How to contribute to Work Packages and Working Groups: now and post-adoption

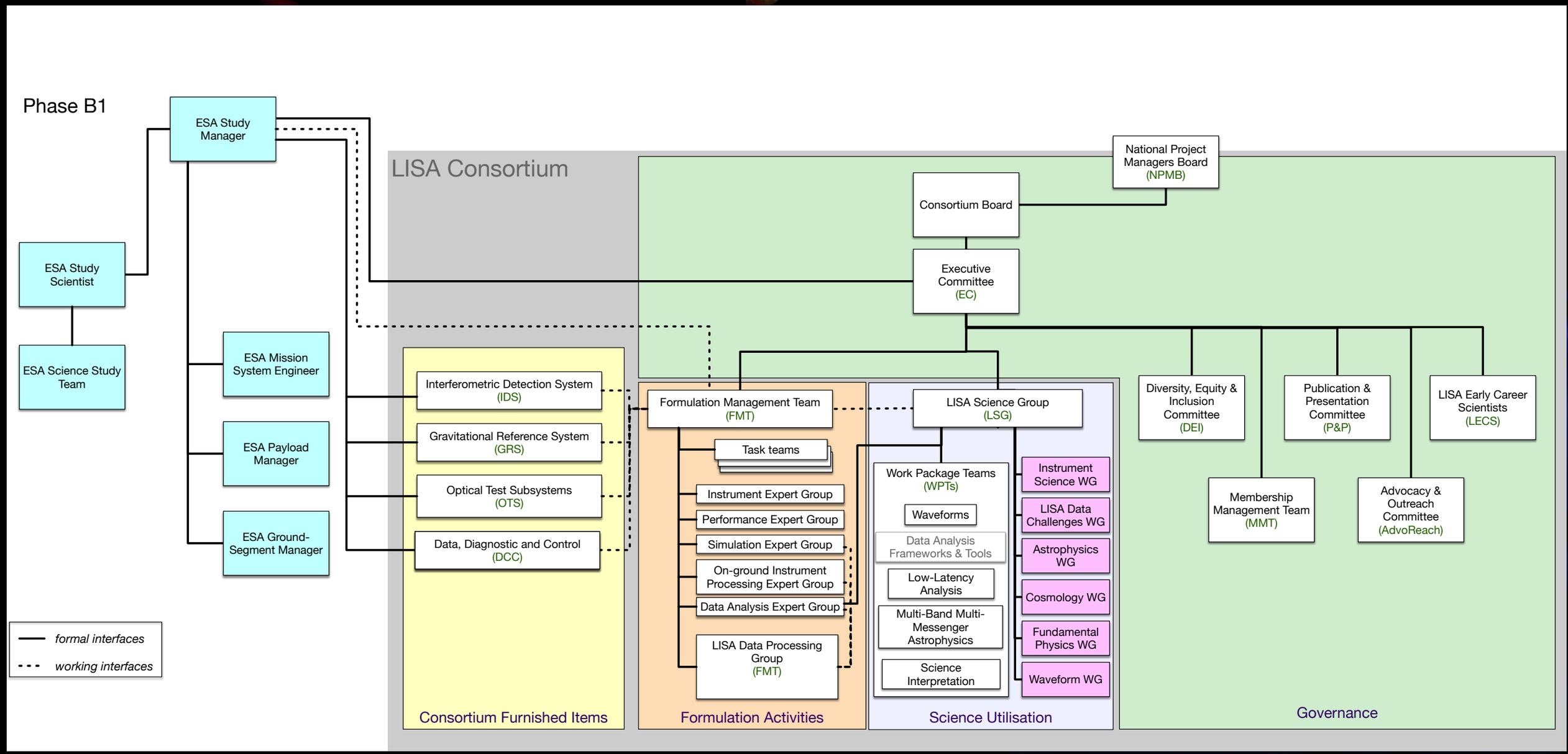
Antoine Petiteau (CEA/IRFU/DPhP & APC)

Fundamental Physics Workshop

Niels Bohr Institute, Copenhagen, 9th August 2023

Consortium Organisation for B1

- Formulation Management Team
- LISA Science Group



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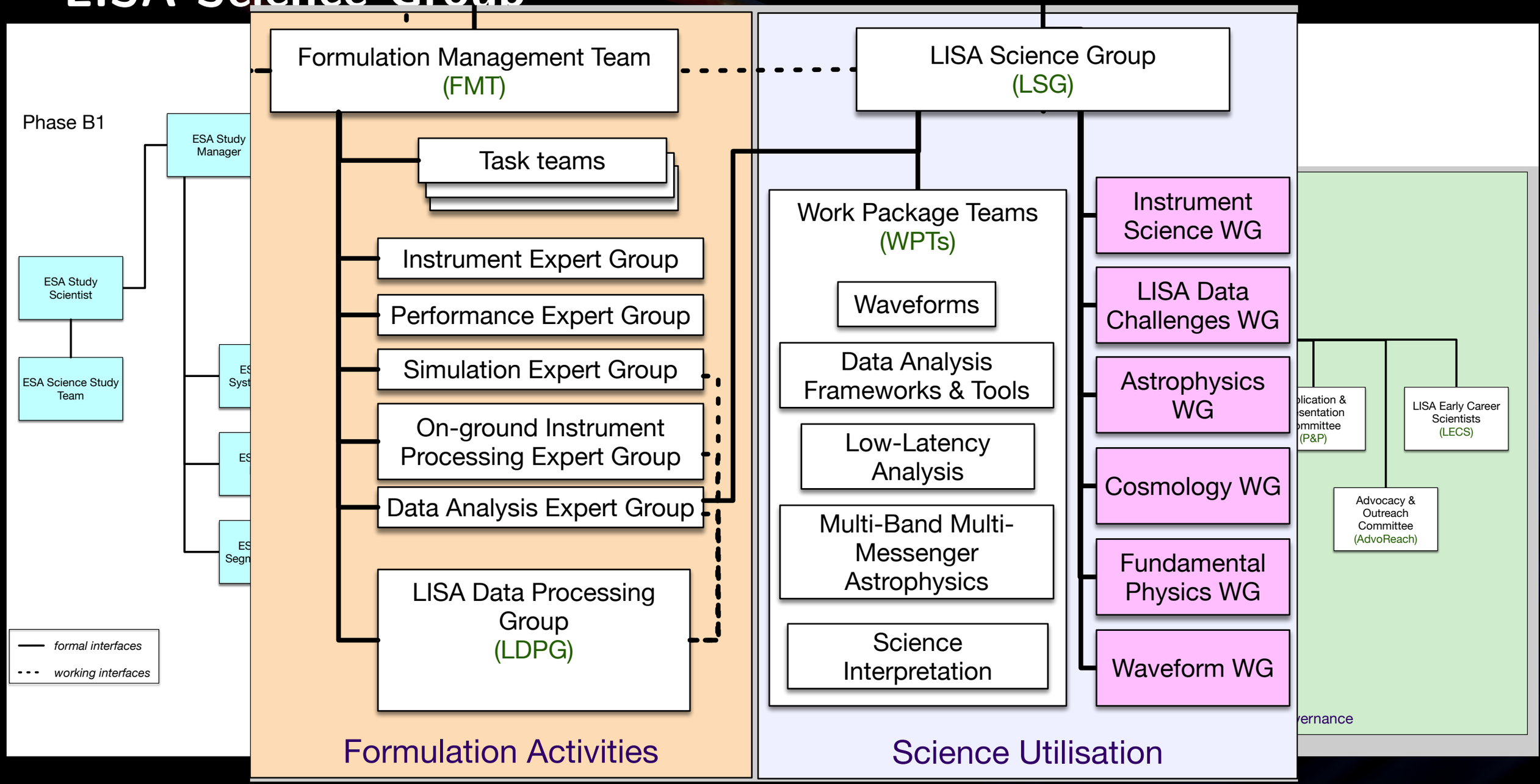
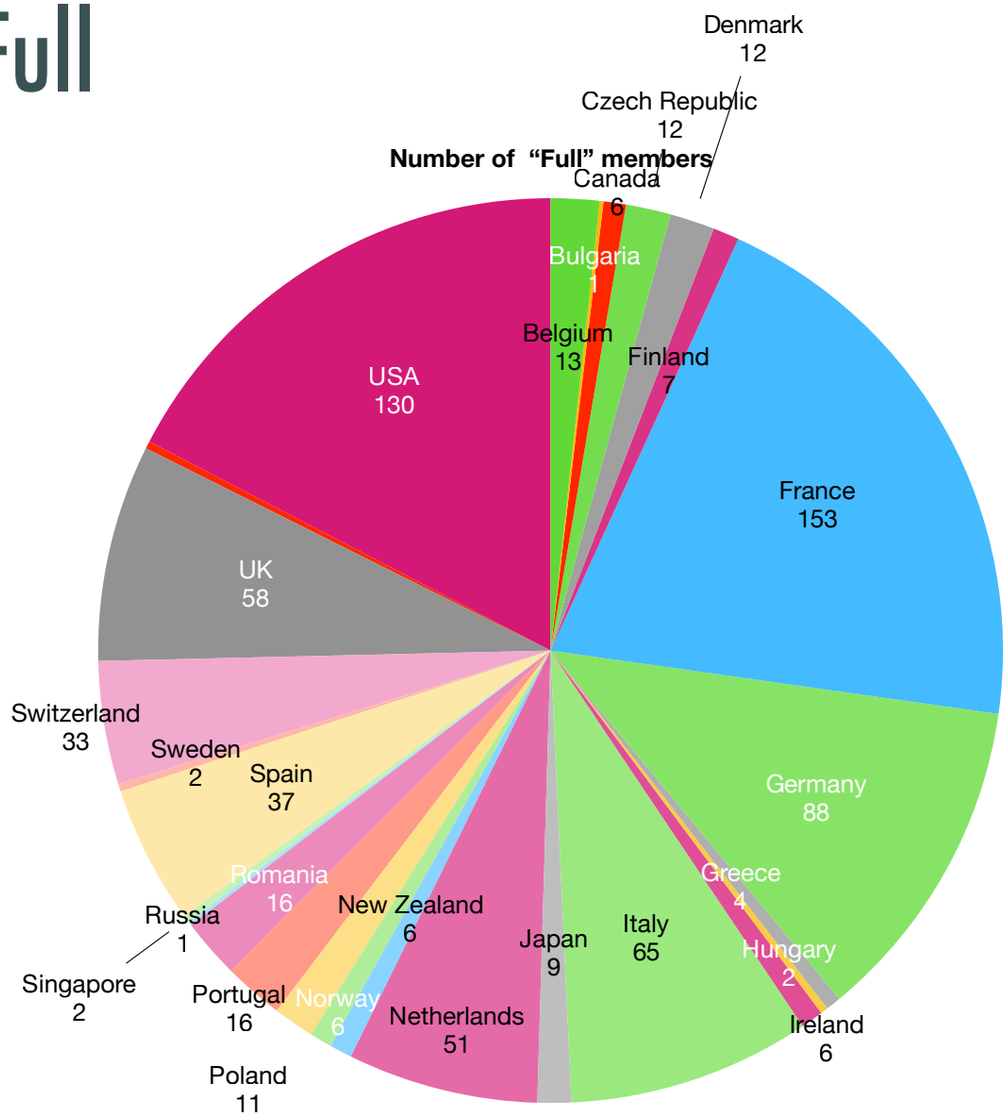


