# LISA Data Processing Group

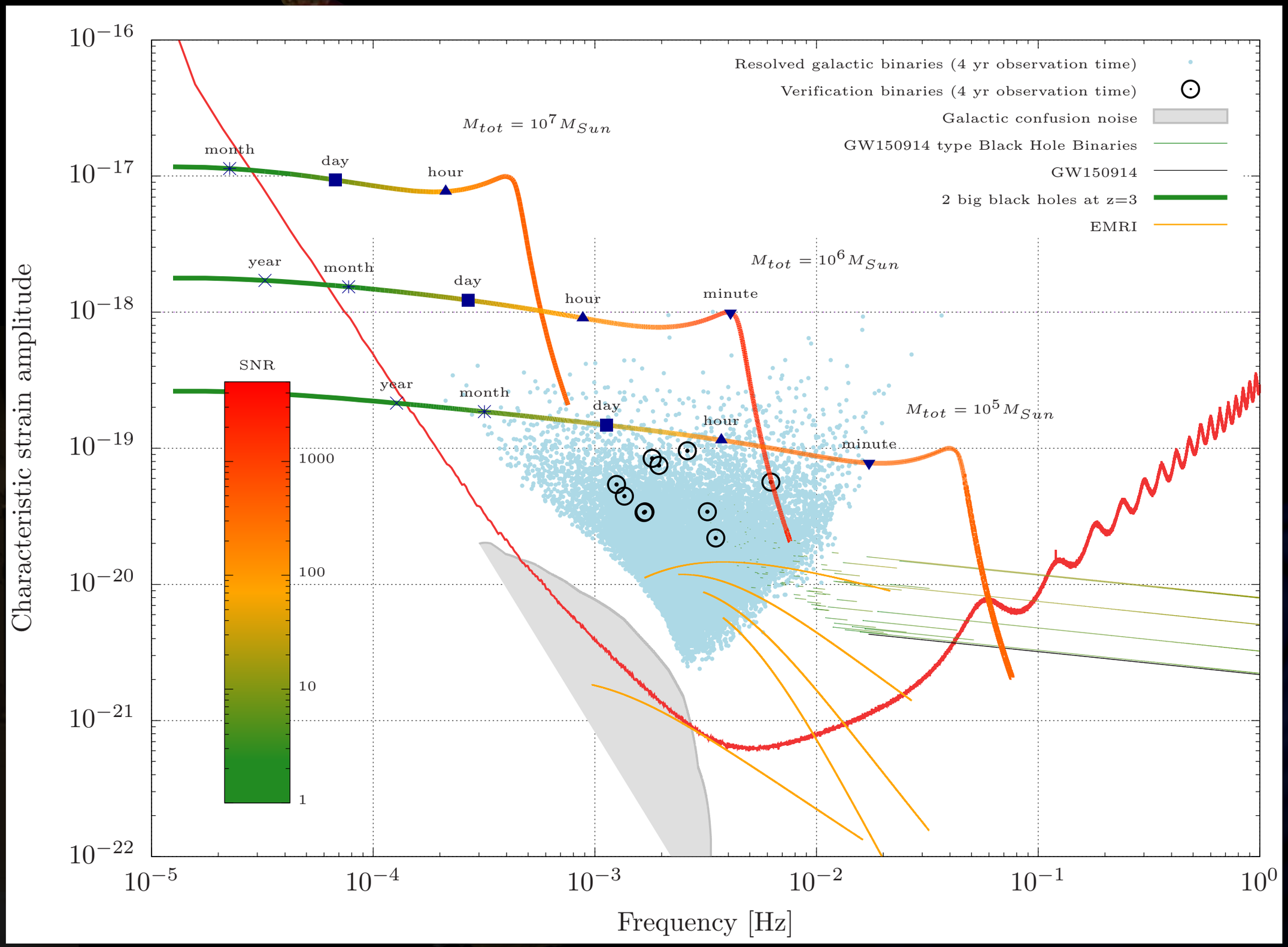
Antoine Petiteau (APC) & John Baker (NASA-GSFC)

