"Science" Documents

Paul McNamara
Joint NLST/SST meeting
Baltimore, August 2018

LISA Science Study Team

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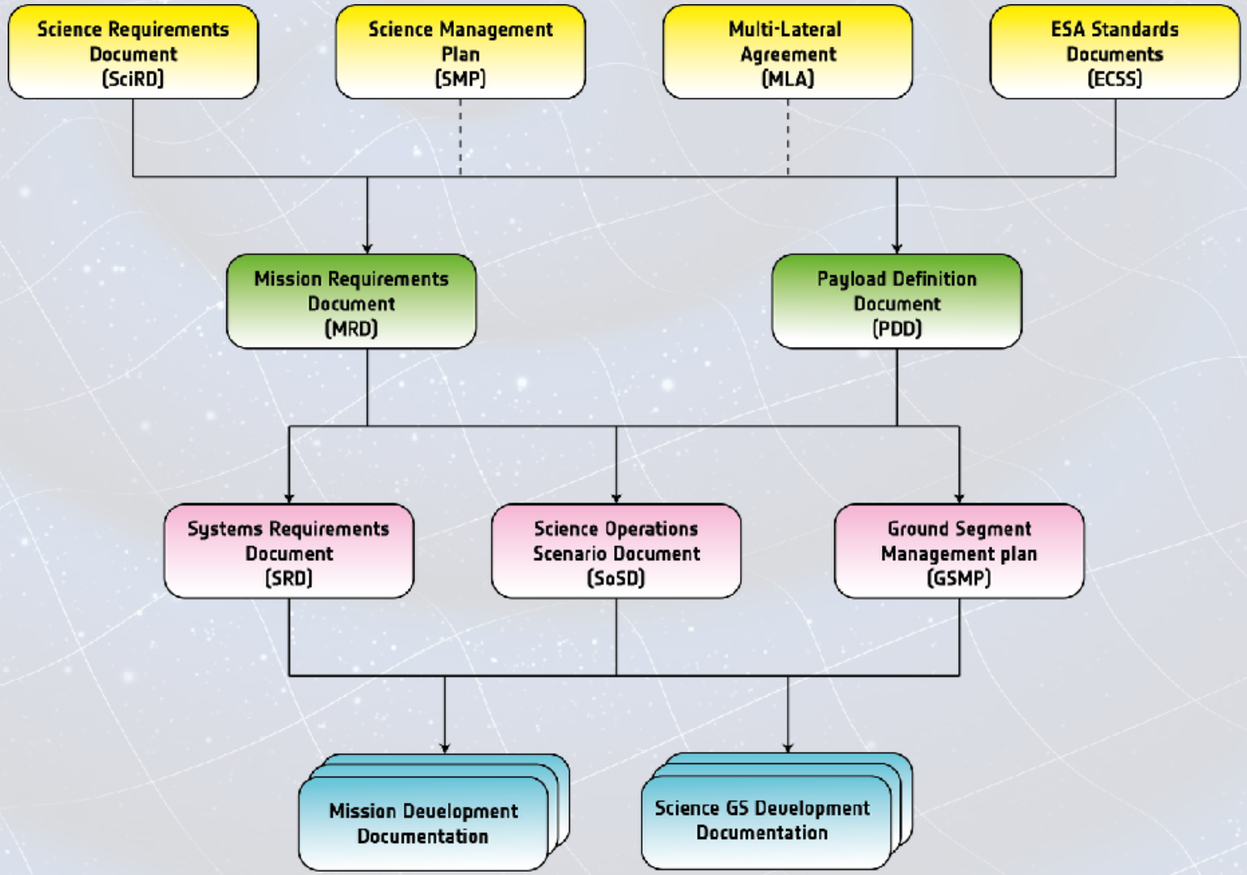
LISA SST Terms of Reference

