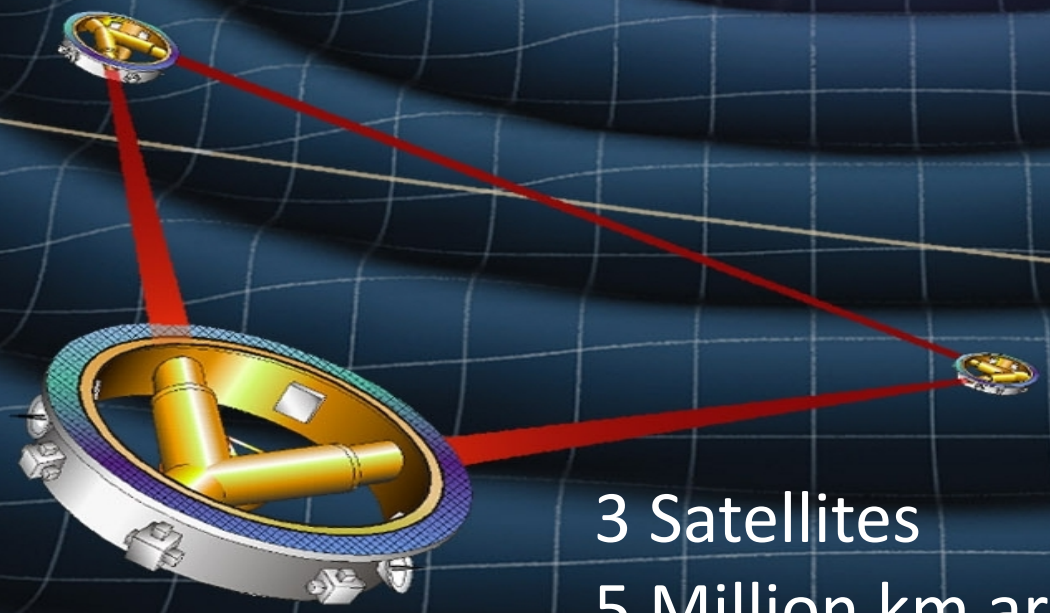

LISA
Karsten Danzmann
Albert Einstein Institute Hannover

LISA in 2010:

18 years of development!



3 Satellites
5 Million km arms
50 Million km behind earth

LISA Science and Astronomy

- 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

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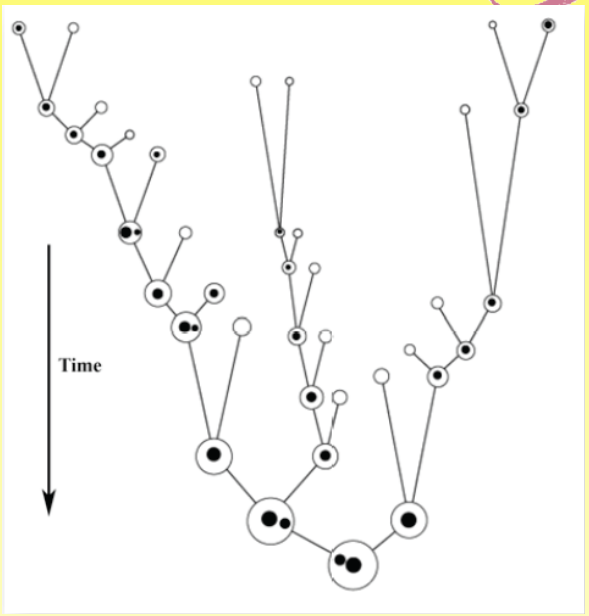
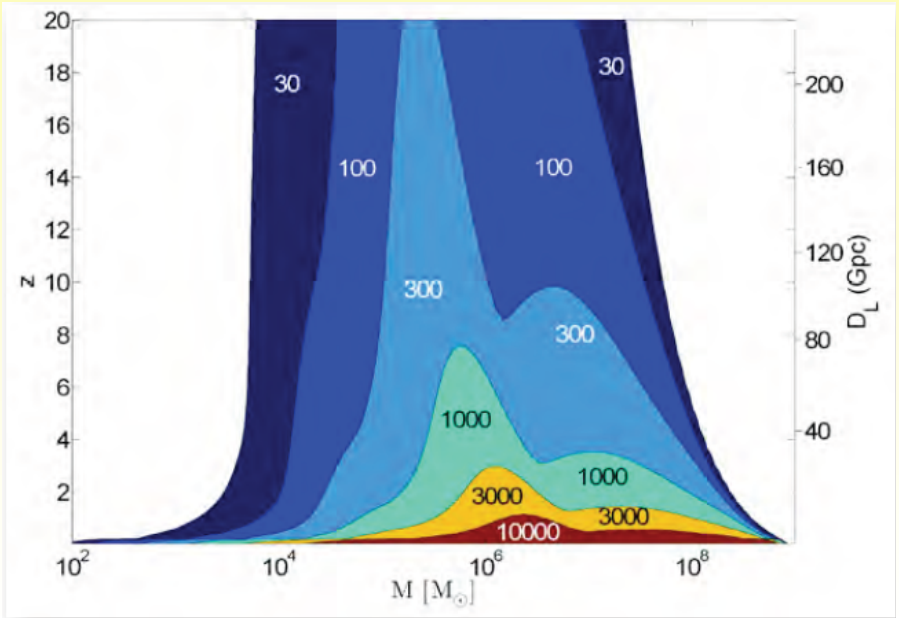
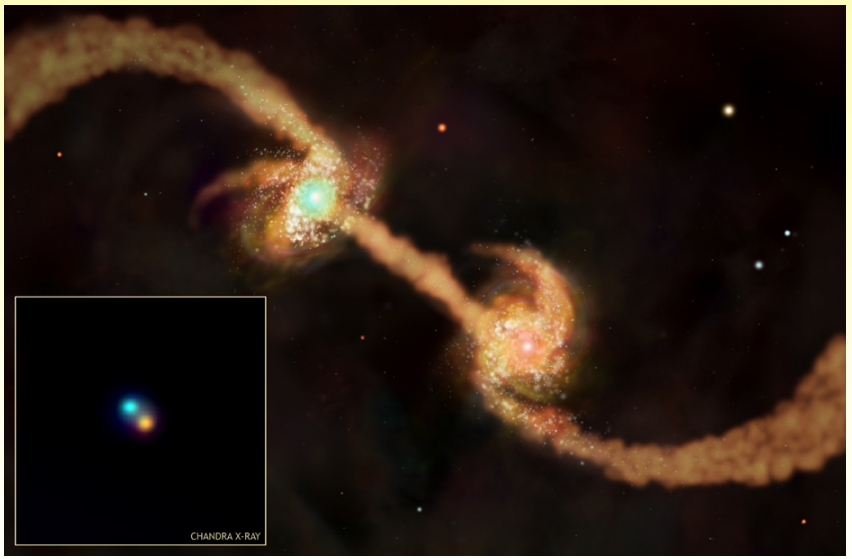
Trace Galaxy Evolution through BH Mergers

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

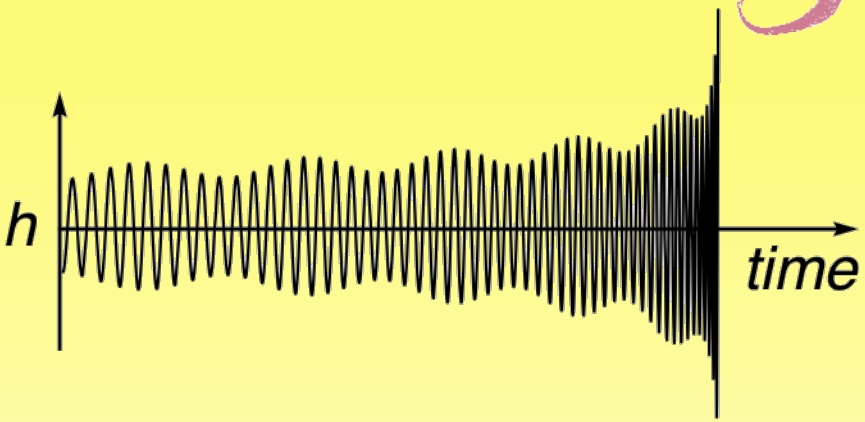






Absolute Distances from Black Hole Binaries

Waveforms of black hole binaries give precise, gravitationally calibrated distances to high redshift



Absolute luminosity distances can be derived *directly* from

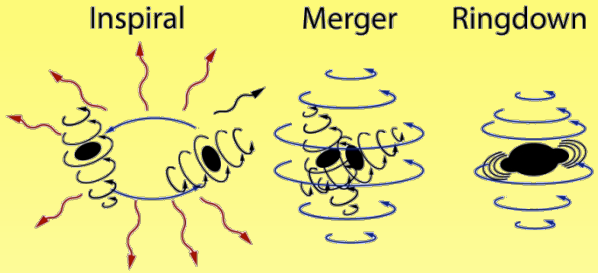
- amplitude
- orbital frequency
- chirp time

$$\text{Distance} \cong c\,\frac{1}{\text{frequency}^2 \times t_{\text{chirp}} \times \text{amplitude}}$$

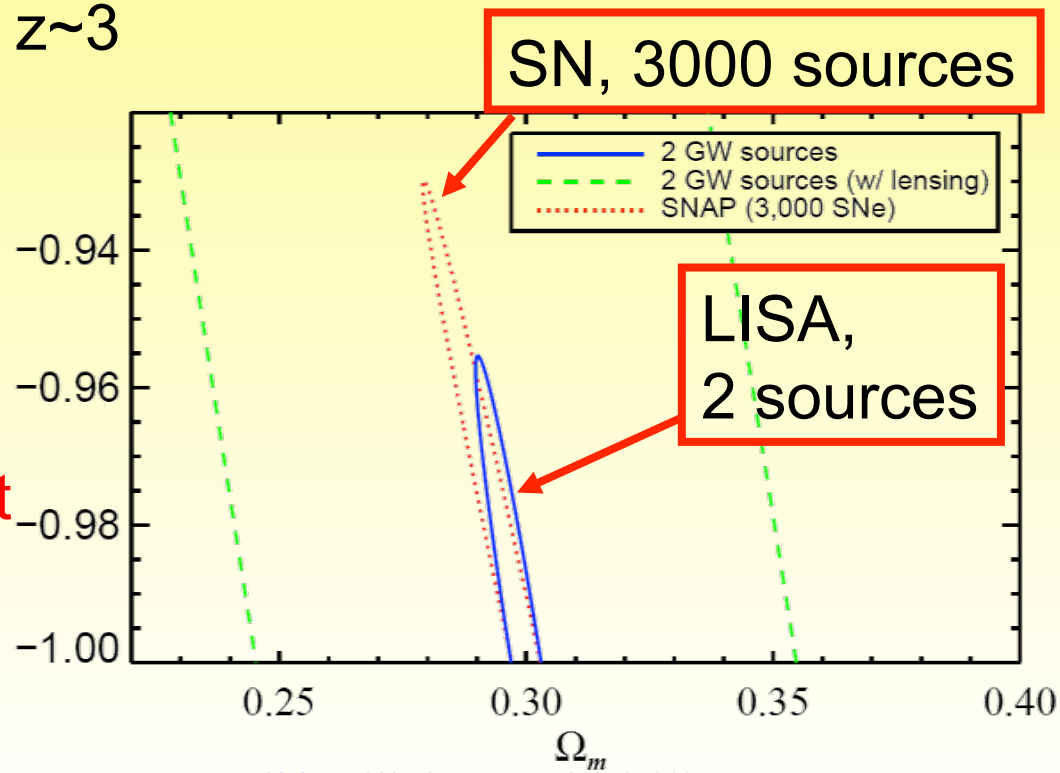
1. Distances accurate to 0.1% to 2% per event
2. Absolute, physical calibration using only gravitational physics

Absolute Distances from SMBH Mergers:

Hubble Constant and Dark Energy



- 100's of events expected to z~3
- 10's out to z~20
- Noise from weak lensing
- Comparable precision to CMB, WL, BAO, CL, SN
- We need to identify the host to get the redshift!
- Optical counterparts?



