
LISA in 2012 and beyond!
20 years after the first LISA proposal in 1992
Karsten Danzmann
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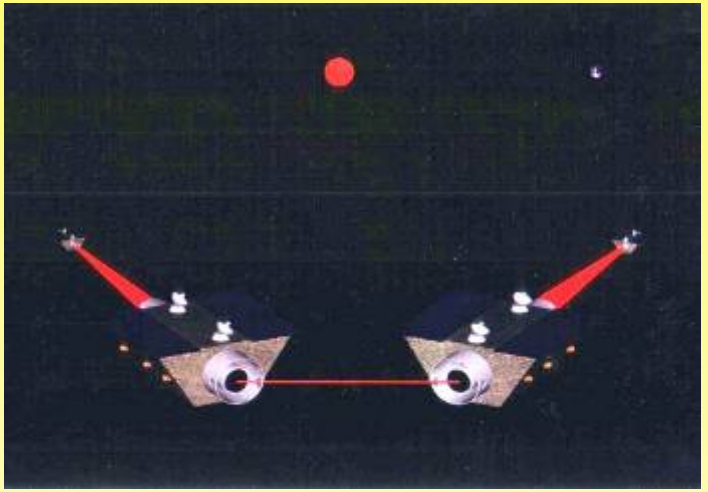
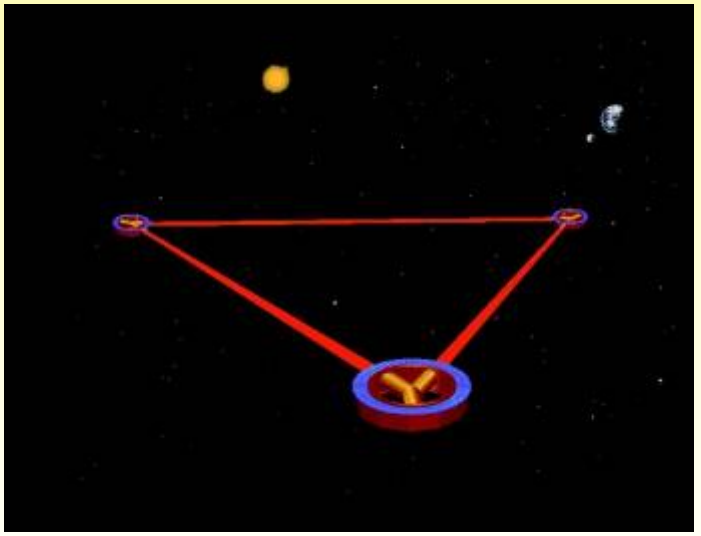
LISA: A Mature Concept

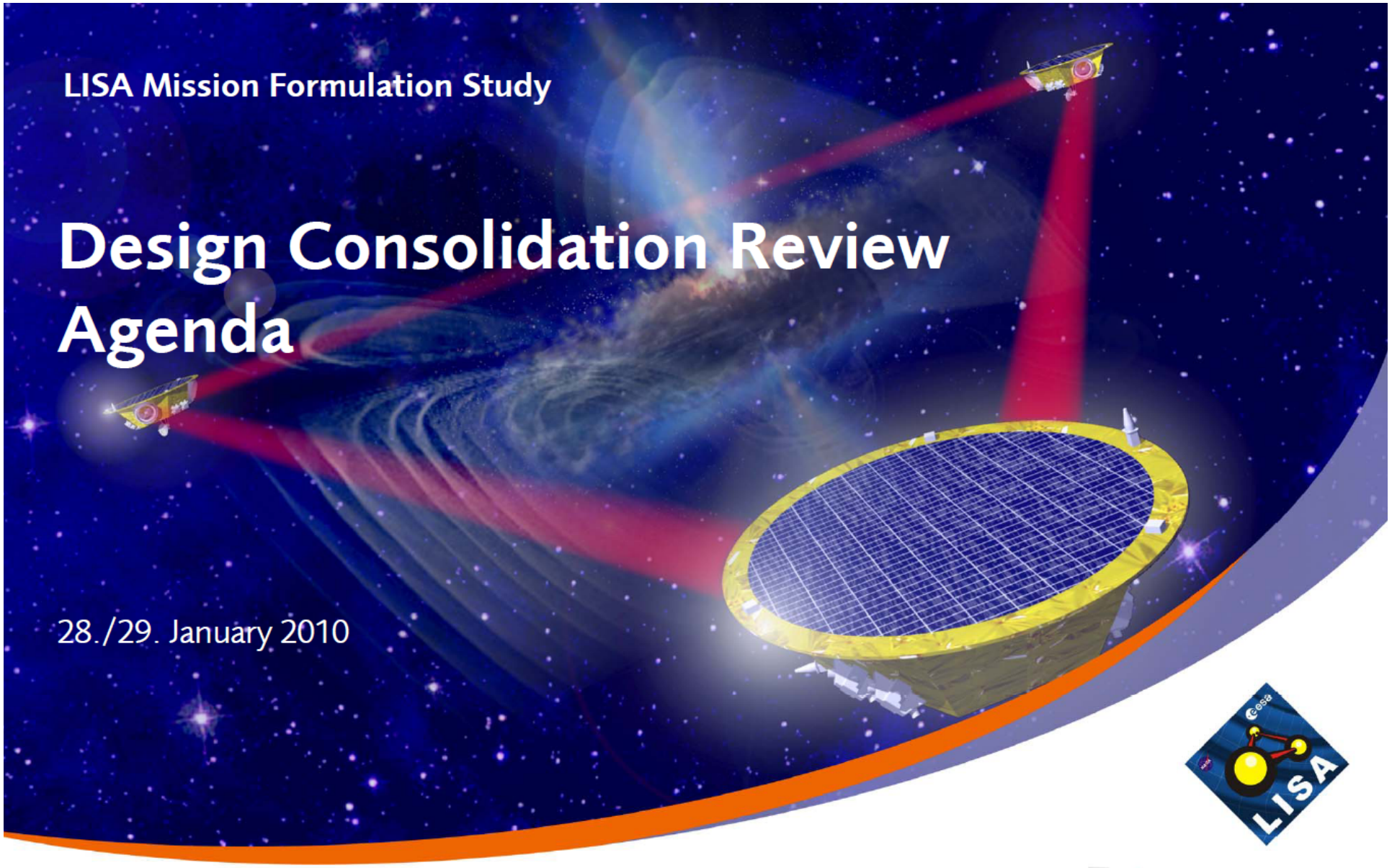
- After first studies in 1980s, M3 proposal for 4 S/C ESA/NASA collaborative mission in 1993
- LISA selected as ESA Cornerstone in 1995
- *3 S/C NASA/ESA LISA appears in 1997*
- **Baseline concept unchanged ever since!**





LISA Mission Formulation Study

Design Consolidation Review Agenda



28./29. January 2010

All the space you need

esa

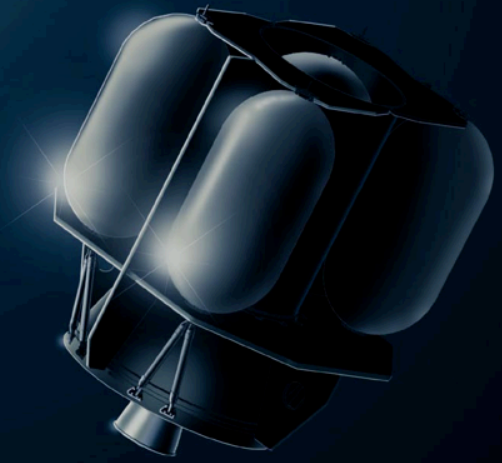
EADS astrium

Overall Study (2)

- Technical Notes – System (198 p.)
  - LISA-ASD-TN-5001 (76 p.)
  - LISA-ASD-TN-5002 (16 p.)
  - LISA-ASD-TN-5003 (26 p.)
  - LISA-ASD-TN-5004 (40 p.)
  - LISA-ASD-TN-5005 (40 p.)
- Other Documents (63 p.)
  - LISA-TNO-TN-3001 (24 p.)
  - LISA-UTN-TN-3002 (17 p.)
  - LISA-UTN-TN-3003 (22 p.)

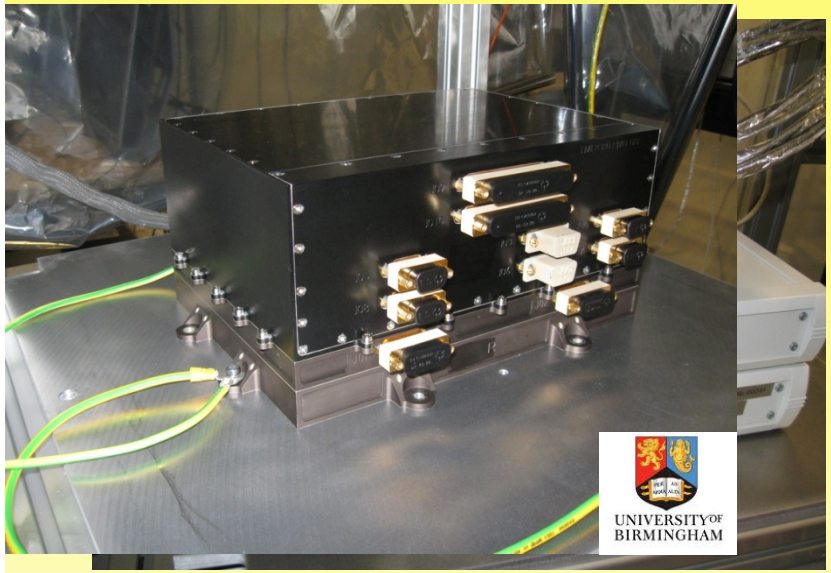
- Total so far: 6540 p.