- 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

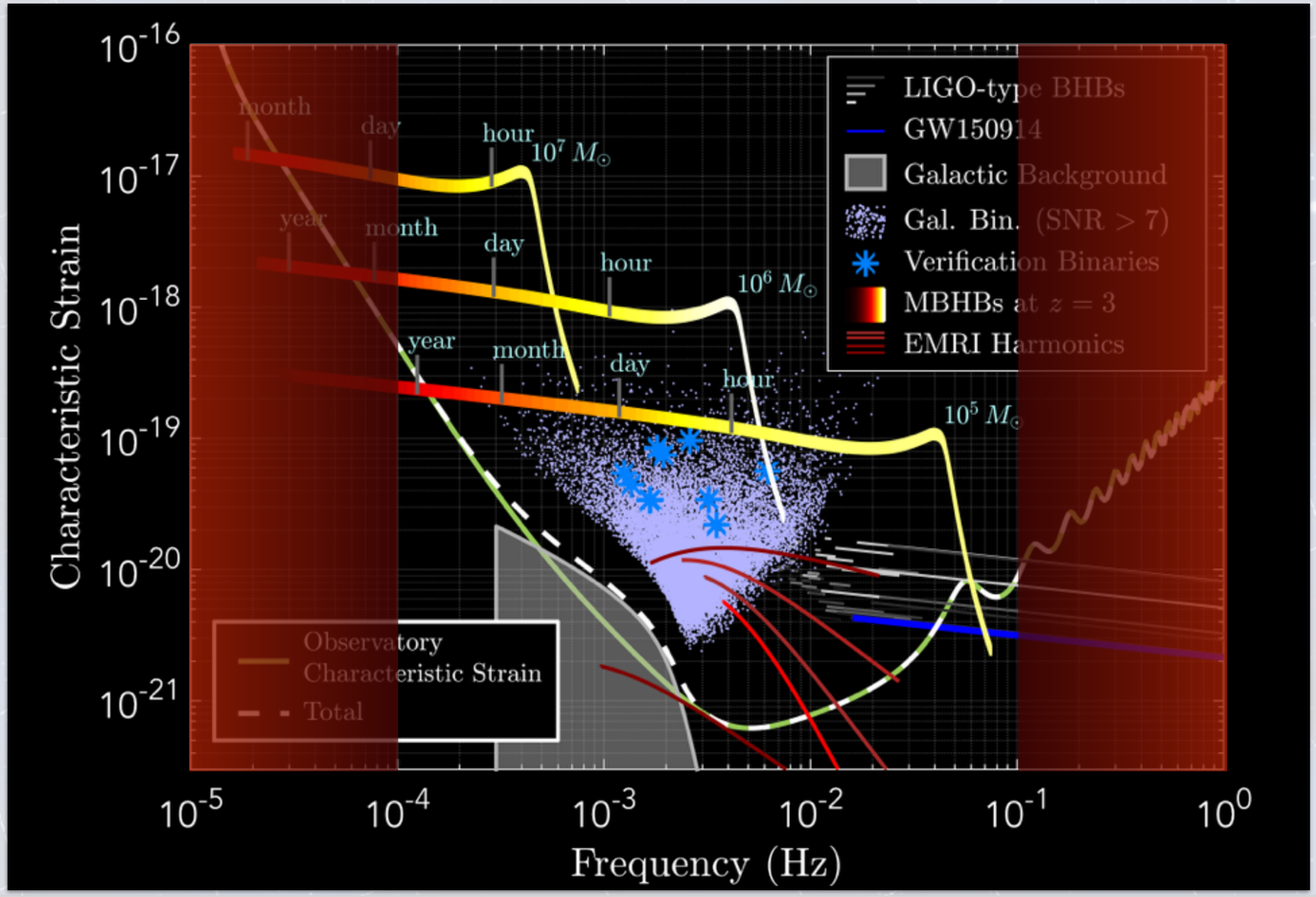


SciRD Assumptions

- 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 15pm/√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 10pm/√Hz single link displacement noise
    - The margin is held at system level
- Low frequency (<1mHz) strain corresponds to an equivalent single test mass acceleration noise of $3fms^{-2}/\sqrt{Hz}$
  - Again, the MRD requires an instrument with $2.4fms^{-2}/\sqrt{Hz}$ (based on LPF heritage), with margin held a system level

SciRD Assumptions

- The SciRD only sets requirements over the measurement bandwidth (100μHz - 0.1Hz)
  - Below 100μHz, 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 20μHz, however, there is no requirement to test at frequencies lower than 100μHz



