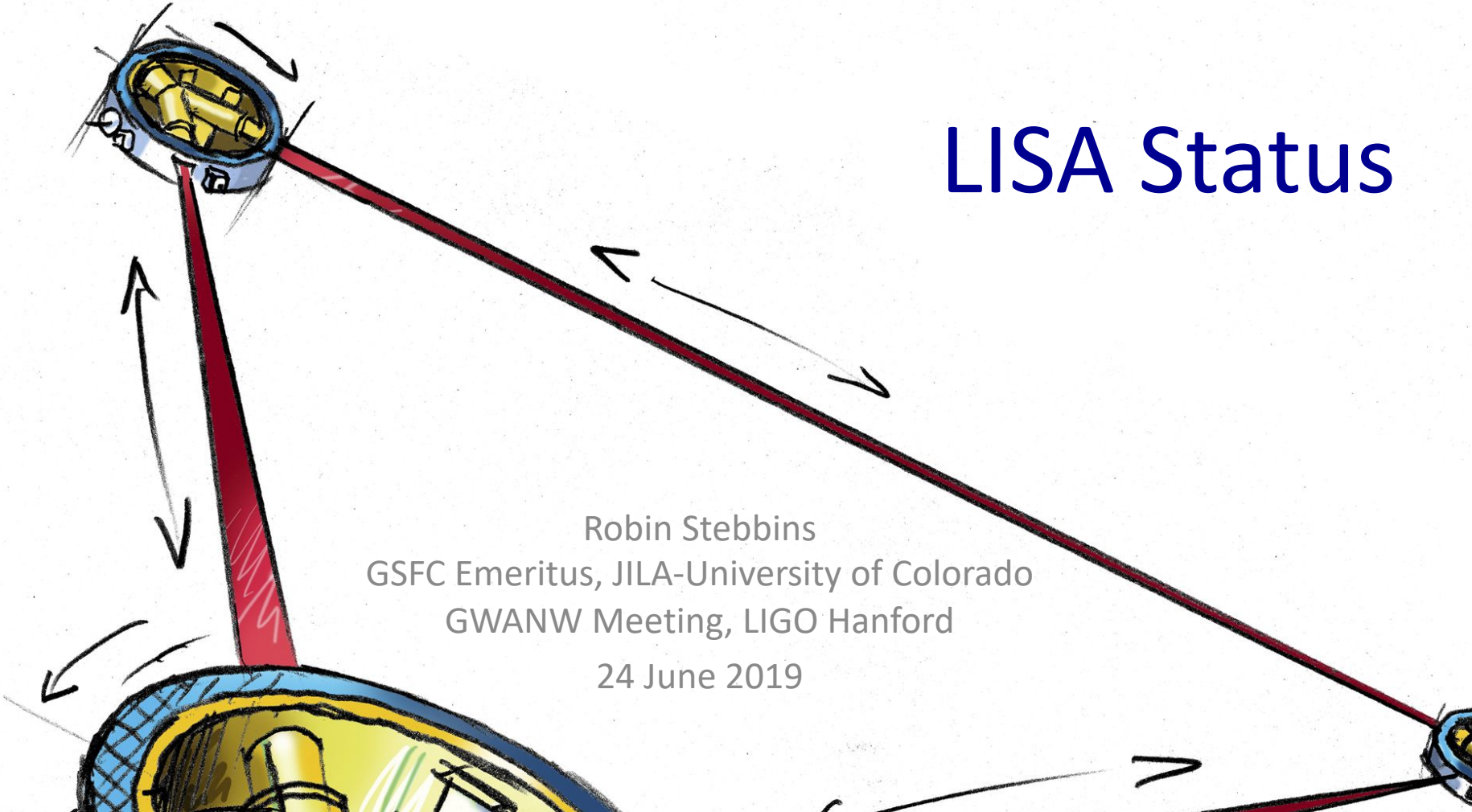


LISA Status

Robin Stebbins
GSFC Emeritus, JILA-University of Colorado
GWANW Meeting, LIGO Hanford
24 June 2019

