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LISA

Outlook

- LISA renamed New Gravitational wave Observer
- Jupiter Icy moon Explorer selected over NGO for Cosmic Vision 2015-2025 launch slot
- ESA continued LISA Pathfinder development even after NGO terminated; launch of LISA Pathfinder occurred in December 2015

Orientation

Description. The Laser Interferometer Space Antenna (LISA) mission was planned to be a constellation of three satellites designed to detect and study gravitational waves from a heliocentric orbit. The LISA Pathfinder mission consists of one satellite to test the feasibility of the system's laser interferometry.

Sponsor. The European Space Agency and NASA were the sponsors of the LISA mission. ESA sponsors the LISA Pathfinder technology demonstrator mission.

Status. The LISA was canceled. The LISA Pathfinder launched in December 2015.

Total Produced. One.

Application. The objectives of the program are to observe gravitational waves from sources involving massive black holes; observe gravitational waves from thousands of double-star systems; determine the number and distribution of such systems in the Milky Way galaxy; and search for a possible cosmic background of gravitational waves, remnants from the Big Bang.

Price Range. The estimated cost to design, produce, and launch both LISA missions (LISA and Pathfinder) was $2.3 billion. The LISA Pathfinder cost a fraction of that amount.

Contractors

Prime

Airbus Defence and Space	http://www.airbusdefenceandspace.com, 31, Ave des Cosmonautes, ZI du Palays, Toulouse, 31402 France, Tel: + 33 5 62 19 62 19, Fax: + 33 5 61 54 57 10, Prime

Subcontractor

INNOLIGHT GmbH	http://www.innolight.de, 10 Garbsener Landstrasse, Hannover, D-30419 Germany, Tel: + 49 0 511 760 7270, Fax: + 49 0 511 760 72799, Email: sales@innolight.de

	(High Stability Laser)
RUAG Space AG	http://www.ruag.com/space/, Schaffhauserstrasse 580, Zurich, 8052 Switzerland, Tel: + 41 44 306 22 11, Fax: + 41 44 306 29 10, Email: info.space@ruag.com (Modulator)
STFC Rutherford Appleton Laboratory	http://www.stfc.ac.uk/, Chilton, Didcot, OX11 0QX Oxfordshire, United Kingdom, Tel: + 44 1235 445000, Fax: + 44 1235 445808, Email: enquiries@stfc.ac.uk (Glass Interferometer)
Tesat-Spacecom GmbH & Co KG	http://www.tesat.de, Gerberstrasse 49, Backnang, D-71522 Germany, Tel: + 49 7191 930 0, Fax: + 49 7191 930 1835, Email: peter.lust@electronicnote.com (High Stability Laser)
Thales Alenia Space	http://www.thalesgroup.com/en/worldwide/space, 100 boulevard du Midi, BP99, Cannes la Bocca, 06156 France, Tel: + 33 4 92 92 70 00, Fax: + 33 4 92 92 31 40 (X-Band Transponder)
University of Florida – Department of Physics	http://www.phys.ufl.edu/, PO Box 118440, Gainesville, FL 32611-8440 United States, Tel: + 1 (352) 392-0521, Fax: + 1 (352) 392-0524, Email: mueller@phys.ufl.edu (Experimental Testbed)
University of Hannover, Universität Hannover	http://www.uni-hannover.de/en, 1 Welfengarten, Hannover, D-30167 Germany, Tel: + 49 511 7620, Fax: + 49 511 762 3456, Email: info@pressestelle.uni-hannover.de (Readout Electronics)

Technical Data

Design Features. The LISA mission plan consisted of three spacecraft in a heliocentric orbit flying in an equilateral triangular formation 5 million kilometers apart. The three LISA spacecraft were expected to launch in 2018.

Each cylindrical-shaped spacecraft was to be 1.8 meters in diameter and 0.5 meters high, with a Y-shaped tubular structure housed within the spacecraft that contained a propulsion subsystem, telecommunications subsystem, attitude control subsystem, and Michelson interferometer. The Y-shaped structure was to be coated with gold and suspended by thermally isolating stressed fiberglass bands. The spacecraft would have been constructed of a graphite-epoxy composite, which was chosen for its low coefficient of thermal expansion.

The solar electric propulsion subsystem was planned to contain two ion engines, one of which was to be used as a backup to the main engine. Upon reaching operational orbit, the propulsion module was planned to separate from the spacecraft.