Holz and Hughes, astro-ph/0504616

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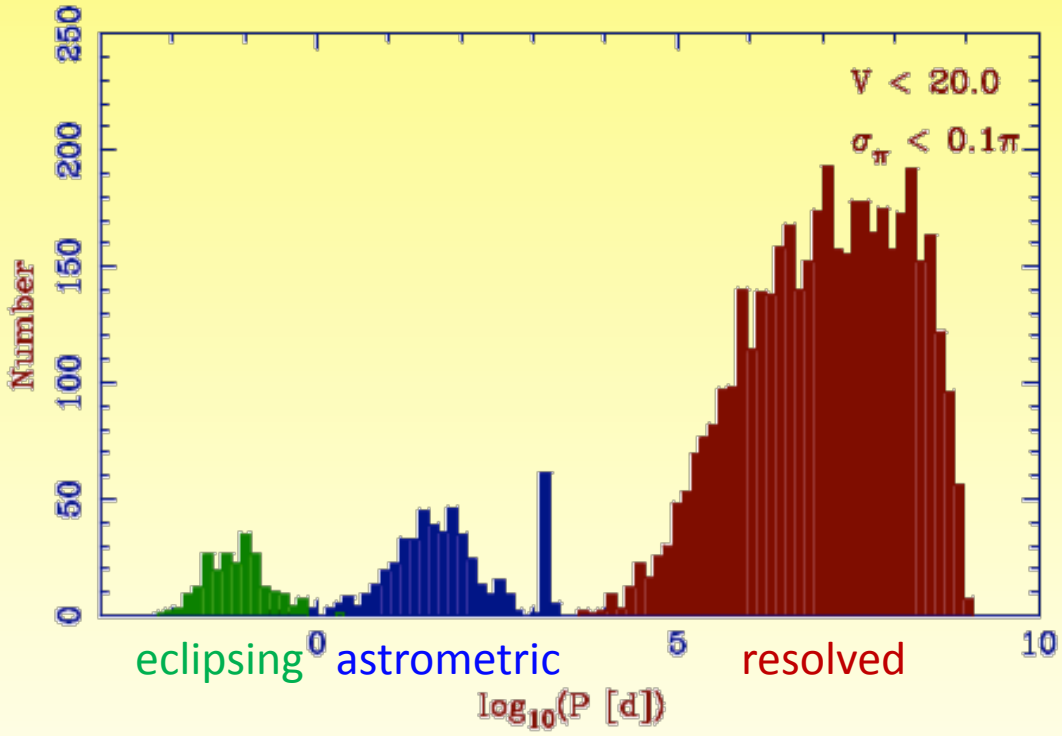
Galactic binaries: relevance

- Probes binary evolution
  - Common envelope
- Type Ia Supernovae
  - Same populations
- Galactic populations/ structure
  - Tracers of star formation
- Binary interactions
  - Mass transfer/tides

GAIA

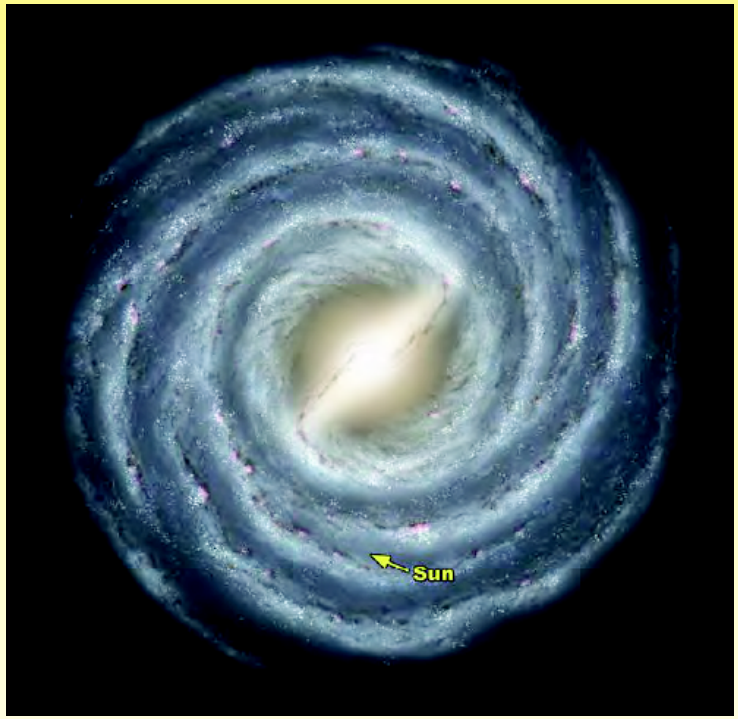
- 4300 resolved WD pairs
  - For tests of IMFM relation and cooling models
- 500 astrometric WD binaries
  - Periods of days, largely unknown parameter space
- 230 eclipsing WD binaries
  - Short periods, none known today



Marsh & Nelemans in prep

LISA: 100 Million White Dwarf Binaries!

- LISA will “see” every binary system in the Galaxy that has a period < 2 hr
- Several 10 000 resolvable in 2 yr
- Synergy between LISA and GAIA:
  - LISA polarisation measurement gives *inclination* of orbital plane
  - LISA gives accurate *distances* to and *masses* of WD/WD binaries whose orbits show effects of gravitational radiation reaction

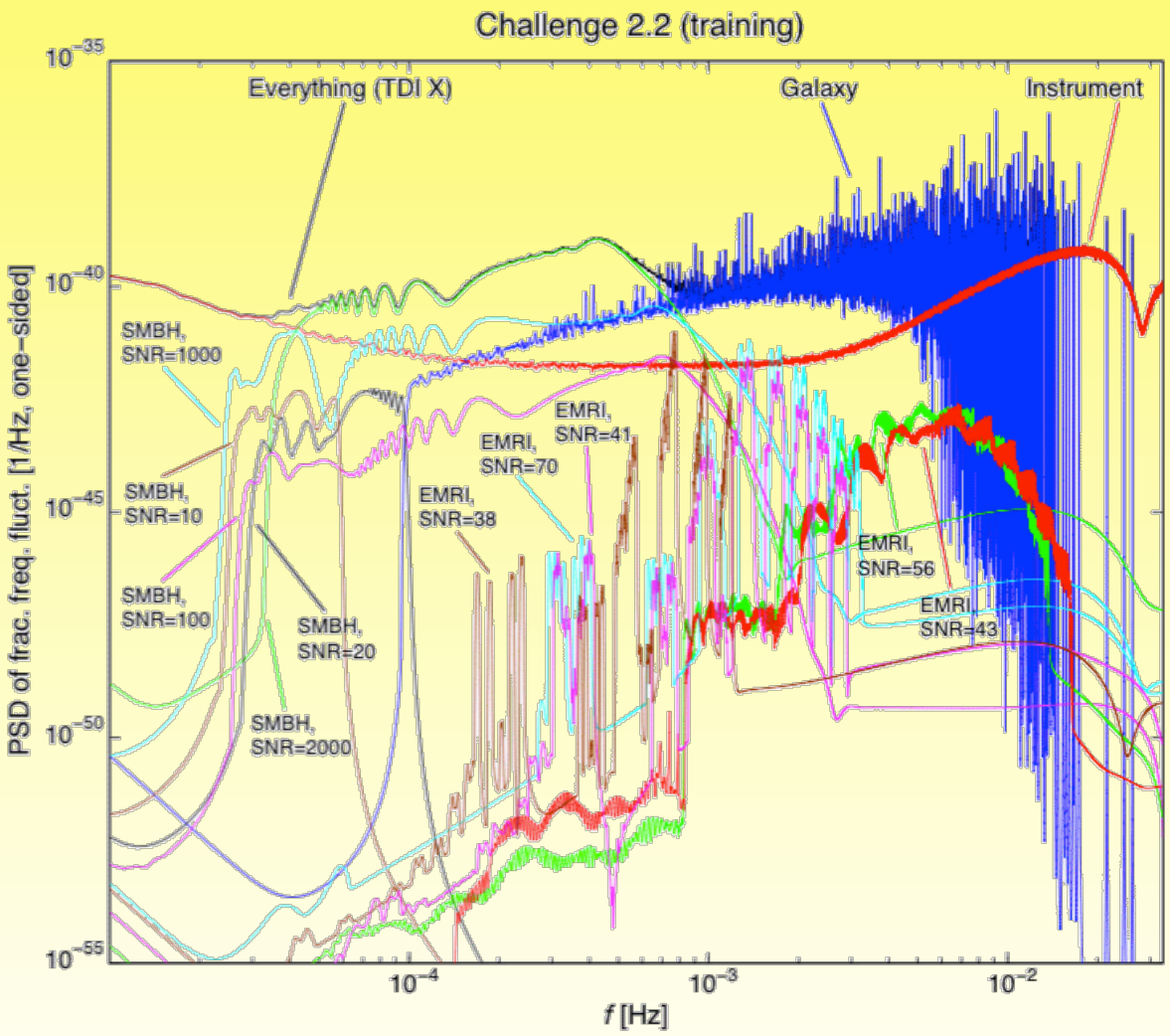


LISA Science Data Archive

- Requirements
  - All data on ground every 6 days
  - 1 day latency to science operations center before a merger
  - 90% net efficiency (gaps, outages, etc < 10%)
- Baseline telemetry
  - Ka-Band, 30 cm antenna, 25 W TWTA
  - 4.13 kbps continuous per S/C
    - 871 bps is main science data
    - Includes 15% coding overhead and 25% margin
  - 4 hr DSN (34m) contact every 48 hr
  - Total data volume per S/C
    - 1 day: 357 Mbits all data/ 78 Mbits science
    - 1 year: 130.4 Gbits all data/ 28.4 Gbits science
    - 5 year mission: 652 Gbits all data / **142 Gbits science**