Organisation

- Full members (803): commitment for Consortium activities
- Associate members (903): no commitment

Full



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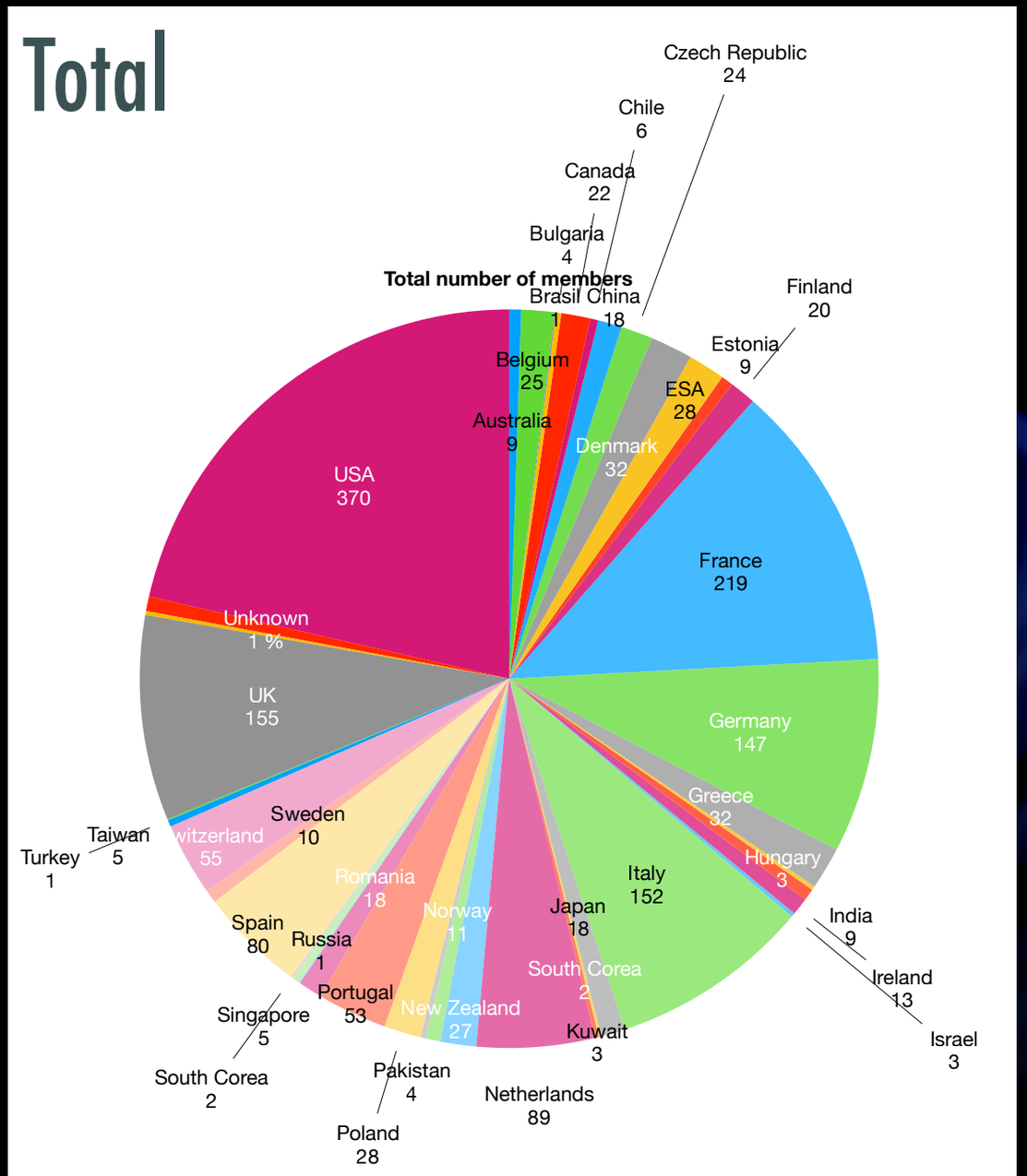


d WGs - A.

Working Groups

- 5 Working Groups:
  - Astrophysics (597)
  - Cosmology (440)
  - Fundamental Physics (483)
  - Waveforms (266)
  - LISA Data Challenge (282)
- Any members of the Consortium can join a Working Group
- Each WG has its own organisation with projects, sub-groups, etc
- Linked to the LSG (see Jon's talk)

LSG Work Packages

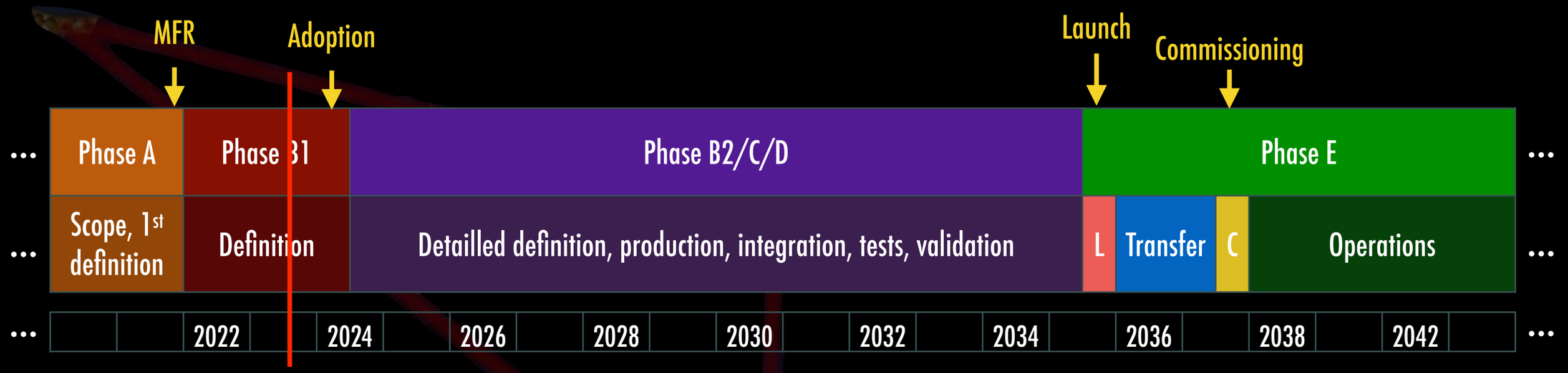
- In LISA Science Group
- 5 Work Package Teams (WPT):
  - Science Interpretation
  - Multi band Multi Messenger Astrophysics
  - Waveforms
  - Low latency
  - Data Analysis Framework and Tools
- Any full members can join
- Initially defined on Work Packages identified by the LSG
- Experts supporting ESA Science Study Team for several science performance studies:
  - Importance of the low frequency for science performances
  - Importance of the duration for science performances
  - Redbook
- Develop the figure of merits (FoM) tool; any contribution is welcome
- An evolution of the LSG is expected after adoption but core activities as FoM will remain.

Contributing to the project

- Formulation Management Team:
  - Support ESA Project Study Team in phase B2
  - For adoption: tasks with associated documents which are almost finished (final internal review is starting)
  - Develop the long term key expertises with Expert Groups:
    - Instrument (restricted),
    - Performances,
    - Simulation,
    - On-Ground Instrument Processing.
    - Data Analysis;

    Any full member can join
- LISA Data Processing Group:
  - Preparation of the Distributed Data Processing Center (DDPC)
  - Experts on data analysis, data processing, IT infrastructure, science close to the data, etc can join

Timeline

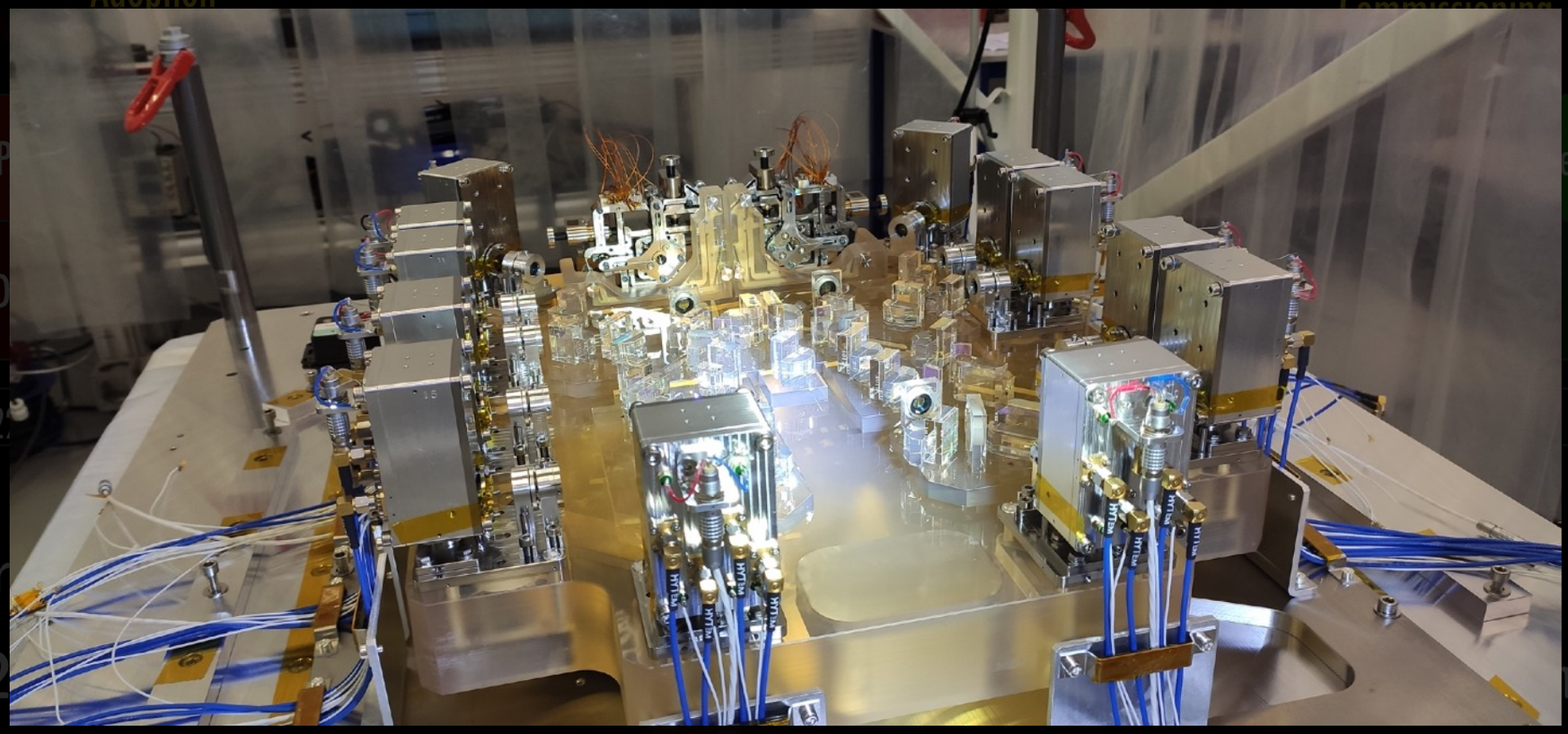


- 1993: first proposal ESA/NASA
- 20/06/2017: LISA mission approved by ESA Science Program Committee
- End 2021: success of the ESA Mission Formulation Review
- Now: accelerated phase B1 with ESA Adoption 25/01/2024
- Long building phase of multiple MOSAs: 6 flight models + test models
- Building of some subsystem models already started
- Launch 2035
- 1.5 years of transfer, 4.5 years nominal mission, 6.5 years extension