The spacecraft would have consisted of an X-band uplink and downlink for communication with Earth and with each other, with data transmitted to Earth weekly. The subsystem was planned to include two X-band antennas with a diameter of 30 centimeters.

A Michelson interferometer, which detects gravitational waves, would have been placed on each spacecraft. The interferometer would have consisted of two optical assemblies, lasers, and a telescope. The instrument was to be mounted on an optical bench that contained injection, detection, and beam-shaping optics. An accelerometer was planned to be located at the center of the optical bench. The three satellites together were planned to function as one large Michelson interferometer.

	Metric	U.S.
Dimensions		
Spacecraft Diameter	1.8 m	5.9 ft
Spacecraft Height	0.48 m	1.6 ft
Spacecraft Launch Mass (each)	400 kg	882 lb
Design Life	2 yr	
Antenna Diameter (2)	30 cm	11.8 in
Telescope Aperture	30 cm	11.8 in
Optical Bench	20 x 35 x 4 cm	7.9 x 13.8 x 1.6 in
Payload Mass	288 kg	635 lb

Variants/Upgrades

LISA Pathfinder. The technology demonstrator mission for the LISA and DARWIN. Previously known as the SMART-2.

Program Review

Background. The LISA mission was proposed by American and European scientists in 1993. The LISA was being designed to observe gravitational waves, which are one of the fundamental building blocks of the theoretical picture of the universe. Although there is strong indirect evidence for the existence of gravitational waves, they have not yet been directly detected.

The scientists originally thought that NASA and ESA could jointly develop the program under the ESA M3 program. ESA then selected the mission for an assessment study, which concluded that the mission was too expensive for M3 consideration. ESA decided that the LISA should be reviewed as a possible cornerstone mission. In order to accommodate the LISA, ESA's Space Science Advisory Committee (SSAC) requested that ESA increase the Space Science budget after the year 2000. This budget request was denied.

Ironically, LISA program managers added another three spacecraft. As a result, the mission's cost skyrocketed.

The SSAC approved the LISA mission but could not give program managers an expected launch date, prompting the LISA's science team to revamp the mission. The six-spacecraft plan was dropped in favor of the three-spacecraft mission. The new, less expensive plan was accepted by ESA and NASA in October 2000.

LISA Pathfinder. ESA is currently focusing on the LISA Pathfinder mission, which aims to prove the technologies that were to be used on the LISA mission. Previously, this mission was known as the SMART-2. This name referred to the scope of the mission that was to prove technologies for the LISA mission, as well as for another ESA mission called DARWIN. However, the mission was revised and now focuses exclusively on LISA technologies.

Instead of the highly accurate formation flight that the LISA was to employ at distances of 5 million kilometers apart, the LISA Pathfinder is testing the LISA concepts and technologies using test masses placed 30 centimeters apart on a single spacecraft.

The spacecraft carries two instruments. The first is the LISA Test Package, a 50-kilogram unit of sensors advanced enough to determine whether a 100-kilogram spacecraft has moved even 10 millionths of a millimeter. The LTP is also validating drag-free technologies using Field Emission Electric Propulsion (FEEP) µN thrusters as actuators and the low-frequency laser interferometry between two proof masses. The second instrument is the Disturbance Reduction System, which is designed to validate technologies required for use on spacecraft that are controlled to follow a trajectory determined only by external gravitational forces (drag-free spacecraft). The Space Technology-7 DRS mission is part of NASA's New Millennium Program.

LIST. In 2001, a joint NASA/ESA LISA International Science Team was formed, made up of 10 U.S. and 10 European scientists. The LIST is co-chaired by professor T. Prince (JPL/Caltech) and ESA's mission scientist, Professor K. Danzmann (University of Hannover). The LIST advises NASA and ESA on all LISA science-related issues.

The European Space Agency coordinated closely with NASA's Goddard Space Flight Center (GSFC), NASA's Jet Propulsion Laboratory (JPL), and industrial partner EADS Astrium (now Airbus Defence and Space). The objective was to formulate a consolidated and optimized LISA mission architecture and design. The study was structured in two phases. Phase 2 was completed in 2008. The study matured LISA mission development by proposing a significantly evolved payload architecture incorporating advanced conceptual ideas into a consolidated baseline design.