Mock LISA Data Challenge

- Blind international challenge
- Rund 1 completed
  - Report published
- Round 2 completed
- Full LISA data stream
  - Instrumental noise
  - 4 MBH events
  - 5 EMRI events
  - 26.1 million Galactic binaries



http://www.tapir.caltech.edu/dowiki/listwg1b:home

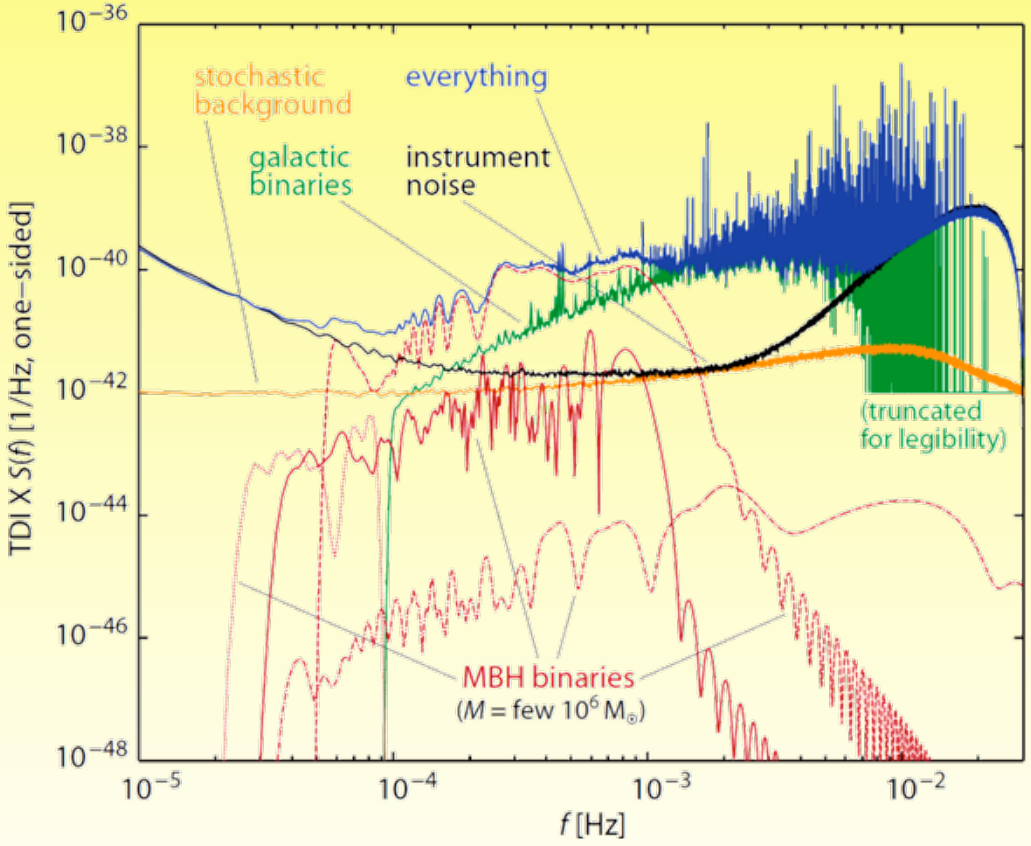
http://astrogravs.nasa.gov/docs/mldc

Currently MLDC Round 4: The "Whole Enchilada"

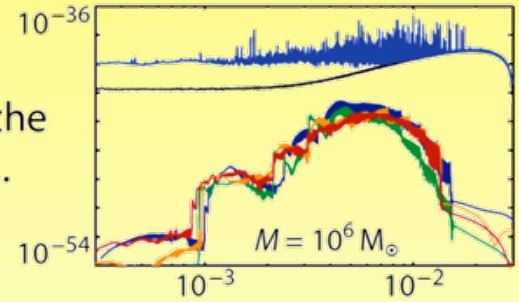
– *Focus on "global fit" problem*

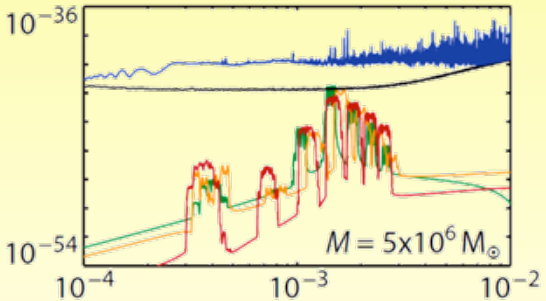
MLDC4, training dataset

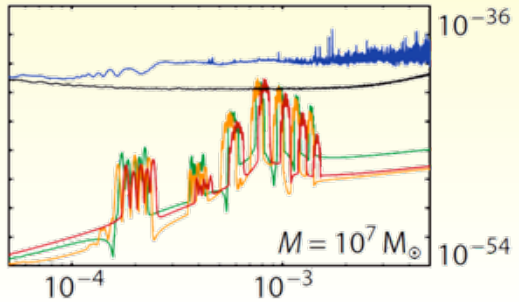
2 years of instrument noise, 60 million Galactic binaries, 4 MBH binaries, 9 EMRIs, 15 cosmic-string bursts, cosmological stochastic background



...plus the EMRIs...

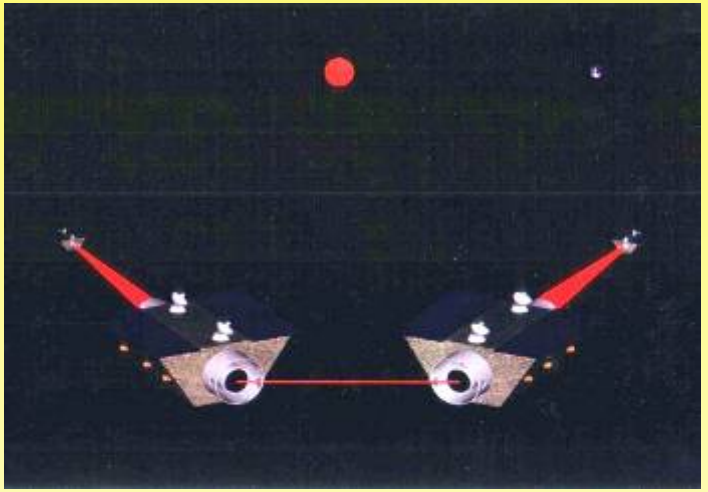


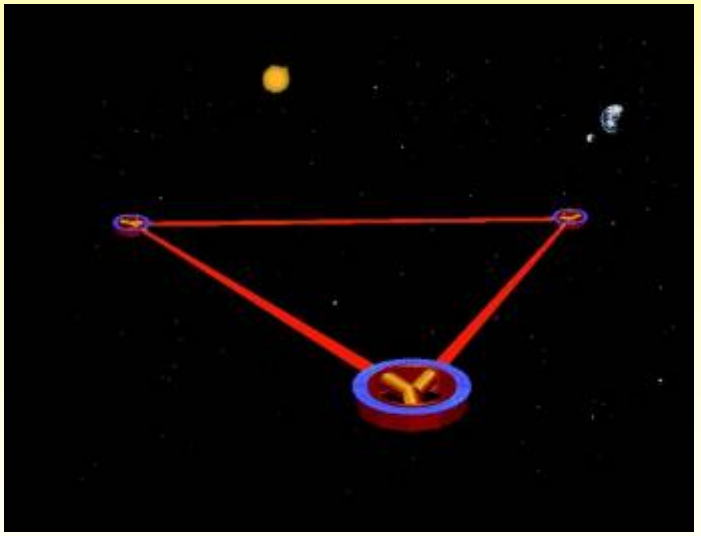




LISA: A Mature Concept

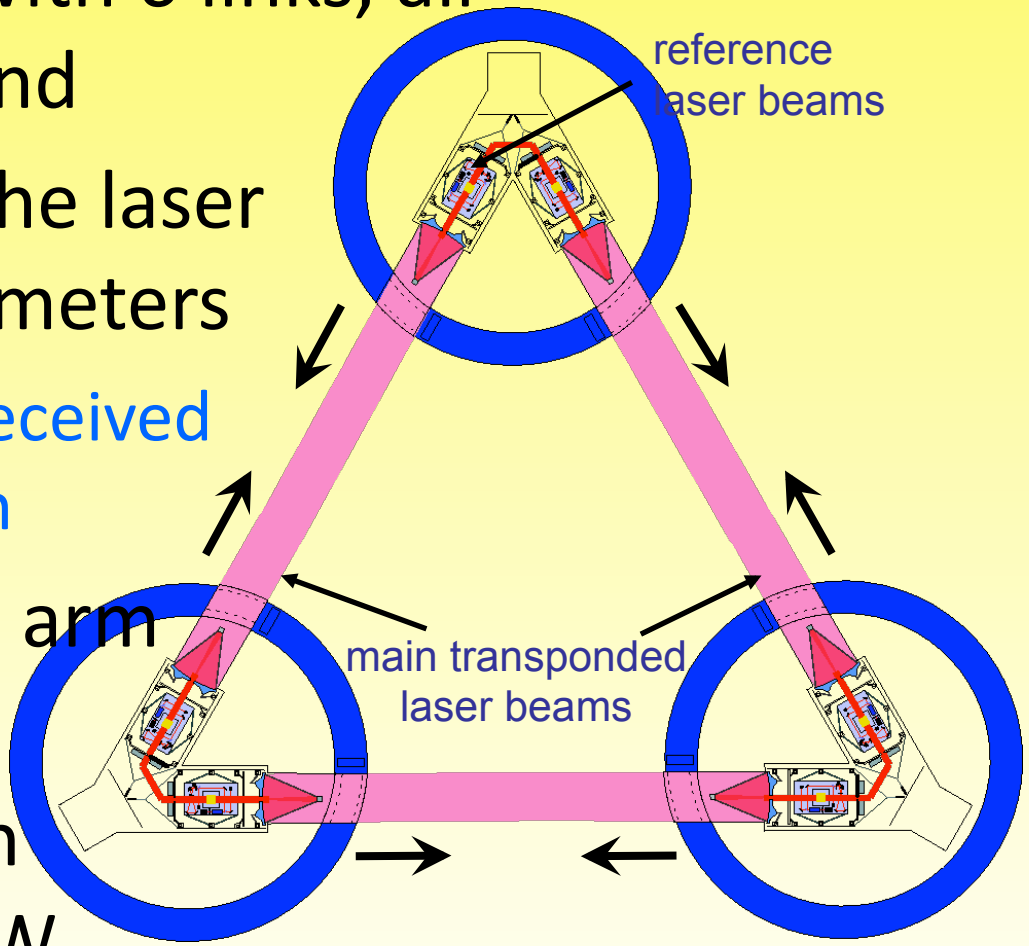
- After first studies in 1980s, M3 proposal for 4 S/C ESA/NASA collaborative mission in 1993
- LISA selected as ESA Cornerstone in 1995
- *3 S/C NASA/ESA LISA appears in 1997*
- **Baseline concept unchanged ever since!**





