

"Science" Documents

Paul McNamara
Joint NLST/SST meeting
Baltimore, August 2018

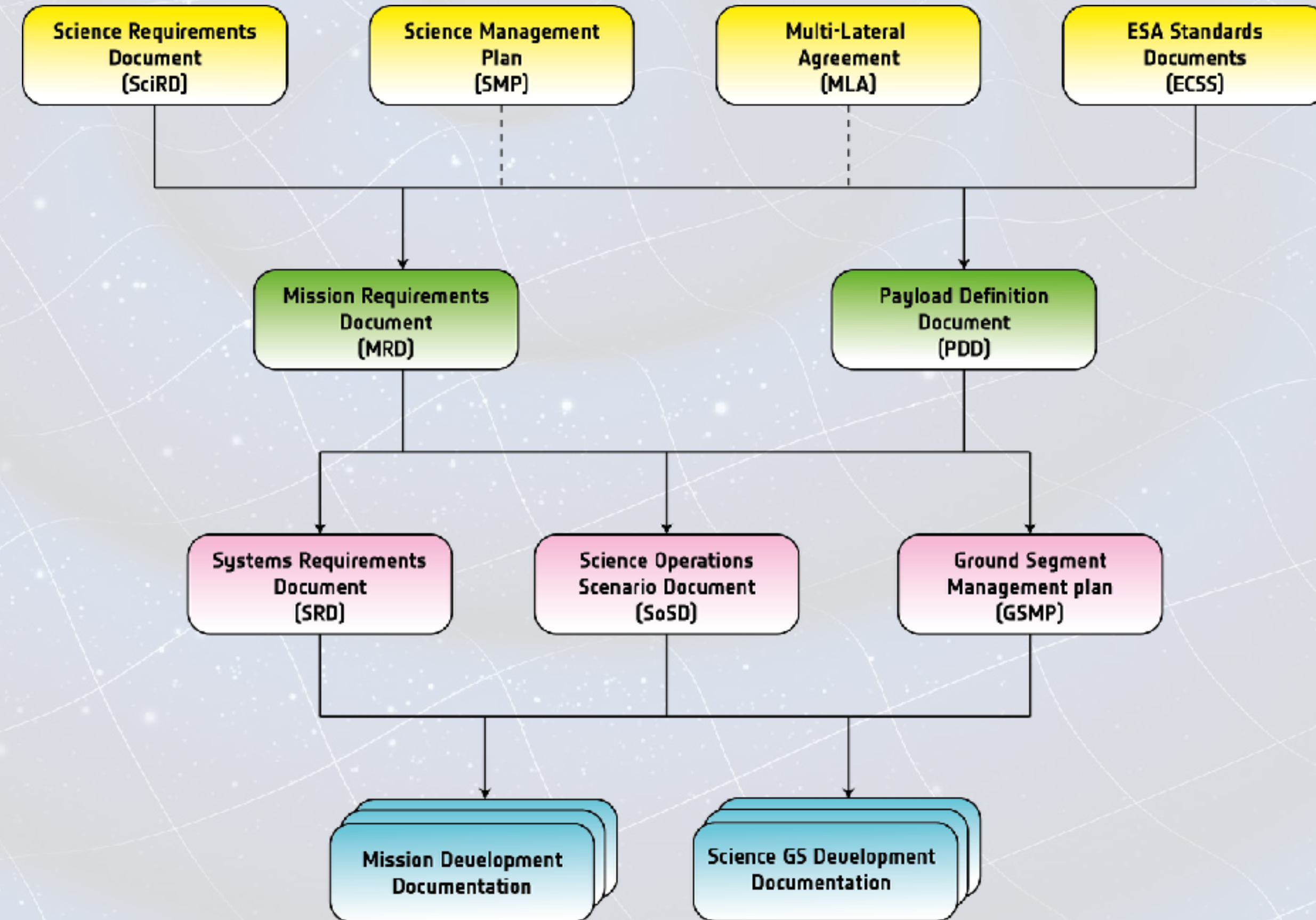
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e The Terms of Reference of the SST include:

- Provide scientific oversight in the fields associated with the science theme “The Gravitational Universe”
- Review and propose updates to the mission scientific requirements
 - Writing and maintaining the **Science Requirements Document (SciRD)**
- Assess the scientific aspects of the mission performance
 - If any science requirement cannot be met, it is the role of the SST to advise ESA on the appropriate course of action
- Assist on making top-level trade-offs
- Assist in setting-up scientific requirements on the Science Ground Segment
 - Review of **Science Operations Assumptions Document (SOAD)**
- Support the preparation of the measurement plan and calibration strategy
- Advise on the preparation of the **Science Management Plan (SMP)**
 - Including defining the data access rights for LISA data following established ESA guidelines
- Preparing for, and overseeing, the analysis of the LISA data
- Act as a focus for the interests of the broad scientific community

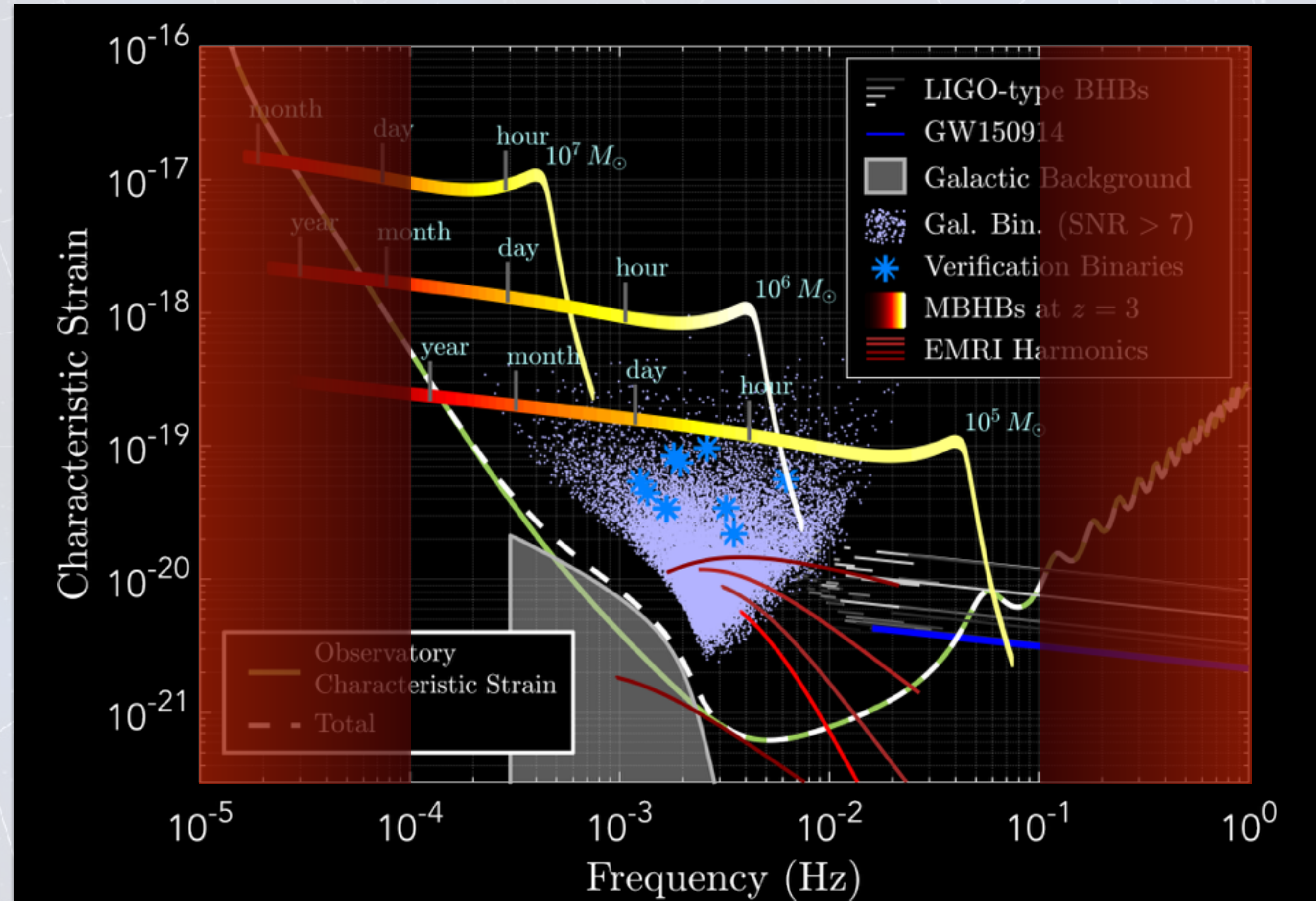
Document Hierarchy

- The SciRD and SMP are two of the highest level documents of any project
- The Science Requirements Document is the highest level requirements document in the mission
 - ESA will build the satellites (constellation) to allow the SciRD requirements to be met
 - All other technical requirements essentially flow down from the SciRD
- The SciRD will be updated during Phase A, so we are not (yet) locked into anything
 - However, the Mission Requirements Document (MRD) is based on the threshold sources listed in the SciRD
 - We will make necessary updates to the SciRD by the end of Phase A



