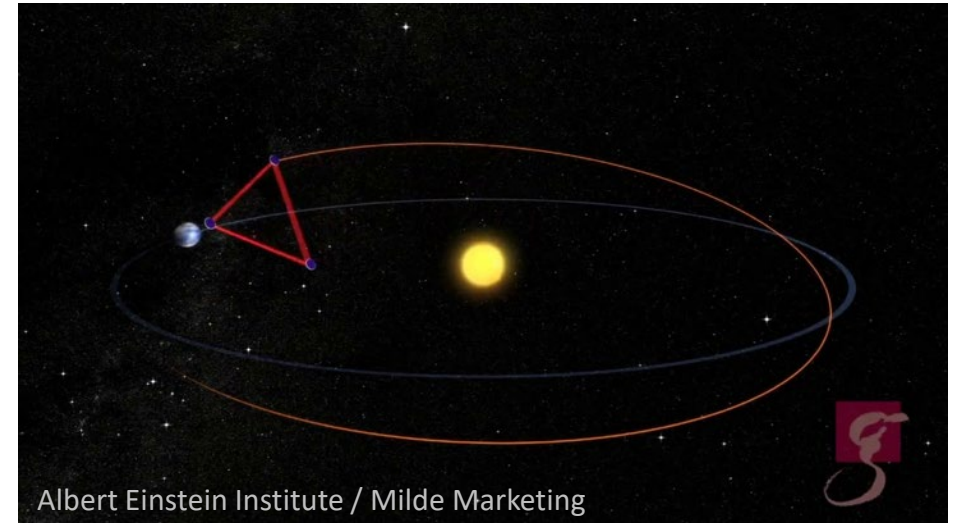
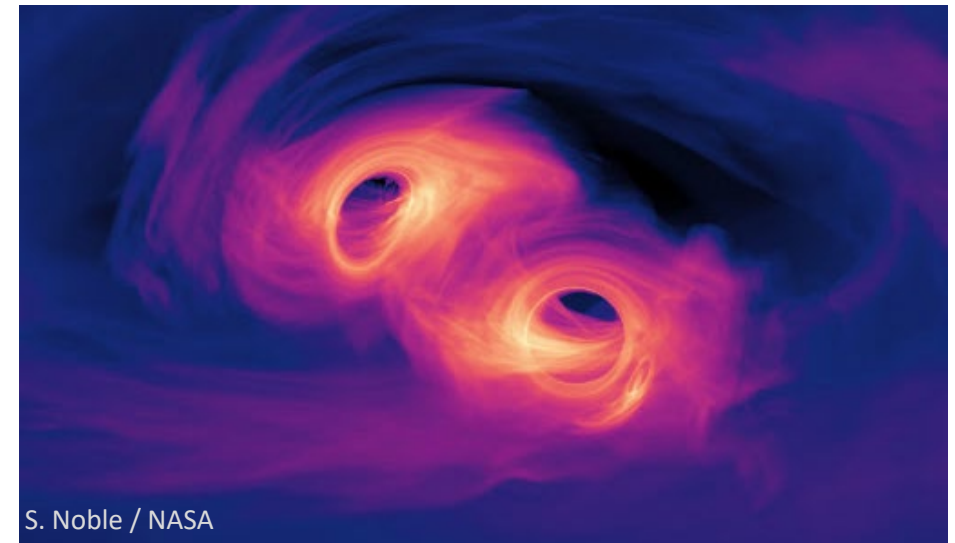

Laser Interferometer Space Antenna

Ira Thorpe, NASA Goddard Space Flight Center
NASA Astrophysics Advisory Committee Meeting
Washington, DC – March 21st, 2024



Albert Einstein Institute / Milde Marketing



S. Noble / NASA



Talk Outline

- **Highlights of recent developments**
- **NASA's Plan for LISA**
- **Formation of LISA Science Team**
- **Plans for Science Ground Segment**



Astro 2020 & LISA

From § 1.6

NASA's Program of Record. NASA's upcoming Roman Space Telescope, and ESA's Athena X-ray Observatory and LISA mission, in which NASA is a significant partner, are essential to the survey's science program. Advice on how to optimize the science return includes: holding a non-advocate review of Roman Space Telescope's science program to set the appropriate mix of survey time to guest investigator-led observing programs; and at the appropriate time, establishing funding for LISA science at a level that ensures U.S. scientists can fully participate in LISA analysis, interpretation, and theory.

NASA HQ and NASA LISA Study Office have been working hard towards realizing the goal of maximizing US participation in LISA science.



LISA's Recent Programmatic History



GWs selected as science theme for 3rd L-class mission

AO issued for L3 mission

LISA Concept selected for Phase A Study

Study advances to Phase B1

Mission Adoption Review

Mission Adoption, Establish Project Proceed to implementation



2013

2016

2017

2020

2022

2023

2024



LISA-relevant technologies competitively funded in SAT

L3 Study Team commissioned to analyze contributions

Technology development moved into Study Office, NASA LISA Study Team stood up

Hardware contribution down-selected to telescopes, lasers, & CMD

Initial formulation activities

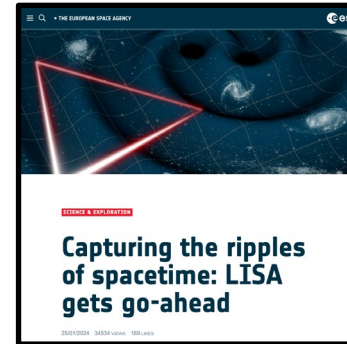
Establish Project, Proceed to implementation

Jan 25th, 2024: LISA is Adopted!

