
Update from the NASA Study Office

Terry Doiron

NASA/GSFC

NASA LISA Study Manager

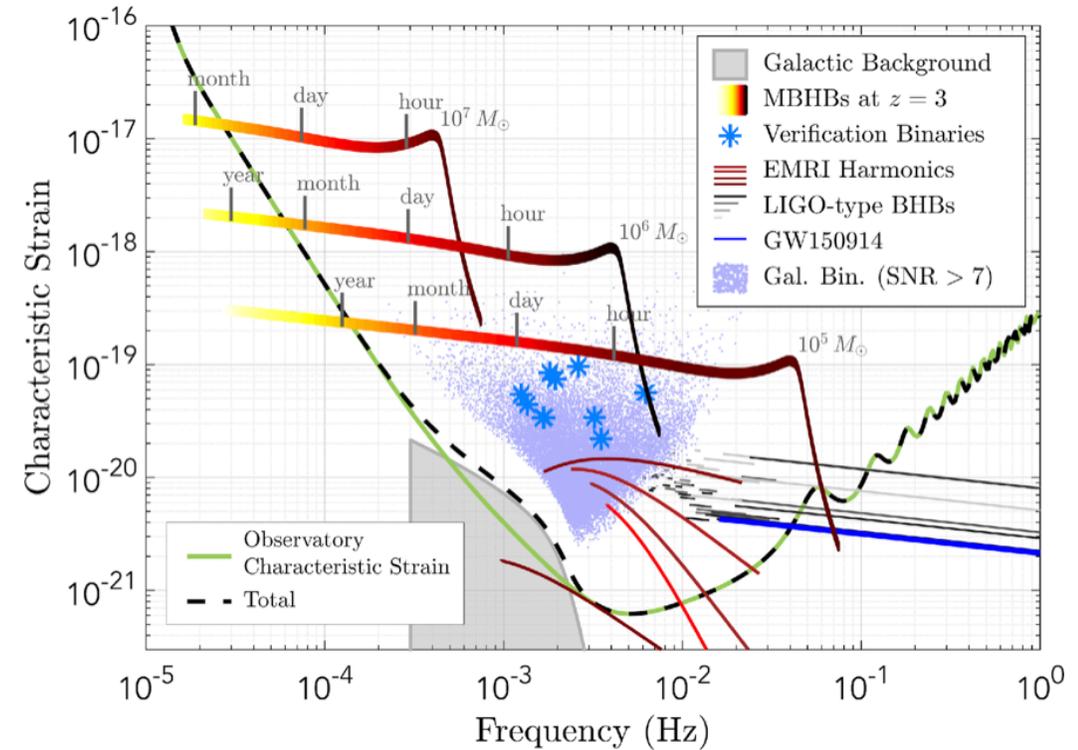
GW SIG Meeting

Honolulu, HI

January 7th, 2020

LISA Project

- **Science Goals**
 - First GW observatory in the milliHertz band
 - Tens of thousands of sources of many varieties
 - Wide applications in astrophysics, cosmology, fundamental physics etc.
- **ESA-led International Project**
 - ESA is the lead agency
 - Instrument and ground-segment deliverables from European member states
 - Hardware, engineering, ground segment, and science deliverables from NASA
- **Target launch in 2034**



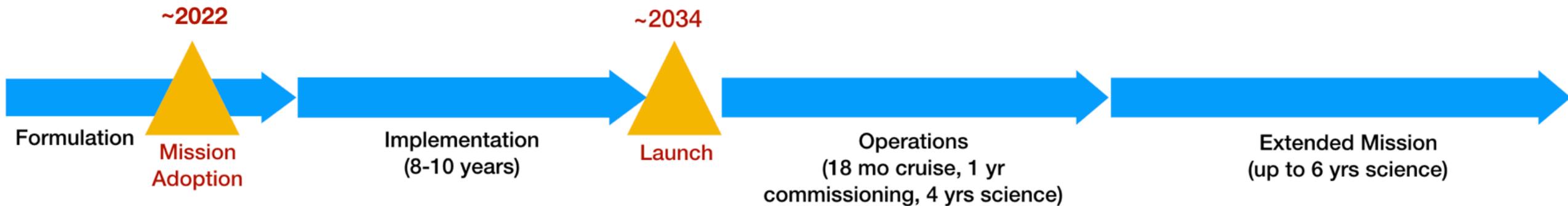
Status and Outlook

- **Currently in Formulation phase**

- Mission design
- Requirements development
- Demonstration of key technologies
- Negotiation of roles and responsibilities

