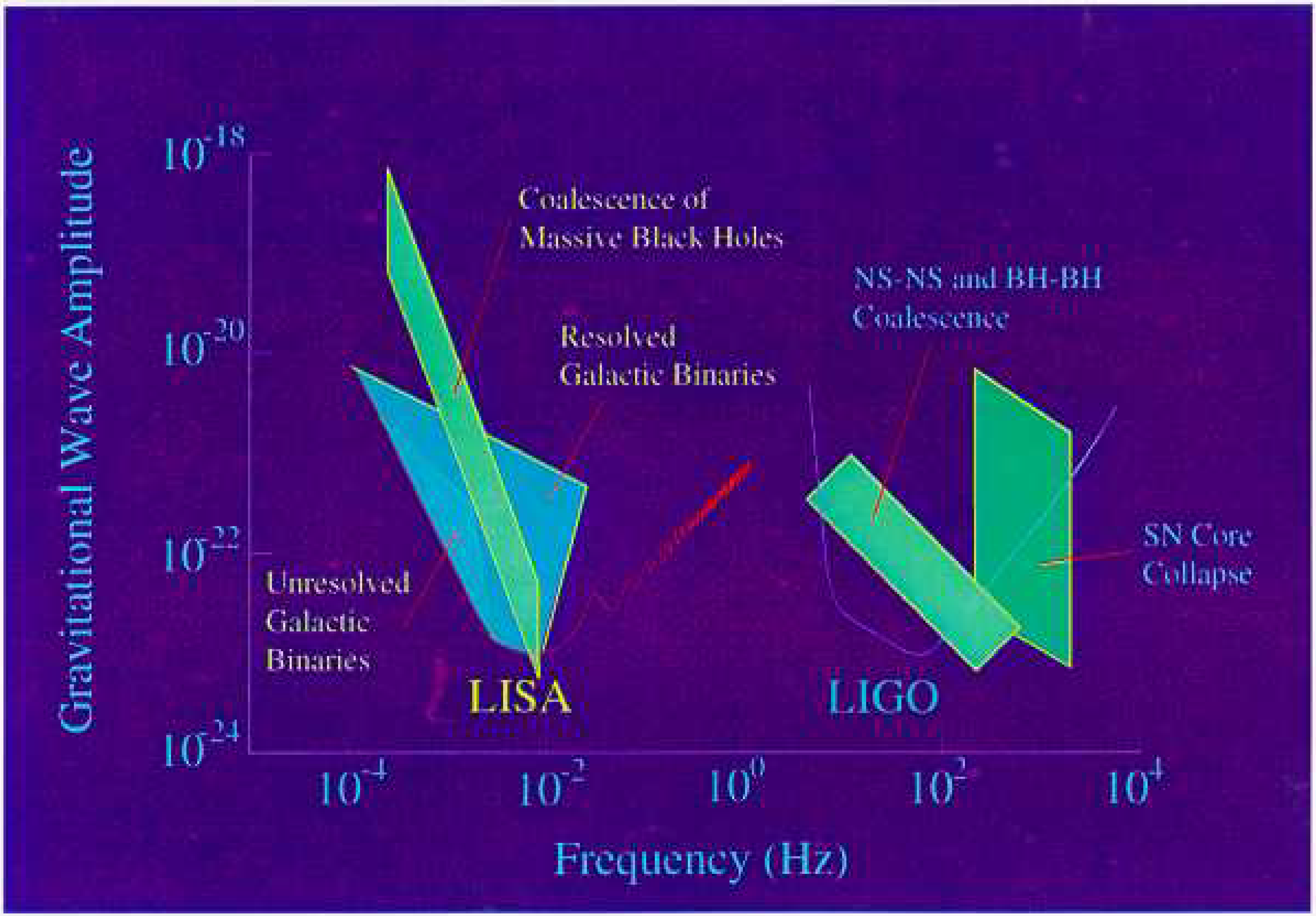
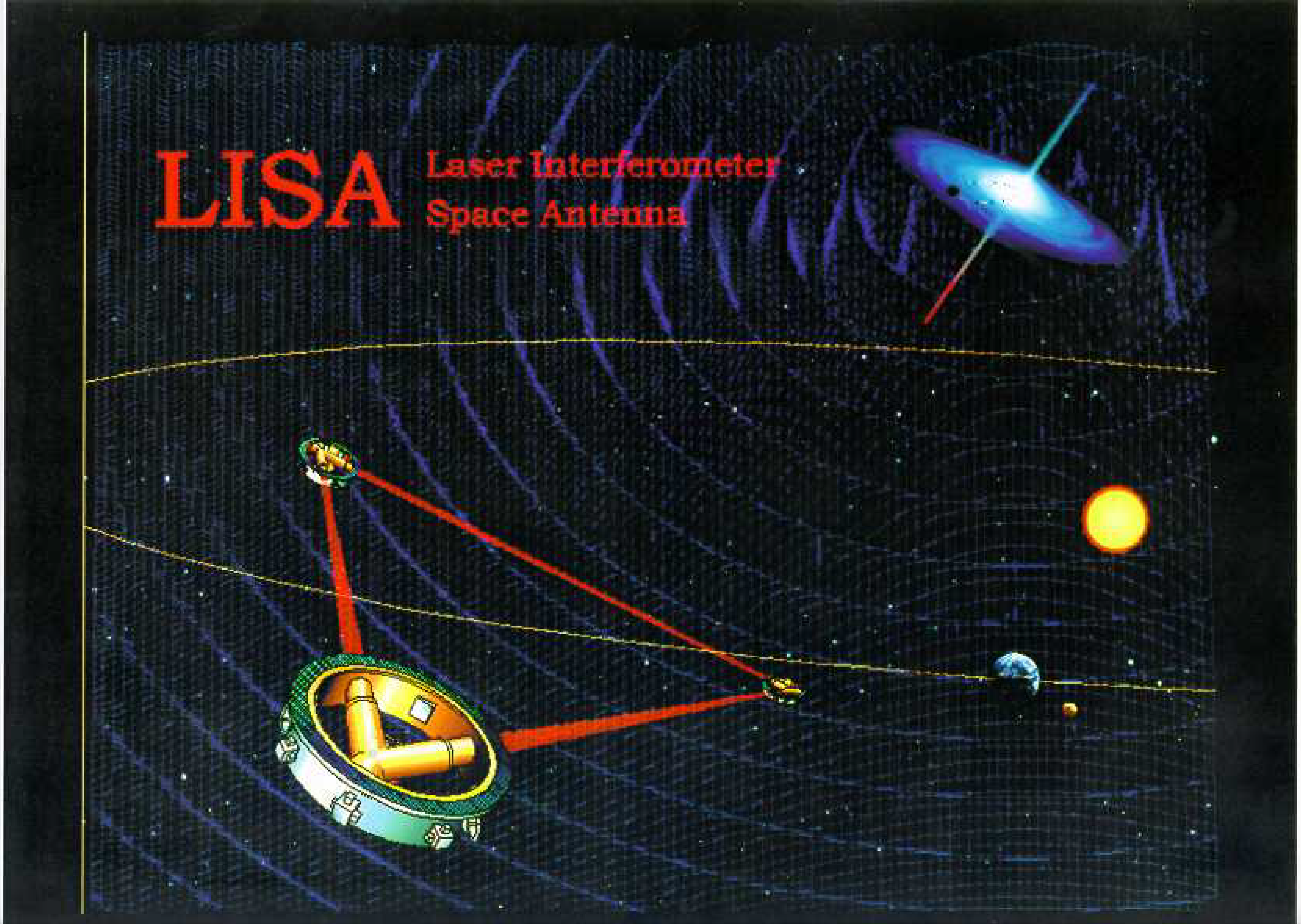
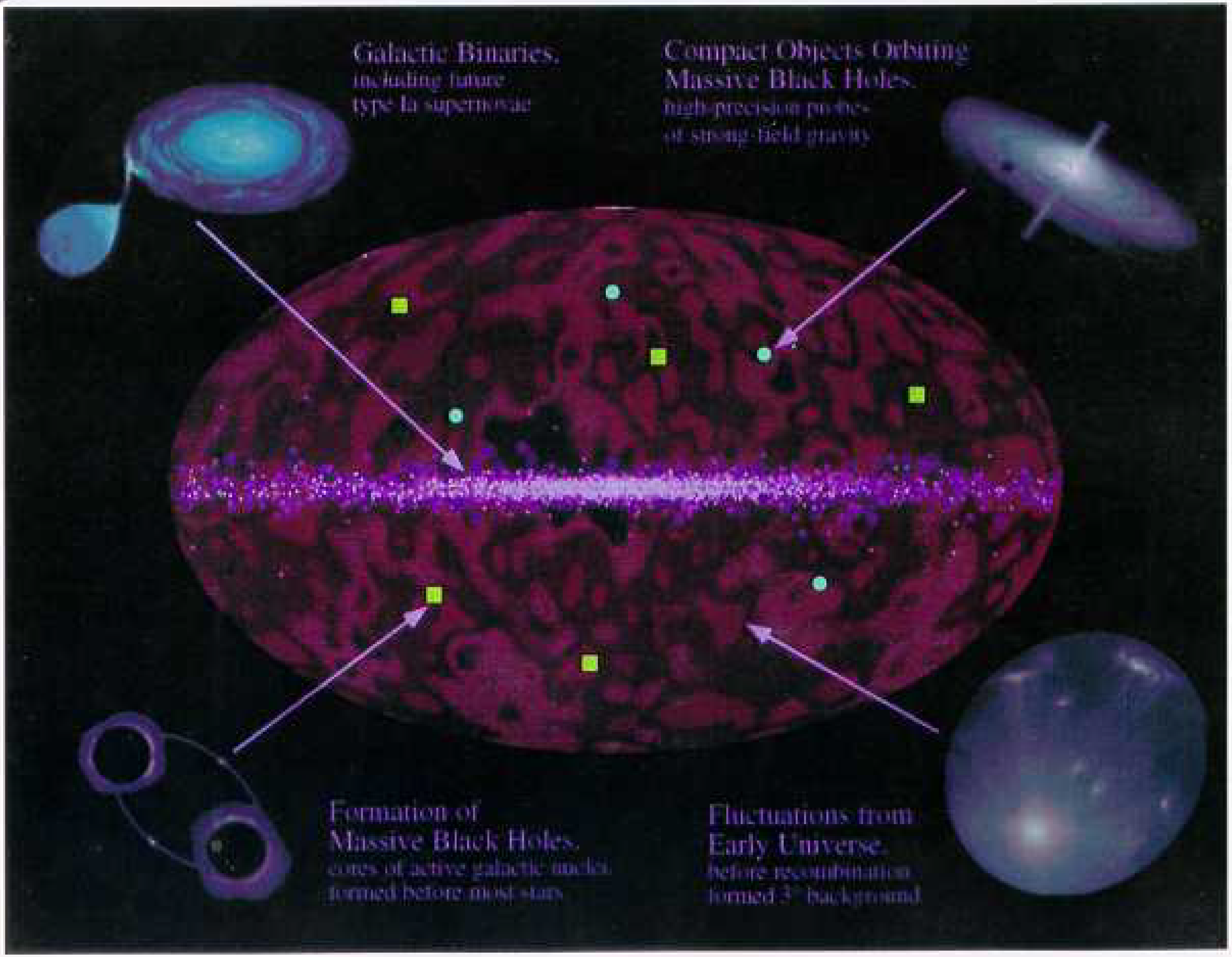
The Gravitational-Wave Spectrum