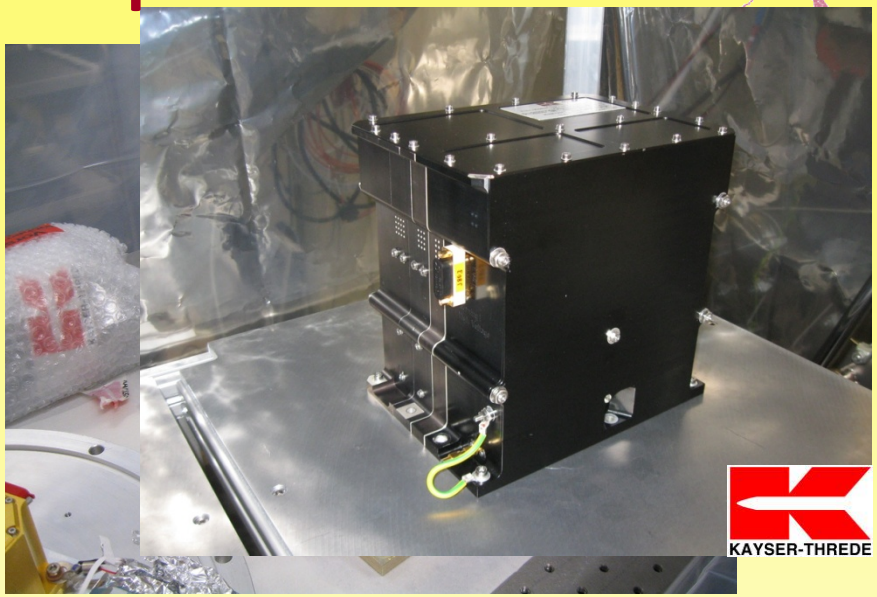
LISA Pathfinder

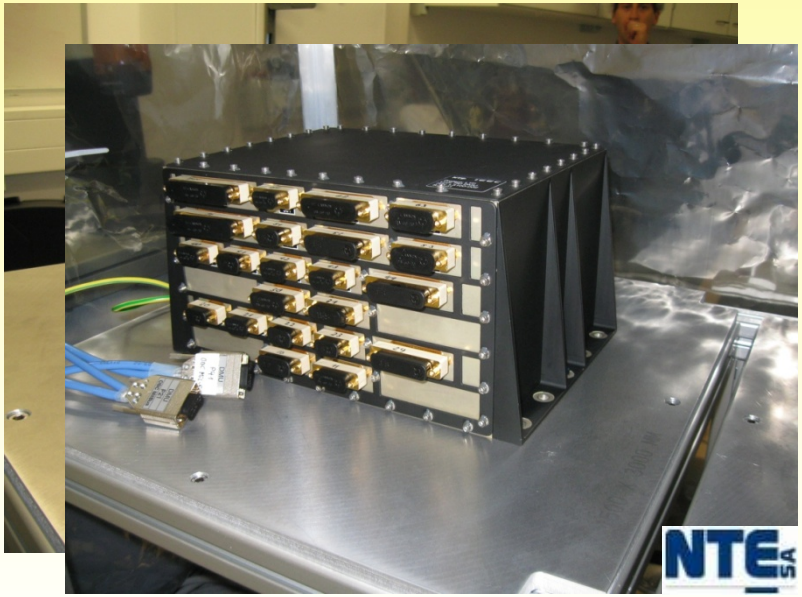


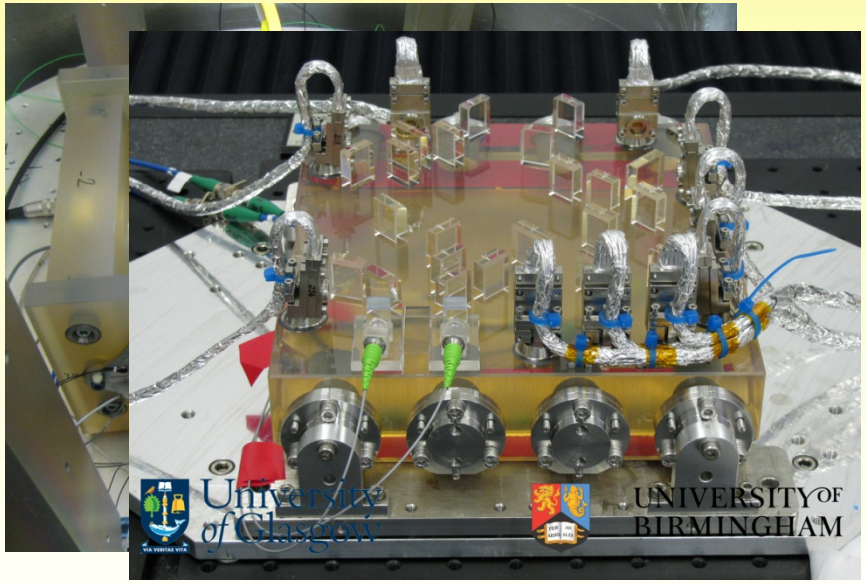
- Testing LISA Technology in Space!

Flight Model Units replace EMs









The Spacecraft

- Waiting for a launch in 2014!

LISA Status

- Precursor LISA Pathfinder in Phase C/D
  - Launch in 2014
- NASA:
  - LISA flagship mission in Beyond Einstein Review!
  - Recommended in Decadal Survey Astro2010 as one of two large mission to start in this decade!
  - In 2011 clear that no money for any large new start this decade, just small contributions
- ESA:
  - LISA Cosmic Vision L1 candidate (1 of 3), launch in 2022
  - All candidates in descoping exercise for ESA-only or ESA-led scenario
  - Downselection in 2012!

LISA, IXO and Laplace Redefinition

- Cost-cap for ESA cost at 850 M€ all-in
- Member state contributions around 200 M€ okay
- Start of implementation in 2015
- Launch in 2022
- ESA feasibility study with ESA-TEC and industrial support
- Technical and programmatic review in Nov-Dec 2011
- Scientific review in early 2012 by SSAC
- Recommendation for the June 2012 SPC to:
  - downselect one
  - downselect two
  - or do not select any mission

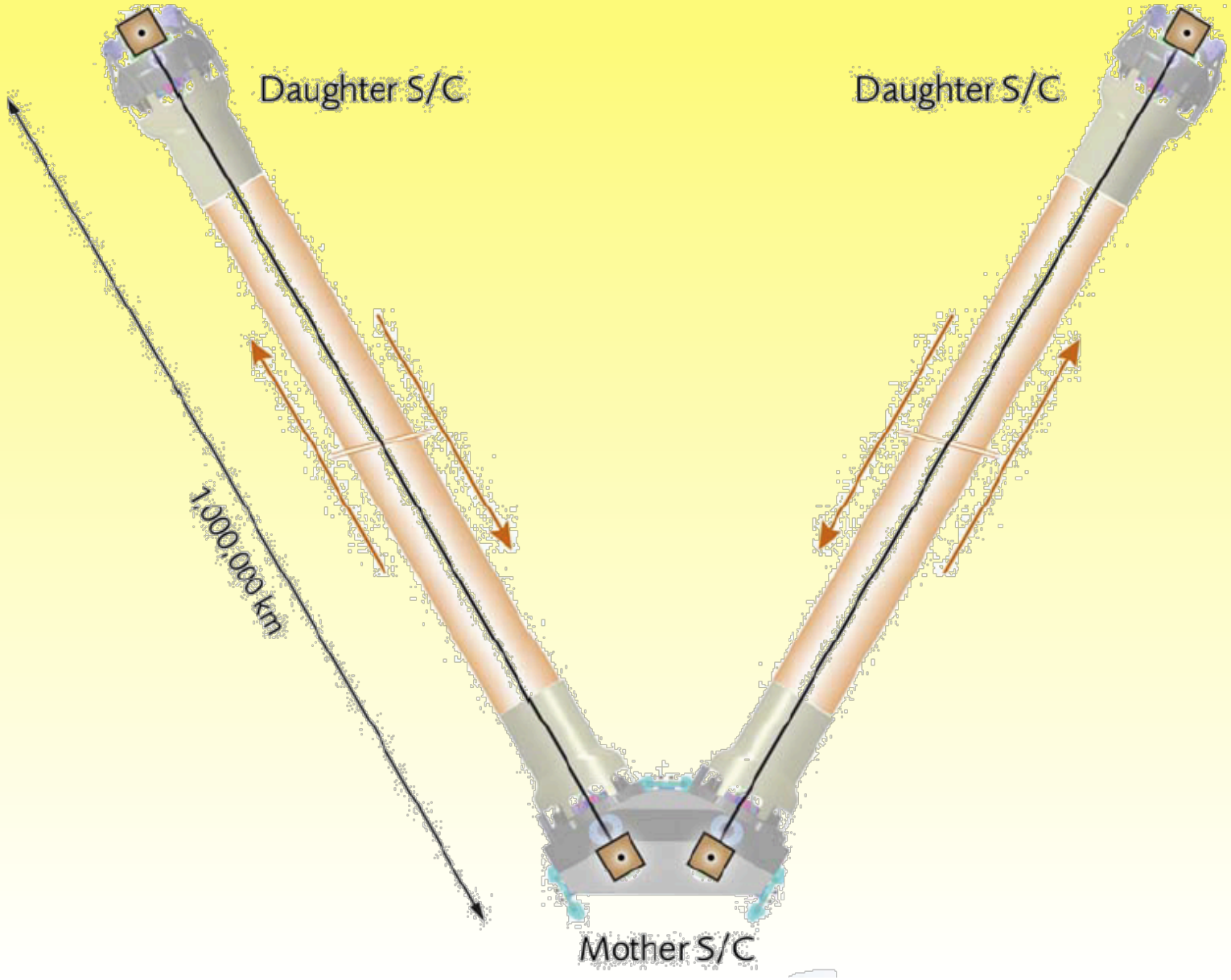
evolved LISA (eLISA) also called Next Gravitational Observatory (NGO) Project + Industry Study