- **Recent progress**

- ESA Mid-Phase A review completed successfully (Dec. 2019)
- Increase to ESA science budget motivated in part by LISA/Athena synergies



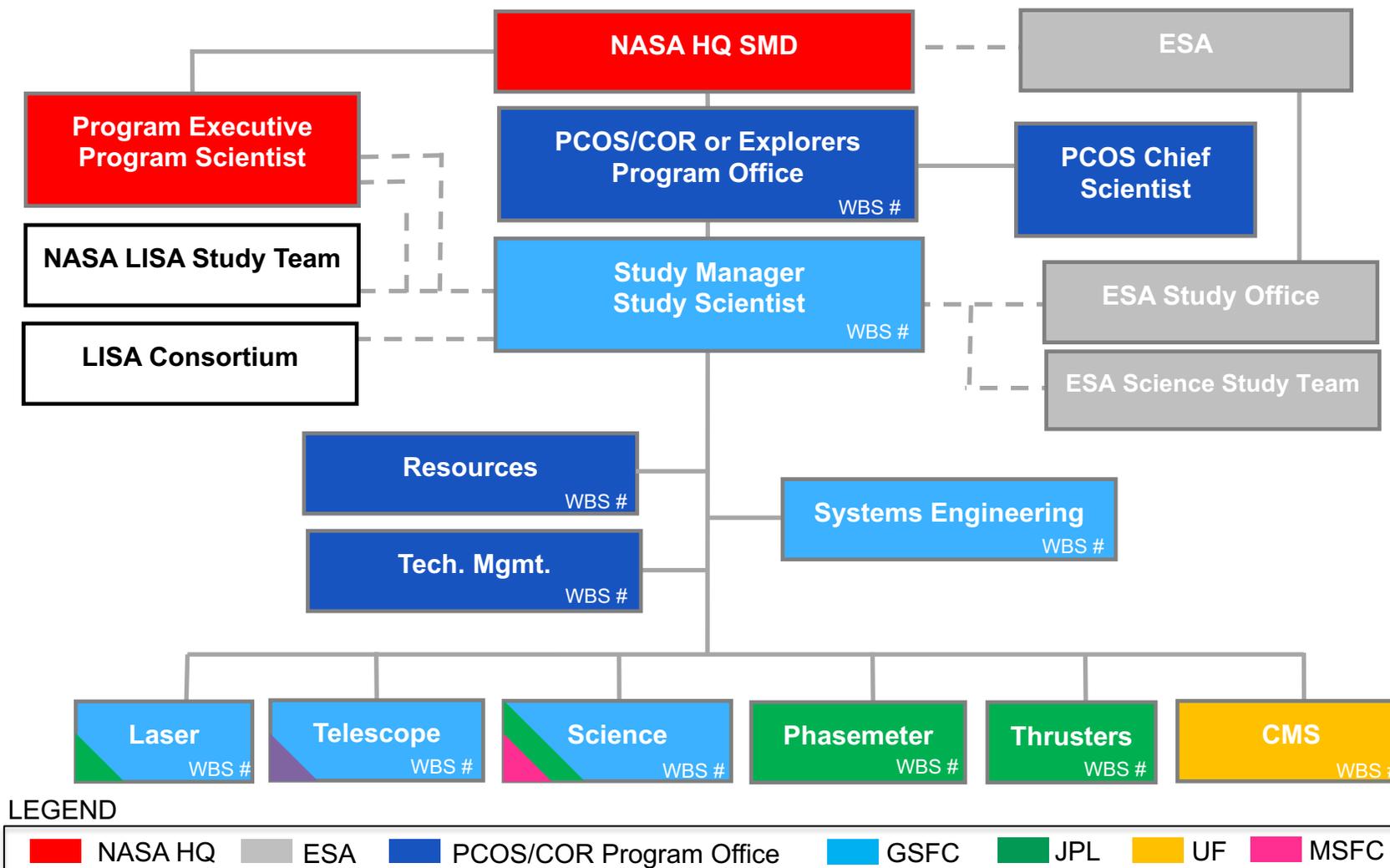
The NASA LISA Study Office



- **“proto-project”**
 - Conducts pre-formulation activities
 - Will evolve into formal NASA Project Office
- **Hosted by Physics of the Cosmos Program**
 - Program responsible for managing science themes including gravitational waves
- **Executed by NASA field centers & partners**
 - GSFC: management, science, and system engineering lead; telescope and laser development
 - JPL: science and systems engineering support; interferometry and micropropulsion development
 - MSFC: science support
 - UF: charge management, telescope testing support