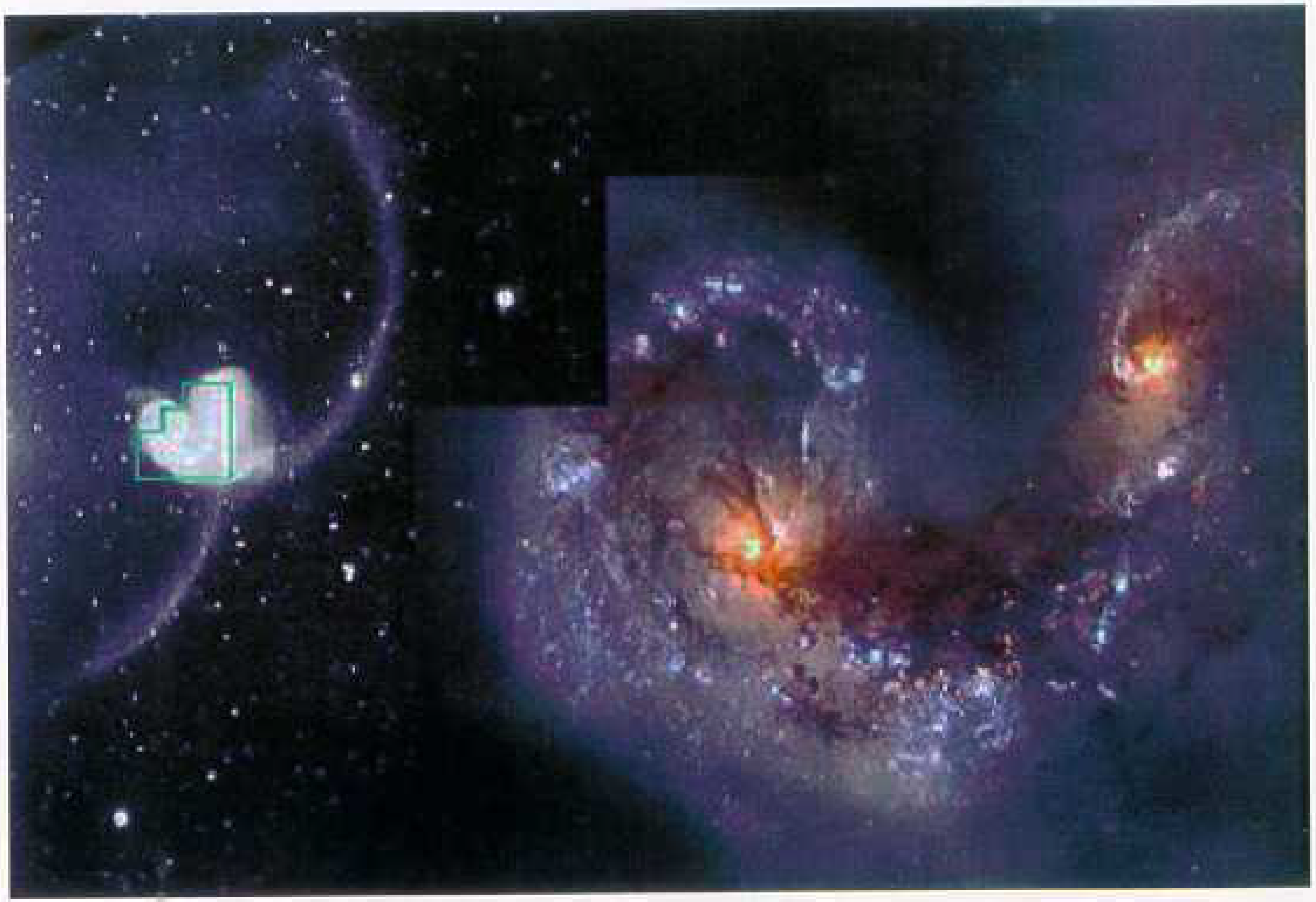



LISA
Laser Interferometer
Space Antenna

The Gravitational-Wave Sky



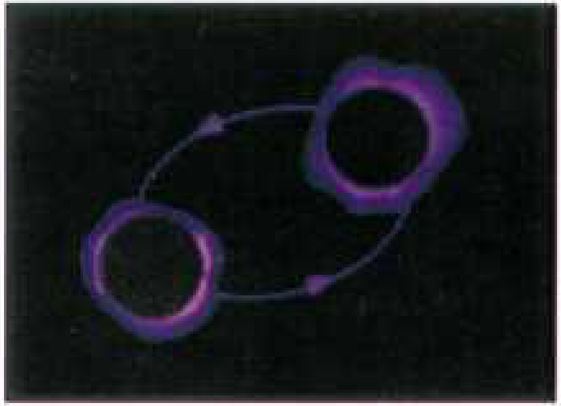
Massive Black Holes in Merging Galaxies



B. Whitmore (STScI), F. Schweizer (Carnegie Institute), NASA

LISA Science Goals

LISA will observe gravitational waves from:



Massive Black Holes; forming from coalescence of seed black holes or from collapse of dense gas clouds, super-massive stars or relativistic star clusters; or coalescing from galaxy mergers

Stellar-mass black holes orbiting massive black holes

Compact binary star systems

The LISA Team

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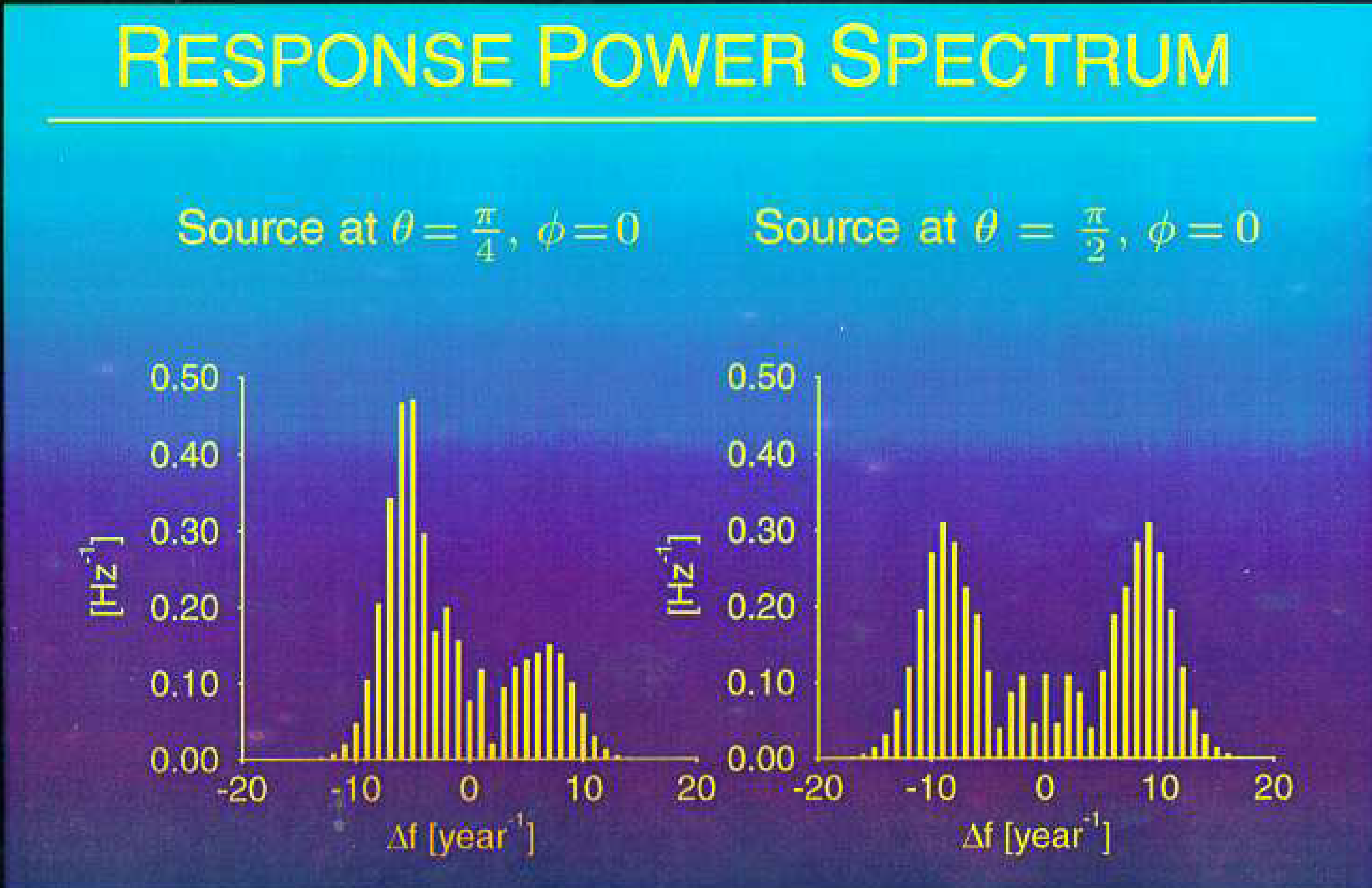
S. Vitale	University of Trento
H. Ward	Glasgow University
W. Winkler	Max-Planck-Institut für Quantenoptik

LISA SENSITIVITY PATTERN

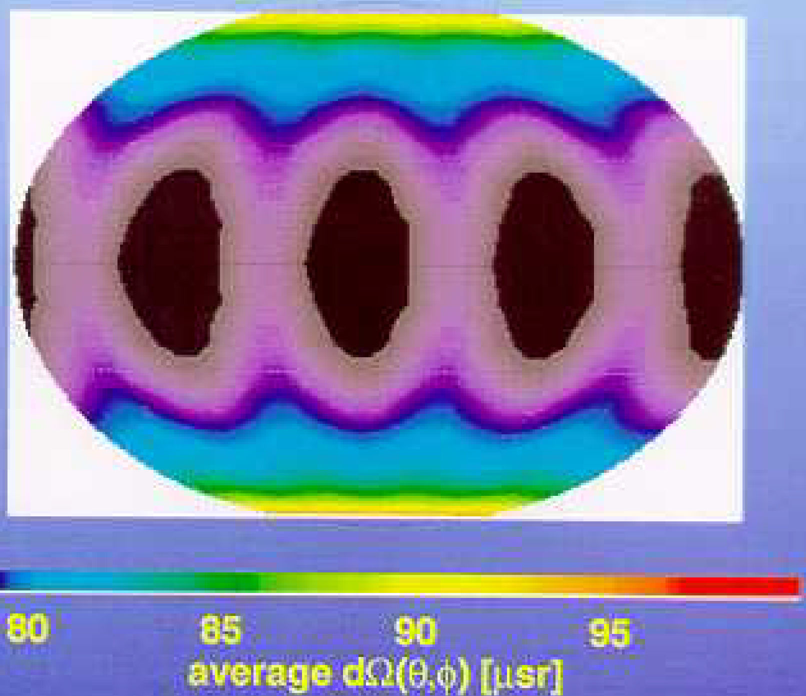
- Plane plus polarized Gravitational Waves



RESPONSE POWER SPECTRUM
Source at $\theta = \frac{\pi}{4}$, $\phi = 0$
Source at $\theta = \frac{\pi}{2}$, $\phi = 0$
0.50
0.40
0.30
0.20
0.10
0.00
[Hz^{-1}]
-20
-10
0
10
20
Δf [year^{-1}]

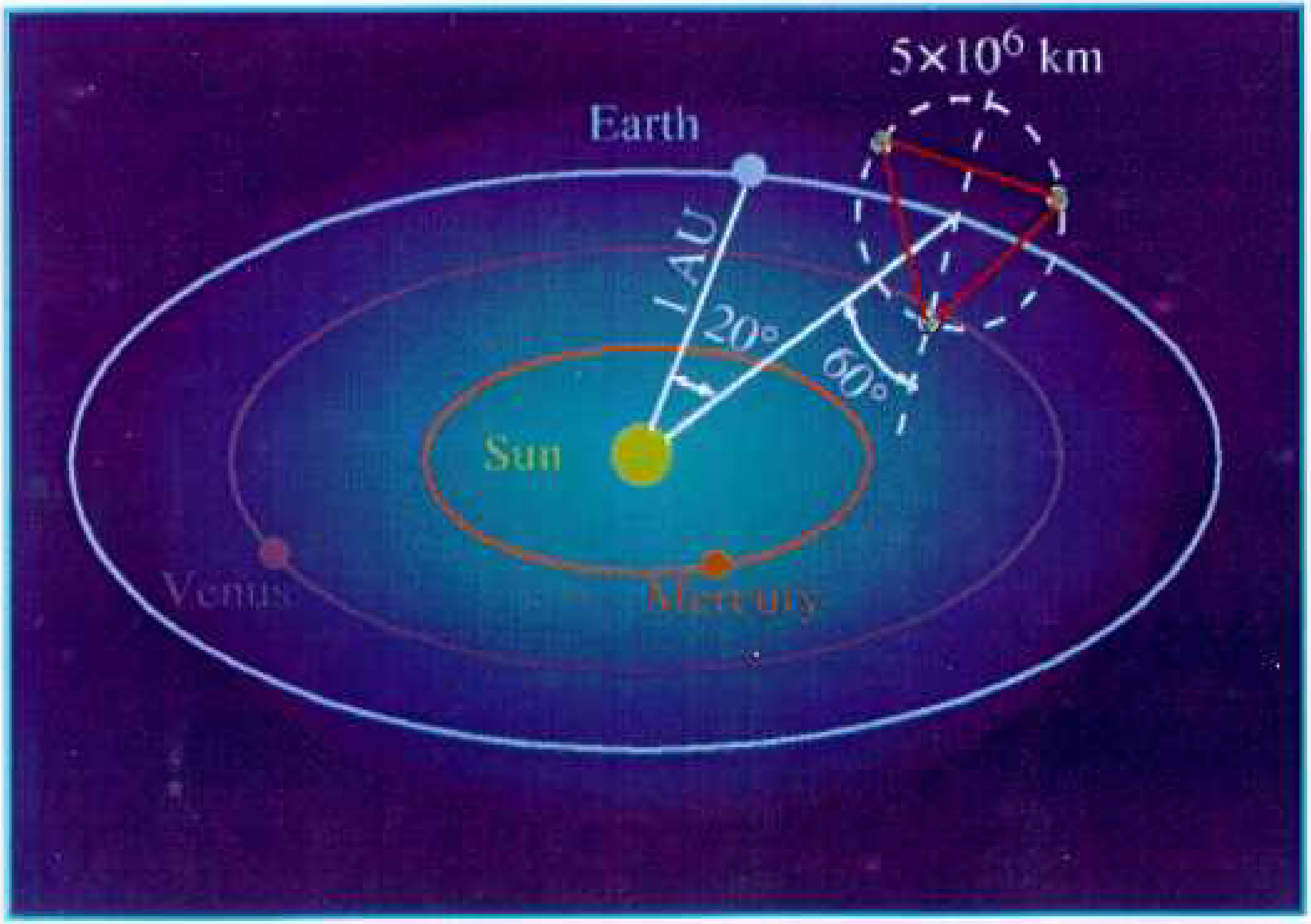
AVERAGED SOLID ANGLE

Average resolution as a function of the source location:



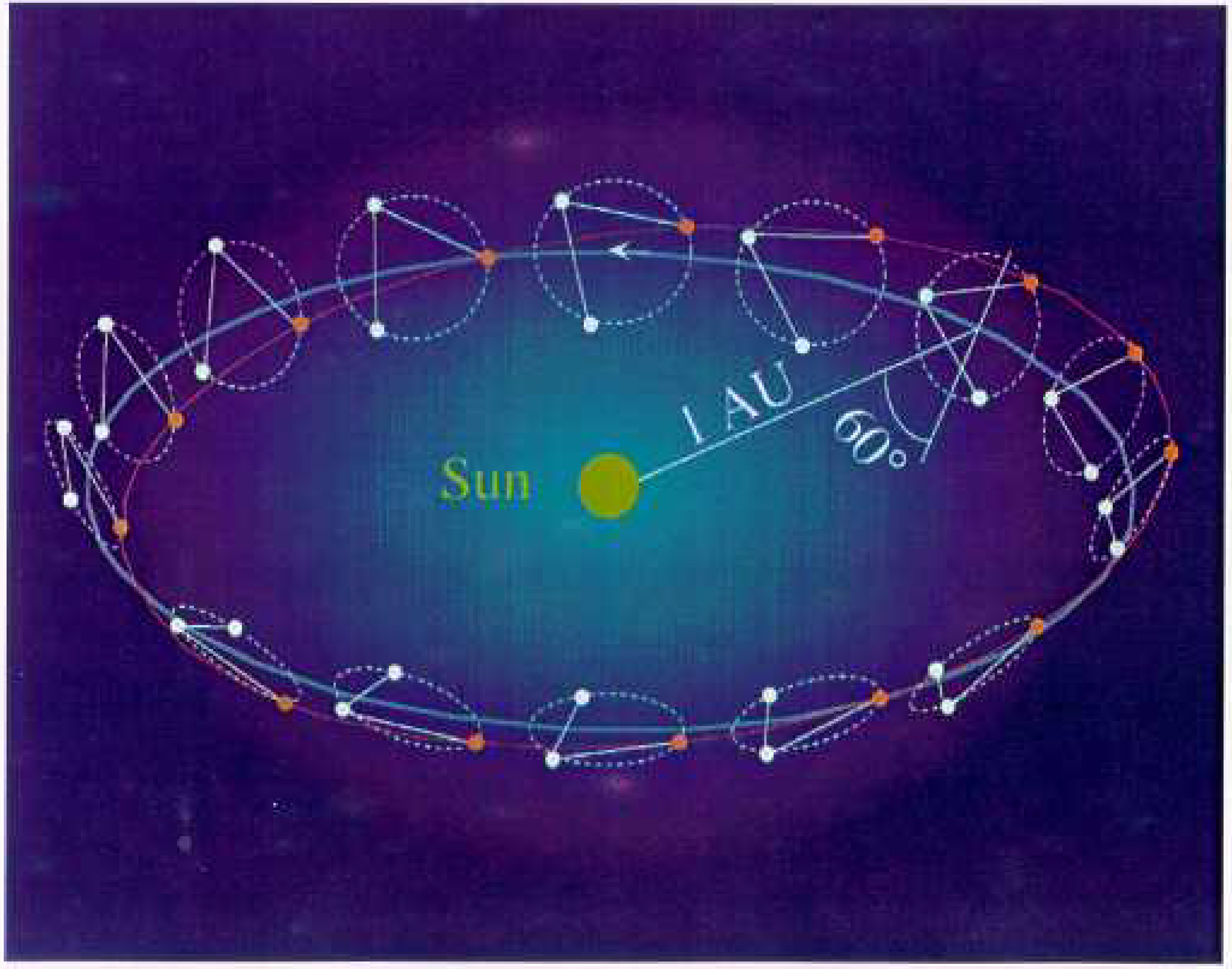
Spacecraft Formation

- Three spacecraft in triangular formation; separated by 5 million km
- Spacecraft have constant solar illumination; payload shielded from sunlight
- Formation trails Earth by 20°; compromise constant arm-lengths vs cost

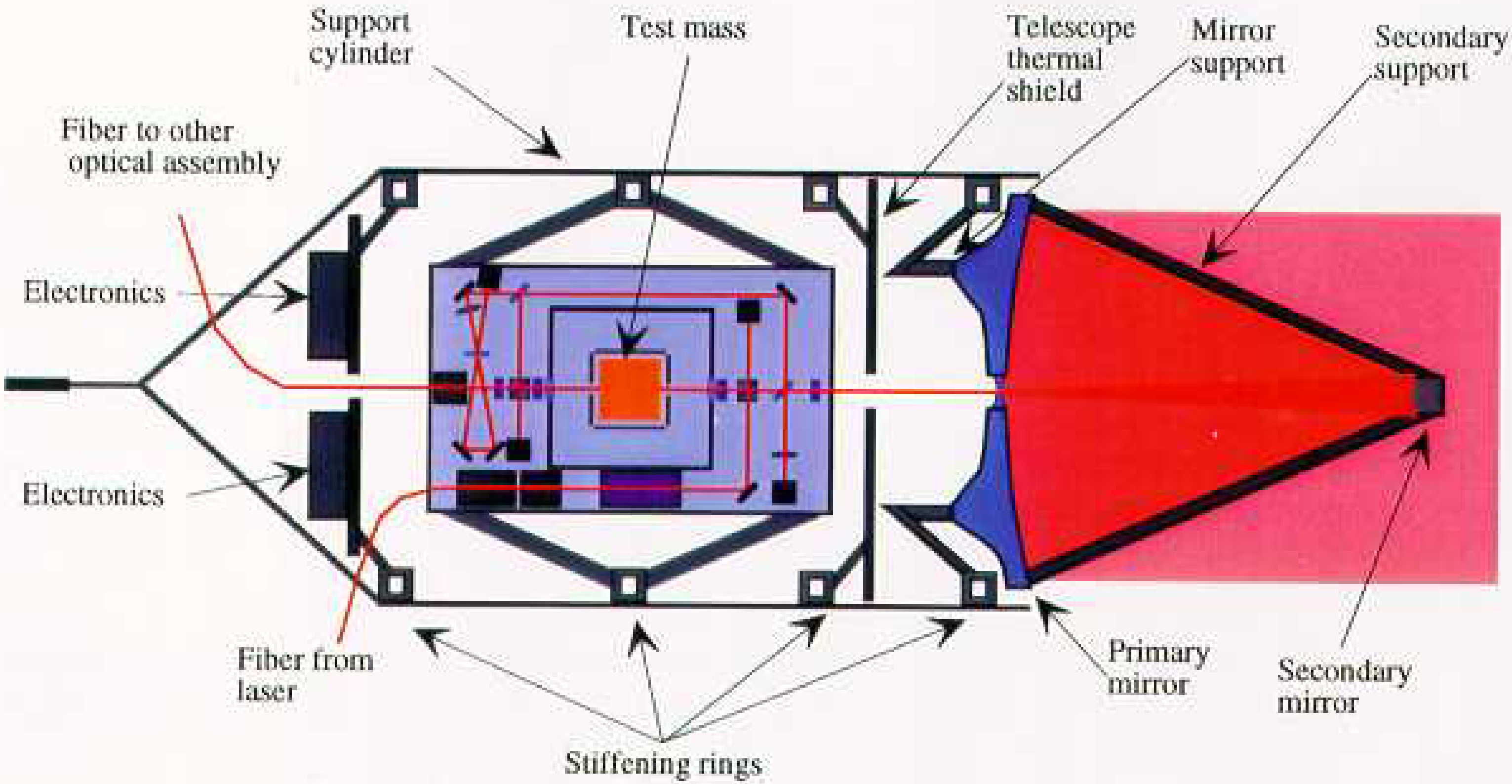


Spacecraft Orbits

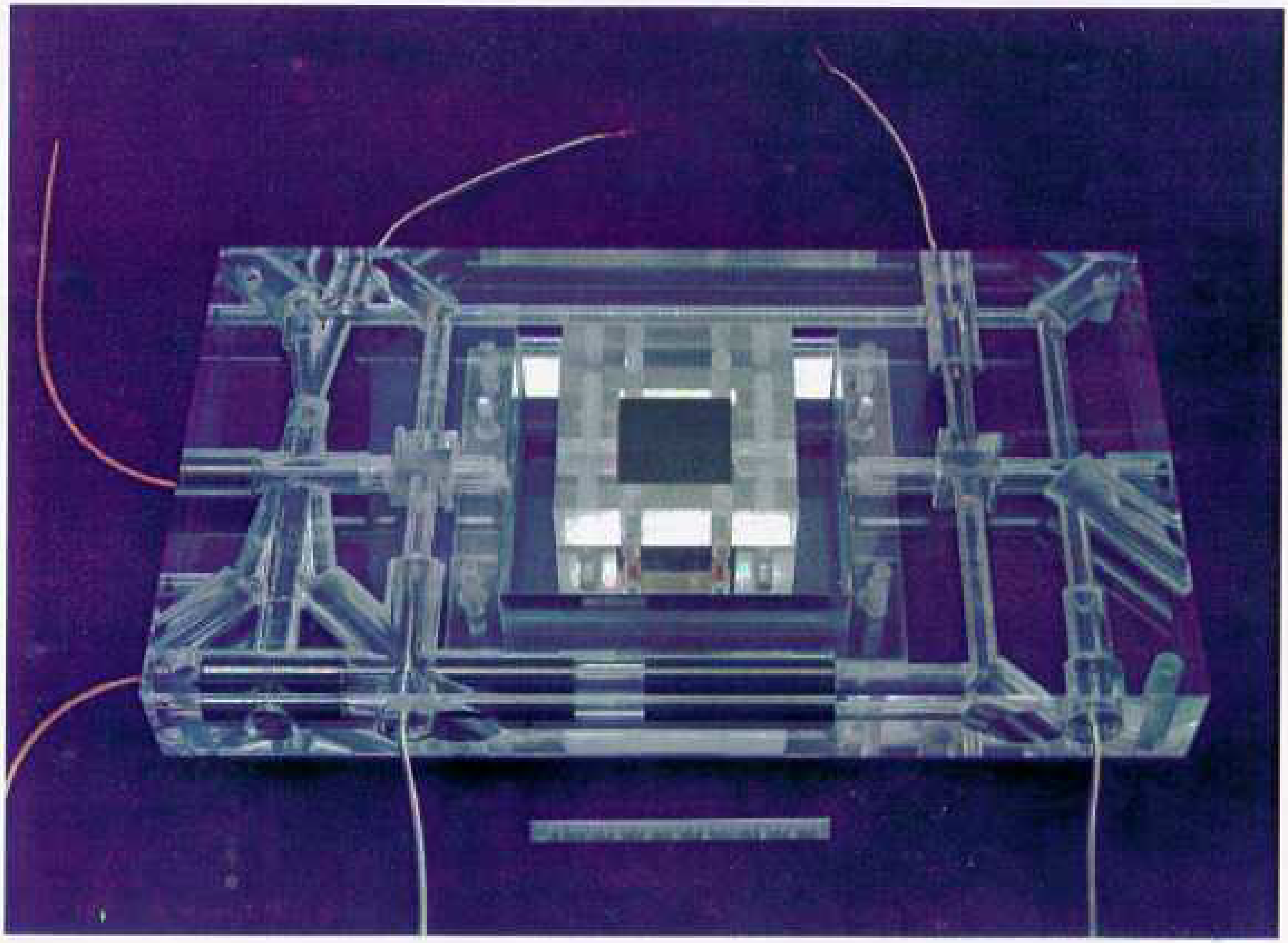
- Spacecraft orbits evolve under gravitational forces only
- Spacecraft fly "drag-free" to shield proof masses from non-gravitational forces