- Goal
  - Identify mission profiles offering substantial cost reduction with minimum science return impact
- Both Astrium-D and Astrium-UK involved:
  - ASU → mission design, orbits, transfer, spacecraft, propulsion module
  - ASD → system engineering, payload
- Basic idea:
  - Save cost by re-using LISA Pathfinder and other existing flight hardware
  - Save mass and optimize orbit to use cheap launcher

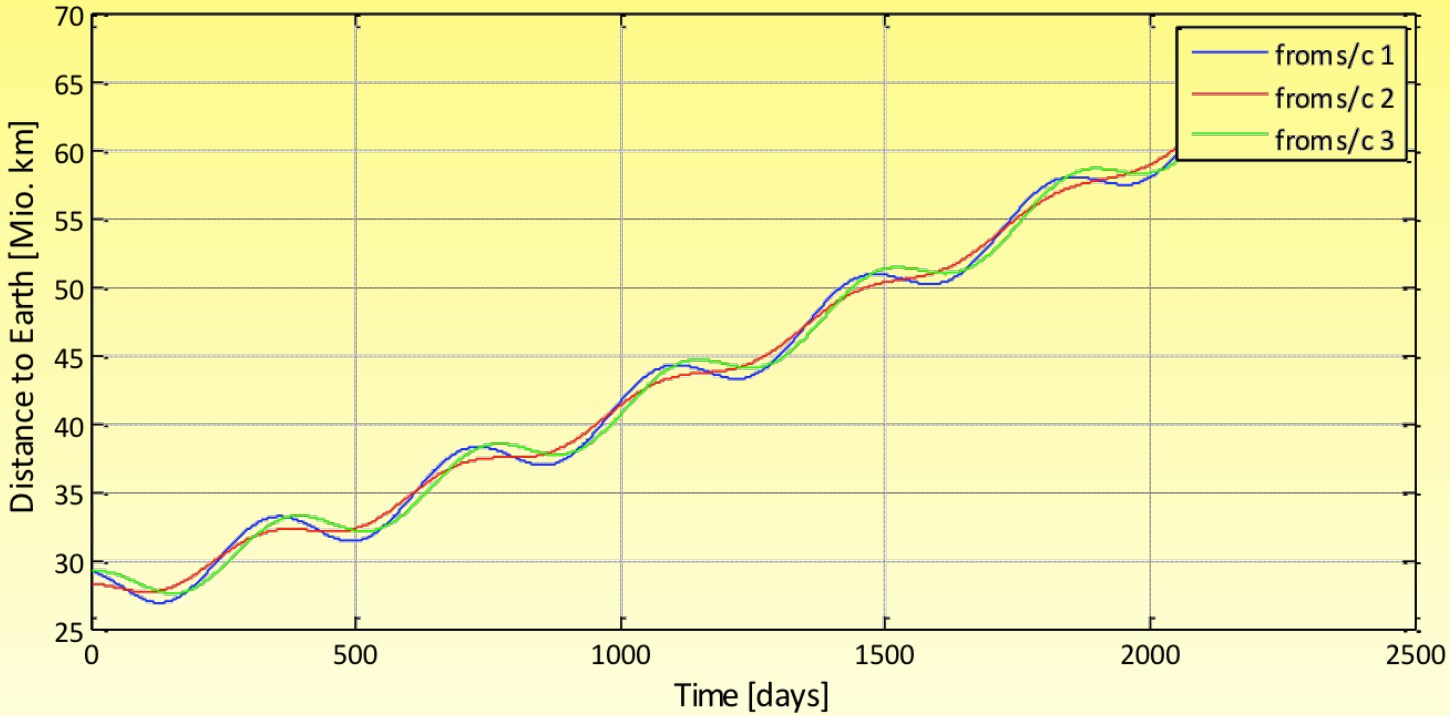
eLISA-NGO Mission Design

- Armlength 1 Million km, 2 arms
- Identical Mother/Daughter S/C, based on LISA Pathfinder
- 3 spacecraft in a V-configuration , nominal angle 60°, max Doppler <10m/s
- Minimize out-of-plane pointing variation to drop point-ahead-actuator on Optical Bench
- Heliocentric slow drift-away orbit, Earth-leading or trailing, starting 10°, 60° inclination wrt ecliptic, range to Earth not exceeding 50 Mkm after 4 years and 65 Mkm after 6 years;
- Launch to sub-GTO, separation from LV, escape and transfer to final orbit by jettisonable propulsion module
- Two Soyuz-FRG launches (or shared Ariane V launch)
- Mission lifetime: baseline 2 years + 2 + 2
- Downlink capability from each S/C, one-axis HGA + LGAs