- The SciRD should be agnostic of the mission architecture
 - It defines the *science* to be delivered by the L3 mission
- However, unlike previous versions of the LISA SciRD, we made assumptions on the mission (see next slides)
 - e.g. we have assumed that we have 6 operational links
 - It does not make much sense not to, given that several requirements require the 6 links
- High frequency strain corresponds to an equivalent of $15\text{pm}/\sqrt{\text{Hz}}$ single link displacement noise
 - We have not included the *wiggles*, but have required that any deviation can only come from the cancellation of GW signal due to choice of armlength
 - NB: The Mission Requirements Document (MRD) requires industry to build a mission with $10\text{pm}/\sqrt{\text{Hz}}$ single link displacement noise
 - The margin is held at system level
- Low frequency ($<1\text{mHz}$) strain corresponds to an equivalent single test mass acceleration noise of $3\text{fms}^{-2}/\sqrt{\text{Hz}}$
 - Again, the MRD requires an instrument with $2.4\text{fms}^{-2}/\sqrt{\text{Hz}}$ (based on LPF heritage), with margin held a system level

- The SciRD only sets requirements over the measurement bandwidth (100 μ Hz - 0.1Hz)
 - Below 100 μ Hz, or above 0.1Hz are a mission goals
 - We ask industry to avoid anything (e.g. switching heaters) which could affect the performance down to 20 μ Hz, however, there is no requirement to test at frequencies lower than 100 μ Hz



- The SciRD should only specify science requirements, however, in order to do this, we also have to levy requirements on the system
 - We have tried to avoid specifying implementation details
- Polarisation:
 - We have required the ability to measure both GW polarisations simultaneously
 - Therefore, we require a minimum of six links
- Data Streams:
 - To allow instrumental effects to be distinguished from GW signals, we require more than one quasi-independent science observables (e.g. TDI X, Y or Z)
 - Again, requires more than 4 working links
 - We require the null data stream (Sagnac) to allow an estimation of the low frequency instrument noise
 - Again, requires the full constellation

● Mission lifetime

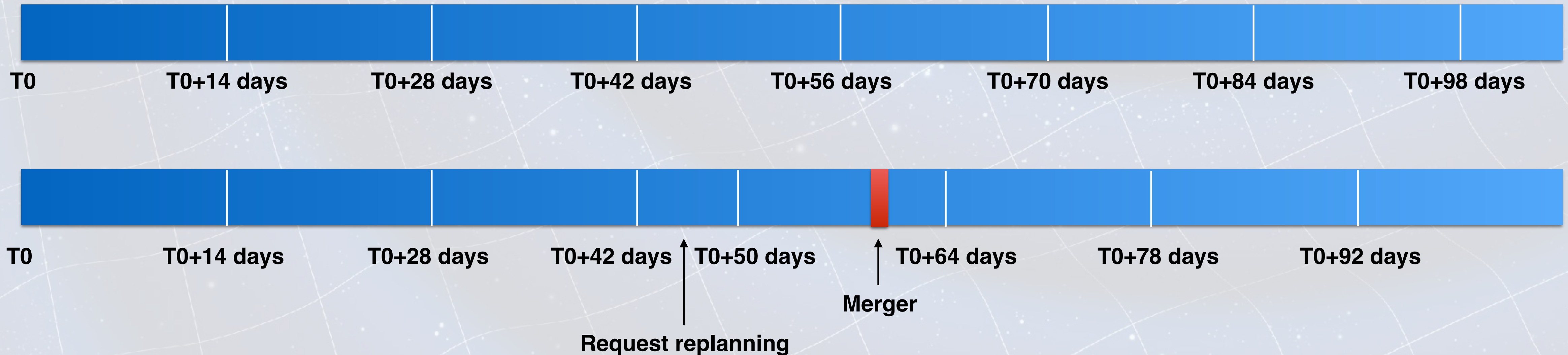
- Nominal in-orbit operational phase (IOOP) is 4 years
 - With 75% duty cycle (based on LPF heritage), leads to 3 years of science data taking
- Mission extension planning is for 6 years (i.e. sizing of consumables)
 - With 75% duty cycle, we then have an additional 4.5 years of science data
- In total we are assuming 7.5 years of science data taking out of a 12.5 year mission (launch to decommissioning)
 - In reality, the 75% is based on LPF - this could be higher if we can remain in science mode while repointing the antenna
 - However, we have to consider the 12.5 year lifetime vs 18 months of LPF