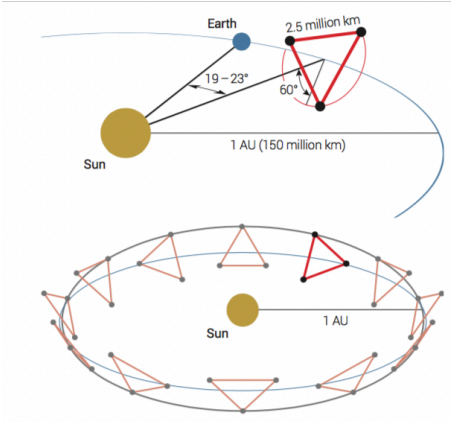
LISA Status

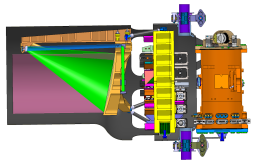
- Mission Concept
- Sources
- Science
- Programmatics
  - Project organization
  - LISA Consortium
  - Budget and schedule

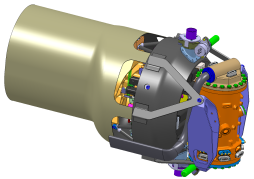
- NASA activities
  - Study organization
  - Astro2020 decadal
  - Technology development

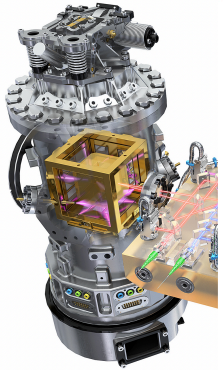
Critical elements of the mission concept

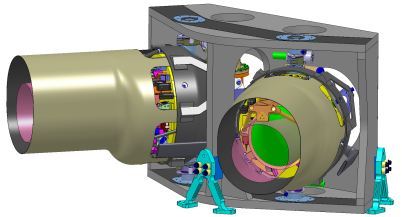
- Laser interferometer using triangular constellation of spacecraft in heliocentric orbits
- Continuous laser interferometric ranging with picometer sensitivity
- Arms millions of kilometers long
- Drag-free masses with femto-g disturbances
- Time delay interferometry (TDI)







