Laser Interferometer Space Antenna
Status & Outlook

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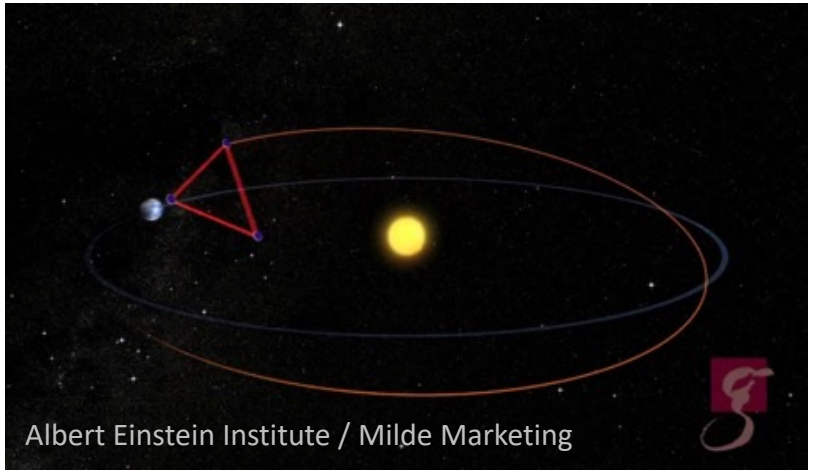
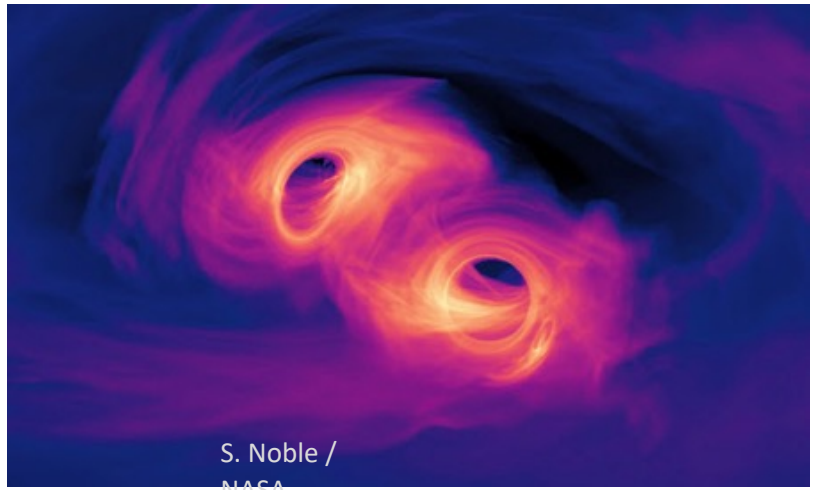
NASA LISA Study Scientist