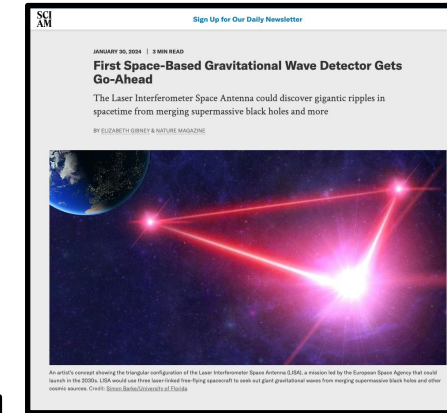


- **Critical milestone for ESA programs**
 - Action of Science Program Committee
 - Marks end of definition study phase
 - Allows ESA to proceed to implementation, including flight procurements
- **Adoption inputs**
 - ESA Technical Review (MAR), incl. NASA-provided technical assessments
 - Science assessment (AWG, SSAC)
 - ESA Inspector General Cost Review
 - [Definition Study Report](#)

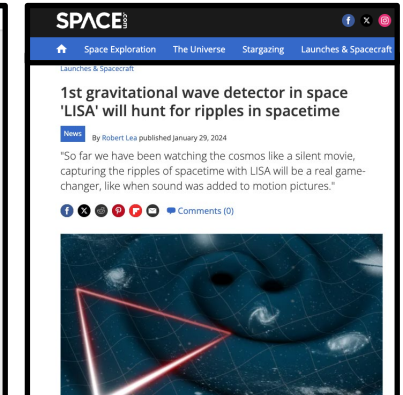
ESA



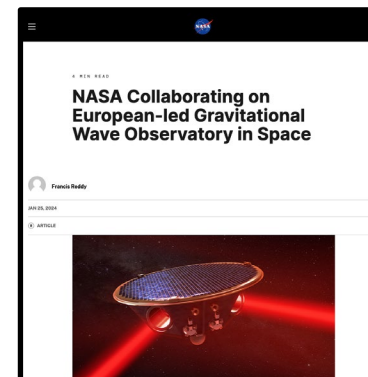
Scientific American



Space.com



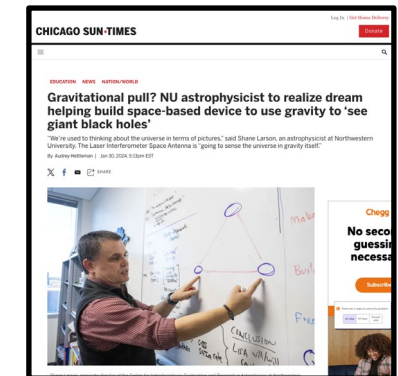
NASA



Ars Technica



Chicago Sun Times



Gizmodo

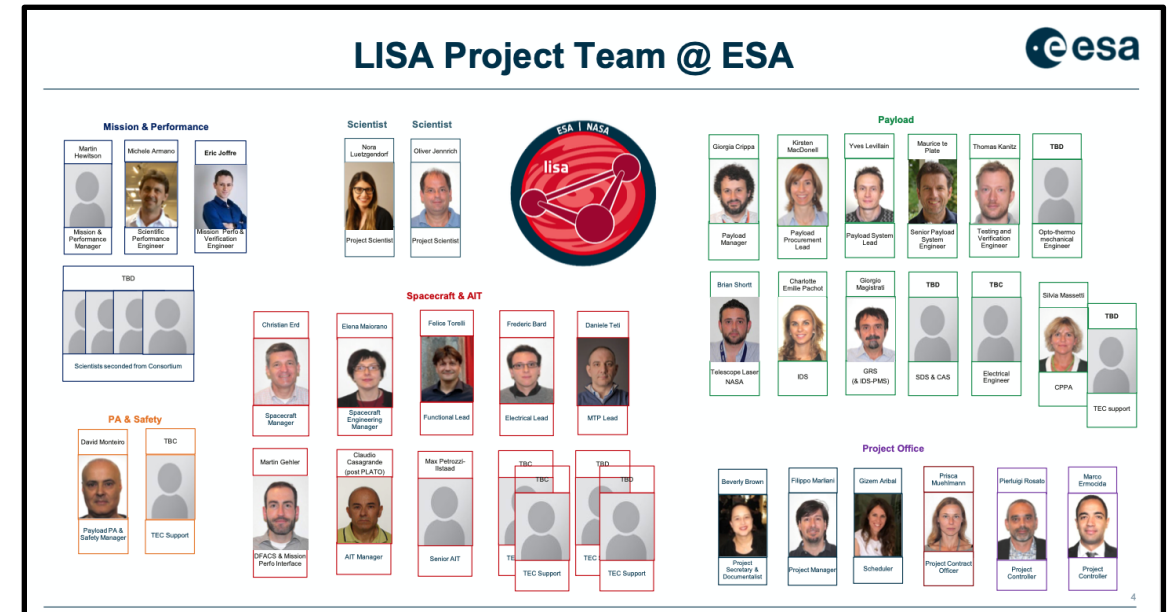


Sample press coverage for LISA Adoption announcement.



