The LISA Science Ground Segment: A Distributed, Multi-Agency Infrastructure for Gravitational Wave Science.

Authors:

Science Objectives

Galactic Binaries

Massive Black Holes

Extreme Mass Ratio In-spirals

Fundamental Nature of Gravity

Expansion of the Universe

Stochastic GW Background

Unforeseen sources

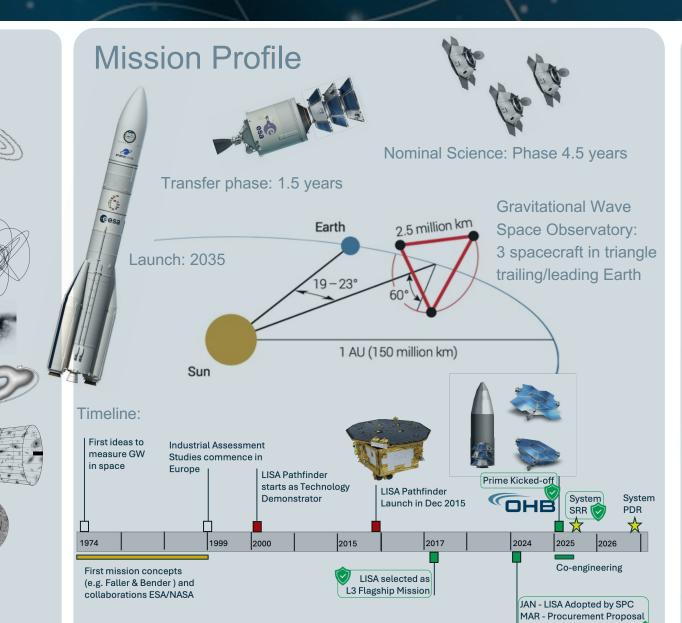
Stellar-Mass Black Holes

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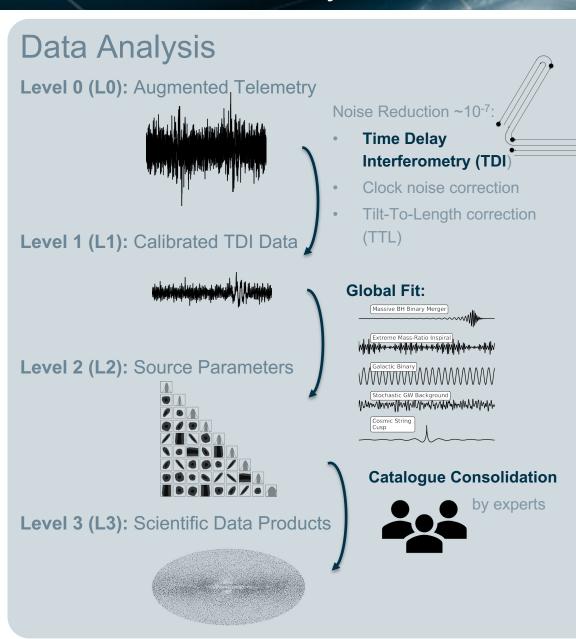
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25th ADASS, November 2025, Görlitz, Germany



Constellation Overview Observational requirement: Gravitational Strain ~10-21 between 100 μHz – 1 Hz Interferometric precision ~pm: Test mass on free-fall ~fm/s2: Interferometry with 10's pW µPa pressure around TM µV actuation stability µ-cycle phase measurements pico-metre pathlength stability Drag-free SC µK temperature stability Nano-g gravitational balancing Payload: Interferometric **Detection System**

esa



ESA | NASA

lisa

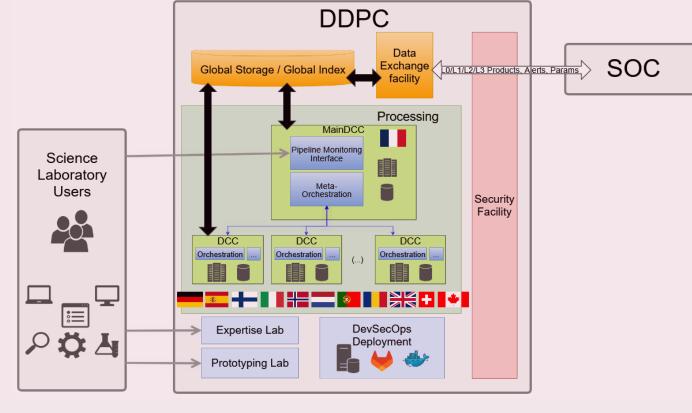
Distributed Data Processing Centre (DDPC)