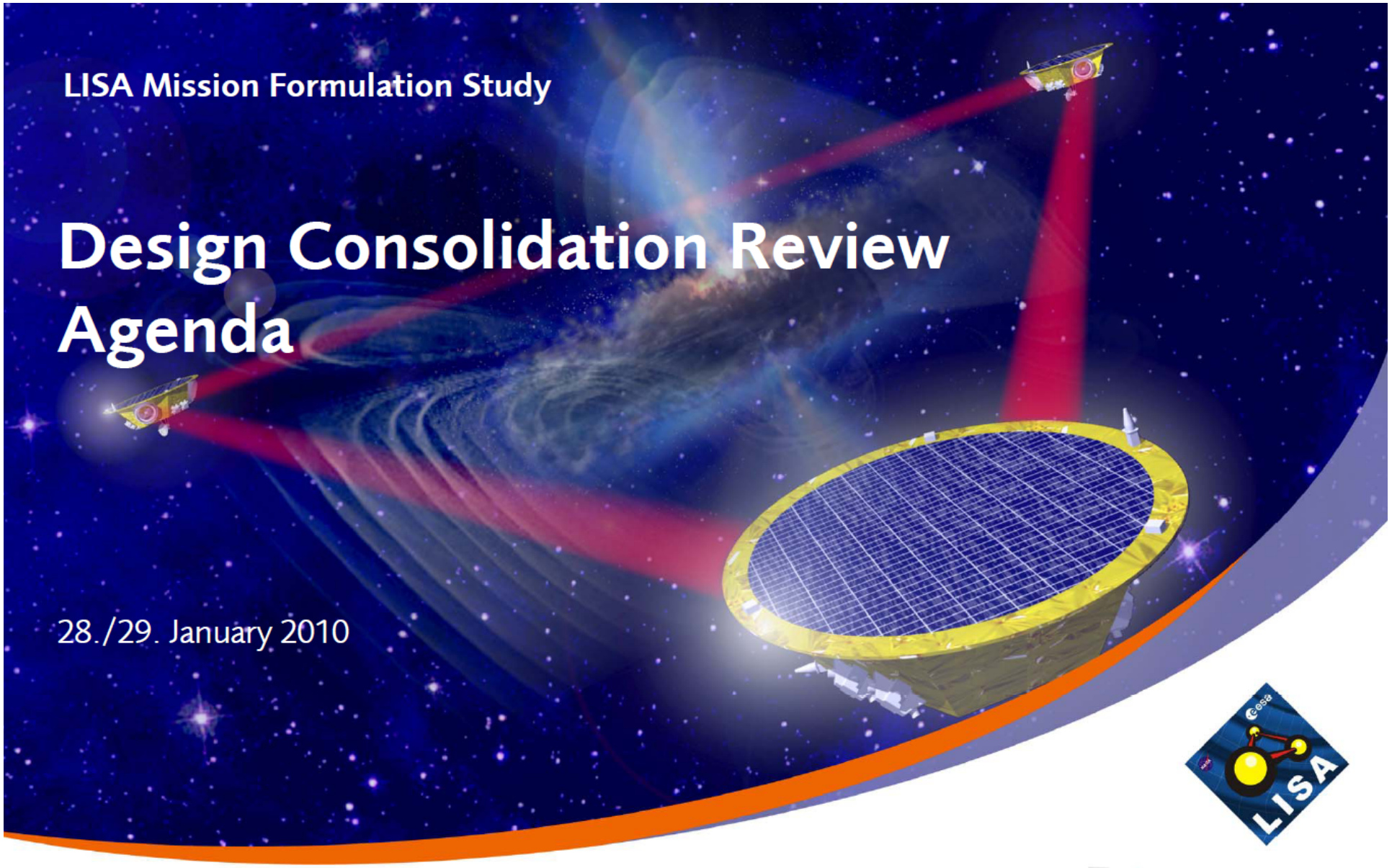
LISA Layout

- Laser transponder with 6 links, all transmitted to ground
- Diffraction widens the laser beams to many kilometers
  - 1 W sent, 100 pW received by 40 cm Cassegrain
- Michelson with 3rd arm and Sagnac mode
- Can distinguish both polarizations of a GW
- Can form Null combination!



LISA Mission Formulation Study

Design Consolidation Review Agenda



28./29. January 2010

All the space you need

esa

EADS astrium

Overall Study (2)

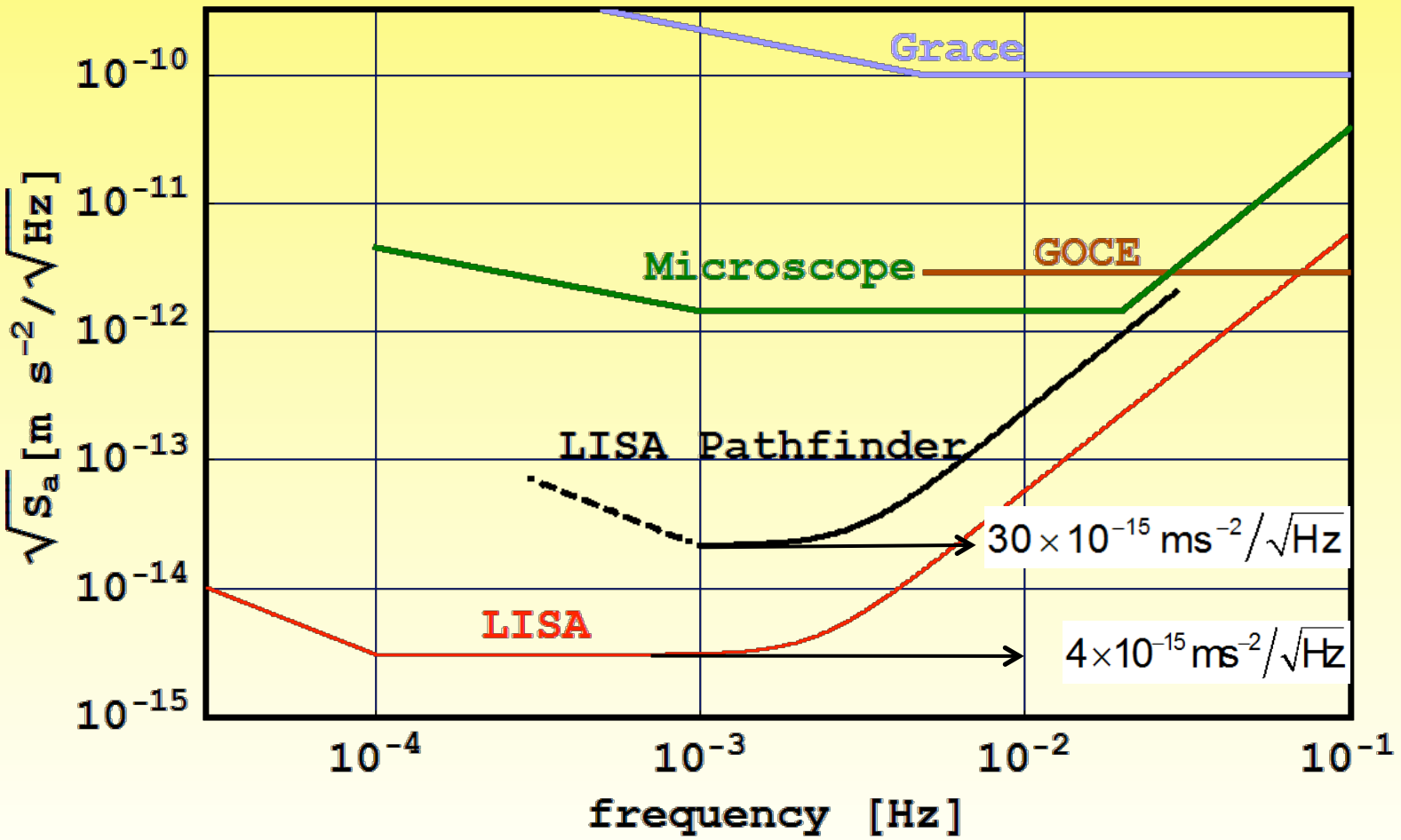
- Technical Notes – System (198 p.)
  - LISA-ASD-TN-5001 (76 p.)
  - LISA-ASD-TN-5002 (16 p.)
  - LISA-ASD-TN-5003 (26 p.)
  - LISA-ASD-TN-5004 (40 p.)
  - LISA-ASD-TN-5005 (40 p.)
- Other Documents (63 p.)
  - LISA-TNO-TN-3001 (24 p.)
  - LISA-UTN-TN-3002 (17 p.)
  - LISA-UTN-TN-3003 (22 p.)

- Total so far: 6540 p.