ESA is rapidly accelerating

- **Large project team in place**
 - Project manager and core project team from PLATO
 - Larger systems engineering team to allow for more hands-on in-house systems engineering
 - New “Performance Management” team to manage unique LISA aspects such as constellation error budgets, science performance assessments, etc.
 - Large science team assembled with open call
- **Immediate emphasis on establishing industrial partner**
 - Invitation to tender expected this Spring
 - Industrial kickoff as soon as December
- **ESA’s pace is putting pressure on partners**
 - ESA Member States with hardware deliverables
 - NASA
 - ESA Member States involved in ground segment

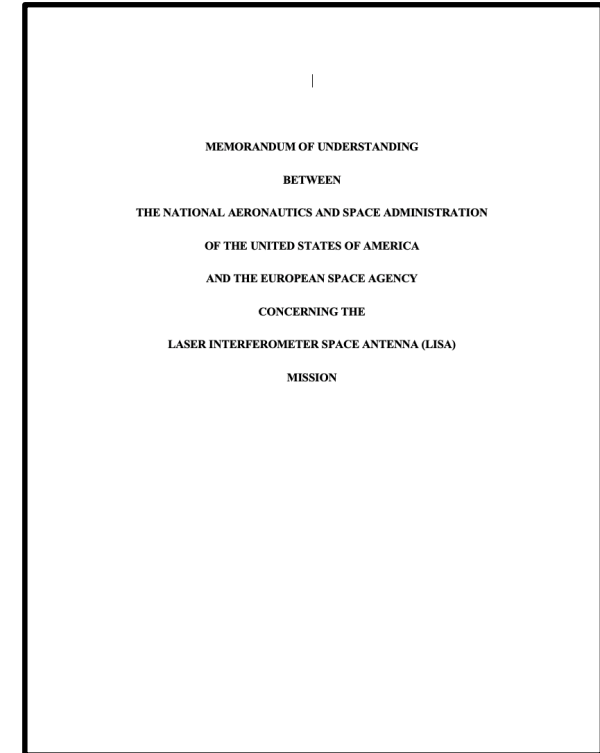


ESA has assembled a large and experienced team (chart from Nov. 23, many positions have since been filled)



NASA/ESA MoU near complete

- **Defines ESA & NASA partnership on LISA**
- **NASA Contributions**
 - Telescope systems
 - Laser systems
 - Charge Management Device
 - Science Analysis Support
 - Systems engineering and science support to ESA
- **ESA deliverables to NASA**
 - Participation in science and engineering teams
 - Access to all relevant data and models necessary for scientific data analysis
 - Public data policy to facilitate open science
- **Status**
 - Technical agreement completed Jan. 2024
 - Ready for signature on US side
 - Review by ESA Council on Mar. 26th
 - Signature expected in April

