



Technology Development for LISA: the Telescope

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Telescope Team



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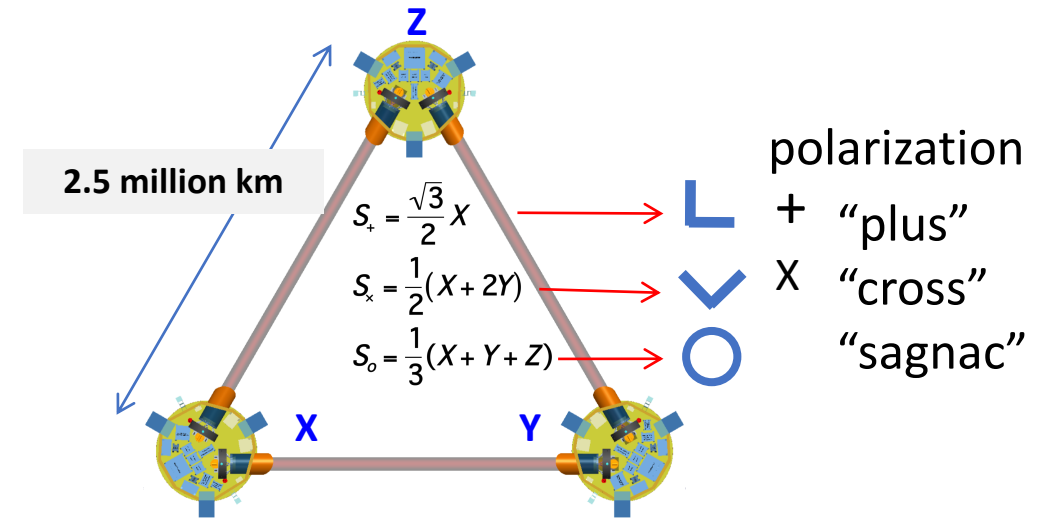
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LISA Mission Summary

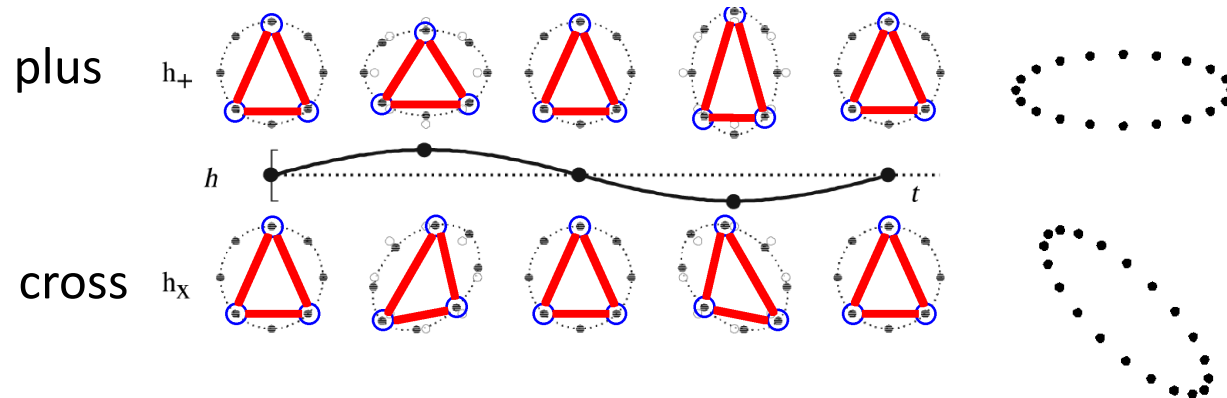
Mission Design

- Three satellites in an equilateral triangle formation with arm lengths of ~2.5 million km.
- Any two arms of this triangle represent a Michelson-type interferometer.
- Gravitational waves deform space-time and can be detected as a change in the length of the interferometer arms ($\sim 10 \text{ pm}/\text{Hz}^{1/2}$).
- Baseline 4 year lifetime + 6 years goal
 - Limited by communications bandwidth