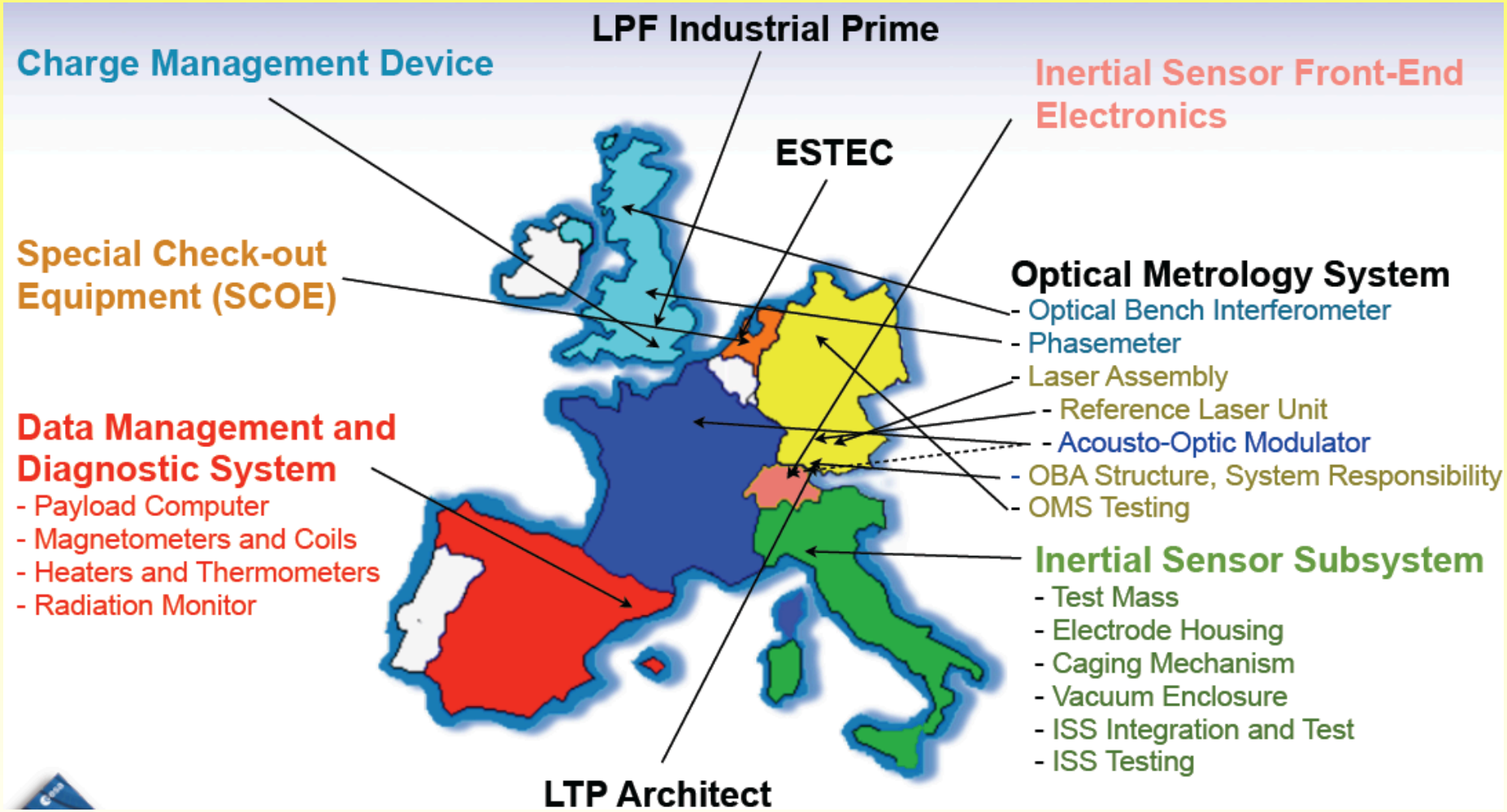
LISA Pathfinder

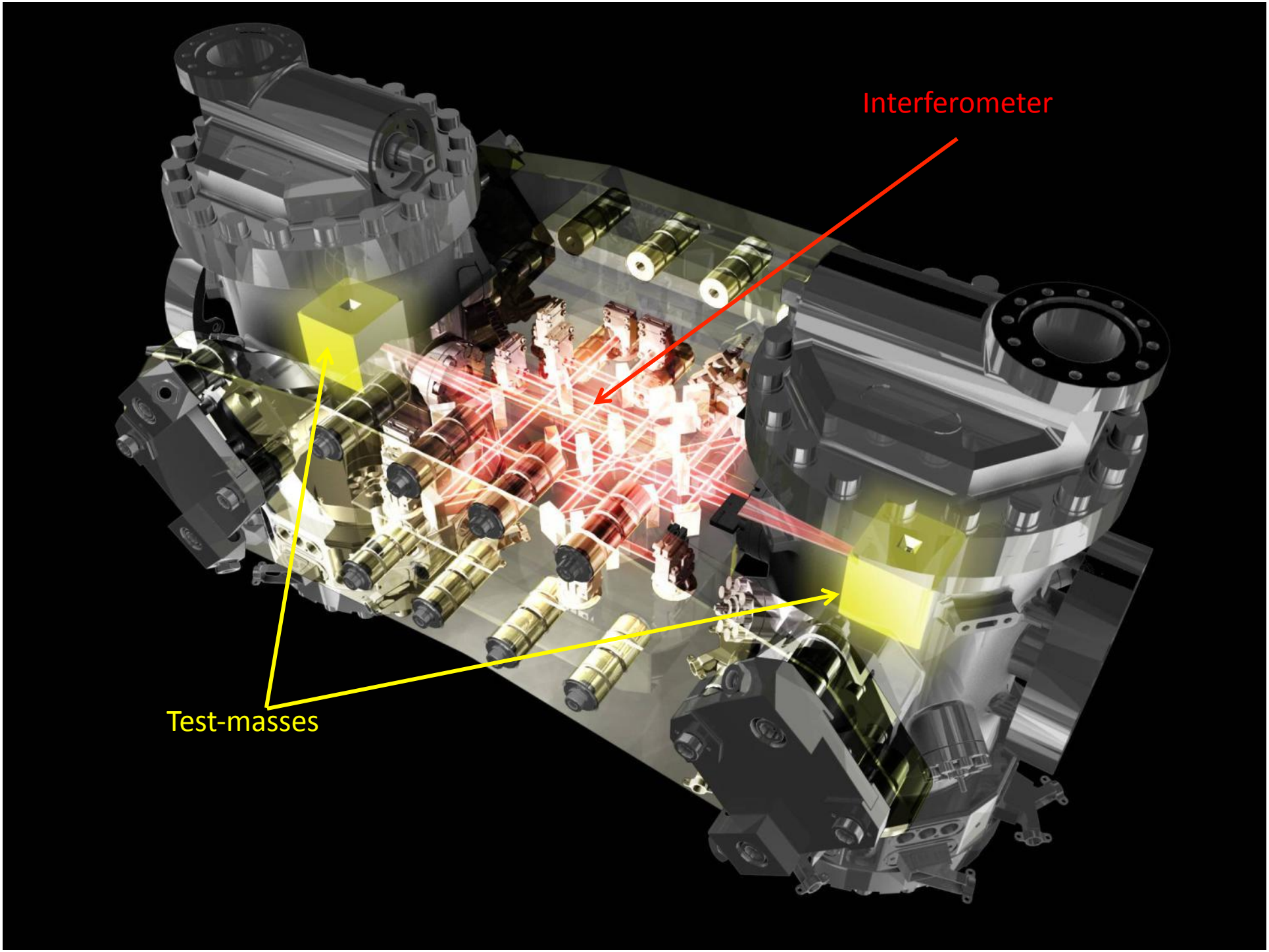
- Testing LISA Technology in Space!