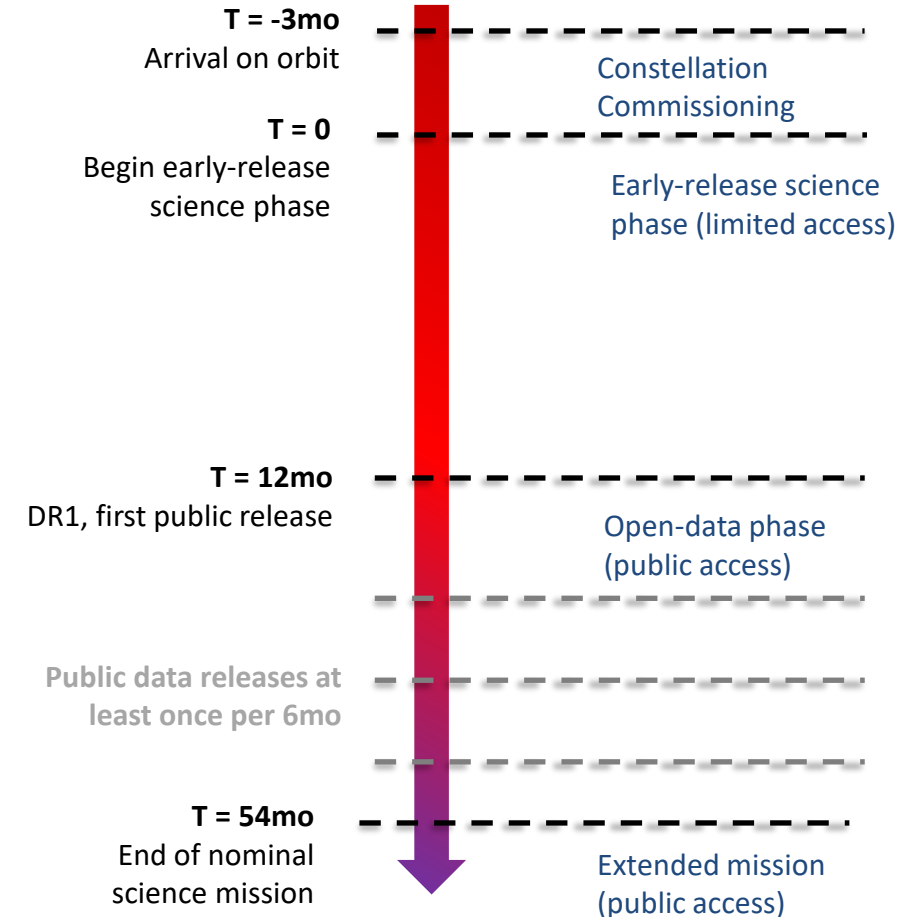


NASA/ESA Memorandum of Understanding on LISA



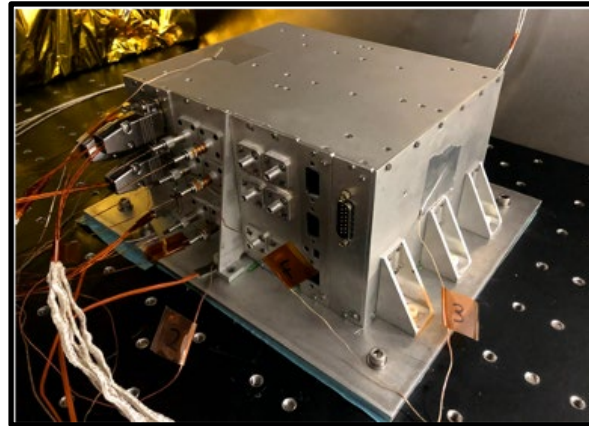
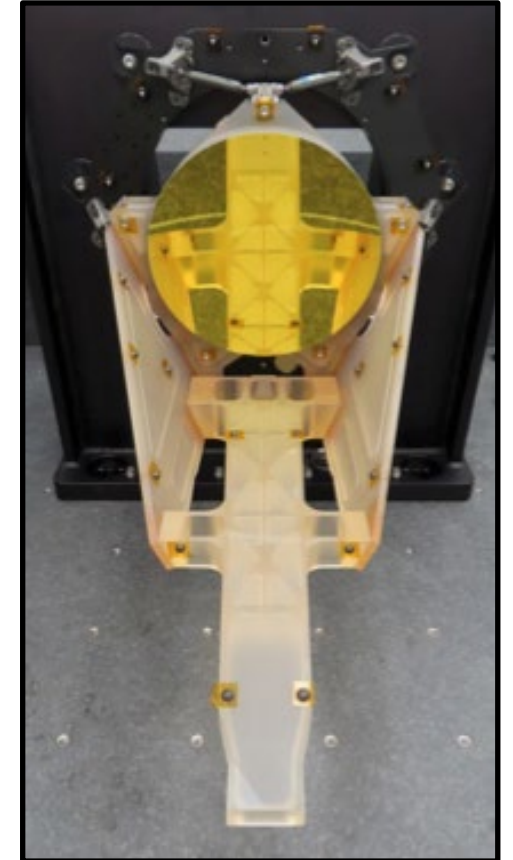
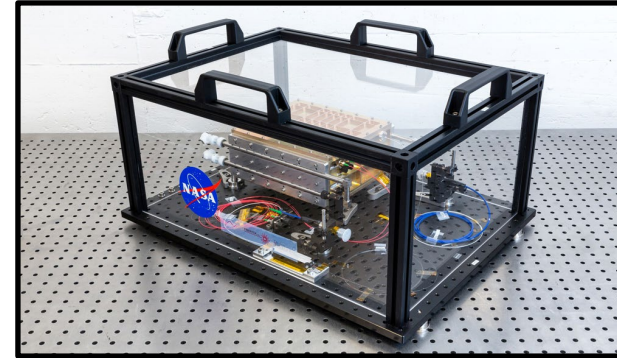
Summary of Science Data Policy

- **Balance multiple factors**
 - Maximizing science opportunity
 - Ensuring validity of results
 - Recognizing past contributions from science community
 - motivating future contributions from science community
- **Highlights of agreement**
 - Initial 12mo “early release science phase” (ERST) with limited data access
 - “Science Topical Panels”, selected in advance, will have access to LISA data and project experts during ERST
 - First public data release at 12mo, likely accompanied by STP publications
 - Remaining 3.5 years of nominal mission in public data mode with releases at 6mo minimum intervals
 - Releases will contain catalogs plus all lower-level data and tools not forbidden by industrial proprietary agreements.
- **Developing details a key task for ESA-NASA LISA Science Team**
 - Selection process for topics and members of Science Topical Panels
 - Details of release contents & process



Current LISA Activities @ NASA

- **Support ESA in Invitation to Tender Process**
 - Detailed review of interfaces to NASA-provided items
 - Review of constellation-level performance budgets and flow-down to individual elements
- **Finalize technology development**
 - Telescope EDU contract nearing successful completion
 - Laser approaching TRL6 milestone
 - Charge Management Device approaching TRL6 milestone
- **Prepare for flight procurements**
 - Assembling documentation
 - Conducting technical reviews



Demonstration units for NASA LISA hardware contributions. Clockwise from top left: TRL5 laser head (GSFC/Fibertek/Avo Photonics), EDU Telescope (NASA/L3 Harris), TRL5 Charge Management Device (U. Florida / Fibertek)