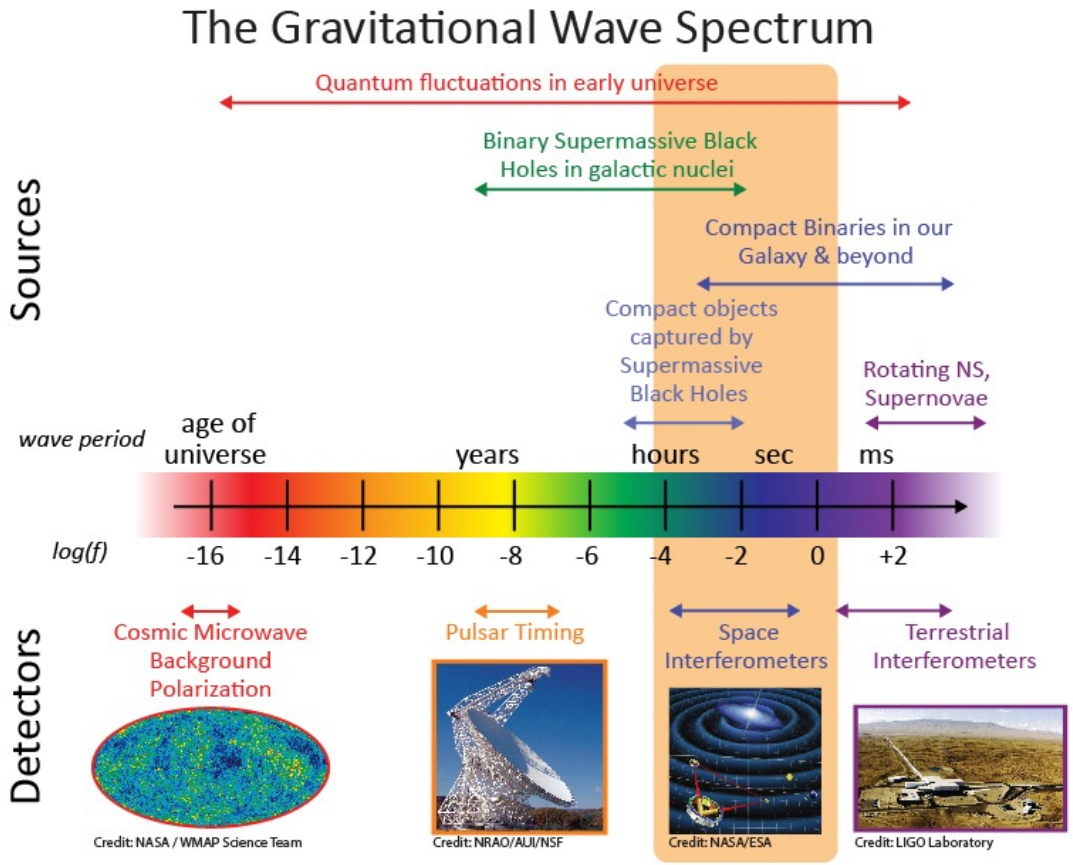
NASA Gravitational Wave Science Interest Group Meeting
241st Meeting of the American Astronomical Society
Seattle, WA
January 9th, 2023





LISA 101

- **Space-based observatory of millihertz gravitational waves**
  - Astrophysics (big/small, near/far,…)
  - Cosmology
  - Fundamental physics
  - ….
- **Triangular constellation of spacecraft**
  - 2.5Mkm arms
  - Drag-free inertial test masses
  - Heterodyne optical interferometry
- **ESA-led international partnership**
  - ESA L-class mission
  - Substantial NASA contribution (> MIDEX, < probe)
  - European National contributions



Programmatic Status

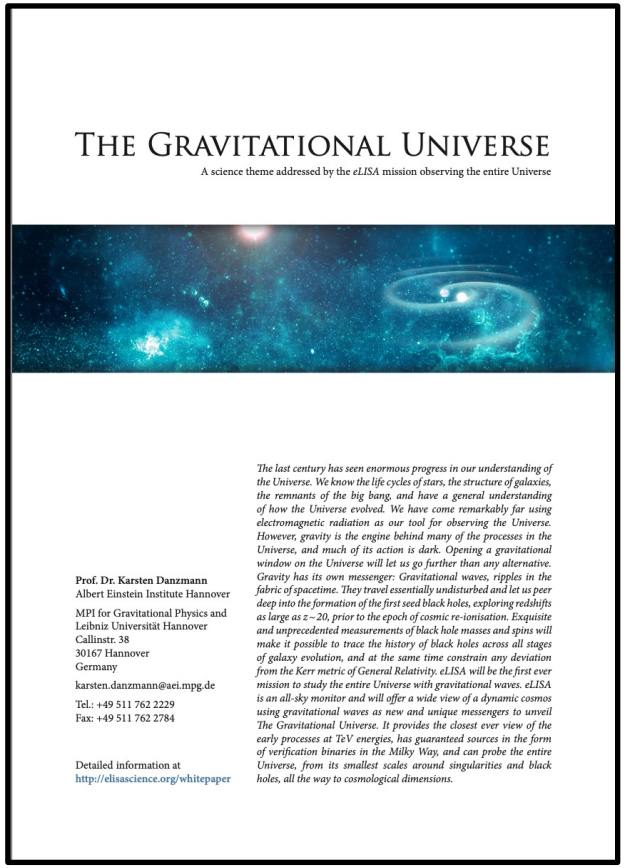
- **ESA Program timeline**
  - 2013: Gravitational Universe selected as L-class science theme
  - 2019: LISA selected as L3, industrial studies commence
  - Nov. 2021: Phase A complete
  - Summer 2023: Phase B1 complete
  - **Nov 2023: Mission Adoption by ESA Science Program Committee**
  - 2024: Phase B2-C-D contracts established
  - 2027 (TBC): PDR
  - 2035 (TBC): Launch
  - Launch+18mo: begin 4 year nominal science mission
  - 2040s (TBC): Potential extended mission