Timeline

MFR ↓ | Adoption | Launch | Commissioning

Phase A	P…	…	e E
Scope, 1st definition	D…	…	Operations
…	202…	…	2042



- 1993: fir…
- 20/06/2… …mittee
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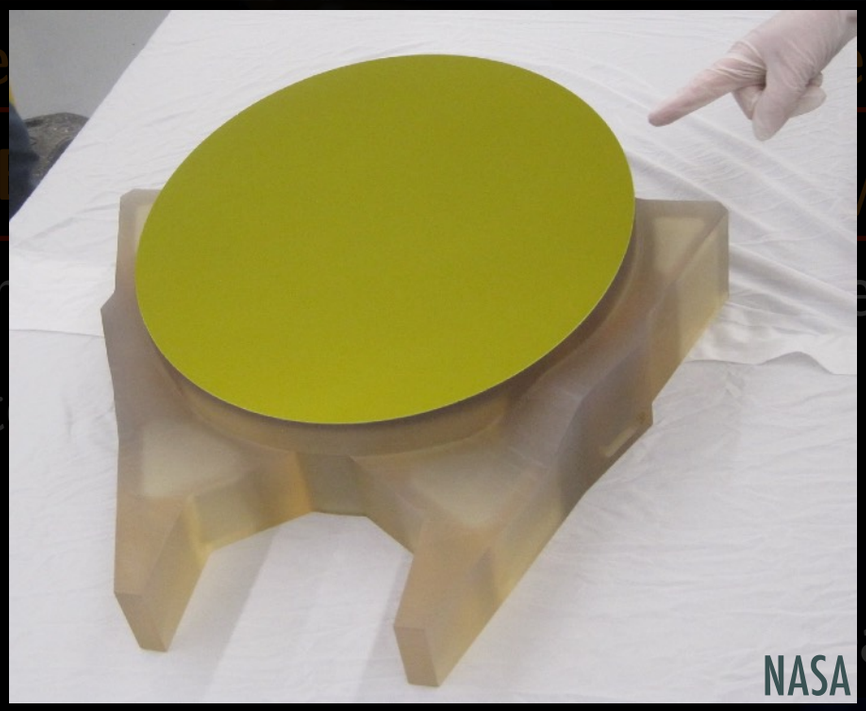
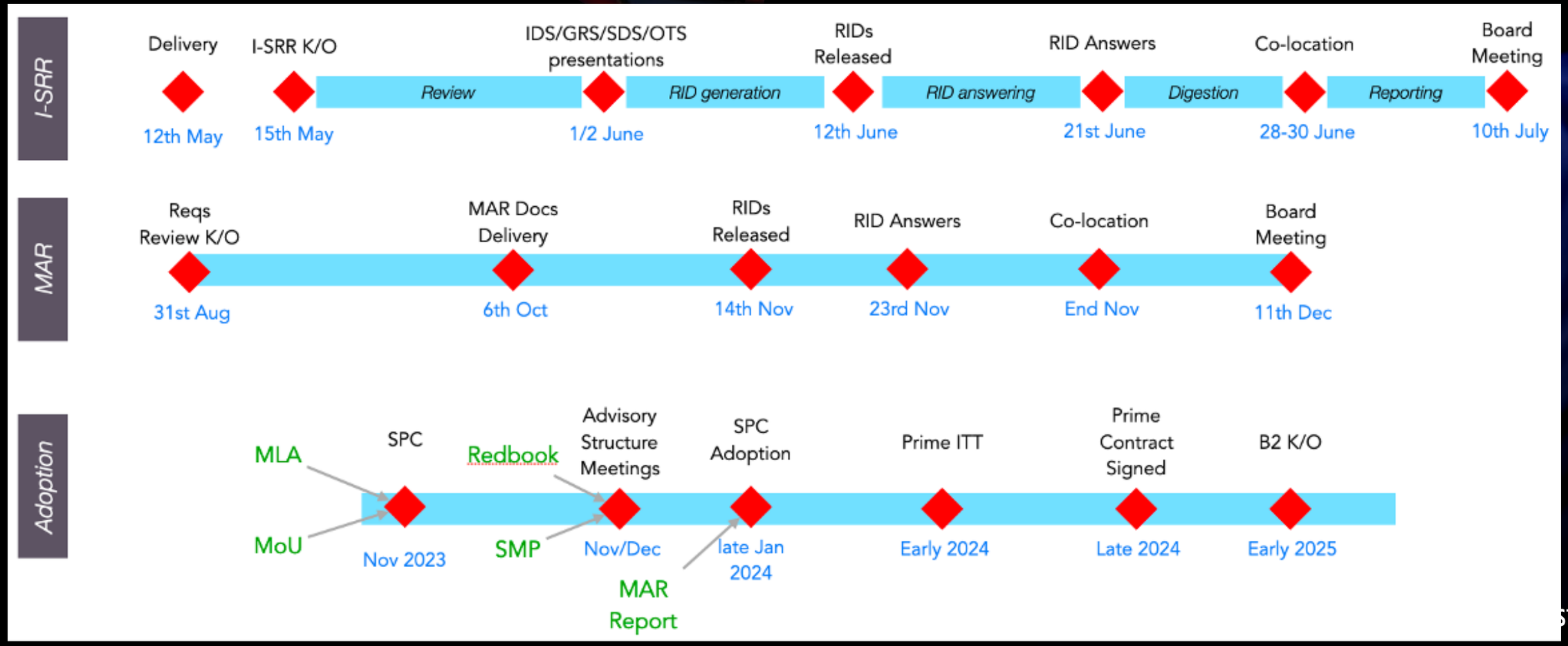


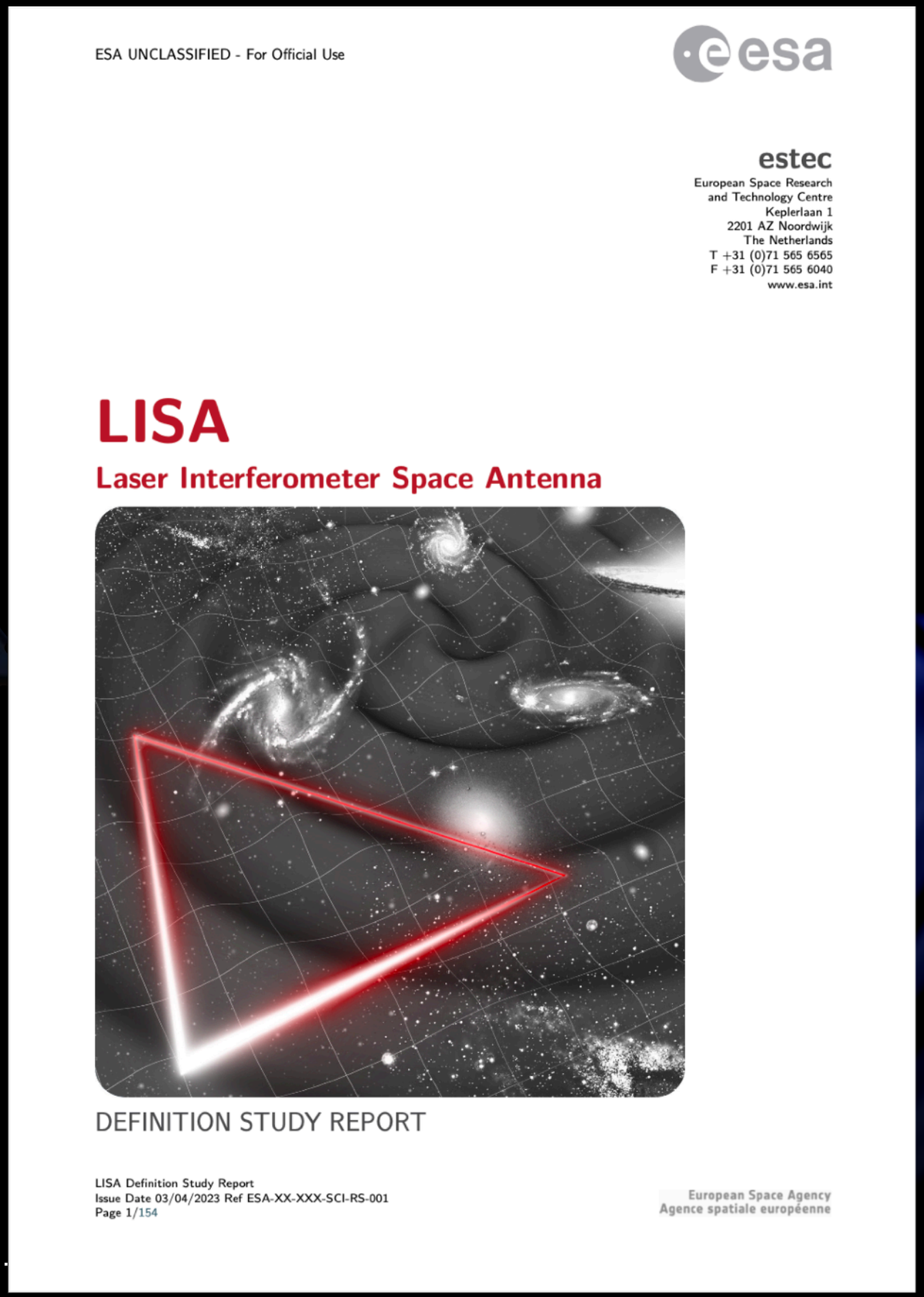
Timeline

- End of phase B1 and adoption:
  - I-SRR: Instrument System Requirement Review => passed
  - MAR: Mission Adoption Review
  - Adoption
  - Selection of the prime (ITT)
- Until 2025, we will work to define the organisation of the Consortium for the rest of the mission; a council will be created to do the work; inputs are welcome.