DDPC hosts the development and execution of the European pipelir

➤ L0-L1 and Low Latency Alert pipelines (core algorithms), Simulation pipelines, L2 pipelines (GlobalFit and Deep Analysis Alert Pipeline), Contribution to L3 catalog generation

The key concepts of the DDPC System design are:

- Central components : Global Storage, Meta-Orchestration, various Labs opened to laboratories.
- Distribution of the processing on several Data Computing Centers (DCCs), provided by a dozen countries.



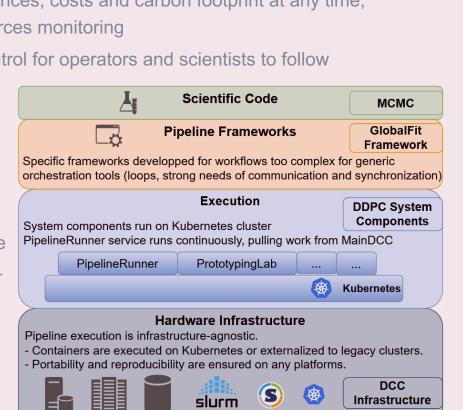
Meta-orchestration goals:

Optimization of performances, costs and carbon footprint at any time, through a detailed resources monitoring

Central monitoring & control for operators and scientists to follow pipelines execution

Meta-orchestration relies on System components run on Kubernetes cluste the ability to run any pipeline PrototypingLab on any of the generic DCCs. **Hardware Infrastructure**

This is achieved through a Cloud-Native design



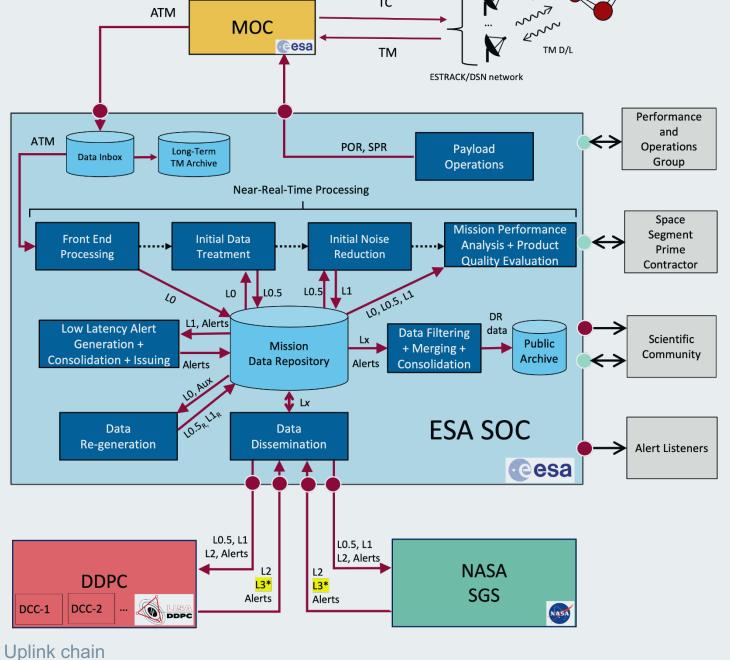
Science Operations Centre (SOC)

Downlink chain

 Near-Real Time Processing: L1 data from Raw TM and Low Latency Alert Issuance within 1h of GW signal detected on-board for Multi-messenger Astronomy

Two Moving Optical Sub-Assembly (MOSA) per SC

- Science Data Archiving and distribution to SGS partners
- Oversee Catalogue Consolidation, Data Releases and User Support



Operational Simplicity: No manoeuvres or pointing; constellation orientation set by orbit