Mission Adoption Milestone

- **What is it?**
  - "third decision" in ESA program
  - Approve a specific mission with a known science case, mission architecture, technical readiness, cost, schedule, management, etc…
- **What are the criteria?**
  - Science capabilities fulfill objectives of science theme
  - Technologies are ready
  - Programmatic constraints (cost, schedule, etc.) are met
  - Political constraints are met
- **What are the inputs?**
  - ESA cost and technical review
  - Definition Study Report ("Red Book")
  - International agreements (NASA-ESA MoU and ESA-Member State MLA)

Science Readiness

- **Science objectives have survived the mission definition phase**
  - Strain sensitivity
  - Mission duration
- **Areas of concern**
  - Performance below formal measurement band (< 0.1 mHz)
  - Mission duration / duty cycle
  - Length of possible extended mission
- **Science case is *robust***



THE GRAVITATIONAL UNIVERSE

A science theme addressed by the *eLISA* mission observing the entire Universe

The last century has seen enormous progress in our understanding of the Universe. We know the life cycles of stars, the structure of galaxies, the remnants of the big bang, and have a general understanding of how the Universe evolved. We have come remarkably far using electromagnetic radiation as our tool for observing the Universe. However, gravity is the engine behind many of the processes in the Universe, and much of its action is dark. Opening a gravitational window on the Universe will let us go further than any alternative. Gravity has its own messenger: Gravitational waves, ripples in the fabric of spacetime. They travel essentially undisturbed and let us peer deep into the formation of the first seed black holes, exploring redshifts as large as z ~ 20, prior to the epoch of cosmic re-ionisation. Exquisite and unprecedented measurements of black hole masses and spins will make it possible to trace the history of black holes across all stages of galaxy evolution, and at the same time constrain any deviation from the Kerr metric of General Relativity. eLISA will be the first ever mission to study the entire Universe with gravitational waves. eLISA is an all-sky monitor and will offer a wide view of a dynamic cosmos using gravitational waves as new and unique messengers to unveil The Gravitational Universe. It provides the closest ever view of the early processes at TeV energies, has guaranteed sources in the form of verification binaries in the Milky Way, and can probe the entire Universe, from its smallest scales around singularities and black holes, all the way to cosmological dimensions.

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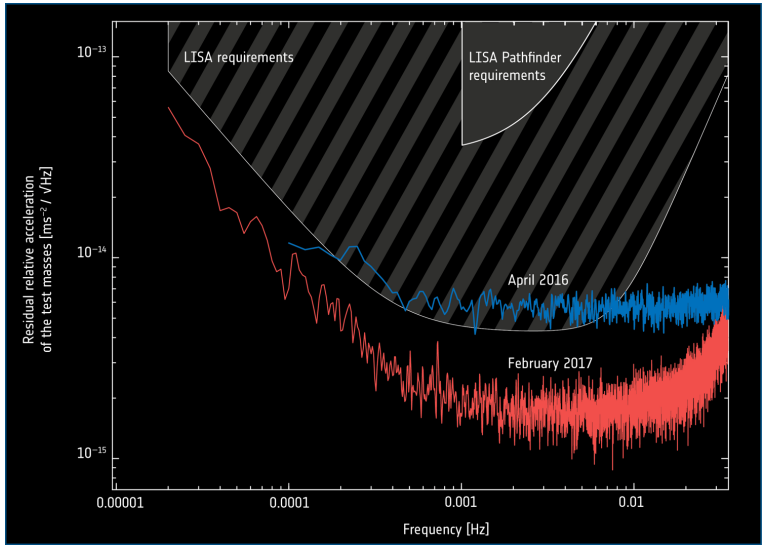
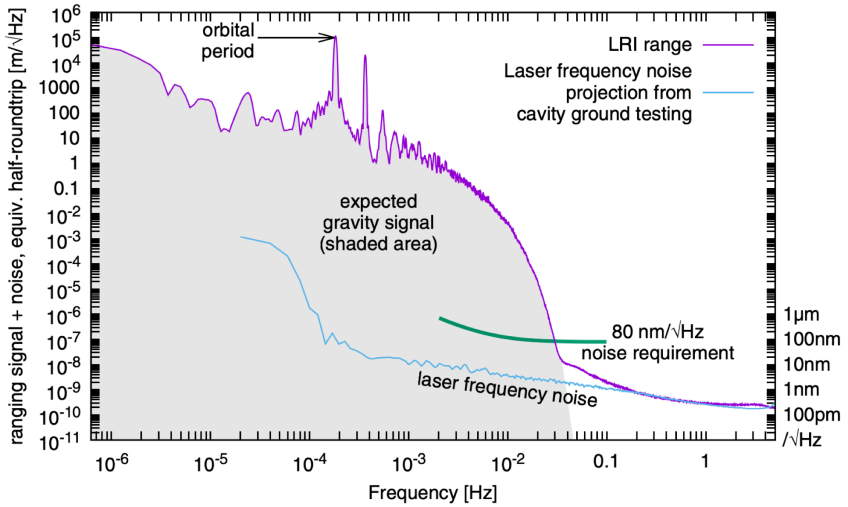
Detailed information at
http://elisascience.org/whitepaper