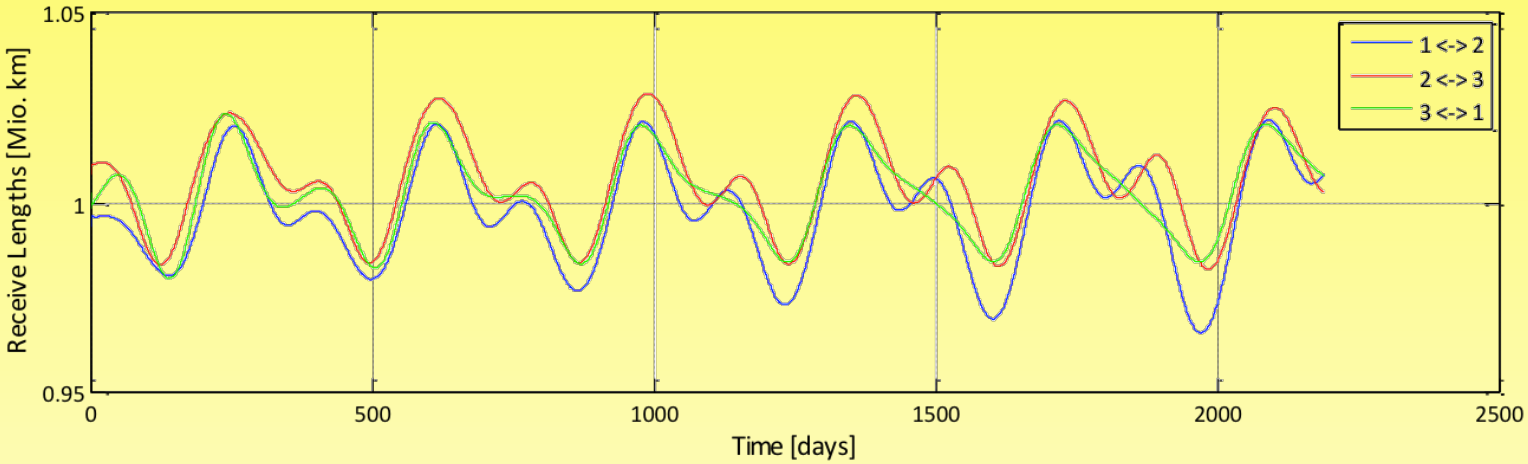
eLISA-NGO Layout

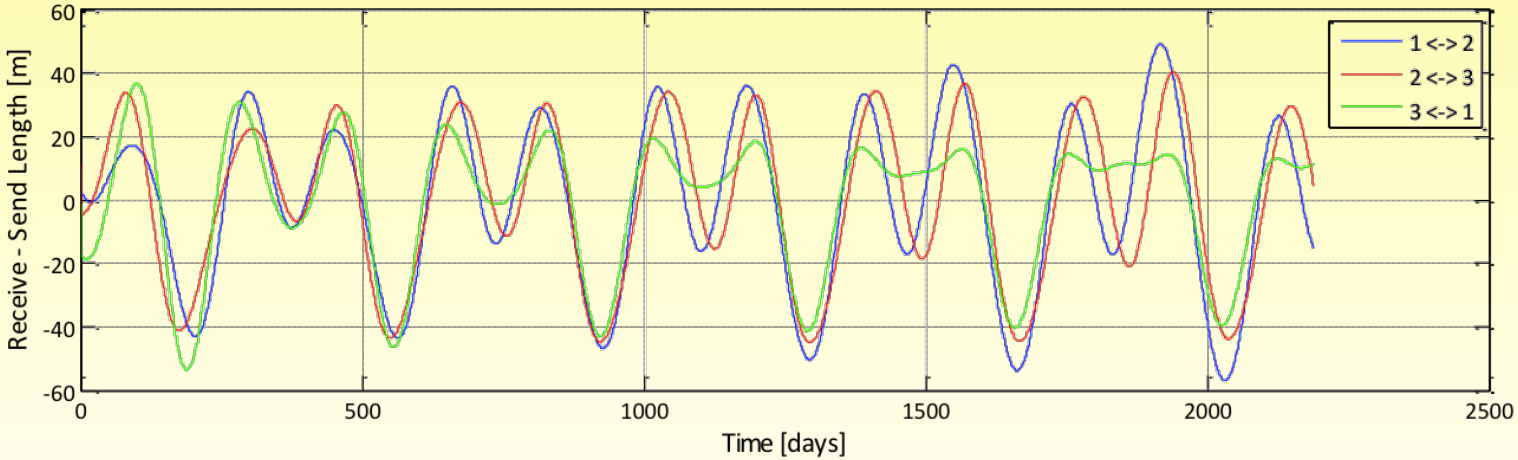


Slow Drift-Away Orbit: Distance to Earth



Arm Lengths


1.05
1
0.95
Receive Lengths [Mio. km]
0
500
1000
1500
2000
2500
Time [days]
1 <-> 2
2 <-> 3
3 <-> 1


60
40
20
0
-20
-40
-60
Receive - Send Length [m]
0
500
1000
1500
2000
2500
Time [days]
1 <-> 2
2 <-> 3
3 <-> 1

Payload

- Mission savings can be achieved in the P/L design:
  - Telescope diameter, laser power
  - in-field of view guidance
  - point-ahead angle removal
  - P/L computer removal etc are possible elements
- Current design based on 20cm telescope and 2 W laser
  - Allows substantial reduction of S/C height
  - Optical Bench diameter reduced to 350mm, both OB sides
  - No internal auxiliary metrology
  - To be traded-off with risk/cost/science return in next phase
- Point-ahead angle mechanism removed thanks to very limited out-of-plane angle excursion
- All other P/L elements unchanged from previous design

Launch Vehicle

- 2 scenarios studied
- Both to sub-GTO, after which S/C proceeds to escape and to station using chemical propulsion module
  - Two Soyuz launches (M + 2 Ds)

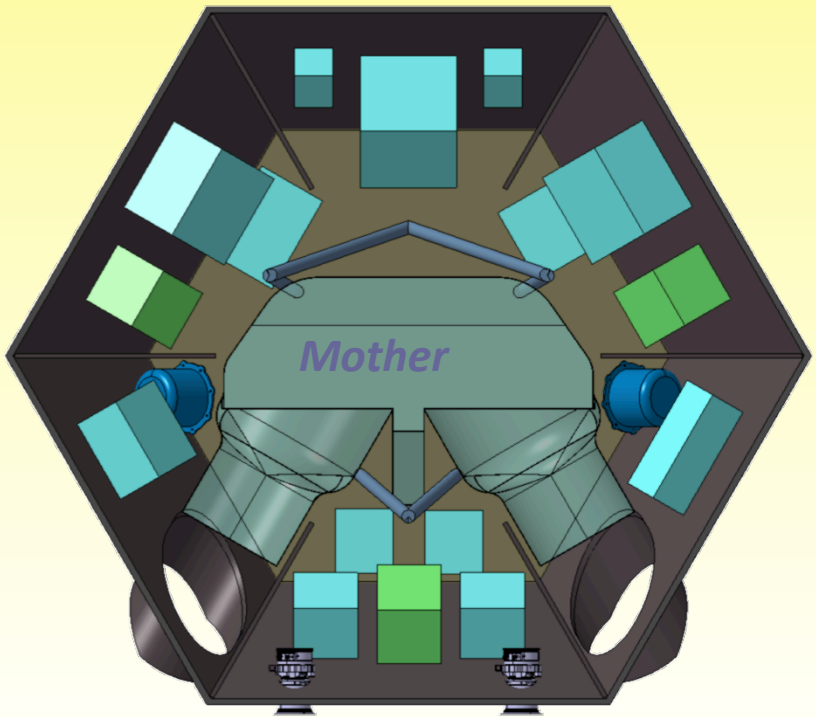
- A single ArV launch (either dedicated or shared)

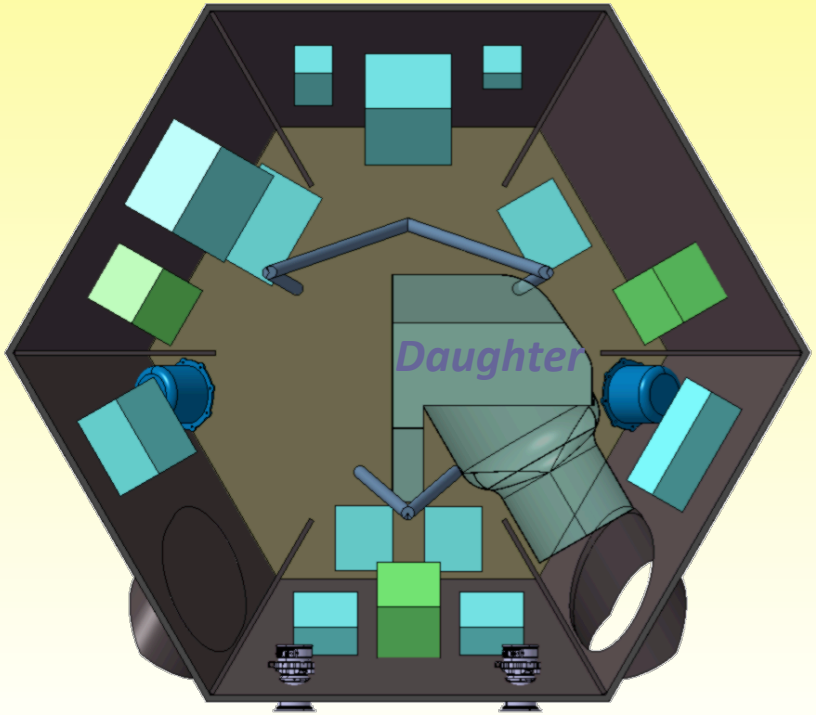
Mother & Daughter S/C Configuration

- Attempt to
  - Maximize re-use of LPF units
  - Use same elements for M and Ds
  - Use same structure
- Assume P/L differences between M and Ds:
  - Two articulated optical assemblies vs 1 telescope
  - One extra payload box (IS-FEE)
  - A few larger payload boxes (Laser Subsystem, Diagnostics Package)
- Platform identical for M and Ds

M & Ds S/C configuration

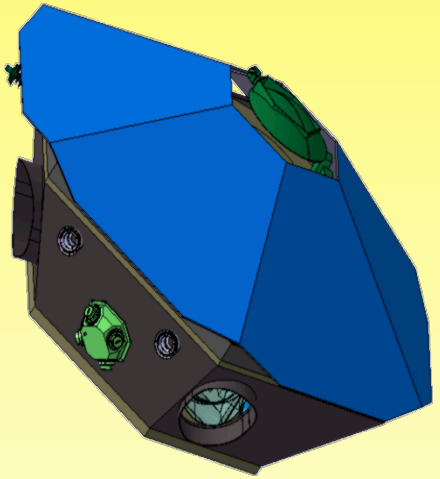
- Optimized accommodation to minimize impact of removal of telescope and FEE between Mother and Daughter