Routine Commanding Offset lock planning for Doppler shift

- Periodic payload settings updates
- **Event-Driven Special Periods**
- Alerts: Enable multi-messenger follow-up Merger time known weeks ahead, sky strain
- location hours before Protected Periods: Up to 14 days of
- uninterrupted science collection
- Low-Latency Periods: Ground contact | SNR near alert time for rapid coordination

NASA Science Ground Segment (N-SGS)

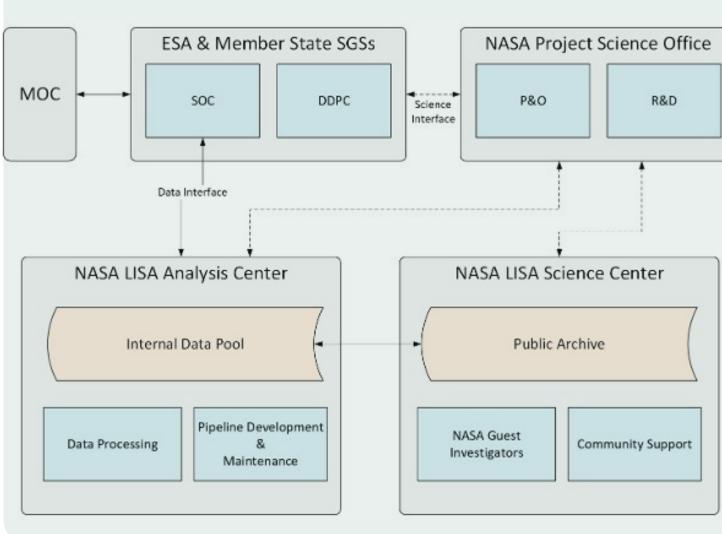
N-SGS Core Functions

- Data Processing & Analysis through the NASA LISA Analysis Center (NLAC)
 - Transforms Level 0.5 and Level 1 mission data into Level 2 science products and provides online alerts through 4 specialized science processing pipelines:
 - Initial Noise Reduction
 - Global Fit
 - Online Analysis
 - Contribution to Catalog Production
- Science Support & Community Engagement through the NASA LISA Science Center (NLSC) Provides public access to LISA data products for data access and
 - Delivers comprehensive user support services for data access and

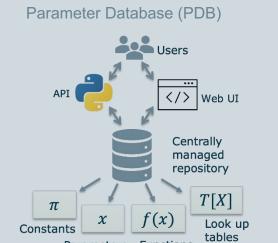
 - Establishes and administers Guest Investigator program with grant funding support

NASA's Goddard Space Flight Center provides overall N-SGS management NASA's Marshall Space Flight Center leads the development and operations of the NLAC

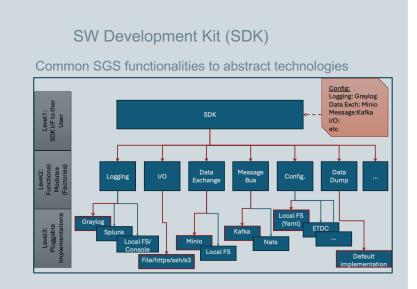
NLSC is planned to be selected via a NASA Announcement of Opportunity competition



Common Tools and Infrastructure



Comon Data Model (CDM) Tool Data model instances definition, management and validation



Conclusions and Outlook

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First alert,

-10 days -6 hours merger

Protected Period -

Low-Latency

LISA's Science Ground Segment (SGS) is a long-term collaboration between ESA (SOC), European Member States (CNES led DDPC), and NASA (NSGS):

- Not a "big data" mission, but requires intensive computation, especially for source recovery (Global Fit).
- Software must be designed for **longevity** (~20 years).
- Built on a cloud-native architecture.
- Supports flexible execution across globally distributed Data Computing Centres (DCCs).
- Emphasis on scalable infrastructure, modularity, performance, and maintainability
- Collaborative tools with built-in quality standards are established early.
- Designed to evolve with mission needs, accommodating extensions, new tools, and unforeseen discoveries.



SW development, version control and CI/CD

ECSS build-in compliance through ESA PA/QA processes and tools (~250 users):



ESA S2E2 Atlassian: Collaboration, documentation, planning, actions, requirements and



ESA Datalabs: Community-focused data science environment (codeto-data)