● Data Products

- We specify that all science data is '*properly filtered and sampled at adequate resolution*'
 - **We need to clarify the filters and resolution required per channel, otherwise this is open to interpretation!**
- Primary science data
 - Measurement bandwidth to 0.1Hz
 - MBW goal of 1Hz
 - Thus minimum sampling rate is 2Hz, but in reality, considering filtering for TDI, we will need data sampled at >3Hz to have a useful bandwidth at 1Hz
 - The sampling rate needs to be fixed asap, as it drives the C&DH and comms system

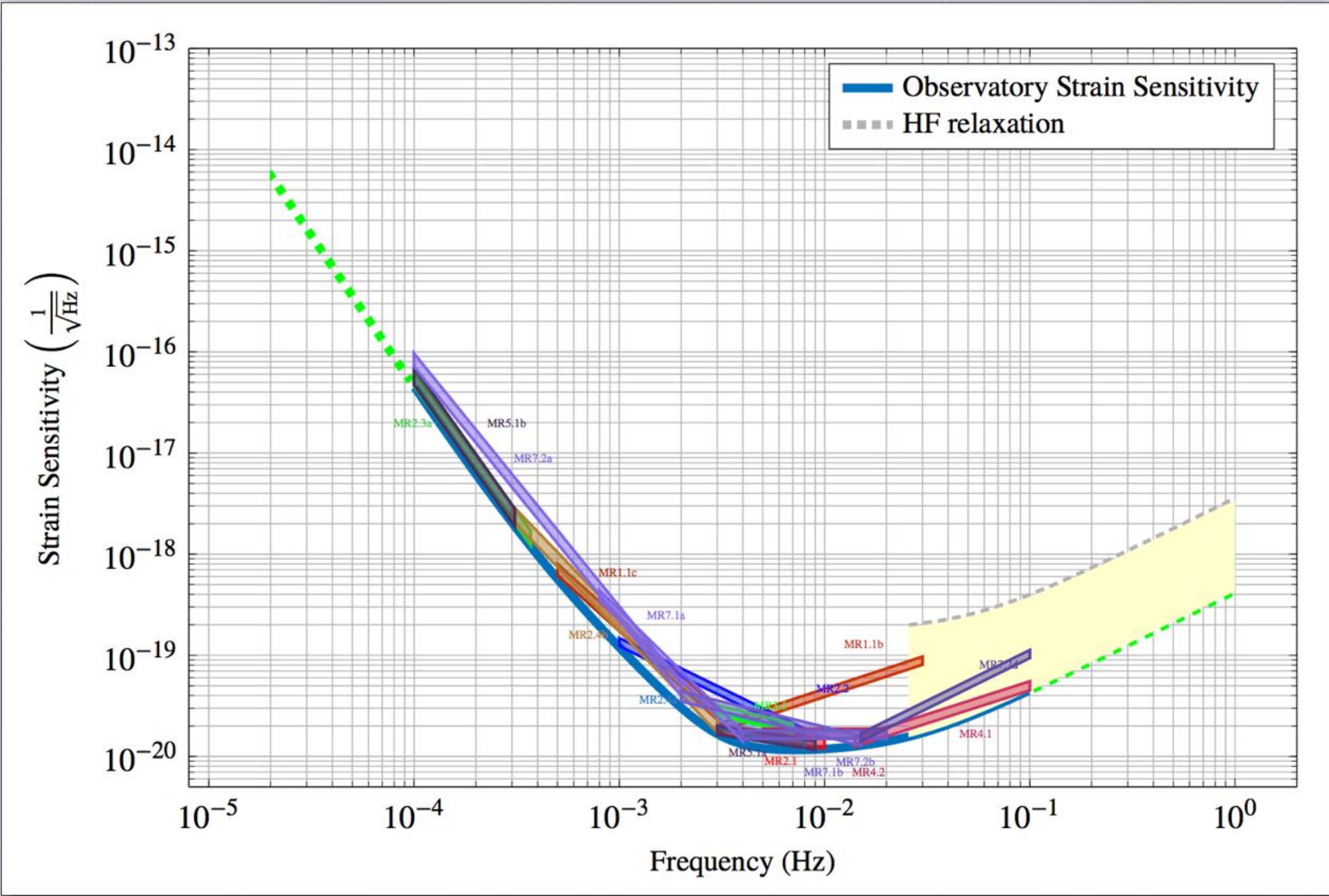
Protected Periods

- We specify that it shall be possible to reschedule any planned interruption (e.g. antenna repointing) to allow for a 14-day protected period
- This should not be a problem, as long as we give ~2day notice to MOC
- Only requires a re-phasing of the antenna pointing
- Do we also want to have the merger in visibility?
 - If so, then this places much stricter requirements (which may not be possible) as the GS usage is scheduled ~6months in advance



SO 1: Study the formation and evolution of compact binary stars in the Milky Way Galaxy.	18
SI 1.1: Elucidate the formation and evolution of Galactic Binaries by measuring their period, spatial and mass distributions.	18
SI 1.2: Enable joint gravitational and electromagnetic observations of GBs to study the interplay between gravitational radiation and tidal dissipation in interacting stellar systems.	20
SO 2: Trace the origin, growth and merger history of massive black holes across cosmic ages	21
SI 2.1: Search for seed black holes at cosmic dawn	22
SI 2.2: Study the growth mechanism of MBHs from the epoch of the earliest quasars	24
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SI 8.1: Search for cusps and kinks of cosmic strings	47
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Sensitivity curve and Mission Requirements



SNR Calculations



- Antoine, Martin and Stas have put together a document describing the calculations of the SNR as quoted in the scared
- If you haven't done so, please review and provide feedback
 - This analysis will underpin the observer tools which will be made available

 Laser Interferometer Space Antenna	Ref: LISA-LCST-SGS-TN-001	
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LISA Science Performance and SNR Calculations

N/Ref:	LISA-LCST-SGS-TN-001
Title	LISA Science Performance and SNR Calculations