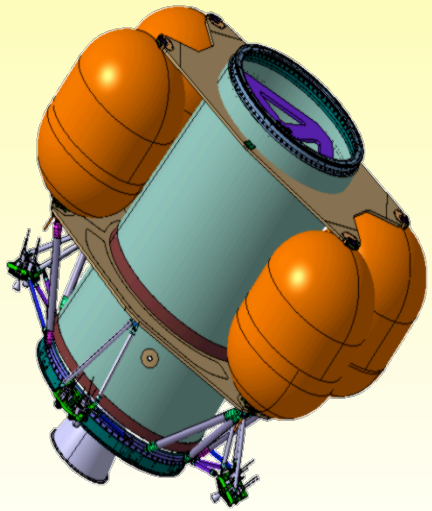




Propulsion Module

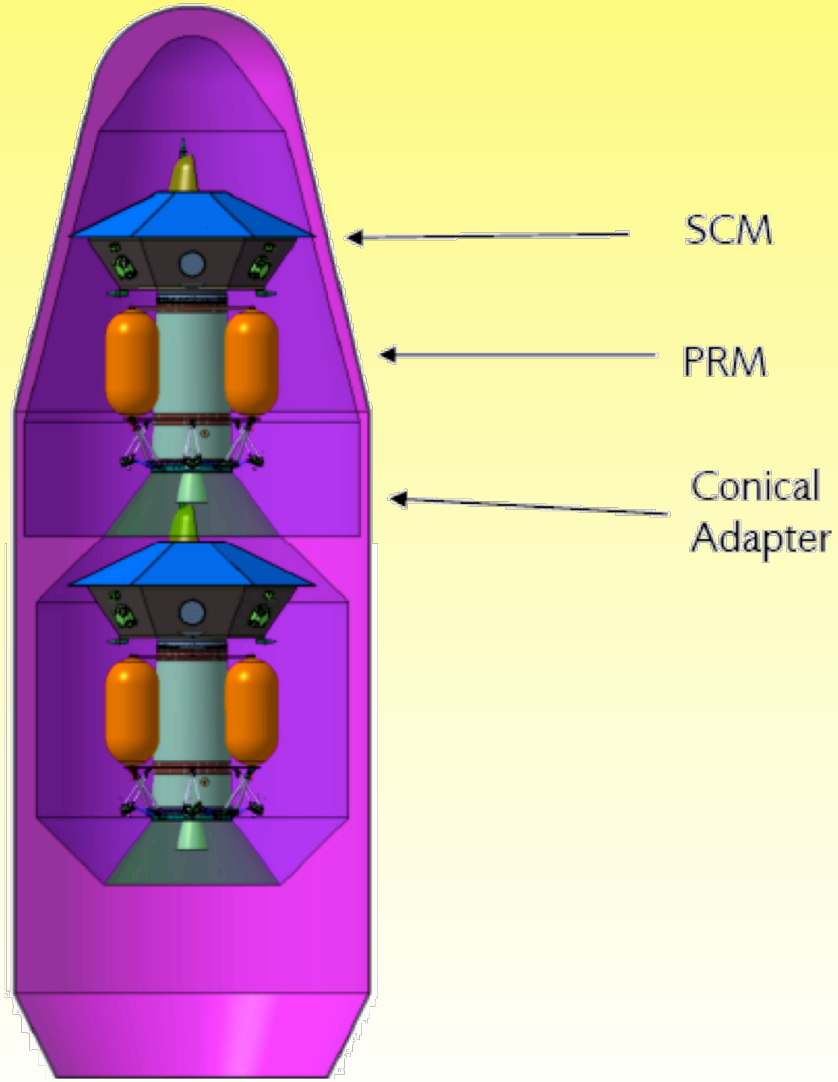
- PM inherited 1:1 from LPF
- Shorten central cylinder and tanks to fit in LV
- Minimal impact on qualification status





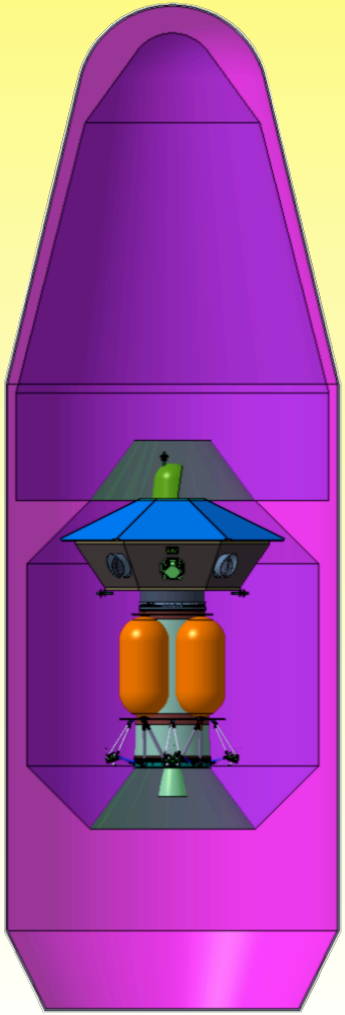
Daughter configuration

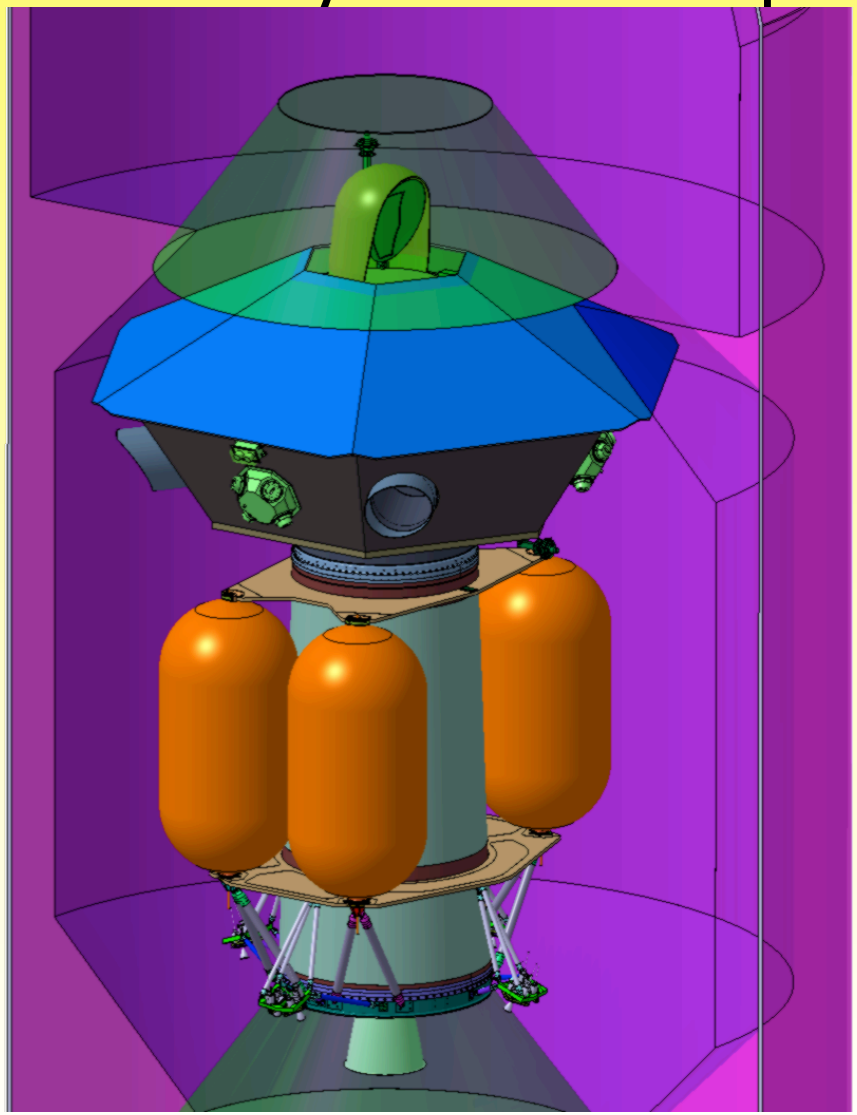
- Two Daughters + PM on Soyuz



Mother S/C for dual Soyuz Launch

- Mother on LPF PM inside Soyuz Dual Adapter (shared launch?)