Gravitational Universe – 2013 selection for L-class science theme:

Technical Readiness – Part 1

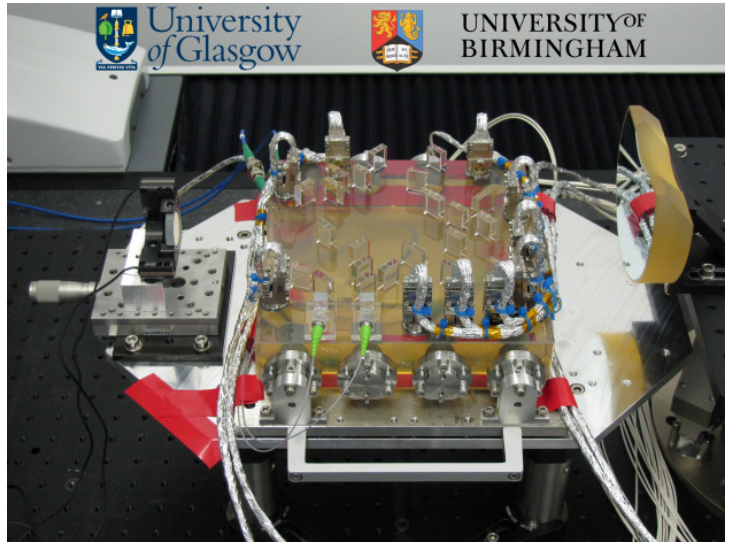
- ***Two* flight demos: LPF and GRACE-FO LRI**
- **LISA Pathfinder**
  - Dedicated tech. demo for LISA
  - Free-flying test mass as inertial reference with full LISA performance
  - Many other relevant technologies
  - Also programmatic pathfinder
- **GRACE-FO LRI**
  - Astro Tech demo on Earth Science mission
  - LISA-like interferometer at nm level over ~300km baseline