System Requirements

- 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

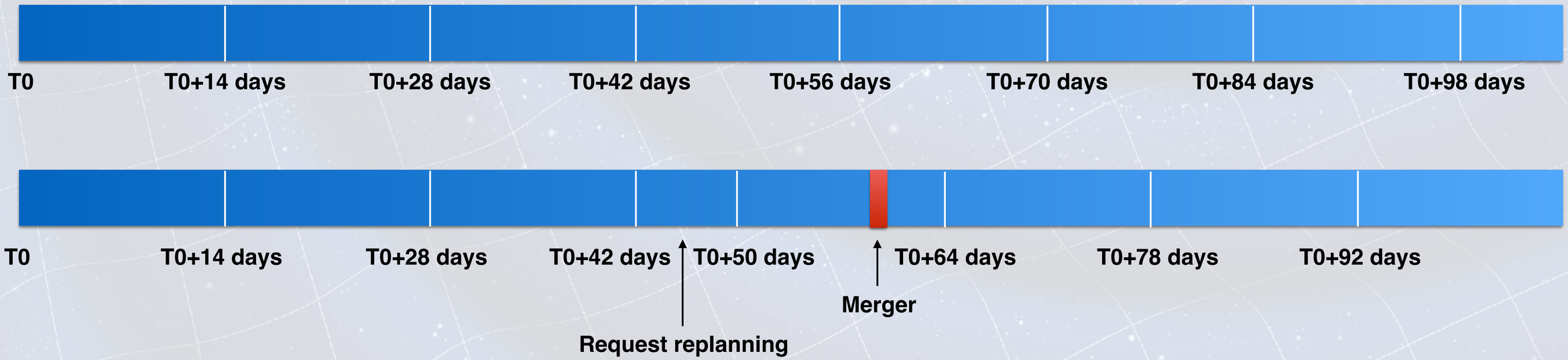
System Requirements [2]

- 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

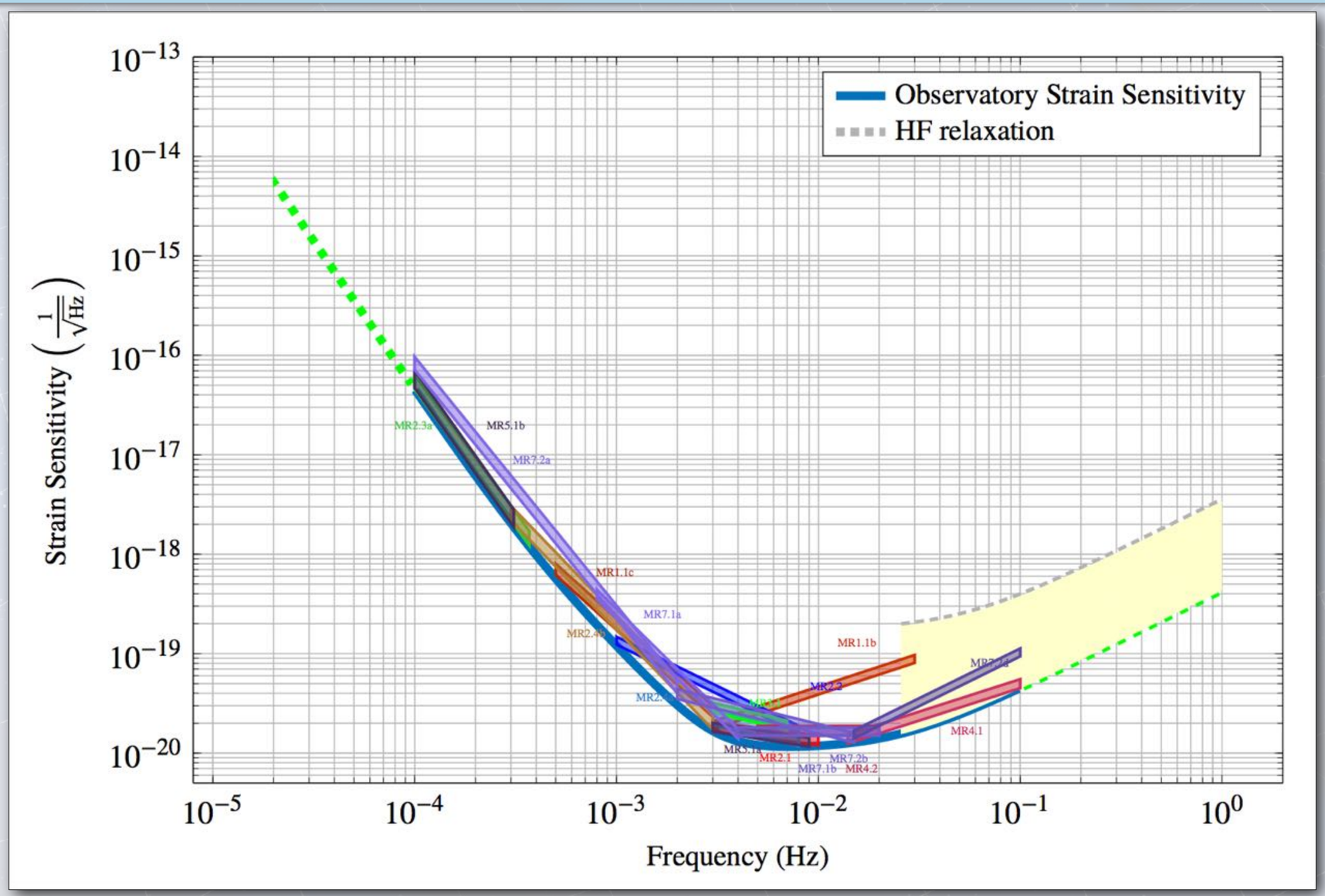
System Requirements [3]

