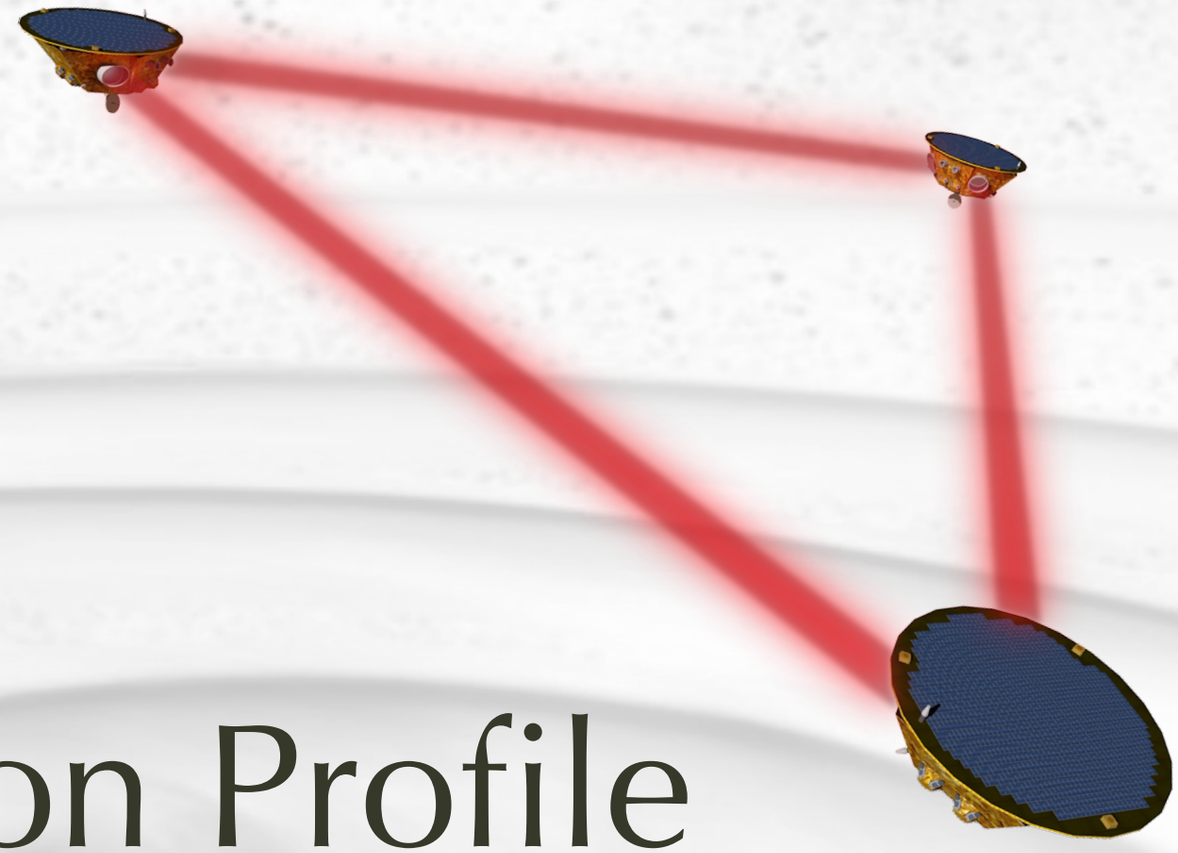
LISA Status & LISA France Activities

H. Halloin et al.
APC - CNRS/Université Paris Diderot

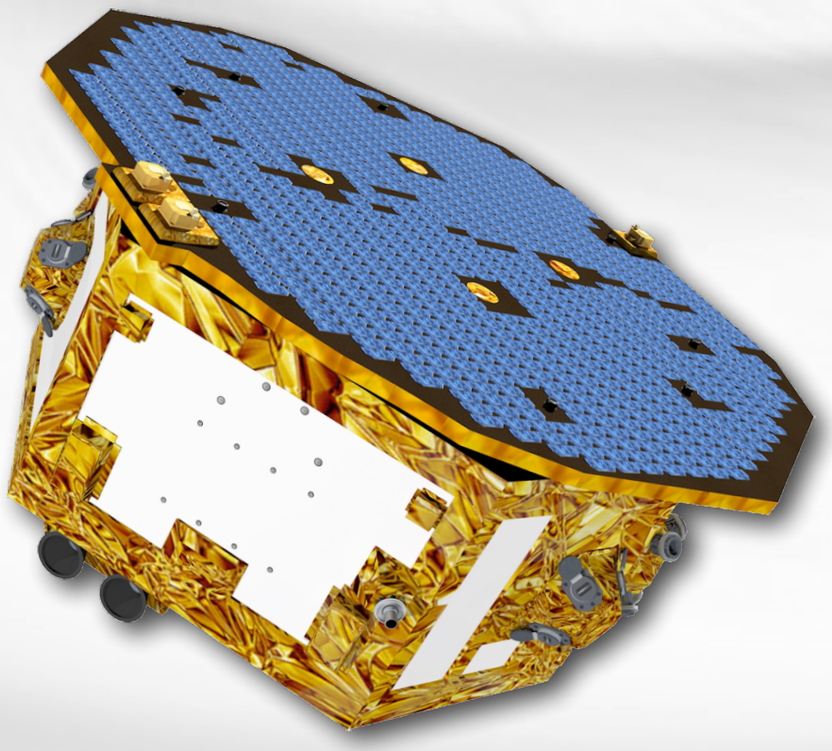
Outline

- LISA Mission Profile
- French Contribution
- Mission Status

lisa

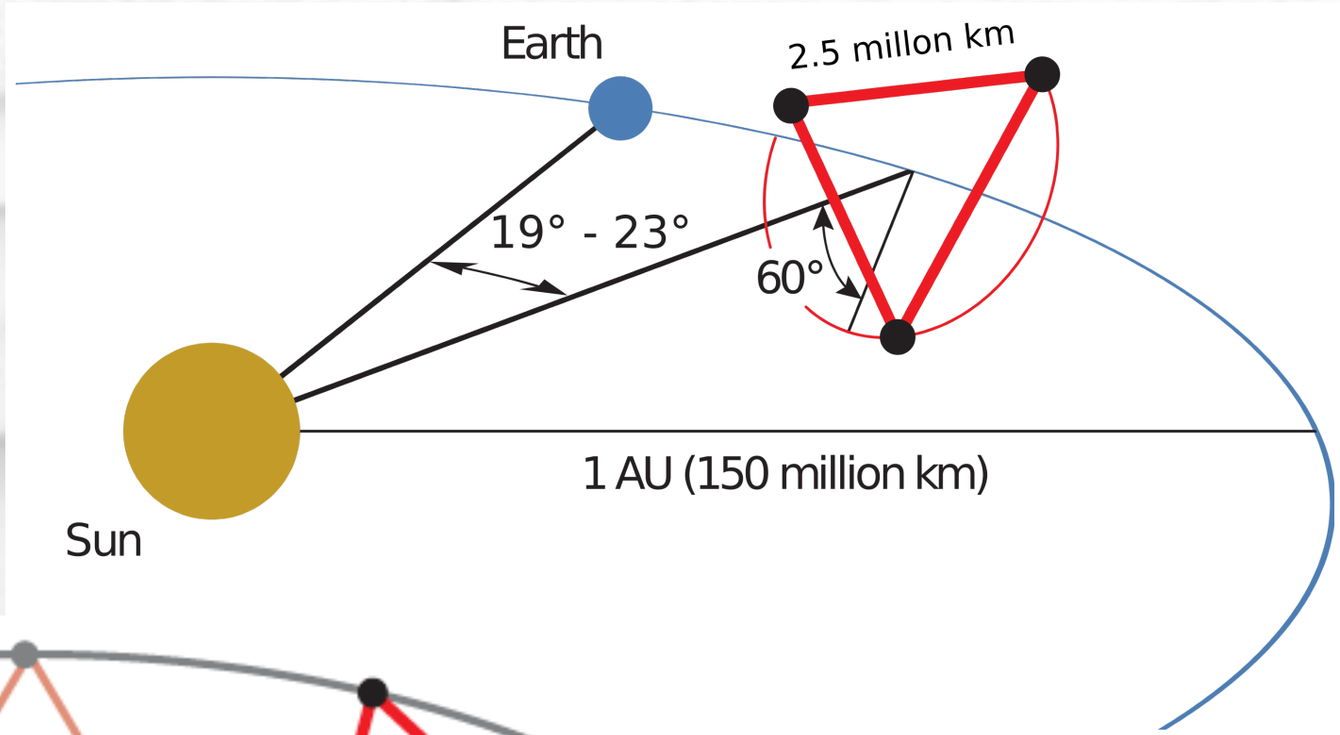


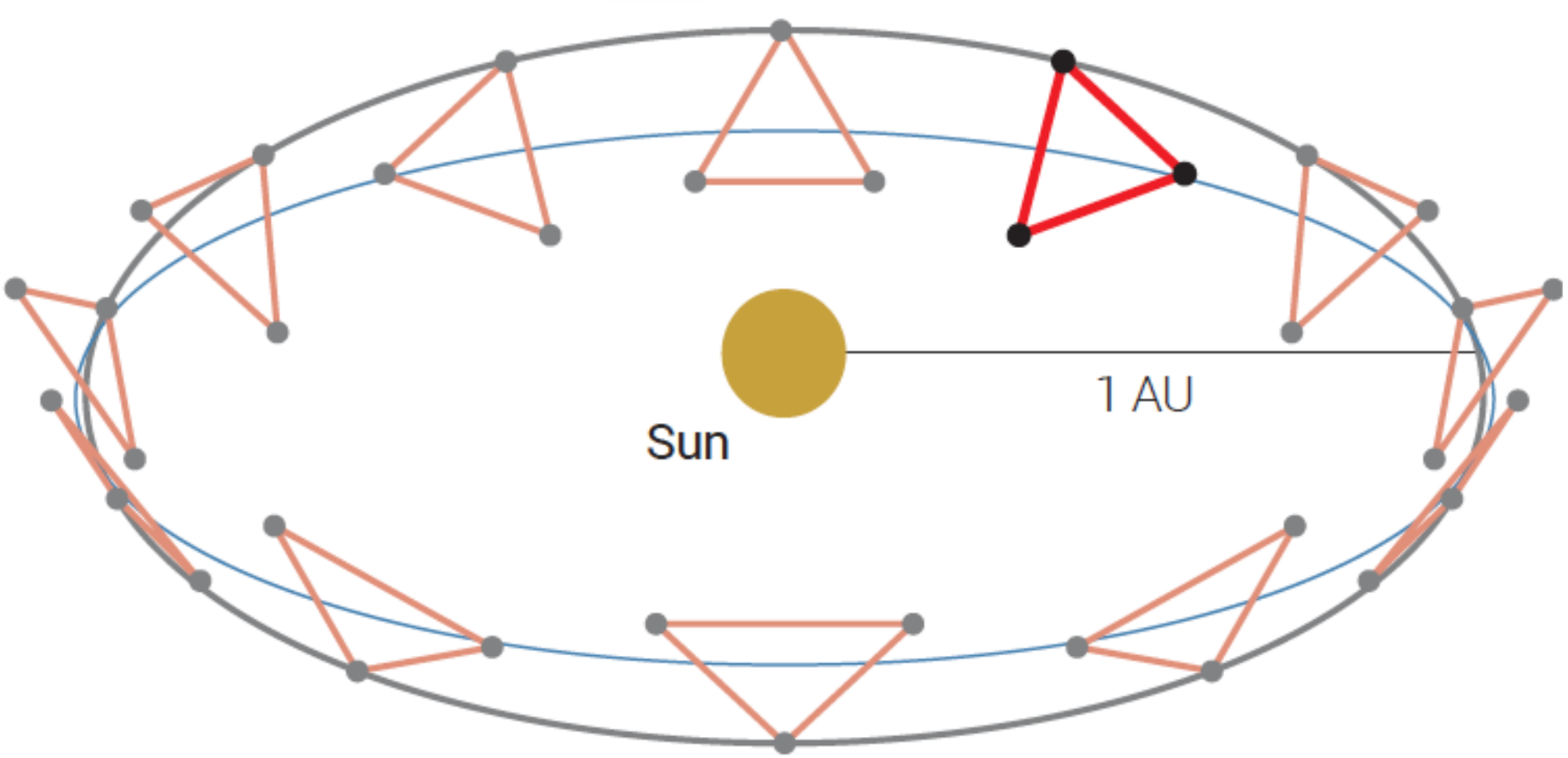
LISA - Mission Profile



LISA mission profile

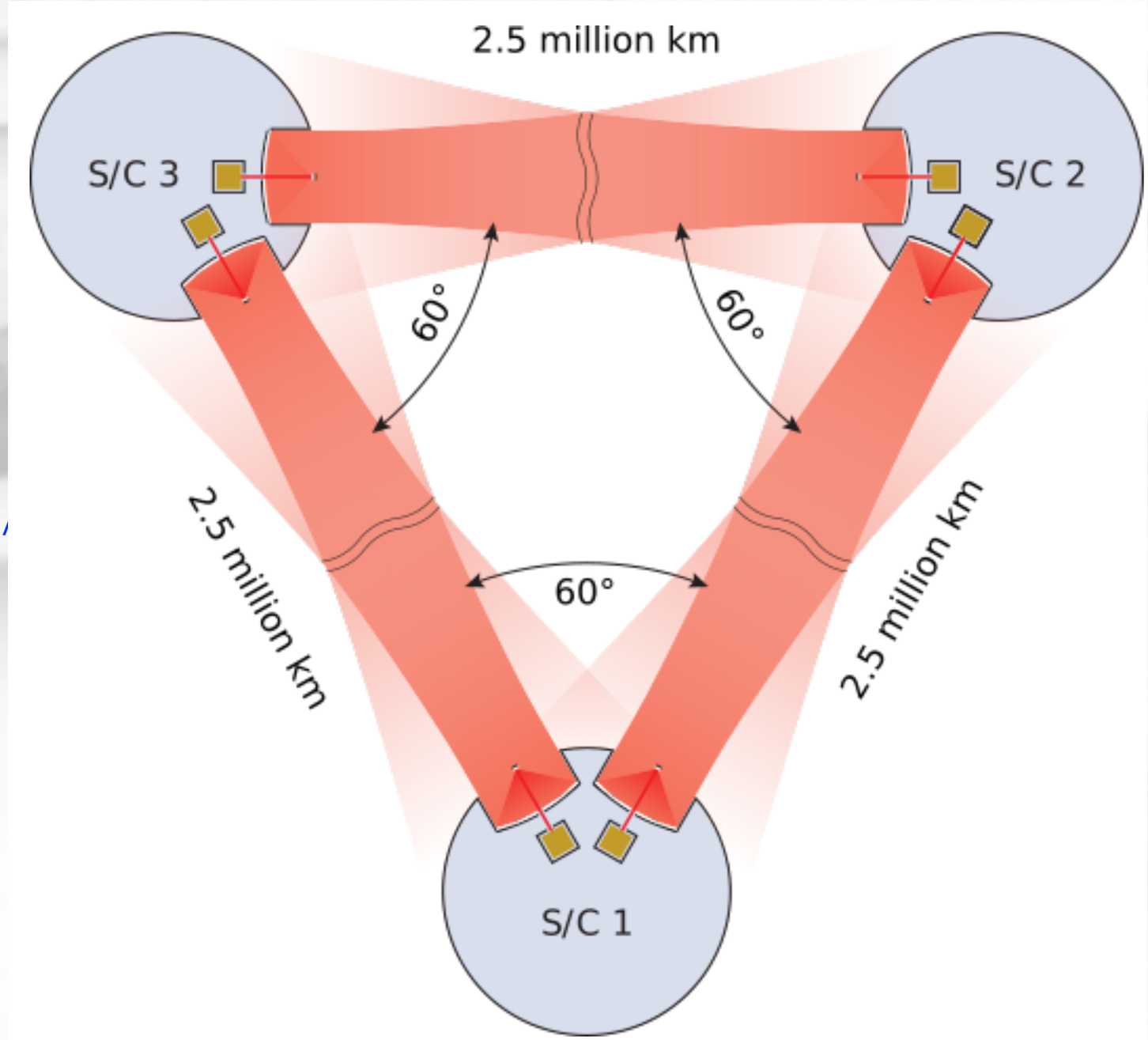
- Long arms interferometer
  - Earth-like orbit, 19° to 23° trailing
  - Mission duration : minimum 4 years (consumables for 10 years)