on behalf of the LDPG

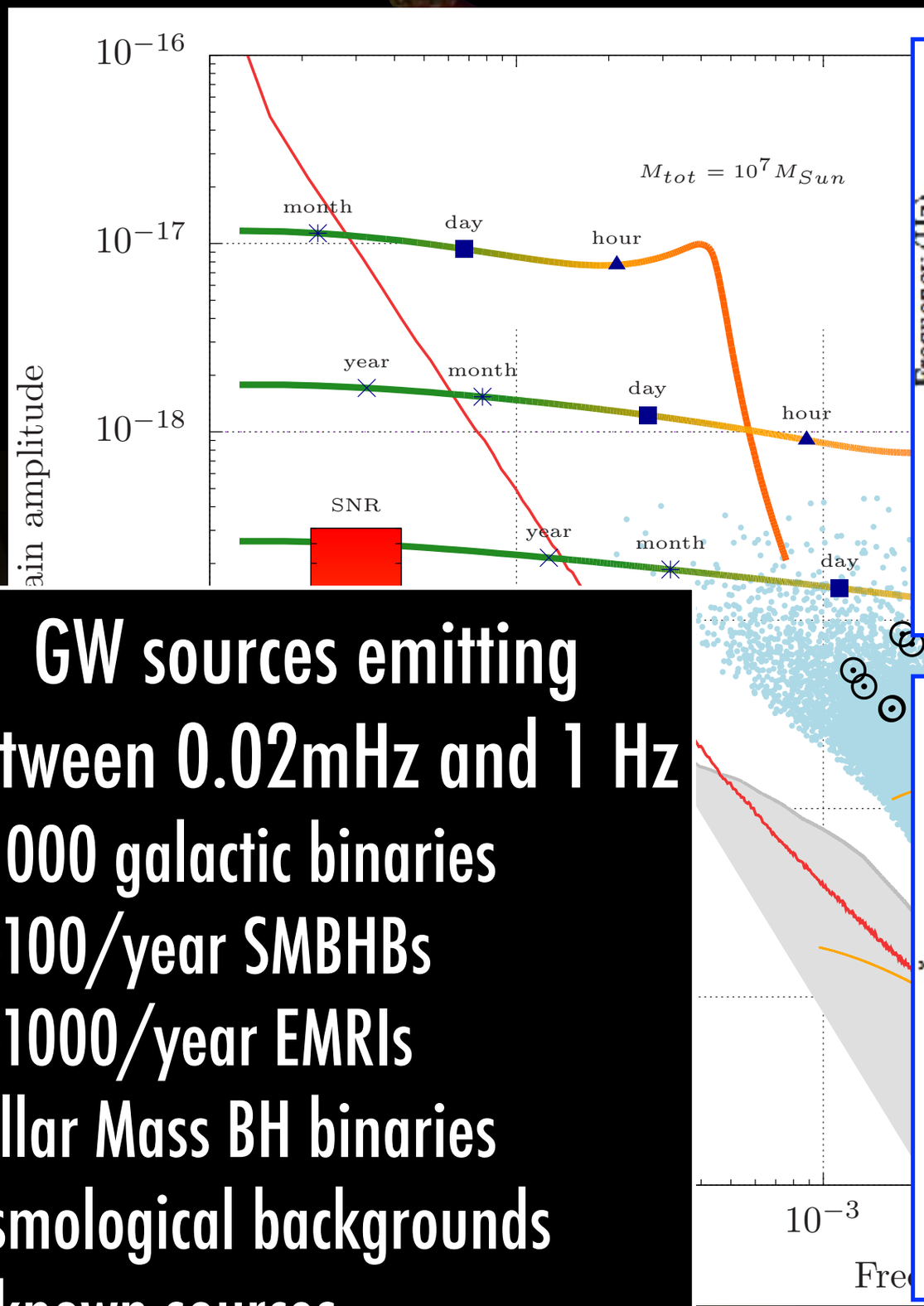
LISA Canada workshop

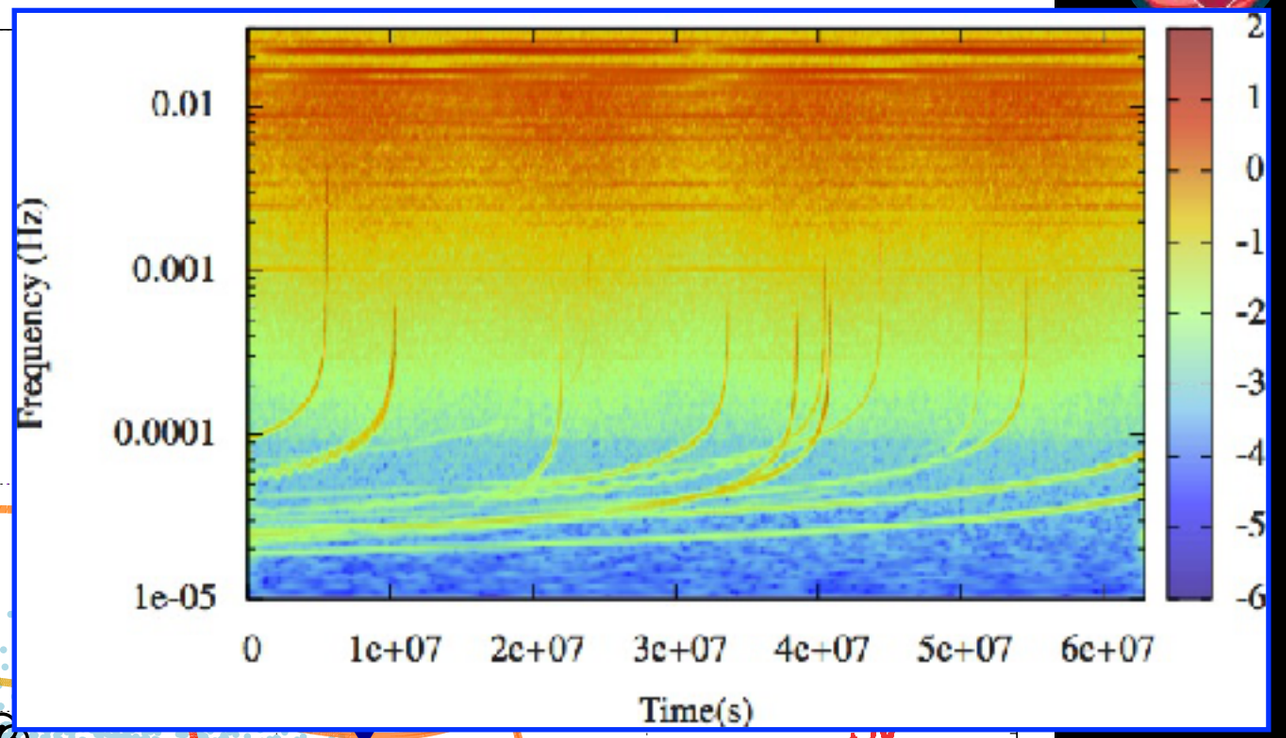
28th April 2021 - Remote

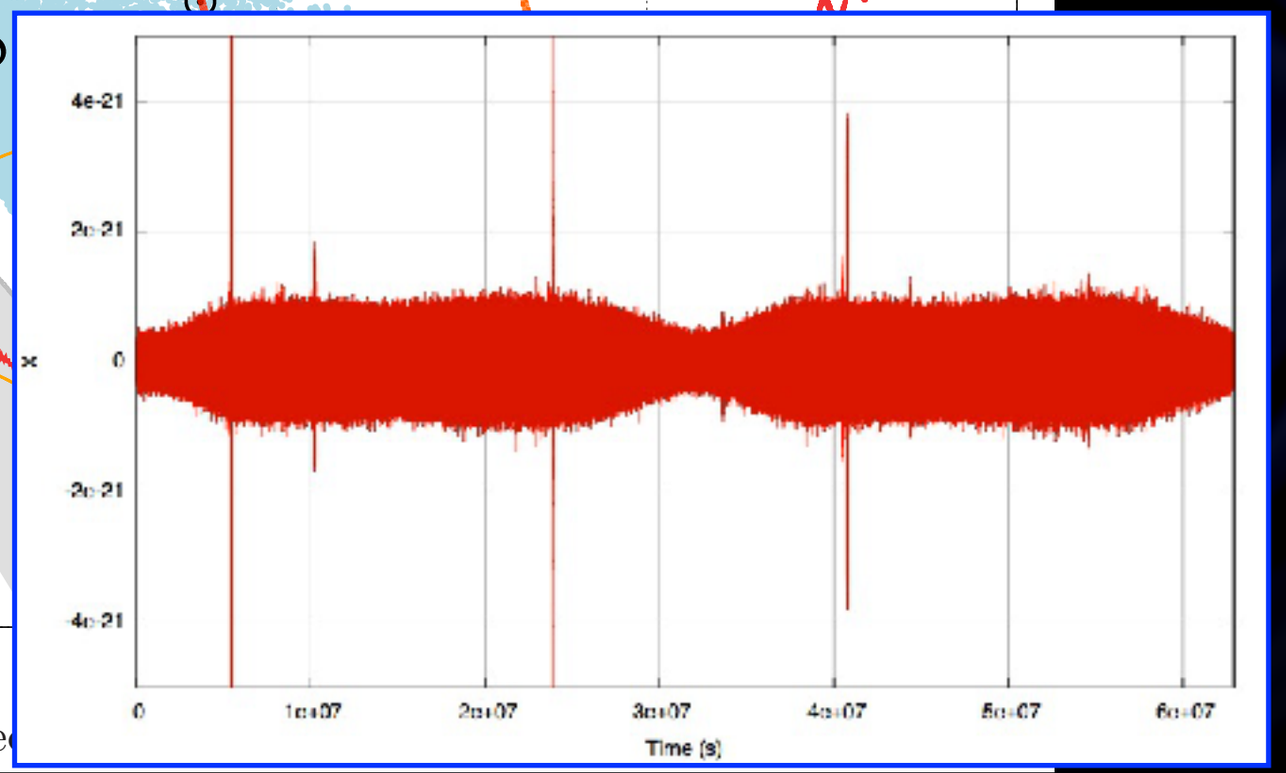
# GW sources


Resolved galactic binaries (4 yr observation time)
Verification binaries (4 yr observation time)
Galactic confusion noise
GW150914 type Black Hole Binaries
GW150914
2 big black holes at z=3
EMRI
$M_{tot} = 10^7 M_{Sun}$
$M_{tot} = 10^6 M_{Sun}$
$M_{tot} = 10^5 M_{Sun}$
month
day
hour
year
month
day
hour
minute
SNR
year
month
day
hour
minute
1000
100
10
1
Characteristic strain amplitude
Frequency [Hz]
$10^{-16}$
$10^{-17}$
$10^{-18}$
$10^{-19}$
$10^{-20}$
$10^{-21}$
$10^{-22}$
$10^{-5}$
$10^{-4}$
$10^{-3}$
$10^{-2}$
$10^{-1}$
$10^{0}$