Optical System

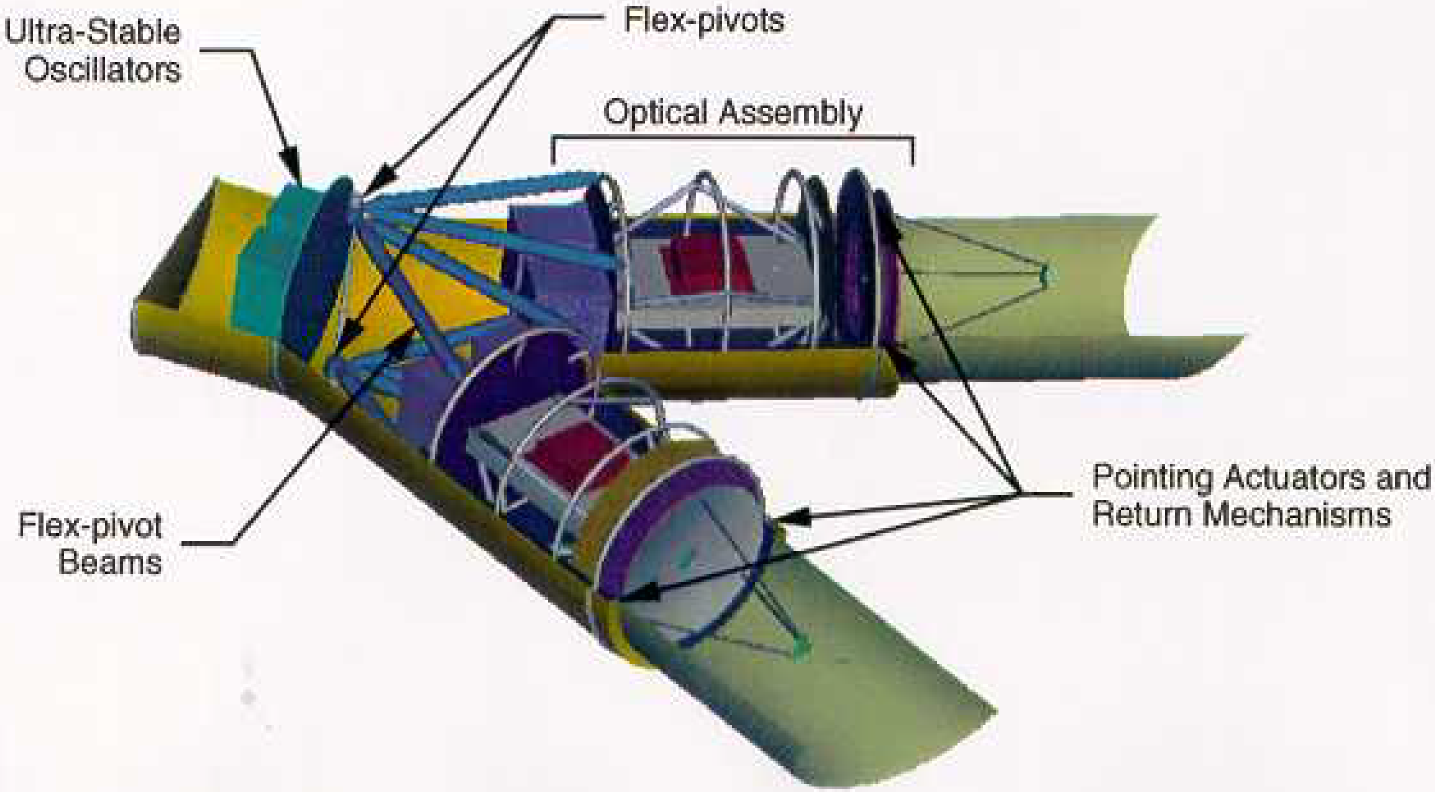


Optical Bench Mock-up

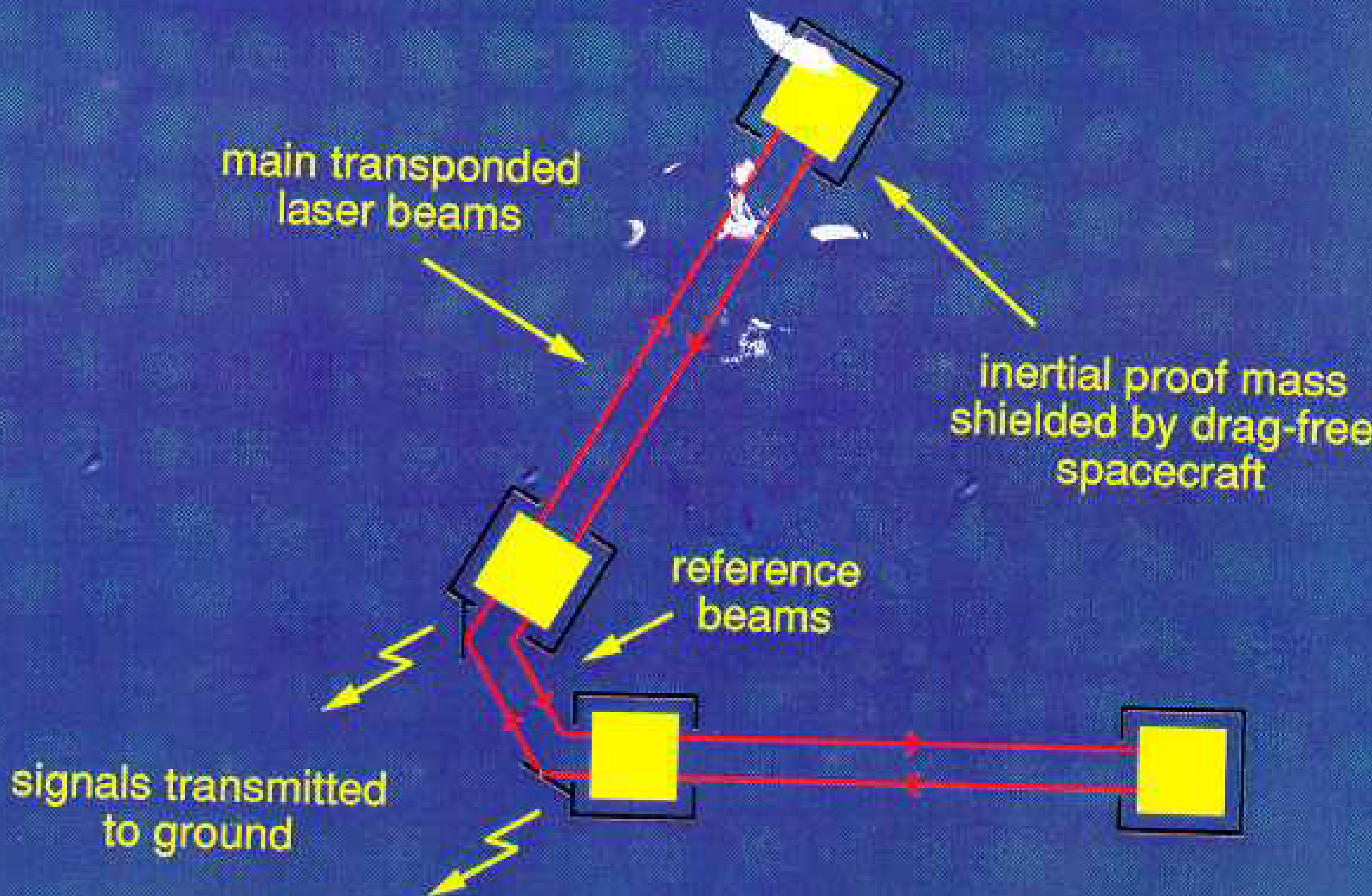


Payload Design

- Two independent instruments
  - 30 cm telescopes, 1 W lasers
  - Measurement noise 20 pm/ Hz
- Telescope pointing changes ±0.5° over year
- Drag-free control law with two proof masses



Outline Layout of LISA



ELECTROSTATIC SERVOCONTROLLED ACCELEROMETER

Design heritage from experience acquired at ONERA with :

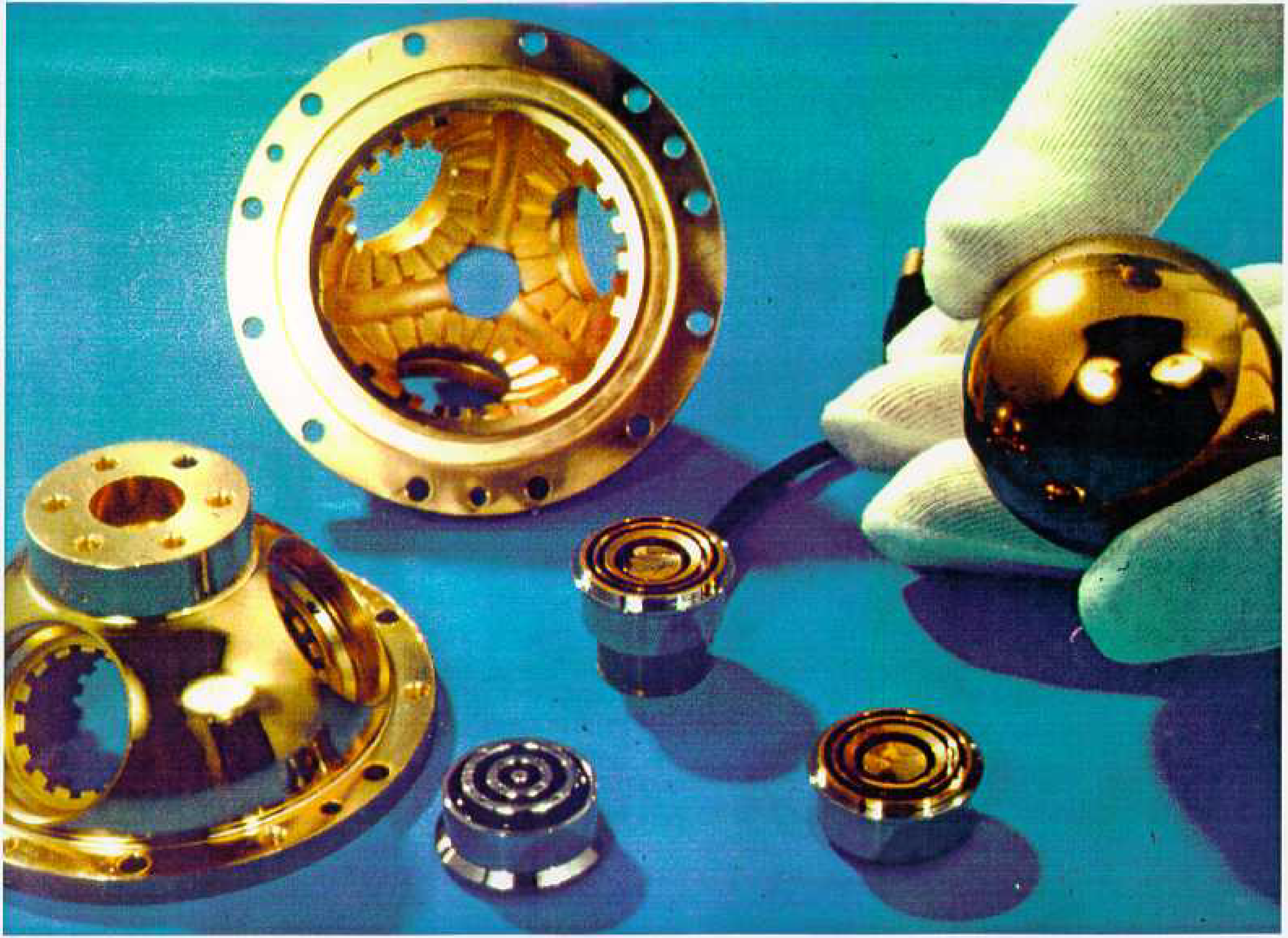
- **CACTUS** sensor,
  payload of french satellite CASTOR-D5B (1975-1979),

  → surface forces measurements : aeronomy, radiation pressures.