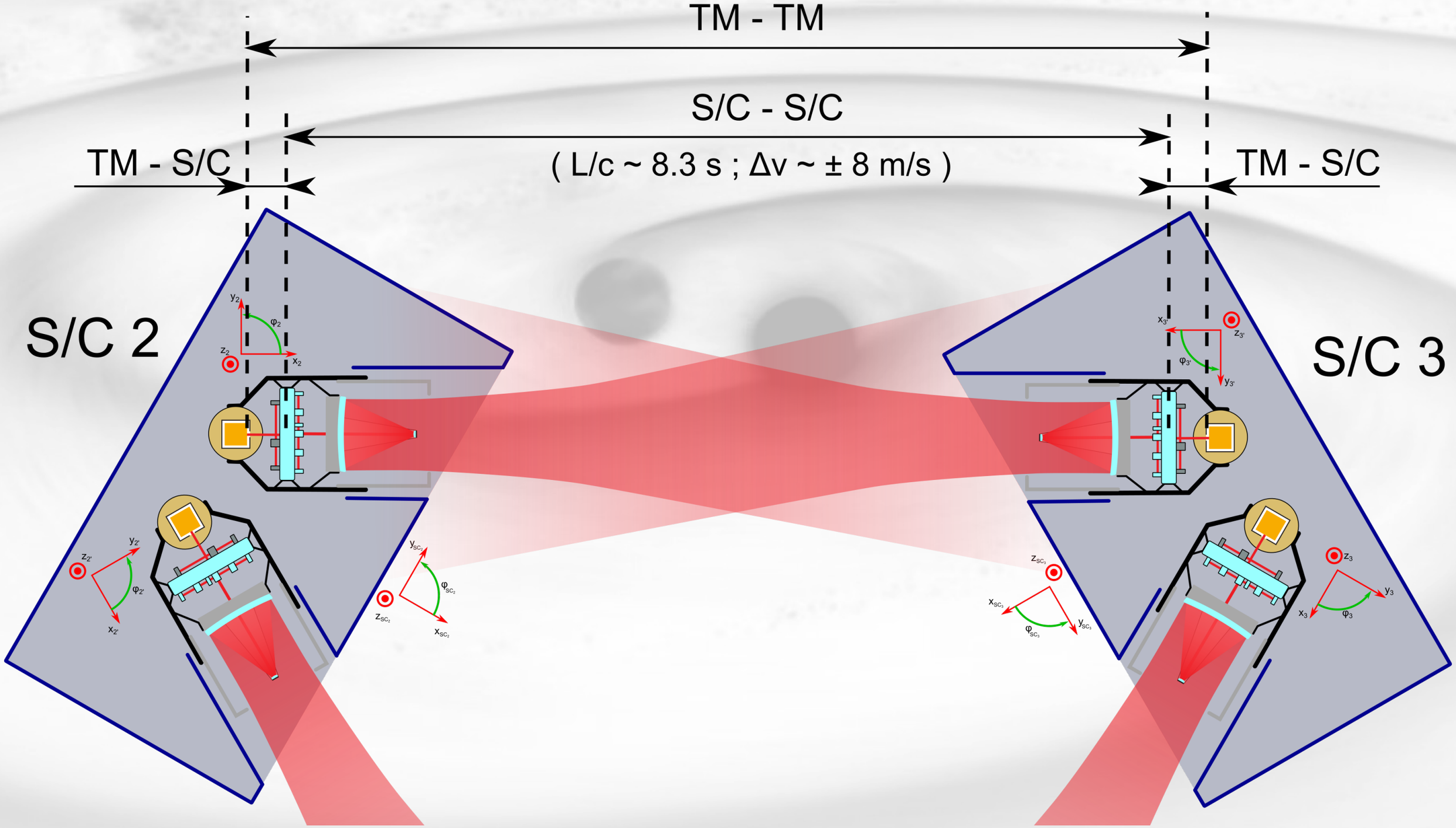


LISA Interferometer

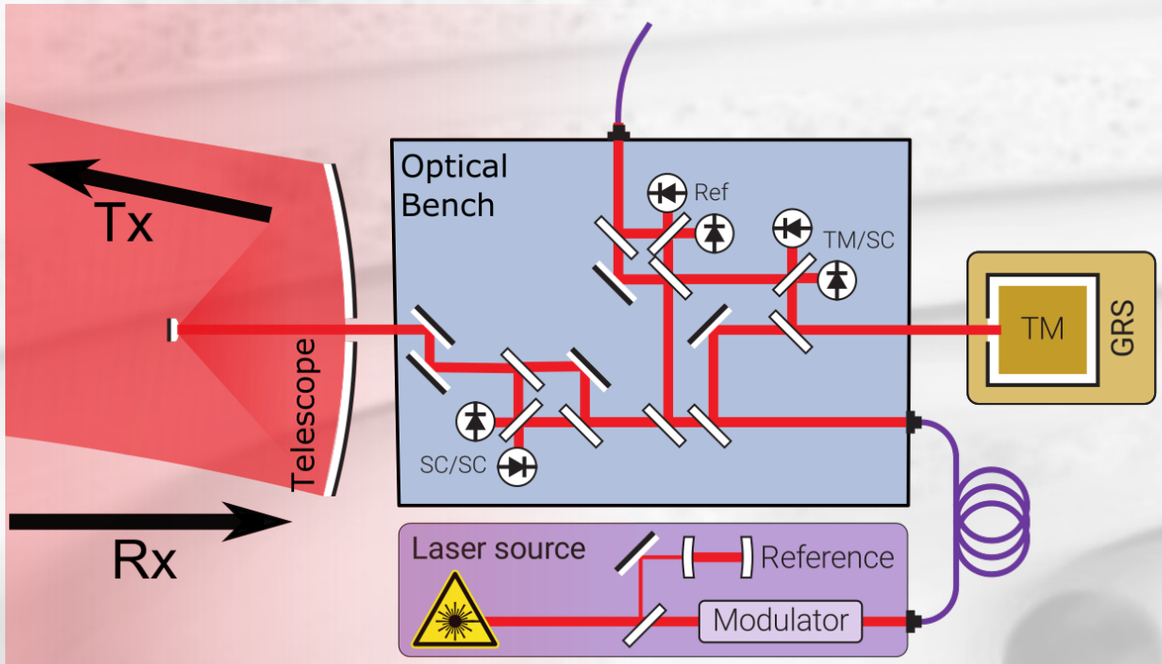
- Equilateral configuration
  - 3 arms / 6 links ; 2,5 Mkm
- Test masses
  - Direct heritage from LPF
  - 2 TM / satellites
  - 2 steerable optical benches / satellite
- Typical metrology requirement :
  ~10 pm/√Hz @ 1 mHz