New NASA/ESA Agreement. In December 2003, ESA headquarters proposed to NASA headquarters a swap of mission roles. NASA would take spacecraft responsibility, while ESA would be responsible for the payload. In 2004, a compromise was reached wherein NASA's Goddard Space Flight Center was to provide the spacecraft (including payload integration and testing), and ESA was to provide the optical bench, optics, and much of the payload hardware. The JPL was to be responsible for the phase meter and associated avionics.

ESA planned to build the three spacecraft propulsion modules and deliver them to the GSFC. The GSFC was also to be responsible for launch vehicle procurement.

LISA

Component Contract Awarded

Thales Alenia Space developed and delivered onboard and ground segment equipment for the LISA Pathfinder program. The company provided the X-band transponder, one of the spacecraft units that acts as the interface between the satellite and the ground segment. It also provided the power-specific check-out equipment hardware and software; simulated the solar panels and batteries; and tested the spacecraft's power subsystem during assembly, integration, and validation.

Disturbance Reduction Agreement

Under an agreement with ESA, NASA supplied the Disturbance Reduction System package that is part of ESA's LISA Pathfinder. The DRS is essentially a highly sensitive thruster system designed to counteract drag on the spacecraft from solar wind and other forces so that truly accurate gravitational measurements can be made.

The LISA Pathfinder completed a number of tests in 2008. In October of that year, the spacecraft successfully completed shock tests, simulating shocks the spacecraft would experience when the launcher and the science and propulsion modules separate. In the following December, the spacecraft successfully completed vibration tests that simulated conditions during launch.

However, the LISA Pathfinder suffered a setback in 2011. Problems were discovered with the hydraulic launch lock and the FEEP system. While correcting these problems did not significantly add to the cost of the satellite – since it had essentially been completed – they did delay the launch to 2015.

ESA is also facing funding issues. In April 2011, it decided to chart a new way forward with its large-class Cosmic Vision programs. ESA originally planned to develop its large Cosmic Vision missions with heavy involvement from international partners; under this original vision, ESA was studying three programs for possible launch. These were the International X-Ray Observatory (IXO), Europa Jupiter System Mission (EJSM), and LISA.

However, with budgets being tightened all over the world, ESA's partners, including NASA, decided they would not partner with it on large-class missions. ESA subsequently reformulated each of these plans. The IXO's name was changed to Advanced Telescope for High-Energy Astrophysics (ATHENA), the LISA's name was changed to New Gravitational wave Observer (NGO), and the EJSM's name was changed to Jupiter Icy moon Explorer (JUICE).

In April 2012, ESA selected the JUICE as the most cost-effective and least risky of the three programs. This resulted in the cancellation of the LISA. Plans to launch the LISA Pathfinder remained in place.

In September 2013, the LISA Pathfinder's optical bench was integrated into the core assembly.

The LISA Pathfinder was launched aboard a Vega launch vehicle in December 2015.

Artist's Depiction of LISA Cutaway

Source: NASA's Jet Propulsion Laboratory

Timetable

Month	Year	Major Development
Oct	2000	LISA selected by ESA as Horizon 2000 cornerstone mission
	2001	Joint NASA/ESA LISA International Science Team formed
Jun	2004	EADS Astrium awarded contract to produce LISA Pathfinder
Oct	2008	LISA Pathfinder successfully completes shock tests
Dec	2008	LISA Pathfinder successfully completes vibration tests
Apr	2012	ESA selects JUICE over LISA for Cosmic Vision large-class mission; LISA Pathfinder still scheduled to launch
Sep	2013	Optical bench integrated into LISA Pathfinder's core assembly
Dec	2015	LISA Pathfinder launched aboard Vega

Forecast Rationale

ESA canceled the LISA program in April 2012. The program had already been restructured and renamed in 2011. Subsequently known as the NGO, the LISA competed against the JUICE and ATHENA for a launch slot under ESA's Cosmic Vision 2015-2025 program. ESA ultimately selected the JUICE for the 2022 launch.

The high cost of the NGO was one of the primary reasons it was not selected. Following NASA's decision to cancel financial support for the program, ESA decided it could not afford the mission, which was expected to cost slightly more than the JUICE. ESA expected the NGO to cost about $1.4 billion, while the JUICE is expected to cost about $1.1 billion. This difference is important, since large-class Cosmic Vision program costs are capped at a total of $1.1 billion.

Despite the cancellation of the NGO program, ESA continued work on the LISA Pathfinder, which is intended to pave the way for missions of greater sophistication in the future. The LISA Pathfinder lifted off aboard a Vega launch vehicle in December 2015.

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