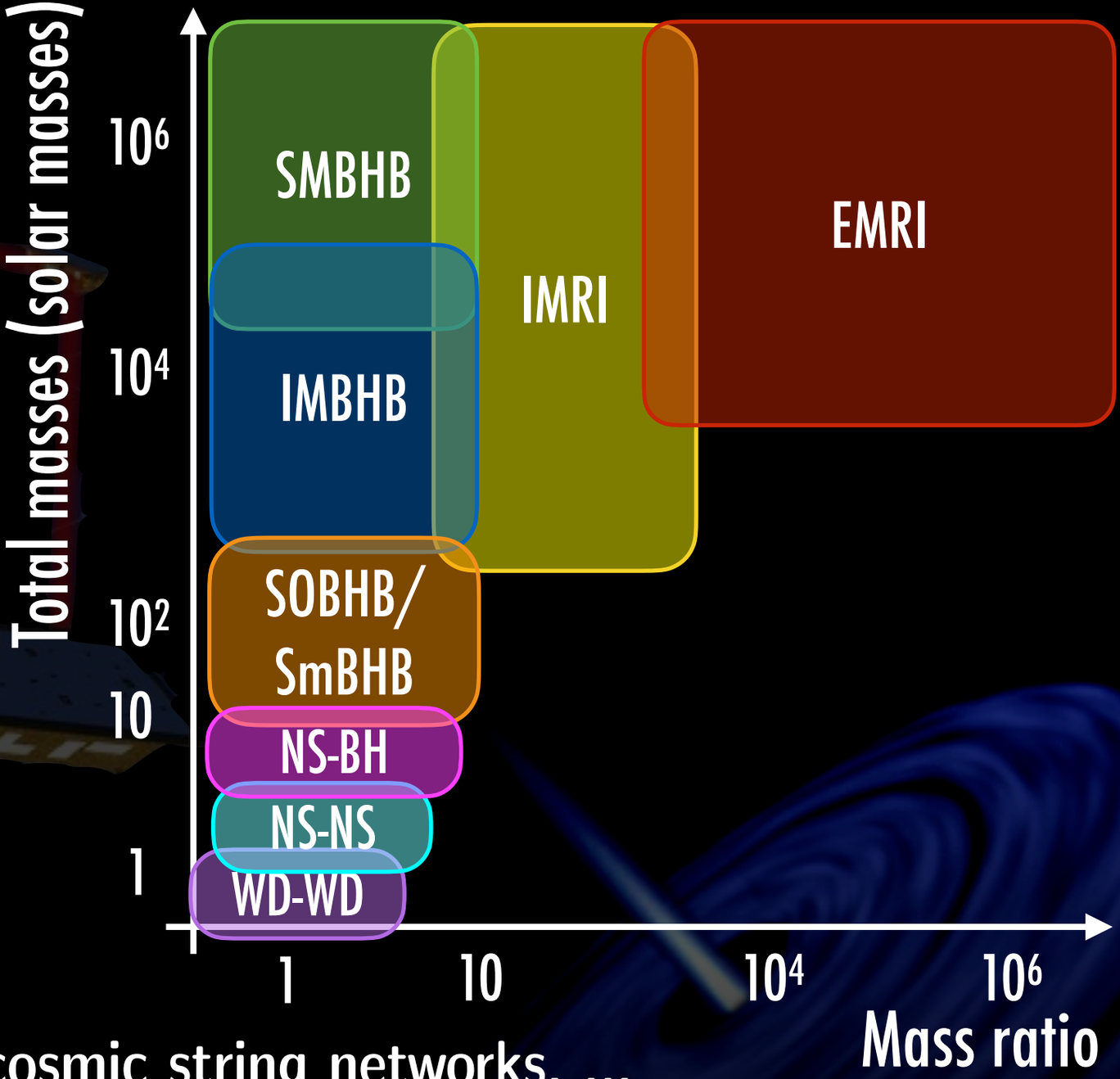
RedBook

- The main science document of the LISA mission which is almost finished.
- The Redbook is written by the LISA ESA Science Study Team with scientists of the Consortium.
- The document is almost in its final version.



GW sources in the mHz band

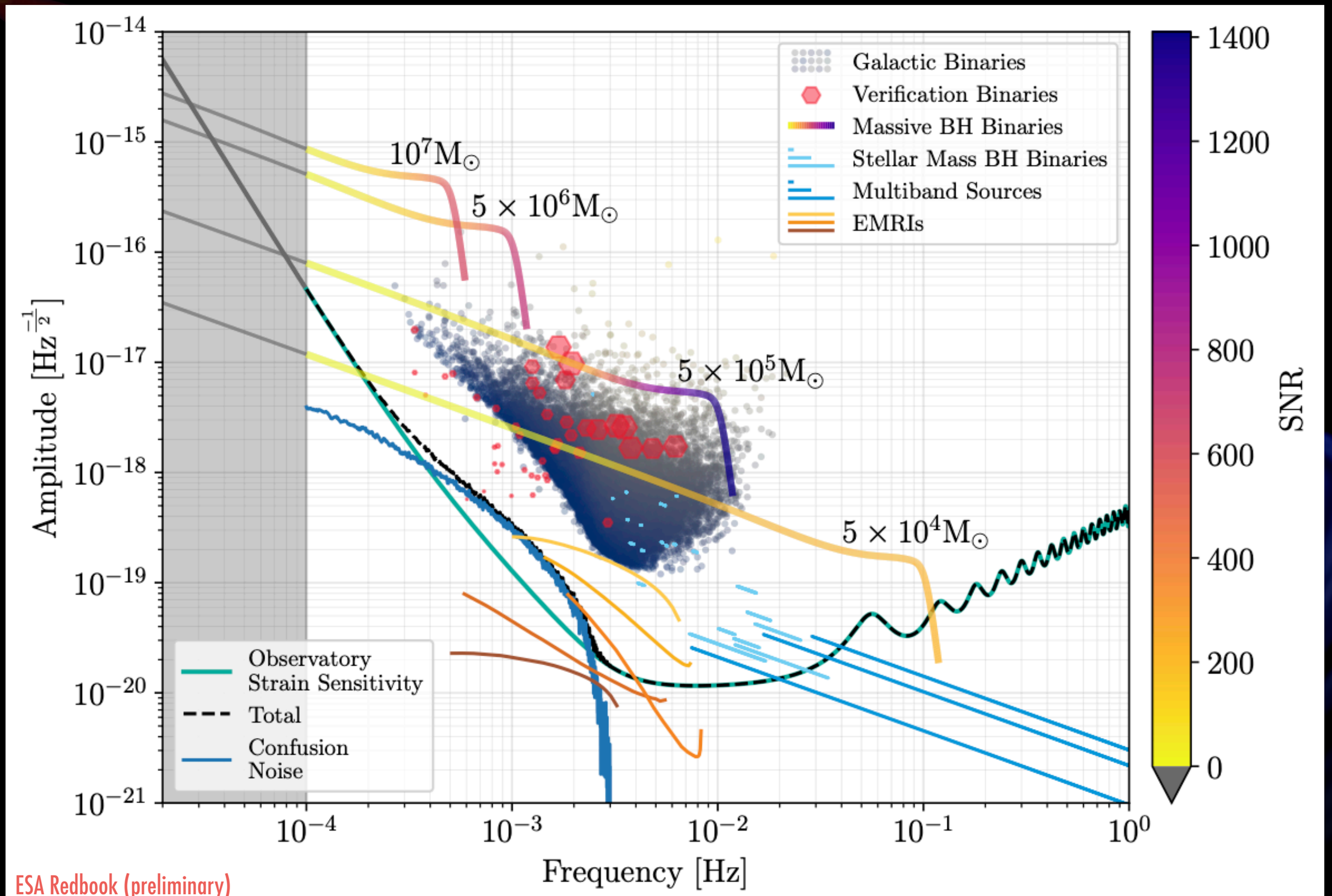
- Binaries: large range of masses and mass ratios:
  - SuperMassive BH Binaries
  - Extreme Mass Ratio Inspiral
  - Stellar mass BH Binaries
  - Double White Dwarfs
  - Double Neutron Stars
  - Intermediate Mass Ratio Inspiral
  - Intermediate Mass BH Binaries
- Stochastic backgrounds:
  - First order phase transitions, cosmic string networks, …
- Bursts: cosmic strings, …
- Unknown?



Mission configuration for adoption

Payload		
Lasers	2 per spacecraft • 2 W ouput power at end-of-life • wavelength 1064 nm • frequency stability (pre-stabilised) 300 Hz/$\sqrt{\text{Hz}}$	
Optical Bench	2 per spacecraft • double-sided use• low thermal expansion (Zerodur)	
Interferometry	heterodyne interferometry • 15 pm/$\sqrt{\text{Hz}}$ requirement • Inter-spacecraft ranging to ~1 m	
Gravitational Reference System	46 mm × 46 mm × 46 mm test mass made from AuPt alloy • electrostatically controlled • optical readout • Faraday cage electrostatic shield housing • electrostatic actuation in 5 DOF	
Telescope	2 per spacecraft • 30 cm off-axis telescope	
Mission		
Duration	4.5 years science orbit • ~6.25 years including transfer and commissioning	
Orbits	Three drag-free satellites in heliocentric orbits • semimajor axis ~1 AU • eccentricity $e \approx 0.0096$ • inclination $i \approx 0.96°$	
Constellation	Equilateral triangle • 2.5×10^6 km armlength • trailing Earth by ~20° • inclined by 60° with respect to the ecliptic • armlength variation <1 % • angular variation ±0.8° • relative velocity between spacecraft <20 m/s	
Data Analysis		
Noise Reductions	Laser noise suppression with time-delay interferometry • Ranging processing and delay estimation • Spacecraft jitter suppression and reduction to 3 lasers • Tilt-to-length effect correction • Clock noise suppression • Clock synchronisation	
Data Levels	Level 0	Primary science telemetry, decommutated, time-stamped, unit-level calibrations applied
	Level 1	Time-Delay Interferometry (TDI) variables (GW strain)
	Level 2	Output from a global fit pipeline, posterior pdfs for all sources.
	Level 3	Catalogue of GW source candidates (detection confidence, estimated astrophys. parameters)

Binaries observed by LISA



ESA Redbook (preliminary)

Science Objectives

Defined in the Science Requirements Doc.:

- SO1: Study the formation and evolution of compact binary stars in the Milky Way Galaxy.
- SO2: Trace the origin, growth and merger history of massive black holes across cosmic ages.