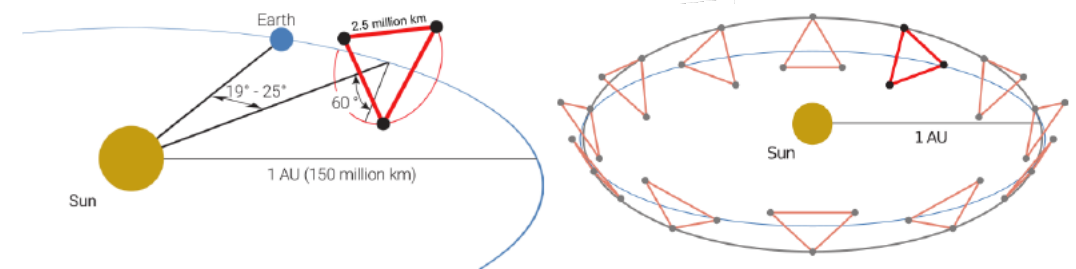
LISA Layout



Constellation Response



Heliocentric orbit



Constellation Triangle rotates once per year as it orbits

Timeline



October 2013:	Selection of "The Gravitational Universe" as science theme for the 3 rd ESA flagship mission (L3)
October 2016:	Call for mission proposals for L3
June 2017:	Selection of LISA as L3 with an anticipated 2034 launch date
May 2018:	Phase A Kick-Off
2018-2021:	Mission Phase A
<end 2021:	Formulation Review (end Phase A)
>2021:	Mission Phase B1
<2024:	Mission Adoption
>Adoption:	Mission Implementation (Phase B2/C/D)
<2034:	Launch
>Launch:	6.5 years operations (+6 years potential extension)

