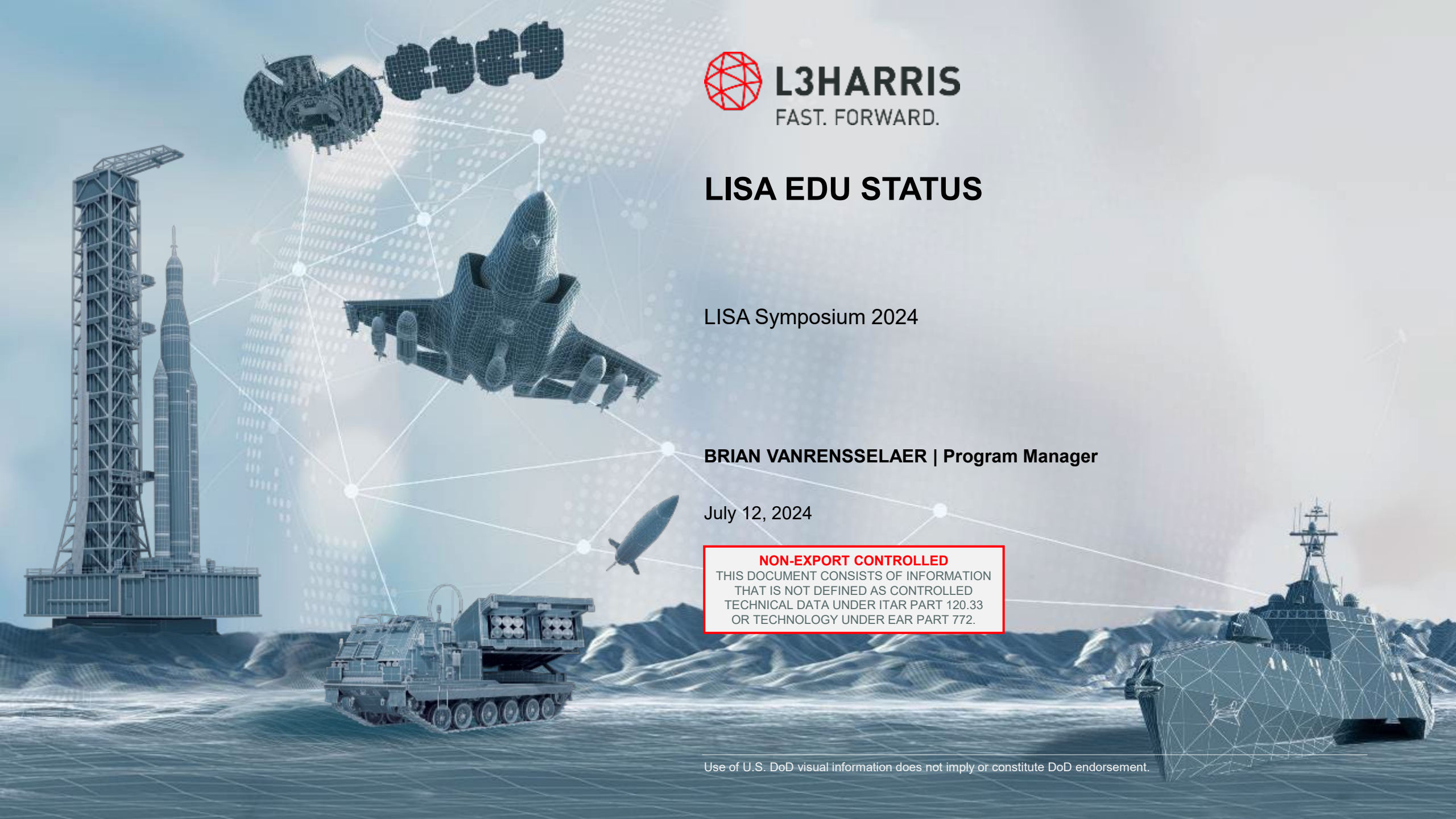

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LISA EDU STATUS

LISA Symposium 2024

BRIAN VANRENSSELAER | Program Manager

July 12, 2024

Agenda

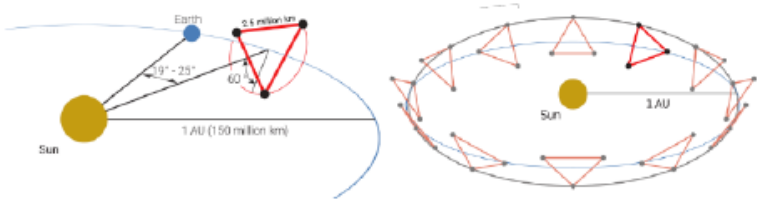
- Mission Overview
- Hardware Build Status
- Conclusion

