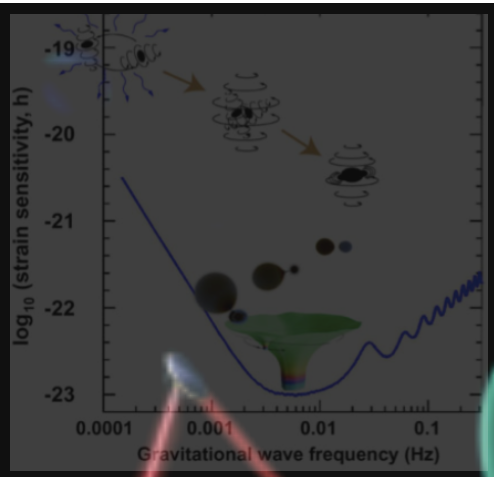

ESA activities towards the Gravitation Waves Space Observatory

Frédéric Safa
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LISA Symposium, Zurich 2016

The Gravitation Wave Observatory in ESA Science Programme

***The Gravitational Universe* was selected by the Science Programme Committee as the science theme for the 3rd ESA flagship mission (L3) in Oct 2013**

- Selection in Oct 2013, following the Senior Survey Committee recommendation
- Based on eLISA white paper (which was derived from NGO study)
- Planned launch date of 2034, ESA CaC 1050 M€
- International collaboration contemplated with NASA contribution
- Science case strengthened by recent gravitation wave detections with LIGO

Laser interferometry (LISA concept) is baselined for L3

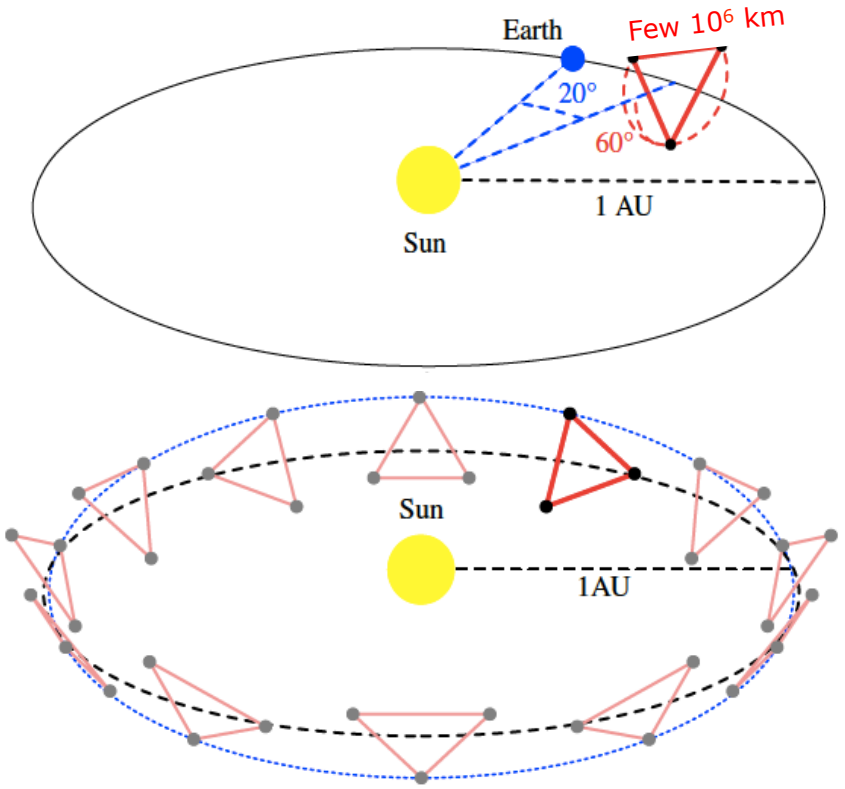
- Confirmed by the Gravitation Observatory Advisory Team set by ESA in 2015
- Builds on LISA-PathFinder good performance in-orbit (2016)

Gravitation Wave Observatory mission concept

Constellation of 3 S/C in trailing orbit and quasi-equilateral configuration, including each a reference mass in free-fall

Measurement of the distance between the reference masses with picometre range accuracy, over frequency range 0.1 mHz to 1 Hz

Measurement concept: laser interferometry using heterodyne detection for phase measurements



Each S/C is on an Earth-like orbit with tiny inclination and eccentricity deviations. The triangle describes a cone of 60 deg half-angle and is rotating with 1 yr period.