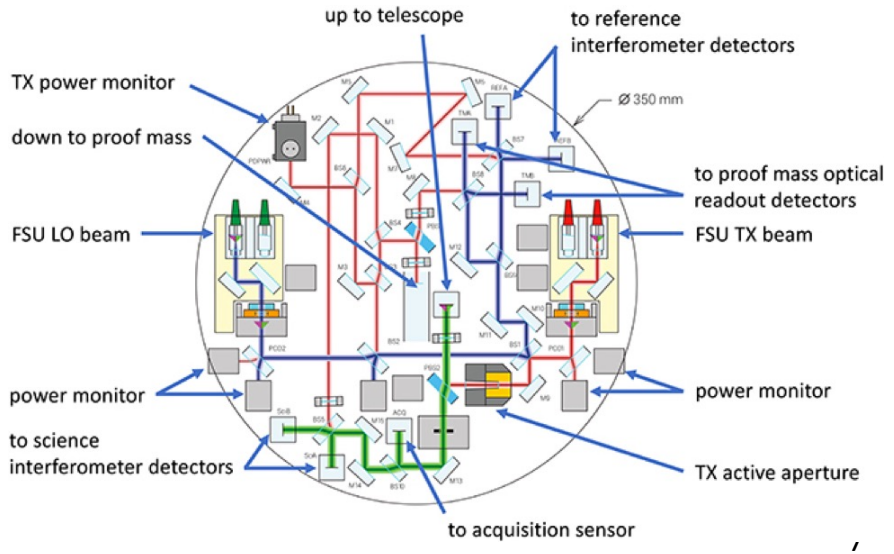




Technical Readiness – Part 2

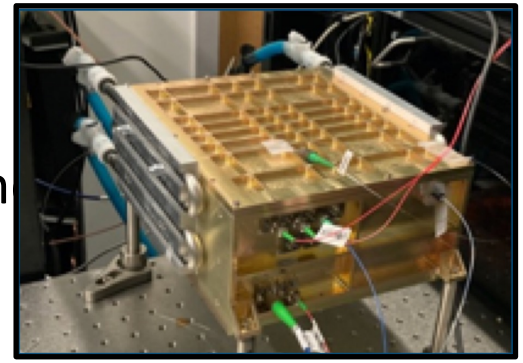
- **New technologies not demonstrated by LPF or LRI**
  - Telescopes
  - High-power lasers
- **Building on LPF and LRI**
  - Longer lifetimes & higher reliability
  - Higher unit count
  - More components (optical bench optics, phasemeter channels)

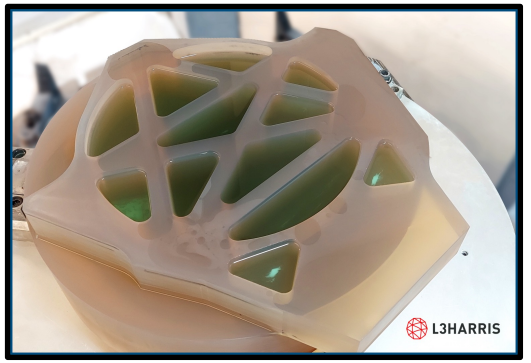


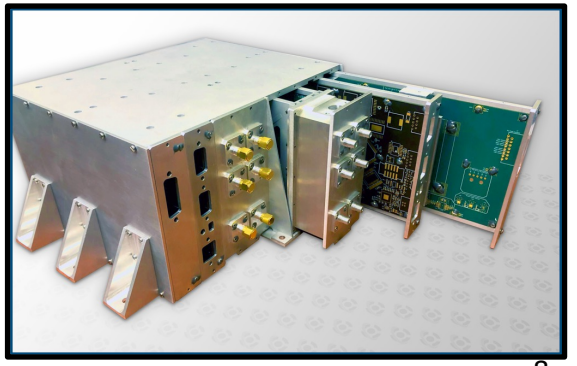


NASA Technology Activities

- **Laser system**
  - Provides light for interferometric measurement
  - High power (2W), continuous operation (5-10yrs), high stability, m transfer
  - MOPA with NPRO seed, fiber modulator, fiber amplifier
- **Telescope**
  - Reduces diffraction losses in inter-spacecraft links
  - Part of interferometric path, must be picometer stable
  - All-glass quasi-monolithic design
- **Charge Management Unit**
  - Provides UV light to control electrical charge on test masses
  - Precise light control, long lifetime
  - UV-LED source improves on LPF's Hg-vapor lamps