Near term goal

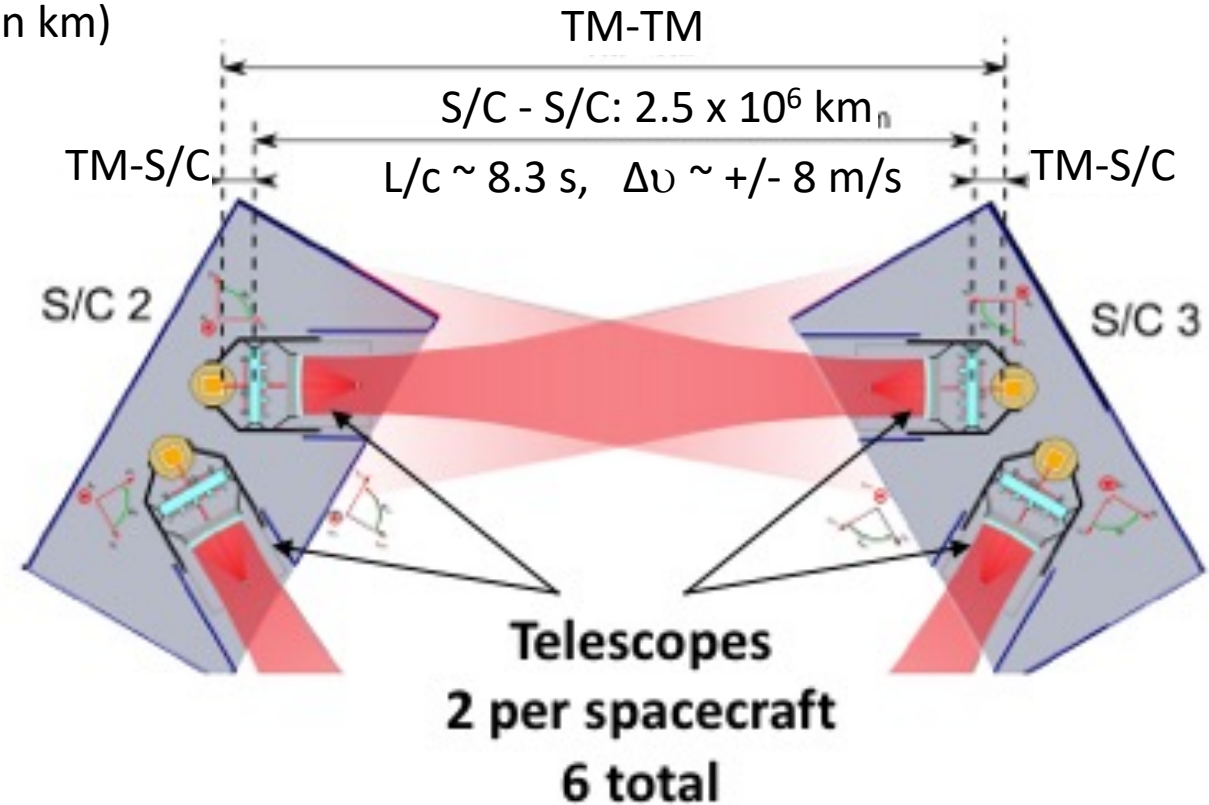
Telescope Functional Description



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- Efficiently deliver power on-axis between spacecraft (2.5 million km)
- Simultaneous transmit and receive (TX/RX)
- Afocal beam expander
 - 300 mm dia. large beam
 - 2.24 mm dia. on bench
 - 134X magnification

- **Application is PRECISION LENGTH MEASUREMENT, not image formation**
 - Keep optical pathlength stable to ~ 1 pm/vHz over the measurement BW
 - Minimize phase noise from coherent transmitter backscattered light
 - Minimize tilt to length (TTL) coupling



Key Challenges/design drivers



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○ Dimensional Stability

- Low CTE material and thermal stability at the 1×10^{-5} K/vHz level, using baffles fixed to the spacecraft that act as a passive thermal filter
- Spacecraft is stable at the 1×10^{-3} K/vHz level per LISA Pathfinder experience.

○ Coherent backscattered light

- Adopt unobstructed design
- Low scatter coatings and dimensionally stable structure so scattered light phase is stable
- Keep spacing between the telescope and optical bench stable

