

APPLICABLE DOCUMENTS

- 1 Baker, et al. “The Laser Interferometer Space Antenna: Unveiling the millihertz gravitational wave sky” (2019) available at <https://arxiv.org/abs/1907.06482>
- 2 Holley-Bockelman, et al. “Empowering LISA Discovery” (2020) available at https://pcos.gsfc.nasa.gov/news/NLST_SSTF_Report_Final.pdf
- 3 Martin, et al. “LISA Independent Review (LIR) Report” to be provided by the LISA Study Office upon request of the review team.
- 4 *SPD-41: Scientific Information policy for the Science Mission Directorate (2021) available at: <https://science.nasa.gov/science-red/s3fs-public/atoms/files/Scientific%20Information%20policy%20SPD-41.pdf>*

1 BACKGROUND

The Laser Interferometer Space Antenna (LISA, <https://lisa.nasa.gov>) is a mission currently under joint study of the European Space Agency (ESA) and NASA that will observe the universe in the millihertz gravitational wave spectrum. These observations are expected to yield a rich and diverse data set that will enable science investigations across a broad range of disciplines in astrophysics, fundamental physics, and cosmology. LISA is a mission that delivers transformative, flagship-scale science as was cited in both the 2000 and 2010 Decadal Surveys. By partnering with ESA, NASA is able to participate in this science at a much smaller cost scale.

ESA is the lead agency for LISA and is responsible for much of the flight segment including the spacecraft bus, launch vehicle, and mission operations as well as ground-segment elements including elements of the science data pipeline and a science archive. NASA currently is making contributions to LISA as a junior partner including a substantial fraction of the science instrument suite (telescopes, lasers, charge management devices), systems engineering support, and preliminary activities in science and data analysis. The remainder of the instrument suite, as well as a substantial fraction of the data analysis pipelines and science, will be contributed by a collection of European National Science and Space Agencies. The LISA Consortium has been formed with the dual purposes of coordinating the deliverables funded by these European National Science and Space Agencies and organizing the development of the data analysis pipelines and science activities.

NASA has created the NASA LISA Study Office (NLSO) at Goddard Space Flight Center (GSFC) within the Physics of the Cosmos Program Office (PCOS) to coordinate technology development for potential hardware contributions and to establish and maintain technical and management interfaces with NASA’s European partners. In addition, the NLSO supports a small team of subject matter experts in gravitational-wave science and data analysis to develop prototype elements of the science ground segment and to coordinate on similar activities with their European counterparts. NASA HQ has also formed the NASA LISA Study Team (NLST), an independent group of US-based scientists with expertise in science disciplines targeted by LISA. The NLST serves as representatives of the future US LISA user community and provides valuable analysis on the potential science impact of various LISA implementation options.

LISA will operate as a survey instrument with minimal adjustment of the observing mode or schedule. Tens of thousands of individual sources will simultaneously be observed; including binary systems of compact objects in the Milky Way, mergers of massive black holes in the early

universe, and a range of other sources at intermediate redshifts. Differences in the source characteristics (persistent vs. transient, coherent vs. stochastic, etc.) require that different analysis techniques are applied to each. A “global fit” algorithm (or algorithms) will be used to identify and characterize all of the sources as well as assess the performance of the instrument. Consequently, the LISA data analysis and science program must be well integrated and coordinated among the participating partners, much like the instrumentation in the flight segment.

ESA’s LISA study is currently approaching the end of Phase A, with the Mission Formulation Review (Phase A completion review) scheduled for Fall 2021. The flight segment and instrument design have been the primary focus of Phase A activities, with only a modest amount of definition and development of the science ground segment. Increased activity in this area is likely during Phase B, which will commence upon a successful completion of MFR. Further ahead, the Mission Adoption milestone is anticipated in 2024. At this milestone, the roles and responsibilities of the partner agencies will be confirmed, including roles in the science ground segment, policies for data access and delivery, etc. This will include the establishment of a formal NASA/ESA agreement in the form of a Memorandum of Understanding. In parallel with the project maturation in Europe, NASA will transition NLSO to a project office at some point before Mission Adoption. In addition to the NASA hardware contributions, the NASA contributions to LISA data analysis and science must be defined. The objective of this study is to provide an initial conceptual definition of these activities as discussed below. This study will not develop detailed requirements for a future science ground segment. Should NASA decide to pursue any of the recommendations made by this panel, those requirements will be developed at a future time.

2 Purpose

The purpose of the LISA NASA Science Implementation Data Center Study (hereafter the SIDC Study) is to conduct a conceptual analysis of the LISA science ground segment and science activities with the aim of identifying potential NASA contributions. The study will seek to answer the following broad questions:

- What should NASA’s role(s) in the LISA science ground segment look like, in terms of architecture, concept of operations, top-level requirements, and interfaces?
- How do the suggested NASA roles fit into existing NASA organizations or entities (e.g. future LISA project, multi-mission archive and data facilities, etc.)? Which components of a NASA contribution may need to be created or competed?
- What is the recommended approach to develop the NASA contributions, including high level schedule and (parametric) budget?
- Are there alternative approaches that should be considered as well? If so, what are their architectures, concept of operations, requirements, and interfaces? How do they differ and what are the pros and cons of each?