LISA and LPF requirements

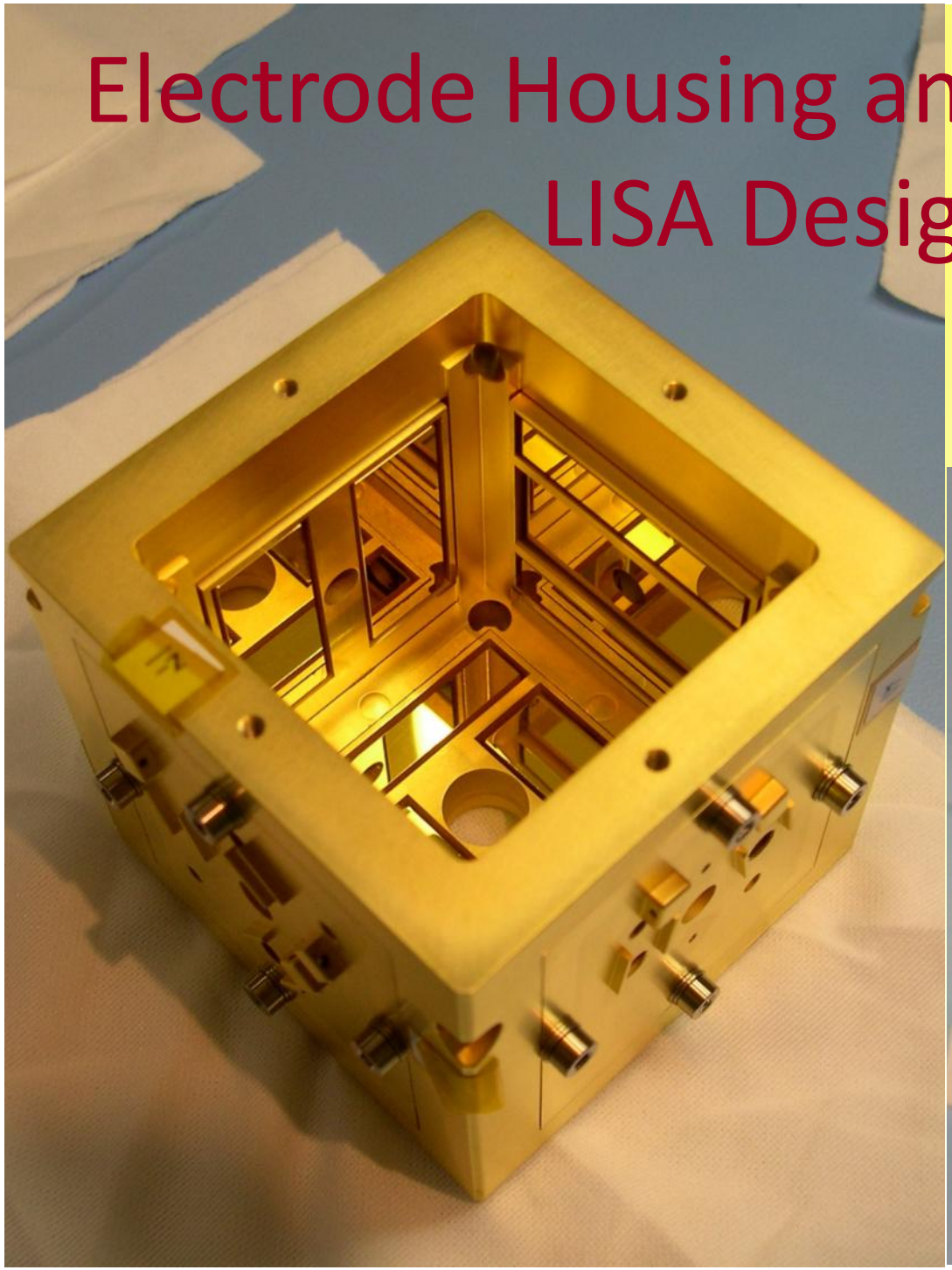


LISA Pathfinder Team

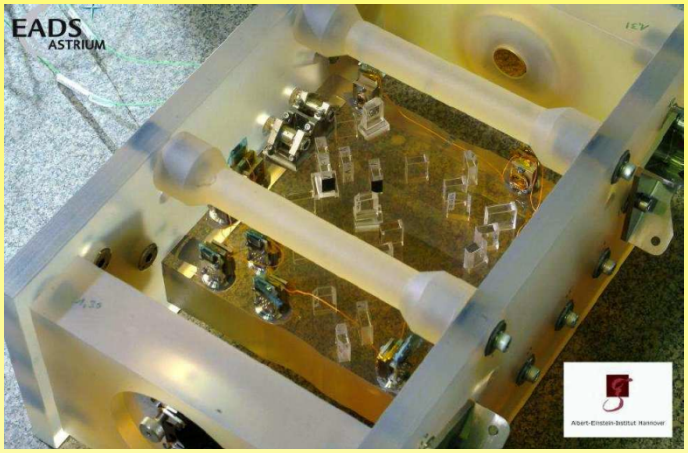


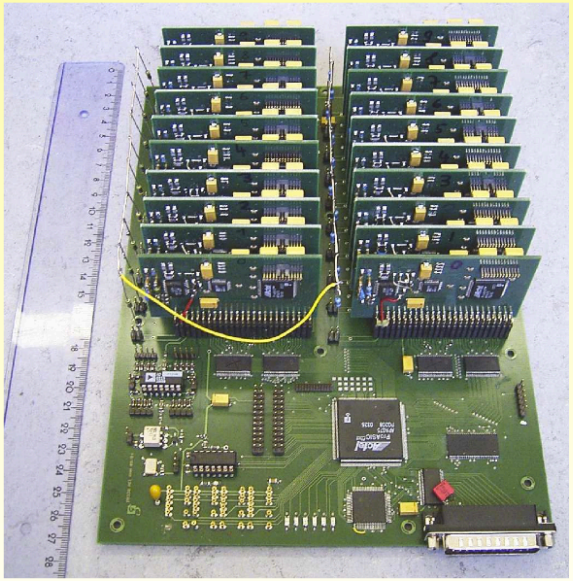

Interferometer
Test-masses

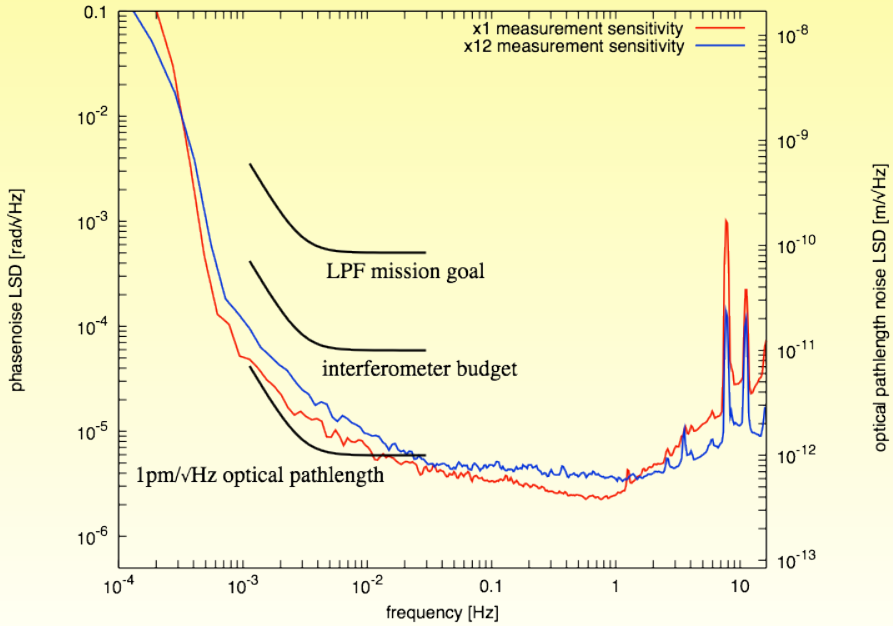
Electrode Housing and Test Mass: LISA Design



Status before EM and FM tests

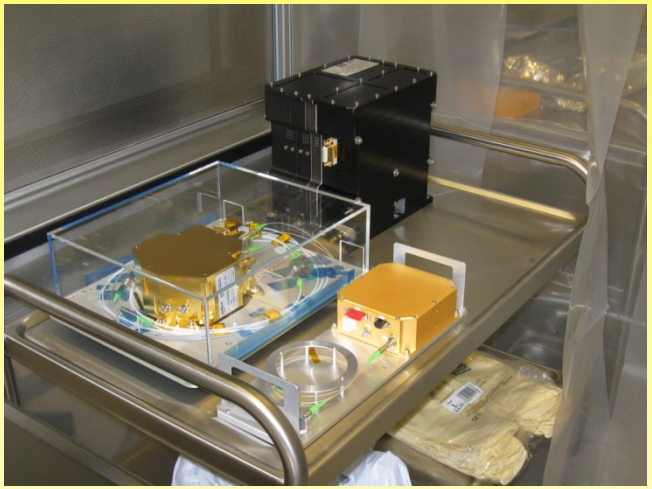


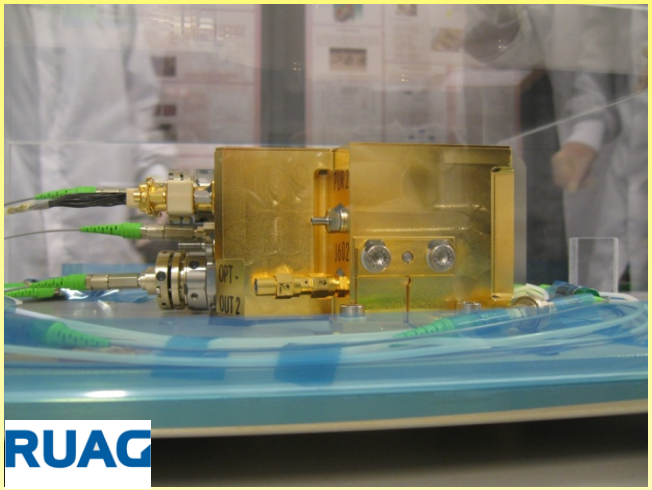


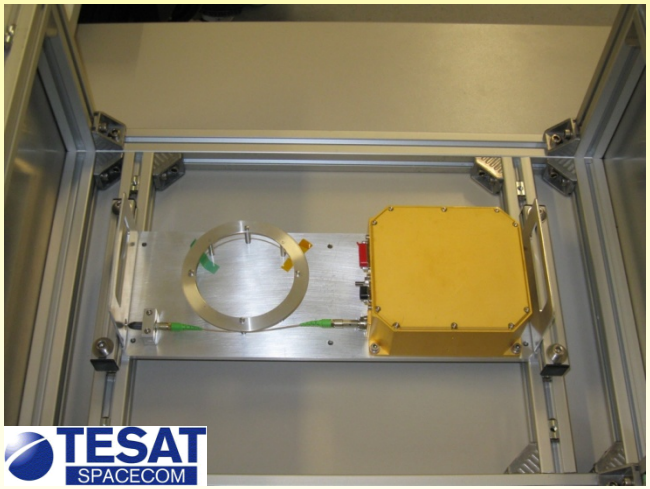


Laser Assembly Flight Model Tests (March 2010)

- integration into testbed
- functional tests
- interface testing
- control loop actuators
- noise behavior