Snapshots from previous studies

LISA-2011 (Atlas V launch)

Payload mass: 392 kg

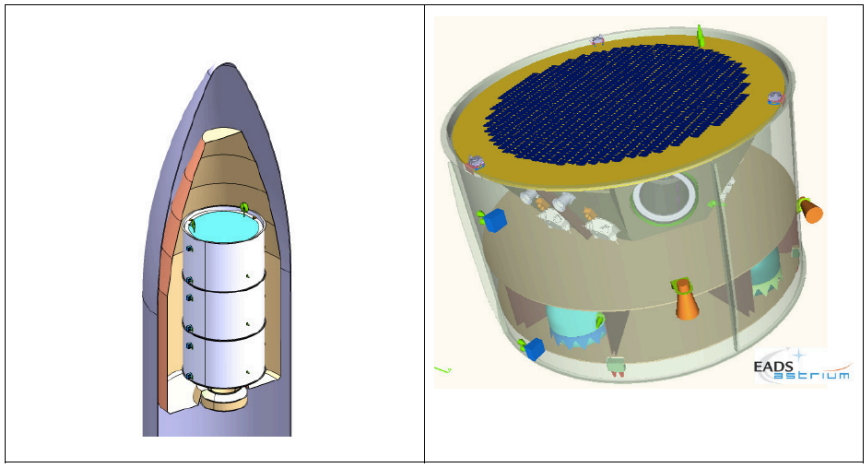
S/C dry mass: 865 kg

PM dry mass: 503 kg

Total dry mass: 3x1368 = 4104 kg

Average ΔV: ~1000 m/s

Launch mass: 6155 kg



NGO-2012 (two Soyuz launches)

Mother Payload mass: 326 kg

Mother S/C dry mass: 750 kg

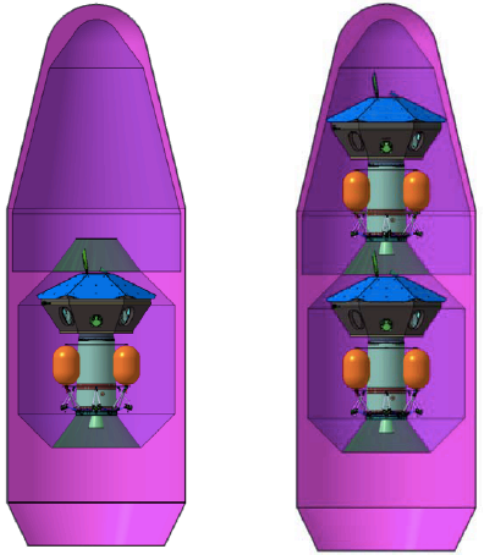
Daughter S/C dry mass: 596 kg

PM dry mass: 212 kg

Total dry mass Mother / Daughter: 1003 / 849 kg

ΔV Mother/Daughters: 1445 / 1760 m/s

Launch mass Mother/Daughters: 1658 / 3166 kg



Extracts from LISA Science Requirements Document (LISA-ScRD-004, 2007)

Baseline requirements [LISA 2011]

- LISA shall have a useful science observing time of 5 years
- LISA shall be designed for 3 spacecraft with 6 working links (two interferometers) and the design shall ensure 2 operating arms for the full mission duration

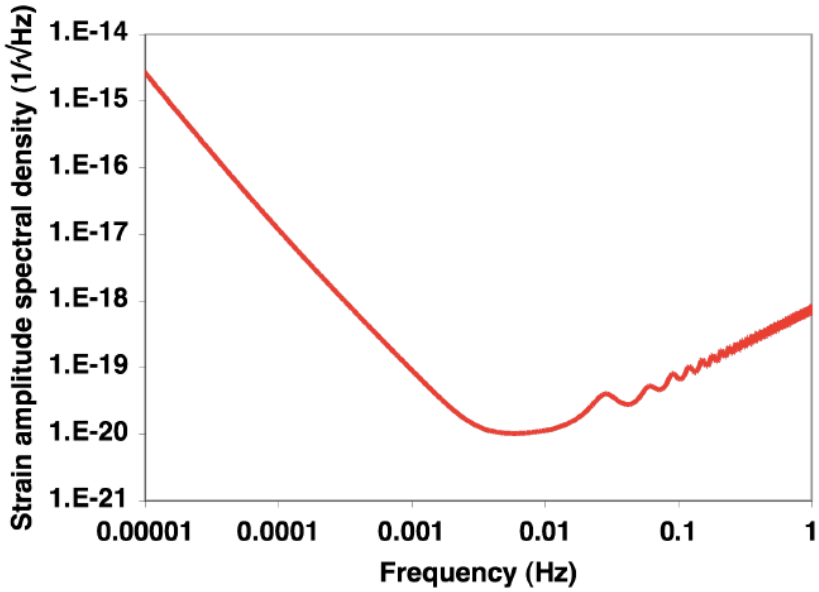
Minimum requirements [NGO 2012]