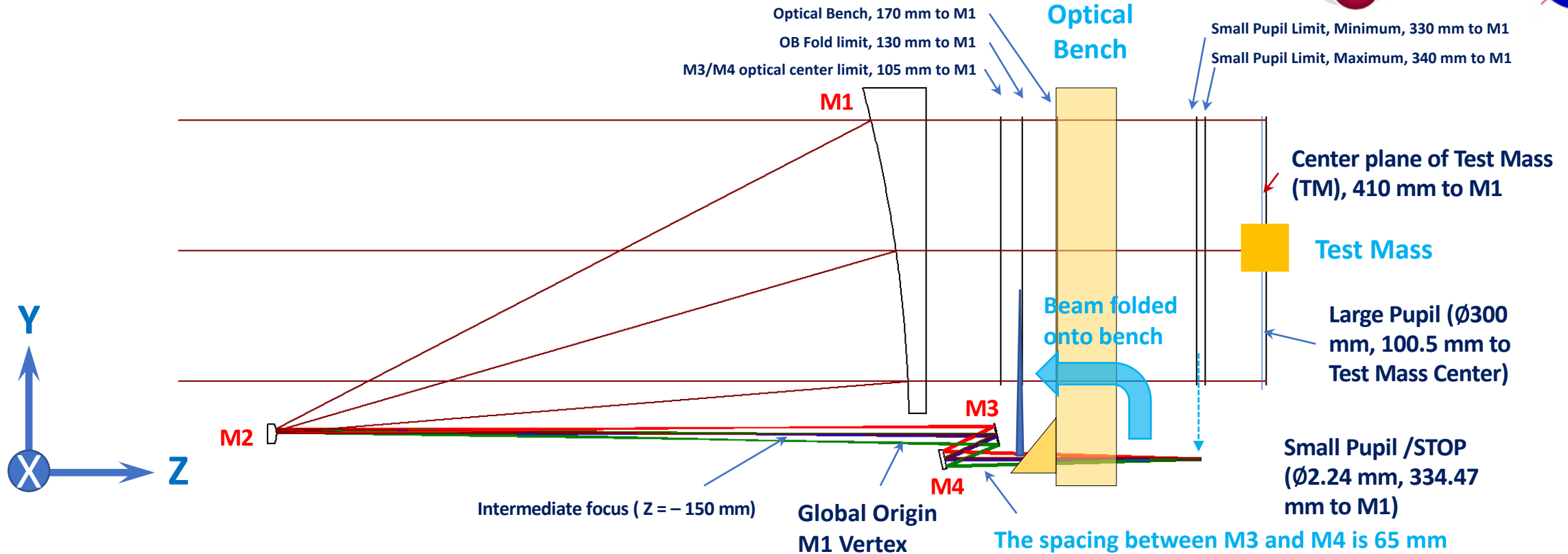
○ Tilt-to-length (TTL) coupling

- Careful design to minimize pathlength differences with field angle (dOPL vs Field)
- Careful alignment of measurement axes (bench to bench and bench to GRS) such that spacecraft tilts do not couple to the length measurement (movable aperture stops help during integration)
- Wavefront errors projected into the far-field will also couple TX angular jitter into an apparent length signal (keep wavefront errors low: $WFE < 35 \text{ nm RMS} = \lambda/30$ at 1064 nm)

Baseline Optical Design



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Global Coordinate System

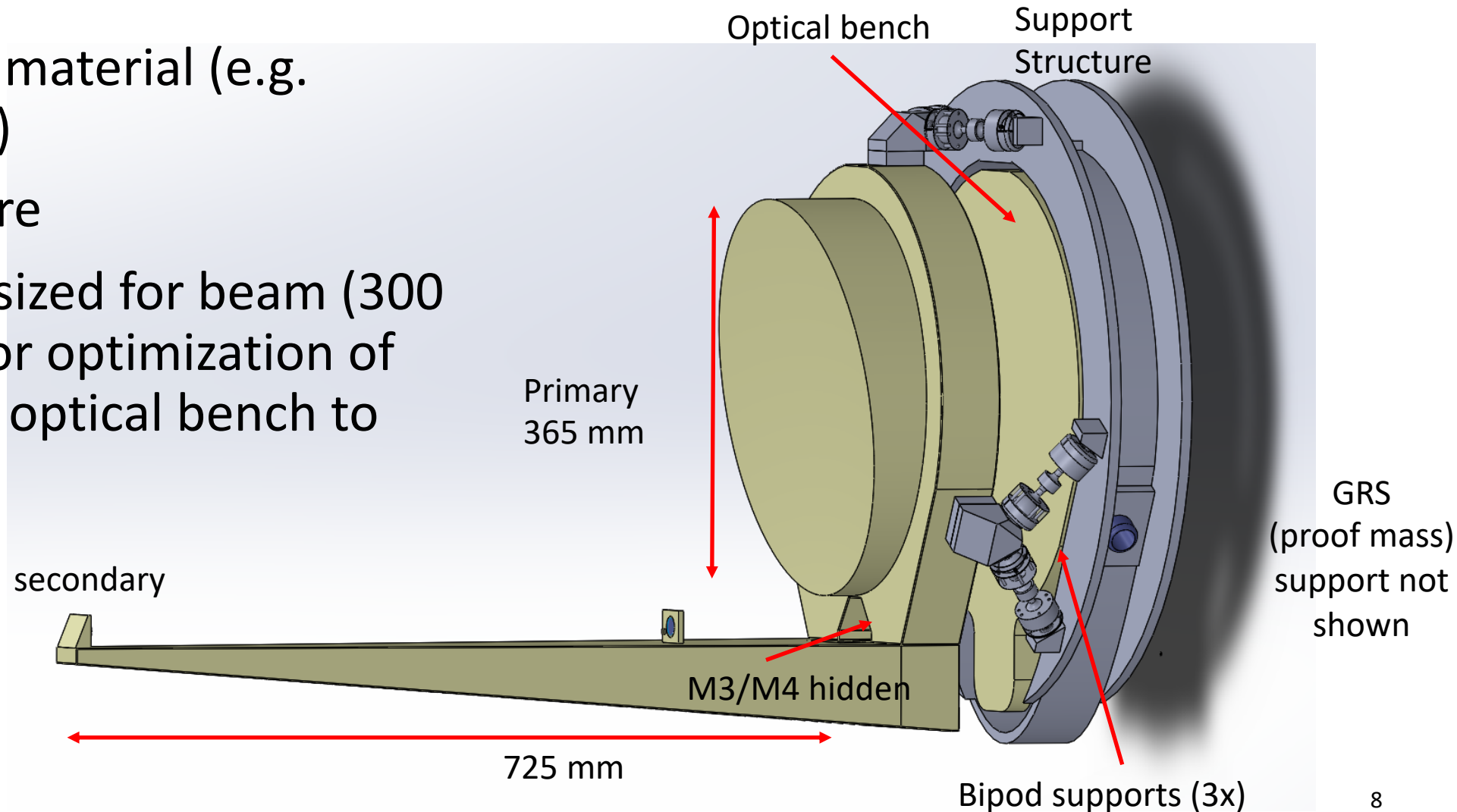
- Origin at M1 Vertex
- Z-axis: parallel to optical axis (object and image space)
- Y-axis: perpendicular to optical axis, within screen
- X-axis: perpendicular to optical axis, into screen