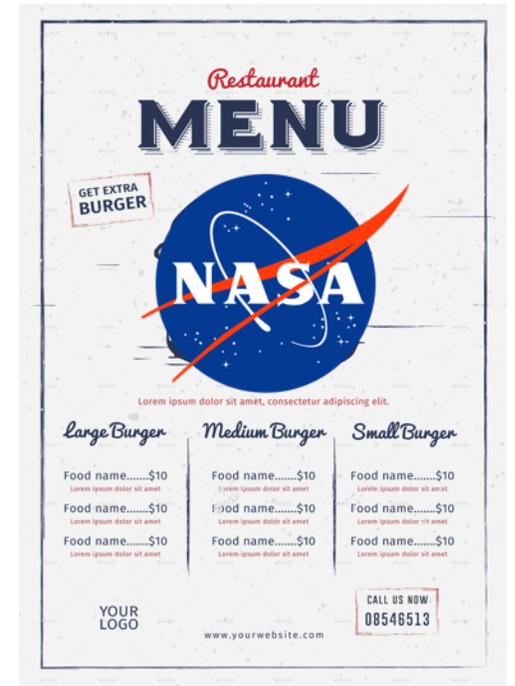


NASA LISA Organization Chart



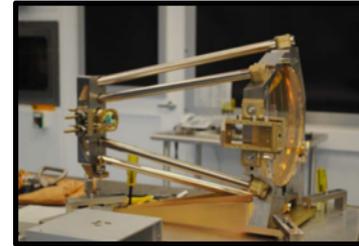
Study Office Near-Term Goals

- **Collaborate with partners (ESA, Consortium) on formulation activities**
 - Mission development
 - Instrument design
 - Science ground segment preparations
- **Develop “menu” of possible NASA contributions**
 - Payload systems and subelements (req. tech development)
 - Spacecraft components
 - Ground segment contributions
 - Operations contributions
 - Science support
 - ...
- **Assess each contribution**
 - Compatibility with partners / ease of interfaces
 - US interest
 - NASA capabilities
 - Cost
- **Work with NASA HQ, ESA, Consortium to consolidate final roles and responsibilities**
 - MoU drafted prior to adoption

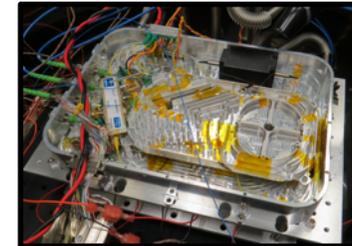


NASA Study Office Technology Development

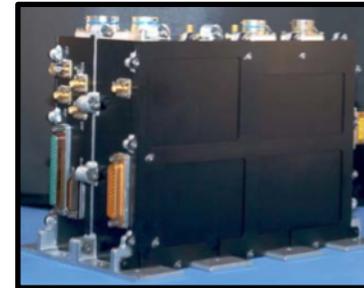
- **Investments are being made in five enabling technologies:**
 - Telescope (Goddard Space Flight Center + U. Florida)
 - Laser System (Goddard Space Flight Center + JPL)
 - Charge Management System (U. Florida)
 - Phasemeters (Jet Propulsion Laboratory)
 - Microthrusters (Jet Propulsion Laboratory)
- **Plans**
 - Demonstrate technology readiness prior to mission adoption
 - Demonstrate key driving requirements to reduce mission risk
- **Study Office Role**
 - Harmonize requirements between ESA/Consortium development and NASA developments
 - Develop contribution scenario(s)
 - Manage cost, schedule and technical risk