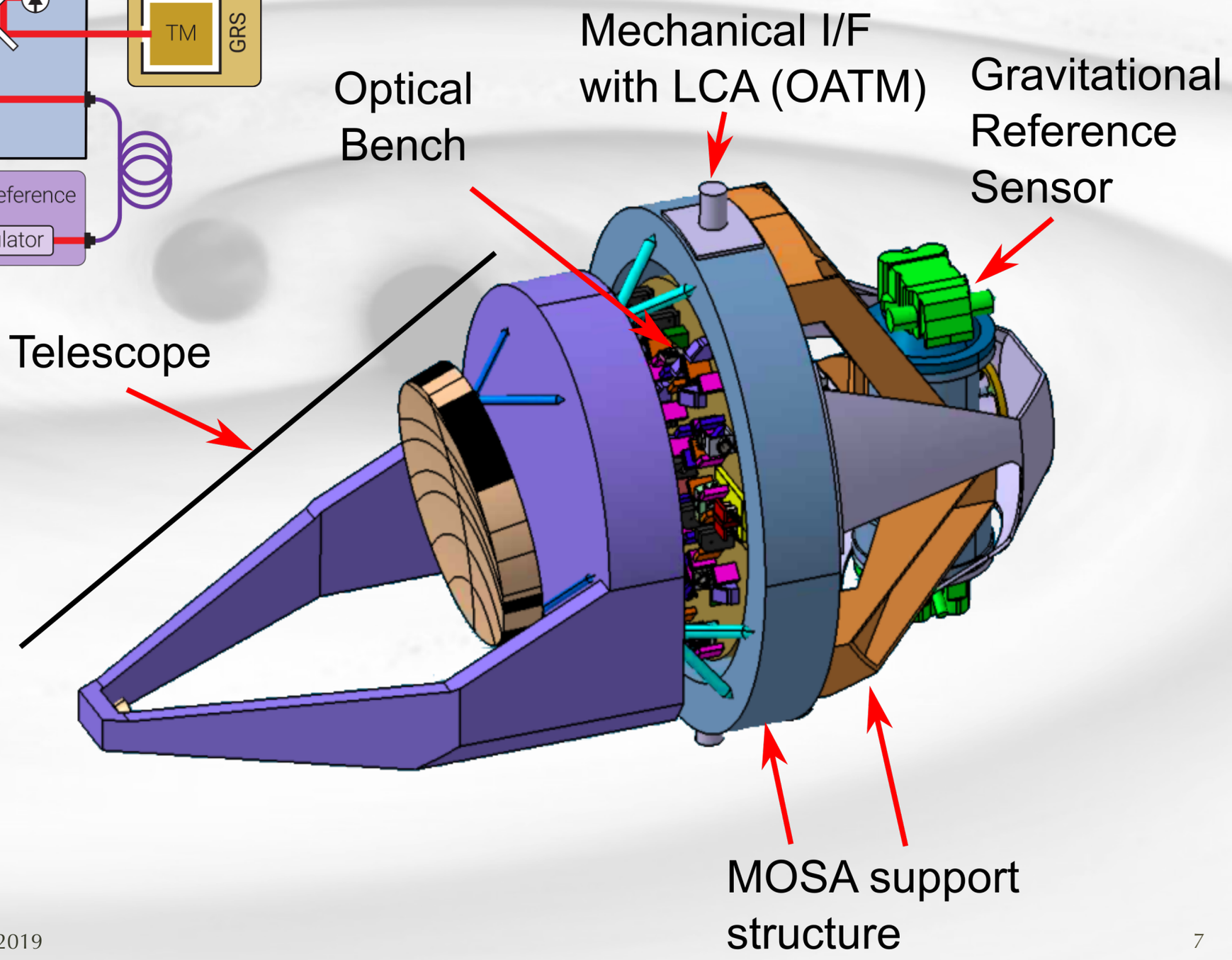


Measurement principle



Scheme of a instrument

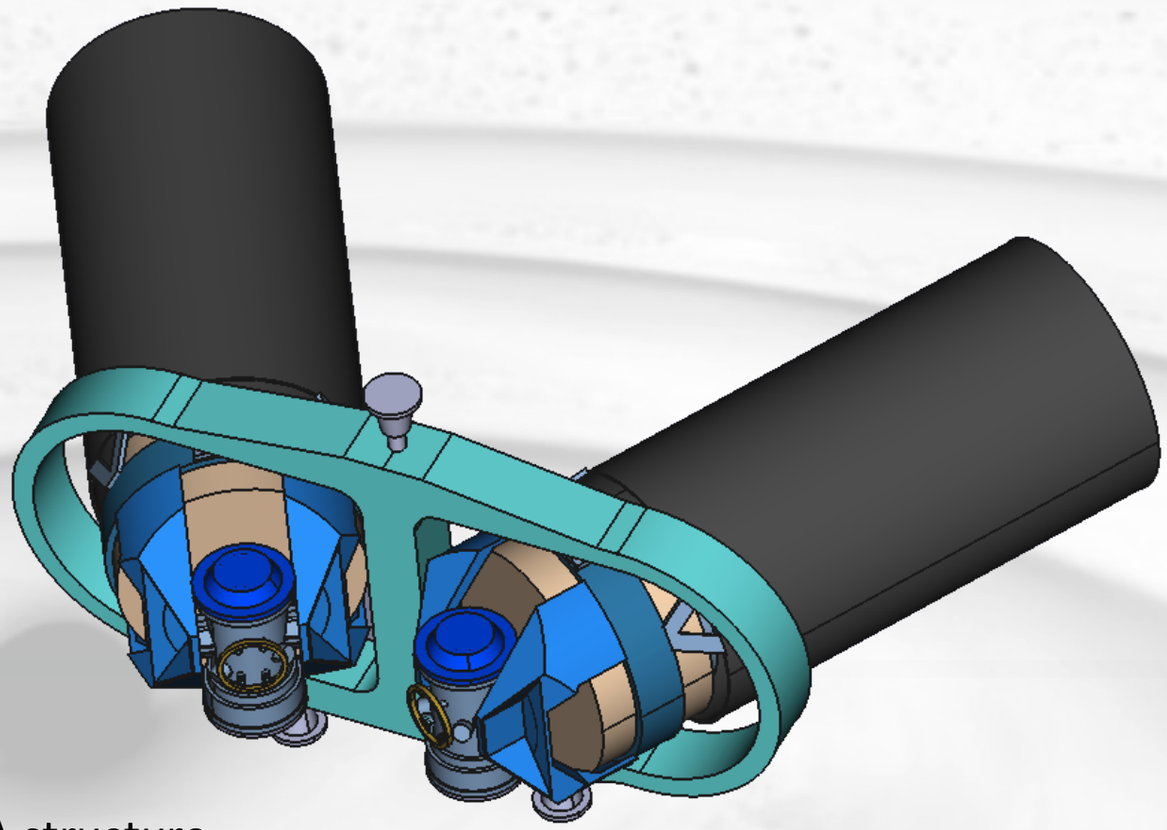


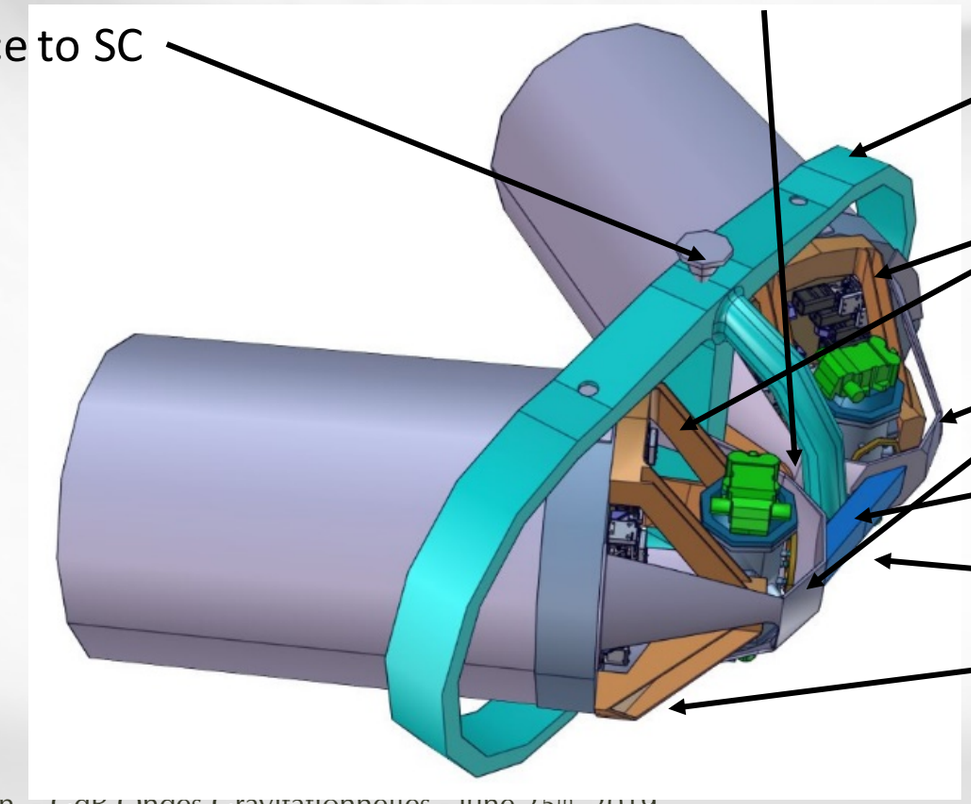


- MOSA = Movable Sub-assembly

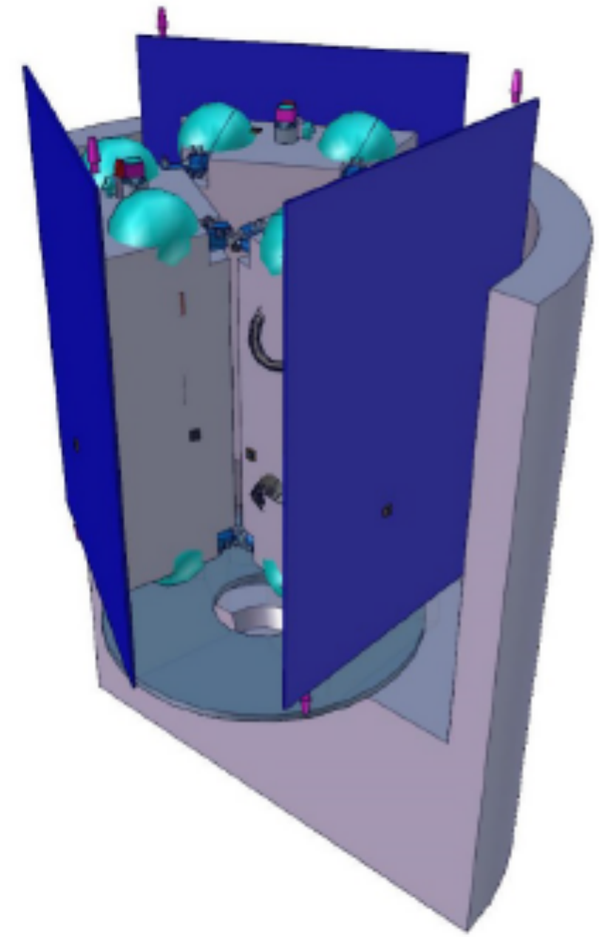
Two MOSAs form an LCA …

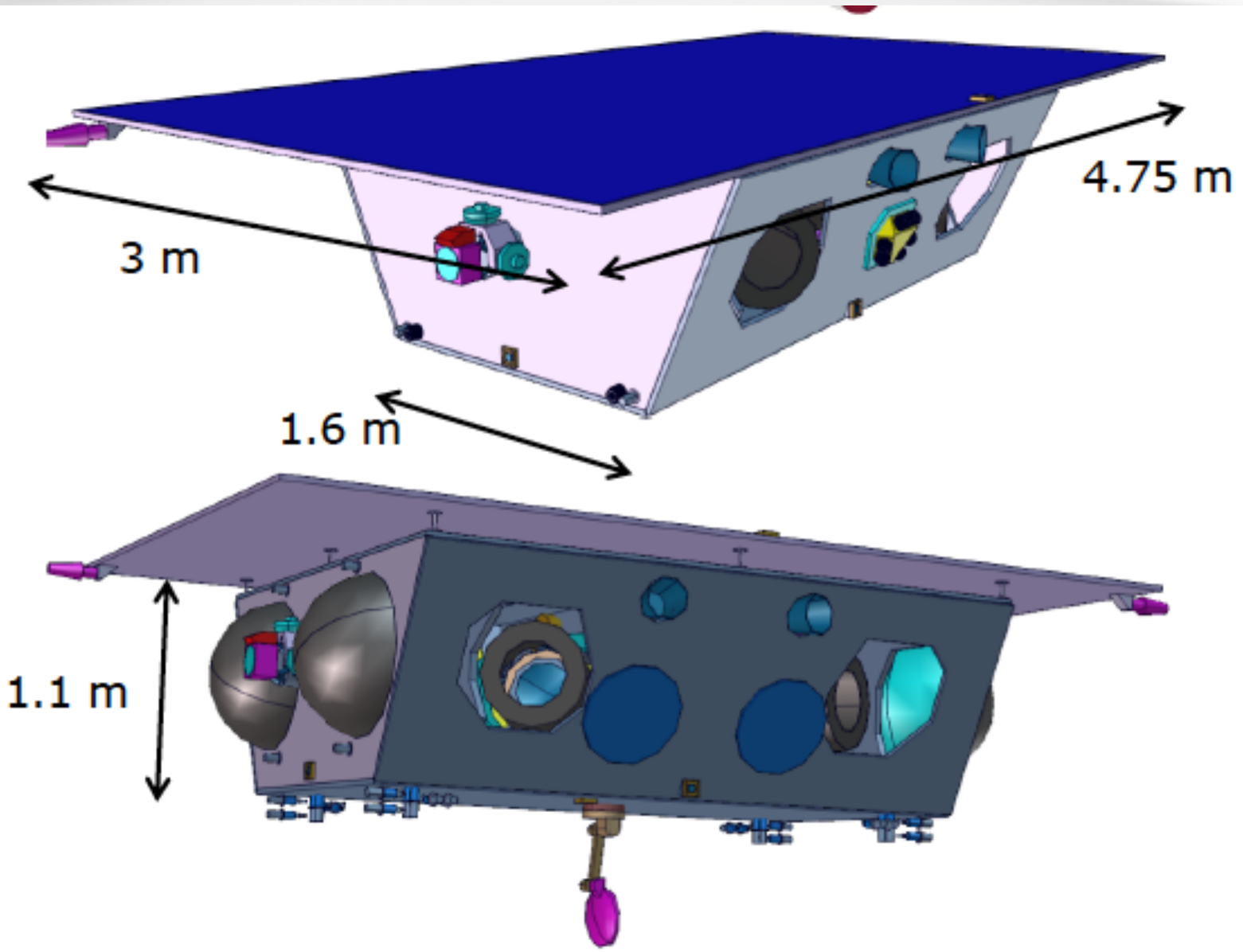
LCA = LISA Core Assembly





Three S/C fit into an Ariane 6.4



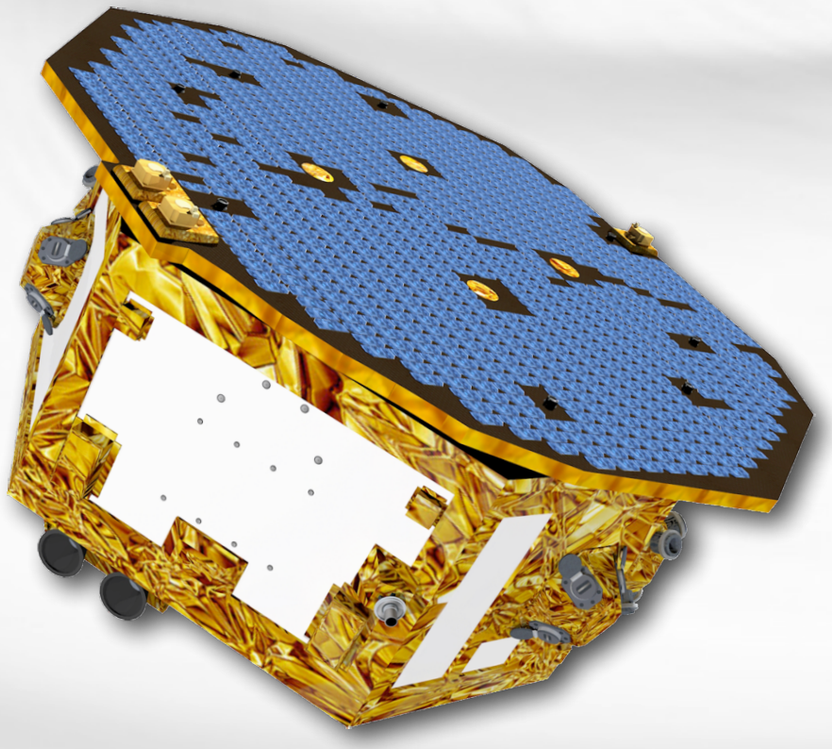


(Some) key performance values

- Drag free performance : **3×10^{-15} m.s^{-2}/√Hz**
  - DC value: ~10^{-11} m.s^{-2}
  - Validated with LISA Pathfinder !
- 6 laser links, 2.5 Mkm
  - Measurement bandpass : [0.1 mHz : 1 Hz]
- Telescopes:
  - ~25 cm diameter,
  - Pathlength stability: ~ 1 pm/√Hz
- Laser
  - Nd:YAG (1064 nm), 2 W emitted (received ~400 pW)
  - RIN : <10^{-8} /√Hz above 5 MHz
  - ~100 Hz/√Hz
- Timing jitter in clock distribution: ~4×10^{-14} s/√Hz
- Absolute ranging accuracy: ~1 m
- Thermal stability (optical bench): < 10 µK/√Hz at 1 mHz
- Laser beam pointing jitter: ~10 nrad/√Hz

lisa

Proposed French Contributions to eLISA



Hubert Halloin - Séminaire CPPM - May 27th, 2019

What contribution for France

Prime: AIRBUS DEFENCE & SPACE, ThalesAlenia Space

esa

NASA

JAXA

Instrument Board
Instrument PI (D), National PIs

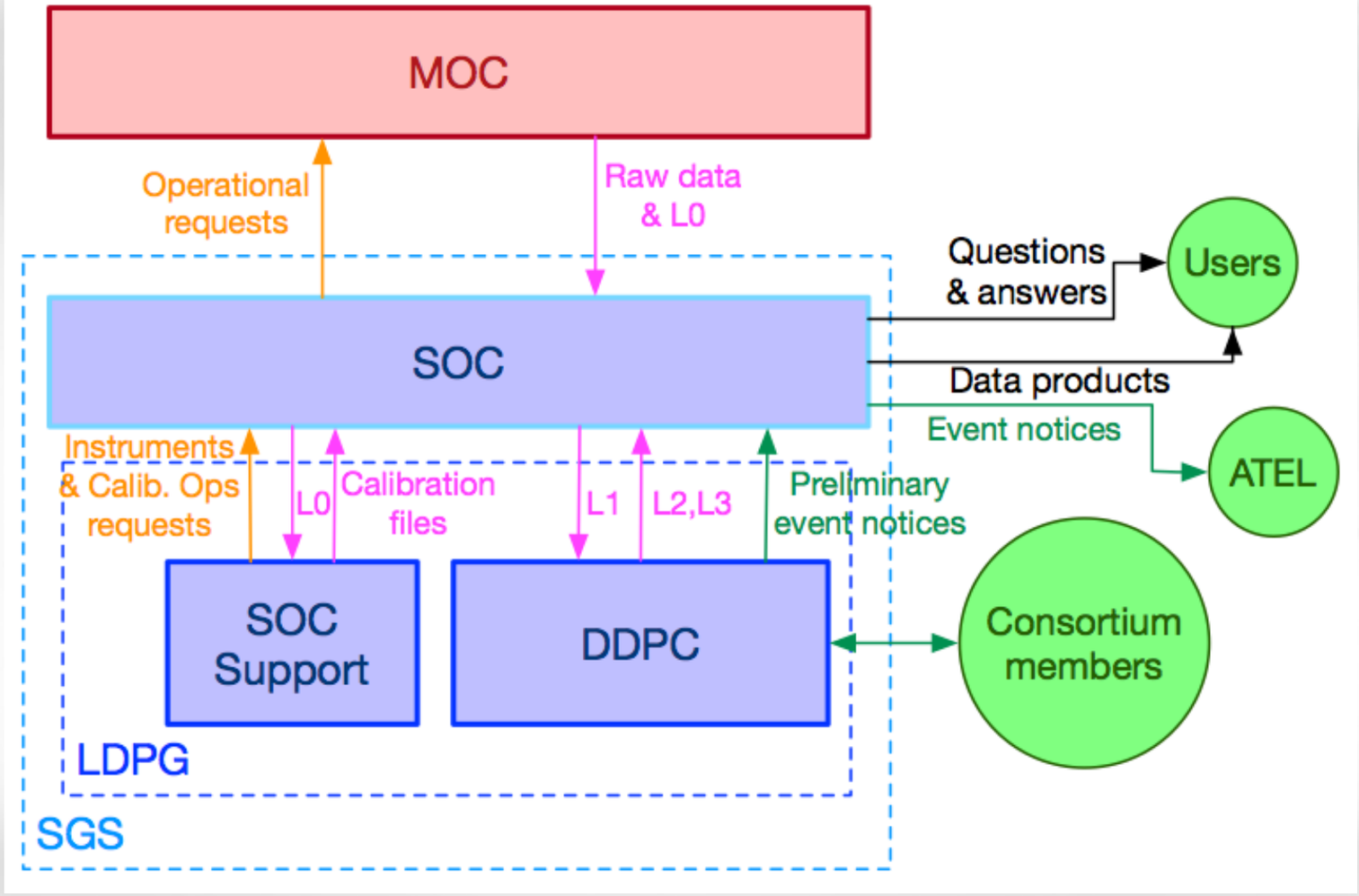
- Telescope
- Charge Management System
- Laser system
- Management, PA/QA
- AIRBUS DEFENCE & SPACE Instrument Architect
- AIRBUS DEFENCE & SPACE System Engineering
- Phasemeter
- **Performance Control**
- **Instrument integration validation and tests**
- **Data Processing Center**
- Optical bench
- Gravitation Reference Sensor
- GRS front end electronics
- Caging mechanism
- Phasemeter support
- Diagnostics System / Instrument Computer
- Photodiodes ?
- OB Mechanisms

Planned main French contributions

- Distributed Data Processing Center
- MOSA AIVT & Perf. Control

Distributed Data processing center

- Development of a Distributed Data Processing Center for LISA
  - Produces scientific L2&L3 data
  - Will host, validate, distribute and maintain data analysis software
  - Supports the LISA community for SW and documentation management
  - Prototype architecture based on virtualization and continuous integration



docker GitLab

jupyter

LISA Data Challenges

- Want to try to analyse Mock LISA Data ?
  - Challenge 1 (Radler) released

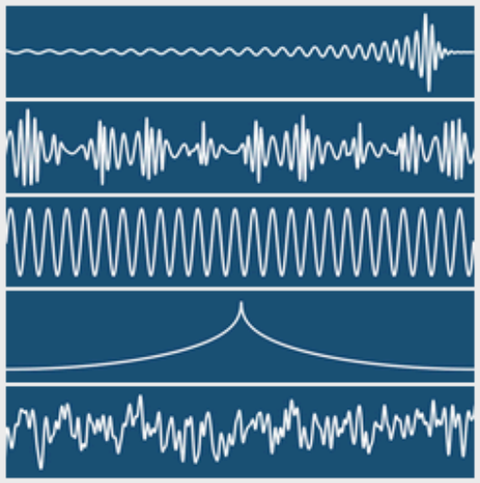
LDC | Challenge 1 | Meetings | Contact | Admin | Login | Sign up

(the new) LISA Data Challenges

...or, as we call them, the **LDCs**—an **open, collaborative effort to tackle unsolved problems in LISA data analysis**, while developing software tools that will form the basis of the future LISA data system.

The LDCs are organized by the **LISA Consortium's LDC working group**. Please join us as we write code and specifications to generate challenge datasets, and we work together to search for gravitational-wave sources and estimate their parameters. If you prefer to explore by yourself, develop your algorithms (or improve ours), then submit your methods and results so we can learn from them.

The LDCs are supported by the LISA Data Processing Center at APC Paris.



Challenge 1

Codenamed **Radler** and released on July 9, 2018, the first challenge seeks to introduce new researchers to LISA data analysis, to rehabilitate existing analysis codes, and to establish our process and standards.

We expect to collect Challenge-1 entries at the end of 2018.

Learn more and download »

Join us

The LDC working group consists of members (both full and associate) of the LISA Consortium: apply here for Consortium membership, or through the LISA Consortium group at your institution.

Coming soon: LDC publication policies.

Inquire about membership »

LDC software

We periodically release all software developed by the working group to build and analyze datasets. Working group members have read/write access to our code repository.