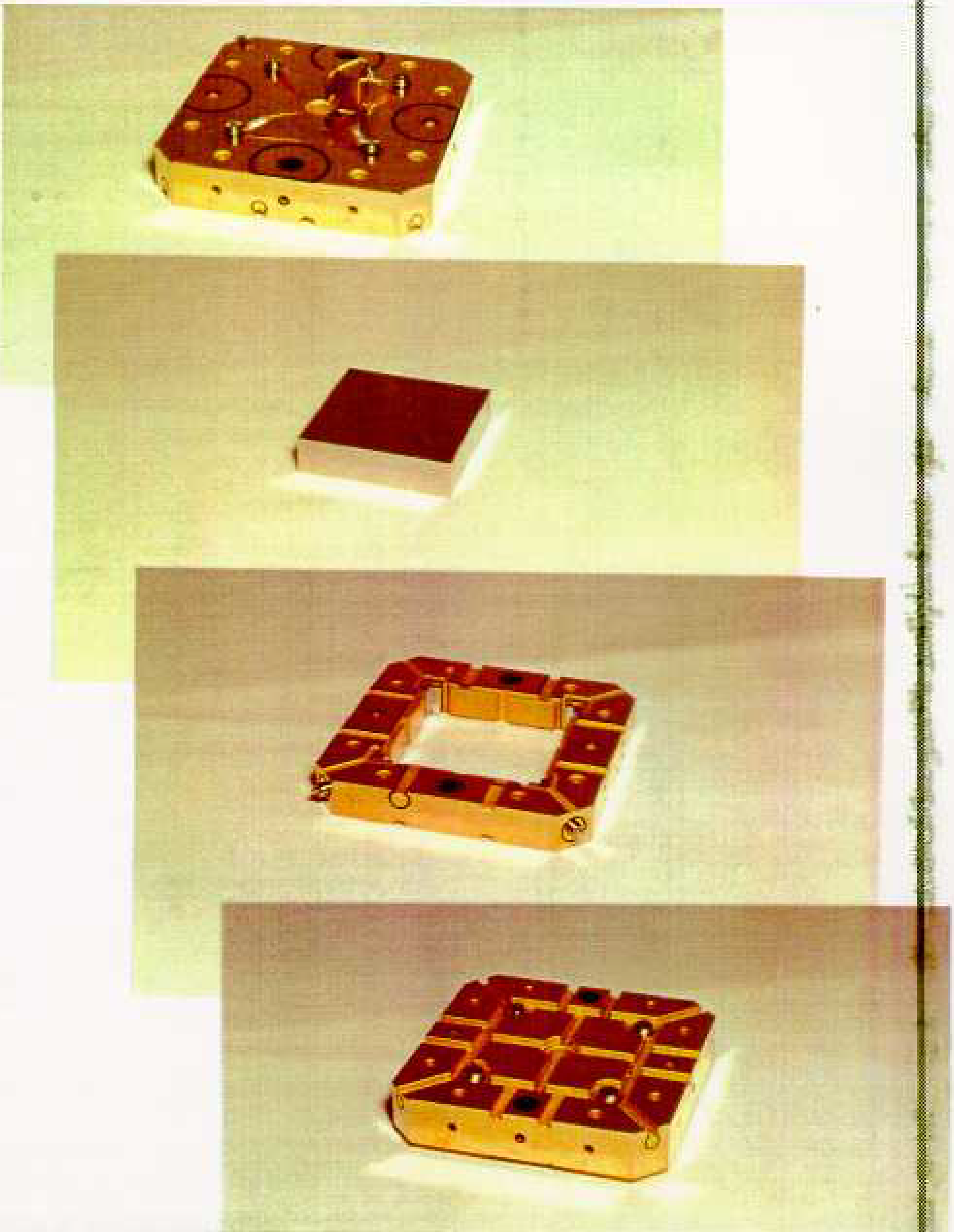
- **GRADIO** accelerometer,
  developed for ESA/NASA ARISTOTELES project (1987-1993)

  → gravity gradient measurements : geodesy, geophysics.

→ general interest for Fundamental Physics missions :
drag-free satellites.

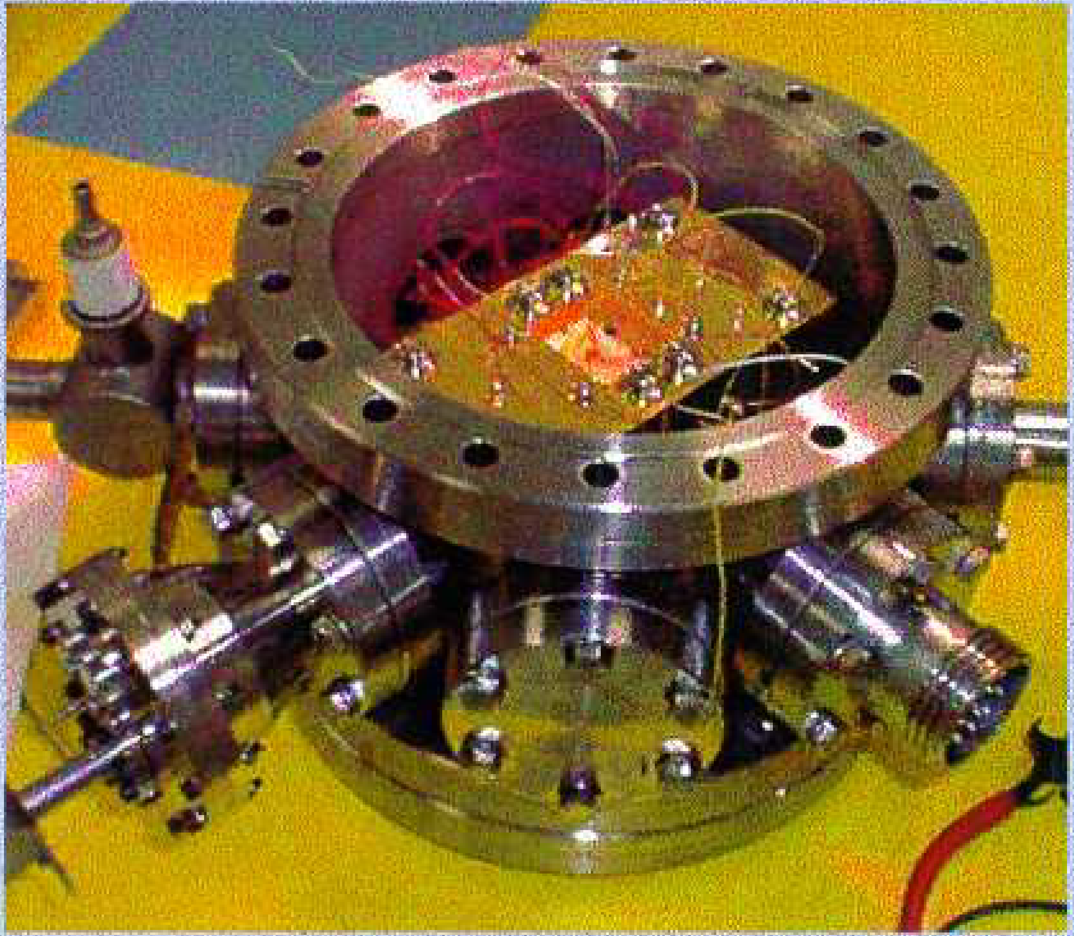


ELECTRODE PLATES AND PROOF-MASS



Gyros, Clocks, and Interferometers : Testing General Relativity in Space - Bad Honnef (Germany) 22 - 27 August 1999

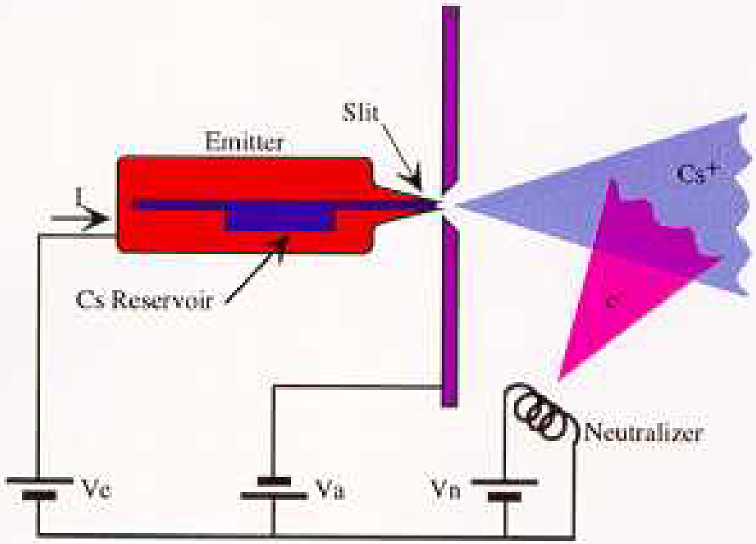
PROTOTYPE BEING INTEGRATED



DMPH

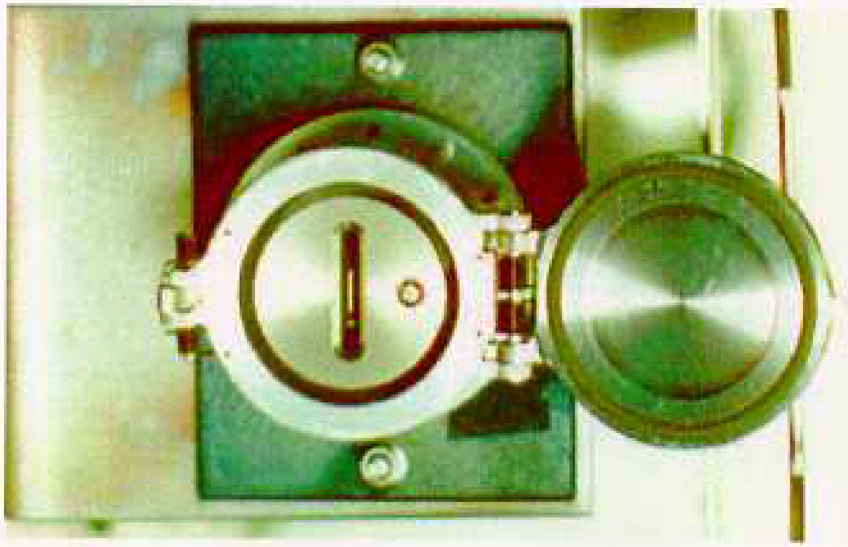
ONERA

Micronewton Thrusters



Schematic drawing of a FEEP thruster

Cesium-based FEEP from Centrospazio



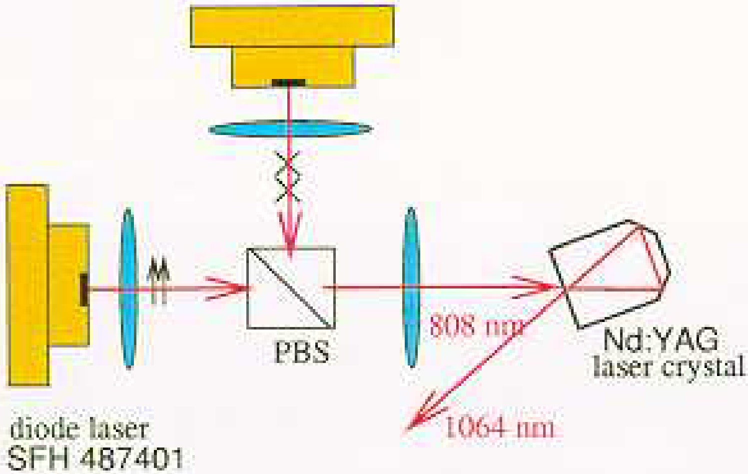

EFD-1E
F1
J05
J03
J04
J02
J01

LASERS IN SPACE

- High output power (~1W)
- Low noise
- Good reliability
- High efficiency
- Compact size