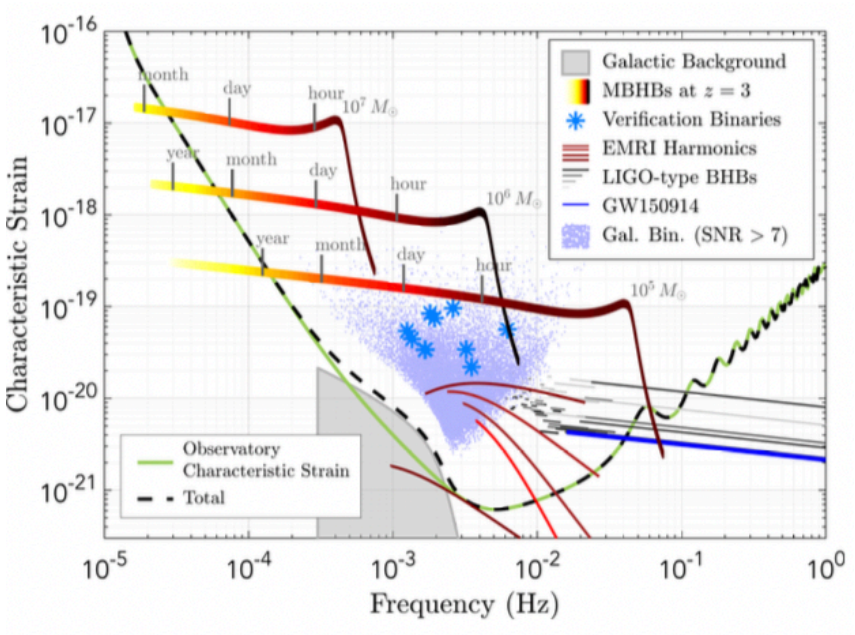


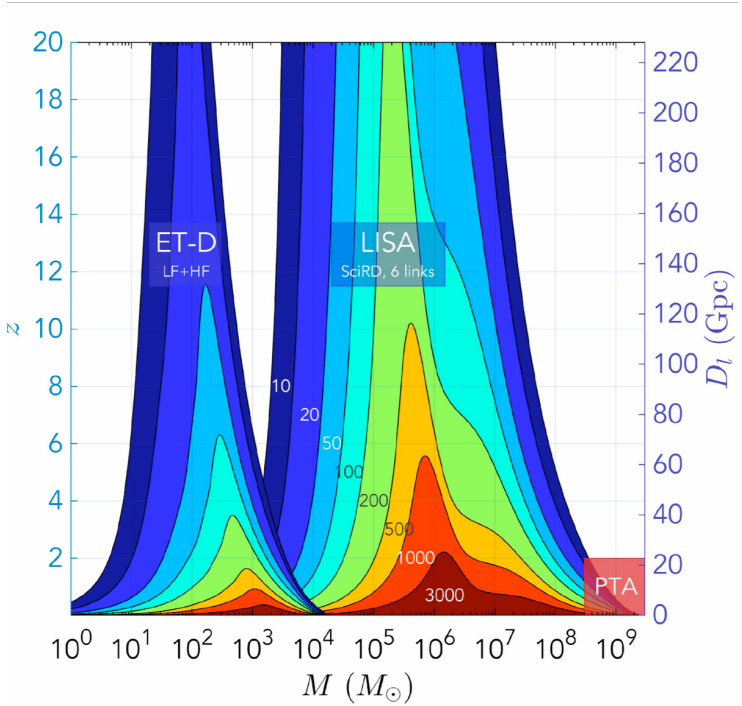


Instrument

Characteristic	LISA
Operating band	0.1mHz – 0.1 Hz, 20μHz – 1 Hz goal
Armlength	2.5 Mkm, could be 1-10 Mkm, set by orbit choices and evolution, and system design choices.
Limiting noises	Spurious low-frequency forces: thermal effects, residual gas, stray electrostatics, shot noise, cross-couplings
Directional information	Orbital motion gives amplitude modulation, frequency modulation and phase modulation
Polarization information	Instantaneous from 2 interferometers, evolves with time.
Instrument lifetime	Fixed, up to 10 yrs. No repairs. Lifetime limited by consumables and orbital evolution.
Outstanding technology challenges	Reliability of lasers and microthrusters, system robustness, stray light

LISA Science





Credit: N. Cornish, M. Hewitson, and the LISA and ET Teams. Created for the Gravitational Wave International Committee (GWIC).

LISA Sources

- MBHBs: ~100 10^4 - 10^7 M_{sun} inspirals/mergers/ringdowns out to z~20
- Stellar-mass compact objects: ~3x10^4 quasi-stationary WD/NS/BH binaries in the galaxy, confusion foreground, optical counterparts
- EMRIs & IMRIs: ~100s/yr EMRIs, rate uncertain
- IMBHs (10^2 - 10^4 M_{sun}): Detection to high z, rate unknown
- Massive stellar BHs (<10^2 M_{sun}): ~100 BH early inspirals out to z~0.1, crossing into the 3G band to merge
- Bursts and backgrounds: Possibly cosmic strings, bursts, discoveries.