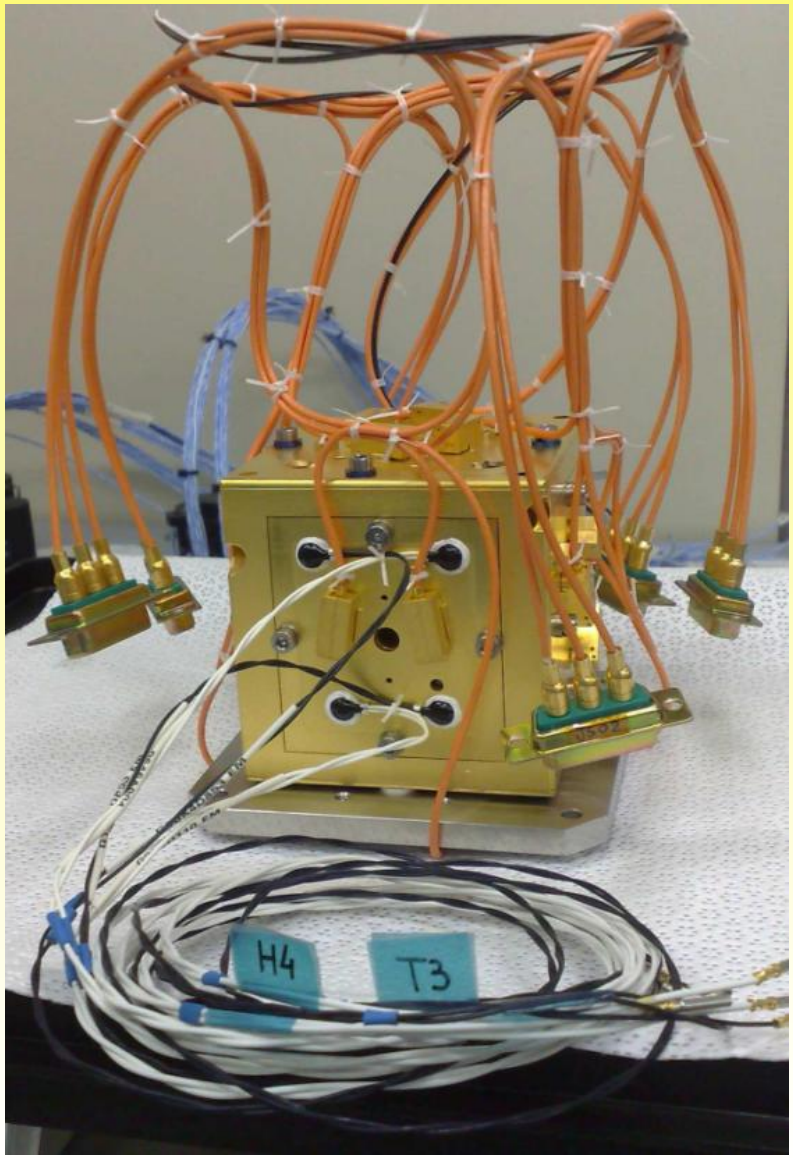
ESA Member State Involvement

- Traditionally:
  - ESA: spacecraft bus
  - ESA member state agencies: science instrument
- In old ESA/NASA LISA:
  - ESA provided everything for LISA
  - Different from other L1 mission candidates
- Hidden cost reserve:
  - Involve member states for eLISA!

What is the Instrument on eLISA?

- Treat like focal plane instrument for Astronomy mission
- ESA responsible for:
  - Satellite platform, including:
    - Telescope, laser and structure for optical assembly mounting
- Member States fund:
  - Scientific consortium to deliver instrument consisting of:
    - Optical Bench with attached Inertial Sensor and detached Phasemeter, Payload Computer TBD

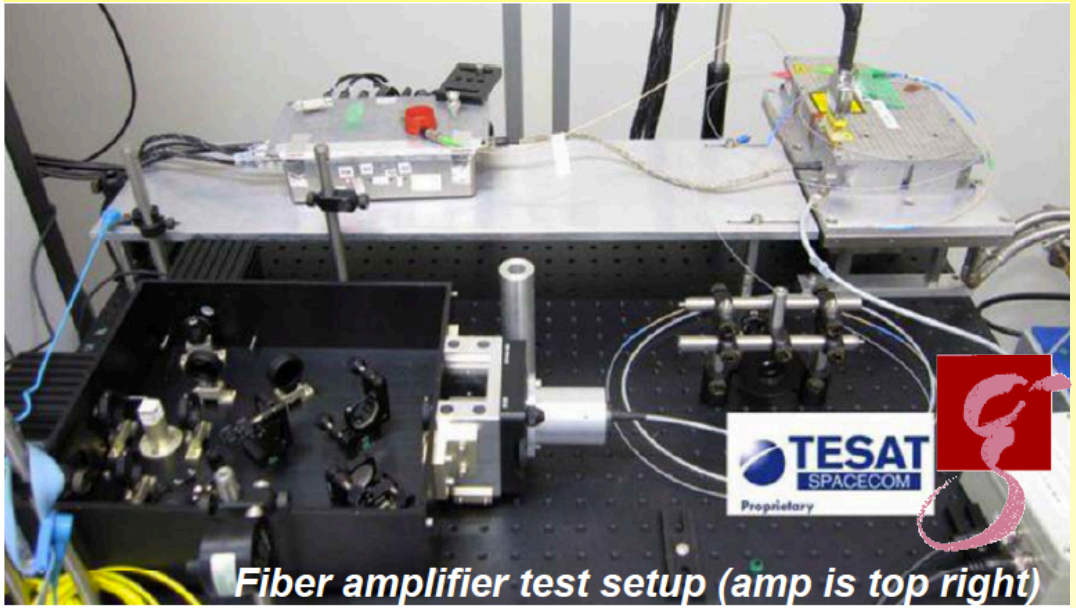
The eLISA GRS Head and Integration: Identical to LISA Pathfinder



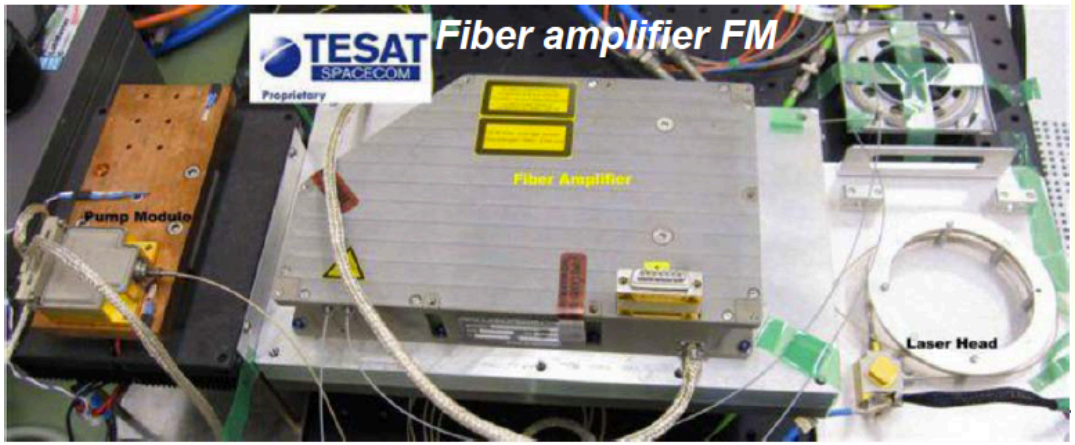
High Power Laser

→Re-use LISA Pathfinder master and ERDS fiber amplifier

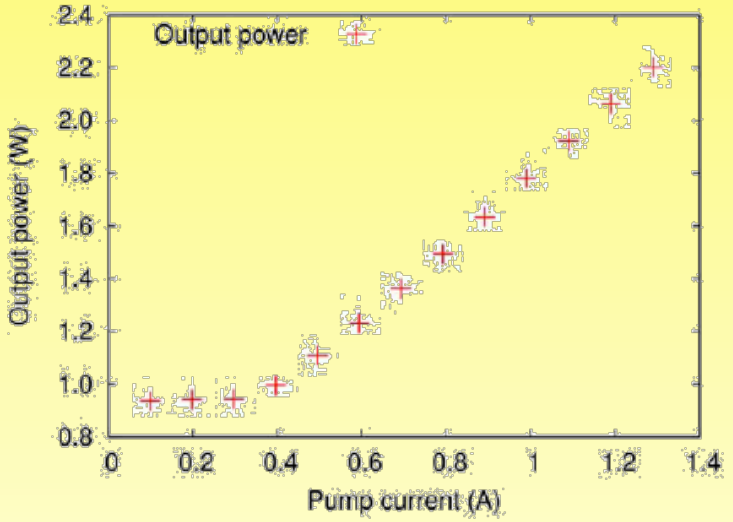
- Tests: Stable low-noise operation up to 2.2 W

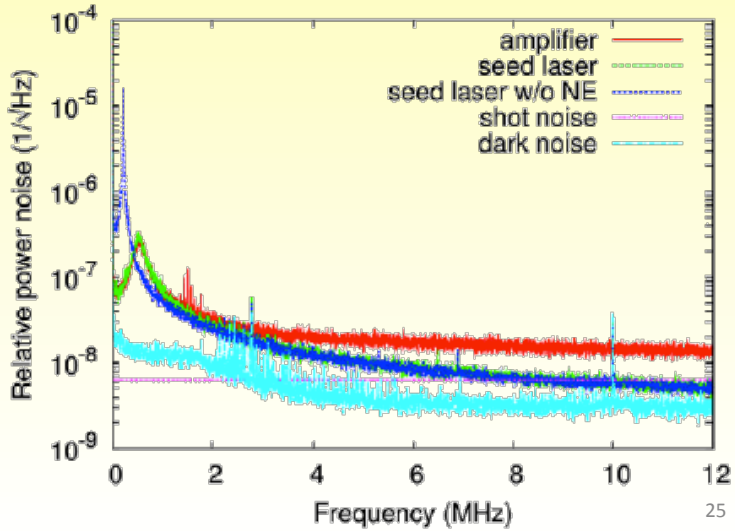


Fiber amplifier test setup (amp is top right)