Telescope



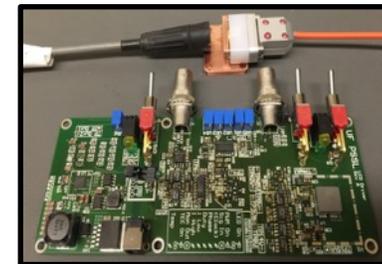
Laser System



Phasemeter



Microthrusters



Charge Management System

Systems Engineering Activities

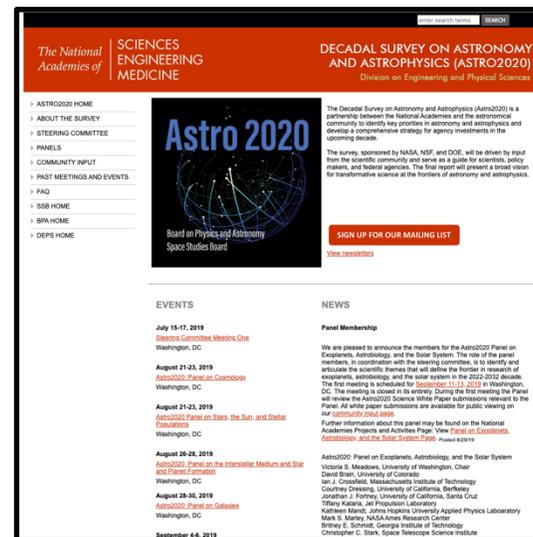
- Support ESA-led activities
 - Systems Engineering Office (SEO)
 - SEO WGs (laser, Tel/OB, contamination, propulsion, ...)
 - Industrial System Study progress meetings
 - Support ESA reviews (e.g. MCR)
- Support Consortium-led activities
 - LIG meetings & payload documentation (e.g. MCR)
 - AIVT meetings
 - Simulation WG
 - Performance modeling WG
- Conduct internal NASA reviews (w/ ESA + LIG participation)
 - Telescope design review
 - Microthruster peer review
 - Charge Management peer review
 - ...

Science Activities

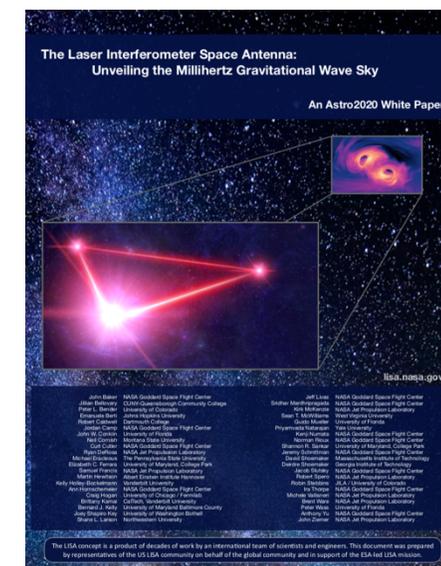
- Support ESA-led activities
 - Science Study Team meetings and task groups
 - Planning and prototyping of potential ground-segment contributions
- Support Consortium-led activities
 - LDPG, LSG calls and meetings
 - Contribute to Science and data analysis WPs and WGs (RGs?)
 - Participate in Consortium face-to-face meetings
- US community activities
 - NLST logistical support (NLST represents future US LISA user community)
 - Support GWSIG / PhysPAG / PCOS activities (NASA's broader interface to community)
- Science Core Team Activities
 - Prototyping LISA analysis infrastructure
 - Providing analysis to support data policy and science ground segment discussions at NLST
 - Response to US Decadal Survey

Decadal Survey Activities

- **Expected Astro2020 Schedule**
<https://sites.nationalacademies.org/DEPS/astro2020/index.htm>
 - Spring/summer 2019: community input via science & mission WPs
 - Summer '19 – Spring '20: panel meetings, RFIs for missions, presentations by missions
 - Summer/Fall '20: report prep. & review
 - Early '21: report released
- **LISA Participation**
 - 11 NLST-organized science WPs
 - Mission WP describing NASA role & case for upscopes
 - Supporting documentation (FAQs, detailed docs, etc.) on lisa.nasa.gov
 - Standing by for RFI response or presentations
 - Responded to request to provide technology development plan and costing information



The screenshot shows the Astro2020 website with a navigation menu on the left, a search bar at the top right, and a main content area with sections for 'EVENTS' and 'NEWS'. The 'EVENTS' section lists dates and topics like 'Astro2020 Panel on Cosmology' and 'Astro2020 Panel on Stars, the Sun, and Stellar Transients'. The 'NEWS' section includes 'Panel Membership' and 'Astro2020 Panel on Exoplanets, Astrobiology, and the Solar System'.