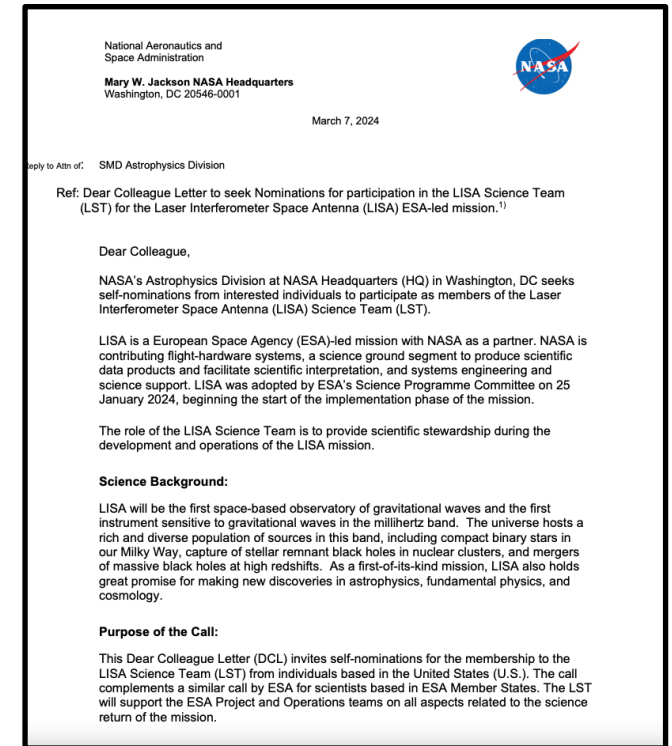
Progress on Transition to NASA Project

- **Formulation Documents Complete**
 - Project Authorization Letter delivered to GSFC Director Lystrup on April 11th, 2023
 - Formulation Authorization Document signed by SMD AA Fox on Oct. 27th, 2023
- **Standing Review Board (SRB) Chair and Deputy Chair selected**
 - Concurrence by HQ and GSFC management
 - Appointments confirmed by AA Feb 2024
- **Lifecycle Review strategy**
 - Study Office has drafted a proposal
 - Under review by GSFC management & HQ
- **Flight Procurements**
 - Proceeding with flight procurement preparation
 - Necessary to meet ESA's schedule needs
- **Transition Schedule**
 - First milestone review in Q3 2024
 - Project Transition complete before 2025
- **Funding needs are being met**
 - FY24 Congressional Budget
 - FY25 President's Request



LISA Science Team

- **Joint ESA & NASA science team for LISA**
 - Co-chaired by ESA & NASA Project Scientists
- **ESA/NASA MoU specified proportional representation**
 - 11 at-large European Members selected by ESA
 - 6 at-large US members selected by NASA
 - 1 LISA Consortium Representative
 - 2 External Scientists appointed by ESA
- **ESA selections in two-step application**
 - Mandatory Notice of Intent closed Feb. 21st
 - Anecdotal reports of strong interest
 - Applications due Mar. 27th
- **NASA selection via Dear Colleague Letter**
 - Issued on March 7th
 - Responses due April 16th
- **Selection process complete by mid-May**