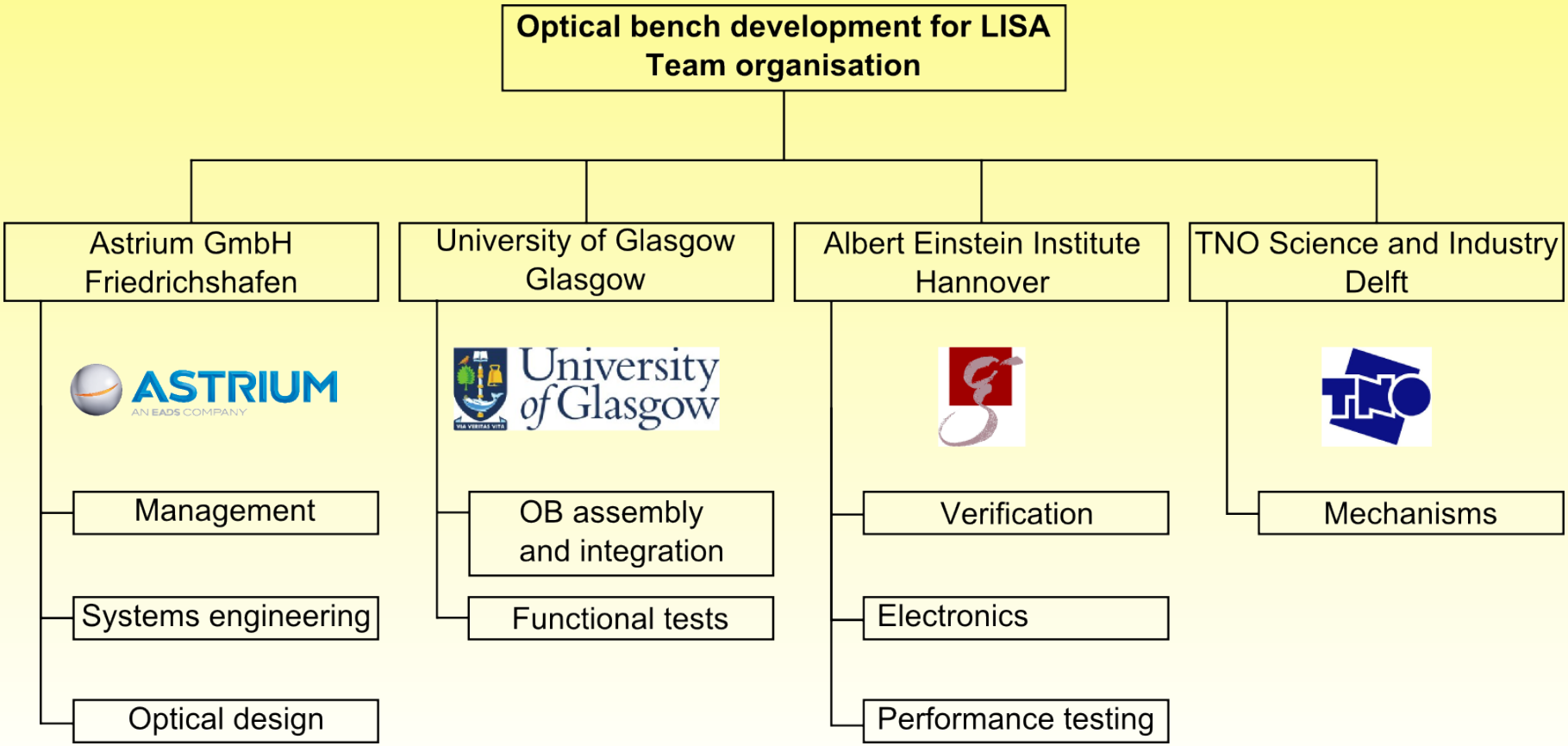
Fiber amplifier FM





Optical Bench

- Funding by ESA
  - Start: May 2009
  - Finish: August 2013



DTU Space
National Space Institute

Max-Planck-Institut
für Gravitationsphysik
(Albert-Einstein-Institut)

axcon
The FPGA Power House

LISA Metrology System

Vol. 1

Technical Proposal

Prepared in response to ESA ITT AO/1-6238/10/NL/HB

Lead Proposer:
National Space Institute – DTU Space, Technical University of Denmark, Copenhagen, Denmark
Represented by: Allan Hornstrup, Head of Astrophysics

Subcontractors:

Max-Planck-Institut für Gravitationsphysik (Albert-Einstein-Institut), Hannover, Germany
Represented by: Karsten Danzmann, Director

Axcon ApS, Kgs. Lyngby, Denmark
Represented by: Rolf V. Østergaard, CEO

DOC. NO. & ISSUE:	LISA/DTUS/SYS/PRO/0001(1)
DATE:	2010-09-28
PREPARED BY:	The LISA Metrology System Proposal Team
AUTHORIZED BY:	Eigil Friis-Christensen, Director
CLASSIFICATION:	Restricted for internal use in ESA and the proposing institutions

- ESA contract under special initiative
- Running since 6 months, now in Phase 2.
- 20-channel prototype
- Professionally engineered
- Hardware space qualifyable

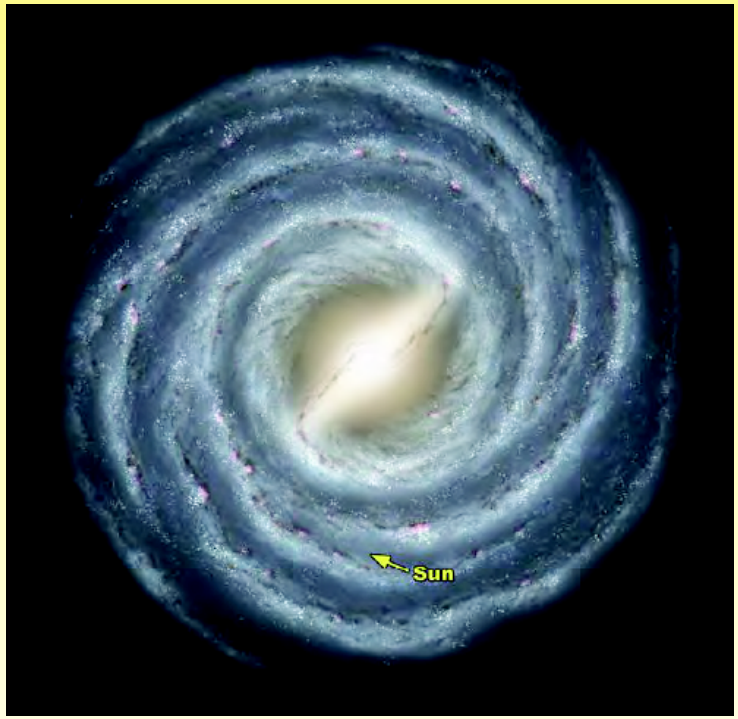
Back to evolved LISA (eLISA) Science

- Cosmology
  - Expansion of universe and Dark Energy equation of state
- Black Holes
  - Evolution, seismology and bothrodesy
- Precision tests of strong gravity
  - No-hair theorem
- Galaxy mergers
  - History and evolution
- Structure of galaxy
  - Complete WD mapping and stellar evolution
- Helioseismology
  - Solar g-modes
- Big Bang
  - Primordial GW radiation

eLISA: 100 Million WD Binaries!

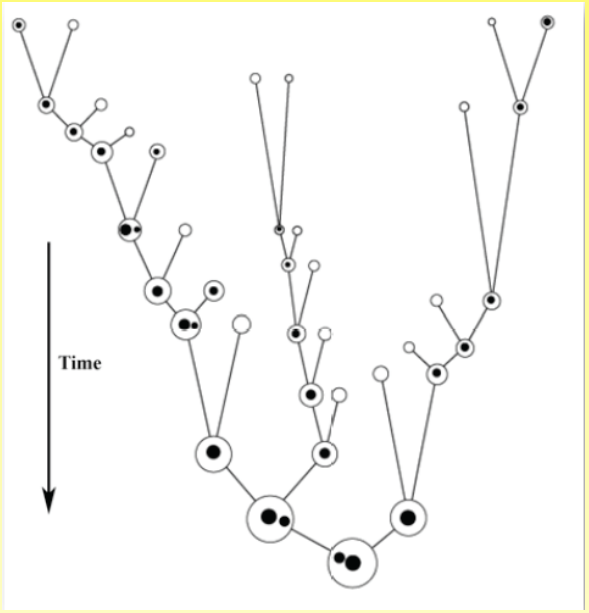
- eLISA will hear every binary system in the Galaxy that has a period < 2 hr
- About 3 000 resolvable in 2 yr
  - <3° location, 10° inclination,
  - distances down to 1 %
- Of the 50 optically known ultra-compact binaries:

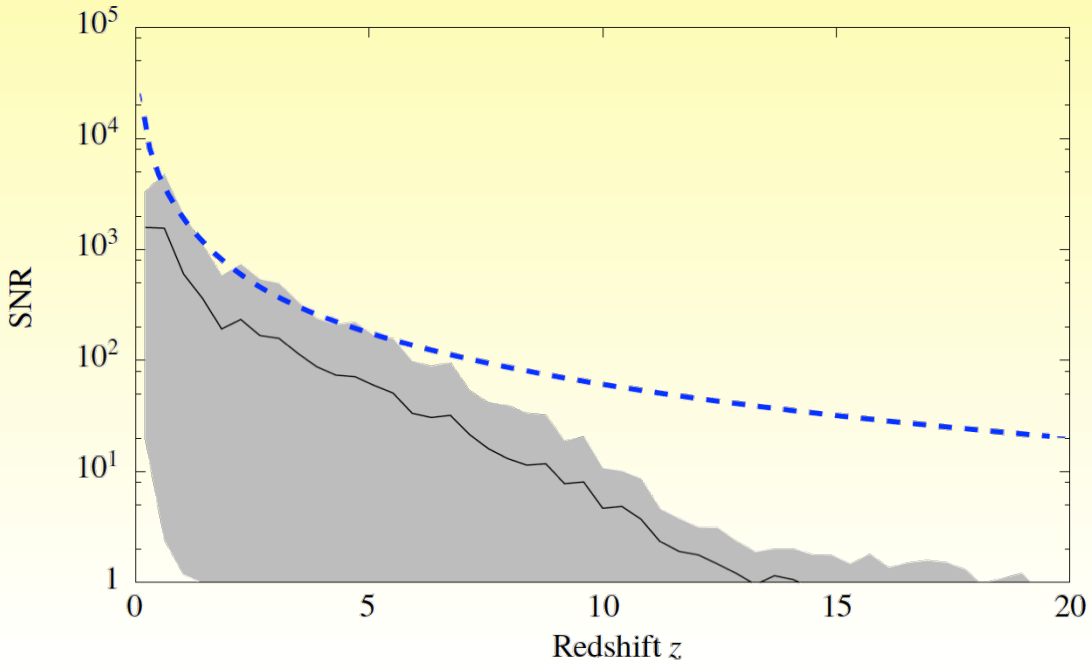
  →8 are guaranteed calibration sources for eLISA-NGO

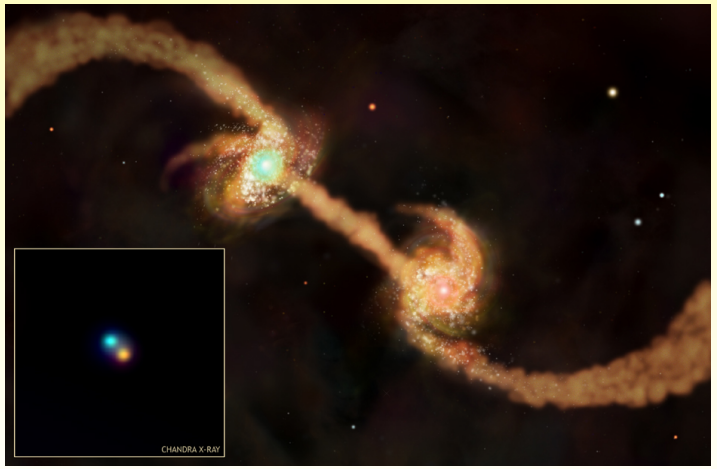


Trace Galaxy Evolution through Black Hole Mergers

- Hierarchical structure formation: many galaxy mergers
- Most galaxies have BH in center:
  → Many BH mergers
- Strong eLISA sources

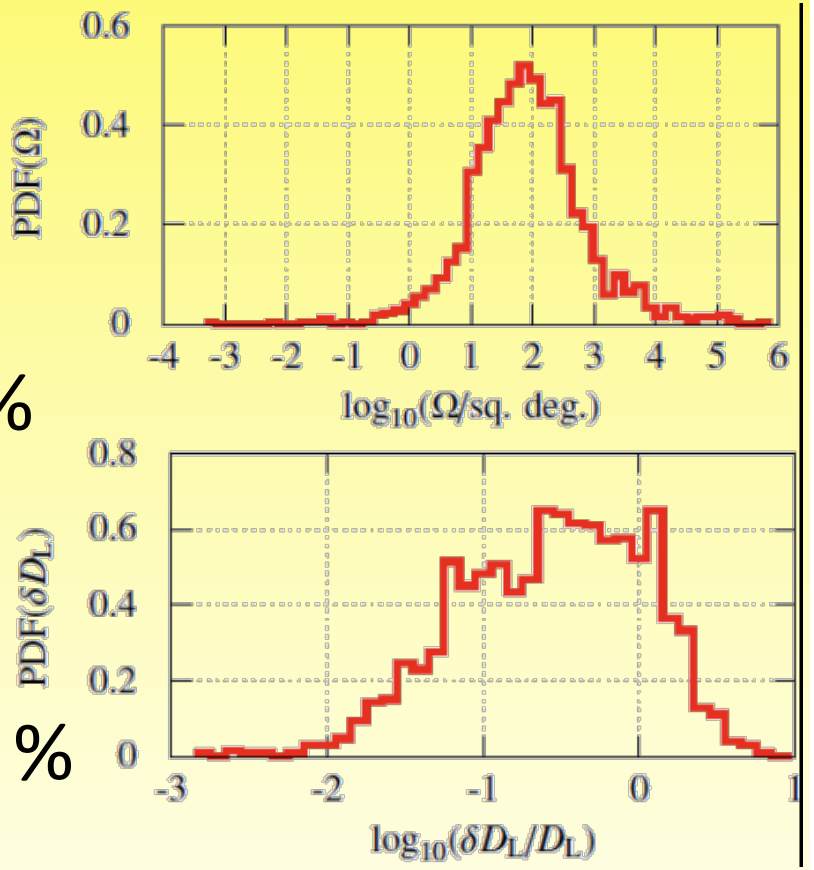






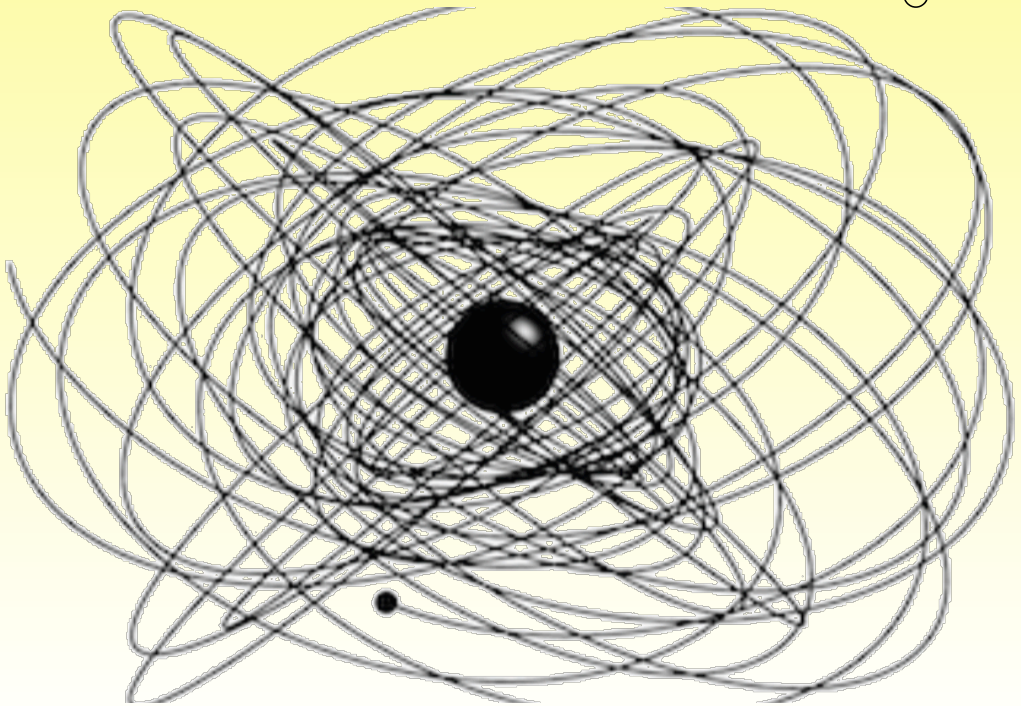
eLISA Black Hole Physics at high SNR

- BBH rest mass 10^4 – 10^7
- Out to redshift $z \approx 7$
- Redshifted mass to 0.1%-1%
- Absolute spin to 0.01-0.1
- Luminosity distance 1 – 50 %
- Sky location 3° - 10 °



Extreme Mass Ratio Inspirals

- SNR 20 up to $z \approx 0.7$ for 10^5-10^6 $M_\odot$
- Dozens of events
- Mass, spin to 0.1% – 0.01 %
- Quadrupole moment to < 0.001 $M_\odot^3 G^2/c^4$



Science Assessment

- eLISA will hear:
  - thousands of galactic binaries
  - tens of extreme mass ratio inspirals (EMRIs)
  - tens to hundreds of SMBH mergers
- But:
  - Parameter estimation accuracy would benefit from 3rd arm
  - Particularly at high redshift (z>10)

- Needs modest financial contribution from international partner! ;-)

→ In any case the Science is grand!

Thank you to the
eLISA-NGO Science Working Team
and all the other friends of LISA
who have contributed!

You will see LISA flying!