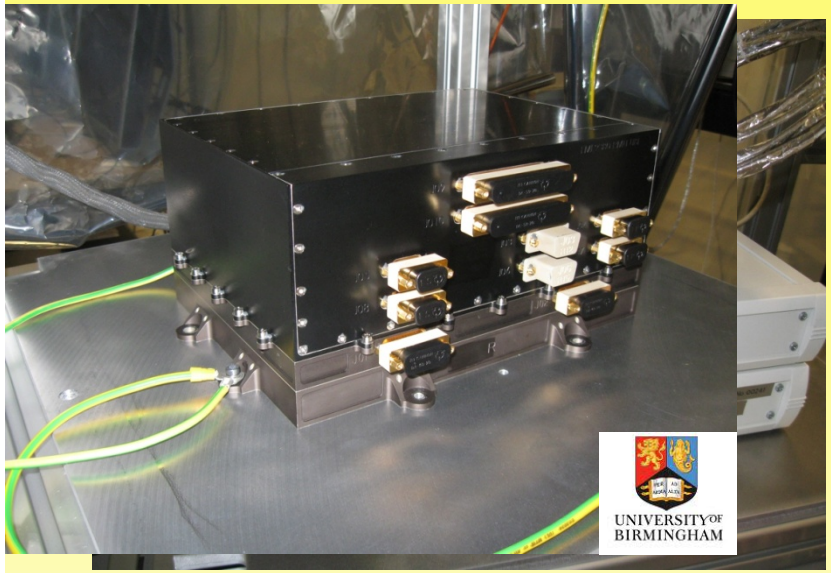


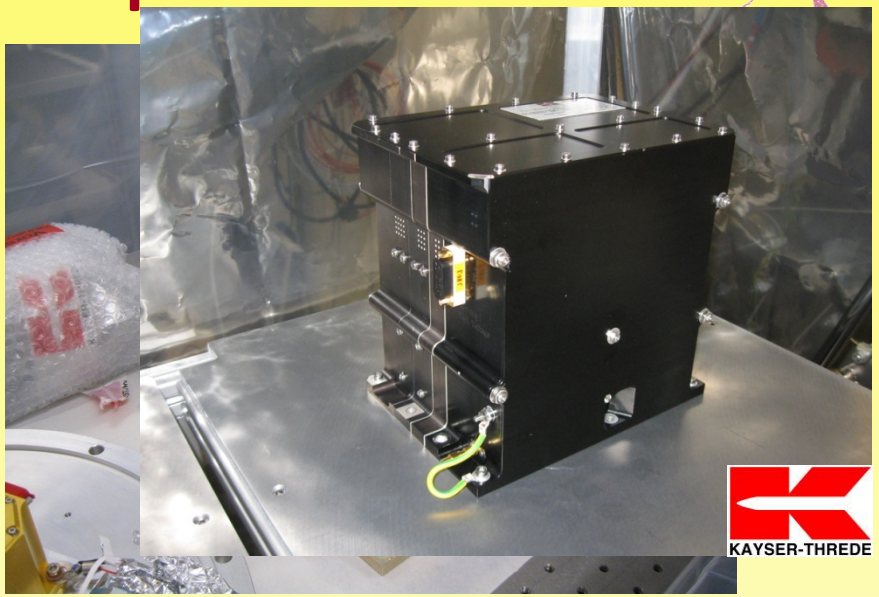


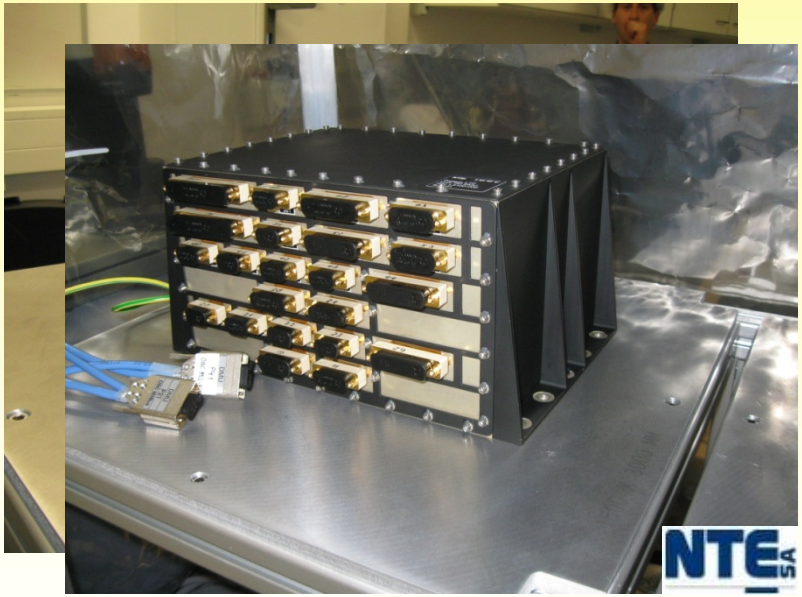
KAYSER-THREDE

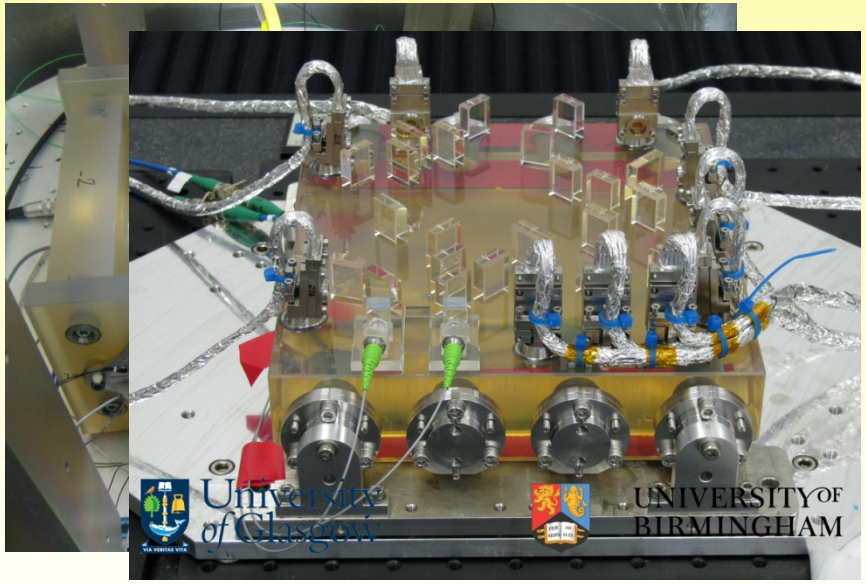
Laser Assembly Test Team

Flight Model Units replace EMs

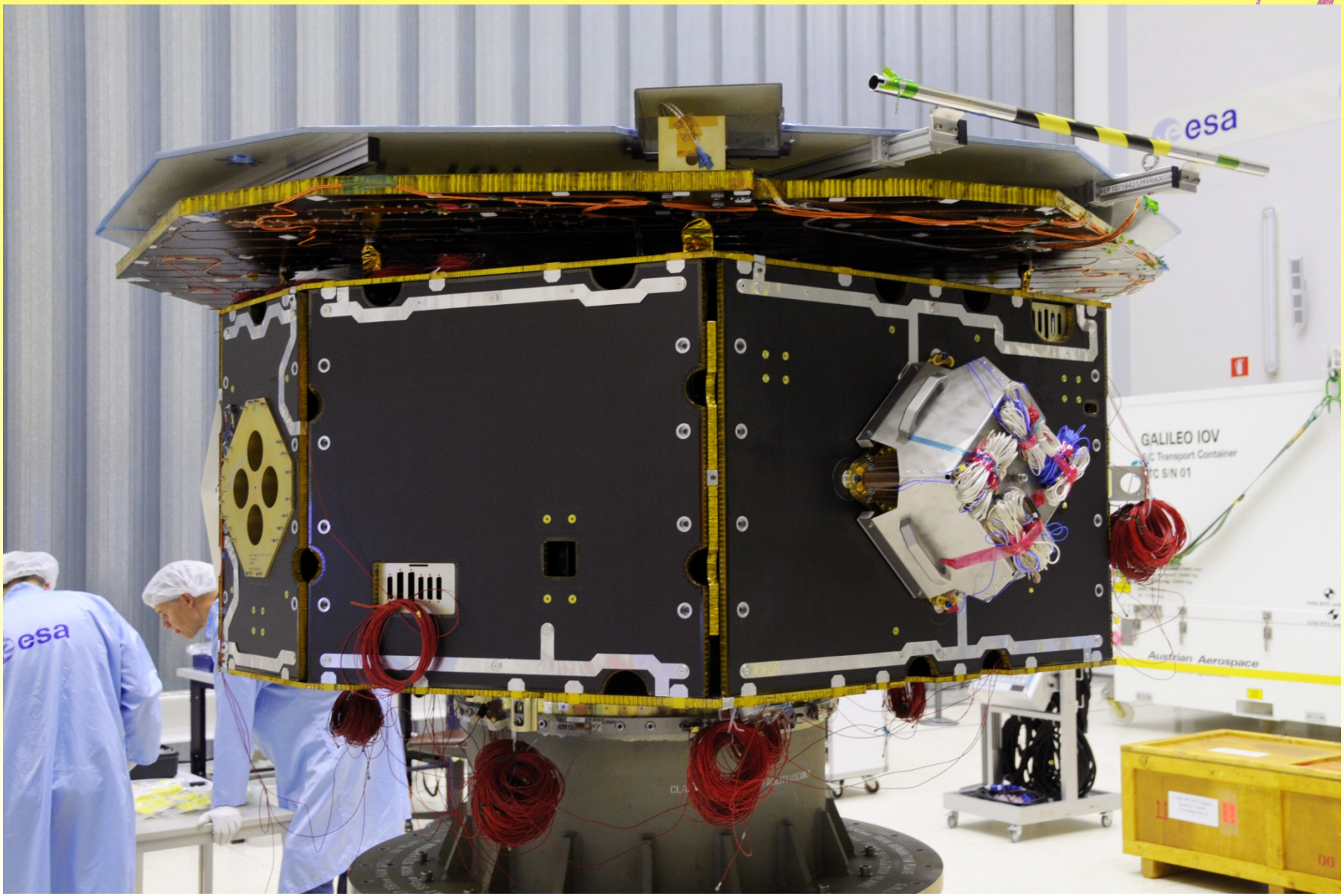




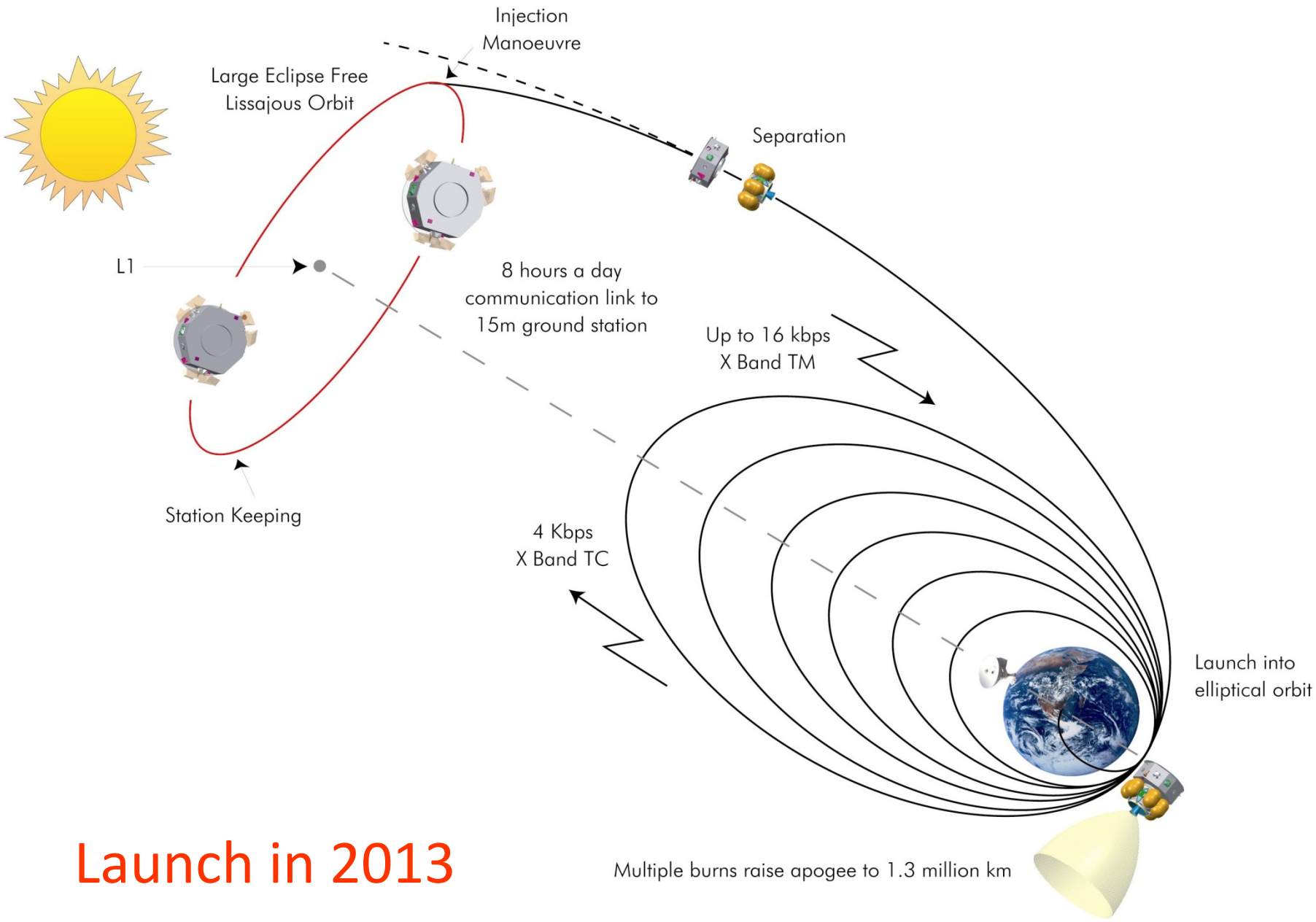




LPF Spacecraft




iABG



Launch in 2013

Lagrange Point L1

Back to LISA:

NASA Beyond Einstein Program Review

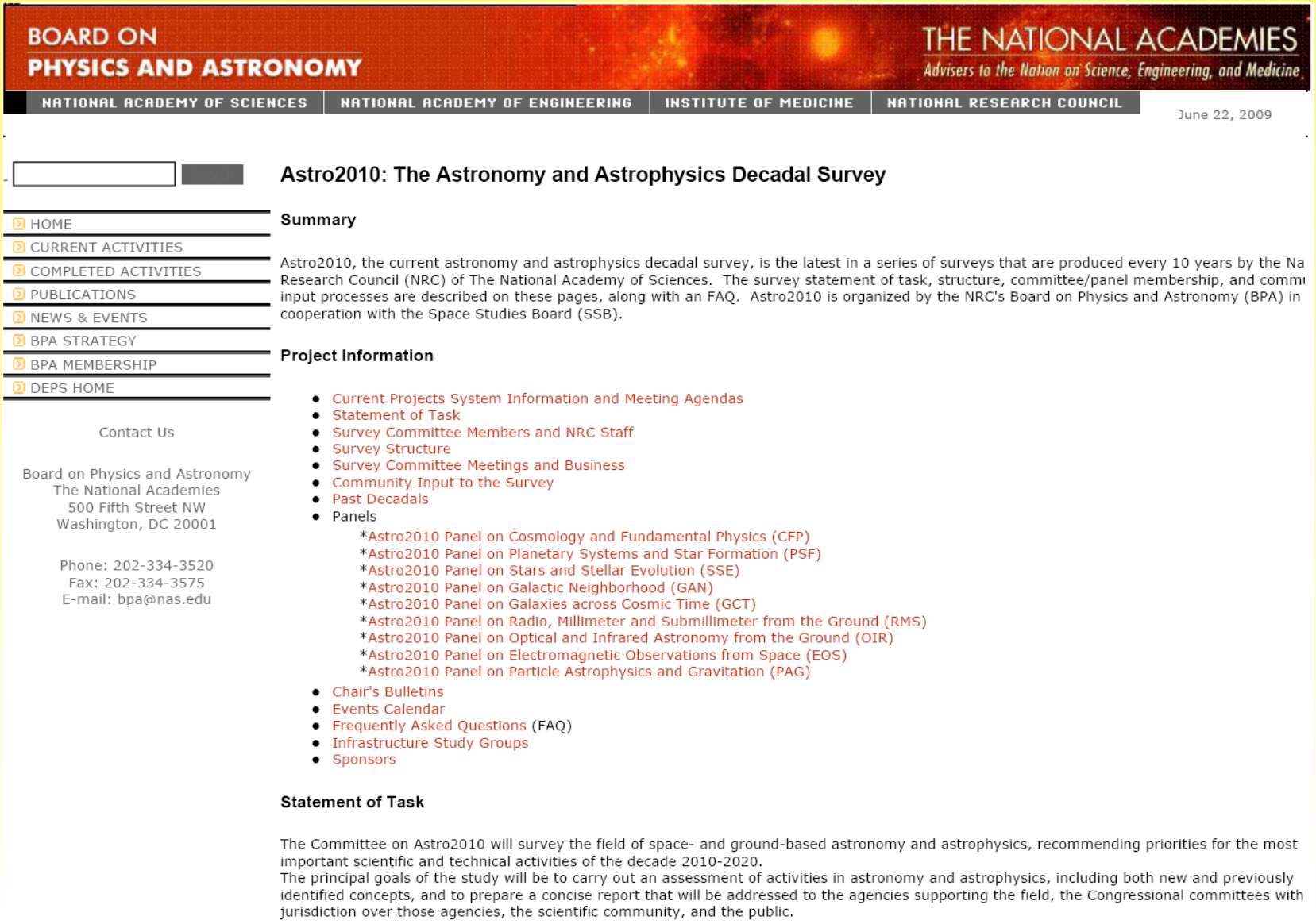
November 2006 – September 2007

National Research Council
The National Academies, Washington, DC

BEPAC Recommendations for LISA:

- "On purely scientific grounds LISA is the mission that is most promising and least scientifically risky. Even with pessimistic assumptions about event rates, it should provide unambiguous and clean tests of the theory of general relativity in the strong field dynamical regime and be able to make detailed maps of space time near black holes. **Thus, the committee gave LISA its highest scientific ranking."**
- " LISA is an extraordinarily original and technically bold mission concept. LISA will open up an entirely new way of observing the universe, with immense potential to enlarge our understanding of physics and astronomy in unforeseen ways**. LISA, in the committee's view, should be the flagship mission** of a long-term program addressing Beyond Einstein goals."
- **"NASA should invest additional Beyond Einstein funds in LISA technology** development and risk reduction, to help ensure that the Agency is in a position to proceed in partnership with ESA to a new start after the LISA Pathfinder results are understood."
- "LISA was recommended second in implementation because of money and programmatics. But even assuming an unnecessarily pessimistic financial contribution from ESA, and being second in Beyond Einstein, the assumed **launch date of LISA as ESA Cosmic Vision Mission L1 in 2018 is still feasible and the committee strongly recommends that."**

After the Review is before the Review: Astro2010 Decadal Survey



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June 22, 2009

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Astro2010: The Astronomy and Astrophysics Decadal Survey

Summary

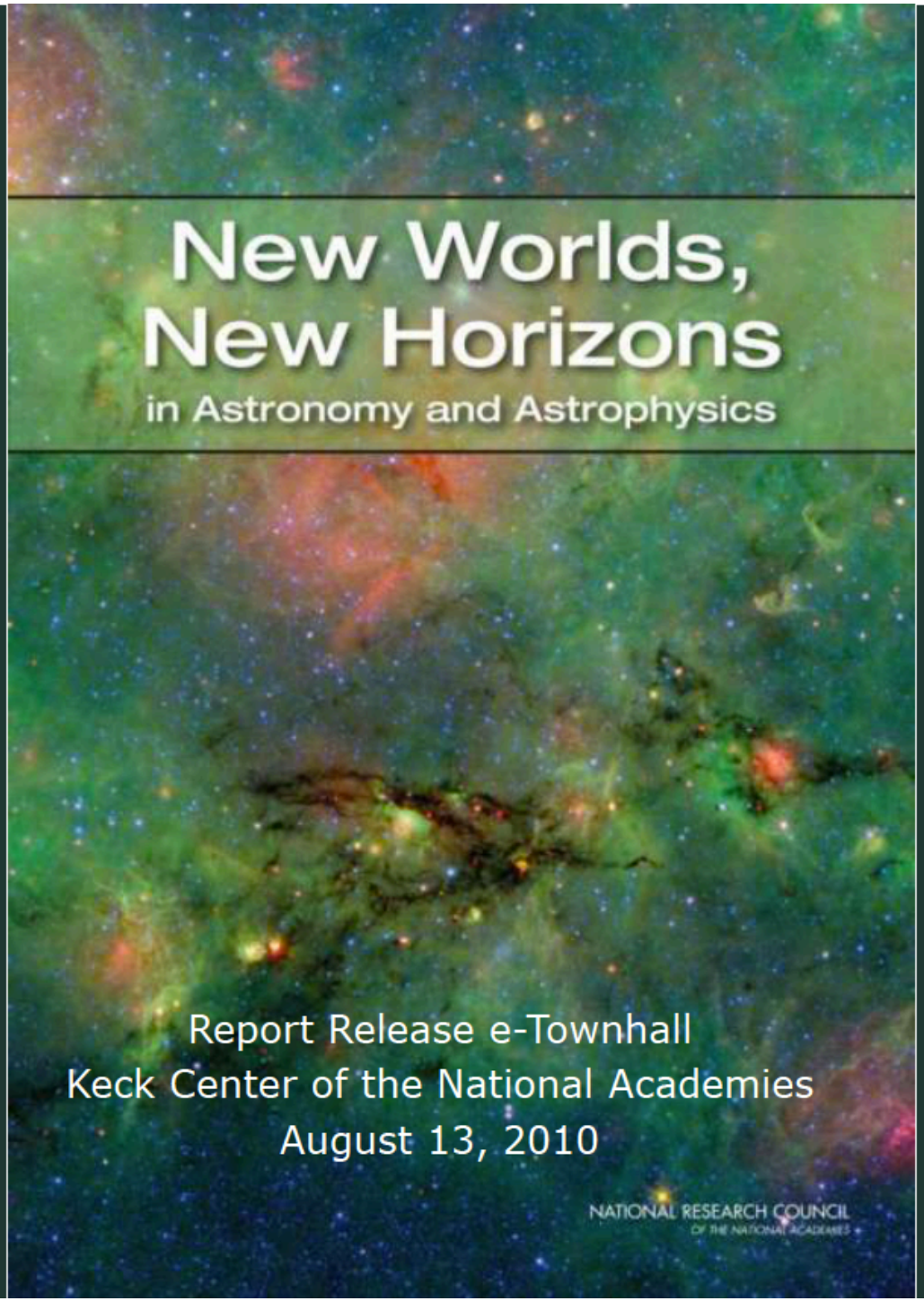
Astro2010, the current astronomy and astrophysics decadal survey, is the latest in a series of surveys that are produced every 10 years by the Na Research Council (NRC) of The National Academy of Sciences. The survey statement of task, structure, committee/panel membership, and commu input processes are described on these pages, along with an FAQ. Astro2010 is organized by the NRC's Board on Physics and Astronomy (BPA) in cooperation with the Space Studies Board (SSB).

Project Information

- Current Projects System Information and Meeting Agendas
- Statement of Task
- Survey Committee Members and NRC Staff
- Survey Structure
- Survey Committee Meetings and Business
- Community Input to the Survey
- Past Decadals
- Panels
  - *Astro2010 Panel on Cosmology and Fundamental Physics (CFP)
  - *Astro2010 Panel on Planetary Systems and Star Formation (PSF)
  - *Astro2010 Panel on Stars and Stellar Evolution (SSE)
  - *Astro2010 Panel on Galactic Neighborhood (GAN)
  - *Astro2010 Panel on Galaxies across Cosmic Time (GCT)
  - *Astro2010 Panel on Radio, Millimeter and Submillimeter from the Ground (RMS)
  - *Astro2010 Panel on Optical and Infrared Astronomy from the Ground (OIR)
  - *Astro2010 Panel on Electromagnetic Observations from Space (EOS)
  - *Astro2010 Panel on Particle Astrophysics and Gravitation (PAG)
- Chair's Bulletins
- Events Calendar
- Frequently Asked Questions (FAQ)
- Infrastructure Study Groups
- Sponsors

Statement of Task

The Committee on Astro2010 will survey the field of space- and ground-based astronomy and astrophysics, recommending priorities for the most important scientific and technical activities of the decade 2010-2020.
The principal goals of the study will be to carry out an assessment of activities in astronomy and astrophysics, including both new and previously identified concepts, and to prepare a concise report that will be addressed to the agencies supporting the field, the Congressional committees with jurisdiction over those agencies, the scientific community, and the public.


New Worlds,
New Horizons
in Astronomy and Astrophysics
Report Release e-Townhall
Keck Center of the National Academies
August 13, 2010
NATIONAL RESEARCH COUNCIL
OF THE NATIONAL ACADEMIES

LISA recommended as one of two large missions to start this decade!

- Independent review found LISA's technical risk, assuming Pathfinder success, to be medium, and the NASA appraised cost, based on a 50 percent participation and including the costs of partnering at such a level, to be $1.4 billion. The cost and schedule risk classification is medium high.
- Overall the recommendation and prioritization for LISA reflect its compelling science case and the relative level of technical readiness.
- Detection of these (SMBH) mergers would provide direct measurements of the masses and spins of supermassive black holes and the geometry of the universe on its largest scales.
- We are on the verge of a new era of discovery in gravitational wave astronomy.

LISA Status

- Mission Formulation Study began in Jan 2005
- Precursor LISA Pathfinder in Phase C/D
  - Launch in 2013
- ESA:
  - LISA Cosmic Vision L1 candidate (1 of 3), launch after 2020, subject to budget constraints, downselection starting 2011!
- NASA:
  - LISA flagship mission in Beyond Einstein Review!
  - Recommended in Decadal Survey Astro2010 as one of two large mission to start in this decade!