# GW sources



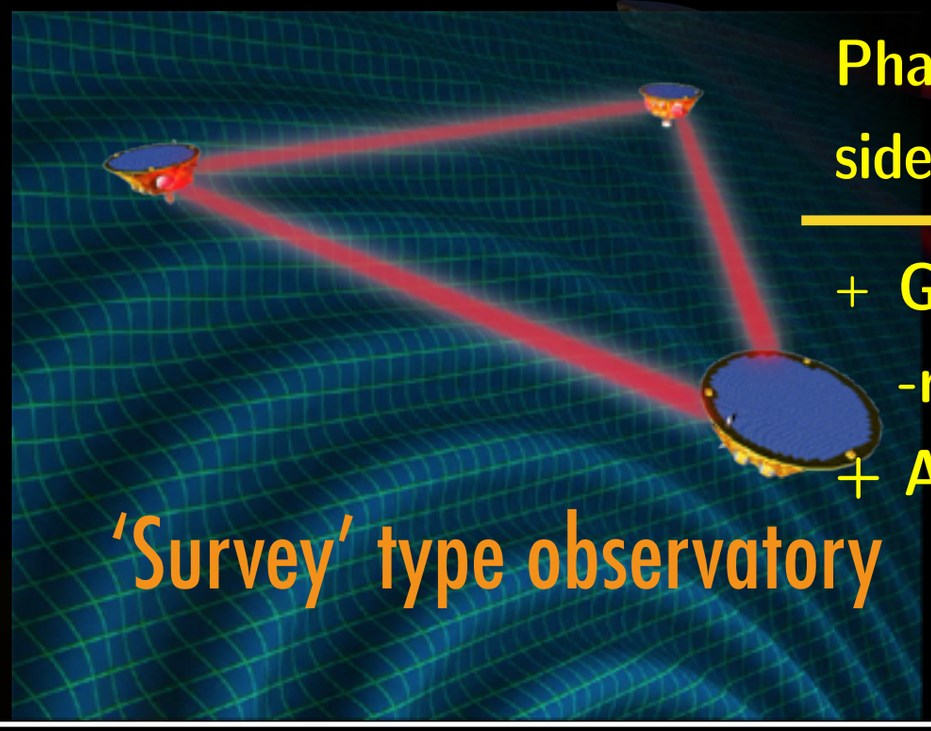




GW sources emitting between 0.02mHz and 1 Hz

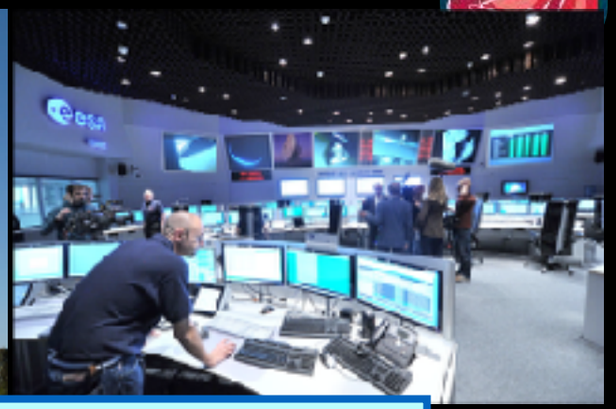
- 25 000 galactic binaries
- 10-100/year SMBHBs
- 10-1000/year EMRIs
- Stellar Mass BH binaries
- Cosmological backgrounds
- Unknown sources

# LISA data




Phasemeters (carrier, sidebands, distance)

+ Gravitational Refe--rence Sensor
+ Auxiliary channels



**L0**

Calibrations corrections

Resynchronisation (clock)

Time-Delay Interferometry
reduction of laser noise

**L1** 3 TDI channels with 2 "~independents"

Data Analysis of GWs

**L2**

**L3** Catalogs of GWs sources with their waveform

GW sources emitting between 0.02mHz and 1 Hz

- 25 000 galactic binaries
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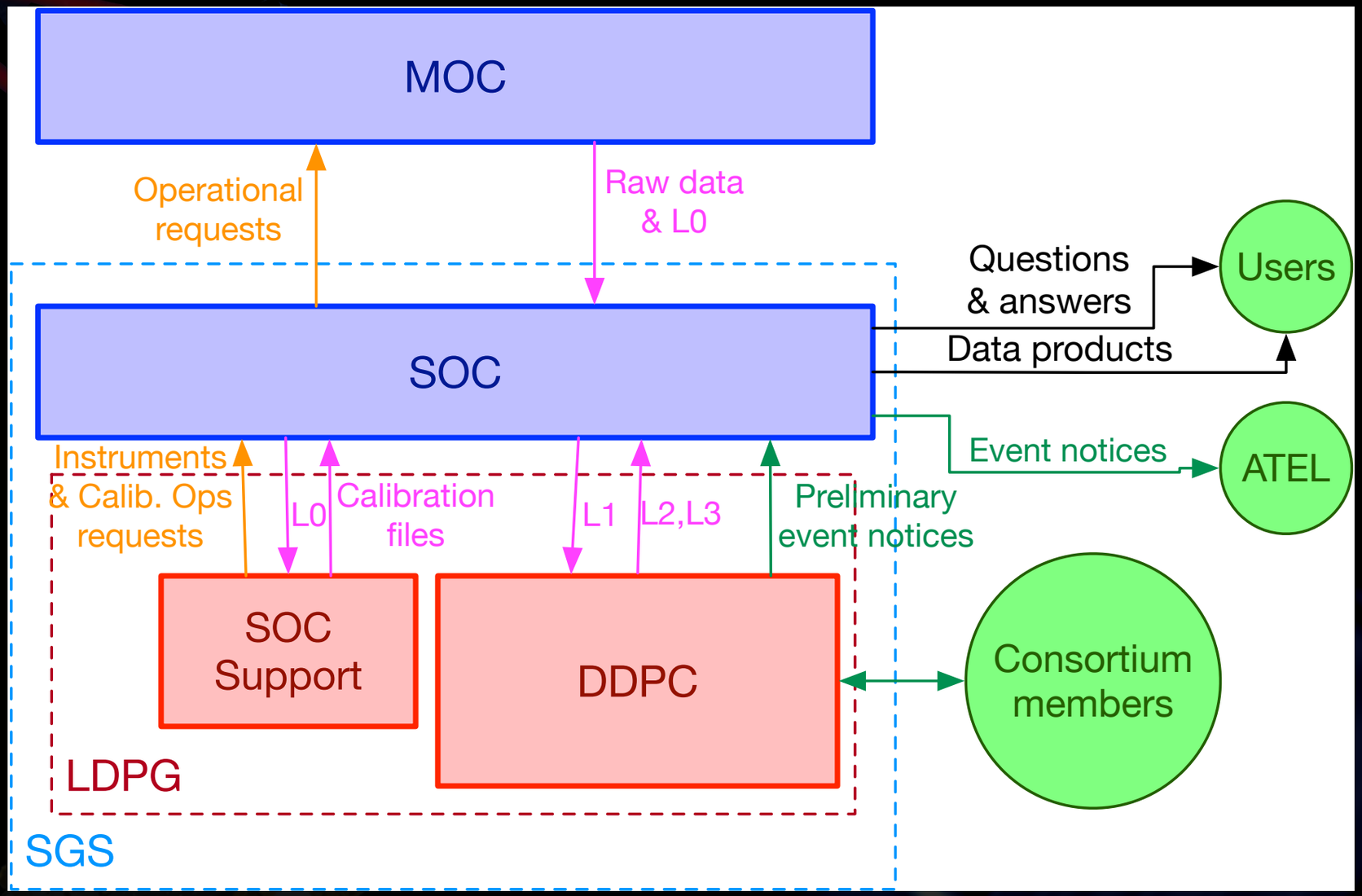
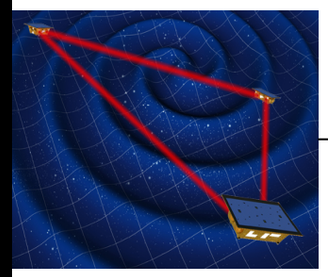
# LISA Ground Segment

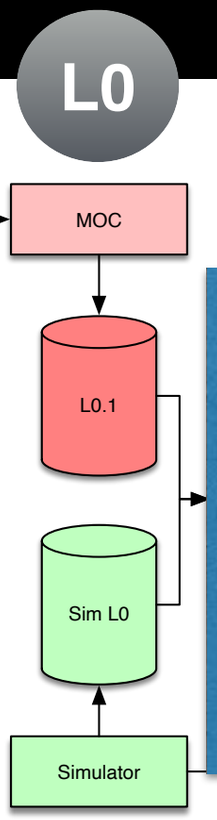
- ESA:
  - Mission Operation Center
  - Science Operation Center
- Consortium:
  - Support to SOC
  - Distributed Data Processing Center:
    - Based on multiple Data Computing Centers
    - First data and analysis of this kind + potential unknown sources => Keep flexibility + continuous evolution + fluctuations of the computational charge