→ Diode pumped Nd:YAG lasers

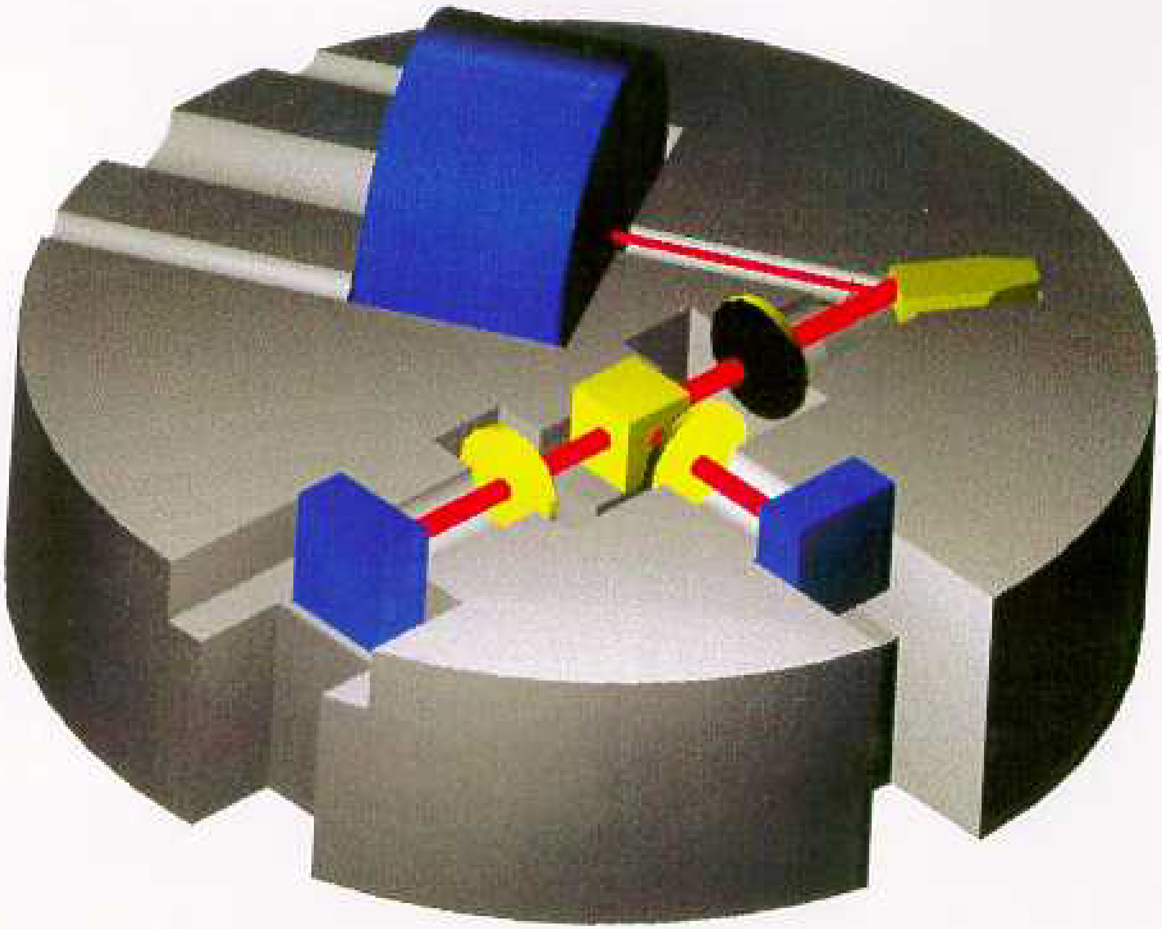
MASTER LASER

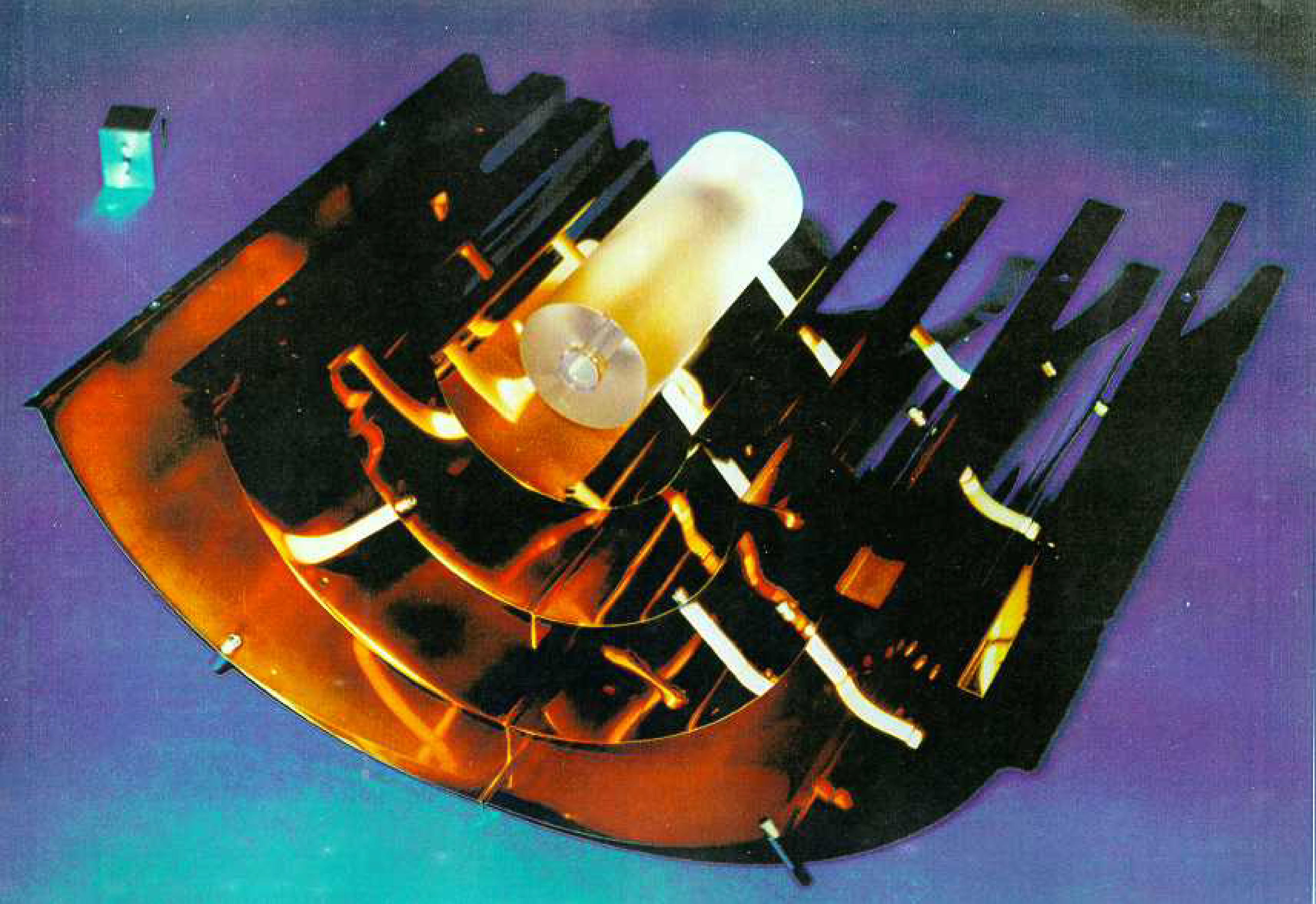


[T. Kane, Opt. Lett. 12 (1987).]

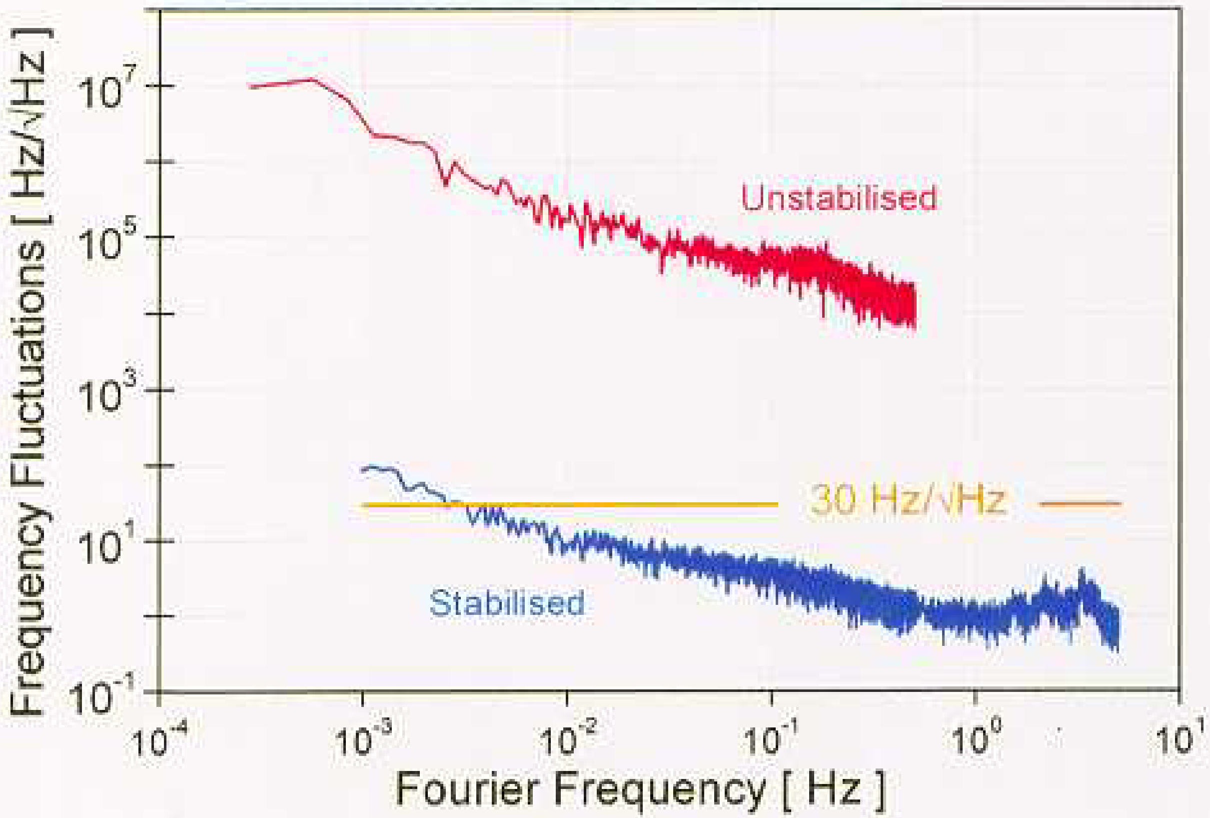
[I. Freitag, Appl. Phys. B 60 (1996).]