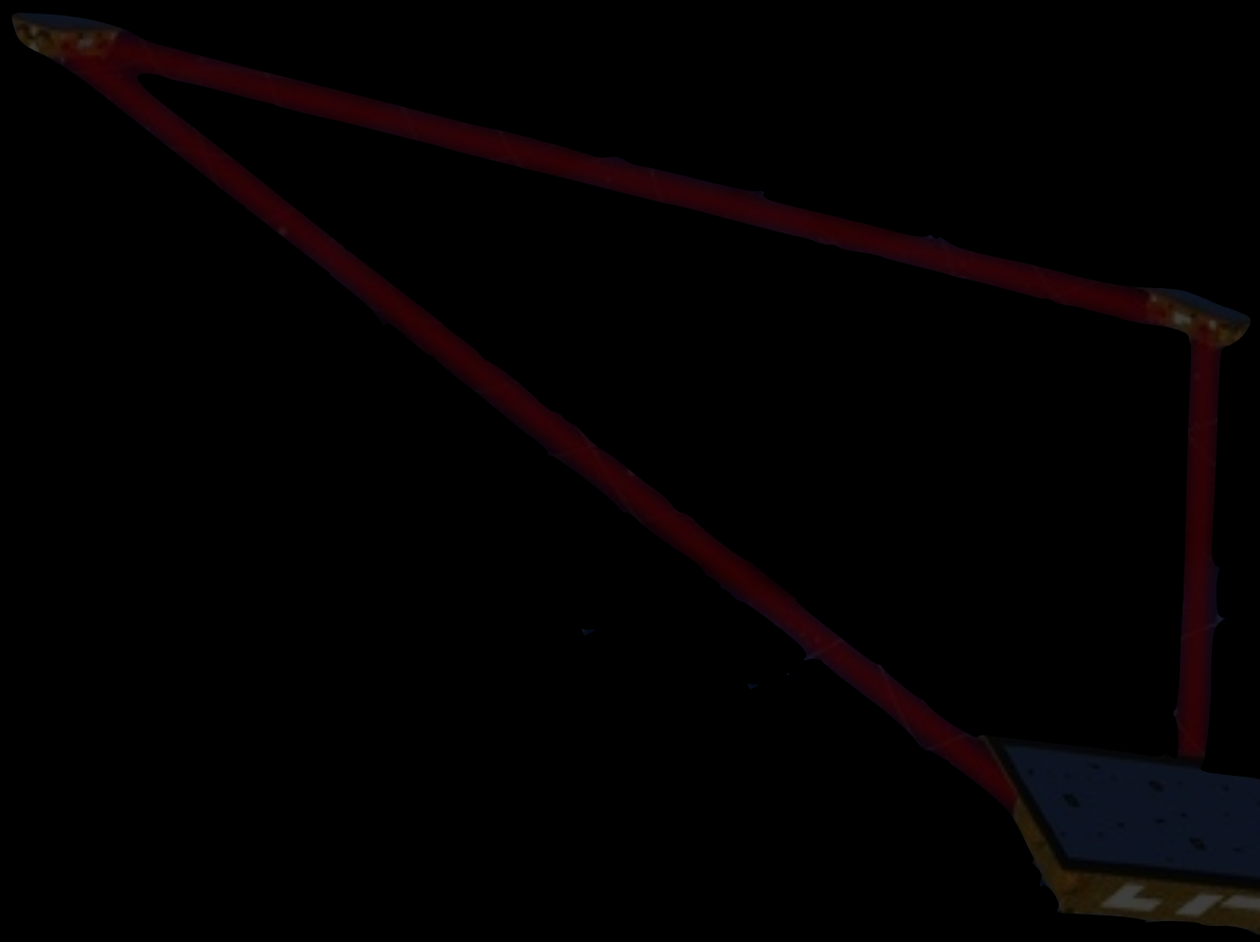
Astrophysics

- SO3: Probe the dynamics of dense nuclear clusters using EMRIs.
- SO4: Understand the astrophysics of stellar origin black holes.
- SO5: Explore the fundamental nature of gravity and black holes.
- SO6: Probe the rate of expansion of the Universe.
- SO7: Understand stochastic GW backgrounds and their implications for the early Universe and TeV-scale particle physics.
- SO8: Search for GW bursts and unforeseen sources.

Fundamental physics

Cosmology

Science Objectives



Science Objectives

- SO5 : Explore the fundamental nature of gravity and black holes :

  - **Are the massive objects observed at centres of galaxies consistent with being rotating Kerr MBHs? Are they MBHs or horizonless ultracompact objects?**
  - **Are there new fundamental fields, extra gravitational degrees of freedom and extra polarisations, as predicted by some extensions of the standard model and of GR?**
  - **Does the fundamental theory of gravity respect Lorentz symmetry and parity invariance?**
  - **How do GWs propagate over cosmological scales?**

Science Objectives

- SO5 : Explore the fundamental nature of gravity and black holes :
  - Use ringdown characteristics observed in MBHB coalescences to test whether the post-merger objects are the MBHs predicted by GR;

SI 5.1 By detecting multiple ringdown "spectral lines" in the post-merger signal of MBHBs LISA can test if merger remnants are indeed Kerr BHs, and place constraints on modifications of GR and on the properties of horizonless massive compact objects.

Science Objectives

- SO5 : Explore the fundamental nature of gravity and black holes :
  - Use ringdown characteristics observed in MBHB coalescences to test whether the post-merger objects are the MBHs predicted by GR;
  - Use EMRIs to explore the multipolar structure of MBHs and search for the presence of new light fields;

SI 5.2 LISA aims to observe small objects spiralling into putative MBHs for thousands of cycles, with SNR in excess of 50, thus testing the structure of the spacetime around these objects, probing the presence of dark matter, and potentially measuring charges on the orbiting body associated with new fundamental fields.

Science Objectives

- SO5 : Explore the fundamental nature of gravity and black holes :
  - Use ringdown characteristics observed in MBHB coalescences to test whether the post-merger objects are the MBHs predicted by GR;
  - Use EMRIs to explore the multipolar structure of MBHs and search for the presence of new light fields;
  - Test the presence of beyond-GR emission channels;

SI 5.3 LISA aims to probe the existence of dynamical fields by searching for additional radiation channels and polarisations that would be a smoking gun for non-GR theories.

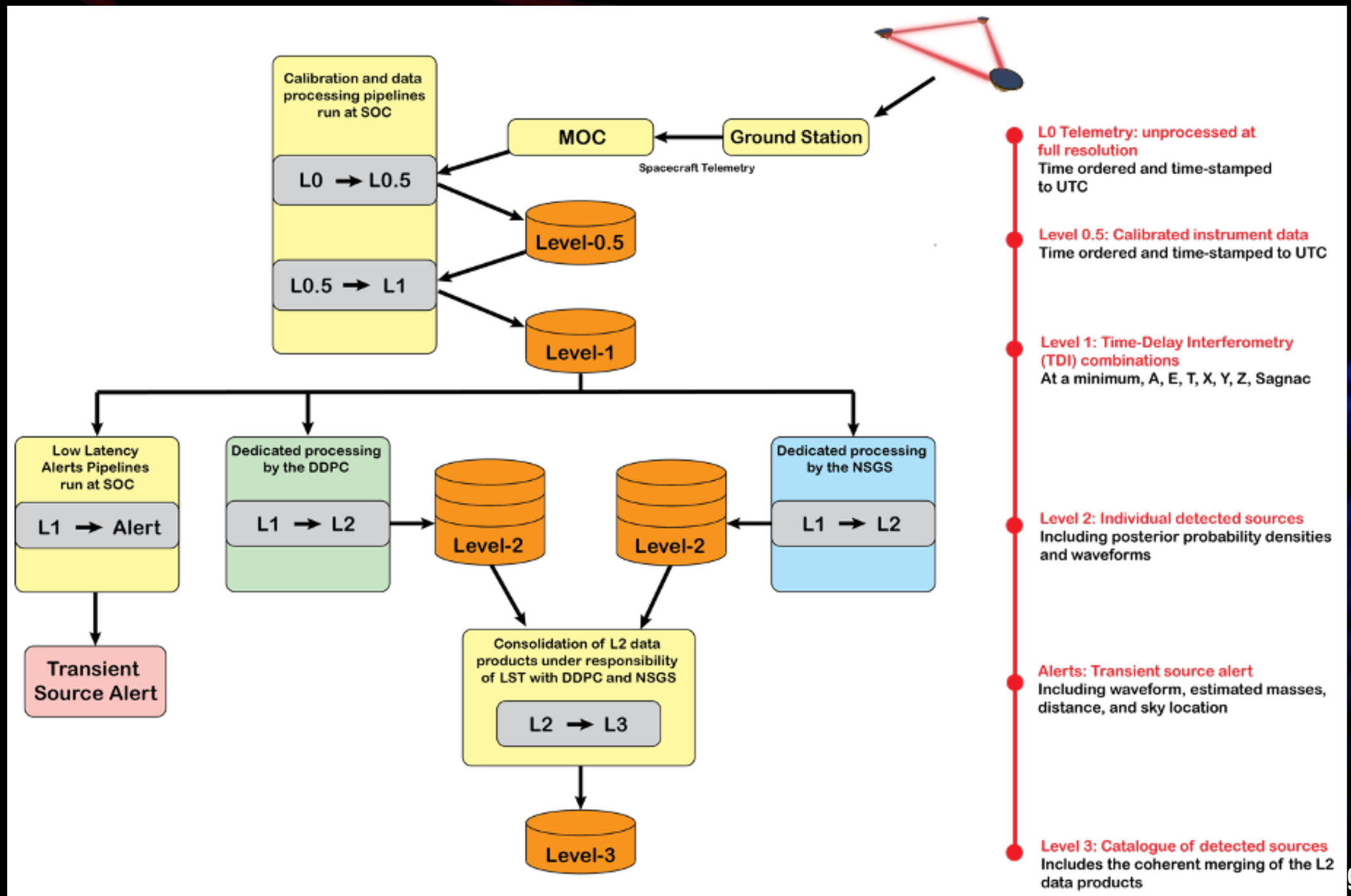
Science Objectives

- SO5 : Explore the fundamental nature of gravity and black holes :
  - Use ringdown characteristics observed in MBHB coalescences to test whether the post-merger objects are the MBHs predicted by GR;
  - Use EMRIs to explore the multipolar structure of MBHs and search for the presence of new light fields;
  - Test the presence of beyond-GR emission channels;
  - Test the propagation properties of GW.

SI 5.4 By detecting GWs from coalescences of golden MBHBs coalescences or/and from EMRIs, all with SNR > 200, LISA can probe the propagation of GWs over very large distances by imposing new stringent constraints on dark energy models, modified graviton dispersion relations, and theories of gravity beyond GR.