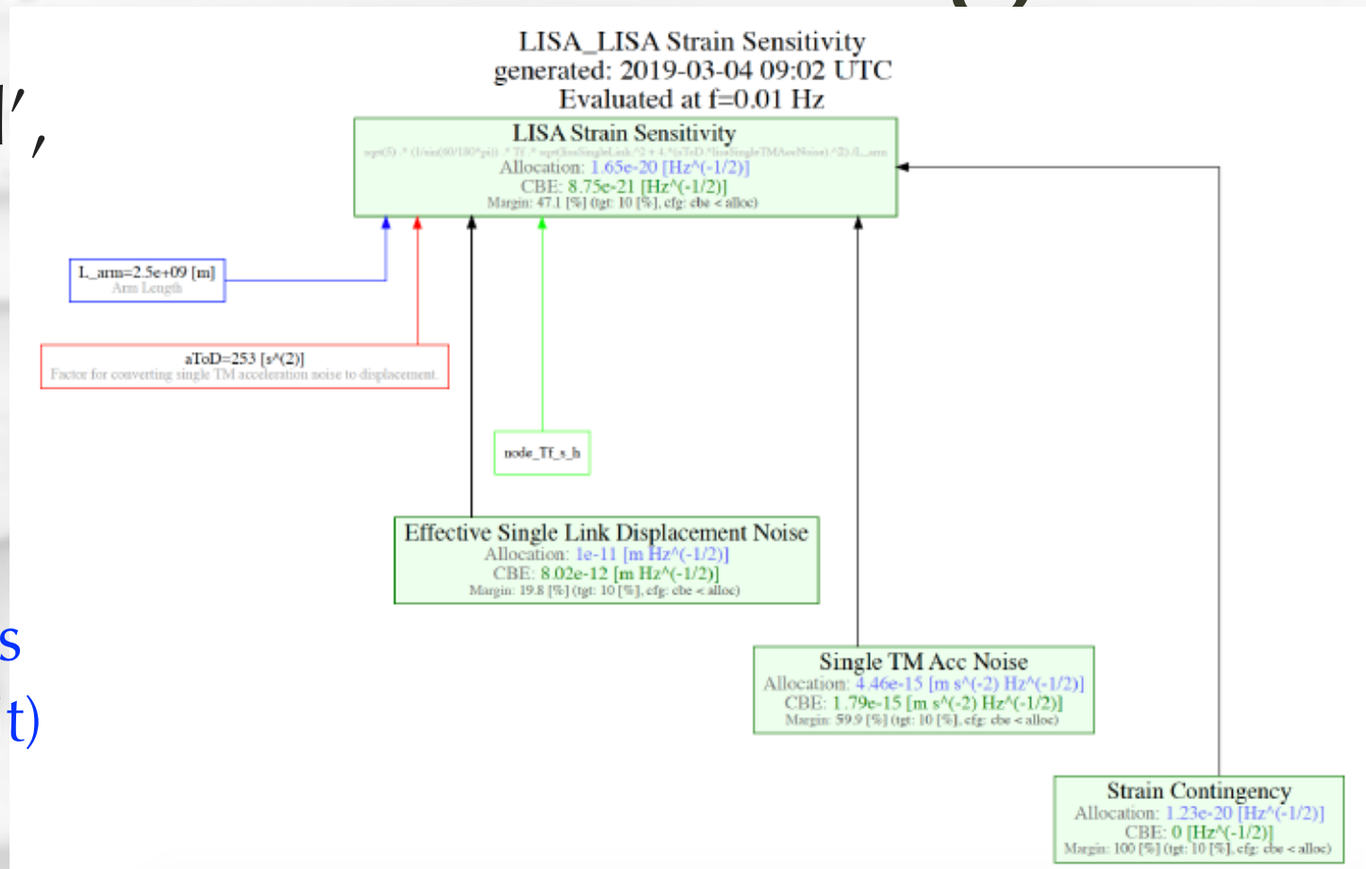
Coming soon: LDC tutorials and example codes.

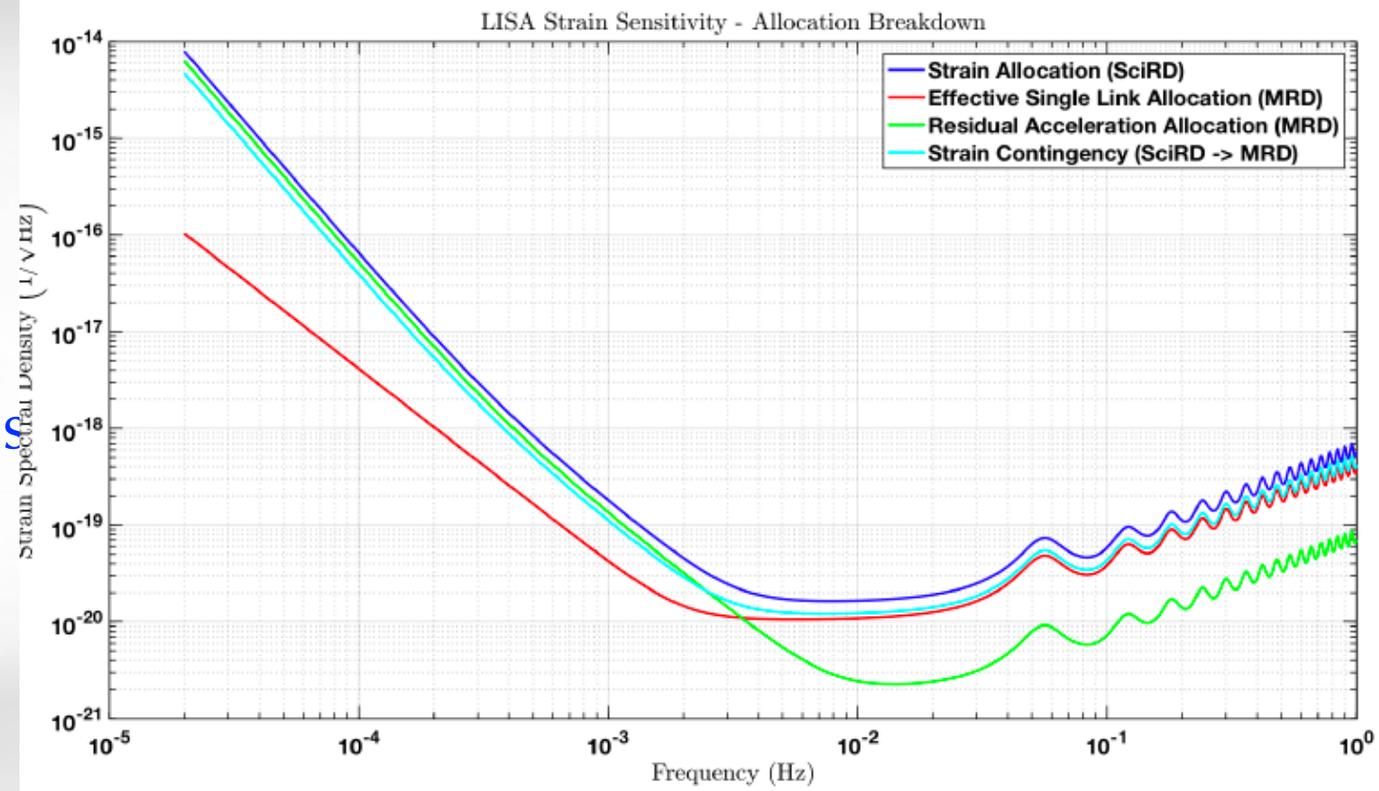
Login to get our code »

Last update: May 25, 2019, 3:43 p.m. © Cécile Cavet

Performance budget

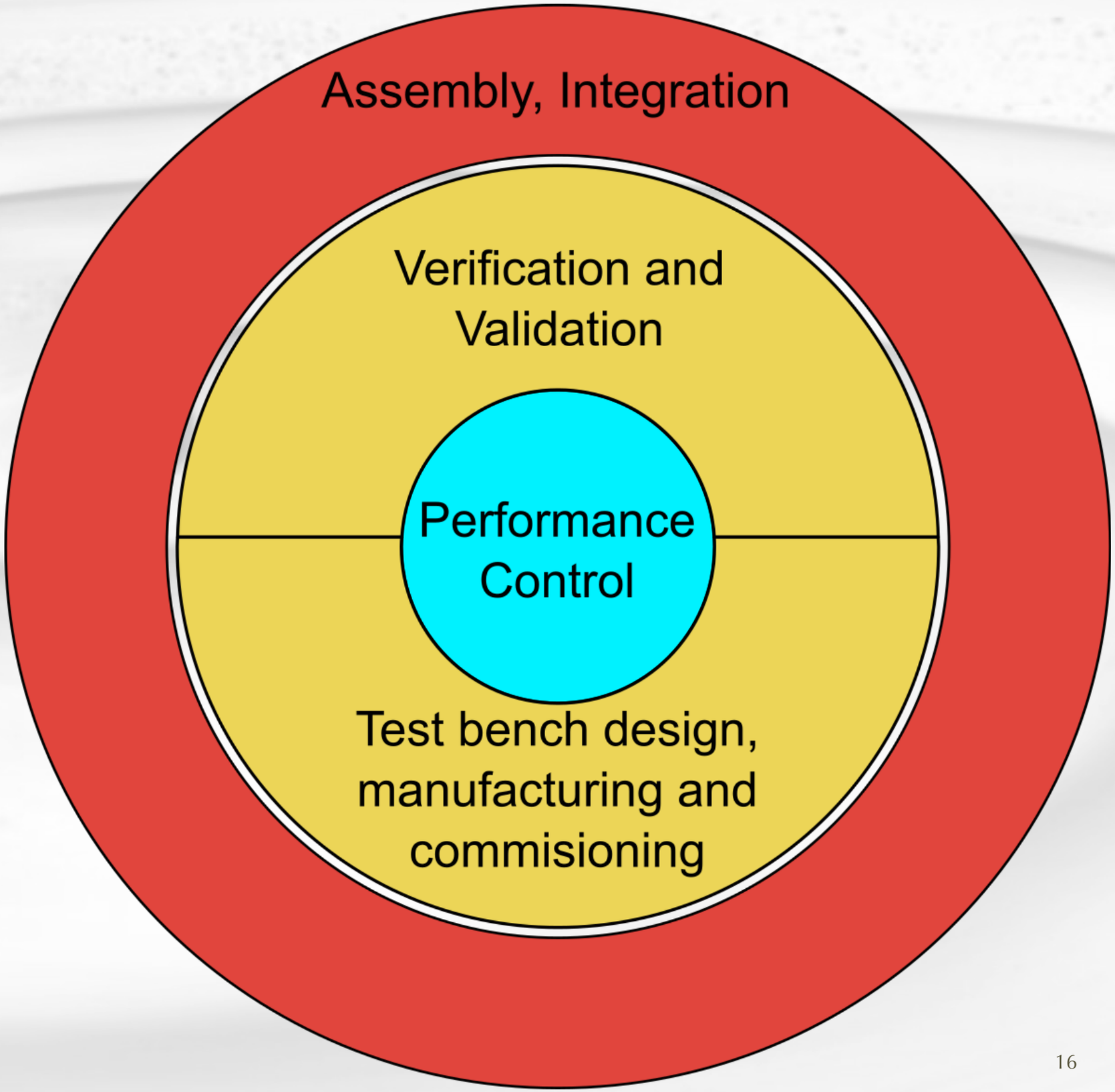
- Objective : build a ‘simplified’, system-level, performance budget
  - => identify critical items
  - => unified view of the system performance
  - => propose required calibrations and tests (on-ground and in-orbit)
  - => allow comparison between experiments and predictions
- Different sources of information
  - specific or ‘end-to-end’ simulations
  - mathematical & physical models
  - lab experiments
  - educated guesses …





Instrument AIVT

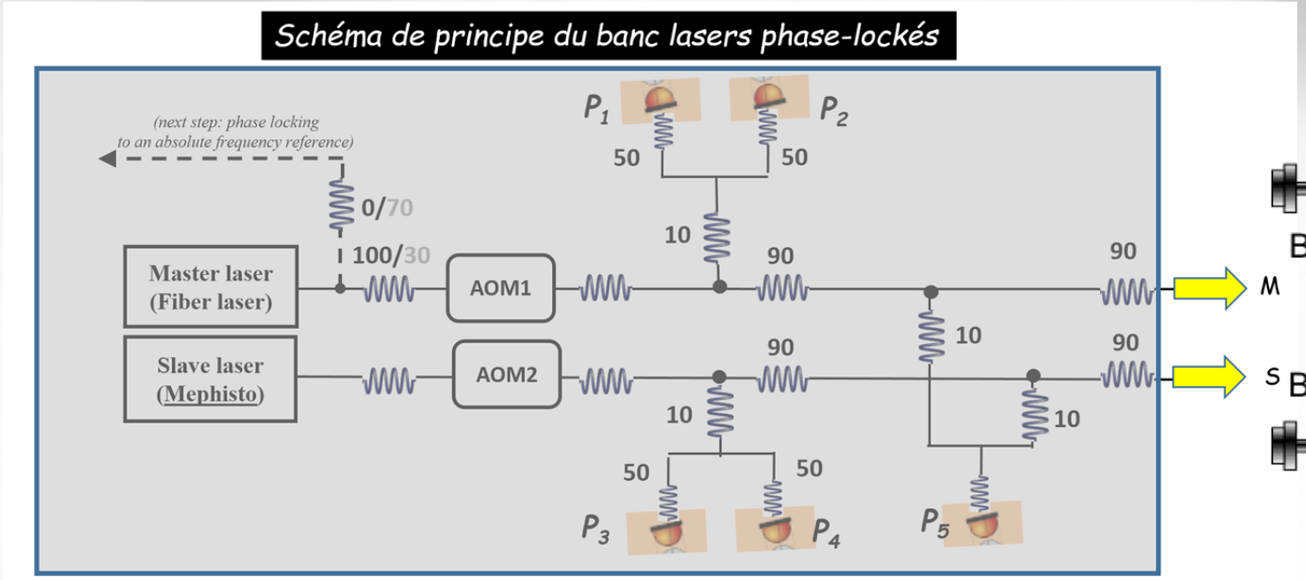
- Verification and validation
  - Convert system requirements into ground measurements (as far as possible…)
- Test benches development
  - Design, manufacturing and commissioning
- Integration and qualification
  - Design of ground support equipments
  - Integration activities …