Laserhead: Solid Fused Silica Spacer



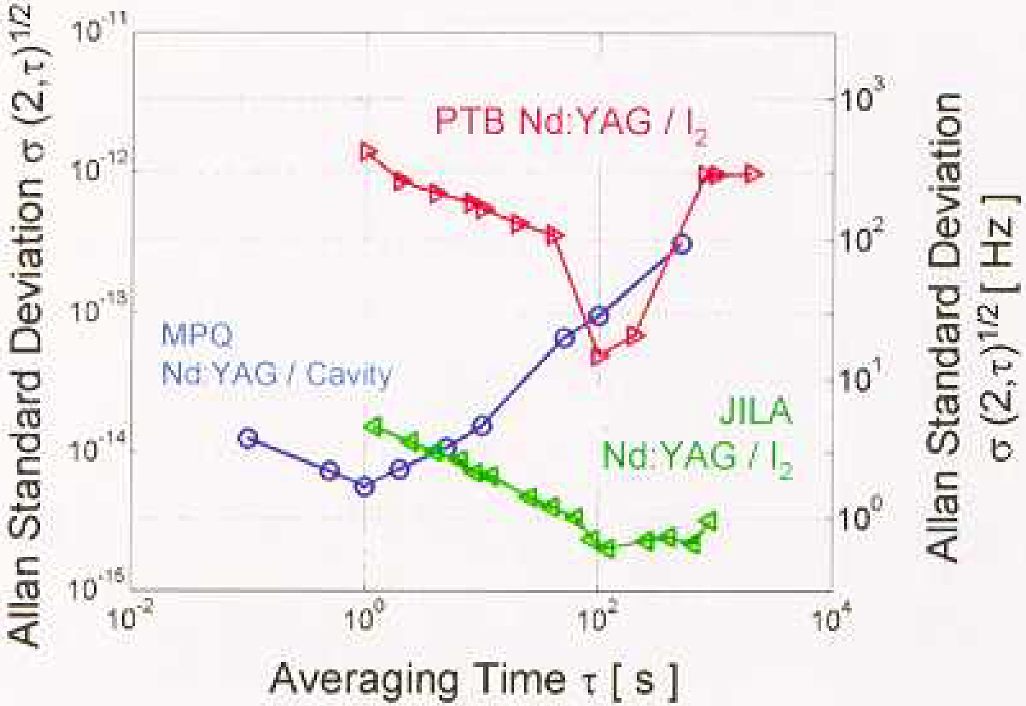


Frequency Stability of NPRO Laser System



Max-Planck-Institut für Quantenoptik

Frequency Stability of NPRO Laser System: Allan Variance

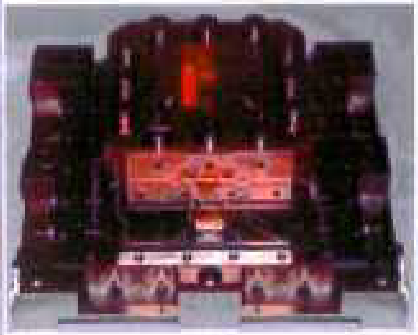


Propulsion Module

- Solar-electric propulsion
  - Use 5 mN xenon-ion engine
    - Hughes XIPS, launched 1998
    - Other vendors available
  - Two engines flown, one spare
  - 500 W from deployed solar array
  - Candidate trajectories found
    - 13 month transfer phase
    - Engine on ~80%
    - Requires steered solar arrays

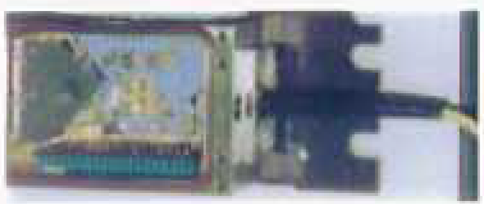
Technology Drivers

Inertial sensors
Noise < 10^{-16} g
rms for 1000 s average



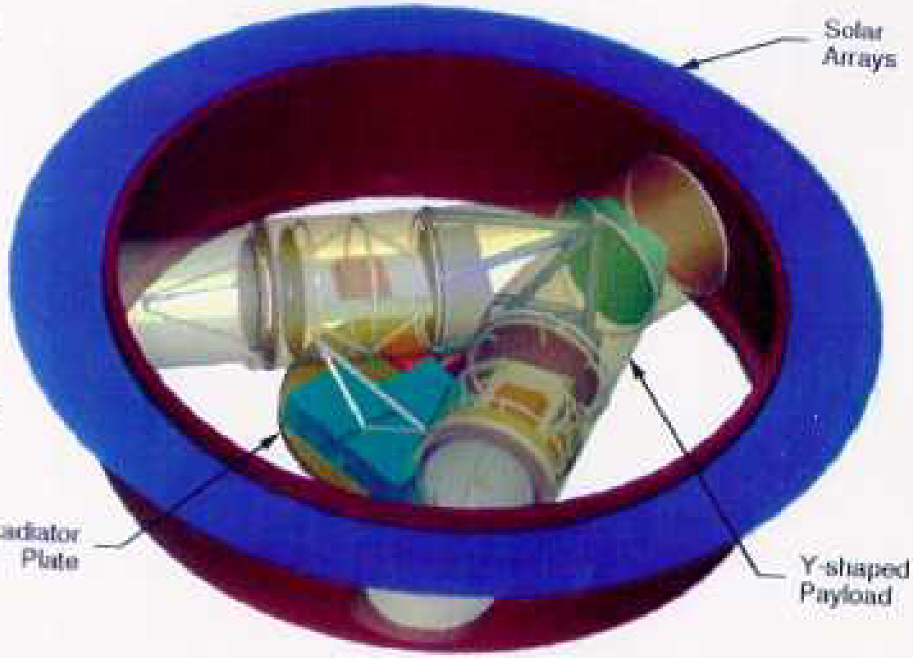
Micronewton thrusters
Range 1-100 μN
Noise <1 μN

Picometer interferometry
Accuracy < 1 pm
rms for 1000 s average
1 W laser



Spacecraft Design

- Short, cylindrical structure
  - Minimum height, maximum diameter, for stacking
  - Graphite-epoxy with low thermal expansion
  - Cover to shield payload from sun (not shown)
- Y-shaped payload thermal shield
- Sun-shield keeps sunlight off sides
  - Solar cells mounted on shield
- 30 cm radio antenna mounted on sides



The LISA Mission

History (1)

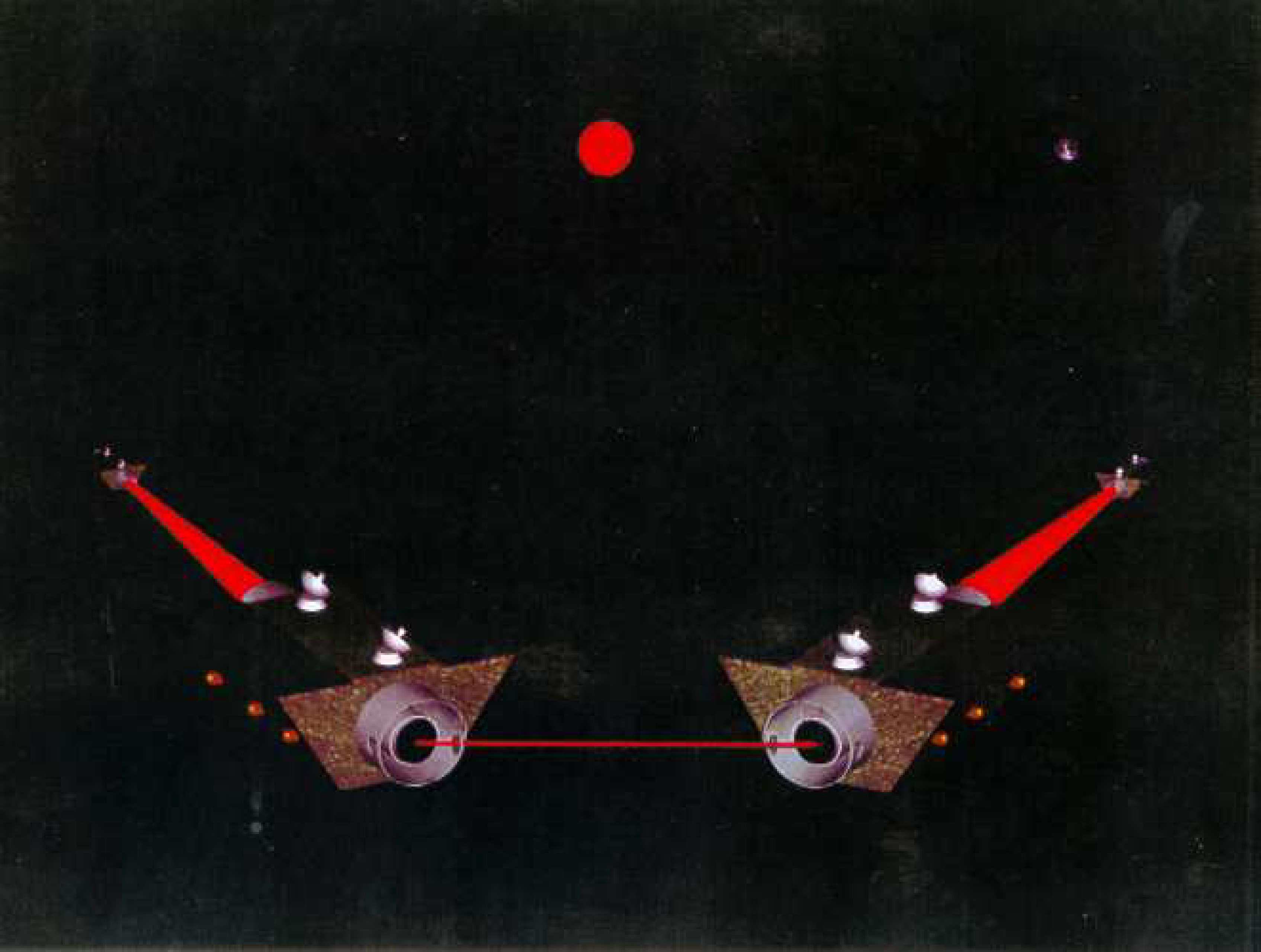
- First studies in the US in 1980s
- M3 proprosal for ESA /NASA collaborative mission in 1993