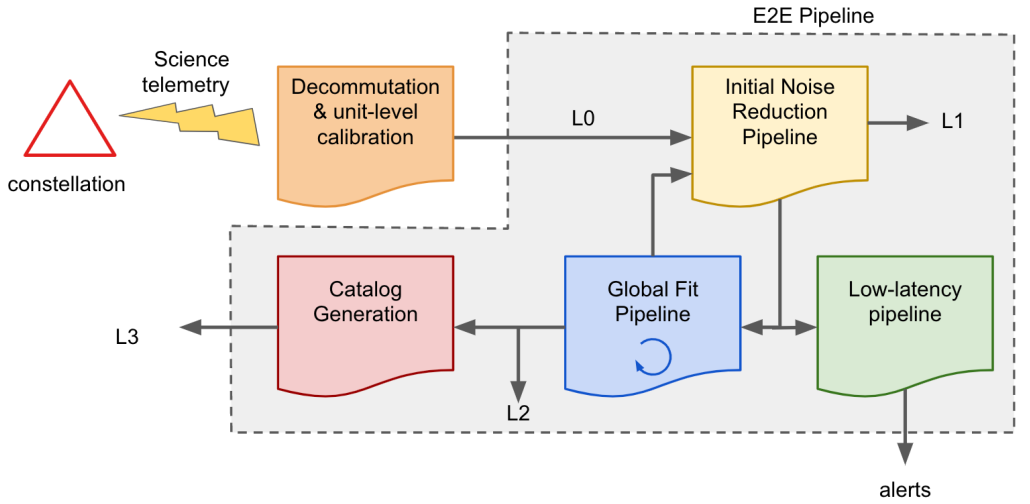
TRL4 laser optical unit prototype (NASA/GSFC); TRL5 ultra-violet light unit (NASA/U. Florida / Fibertek); primary mirror assembly for telescope engineering development unit (NASA / L3 Harris)

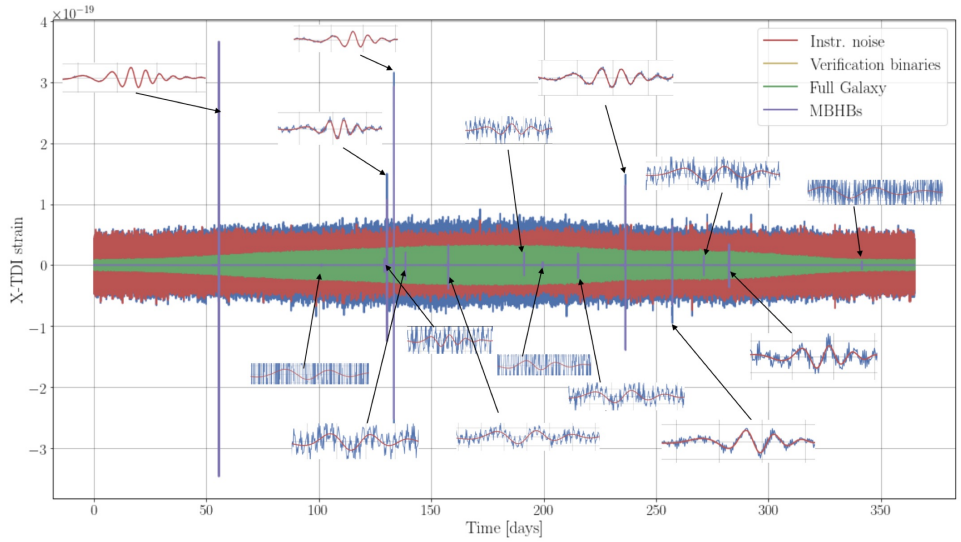
NASA Programmatic Status

- **Currently a Study Under PhysCOS Program Office**
  - Technology Development
  - Systems engineering
  - Technical & managerial interface with Europe (ESA + ESA partners)
  - Science ground segment prototyping
  - Science stewardship (with NASA LISA Study Team)
- **Plan to transition to project in CY23**
  - Project Office at GSFC
  - Science and systems contributions from JPL & MSFC
  - Contracts to UF (charge management) and industry (laser, telescope)
  - Likely hold combined KDP A/B to start project in phase B

Science Ground Segment

- **Signal analysis is an enabling technology for LISA**
  - Technical readiness from LIGO/Virgo and PTAs
  - More technology development to do
- **Mission Adoption requires a plan for implementing the production SGS**
  - Shared responsibility between ESA, NASA, and European member states
  - Challenging problem to share responsibilities for a highly-coupled, complex technical system





Science Participation and Data Policy

- **What model should LISA follow?**
  - Principal Investigator
  - User Facility
- **Considerations**
  - Validating results from a new and complex instrument
  - Maximizing science through broad, and equitable, participation
  - Appropriately recognizing past contributions and motivating future ones
- **Specific Questions**
  - Is there a science validation period?
  - Who does the science validation?
  - How are data releases managed?
  - How are science investigations managed?