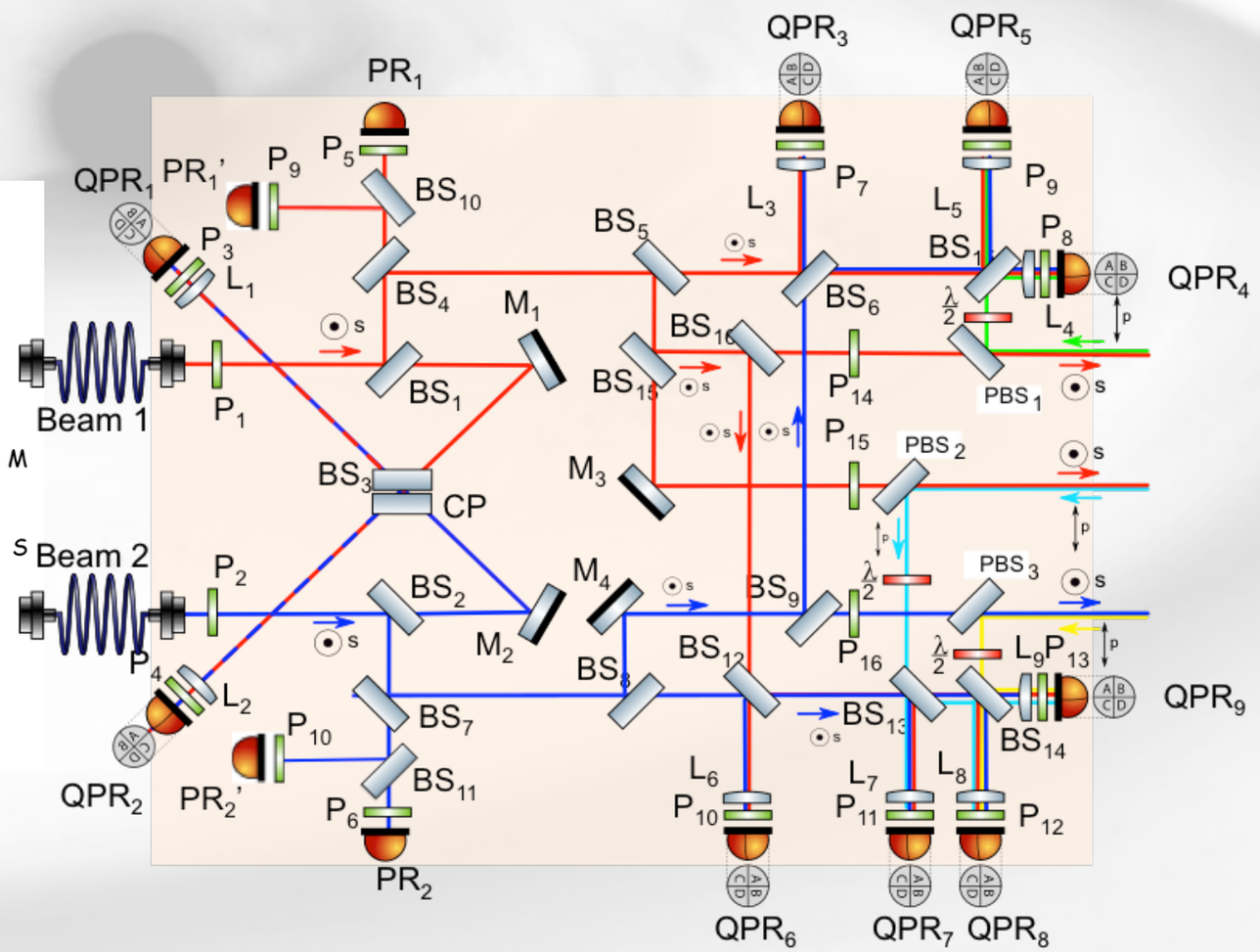


Instrument AIVT

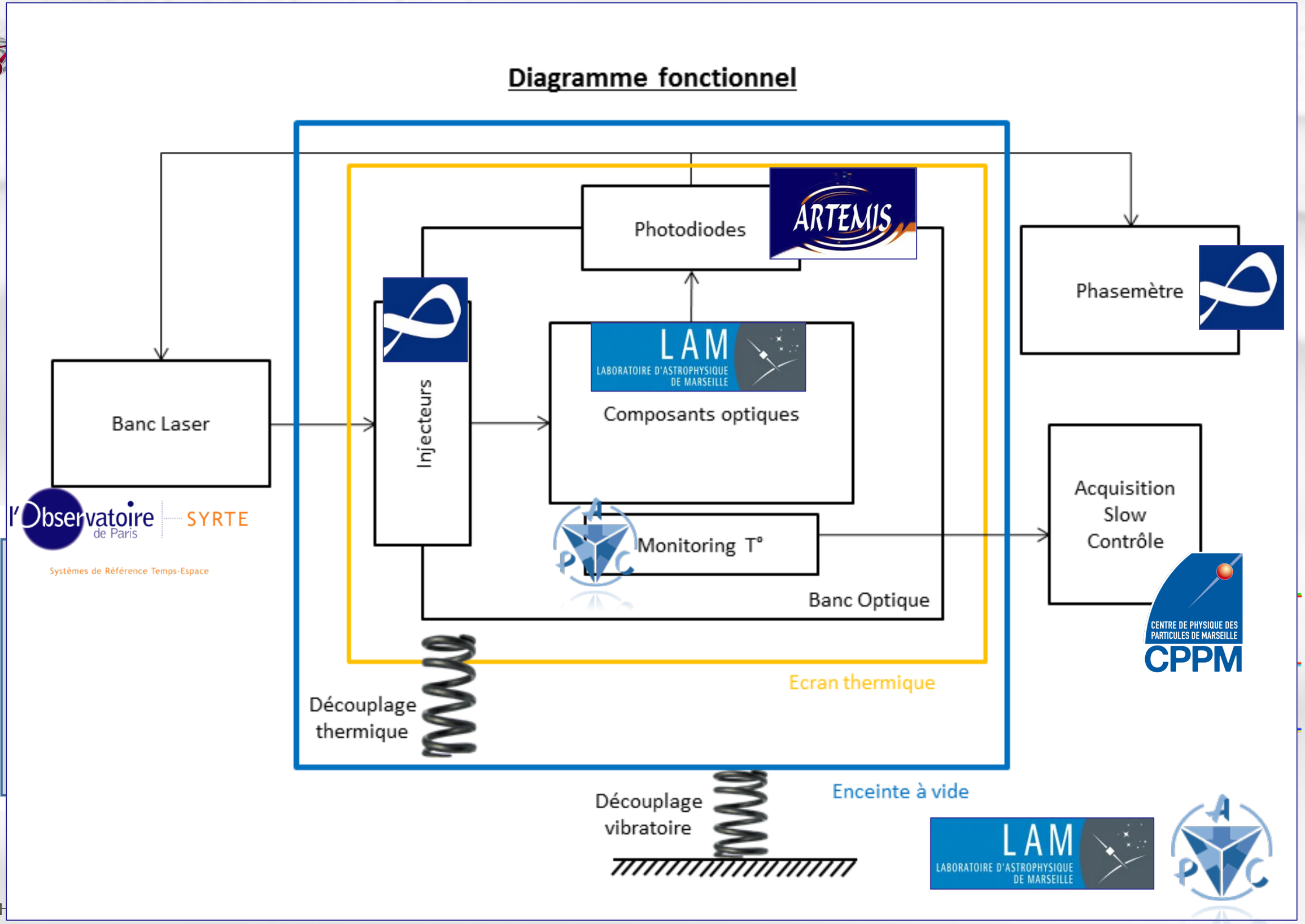
- Current activities
  - Review of available infrastructures and expertises (labs and industries)
  - AIVT sequence planning
  - Tests definition and requirements
  - List and requirements on GSEs
  - Interferometric bench prototype to gain experience and qualify infrastructures.

Collaboration of French labs + CNES

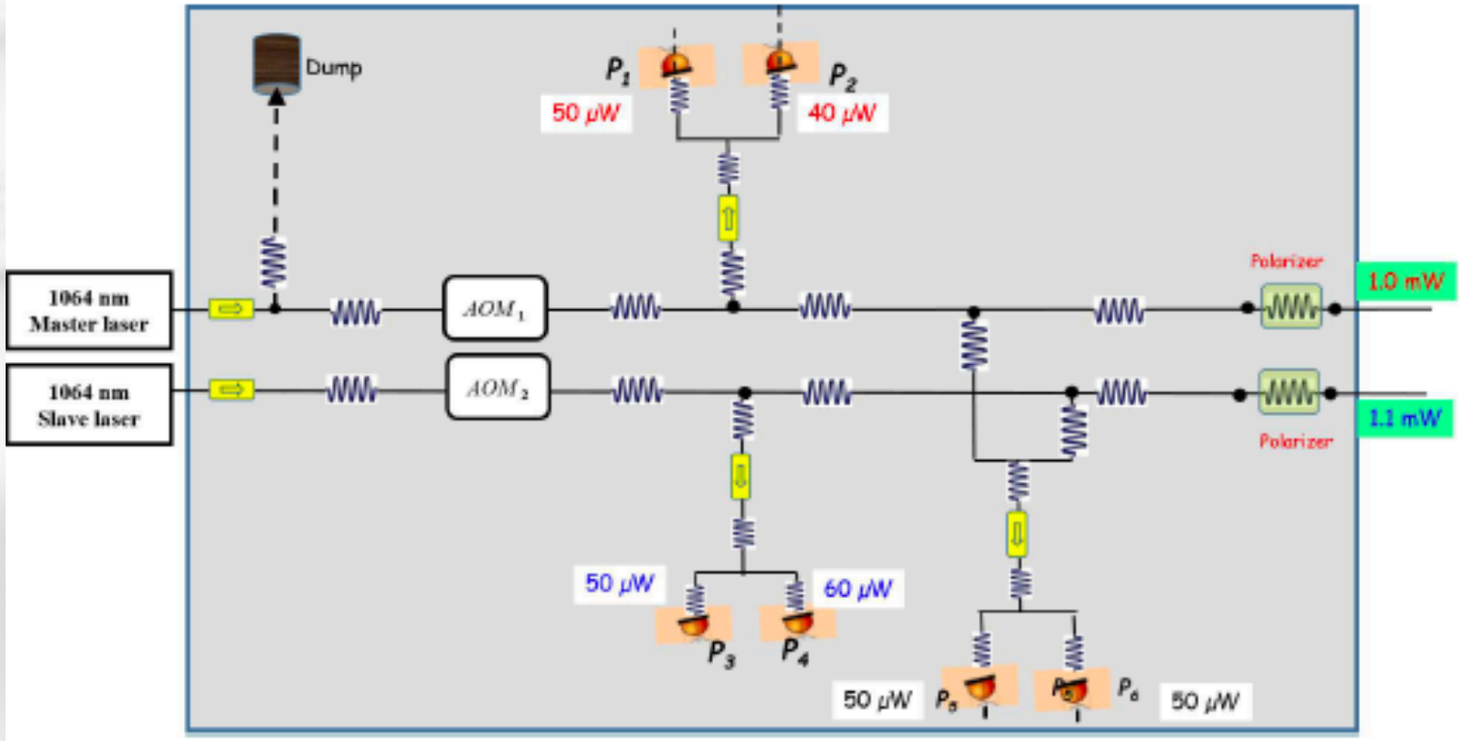


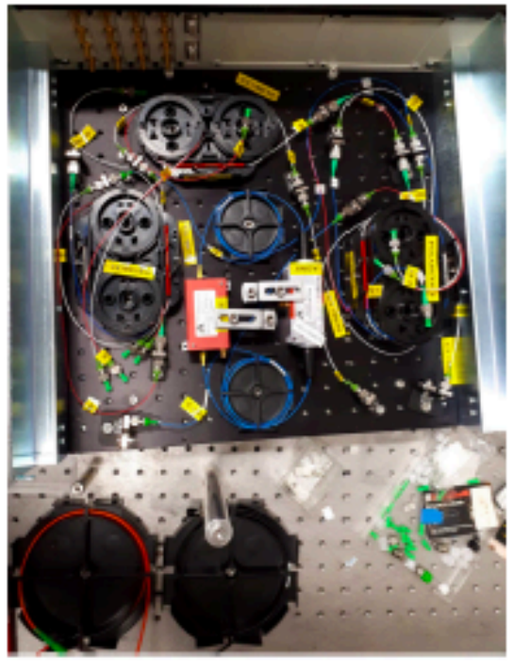


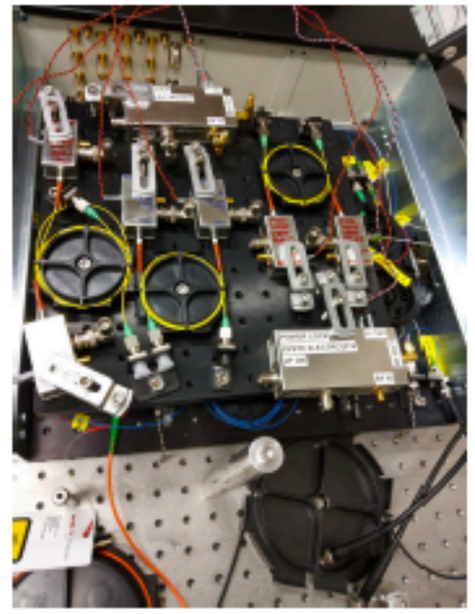
Instrument AIVT



Laser source @SYRTE







Banc optique
niveau supérieur:
* Six photodiodes
* 2 Power lock

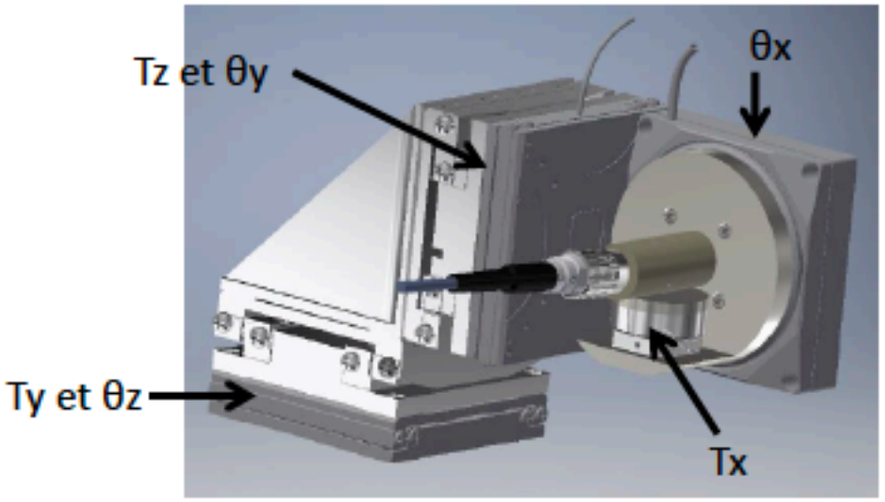
Banc optique
niveau inférieur:
* AOM's
* Distribution signaux optiques

Les puissances optiques sont optimisées selon deux critères:
1°/ Puissance de sortie vers le banc IFO ~1 mW pour chaque laser
2°/ Puissances incidentes sur les photodiodes ~50 µW, représentatives (?) des puissances qui seront mises en jeu sur le banc IFO (TBC).

Laser injection @CEA/IRFU

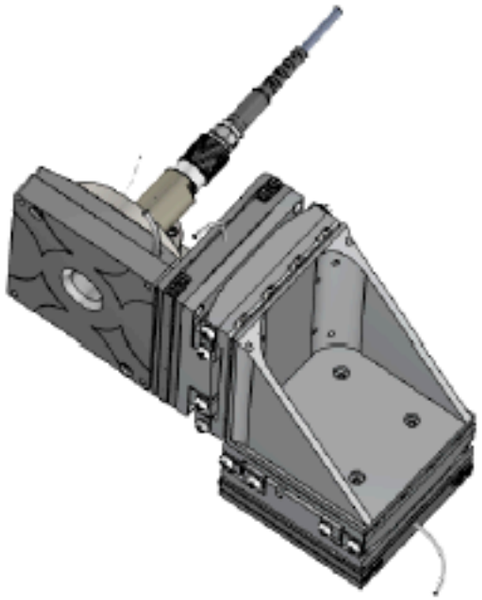
LISA – Injecteurs

Concept N°1 : Montage à base de platines de translation et rotation

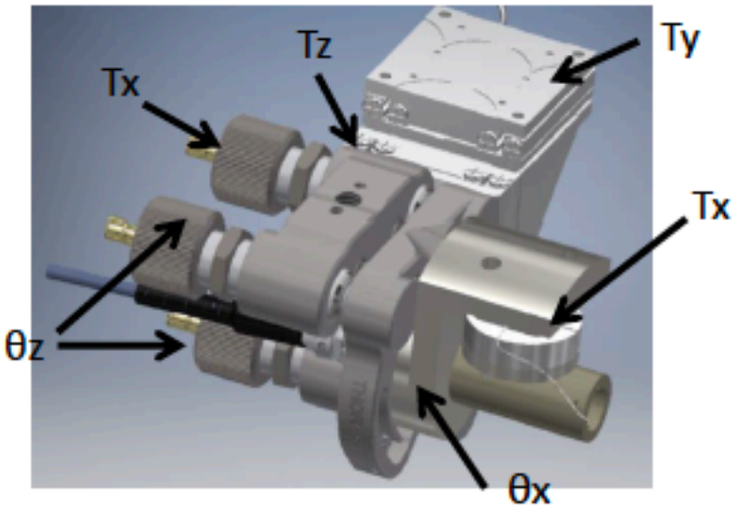


Avantages :
- Dynamiques et résolutions des réglages OK
- Ajustement - reprise des réglages sous vide

Inconvénients :
- Encombrement hors spec
- Hauteur faisceau hors spec
- 6 voies de piezzo – coût élevé
- Rotation hors axe = nécessite des mvt combiné