- 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



Science Objectives - See SciRD

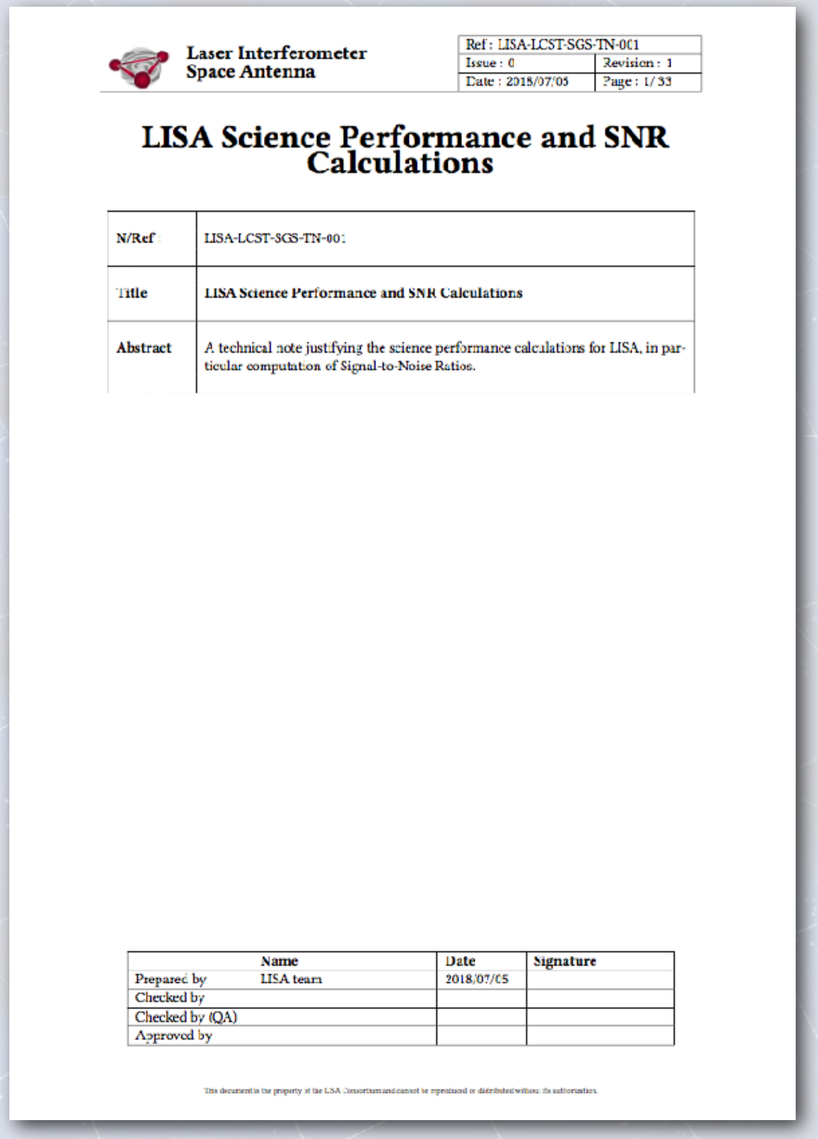
Sensitivity curve and Mission Requirements