3 SCOPE

The NASA LISA Science Implementation Study will consider all aspects of potential NASA activities in the LISA science ground segment and related science support. These include development and operation of data analysis pipelines to produce the LISA science data products from low-level mission data products, archives/investigator facilities to serve these products to the US-based LISA user community, and direct support to the US community to

facilitate science investigations (e.g. Guest Investigator programs, theory investigations, etc.). An overview of the LISA science ground segment and potential US roles can be found in the NLST report *Empowering LISA Discovery* listed in the Applicable Documents section above.

4 ASSUMPTIONS

The study will operate under the following assumptions:

Development Schedule – Establishment of NASA project in 2023 (TBC), NASA KDP-A/B in 2023 (TBC), NASA ESA Mission Adoption review in 2024. Note that a NASA/ESA Memorandum of Understanding defining roles and responsibilities, including science ground segment roles, is a prerequisite for Adoption.

Operational Schedule - Launch in 2035, 18 months cruise, 9 months science commissioning, 4 year baseline science operations, and potential 6 year extended mission operations.

Budget – A budget for NASA’s science contributions has yet to be established. However, NASA hardware contribution is capped at \$400M.

International Partnerships – NASA’s formal partnership on LISA will be with the European Space Agency (ESA). NASA will work with ESA to coordinate ground segment and science activities with those of contributing ESA member states, including those organized under the auspices of the LISA Consortium.

Data Policy – Standard NASA policies for data access and availability, which promote open access, will apply to all data produced by the NASA LISA project (see [SPD-41 “Scientific Information Policy for the Science Mission Directorate”](#)).

5 COMPOSITION OF THE STUDY TEAM

In addition to the chair, a Study Manager will facilitate distribution of review materials, take meeting notes, and provide additional logistical support as needed. The study panel shall consist of independent subject matter experts with the following expertise:

- Gravitational wave astrophysics
- Signal processing / data science / science algorithm development and operations
- Science ground segment / data center / archive development and operations
- NASA Science Program / Project management
- NASA Data Policies

Members of the NLSO and NLST can be made available to provide technical expertise on LISA data analysis, information on current European activities, and other relevant information to the SIDC Study Team.

The SIDC Study Team will make recommendations to the PCOS Program Office, and the Program Office will use these recommendations to propose an implementation plan and corresponding budget for NASA’s science contributions to LISA. NASA HQ will have the decision authority for choosing which recommendations to implement. This will remove any

perceived conflicts of interest for the study team in future competitive procurements.

6 STUDY CONDUCT

The Physics of the Cosmos (PCOS) Program Manager will select the Study Chair and Study Manager. The Study Chair will nominate panel members with concurrence by the PCOS Program Manager. Panel members will be independent of the LISA Study / Project office, and they can originate from within or outside NASA. The PCOS Program Manager may also invite observers or ex-officio members from NASA to participate in the panel activities. The Study Manager will support the Chair by coordinating schedules, setting up meetings, taking minutes and documenting results. The Study Manager will ensure that all briefings and reading materials will only include content that is already public domain. This will ensure that the study team does not have access to information that might create a conflict of interest.

The results of the review will be pre-briefed to the LISA Study Manager, LISA Study Scientist and the GSFC Astrophysics Director/PCOS Program Manager and Chief Scientist and their deputies prior to the final presentation to the HQ Program Executive (PE) and Program Scientist (PS). The PE and PS will be briefed prior to briefing the HQ APD Director and their deputy.

7 STUDY DELIVERABLES

The study shall deliver a report with the following content:

- A scenario or scenarios for NASA participation in the LISA ground segment and science activities
- For each scenario, develop a block diagram of the conceptual architecture indicating key interfaces
- For each scenario, a high-level identification of the data products and a plan for access by the US-based user community
- For each scenario, an assessment of the cost, schedule, and science impact
- For each scenario, a description of the required interface with international partners, *including data access*
- For each scenario, a list of potential acquisition strategies and an assessment of the pros/cons for each. This team will be disbanded and will not participate in the initiation of any procurement processes for any acquisition strategies advocated by this study. In this way, the participants will not be subject to any unfair access or conflict of interest.
- A recommendation for a particular scenario if more than one are evaluated.
- Prioritization of scenarios, as well as activities/tasks/elements within each scenario, adequate to permit NASA to make a cost-constrained implementation decision for a range of cost constraints.

8 SCHEDULE

This study will commence in early fiscal year 2022 with a team kickoff. The goal is to complete the study in sufficient time to inform PPBE24 in Spring 2022. The notional study schedule is as follows:

- Selection of Team no later than the end of September 2021
- Review to be completed by the end of February 2021

- Final Report by the end of March 2022

9 SUNSET

The team should be disbanded after delivery and presentation of the final report to NASA Headquarters. Further dissemination or distribution of the study products will be at the discretion of NASA HQ