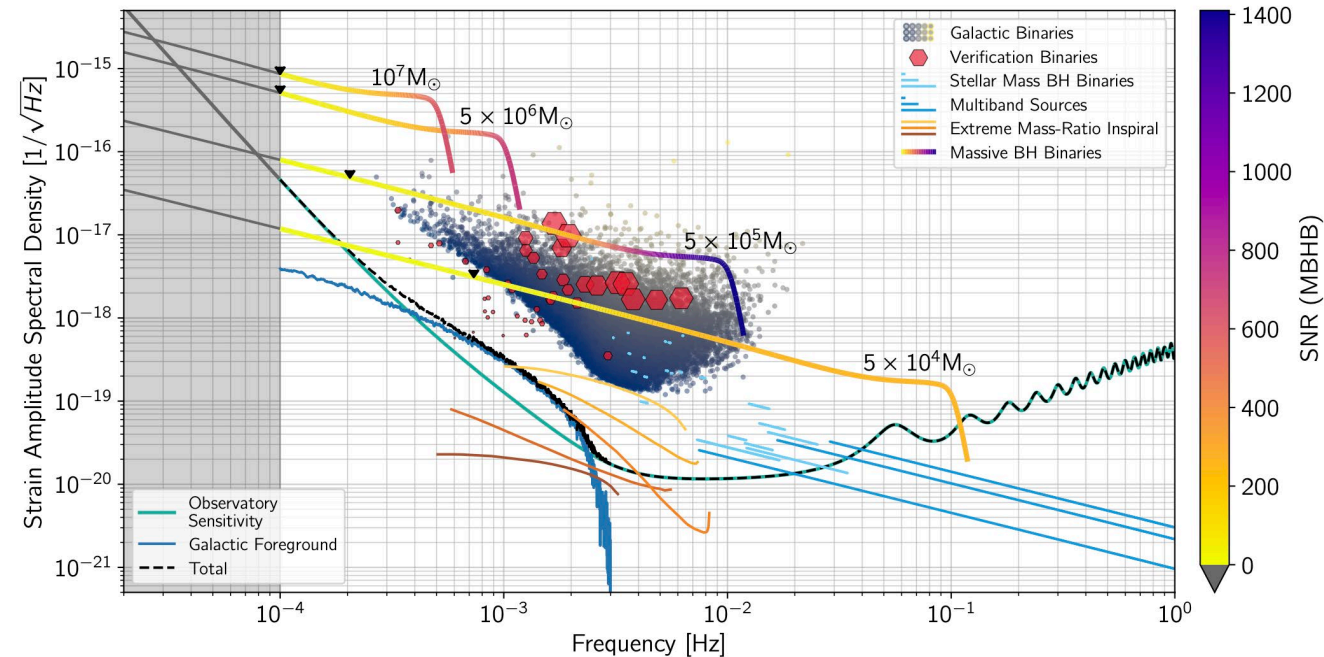


First page of NASA Dear Colleague Letter issued on March 7th. [Link to letter and more information on PhysCOS website.](#)



LISA Science Ground Segment - Background

- **LISA is a “spacetime seismometer”**
 - Simple operations, complex signal analysis
 - Data stream is a mix of many astrophysical signals and instrument noise
- **Extracting scientific data products from S/C telemetry is a multi-step, iterative process**
 - Collect & calibrate individual S/C signals
 - Build constellation-level products
 - Search for GW signal candidates
 - Construct source catalogs
- **Many Different Source classes**
 - Persistent & transient
 - Galactic and extra-galactic
 - Modeled and unmodeled
 - Resolved & unresolved
 - Individual coherent & stochastic



Gravitational Wave spectrum in the LISA band showing instrumental noise (green and black curves) as well as representative astrophysical sources of various classes. From ESA Definition Study Report.

Science Ground Segment – Global picture

- **Broad scope of activities**
 - S/C Command and Telemetry
 - Payload subsystem monitoring and maintenance
 - Instrument (constellation) performance monitoring and maintenance
 - Signal identification, extraction, and characterization
 - Production & publication of scientific data products
 - Support for scientific investigations (tools, grants, etc.)
- **Multiple international partners**
 - ESA Mission Operations (ESOC)
 - ESA Science Operations & Project Science
 - ESA Member States per Multi-Lateral Agreement (CNES lead, ~10 partners)
 - NASA (per MoU)

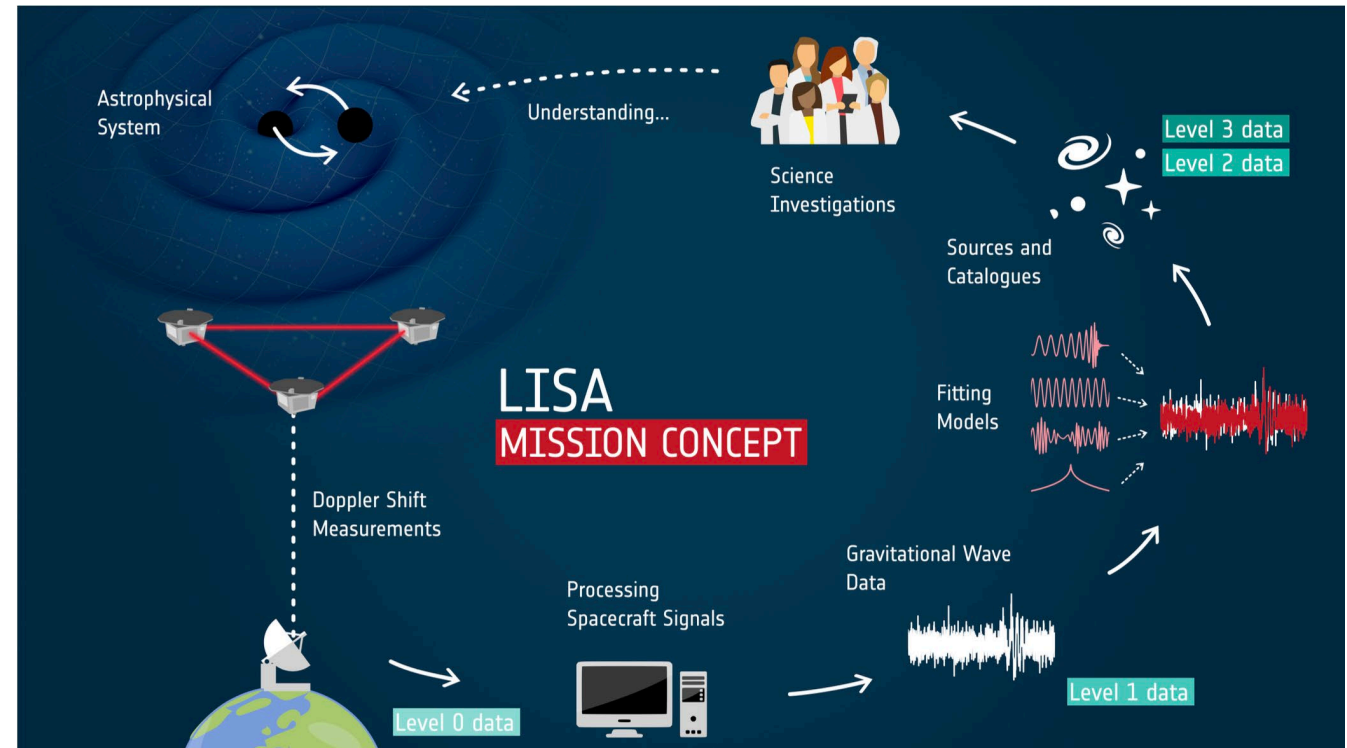
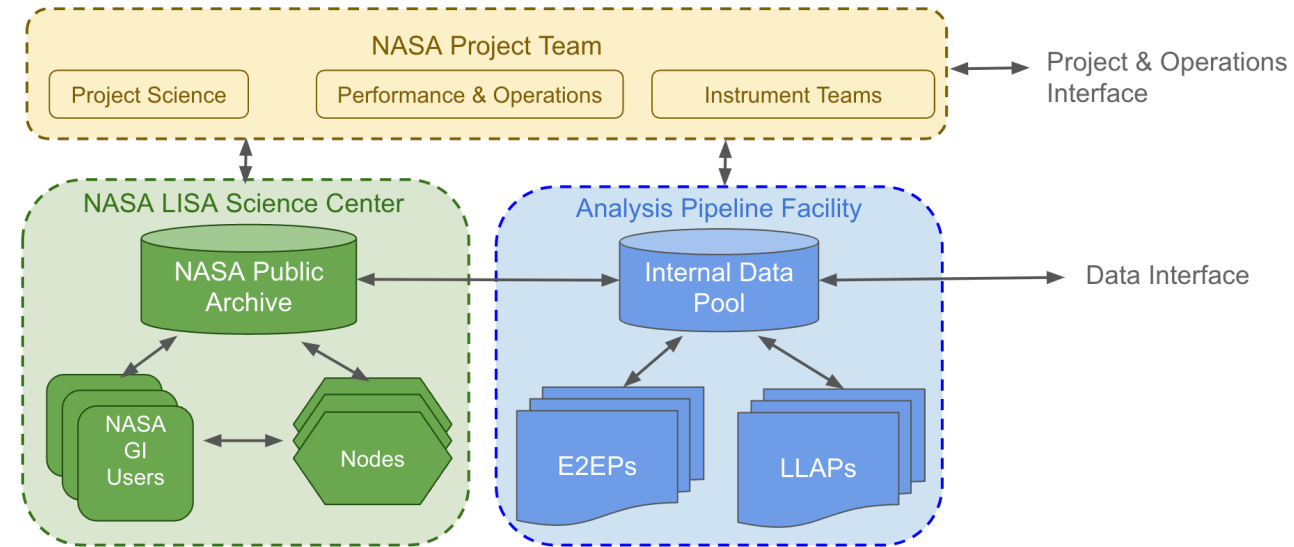