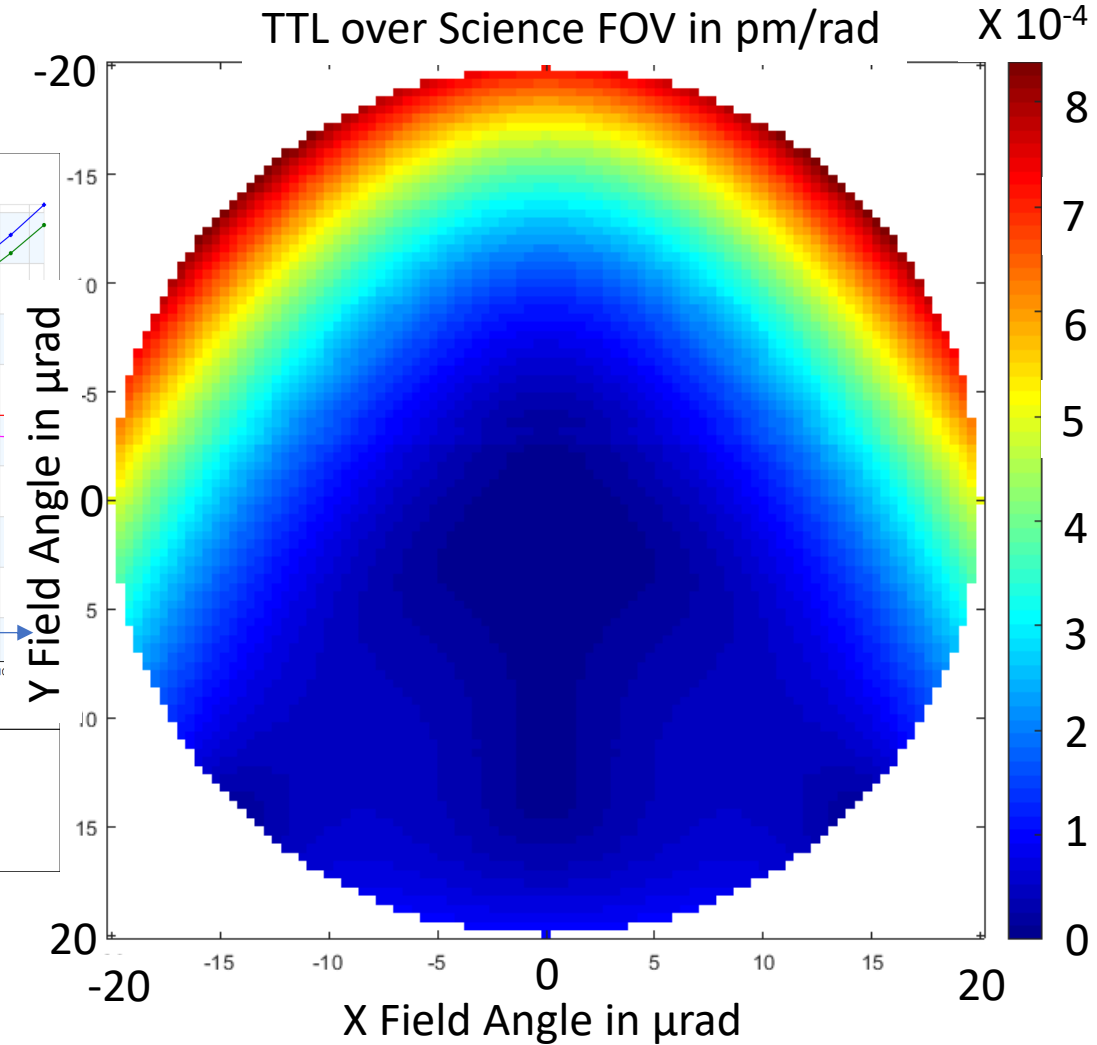
	Type	Conic	Radius (mm)	Clear Aperture (mm)	Edge Diameter (mm)
M1	Parabola	-1	-1475.246	345.3	365
M2	Hyperbola	-1.0928	-25.813	6.4	25.4
M3	XY Polynomial	0	Infinity	24.6	27.4
M4	Flat	0	Infinity	21.0	27.4