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	
Issue : 0	Revision : 1
Date : 2018/07/05	Page : 1/ 33

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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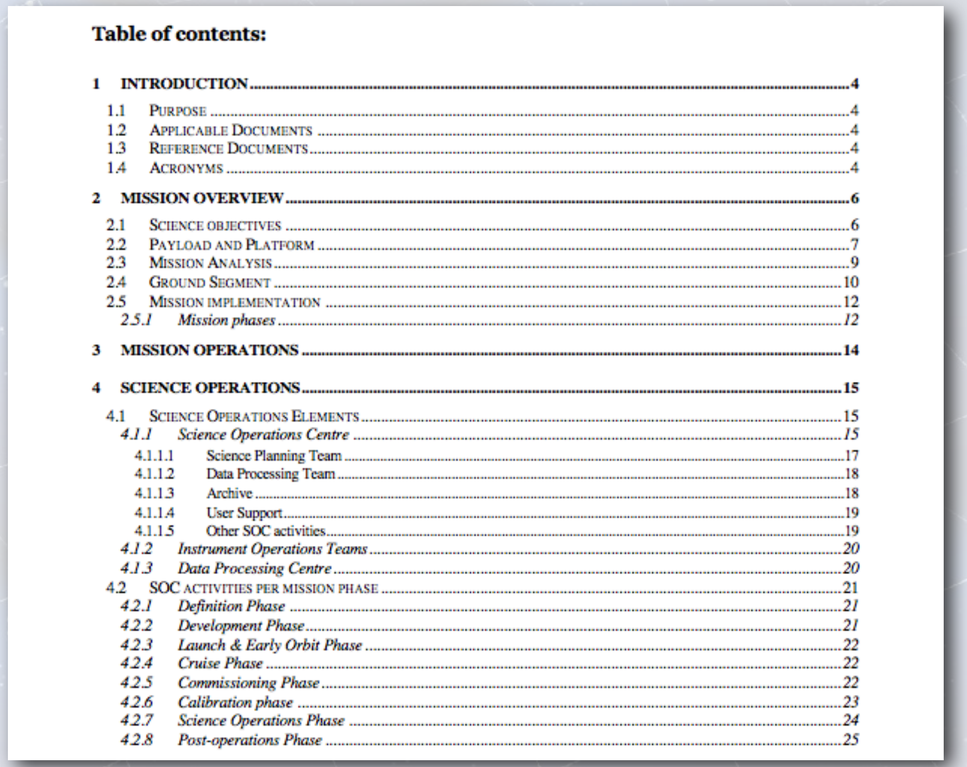
Science Operations Assumptions Document (SOAD)

- 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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SOAD schedule

- 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

Science Management Plan (SMP)

- 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)