# Segment sol LISA

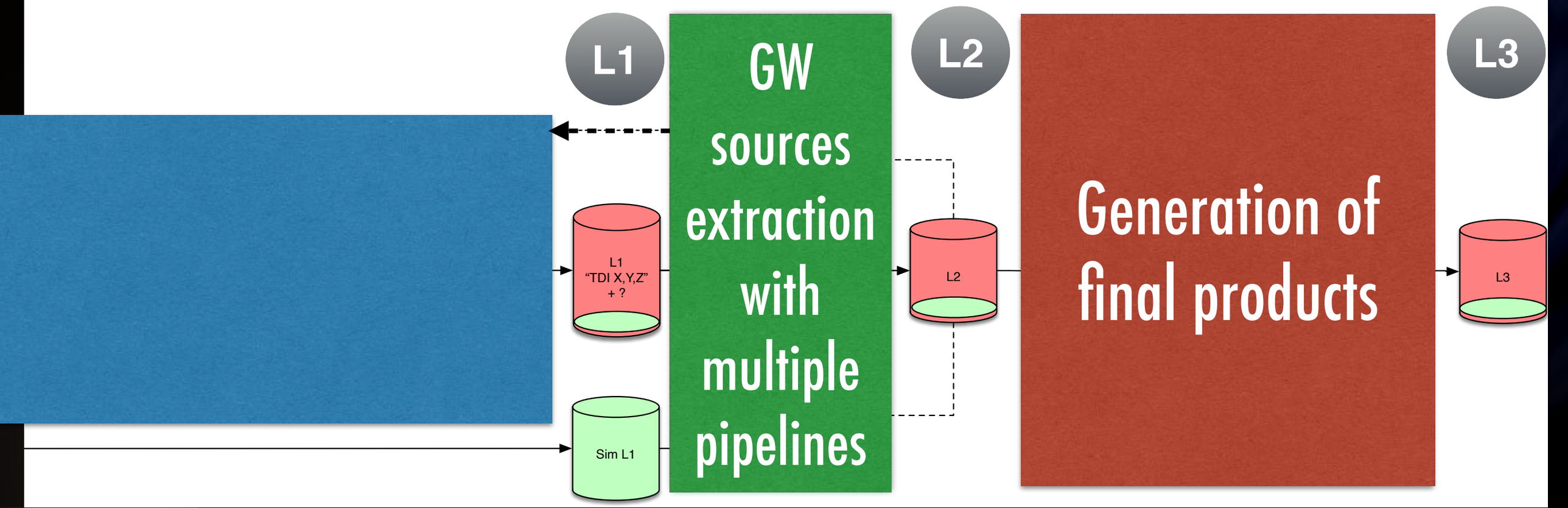


Telemetry:
+ Phasemeter
+ DFACS
+ GRS FEE
+ CGT
+ CMS
+ SciDiag
+ Housekeeping





Initial Noise Reduction pipeline (TDI, etc)



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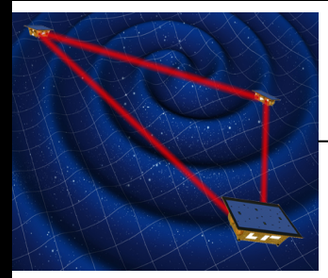

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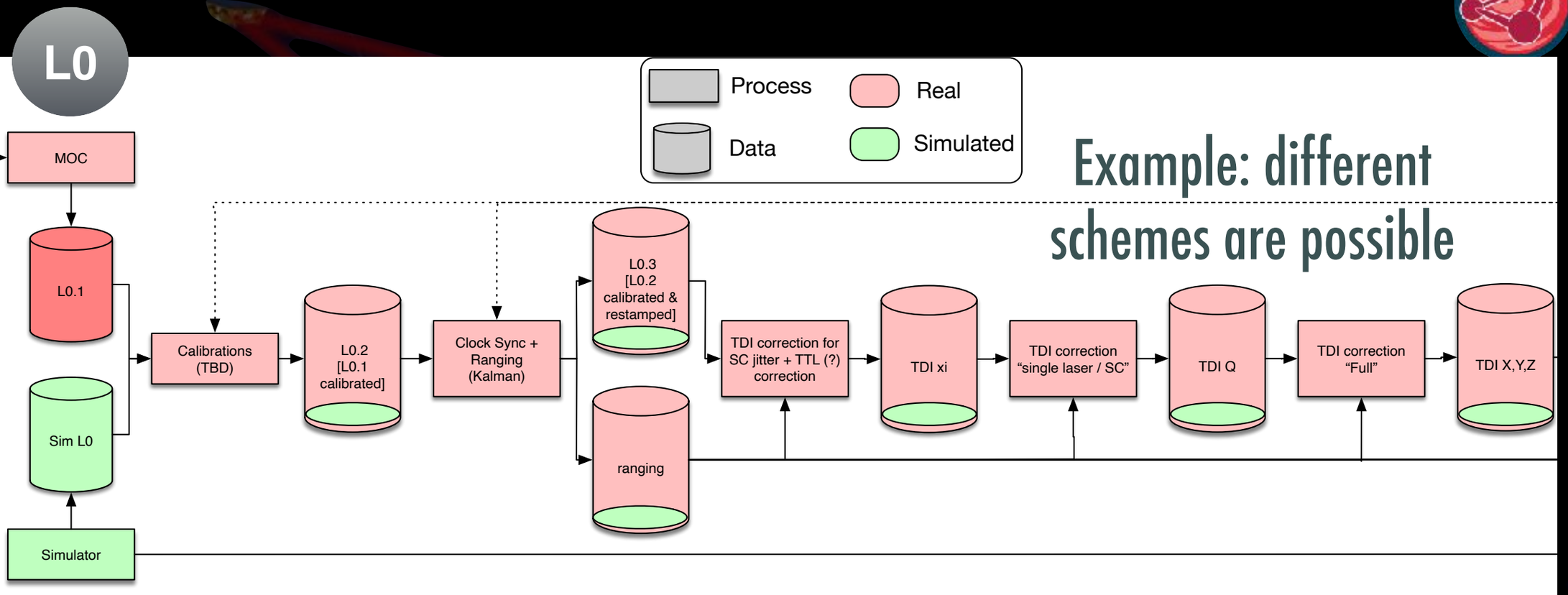
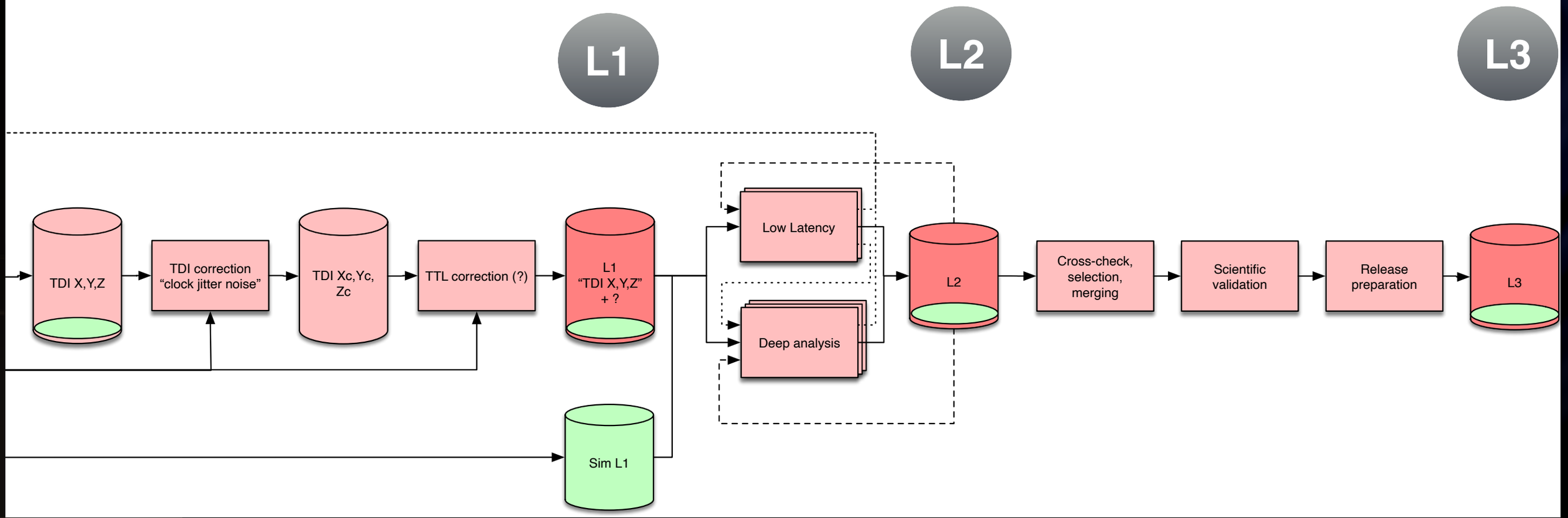
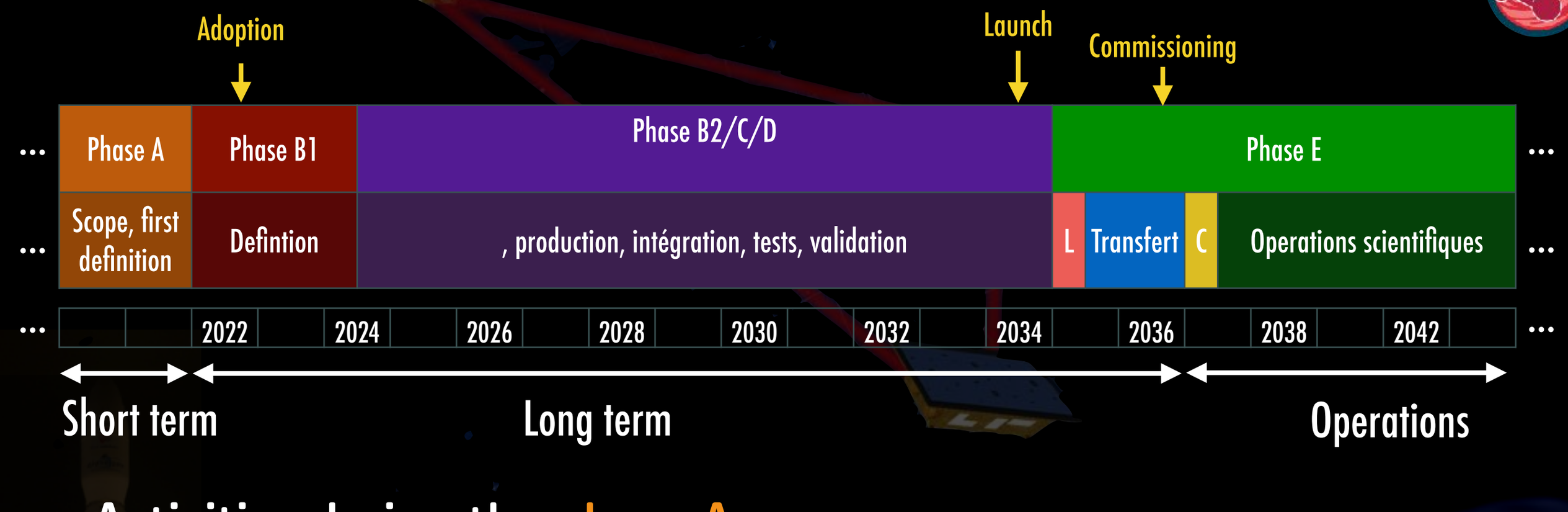