Mission Overview

Flight Mission Design

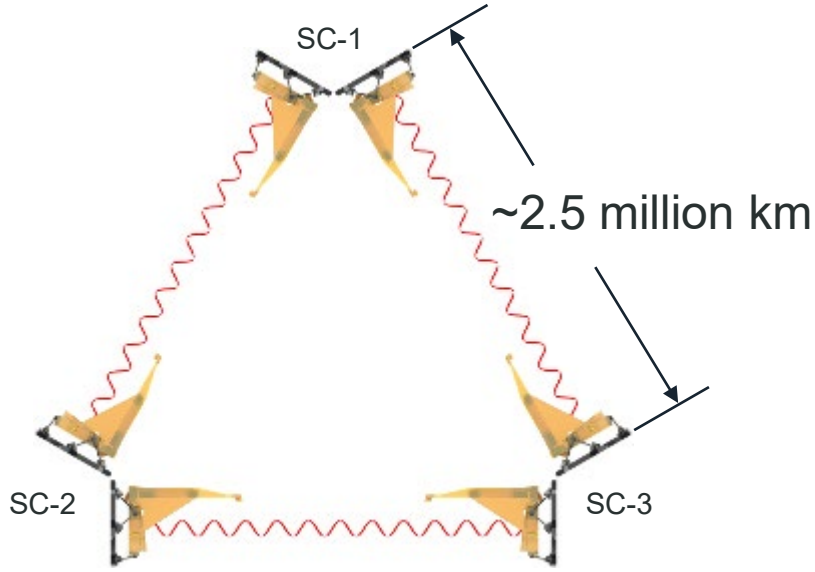
- Three satellites in an equilateral triangle formation with arm lengths of ~2.5 million kilometers.
- Any two arms of this triangle represent a Michelson type interferometer.
- Gravitational waves deform space-time and can be detected as a change in the length of the interferometer arms (~ 10 pm/Hz$^{1/2}$).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

Heliocentric Orbit



Constellation Triangle rotates once per year as it orbits

Each spacecraft has 2 telescopes that transmit and receive simultaneously and are in the optical path between the pairs of free-floating test masses at the end of each arm.



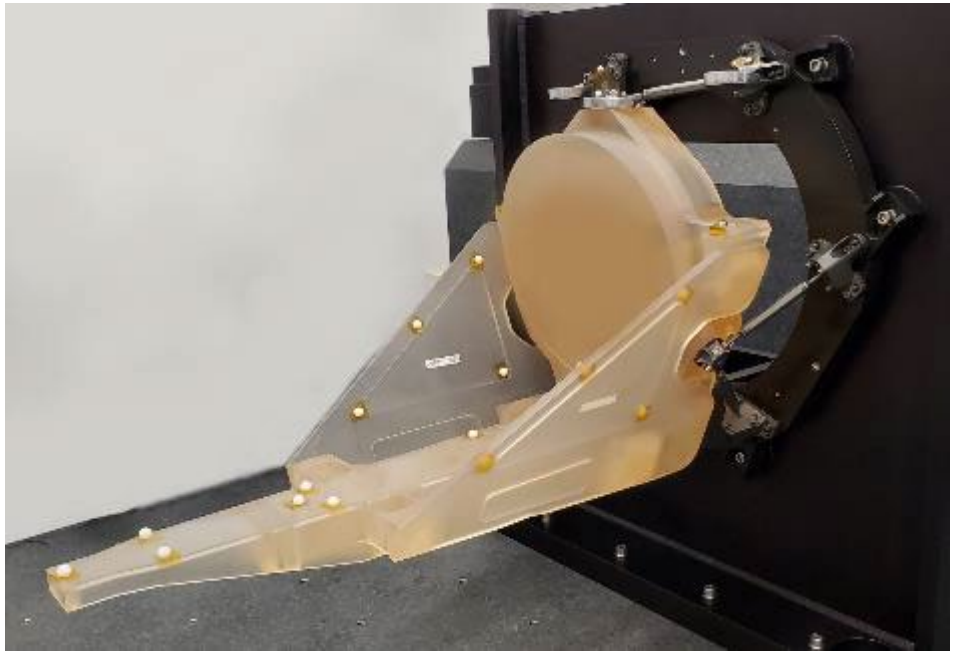
Behind each telescope is an optical bench with a laser at 1064 nm and a free-floating test mass.