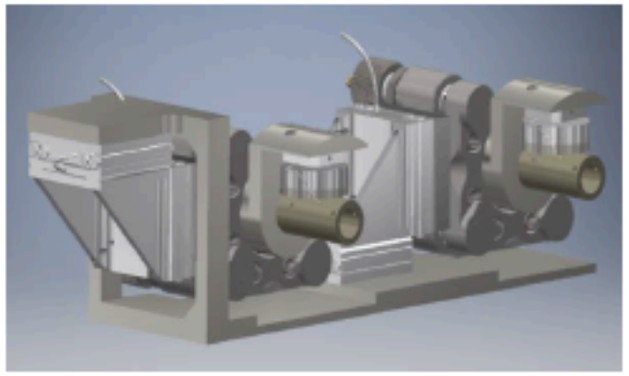


Concept N°2 : Montage à base de platines et support hybride



Avantages :
Encombrement réduit
Hauteur faisceau OK
Dynamiques et résolutions des réglages OK
Ajustement – reprise des réglages sous vide
Mvt combinés peuvent être réduit

Inconvénients :
θx manuel - pas de reprise sous vide
Tjs 6 voies de piezzo malgré θx manuel



Concept N°3 : Outil de réglage déporter -> pas de reprise des réglages

A étudier

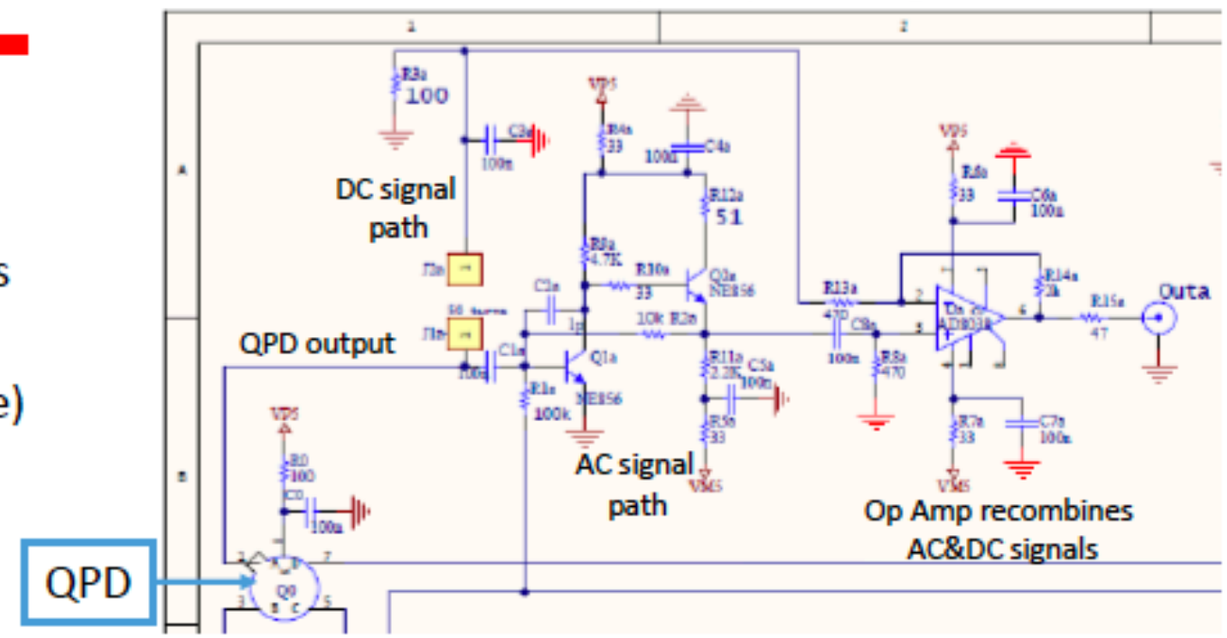
Objectifs:
Réduire l'encombrement
Réduire le coût

Photoreceivers @ARTEMIS/OCA

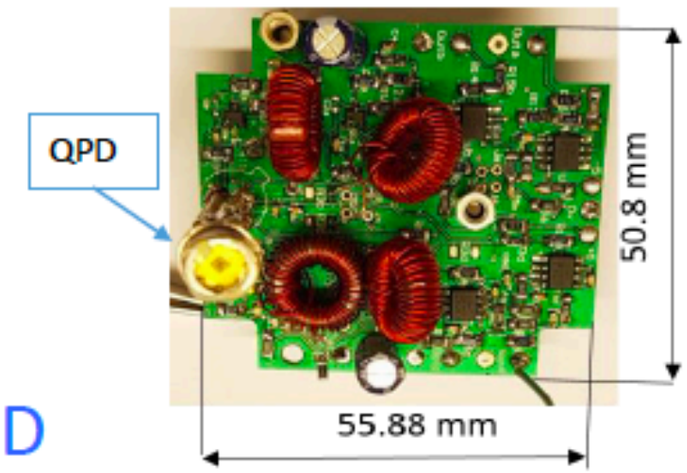
Front End Electronics (FEE)

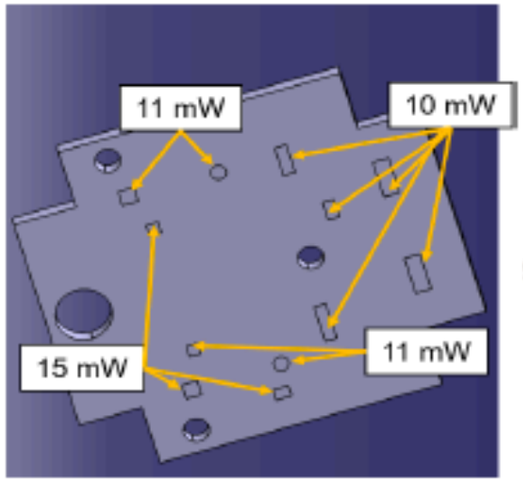
- FEE-QPD
  - 1st prototype designed and manufactured
    - Pre-amplifier sensing similar to AEI, cascade transistors
      - First stage amplification
        - 2-discrete transistors (10 kΩ transimpedance)
      - Second stage amplification
        - Operational amplifier AD8038: gain 5.25
    - Total gain: 52.6 kΩ
  - 2nd prototype to be manufactured during summer, later Sept.

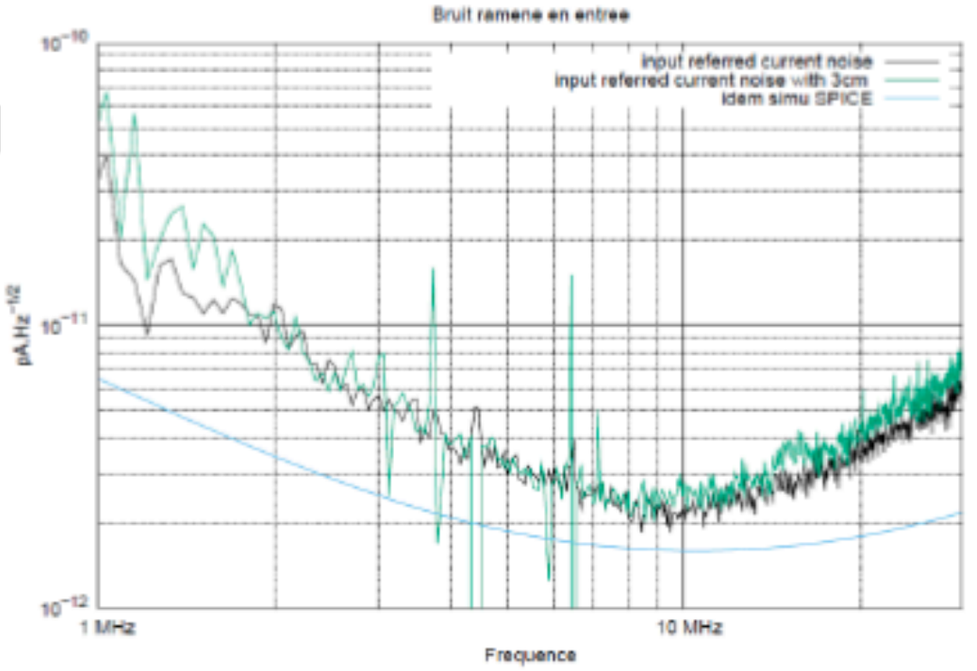
One channel pre-amplifier design — *JP. Coulon*



First-prototype FEE-QPD







- FEE-SEPD
  - Requirements to be defined

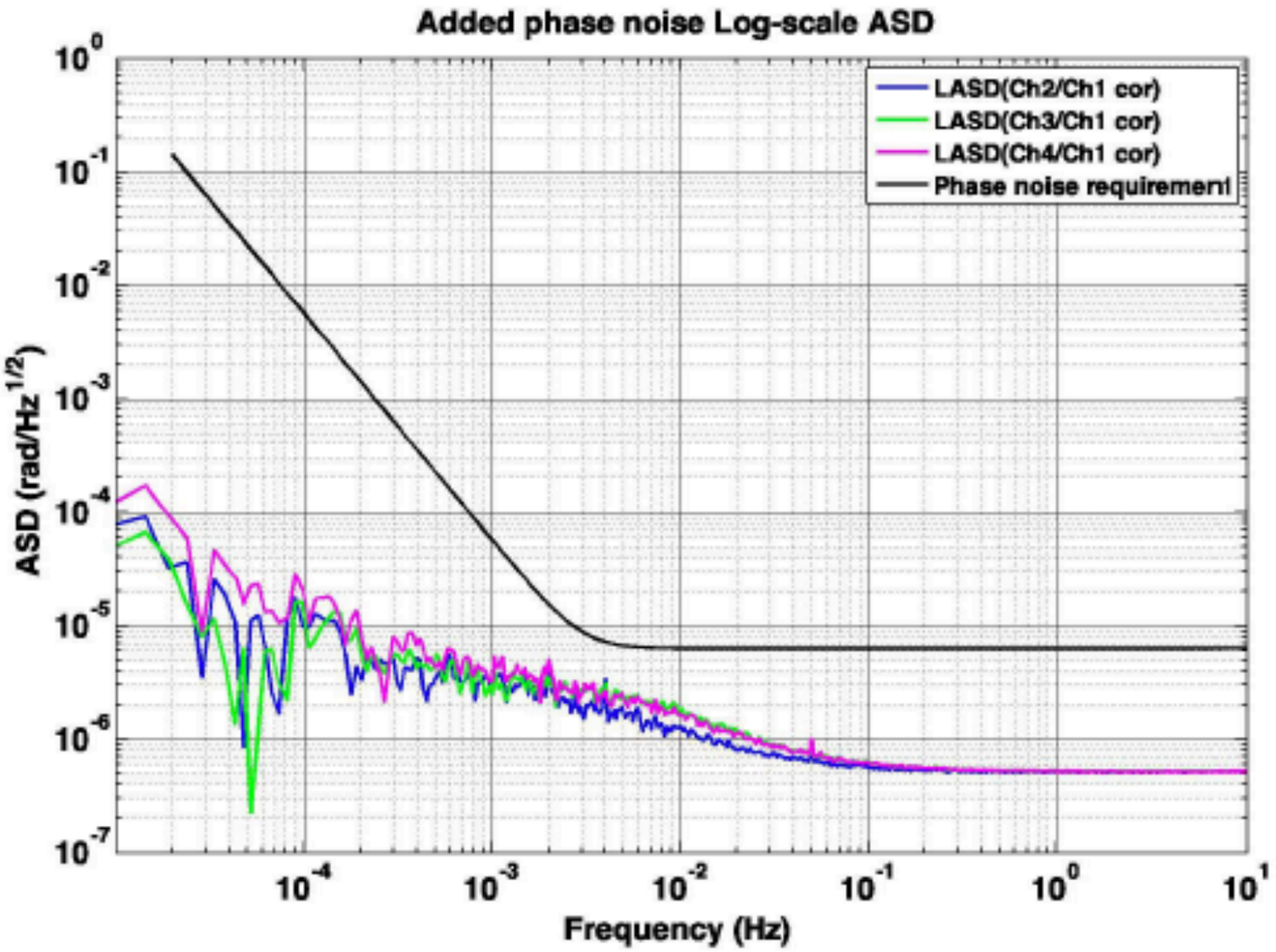
PR characterisation and command/control

Caractérisation des photodiodes LISA @CPPM

- Ressources financières
  - Collaboration avec ARTEMIS
  - Demande conjointe de financement PACA
  - Demande de financement LabEx OCEVU pour l'achat d'un analyseur d'impédance (30k€)
- Ressources humaines
  - J. Royon, IE électronicien, à 50% à partir de début juillet
  - Adaptation du banc + mise en œuvre des photodiodes + réalisation des mesures
- CPPM intéressé par étendre les activités photodiodes
  - Mise en place d'une plateforme de caractérisation infrarouge en cours au laboratoire
  - Forte expertise sur les tests de résistance aux radiations (développement de moyens en collaboration avec xx)

Phasemeter @CEA+APC

Avec correction de Jitter



- **Fréquence d'échantillonnage**
  - **100 MHz (externe)**
  - **Générateur AEROFLEX 2023A**
- **Fréquence de mesure:**
  - **16,001 MHz**
- **Fréquence de correction:**
  - **22,001 MHz**
- **Synthétiseur:**
  - **AFG3102 TEKTRONIX**
  - **Voie 1: Mesure**
  - **Voie 2: Correction**
- **Mesures et références additionnées avec combiner ZFRSC-42-1-S+ (Minicircuits)**
- **Sortie splittée en 4 avec splitter ZMSC-4-1+ (Minicircuits)**

Performance model @APC

5 Summary

Table 30 summarizes CBE noise contributions in ascending order. Some of them refer to a maximum value. A margin of 20% and 100% is assigned to the thermal noise ASD of optical components and that of the Invar OB respectively. In the current version of the performance model, the contribution of straylight and TTL are not estimated yet.