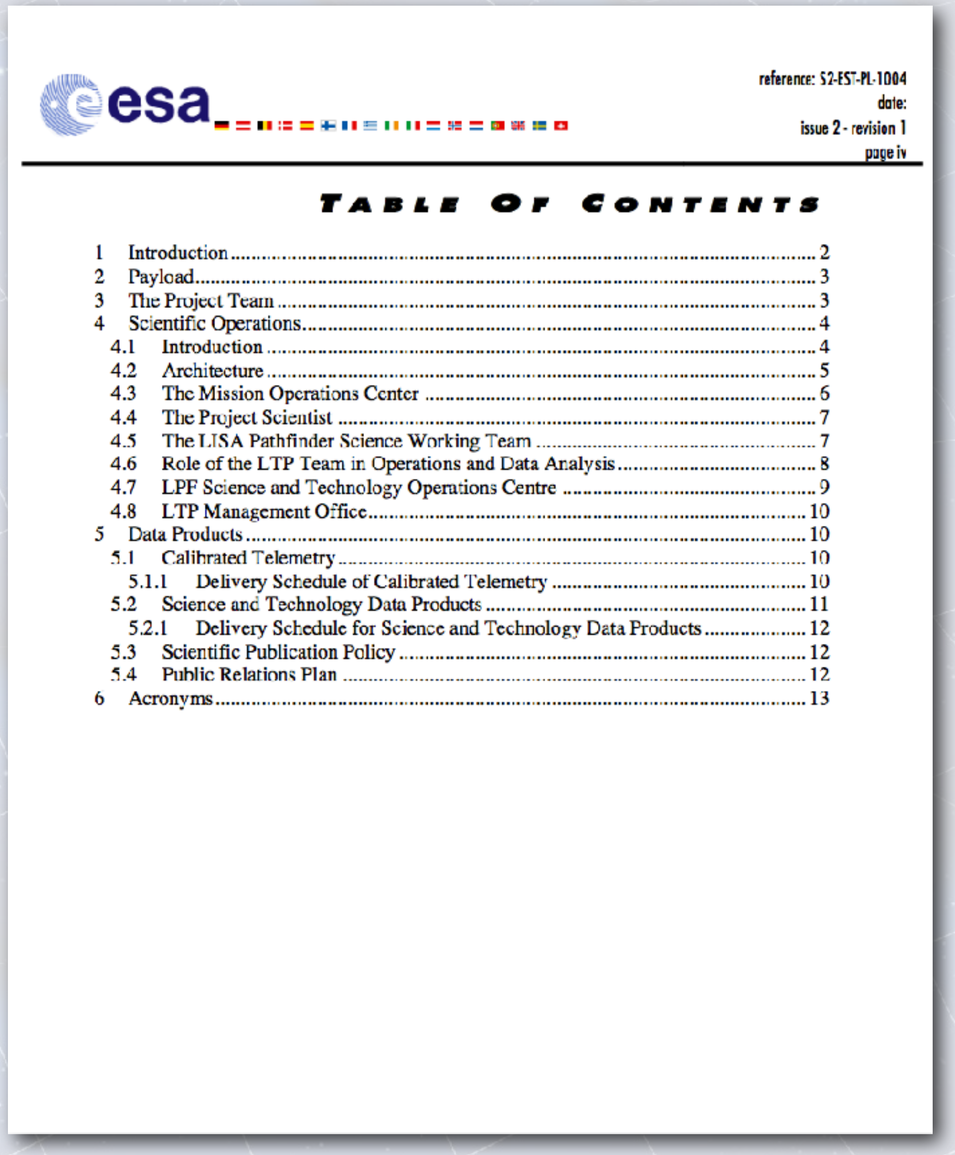
As concerns the Science Teams

- 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 schedule

- 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)