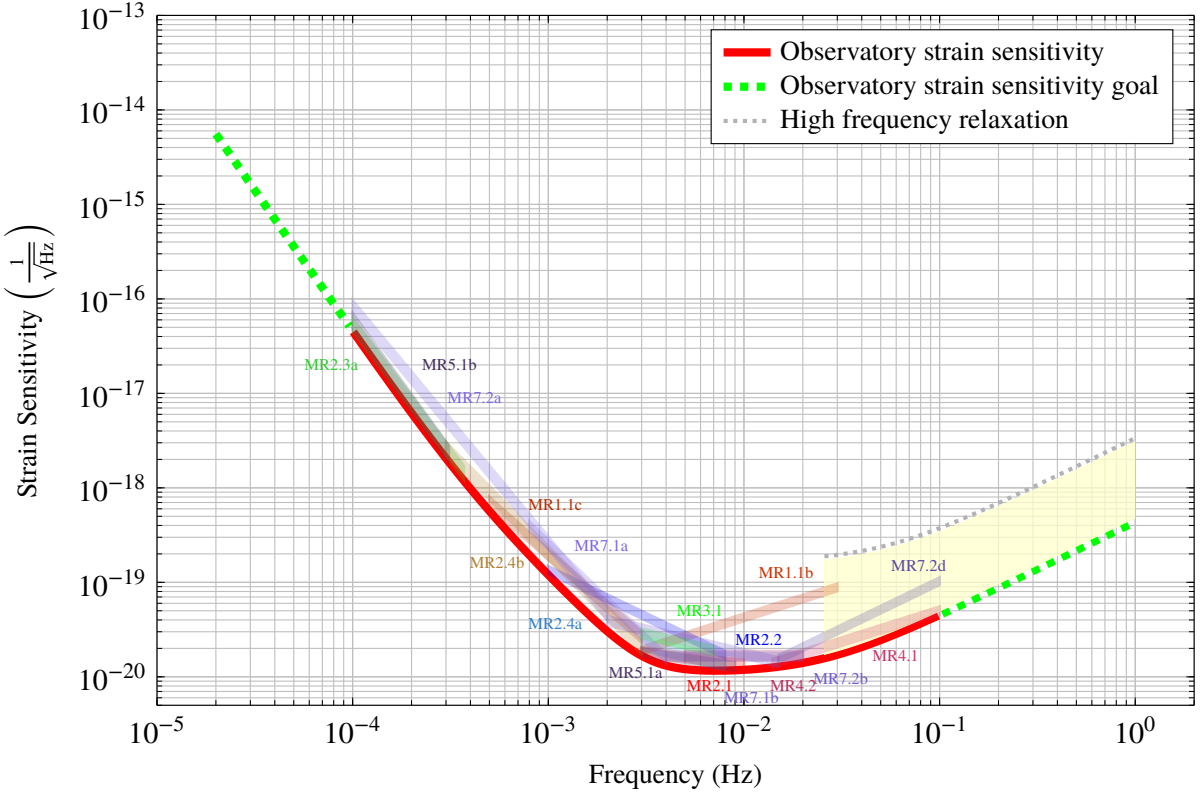
LISA signals and data analysis

- Tens of thousands of superimposed sources, requiring simultaneous fitting
- SNRs up to 10^4 enable high precision measurement of source parameters, like mass, spin vectors, orbital parameters, distance, sky location
- All sky instrument with sky location encoded in the waveforms through amplitude, frequency and phase modulation
- Merger events weekly, sources emerging and disappearing constantly
- Most galactic binaries and EMRIs are detectable for the duration of the mission
- MBH mergers predicted weeks to months in advance. Prediction alerts will be sent out, with progressively improving information.
- Source information improves with weekly-monthly catalog updates
- Sagnac mode allows monitoring the instrument noise constantly.

LISA Science

- Study the formation and evolution of compact binary stars in the Milky Way Galaxy
- Trace the origin, growth and merger history of massive black holes across cosmic ages
- Probe the dynamics of dense nuclear clusters using extreme mass-ratio inspirals (EMRIs)
- Understand the astrophysics of stellar origin black holes
- Explore the fundamental nature of gravity and black holes
- Probe the rate of expansion of the Universe
- Understand stochastic GW backgrounds and their implications for the early Universe and TeV-scale particle physics
- Search for GW bursts and unforeseen sources

Noise Requirements, derived from Science Requirements



Project Organization

- ESA-led mission. NASA is a junior partner. JAXA may join. Roles and responsibilities not finalized.
- ESA Study Office formed, System Engineering Office staffed.
- Instrument proposal by LISA Consortium
- Phase A (Conceptual Design) is in progress
  - Competing prime contractors: Airbus Defence and Space GmbH and Thales Alenia Space S.p.A.
  - Instrument contract to AEI/Hannover
  - Activities: Mission Definition Review (MDR) completed, trade studies, design consolidation, contract management, technology development, Mission Consolidation Review (MCR) in progress
- Science Study Team (SST): Science Requirements Document completed, Athena/LISA Working Group, Data Policy study in progress.