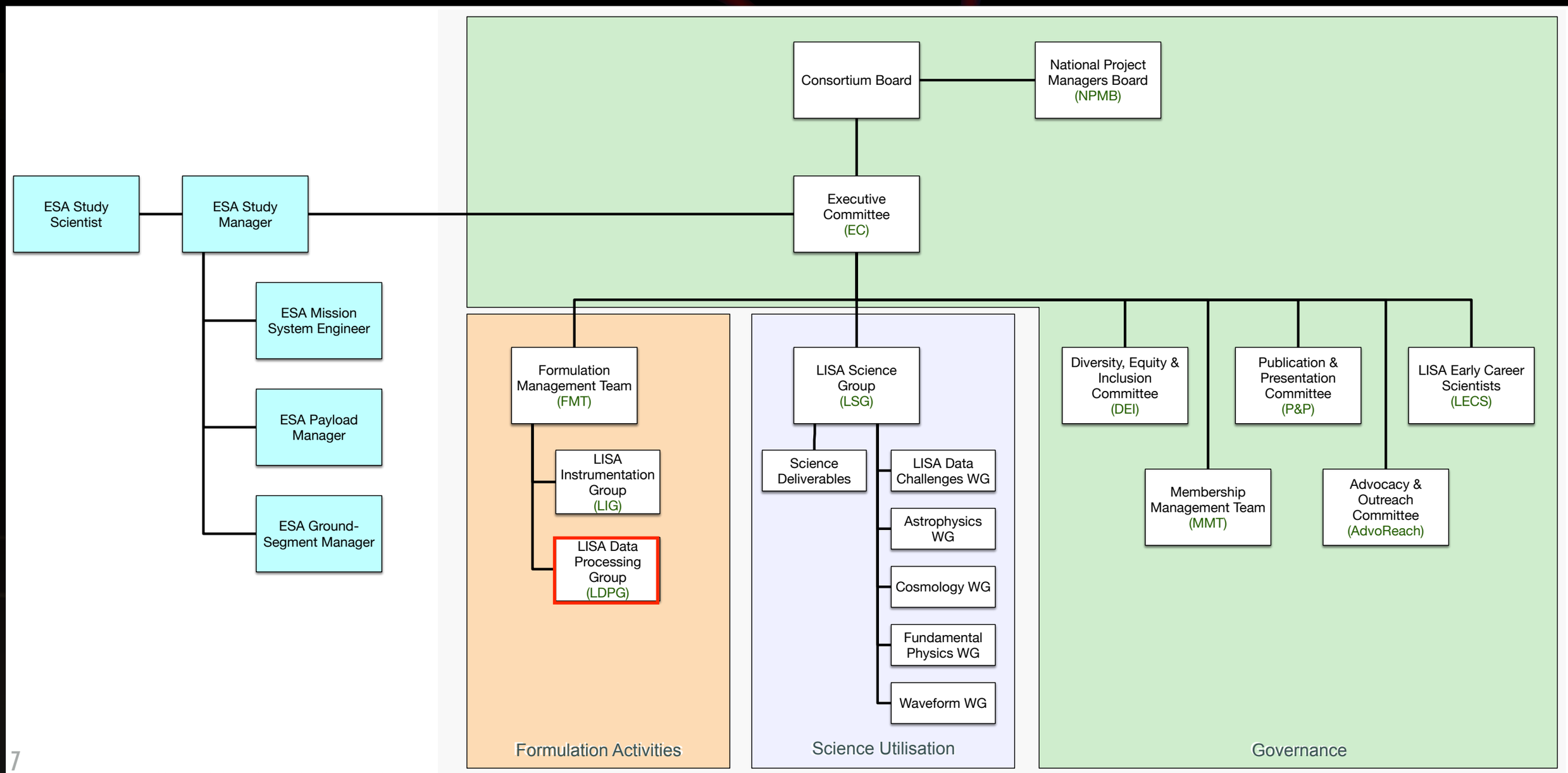
# LISA timeline




- Activities during the phase A:
  - Definition, scope, organisation
  - First mission of this kind + large number of overlapping sources: challenge for data analysis => development and prototyping started very early
  - Support & contribution to Consortium activities: figure of merits, performance model, simulations, ...

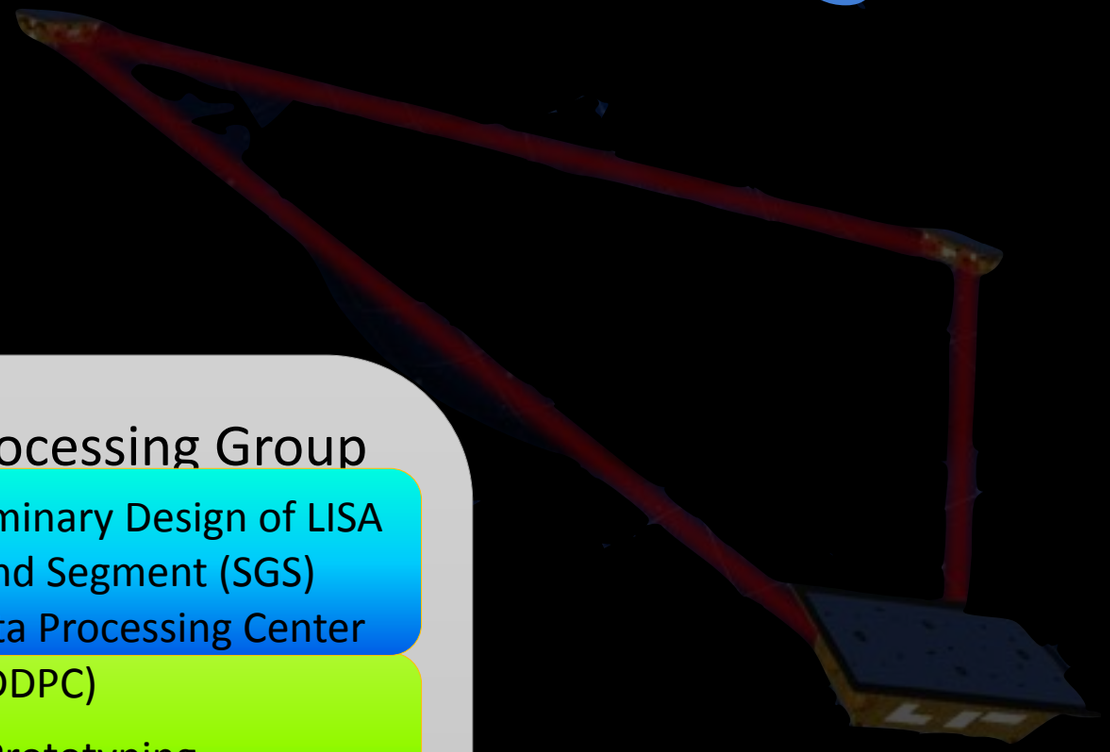
# Consortium (New) Organisation

- LDPG is part of the formulation activities organised by the FMT
- Some activities are done together with FMT & LIG
- Some others Ground Segment activities are fully delegated to LDPG