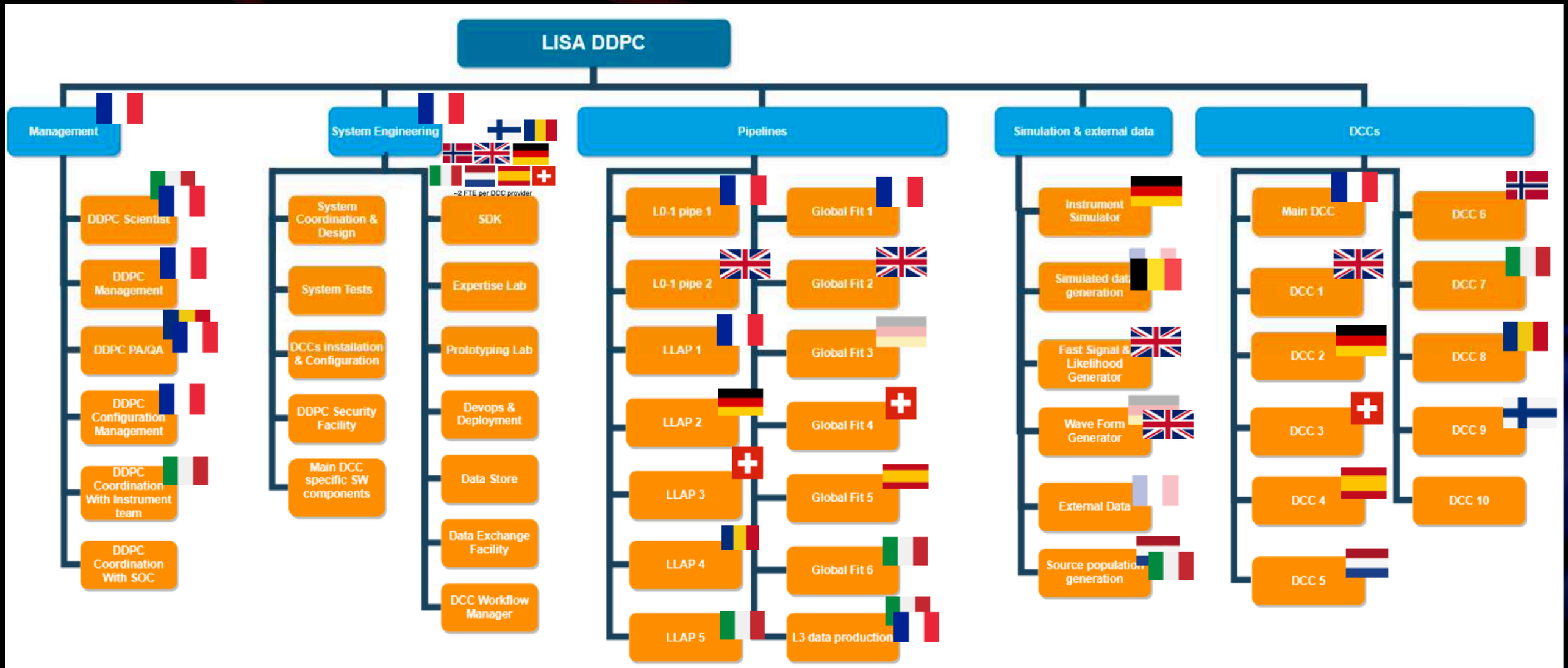
Ground Segment

- Organisation of the LISA Ground Segment (preliminary Science Management Plan version)



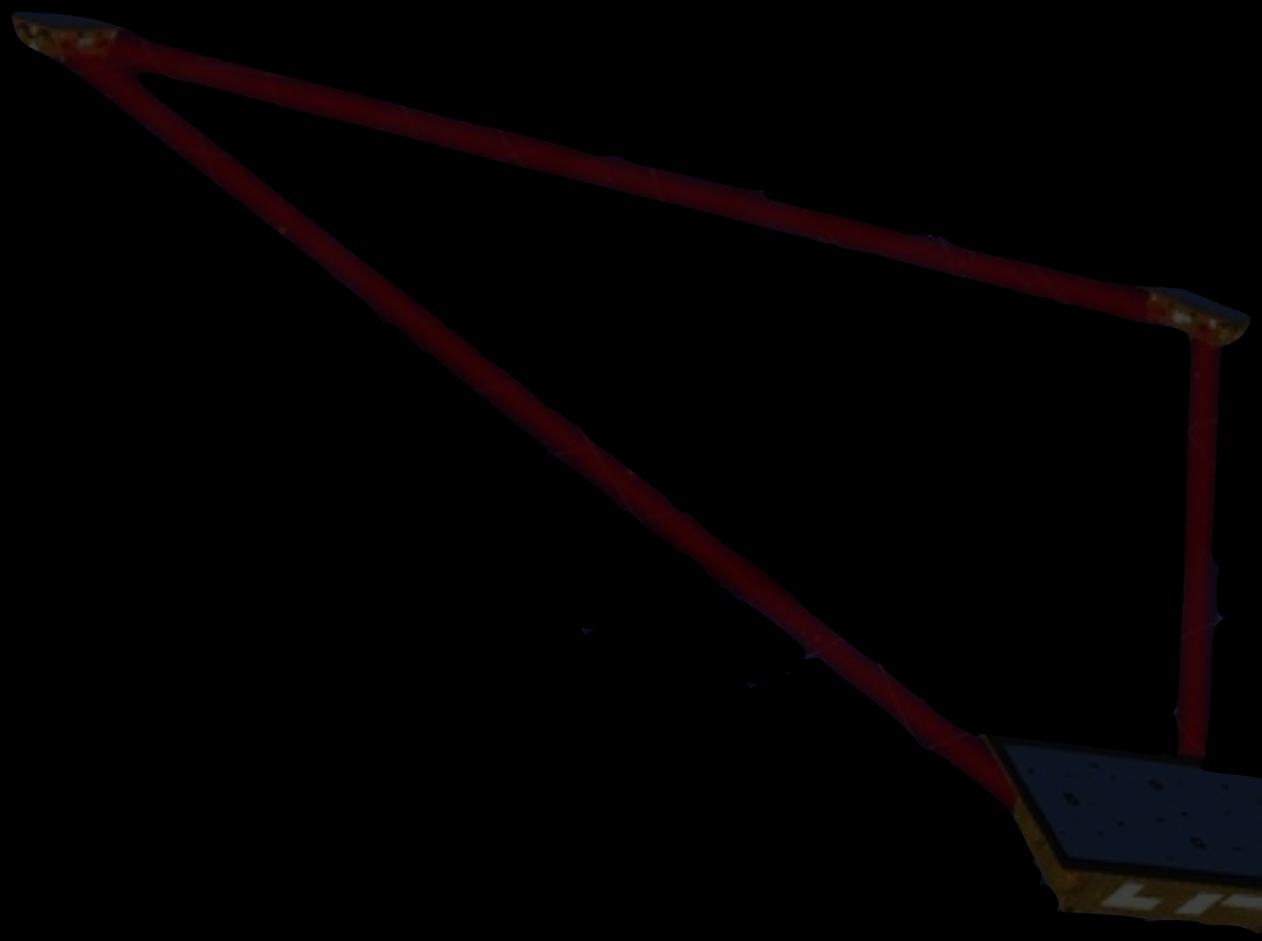
DDPC WBS

- "Work Breakdown Structure" with the mapping of responsibilities between "ESA Member States"



- DCC: Data Computing Center (hardware)
- LLAP: Low Latency Alerts Pipeline

LISA Data Challenge



LISA Data Challenge

- Two big purposes:
  - Provide a productive playground for research
  - Validate the LISA science ground segment
- LISA Data Challenge process:
- Last challenges:

LISA Data Challenge

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Design specific challenges

- Last challenges:

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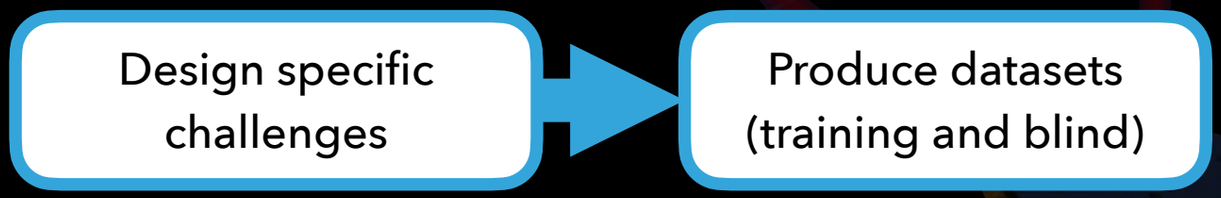

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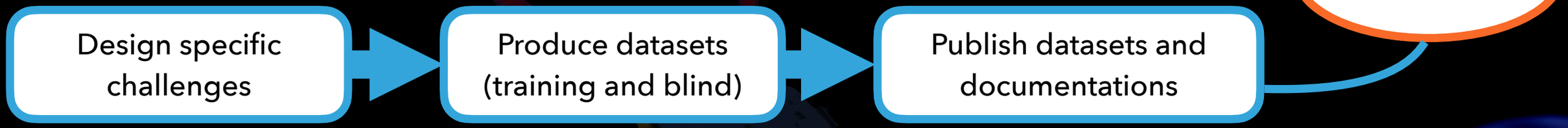

- Last challenges:

LISA Data Challenge

From Q. Baghi

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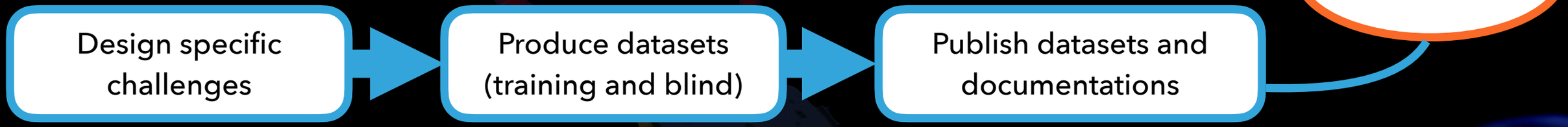