LISA Consortium

- Successful proposal for instrument design, following successful mission proposal (L3)
- Consortium formed
  - Organizational structure, bylaws, topical groups, working groups, etc. created
  - ~14 member states + US members
  - >1,000 members
- Responsible for development and provision of nationally funded contributions (Moving Optical Subassembly and subsystems) and provision of data processing
- Activities: instrument design, key performance parameters, internal and external interfaces, model plan, AIVT plan, science and data analysis preparation, instrument simulation, etc.
- Join at elisascience.org

Schedule and Budget

Schedule

- June 2017 – LISA selected as L3
- May 2018 – Phase A started
- 2018-2020 – Phase A
- Mid 2020 – Formulation Review
- 2020 – Phase B1 start
- 2024 – Adoption
- 2025 – Phase B2, C and D
- 2034 – Launch
- +6.5 yrs – Ferry, commissioning, baseline science operations
- +4 yrs – Extended operations

Budget (very rough)

- ESA L-class cap – 1.04 Beuro
- Member states - ~200 Meuro, TBC
- NASA - $400M for flight system + $100M for science analysis

NASA Organization

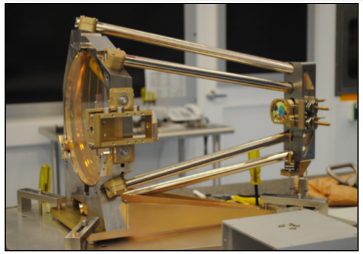
- Study Office: Study Manager, Study Scientist, Systems engineer
- NASA LISA Study Team (NLST): 18 members, Kelly Holly-Bockelmann chair
- LISA Core Team: GSFC, JPL and U Florida scientists and technologists
- More info at lisa.nasa.gov

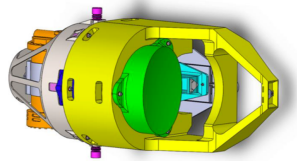
- Activities
  - Participate in mission formulation (management, system engineering, design definition, requirements flow-down, trade studies, etc.)
  - Support HQ with analysis and studies (e.g., data center, data policy)
  - Participate in Consortium activities
  - Prepare for Astro2020
  - Technology development

LISA Technology Development

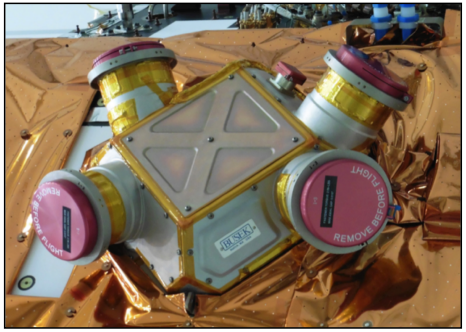
Heritage of LISA Pathfinder and GRACE Follow-On missions.

- Telescope
- Laser
- Charge management system
- Phasemeter
- Microthrusters
- Optical bench manufacture
- Precision mechanisms

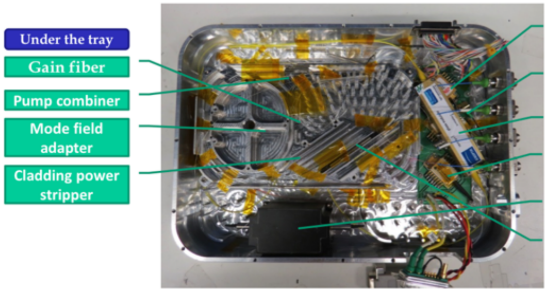


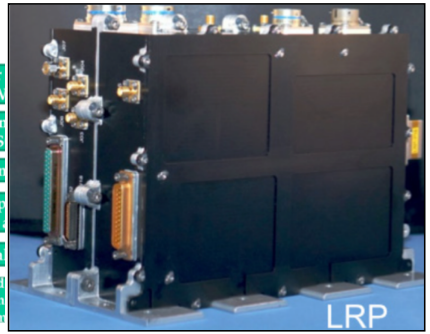


(top) Telescope functional prototype for scattered light tests. (bottom) Draft mechanical design (yellow)



Colloidal Micronewton thruster cluster on LPF. (JPL/J. Zeimer)





Laser Ranging Processor (FM) for GRACE-FO LRI (JPL/Klipstein)

Summary

- LISA is established and advancing at both ESA and NASA.
- Phase A is approaching the midway mark; MCR in progress.
- ESA, NASA, Member States and Consortium are all examining their roles and responsibilities.
- Technology development on track for nominal schedule
- NLST
  - On track with decadal preparations
  - Various outreach activities
  - Carrying out ‘analyses’ as requested