The much longer baseline spacing between test masses and the quiet environment in space will allow the LISA Mission to measure much lower frequency gravitational waves than LIGO

LISA EDU Program Hardware Build Status

The Structural Thermal Model (STM) was successfully assembled

- Accomplished nearly flawless machining of complex ZERODUR® parts
- Successfully demonstrated integration with minimal-to-zero redesign or process changes required
- Experienced failure during environmental testing
  - Test campaign undertaken to inform root cause
  - Design and process improvements identified for potential flight implementation
- Telescope repaired and delivered to University of Florida for stability testing



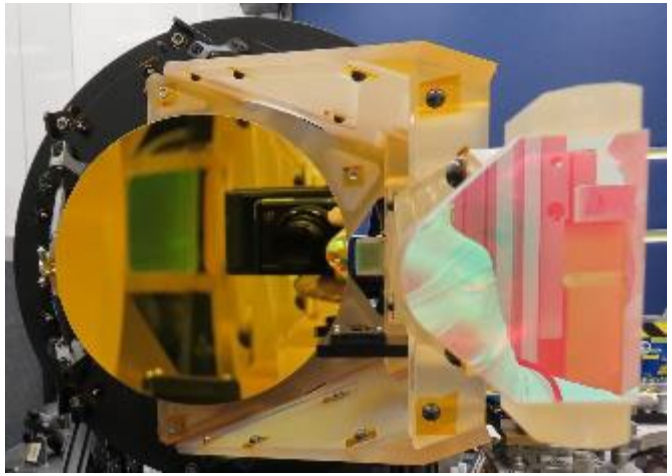
Integrated STM

Initial path length stability results are promising even with non-optimal CTE telescope. Testing planned with EDU1 will better simulate flight design and construction. Performance improvement expected with material and future process optimization.

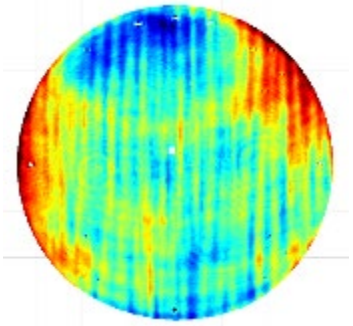
LISA EDU Program Hardware Build Status

The Engineering Development Unit #1 (EDU1) was successfully assembled

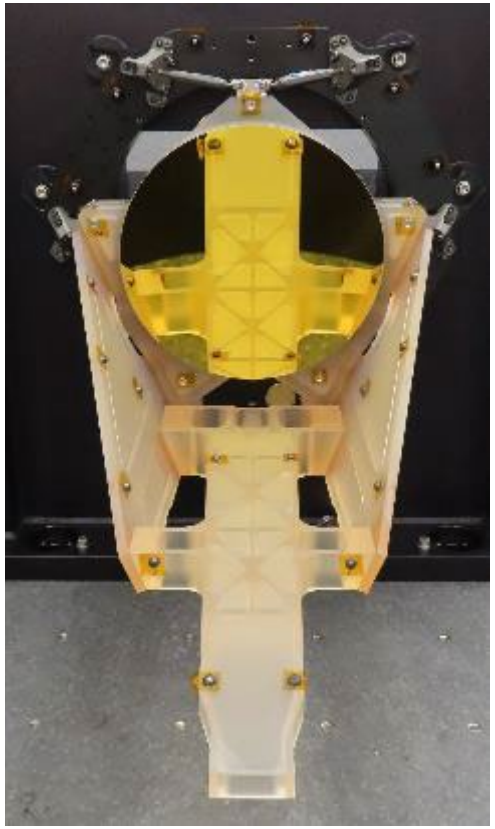
- Demonstrated nearly flawless finishing of optical components
- Successfully assembled M1 to support structure and verified optical performance of <7nm RMS SFE
  - Mid-spatial frequency improvements made on EDU2 M1, further improvements possible
- Integrated Gussets to Tower and M1A
- Successfully aligned and integrated M2 and M3/M4 subassembly
- Conducted multi-orientation telescope level performance testing and demonstrated excellent WFE performance
  - WFE <22nm RMS (<25nm with uncertainties included)
  - Well below 40nm requirement
- Delivered completed EDU1 telescope to NASA GSFC