esa

reference: S2-EST-PL-1004
date:
issue 2 - revision 1
page iv

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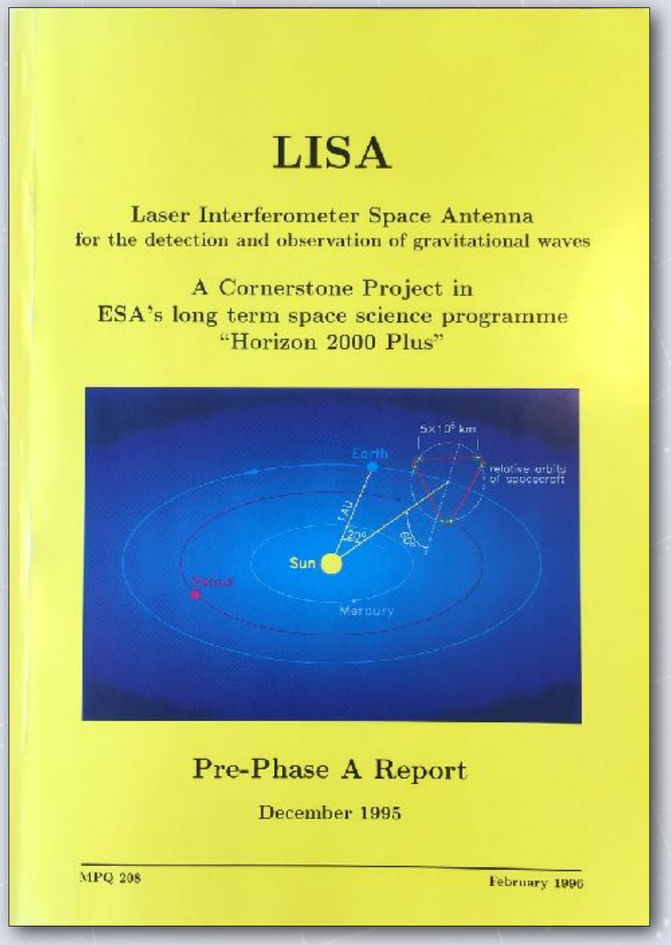
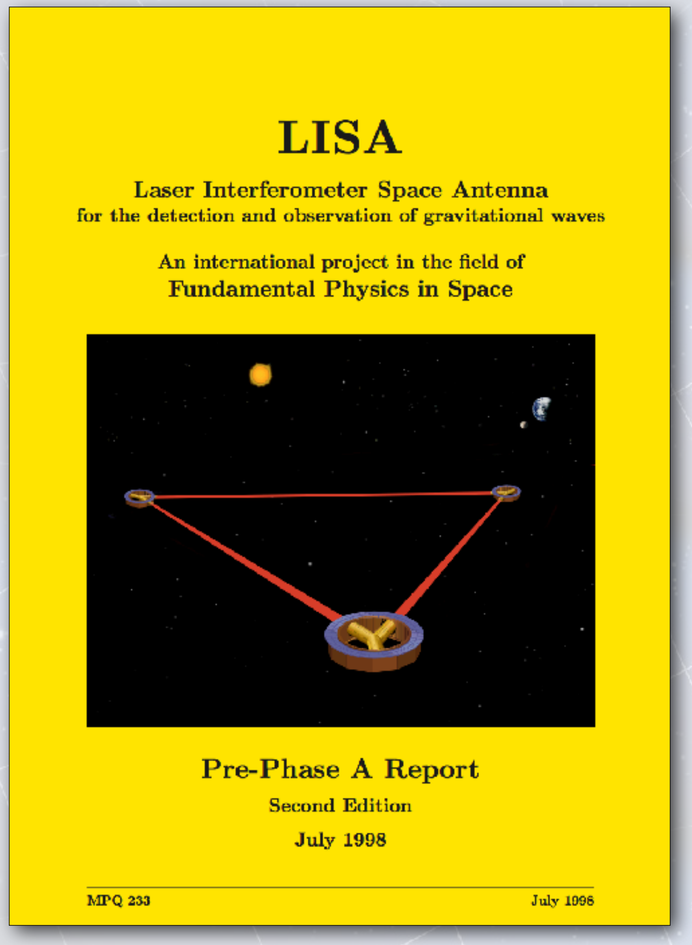
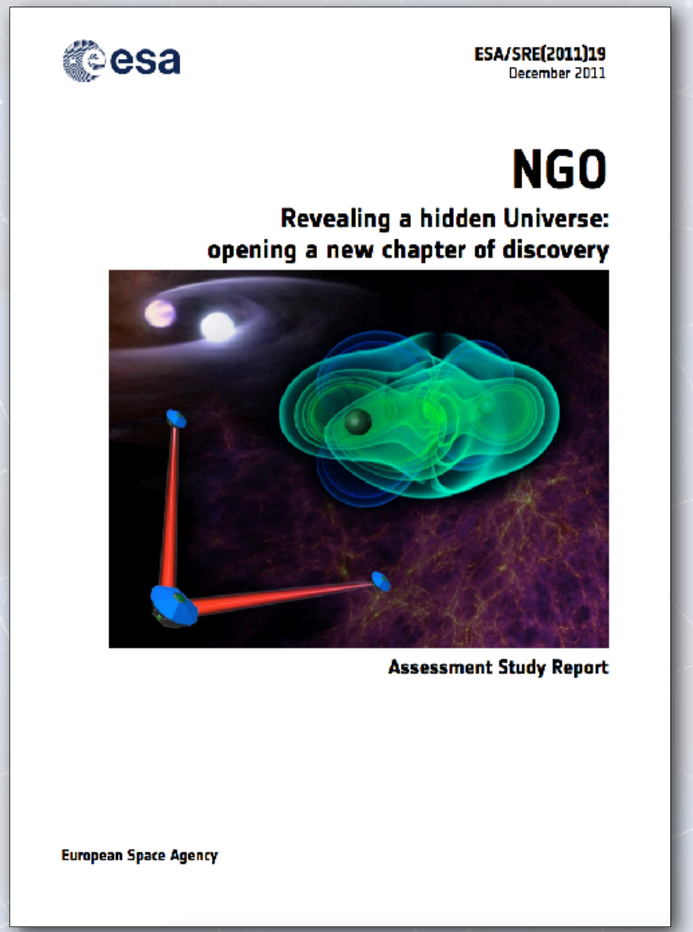
Yellow Book….

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







Conclusions

- 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