*Note: only formal reporting lines are shown*

# LDPG Working Groups



LISA Data Processing Group

WG1/WG2: Preliminary Design of LISA Science Ground Segment (SGS) / Distributed Data Processing Center (DDPC)

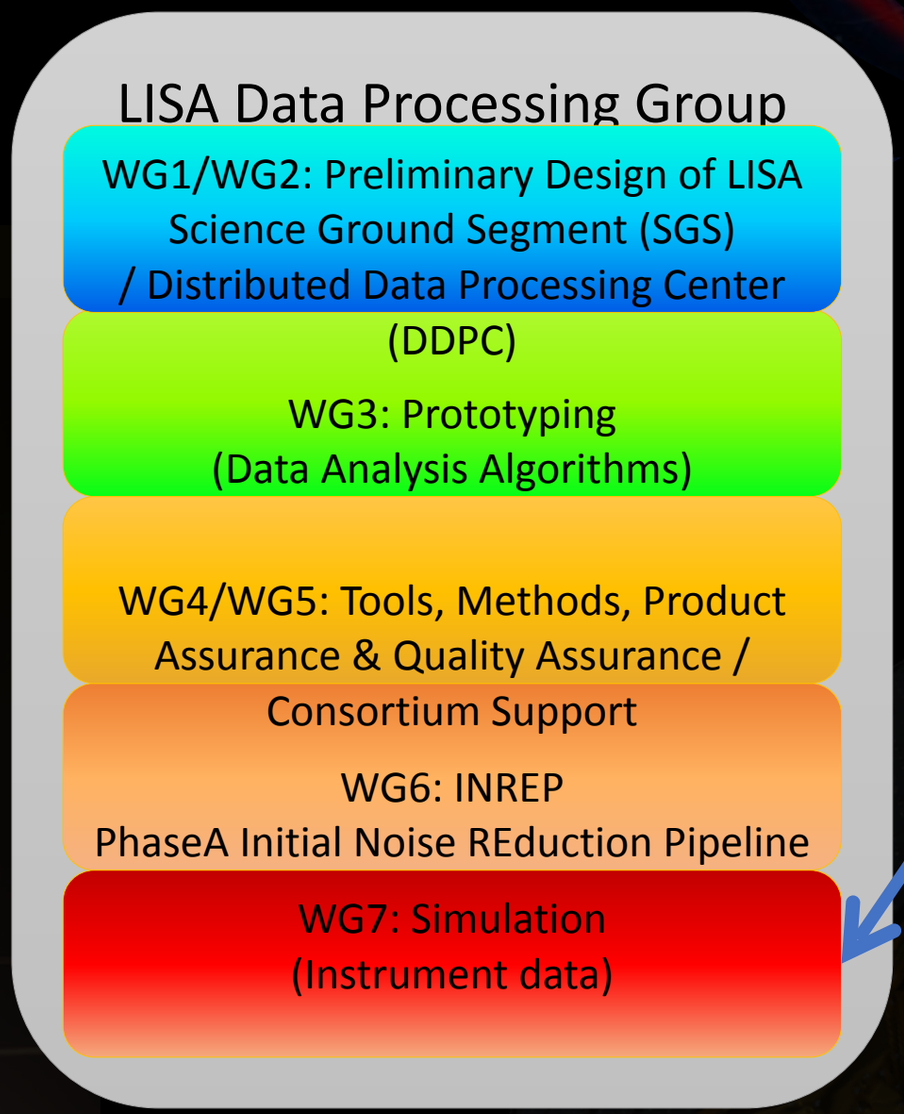
WG3: Prototyping (Data Analysis Algorithms)

WG4/WG5: Tools, Methods, Product Assurance & Quality Assurance / Consortium Support

WG6: INREP PhaseA Initial Noise REduction Pipeline

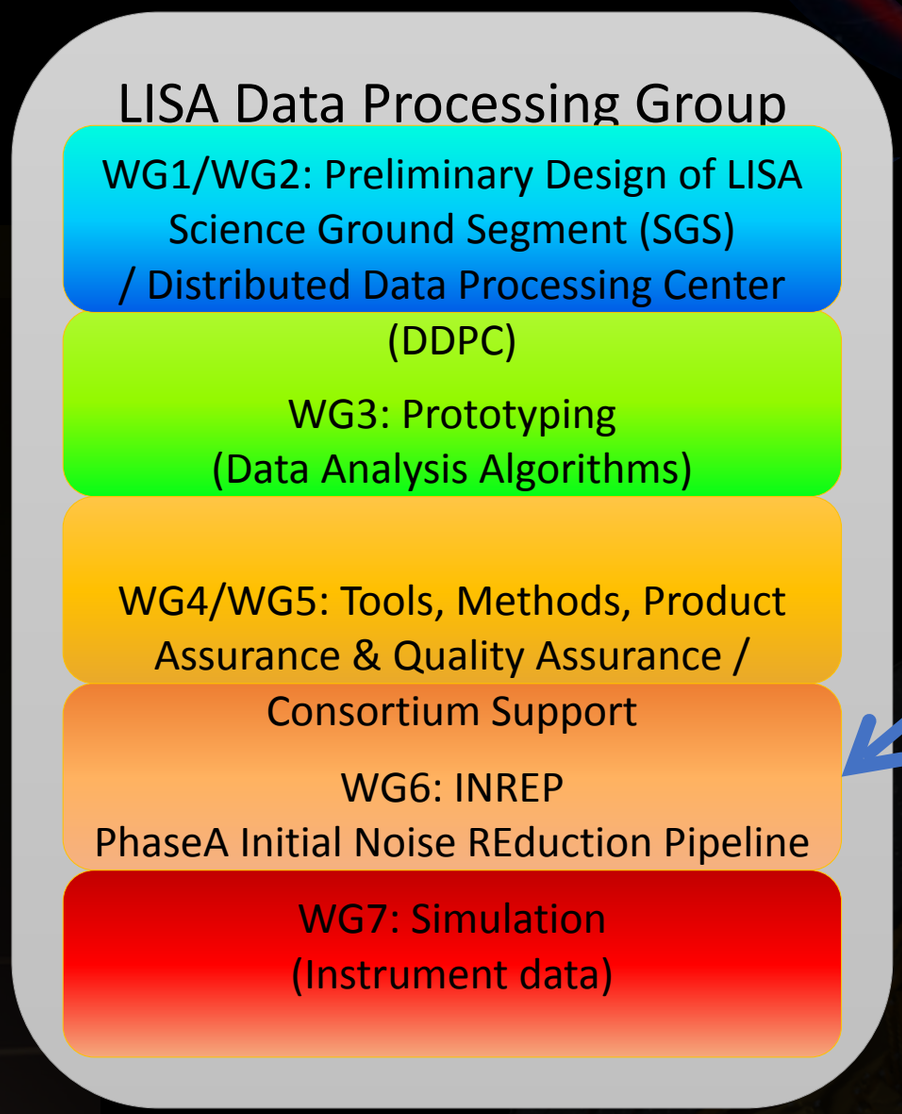
WG7: Simulation (Instrument data)

# LDPG Working Groups




- WG7: Instrument Simulation
  - LISANode: now the core instrument simulator
    - Time domain simulator C++/python
    - Simulate instrument: noise sources, beams, on-board processing
    - Constant increase of realism following instrument development
  - External modules for orbits, frequency plan, glitches, etc
  - Others simulators developed and used in parallel:r
    - LISADyn: 3D dynamics spacecrafts + test-mass (on-going integration)
    - LISAInstrument: Fast full python
    - SimScape: thermo-mechanical, etc
    - Optics (ifocad): beam propagation