Abstract	A technical note justifying the science performance calculations for LISA, in particular computation of Signal-to-Noise Ratios.

	Name	Date	Signature
Prepared by	LISA team	2018/07/05	
Checked by			
Checked by (QA)			
Approved by			

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- The SOAD is written by the Science Operations Systems Lead (SOSL)
 - Uwe Lammers based at ESAC
- The SOAD focusses primarily on the activities of the Science Operations Centre (SOC)
 - Also identifies the interfaces to the science community (in our case the DPC)
- The SOAD is used to provide the first estimate the cost of the science ground segment
- It defines:
 - Data Products (Level 0 - Level 3)
 - Ground Segment elements (MOC, SOC, DPC)
 - Description of the mission phases
 - Short description of the mission operation responsibilities (MOC)
 - Short description of the science operations responsibilities (SOC)
 - Short description of the DPC responsibilities
 - Science archive requirements
 - High level interface definition between all parties
 - Detailed description of the SOC tasks per mission phase

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- Several SOADs have been written in the past for LISA
 - Both for old-LISA and NGO
- These versions are being updated for the current LISA
 - First draft exists, but is in a very rough form
- A first meeting between the SOSL, PS and DPC was held in July
 - Uwe will now update the SOAD with the inputs from this meeting
 - Next draft is scheduled for Autumn 2018
- The costing will be worked with the ESA study office as part of the mission costing exercise

- The LISA Science Management Plan (SMP) defines the top-level management scheme which will be used to achieve the scientific objectives of the LISA mission up to, and including, the post operations phase.
 - Unlike the other top-level documents, the SMP requires approval by the ESA advisory structure, including the Science Programme Committee (SPC)
- The SMP defines the roles and responsibilities of all parties involved in science exploitation, including ESA, the LISA Consortium and the science community at large
 - The SMP provides input to the Multi-Lateral Agreement (MLA) between ESA and the National Agencies. The MLA supercedes the SMP in relation to the payload provision
- The SMP will be presented to the SPC before adoption (end of Phase B1)