EDU1 after M2 Integration *



EDU1 Telescope Center Field WFE Plot Average of Two Orientations



EDU1 before small optic integration *

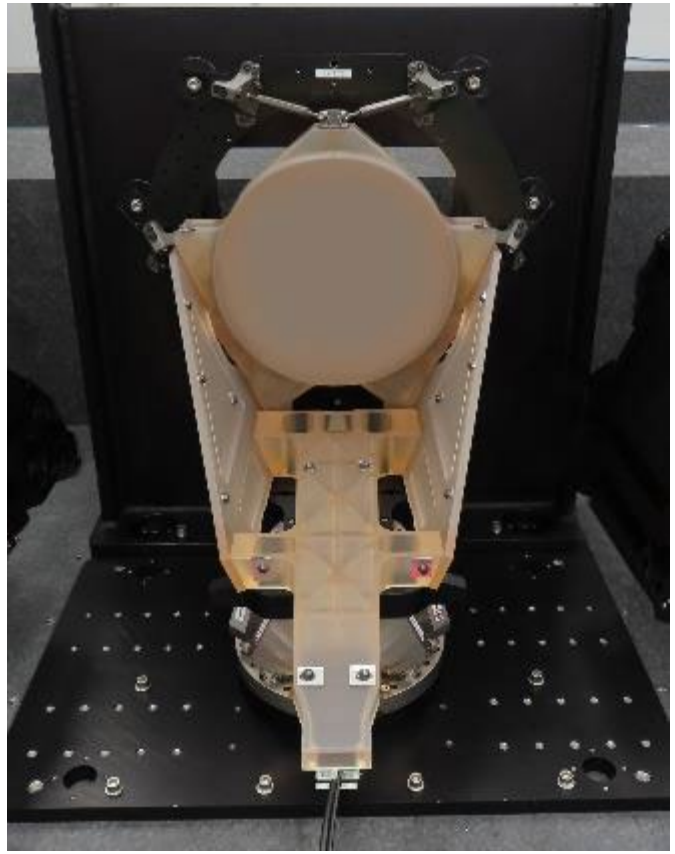
Telescope wavefront error <22 nm meets 40nm requirement with significant margin

* Image has been edited to remove technical details

LISA EDU Program Hardware Build Status

The Engineering Development Unit #2 (EDU2) assembly was partially assembled

- M1 finished to achieve surface error of <5 nm RMS SFE
- Structural components including tower, gussets, and brackets completed
- M2, M3 and M4 optics all successfully completed
- M1 assembled to support ring
- Integrated Gussets to Tower and M1A
- Telescope delivered to NASA GSFC for future use



EDU2 after gusset integration *

Process improvements implemented to enable accelerated integration

* Image has been edited to remove technical details

Conclusion

Accomplishments:

- Delivered three telescopes as part of 4-year development effort that included design, manufacture, assembly, integration and verification of a pioneering telescope:
  - Designed all-ZERODUR® telescope to minimize path length change
  - Created tool to analyze performance utilizing 3D CTE distribution across telescope
  - Developed novel assembly methods for all-glass structure
  - Precision aligned with stable assembly techniques
  - Significantly improved production rate as process improvements were implemented
  - Demonstrated exquisite alignment and telescope WFE performance capability

Path forward:

- Well positioned to leverage experience gained to enable flight mission
  - Understanding of all-glass telescope construction will yield improved designs, metrology, and assembly processes
  - Manufacturing lessons learned enable higher quality and expedited completion of parts
  - Understanding of process enables schedule efficiency improvements and optimization
  - Further risk reduction potential in telescope mounting and performance

The successful LISA EDU telescope development achieved significant risk reduction for the program. L3Harris and NASA are well positioned to apply lessons to enable the flight mission.

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