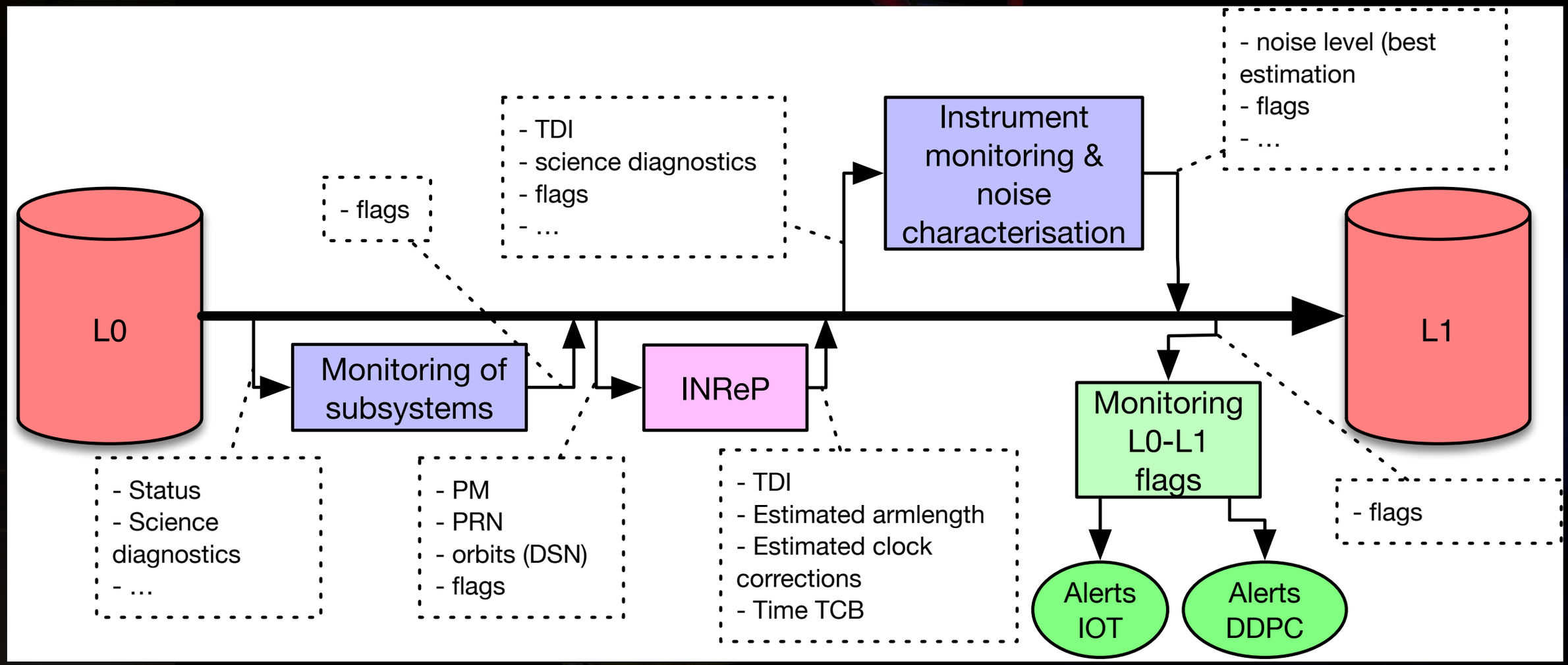
# LDPG Working Groups



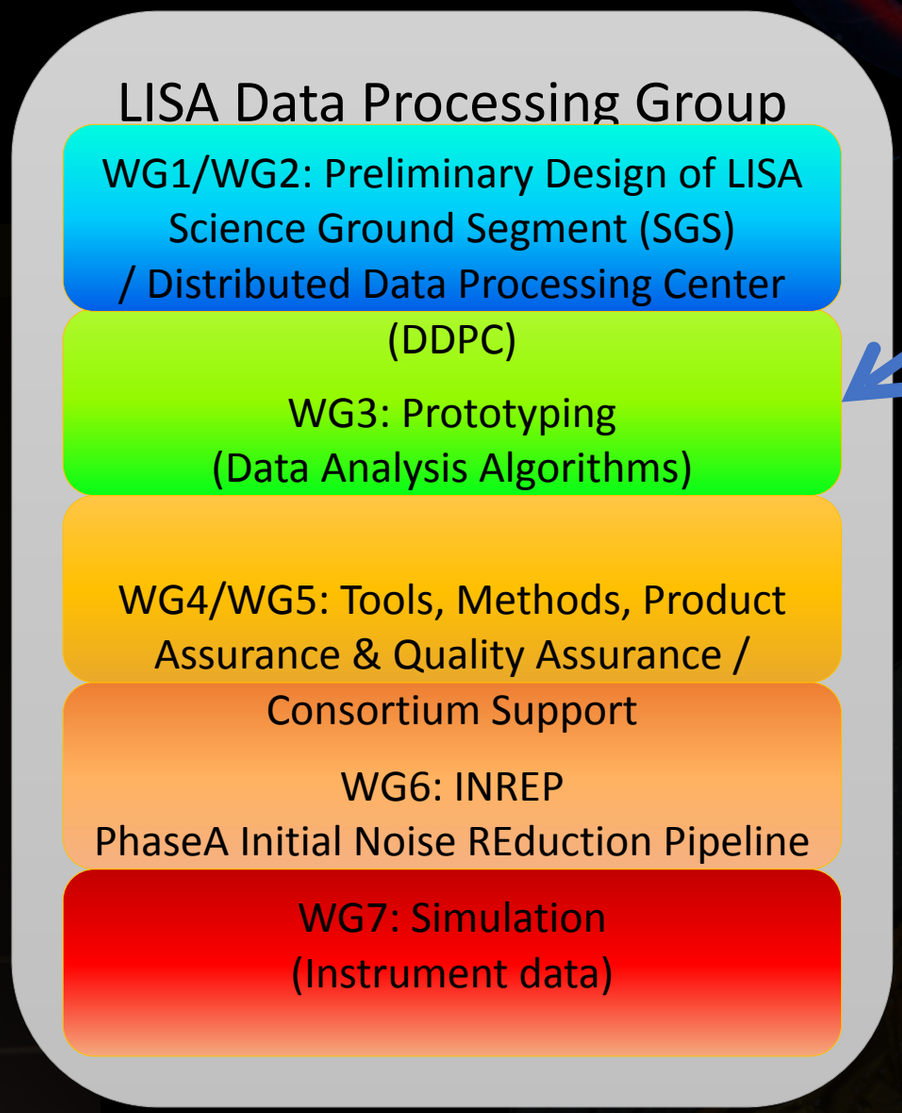

- **WG6 Initial Noise REduction Pipeline**
  - Processing to generate "L1" ~ TDI data
  - Current plan: mainly developed by the Consortium to be operated by ESA
  - Core activities/tasks:
    - INREP specifications & interfaces (MFR)
    - Reference implementation
    - Transfer functions, analytical formulation, validation via simulation

# L0 to L1

- From telemetry data + auxiliary data (L0) to data ready to be used for GW extraction
- Example of possible components:



# LDPG Working Groups




## WG3 Prototyping

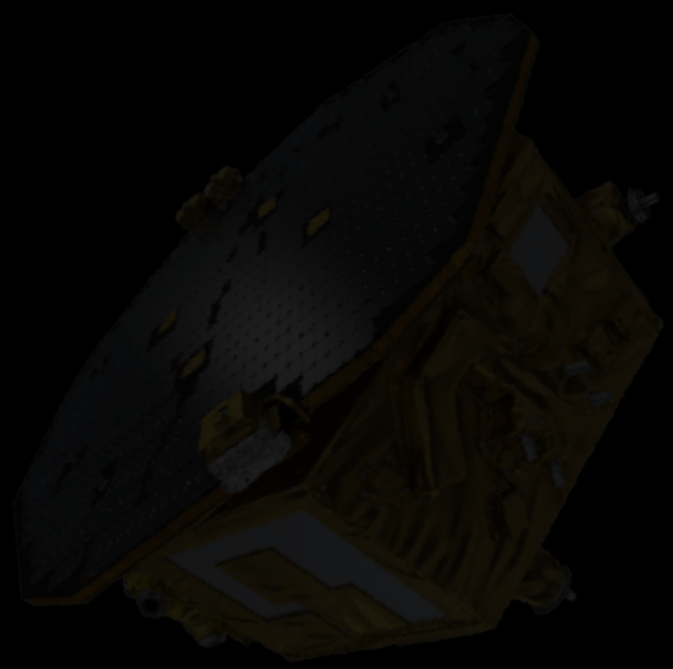
- Software for LISA Data Challenges: Prototyping of codes, workflows, etc
  - LDC1a: Simple sources with standard noises (writing up)
  - LDC2a: Mixed sources with simple noise
  - LDC2b: Simple sources with more noise realism
  - LDC1b: Another pass at simple sources (esp EMRIs SOBHs)
- Use LDC outcomes and activities to estimate resource needs