Illustration of LISA ground segment cycle from ESA Definition Study Report (ESA/N. Lutzendorf)



Science Ground Segment – NASA Plan

- **Primary functions**
 - Component and constellation-level instrument analysis
 - GW signal identification
 - Production of scientific data products
 - Distribution of data products & science support
- **Project Team**
 - Build on study office staff incl. GSFC, MSFC, & JPL
 - Integrate expertise in instrumentation, data analysis, astrophysics
 - Coordinate with ESA and member states
- **Analysis Pipeline Facility**
 - Develop & operate core production pipelines
 - Tightly integrated with the rest of the NASA project team
 - Close coordination with ESA
 - Follow “hardware model”
- **Science Center**
 - Support the US-based science community
 - Provide public data, tools, expertise
 - Coordinate Guest Investigator program
 - NASA Plans to Compete the LISA Science Center



Notional elements of NASA Project contributing to SGS. From NASA Science Implementation Plan.

Current work on Analysis Pipeline Facility

- **“Technology Development” for pipelines**
 - Conduct large-scale mock data exercises
 - Coordinated with European partners
 - Substantial progress in demonstrating tall-pole capabilities
- **Interface with ESA & Member States**
 - Formalize requirements & interfaces
 - Develop management structure
- **Transition from R&D to project deliverable**
 - Adding management and engineering support to complement existing scientific expertise
 - Identifying programmatic and technical milestones

Prototype “global fit” code simultaneously extracts multiple astrophysical signals and estimates instrument noise in simulated LISA data. From ESA Definition Study Report based on work from T. Littenberg (NASA/MSFC)