Livas: APS April Meeting Session G16
"freeform" optic

Notional CAD Model

- Single Low CTE material (e.g. Zerodur or ULE)
- 2-piece structure
- Primary is oversized for beam (300 mm) to allow for optimization of alignment with optical bench to minimize TTL





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Alignment Tolerances

- Cassegrain tolerancing inputs are at the edge of metrologists' advice
 - few microns in ROC, 0.01% in conic, few microns in position
 - Driven by angles of incidence, need a longer telescope or a smaller primary to significantly alter
- M3/M4 tolerancing inputs are much more relaxed, angular alignment requirements are difficult but within the realm of “routine” (2 arcsec = 10 μ rad requirement)
- If these inputs are satisfied, then the image of the stop places well and the boresighting is tightly controlled (keeps TTL of integrated system to an acceptable level)
 - Magnification variation produces +/- 1.5 mm spread in beam sizes
 - WFE within requirements



Current Status: procurement just started

Contract Award for Engineering Development Units (EDUs)

March 16, 2020

CONTRACT RELEASE C20-007

NASA Awards Laser Interferometer Space Antenna Telescopes

NASA has awarded the Laser Interferometer Space Antenna (LISA) Engineering Development Unit Telescope contract to L3Harris Corporation of Rochester, New York.

This is a cost-plus, fixed-fee contract with a total value of \$20,091,645. The period of performance is 36 months.

LISA is an international project led by ESA (European Space Agency) as a space-borne gravitational wave observatory. LISA is planned to consist of three spacecraft that are separated by 2.5 million kilometers in an Earth-trailing orbit. These three spacecraft relay laser beams back and forth between different spacecraft and the signals are combined to search for gravitational wave signatures that come from distortions of spacetime. The study of the universe through gravitational waves will yield a revolutionary perspective on the universe, which has been intensely studied using electromagnetic waves in many wavelength bands.

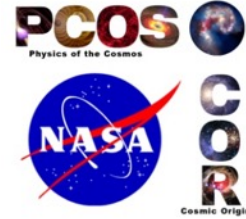
Nominal Schedule:

- 19 Mar 2020 Contract Start
- 27 Mar 2020 kick-off meeting
- 19 Sep 2021 STM delivery (+18 mo)
- 19 Mar 2022 EDU#1 delivery (+24 mo)
- 19 Sep 2022 EDU#2 delivery (+30 mo)
- Nov 2023 Adoption (ESA)

Summary



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- Proposed design meets key requirements
 - Dimensional Stability
 - Coherent backscattered light
 - “Intrinsic” tilt-to-length coupling
 - Can accommodate dynamic stop placement during alignment
- Tertiary mirror design is a freeform optic, but with small (< 2 microns RMS) deviations from a sphere
- Alignment requirements are tight, but possible
- Mechanical design with all-glass construction meets stiffness requirements
- Contract awarded to procure a structural thermal model (STM) and 2 engineering development units (EDU) for testing
- Currently developing plans for EDU testing