The screenshot shows the cover of an Astro2020 White Paper titled 'The Laser Interferometer Space Antenna: Unveiling the Millihertz Gravitational Wave Sky'. It features a graphic of the LISA mission concept and a list of authors and their affiliations at the bottom.

NASA LISA Study Team

- **Independent group of scientists representing the future US LISA user community**
 - Provide input to NASA HQ and NASA Study Office on LISA science questions
 - Represent LISA science to Astro2020
 - Interface with broader US research community
 - Interface with LISA Consortium (communication only, no expectation or funds to perform Consortium work)
- **NLST Augmentation in October**
 - 3 members retired (+1 prior retirement)
 - Craig Hogan
 - Brittany Kamai
 - Guido Mueller (moved to core team)
 - 7 members added
 - Krista Lynne Smith (Stanford / SMU)
 - Xin Liu (U. Illinois)
 - Zoltan Haiman (Columbia)
 - Matthew Digman (Ohio State)
 - Marcelle Soares-Santos (Brandeis)
 - Kayhan Gultekin (Michigan)
 - Jeremy Darling (U Colorado / CASA)
 - **Kelly Holley-Bockelmann** remains chair

New NLST Tasks from NASA HQ

- Describe “ science value” of data products
 - inform data policy discussions
- Outline community needs/desires for US ground segment contributions and science participation
 - inform SGS budgeting and negotiation for SGS roles with partners
- Preliminary deliverables due Feb 1, 2020
 - Please fill out the LISA interest survey

<https://forms.gle/a2JUHugfYQubiy2w6>

Charge to the augmented NLST

October 7, 2019

Introduction

NASA is pursuing a role as a junior partner on the ESA-led LISA mission, which has an expected launch date in the 2030s. NASA's contributions may include elements of the flight system, engineering support, and contributions to the science ground segment. In response to the NASA contributions, ESA will provide the US research community access to LISA data and opportunities to participate in LISA science. During the mission, NASA will support US scientists in their exploitation of the LISA data. NASA has begun early discussions with ESA regarding participation in the science ground segment and access to LISA data for the US community through the public release of data and data products.

NASA is charging the NLST, as proxies for the future LISA user community in the US, to provide scientific analysis to inform these discussions as well as the NASA policy and budget formulation processes surrounding LISA. The NLST is encouraged to collaborate with experts inside the NASA LISA Study Office and coordinate with European colleagues within the LISA Consortium, but should still retain their independent voice. This charge is broken into the following tasks.

The Tasks

NASA wants its discussions with ESA to be informed by factual knowledge about the needs of the US community for performing LISA science. To this end, the NLST is hereby tasked with the following:

- **Identify the US communities that are most likely to use the LISA data for scientific investigations.**
 - What kind of research projects and related activities will they be likely to do?
 - What are their anticipated needs?
 - Is there any precursor science that should be supported ahead of the launch?
- **Identify the likely LISA data products and assess their scientific value and their utility to the US astrophysics communities.** LISA will produce a rich set of data products at a variety of levels (e.g., catalogs, individual system parameters with error bars, residuals from global fits, TDI "strain" data, lower-level instrument data, etc.). Issues the NLST will focus on include:
 - What science is done with each type of data?
 - What kind of data are needed by the various categories of LISA users?
 - How is scientific opportunity affected by access to data at different levels?
 - What are the impacts of latency?

LISA Preparatory Science Grants

- **NASA/HQ funded grants to support LISA-related science**
 - Refine the LISA science case
 - Develop the future LISA user community
- **Process**
 - Selected through standard NASA peer-review process
 - Independent of NASA Study Office and NASA LISA Study Team
 - No obligation (or prohibition) to work with NASA Study Office or Consortium
- **First cohort awarded in 2018**
 - Progress presented here (poster session 376 and oral session 360)
- **Intent is to hold additional calls in the Future**

NASA Participation in Science & Data Analysis

- A “science ground segment” (SGS) consisting of algorithms, computing infrastructure, personnel, etc. will be required to deliver the mission science objectives.
- The SGS is a complex, integrated system with contributions coming from The Consortium, ESA, and NASA.
- NASA management is continuing discussions with ESA management about data access
- In addition to NASA’s commitments to SGS elements, NASA will conduct activities to facilitate exploitation of LISA data & science by the broader US research community
 - Guest Investigator grants
 - Data archives, tools, help desks, etc.
- **Data access rights are a complex issue which will require continued conversation**