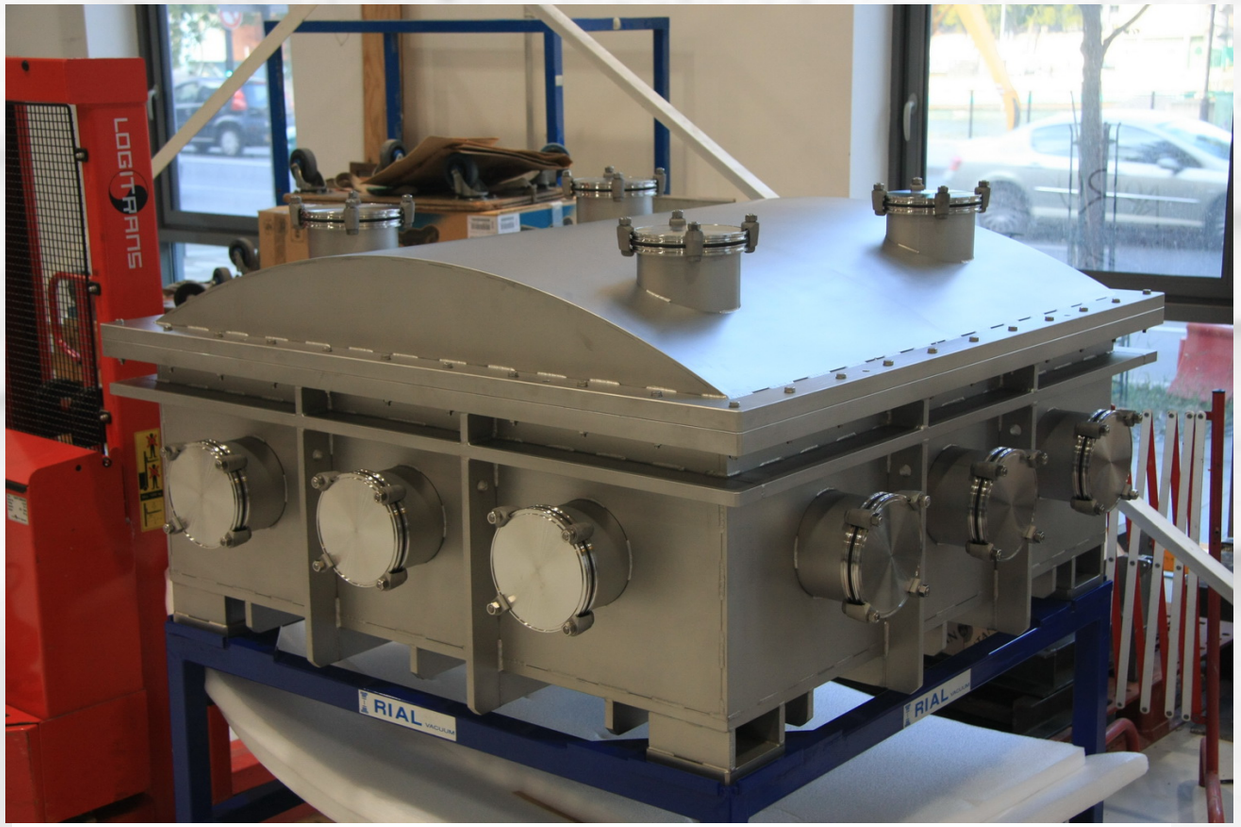
Noise Parameter	Value	Description
$\tilde{s}_{\mathrm{Res,Frequ},REF}$ (pm/$\sqrt{\mathrm{Hz}}$)	1.1×10^{-4}	Residual frequency noise in REF interferometer
$\tilde{s}_{\mathrm{Vib,APC}}$ (pm/$\sqrt{\mathrm{Hz}}$)	$1.1\,10^{-3}$	Vibration noise ASD at the APC laboratory
$\tilde{s}_{\mathrm{Therm,OB,Zer},REF}$ (pm/$\sqrt{\mathrm{Hz}}$)	2.0×10^{-3}	Zerodur OB thermal noise in REF interferometer
$\tilde{s}_{\mathrm{Therm,P,r}}$ (pm/$\sqrt{\mathrm{Hz}}$)	2.4×10^{-3}	Thermal noise ASD per remote polarizer
$\tilde{s}_{\mathrm{QPR,1f}}$ (pm/$\sqrt{\mathrm{Hz}}$)	2.68×10^{-3}	RIN@1f ASD
$\tilde{s}_{\mathrm{2f}}$ (pm/$\sqrt{\mathrm{Hz}}$)	8.47×10^{-3}	RIN@2f ASD
$\tilde{s}_{\mathrm{shot,max}}$ (pm/$\sqrt{\mathrm{Hz}}$)	8.67×10^{-3}	Maximum shot noise ASD
$\tilde{s}_{\mathrm{Res,Frequ},UNEQ}$ (pm/$\sqrt{\mathrm{Hz}}$)	2.13×10^{-2}	Residual frequency noise in UNEQ interferometer
$\tilde{s}_{\mathrm{QPR,Chain,max}}$ (pm/$\sqrt{\mathrm{Hz}}$)	3.97×10^{-2}	Maximum chain noise ASD
$\tilde{s}_{\mathrm{Therm,OB},Invar,REF}$ (pm/$\sqrt{\mathrm{Hz}}$)	6.0×10^{-2}	Invar OB thermal noise in REF interferometer
$\tilde{s}_{\mathrm{Therm,CP}}$ (pm/$\sqrt{\mathrm{Hz}}$)	0.17	Compensation plate thermal noise ASD
$\tilde{s}_{\mathrm{Therm,M}}$ (pm/$\sqrt{\mathrm{Hz}}$)	0.28	Mirror thermal noise ASD
$\tilde{s}_{\mathrm{Therm,P,c}}$ (pm/$\sqrt{\mathrm{Hz}}$)	0.24	Thermal noise ASD per close polarizer
$\tilde{s}_{\mathrm{Therm,OB},Zer,UNEQ}$ (pm/$\sqrt{\mathrm{Hz}}$)	0.4	Zerodur OB thermal noise in UNEQ interferometer
$\tilde{s}_{\mathrm{Therm,BS,r}}$ (pm/$\sqrt{\mathrm{Hz}}$)	0.43	Thermal noise ASD per remote beam splitter
$\tilde{s}_{\mathrm{PMS,pm,max}}$ (pm/$\sqrt{\mathrm{Hz}}$)	1.16	Maximum phase noise ASD
$\tilde{s}_{\mathrm{Therm,L}}$ (pm/$\sqrt{\mathrm{Hz}}$)	2.06	Thermal noise ASD per lens
$\tilde{s}_{\mathrm{Therm,BS,c}}$ (pm/$\sqrt{\mathrm{Hz}}$)	8.95	Thermal noise ASD per close beam splitter
$\tilde{s}_{\mathrm{Therm,inj}}$ (pm/$\sqrt{\mathrm{Hz}}$)	8.52	Injecting fiber thermal noise ASD
$\tilde{s}_{\mathrm{Therm,OB},Invar,UNEQ}$ (pm/$\sqrt{\mathrm{Hz}}$)	12.0	Invar OB thermal noise in UNEQ interferometer

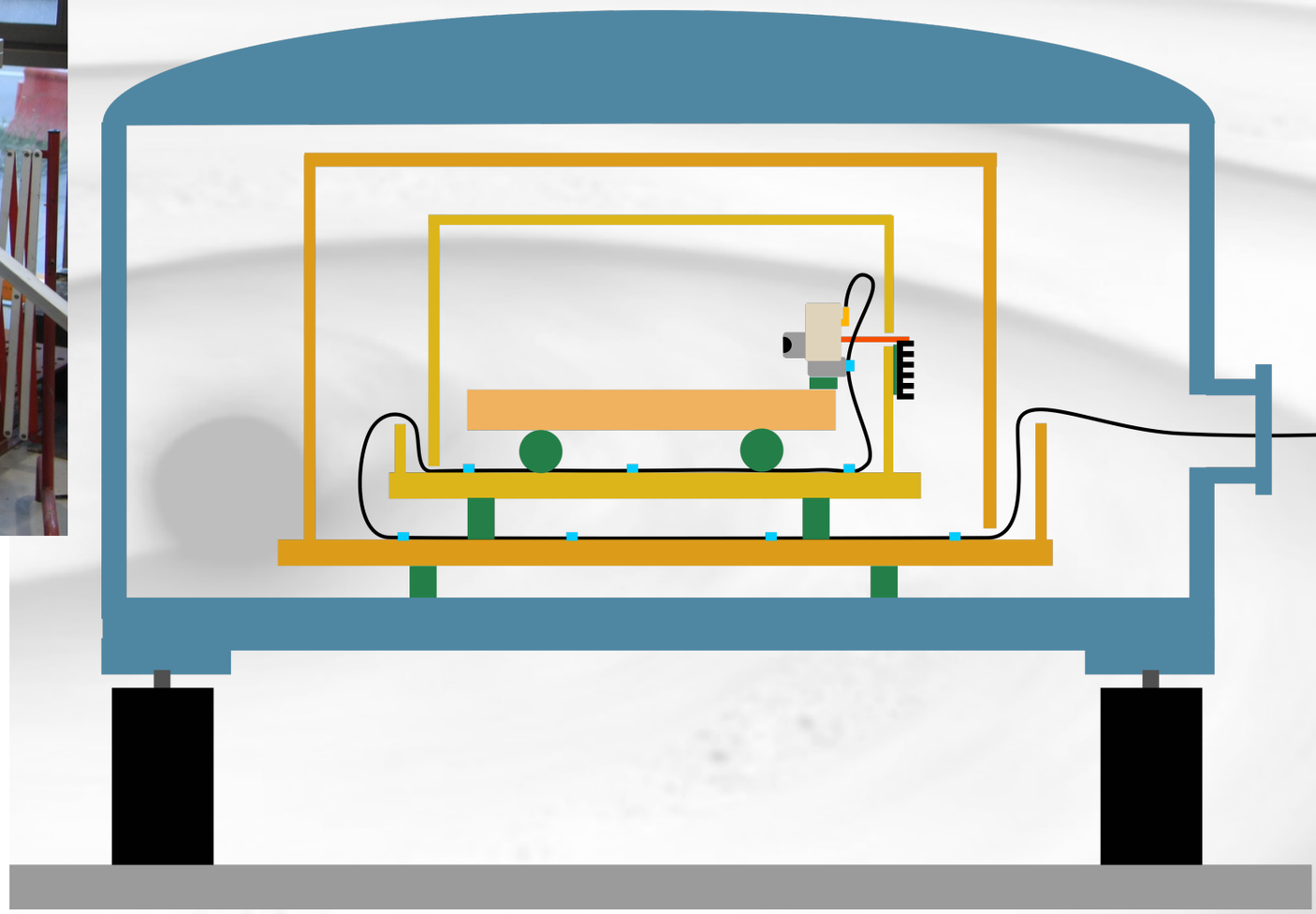
Table 30: Summary table on CBE noise contributions

Thermal noise from the Invar OB and the injecting fiber are dominant. Minimizing power dissipation leading to production of hot spots in the set-up contributes to decrease thermal noise from beam splitters, lenses and polarizer close to a QPD. Improvement on the estimation of the thermal noise contributions needs a thermal model together with local temperature measurements using thermal sensors properly installed inside the vacuum chamber at the APC laboratory and the ERIOS tank of the LAM laboratory. TTL noise estimation needs optical simulations as inputs in the performance model. No proper model currently exists to assess straylight contribution to the noise. A next version of the IFO performance model is including a CBE of the sample timing noise ASD.