- The important aspects of the SMP related to the science teams are:
 - Definition of data products
 - Already defined in the SOAD
 - Data rights, in particular any proprietary period will be defined in the SMP (and approved by SPC)
 - This will likely be the most contentious topic in the SMP
 - ESA have been burned in the past with access to data...
 - Delivery schedule of data from satellite to DPC
 - Again this will have been defined in the SOAD and SGS documents
 - However, in other (PI) missions this may not be the case
 - Public outreach
 - Requirements on ground/space based follow-up observations
 - Not required for LISA

- SMP is written by the Project Scientist with input from:
 - Science Study Team
 - NLST
 - ESA Study Manager (Martin)
 - Science Operations System Lead (Uwe)
 - Consortium Board
 - ESA Executive
- First draft written during Phase B1 (mid-2020)
 - First release by end B1
- Approval by ESA advisory Structure (around time of adoption)
 - AWG
 - SSAC
 - SPC
- Changes to the SMP are not advised, as any change must go through the full approval cycle!
 - This can take more than one year (e.g. Plato SMP)

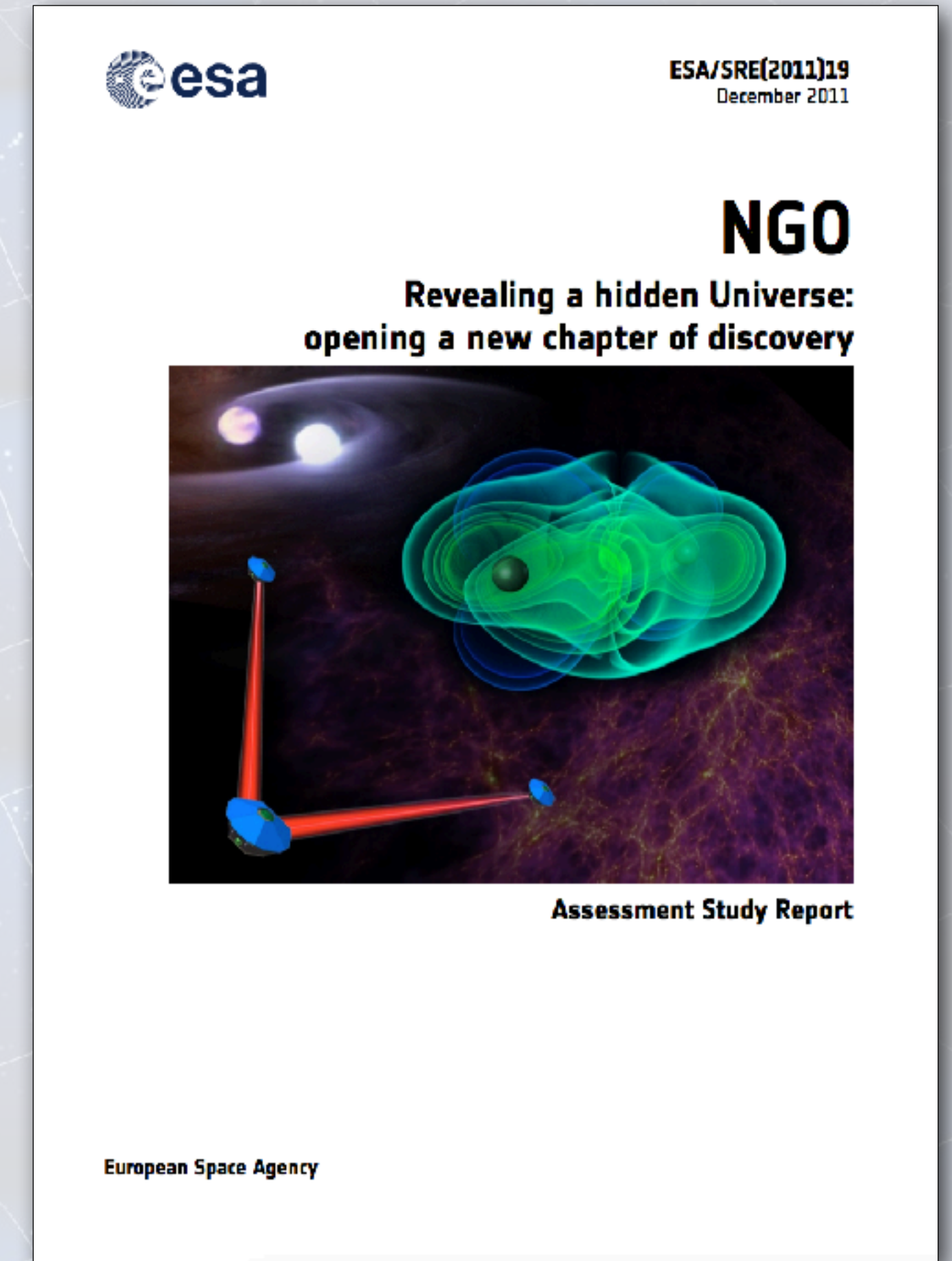
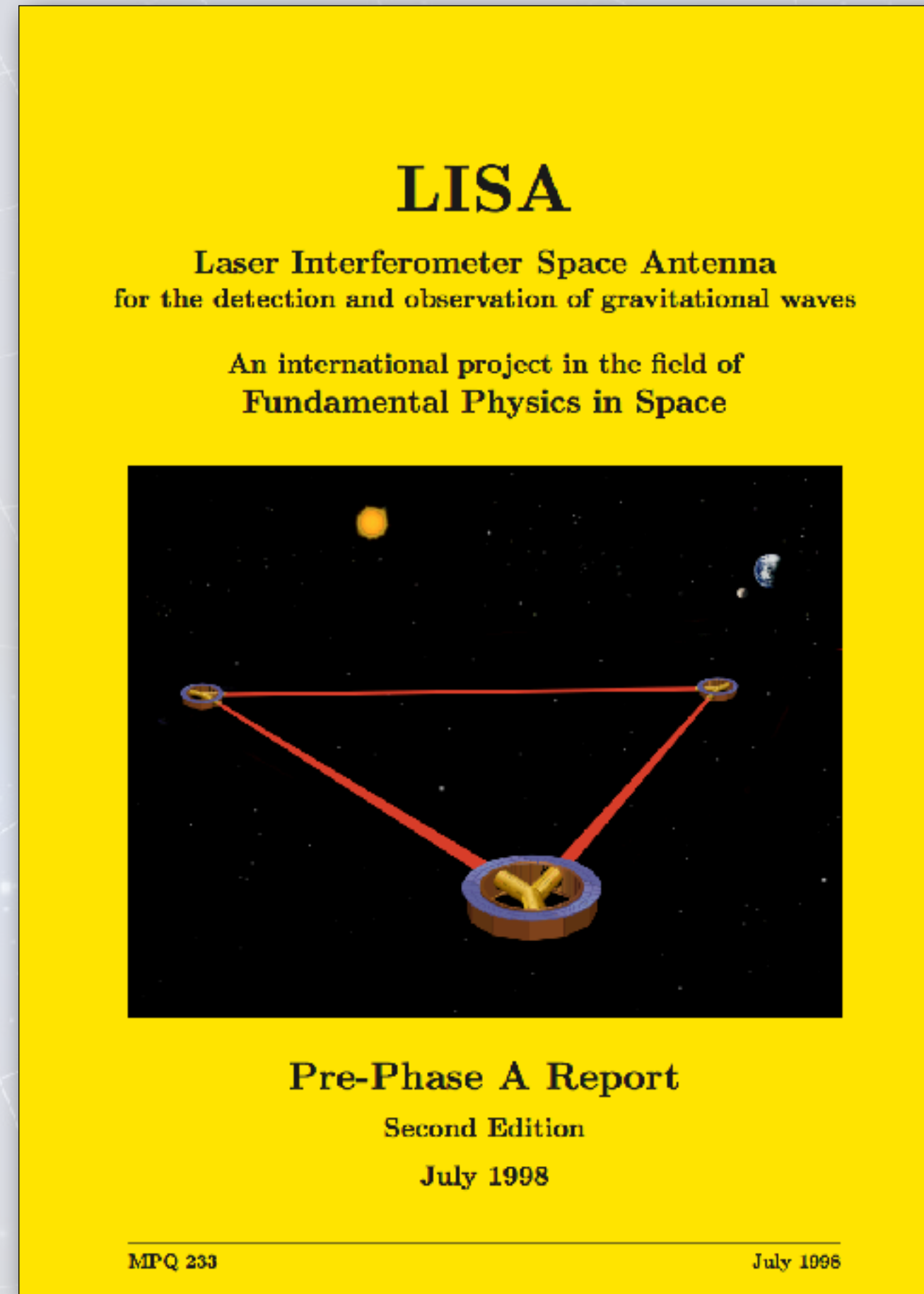