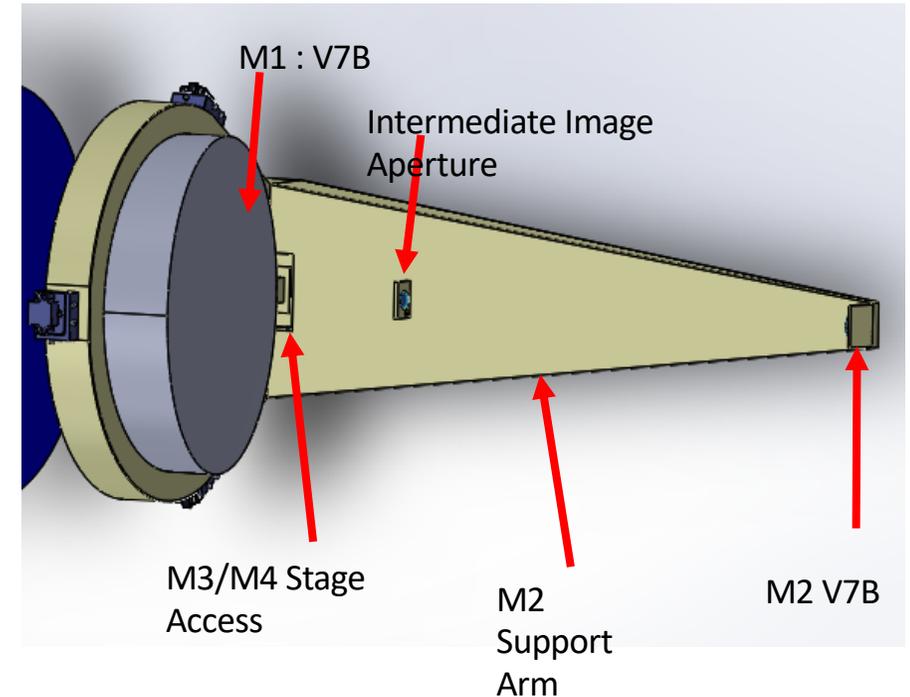
Summary

- **Steady Progress being made on multiple fronts**
 - Technology development proceeding on schedule, though microthruster and phasemeter technologies are now being slowed down
 - Good engagement with European-led systems engineering and design activities
 - Initial work to understand complexity of science ground segment and associated data flow
 - Initial input provided to Astro2020, preparing to respond to further inquiries
- **Much work ahead of us**
 - Continued development of technologies
 - Consolidation of spacecraft and payload designs as well as roles and responsibilities
 - Initial outlining of science ground segment and potential US contributions
 - Response to further inquiries from Astro2020

BACKUP

NASA Technology Development Progress - Telescope

- Procurement process for prototype models (1 structural + 2 optical performance) underway
 - RFP released Sept. 16
 - Proposals received Oct. 23
 - Contract target early 2020
- Internally developed reference design as proof of concept (right) and for interface discussions with ESA/Consortium partners
- Preparing facilities for optical tests at GSFC and UF
- Supporting SEO Tel/OB WG and LIG activities



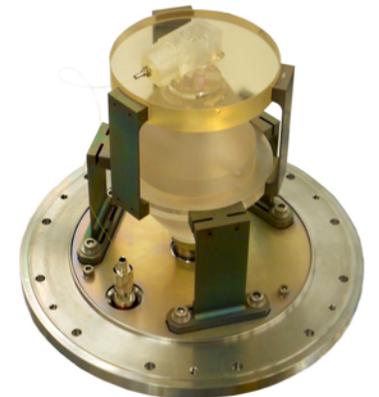
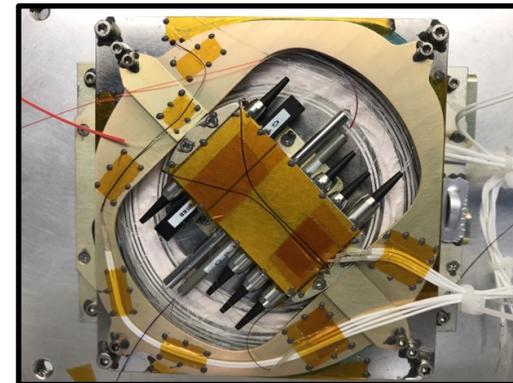
CAD model of NASA proof-of-concept design