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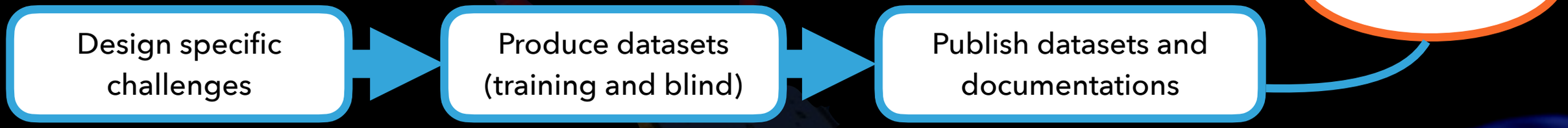
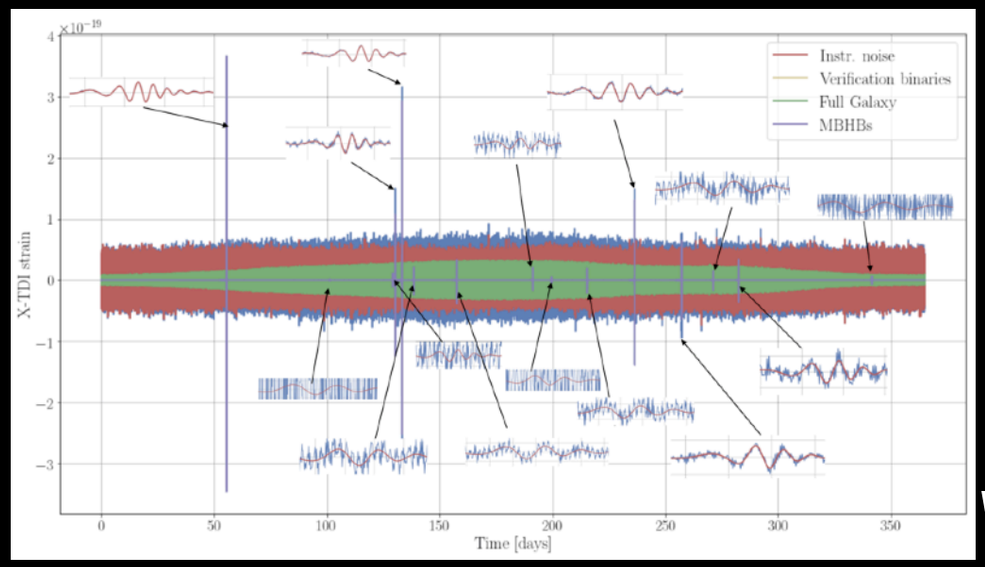
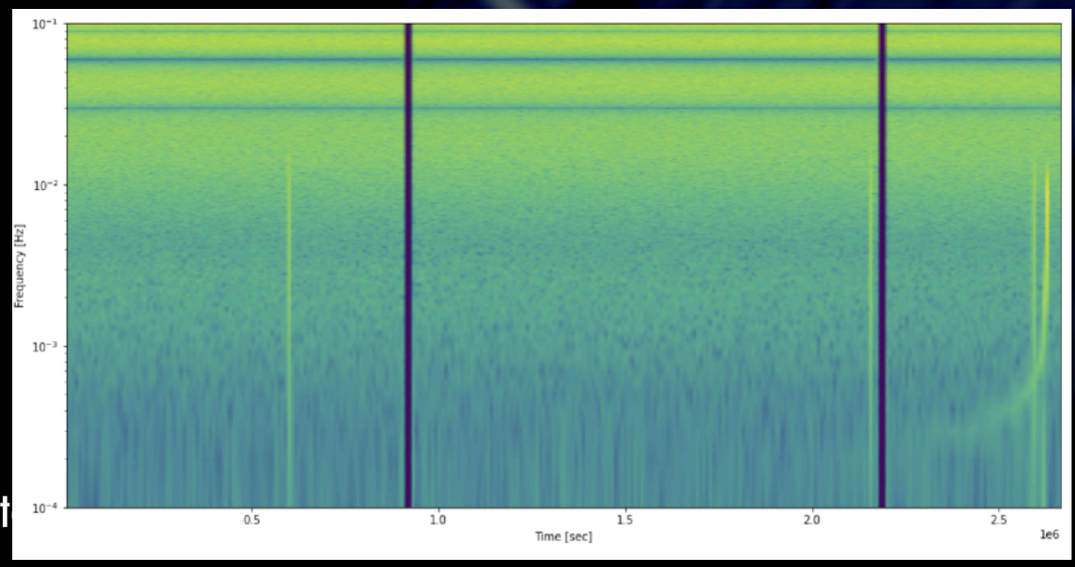


- Last challenges:

SMBHBs + Galactic binaries



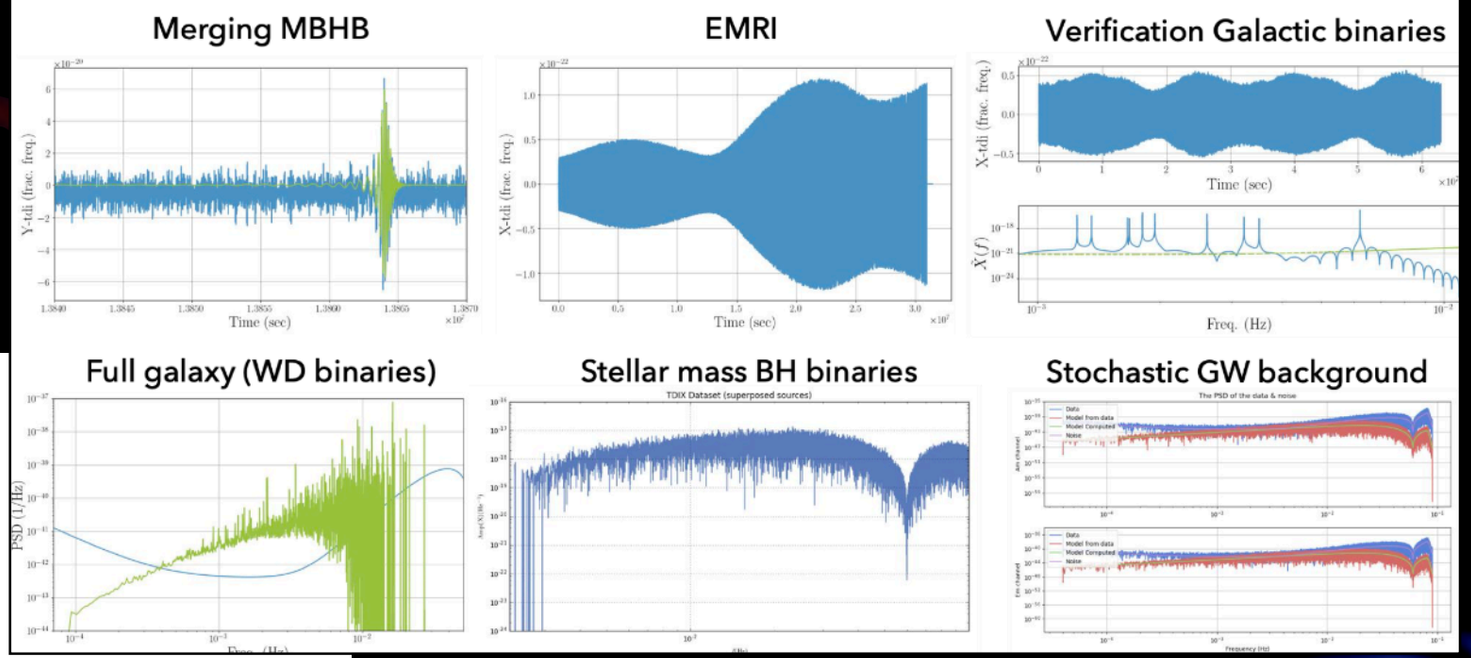
One SMBHB + gaps + glitches



LISA Data Challenge

- Past challenges:

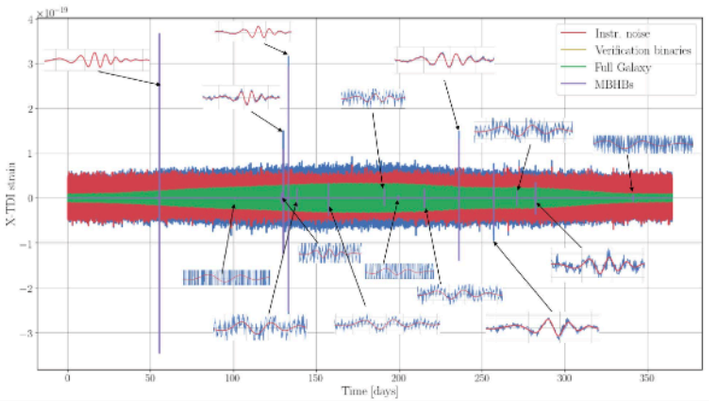
Past challenges: Radler

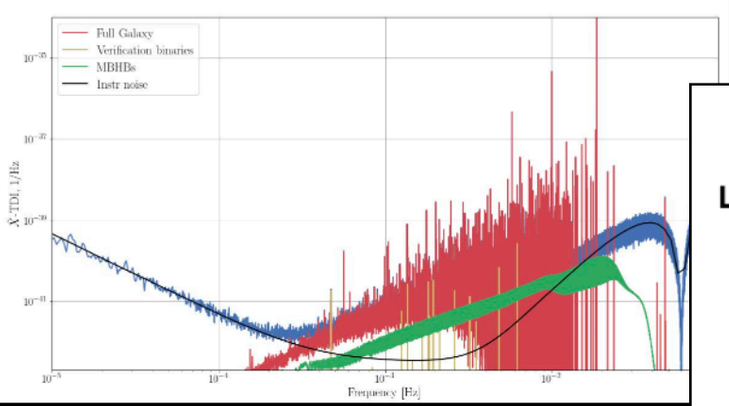


The first enchilada: Sangria

LDC 2a: Sangria

- Mixing of 2 source types:
  - Galaxy: 3 x 10^7 compact binaries
  - MBHBs: 15 mergers drawn from an astrophysical population

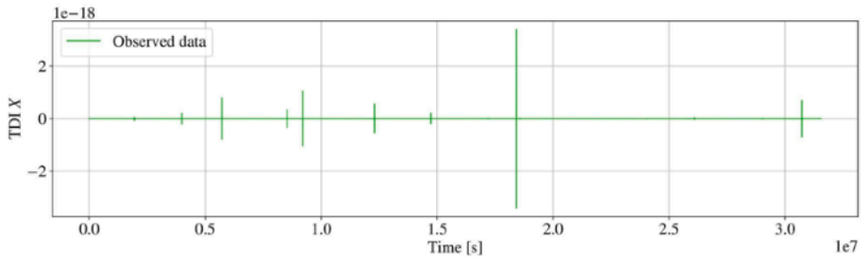




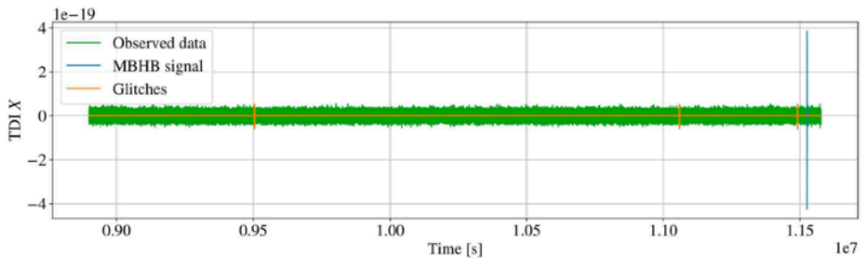
From Q. Baghi

Including artefacts: Spritz

LDC 2b VGBs: LPF-like glitches (4/day) + gaps + 36 verification Galactic binaries