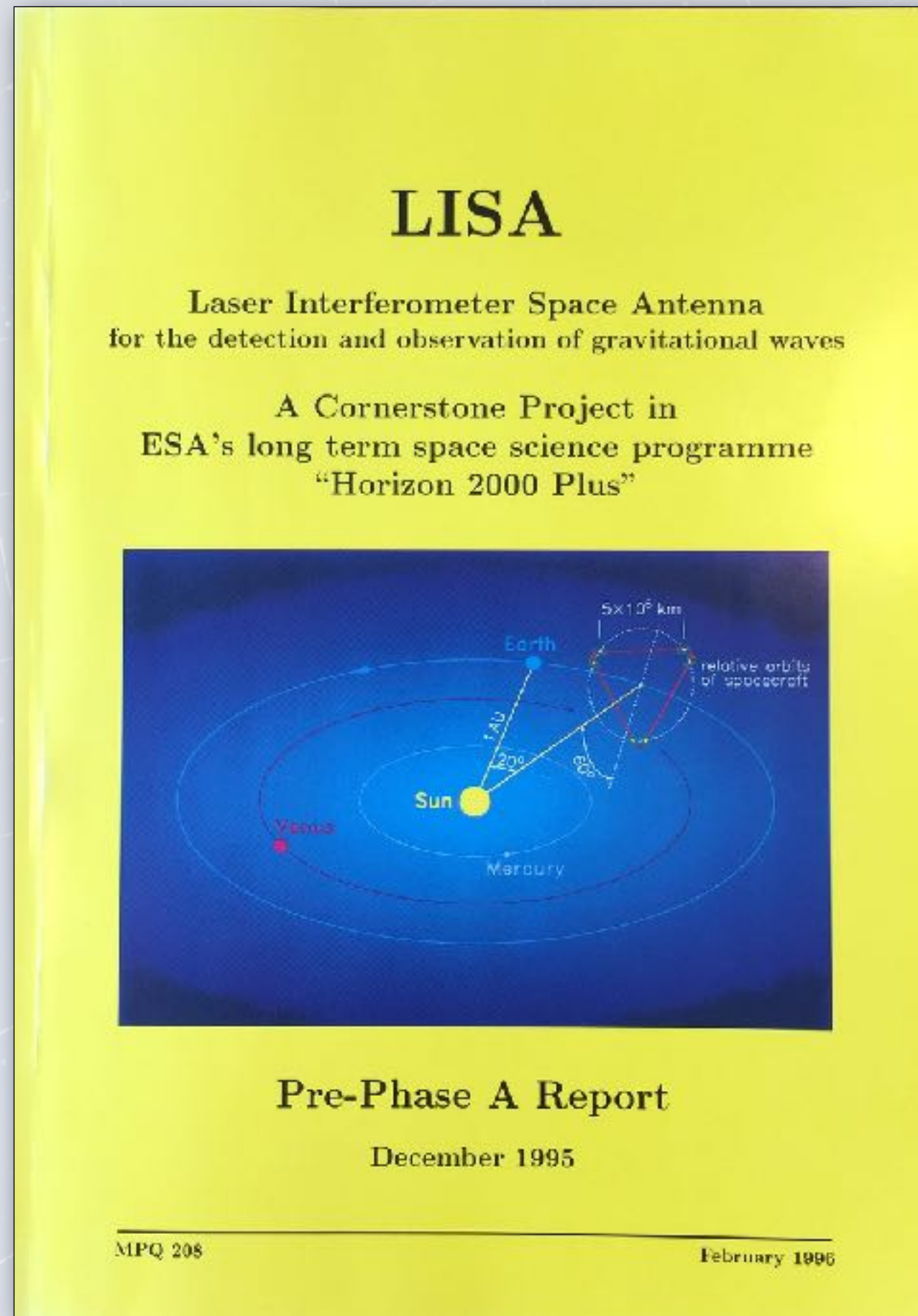


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• Yes....we need *another* Yellow Book by the end of Phase A



- The SciRD is available for comment
 - If you do not have a copy, please let me know
 - The document is also available via the ESA LISA web pages
 - Comments are always welcome
- There are still many TBD/TBCs which will be removed before end Phase A
- The definition of the Science Ground Segment is underway
 - First release of the SOAD in Autumn
- The SMP is a crucial document for the mission
 - The first draft will be released after Phase A
 - Scheduled for mid-2020