NASA Technology Development Progress - Laser

- **Master Oscillator: (mNPRO)**
 - First set of prototypes performing well
 - Design for next set of prototypes underway
- **Fiber Amplifier**
 - Vendor selected (FiberTek)
 - First units to arrived GSFC Nov.
- **Frequency reference (JPL lead)**
 - Contract initiated with Ball aerospace to capture lessons learned from GRACE-FO cavity
- **Reliability**
 - Initiated reliability study of pump diodes w/ LGS
- **Interfaces & Systems**
 - Participating in SEO Laser WG & LIG activities
 - Preparing to deliver prototype lasers to ESA partners for test in Spring 2020

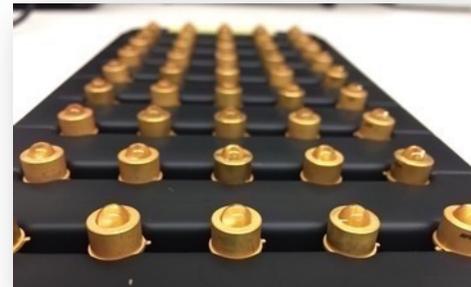
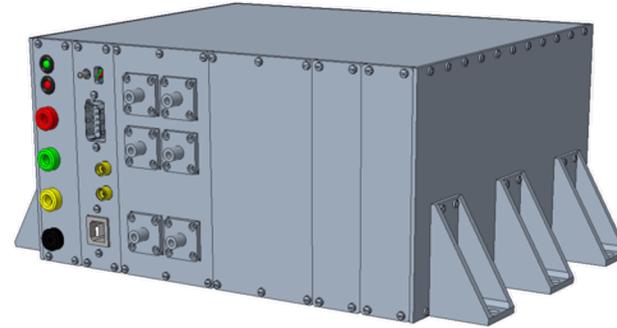


(top) mNPRO master oscillator under test at GSFC. (bottom left) Fiber amplifier. (bottom right) frequency reference cavity for GRACE-FO.



NASA Technology Development Progress – Charge Management

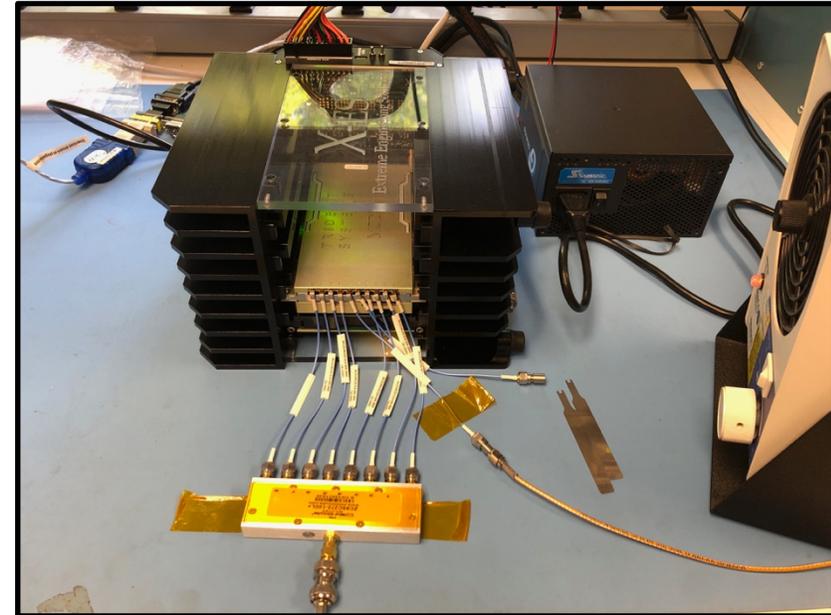
- **TRL4 Charge Management Device delivered to U. Trento for testing**
 - 1st delivery of LISA (prototype) hardware to Europe
 - Integrated with U. Trento torsion pendulum for system-level testing of charge control
 - TRL4 milestone review passed on Nov. 19
- **TRL5 Unit design underway**
 - Mid-TRL 5 peer review held on Nov. 18 (ESA + LIG participation)
 - TRL 5 scheduled completion Sept. 2020
- **Working with GSFC photoincs group to evaluate options for fiber harness and conduct radiation testing**
- **Supporting SEO Charge Management WG and LIG activities**



(top left) TRL 5 design. (bottom left) UV LEDs used for performance/lifetime testing. (right) TRL4 charge management unit in place at U. Trento torsion pendulum facility.

