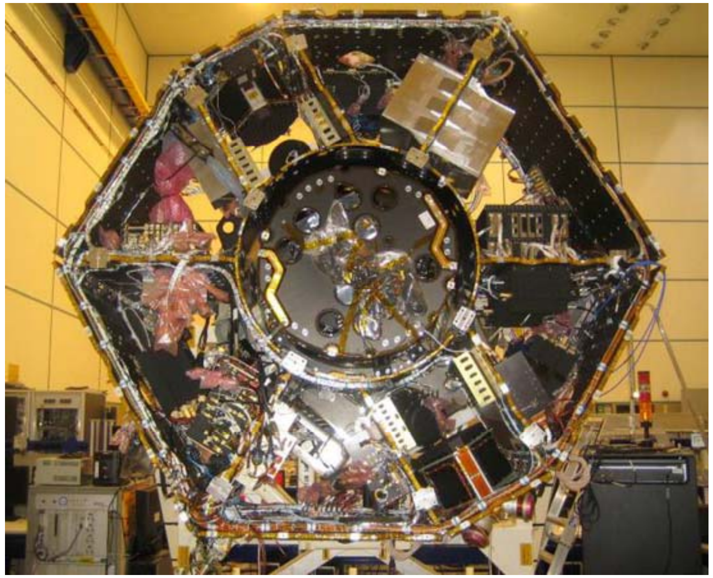




Workplan to solve the problem in place. Alternatives exist (colloids) and are ready to fly

LPF current status

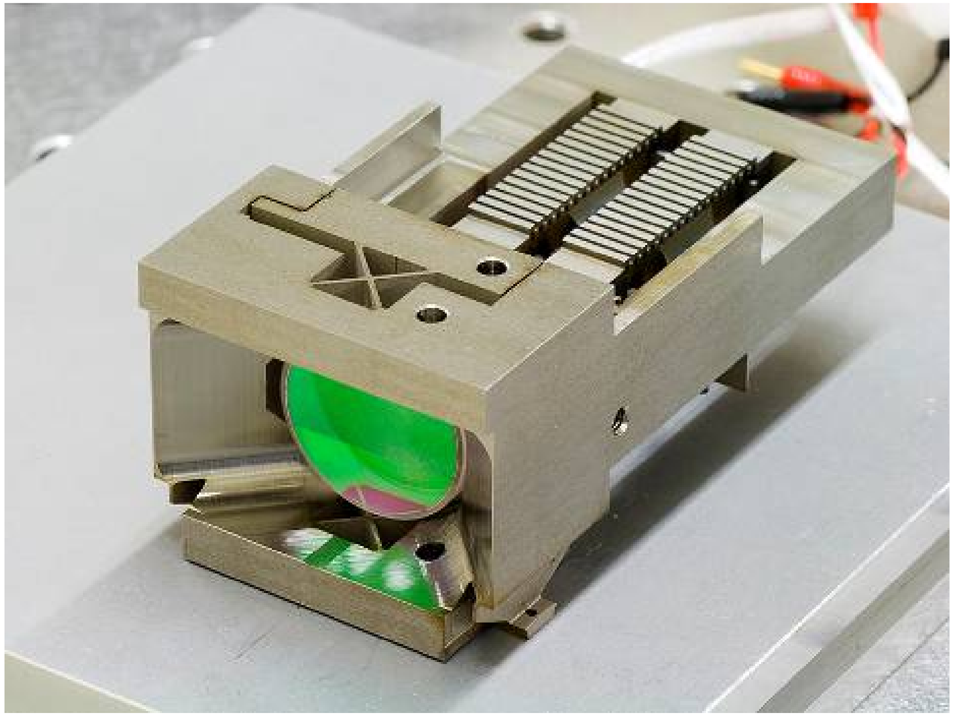
- Successful CDR for Payload, spacecraft, science ground segment and Mission
- Most flight units tested and delivered
- Spacecraft bus integration almost complete
- Propulsion module integration complete
- Integrated System Test campaigns started
- Launch Lock and FEEPs Review in April 2011
- Earliest launch end 2013



Technology Development Activities

- *Technology development done during phase 0/A*
- *Achieve technology readiness by mission adoption*
- *LISA has an approved technology development plan that includes, inter alia*
  - *Optical Bench*
  - *Point-Ahead Angle mechanism*
  - *Phasemeter*
  - *UV light sources*
  - *Optomechanical characteriz.*
  - *GRS Front-End Electronics*
  - *….*

Solid technology plan, leading to timely maturity



Point-Ahead Angle Mechanism

ESA-NASA cooperation

- ***Long-standing cooperation, started in 2000***
- ***Parallel organizational structures within the two Agencies***
- ***ESA and NASA Project Managers jointly coordinate Mission Formulation activities***
- ***Scientific community organized in the LISA International Science Team (LIST)***
  - *15 members from Europe and 15 from US, European and US co-chairs*
  - *Actively supports the Mission System Engineering*
- ***The working scenario for Implementation is based on:***
  - *One Agency having a clear lead role and being responsible for mission success*
  - *Each Agency individually managing the procurement and delivery of the assigned mission elements*

Possible cooperation scenarios

- *Four scenarios with acceptable division of responsibilities for Implementation Phase studied*
- *One used as baseline for the Mission Formulation activity and for the Review*

Scenario type:	***Working scenario***	
	ESA	*NASA*
Mission lead - System Engineering	X	
Support to System Engineering		X
Real-time Testbed	X	
Spacecraft		X
Payload	X	
Phasemeter		X
System Assembly Integr. & Verific.	X	
Flight Software	X	
Propulsion Module	X	
Micropropulsion	X	
Ground operations		X
Launch Vehicle		X
Science Ops./Guest Investigator	X	X

CV Review outcome

- ***Mission design adequate to support the mission***
- ***Sound development approach***
- ***Budgets correctly established***
- ***All Technology Development Activities (TDAs) in place***
- ***Clear path to TRL 5 for all critical technologies***
  - *TRL 5 achieved timely prior to mission adoption*
  - *Following areas require attention*
    - *Laser*
    - *Micropropulsion*
    - *GRS*
    - *(All are covered by dedicated TDAs)*
- ***Overall development risk compatible with L-mission schedule***
- ***Co-operation scheme allows clear responsibilities and simple interfaces***

Way forward into Definition

- ***The workplan leading to the Definition phase includes work in the following areas:***
  - *System Requirements Document preparation*
  - *Detailed Separation analysis*
  - *Intelligent Propulsion Module*
    - *Shifting functions from sciencecraft to propulsion module*
  - *Consolidation of optical design*
  - *Micropropulsion lifetime demonstration*
  - *Alternative micropropulsion systems*
    - *Colloidal*
    - *Indium*
    - *RFT*
    - *Cold gas*
  - *Contamination*
    - *Optical surfaces*
    - *Fibres*

Conclusion

- *The mission concept is mature and well studied*
- *The technical baseline is feasible*
- *Technology Development Activities*
  - *Are well defined*
  - *Address critical areas*
  - *Lead to timely technology readiness*
- *A co-operation scenario exists that allows clear responsibilities and simple interfaces*
- *The overall development risk is compatible with L-mission schedule*

We are ready to go !