  - selected for Assessment Study as ESA-only

  - trade-off helio- vs. geocentric

  → heliocentric chosen

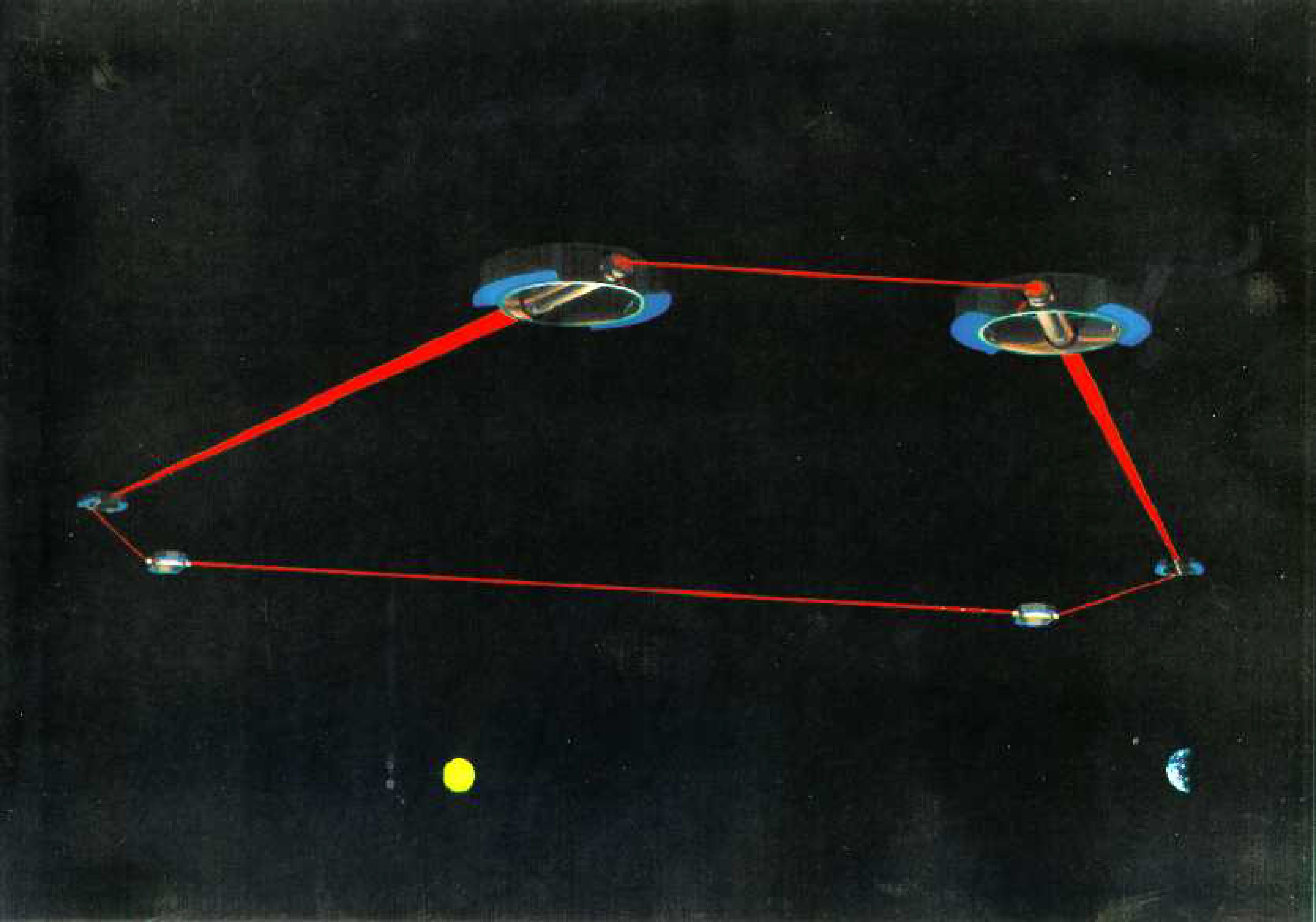
  - above cost ceiling for M missions

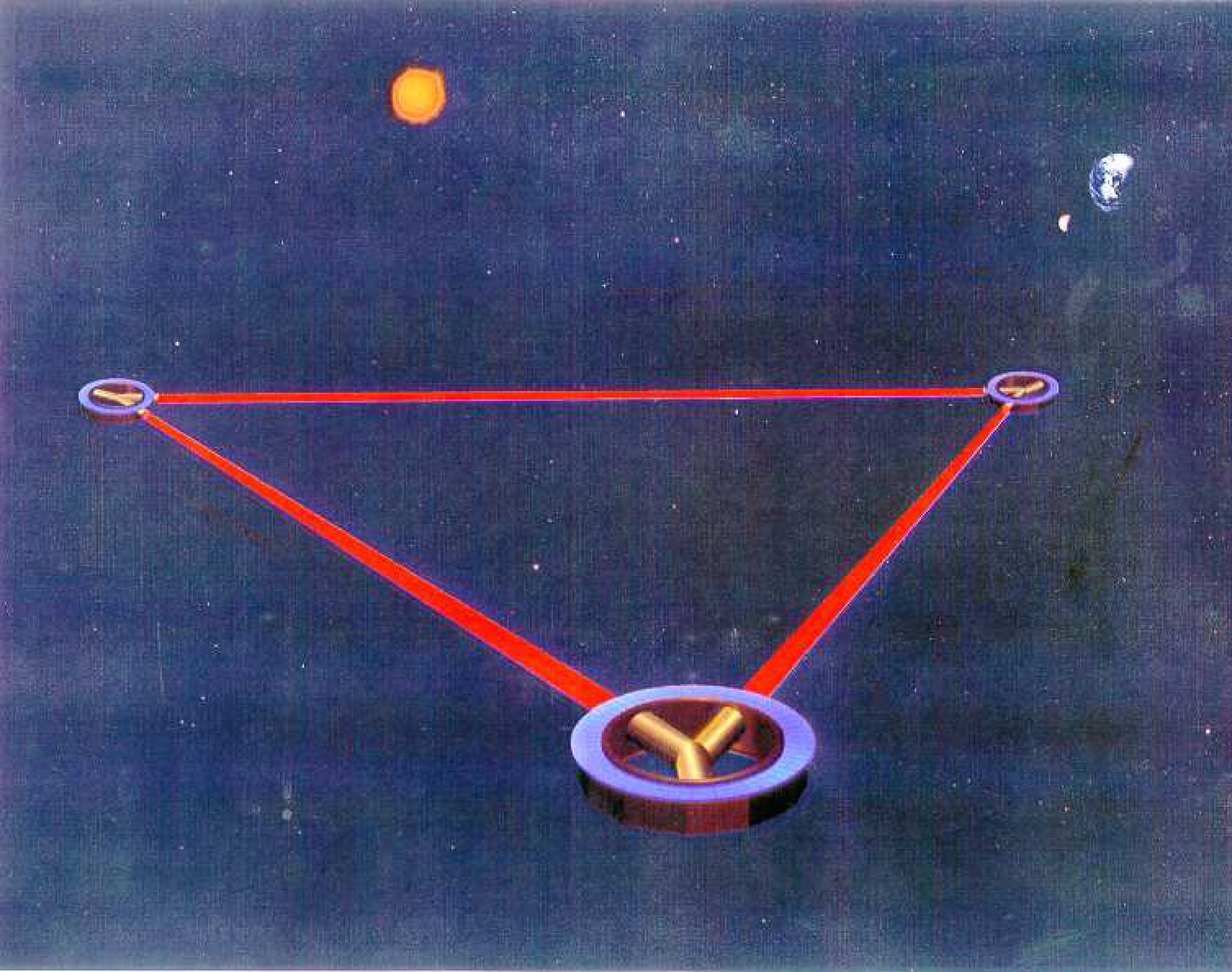


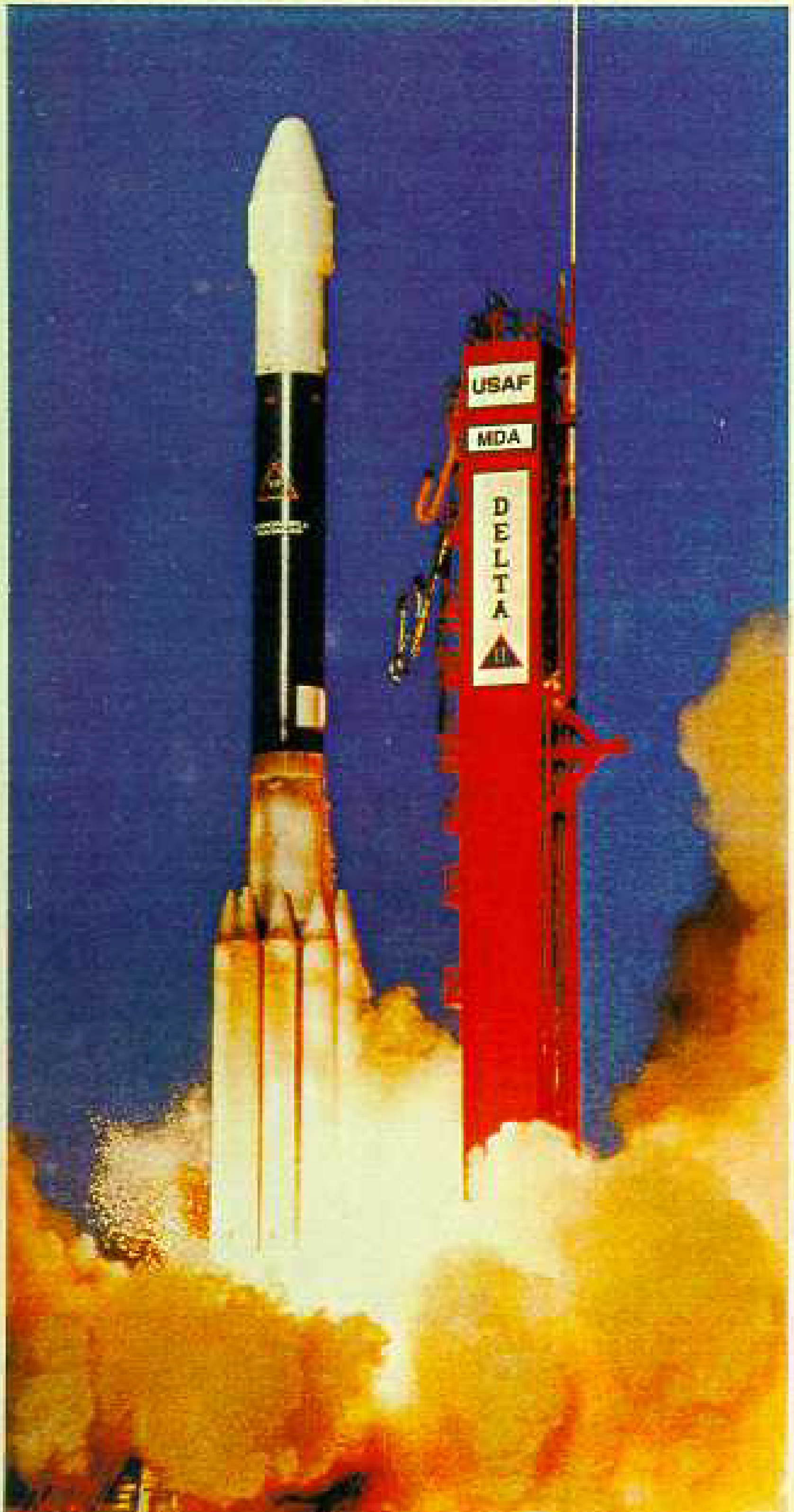
The LISA Mission

History (2)

- Proposal in 1993/4 for 6 S/C LISA as ESA Cornerstone Mission
- LISA selected as Cornerstone in 1995
- LISA Pre-Phase A report finished 1996
- NASA/JPL Team-X study of 3 S/C LISA in 1997
- Begin of Phase-A study of ESA - LISA in 1997







DELTA II

Payload Planners Guide

McDonnell Douglas Aerospace

MCDONNELL DOUGLAS

DAVID FARLESS

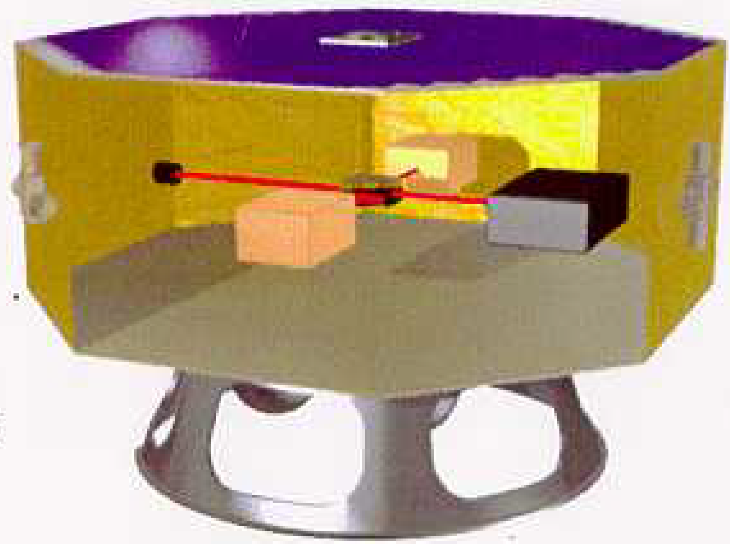
LISA PHASE A STUDY

Planned Meeting Dates in 1999

Phase A kick-off	ESTEC	3 May
Preliminary Concept Review	RAL	15 June
Phase 2 Progress	ESTEC	17 August
Phase 2 Completion	RAL	19 October
Industrial Contractor Presentation	ESTEC	7 December
Presentation to the Science Community	TBD	

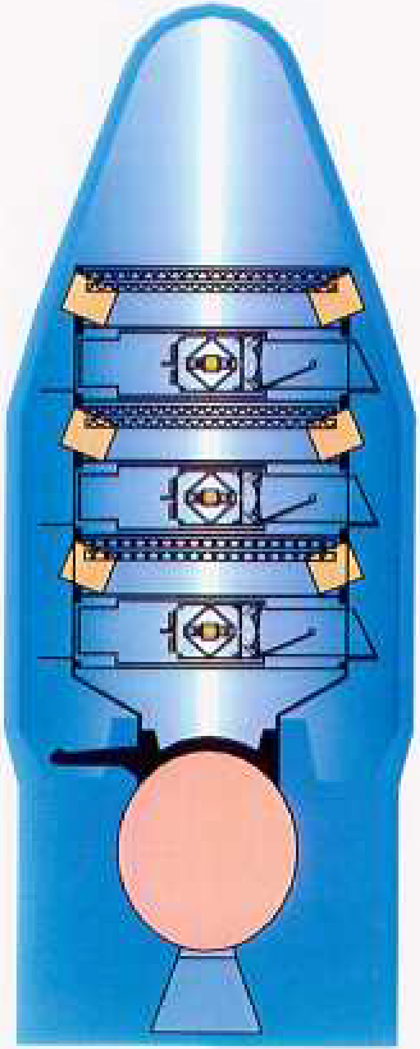
Technology Flight Demonstration

- Of the key LISA technologies, only one, the low-noise inertial sensors, requires a space environment for testing
- The LISA Technology peer review panel recommends a flight demonstration
- One of three competing mission concepts for the New Millennium ST5 opportunity could validate the LISA inertial sensors
  - Selection July 1999
  - Launch 2002/2003
  - $28M cost cap (all inclusive)
  - Two inertial sensors on one spacecraft
- Other flight demonstration opportunities are being studied in Europe.



Launch Configuration

- Three spacecraft & propulsion stages
- Delta-II 7925H launch vehicle
- Launch into Earth-escape orbit
  to drift behind Earth
- Spacecraft and propulsion stages separate,
  target each vertex independently



Technical Kick-off Meeting

Dornier, 21/22 June 1999

Hand-out

Contents

- Orbit and Operations
- Propulsion Module
- System Performance
- System/Payload Concept Options
- Attitude Control
- PL Electro-optical Design
- Mechanical/Thermal Configuration
- Reaction Control
- RF Telecommunication

Technical Kick-off Meeting
Dornier, 21/22 June 1999

Hand-out

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