NASA Technology Development Progress – Phasemeter

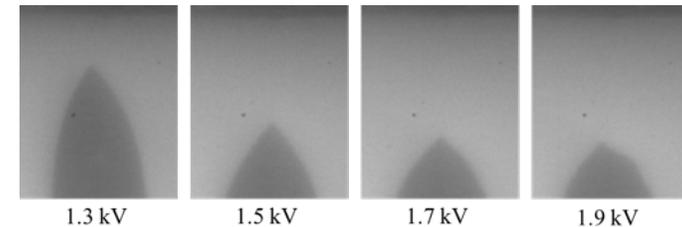
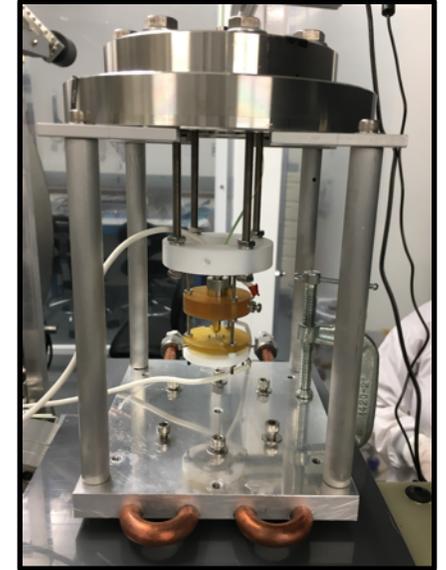
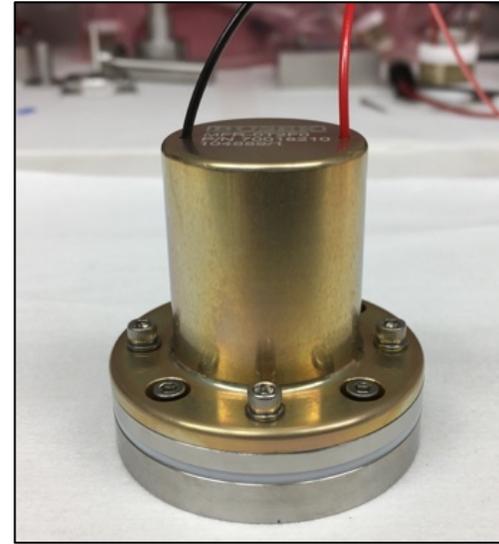
- **In-flight results from LRI instrument published**
 - includes LISA-like phasemeter (LRP)
 - Noise performance beats requirements
 - limited by frequency stability of laser (only one arm)
- **Working with Industry to produce scalable LISA prototype**
 - First boards now under test
- **Supporting SEO and LIG activities**



8-channel phasemeter prototype card (Trident Systems) under test at JPL.

NASA Technology Development Progress – Microthrusters

- **Developed LISA design based on lessons learned from ST7**
 - Preserve heritage of basic design
 - Increased lifetime through improvements to valves and electrode geometry
- **Fabricating prototype components for testing**
- **Performing in-situ beam profiling (UCLA) to inform lifetime models**
- **Working with ESA and contractors to study configuration options**



(top left) Redundant microvalve at Busek (top right) single emitter thruster under test at JPL (bottom) in-situ microscopy of Taylor cones and electrospay at UCLA.

Update on NASA's Technology Development Activities

- **NASA has made the decision to slow down development of the microthruster and phasemeter technologies**
 - Telescope, Laser, and charge management device are highest priority for NASA based on ESA input and internal NASA assessments
- **Impacts**
 - At HQ direction, NASA Study Office, in consultation with JPL managers, has developed strategy for mitigating impacts by funding highest priority activities.
 - Design study for stabilization cavity (part of laser) will continue at previous pace.
 - Key JPL team members are contributing to NASA systems engineering team