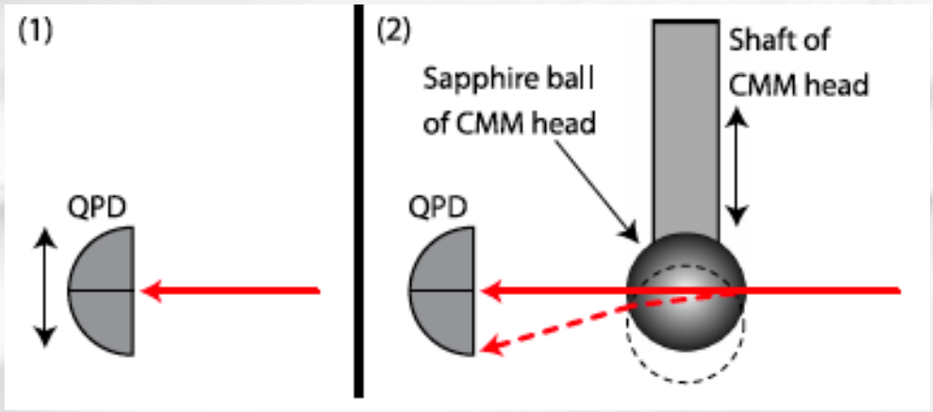
Contents

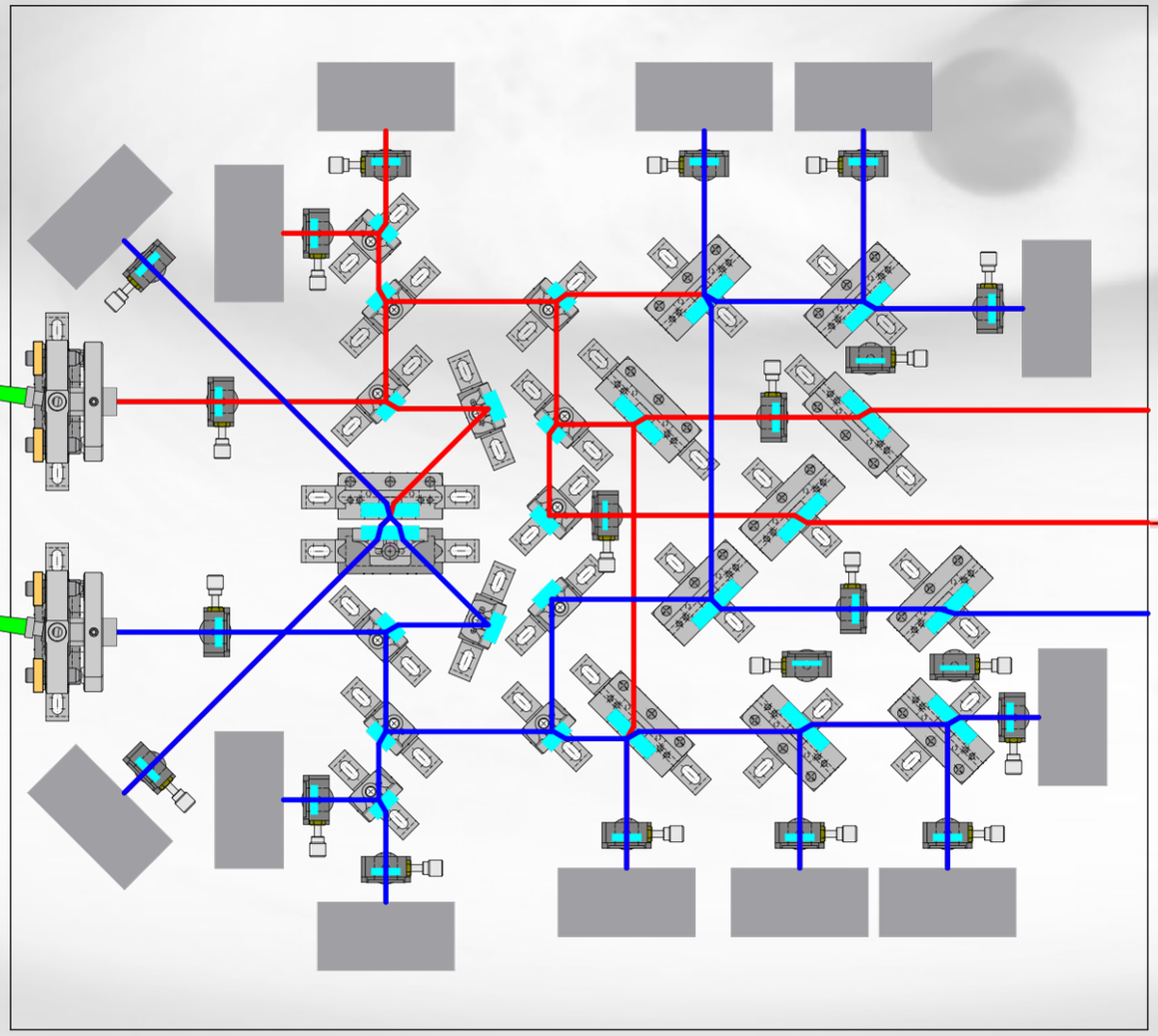
Characterization under vacuum @ APC

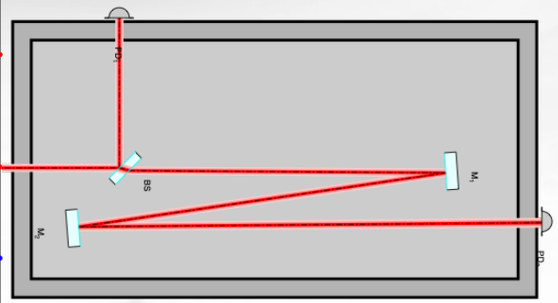




CMM-assisted bench tuning @APC







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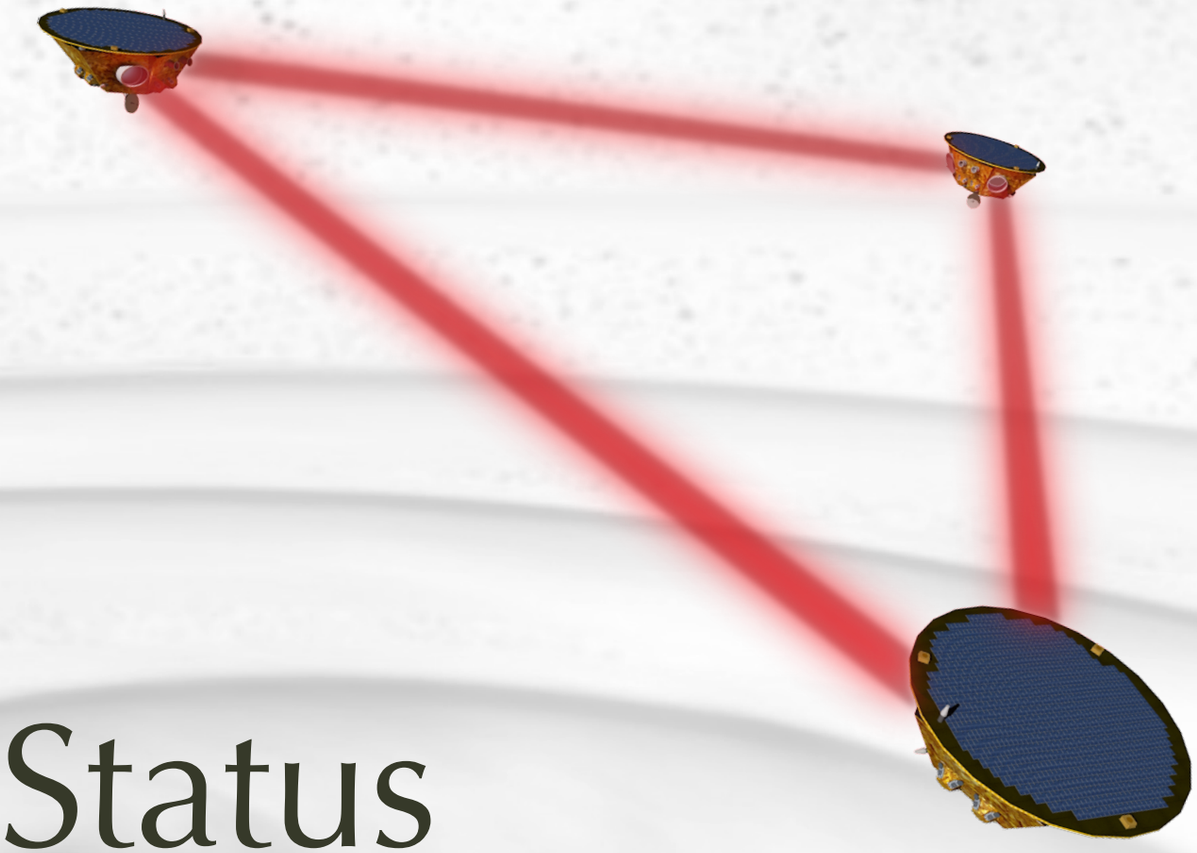
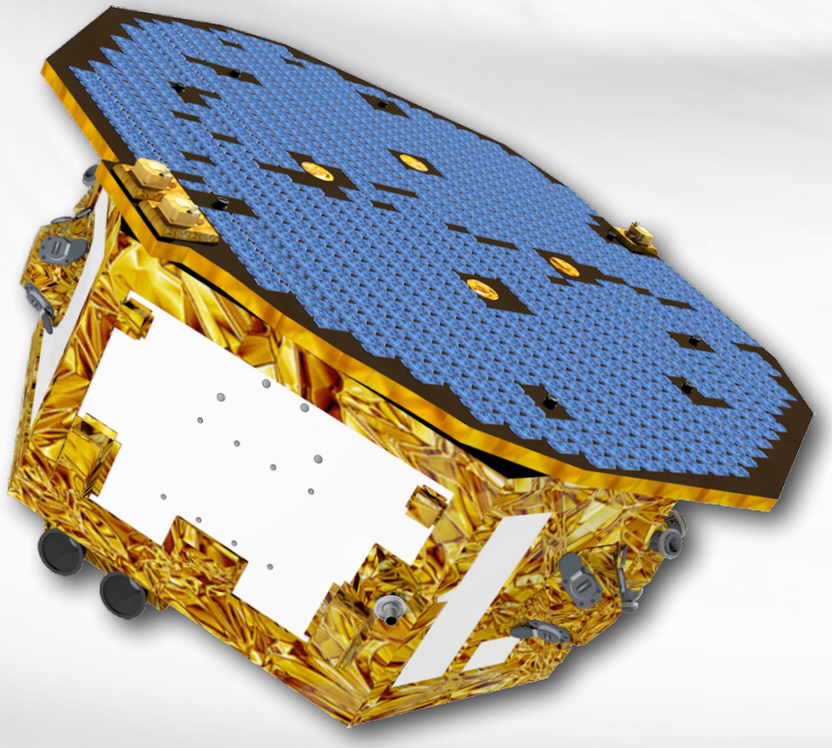


Mission Status



Consortium reloaded…

- New registration process to the LISA Consortium since Apr. 2018
  - https://signup.lisamission.org/
- Two levels of participation
  - Members (participate to the design of the mission)
  - Associate (interest and/or punctual contrib. to LISA studies)
  - First round of applications in April
  - >1000 members (incl. ~500 associates)
- French institutes : CNES + 16 labs
  - APC, ARTEMIS, CEA/DSM/IPhT, CEA/IRFU (DAp, DEDIP, DIS, DPhN, DPhP), CPPM, IAP, Institut Fresnel, LAM, LESIA, LMA, LPC Caen, LPC2E, LUTh, ONERA, SYRTE

https://signup.lisamission.org/

lisa

Consortium application form

Name

e.g. Albert Einstein

E-Mail

e.g. user@example.com

Affiliation

e.g. AEI Hannover

Application type

- ○ Group
- ○ Associate

Application document

Parcourir... Aucun fichier sélectionné.

(Spreadsheet format preferred, PDF will also be accepted.)

Comments

(optional)

Step by step

1. Download the application template below
2. Download and read the Consortium application process document linked below
3. Fill out the application template
4. Fill out this application web-form and attach completed application document
5. Submit application and wait for confirmation E-Mail

If you run into issues or have questions with regards to your LISA consortium application please contact us

Your application will be reviewed and you will be notified of the outcome in due course.

The following documents are available for

Mission status

Event	From	To	Status
Phase 0 for instrument contributions	**2017-JUL**	**2017-NOV**	
Mission Definition Review (MDR)	**2017-NOV-27**		
Phase A (mission **& instruments**)	2018-JUN	2020-NOV	
Mission Consolidation Review (MCR)	2019-JUL	2019-NOV	
Mission Formulation Review (MFR)	2020-JUN	2020-SEPT/NOV	
Adoption	<=2024		
Implementation (Phase B2/C/D)	8.5 years		
Launch			
Transfer & Commissioning	2.5 years		
Operations	4 years		
Extension (TBD)	6 years		10 years total of science

- Mission Consolidation Review (MCR)
  - Mid Phase A
  - Baseline definitions + options and trade-off
- Mission Formulation Review (MFR)
  - End Phase A
  - System-level trades closed
  - Identification of national contributions
- Mission Adoption Review (MAR)
  - End Phase B1
  - Prepares for mission implementation
  - Multilateral Agreements (MLA) et Memorandum of Understanding (MoU) signatures

Development schedule

Aujourd'hui

2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032

Spec

STM AIT
March 22 – Sept 23

Test

MOSA PFM + FMs
Nov 26 – Feb 31

EQM MOSA
Ap 22 – Aug 26

SCs PFM + FMs
2030– 2033

EQM Spec

EQM OMS Procurement
Feb 22 – Ap 24

OMS EQM AIT

OMS EQM Test

MOSA EQM AIT

MOSA EQM Test

EQM OMS GSEs

Phase A End
March 20

Instr. Req. Review
Nov 20

Mission Adoption
Feb 23

Instrument PDR
March 24

Instrument CDR
Nov 26

Instrument QR
Aug 28

Latest Need Date Last MOSA
Dec 30

2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032

Proto bench #1

IFO Zerodur test bench #2
01/07/19 - 03/12/21

Upgrade IFO

IFO Zerodur test bench #3
09/04/20 - 04/11/22

FFOGSE manufacturing & test

FFOGSE TDA - part1
01/10/19 - 22/11/21

FFOGSE TDA - part2
23/11/21 - 24/05/24

More info on https://www.lisamission.org/

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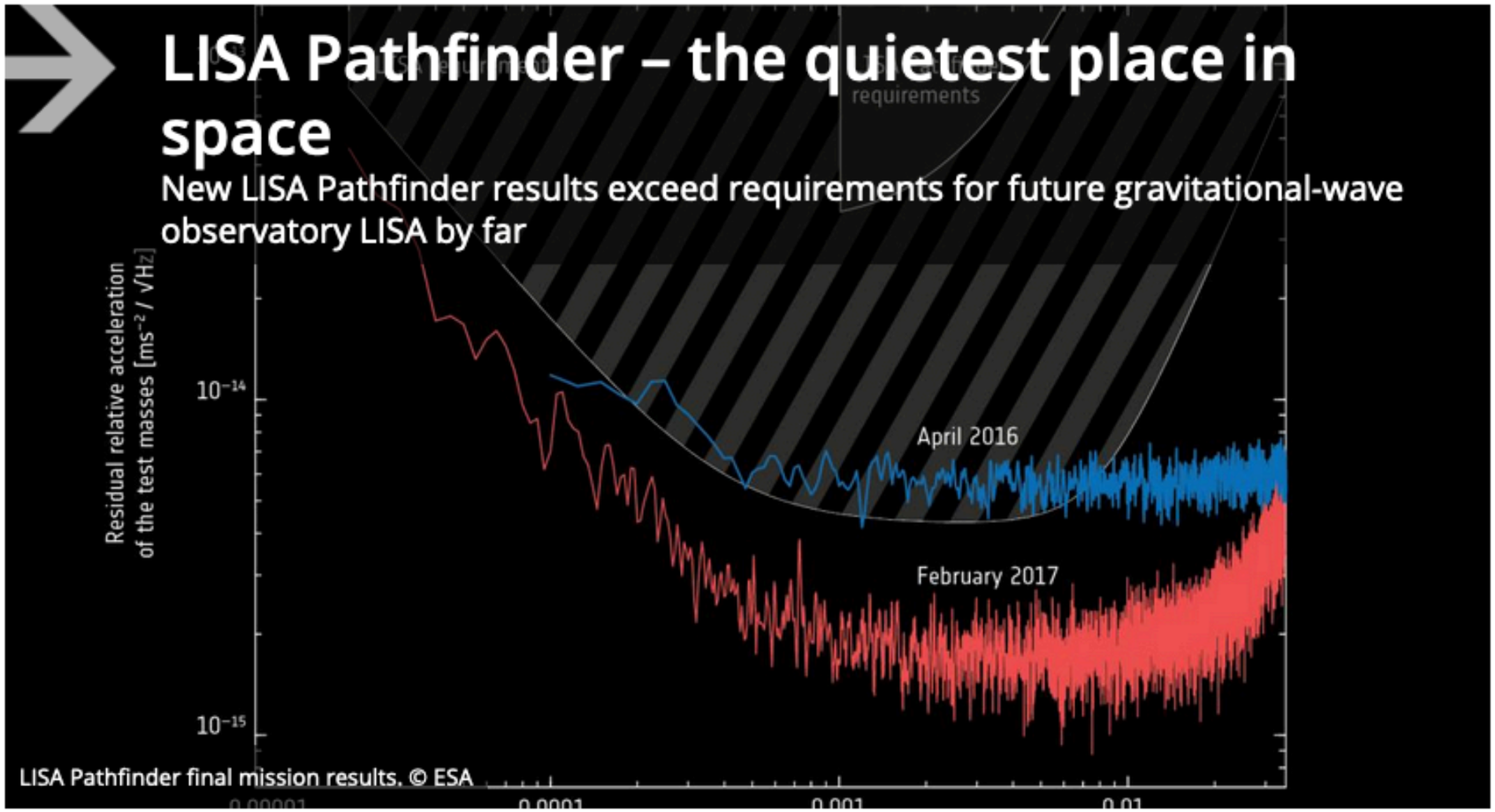
LISA — We will observe gravitational waves in space

Search

LISA MISSION | LISA PATHFINDER | GRAVITATIONAL WAVE ASTRONOMY | CONTEXT 2030 | CONSORTIUM

LISA Pathfinder – the quietest place in space

New LISA Pathfinder results exceed requirements for future gravitational-wave observatory LISA by far



LISA Pathfinder final mission results. © ESA

1 2 3 4 5 6 7 8 9

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LISA & LISA Pathfinder

LISA Consortium Internal

Register as scientist

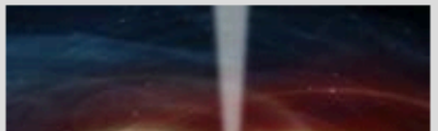
Code of conduct

Newsflash

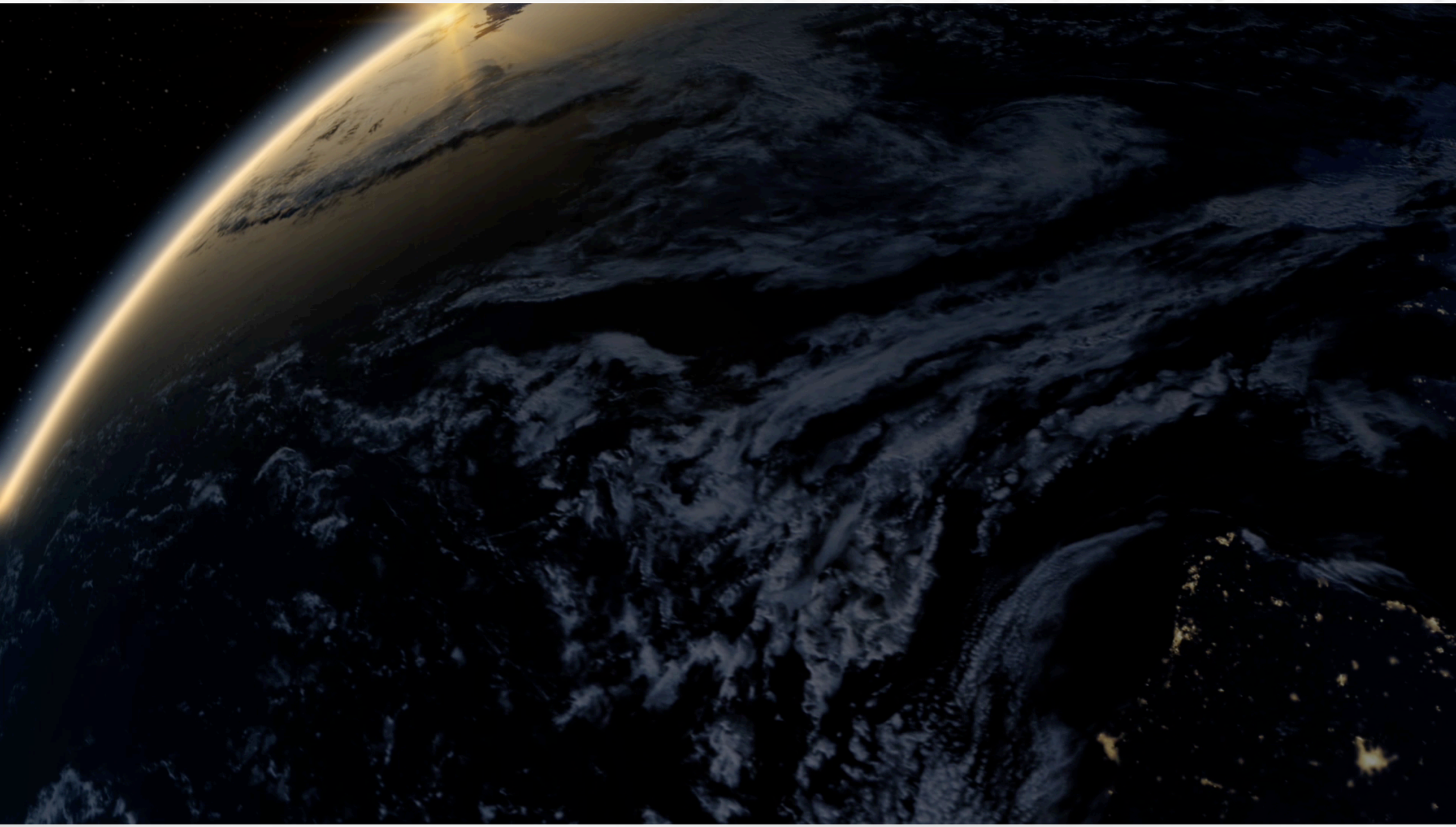
LISA Consortium Reboot

We are now ready to reboot the Consortium and ask you to apply. You will find all necessary information on the Application Portal here: https://signup.lisamission.org

Images



Thank you



Thank you