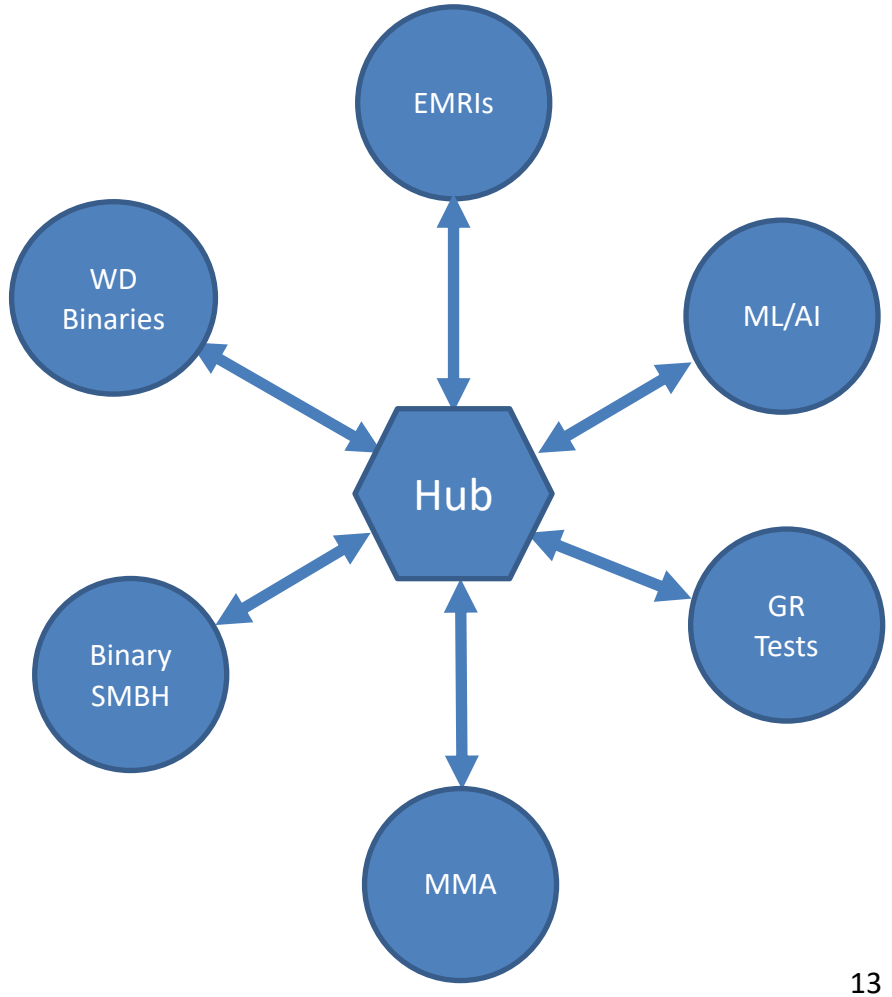
NASA's SGS & Science Activities

- **Community Guidance**
  - Astro2020: "…ensure US scientists fully participate in LISA analysis, interpretation, and theory"
  - NASA LISA Study Team Reports: detailed analyses of participation models
  - Science Implementation Data Center panel: specific implementation recommendations
  - Ongoing input from NLST
- **Study Office Activities**
  - Develop operational concept for SGS and science participation
  - Maintain technical discussions with ESA and Member state partners
  - Support APD in formal discussions with ESA

NASA Science Model

- **NASA deliverables to ESA**
  - End-to-end pipeline to produce all data levels
  - Participate in process to consolidate data products (catalogs) for public release
- **Hub and Node (satellite) model**
  - Hub: responsible for deliverables
  - Nodes:
    - mini-science centers to boost science return
    - Focus on specific topics & communities
    - competitive

Notional nodes shown



Summary

- **2023 is shaping up to be a milestone year for LISA**
  - Complete ESA Phase B1
  - Establish NASA project
  - Formalize international agreements
  - **Mission Adoption**

THANKS / QUESTIONS