# Global picture

- Current organisation:

Simulation

Science Ground Segment Processing



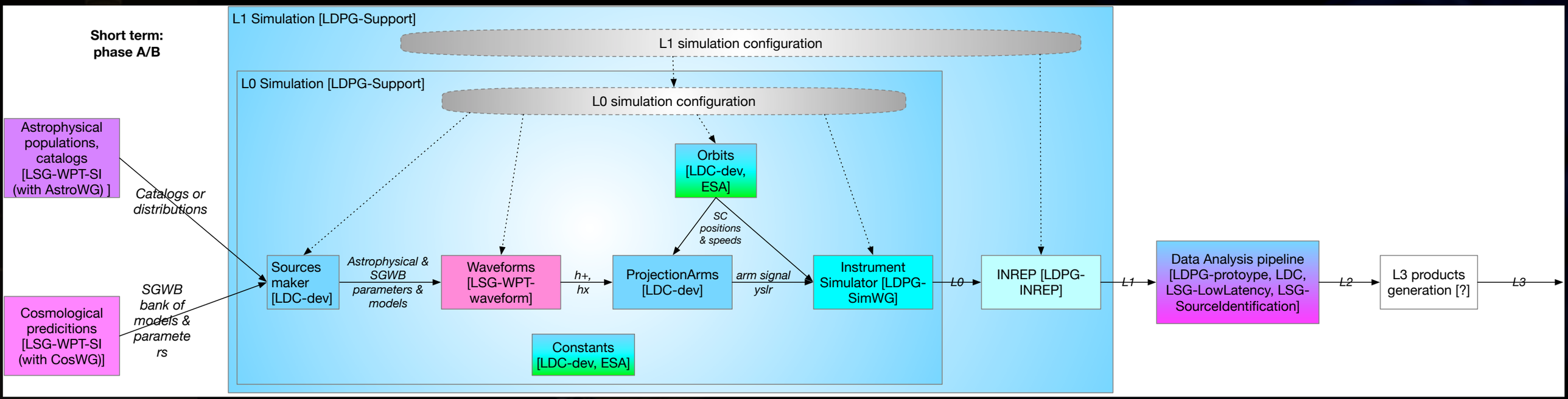
# Global picture

- Current organisation:

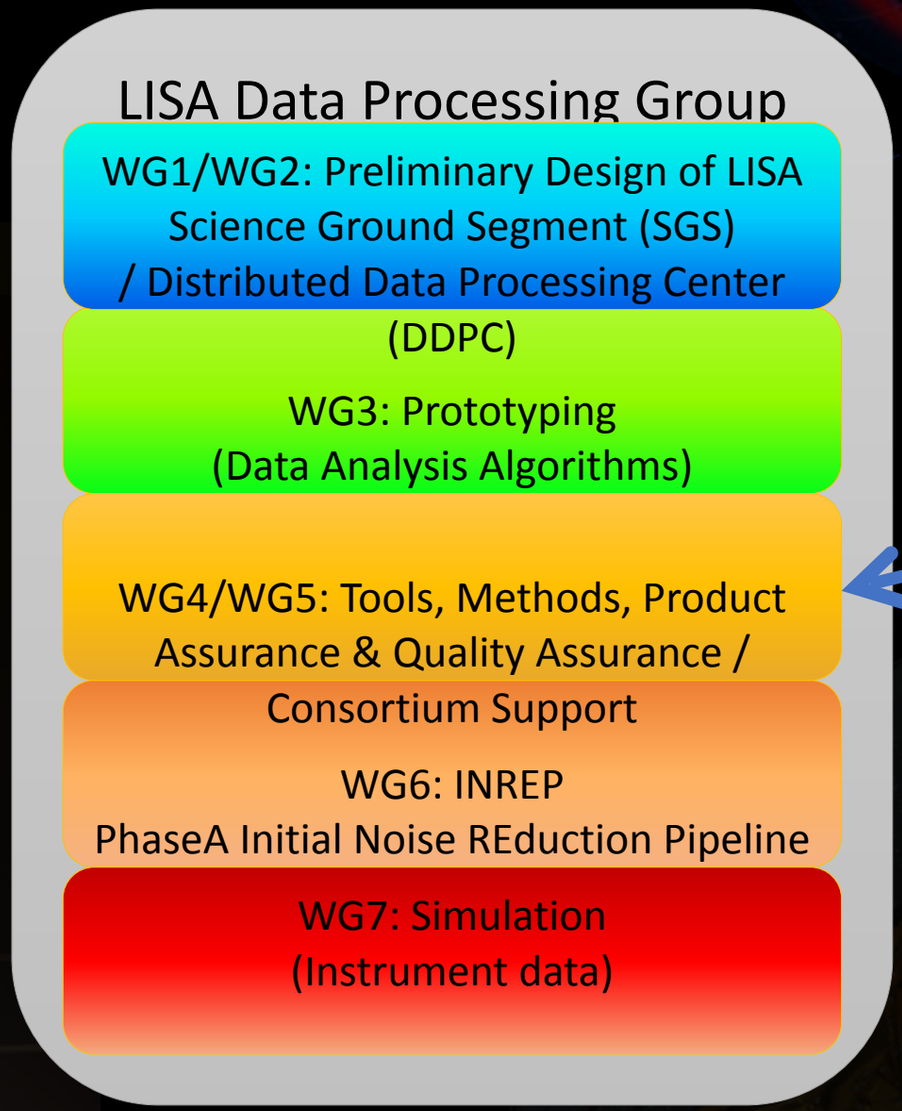
## Simulation

## Science Ground Segment Processing

**Short term: phase A/B**



# LDPG Working Groups




- **WG4: Tools, Methods, Product Assurance & Quality Assurance:**
  - Common Development/Reference Environment:
    - Define a common basis for the Consortium codes
    - Docker & Singularity
  - Define processes for software release, docs, etc
  - JIRA/Confluence
  - Parameter Data Base:
    - Single data base for « all » parameters used in LISA
- **WG5 Support examples:**
  - Infrastructure for LDC processing
  - Figures of Merits (FoM) infrastructure [defined by the LISA Science Group]
  - Support implementation of Performance Model tool….

# LDPG Working Groups

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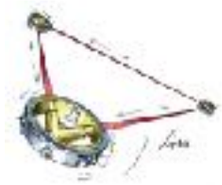
WG6: INREP PhaseA Initial Noise REduction Pipeline

WG7: Simulation (Instrument data)

- Design of the future DDPC (long term)
- Current activities:
  - Data Analysis Logic Concept
  - Architecture Concept Challenge
  - Data Model Basics
  - Operations Concept

# Notional LISA data flow:
# Future approaches to LISA SGS?



ESA MOC

Telemetry Conversion to Engineering Values

L0

”TDI” Processing

L1

Source Catalogs Alerts Auxiliary Products

ESA SOC

L2/L3

Consortium Data & Science

Global Fit(s)

L2/L3

”Key Science Projects”

DCC

DCC

DCC Canada?

Community Science Projects

??

- Are direct-to-ESA contributions an option?

- Contribute in diverse ways to science and data processing development
- Many countries working together here.

- Site a LISA Data Computing Center in Canada

- “External” participation with science data
- 15+ years away !

# Conclusion

- LDPG is defining, organising, developing, implementing and operating the Consortium contribution to the LISA Science Ground Segment.
- Activities on:
  - Prototyping for data processing:
    - Simulation
    - Initial Noise Reduction Pipeline
    - Data Analysis with LDC
  - Support
  - Definition, organisation of Distributed Data Processing Center
  - Any contribution is welcome!

# Thanks