- Sensitivity degraded by a factor 5, over frequency range 0.1 mHz to 10 mHz
- Science observing time of 2 years with 75% duty cycle
- Four measurement links (one interferometer) for the duration of scientific observations

Goal requirements [LISA 2011 goal]

6 working links for the full mission duration;

Extended mission duration of 8.5 years



Instrument sensitivity requirement

ESA activities towards L3 implementation

Technology development activities resumed in 2016

- Highest priority on the laser development and on the telescope
- The technology work plan will be regularly updated for taking into account the mission definition activities
- Requirement to reach ISO TRL 6 at the time of mission adoption
- Objective to reach qualification of critical equipment (e.g. Laser subsystem) by the mission adoption

Mission definition studies will be initiated in 2017

- Gravitation Wave Working Group in place for resuming discussions on the Member States and International contributions
- Call for L3 mission is being prepared
- Shall take full benefit of LISA-PathFinder heritage

Launcher and orbit transfer aspects

L3 is likely to make use of a European launcher

- Candidate launchers are Ariane 6.2 or Ariane 6.4
- From previous studies, compatibility with A6.2 is unlikely

Ariane 6.4 is suitable for L3. Launch strategy is being revisited

- On going work at ESA, preliminary results will be communicated in the Call for L3 mission
- Via GTO (shared launch) or direct escape (full launch)
- Expected capability 11 tons to GTO, 7 tons to direct escape
- Explore Moon Gravity Assist for lowering ΔV
- Wide range of ΔV estimates, with potential impact on the overall architecture and development approach
  - ~ 1500 m/s from GTO, drifting orbit
  - ~ 600 m/s for direct escape and direct transfer, drifting orbit
  - ~ 300 m/s additional for drift removal

How to get there

LISA-PathFinder excellent results and LISA previous studies allow to resume the mission definition on solid ground.

Some work is needed for enabling the flight HW development phase:

- Mission profile and scenarios for Ariane 6.4
- Payload definition concept and trade-offs
- Straylight management
- Technology developments on critical subsystems: telescope, high power laser, optical bench, etc. Reach ISO TRL 6 or better.
- Secure the phase measurement at picometre accuracy with on-board phase monitoring device
- Industrialization for a small series production: find the right balance between pre-qualifications before adoption and qualifications during the project development phase
- Meet ESA programmatic boundaries and consolidate international collaboration

Tentative Schedule

Action	Date	targeted milestone
Issue Call for L3 mission	Oct 2016	
Mission proposal assessed	Apr 2017	Preliminary structure of the payload consortium and Member states contributions
Phase 0 completed	Sept 2017	Preliminary system concept and trade-offs; Science and Mission Requirements; compatibility with ESA CaC boundary
Industrial Phase A completed, including payload definition	S2 2020	Parallel industrial Phase A contracts (2 yrs). Mission baseline configuration, incl. space segment definition, development plan & cost, and baseline collaboration scheme

Tentative Schedule (2/3)

Action	Date	Expected milestone
Technology maturation	By mid 2022 (target)	Reaching ISO TRL > 6 for equipment and instrument levels. Confirm/consolidate collaboration scheme. ~ 6 yrs from now; ~ 4 yrs from Phase A start
SPC decision to proceed in Phase B1	By mid-2022	Subject to compatibility with core science objectives and ESA CaC boundary
Phase B1 industrial study completed	early 2024	Parallel contracts (18 mo) Mission baseline consolidation; Preparing Space segment industrialization; Frozen collaboration scheme; ESA CaC consolidation

Tentative Schedule (3/3)

Action	Date	Expected milestone
Mission adoption by the Science Programme Committee	mid-2024	Subject to mission definition/ technology maturity and compatibility with ESA cost at completion cap
Prime contractor kick-off	Q1 2025	Industrial competition and selection of the Prime contractor
Flight Acceptance Review	Late 2033	Space segment qualification and flight acceptance. Note: 8.5 years development assumed, current best estimate to be reviewed in the Phase A
Launch	End 2033/ early 2034	Injection towards science orbit. Note: about 14 mo needed to reach operational orbit

Securing a timely implementation

- **Do not inflate the mission objectives**

  Design iterations and technology developments are highly time consuming

  Prioritize the science objectives; Enable efficient balance between engineering/cost constraints and science during the mission definition
- **Fully seize LISA-PathFinder heritage**

  GRS, optical bench, understanding of systematics. Change with needs to be.
- **Stabilize key mission and interface requirements by the end of Phase A, including collaboration scheme**

  Partly depends on the above
- **Timely technology developments and pre-developments**

  Member States and Partner investments in parallel to ESA;

  Target qualification for critical equipment before the Prime kick-off, for securing/lowering the development schedule.

The end