LDC 2b MBHB-1: 3 short loud glitches + gaps + MBHB



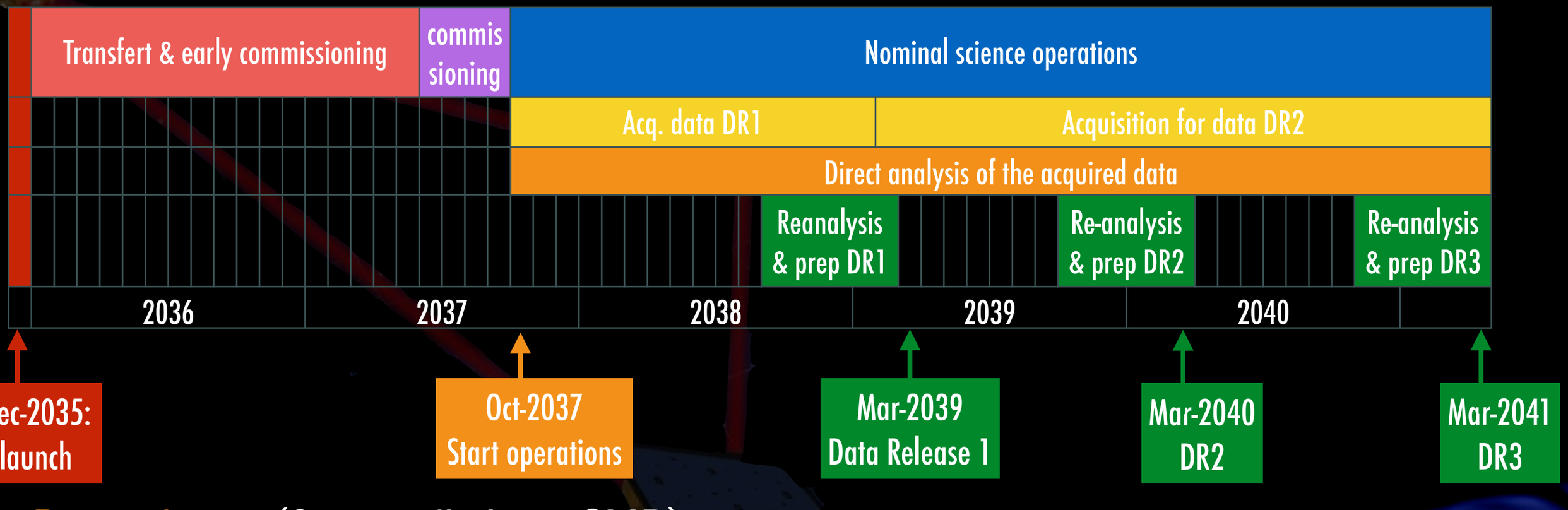
LISA Data Challenge

- In the future:
  - The preparation of the core pipelines for producing L1, L2 and L3 data (Global fit, MBHBs, EMRIs, ...) will be mainly managed by the DDPC (and not anymore by the LDC):

    => Project organisation with commitments, short deadline, etc
  - The LDC will managed the preparation of the others pipelines as for examples:
    - Modify GR
    - Search for more hypothetical sources
    - Science interpretations (ex: population models, ...)

    (without commitments and with long deadline)

Data policy (preliminary)



- **Data releases** (from preliminary SMP) :
  - DR1:
    - 18 months after the start of the operations;
    - Data L0.5 to L3 (catalogues - final products usable for science interpretation);
    - Includes at least the analysis of 6 months of data (minimal duration necessary to the observation of verification binaries);
    - Importance of the data validation.
  - Then Data Release every year.

Data policy (preliminary)

- Data releases : DR1 after 18 months of data L0.5 à L3 then DR every year
- Science Interpretations (from SMP preliminary version):
  - "Science Topical Panels" (STP):
    - Groups defined by the ESA LISA Science Team on open calls;
    - Can access the data during the "Early Science Time" (18 months before DR1);
    - Start working with DDPC in advance to prepare the analysis.
- Publications including always in the authors the "Instrument Builders":
  - Papers on validations, performances et description of products;
  - Papers from STPs (STP as additional authors).

Organisation for development & implementation (preliminary)

ESA LISA Project Team (Project Manager)

LISA Science Team (Project Scientists)

ESA Performance and Performance & Operations Team

Industrial Prime Contractor

NASA (Telescope, Laser, CMD)

Instruments Providers (IDS, GRS, OTS, SDS)

LST Working Groups

Mission Operation Center

Science Operation Center

NASA Ground Segment

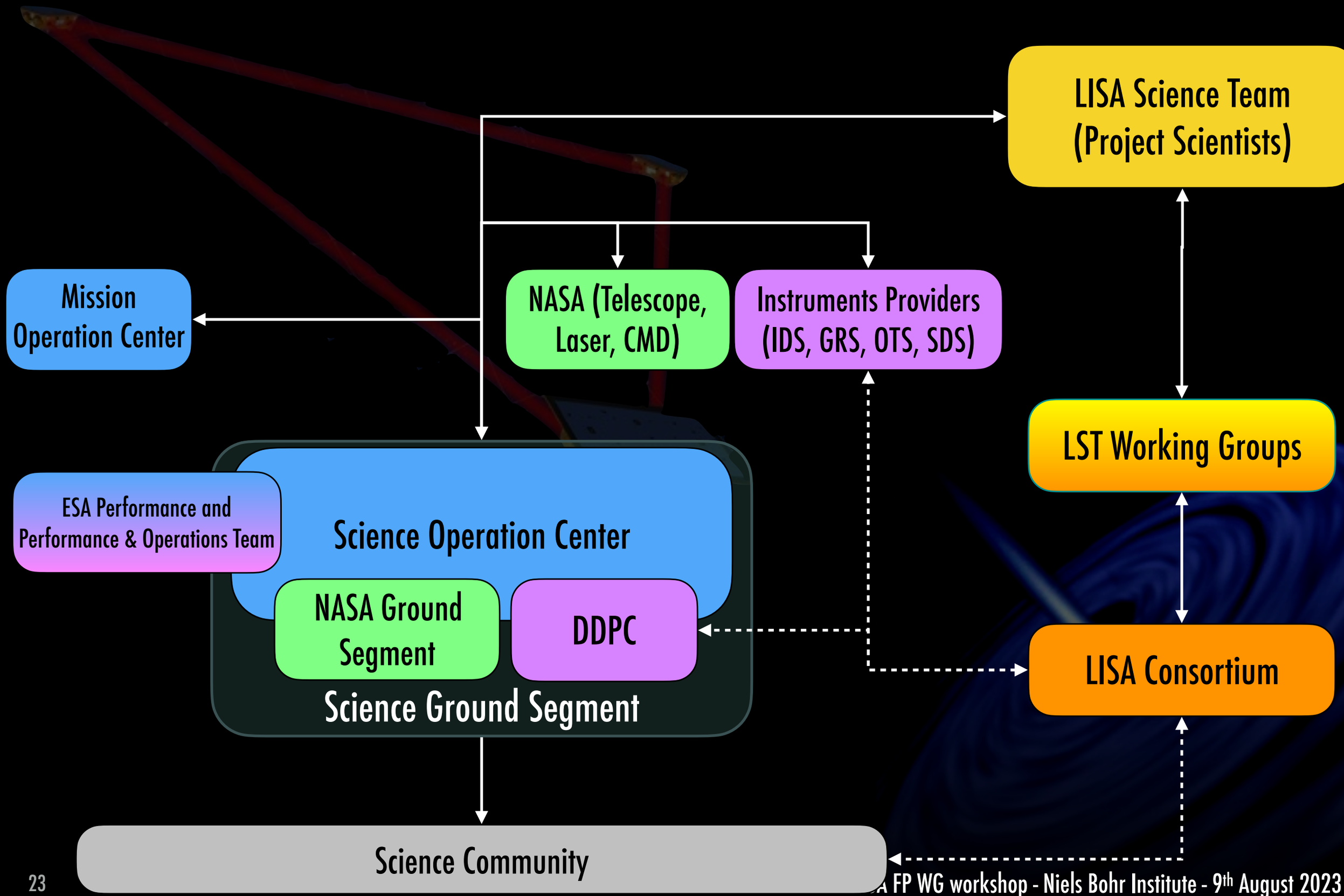
DDPC

Science Ground Segment

LISA Consortium

Science Community

Organisation for operations (preliminary)



How to contribute after adoption

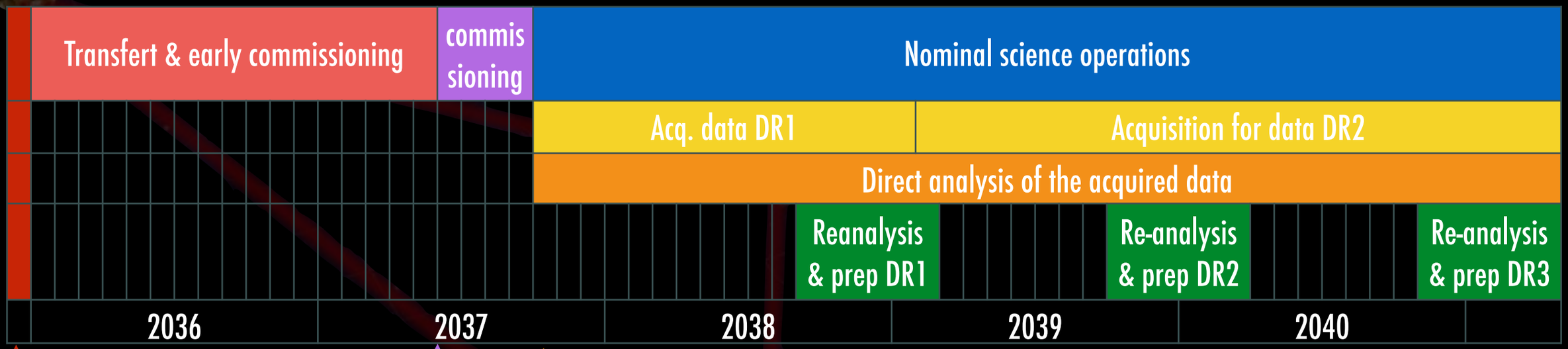
- Contribution to the project:
  - To the DDPC (or the NGS?) for the data analysis activities (excluding science interpretation) via the Work Packages
  - To the instrument subsystems
- Contribution to the LISA Science Study Team (LST), being part of:
  - the LST itself (open call)
  - the LST working groups (no clear yet how they will be formed)
  - the Science Topical Panels (open calls?)
- Contribution to the Consortium:
  - Consortium will have groups ...
  - But detailed organisation depends on the LST organisation
- In any case, Fundamental Physics WG, Astrophysics WG, Cosmology WG will still exist either in the LST or in the Consortium.

Conclusion

- In the current organisation, contributions are possible:
  - In the WGs directly for all Consortium members
  - In the LSG, FMT Expert Groups and LDPG for full members
- LISA adoption is planned for 25th January 2024
- The Consortium will evolve with the adoption but the new organisation will only be in place at the end 2024.
- Important role is expected for the ESA LISA Science Team with its Working Groups and its Science Topical Panels
- Current WGs will still exist.
- Evolution of the LDC, with the core pipelines managed by the DDPC.

Thank you

Commissioning



Dec-2035: launch

Oct-2037 Start operations

Oct-2037 Start commissioning

- Commissioning in 2 phases:
  - transfert
  - commissioning