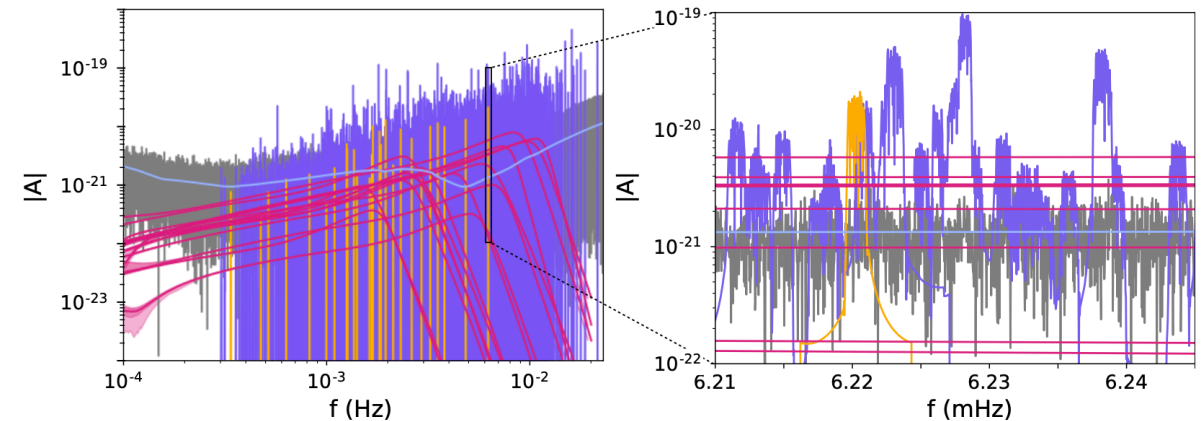
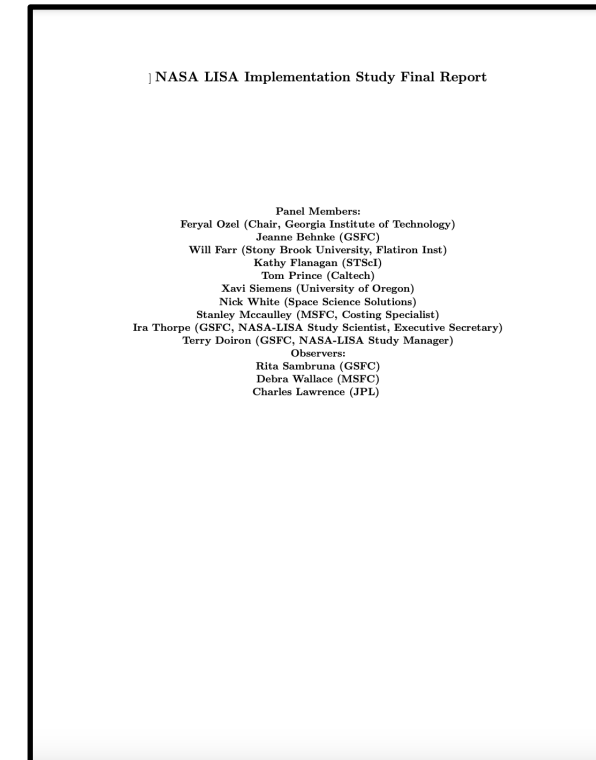


Figure 8.6: Results from global fit analysis of LDC2a data showing simultaneous reconstructions of the resolvable Galactic binary (purple), verification binaries (orange), massive Black Hole mergers (magenta), residuals (grey), and noise model (blue). The right panel focuses on the frequency interval containing HM Cancri. Both plots display the amplitude spectral density of the TDI A Channel.



Science Center Activities

- **Adding support to develop plan for a possible competitive acquisition of the Science Center**
 - Functional Requirements
 - Cost & Schedule
 - Interfaces to other NASA and international entities
 - Reference architectures
- **Primary Goals (identified in SIDC report)**
 - Provide access to full array of data products
 - Enable broad participation in LISA science & analysis
- **NASA Plans to compete the LISA Science Center**



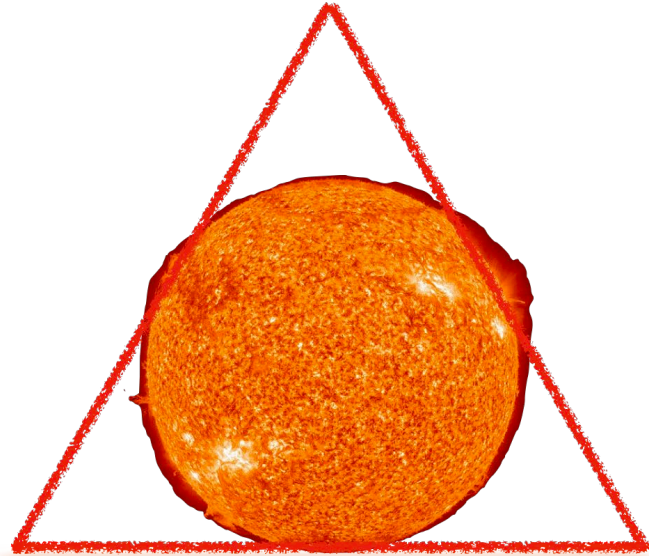
Science Implementation Data Center (SIDC) committee final report by Özel, et al.



Summary

- **LISA is moving forward**
 - 50 years since Bender & Weiss discussed space-based GW detector at a NASA meeting!
 - ESA has committed to LISA as its next flagship astrophysics mission
 - NASA is an essential partner involved in many aspects of the mission
- **NASA is transitioning LISA to a Project**
 - Technology development nearly complete
 - Project structure at GSFC in development
 - Ready for KDP reviews in the near future
- **Groundwork laid for robust US science participation**
 - Negotiated data policy consistent with open science principles
 - US representation in ESA science team provides “seat at the table”
 - “Technology Development” for key ground-segment functions demonstrating progress
 - Plans for science center in development

Thanks / Questions



$$2\sqrt{3}R_{\odot} \approx 2.4 \text{ Gm}$$